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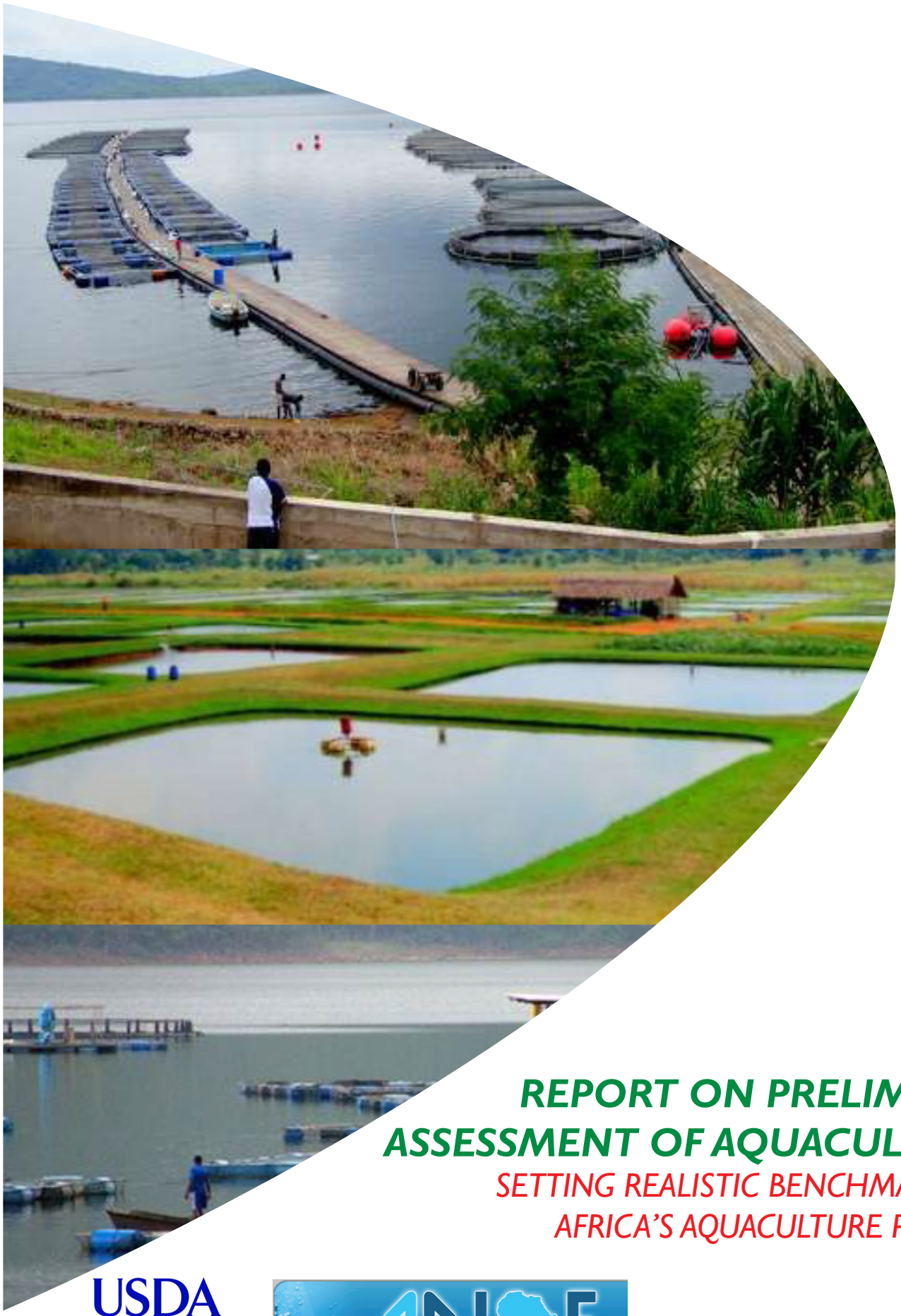

REPORT ON PRELIMINARY ASSESSMENT OF AQUACULTURE - SETTING REALISTIC BENCHMARKS FOR AFRICA'S AQUACULTURE PROGRAM

USDA

ANAF Aquaculture Network for Africa

REPORT ON PRELIMINARY ASSESSMENT OF AQUACULTURE -

SETTING REALISTIC BENCHMARKS FOR AFRICA'S AQUACULTURE PROGRAM

AU-IBAR and FAO Aquaculture Project

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EXECUTIVE SUMMARY

A two-person USDA aquaculture team was asked by AU-IBAR, ANAF, and FAO to review the current status of commercial aquaculture in Ghana, Uganda, Kenya and Nigeria. The team travelled from July 7 through July 28, 2013 and saw the breadth of the industry – feed suppliers, hatcheries (seed suppliers), table fish production in cages, ponds and tanks, and fish marketing venues. We met with a wide range of government officials, private farmers and various fish associations and thank all of those involved for their efforts.

Commercial fish farming is a reality and appears sustainable in all of the countries visited. While the production estimates may be high, small, medium and large- scale commercial fish production (of Tilapia nilotica, Clarias gariepinus, or both) exists and in most cases is in a rapid growth phase. Total freshwater aquaculture production in the four countries may exceed 300,000 metric tonnes annually, but no good method of data collection for production estimation currently exists.

Most feed is imported but there is an expansion of local feed mill capacity underway in the countries visited, using largely locally-sourced materials. Collection of data on total amount of feed imported and manufactured in-country may provide the most accurate estimate of aquaculture production. The long-term growth and success of the industry will likely depend on quality pelleted feed produced by modern mills using rations designed specifically for the species and life stage being grown. Reduction of feed costs is essential, and least-cost formulation as well as local sourcing of ingredients can be used in part to achieve this. The feed quality advertised must be the feed actually sold, and this can likely only happen with uniform labeling requirements. The bulk of the feed supporting major fish production in the countries visited will likely remain imported feed with an increasing portion from large modern mills located in-country.

One high-level government official remarked that "commercial fish farmers are now three steps ahead of the government, and the government is struggling to catch up". As we go forward, it is everyone's hope that we (the public sector) "catch up" by truly becoming relevant, by solving technical issues, by initiating appropriate

collaborative research and information transfer, protecting the environment and natural resources while promoting and facilitating aquaculture for the good of all, and by partnering with this new industry for the future of the people. We saw very positive signs of governments very supportive of commercial aquaculture development in all countries visited. This positive attitude, coupled with the existing political stability, will do much to promote future investor confidence.

We expect that as the aquaculture industries develop, fish producer and other industry associations will have an increasing influence on government regulation and policy as it relates to aquaculture. The day will come when they will truly "have a seat at the table" when these issues are being discussed and policy decisions are being made. This will not come easily, but the alternative is for the public sector to catch up by slowing down the growth of the industry with increasing rules, regulations and permits.

While there may be sporadic short-term local shortages of all-male tilapia and clarias seed in the future, the hatchery business is generally so profitable that supply and demand forces will regulate seed supplies. A greater concern in the future is that when there are so many hatcheries that there is a glut of seed, and hatcheries are no longer that profitable, those farmers must successfully transition to table (food) fish production, which generally has a smaller profit margin.

The team recommends introduction of non-native species (such as Chinese carp or Pangasius sp.) not be allowed without a serious, science-base discourse leading to a formal national policy. However, the team believes that risks of negative impacts on the ecosystem are likely insignificant when using genetically improved native species (i.e., Tilapia nilotica or Clarias gariepinis).

Fish production could easily double in a few years, especially if concise, simplified policies for licensing cage farms in Lakes Volta and Victoria are put in place. There will doubtless be a few bumps in the road as the industry expands, with localized periodic shortages and surpluses. Fish is very perishable, and the breakdown of an ice factory, even if temporary, could have a major impact on the steady flow of fish to the market.

However, we saw great optimism, and people with great visions of how the market could be expanded, both geographically and vertically through further processing and innovative products. The demand for fish in the countries visited is not limitless, but for all practical purposes it is apparently barely tapped at present. Major efforts will be necessary (and in many cases are already underway) to expand markets to other areas once the demand for fish is met in the major cities. More dispersed distribution networks throughout the countries will be necessary, and we saw efforts on this already underway.

We also agree with the efforts to stimulate demand for smaller tilapia (and clarias). Currently, a target market size of 400-500 g for tilapia (and 1 kg for clarias) may be the norm. This requires about nine months from egg to harvest for both species. Decreasing the market size to 100-300 g for tilapia, for example, may allow a farmer to double production by reducing the production period. Even if sold at a slightly lower price, which may not be necessary with aggressive marketing, a farmer may show a greater profit due to volume. We saw a great deal of marketing creativity, and a lot of ideas proposed. While there will likely be short-terms periods of glut and shortage, we feel confident that markets will be developed and expanded to meet the increased production already planned.

In all four countries we saw many examples of private sector involvement in the training of the next generation of fish culturists. We saw college students serving internships on private farms, larger and more productive farms/hatcheries providing (paid) training programs to their customers in an effort to increase their (the participants' skill levels, and true public-private partnerships in which the private sector contributed significant funds to the development of a training center that was operated with personnel from both sectors. We are big believers in the need for "hands on" as well as academic training and we saw all of these developments as very positive. We certainly see all of these practices expanding as fish production does.

The responsible agencies are understandably reluctant to "open up" Lakes Victoria and Volta to unregulated expansion of cage farming operations without a clearer understanding of possible environmental impacts. While providing that is beyond the scope of this trip and report, we see little risk in a controlled, permitted expansion of cage farming on those very large lakes, perhaps in designated "enterprise zones", with concurrent monitoring efforts.

BACKGROUND

Aquaculture is not new to Africa. Significant efforts by national and international organizations have been made for over half a century, largely with little significant and sustained growth in freshwater fish production. Several good reports analyzing aquaculture development programs in Africa, their general lack of success, and the lessons learned have been published by the Food and Agriculture Organization of the United Nations (FAO). Suffice to say that while aquaculture has historically been seen as holding great promise, that promise has largely remained unfulfilled in much of Africa.

That pattern has apparently changed significantly in recent years. The FAO and African countries are placing ever-increasing importance on the aquaculture sub-sector, not only for the historical intentions of improving food security and resource use, but also in regard to new expectations linked directly to today's major macro-economic challenges – improving national fish supply while making a significant impact on job creation and economic growth. FAO's Special Programme for Aquaculture Development in Africa (SPADA) was particularly instrumental in effecting this change.

Recently significant private-sector investments (with some public-sector and third- party support) have been made in all areas of aquaculture – feed mills, processing and marketing facilities, seed (fingerling) production and table (food) fish production. The parties involved have come to feel that sustainable private-sector commercial aquaculture has arrived in Africa.

In 2011 a process was started, in conjunction with the African Union Inter-African Bureau for Animal Resources (AU-IBAR), the Aquaculture Network for Africa (ANAF), and with FAO support, to have the United State Department of Agriculture (USDA) field a mission of two expert third-party aquaculturists to assess the status of fish farming in Ghana, Uganda, Kenya, and Nigeria. These countries have performed relatively well in areas of tank, pond and cage culture of tilapia and clarias (African catfish) in Sub- Saharan Africa (SSA) and would therefore be worthwhile to share experiences and lessons learned with other SSA countries. The assessment was conducted from July 7-28, 2013 with financial support from FAO (in-country costs, logistics and travel) and USDA (providing salaries for the assessment team), with overall leadership and direction provided by AU-IBAR, and with in-country preparation, logistics, and coordination provided by ANAF (and FAO in Nigeria) through their country focal points.

While reviews and assessments of the potential of aquaculture in Africa have been periodically undertaken, these have most often been based on best estimates of what could be accomplished based on the trajectory of the sub-sector in other regions of the world, and have generally proven to be poor predictors of actual growth and production on the continent. With a pivotal shift in paradigm to a business-orientated model over the past five years, for the first time it is possible to review and assess real investments in aquaculture in Africa to see what has worked and what has not. This assessment was not seen as another overall statistical survey of fish production which was not possible in the short time allowed, but rather as a "snapshot" of the better examples of various points in the value chain of the young African aquaculture industry.

Aquaculture offers important assets as an un- and under-utilised sub-sector. However, to ensure aquaculture's growing political support and to make efficient use of its limited human and financial resources, an objective assessment of actual achievements is critical, and that realistic and attainable targets are established to measure the use of these resources for which there is also growing competition.

The goal of the assessment was to generate products of real value: first, as evaluation of the relative state of fish farming (i.e., how well people are doing -- application vs. theory); second, a setting of realistic targets (what general levels of magnitude should we be expecting for profitable yields from major systems); and third, identifying both opportunities and constraints. It was also expected to flag some specific farms, practices, and other industry components that could provide case studies, pilots or models for future use.

This assessment of the aquaculture industry in Africa is the first step in a process aimed at promoting expanded investment in Africa's aquaculture industry by providing a realistic assessment of the current status of commercial aquaculture and establishing achievable benchmarks for the productive capacity of the African aquaculture sub- sector. Specifically, the Terms of Reference for the team was:

1. Liaising with AU-IBAR to ensure the necessary financial resources are available for the work cited in items 2 through 8 below.
2. Estimation of achievable yields [setting expectations] from the systems under examination based on farm visits, interviews with those involved in the production side of the value chain, etc.
3. Identification of areas where improvements [level of adoption of available technologies] can be made, or gaps requiring research along the production side of the value chain.
4. Possibilities for optimising feed and seed supply mechanisms.
5. Review of data collection and record keeping at farm level and across the reporting hierarchy [optimizing data resources] to advise on improvements.
6. Review of marketing, harvesting, and distribution systems and their effectiveness.
7. Assessing investment in the sector.
8. Preparation of report on findings and recommendations on sustainable aquaculture development in Africa.

This assessment was to be undertaken with the view of elaborating, packaging and disseminating best practices for expeditious development of the African aquaculture industry.

1. INTRODUCTION

Our team departed the USA on July 7, 2013 and returned on July 28 (see Itinerary, Appendix 1). This only allowed for four working days in Ghana, 3-1/2 days in Uganda, three days in Kenya, and two field days days in Nigeria with a third day for visits with government personnel and debriefings. This was not much time on the ground, but due to the outstanding preparation and in-country logistics by AU-IBAR, ANAF, and FAO Nigeria, we were able to see the breadth of the industry. We visited existing, newly constructed, and under-construction major feed mills that were intended to maximize the use of locally-sourced ingredients to reduce feed costs as well as small scale (local) facilities that produced hard (sinking) pellets or quasi-formed pellets using a cooperative grinder; private hatcheries for tilapia (Tilapia nilotica) producing both mixed-sex and mono-sex seed; private hatcheries for African catfish (Clarias gariepinus) using induced spawning with fresh pituitary and hand-stripping, happa spawning, and spawning in small tanks (the so-called Indonesian method); table fish production of clarias and tilapia in cages, tanks and ponds; fish processing and marketing mechanisms for both tilapia and catfish; private entrepreneurs supplying training, equipment and supplies to the area farmers; as well as government aquaculture research facilities and hatcheries (see both Itinerary, Appendix 1, and List of Contacts, Appendix 2, for details).

The growth and development of the African aquaculture industry in the past decade (actually in many cases during the past five years) can only be described as remarkable, even phenomenal. As scientists we limit the use of superlatives in our writing, but in this case we feel it is justified. Those who have been involved for a lifetime with aquaculture development projects in Africa never realistically imagined this reality; village-level private hatcheries hormone spawning catfish and sex-reversing tilapia and selling tens of thousands of fingerlings a month; larger hatcheries producing/selling several million sex-reversed tilapia and/or clarias monthly with genetic improvement programs implemented to some degree; individual feed mills producing 40 tonnes/day of high quality extruded (floating feed) made with 70% locally-sourced ingredients to reduce costs to farmers; a wholesaler on the outskirts of a major city moving nearly 400 t/month of gutted, iced tilapia to both wholesalers and retailers with plans to double production; private farmers producing over 5 t/ha/year of 300-500 g tilapia in earthen ponds and 200 kg or more per m3 of clarias in intensive tank systems; private farmers offering appropriate, practical training to other farmers, serving as both a source of seed and information/technical support.

A mention of any of these events only a few years ago would have been received with great skepticism, but these are the new realities in the countries we visited. This is not to say that every hatchery is efficient, every farmer is prosperous, and the struggle to develop an industry in Africa is over - it has only started, but what an amazing start. One high-level government official remarked that "commercial fish farmers are now three steps ahead of the government, and the government is struggling to catch up". As we go forward, it is everyone's hope that we (the public sector) "catch up" by truly becoming relevant, by solving technical issues, by appropriate collaborative research and information transfer, protecting the environment and natural resources while promoting and facilitating aquaculture for the good of all, and by partnering with this new industry for the future of the people. The time has likely come, or will come soon, for the industry to have a seat at the table with government when issues related to aquaculture are being discussed and decided. This will not come easily, but the alternative is for the public sector to catch up by slowing down the growth of the industry with increasing rules, regulations and permits. The good new is that for the most part we saw government fisheries departments that (rightly) viewed this new industry as their success after decades of dedication, were very supportive of private aquaculture, and were working hard to adjust to the new reality.

The planning, organization, and execution of this mission was truly remarkable. When first proposed, we didn't think there was a high probability of actually producing an effective mission involving five countries (USA, Ghana, Uganda, Kenya and Nigeria), three cross-boundary agencies (FAO, AU-IBAR, and ANAF, and our own large bureaucracy - USDA). Simply getting everyone to agree on an itinerary, given all of the government poliicies, and all of the on-going duties, obligations and travel of those involved, seem unlikely. Our grattitude goes to everyone for being so positive about this work (and the larger picture of the importance of aquaculture), and so amenable to the frequent changes in the planned program. However, the greatest credit for any good that may result from this project will have to go to AU-IBAR, for their organization, coordination and execution of this project. The dozen or so individuals (in both AU-IBAR and ANAF) central to planning this project will appreciate this, and will also breathe a sigh of relief now that their e-mail in-box will finally lighten up. Our deep appreciation to all of those involved.

2. THE STATUS OF COMMERCIAL AQUACULTURE

We believe that the original premise, that sustainable commercial aquaculture exists in the four countries visited, is correct. We do not have a crystal ball which allows us to see into the future, but it is our assessment that, barring major national or international political events that could impact all segments of the economies in the countries visited, we see no reason why private-sector commercial aquaculture will not rapidly expand. Aquaculturists have several very good culture species to work with including Tilapia nilotica (Nile tilapia) and Clarias gariepinus (African catfish) as the current dominant production species across the continent. Heterobranchus sp. (another air- breathing native catfish) has been used to produce hybrids with clarias which appear to have even faster growth than clarias. The common carp and mirror carp (Cyprinis carpio), while not native to Africa, has been introduced into the target countries in some cases over a half-century ago with no apparent ecological impacts and have been accepted as legitimate culture species. Lates niloticus (Nile perch or Capitan) is available as a secondary (predatory) species, and Heterotis niloticus is available as an interesting, if technically problematic culture species. There has been interest in further introduction of exotics, such as the Chinese carps and Pangasius sp., but we see little need and have great concerns with this. The larger question of translocating/introducing genetic stocks will be discussed more fully later.

One of the technical problems blocking aquaculture development in Africa has been the availability of seed – fingerlings or small fish to stock ponds. While tilapia spawn readily making at least some fingerlings available for stocking ponds, they mature at a young age (4-5 months), and the traditional use of mixed-sex tilapia to stock ponds typically results in a pond full of fish too small to market at a premium price. Fingerlings of clarias, a fish in high consumer demand across much of sub-Saharan Africa, have never been available in sufficient numbers to justify commercial culture. Due to the diligent efforts of public-sector aquaculturists, both of those technical issues have been largely solved. Appropriate technology has been developed and introduced to the private sector across the continent to produce all-male tilapia fingerlings, making production of a crop comprised primarily of high-value large fish possible, and also to spawn clarias in large numbers using injections of fresh pituitary and hand-stripping.

Figure 1. Tilapia fry in hatching jar.

In all countries visited we saw private hatcheries, some of them very "low-tech", mass-producing all-male tilapia fry, with the largest hatchery (in Ghana) producing over 2 million fry weekly. While there is little clarias production in Ghana due to a market preference for tilapia, we saw numerous private sector clarias hatcheries across the other countries. We observed literally tens of millions of clarias eggs, fry and fingerlings, many of them in very simple rural hatcheries. The technology transfer programs in those ecountries have indeed been very successful. While there may be sporadic, short-term local shortages of all-male tilapia and clarias seed in the future, the hatchery business is generally so profitable that supply and demand forces will regulate seed production. A greater concern in the future is that when there are so many hatcheries that there is a glut of seed, and hatcheries are no longer that profitable, those farmers will need to successfully transition at least some efforts to table (food) fish production, which generally has a smaller profit margin.

Millions of fingerlings, without a reliable supply of quality feed, does not make an industry. For decades extension programs have been training rural farmers to gather and use scarce local resources (rice bran, animal manure, kitchen wastes, etc.) to feed the fish and fertilize the ponds. It is impossible to base an industry on that type of feed. The breakthrough that really allowed for commercialization of aquaculture throughout the region was the importation of commercial aquaculture feeds. We don't know who or where the first entrepreneur was

Figure 2. Clarias swim-up fry in hatchery.

that took the risk to import that very expensive feed, but they broke the mold of subsistence farming and demonstrated that commercial aquaculture is possible and can be profitable in Africa.

Figure 3. Feed being delivered from a new mill in Ghana.

While imported aquaculture feed dominates the industry in Africa, investments are now being made in modern feed mills that will use a majority of locally-sourced materials, reducing the final price to farmers. One of the team members talked to a feed importer two years ago in Ghana who talked of his plans to build a modern feed mill in Accra; this year the team visited that mill in operation, making feed for both Ghana and for export to Nigeria. The team also visited a new mill under construction in Kenya (near Nairobi) that is planned to be in operation by fall, also using a majority of locally-sourced ingredients, and the Nigerian Institute for Oceanography and Marine Research, while not private sector, was replacing a low-capacity extruder with a larger-capacity mill. These investments demonstrate great confidence in this young industry.

Figure 4. New feed mill under constructiojn in Kenya

Figure 5. Shrimp from Lake Victoria use in a locally manufactured feed

We did see a variety of local feed manufacture alternatives, from feeding a locally-sourced meal-type feed and a group-managed grinder used to form feed aggregates in Kenya, to a privately-owned (small) hard pellet mill use to manufacture sinking pellets in Uganda. However, the bulk of the feed supporting major fish production in the countries visited will likely remain imported feed with an increasing portion from large, modern mills located in-country.

Figure 6. Iced tilapia being delivered from cage farm.

Marketing is of increasing importance. When a nation's fish production was largely based on the harvest of individual small (0.01 ha) ponds at Christmas, notification of neighbors for pond-bank sales was the only preparation necessary. With daily harvests/sales of 25 t and annual single-farm production of 4000 t of tilapia, as we saw in Ghana, marketing is important and has already received private investment with plans for more. The team never thought they would see aquaculture fish production of this magnitude but they did throughout the trip. Private ice plants, cold storage facilities and trucks loaded with thousands of kilos of iced fish are now common fixtures and events. In Uganda particularly, much of the fresh fish produced is iced on trucks at the pond bank and exported to neighboring Rwanda and Congo, countries with less wild harvest.

The demand for fish in the countries visited is not limitless, but for all practical purposes it is apparently barely tapped at present. Major efforts will be necessary to expand markets (and in many cases are already underway) once the demand for fish is met in the major cities. More dispersed distribution networks throughout the countries will be necessary, and we have seen efforts already underway. In Ghana, for example, one major farm was periodically delivering small lots of fish to a group of women retailers who sold fresh, iced tilapia

along a major highway. Clarias is somewhat less familiar to consumers and in lesser demand than tilapia in some areas. The production potential of clarias is so great that we feel consumer education/promotion/sales efforts to increase the demand are warranted.

We also agree with the efforts to stimulate demand for smaller tilapia (and smaller clarias too). Currently, a target market size of 400-500 g for tilapia may be the norm. This requires about nine months from egg to harvest. Decreasing the market size to 100-300 g, for example, may allow a farmer to double production by reducing the production period. Even if sold at a slightly lower price, which may not be necessary with aggressive marketing, a farmer would likely show a greater profit due to greater volume and quicker turnover. We saw a great deal of marketing creativity, and a lot of ideas proposed along the way. While there will likely be short-terms periods of glut and shortage, we feel confident that markets will be developed and expanded to meet the increased production already planned.

Figure 7. Women selling tilapia from cage farm at roadside stand in Ghana.

There were other signs of a growing industry infrastructure that were seen throughout the trip. Many private farms are now offering farmer training, both alone and in collaboration with the government, and one of the feed mills visited made a major

contribution to a public/private training center to be run collaboratively with the government. Many hatcheries, in addition to providing advice and training to their customers (helping to assure their success and customer loyalty), are also acting as aquaculture equipment supply centers, selling a variety of feeds, chemicals and equipment. We certainly see all of these practices expanding as fish production does.

Aquaculture fish production (primarily clarias) has been estimated at 200,000 t/year in Nigeria, clearly the current "powerhouse of fish production" of the countries visited, but there is very significant production in all of the others. Ghana's aquaculture production may be near 30,000 t/year, and Uganda and kenya both likely produce in excess of 10,000 t/year, with some estimates quite a bit higher but difficult to substantiate. Regardless, we see this as only the start, with almost everyone we talked to planning on expansion, in some cases major expansion. Expansion could be realized fairly quickly through increased cage production in Lakes Volta and Victoria, if policy and permitting issues can be resolved.

The responsible agencies are understandably reluctant to "open up" those and other lakes to unregulated expansion of cage farming operations (and even pond culture) without a clearer understanding of possible environmental impacts. While providing an enviromental impact assessment is beyond the scope of this trip and report, we see little risk in a controlled permitted expansion of cage farming on those very large lakes with concurrent monitoring efforts. Unfortunately, while ultimately signing off on a permit for cage farming operation or even a small expansion of an existing operation may be intimidating for most bureaucrats, resulting in the responses like "we need more study" or "we need more information on the application" which are neither an answers nor solutions. As we go forward in dealing with an industry that is now "three steps ahead of the government", the government needs to remain relevant by dealing with and solving some complicated issues (which they apparently are as we speak), and not simply regulating the industry out of existence, which is both possible and actually quite easy.

Figure 8. Large tilapia cage farm on Lake Volta in Ghana.

This discussion of government relevance should not be taken as meaning that the governments/ministries/ fisheries departments in these countries are "anti - aquaculture", or a roadblock to expansion of the industry. Rather, it should be seen that their decades of persistent support of aquaculture have finally paid off. No-one is happier, and no-one should be prouder of the development of a private commercial aquaculture industry than the officials of the governments of those countries we visited. Thousands of private-sector jobs have been and are being created, hundreds of millions of kilos of fresh fish are being raised annually and are now available to feed their nations, and the industries are now in a position to largely expand on their own.

3. TECHNICAL ISSUES GOING FORWARD

There are a number of technical issues which can potentially affect the stability and growth of the aquaculture industries in the countries visited. Many are somewhat universal to warmwater aquaculture and may apply across a broader geographic area. Some are simply facts, some are merely "bumps in the road" that will resolve themselves over time, and others are economic or policy issues that must/should be dealt with by the governments, the private sector themselves, or in many cases, a collaboration between the two.

Culture systems and production potential

There are three major production systems currently in use in the countries visited – cages, earthen or lined ponds, and small concrete or earthen lined "tanks". Of these, probably the most profitable is the production of fish, mainly tilapia, in cages placed in large public waters but the intensive tank culture of clarias is noteworthy.

Cages. Ghana has made by far the greatest progress in supporting/developing cage culture in public lakes but we visited one large farm in Uganda on Lake Victoria, and know of plans for expansion of cage farming in Lake Victoria from both the Kenyan and Ugandan sides. Much of the current fish production in Ghana (not to diminish the importance of pond production) is tilapia raised in large cage farms producing 1000- 4000 t/year.

Figure 9. Workers feeding tilapia at cage farm on Lake Volta.

Most large cage farms in Ghana have plans for major expansion. Currently all Ghanian cage production is in Lake Volta, one of the largest lakes in the world by surface area at 8,500 km2, but expansion to other lakes is planned. The market preference in Ghana for tilapia has directed most cage production toward that species, but clarias would also do extremely well in cages.

There is great debate among scientists studying cage production as to the benefits/economics of " low density – high volume" versus "high density – low volume" cage production systems. We will not enter that debate. Suffice to say the most of the large operations we saw in Ghana use large round or square cages. The major advantage of cage farming is that of reduced capital investment per unit of fish production relative to ponds or tanks. Barring license fees, the land (water in this case) is free, and cages are generally cheaper to build than ponds with associated wells, drains, valves, etc.

Most farms raised all-male, sex-reversed tilapia using fairly well-established production techniques. Brood fish are either spawned in tanks or happas, and either eggs are removed to a jar hatchery or young fry are

collected after incubation by the female. They are fed a hormone (17-α-methyltestosterone) for 30 days and then reared in ponds or cages until large enough (30 g or larger) to stock in grow-out cages. The main market slot is a 150-400 g fish which can be produced from a 2 g sex-reversed fry in about nine months (5-6 months from stockers).

Feed conversion ratios with tilapia in cages may average 1.5-1.8 depending on the feed and the feeder. Most producers use imported (and more recently domestically- produced) commercial extruded/floating for tilapia, although at least one small cage producer in Uganda was using a locally-produced sinking pellet. Overall annual production may average around 50-60 kg/m3. Managers believe that production could be increased to 100 kg/m3 with a faster growing fish and a better feed. Higher production may also be possible with smaller cages, by developing markets for smaller tilapia (which can be produced in a shorter period), or by raising clarias where there is a market for that species.

Figure 10. Satellite view of pond- based farm in Uganda.

Ponds. Ponds are the traditional production units across Africa. Government approval is generally much easier (often little or no permitting is necessary for building ponds on privately-owned land), although capital costs (land, dirt work, pond liners where necessary, wells, piping, pumps etc) are much higher than for cages. With innovative management, mixed-sex tilapia can be raised successfully, but with the currently available technology for sex-reversing tilapia, most fish producers are now raising all-male tilapia. Monosex tilapia is generally viewed as the only way to economically produce larger (200-500 g) tilapia which are the preferred market size. If markets could be developed for smaller fish, which we believe is possible, mixed-sex production (which would be easier) would likely be more profitable.

Production/management techniques are so variable as to defy generalization. Sex-reversed (1-2 g) tilapia fry may be reared for an additional period to a stocker size (20-50 g) or simply stocked as fry. A variety of other species may be reared as companion species (polyculture), including clarias, common carp, Nile perch (predator control of any unwanted reproduction), or Heterotis niloticus. Monoculture of tilapia was most common and clarias the most likely co-cultured species due to availability of fingerlings.

Figure 11. Tilapia being fed a meal-type feed.

Most pond operations we visited would be classified as small commercial and used a variety of feeds. Locally-produced feeds were most common on smaller operations with more limited cash flow. Meal- type feeds, blended from ground local ingredients which could also include shrimp or fish from lake Victoria, were most common on smaller farms but also less effective. While tilapia and even clarias will eagerly come to feed on a meal-type feed, much of the feed is not consumed but merely acts as expensive fertilizer. Overall, it is likely that the more expensive commercial floatingfeed may in fact be more economical than meal-type feeds. This may be a good topic for an on-farm research project.

Both tilapia and clarias are excellent species for pond production. Tilapia, being a facultative-filter feeder, can consume algae which grows in any pond receiving nutrient (feed or fertilizer) inputs. This both reduces the protein requirements in the supplemental feed and improved the FCR. While we did not see any major earthen pond production of clarias, clarias producers generally all believed that clarias did better (grew faster and had better FCR) in earthen ponds than in lined ponds or concrete tanks.

Production rates are understandably all over the board to due highly variable management practices. Production of tilapia in monoculture at rates up to 5000 kg/ha/year are achievable with a good stocking, harvesting and feeding program. While tilapia are very low-oxygen tolerant, feeding at higher rates to increase production above that would likely see reduced growth rates unless aeration was used. While undoubtedly use of supplemental aeration will come to Africa, at present a lack of reliable affordable electrical service and the cost of aerators would likely limit application of intensive aeration.

Pond production of tilapia can be increased through known management techniques: use of quality feeds; reducing the production cycle (more crops/year) by using a faster-growing variety of Nile tilapia or producing and marketing smaller fish; using larger stockers; polyculture with other species, clarias and common carp being the most likely candidates. It may be likely that in areas of cooler water temperatures, such as central Kenya, the common carp, if marketable, may be a better culture fish due to its lower temperature tolerance.

Tanks. The term "tank" as a production system was new to us but very descriptive. A tank in this context is a small (10-100 m2 or so) earthen pond (with a waterproof liner to prevent seepage and erosion), concrete, or fiberglass structure typically used to produce clarias. In areas of seasonally cooler temperatures the tanks may be covered with a greenhouse to minimize temperature drop at night.

While we saw a bit of tank clarius production on one farm in Kenya (with roots in Nigeria), this system was most widely used (of the places we visited) in Nigeria for the production of clarias table fish. There tanks may be stocked with up to 100 clarias (2"-6" long fingerlings) per m3 which can grow out to 1 kg in as little as six months, resulting in a pretty amazing production rate of about 200 kg/m3/year. Fish are fed a 30-40 % protein commercial floating (usually imported) feed, and water is drained down and refilled with fresh water daily to flush out the ammonia, nitrite, carbon dioxide and suspended solids. While we did not have an oxygen meter, we presume that the dissolved oxygen concentration remains near zero pretty much all the time. Due to the constant anoxic conditions, tilapia production would not be possible at economical densities without constant aeration. While we did not have access to all of the background research on clarias production and physiology, the tolerance of clarias to ammonia and nitrite, and the potential for increasing growth through some aeration are key topics for future work since they directly impact one of the main management practices – flushing of water. While we are NOT generally advocates of recirculating systems, the potential to reduce production costs and minimize water usage through at least partial re-use would definitely be interesting. The production potential of clarias is so great that increased marketing/promotion efforts in areas of low/moderate clarias demand would be worthwhile.

Figure 12. Empty "tank" used to produce clarias.

Figure 13. Clarias at feeding time in intensive tank culture.

Feeding, feeds, and feed quality

Lack of feeds has long been a major limiting factor in African aquaculture. For decades, extension agents across the continent have been working with subsistence fish farmers to collect and use local waste or

underutilized materials as supplemental feed for their fish, primarily tilapia. While it is possible for a one-pond farmer to collect enough goat droppings, cassava leaves or mill sweepings to increase production in their 100 m2 pond to 1000 or 1500 kg/ha, or perhaps more, a commercial industry cannot be built nor sustained on household waste. In spite of everyone's best efforts, major freshwater fish production was only a dream until people began to import quality commercial floating feed. This was the major breakthrough that allowed serious expansion as well as intensification of production.

While these feeds are generally of very high quality, they are also very expensive due to the added trans-oceanic shipping, costing as much as US$2.00/pound for the smallest pellet, highest protein feed. Feed may amount to 70-80% of the cost of production in the areas visited. With cheap labor and relatively little investment in production systems in some cases feed costs of this magnitude may be tolerable but not idealand all efforts should be made to increase efficiency and reduce feed costs.

The demand for feed by an expanding commercial industry has spurred competition and modern local mills have been and are being built with the aim of using a majority of locally-sourced materials to reducing shipping/total feed costs. However, while local sourcing can reduce shipping costs, feed prices will be largely based on world grain prices. There were some instances of conflicting government policies, such as putting an import duty on feed (which is passed on to the farmer), while selling fingerlings from government hatcheries at a subsidized price, which limits the growth and profitibility of private-sector hatcheries.

There are feed distribution networks (all bagged feed, no bulk feed) being established everywhere we visited. Competition and the demand for feed should stimulate continued development of local feed mills making feed more widely available.

We also saw a greal deal of interest by feed manufacturers in providing technical assistance and training to their customers. It is in a feed mill's interest (and a hatchery's as well) to have successful customers. A farmer who makes money will stay in business, expand, and buy more feed and fingerlings, usually but not always from the supplier(s) who helped him succeed. In one case a new feed mill made a substantial donation to a training center that will be operated jointly with the government and used to train both farmers and goverment technicians. This type of private/government collaboration is both good and essential as we go forward.

Figure 14. Hard (sinking) pellet being manufactured on-farm in Uganda.

There are also a variety of local feed manufacture solutions, ranging from a farmer-formulated meal-type diet (which has been likened to expensive fertilizer due to the inefficiency of feeding a powdered/meal feed), to producing a quasi-pellet with a grinder (which also entails the problem of drying the feed), to small mills which produce water-stable, hard sinking pellets. While all of these as well as other solutions to produce feed for the industry will continue, the long-term growth and success of the industry will likely depend on quality pelleted feed produced by modern mills using a rations designed specifically for the species and life stage being grown. Costs need to come down, and least-cost formulation as well as local sourcing of ingredients can be used in part to achieve this. The feed quality advertised must be the feed actually sold, and this can likely only happen with uniform labeling requirements.

We have frequently heard the suspicion that some feed sold may contain far less protein (the most expensive component of feed) than promised. Labelling and government inspection can do much to prevent this. If a farmers wants to use a 20% protein feed because it is cheap even though it may result in poor growth


35% FRY / FINGERLING CATFISH FOOD

GUARANTEED ANALYSIS

CRUDE PROTEIN, minimum 35.0%
CRUDE FAT, minimum 2.5%
CRUDE FIBER, maximum 7.0%
PHOSPHORUS, not less than 0.7%

INGREDIENTS: Plant Protein Products, Animal Protein Products, Grain Products, Processed Grain By-Products, Forage Products, Vitamin A Supplement, Vitamin D3 Supplement, Vitamin E Supplement, Riboflavin, Pantothenic Acid, Niacin, Vitamin B12 Supplement, Choline Chloride, Menadione Sodium Bisulfite, Thiamine Mononitrate, Ascorbic Acid, Pyridoxine Hydrochloride, Folic Acid, Ethoxyquin A Preservative, Salt, Dicalcium Phosphate, and Traces of Manganous Oxide, Calcium Iodate, Copper Oxide, Cobalt Carbonate, Zinc Oxide and Iron Carbonate.

Figure 15. Label on bag of fish feed in the USA.

and overall economics, that is his choice. Information and training can minimize but never eliminate poor choices by some farmers. But even if a farmer makes a poor choice in feed, he should get what he is paying for.

There is generally a lack of good research-based technical information available on feed requirements and economics of feeding the various life stages of both tilapia and clarias in commercial systems. Efforts should be made first to compile all nutritional research available and then to fill the gaps with applied research. In many cases collaborative on-farm research between university/government scientists and the private sector would be appropriate. Comparing diets/formulations/feeding strategies in the actual production facilities would likely produce the most relevant results.

Data collection

A tremendous amount of effort has been expended in the last half-century in collecting data on aquaculture production in Africa – the number of farmers, total area of ponds, and total fish production. It has proven to be a hopeless task. With thousands of farmers scattered around the country, more ponds built and abandoned every year, most fish sold at the pond bank, and an understaffed and underfunded extension service, one has to ask "why bother?". Well, one answer is that it is important. If the government is spending scarce money to develop a sector of the economy, it is reasonable to expect some estimate of the results. So the question may be, how do we most easily and accurately do this?

Getting data directly from the farmers is likely the most expensive and least reliable method. If everyone producing fish had to get a permit, and one requirement of the permit was to file a production report with the government annually, and that system actually worked, it could be done. However, we feel the need for data alone does not justify the requirement for permits, reports, etc., for everyone raising fish. A large cage operation using a public body of water could easily be required to do so, but for the hundreds of small, largely subsistence operators just trying to raise a few fish to supplement their income, the need for data does probably not justify the red tape, especially given the low likelihood of everyone accurately reporting the data.

Data could also be collected through point of sale if most fish were processed or marketed through a limited number of outlets. That clearly is not the case in Africa but is worth considering if the infrastructure is deveolped in the future.

Collecting data on fingerling sales is a possibility. While we would not recommend registration/licensing of all fingerling producers solely for the purpose of data collection, there are fewer hatcheries than total fish producers and some form of "certification" or licensing has been at least discussed in all of the countries visited. Knowing the total tilapia and clarias fry/fingerling sales alone would give a good benchmark for annual increases or decreases. With a small amount of verification or groundchecking on survival rates, production and sales of a few selected farmners, the total fingerling sales could be turned into a fairly reasonable estimate of fish production.

Probably the easiest means of collecting useful data would be to collect volume of feed imported and manufactured. While some small producers buy raw materials locally and some manufacture crude pellets, now and in the future the bulk of the fish produced will be from feeding commercial feeds and there is a very limited number of sources/outlets. Most if not all countries require an import permit for feed of foreign manufacture even if they do not levy an import duty on it. While the bureaucracy now may be so cumbersome

Figure 16. Feed storage at farm in Kenya.

as to make summarizing this data difficult, the lack of government efficiency should not require increased red tape for the farmers. This data on imported feed could be collected relatively easily. There are relatively few large commercial feed mills in each country, and these would be easy to survey annually. Even breaking down these data by tilapia growout (lower protein), clarias growout (higher protein), or fry/fingerling feed (high protein meal or micropellet) would be easy. Again, by sampling only a few farmers, reasonable FCRs could be determined, easily converting tons of feed into tons of fish.

Improved record keeping on farms is also essential if aquaculture is to be viewed as a business, which it is, and we see that happening. On one operation, they were calculating profitability on each segment (hatchery, grow-out, and marketing) of their business. Another large cage producer was moving toward computerized records, including bar codes on tanks to allow scanning of stocking, harvest, and feed records.

Seed (fingerling) availability and quality

Techniques for mass production of both sex-reversed tilapia and clarias are now widely known and practiced. Throughout the trip we saw numerous small and large hatcheries using fairly simple equipment, producing millions of fry and fingerlings of both species. Once the techniques were developed and promoted by fisheries departments and assisting aid missions and NGOs, farmers saw great profits in running a hatchery.

As with the development of any new animal industry, shortage of seed is the first factor limiting commercial production. With fish, it is usually far more profitable to produce a 1 g fry and sell for 10 units (10,000 units/kg), than to grow it out to 500-1000 g food size and sell it for 300 units/kg. This economics has given a huge push to the expansion of private hatcheries throughout the four countries visited, and that is a good thing. Governments can now largely get out of the fingerling business and refocus their valuable resources on more important privorities.

This is not to say that all hatcheries are operating at peak efficiency. Since both tilapia and clarias are easy to spawn (clarias require a pituitary injection but they produce a lot of eggs), almost no-one is making any special efforts at brood stock maintenance or use brood stock diets, both of which could show big improvements in fecundity, hatch and survival rates. Clarias, producing a smaller fry, often show highly variable survival when reared in ponds. Attention to zooplankton management (and management of critical size prey items for the small fry) and insect predation (which is likely the major cause of predation, not frogs as frquently suggested) could result in great increases in hatchery efficiency.

Some hatcheries are already seeing increased competition and in some cases the fingerling market is already being flooded. Likely, those hatcheries which are able to produce their seed a bit cheaper, offer consistent quality (many reputable hatcheries offer a money-back guarantee for a limited time after delivery), and/or provide other services to their customers, such as advice, training and sales of feed and equipment, will prosper. Those which can't survive as hatcheries will have to turn to table fish production, although less profitable. Some will opt to go out of business. This trend will likely be seen in the near future.

There is a long history of government hatcheries in Africa lamenting the poor quality or "inbred" tilapia being sold to naïve farmers by unscrupulous private hatcheries. In many cases private fingerling sales have been banned, or government fingerlings were (and still are) sold at a highly subsidized price to encourage farmers to purchase these "high quality" government fingerlings. In most cases this was merely

self-preservation.

On this trip we heard numerous complaints, largely by government officials looking for a role in the future (but also some by larger hatcheries not liking the competition), of "poor quality" seed being sold, and the need to certify or license hatcheries. There is an understandable and commendable desire to protect these farmers by assuring some level of seed quality. However, definition and regulation of seed quality will be an extremely difficult task given the limited personnel and resources available to public agencies.
A more effective approach would likely be education of farmers about what is good quality seed by delivery of information through web based media or training sessions. Training workshops could be a good opportunity for public/private partnership to educate beginning farmers about issues like seed quality. Indeed examples of public/private partnerships for farmer training were observed and seem an ideal method to reduce costs of training for public agencies while promoting competition to ensure good quality seed being produced by private hatcheries. There may be some early incidents of inexperienced farmers being taken advantage of, but market forces will likely resolve the problems related to seed quality.

Genetic resources and available culture fish

The majority of aquaculture production in the countires visited is currently based on the Nile tilapia, Tilapia nilotica, and the African catfish, Clarias gariepinus. These two fish species are native to the continent, have well-established culture techniques, are in generally high demand in local markets, are traditionally sold "head-on", and are currently being produced in substantial numbers across the countries visited. While we observed incidental production of other species, for the foreseeable future the majority of aquaculture production in the region will be based on tilapia and clarias.

Figure 17. Clarias sold "head-on".

Fish culturists and fisheries managers are always looking for a "better fish". Although there may be some benefits from an aquaculture viewpoint for importation of some exotic culture species, the risk of negative impacts on native fish and ecosystems almost certainly outweighs the benefits to aquaculture. Introductions of exotic species have been commonplace around the world, including Africa, and examples of negative impacts on native species and ecosystems are prevelant. There have also been some benign (perhaps even beneficial) introductions. For example, common carp or mirror carp (Cyprinis carpio), have been introduced a half-century or more ago to most of the countries visited as potential culture fish and are now considered part of the natural system with no apparent adverse effects. However, as a general rule there is no way to predict the outcome of an introduction and no way to reverse the decision once made.

On this trip we heard anecdotal reports that Chinese carps (silver, bighead, and/or grass carp) may have been introduced in Uganda and we also heard private sector interest in the importation of Pangasius sp. (Asian catfish, "basa" or "tra") for aquaculture in Ghana. The team recommends introduction of non-native species not be allowed without a serious, science-base discourse leading to a formal national policy.

There is really little need for additional culture species in the countries visited. Tilpia nilotica and Clarias gariepinus are two excellent fish for aquaculture with large market demand in the region. The best path forward would be to select for improved aquaculture performance in these two species. The development of long-term breeding programs for these two speices is warranted and underway in several locations visited. There are other native species with a history of although marginally developed production technology in Africa, such as Heterobranchus sp.(potentially very useful as a hybrid with clarias), Heterotis niloticus, and

Lates niloticus (most often used as predator control in tilapia ponds), to name only a few already being cultured to some extent.

Although development of feed mills, production facilities, markets, and improved management practices may provide greater immediate impacts on the expansion of aquaculture production, genetic improvement programs can play an important role in improving productivity and profitability of aquaculture in Africa. Once management practices are at a high level given local resources, such as with some of the tilapia cage farms we saw in Ghana and clarias tank production in Nigeria, improved genetic stock can make a difference. Government agencies and private entities have begun the process of developing and implementing genetic improvement programs and addressing issues related to development and use of genetically improved fish for aquaculture production.

In the countries visited, public and private groups are making serious commitments to breeding and are in various stages of developing breeding programs for both tilapia and clarias. In Ghana, the Akosombo strain of tilapia, which was developed from fish sourced from Lake Volta, has been selected for increased growth for nine generations and scientists there report a 30% improvement in growth relative to the control population. The Akosomba strain has been distributed to government hatcheries and producers and is widely utilized in Ghana. Genetic improvement programs are also being conducted for tilapia and clarias by scientists in Sagana Kenya with plans to release these fish to farmers.

Figure 18. Hapas used in selective breeding program for clarias at Sagana, Kenya.

Flying somewhat under the radar but of potentially great signifi cance is the development of an improved line of clarias by Dutch researchers. While we did not see performance data on this line, it has been introduced and is widely cultured in both Nigeria and Kenya.

These pedigree-based breeding programs utilize tracking of both phenotypes and pedigrees of large populations, requiring significant economic resources and long- term commitment in order to produce significant results. Due to the high costs of initiating and continuing these breeding programs, it would be beneficial for public entities in the region to consider sharing resources or at least sharing germplasm and information with other countries and private companies. This has already been initiated by the six countries sharing the Volta basin through the Volta Basin Authority. In east Africa, development of a unified breeding program for the region could possibly be established through coordination by the Lake Victoria Fisheries Organization based in Jinja, Uganda. Again, inclusion of private sector input and collaboration in development of regional breeding programs will be beneficial, especially since there is now a viable industry.

The private sector's primary interest in breeding programs is to increase production and profitability of private-sector aquaculture, while the public sector has dual roles of promoting expansion of aquaculture (and the associated benefits of food security and economic growth) while also protecting the environment and natural resources. Additionally, aquaculture development is ongoing or planned for large lakes (such as Lakes Volta and Victoria) that are bordered by or impact several countries. Timely, unified decisions among

the countries involved in the introduction of genetically improved fish will provide a known regulatory environment necessary for planning future private sector investments.

How the roles of public and private entities in breeding programs will develop in the region is uncertain. There may be a more immediate opportunity for private breeding involvement with tilapia since there are several very large companies producing tilapia who have the resources to initiate breeding programs and some already have to some extent. There are fewer large commercial producers of clarias with the resources required for large breeding programs, and the role of government in catfish breeding may be more essential. Regardless, the public sector should encourage development of private sector breeding programs. This can be facilitated by private sector input on what traits are important in public breeding programs, initiating/speeding the transfer of germplasm currently held by public sector to private sector, and by public-private collaborative testing of germplasm performance to provide unbiased evaluation and delivery of performance data to producers.
The question that needs to be considered is not if cultured fish will escape and possibly interact with native fish population and the ecosystem, but what are the

potential impacts when they do? These issues are currently being debated more extensively with tilapia given the rapidly expanding cage culture on Lakes Volta and Victoria, but the same issues apply to clarias. Currently, the most common approach of public agencies in the region is to initiate tilapia breeding programs with fish from populations native to the region or drainage. However, there are other sources of Tilapia nilotica that have been selected for improved performance (for example the GIFT line of Tilapia nilotica developed in Asia from African sources has been brought in to the Akosombo facility where they are being compared to the Akosombo line) and there is great interest among private sector in importing and using all of these improved lines.

Should farmers be allowed access to the GIFT line, knowing they will likely achieve faster growth and higher production using that line, or does the government deny farmers access to a faster growing fish due to fears of "genetic contamination" of naturally existing stocks? We now have the technology to analyze and quantify thousands of genetic markers or "bits" of genetic code. While different populations of tilapia within an area may have slightly different percentages of some of these markers, as do fish removed from those populations and subjected to traditional selection programs, few if any professional ichthyologists or fish biologists could differentiate between a "native" Lake Volta fish, an Akosombo tilapia, or a GIFT tilapia without some serious DNA fingerprinting. They are all Tilapia nilotica.

There are some additional thoughts as to what truly constitutes a native stock. Lake Volta itself was created in 1965 when the dam was completed, dramatically altering the environment and certainly impacting the formerly riverine ecosystem. There are undocumented reports of introductions of tilapia into Lake Volta with the (probably correct) assumption that this would improve commercial fishing and the overall economic impact of the lake. The current concerns over potential genetic contamination of a relatively recently established population by the incidental introduction of the same species seems, at a minimum, a bit overblown.

The dual role of government to foster aquaculture growth while also protecting natural resources results in a tendency for government agencies to suggest more time is needed to study the potential impacts, and more time, and more time. The best course may simply be to make the decisions of use and regulation of genetically improved fish based on the science available and historical data, while taking into consideration the benefits on growth in aquaculture and the potential impact to the environment.

Therefore, although we feel that comparing lines of tilapia (or clarias) developed elsewhere to native populations or selected lines derived from native populations is useful to determine their relative value to aquaculture, it is our opinion that the genetic threat to 'native populations' posed by use of genetically improved Tilapia nilotica from outside the region is not substantially different from that of genetically improved fish developed from the native population. The team believes that risks of negative impacts on the ecosystem are small when using genetically improved native species (i.e., Tilapia nilotica or Clarias gariepinis).

Marketing

"Back in the day", we didn't need to worry about marketing fish. It was a rare African pond harvest which couldn't be sold on the pond bank after notifying friends and neighbors a day or two earlier. Those days are thankfully behind us. We now are looking at daily harvests from some operations of 10-25 metric tons of fish – that quantity of fish cannot be weighed out and sold at harvest a kilo or two at a time on the farm. Marketing now is a serious business.

The good news is that Africans love fish, and while the demand for fresh tilapia and clarias (also often smoked) is not unlimited, it almost appears so at this time. The physical infrastructure (roads, electricity, communications) in the countries visited ranges from that of any modern city in the world to relatively non-existent. However, as fish are sold first in the population centers, and most fish production is relatively close, availability of roads, transportation and most important, ice, are generally available.

In Ghana, one large cage producer established a quasi-independent subsidiary that distributes over 4,000 t of fresh tilapia each year, with plans for major expansion. We saw several farmers operating large smokehouses and working on EU certification for clarias, and heard of (unfortunately didn't visit) a processing facility for clarias near Entebbe for export to the Congo. Farms in Uganda routinely shipped iced tilapia to neighboring Rwanda and Congo where fish was in even higher demand than in Uganda. Everyone we visited that talked of plans for expansion of production also talked about their plans for marketing.

It will doubtless be a challenge. Fish production could easily double in a few years, especially if simplified policies for licensing cage farms in Lakes Volta and Victoria are put in place, and fish is very perishable. There will doubtless be a few bumps in the rode as the industry expands, with localized periodic shortages and surpluses. The breakdown of an ice factory, even if temporary, could have a major impact on the steady flow of fish to the market. However, we saw great optimism, and people with great visions of how the market could be expanded, both goegraphically and vertically through further processing and innovative products.

More effort need to be put into market development for clarias than for tilapia. Tilapia is more universally desired than clarias, but clarias has tremendous production potential if they can be successfully marketed. From the farmers' standpoint, a greater effort needs to be made on the marketing of smaller fish. The greatest single way to increase the production/unit area of any facility is by selling a smaller fish, and the aim of producing a 400-500 g tilapia or a 1 kg clarias is definitely limiting.

Fish farmer associations

On this trip we met with the leadership of several fish farmer associations. We feel that formation of these associations is an important first step in the development of the future relationship between the public and private sectors. However, at present they are really just getting started and in most cases do not appreciate their potential influence on policy.

We expect that as the aquaculture industries develop, these associations will have an increasing influence on

government regulation and policy as it relates to aquaculture. The day will come when they will truly "have a seat at the table" when these issues are being discussed and policy decisions are being made. For example, we can't imagine developing a policy on cage culture in a public lake without at the very least soliciting the input of people interested in starting a cage farm, or better yet, an association that represents all of them. Several major fish producers

Training

Training in new skills and techniques is a cornerstone of progress in any technical field, including aquaculture. There is a history worldwide of aquaculture courses, training centers, and training programs designed to improve the skill level of government hatchery workers, extension agents and interested and practicing private farmers. The impact of these has been highly variable. The team members have themselves been involved in many of these efforts. On this trip was saw a new process under way, one that we see as key to the future of commercial fish farming in Africa.

In all countries we saw private sector involvement in the training of people in commercial fish farming techniques. Who better to train people in the actual practices used to raise fish commercially (and profitably) than people who actually do that for a living. Not to say that every good fish farmer will make a good teacher or mentor, but it's difficult to teach a skill that you yourself have not mastered.

In all four countries we saw many examples of private sector involvement in the training of the next generation of fish culturists. We saw college students serving internships on private farms, larger and more productive farms/hatcheries providing (paid) training programs to their customers in an effort to increase their (the participants') skill levels, and true public-private partnerships in which the private sector contributed significant funds to the development of a training center that was operated with personnel from both sectors. We are big believers in the need for "hands on" as well as academic training and we saw all of these developments as very positive.

This is not to minimize the role of government. One of the primary missions of the public sector is education. Managers of large farms we visited, some employing hundreds of people, bemoaned the fact that trained, skilled employees were not available. We see indications of the government stepping up to fill this need, but curricula (and perhaps even the execution to some degree) should be developed in coordination with the future employers. Students must be educated and trained in the skills that will actually be needed in the workplace.

APPENDIX 1, ITINERARY

July 7 2013 Depart USA for Ghana.

July 8 2013 Arrived Accra, Ghana, met by Emmanuel Nii Aryee (Deputy Director of Fisheries).

July 9 2013 Meet Deputy Regional Representative for Africa, FAO, Accra.
Visited Volta Catch Limited (Distribution Center for Tropo Farms), Accra. Met with Minister of Fisheries and Aquaculture Development, Accra.

July 10 2013 Visited Ashaiman Aquaculture Demonstration Station.
Visited Raanan Feed Mill, Accra.
Drove to Akosombo; met District Director Fisheries Commision. July 11 2013 Visited Crystal Lake Fisheries.
Visited West African Fish Ltd., Lake Volta.

July 12 2013 Visited Aquaculture Research and Development Center, CSIR-Water Research Institute, Akosombo.
Visited Tropo Farms cage site and hatchery, Lake Volta.

July 13 2013 Depart Accra, Ghana.

July 14, 2013 Arrived Kampala, Uganda.

July 15, 2013 Met by Andrew Alio (Principle Aquaculture Officer, Ministry of Agriculture Animal Industries and Fisheries) and Bright Onapito (Aquaculture Information Expert, Aquaculture Network for Africa).
Visted SON (Source of Nile) farm, Jinja (on Lake Victoria). Visited Lake Victoria Fisheries Orgranization, Jinga.
Visited Salama Integrated Fish Farm Ltd., Busia District. July 16 2013 Visited Namuyenje Fish Farm, Mukono District.
Visited Manjori Fish Farm, Mukono District.
Visted Ugachick Poultry Breeders LTD, (feed mill), Kamapala. July 17 2013 Visited Greenfields Fish Farm (Lake Victoria), Entebbe.
Ssisa Integrated Fish Farm, Wakiso District.

July 18 2013 Office of Department of Fisheries Resources, Entebbe.
Departed Entebbe, Uganda to Nairobi, Kenya.

July 19 2013 Met by Ms. Betty Nyandat (Assistant Director of Fisheries, Kenya) and Mr. Godfrey Monor (Director of Fisheries), Nairobi.
Visited Sigma Feeds LTD., Nairobi. Visited Jambo Fish, Nairobi.
Visited Kamiti Fish Farm, Kiambu District. Met with Chairperson and Vice- Chairperson of Commercial Aquaculture Society of Kenya – CASK.

July 20 2013 Visited National Aquaculture Research and Development and Training

Center/Kenya Marine and Fisheries Research Insitute, Sagana.
Visited Green Algae Fish Farm, Sagana. Visited Mwea Fish Farms, Mwea.

July 21 2013 Sunday. Day off for writing.

July 22 2013 Visited Kamuthanga Farm – Recirculating System, Machakos County.
Visited Nthongoni Fish Farm, Kimutwa.
Visited Central Aquatic Farmers Feed Cluster, Machakos. July 23 2013 Depart Nairobi, Kenya for Lagos, Nigeria.

July 24 2013 Met with Istifanus Pwaspo (National Project Coordinator, Sustainable Aquaculture Systems for Nigeria) and Kudomi Damilola (FAO Associate Professional Officer).
Visited Temitayo Farms, Lagos. Met with President of Catfish Farmers Association of Nigeria - CAFAN. Visited Timmod Farms, Lagos.
Visited Quicklink Farms at Lagos State Commercial Agriculture Development Project, Lagos.
Visited two additional farms at the Development Project.

July 25 2013 Visited Nigerian Institute for Oceanography and Marine Research Headquarters (NIOMR) and NIOMR farm, Lagos.

July 26 2013 Departed Lagos for Abuja, Nigeria.
Met with/debriefed officials from the Federal Ministry of Agriculture and Rural Development.
Met with President of Fisheries Society of Nigeria (FISON), three other FISON members.
Debriefing with FAO.

July 27 2013 Depart Abuja for USA.

July 28 2013 Arrive USA.

APPENDIX 2. CONTACTS.

Ghana

Emmanuel Nii Aryee	Deputy Director of Fisheries, Accra, Ghana.
Lionel Awity	FAOSFW, Accra, Ghana.
Lamourdia Thiombiano	Deputy Regional Representative for Africa, FAO, Accra, Ghana.
Michael Akuoko	Operations Manager, Volta Catch Limited, Accra, Ghana.
Nayon Bilijo	Minister of Fisheries and Aquaculture Development, Accra, Ghana.
Edmund Datuah	Hatchery Manager, Ashaiman Aquaculture Demonstration Station
Raanan Berzak	Managing Director, Raanan Feed Mill, Accra, Ghana.
Jacques Magnee	Aquaculture Expert/Commercial Director, Raanan Feed Mill, Accra, Ghana.
Hannah Agyei-Boakye	District Director Fisheries Commision, Akosombo, Ghana.
Patricia Olivia Safo	Managing Director, Crystal Lake Fisheries, Dodi Asantekrom, Ghana.
Lars Lynge	Director, West African Fish Ltd., Lake Volta, Ghana.
Joeseph N. Padi	Aquaculture Geneticist and Hatchery Production Expert, CSIR/WRI/ARDEC, Akosombo, Ghana.
Seth Koranteng Agyakwah	Aquaculture Geneticist, CSIR/WRI/ARDEC, Akosombo, Ghana.
Francis Anani	PhD student, CSIR/WRI/ARDEC, Akosombo, Ghana.
Nicolas De Wilde	General Manager, Tropo Farms, Lake Volta, Ghana.
Jamien O'Keefe	Hatchery Manager, Tropo Farms, Asutsuare, Ghana.

Uganda

Andrew Alio	Principle Aquaculture Officer, Ministry of Agriculture Animal Industries and Fisheries, Entebbe, Uganda.
Bright Onapito	Aquaculture Information Expert, Aquaculture Network for Africa, Jinja, Uganda.
Robert Osinde	General Manager, SON (Source of Nile) Farm, Lake Victoria, Buikwe District, Uganda.
David Obedi	Production Assistant, SON (Source of Nile) Farm, Lake Victoria, Buikwe District,

Olivia Mkumbo	Senior Scientist, Lake Victoria Fisheries Orgranization, Jinja, Uganda.
Samson Abura	Information and Database Officer, Lake Victoria Fisheries Orgranization, Jinja, Uganda.
Philip Adome	Owner/Director, Salama Integrated Fish Farm Ltd., Busia District, Uganda.
Kibuuka Godfrey	Farm Manager, Namuyenje Fish Farm, Mukono District, Uganda.
Moses Farm	Manager, Manjori Fish Farm, Mukono District, Uganda
Mr. Aga Sekalala	Managing Director, Ugachick Feeds, Kampala.
Kubiriza Godfrey	Lecturer, Makerere University, Makerere, Uganda.
Kasongo Ngoy	Greenfield Fish Farm, Lake Victoria, Entebbe, Uganda.
Ben Musoloza	Owner, Ssisa Integrated Fish Farm, Wakiso District, Uganda.
Wadanya L. D. Jackson	Acting Head of Fisheries, Office of Department of Fisheries Resources, Entebbe, Uganda.

Kenya

Betty Nyandat	Assistant Director of Fisheries, Nairobi, Kenya.
Godfrey Monor	Director of Fisheries, Nairobi, Kenya.
Kirtesh Shah	Managing Director, Sigma Feeds LTD., Nairobi, Kenya.
John Momanyi	Sales and Marketing Manager, Sigma Feeds LTD., Nairobi, Kenya.
Willy Fleuren	Jambo Fish, Nairobi, Kenya.
Otieno Okello	Chairperson Commercial Aquaculture Society of Kenya (CASK), Kiambu District, Kenya.
Suzanne Njeri Kuria	Owner, Kamiti Fish Farm, Vice-Chairperson of CASK, Kiambu District, Kenya.
Isaac Wanee	National Aquaculture Research and Development and Training Center, Sagana, Kenya.
Paul Orina	Research Scientist, Kenya Marine and Fisheries Research Insitute, Sagana, Kenya.
William Njaremwe	Managing Director, Green Algae Fish Farm, Sagana, Kenya.
Anthony Mwangi	Manager, Mwea Fish Farms, Mwea, Kenya.

Christopher Nyaga	Machakos, Kenya. Kamuthanga Farm – Recirculating System, Machakos County.
Steven Mwamiki	Farm Manager, Nthongoni Fish Farm, Kimutwa, Kenya. Francis Kikwati Secretary of Central Aquatic Farmers Feed Cluster, Machakos, Kenya.

Nigeria

Istifanus Pwaspo	National Project Coordinator, Sustainable Aquaculture Systems for Nigeria , Department of Fisheries, Abuja, Nigeria.
Kudomi Damilola	FAO Associate Professional Officer, Abuja, Nigeria.
Tayo Akingbolagun	Owner of Temitayo Farms and President of Catfish Farmers Association of Nigeria, Lagos, Nigeria.
Rotimi Omodehin	Managing Director, Timmod Farms, Lagos, Nigeria.
Olawunmi Omodehin	Executive Director, Timmod Farms, Lagos, Nigeria.
Bolaji Dania	CEO Quicklink Farms and President of Lagos State Commercial Agriculture Development Project, Lagos, Nigeria.
E. Olusegun Oyewo	Acting Executive Director, Nigerian Institute for Oceanography and Marine Research Headquarters (NIOMR), Lagos, Nigeria.
Gbola Akande	Director, Post-harvest Fisheries Specialist, NIMOR, Lagos, Nigeria.
Patricia E. Anyanwu	Director/Head Aquaculture Dept., NIMOR, Lagos, Nigeria.
B.B. Solarin	Director Fisheries Resources, NIMOR, Lagos, Nigeria.
O. Rahman Oguntade	Research Officer, NIMOR, Lagos, Nigeria.
Mani Rabe	Assistant FAO representative in Nigeria, Abuja, Nigeria.
Joeseph Nyager	Director/Chief Veterinary Officer, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.
Obibba Anozie	Acting Deputy Director of Fisheries, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.
I.P. Ogar	Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.
S.O. Ayeni	Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.
J.O. Babtunde	Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.
A.O. Abioye	Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.

Abba Abdullah	President, Fisheries Society of Nigeria (FISON), Abuja, Nigeria.
D.J. Sabo	Member of FISON, Abuja, Nigeria.
M.N. Adebiyi	Member of FISON, Abuja, Nigeria.
Arc Aminu Dabo	Member of FISON, Abuja, Nigeria.

APPENDIX 3, FARMS/FACILITIES OF SPECIAL NOTE

While not specifically tasked in the Terms of Reference, we were asked to identify/highlight some farms and other critical institutions/steps in the value chain for possible future use as case studies or examples in future publicity. Two disclaimers are necessary. First, this list is limited to only the operations we personally visited, which in most cases represent a small portion of the industry in each country. Thus many outstanding examples of the industry were not available for consideration, and this was perhaps especially true in Nigeria. Second, exclusion of any operation that we visited from this list does not imply that it is not worthy of highlighting. We wanted to give examples of the breadth of the industry and eliminated many similar but impressive operations to minimize excessive duplication.

Tropo Farms (on Lake Volta, Ghana)

Vertically integrated cage operation producing 4,000 t/year in square cages, hatchery producing 2.5 m tilapia fry/week (which are then sex-reversed); subsidiary marketing arm (Volta Catch LTD) markets all of the tilapia (gutted, on ice) to Accra.

West African Fish (WAF), (on Lake Volta, Ghana)

Started first cage production in 2008, produce approximately 4,000 t/year (with a permit for up to 8,000 T/ year) in large round cages; has own hatchery which produced about half of their fry needs but also buy sex-reversed fry; set up roadside marketing of fish by women through fisheries extension agent.

Raanan Fish Feed, West Africa LTO (Accra, Ghana)

New modern mill opened in 2013 with plans to source 60% local materials: now produces about 80 tlday, some for export: does collaborative farmer training with the Ministry of Fisheries.

S.O.N. Fish Farm, LTD (Jinja, Uganda)

Pond/Cage operation. subsidiary of Lake Harvest Zimbabwe (mother company. African Century. LTD. UK) First major cage operation in Lake Victoria. 45 t/month production. primarily sold on ice to Rwanda

Salama Integrated FishFann (Busia, Uganda)

Built small hatchery with some assistance fi'om USAID, has a capacity of 150,000 tilapia and 100,000 clarias seed/month, integrated with poultry and hogs.

Namuyenge Fish Farm (Muhono, Uganda)

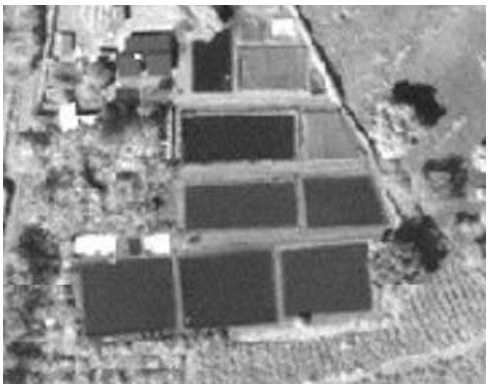
Cages in pond, integrated with large poultry operation, makes own hard (sinking) pellets, college intern, sex-reverses tilapia, sells some (50 kg/week) food fish to Rwanda

SSisa Integrated Fish Farm (K'la/Entebbe, Uganda)

Seven acres under water, prod. of 19.5 ttyear, tilapia, mirror carp, d arias and nile perch; small hatchery for clarias and tilapia.

Green Algae Highland Fish Farm (Sagana, Kenya).

Integrated small farm, spawns clarias with Indonesian method, sex-reverses tilapia, raises ornamental fish, zero-grazing cattle, intensive clarias table-fish production in small lined ponds.



Jambo Fish (Nairobi, Kenya)

Sell high volumes of clarias fingerlings, as well as fish feed and aquaculture supplies; provides (paid) farmer training; focusing also on market development of food-size clarias. May be greatest technical resource for clarias production in Kenya, with home base in Nigeria (Durante Farm, Ibadan)

Jambo Fish Limited – Fingerlings Price Lists

Type of Fish	Age	Price/Piece
Catfish	1 Week	3.00
Catfish	2 Weeks	5.00
Catfish	3 Weeks	8.00
Catfish	4 Weeks	10.00
Tilapia *All male*	3 Weeks	10.00
Tilapia *All male*	4 Weeks	15.00

Mwea Aquafish Farm (Wang'uru, Kenya)
In operation for four years, primarily sex-reversed tilapia and catfish seed (capacity of 300,000/year) but some table fish, farmer training, college interns, do on-farm collaborative research

Sigma Feeds LTD (Nairobi,Kenya)

New modem fish feed mill under construction to be opened by October 2013 with plans to source 60% local ingredients.

Tayo Akingbolagum, Temitayo Farms (President Catfish Farmers Association of Nigeria) (Lagos, Nigeria).

Has catfish hatchery, tank grow-out (20 t/year in five 24-m3 tanks), and smoked fish marketing operation, but is also President of the Catfish Farmers Association of Nigeria with 24 State chapters and several thousand members.



Rotimi Omodehin and Olawunmi Omodehin, Timmod (Farm) Investment LTD, Ago-Okuta, Lagos, Nigeria.

Operates a clarias hatchery, a 22-tank (21 m3 each) production farm, and a separate marketing arm (Bis-Bin) operated by his wife that processes, smokes and sells all fish produced. Virtually no fresh sales; are working for EU export certification.




(Mrs) Bolagi Dania, Quicklink Farms, Ikorodu, Lagos, Nigeria, and president of Ikorodu Fish Farm Estate (Government-established "enterprise zone" for tank farmers), Odogunyan, Ikorodo, Lagos, Nigeria.

Runs efficient catfish hatchery for both own stocking and extra fingerling sales, produces 400 t/year of clarias in approximately 1 ha of tanks, and sells all fresh at the farm gate.

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