Opportunities and Challenges for African Aquaculture

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Abstract

Starting from a small base, aquaculture production in Africa registered annual growth rates equal to or above those in other regions. This expansion was due to significant increases in a few African countries. Increasing demand coupled with rapidly dwindling catches from capture fisheries, the implementation of novel participatory approaches to technology development and transfer, and the emergence of a few successful large-scale tilapia culture operations directed at the export market offer opportunities for further expansion in both the small-scale and large-scale commercial sectors. Existing biotechnical, economic and institutional challenges, which include lack of national policies to guide aquaculture development, unfriendly investment policies, the absence of linkages between farmers, research/technology development and extension, and unfavorable investment climates, are currently being addressed in a number of African countries. Long-term economic sustainability of African aquaculture will depend on the development and implementation of national policies that ensure the social and environmental sustainability of the industry.

Introduction

Africa has big potential for fish farming with 37 per cent of its surface area suitable for artisanal and 43 per cent suitable for commercial fish production (Aguilar-Manjarrez and Nath 1998). Although Africa contributed less than 1 per cent to global aquaculture production (251 000 t in 1999), the production has been expanding since 1984 at a rate equal to or greater than the global rate, albeit from a much smaller base (FAO 1997). If the statistics are to be relied, over 90 per cent of reported aquaculture production comes from Egypt and Nigeria. Madagascar (6 000 t) and Zambia (4 000 t) add another 4 per cent. The rest of the continent combined, contributes less than 5 per cent to overall output (FishStat 2001). Unfortunately, these figures are probably not very accurate. Institutional motives for over-reporting combined with inadequate/poor data collection and analysis leave us with a very fuzzy image of the actual status of aquaculture sector in Africa. Reliability of statistics could be improved from personal interviews with government officials and farmers, along with direct observation of the situation on the ground. The current status of African aquaculture as stated in the paper is based on such personal knowledge, combined with the findings of a review of the subject recently done by the Committee for the Inland Fisheries of Africa (CIFA) in consultation with a variety of stakeholders (FAO 2000).

Traditional Aquaculture

The contribution of traditional African aquaculture systems to overall production is not well documented. These systems are believed to have arisen independently in different regions particularly in floodplains and lower courses of rivers characterized by seasonal cycles of flooding and drought and include the damming of natural depressions, drain-in ponds and brushparks (ICLARM-GTZ 1991). These systems are common in West Africa and in the Nile Delta and typical production ranges from 0.1 to 3.8 t/ha/year (Table 1).

Drain-In Ponds

Drain-in ponds are mainly found in the Nile Delta and West and Central Africa. There are two major types of drain-in ponds: *ouedos* and *ahlos* of West and Central Africa, and the *hoawash* (Figure 1) which are mainly found in the Nile Delta. Both types of drain-in ponds are used to culture tilapias.

The *ouedos* are used by people living in the Ouémé valley of Benin to catch fish when floodwaters recede in the floodplain (Nzamujo 1995). Fish holes are also used in the deltaic floodplains of Cameroon (Balarin 1985). The fish holes, which are 50 to 1 500 m long and 4 m wide, are constructed from natural water channels and are deepened to about 1.5 m below the dry season water table (ICLARM-GTZ 1991). Fish, predominantly tilapias, enter naturally into the fish holes during the wet season and are trapped as floodwaters recede. The fish are then harvested using nets or mobile reed barriers.

During the dry season, animals graze in the fish holes and their manure fertilize the fish holes (Nzamujo 1995). The *ouedos* are integrated with agriculture in Benin where maize is cultivated in the drawdown areas between ponds and vegetables are cultivated on the banks around the drawdown areas (Welcomme 1983).

Ahlos are fish holes with tree branches inside to provide refuge and food for the fish. The *ahlos* are a combination of the brushparks/*acadjas* and *ouedos* (Welcomme 1971). The problems faced by these systems include population growth, deforestation due to cutting of trees to provide branches for the *ahlos*, accumulation of undecomposed branches which reduce water flow and the indiscriminate harvesting of smaller fish thus reducing recruitment into the rivers and lakes (Nzamujo 1995; Welcomme and Kapetsky 1981).

Brushparks

Brushparks (Figure 1) consist of branches, bushes or other soft vegetation stuck into muddy bottoms of lagoons, lakes or rivers (Welcomme and Kapetsky 1981). Brushparks are used in various parts of the New World, for example Ecuador, Madagascar, Malawi, Mexico, Bangladesh, Indonesia, and West Africa (Welcomme and Kapetsky 1981; Kapetsky 1981; Williamson 1972). In Africa, brushparks are common in West Africa where the black chinned tilapia *Sarothederon melanotheron* constitutes about 60 per cent of the species caught from the brushparks. Brushparks are extremely productive (Table 1) and their yields, which range from 5 to10 t/ha/year are comparable to modern intensive aquaculture operations (Welcomme and Kapetsky 1981). The high productivity of brushparks is attributed to high nutrient loading resulting frm the decomposition of the wood in the brushpark. The brushwood and branches in the brushpark also act as a growth substrate for epiphytic algae, attract insects and provide breeding sites for fish.

Attempts have been made to improve the management of brushparks in Benin through the stocking of Nile tilapia *(Oreochromis niloticus)* and the use of conventional feed instead of using branches to promote and attract food. However, high costs associated with setting up the enclosures and supplementary feeds have made it difficult for local communities to adopt the technology (Nzamujo 1995).

Figure 1. A brushpark in a lake in Nigeria (top) and a *howash* in the Nile Delta, Egypt (bottom)

Brushparks compete with adjacent capture fisheries by attracting the juveniles from the open water to the brushpark, and there is also competition for space and resources. Brushparks contribute to local deforestation and environmental degradation as well (Welcomme and Kapetsky 1981). To minimize deforestation and accumulation of organic matter in the system, Hem and Avit (1996) used bamboos, which last up to six years compared to soft wood branches that need to be replaced annually. The conflict between the brushparks and capture fisheries is exacerbated when the brushpark is used as a fish aggregation device. This occurs when harvesting is undertaken at short intervals (three months), thus not allowing the fish to breed and grow inside the brushparks. (Hem and Avit 1996). The prolific spread of brushparks in Benin has also been shown to result in serious social conflicts between brushpark owners and navigators (Pliya 1980).

Introduced Culture Systems

Most African aquaculturists use culture technology imported from Asia, Europe and

North America as part of rural development projects. Most of these are based on earthen ponds. According to King (1993), over 90 per cent of cultured fish in Sub-Saharan Africa come from earthen ponds of 200 to 500 m^2 fed with locally available, low-cost agricultural by-products. In general, the production from these ponds is input-limited, both in terms of quality and quantity resulting in yields of 1 000 to 2 000 kg/ha/year. However, these ponds are multiple purpose facilities for the farming households rather than just for fish production (Brummett and Noble 1995). Field studies have indicated that a good percentage of the fish grown in such systems are bartered or consumed directly by the farm households and so never enter the cash economy (Brummett and Chikafumbwa 1995). Almost all of these fish are disposed of on the pond-bank within minutes of harvest, a finding that might mean that actual fish production in Sub-Saharan Africa is much more than that reported in official statistics.

Commercial systems in Africa are few in number and idiosyncratic, making analyses of systems and trends rather difficult. In Zambia, commercial pig-fish systems routinely produce yields of up to 5.4 t/ha. For example, the Kafue Fisheries Company in Zambia, which at 1 870 ha is the largest integrated fish farm in Africa, covers 37 ha of water and produces 1.5 t/week of 180 to250g sized fish of mostly indigenous tilapias *(O. andersonni, O. mossambicus, O. niloticus, Clarias gariepinus* and *Cyprinus carpio)*. Production is sold in Lusaka (the Zambian capital) at 3 000 Zambian Kwacha per kg, equivalent to about US$0.81 (Lally 2000; Edward Lally personal communication). Other animals produced on the farm are pigs and ducks.

In Egypt, where aquaculture is reputed to be a booming industry (Wassef 2000), producers in the Fayoum depression south of Cairo are typical. These farmers operate 1 to 2 ha earthen ponds, producing primarily *O. niloticus* and mullets (a mixture of mostly wild-caught *Mugil cephalus* and *M. lazera*), sometimes with aeration. New hatchery systems developed in Asia have been built by private investors to permit the use of sex-reversal technology (Figure 2). Pelleted diets manufactured locally by animal feed companies are used to achieve fish standing stocks of up to 3 000 kg/ha/cycle.

Raceway or tank systems (Figure 3) are less common than ponds, but in situations where water is either available by gravity or is being pumped for other purposes, these can also be profitable. On the Namibian coast, oysters are being raised in evaporation raceways operated by a salt export company and are sold to restaurants to increase the economic efficiency of the salt enterprise. Likewise, Baobab farm in Mombassa, Kenya has been operating since the early 1970s with water pumped to supply the Bamburi Cement Plant. The Baobab system incorporates novel circular spawning tanks that can produce up to 60 000 fry of 2 g each per month. Growth rates of about 1.5 g/day can produce 250 to 400 g market sized tilapias in eight to nine months.

Table 1. Summary of the characteristics, inputs and expected yields of selected traditional extensive African aquaculture systems (ICLARM-GTZ 1991).

System (Dimensions)	Essential Inputs	Accessory Equipment	Time to Harvest	SeedStock	Extrapolated Yield (t/ha/year)
Damming; Depressions (≥ 1ha)	Excavation, supplemental feed	Nets	Various, often unregulated	Adventitious entry of wild stock	0.25-0.5
Drain-in Ponds					
Howash (1-20ha)	Earthen dikes, pumping, manure, feeds	Pump, boat, nets	1-10 yrs	Adventitious entry of wild stock	0.5-4.5
Ouedos (20-1250m trench)	Excavation	Net/traps	4 mos	"	1.0-2.1
Ahlos(30m trench)	Excavation, branches	Net	1 yr	"	1.0
Brushparks					
Acadjas	Branches	Canoe, Nets	1-6 yrs	"	4-20
Adokpo	Branches	Canoe, Nets	4-8 mos	"	8-10
Barachois	Stone wall	Seine net	1 yr	"	0.1

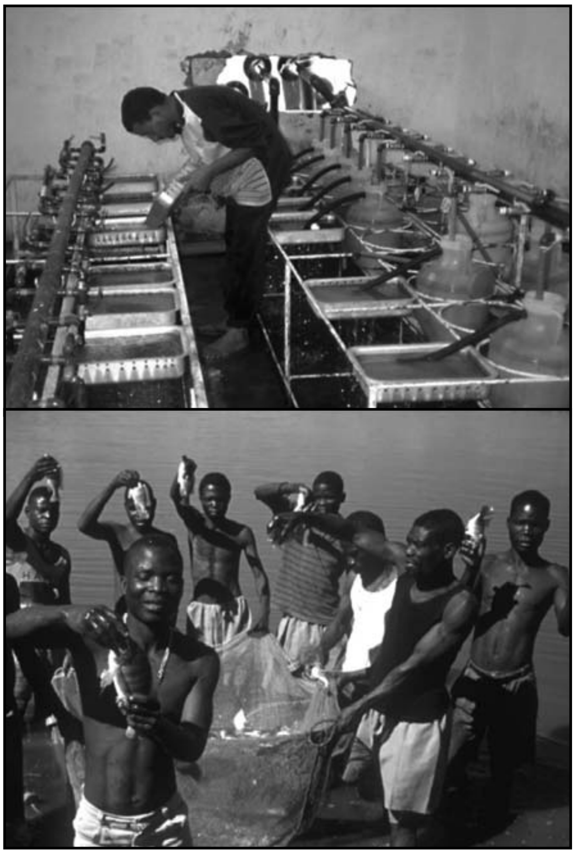

Figure 2. Improved hatchery systems for pond farming of tilapias on a privately owned farm in Egypt (top) and the employment potential of a pond-based tilapia farm in Malawi (bottom).

Feeds manufactured from local by-products are used. Regular grading to ensure that only the fastest growing individuals are maintained is a key to the success of the operation. The culls are fed to crocodiles, the skins of which add to the profitability of the system.

Raceways are also being used in Zimbabwe for outgrowing tilapias (*O. niloticus*) from 50 g to about 700 g in eight months (Windma'r et al. 2000a). A raceway 650 m long with average water flow rate of 1.7 m^3 per second in the Zambezi River is employed to produce 480 t of whole tilapia. The raceway facility in Zimbabwe also incorporates a recirculating system for a pond and tank-based hatchery unit. The tilapia is processed into fillets and are exported fresh or frozen to the European Union Market. Raceways are also being used in Kenya to produce *O.niloticus*. Balarin and Haller (1979) reported that 10 x 1.5 x 0.4 m deep raceways were being employed to rear fry. The raceways used water from production tanks where the water was exchanged at three to four times of the water volume per hour. The fish were fed a 22 per cent crude protein diet and harvests of 22.5 kg/m^3 were attained.

Figure 3. Trout farm in Zimbabwe (top) and an oyster farm integrated with a salt production facility, Namibia (bottom).

Cage culture systems, which exist as pilot or fully operational systems in Southern and West Africa, have so far not significantly contributed to overall production. For example, in 1992, cage culture systems contributed about 2.5 per cent to the total tilapia production (7 755 t) in Nigeria (Ezenwa 1994). Cages are usually made out of wire mesh and securely locked to avoid losses from crocodiles, which are prevalent in most African lakes, rivers and reservoirs. While not much information is available on cage culture in Africa, existing data indicate that low lake levels adversely affect the cage culture of tilapias. The high cost of production makes them an uncompetitive, cheap imported marine species (Marshall and Maes 1994). Returns to small-scale cage culture have also been reported to be unpredictable and dependent on the cost of fingerlings, feed (which can amount to 60 to 70 per cent of the total cost) and the fish itself (Marshall and Maes 1994). There are, however, a few successful cage culture operations in Africa. The largest is in Lake Kariba with an annual production capacity of 2 000 t of whole tilapia (Windmar et al. 2000 b). Other countries in Africa such as Malawi and Kenya have either established some tilapia cage culture operations or are in the process of establishing these facilities.

Challenges and Opportunities for the Future

The entry of African aquaculture into global prominence faces considerable challenges. There are, however, reasons for optimism. Despite high risks and investment costs, high and increasing demand and market value of fish are encouraging. If social and environmental sustainability issues can be successfully addressed, increasing market demand and higher prices should open opportunities for a range of producers and investors. Increasing productivity of both large and small-scale aquaculture will require major investments in research, development and extension (see below) as well as policy shifts. The strategies for addressing problems of the small-scale and larger commercial operations will probably be different.

Improved Systems

The majority of beneficiaries of aquaculture development projects have been rural small-holders operating mixed farming systems in which aquaculture plays a more or less minor role compared to staple crop production. It is impossible to determine the total output of these farms, but continent-wide they number in the hundreds of thousands. These farmers lack both the knowledge and means to break into commercial aquaculture. However, as they are by far the largest and most needy group of African farmers, the equitable distribution of the benefits from aquaculture development will require approaches that cater to their needs.

Such options as integrated farming where animal and crop residues and by-products are used as feeds in a fishpond can help to overcome material constraints. The use of participatory strategies for technology transfer may be important in the building of capacity within this group. Traditional aquaculture systems that are widely practiced in some parts of West Africa offer future opportunities for increasing small-scale tilapia production in other parts of Africa (Machena and Moehl 2000; ICLARM-GTZ 1991). However, research on improved practices, community management and tenural rights are needed to increase productivity and assess the possibilities for their commercialization.

Table 2. Major constraints to commercial aquaculture in Sub-Saharan Africa (Brummett and Williams 2000).

- Generally poor infrastructure
- Essential inputs lacking or difficult to access
- Political instability
- Cash-limited local markets
- Poor quality/quantity extension services

Hecht (2000) suggests that donor funding on aquaculture production, which targeted the "poorest of the poor" had been misdirected and proposes the targeting of small-scale entrepreneurs in this sector in order to increase productivity. However, successful commercial farming systems in Africa are not easy to characterize as being more successful than small-scale projects. Many commercial systems are relatively small or pilot-scale operations, focused on producing high value species for export. Their viability often relies on idiosyncratic circumstances and is often short-lived. The main constraints to commercial aquaculture (Table 2) are common to most agro-industries in Africa. Generally poor infrastructure such as poor telecommunications, bad roads, irregular air services and unreliable electricity means that many types of equipment will not function when they are most needed; thus it will be difficult to store fish for any length of time and many markets will be inaccessible. The lack of essential inputs such as feeds, fertilizers, chemicals, fuel and spare parts or their volatile prices severely restrict a farmer's ability to predict yields and make any sort of reliable economic forecasts. Political instability has been Africa's bane for many years and can threaten not only the economic viability of an enterprise, but has also claimed the lives of investors and farm managers. The general poverty of African communities, and their consequent reliance on barter, is why most commercial farms look to external markets. Lack of expertise, both in the extension services and among potential farm managers, means that production systems must be easy to operate. Since many commercial farms make their profits on the margin of systems that are being pushed to their limits, having to rely only on safe technology severely restricts the range of economically viable enterprises that can develop.

There is scope to increase tilapia production from large-scale commercial systems both for domestic consumption and for export. Currently, only a few African countries such as Zimbabwe, Uganda and South Africa are exporting tilapias to Europe and the United States of America (Windmar et al. 2000 a; American Tilapia Association 2001). Tilapia exports from Uganda to the United States market are likely from capture fisheries, since Uganda does not have a developed commercial aquaculture sector. The success of Zimbabwe tilapia producers in profitably producing tilapias for the export market suggests that this sector could significantly contribute to tilapia production in Africa. The major challenges facing the development of large-scale commercial tilapia farming are environmental sustainability in the face of unregulated importation of exotic fish species and their hybrids, access to capital, poor infrastructure to maintain the cold chain necessary for exporting high value perishable commodities, and the availability of cheap feeds. Most of the ingredients used in commercial tilapia diets are imported and customs duties make their prices prohibitive. As for the small-scale sector, enabling policies are required to further develop tilapia production by large-scale commercial farmers. Some African countries have or are in the process of removing import duties on capital equipment and supplies used in the aquaculture sector.

Germplasm

Artisanal producers typically grow indigenous tilapias (mostly *O. niloticus* and *O. mossambicus*) and African catfish (*C. gariepinus*), although the parental lines for cultured populations often originated outside of the basins or even the countries in which they are currently being grown (Pullin 1988). Of 212 freshwater fish introductions for African aquaculture, only 33 (16 per cent) resulted in the establishment of an industry with output of more than 10 t/year in 1997 (Brummett 2000a; FishBase 2001; FAO 1999). Of the introductions that resulted in the establishment of an industry, 10 (30 per cent) were of *C. carpio* from Asia and Europe and 7 (21 per cent) were of *O. niloticus* from other African countries. The balance was of mixed cyprinids and rainbow trout (*Oncorhynchus mykiss*).

This situation may, however, be changing, particularly in commercial systems. For example, over 20 years of regular culling (a form of uncontrolled selective breeding) at Baobab in Kenya has led to the creation of a Baobab strain of *O. niloticus.* Recently, a mixture of *O. niloticus* and *O. spilurus* broodfish were imported from Lake Turkana to diversify the stock. Genetic introgression among these stocks is likely.

At Kafue, most production is based on the indigenous *O. andersonii* and *O. mossambicus*. In the last few years, imported *O. niloticus* have been added. At Lake Harvest, Zimbabwe introduced *O. niloticus* are the main cultured species.

The management of non-native and/or improved species is a major challenge for African aquaculture. Pressures from producers have led to the introduction of *O. niloticus* from other African countries for culture in large-scale commercial systems in Zambia and Zimbabwe, and elsewhere interest in tilapia hybrids and YY "supermale" tilapias is increasing. Although guidelines for the importation of alien fish species exist (for example. FAO Code of Conduct for Responsible Fisheries), weak regulatory mechanisms, the absence of policies and understaffing in most African countries do not allow the enforcement of regulations regarding the importation and management of exotic species. Environmental sustainability with respect to alien species can only be achieved if regulations on the importation and use of alien tilapias are enforced and systems are managed according to accepted best management practices to minimize the impact of escapes on local biodiversity. This is also true with respect to effluent from large-scale commercial tilapia farms.

Research, Development and Extension

Although the majority of the systems used in African aquaculture were introduced through technology development and transfer projects, the current state of most research, development and extension (R, D & E) in Africa is poor. Low levels of annual expenditure have rendered national and regional programs more or less incapable of managing the growth of the industry. A large percentage of governmental aquaculture facilities are either abandoned or dysfunctional for various reasons (FAO 2000). Despite a number of projects aimed at introducing multi-disciplinary, holistic and participatory approaches, aquaculture extension remains very much top-down and poorly trained. In terms of human resources, extension, arguably the most difficult aspect of technology development and transfer, is normally the entry-level position to government service and, hence, is normally staffed by inexperienced and/or poorly motivated personnel (van der Mheen 1999).

To provide needed support to the development of aquaculture, Coche et al. (1994) recommended a thorough overhaul of the R, D&E system in Africa. In particular, governments should: (i) provide adequate training for both research and extension and; (ii) develop information systems that can systematically provide farmers with access to technology.

In these times of structural adjustment and fiscal austerity, neither of these suggested changes has been broadly implemented. In fact, most African states are dropping aquaculture from their funding portfolios without any provision for either future support to the industry, or its regulation. For example, a working group on aquaculture development in Africa recently agreed to recommend to their respective governments a plan that would:

- Privatize at least half of government aquaculture facilities by 2004.
- Transfer to Fish Farmer Associations and NGOs the main responsibility for the majority of services now provided by the government (such as fingerling production, breeding programs, feed formulation, technology adaptation, and demonstration.)

Individual private operators are thus being put in the position of choosing the type of production system that will guide investment and the type of germplasm to be used. Unfortunately, in Africa's uncertain investment climate, high-risk/short-term profit systems are favored. Some common features of these systems render them socially and/or environmentally unsustainable:

- An export-orientation that can actually reduce local availability of fish. For example, high-value shrimp farms built in mangroves, using locally produced fishmeal.
- Importation of trained expatriates, reducing job and training opportunities for local technicians.
- Use of high external inputs, sometimes imported, that keeps prices high and can have negative environmental consequences through eutrophication.
- Use of alien species or hybrids that once escape to the wild, often have negative impacts on indigenous species and ecosystems.

The development and dissemination of information, and the implementation of participatory approaches that target the different needs of a wide range of farmers could solve some of the technological adoption problems facing aquaculture production in Africa (Brummett and Williams 2000; Harrison 1994). New approaches that employ a participatory approach to technology development and transfer for production of tilapia and other aquaculture species offer new opportunities for increasing production of small-scale tilapia ponds. The participatory approach to technology development and transfer allows farmers to be part of the technology development process, and in so doing farmers gain a greater understanding of the functioning of their production systems and are better able to guide the system towards greater productivity (Brummett and Williams 2000). Of course, such a radical change in how aquaculture research and extension is conducted requires the commitment of government policy-makers and the formulation of appropriate policies that will allow such shifts in technology development and transfer approaches to occur. However, in most African countries, aquaculture policies to guide the development of aquaculture production are non-existent (FAO 1999; Machena and Moehl 2000). The institutional changes that are occurring with respect to technology development and transfer, and the removal of the constraints to aquaculture development alluded to earlier, require African governments to develop policies that address the existing constraints.

Table 3. Prices for farmed tilapias from selected African countries.

Country	Year	Price (US$/kg)
Egypt	2001	1.50 (100-200 g) 1.90 (>200 g)
Malawi	2001	1.00-1.50 (all sizes)
Nigeria	2001	0.83 (100-200 g) 1.00 (>200 g)
Zambia	2001	0.83 (220 g)

Markets

Local demand for aquaculture products in many African countries is high and is projected to increase in the future. For example, in Malawi, fish produced in rural areas are sold out the day before harvest, and local demand for tilapias is so great that pond fish rarely reach the urban markets. In Zambia and Egypt, most of the production is targeted towards urban markets, which absorb all the premium high value fish, the remainder being sold locally. Table 3 presents tilapia prices for some selected African countries.

Tilapia prices are generally high and depend on the size and/or quality (freshness) of the fish. For example, in Nigeria, Uganda and Egypt large-sized pond fish (200 g) are sold at higher prices compared to small ones (100 g) (Adesulu 2000; Afolabi et al. 2000; Gamal El. Nagar personal communication). In Malawi, however, fish size does not affect the price of tilapias, although freshness has an impact (Brummett 2000b). Rapid urbanization and population growth, especially in Sub-Saharan Africa, is likely to increase demand for fish in the future. If the constraints to the development of socially and environmentally sound aquaculture described above can be overcome, the economic viability of fish production should be assured for many years into the future.

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