PART 2

REGIONAL SYNTHESES, COUNTRY CASE STUDIES AND THEMATIC REVIEWS AND CONTRIBUTED PAPERS ON FRESHWATER FISH SEED RESOURCES FOR SUSTAINABLE AQUACULTURE

6. REGIONAL SYNTHESES

6.1 Freshwater fish seed resources and supply: Africa regional synthesis

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ABSTRACT

The availability and quality of fingerlings for stocking in aquaculture ponds have repeatedly been identified as a key constraint to the development of aquaculture in Africa. Government hatcheries have generally failed to achieve sustainability and the private sector is impeded by the lack of marketing information and appropriate technological assistance. At present, the main aquaculture species in the continent are Nile tilapia (*Oreochromis niloticus*) and the African sharptooth catfish (*Clarias gariepinus*). While the tilapias are easy to reproduce on-farm, poor broodstock management had resulted in reduced growth rates in many captive populations. Catfish are mostly reproduced in hatcheries, but availability of broodstock and high mortality rates in larvae are key problems still requiring research. Of the countries reviewed, Egypt (1.2 billion tilapia and 250 million carp fingerlings produced) and Nigeria (30 million fingerlings produced) report the highest number of modern private commercial hatcheries, although most of these are unregulated and lack accreditation and certification systems. Ghana, Cameroon, Uganda and Zimbabwe rely almost entirely on semi-commercial systems producing unreliable quantities and quality of seed. Interventions to improve the quality of extension services, make credit more available and build partnerships between public and private sectors to address key researchable topics are recommended to improve the availability of fish seed to African fish farmers.

INTRODUCTION

The availability and quality of fingerlings for stocking in aquaculture ponds have repeatedly been identified as a key constraint to the development of aquaculture in Africa (FAO 2000, 2001; Moehl and Halwart, 2005). However, in most African countries, would-be hatcheries find themselves in a conundrum: achieving profitability for the fingerling producer is impossible without an adequate number of grow-out farms to purchase fingerlings while, at the same time, the profitability of grow-out depends largely on the availability of good quality fingerlings when needed. Clearly, some external interventions are needed, either in the form of cash injections to help farmers through run-in, or provision of fingerlings through externally financed

TABLE 6.1.1
Authors of country case studies

Country	Author
Cameroon	Randall Brummett, WorldFish Center, Yaoundé
Egypt	Magdy A Saleh, General Authority for Fish Resources Development, Cairo
Ghana	Patricia Safo, Crystal Lake Fish, Ltd., Akosombo
Nigeria	Akintunde Nureni Atanda, Aquaculture and Inland Fisheries Project, Abuja
Uganda	Wilson Mwanja, Fisheries Department, Entebbe
Zimbabwe	Patrick Blow, Lake Harvest Aquaculture, Ltd., Kariba

hatcheries. For many years, foreign donors have invested hundreds of millions of dollars in the construction of government-run hatcheries throughout the continent, largely to no avail. Efforts are now underway to understand past failures and generate new initiatives to overcome these key constraints. This report synthesizes country case studies executed in Cameroon, Egypt, Ghana, Nigeria, Uganda and Zimbabwe (Table 6.1.1) and strives to indicate directions for new investments on the part of governments and international development agencies.

STATUS OF AFRICAN AQUACULTURE

Although there are several indigenous aquaculture systems in Africa, what we might call modern style aquaculture based on drainable ponds, raceways or cages began under the colonial administrations of the late 1940s. Research and extension to develop culture technology for a number of species was established and hundreds of thousands of ponds were constructed. In the 1960s, most newly independent African governments dropped support to aquaculture and many of the fishponds built up to that point were abandoned. In the 1970s, 1980s and 1990s, aquaculture, as a tool in rural development, was adopted by a number of international donor agencies, the major focus being on small-scale/low-tech systems that could easily integrate into traditional farming methods. In many cases, donor-funded aquaculture projects saw important success, although most positive impacts were short-lived and ended within a couple of years after donor support was withdrawn. Currently, African aquaculture contributes less than 1 percent to global production, with only larger-scale investments in Egypt, Ghana, Nigeria and Zimbabwe producing significant quantities of fish.

While African capture fisheries have been (over) exploited to their maximum 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 percent of total animal protein intake in the form of fish (compared to 25.7 percent in Asia). Even though total fish supplies have increased, they have not kept pace with population and Africans currently consume an average of 7.7 kg/per/yr (6.4 million tonnes total) down from a peak of over 9 kg (4.6 million tonnes total), in the early 1980s. Just to get back to 1982 consumption levels, there is a 1.3 million tonnes shortfall in supply. Nevertheless, in 15 African countries, fish represent over 30 percent of animal protein consumption (FAO, 2005) as shown in Table 6.1.2.

WATER RESOURCES FOR AQUACULTURE

Most African countries rely on surface freshwater for aquaculture, with the vast majority of the continent's many small farmponds being filled by diverting small watercourses.

TABLE 6.1.2
Animal protein consumption (percentage) of 15 African countries

Malawi (44.2 %)	Equatorial Guinea (58.2 %)	Angola (35.7 %)
PR Congo (45.3 %)	Ghana (58.6 %)	Côte d'Ivoire (36.0 %)
Gambia (47.3 %)	Sierra Leone (66.4 %)	Senegal (37.5 %)
Uganda (31.6 %)	Tanzania (32.8 %)	Togo (39.7 %)
Guinea (34.9 %)	Cameroon (49.0 %)	Nigeria (40.0 %)

Increasingly, cages placed in large waterbodies are favoured. Substantial mariculture is limited to mussel farming in South Africa and seaweed culture in Tanzania.

Cameroon is a water-rich country with some 35 000 km^2 of aquatic habitats representing many of the key aquatic ecosystems that prevail over the continent: large natural lakes (Lake Chad), reservoirs on dammed rivers (e.g. Lagdo, Mape, Bamindjing), crater lakes (e.g. Barombi Mbo, Nyos), large rivers (e.g. Benue, Sanaga, Cross, Mungo, Wouri, Dibamba), rainforest rivers (Nyong, Ntem, Kienke, Ndian, Lobe, Lokoundji) and thousands of kilometers of first and second order streams (representing 86 percent of total freshwater resources).

In Egypt, except for some well-based farms in the Western Desert, virtually all of the water used in aquaculture comes from the Nile River, consequently most fish farms are located in the Nile Delta, especially the northwest near the town of Kafr el Sheikh. As a generally water-poor country, Egypt prohibits the first use of water for aquaculture, requiring fish farmers to access drainage water coming out of agriculture irrigation systems, creating potential problems with purity and contamination with sewage and agricultural chemicals.

About 70 percent of the total land area of Ghana is drained by the Volta river system, including the Volta Lake, which covers some 8 500 km^2 plus 1 684 km of tributaries, including the Oti, Pra, White Volta, Black Volta and Asukawkaw rivers. Outside of the Volta system, the major inland water resources include the Densu, Ayensu, Okye, Kakum, Pra, Ankobra, Tano and Bia rivers and Lake Bosumtwi. Some 89 coastal, brackishwater lagoons also have potential for fish farming.

Nigeria has abundant riverine and lacustrine resources that could be used for aquaculture, but most fish farms are located in the southwest to be close to the big markets in Lagos and Ibadan. In these areas, competition for water is rampant, with many industrial and domestic users all fighting over limited resources. In response, the Nigerian aquaculture industry is intensifying with increasing use of recirculation/biofiltration systems.

Uganda also has many water resources that could support aquaculture, with 31 of 56 districts having been identified as suitable for fish farming. An estimated 650 hectares are currently under aquaculture. In addition, 43 small lakes and dams (1 476 km^2 total surface area) are being used for extensive, culture-based fisheries. Lakes Victoria and Kyoga have been identified as potential sites for intensive, commercial cage-based tilapia and/or Nile perch farming systems.

Zimbabwe is a generally dry country, so most of the aquaculture is based in the Eastern Highlands (Nyanga) and the large, man-made Lake Kariba. There are only six aquaculture installations, three producing tilapia and three growing trout. While some 800 tonnes of tilapia products are sold on the local market each year, aquaculture in Zimbabwe is primarily an export and/or luxury market business.

FISH SPECIES IN AFRICAN AQUACULTURE

Because of the continent's long and diverse geological history, Africa is home to a wide variety of indigenous and endemic species; at least 3 200 freshwater having been reported (FishBase, 2004). Since the 1940s, dozens of these have been evaluated as aquaculture candidates at a number of research stations:

- Djoumouna (PR Congo)
- Landjia (Central African Republic)
- Foumban (Cameroon)
- Bouaké (Côte d'Ivoire)
- Sagana (Kenya)
- Abbassa (Egypt)
- Anamalazaotra and Ampamaherana (Madagascar)
- Kipopo (DR Congo)

- Kanjasi (Uganda)
- Chilanga (Zambia)
- Henderson (Zimbabwe)
- Akosombo (Ghana)
- Domasi (Malawi)
- Port Harcourt (Nigeria)

The main indigenous species for which reproduction and practical grow-out techniques were established were the tilapias (especially *Oreochromis niloticus, O. mossambicus* and *O. aureus, Sarotherodon galilaeus, S. melanotheron, Tilapia rendalli*), the catfishes (esp. *Clarias gariepinus*, *Heterobranchus longifilis* and their hybrid often referred to as "Heteroclarias") and the African boneytongue (*Heterotis niloticus*). In addition, most of the main international aquaculture species have been imported and tested for African aquaculture at one time or another, but only the rainbow trout (*Onchorhyncus gairdneri*) and common carp (*Cyprinus carpio*) have really stuck, probably due to their relative hardiness. A number of Chinese carps are reportedly produced in Egypt, but mostly for weed and disease control rather than as table fish.

At present, the main aquaculture species on the continent are the Nile tilapia (*O. niloticus*) and the African sharptooth catfish (*C. gariepinus*). Both of these are indigenous to the Sudano-Nilotic Ichthyological Province that dominates northern Africa, but are not naturally found elsewhere. Somewhat unfortunately, both of these are also highly invasive, "weeds" capable of taking over ecosystems when they escape from aquaculture facilities (which they always eventually seem to do). Following the publication of the Codes of Conduct for Responsible Fisheries (2002), The Nairobi Declaration on The Conservation of Aquatic Biodiversity and Use of Genetically Improved and Alien Species Aquaculture in Africa (2002) and the Dhaka Declaration on Ecological Risk Assessment of Genetically Improved Fish (2003), the fear that these fish will get out and ruin biodiversity has led African governments to more or less ban further imports of alien aquaculture candidates, pending more research into potential environmental impacts.

SEED RESOURCES AND SUPPLY

Since its inception in Africa, aquaculture has relied on two main sources of fingerlings: unregulated spawning in production ponds and government hatcheries. For some species, such as *Heterotis niloticus, Chrysichthys nigrodigitatus*, *inter alia,* fingerlings are captured from the wild. Lack of fingerlings where and when they are needed by fish farmers is one of the greatest constraints to aquaculture expansion in the continent. A summary of case study of countries is shown in Table 6.1.2.

Cameroon

In Cameroon, 32 national fish stations were designed with the primary objective of producing fingerlings to support the growth of aquaculture.

Although these stations are largely dysfunctional, some of the most important of them possess considerable infrastructure and potential for contributing to aquaculture development if either properly managed or transferred to the private sector. As these government stations have failed to alleviate any of the main constraints to aquaculture, fish farmers have increasingly turned to other suppliers for information and fingerlings. Over 90 aquaculture non-governmental organizations (NGOs) include aquaculture in their remit and a few have attempted to operate small hatcheries to supply their members with seed. At present, five private hatcheries (three catfish, two tilapia) are the main suppliers of high-quality fingerlings in the country, producing some 1.4 million catfish and 3.3 million tilapia per year.

Egypt

In Egypt, the large and diversified aquaculture industry makes data collection extremely difficult. Virtually all of the fish cultured in Egypt come from hatcheries. For tilapias, some farms maintain their own capacity, but the majority of seed come from private hatcheries. To reach the recorded 190 000 tonnes harvest of cultured tilapia, an estimated production of 1.2 billion fingerlings would have been produced. Production from government and licensed private hatcheries in 2004 was only 150 million fingerlings, the balance having been produced elsewhere. As current demand strongly outstrips supply, hatcheries are more and more frequently selling fry as small as 0.5-1.0 g, leaving growers to nurse them up to stocking size. Carp (*Aristichthys nobilis, Ctenopharyngodon idella, Cyprinus carpio, Hypophthalmichthys molitrix, Mylopharyngodon piceus*) seed are produced almost exclusively in government hatcheries, for stocking in ricefields and the country's extensive network of irrigation channels for control of bilharzia snails, macrophytic weeds and abundant algae blooms hatcheries and nursery stations. A total of 250 million carp seed were reportedly produced and stocked in 2004.

Ghana

In Ghana, the major constraints to successful aquaculture among producers are the poor and erratic quality of fish seed available for stocking. Two major factors influence the cost of fish seed: the high cost of production from government breeding centres and insufficient supply. Pilot tilapia hatcheries have been established in Accra (1993), Akosombo (1996) and Kumasi (1997). The Accra centre, with a target of 180 000 seed/year, produces a paltry 40 000. The Kumasi centre with a target of 100 000 seed/year produces only 4 000 seed/year. The Akosombo centre, operated by the Water Research Institute, is better regularly meeting its production target of (a very modest) 100 000 seed/year. Shortfalls in achieving production targets are attributed to predation, cannibalism theft and storms killing brooders. Though fish seed prices are subsidized by government, poor production keeps costs high.

Nigeria

The supply of fish seed in Nigeria can be from either of two sources, i.e collection from natural waters (wild sources) and from hatchery production based on controlled spawning. Fingerling collection from the wild is found to be unreliable, because it is seasonal and usually contains mixed species, some of which do not meet the criteria of good aquaculture candidates. The correct age of fish and fingerlings are difficult to determine. This has led to the dependence on hatchery-bred fish with known history. Several fish hatcheries have been established in the country with most of them in the south. The tilapias are usually allowed to spawn naturally in ponds and tanks, while the mud catfishes and carps are subjected to hormone-induced spawning. These practices require a lot of skills and these have been transferred to various interested practitioners through short courses in fish seed multiplication around the country. The earliest of such training programmes by the Federal Department of Fisheries was assisted by FAO between 1978 and 1981, when two Fish Seed Multiplication and Fish Farming Demonstration Centres were established at Panyam Fish Farm in Plateau State (north central Nigeria) and Oyo Fish Farm (southwest). Regular on-farm, hands-on training were organized for prospective fish farmers and fish seed producers at these centres. Two additional centres were later established at Umina-Okigwe (southeastern Nigeria) and Mando Road, Kaduna (north western Nigeria).

The characteristic feature of the current phase of aquaculture development in Nigeria is the emergence of private sector investors as the driving force. This is also complemented with government policy of divesting its farms to the private sector. Most recent investment in aquaculture has been targeted towards catfish farming.

Presently live catfish attract premium price in Nigeria, with a high ROI (return on investment) of between 30 to 40 percent in some very successful enterprises. This holds the major attraction to the private sector investors in Nigeria. Currently about 90 percent of farmed fish in Nigeria is catfish while in the last four years almost all hatchery infrastructure and table fish production systems have been exclusively targeted towards the production of catfish.

It is estimated that fish seed production has jumped from 3 million in 2000 to about 30 million in 2005. The emergence of high volume producers who have invested in intensive re-circulating and flow-through fish production systems have been largely responsible for the phenomenal increase in the volume of production of both fingerlings and table fish.

The total estimated total current investment in aquaculture including hatchery facilities in Nigeria is put at N$10 billion (US$75 million). There are about 30 small-, medium- and large-scale intensive, closed recirculating and flow-through systems in Nigeria especially in the southwest and south-south zones where over 77 percent of all fish farms and hatchery infrastructure are located. Investments are still growing, especially with the renewed awareness being created by the government through the Presidential Initiative on Fisheries and Aquaculture and the recent continental New Partnership for Africa's Development (NEPAD) Fish for All Summit held in Abuja, Nigeria.

Of the 2 642 private fish farms that have been inventoried by the Aquaculture and Inland Fisheries Project (AIFP) in December 2004, about 500 are commercial, although most of them are poorly managed. More than half of the 500 commercial fish farms have small- to medium-sized hatcheries built beside them and again most of these are either abandoned and at best under producing (at times not more than 5 percent of installed capacity). Abandonment has been due largely to the technical incapabilities of the hatchery managers, as most of them are either poorly trained or inadequately remunerated and in other cases, both.

Presently seed supplies from government and public sectors, hatcheries (including research institutes and universities) are about ten percent of the total. The current picture of seed supply in Nigeria is as follows: private sector farms and hatcheries about 80 percent (24 million), public sector about 10 percent (3 million), collection from the wild about 9 percent (2.7 million), importation and other sources about 1 percent (0.3 million).

Uganda

Uganda's current seed production industry can be categorized into three groups: small-scale, medium-scale and large-scale. The small-scale hatcheries produce largely for rural communities and are usually limited by capacity to supply seed to the district in which they occur. The small-scale hatcheries are those considered to produce less than 200 000 fingerlings of any one species a year or those producing not more than 300 000 fingerlings in total a year. The second category is medium-scale - this category targets emerging commercial grow-out farmers and produces seed that can be sold beyond district of production. Many of the medium-scale producers came up during the government's programme of stocking and restocking of water bodies and have since transformed into commercial hatcheries. Medium-scale hatcheries produce between 300 000 to 1 million fingerlings a year. Large-scale hatcheries are only starting to come up and they are categorized as those that produce over 1 million fingerlings a year.

Small-scale hatcheries are limited in technical capacity and resources. Normally, these category of hatcheries are rural-based and credited for bringing quality fish seed in the reach of the rural fish farmers. This category has a risk of not giving the farmer a quality product given the limited resources and remoteness of hatcheries for effective monitoring by the regulatory agencies. Medium-scale hatcheries are always careful to keep up the quality of their products as they largely depend on commercial fish farmers coming back to buy more seed from them. There is a tendency with this category of hatcheries to over produce seed to meet either the market demand and to meet deadlines. In so doing, this category of hatcheries is likely to lead to increased fish escapes, over-fertilization and failure to adhere to guidelines to ensure quality fish seed production. The large-scale hatcheries are normally well planned and designed. Initially, a single public hatchery, Kijjansi Aquaculture Research and Development Centre (KARDC) was the only large-scale fingerling producer, but in recent years the number of larger private investments have come on-line to meet growing demand for quality fish seed. Many of the large-scale hatcheries are clearly around the central administrative district and supply fish seed only to large-scale farms. One such hatchery (SUNGENOR) specializing in improved tilapia seed from the GIFT strain of Nile tilapia will be supplying seed for its out grower scheme where farmers sell back the fish to the company's fish processing and export partner (NGEGE Ltd).

On the whole, fish farming remains an alien practice, a situation that was not helped by the manner in which aquaculture was first considered and introduced into the country. The practice was considered to be non-income generating and only for fish protein provision for the rural communities who did it on subsistence with little or no input other than the fish seed. However, with time the practice has began to attract profit and income, thus generating oriented fish farmers who have started to invest commercially and expand production targeting local, regional and international markets. This level of farmers have better-constructed production units, have designed measures against predators (small reptiles and birds) and are using formulated fish feed either bought from feed firms or manufactured on farm. These fish farms are also better located and are employing technically trained persons or seeking advise from competent aquaculture service providers.

Zimbabwe

Farmed tilapia seed are available from two private hatcheries: Lake Harvest Aquaculture (Pvt) Ltd. (LHA), established in 1997 in Kariba (365 km northwest of Harare) and producing around 3 000 tonnes per annum of whole fish and 'The Bream Farm', established in the early 1980s in Kariba and producing less than 100 tonnes per annum harvest (mainly on a recreational put-and-take basis). Lake Harvest Aquaculture produces around 2 million fry per month for nine months of the year (i.e. when water temperatures are warm enough to breed outdoors). The Bream Farm produces around 1 million fry per annum. Both farms produce tilapia seed almost exclusively for their own use. Little to no seed are sold to third parties because demand is low and Nile tilapia, the only species where whose seed are produced in hatcheries in Zimbabwe, is not supposed to be moved out of the Zambezi Valley (includes Lake Kariba), except by way of permit from the government's Parks and Wildlife Authority. Such permits are difficult to obtain. There are currently no operational government hatcheries for tilapia in Zimbabwe, although attempts are being made by the government to resuscitate one or two defunct government hatcheries.

There are also three commercial trout farms:

- Clairmont Trout Farm, established in the 1970s or earlier and producing no more than 50 tonnes per annum;
- The Trout Farm, established in the 1970s or earlier and producing less than 5 tonnes per annum;
- Inn on Ruparara, established in the 1990s and producing less than 20 tonnes per annum.

Each of these has its own small hatchery for on-farm use. The Government hatchery in Nyanga produces seed for local dam stocking, essentially for recreational put-and-take fishing.

MARKETING

Unlike in parts of Asia where large numbers of middlemen buy from hatcheries and sell to grow-out farms, very little efforts are made in Africa to market fingerlings. By and large, producers either place an order with a hatchery or simply show up to buy fish. In some cases, larger orders might be delivered by the hatchery to the farm.

For the tilapias and larger catfish/carp operations, such as in Egypt, this is not a major problem as fish can be spawned most of the time and can affordably be maintained in holding facilities. However, for smaller-scale and, particularly catfish, hatcheries elsewhere on the continent, fingerlings are produced in batches. If buyers are not immediately available when needed, tilapia fingerlings often go on to reach precocious sexual maturity making them useless for commercial farming, while the catfish cannibalise each other.

Synchronisation between fingerling supply and demand is a key problem in African aquaculture. Egypt has a particular problem because of the strong seasonality of their climate, forcing hatcheries to use expensive technology to get fingerlings ready early so they can be stocked out as soon as the weather warms in the spring. Efforts on the part of hatcheries to adapt to the grow-out cycle and aggressively market their products and thus make them more easily available to producers could help in hatchery profitability, ultimately bringing prices down.

SEED PRODUCTION FACILITIES, TECHNOLOGY AND ECONOMICS

The hatchery systems employed in Cameroon, Nigeria, Ghana and Uganda are typical of small-scale hatcheries throughout the continent. In hatcheries, tilapia fingerlings are produced in open ponds of 50-50 m^2. Broodfish are randomly stocked at a rate of one male to one female. Fingerlings are captured with a dip net or fine-mesh seine net beginning at ±50 days after broodfish stocking and is repeated every 21 days until capture begins to decline (normally after about three months). Harvested fingerlings averaging about 10 g are held for two days to recover from the harvest operation and sold. Production costs vary around US$0.5 cent to US$1 per fingerling, while retail prices vary with season, size and supply/demand imbalances, averaging between US$3-5 cents 5-10 g mixed-sex fingerlings. Very few hatcheries are experimenting with hormone sex-reversal or hand-sexing to get all male populations.

Most farmers, however, do not rely on hatcheries for tilapia but instead either (a) captures them from the wild where the farmers buy the fingerlings from fishermen, or (b) some of these farms produce their own. Local fishermen usually scoop up “clouds” of fry as they school in the shallows (wild) or remove young fry from their mother’s mouth and sell to the farmers who in turn transfer them to some type of rearing container and feed them. The majority of African fish farmers use mixed-sex tilapia systems to generate their seed, i.e. they use the customary techniques where the fish is harvested in the pond after six months, selling or eating the larger fish and keeping the smaller individuals for restocking. However, since extreme care is not taken, individuals that are used for restocking are usually already sexually mature and begin reproducing almost immediately after stocking. Another alternative method used is to hold broodfish in a net enclosure (*hapa*) where their spawning is closely monitored. In this way, the age of the fingerlings are well known and the risk of stocking sexually mature individuals is eliminated. The *hapas* are usually placed in the farmer’s grow-out ponds.

Basic catfish reproduction technology has been well-established over the last 20 years as described by de Graaf and Janssen (1996). Typically, female *C. gariepinus* are injected with 4 000 IU/kg of human chorionic gonadotropine (HCG), pituitary extracts or other hormone analogs to induce final gonadal maturation and stripped after approximately 12 hrs. Eggs of all females are pooled and then dry fertilized with mixed milt from nine sacrificed males. Fertilized eggs are poured onto 70 x 50 cm wooden framed nylon-mesh screens where they adhere and are submerged to 40 cm depth in 1 m^3 *hapas* installed under the water inlet pipe (to ensure adequate exchange of fresh water) in small earthen ponds, or in indoor cement tanks. Eggs hatch within 30-35 hrs and are subsequently held in their *hapas* for two days prior to stocking, by which time they have reached an average individual weight of 2.3 mg.; hatching and survival rate to two days average 95 percent.

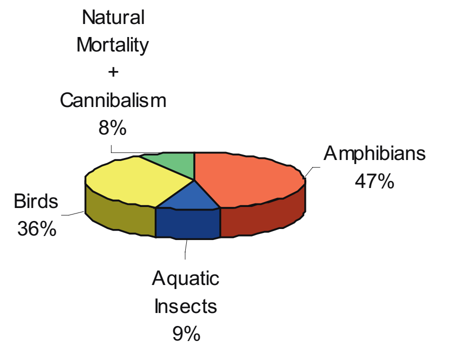
Few farmers, however, want such small seed, 7-10 g being the minimum size to insure decent survival rates. As catfish fry are susceptible to a wide range of predators (Figure 6.1.1) including cannibals, the greatest problems encountered by catfish hatchery operators concern larval survival. Three basic nursing systems are used:

Low intensity: Ponds are prepared by drying, cleaning and installing compost cribs comprised of wooden stakes driven into the mud at approximately 10 cm intervals to enclose 10 percent of the pond surface area. Ponds are then surrounded by a 1 m high fence fabricated of locally produced nylon mesh bags or aluminum roofing material to in an effort to exclude frogs, one of the most important larval predators. The compost cribs are filled with 7 kg/are[1] total dry weight (approximately 20 kg wet material) of cut grasses mixed with 0.2 kg/are of wood ash. Ponds are then filled and stocked within three days (to avoid infestation by insects) with two-day old *C. gariepinus* larvae at a rate of 7.5 per m^2. Once per week, the compost is churned using a stick and another dose of grass and wood ash added.

Medium intensity: Ponds are prepared as in System 1, but instead of compost, ponds are limed with 2.5 kg/are of quicklime (CaO), fertilized with 20 kg/are (dry weight) of chicken manure and fed a daily supplement of wheat bran at a rate of 1 kg/are. Stocking rate is 15 two-day old larvae per m^2.

High intensity: Ponds are prepared as in System 2, but from Day 11 onwards, are fed twice per day with a 1:1 mixture of wheat bran and palm nut cake at a rate of 1.0 kg/are (2.0 kg/are/day total). Two-day old larvae are stocked at 30/m^2. As in treatments 1 and 2, a frog fence and last-minute filling are the only anti-predator strategies employed.

FIGURE 6.1.1
Main predators of catfish larvae



Production cost factors vary with country, but are generally proportional to the values shown in Tables 6.1.3 and 6.1.4. A key element in profitability of all hatchery systems is intensity, with hatcheries that are able to maintain high densities making the most money. Average survival rate is about 37 percent in well-managed systems.

In Egypt, hatchery systems are more intensive than elsewhere in the continent. The most common system among industrial hatcheries is based on indoor breeding tanks to facilitate spawning one or two months earlier than that produced in outdoor systems (due to the cold winters and relatively short growing season in Egypt). Larger one-year old brooders are selected from the harvest. In late winter, broodfish are stocked at a rate of three to four females per male in each square meter of the breeding tanks. Water temperature is raised to the optimum breeding temperature (26 °C to 29 °C) by boilers. Incubating eggs are collected from females and transferred to hatching jars

[1] 1 are = 1/10 hectare

TABLE 6.1.3
Summary of fingerling supply characteristics in six African country case studies

	Cameroon	Egypt	Ghana	Nigeria	Uganda	Zimbabwe
Main Culture Systems	small semi-intensive ponds	large semi-intensive ponds; some cages in the Nile.	intensive cages in Volta Lake; intensive pond systems, small semi-intensive ponds	small, semi-intensive ponds; some new raceway systems in SW	small semi-intensive ponds; extensive small dams; planned cages L. Victoria	intensive cages in Lake Kariba; semi-intensive small waterbodies for trout.
Main Culture species	*Clarias* *Tilapia*	tilapia, mullets	*Tilapia*	*Clarias heterobranchus*	*Clarias* tilapias	*Tilapia*
Other species	*Heterotis niloticus*	carps	*Clarias heterobranchus*	*Tilapia* Ornamentals		trout
Total Reported Production (TPA)	324	471 500	6 000	50 000	15 000	3 225
Main Source of Fingerlings	hatcheries for catfish, pond residuals for tilapia.	private hatcheries	wild fishery or pond residuals for tilapia.	wild fishery, small and medium-scale hatcheries	private hatcheries	private, vertically integrated grow-out farms
Number of Hatcheries	14 private, 8 government	480 private, 10 government	4 large private, 5 government	500 small (s, 20 %) 200 medium (m, 60 %) 20 large (L, 20 %)	8 government (10 %), 45 private (90 %)	1 government (trout), 6 private (3 trout, 3 tilapia)
Main Hatchery Systems	small open ponds	hapas in ponds for tilapia, indoor tanks for carps, increasing use of greenhouses for early tilapia spawning	small open ponds or tanks	(s) small static ponds/ tanks (m) indoor flow-through tanks, small ponds (L) indoor recirculating raceways	small ponds or indoor tanks, semi-intensive	modern, pond-based
Estimated Number of Fingerlings Produced	3 300 000 tilapia 1 400 000 catfish	1 000 000 000 tilapia 250 000 000 carps	< 1 000 000 from government, unknown from private sector	30 000 000 (80 % catfish)	42 300 000 (80 % catfish)	19 000 000 tilapia, trout unknown
Estimated Future Fingerling Demand	not estimated	10 000 000 000	not estimated	500 000 000 growing to 2-3 000 000 000	450 000 000 by 2 011 + 296 000 000 for small waterbodies	not estimated
Main Problem	irregular demand not coordinated with irregular supply	strong seasonality; demand outstripping supply; decreasing size of fingerlings delivered.	inadequate hatchery capacity and poor management	inadequate water supply, poor training of technicians, poor and/or too few broodstock	lack of knowledge regarding economic performance of commercial systems	poor genetic quality of broodstock, high feed costs
Future Trends	growing steadily from a smallholder base	intensifying to reduce water requirements	growing steadily from an SME base	rapid, rather disorganized expansion	growing, with focus on medium and larger-scale investments.	unknown

TABLE 6.1.4
Average costs (US$) per square meter of pond surface area, for nursing *Clarias gariepinus* in Cameroon (Yong Sulem and Brummett, 2006)

System	Larvae	Pond Inputs	Labor	Depreciation on Predator Fence	Depreciation on Ponds and & Equipment	Total Cost per m²
1	0.075	0.02	0.47	0.03	0.03	0.61
2	0.15	0.10	0.75	0.02	0.03	1.05
3	0.30	0.19	1.15	0.03	0.03	1.70

where they are kept until the yolk sac is absorbed. Fry are then transferred to nursing tanks (small shallow tanks each of 2-3 m^2) and fed with hormone-treated feeds for sex reversal. Hormone treatment extends to four weeks afterwhich fry are moved to outdoor nursing tanks (10-20 m^3) under greenhouses or to nursery ponds (1 000-4 000 m^2). Depending on the season and demand, fingerlings are sold as fry (0.5-1 g) or as fingerlings (3-5 g). Seeds are usually available at the beginning of the growing season in late March or early April.

Many private Egpytian farms also produce their own seed in hapas installed in ponds. Hapa spawning starts when the water temperature reaches the levels required for breeding in mid-April and continues through September. Broodfish are stocked at three to four females per male per square meter. Hapas are examined for the presence of free swimming fry which are collected by scoop nets. Collected fry are usually stocked in nursing ponds and harvested at marketable fingerling sizes by draining. A modification of this system with *hapas* installed in small ponds or concrete tanks under greenhouses is presently expanding to facilitate earlier production of fry. The increase in water temperature in the greenhouse facilitates tilapia spawning in tilapia at least one month before the natural breeding season.

Egyptian carp hatcheries are composed of three main units, namely: (a) broodstock ponds are earthen ponds each with 400-1 000 m^2 area and about 1.25-1.5 m deep, (b) indoor facilities, a building including a large hall with circular brood tanks, aquaria and hatching jars or containers, a laboratory, filters and water quality control facilities, boiler and staff rooms and (c) nursery facilities include suitable numbers of earthen ponds each of 1-1.5 acres and 1.25-1.5 m deep.

The different carp species introduced to Egypt cannot spawn naturally in the local environment. Spawning occurs through induced breeding by injecting the ripe broodfish with locally prepared common carp pituitary extract and stripping of females and males. Fertilization takes place when eggs and milt are mixed in a plastic vessel. Fertilized eggs are then incubated in hatching jars with running water from the bottom to the top. Hatched fry are collected and kept in glass aquaria and then moved to nursery ponds.

Zimbabwe is also a special case in that its tilapia production is concentrated at just a couple of larger-scale farms. They also, unlike the rest of the countries studied, grow trout commercially. Lake Harvest, Ltd. is, by far, the dominant producer in the country and uses open pond spawning and modern tilapia sex-reversal technology to produce all-male Nile tilapia fingerlings for stocking in their grow-out cages. Technology used on the trout farms is not known, but probably based on traditional trout spawning techniques.

SEED MANAGEMENT AND QUALITY

Among the countries studied in this review, only Egypt has any regulations on the maintenance of quality in fish seed production systems and this extends only to control of diseases and parasites through the use of broodstock isolation, disinfectants and prophylactic medication. However, even in Egypt, the rules are largely ignored and, anyway, only employed on an estimated 10 percent of hatcheries licensed by the government.

Genetic management is by far the greatest quality issue in African hatcheries and deterioration of the genetic quality of cultured populations is a serious problem. For the highly fecund carps and catfishes, there is always the temptation to use the fewest number of broodfish possible to get a certain number of eggs. For catfish, males are usually sacrificed and so are used to fertilize as many females as possible. From these, offspring of minimal numbers of parents will be selected the next generation of brooders and after several generations of mating, such bottlenecks lead to inbreeding which can reach levels sufficient to lower growth, decrease fecundity, reduce fitness and generate deformities.

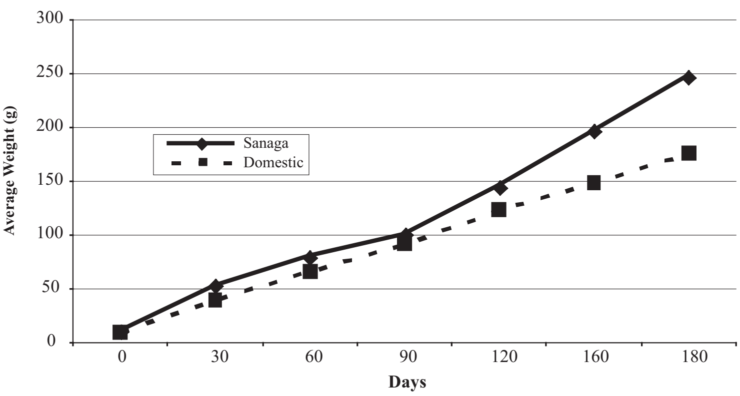
Tilapia presents a somewhat different challenge, but the outcome is the same. The typical practice at harvest is to sell or eat all fish of a certain minimum size, leaving smaller individuals to be either sold as fingerlings to other farmers or continue growing in the pond. In the case of tilapia, only a part of these small fish are actually fingerlings; many being small sexually mature adults. Such selection for smaller adults amounts to inadvertent selection for slow growth and/or early sexual maturation.

In most cases, the numbers of broodfish used are far inferior to the numbers needed to maintain adequate genetic variability in the population. This is particularly troublesome for imported alien species for which new broodstock are difficult to obtain (e.g. carp populations in Egypt). Also, as male tilapia is highly territorial and competitive for mates, a relatively small percentage of males (the most aggressive, not necessarily the fastest growing) dominate the fertilization of the females. Without some methods of ensuring that most males are represented, effective breeding number (N_e) will be less than anticipated and the population can become inbred, reducing growth and viability while increasing phenotypic variation.

Genetic drift, especially the founder effect, is another mechanism that can lead to loss of genetic diversity and the potential for inbreeding. Small founder populations are more common than not in African aquaculture and, indeed, aquaculture in general. Being expensive, difficult and often illegal, individuals who seek to acquire exotic broodfish, often resort to minimal numbers, thus building low genetic diversity into their production systems from the outset. Cumulatively, these various broodstock management mistakes have induced birth deformities and reduced the growth of tilapia, carp and catfish populations held on hatcheries by up to 40 percent (Figure 6.1.2).

FIGURE 6.1.2

Comparison of growth among feral and captive populations of *Oreochromis niloticus* in Cameroon



Source: Brummett, Etaba Angoni and Piouomogne (2004)

CERTIFICATION

In Cameroon, Ghana, Nigeria and Zimbabwe, the need for some kind of seed quality certification is recognized, but no system is currently in place.

In Egypt, there are two kinds of certificates: the Health Certificate issued by the General Authority for Veterinary Services and the Certificate of Origin issued by the General Authority for Fish Resources Development (GAFRD). The health certificate is issued for batches of seed approved free of contagious disease and pathogens or parasite or its infectious stages. The procedure involves a series of detailed inspections and laboratory examinations. The certificate of origin indicates the source of the seed, brood, establishment and date of production. Both certificates are issued if requested by the buyer especially for export purposes; neither deals with the issue of genetic quality.

Uganda is more advanced in the seed certification process. All fish seed producing, supplying and fingerling-raising farms and companies have to be certified by law. This follows the making of the statutory instrument regulating aquaculture activities under the Fish Act 1964 known as the Fish (Aquaculture) Rules 2003 instrument number 31. The operator has to apply using a formatted application form, submit the application to the Chief Fisheries Officer or to a person designated by the Chief Fisheries Officer to work on his or her behalf. Inspectors are then dispatched to the aquaculture establishment to inspect and ensure that all requirements and plans are in place to ensure responsible production of quality fish seed. Upon receiving the report of the Inspectors, the Chief Fisheries Officer then issues a Fish Seed Production Certificate. This process ensures that farmers get quality fish seed and to prevent ecosystem alteration and ecological and genetic disruption from either escape of farmed fish or entry of unwanted fish into the production system. In essence, one is not allowed to produce or pass on fish seed without certification.

LEGAL AND POLICY FRAMEWORKS

Legal and policy frameworks under which aquaculture are regulated are non-existent, vague and/or unenforced. When they exist at all, there are two general types of aquaculture laws: 1) those that are more about control and taxation (Egypt, Nigeria, Zimbabwe) and 2) those designed to encourage development (Cameroon, Ghana, Uganda). Most African countries have expressed a strong interest in aquaculture development, even when financial and human resources are being diverted to more pressing issues such as education and health care.

Cameroon

In Cameroon, the Ministry of Animal Industries and Fisheries (MINEPIA) is charged with the promotion of aquaculture for food security and rural economic development (RDC, 2003). However, current regulations in Cameroon barely mention aquaculture and make no specific reference to fingerling supply or quality. Nevertheless, the government is actively advocating the expansion of aquaculture and there is a long-standing policy of providing some basic support through the operation of government stations (RDC, 1997). Although there are no specifics provided and no funding mechanism identified, the Rural Development Strategy Paper (RDC, 2002) noted several prospective roles for government in the promotion of aquaculture, such as:

- extension of appropriate techniques for aquaculture
- training of extension agents and farmers
- development of a functional technical and economic framework
- advising banks on the viability of aquaculture and opening lines of credit for investors
- promoting private sector fingerling production
- involving women and youth in aquaculture
- organization of restocking programs

Although not part of the legal code, the newest policy document that deals with aquaculture is the Poverty Reduction Strategy Paper (RDC, 2003). This document emphasizes “the lifting of constraints to the production of fingerlings and transferring technical solutions to peasant farmers” as main areas of government engagement. Although MINEPIA extension staff are more or less committed to lifting constraints to aquaculture, there currently exists no structure formally charged with the assurance of fingerling or broodstock quality, or any quantitative criteria against which such assurance could be given.

Egypt

In Egypt, aquaculture legislation is more advanced than in the other case studies. However, compliance and enforcement remain low, with over 90 percent of farms and hatcheries operating without licenses. In addition, there are no stipulations concerning seed quality or any policies designed specifically to support sectoral growth. The GAFRD is the licensing agency for all aquaculture in Egypt. Presidential decrees define land and waterbodies under GAFRD's jurisdiction and give it the right to implement fisheries and fish farming laws. The GAFRD has the authority to lease out wetland and all lands that are within 200 meters of the sea and lakeshores. The Fisheries and Fish Farming Law outlines codes for the construction of fish farms.

Article 48 of the law forbids the construction of a fish farm except on wasteland, which is not suitable for agriculture and agriculture drainage or lake waters are the only source of water for these farms; use of irrigation water is strictly forbidden. Exempted from this rule are government hatcheries. Article 48 of the Law 124/83 stipulates that fish farm or hatchery construction requires the approval of the Ministry of Irrigation delimiting the amount of water volume allowed for use, the source, size of inflow sluice and the method of draining.

In the second chapter of the Fisheries and Fish Farming Law, Article 17 states that it is not allowed to use or introduce alien fish, eggs or larvae into Egypt for any reason except after having a written permit of the GAFRD and after consulting the National Institute of Oceanographic and Fisheries.

Ghana

In Ghana, aquaculture has been regarded as a type of fishery and hence is included in other fishery legislation, lowering its value to the aquaculture sector. On the other hand, Ghana has a pro-user attitude reflected in the following guidelines for government when dealing with fishery-related enterprises:

- contract private companies to produce seed for the industry
- improve Ghana's access to international markets within the domain of the international fish trade
- obtain optimum benefits for Ghanaians as owners of fish-related enterprises, as employers of the fishing industry, as consumers of fish products and as beneficiaries of foreign exchange earnings from fish trade
- enhance investment in a private sector-driven industry.

It is noteworthy to observe that the current Fisheries Act (2000) of Ghana conforms to FAO's CCRF.

Nigeria

As in Ghana, the Nigerian seed industry only benefits from generalized fisheries policy and a legal framework that emphasizes capture fishery and mostly deals with licensing. The umbrella national fisheries legislation is the Inland Fisheries Decree 108 of 1992 and the Marine Fisheries Decree of 1991. However, export or import of live fish (including seed) is to be carried out with the permission of the Minister of Agriculture. States also provide for the registration of premises where any commercial activity (including seed production) is carried out. The Environmental Impact Assessment (EIA) Decree of 1988 also recommended the carrying out of EIAs for activities that may impact negatively on the environment (e.g. intensive water recirculation seed production systems which generate a lot of ammonium liquid and gaseous waste discharges) on any land area up to 50 ha.

Uganda

As with their seed certification legislation, Uganda is advanced in its concern for suitable legislation regarding the importance of the sector (Fish Act 1964), the delineation of the public sector's role in aquaculture (Fisheries Sector Strategic Plan 2002) and the regulations under which producers must operate (Fishery and Aquaculture Rules 2003). These policy instruments are still evolving to take into consideration the changing face of Ugandan aquaculture, but they are generally focussed on supporting the growth of aquaculture by ensuring that best management practices are respected.

Zimbabwe

As part of the Parks and Wildlife Authority and considering the relative unimportance of aquaculture to the national economy, the only specific regulation relating to aquaculture are restrictions imposed on the dissemination of alien species, particularly the Nile tilapia, which cannot legally be grown other than in the Zambezi valley.

KEY STAKEHOLDERS

Main stakeholders for each case study country are listed in Table 6.1.5. To ameliorate the weak policy environment within which aquaculture functions and to strengthen the working relationships among the various stakeholders, a new African initiative on the part of the FAO and the WorldFish Center to develop Strategic Frameworks for Aquaculture Development was elucidated in 2003. In this document, the roles of the key groups of stakeholders in resolving the general shortage of quality fingerlings are addressed:

Government should:

- provide regular information on sources and prices of good quality seed to private farmers;
- provide guidelines in producing/ensuring good quality seed through such measures as seed certification;
- maintain broodstock of selected culture organisms corresponding to the identified production systems;
- encourage commercial farmers and hatcheries to facilitate access to quality seed for the entire sub-sector.

Direct investors (seed producers) should:

- produce and distribute quality seed;
- sell products at a fair price;
- find mechanisms to facilitate access to high quality seed throughout the sub-sector;
- as appropriate, assist outreach program in promoting good management practices favouring improved yields;
- monitor results.

Producer organizations should:

- serve as a forum for information sharing among stakeholders;
- lobby for collective bargaining and appropriate public sector intervention;
- link with research organizations.

TABLE 6.1.5
Fingerling survival, final average weight, number harvested and profitability data per m² for *Clarias gariepinus* nursing systems (over 35 days) in periurban Yaoundé, Cameroon. Price of fingerlings is dependant upon size of fingerlings: >5 g = $0.20, 2-5 g = $0.15, < 2 g = CFA $0.10 (Yong Sulem and Brummett, 2006)

System	Survival (%)	Final Average Weight (g)	Number Harvested per m²	Gross Revenue per m²	Net Profit per m²
1	48.5 ± 26.31	5.9 ± 2.23	3.6 ± 1.97	0.64 ± 0.33	0.03 ± 0.37 a
2	46.8 ± 43.35	5.5 ± 3.23	7.0 ± 6.50	1.05 ± 0.97	0.01 ± 0.97 a
3	28.4 ± 6.12	4.2 + 0.31	8.5 ± 1.84	1.45 ± 0.54	-0.25 ± 0.55 a

TABLE 6.1.6
Summary of key stakeholders in aquaculture development in six case study African countries

	Cameroon	Egypt	Ghana	Nigeria	Uganda	Zimbabwe
Lead Government Agency	Ministry of Animal Production and Fisheries	General Authority for Fish Resources Development (GAFRD)	Ministry of Fisheries	Federal Department of Fisheries, State Fisheries Divisions	Dept. of Fisheries Resources (DFR)	Parks and Wildlife Authority
Extension Services	National Agriculture Extension Program (PNVRA)	GAFRD extension and training directorates	Directorate of Fisheries	Aquaculture and Inland Fisheries Project, State Agriculture Development Programmes, Private Consultants	Aquaculture Unit (DFR), National Agricultural Advisory Services (private)	Department of Agriculture and Rural Extension
Research & Training Institutes	University of Dschang, Institute for Agriculture Development Research	Universities of Cairo, Ein Shams, Alexandria, Suez Canal, El Azhar, El Mansura, Tanta, Asuit, Zagazig, El Fayum, Aswan. Aquaculture Research Center	Water Research Institute (WRI), Kwame Nkrumah University of Science and Technology	National Institute of Freshwater Fisheries Research (NIFFR), National Institute of Oceanographic and Marine Rsch (NIOMAR), State Universities (especially Pt. Harcourt, Ibadan)	Fisheries Resources Research Institute, Kajjansi Aquaculture Research and Development Centre, Makarere University	University of Zimbabwe
Dominant Producers	None	Not specified	Crystal Lake Fish, Ltd; Pacific Farms, Ltd; Tropo Farms, Ltd.	Durante Fish Industries; Felimar Aquaculture Centre; Chi Farms	200 small commercial farmers	Lake Harvest Aquaculture, Ltd.
Other Notable Producers	3 000 small-scale investments	Not known	Afife and Libga stations (government); Aquafarms Ltd; Newco, Ltd;	Zartech; Oris Aquatics; Idomor Fish Hatchery; Gasedado Farms	11 000 smallholders	The Bream Farm, Mazvikadei Fish Farm, Clairmont Trout Farm, The Trout Farm, Inn on Ruparara
Producer Organizations	Evolving as fingerling/feed and marketing service providers	Egyptian Aquaculture Society	A number of small producer organizations	Fisheries Society of Nigeria, Association of Fish Farmers and Aquaculturists, Catfish Farmers Association, United Fisheries Association, Association of Fingerling Producers, Union of Fishermen and Seafood Dealers, Association of Ornamental Fish Exporters	20 district and five national fish farmers' associations	None
Other Stakeholders	NGOs, WorldFish Center, FAO, CIRAD	WorldFish Center	Bilateral Donors, FAO, WorldFish Center.	Nigeria Agriculture and Rural Development Bank, FAO, WorldBank, Bilateral Donors, Oil Companies	4 large-scale fish processing plants	Department of Livestock and Veterinary Services; FAO dam stocking program

FUTURE PROSPECTS AND RECOMMENDATIONS

Aquaculture has an important role to play in African economies and food security. 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 conclusions: 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. The reviewers, engaged in the six case studies outlined in this document, agree that governments should relegate itself to a facilitating role and that, to remedy the critically important problem of fingerling supply and thus help aquaculture grow to the point where it can serve as an engine for rural economic growth - governments, donors and development agencies should strive to:

1. Support the development and implementation of Strategic Frameworks for Aquaculture Development to target extension efforts, clarify the expected roles for various stakeholders and establish the foundation for realistic and practicable legislation.
2. Target extension and research at the growth of a horizontally-integrated aquaculture sub-sector (emphasizing the critical role of private sector hatcheries) that can maximize economies of scale and the number of secondary economic opportunities created by aquaculture.
3. Work with NGOs and banks to make credit available to small- and medium-scale hatcheries, e.g. through loan guarantees.
4. Encourage the development of NGOs and farmers' organizations as partners in the delivery of key services such as marketing, feed and fingerling supply.
5. Engage large-scale farms to undertake adaptive research in partnership with government scientists. This will refocus research to become more relevant to immediate development problems as well as releasing pressure on weak government infrastructure and research budgets.
6. Create tax and/or credit incentives for vertically-integrated private farms to improve the global availability of fingerlings. Excess capacity engendered through use of improved technology can create surpluses that can be sold at fair prices to small-scale operators.
7. 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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