Aquaculture and food security, poverty alleviation and nutrition in Ghana: Case study prepared for the Aquaculture for Food Security, Poverty Alleviation and Nutrition project

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AQUACULTURE AND FOOD SECURITY, POVERTY ALLEVIATION AND NUTRITION IN GHANA: CASE STUDY PREPARED FOR THE AQUACULTURE FOR FOOD SECURITY, POVERTY ALLEVIATION AND NUTRITION PROJECT

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EXECUTIVE SUMMARY

This study provides an overview of the aquaculture sector in Ghana. It assesses the actual and potential contribution of aquaculture to poverty reduction and food security, and identifies enabling conditions for and drivers of the development of Ghana's aquaculture sector. The study uses data collected from a variety of primary and secondary sources, including key informant interviews with actors within the aquaculture sector and relevant secondary literature.

Overview of the aquaculture sector in Ghana

Aquaculture is currently practiced in all 10 regions of Ghana, most prominently in the southern and central belts. The main fish species cultivated are Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*). Tilapia species represent over 90 percent of farmed fish production. Pond aquaculture is the main production system in terms of number of farms, and is mainly small scale and semi-intensive. However, in the last five to seven years the dominant culture system for tilapia production has changed, and the vast majority of tilapia is now farmed intensively in cages in Lake Volta. Aquaculture production increased from 950 metric tons in 2004 to over 27,000 metric tons in 2012. This growth is due mainly to increased production from a small number of large-scale cage farms. Overall, cage farms currently account for less than 2 percent of farms by number but much more by production. In 2012, for example, aquaculture production from cages was over 24,000 metric tons compared to less than 2,000 metric tons from ponds and tanks. The growth in aquaculture production is also attributed to increased availability of quality fingerlings and feed for fish production. The number of private hatcheries, which currently produce the majority of fingerlings in Ghana, has increased in recent years as a result of the rapid growth of cage farming. The establishment of a feed mill in Ghana in 2011 by Ranaan, an Israeli company, has greatly improved the reliability and availability of feed supply to fish farmers in Ghana.

Actual and potential impacts of aquaculture on poverty and food security in Ghana

The study assesses direct and indirect poverty impacts of small-scale pond aquaculture in Ashanti Region and cage aquaculture by small and medium enterprise — termed "SME" — cage farms in Lake Volta, Eastern Region, drawing on the findings of an earlier study.[1] These findings suggest that overall, aquaculture has higher potential to impact poverty through indirect impact pathways, such as economic multiplier effects, than directly through increasing the incomes and food security of poor fish-farming households. While poor households have been able to adopt aquaculture in Ashanti Region, small-scale pond aquaculture does not have strong positive direct impacts on the poverty and livelihoods of these households. However, small-scale aquaculture does appear to have positive direct impacts on the livelihoods of non-poor fish-farming households who are trained or use better management practices (termed fish farming type A). The level of these impacts is dependent largely on the household and livelihood characteristics, as well as the knowledge and management practices, of these farmers and is also likely to be influenced by the infrastructure and institutional context. There is potential to increase aquaculture's direct poverty impact, however, if poor fish-farming households are able to overcome their resource constraints and benefit from fish farming type A. The potential economic multiplier effects and associated backward, forward and consumption linkages are estimated to be stronger for small-scale pond aquaculture (fish farming type A) than for SME cage aquaculture. Thus, for equivalent increases in scale, small-scale pond aquaculture (fish farming type A) is found to have more potential to generate broad-based, pro-poor economic growth than SME cage aquaculture.

Drivers of aquaculture development in Ghana

At present, the actual and potential growth of the pond aquaculture sector is much lower than that of the cage sector. Much of the growth of the sector has come from the establishment and growth of a few large-scale cage farms. The SME cage sector has developed as a result and is now also beginning to take off. Two categories of key factors are identified as important in driving the development of the sector: i) enabling conditions and developmental processes, such as increasing urban demand for fish, macroeconomic policy reforms encouraging economic growth and foreign direct investment, and government support of the aquaculture sector; and ii) specific events and actors, such as the establishment of the pioneer farms Tropo Farms Ltd. and Crystal Lake Fish Ltd. and the introduction of low-cost cage technology. The former can be seen as having enabled the latter to be the catalyst for the cage aquaculture sector. Pond aquaculture in Ghana, on the other hand, has not experienced significant growth over the years. It is suggested that the small-scale rural pond sector in Ashanti Region is stuck in a "low-level equilibrium trap." This is due to high transaction costs and risks influenced by the demanding techno-economic characteristics of farmed fish — such as perishability, long production cycles, dispersed rural farmers, and the need for multiple and coordinated inputs — which require a high level of institutional development.

Conclusion

Pioneer farms such as Tropo Farms were able to overcome constraints to the sector, such as access to input and output markets, appropriate technology, etc., partly through vertical integration of input supply, production and marketing activities due to their high levels of financial and technical capabilities. Their success encouraged new SME cage farmers, feed suppliers and fingerling suppliers to make simultaneous and complementary investments in the cage-farmed tilapia value chain, thus helping the sector take off. Tropo's ability to overcome constraints through vertical integration (a type of nonmarket institutional arrangement) indicates the importance of institutional innovation for aquaculture development and provides some lessons for the development of the small-scale pond aquaculture sector. Coordinated value chain development facilitated by institutional innovation is required in order to overcome the challenges to growth of the small-scale pond aquaculture sector in Ghana and thereby maximize its poverty impact potential.

INTRODUCTION

This study provides an overview of the aquaculture sector in Ghana, assesses the actual and potential contribution of aquaculture to poverty reduction and food security, and identifies enabling conditions for and drivers of the development of the sector. This study is part of the Aquaculture for Food Security, Poverty Alleviation and Nutrition project, which aims to better understand and then improve aquaculture's contribution to food and nutrition security and poverty alleviation. Work Package 4 of the AFSPAN project, under which this study falls, seeks to provide a better understanding of the role of aquaculture systems, scales, enterprise structures and institutional arrangements in improving rural livelihoods, through conducting country-level case studies in Asia and Africa.

Ghana was chosen as a case study country because of its small but diverse and rapidly growing aquaculture sector, which shows significant promise as a growth industry. The sector encompasses a range of different production systems. It is primarily composed of small-, medium- and large-scale commercial tilapia cage aquaculture and small-scale pond aquaculture. A doctoral study completed in 2008[2] gives a detailed overview of the pond aquaculture sector in Ghana and the financial viability of pond-based fish farmers. Another recent study conducted as part of a doctorate[3] also provides a comprehensive assessment of the direct, indirect, actual and potential impacts of the development of both pond and cage aquaculture systems on poverty and economic growth in Ghana. The present case study reviews and builds upon this existing body of knowledge by providing an up-to-date overview of Ghana's aquaculture sector and undertakes additional analyses of the enabling conditions for and drivers of aquaculture development in Ghana.

DATA SOURCES AND METHODOLOGY

Data were collected from a variety of primary and secondary sources. Primary data were collected during fieldwork conducted in Ghana between August 9 and 23, 2013, mainly through key informant interviews with relevant public and private actors within the aquaculture sector. (See Appendix 1 for a full list of people interviewed.) Relevant secondary literature was also reviewed.

The overview of the aquaculture sector presented on pages 8 to 15 is based on secondary data, including government reports, published articles and studies, and gray literature, supplemented with information gathered from key informant interviews. The analysis of aquaculture poverty impacts in Ashanti and Eastern regions presented on pages 16 to 27 is based on the findings of Kassam[4] and Asmah[5] and supplemented with information from interviews with Fisheries Commission staff from Ashanti and Eastern regions, staff from the Water Research Institute in Accra and Akosombo, a focus group discussion with 10 small-scale pond aquaculture farmers in Ashanti Region who are members of the Adansi Fish Farmers' Association, one fingerling producer in Ashanti Region, and one large-scale, two medium-scale and two small-scale cage farmers in Lake Volta, Eastern Region. Primary data could not be gathered from communities where aquaculture systems have developed due to time constraints. However, the findings of Kassam reviewed on pages 16 to 27 are based on primary data gathered from fish farmers and communities in Ashanti and Eastern regions where aquaculture systems have developed. The discussion of enabling conditions for and drivers of development of the aquaculture sector presented on pages 28 to 35 is based on information gathered from key informant interviews.

Traders packing farmed tilapia on ice at Tropo Farms wholesale and retail outlet in Tema

OVERVIEW OF THE AQUACULTURE SECTOR IN GHANA

Background

Ghana is located just north of the equator in West Africa and has a total land area of 238,539 square kilometers and a 536-kilometer coastline. Ghana's population was 25.37 million in 2012,[6] 48 percent of which was rural.[7] The country has 10 administrative regions (see Figure 1): Greater Accra (where the capital, Accra, is located), Volta, Central and Western regions in the south, Ashanti, Eastern and Brong Ahafo regions in the central belt, and Northern, Upper East and Upper West regions in the north. The regions are further divided into 138 individual metropolitan, municipal and district assemblies. The Ghana Living Standards Survey divides rural areas into three ecological zones: savannah in the northern belt, forest in the central belt and coastal in the southern belt, with the savannah zone being the poorest and the forest zone being the least poor.[8]

Figure 1. Map of Ghana

Ghana's economy is based predominantly on natural resources and agriculture, oriented around primary commodity production and export, particularly of cocoa, timber and gold. Ghana's gross domestic product was estimated at $40.71 billion in 2012.[9] The agriculture sector — crops, livestock, fisheries and forestry — contributed approximately 23 percent of GDP in 2012[10] and is the largest industrial sector, employing over 40 percent of the economically active population aged 15 years and older.[11] Since the mid-1980s, Ghana's economy has been growing relatively steadily, though GDP growth almost doubled from 8 percent in 2010 to 14.4 percent in 2011, but went back to 7.9 percent in 2012. The GDP per capita was estimated at $1,605 in 2012,[12] making Ghana a low-to-middle-income country with the highest per capita income in West Africa.[13] Ghana's poverty rate has declined substantially over the past two decades, from 51.7 percent in 1991–1992 and 39.5 percent in 1998–1999 to 28.5 percent in 2005–2006.[14] Poverty has decreased more in rural areas, both in absolute and relative terms; however, regional inequality has increased, and the poverty rate remained as high as 62.7 percent in the north in 2005–2006, although it had fallen to 20 percent in the rest of Ghana.[15] The overall poverty reduction is attributed to improvements in economic growth over the past decade, driven in part by high prices for cocoa and gold.

Freshly harvested farmed Nile tilapia

Fisheries sector

The fisheries sector, which includes marine and inland capture fisheries as well as aquaculture, accounted for nearly 7 percent of Ghana's agricultural GDP and 1.7 percent of national GDP in 2011.[16] It has been estimated that fisheries contribute directly and indirectly to the livelihoods of over 2.2 million people in Ghana,[17] which is just under 10 percent of the population.

Fish consumption and demand

Fish is estimated to represent approximately 60 percent of average animal protein intake in Ghana.[18] Average per-capita fish consumption — estimated to be 21.7 kilograms in 2009[19] — is one of the highest in sub-Saharan Africa.[20] The Ghana Living Standards Survey (Fifth Round) estimated the overall food budget share in rural Ghana of fish and seafood — both cash expenditure and home-produced — was nearly 27 percent. This is higher than the 15 percent share for bread and cereals and the 7 percent share for meat,[21] indicating the importance of fish in the consumption and expenditure of rural households.

Domestic production

Domestic fish supply in Ghana comes from marine fisheries, inland fisheries (from lagoons, dams, rivers, Lake Volta, etc.), aquaculture and imports. Marine capture fisheries production has been following a decreasing trend, from approximately 490,000 metric tons in 1999 to just over 330,000 metric tons in 2011.[22] However, overall fish production increased by 10 percent between 2009 and 2012, from approximately 415,000 metric tons in 2009 to over 455,000 metric tons in 2012.[23] Of this increase, approximately 20,000 metric tons originated from aquaculture, 15,000 metric tons from inland fisheries and over 5,000 metric tons from marine fisheries. Marine fisheries accounted for 73 percent, inland fisheries accounted for 21 percent and aquaculture production accounted for 6 percent of total fish production in 2012.[24]

Aquaculture production increased from 950 metric tons in 2004 to 5,594 metric tons in 2008. Between 2009 and 2012, production is estimated to have almost quadrupled, from 7,154 metric tons to 27,451 metric tons.[25] However, it is possible that these official aquaculture production figures are overestimated; this possibility is discussed in more detail below. The growth in aquaculture production is due mainly to increased production from large-scale cage farms but is also attributed to increased availability of quality feed and fingerlings, as well as improvements in data collection.[26] Ghana imported over 175,000 metric tons of fish in 2012, valued at over $160 million f.o.b., highlighting the potentially important role of aquaculture in meeting domestic fish requirements. The majority of imported fish came from Mauritania, Namibia, Spain and the Netherlands, and the species were mainly horse mackerel, mackerel and sardines.[27] Fish exports were approximately 46,200 metric tons, valued at over $160 million. The majority of exported fish was frozen tuna sent to Spain and Cote d'Ivoire. Various demersal species were also exported to Japan, and some cuttlefish, crabs and lobsters were exported to China.

Aquaculture sector

Production systems

Fish farming in Ghana began in the north in 1953 and is currently practiced in all 10 regions, most prominently in the southern and central belts. The main fish species cultivated are Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*). Tilapia species represent over 90 percent of farmed fish production, with catfish and other species making up the remainder. Pond aquaculture is the dominant production system in the southern and central belts, accounting for over 98 percent of farms there,[28] and is mainly small scale and semi-intensive. In the last five to seven years, the dominant culture system for tilapia production has changed, and the vast majority of cultured tilapia is now being farmed intensively in cages.

Smoked catfish, demand for which is higher in inland areas (e.g, Ashanti Region) than in coastal areas

Year	Ponds and tanks (metric tons)	Cages (metric tons)	Dugouts, reservoirs and dams (metric tons)	Total production (metric tons)	Value ($)
2009	864	4,912	1,378	7,154	24,605,000
2010	1,093	7,581	1,526	10,200	28,516,000
2011	1,469	16,245	1,378	19,093	50,520,000
2012	1,772	24,249	1,431	27,451	-

Source: Ministry of Fisheries and Aquaculture Development (2013); FAO. (2004–2013). Fishery and aquaculture country profiles: Ghana. In *FAO Fisheries and Aquaculture Department (online)*. Rome: Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/fishery/countrysector/FI-CP_GH/3/en

Table 1. Aquaculture production by production system from 2009 to 2012

The first cage farm was established in 2001, and cage farms currently account for less than 2 percent of farms by number but much more by production. The cage farms are mainly located in Asuogyaman and South Dayi districts of the Eastern and Volta regions, respectively, with the vast majority in Lake Volta. Fish farming in the Northern, Upper East and Upper West regions in the north is largely carried out in extensive or culture-based fisheries. These fisheries exist at irrigation sites, reservoirs and earthen dams known as dugouts due to the relatively poor rainfall distribution pattern. Table 1 shows production levels from the different aquaculture production systems from 2009 to 2012.

It is possible that the aquaculture production figures reported by the Ministry of Fisheries and Aquaculture Development and the Fisheries Commission (Table 1 and Table 2) are overestimated, particularly for cages, as they are not based on reliable survey data and are in part estimated based on numbers of cages, with assumed stocking densities and yields. Data on production from ponds may be underestimated, as production from small-scale rural pond farms in more remote areas is not all recorded by Fisheries Commission staff and thus their production is not captured by these figures. Interviews with key informants suggest estimates for total aquaculture production of between 15,000 and 20,000 metric tons for 2012.

Table 2 shows aquaculture production levels for 2012 by production system and region. Pond farms are mainly spread between Greater Accra, Ashanti, Brong Ahafo, Western, Volta and Central regions. The majority of cage farms are located in Eastern Region and in community-owned dugouts, reservoirs and dams in the three northern regions. While Table 2 shows the number of production units (ponds and cages), reliable, up-to-date information on exact numbers of functional fish farmers is not available. The recently launched Ghana National Aquaculture Development Plan states that there are 2,869 small-scale farms.[29] This figure is largely made up of small-scale rural pond aquaculture farms, commonly classified as noncommercial and producing less than 1 metric ton per annum per farm, in addition to approximately 10 commercial pond aquaculture farms. However, it is not clear if this estimate also includes community-owned dugouts in the north or how many of these farmers are functional.

Estimates by Kaunda et al.,[30] supplemented with data from key informant interviews, lead to the following estimates for numbers of functional commercial cage aquaculture farms in Lake Volta at present: i) approximately 100 small-scale cage farms producing 1–50 metric tons per annum per farm; ii) approximately 10–15 medium-scale cage farms producing 50–1,000 metric tons per annum per farm; and iii) two large-scale commercial cage aquaculture farms (Tropo Farms

Large-scale cage farm (West African Fish) in Lake Volta

Region	Pond aquaculture			Cage aquaculture			Other (dugouts, reservoirs, dams)	All sources
	No. of ponds	Total surface area (hectares)	Production (metric tons)	No. of cages	Volume (cubic meters)	Production (metric tons)	Production (metric tons)	Production (metric tons)
Greater Accra	275	75	158	350	43,750	1,531	0	1,689
Ashanti	1,205	151	385	39	4,875	20	0	405
Northern	90	3	1	0	0	0	451	452
Eastern	292	30	76	1,473	179,223	19,768	0	19,844
Brong Ahafo	1,393	65	260	0	0	0	0	260
Western	644	83	207	3	225	8	0	215
Upper East	49	13	35	0	0	0	599	634
Upper West	17	1	0	10	1,000	2	380	382
Volta	247	98	283	416	50,900	2,919	0	3,202
Central	537	185	368	0	0	0	0	368
Total	**4,749**	**704**	**1,772**	**2,291**	**279,973**	**24,249**	**1,430**	**27,451**
Source: Ministry of Fisheries and Aquaculture Development. (2013). 2012 annual report. Accra, Ghana: Ministry of Fisheries and Aquaculture Development.								

Table 2. Aquaculture production by production system and region

and West African Fish Ltd.), which are estimated to contribute between one-third and one-half of total aquaculture production in Ghana. The vast majority of cage farms (over 60) are located in Asuogyaman District in Eastern Region, with most small-scale cage farms clustered between Akosombo Dam and Kpong Dam. Clusters of SME cage farms are also developing in areas such as Kpeve in South Dayi District of Volta Region, Sedom in Asuogyaman District and Akrusu in Upper Manya Krobo District of Eastern Region, though exact numbers are not available.

Production practices of pond aquaculture farmers

The primary species cultured by nearly all pond-based farmers is Nile tilapia. Over 50 percent of pond farmers produce tilapia in a mixed culture with catfish and mudfish (*Heterobranchus* spp.), and over 10 percent produce tilapia in a mixed culture with snake head (*Channa striata*), heterotis (*Heterotis niloticus*) and a variety of other endemic species.[31] Seed of these endemic species is mainly sourced from the wild. Catfish (*Clarias* spp.) farming is more predominant in Ashanti than in other regions due to the high demand for smoked catfish there. Farmed catfish is mainly used for smoking, although some farmers in Ashanti Region sell catfish live to buyers in Accra. There is a growing market for live catfish in Nigerian restaurants in Kumasi and Accra.

The majority of pond aquaculture is semi-intensive. Many farmers apply organic fertilizer such as chicken droppings, though very few apply inorganic fertilizer.[32] The most common feeds used by small-scale rural pond farmers are wheat bran, maize bran, rice bran and other cereal brans, which are readily available on the market. Other supplementary feeds include agricultural wastes such as cocoyam leaves, agricultural-industrial byproducts such as local brewery waste, and household food waste. A minority of pond farmers use commercial floating feed, which is relatively expensive. Commercial feed was all imported until 2011, when Ranaan, an Israeli feed company that has dominated the imported fish feed market in Ghana since 2005, established a feed mill in Ghana. Pond farmers use both all-male and mixed-sex tilapia fingerlings. They obtain tilapia and catfish fingerlings from government and private hatcheries, from other farmers, and from the wild.

Small-scale cage farm in Lake Volta using locally produced cages

Asmah[33] estimated that the average size of noncommercial[34] pond farms, which account for nearly 97 percent of all pond farms, is 0.36 hectares, with a median of 0.06 hectares. She identified five noncommercial pond farm types with mean production ranging from 1,436 kilograms per hectare per year to 4,423 kilograms per hectare per year, compared to a medium-sized intensive commercial pond farm, producing 46,000 kilograms per hectare per year of catfish and tilapia. The Ministry of Fisheries and Aquaculture Development and the Fisheries Commission estimate an average yield of approximately 2.5 metric tons per hectare per year for pond farms.

Production practices of cage aquaculture farmers

Cage farmers all farm tilapia intensively using commercial floating feed and all-male fingerlings bought from public or private hatcheries. There are no reliable data on production from cage farms. However, Table 3 shows that the Ministry of Fisheries and Aquaculture Development estimates each cage of 125 cubic meters to produce approximately 10 metric tons per year based on two cycles of 5 metric tons per cage per year. This may be realistic for some medium- and large-scale commercial cage farmers but is likely to be an overestimate for small-scale cage farmers who have lower financial and technical capacity (discussed in more detail on pages 16 to 27). A survey of cage farms conducted by Kassam in 2011 showed that small-scale cage farms typically consist of one to 10 cages with a total area of 125 cubic meters to 1,250 cubic meters, based on cages measuring 5 by 5 by 5 meters. Small-scale cage farms produced 10 to 50 metric tons of tilapia per farm in 2010. The five medium-sized farms surveyed by Kassam each had on average the equivalent of approximately 50 cages (62,500 cubic meters) and produced between 50 and 70 metric tons each in 2010, with production growing steadily in 2011. Interviews conducted with two of these five medium-scale cage farms for the present study indicate that production from medium-scale farms has increased, ranging between 200 and 1,000 metric tons per farm in 2012. The two large-scale cage farms combined produced 4,800 metric tons in 2010, and more than double that amount in 2012.

Marketing

Farmed fish is generally marketed at the farm gate during harvest, where it is sold fresh and unprocessed. Small-scale pond farms in rural areas sell mainly to consumers from the local community. Some farms, especially those closer to towns and urban centers, sell directly to retailers such as tilapia "joints" — local restaurants found at roadsides of busy towns that serve grilled tilapia, usually with "banku"[35] — and to local fish traders, most of whom are women, who go on to sell to consumers and retailers. Some farmers also sell their fish directly to consumers in the village.

Like pond farmers, most SME cage farmers sell fish at the farm gate during harvest. The majority of cage-farmed fish is distributed to markets in Accra and other urban centers — mainly in the south — such as Kasoa and Tema.

This fish is distributed by a network of primarily female fish traders, some of whom also trade in wild-caught fish from Lake Volta. Many of these traders are from Accra and its surrounding areas or from towns and communities around Lake Volta, such as Kpong and Asutuare, where wild-caught fish from the lake has traditionally been traded. Very few of these traders are from communities located around the SME cage farms, however. The majority of SME cage farms sell to traders and wholesalers. They also sell directly to consumers and to retailers such as "cold stores" (shops selling frozen food such as fish and meat), hotels, restaurants and tilapia joints. Most of the fish sold at the farm gates is scaled and degutted by local women for a fee paid by the buyer. Buyers often carry their own ice blocks to the farm to chill the fish before transporting to their destinations. Many farmed fish traders work in groups and share transport costs; for example, hiring "trotros" (private minivans) together.

The same network of traders and wholesalers who buy fish from the SME cage farms also buy from the two large-scale cage farms on Lake Volta: West African Fish and Tropo Farms. However, the large-scale farms do not sell directly at the farm gate. West African Fish sells fish twice a week at the marketplace it created locally at Asikuma, while Tropo Farms does not sell any fish locally and sends it all directly to its three urban outlets in Accra, Tema and Kasoa, where fish is sold fresh on ice and degutted, both retail and wholesale, nearly every day. At present all farmed fish is sold within Ghana and is not exported.

Farmed fish prices

The price of farmed fish depends on the species, size and location of the market. For most small-scale pond farms, fish buyers tend to sort the fish, select what they want and negotiate prices. The current price for pond-farmed fish in Ashanti Region is approximately 7 Ghanaian cedi ($3.29) per kilogram[36] for catfish and 6 cedi per kilogram for tilapia, regardless of size. On the commercial cage farms, the fish are graded and priced by size and sold per kilogram with prices following those set by the large-scale farms. Fish are graded, in order of size, as follows: Size 3 is 650 grams and above (or three pieces per 2 kilograms); Size 2 is 450–500 grams (or two pieces per kilogram); Size 1 is 300–450 grams (or three pieces per kilogram); regular size is 250–300 grams (or four to five pieces per kilogram); and economy size is less than 250 grams (or five to six pieces per kilogram). Size 1 and above (over 400 grams) are classed as "table size" and are demanded by hotels. Size 1, economy and regular sizes are demanded by restaurants, tilapia joints and "chop bars."[37] The size of fish most preferred by consumers was found by Asmah[38] to be 200 grams (regular or economy). In 2012, the average price of Size 1 farmed tilapia was 6.5 cedi per kilogram.[39] August 2013 prices for fish from SME cage farms were as follows: Size 3 = 9 cedi per kilogram; Size 2 = 8 cedi per kilogram; Size 1 = 7.4 cedi per kilogram; regular = 6.5–6.9 cedi per kilogram; and economy = 5–5.5 cedi per kilogram.[40]

Year	Public hatcheries	Private hatcheries	Total
2005	261,900	6,583,000	6,844,900
2006	1,420,200	11,024,150	12,444,350
2007	1,927,830	14,556,056	16,483,886
2008	1,266,900	43,733,060	44,999,960
2009	1,361,000	41,301,907	42,662,907
2010	998,000	8,112,500	9,110,500
2011	1,583,000	34,847,390	36,430,390
2012	16,144,030	63,236,239	79,380,269

Source: Abban, E.K., Asmah, R., Awity, L., and Ofori, J.K. (2009). Review on national policies and programmes on aquaculture in Ghana. SARNISSA. Retrieved from www.sarnissa.org; Ministry of Fisheries and Aquaculture Development. (2013). 2012 annual report. Accra, Ghana: Ministry of Fisheries and Aquaculture Development.

Table 3. Supply of tilapia and catfish fingerlings, 2005–2012

Aquaculture inputs

As noted above, small-scale cage and pond farms buy fingerlings from public and private hatcheries, while pond farms also obtain fingerlings from other farmers and from the wild. Several medium-scale cage farms and both large-scale cage farms produce their own fingerlings. The number of private hatcheries has increased in recent years as a result of the rapid growth of cage farming, as has the productivity of government hatcheries such as the Water Research Institute in Akosombo. In 2005, there were seven hatcheries (three public and four private), three producing only tilapia fingerlings, two producing only catfish fingerlings, and two producing both tilapia and catfish fingerlings. In 2012, the number of hatcheries had increased to 19 (three public and 16 private), 15 producing only tilapia fingerlings and four producing both tilapia and catfish fingerlings. Table 3 shows the overall growth of fingerling production between 2005 and 2012.

Private hatcheries currently produce the majority of fingerlings in Ghana. Data from the Ministry of Fisheries and Aquaculture Development (shown in Table 3) suggest that private hatcheries produced approximately 80 percent of fingerlings in 2012. The Ministry of Fisheries and Aquaculture Development's data show that there were approximately 16 private hatcheries (including cage farms producing their own fingerlings) in 2012. The vast majority of these are located in Eastern Region in order to supply cage farms, with one in Ashanti Region, one in Greater Accra Region, one in Western Region and one in Central Region. Currently there are three public hatcheries: the Ashaiman Aquaculture Demonstration Center in Greater Accra; the Pilot Aquaculture Center in Kumasi, Ashanti Region; and the hatchery for the Water Research Institute in Akosombo, Eastern Region. Over 95 percent of fingerlings were produced in Eastern Region in 2012.[41]

The Ministry of Fisheries and Aquaculture Development's estimates include production from a number of cage farms that produce their own fingerlings and do not sell to other farmers (e.g., Tropo Farms). Key informant interviews in 2013 suggest that the main hatcheries in Eastern Region supplying fingerlings to cage farmers at present are Fish Reit, estimated to produce 12 million fingerlings per year, and Crystal Lake, estimated to produce 12–14 million fingerlings per year. Both of these are private hatcheries. The Water Research Institute is also estimated to produce 14 million fingerlings per year, though some of these fingerlings are produced for research activities and not for sale. This suggests that the figures in Table 3 do not reflect the number of fingerlings available for sale on the market at present. There are currently a number of new hatcheries being established in Eastern Region to meet the high demand for fingerlings from the increasing number of cage farms in Lake Volta.

The average price of 2-gram to 5-gram tilapia fingerlings ranges from 0.10 to 0.15 cedi, and the average price of 10-gram fingerlings ranges from 0.20 to 0.25 cedi, depending on whether they are sourced from private or public hatcheries. Prices are higher at private hatcheries compared to public hatcheries, which produce fingerlings at a subsidized rate for farmers. The price of 5-gram to 10-gram catfish fingerlings is approximately 0.40 to 0.50 cedi.

Between 2005 and 2011, all commercial floating fish feed was imported, mainly from Ranaan in Israel. SME cage farmers suffered from unreliable supply and high prices of fish feed. The establishment of a feed mill in Ghana by Ranaan has largely stabilized fish feed supplies. Raanan's factory is located in Pram Pram, just outside of Accra, and mainly services the southern part of the country. Ranaan also exports its feed produced in Ghana to Nigeria. In 2005, Ranaan was exporting 70 metric tons of feed per month to Ghana. Currently, Ranaan's feed factory produces 1,300 metric tons per month for both Ghana and Nigeria. The capacity of the feed mill is 2,500 metric tons per month, and Ranaan is currently aiming to produce 1,500 metric tons per month. Ranaan's main grower feed (33 percent protein, 6-millimeter pellets) was being sold for 40 cedi for 20 kilograms in August 2013. Ranaan's feed is cheaper than most other imported feeds currently available in Ghana.[42] Local feed prices have increased since the establishment of the feed factory; in 2011, Ranaan's grower feed was only 33 cedi for 20 kilograms. The increase is due partly to an increase in the price of feed ingredients such as soya bean. However, the reliability and availability of feed supply in Ghana has greatly improved. Since 2011, a large number of feed distributers have also opened up around Atimpoku and Akosombo in Eastern Region to supply the growing cage farming sector. In 2011, only Nicoluzzi feed from Brazil was being sold in the Akosombo area. In August 2013, there were at least seven different feed depots selling feed produced by a variety of companies, including Ranaan, Skretting, Nicoluzzi, Coppens, Cargill AquaFeed, Beacon and Pira.

Organizational and legal framework

Until 2005, fisheries and aquaculture fell under the remit of the Ministry of Food and Agriculture. In 2005, a separate Ministry of Fisheries was established; however, this was disbanded and aquaculture returned to the Ministry of Food and Agriculture following the 2008 elections. A new Ministry of Fisheries and Aquaculture Development was established in 2013. The Fisheries Commission was formed in 1993 to advise the minister on issues related to sustainable exploitation of fisheries resources. The Fisheries Commission is the lead institution for promotion and development of aquaculture and has been working through the Department of Fisheries under the Ministry of Food and Agriculture, through the Ministry of Fisheries, and now under the newly created Ministry of Fisheries and Aquaculture Development as the implementing agency. There are Fisheries Commission offices in all 10 regions, and extension services are provided for free to current and prospective fish farmers by Fisheries Commission staff at regional and district levels.

The Water Research Institute, under the publicly funded Council for Scientific and Industrial Research, carries out aquaculture research at the Aquaculture Research and Development Centre in Akosombo on Lake Volta. The Water Research Institute's Aquaculture Research and Development Centre was established in 1991 and provides a range of technical support to the aquaculture sector. The Water Research Institute carries out research and development activities related to aquaculture production systems and sells fingerlings to farmers. The Water Research Institute's genetic improvement program, in collaboration with WorldFish, has led to the development of the "Akosombo strain," which is reported to grow 30 percent faster than the indigenous Nile tilapia strain. Other institutions relevant to the aquaculture sector include the Environmental Protection Agency, which grants licenses based on environmental impact assessments required by fish farmers, and the Water Resources Commission, which regulates and manages the use of water for any activity.

The Fisheries Act of 2002 is the main legislative instrument, while the Fisheries Regulations of 2010 are the main support measures for the fisheries and aquaculture sectors. The regulations cover various aspects of aquaculture: inputs such as seed, seed production certification, responsible aquaculture practices, import of live fish and transfer of fish within the country. The Environmental Protection Agency Act of 1994 seeks to ensure that aquaculture projects do not damage the environment. The Environmental Assessment Regulations of 1999 require both land-based and cage aquaculture activities to undergo environmental impact assessments.[43]

Production of "Akosombo strain" tilapia fingerlings in net hapas at the Water Research Institute's Aquaculture Research and Development Centre in Akosombo, Lake Volta

ACTUAL AND POTENTIAL IMPACTS OF AQUACULTURE ON POVERTY AND FOOD SECURITY IN GHANA

This section assesses the actual and potential direct and indirect impacts of aquaculture on poverty, food security and economic growth in Ghana, drawing on the findings of Kassam[44] and Asmah[45] and supplemented with data gathered from fieldwork in August 2013.

Direct and indirect impact pathways

Direct poverty impacts are those which affect the welfare of households who adopt aquaculture; for example, through benefits such as increased regular income or fish consumption. The poverty impact of these benefits depends on the socio-economic status of adopting households and will only be significant if the poor adopt aquaculture. Indirect poverty impacts affect the welfare of the poor through aquaculture adoption by both poor and nonpoor farmers, through a variety of potential impact pathways. For example, aquaculture development increases fish supplies, potentially increasing the availability and lowering the price of fish in local and urban markets. This may benefit poor consumers if production is not exported and if the poor consume the species produced by aquaculture; however, price reductions may not necessarily help poor producers. Aquaculture development can also increase employment of the poor on fish farms and can potentially increase the marginal productivity of labor, leading to higher rural wage rates.

Other potential indirect impacts include employment, wage and income effects on other sectors, which could benefit the poor through production, consumption and other economic growth linkages.[46] Production linkages include backward linkages from the farm in demanding inputs and services for aquaculture production, and forward linkages from the farm in demanding processing, marketing, storage and transport of production. Consumption linkages arise when increased farm income is spent on other locally produced goods and services, often in the rural nonfarm economy, and have been found to be the most important types of growth linkages, especially in sub-Saharan Africa.[47] These economic linkages enable increases in aquaculture production to stimulate growth in other sectors, producing an economic multiplier effect which could have positive impacts for a range of poor people, including landless farm workers, net labor-selling smallholders, and the rural nonagricultural and urban poor. Table 4 summarizes these various direct and indirect impact pathways from aquaculture.

The extent to which aquaculture will realize its potential to contribute to rural development and poverty reduction is likely to be context-specific and dependent on a number of factors, including the level of engagement by the poor, the scale of adoption, the relative importance of livelihood and production effects compared to consumption effects benefiting poor consumers, and the significance of indirect effects such as economic growth linkages arising from different aquaculture production systems and their associated economic multiplier effects.

The following section explores the direct and indirect poverty impacts of small-scale pond aquaculture in Ashanti Region and SME commercial cage aquaculture in Eastern Region. The section draws heavily on the findings of the study by Kassam that assessed the direct poverty impacts of small-scale pond aquaculture using a household survey to compare the livelihood assets, strategies and outcomes of 69 small-scale pond aquaculture farmers and a comparison group of 74 non-fish-farming households in three rural districts in Ashanti Region.[48] The actual and potential indirect poverty impacts generated by both small-scale pond aquaculture in Ashanti Region and SME commercial cage aquaculture in Lake Volta, Eastern Region, were assessed by Kassam using data from the household survey of small-scale pond farmers, a survey of 14 small-scale and five medium-scale cage farms in two districts in Eastern Region,[49] focus group discussions with seven communities located around cage farm clusters to explore indirect impacts and linkages of cage aquaculture, and key informant interviews. Potential local and national economic multiplier effects were also estimated for small-scale pond aquaculture and SME cage aquaculture systems using a fixed-price semi-input-output model.[50]

Potential impacts	Pathway
Direct impacts affecting adopters	
Income	Increased on-farm income from own enterprise production
Consumption	Enhanced food and nutrition security from increased household fish consumption or as a result of higher incomes from sale of fish (especially where women are producers and in control of family income)
Farm sustainability	Increased farm sustainability through integrated agriculture-aquaculture, enabling more effective use of on-farm inputs
Indirect impacts affecting non-adopters	
Consumption	Increased availability of fish for poor consumers
	Lower prices of fish for poor consumers, which could also negatively affect poor fishers
Employment	Increased employment of poor laborers on fish farms (potentially also boosting rural wage rates)
Economic growth/ multiplier	Increased employment, wage and income effects in the aquaculture value chain through production linkages
	Increased employment, wage and income effects in other sectors through consumption linkages, increasing the demand for locally produced goods and services, creating an economic multiplier effect, and boosting local economic growth
Environmental	Privatization of previously common-access grounds used by the poor, degradation of capture fisheries habitats, etc.
Source: Kassam, L. (2013). Assessing the contribution of aquaculture to poverty reduction in Ghana, p. 25 (Doctoral dissertation). London: School of Oriental and African Studies.	

Table 4. Summary of potential impacts of aquaculture

Direct poverty impacts of aquaculture in Ghana

Socio-economic characteristics of small-scale fish farmers

As noted above, for aquaculture to have direct poverty impacts, poor households need to be able to adopt aquaculture. The relatively high investment and working capital costs of pond aquaculture in Ghana, involving pond construction, stocking and feeding, are likely to be too high for the average poor farmer to engage in. For example, in 2010 the cost of constructing a 500-square-meter pond in Ashanti Region was 2,000 cedi ($1,400[51]), which is just under Ghana's average annual income per capita (estimated at $1,605 in 2012). Fish ponds are in fact often seen as an indicator of wealth or status in Ashanti Region. The difficulty for the poor of adopting aquaculture is reflected in the results of participatory wealth rankings conducted in 2010 in three communities in Ashanti Region, covering 257 households. These wealth rankings found that a much higher percentage (22 percent) of households in the highest wealth category were involved in aquaculture compared to the medium and less wealthy groups (7 percent and 6 percent, respectively).[52] This suggests that although less wealthy or poor households are able to adopt pond aquaculture in these communities, fish farmers are more likely to be wealthy.

Most small-scale rural pond aquaculture farmers in Ghana are male crop farmers engaged in diversified farm and nonfarm livelihood activities. The majority of fish farmers in Ashanti Region are primarily cocoa farmers who also produce other crops such as cassava and plantain. Some fish farmers, or members of their households, are also engaged in one or more nonfarm enterprises. Very few small-scale pond farmers undertake aquaculture as a primary or specialized activity.

Production practices and training

The main species cultured by nearly all small-scale fish farmers in Ashanti Region is Nile tilapia, with most producing it in a mixed culture with catfish and a small percentage in a mixed culture with heterotis. Kassam found that the fish farmers surveyed owned an average of two ponds, of approximately 550 square meters each, and harvested one pond in 2010.[53] Poor farmers[54] were found to have smaller ponds, smaller total area of ponds and smaller total area of functional ponds than nonpoor farmers, as shown in Table 5.

Most small-scale pond aquaculture in Ashanti Region is semi-intensive. Farmers use mainly local feed such as maize bran and groundnut peel, rather than commercially formulated floating feed. Only one-quarter of fish farmers surveyed by Kassam used commercial feed.[55] However, interviews with key informants and fish farmers for the present study suggest that the number of farmers using commercially formulated feed was rising as a result of Ranaan's training courses held in Kumasi in 2012 (discussed more below). Many pond farmers also fertilize their ponds, mainly with organic fertilizers such as poultry droppings purchased from the local market. Kassam found the use of fertilizer to be an important difference in the production practices of poor and nonpoor fish farmers, with only 33 percent of poor fish farmers compared to 56 percent of nonpoor fish farmers surveyed using fertilizer.[56]

Many farmers in Ashanti Region have received some form of training in aquaculture, mainly from fisheries extension staff and often through district-level fish farmers' associations, though the level and quality of this training is not known. Ranaan has conducted six free five-day training courses for fish farmers in Ashanti Region since November 2012, in collaboration with the Regional Fisheries Commission. These courses were held at the government-owned hatchery Pilot Aquaculture Centre in Kumasi for a year. So far, 114 farmers have been trained: 85 from Ashanti Region, 23 from Brong Ahafo Region, five from Eastern Region and one from Northern Region. Key informant interviews with Fisheries Commission staff, Ranaan and fish farmers who have attended these training courses all indicate that the impact is very positive. Farmers who have the financial resources to increase the use of commercially formulated feed and institute other recommended management practices such as sorting of fish, which requires an extra pond, have seen increases in production and profit within one production cycle.

Productivity and profitability

In general, however, the productivity and profitability of small-scale pond farmers in Ghana is relatively low.[57] This is especially true of poorer farmers. Kassam found that, on average, fish farmers surveyed in Ashanti Region harvested 160 kilograms of fish in 2010, with a yield of approximately 2 metric tons per hectare per year — 1.3 metric tons per

	Fish farmers		
	Poor	**Nonpoor**	**Total**
Average area of individual ponds owned (m^2)	408.3 (67.75)	659.9 (139.81)	552.1 (85.91)
Average total area of ponds owned (m^2)	787.2 (175.83) (n = 27)	1187.5 (234.64) (n = 36)	1016.0 (154.76) (n = 63)
Average total area of functional ponds owned (m^2)	681.5 (117.29) (n = 27)	1165.3 (230.36) (n = 36)	957.8 (143.23) (n = 63)
Total households (No.)	30	38	68

Source: Kassam, L. (2013). Assessing the contribution of aquaculture to poverty reduction in Ghana, p. 140 (Doctoral dissertation). London: School of Oriental and African Studies.
Note: Standard error in parentheses.

Table 5. Size of ponds owned by poor and nonpoor fish farmers


Local women scaling and degutting freshly harvested tilapia from a cage farm in Lake Volta

hectare per year for poor fish farmers and 2.5 metric tons per hectare per year for nonpoor fish farmers. Compared to poor fish farmers, nonpoor fish farmers harvested over four times as much fish, sold over five times as much fish, and received over five times as much revenue from the sale of fish in 2010.[58] On average, poor fish farmers sold over 60 percent of their harvest, consuming and gifting the remainder, while nonpoor farmers sold nearly 80 percent of their harvest.[59] Participatory budget exercises conducted with four groups of fish farmers reported by Kassam show a range of positive and negative profit margins.[60] This suggests that small-scale fish farming is not profitable for many farmers even though the potential is there.[61] Other more in-depth studies of the profitability of fish farming in Ghana have been undertaken that suggest small-scale pond aquaculture can be profitable.[62] For example, nearly 50 percent of noncommercial pond aquaculture farmers surveyed in Ghana by Asmah were found to have positive net profits and be financially viable.[63]

Poverty impacts

This section further explores the direct poverty impacts of aquaculture through a review of Kassam's comparison of poverty indicators between fish-farming and non-fish-farming households. The poverty indicators reviewed are farmers' own perceptions of aquaculture impacts, income, household wealth and food security. However, comparison of impact indicators between fish-farming and non-fish-farming households does not take into account possible differences in household characteristics other than participation in fish farming, which may cause differences between groups. Therefore, the results of a multiple regression income determination model, which controls for household characteristics between fish-farming and non-fish-farming households, is also reviewed to better understand the effect of fish farming on household income.

Farmers' perceptions of impacts of aquaculture

Overall, 60 percent of farmers surveyed by Kassam reported that fish farming had increased fish for home consumption, 40 percent reported that fish farming had increased household income, and 13 percent felt that it had had no impact. However, nonfunctional fish farmers or those who had completely abandoned their ponds were not surveyed, thus potentially biasing these results. Also, 25 percent of all fish and nonfish farmers surveyed indicated that fish farming has negative impacts on the poor due to the high costs involved.[64]

Income and wealth

Average household income of small-scale fish farmers was estimated to be just under 4,500 cedi, 30 percent higher than non-fish-farming households.[65] Fish farming contributed approximately 8 percent to household income for both poor and nonpoor fish-farming households in 2010.[66] Fish-farming households were also found to be better off than non-fish-farming households in terms of household wealth, measured by a household asset index.[67] The largest difference was found between nonpoor fish-farming and non-fish-farming households, with the former significantly wealthier than the latter.[68] These results suggest that there may be an asset threshold over which fish farming allows higher income and asset accumulation. This could indicate that fish farming has a higher potential to increase the wealth of nonpoor households who are above the asset threshold than poor households who are below the asset threshold.[69] Key informant interviews conducted for the present case study support these findings and suggest that it is very difficult for poor fish farmers to significantly increase income through fish farming due to their limited resources. This state of affairs calls into question the potential for aquaculture to have significant direct impacts on poverty.

Food security and food vulnerability

Kassam found little difference in the frequency of fish and meat consumption among fish-farming and non-fish-farming households. In both the rainy and dry seasons, poor fish-farming households ate fish more frequently than nonpoor fish-farming households, who ate more meat. This indicates that fish was a more pro-poor animal-source food than meat. Overall, fish was eaten by both poor and nonpoor households on approximately six days a week, showing the importance of fish in Ghanaian diets.[70] The actual amount of fish eaten by households was not measured, however, and may have revealed more differences than measuring only frequency of consumption. Comparison of food consumption indices based on dietary diversity and frequency of consumption also showed very little difference in food security between fish-farming and non-fish-farming households,[71] suggesting that aquaculture has limited direct impact on the food security of fish-farming households in Ashanti Region. However, a small difference was found in terms of food vulnerability — the ability of household heads to provide adequate food — with fish-farming households being slightly better off than non-fish-farming households in 2010.[72]

Determinants of income

It is very difficult to assess the impact of or attribute any changes to an intervention or technology such as aquaculture without a realistic counterfactual scenario. Comparing impact indicators between treatment and comparison groups (i.e., fish-farming and non-fish-farming households) may provide some indication of potential impact, but unless households have been randomly placed into these groups using an experimental design or have been formally matched, these comparisons may not take into account possible differences in household characteristics other than participation in fish farming that may be causing the differences in income and wealth seen between the two groups surveyed by Kassam. For example, higher income could cause households to adopt fish farming in the first place, rather than fish farming causing higher incomes.

In order to overcome this obstacle, Kassam used a multiple regression income determination model to control for differences in observable characteristics between these two household groups and understand the factors that

Small-scale polyculture (tilapia and catfish) aquaculture pond in rural Ashanti Region contribute to the differences in income between fish-farming and non-fish-farming households.[73] The income determination model separated fish-farming households into two groups: i) those that had been trained or used fertilizer, a proxy for good management practices (termed fish farming type A); and ii) those that had not been trained and did not use fertilizer (termed fish farming type B). Aside from fish farming type, independent variables also included household size, total farm area, years of association membership, district, households with sources of off-farm income, difficulty in accessing input and output markets, and households who faced a crisis or shock in 2010.[74] The results of the income determination model suggest that when controlling for other factors, participation in fish farming type A is likely to increase household income by 54 percent, and participation in fish farming type B is unlikely to be associated with increased income when compared to non-fish-farming households. These results suggest that type A small-scale pond aquaculture has a positive effect on income, but type B does not. These results also suggest that small-scale pond aquaculture is not necessarily associated with higher incomes unless farmers have been trained or employ good management practices. Thus, while small-scale fish farming type A is likely to have a positive impact on the income and other related indicators of nonpoor farmers, small-scale aquaculture type B is unlikely to have much impact on poor farmers, unless their resource constraints can be overcome and they engage in type A.[75]

Indirect impacts of aquaculture in Ghana

The presence of direct impacts from small-scale aquaculture (fish farming type A) suggests that indirect poverty impacts should also be present and potentially important. SME commercial cage aquaculture on Lake Volta is unlikely to have direct impacts on poverty via adoption by poor farmers, as the poor are unable to afford cage aquaculture due to the high costs of investment and working capital; for example, the cost of a single 125-square-meter cage in 2010 was approximately 2,500 cedi. The remainder of this section thus explores the actual and potential impacts of financially viable small-scale pond aquaculture (fish farming type A) in Ashanti Region and SME cage aquaculture in Eastern Region on poverty and economic growth through indirect impact pathways, including production linkages along the value chain and consumption linkages, which together generate economic multiplier effects; food security impacts through increased fish supply; environmental linkages; and direct and indirect employment effects.

Indirect impacts of small-scale pond aquaculture

Backward linkages

The backward production linkages of small-scale pond aquaculture (fish farming type A) are strong due to the high proportion of nontradable inputs (i.e., those inputs not imported or exported to or from the area and that do not have tradable substitutes available locally). These inputs are mainly fingerlings and feed such as maize bran, and some fertilizer and lime, which are produced and consumed locally within Ghana and thus contribute to the sector's multiplier effect.

Forward linkages

Forward linkages generated by direct and indirect sales to other sectors are weaker for small-scale pond aquaculture. As noted above, most farmers sell fresh fish unprocessed, directly to consumers at the farm gate. This means distribution and processing of farmed fish are currently not important. However, there is potential for stronger forward linkages if adoption of pond aquaculture increases, as growth of the fish supply in rural communities would require increased processing, trading and distribution activities, which would be carried out mainly by poor women.

Consumption linkages

Consumption linkages are very important indirect pathways to impact on poverty and are often overlooked in analyses that concentrate on indirect impacts through the value chain (i.e., backward and forward linkage effects). Consumption linkages arise when additional income earned through aquaculture by fish-farming households and laborers on fish farms is spent on nontradable goods and services, which stimulates further demand for local industry and services. Consumption linkages are estimated by Kassam to be strong for small-scale pond aquaculture in Ashanti Region; for every extra dollar of income earned by fish farmers, it is estimated that 44 percent will be spent on regionally nontradable goods and services, and 62 percent will be spent on nationally nontradable goods and services.[76] If spending of extra income by fish farm employees is also considered, consumption linkages may be even stronger. This is because marginal budget shares for nontradable goods are higher for poorer people, as they tend to spend a higher share of their income on locally produced goods and services. Due to the low level of development of the pond aquaculture sector in Ghana at present and the small numbers of fish farms in dispersed villages, the impact of consumption linkages generated by pond aquaculture is not generally seen at the community level, though there is high potential for increasing local economic activity if the sector were to develop.

Increased food security

Increased fish supply from aquaculture can improve local food security and can also lead to cost-of-living linkages when reduction in fish prices raises people's real incomes, which are then spent on local goods and services, generating consumption linkages. In many of the rural communities where small-scale pond farms are located, the majority of fish available is processed (smoked and dried) and comes from the coast or from inland fisheries. The supply of fresh fish is not regular and does not meet demand at prevailing prices. Key informant interviews suggest that these rural communities benefit greatly from cheaper and increased supply of fresh fish when fish ponds are harvested. The majority (57 percent) of all fish and nonfish farmers surveyed by Kassam indicated that fish farming has increased fish supply in the community, though the results also suggest that the poor benefit less than the nonpoor from increased local fish supply.[77] At present, however, due to the small number of pond farms in villages and the long periods between harvests (production cycles typically range from six months to two years), increases in local fish supply are infrequent. However, as households spend a significant proportion of their cash income on fish, the potential for increased adoption of small-scale pond aquaculture in rural communities to increase fish supply, reduce prices, impact on local food security and increase real income is strong. The potential for increased adoption of small-scale pond aquaculture is potentially higher than for SME and large-scale cage aquaculture, where increased production may not lead to price reductions and where fish is not usually sold to communities located around the cage farms (discussed further below).

Indirect impacts of SME cage aquaculture

Owners of small-scale cage farms in Lake Volta are mainly professionals from Accra who have established cage farms for investment purposes and not as a primary occupation or livelihood activity. These farm owners are well-educated and relatively well resourced. However, as these farms have been established only recently, farm owners' level of technical and market information is variable. While the Fisheries Commission has limited data on cage farms, key informant interviews for this case study suggest that there is a high turnover of small-scale cage farms, with many going out of business and new ones coming up at an increasing rate. This could partly be due to the lack of experience and expertise of small-scale cage farm owners, and because they leave the running of their farms to often untrained and casual laborers, leading to low productivity and profitability. However, as the pool of trained cage farm workers is increasing — partly through high turnover of staff at large-scale cage farms — and workers and farm owners are gaining experience, small-scale cage farms may also be doing better. A number of medium-scale cage farms are owned by expatriate entrepreneurs (including one Lebanese and two Taiwanese) with good technical knowledge, and for whom fish farming is their primary occupation. Unlike the small-scale farms, the majority of medium-scale cage farms employ some trained staff. Medium-scale cage farms are more successful than the small-scale cage farms, and key informant interviews indicate that these medium-scale farms have been steadily increasing production over the past two to three years. In relation to small-scale cage farmers, medium-scale farmers have better access to technical and market information and have a stronger bargaining position in relation to buyers. While the characteristics of small- and medium-scale cage farm owners are different, they are grouped together here as SMEs because their indirect impacts on poverty via economic linkages are likely to be similar, given equivalent increases in scale, due to their similar production systems.

The local marketplace established at Asikuma by West African Fish where it sells freshly harvested farmed tilapia to traders and wholesalers several times a week

Backward linkages

SME cage farmers have much weaker backward linkages than small-scale pond aquaculture farmers. Fingerlings and feed are the main inputs into SME cage farming, and while fingerlings are a nontradable input that is produced and consumed within Ghana, commercial feed makes up the majority of input costs and is classed here as a tradable input; thus, it does not contribute to local economic growth. As noted earlier, Ranaan has now established a feed mill in Ghana and is producing feed locally. Some of this feed is being exported to Nigeria, and thus is not exclusively consumed locally, and there are also a number of other imported feed substitutes on the market whose prices are correlated with the price of Ranaan feed. Locally produced and consumed goods that have tradable substitutes available locally and whose prices are correlated are classed in the agricultural linkage literature and multiplier models as tradable goods.[78] Thus they are not thought to contribute to a sector's backward linkages and hence economic growth, aside from employment created at the local feed mill in this case. Medium-scale cage farmers may have even weaker backward linkages, as some produce their own fingerlings and do not buy from hatcheries, and some also import feed directly from abroad. Other inputs into SME cage aquaculture include the cages themselves, though this represents a very small proportion of input costs. Cages are locally produced for all small-scale farmers and for some medium-scale farmers.

Forward linkages

SME cage aquaculture in Lake Volta has stronger forward linkages than small-scale pond aquaculture in Ashanti Region, as cage-farmed fish is used as an input into other sectors, unlike pond-farmed fish, which is mainly sold directly to consumers. Until recently, all SME cage farms sold fish fresh at the farm gate. Recently, one medium-scale farmer opened a wholesale outlet in Accra and is selling fish on ice and frozen fish. Another medium-scale farmer was planning to open a wholesale and retail outlet in Kasoa, very close to one of Tropo Farms' three outlets, later in 2013. Many small-scale cage farms and the majority of medium-scale cage farms sell directly to retailers, including cold stores, hotels, restaurants and tilapia joints. As noted above, most cage-farmed fish is distributed to markets in Accra and other urban centers by a network of primarily female fish traders, some of whom also trade in wild-caught fish from Lake Volta. Very few of these traders are from communities located around the cage farms, as farmed fish is not sold to traders on credit, unlike wild-caught fish sold by fishers. The majority of SME cage farms sell to traders and wholesalers, and most cage farms also sell to consumers. The same network of traders and wholesalers buy fish from all the SME and large-scale cage farms on Lake Volta. Kassam estimated that in 2011 there were 20 wholesalers and over 200 traders within this network, and an additional 400 traders who buy only from Tropo Farms' wholesale and retail outlets in Accra. This network of traders has grown, and key

Medium-scale cage farm in Lake Volta using imported circular cages

informant interviews in 2013 suggested that the number of traders has increased by over 30 percent. As noted earlier, all fish is sold fresh and unprocessed, and scaling and degutting is undertaken by women from local communities on harvest days at the farm; they are paid by customers, mainly traders. This creates casual employment for a large number of poor women from communities where SMEs are located, several times per month.

Consumption linkages

The marginal budget shares for nontradable goods for small-scale cage farmers estimated by Kassam suggest that 37 and 49 percent of each extra dollar of income earned by small-scale cage farmers would be spent on regionally and nationally nontradable goods, respectively.[79] This suggests lower consumption linkages than from small-scale pond farmers, which is to be expected, as wealthier people such as cage farm owners are likely to spend a larger proportion of their income on imported or tradable goods. Labor represents a low proportion of input costs and value added for SME cage farms, so consumption linkages are largely from farm owners. The impact of consumption linkages may not be felt by local communities around cage farm clusters, as the sector is still very small, clusters of farms have only recently developed, and consumption linkages are mainly from farm owners, most of whom live in Accra. Community focus group discussions conducted by Kassam suggested that more remote communities are more likely to perceive an impact from increased commercial activities due to farm workers spending money on food from local traders, in bars and food stalls, renting rooms locally, etc. The impact of consumption linkages is more apparent in the communities located around the medium- and large-scale farms by virtue of their size and the large number of workers they employ.

Increased food security

Communities near SME cage farms could potentially benefit from cheaper and increased fish supply during harvests, especially with the trend of overfishing and declining fish catch from Lake Volta over the years.[80] However, due to the relatively small number of functional cage farms at present and production cycles of approximately six months, harvests from small-scale cage farms are infrequent. Focus group discussions conducted by Kassam with communities close to small-scale cage farms and key informant interviews undertaken for the present study indicate that the impact of cage farms on local fish consumption is limited. Some community members are able to buy small-sized farmed tilapia on harvest days due to its cheaper price compared to large fish and the higher demand for larger-sized fish (i.e., those of Size 1 or 330 grams and over). Small-scale cage farms are also more likely to produce a higher proportion of smaller-sized fish than medium- and large-scale cage farms due to their lower technical knowledge and financial resources to pay for commercial feed throughout the production cycle, as well as their tendency to harvest early. Thus local communities surrounding medium-scale farms are less likely to benefit from increased supply of fish, as these farms usually harvest larger fish than small farms, and these larger-sized fish are too expensive for local consumers compared to wild-caught fish. Several medium-scale farms also do not sell to community members; for example, in 2013 Maleka Farms in Akuse stopped selling at the farm gate and is selling at an outlet in Accra, Lee Farms is currently in the process of establishing an outlet in Kasoa, and Sun Woo Farm sells only to wholesalers.

Increased fish supply is likely to impact on the poor when the species produced is consumed by poor consumers or when prices reduce to a level which the poor can afford. Generally in Ghana, tilapia is a high-value fish demanded by better-off consumers, whereas poorer consumers eat cheaper fish such as "one man thousand" (*Sierrathrissa leonensis*) and catfish from inland fisheries, as well as small pelagics from the sea. Also, on a national level there does not seem to be much potential at present to decrease the price of fish through increased production of tilapia from cage aquaculture. As shown in Table 1 (page 10), in 2012 aquaculture production was estimated to be just over 27,000 metric tons, most of which was tilapia. Kaunda et al.[81] estimate tilapia demand to be between 60,000 and 120,000 metric tons per year and argue that the market can absorb a substantial increase in tilapia supplies without leading to major price reductions. They also note that tilapia is priced alongside the better demersal species sold in Accra, differentiated from small pelagics that retail for less than half the price per kilogram for tilapia. The local price of farmed tilapia has been rising steadily. For example, in 2011 the farm-gate price for Size 1 fish from medium-scale farms was 5.2 cedi per kilogram, and in August 2013 the price was 7.4 cedi per kilogram; however, the price in terms of U.S. dollars has not changed due to the depreciation of the Ghana cedi. Thus, in Ghana, tilapia is a high-value product, the price of which is related to other high-value fish products. Therefore, increased supply will not necessarily decrease its price or benefit poor consumers, who are unlikely to demand high-value fish such as tilapia until the current high demand for fish is met.

Environmental linkages

Kassam found that some communities around medium-scale cage farms that use water from the lake for drinking, bathing and general household use have experienced decreased water quality since the fish farms were established. They reported that they could no longer bathe in the water, which makes them itchy and produces rashes in children. A 2011 study by the Water Research Institute found that there were no clearly detectable negative impacts of cage aquaculture on water quality. They attributed this to the large volume of the lake relative to the number of fish cages.[82] However, since the study was conducted in 2010, cage aquaculture has been growing, and it is likely that clusters of SME cage farms — and especially large-scale cage farms being established on the lake — could have cumulative negative environmental and ecosystem effects.

Comparison of multiplier effects between aquaculture systems

Kassam estimated potential multiplier effects for different aquaculture systems. These multipliers quantify the overall effect of the production and consumption linkages described above and estimate the amount of added income generated within the region and nationally by an extra dollar of income from each aquaculture system. Multiplier estimation thus allows comparison of the potential economic growth created by the development of financially viable small-scale pond aquaculture (fish farming type A) in Ashanti Region and SME cage aquaculture in Eastern Region. The potential regional and national multipliers from small-scale pond aquaculture (fish farming type A) are estimated to be between 1.6 and 1.8, and between 3.0 and 3.5, respectively. The potential regional and national multipliers from SME cage aquaculture are estimated to be 1.1, and between 1.5 and 1.6, respectively.[83] This means that an extra dollar of income from small-scale pond aquaculture in Ashanti Region is estimated to generate between $0.60 and $0.80 of further income within the region and between $2.00 and $2.50 of further income nationally. An extra dollar of income from SME cage aquaculture in Eastern Region is estimated to generate $0.10 of further income within the region and between $0.50 and $0.60 of further income nationally. It must be noted that these multiplier estimates reflect the potential multiplier effects of relatively well managed and financially viable small-scale pond and SME cage farms in Ghana, rather than the actual multiplier effects of the sectors at present.

While economic growth does not necessarily translate directly into poverty reduction, many studies have highlighted the strong relationship between agricultural growth and reduced poverty.[84] For example, Irz et al. find that a 1 percent increase in agricultural yields decreases the percentage of the population living under the $1 per day poverty line by 0.91 percent, and by 0.96 percent in sub-Saharan Africa.[85] Also, the effectiveness of economic growth to reduce poverty depends in part on the overall equality of income distribution. If growth is generated by those in higher-income groups, such as SME commercial cage farmers, more income growth is needed to reduce poverty than if growth is generated by those in lower income groups, such as small-scale rural pond farmers.

Employment generation by different aquaculture systems

Estimation of potential economic multipliers takes into consideration on-farm and value chain employment effects from each aquaculture system. However, to get a better understanding of the potential impact of aquaculture on poverty via employment linkages, this section compares the level of employment generated by the two aquaculture systems directly on-farm and indirectly along the value chain. The characteristics of those who are employed, such as on-farm laborers and farmed fish traders, are also briefly explored.

On average, fish farming type A farms were estimated to generate 0.2–0.3 full-time equivalent jobs per farm in 2010, depending on whether pond construction was included.[86] All employment generated by small-scale rural pond farms, such as for feeders, caretakers, security guards and seasonal labor for harvesting, is suitable for unskilled, poor, rural wage laborers. All of the four full-time equivalent jobs generated per small-scale cage farm and 17 of the 24 full-time equivalent jobs generated per medium-scale cage farm estimated by Kassam were found to be suitable for unskilled laborers.[87] The majority of on-farm jobs created by SME cage aquaculture at present — such as feeders, security guards and general laborers, along with divers, most of whom are local fishers — are suitable for unskilled laborers to be trained on the job. As noted above, medium-scale farms have been expanding their production and hence employment generation. Interviews with two medium-scale cage farmers suggest employment per farm has approximately doubled between 2011 and 2013.

Additional employment is created throughout the aquaculture value chain in feed mills, hatcheries, transportation services, ice manufacturing, cage construction and production, sale of materials such as drums, pipes, ropes and nets, production of water pumps, construction of buildings, in chop bars and "banku" and tilapia joints, etc. Small-scale pond aquaculture has an undeveloped value chain at present and thus currently does not create much indirect employment. It has weak forward linkages that do not generate much employment for fish traders or processors. However, its stronger backward linkages have the potential to generate employment related to production and distribution of inputs such as rice and maize bran, groundnut peel, organic fertilizer, and lime. The SME and large-scale cage farm value chain is more developed. Thus, while backward linkages are weaker than for small-scale pond aquaculture, their effects are more visible. Cage farming has stronger forward linkages than pond aquaculture. Overall, these production linkages have created indirect employment opportunities for workers in feed mills and hatcheries, poor local women who scale and degut fish, and fish traders. The majority of indirect employment created by the cage aquaculture sector is for low-income female fish traders from Accra and surrounding areas, as well as fish trading centers around Lake Volta. These traders buy from the SME cage farms and the large-scale farm retail outlets of Tropo Farms, to sell to hotels, restaurants and tilapia joints. Many traders sell house to house direct to consumers in Accra, as they cannot afford to pay for a market stall. Kassam estimated that overall at least one indirect job is generated in the value chain for cage-farmed fish for each direct job generated on-farm.[88]

While the small-scale pond aquaculture sector does not create as much direct and indirect employment as the SME cage sector at present, equivalent increases in investment and scale could change this. For example, Kassam estimated that small-scale pond aquaculture generates 0.3 full-time equivalent on-farm jobs per $1,000 invested (including pond construction) and 0.03 full-time equivalent jobs per $1,000 (not including pond construction), while small-scale cage aquaculture generates approximately 0.1 full-time equivalent on-farm jobs per $1,000 invested, and this is likely to be lower for medium-scale cage aquaculture.[89] While these estimates are only an approximation, they provide an indication that if employment generated by pond construction is taken into consideration, small-scale pond aquaculture could potentially create more employment per dollar invested than SME commercial cage aquaculture. Similarly, the multiplier estimates given above suggest that small-scale pond aquaculture (fish farming type A) has the potential to create more economic growth — and hence indirect employment — than SME cage farming, given equivalent increases in scale.

Summary of direct and indirect poverty impacts

This assessment of direct and indirect poverty impacts from small-scale pond aquaculture in Ashanti Region and SME cage aquaculture in Eastern Region suggests that overall, aquaculture has more potential to impact poverty through indirect impact pathways, such as economic multiplier effects, than directly through increasing income and food security of poor fish-farming households. While poor households have been able to adopt aquaculture in Ashanti Region, small-scale pond aquaculture does not have strong positive direct impacts on the poverty and livelihoods of these households. However, small-scale aquaculture appears to have positive direct impacts on the livelihoods of nonpoor fish-farming households. The level of these impacts is dependent largely on the household characteristics, livelihood characteristics, and knowledge and management practices of these farmers (dependent on fish farming type), and is also likely to be influenced by the infrastructure and institutional context. There is potential to increase aquaculture's direct poverty impact, however, if poor fish-farming households are able to overcome their resource constraints and benefit from fish farming type A, following good management practices. The potential economic multiplier effects and associated backward, forward and consumption linkages were found to be stronger for small-scale pond aquaculture (fish farming type A) than for SME cage aquaculture. While not all the benefits of economic growth from each aquaculture system are likely to accrue to the poor, for equivalent increases in scale, small-scale pond aquaculture (fish farming type A) has more potential to generate broad-based, pro-poor economic growth than SME cage aquaculture.

Sorting and grading farmed tilapia which has been freshly harvested from a cage farm in Lake Volta

DRIVERS OF AQUACULTURE DEVELOPMENT IN GHANA

While the potential poverty impact of small-scale pond aquaculture may be larger than SME cage aquaculture given equivalent increases in scale, at present the actual and potential growth of the pond aquaculture sector is much lower than the cage sector. Pond aquaculture has existed in Ghana since the early 1950s and has been the main focus of government and donor efforts to develop the aquaculture sector over the years. However, it has developed much more slowly than commercial cage culture, which started relatively recently in 2001. Since 2005–2006, cage aquaculture has been growing rapidly. This growth is reflected in annual total aquaculture production, which increased from just over 1,000 metric tons in 2005 to over 27,000 metric tons in 2012. Production from cage aquaculture — particularly from the two large-scale commercial cage farms — is the main source of this growth and currently accounts for nearly 90 percent of all farmed fish in Ghana. Production from pond aquaculture also increased during this time, although at a much lower rate than cage aquaculture. For example, between 2009 and 2012 production from pond aquaculture grew on average under 30 percent per year (from a very low base), compared to production from cage culture, which increased over 70 percent per year on average.

This section analyzes the enabling conditions and drivers for the development of the aquaculture sector in Ghana. The focus is particularly on the cage sector, which has shown increased growth recently, both in terms of production and in terms of new entrants to the sector. The information for this section was gathered primarily through interviews with key staff at the Ministry of Fisheries and Aquaculture Development and Fisheries Commission in Accra, Kumasi and Akosombo, staff from the Water Research Institute in Accra and Akosombo, pond and cage aquaculture farmers (particularly pioneer farmers in both sectors), and private sector service providers such as feed and fingerling producers (see Appendix 1). The interviews focused on gaining a historical perspective on the development of the aquaculture sector in order to distill the key enabling conditions, events, processes, actors and policies that have shaped this development.

The key enabling conditions and drivers that have shaped the development of the aquaculture sector in Ghana are the following: suitable natural resources; increasing urban demand for fish; macroeconomic policy reform encouraging economic growth and an attractive investment climate; government and international donor support of the aquaculture sector; the key role of pioneer farmers in both pond and cage aquaculture sectors; and a ban on tilapia imports. Some of these influences, such as the high demand for fish and a friendly investment climate, have provided the enabling conditions for aquaculture to develop and have encouraged the private investment needed to make the key change from a primarily noncommercial livelihood activity (mainly pond aquaculture) to a commercial activity (mainly cage aquaculture). However, other factors — particularly the role of pioneer farmers — provided the catalyst for the growth of cage aquaculture in recent years, and were enabled by these broader conditions and developmental processes. These enabling conditions and drivers are explored in turn below.

Medium-scale cage farm in Lake Volta using locally produced cages

Suitable natural resources

Ghana has favorable biophysical factors suitable for aquaculture.[90] The country is drained by a large number of streams and rivers; Lake Volta and its tributaries drain over two-thirds of the country. Over 90 percent of Ghana's land area has been found to be suitable for pond aquaculture in terms of water availability and water and soil quality.[91] Lake Volta is also very suitable for cage aquaculture development. Only 1 percent of the area of Lake Volta — approximately 8,500 hectares of water — would be more than 10 times the area used for pond-based aquaculture,[92] estimated to be 704 hectares in 2012 (see Table 2). Ofori et al. estimate that if cage farmers in Ghana can produce between 50 and 150 kilograms per cubic meter every 9 months — similar to yields reported elsewhere in Africa — the production from less than 100 hectares of cages could be equivalent to the inland capture fisheries production of 90,000 metric tons, although it is questionable whether this represents a realistic scenario.[93]

Increasing urban demand for fish

Domestic demand for higher-value products such as vegetables and for some animal products such as chicken and fish has been increasing due to rapidly growing urban markets in Ghana. Over the past decade, the urban population has been growing at an average of 4 percent per year, compared to the overall annual population growth of approximately 2.5 percent.[94] Ghana's strong economic performance since the mid-1990s has also had a significant impact on poverty and urban incomes. The trends of urbanization, economic growth and poverty reduction have led to changing domestic food markets in Ghana. This change is shown by the rapid development of supermarkets that target better-off consumers, along with more broad-based changes in food habits, illustrated by the growth of the chicken meat market.[95] Similarly, significant urban markets exist for aquaculture products in Ghana — a factor driving much of the private sector-led aquaculture development in sub-Saharan Africa. The demand for fresh fish is especially high in the south, in Accra, along the coast and around Lake Volta. The demand for processed fish such as smoked catfish is higher in inland areas such as Ashanti Region. At the same time as fish demand is increasing, marine and inland capture fisheries are following a decreasing trend. This situation provides significant opportunities for aquaculture development.

Macroeconomic policy and governance

Ghana's positive economic performance over recent years, supported by relative peace, political stability, macroeconomic reforms and public investments in infrastructure, have encouraged an influx of foreign direct investment in various forms. Foreign direct investment jumped from approximately $144 million in 2005 to nearly $1.4 billion in 2007[96] and was over $3.3 billion in 2012, making Ghana the fifth-largest recipient of foreign direct investment in Africa.[97] This trend is also reflected in the level of foreign investment in the cage aquaculture sector in recent years. The majority of medium- and large-scale cage farms are owned by foreign investors. The government has been actively building a policy and regulatory environment that is more conducive to enterprise development. Ghana was accordingly ranked twice as a top 10 reformer globally by the World Bank's Doing Business report.[98]

Government promotion of the aquaculture sector: A historical perspective

The government has supported and promoted aquaculture in various ways since the 1950s. While much of this support does not appear to have contributed directly to the recent growth in cage aquaculture, it has played a role in the development of the pond aquaculture sector, raised awareness within the country of aquaculture's importance in meeting increasing fish requirements, and encouraged investment into the sector — more recently, into the cage aquaculture sector. All of these can be seen as contributions to the enabling conditions for the development of aquaculture in Ghana.

As noted on page 9, fish farming was started in Ghana in 1953 by the former Department of Fisheries in the north. Ponds were built to serve as hatcheries to support the colonial administration's culture-based reservoir program, intended to supplement the national demand for fish and increase livelihood opportunities for communities living near small reservoirs. After independence in 1957, the government adopted a policy of developing fish ponds within all irrigation schemes in the country. State-owned irrigation facilities aimed to develop 5 percent of each scheme into fish farms. In the 1970s, the government established a fish hatchery within Ashaiman Irrigation Scheme in southern Ghana to provide subsidized tilapia fingerlings to fish farmers. In the 1970s and 1980s, when

Photo credit: Laila Kassam

Circular tanks for tilapia fingerling production at Crystal Lake farm

production from marine capture fisheries was already decreasing, various government programs encouraged people to go into aquaculture. These programs were advertised on the radio, offered training courses through the Department of Fisheries and provided support for pond construction. However, lack of adequate technical knowledge, finance, logistical support and extension meant that many aquaculture enterprises failed. The few surviving pond farms continued to operate on a semi-subsistence level, mainly practicing polyculture of tilapia and catfish using very low input technology.

By the mid-1980s, the government had started to invest in training of Department of Fisheries staff in aquaculture, some of whom were supported by international organizations such as the African Development Bank and the Food and Agriculture Organization of the U.N. to undertake graduate studies in aquaculture overseas. During this time, the core of middle-level government professionals were trained, and this training trickled down through the universities and colleges. The Water Research Institute's Aquaculture Research and Development Centre was established in Akosombo, Eastern Region, in 1989 to undertake aquaculture-related research. In 1999, the Water Research Institute began collaboration with WorldFish to undertake a project to develop improved tilapia strains for aquaculture. The project developed the "Akosombo strain" of Nile tilapia; in 2006, "Akosombo strain" fingerlings were released for sale to the public. Currently, the Water Research Institute in Akosombo is one of the main hatcheries supplying SME cage farms in Lake Volta.

While the government did not provide much support to the sector between the mid-1980s and 2000, between 1990 and 2004, the technology of fingerling production improved. In addition to earthen ponds, concrete ponds and hapas were used to undertake fingerling production by farmers supported by the Department of Fisheries. Some of these farmers were supported by the FAO to go on study exchanges and trainings abroad to learn about fingerling production. The government also built a bigger hatchery in Ashanti Region to serve the central and northern parts of the country. Induced breeding of catfish, introduced by the Department of Fisheries, increased the supply of catfish fingerlings available to fish farmers. Introduction by the Department of Fisheries of fish feed formulation at farm level using local ingredients also became more popular. However, all of these activities were being performed on a relatively small scale and did not contribute to any significant growth in the sector. This is reflected in the low production of aquaculture in the 1980s and 1990s, which hovered around the 400–500 metric tons mark.

In 2000, Tropo Farms started operations in Asutuare, Eastern Region, and introduced modern commercial pond farming to Ghana with good-quality fingerlings, feed, aerators, etc. In 2001, the first cage farm, Crystal Lake, was established on Lake Volta. These two fish farms pioneered commercial fish farming in Ghana and provided the catalyst to growth of the sector (discussed in more detail below).

In 2005, the Ministry of Fisheries was created. Under the strong promotion of aquaculture by the minister, Hon. Gladys Asmah, free extension services to fish farmers were provided by fisheries extension staff, fingerlings were produced at government hatcheries, and fish farmers' associations were established. She also organized tilapia fairs and bazaars to encourage demand and overcome skepticism regarding consuming farmed fish. The minister also used the success of Crystal Lake and Tropo Farms to raise the profile of the aquaculture sector considerably. She also increased awareness of aquaculture as a profitable investment opportunity among financial institutions, organizing visits for financial institutions, members of parliament and key private sector actors to Tropo Farms on harvest days. In 2008, the Ministry of Fisheries was reconstituted as the Fisheries Commission and brought back under the Ministry of Food and Agriculture, and in 2013 the new Ministry of Fisheries and Aquaculture Development was created. The current focus is on promoting commercial aquaculture. To encourage commercial investment in the aquaculture sector, there is a five-year tax holiday on aquaculture activities, and aquaculture goods are duty- and value-added-tax-exempt. The Fisheries Commission and Ministry of Food and Agriculture have recently produced a Ghana National Aquaculture Development Plan, with support from the FAO, which aims to increase production of commercially farmed fish from 10,200 metric tons in 2010 to 100,000 metric tons in 2016, boosting the market share of farmed fish to 30 percent.[99] The strategy is based on supporting the development of commercial aquaculture through the development of high-priority aquaculture zones, which are likely to be in Lake Volta.

Donor support

Ghana's aquaculture sector has also been supported by international organizations over the years. From 1996 to 2002, the World Bank funded the Fisheries Sector Capacity Building Project, aimed at strengthening the Department of Fisheries' capacity and supporting improved aquaculture extension services and higher-quality fingerlings. In 2002, the FAO funded a project to strengthen the organizational capacity of fish farmers' associations and supported the development of the National Fisheries and Aquaculture Policy in 2006. As mentioned above, the Water Research Institute collaborated with WorldFish to develop the "Akosombo strain." The Aquaculture and Fisheries Collaborative Research Support Program, which is known as AquaFish CRSP and funded by the U.S. Agency for International Development, has also been supporting aquaculture through research and training of pond fish farmers. In July 2011, the World Bank approved an investment of $53.8 million to implement the West Africa Regional Fisheries Program, a five-year fisheries and aquaculture project in Ghana of which $8 million is earmarked for aquaculture development. However, it is unclear how much these activities have contributed to the development of the aquaculture sector in recent years. Apart from the development of the "Akosombo strain," most of these interventions have been focused on the pond aquaculture sector, which has not shown any significant development over the years.

Pioneer farmers

Despite many years of support to the aquaculture sector in Ghana by the government and donors, the sector did not really take off until the entry of Tropo and Crystal Lake Fish farms. The success of Tropo Farms, in particular, is a key driving force in the cage aquaculture sector. The impact on the sector can be traced back to Tropo Farms' entry into the pond aquaculture sector in 1999–2000. A brief history of Tropo Farms and Crystal Lake is described below, followed by a discussion of their key impacts on driving the development of the sector.

Tropo Farms was established by Mark Amechi, a half-German, half-Nigerian expatriate with a Master of Science in aquaculture from the Asian Institute of Technology in Thailand. Amechi came to Ghana in 1997 to set up a fish farm, attracted in part by the fact that Ghana had an easier business environment than his original choice of Nigeria. Amechi established a large pond aquaculture farm in Asutuare, Eastern Region, near Lake Volta. Tropo Farms became operational in 2000. Due to the lack of good-quality fingerlings in Ghana at the time, Tropo Farms imported genetically improved farmed tilapia, known as GIFT, broodstock from Nam Sai Farms in Thailand and started producing fingerlings. There was no commercial feed on the market, so Tropo Farms initially prepared feed from locally available materials such as soya, and later started to import commercial feed. Soon Tropo Farms was producing 800 grams of tilapia and selling regularly at the farm gate.

In 2000, the first cage farm, Crystal Lake Fish, was established in Lake Volta by a female Ghanaian entrepreneur, Patricia Safo, with support from the Danish International Development Agency. After successfully piloting cage technology with the Water Research Institute in Akosombo, Crystal Lake imported large round cages. The Water Research Institute supplied fingerlings for the first two cages. Like Tropo Farms, Crystal Lake prepared its own feed until 2005, when Ranaan feed became available on the market.

In 2003, the Ghana Environmental Protection Agency found out that Tropo Farms had been importing GIFT, which was banned. The EPA required all GIFT broodstock, fingerlings and fish to be destroyed. Tropo Farms then moved into cage aquaculture in Lake Volta, and started production in September 2006. Unlike Crystal Lake, Tropo Farms used small 6 by 6 by 6-meter cages built with low-cost materials available in Ghana. These were based on a design commonly found in Thailand, which was adopted as a result of Amechi's familiarity with aquaculture there. Tropo Farms used the pond farm at Asutuare as a hatchery, using "Akosombo strain" broodstock from the Water Research Institute to breed a new Tropo strain. Fingerlings were produced primarily for the cage farm, and for a time excess fingerlings were sold to other farmers. Tropo Farms also imported commercial floating feed from Brazil.

As discussed above, much of the rapid growth in aquaculture production since 2006 has come from Tropo Farms. Tropo Farms reported production figures of approximately 3,000 metric tons in 2010, 4,500 metric tons in 2011 and 6,500 metric tons in 2012, though these figures are likely to be higher. In 2013, Tropo Farms established a new offshore site with plans to import 72 industrial-size round cages from Turkey in order to produce over 20,000 metric tons per year. Tropo Farms is also building a new hatchery to supply enough fingerlings for the offshore site. Currently, Tropo Farms is considering taking on a partner to help finance this large increase in production.

Crystal Lake was not as successful as Tropo Farms and found fingerling production to be more profitable. Now Crystal Lake is the largest private hatchery in Ghana, estimated to be producing 15 million fingerlings per year.

These two pioneer fish farms have played a key role in shaping the development of the sector through opening up the market for fresh tilapia; introducing low cost, locally made cage technology; demonstrating the possibility of commercial aquaculture in Ghana, thus encouraging new entrants; and easing input constraints to the sector. These have all played an important role in driving the growth of the sector and are discussed below.

Opening up the market for fresh tilapia

While the demand for fish is high and increasing in Ghana, and the demand for fresh fish is especially high in the south, harvest of wild tilapia from Lake Volta is seasonal (during the July to September rainy season), stocks are decreasing and the size of tilapia is generally small. Thus when Tropo Farms set up in Ghana, prices for wild tilapia were high, sizes were small, and tilapia was mainly fried or salted and dried to make "kobi." When Tropo Farms started to produce and sell a regular supply of large-sized tilapia at a lower price than wild tilapia, demand increased and retailers such as hotels and restaurants began to buy large amounts of farmed tilapia. Restaurants in Accra such as Blue Gate started to specialize in grilled tilapia and "banku." Though these retailers had previously been getting wild tilapia from Weija Lagoon in Accra, the farmed fish supply was more reliable and fish sizes bigger. Grilled tilapia became something of a delicacy, and fresh grilled tilapia was introduced to chop bar operations. The farmed tilapia from Tropo Farms also tasted better and was fresher than wild tilapia from Lake Volta, which was landed at Yeji in the north of Lake Volta, packed on ice and transported to Accra. Thus Tropo Farms opened up the market for fresh tilapia, which has been growing ever since. Tropo Farms was also able to attract and tap into the well-established network of wild-fish traders to help market farmed fish. Tropo Farms developed relationships with powerful fish wholesalers and traders known as "fish mammies," along with other traders, and encouraged them to organize themselves into groups. This growing network of fish traders and wholesalers now buy and sell farmed fish from all the SME cage farms on Lake Volta.

Raised awareness of commercial aquaculture

The success of Tropo Farms started to raise awareness that aquaculture could be a successful commercial activity in Ghana. Before Tropo Farms, aquaculture was not really seen as a profitable commercial enterprise. The few commercial farmers at the time were producing fish well below table size, and harvesting only one to two months of the year, primarily during the dry season when supply of tilapia from the wild was low. Tropo Farms' urban marketing outlets, which opened in 2007–2008, further raised awareness among potential investors that aquaculture was a profitable activity, encouraging investment from SMEs into the sector. Since 2010, there have also been a number of fish-farming investment schemes that have established cages on Lake Volta and have promised investors unrealistically high returns within a year. One scheme, the Fish Farmers' Brigade, collapsed in 2012, and the director is currently facing legal proceedings. This has not deterred other similar schemes, nor has it deterred investment into the sector; rather, the advertisements have fuelled a perception that fish farming is easy money, which has further encouraged individuals to enter into cage aquaculture.

Introduction of low-cost cage technology

When Tropo Farms started cage aquaculture in 2006, they — unlike Crystal Lake — used low-cost cages built with locally available materials such as galvanized pipes and blue plastic drums, showing that cage aquaculture was possible for SMEs and not just large investors. During this time, the Water Research Institute was also piloting cages made with a similar design and local materials and promoting their use with fish farmers. Cages similar to those first introduced by Tropo Farms and piloted by the Water Research Institute are now used by the majority of SME cage farms in Lake Volta. Mark Amechi credits his graduate education at the Asian Institute of Technology in Thailand as being very important in helping him understand appropriate cage technology for aquaculture in Africa. Amechi's training in aquaculture was also an important factor in his success as a fish farmer in Africa; this transfer of knowledge can also be seen as an indirect driver of the development of the aquaculture sector in Ghana.

Easing of input constraints

By producing fingerlings and selling the excess, Tropo Farms and Crystal Lake were able to ease one of the main constraints to the sector: lack of good-quality fingerlings on the market. The existence of large commercial farms also encouraged the importation of Ranaan feed by Dizengoff Ghana Ltd. in 2005. Ranaan feed was initially being sold only to Crystal Lake and a handful of pond farmers, but the importation of feed grew with the establishment of new SME cage farms. The establishment of new farms was encouraged by the presence of feed and fingerling suppliers, as well as high demand for tilapia. While an increasing number of private hatcheries and feed suppliers have now been set up and are supplying inputs to the sector, the role of these pioneer farmers in easing initial input constraints at the critical time of take-off was very important. These input constraints would have been very difficult for smaller farmers, who lacked the technical, financial and institutional capabilities of larger farmers, to overcome. The lower input requirements of small farms would also not have provided the necessary incentives for private feed and fingerling suppliers to make investments in the value chain.

Government ban on tilapia imports

While Ghanaian aquaculture is profitable, it is not competitive with the world's low-cost leaders, such as China. Once Tropo Farms and Crystal Lake had become established, showing the commercial potential of the aquaculture sector, the Fisheries Commission decided to institute a ban on tilapia imports in 2005 to protect the sector and encourage its growth. While officially there is no legislation banning the import of tilapia, the Fisheries Commission gives permits for all fish imports and thus is able to deny permits to those wanting to import tilapia. However, due to difficulty in enforcing the ban, there is still some frozen tilapia from China and Taiwan being sold in cold stores and supermarkets at a lower price than Ghanaian farmed tilapia, though quantity and price data are not available. It is unclear, however, how important this ban has been for the development of the sector. While it appears to be an important enabling condition for aquaculture's growth in Ghana, many key informants reported that despite its low price, there is very little demand for cheap frozen tilapia imports, as most people want to buy fresh tilapia. The frozen imports have an inferior taste compared to fresh farmed tilapia, and most consumers can tell the difference.

Development of the pond aquaculture sector

This section has focused on the development of the cage aquaculture sector, concentrating especially on the role of large-scale commercial cage aquaculture farms in shaping the development of the cage sector. The enabling conditions and drivers for the pond aquaculture sector have not been explored, as pond aquaculture in Ghana has not experienced significant growth over the years. While the number of pond farms has been estimated to grow at 16 percent per annum since 2000,[100] this is from a very low base. Pond aquaculture represents a very small and decreasing relative contribution to overall aquaculture production, even though small-scale pond farmers still represent the majority of fish farmers in Ghana.

Kassam argues that the small-scale rural pond sector in Ashanti Region is stuck in a "low-level equilibrium trap." This is due to high transaction costs and risks, influenced by the demanding techno-economic characteristics of farmed fish, such as perishability, long production cycles, dispersed rural farmers, and the need for multiple and coordinated inputs, which require a high level of institutional development. Small-scale pond and cage farmers also have low transaction volumes and frequencies. This reduces the incentive to establish nonmarket institutional arrangements, such as relationships with input suppliers and buyers or traders, due to the high fixed costs per transaction, and is thus likely to hinder market development. Medium-scale cage farmers have medium transaction volumes and frequencies, and large-scale cage farmers have high transaction volumes and frequencies. Higher transaction volumes and frequencies increase the potential for hybrid or hierarchical contractual forms and vertical integration (e.g., Tropo Farms produces its own fingerlings and markets fish in urban outlets) and are thus likely to encourage market development.

Most small-scale rural pond farmers also do not have the technical, financial or institutional capabilities to overcome these high transaction costs and risks, unlike SME and large-scale cage farmers, who are better resourced. The outcome of this situation implies that at the moment, new entrants have little incentive to adopt small-scale pond aquaculture, current farmers have little incentive to intensify production, and traders have little incentive to invest in marketing fish from small-scale rural pond farmers in urban markets. The situation may gradually evolve if local demand for fish rises due to higher local incomes. However, production levels and market development of the rural pond aquaculture sector are unlikely to shift to a much higher, more commercial equilibrium in the short to medium term unless producers are able to benefit from higher urban market prices through developing institutional arrangements to reduce transaction costs and risks and increase nonmarket coordination along the value chain.[101]

A key difference between the pond and cage aquaculture sectors that also contributes to the difference in their development is the location of farms and their access to urban markets offering high prices. Most SME cage farms around Lake Volta are relatively close to Accra and are easily accessible by an established network of fish traders. Most cage farms can be reached by a combination of public transport and hiring a shared or private taxi. Large-scale cage farms, which are located in the main part of the lake, are in more remote areas. However, they have built roads and established outlets and market areas in more accessible areas. Small-scale rural pond aquaculture farmers are much more dispersed and are more difficult to reach due to poor roads and poor public transport, and thus have to sell at the farm gate, mainly to community members, at relatively low prices.

As noted above, the demand for fresh tilapia in the south, along the coast and around the lake — and especially in markets in and around Accra — is also very high. The demand for fresh tilapia is not as high in inland areas as it is in the south, as people in inland areas are used to eating processed fish. For example, the Fisheries Commission staff interviewed in Kumasi noted that only in the past two years has the demand for fresh tilapia picked up in Kumasi. This is partly due to the fact that in Ashanti Region there has been a perception that farmed fish is inferior in taste to wild-caught fish, which appears to be the case when manuring and local feed is used rather than commercially formulated feed. Without using expensive commercial feed, fish are also not able to grow to table size, and there is lower demand for small-sized fish. Tropo Farms' initial success in pond aquaculture can be partly attributed to its location close to Lake Volta, where demand for fresh fish is very high, as well as to the large fish sizes being produced due to initial use of imported GIFT broodstock, and the improved taste once Tropo Farms started to import commercial feed. While the demand for smoked catfish in Kumasi is much higher than for fresh tilapia, there is competition from wild-caught catfish, and prices are not that high.

New commercial investors into aquaculture are more likely to invest in cage rather than pond aquaculture due to a number of other advantages, including the relative ease of leasing land on Lake Volta compared to finding suitable locations and land to site ponds; the low capital outlay required for cages compared to ponds; and the higher production intensity, yield and profit margins of cage compared to pond aquaculture.[102] Thus the growth potential for cage aquaculture appears to be much greater than for pond aquaculture at present.

Summary

This section has taken a historical perspective on the development of the aquaculture sector in Ghana, focusing especially on the cage aquaculture sector. Much of the growth of the sector has come from the establishment and growth of a few large-scale farms. The SME sector has developed as a result and is also beginning to take off. The key factors identified as important in driving the development of the sector can be put into two categories: i) enabling conditions and developmental processes, such as increasing urban demand for fish, macroeconomic policy reforms encouraging economic growth and foreign direct investment, and government support of the aquaculture sector; and ii) specific events and actors, such as the establishment of the pioneer farms Tropo Farms and Crystal Lake and the introduction of low-cost cage technology. The former can be seen as having enabled the latter to be the catalyst for the cage aquaculture sector to take off. These factors are summarized in Table 6.

Key event or technical change	Shift from ponds to cages
	Introduction of low-cost cage technology
	"Akosombo strain" fingerling production by the Water Research Institute
Key infrastructure and processes	Rising urban incomes and demand for fish
	Urbanization
	Economic growth
	Increasing foreign direct investment
Key actors	Government
	Water Research Institute
	WorldFish
	Pioneer farmers (Tropo Farms, Crystal Lake)
	Private sector (Ranaan feed, wild fish traders, private hatcheries)
Key policies	Ban on tilapia imports
	Macroeconomic reforms leading to economic growth and encouraging foreign direct investment
	Five-year tax holiday for fish farms
	Value-added tax and duty exemptions for aquaculture goods

Table 6. Key features of commercial aquaculture development in Ghana

CONCLUSION

This case study has provided an up-to-date overview of the aquaculture sector in Ghana, covering both the pond and cage aquaculture sectors. The direct and indirect poverty impacts of two key aquaculture systems in Ghana were compared: small-scale rural pond aquaculture in Ashanti Region and SME commercial cage aquaculture in Lake Volta, Eastern Region. The findings of this comparative analysis suggest that poor farmers are able to adopt pond aquaculture; however, due to the resource constraints of poor households, there is limited potential for pond aquaculture to directly reduce poverty. The analysis indicates that aquaculture's indirect poverty impacts are likely to be stronger than its direct poverty impacts. Given equivalent increases in scale, small-scale pond aquaculture by nonpoor farmers who have been trained or use good management practices holds the greatest potential for poverty impacts. This is because financially viable small-scale pond aquaculture has strong indirect poverty links and multiplier effects. SME cage aquaculture, on the other hand, has weaker indirect poverty impacts, but higher growth potential.

The enabling conditions and drivers of the development of the aquaculture sector were also analyzed, highlighting the key role of pioneer farmers, particularly Tropo Farms, in providing a catalyst to growth of the cage aquaculture sector. Pioneer farms such as Tropo Farms and Crystal Lake were able to overcome constraints to the sector — access to feed and fingerlings, market access, appropriate technology, etc. — partly through vertical integration of activities due to their high levels of financial and technical capabilities. Their success encouraged new SME cage farmers and feed and fingerling suppliers to make simultaneous and complementary investments in the cage-farmed tilapia value chain, and thus helped the sector to take off.

The ability of Tropo Farms to overcome constraints through vertical integration of fingerling production and grow out, and eventually integration of marketing through opening urban wholesale and retail outlets, indicates the importance of institutional innovation for aquaculture development. It also provides some lessons for the development of the small-scale pond aquaculture sector, and to some extent the small-scale cage sector. While medium- and large-scale cage farmers have resources and higher returns which enable them to overcome constraints through various institutional arrangements that coordinate individual activities in the supply chain, small-scale pond and cage farmers require support for institutional development to encourage system development. This is especially true of the small-scale pond farmers. Kassam thus argues that the key challenge for small-scale pond and cage aquaculture development is to develop coordinated supply chains that are able to offer farmers a range of input (feed and fingerlings), financial, technical, information and other services at the same time as enabling them to access urban and other markets that offer higher prices. As such, coordinated value chain development facilitated by institutional innovation is required to overcome the challenges to growth of the small-scale pond aquaculture sector in Ghana in order to maximize its poverty impact potential.

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APPENDIX 1: LIST OF KEY INFORMANTS

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Nana Siaw	President of Ashanti Fish Farmers' Association Owner of Kumah Farms (hatchery and pond aquaculture farm), Ashanti Region	
Joshua Gbenya	Manager, Tokorozawa Enterprises (small-scale cage farm), Sedom, Eastern Region	
Naga Murali	Owner of Delta Fisheries (hatchery and cage farm), Eastern Region	chnmurali@gmail.com
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NOTES

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[34] The term "non commercial" is somewhat misleading in this context, as many ponds falling in this range produce a marketable surplus. For instance, Kassam found that, on average, pond farmers harvested 160.6 kilograms, of which they sold 127.1 kilograms (79 percent), consumed 25.7 kilograms (16 percent) and gave away 12.5 kilograms (8 percent). Even "poor" farmers sold over 60 percent of their harvest.

[35] "Banku" is a local starchy staple food made from fermented maize or cassava flour dough, cooked in hot water and made into a thick paste, usually served with fish, soup or stew.

[36] The exchange rate was 1 cedi = $0.47 in August 2013. Retrieved from http://www.exchange-rates.org/Rate/GHS/USD/8-16-2013

[37] "Chop bars" are more affordable places to eat than restaurants and tilapia joints and serve a range of Ghanaian dishes. Most chop bars tend to serve boiled or steamed tilapia, unlike restaurants and tilapia joints, which serve grilled tilapia.

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[39] The average 2012 exchange rate was 1 cedi = $0.56. Retrieved from http://data.worldbank.org/indicator/PA.NUS.FCRF

[40] The largest cage farm, Tropo Farms, sells at a higher price than the other cage farms, as fish is sold already degutted and is sold at the retail and wholesale outlets in urban centers, not at the farm gate. Tropo Farms' current wholesale prices are as follows: Size 3 = 9.6 cedi per kilogram; Size 2 = 9.2 cedi per kilogram; Size 1 = 8.6 cedi per kilogram; regular = 8 cedi per kilogram; and economy = 6.2 cedi per kilogram.

[41] Ministry of Fisheries and Aquaculture Development. (2013). 2012 annual report. Accra, Ghana: Ministry of Fisheries and Aquaculture Development.

[42] In August 2013, the price of Nicoluzzi feed from Brazil was 65 cedi per 25 kilograms (2.6 cedi per kilogram) for 6.5-millimeter pellets and 32 percent protein. The price of Coppen's feed from Holland was 46 cedi per 15 kilograms (3 cedi per kilogram) for 3–6-millimeter pellets and 35 percent protein.

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[48] These districts are Amansie West, Amansie Central and Adansi North.

[49] These districts are Asuogyaman and Lower Manya Krobo.

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[51] The June 2010 exchange rate was 1 cedi = $0.70. Retrieved from http://www.exchange-rates.org/Rate/GHS/USD/6-16-2010

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[53] Reasons for only harvesting one pond a year on average may include long production cycles, which are sometimes over a year, and the fact that not all ponds are functional due to lack of working capital for stocking and feeding.

[54] Those under the international poverty line of $1.25 per day at 2005 Purchasing Power Parity, adjusted for the 2010 PPP rate for Ghana (390.55 cedi), were classed as poor.

[55] Kassam, L. (2013). Assessing the contribution of aquaculture to poverty reduction in Ghana, p. 133 (Doctoral dissertation). London: School of Oriental and African Studies. Available at http://eprints.soas.ac.uk/17842/1/Kassam_3547.pdf

[56] Kassam, L. (2013). Assessing the contribution of aquaculture to poverty reduction in Ghana, p. 132 (Doctoral dissertation). London: School of Oriental and African Studies. Available at http://eprints.soas.ac.uk/17842/1/Kassam_3547.pdf

[57] See Asmah, R. (2008). Development potential and financial viability of fish farming in Ghana (Doctoral dissertation). Stirling, U.K.: University of Stirling.

[58] Kassam, L. (2013). Assessing the contribution of aquaculture to poverty reduction in Ghana, p. 143 (Doctoral dissertation). London: School of Oriental and African Studies. Available at http://eprints.soas.ac.uk/17842/1/Kassam_3547.pdf

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