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Review

# African aquaculture: Realizing the potential

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**Abstract**

Despite 40 years of research and development, and hundreds of millions of dollars spent, aquaculture is struggling to realize its high biophysical potential in Africa. Hampered by ineffective institutional arrangements and donor-driven projects, the substantial gains in desperately needed food security and economic growth predicted by development agencies have generally not been achieved. Nevertheless, African aquaculture has demonstrated its competitiveness, producing fishes that feed low on the food chain in a range of well-adapted, environmentally friendly and profitable farming systems that meet the needs of a broad spectrum of user-groups. Key constraints to broader growth include lack of good quality seed, feed and technical advice; poor market infrastructure and access; and weak policies that, rather than accelerate, impede expansion, largely by emphasizing central planning over private sector initiative. If African aquaculture is to make substantial and much needed contributions to the continent's development, government policy should attempt to facilitate the alleviation of key constraints and rely more heavily on commercial investments to lead future growth. Evidence to date indicates that a pragmatic business approach focusing on small and medium-scale private enterprises would produce more benefits for more people than centrally planned and government led development projects.
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## Introduction: a brief history of African aquaculture

In the 1940s and 1950s, the colonial powers in Africa saw the potential of aquaculture as a viable means of food production and invested substantial resources to support its development. Early efforts concentrated on basic research and development to elucidate practical technologies for a range of mostly indigenous species. Research stations were built in most parts of the continent during this period.

| | |
|---|---|
| Djoumouna (Republic of the Congo) | Anamalazaotra and Ampamaherana (Madagascar) |
| Landjia (Central African Republic) | Kipopo (DR Congo) |
| Foumban (Cameroon) | Kajjansi (Uganda) |
| Bouaké (Côte d'Ivoire) | Chilanga (Zambia) |
| Sagana (Kenya) | Henderson (Zimbabwe) |

The main species investigated were indigenous tilapias (esp. *Oreochromis niloticus*, *O. mossambicus*, *O. macrochir* and *O. aureus*; *Sarotherodon galilaeus*, *S. melanotheron*; *Tilapia rendalli*), African sharptooth catfish (*Clarias gariepinus*), the African boneytongue (*Heterotis niloticus*) and alien common carp (*Cyprinus carpio*) imported from Europe. Reproduction and culture options for all of these species were established and *O. niloticus* in particular has become one of the most important aquaculture species in

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Table 1
Budgets for piloted small-scale, artisanal aquaculture systems in Rwanda and Niger with and without project subsidies (Lazard and Mikolasek, 2003)

| Production system | 400 $m^2$ pond<br>1450 kg/ha/yr<br>Rwanda | | 20 $m^3$ Cages<br>423 kg/cage/yr<br>Niger | |
|---|---|---|---|---|
| Costs | Project data | Without project subsidies | Project data | Without project subsidies |
| Opportunity on land | | $1.75 | | |
| Fingerlings | $1.46 | $1.62 | $110.60 | $92.17 |
| Feed/fertilizer | $2.57 | $2.85 | $265.50 | $221.25 |
| Labour | $5.00 | $5.55 | | $30.00 |
| Depreciation | $0.63 | $1.39 | | $100 |
| Misc. | | $0.91 | $115.10 | $45.75 |
| Fish sales | $14.17 | $10.68 | $676.70 | $563.92 |
| Net income | $4.52 | −$3.40 | $185.50 | $74.75 |

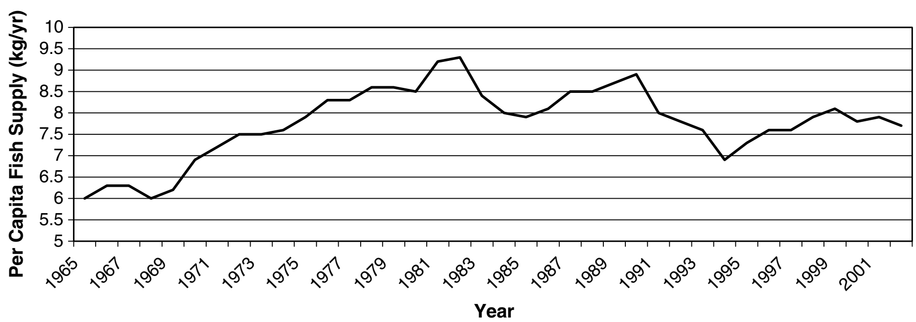


Fig. 1. *Per capita* fish supply in Africa 1965–2002 (FAO 2005a).

the world, albeit largely outside of Africa.[1] Within Africa, large *O. niloticus* are luxury items, while small individuals are a staple source of protein for the poor. *C. gariepinus* is particularly popular in West and Central Africa where catfishes dominate local inland fisheries and traditional cuisine.

In the 1960s, in light of pressing needs in other sectors, most newly independent African governments deprioritized support to aquaculture and hundreds of thousands of recently-built ponds were largely abandoned. In nine African countries, Meschat (1967) documented a precipitous decline from over 300,000 ponds in 1960 to less than 20,000 by 1966. In the 1970s, 80s and 90s, aquaculture was adopted as a tool in rural food security and economic development by a number of international donor agencies who effectively took over from government the role of prime mover in the development of the sector (Pillay, 1977). Many projects were targeted directly at the artisanal farming sector in hopes that low external input systems would evolve into productive enterprises. In most cases, these saw important successes, although most positive impacts were short-lived and ended within a few years after external support was withdrawn. Even with project subsidies, the returns from these small-scale operations were simply too low to attract the attention of even poor farmers (Table 1) (Hambrey, 2004). Currently, African aquaculture contributes less than 1% to global production, with only larger-scale investments in Egypt, Ghana, Nigeria and Zimbabwe producing significant quantities of fish.

## Why aquaculture?

While African capture fisheries have been (over) exploited to their maximum (FAO, 1999) and aquaculture has languished, African demand for fish has grown. Africans are second only to Asians in the importance of fish in the diet, with 17.4% of total animal protein intake in the form of fish (compared to 25.7% in Asia). Only about 10% (430,000 tons, valued at $1.2 million in 2003) of Africa's nearly 4 million tons of total fish production (aquaculture + capture fisheries) is exported. Even though total fish supplies have increased, they have not kept pace with population and Africans currently consume an average of 7.7 kg/pers/yr (6.4 million tons total) down from a peak of over 9 kg (4.6 million tons total) in the early 1980s (Fig. 1). To meet demand, African countries currently import about 4.2 million tons of fishery products at a net loss of $3 thousand million. However, just to get back to 1982 consumption levels, there remains a 1.3 million ton shortfall in supply. Nevertheless, in 15 African countries, fish still represent over 30% of animal protein consumption (FAO, 2005b):

[1] Asia produces over 1 million tons of tilapia per year, compared to 180,000 tons from Africa, mostly Egypt (FAO, 2005a).

| | |
|---|---|
| Malawi (44.2%) | Sierra Leone (66.4%) |
| Congo (45.3%) | Tanzania (32.8%) |
| Gambia (47.3%) | Cameroon (49%) |
| Uganda (31.6%) | Nigeria (40%) |
| Guinea (34.9%) | Angola (35.7%) |
| Equatorial Guinea (58.2%) | Côte d'Ivoire (36.0%) |
| Ghana (58.6%) | Senegal (37.5%) |
| Togo (39.7%) | |

With this substantial market to satisfy combined with adequate water and land resources to produce an estimated 1.5 thousand million tons of fish per year through aquaculture[2] (Kapetsky, 1995), the lack of aquaculture development in Africa is something of a mystery. The amount of money invested by international donors and development agencies over the last 30 years has been huge. According to Lazard et al. (1991), African aquaculture development received some $72.5 million over the period from 1978 to 1984, versus $171.3 million for Asia and the Pacific. For this less than 3-fold funding difference, Asian countries produce 1000 times more fish than Africa.

To be fair, much of the money invested was in non-performing infrastructure such as the large number of hatcheries and government stations constructed, including the African Regional Aquaculture Centre (ARAC) in Port Harcourt, Nigeria and the Central Laboratory for Aquaculture Research (CLAR) in Abbassa, Egypt. Without going into the details of why these facilities collapsed, the failure of these investments to produce positive or sustainable outcomes is one of the clearest examples of how poorly aquaculture has been managed in Africa (see also Moehl et al., 2006). This review will look in greater detail at both failed and successful aquaculture ventures in Africa and glean lessons that can be used to guide more successful efforts in the future.

## Supporting african aquaculture; who is in charge?

The question of who is "in charge" of aquaculture development in Africa has plagued the sector for many years. Many African governments assume that it is their responsibility. However, despite having been practiced for over 50 years, with hundreds of small and large projects having been implemented, aquaculture has still to find a comfortable home in most African bureaucracies. Aquaculture policy makers have been variously housed in Ministries of Agriculture, Animal Production, Fisheries, Natural Resources, Parks and Wildlife. Aquaculture research is generally located separately in the Ministry of Science or Technology. Except in the few cases where it has an independent service (e.g., Malawi), aquaculture extension is typically handled by generalists from the Ministry of Agriculture, who often have little or no training, formal or otherwise, in fish culture, and virtually no contact with the subject matter specialists housed in separate ministries or research facilities.

In whatever Ministry aquaculture finds itself, the current institutional structure remains fraught with long chains of bureaucracy linking policy makers to technology users (Table 2). This arrangement results in the loss of financial resources and important technical information going from tax-payers to government to research to extension to farmers, as well as misinterpretation of the needs and constraints of farmers on the part of policy makers.

In a review of government and aquaculture in Africa, FAO (2001) listed capacity building as the first priority on a list of strategies to support the development of the sector. They went on to note the near total lack of existing legislation: "General policies include improved governance, measures to ensure political and policy stability, secure property rights and reduced corruption. Sectoral policies include the development of appropriate legal, regulatory and administrative frameworks, marketing strategies and encouraging pioneer associations. It was noted that effective extension services, the role of the government to put in place appropriate aquaculture-specific policies, legislation and regulations, institutional support and appropriate land laws are necessary for the emergence and/or development of commercial aquaculture".

For policies and the institutions that derive them to make any meaningful contribution to development, they must be based on realistic expectations. In light of the fact that African governments have and will continue to prioritise comprehensive health care, education and other critical social services over aquaculture, a comprehensive approach to government leadership is probably not feasible at the present time and most governments have limited themselves to the general and rather vague policy of "creating a conducive environment for fish production as a means of achieving food security and poverty alleviation". This policy has proven sufficiently flexible to permit foreign donors and development agencies to intervene on behalf of government, applying whatever criteria and objectives they see fit, which mostly involve directly targeting the "poorest of the poor" to achieve anticipated rapid gains against rural poverty and hunger. As was mentioned above, few if any of these interventions have had sustained impact.

Clearly, if government leadership is the key to success, aquaculture will only receive the attention it needs to flourish in the longer term, if at all. Alternatively, development models that allocate to government the role of facilitator and transfer the role of motivator to the private sector could produce better outcomes more quickly (Lazard et al., 1991). For example, market-driven models for development rely only obliquely on government policy, and usually then only in terms of relaxed regulation rather than any positive intervention or financial contribution.

Defining a clear role for government in light of prevailing lack of financial and human resource capacity is only just beginning in most African countries. In the late 1990s,

[2] Compared to the 51 million tons produced globally in 2003 (FAO, 2005a).

Table 2
Institutional structure and current aquaculture extension approach in five countries of sub-Saharan Africa (Brummett et al., 2004a)

| | Cameroon | Côte d'Ivoire | Kenya | Madagascar | Zambia |
|---|---|---|---|---|---|
| Ministry in Charge | Ministry of Animal Husbandry and Fisheries; Ministry of Agriculture | Ministry of Agriculture (MINAGRA) | Ministry of Agriculture and Rural Development | Ministry of Fisheries and Aquatic Resources | Ministry of Agriculture, Forestry and Fisheries |
| Main Extension Organism | National Agriculture Research and Extension Program (PNVRA) | National Rural Development Agency (ANADER) | Fisheries Department | National Agricultural Extension Program | Agriculture Research and Extension Project |
| Current Main Alternative Service Provider(s) | Institute of Agricultural Research for Development | Aquaculture and Rural Development Association (APDRA) | Moi University and local NGOs | Local NGOs | Participatory Extension Systems (FAO); Rural Aquaculture Extension Promotion (Peace Corps) |
| Structure | – National coordinator PNVRA | – National coordinator ANADER | – Director of Fisheries | – Technical Director with 3 cells (training, extension, monitoring and evaluation) | – Permanent Secretary |
| | – Provincial coordinator | – Regional MINAGRA and ANADER offices. | – Sub-Director for Aquaculture | – Provincial | – Senior Field Services Coordinator |
| | – Subject matter specialists | – Farmers | – Assistant Director (by region) | – Sub province | – Senior Fisheries Officer (province, district) |
| | – Area Extension Agent | | – District Fisheries Officer | – Zone or Brigade | – Aquaculture extension officer |
| | – Contact farmer | | – Fisheries Officer | – Private Fingerlings producers (PFP) | – Camp officers |
| | – Farmers | | – Fisheries Assistant | – Rice fish farmers | – Farmer Motivators |
| | | | – Farmers | | – Farmers |
| Approach by the Main Extension Institution | T&V | T&V/Promotion of commercial units (pilots) | T&V/ Aquaculture Demonstration Centres | T&V/practical training, close contacts with private fingerling producers | T&V/ Participatory |
| Alternative Approaches being Investigated | Farmer Scientist Research Partnership (WorldFish) | A number of participatory research projects (esp. APDRA) | Various participatory approaches. | Regional Development Working Groups; heavily bureaucratic. | Farmer Field Schools |
| Place of Aquaculture | With animal husbandry and capture fisheries | With forestry and agriculture | With agriculture and wildlife | Independent Ministry | With agriculture and forestry |
| Ratio Fish Farmers: Extension Agents | 600 | | 64 | 1200 | 800 |

foreign donors assisted Côte d'Ivoire and Malawi to devise Strategic Frameworks for Aquaculture Development (Lazard and Koffi, 1996). However, for most African countries, it has only been in the last five years that any serious efforts have been made to define strategic objectives and develop legal or policy instruments to deal with aquaculture. Questions such as access and tenure to land, permitting, environmental impact assessment (EIA), government's capacity and role in encouraging development, etc. had been largely put aside pending the emergence of a viable aquaculture sector. Whether policies can actually create sustainable development is debatable, but the absence of any clear position on at least the questions of assured access to land and water resources is surely a constraint to potential fish farmers seeking to protect their investments.

In a series of regional meetings of African aquaculture experts and senior government officials convened by the FAO between 1987 and 2004,[3] a number of commonalities among African countries in terms of aquaculture development strategy have been identified (FAO, 2000; Moehl et al., 2005). The most important of these is the replacement of foreign donor priorities (e.g., poverty alleviation among the poorest of the poor; cheap food for low-income urban consumers) with those of local decision makers and farmers, particularly a supply-side emphasis on aquaculture as a commercial venture (at a variety of scales and

[3] Thematic Evaluation of Aquaculture, 1987, Rome; Expert Consultation on Small-scale Rural Aquaculture, 1996, Rome; Africa Regional Aquaculture Review, 1999, Accra, Ghana; Technical Consultation on Legal Frameworks and Economic Policy Instruments for Sustainable Commercial Aquaculture in SSA, 2001; Arusha, Tanzania; FAO/WorldFish Center Workshop on Small-Scale Aquaculture in SSA, 2004, Limbe, Cameroon.

intensities) that can serve to generate income and create secondary business opportunities and generalized economic growth (Delgado et al., 1998).

Based on these findings, Strategic Frameworks for Aquaculture Development have been completed for Cameroon, Ghana, Madagascar and Zambia as a first step in the process of more detailed planning (c.f.: MINEPIA/FAO, 2005). In this approach, the roles of the private sector, government, non-governmental organizations (NGO) and international donors are clarified (from the point of view of national government). As of early 2007, Angola, Nigeria, DR Congo and Guinea all have Strategic Frameworks in the pipeline and Uganda, Kenya, Mozambique and Burkina Faso are moving rapidly in the same direction.

Whether these initiatives to redefine the role of government in managing aquaculture development will result in any substantial changes on the ground, however, remains to be demonstrated. What is known is that, given the right combination of management, technology and investment strategy, aquaculture can make important contributions to African development. To determine the right mix of these ingredients, the objectives for the sector should be made clear.

## Aquaculture, food security and economic growth

The most obvious outcome of successful aquaculture is an increase in the amount of fish available for human consumption, either locally or globally. When aquaculture is linked to markets, synergistic business opportunities are created that can enhance its impact beyond simple fish production to include employment, infrastructure development and economic growth.

### *Food security*

An estimated 70% of Africans are both farmers and consumers of agricultural products, making their livelihoods on small-scale, mixed enterprise farms, producing food crops primarily for the family and only secondarily for sale in the cash economy (World Bank, 2000). Although rarely captured in official statistics, small-scale integrated aquaculture systems of the type promoted by governments and development agencies since the 1970s, have had substantial impact on rural food security. Systems that rely on recycled agricultural by-products and simple technology have been able to double production of small farms, albeit from a very low base (Brummett and Noble, 1995; Prein et al., 1996, 1999; Lazard, 2002).

The best available estimates of total aquaculture potential in Africa were made by FAO using a GIS model that related soil type, precipitation, evapotranspiration, seepage, slope, agricultural activities, animal husbandry activities, human population, roads, market size and temperature to established fish production parameters (Kapetsky, 1994; Aguilar-Manjarrez and Nath, 1998). The model estimated that 37% of sub-Saharan Africa is suitable for small-scale, artisanal fish farming, which if realized could have substantial impacts on household food security (Fig. 2).

The output of these mostly rural farms is consumed almost entirely by the farm family and the immediate community having important local impact on food supplies, but larger-scale commercial fish farms also contribute to food security. The most important recent trend in aquaculture as a provider of food has been the decline in prices associated with increased production. While luxury seafoods such as trout, shrimp, oysters, etc. remain accessible only to wealthier consumers, international wholesale prices for species of particular interest in Africa are down to about $1000 per MT (Fig. 3). At this price, even lower income consumers are beginning to benefit from commercial fish farming. If the estimates of Aguilar-Manjarrez and Nath (1998) are reasonably accurate, Africa has the physical potential to produce almost 300 times the amount of fish currently produced globally. If even a small percentage of this were realized, fish would be readily available to all African consumers (Lazard, 2002).

### *Profitability*

Although rarely true at the artisanal level, commercial aquaculture can produce significant profits even at a modest scale (Table 3). The key to profitability of aquaculture systems is the level of management and production intensity, that is, the number of fish that the system can produce per unit area or volume (Koffi et al., 1996; Yong Sulem and Brummett, 2006). Intensification is a function of oxygen supply, metabolic waste removal and feed inputs. Of course, not all technologies are economically viable, the marginal cost being higher than the marginal benefit. In general, production systems are maximally profitable at some intermediate level of intensification. Oxygen supply and metabolic waste removal normally require pumping and are extremely expensive to implement under most conditions of African aquaculture. Consequently, in Africa, intensity is a function of feed quality and amount fed relative to the natural rate of metabolite breakdown in ponds, or flushing in cages.

The most important culture species in Africa, Nile tilapia and sharptooth catfish, are omnivores and can consume nearly any type of organic matter available. Composts and other fertilizers are often used to boost natural fertility. Supplemental feeds, which enhance the fish's utilization of natural feeds, can be used to further increase production. As stocking rates increase beyond the capacity of the natural system to produce enough food, or in cages where natural foods are not accessible by the fish, complete (pelleted) diets are required.

Whether for food or income, aquaculture has potential to meet both local and national objectives. The tropical climate prevailing in most regions combined with highly efficient fish species and available feed inputs presents

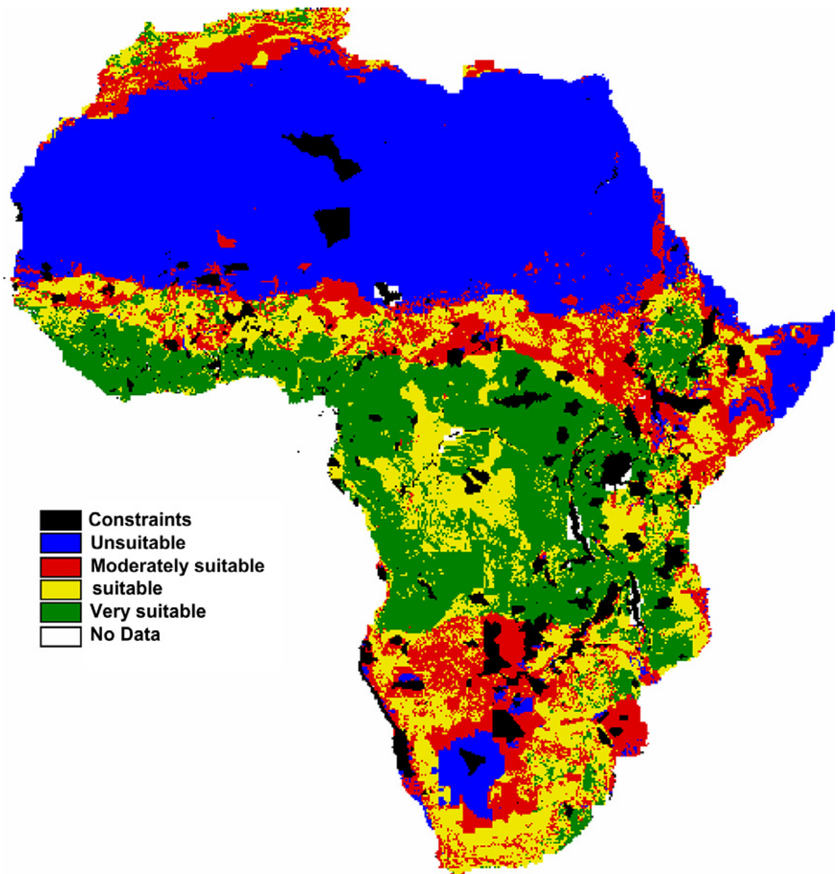


Fig. 2. GIS assessment of potential for small-scale/artisanal aquaculture in Africa (Aguilar-Manjarrez and Nath, 1998).

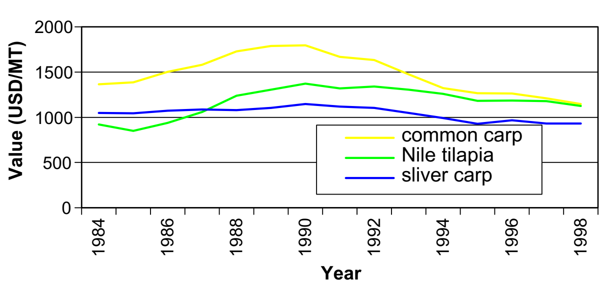


Fig. 3. Reported value of aquaculture production for some culture species used in African aquaculture (after FAO (1999)).

producers with a range of options for how to turn these natural resources into fish.

## Aquaculture technology options for Africa

Aquaculture is highly flexible and adaptable to a wide range of environments, markets and investment levels from small ponds that produce a few kg of fish for home consumption up to high density raceways or cages that can carry hundreds of kg per $m^3$.

Ponds are the cheapest and simplest systems to build and manage, the main problem being that they must be sited in areas where the soil is heavy enough to hold water and the topography has enough slope to permit complete draining without the use of expensive pumping.[4] Ponds also take up a lot of space as their carrying capacity seldom reaches 1 kg per $m^2$, being limited by the ability of the natural ecosystem to produce oxygen and absorb metabolic wastes. On the other hand, fish growing in the more or less natural environment of ponds are at relatively reduced risk of stress and disease and if properly fed can grow efficiently on a combination of low-value inputs and natural foods.

Raceways are round or elongate, usually built of cement with water flow-through or recirculation through a biofilter to add/replace oxygen and remove metabolic wastes. Raceways take up less space than ponds, are easy to harvest and can carry as much as 100 kg/$m^3$ of *O. niloticus* (Losordo et al., 2001) or 400 kg per $m^3$ of *C. gariepinus* (Hecht, 1997). However, they are expensive to build and require electricity and/or a high volume of water, although most of the water is of good quality at the outfall and can be used for other purposes. Because there are no natural foods in raceways, the fish must be fed a complete diet. In addition, the artificial environment creates the potential for disease and mechanical damage to fish living in cramped quarters.

[4] Depending upon land value and/or water supply it can be cost-effective to use plastic liners in areas where pond construction would otherwise be impossible.

Table 3
Enterprise budget (XAF) for a commercial Nile tilapia production system in Cameroon stocked at 3 fish per $m^2$ and grown from 5 to 150 g in 120 days on inputs of purchased feeds and hired labour. $1 USD = XAF 500

| | Number per cycle | Unit price | Total cost | Amortization period | Amount | Percent of total |
|---|---|---|---|---|---|---|
| Capital | | | | | | |
| Pond construction ($m^2$) | 2000 | 1000 | 2,000,000 | 10 yrs | 66,667 | 9.39 |
| Equipment | | | 100,000 | 5 yrs | 6667 | 0.94 |
| | | | | | | 10.33 |
| Stocking | | | | | | |
| Fingerlings (number) | 6000 | 25 | 150,000 | | 150,000 | 21.12 |
| | | | | | | 21.12 |
| Operations | | | | | | |
| Feed (kg) | 1027.5 | 250 | 256,875 | | 256,875 | 36.17 |
| Labour (person 8 h days) | 100 | 1500 | 150,000 | | 150,000 | 21.12 |
| Transport (return trips to market) | 4 | 20000 | 80,000 | | 80,000 | 11.26 |
| | | | | | | 68.55 |
| Total production costs (per cycle) | | | | | 710,208 | 100.00 |
| Total investment | | | | | 2,736,875 | |
| Revenues | | | | | 1,027,500 | Gross |
| Fish sales (kg) | 685 | 1500 | | | | |
| Productivity (kg/ha) | 3425 | | | | | |
| | | | | | 317,292 | Net per cycle |
| Cycles per year | 3 | | | | 951,875 | Net per year |
| Total fish production per annum ($T$) | 2.05 | | | | 34.78 | ROI |

Recirculating systems are normally based on raceway technology with a filtration system installed to remove nitrogenous wastes, add oxygen and cycle the water back to the fish. These systems are very popular in areas close to big cities where land and water are scarce and expensive. They are, however, complicated and expensive to build and operate and even short electricity failures can result in disaster. Also, being unnatural environments, the fish face the same constraints as in raceways, including the need for a complete diet.

Cages come in many shapes and sizes depending upon the availability of materials, the type of waterbody into which they are installed and the amount of money available to invest (Fig. 4). The number of cages that can be installed in any given waterbody depends upon depth, water current and wind velocity all of which contribute to the circulation of water through the cage. Fish in cages lack access to most natural foods, so production depends upon the provision of a complete pelleted diet. Cages are easy to harvest and are modular so that the system can be scaled up as the farmer gains experience and the market grows.

In smaller waterbodies, cages have a big advantage over capture fisheries in terms of resource utilization. Instead of having a mixed flock of different species and ages, caged fish are all in one place so they can be easily fed and managed. The highest natural productivity of small waterbodies is no more than 300 kg/ha. The same waterbody used for fed cages would be at least 3 tons per hectare.

*Freshwater*

All food production systems require water and conflicts over access to increasingly scarce resources is creating conflict in almost all African countries. Although plants

Fig. 4. Fish cages used for tilapia production. Left, large-scale cages of Lake Harvest, Ltd. in Lake Kariba, Zimbabwe produce 50 kg of tilapia per $m^3$. Right, small-scale cages installed by a community development project in Dzemeni, Ghana on the Volta Lake produce up to 25 kg per $m^3$. Photos: RE Brummett.

Table 4
Water requirements for some aquaculture systems of relevance to Africa (Phillips et al., 1991)

| Species | System | Production (mt/ha) | Water requirement ($m^3$/mt) |
|---|---|---|---|
| *Clarias batrachus* | Intensive, static ponds | 100–200 | 50–200 |
| *Oreochromis niloticus* | Extensive, static ponds | 0.05–0.3 | 3000–5000 |
| *O. niloticus* | Sewage, minimal exchange ponds | 6.8 | 1500–2000 |
| *O. niloticus* | Intensive, aerated ponds | 17.4 | 21,000 |
| *C. carpio*/*O. niloticus* | Conventional ponds | 3 | 12,000 |
| *C. carpio*/*O. niloticus* | Semi-intensive ponds | 9 | 5000 |
| *C. carpio*/*O. niloticus* | Intensive ponds | 20 | 2250 |
| *Cyprinus carpio* | Intensive raceways | 1443 | 740,000 |
| *Ictalurus punctatus* | Intensive ponds | 3 | 6470 |

provide more food per liter of water than animals, animals provide higher quality protein. Among animals, fish, because they are cold-blooded and float in water rather than using energy and nutrients to produce heavy bones to resist gravity, are by far the most efficient energy users. Channel catfish (*Ictalurus punctatus*), for example, gain 0.85 g of weight for every gram of feed consumed, compare to 0.48 g in chickens, the most efficient warm-blooded animal, and 0.13 in beef cattle (Lovell, 1989). Fish production, being conducted entirely underwater, would seem to be potentially one of the greater water consumers. However, consumptive use of water by aquaculture is, in theory, negligible. Also, aquaculture has the advantage over rainfed plant crops by being somewhat disconnected from rainfall periodicity. Through the use of recirculation technology and/or integration of cage aquaculture into other water use schemes, consumptive use of water can be reduced even further to the amount lost to evaporation and leakage, which, in water stressed areas are often controlled with the use of plastic liners and/or greenhouse-like covers.

Tilapia culture in ponds is growing rapidly and typically produces standing crops of 5–6 tons per hectare with a consumptive water use of about 2800 l/kg of fish produced, including the amount needed for feed production[5] (Brummett, 1997), less than the 3500 l/kg required for broiler chickens (Piemental et al., 1997). Lazard (2002) reported production of up to 15 tons/ha/year of tilapia in static water ponds in Côte d'Ivoire. In South Africa, pond-based flow-through systems can produce *C. gariepinus* standing stocks of up to 40 tons/ha/8 mos with a water exchange rate of 2–6 l/s/ha, equivalent to 3600 l/kg. Overall, commercial freshwater aquaculture, probably uses something on the order of 5000 l of water per kg of fish produced (Table 4), although most of this use is non-consumptive, being either directly usable for other purposes or indirectly usable following settling or biofiltration to remove excessive nutrients and/or suspended solids.

[5] Producing the feed used by commercial fish growers requires approximately 1.54 million liters of water to produce 1 metric ton of fish food, containing 48% soybean meal and 41% corn meal (Lovell, 1989).

### *Mariculture*

Aquaculture in marine or brackish water ecosystems can avoid conflicts with other sectors over use of freshwater, but good coastal sites for mariculture are scarce in Africa. Offshore cages of the type used in salmon farming could be deployed, particularly in the relatively calm Gulf of Guinea, but this expensive technology will only be available to the largest scale of producer and would be, for the foreseeable future, dominated by foreign investors who already have the know-how, capital and markets necessary for success. Also, piracy in all of its guises is rampant along both the eastern and western coasts of Africa and offshore floating cage installations are hard to hide.

In addition to a general lack of good sites, larval rearing is a major problem for most marine species. As the eggs and fry of marine fishes tend to be very small, they are difficult to feed and protect from predators, requiring sophisticated, usually land-based, hatchery facilities with their attendant high land values and expensive pumping costs. Also, the majority of marine fish culture candidates are carnivorous, requiring high quality (i.e., high protein with a large fishmeal component) feed. Not only is such feed expensive, but in a continent with chronic food insecurity, the decision to feed forage fish (in the form of fishmeal) to carnivores destined for high-end, usually export markets will be politically difficult to justify.

Globally, one of the most successful types of mariculture is the production of penaeid shrimps in coastal ponds, often carved out of mangrove forests. Nigeria, Guinea, Côte d'Ivoire, Kenya, Senegal, Tanzania and South Africa have all experimented, albeit largely unsuccessfully, with shrimp culture. Currently, Madagascar is the leading African producer of cultured shrimp, with annual output of 6000 tons.[6] A planned expansion of shrimp culture in Mozambique is being undertaken to take advantage of existing processing infrastructure and market development investments already made by the large (5000–6000 tons per annum, TPA) shrimp fishing fleet.

Such investments, if judiciously located, could represent viable business opportunities in some areas. However,

[6] Compared to 1.3 million tons globally (FAO, 2005a).

there is little local or regional trade in shrimp and as they have achieved commodity status in the international seafood trade, new investments will *per force* be large-scale and as intensive as possible to compete in well-developed international markets. Shrimp also require high protein/high fishmeal feeds and, as with carnivorous marine finfish, the sustainability of their production in protein-starved Africa is questionable.

As few benefits from large-scale shrimp farming are expected to return to local communities, the trade-off costs for coastal shrimp production must include the reduction of the mangrove and/or other spawning and nursing habitat of the many littoral marine fishes that form the basis of huge artisanal coastal fisheries. Most cost-benefit analyses that include social and opportunity costs have shown that coastal shrimp farming actually reduces the amount of fish in local markets as well as local economic opportunities (Primavera, 1997).

In contrast, Eucheuma and Gracillaria seaweeds take advantage of natural fertility to produce valuable export products using relatively simple technology to the benefit of the local population. In Tanzania, especially Zanzibar, 7000 tons of *Eucheuma* seaweeds are cultured by an estimated 20,000 small-scale growers in satellite production schemes operated by two large exporting companies using technology and seedstock imported from the Philippines (King, 1992). Production technology is relatively simple, being based on algae seedlings attached to a network of wooden stakes and monofilament anchored onto tidal flats. Producers can earn about twice the average income of an entry-level civil servant. With global trade on the order of 250,000 TPA (and rising) and an average wholesale price of about $900 per ton, African producers could be competitive, but good sites are scarce (King, 1992). Namibia, South Africa, Senegal, Mozambique and Madagascar have all piloted seaweed production of various types, but their total annual production does not exceed 200 tons, combined (FAO, 2005a). However, seaweeds can be effectively grown in relatively polluted waters where they have been shown to remove up to 90% of excess nitrogen, serving as an effective biofilter (Troell et al., 2005). With some modifications of the current production system, seaweed culture could be adapted for use in such areas as the heavily polluted West African lagoons.

Another group of marine organisms amenable to relatively low-tech culture techniques is the filter-feeding or algal grazing mollusks including, mussels, clams, abalones and oysters. African bivalve culture is dominated by South Africa, which by the late 1990s was producing nearly 3000 TPA of mostly Mediterranean mussel (*Mytilus galloprovincialis*) and nearly 1000 TPA of perlemoen abalone (*Haliotis midae*). Namibia, Sierra Leone, Senegal and Mauritius have pilot bivalve farming projects, but together produce less than 150 TPA. As bivalves feed on and accumulate particulate matter, including pathogenic bacteria and viruses, they must be reared in sites protected from contamination by human or animal wastes. Bacteria can be effectively removed through depuration in clean running water for 48 h. Viruses and vibrios, particularly Hepatitis A, cannot be effectively removed through depuration (Pivirotto, 1993). As with other types of mariculture in Africa, the main constraint to the expansion of bivalve mariculture is the shortage of suitable sites, in particular, protected bays away from sources of human pollution.

## Investment strategies

Although there exists a wide range of aquaculture systems with theoretical application in Africa, the vast majority of systems fall into one of four categories: extensive, artisanal, small/medium-scale commercial and large-scale commercial. All categories of aquaculture have the potential to be profitable and sustainable and which category to promote needs to be evaluated against the overall objectives for the sector.

### *Extensive aquaculture*

All over the continent, rural communities utilize small waterbodies, either temporarily or permanently, for fish production. Often, this simply involves the periodic capture of wild fish, but increasingly, productivity is being enhanced through the use of stocking or other aquaculture practices. In the Guinea rainforests, for example, controlled stocking of small dams (2000–10,000 $m^2$) with or without fertilization is being used to increase typical background productivity of normally no more than 100 kg/ha up to between 600 and 2500 kg/ha/yr (APDRA-F, 2007). In the Lower Shire River valley of Malawi local communities stock otherwise fishless temporary waterbodies, locally known as thamandas, with fingerling tilapias and catfishes, producing an average of 600 kg/ha (range 300–1575 kg/ha) in a 2–3 month growing season (Chikafumbwa et al., 1998).

In Burkina Faso, traditional reservoir management systems have evolved in the direction of restocking after annual drying with fingerlings of *O. niloticus*, *Labeo coubie* and/or *C. gariepinus* produced through artificial reproduction of adults captured at harvest and held over the dry season (Baijot et al., 1994), increasing productivity from 50–100 kg/ha/y up to over 600 kg/ha/yr. In Niger, natural temporary waterbodies stocked with *C. gariepinus* can produce up to 200 kg/ha/year depending on rainfall, returning an average of $1400 per person per year to the fish farmers/fishermen involved in their management (Doray et al., 2002). In Southern and Eastern Africa, there are between 50,000 and 100,000 small dams producing between 1 and 3 million tons of fish per year, most of which is consumed by rural communities (Haight, 1994).

These types of decentralized fish production systems could have broad applicability across Africa's vast dry savannah area, including all or parts of virtually every African country. While such extensive aquaculture may not be the most productive in terms of fish output, the additional benefits of water table replenishment, flooding and erosion control and possibilities for multiple uses such as livestock watering, irrigation and capture fisheries could return substantial benefits to local communities and help in the fight against desertification (Roggeri, 1995), if ownership and management arrangements can be negotiated among the various and sometimes disparate user-groups (Fig. 5).

### *Artisanal farming systems*

Over 90% of African fish farmers operate one or a few earthen ponds of generally less than 500 $m^2$ in surface area, constructed and operated with family labour (King, 1993). These ponds typically produce between 300 and 1000 kg/ha (15–50 kg per crop), on an annual harvest cycle usually corresponding to fingerling availability, water supply or local demand. About half of the output from these systems is consumed by the family and half sold or bartered to neighbours. Little of the crop is sold for cash, either due to lack of access to wealthier markets or out of a need to meet more local food security priorities (Brummett, 2000). In these systems, the fishpond plays a role similar to that of the chicken coops, pig stys, fruit tree orchards, herb gardens and other micro-enterprises undertaken by smallholders to generate small amount of cash for emergencies, school fees, etc. (Satia et al., 1992).

Few of the inputs for artisanal aquaculture are purchased, productivity being based almost entirely on composts, manures and other organic materials found on the farm and recycled through the pond. The best fish productivity in such systems in Malawi, where they have been intensively studied, is about 1500 kg/ha/yr, mostly of small tilapias (Brummett and Noble, 1995). These "farmponds" are generally integrated into other food production systems such as vegetable gardens where they serve as sources of emergency irrigation water and as bio-processors for by-products and wastes, turning low quality materials into valuable fish at minimal cost. In Malawi, farms with integrated fishponds produce almost six times the cash generated by the typical smallholder (Brummett and Noble, 1995). Similar systems exist throughout the continent, producing thousands of tons of fish annually for rural families.

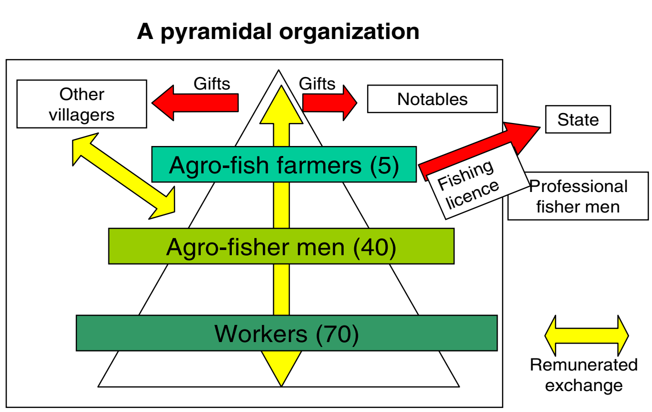


Fig. 5. Social organization for extensive fish farming in Tafouka lake, Dosso Department, Niger (Mikolasek et al., 1999).

Diversifying a smallholding by integrating aquaculture can also affect the ecological sustainability and economic durability of small farms. In Malawi, a serious drought from 1991 through 1995 had a major negative impact on smallholding agriculture. Yet in all cases studied, even though staple crops failed and farmers lost money, the integrated fishpond sustained the farm. By retaining water on the land, ponds enabled farmers to continue food production and balance economic losses on seasonal cropland. For example, in the 1993/94 season, when only 60% of normal rain fell, average net cash income to integrated farms was 18% higher than to non-integrated farms (Brummett and Chikafumbwa, 1995).

In areas with high population pressure, integrated aquaculture systems can help keep people alive and on the land producing food for themselves and their communities. However, as they generate minimal cash revenues and therefore no liquid capital for reinvestment and expansion, especially the purchase of inputs, they create little or no economic growth (Delgado et al., 1998).

### *Small and medium-scale enterprises (SME)*

With millions of small and medium-scale farmers in Africa and a limited number of viable cash-crops, markets for coffee, tea, cacao, bananas, etc. are often saturated. Many of the more entrepreneurial farmers have seen the potential to diversify their cash-crop investments by shifting some capital out of these traditional cash-crops to aquaculture. These farmers build more ponds, use higher technology, employ hired labour, purchase fingerlings and/or inputs (esp. feeds and/or fertilizers) and understand the concept of cash-flow. Rather than eat or give their fish away, they transport them to a town or city (almost always a local or regional market, never export) where wealthier consumers pay cash. The main difference, however, between SME and artisanal farmers is motivation; artisanal farmers primarily seek food security and farm diversification, while SME farmers seek cash, often at the expense of diversity and, sometimes, sustainability (Brummett et al., 2005).

SME exploitations, being in the minority and surrounded by artisanal farmers, are subject to the plethora of social levelling mechanisms common in rural African communities and are usually obliged to sacrifice a percentage of their production (±30% in Cameroon according to Brummett et al. (2005)) to maintain their position in local society and minimize the threat of theft and/or sabotage (Harrison et al., 1994). Other constraints include high transportation costs (for farmers distant from wealthier urban markets) and the lack of marketing infrastructure, especially ice plants and clean facilities, which limit the ability of producers to negotiate decent prices as fish start to decay towards the end of the day (Brummett, 2000).

In South Africa, the SME segment of the aquaculture sector is relatively well-developed and is represented by the Aquaculture Association of Southern Africa (www.aasa-aqua.co.za), which produces a newsletter and holds regular meetings funded by a growing number of secondary beneficiaries of aquaculture development, including banks, feedmills and processing plants. It also facilitates information dissemination, funds research and lobbies government on behalf of the industry. Over 4000 TPA of sharptooth catfish and bilvalves (mentioned above), rainbow trout (*Oncorhyncus gairdneri*), tilapia (*Oreochromis mossambicus*) and a number of ornamental fishes are produced for local markets. Several experimental species (e.g., Australian freshwater crayfish, *Cherax* spp., and abalone, *Haliotis* spp) are also being piloted for commercial culture.

Aquaculture SME's are also expanding in Nigeria where over 2000 farms with an estimated 60,000 ha under water produce 25–30,000 TPA (AIFP, 2004), mostly of sharptooth catfish, which are highly prized in the Nigerian market (Moehl, 2003). According to the farmers, this remarkable growth was achieved with virtually no support from the Nigerian national aquaculture research and extension services.

Even more recently, small and medium-scale aquaculture investments have been growing in Cameroon, Ghana, Uganda, Angola, DR Congo, Zambia and Kenya. Once a node of (mostly French) donor-assisted SME development, Côte d'Ivoire has, since the coup d'état in 2000, reverted to mostly artisanal production.

In general, however, SME's have received little attention from African governments and even less from international donors, as they are not perceived to represent "the poor". They also tend to shy away from group activities where the economic viability of their operations might be compromised by the need to include unproductive partnerships. In fact, they often tend to make themselves scarce when development agents come to town and so are seldom included in surveys. In as much as they often own more successful farms, they are indeed wealthier than many of their neighbours. On the other hand, one could argue that the best farmers ought to be taking the lead in development, rather than being excluded because they do not agree with the prevailing development paradigm.

### *Large scale commercial*

There are a few successful large-scale, commercial aquaculture investments in Africa, most notably in Tanzania (racks, seaweeds, export), Mozambique (ponds, shrimp, export), Zambia (ponds, tilapia, local markets), Zimbabwe (cages, tilapia, export), Ghana (cages, tilapia, local markets) with new investments coming on line in Uganda (cages, tilapia, export) and Kenya (cages, tilapia, local markets). Most of these have been built using foreign or foreign-earned capital and rely on foreign or foreign-trained technical expertise. Although all are not yet at full capacity, these farms each have planned production in excess of 1000 TPA and are targeting markets in larger African cities and/or the ever-growing international tilapia trade. All are vertically integrated to one extent or another, including feed manufacture, fingerling production, selective breeding programs, processing plants, retail sales outlets (local and overseas) in addition to production facilities.

Currently dominating this sector are cage-based tilapia systems using modified[7] Scandinavian salmon cage technology, most notably in Volta Lake and Lake Kariba. The largest of these is Lake Harvest, Ltd. based in Kariba, Zimbabwe where 3000 TPA of 750 g tilapia are grown in 500 $m^3$ cages at a density of 50 $kg/m^3$ (Fig. 4a). The company works with local feed manufacturers to ensure high quality feed supply, operates its own hatchery and selective breeding facility and owns a state of the art processing plant which produces fresh fillets for air shipment to luxury markets in Europe. The capital cost for construction and run-in, most of which was met by the Commonwealth Development Corporation, was in the region of $10 million. Sadly, current government policy in Zimbabwe works against the profitability of export-oriented agriculture and Lake Harvest is now diversifying its holdings into Uganda where the business climate is more conducive.

Most African governments welcome large-scale aquaculture investments as employers, foreign exchange earners and, for those targeting local markets, fish suppliers. Access to land and water resources is generally good and most environmental regulatory bodies have been willing to negotiate permits. Although some of the big farms are reluctant to cooperate, most have shown a willingness to get involved in the broader development of the sector, contributing actively to government planning, initiatives aimed at providing assistance to smaller fish farms and/or other types of development activities. In Tanzania for example, the seaweed industry is based almost entirely upon satellite producer schemes that provide jobs for thousands of rural growers. On the downside, aquaculture production systems are not highly labour-intensive, requiring between 0.05 and 0.1 person-year per ton of fish produced. While this may be an important incentive for producers, maximizing the economic growth potential of aquaculture will require that governments interested in rural poverty alleviation encourage the development of an horizontally integrated aquaculture industry where technical assistance providers, feed growers and manufacturers, equipment and input suppliers and marketing chains create additional employment and business opportunities.

## *Constraints to growth*

For the food security and economic growth benefits of aquaculture to be fully realized, several key constraints to its widespread development must be addressed. Constraints to aquaculture development in rural Africa are similar to

[7] For example, the use of special netting material that can resist the teeth of the predatory tiger fish, *Hydrocynus vittatus*.

those facing other commercial enterprises: poor infrastructure (Coche et al., 1994), lack, or volatile prices, of essential inputs (Williams, 1997), political instability (UNDP, 1998), poor market development (Hecht, 1997; Masser, 2000) and lack of the necessary R&D to backstop industrial growth (Lazard et al., 1991). In addition to these general macro constraints, specific constraints related to aquaculture production and commercialisation have been identified by Moehl et al. (2005) as

- unavailability of good quality fingerlings for stocking,
- unavailability of complete feeds,
- inadequate access to technical information,
- lack of marketing infrastructure, information and organisation, and
- inappropriate policies.

*Quality fingerlings*

Many of the fish being grown on African farms are of poor genotypic and/or phenotypic quality. Tilapias are especially prone to bad hatchery management, which can result in cultured fish that perform an average of 40% worse than wild fish (Brummett et al., 2004b). These problems are exacerbated when alien species are produced from a small number of imported broodfish (Brummett, 2004).

From a competition point of view, most tilapia producers outside of Africa are growing selectively bred or otherwise improved strains that grow nearly twice as fast as African wild stocks. For African farmers to be competitive they must be growing high-quality fingerlings. However, concerns for biodiversity have limited the importation of faster growing species and/or strains to a few places where private farmers have opted to ignore the rules.

To make African fish farmers more competitive and reduce the environmental risks inherent in the importation of alien species or strains, breeding programs for suitable indigenous species need to be established.

*Feed*

Suitable materials for fish feed manufacture are available in most African countries (Moehl and Halwart, 2005) but feedmills are few and far between and demand is generally insufficient to justify industrial scale production. Because of high transport costs and quality issues with locally manufactured diets, pelleted feeds imported from Europe are sometimes cost-efficient and are being used by farmers in Nigeria and Ghana. Farm-made aquaculture feeds are labour-intensive and require the farmer to collect and store sometimes large quantities of often foul-smelling and partially liquid materials, which attract rats and drive away neighbours. The use of chemical or dried organic fertilizers offers options for some farmers, but at the cost of reduced productivity.

*Technical assistance*

Due primarily to low levels of investment, extension services are weak in most African countries. The problem is exacerbated by the widespread adoption of the expensive Training and Visit (T&V) system, which requires heavy investments in training and backstopping in order to put adequately qualified subject matter specialists into the field. Privatised extension systems face the same problem.

In recent years, alternative extension approaches that rely more on joint learning and evolutionary adoption have been tested and these might solve some of the problems currently faced in making productive technology available to fish farmers (Shivakoti et al., 1997). One such approach, specifically designed for aquaculture, employs Research-Extension Teams (RET) linking research scientists with extension agents to work with farmers to evolve solutions to problems *in situ*. Tested in Cameroon, the provision of RET services helped farmers increase their yields from 498 kg/ha up to 2525 kg/ha at an average cost of $915 per rural farmer per year in salaries, equipment and vehicle operation/depreciation. In periurban areas where transportation was less expensive and phones could be used to contact farmers, costs averaged $143 per farmer per year (Brummett et al., 2005).

*Markets for inputs and outputs*

Aquaculture input markets are plagued by a chicken-or-egg conundrum: aquaculture credit institutions, hatcheries and feedmills cannot be profitable without an adequate number of fish farms to buy their products, and fish farms cannot be profitable without adequate supplies of credit, reasonably priced fingerlings and feed. For small and medium-scale investors, fingerling and feed availability are often linked to the lack of credit and most rural credit schemes have failed to achieve sustainability (largely due to the habit among artisanal farmers of not paying back loans).

To get out of this loop, a number of interventions have been tested including the direct intervention of government, the formation of cooperatives, the development of private-sector satellite schemes and the engagement of non-governmental (NGO) to serve as intermediaries. Some of these approaches have shown promise, but none have been sufficiently successful to be broadly recommended.

Local and regional marketing infrastructure for the sale of foodfish produced is a key constraint, especially for SME and even some larger-scale systems. Bad roads, police harassment, absence of storage facilities (e.g., ice) and unsanitary market stalls seriously limit the ability of producers to get fair prices for their fish. Consumers also suffer from shortfalls in supply and less than perfect quality in the fish they eat.

*Security of investments*

The shortage of realistic government policies serves to limit the growth of aquaculture by increasing the uncertainty and risk of investments. While larger-scale investors can negotiate with central government over permits and access to specific water resources, smaller-scale operators are generally obliged to work with traditional local authorities for land and/or water. At startup, this is not particularly difficult as most chiefs would like to see development of unused resources and are often willing to grant significant concessions, even to outsiders. However, once an investment becomes profitable and attracts the attention of the community, traditional leaders and village notables have been known to resort to extortion and appropriation to reduce conflict, or more typically, increase their personal share of the profits.

## Realizing the potential

There have been a number of reviews of African aquaculture conducted over the last 20 years and all of these have come to more or less the same conclusion: aquaculture is a viable economic and livelihood alternative at a range of levels and intensities, but African governments and international donors have failed as primary motivators in its sustainable development. Part of this is due simply to the short funding cycles preferred by donors coupled to the general incompetence and corruption of many African governments, which feel responsible for all aspects of the lives of their citizens, but have neither the knowledge nor financial assets to implement meaningful interventions.

Equally important, however, is the mismatch between the priorities of donors, governments and farmers. There is the need for policy makers who sincerely want to help aquaculture grow to prioritise the immediate needs of producers over those of consumers. Negative pricing policies that keep agricultural products cheap have plagued African agriculture for many years and undermine growth in virtually all sectors. In most cases, this will mean targeting SME investments that generate revenues both directly and through the value chain.

For the vast majority of Africa's farmers, artisanal, integrated aquaculture systems can offer substantial benefits in terms of diversifying and stabilizing farm output to ensure family food security. Water storage in fishponds or small dams used for cage aquaculture can play a critical role in seeing vulnerable farms through the cyclical droughts that plague Africa. However, the best farmers tend to take a business-like approach and only by enabling the growth of profitable commercial aquaculture will fish supplies increase, ultimately bringing prices down to the point where quality fresh fish become accessible to all consumers.

In the face of ineffective extension and the absence of donor support for SME investments, several African countries (e.g., Zimbabwe, Uganda, Ghana, Angola) have turned to large-scale, foreign-backed aquaculture in order to meet short-term food security and forex generation targets. While these farms are making positive contributions to national objectives, far more employment and general economic development are generated by small and medium-scale enterprises. Getting people out of poverty is a function of income growth, however the distribution of wealth is crucial to the rate at which income growth by investors is translated into national poverty reduction. A 1% increase in Gross National Income (GNI) in economies with high inequality (Gini coefficients of ~0.6) reduces poverty by only 1.5% per annum. With more equitable distribution of wealth (Gini coefficients ~0.2), the same increase can reduce poverty by twice as much (Lustig et al., 2002). By inference, if investing in the economy is dominated by the upper 20% of the population, at least twice as much income growth is needed to significantly reduce poverty than if investment is driven by investments made by the lowest 20% of the population. Most analysts (e.g., Delgado et al., 1998; Winkelmann, 1998) agree that large-scale systems have relatively less economic impact and tend to concentrate wealth more than would a larger number of smaller-scale investments. Consequently, for aquaculture to meet local, national and international objectives of food security and poverty alleviation, governments, donors and development agencies should strive to

1. support the development and implementation of Strategic Frameworks for Aquaculture Development to clarify the roles of various stakeholders and establish the foundation for realistic and practicable legislation,
2. in light of the expense and low expectations for economic growth achievable by dispersed artisanal farmers, target extension and research at the growth of an horizontally integrated SME aquaculture sub-sector that can maximize the number of secondary economic opportunities created through the aquaculture value chain,
3. help make credit available to SME investments, e.g., through loan guarantees,
4. include NGOs and farmers' organisations as partners in the delivery of key services such as marketing, feed and fingerling supply,
5. engage larger-scale farms through, for example, tax and or credit initiatives to participate actively in the development of the sector and help create opportunities for other, smaller-scale, investors,
6. invest in marketing infrastructure such as roads, retailing facilities and ice plants; reduce the arbitrary interference of law enforcement authorities in legal commerce,
7. invest in research to test the feasibility of cage culture in the Gulf of Guinea and seaweed farming in in-shore polluted waters,
8. establish standards for environmental impact assessment, especially for cages in lakes and larger waterbodies, and
9. create, through selective breeding, realistic options (to the importation of alien species/strains) for improving the quality of fish currently cultured.

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