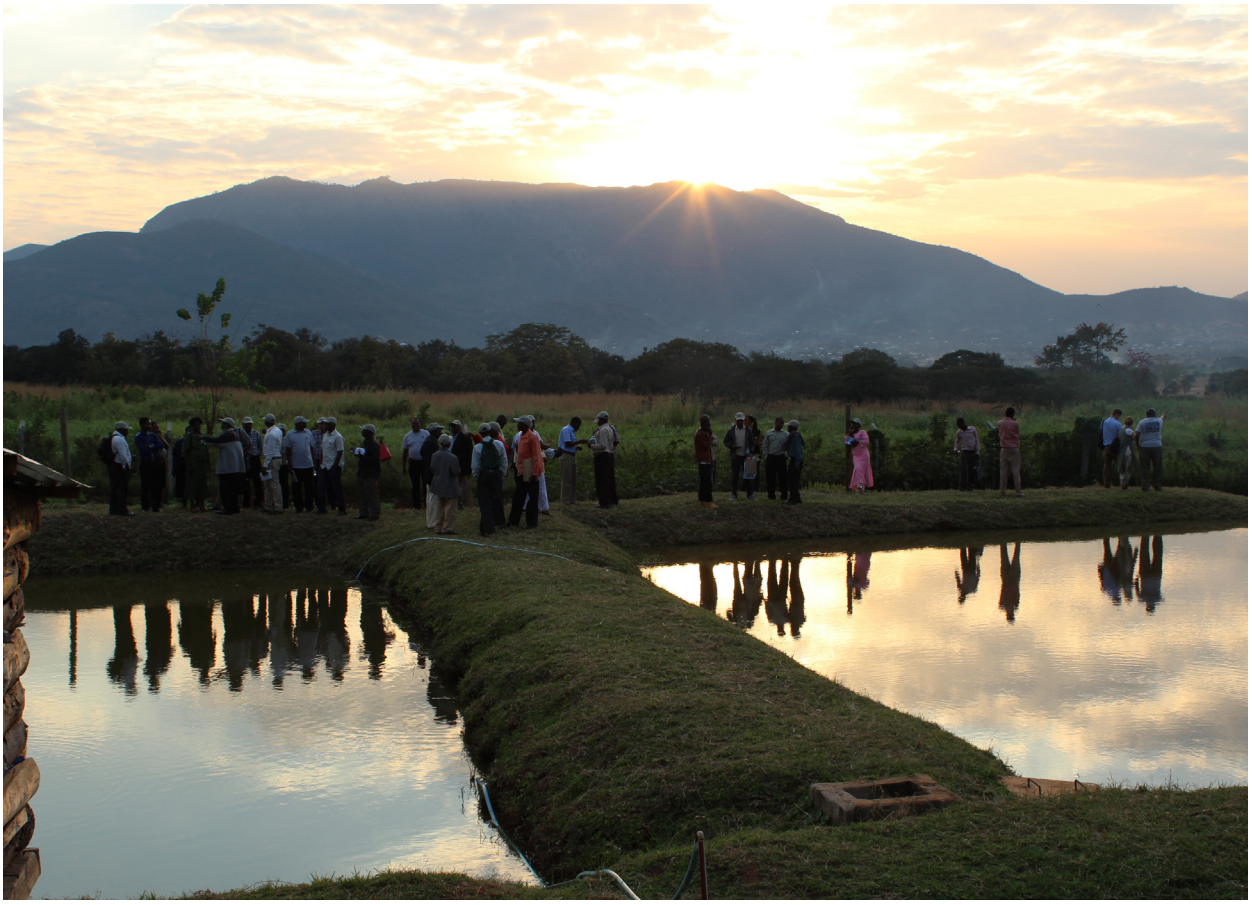
Feed The Future Innovation Lab For Collaborative Research On Aquaculture & Fisheries (AquaFish Innovation Lab)

SIRTD Associate Award Final Report

01 October 2010 - 30 December 2014



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AQUAFISH INNOVATION LAB
SIRTD FINAL REPORT

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Cover Photo
A group of workshop participants tours the research ponds at Sokoine University of Agriculture during a training event in Morogoro, Tanzania. 2014. Photo by Caleb Price.

Photos
All photographs included in this publication are provided courtesy of the AquaFish Innovation Lab.

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I. EXECUTIVE SUMMARY

Oregon State University (OSU) was awarded the Strategic Investment in Rapid Technology Dissemination (SIRTD) Associate Award in October 2010 under the AquaFish Collaborative Research Support Program (CRSP) Leader Award. The project, titled *Enhancing the Profitability of Small Aquaculture Farm Operations in Ghana, Kenya, and Tanzania*, focused on technology adoption involving best management of inputs for fish production to provide economic, environmental, and agronomic efficiency of aquaculture in sub-Saharan Africa. The project used evidence-based efforts to decrease poverty and increase food security through sustainable intensification of aquaculture, expansion of markets and trade, and strengthening economic resilience in vulnerable rural communities of Ghana, Kenya, and Tanzania.

The SIRTD project was active from October 2010 to December 2014, with OSU serving as the Lead Institution and Management Entity (ME) for the project, and Purdue University and Virginia Polytechnic Institute and State University (Virginia Tech) serving as partnering institutions.

The project involved four institutions in the three project countries: Kwame Nkrumah University of Science and Technology (KNUST) in Ghana; the Ministry of Fisheries Development in Kenya; and Sokoine University of Agriculture (SUA) and the Ministry of Natural Resources and Tourism in Tanzania. The project initially began in Ghana with the first Best Management Practice (BMP) workshops and the establishment of demonstration farms in three regions; project activities were then replicated in Kenya. Surveys were conducted in Kenya and Ghana to evaluate BMP adoption rates over the duration of the project, while efforts in Tanzania focused primarily on training workshops and the production of outreach materials.

Target technologies examined for this project included effluent management practices and nutrient management practices, both of which were analyzed based on financial profitability. Effluent management practices included water reuse to reduce negative environmental impacts and decrease input costs. Nutrient management practices included the effects of feed on water quality and fish growth by testing different feed types (e.g., floating versus sinking) and feeding strategies. This project focused on scaling up innovations from previous Aquaculture CRSP and AquaFish CRSP work and accelerating BMP adoption rates in Ghana, Kenya, and Tanzania by utilizing three innovation diffusion techniques: 1) Central Media (series of workshops at the regional level and extension follow-ups), 2) Demonstrations (BMPs in use at selected farms), and 3) Lateral Diffusion (farmer-to-farmer extension).

Over the duration of the project, eight BMP demonstration farms were set up in Ghana and seven in Kenya. Fourteen short-term trainings on BMPs were held in all three countries, reaching a total of 842 people, 214 (25%) of whom were women. The project also supported 17 long-term degree students at seven universities in Ghana, Kenya, and the US, 10 (59%) of whom were women. Of these students, three received Bachelor's degrees, nine Master's degrees, and five PhD's.

Short- and long-term trainings and demonstration farms were effective methods for disseminating reliable information and building networks and connections that extend beyond the life of the project. Outreach materials such as posters, leaflets, and radio broadcasts in local languages, were used to educate the public and to promote adoption of BMPs. Project results were disseminated to scientific and technical

audiences through 16 presentations at international academic conferences and four articles in scientific journals and trade magazines.

In order to measure BMP adoption rates, baseline surveys in Ghana and Kenya assessed management practices used prior to intervention. Follow-up surveys were conducted throughout the project to measure the effectiveness of the dissemination techniques and to ascertain which technologies had been adopted. Over the project period, the percentage of fish farmers that used the improved feeding BMP increased from 49% to 80% in Ghana and from 33% to 56% in Kenya. Over the same period, the percentage of fish farmers that used the water reuse BMP increased from 0% to 25% in Ghana and from 26% to 47% in Kenya. Although all methods of dissemination were effective, survey results showed that workshops had the greatest impact on adoption rates in Ghana. In Kenya, no specific method of outreach was identified as having the greatest impact; however, adopting either BMP was heavily influenced by the level of education of the farm operator.

The SIRTD project has been a great success for adoption of technologies and management practices that increase profitability and mitigate negative environmental impacts, as well as for illustrating effective methods of dissemination and identifying obstacles to and opportunities for adoption of BMPs.

BMP demonstration pond in Nakuru, Kenya.

II. INTRODUCTION

Feed the Future (FTF) is a United States Government initiative designed to reduce poverty and hunger. Recognizing that agriculture and rural development have long been neglected in international aid programs and the severe impact that poverty has on livelihoods, health, and ecosystems, FTF renews a USAID commitment to reinvest in activities that lead to sustainable food security globally. To align its strategies and goals with those of the FTF initiative, USAID issued a Request for Assistance (RFA) under the Strategic Investment in Rapid Technology Dissemination (SIRTD) program within Economic Growth and Trade (EGAT) for work in this crucial area in 2010.

AquaFish CRSP (now AquaFish Innovation Lab), based at Oregon State University (OSU), responded to USAID's RFA with a project addressing FTF's food security goals by investing in strong, evidence-based efforts. This project, titled *Enhancing the Profitability of Small Aquaculture Operations in Ghana, Kenya, and Tanzania*, shared the FTF aim of accelerating progress towards meeting the poverty and hunger goals of the United Nation's Millennium Campaign, and worked towards these goals by helping increase agricultural productivity, expand markets and trade, and increase economic resilience in vulnerable rural communities.

This project, funded as an Associate Award (AA) under the AquaFish Leader Award, worked in three FTF focus countries: Ghana, Kenya, and Tanzania. Project efforts primarily occurred in Ghana and Kenya to leverage work done by AquaFish, consolidate adoption of technologies, and ensure measurable impact; and associated activities took place in Tanzania. The SIRTD project focused on the adoption of BMPs by small-scale aquaculture producers. Increased access to inputs was combined with strategies to help ensure their safe and sustainable use. AquaFish technologies were refined and tailored to local conditions by supporting national research institutes and building local research capacities, including training local researchers and technicians. Gender inequalities that inhibit women's roles in aquaculture enterprises (such as lack of access to information, inputs, and technology) were anticipated and addressed through workshops that aimed to provide women with equal access to affordable inputs and improved technologies.

Background

The accelerating pace of aquaculture growth in sub-Saharan Africa has received positive attention due to the potential for the industry to contribute to development and food security by providing jobs and supplementing wild fish protein. Concerns have been raised, however, that the industry may come under scrutiny for its environmental practices and the need for regulations. Improved technologies and management practices in aquaculture exist and are now widely recognized as a more viable alternative to conventional aquaculture production methods, and their widespread adoption can help mitigate the need for prohibitive regulations on smallholder fish farms.

The adoption of BMPs in fish production requires strategies that integrate profitability and efficiency in fish farming enterprises. Production options that consider both these issues were studied by the Pond Dynamics/Aquaculture (PD/A) and Aquaculture CRSPs, and resulted in the development of decision support tools that assessed farm profitability. The tools utilized enterprise budgeting to estimate profitability of aquaculture operations while considering management practices and technologies used. Methods for farm-level record keeping led to improved understanding of the costs and returns associated with fish farming. This type of documentation is important when securing loans from banks.

In November 2009, AquaFish held a two-day workshop in Ghana under the Leader Award attended by 60 participants, including fish farmers, fisheries commission officials, extension officers, regulators, and researchers. The workshop was held in the local language and also served as a trial run for one of several outreach methods that could be used together to disseminate BMP guidelines and facilitate adoption. Farmers who participated in the workshop showed great enthusiasm for the concepts presented, with many expressing interest in setting aside ponds for AquaFish demonstration and research sites. The workshop successes included: 1) training extension officers who could follow up with farmers implementing BMPs in a sustained outreach program; 2) reaching a core group of farmers who are expected to continue to spread the BMP ideas to other farmers; and 3) informing regulators that the aquaculture industry has an active program of examining its environmental practices and continually working on improving practices, thereby reducing costs of creating a formal regulatory process.

Target Technologies

This project focused on technology adoption involving BMPs for fish production to provide economic, environmental, and agronomic efficiency in aquaculture in sub-Saharan Africa. Target technologies examined under this Associate Award project included effluent management practices, nutrient management practices, and profitability analysis.

Effluent Management Practices

Improved effluent management practices include guidelines on pond operation, management of settling ponds and vegetation ditches, draining into wetlands, top-releases for partial drainage, and water reuse (by holding or recirculating to other ponds). Specific issues include frequency of drainage, installation of drain outlets, and water level maintenance. Of these practices, emphasis is being placed on water reuse to provide the greatest environmental benefits because intentional drainage, which accounts for most effluent output, can be avoided for longer periods of time than has been traditionally practiced. In areas facing water scarcity, farmers successfully adapted harvesting methods that involve little or no draining. Even in areas with reliable water sources, water reuse can benefit farmers financially and improve production efficiency since nutrients can be retained from previous production cycles and incorporated into the biomass of the new crop.

Nutrient Management Practices

Better nutrient management practices include fertilizing and feeding regimes that reduce waste and prevent water quality deterioration that threatens fish health. One improved fertilization method uses slow-release sacs of fertilizer that can be removed from the pond when the desired plankton concentration is achieved. Avoiding excessive feeding saves on input costs and translates directly into farm profitability. Feed that is not eaten functions as expensive fertilizer and can lead to highly eutrophic water conditions, both reducing yields and escalating operation costs. Feeding is best regulated by observing how much feed the fish are consuming and adjusting the amount offered accordingly. This is more easily done when extruded (floating) feeds are used as opposed to pelleted (sinking) feeds. Sinking feeds often result in high nutrient loads and poor feed conversion ratios (FCR = weight of feed fed/fish weight gain).

Profitability Analysis

Appropriate stocking and feeding regimes can reduce the cost of production through reduced aeration, better water quality, higher survival, reduced use of medication and chemicals, and improved feed conversions. Previous work conducted under the ACRSP measured performance indicators and the profitability of Nile tilapia (*Oreochromis niloticus*) production in Ghana. Initial profitability analyses that included variable costs, fixed costs, owned inputs, yield, and revenues showed that integrating economic, social, and environmental objectives into aquaculture production through the inclusion of BMPs could result in increased profits.

Outreach and Diffusion Techniques

Three diffusion techniques were used throughout the project: 1) Central Media (series of workshops at the regional level), 2) Demonstrations (BMPs demonstrated at selected farms), and 3) Lateral Diffusion (farmer-to-farmer extension of BMPs).

Central Media

The central media diffusion technique was used to maximize first exposure to BMPs. This was accomplished through a series of workshops at the regional and national levels, targeting as many farmers as possible to expand first exposure to BMPs. These workshops included regional extension officers (i.e., a train-the-trainer model) who are expected to follow up with adopters and liaise between adopters and researchers to provide reliable advice and help sustain adoptions. Communications media were developed in local languages. In Ghana, the Western, Ashanti, and Brong Ahafo regions were targeted, where there are an estimated 2,869 fish farmers with approximately 4,500 farm ponds. In Kenya, approximately 600 farmers were targeted, and about 100 in Tanzania. Fourteen workshops were held throughout the project, reaching 842 farmers and extension workers.

BMP Demonstrations

On-farm BMP demonstrations are crucial for showing farmers the benefits that can be achieved with BMPs. In the Ashanti and Brong Ahafo regions of Ghana, AquaFish projects had already established working relationships with many farmers prior to the beginning of this project. Eight sites were used for BMP demonstrations and BMP testing in Ghana, with four in the Ashanti region, and two each in Western and Brong Ahafo regions. In Kenya, the two focal BMP management schemes (i.e., water reuse and nutrient management) were demonstrated in three provinces at seven different sites: Rift Valley (2), Western (2), and Central (3). Data were collected from these sites, including stocking densities, fertilization rates, feeding rates, water quality, yields, and FCRs. These ponds were managed by fisheries extension officers and AquaFish-supported graduate students with cooperation from the farmers. Workshop participants visited the farms to see the benefits of BMPs in a real commercial aquaculture enterprise. Data from these ponds were compared to data from ponds under 'regular' management within the same farms and used for a with-versus-without analysis of the benefits and costs of BMP implementation.

Lateral Diffusion

Through regional workshops and demonstrations, participants established a business enterprise network in each country. Under the innovation diffusion model, farmers exposed and trained in workshops constitute nodes in a social network. These farmers then spread information to other farmers who also become nodes, propagating their own networks and laterally transmitting knowledge without the direct involvement of extension personnel. This method increases the sustainability of the teachings and decreases the reliance on extension agents that may be under temporal or geographic limitations.

Gender Integration and Analysis

AquaFish is dedicated to improving gender inclusiveness in the aquaculture and fisheries sectors across the spectrum of AquaFish projects and activities. FTF also requires that agricultural interventions involve both men and women, including investments in sustainable labor-saving technologies so that shifts in the gender division of labor and products do not systematically disadvantage one gender over the other.

Providing equal opportunities for women's involvement is necessary because direct involvement of women is a key to advancing economic and social development, not only in aquaculture but also for a holistic household and family economy. Women play a major role in the production, processing, and marketing of agricultural products in Ghana, Kenya, and Tanzania, but agricultural information and production resources are not reaching and benefitting them equally. During the SIRTD project, it was ensured that no one was excluded from participating in trainings or educational activities and

opportunities based on gender. Additionally, two short-term trainings (one each in Ghana and Kenya) were held that centered on women's roles in aquaculture and encouraged women's participation. Qualified women graduate students from host countries were selected for long-term trainings and efforts were made to invite all known women fish farm proprietors and joint owners of fish farms/ponds to short-term trainings.

A group photo from a women's SIRTD training workshop in Kenya.

III. COLLABORATING INSTITUTIONS & PERSONNEL

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Emmanuel Frimpong, US Co-PI

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Nelson Agbo, HC Investigator (FY14)*

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Sammy Macharia, HC Investigator
Judith Amadiva, HC Investigator

Ministry of Natural Resources and Tourism, Tanzania
Kajitanus Osewe, HC Co-PI (FY11-FY13)*

Sokoine University of Agriculture, Tanzania
Sebastian Chenyambuga, HC Co-PI
Nazael Madalla, HC Investigator (FY14)*

*Fiscal year (FY) in which participant joined the SIRTD project.

IV. RESULTS & OUTCOMES

GHANA

Outreach

Five workshops were held in Ghana throughout the course of this project (Table IV-1). The first of these workshops was focused on training project personnel on BMP technologies, and methods for extension and outreach. The subsequent four workshops focused on extending best management practices to fish farmers in four distinct regions in Ghana. One workshop, held in January of 2013, focused specifically on training women fish farmers, and featured six women trainers and resource staff from Ghana who helped facilitate the training event.

Table IV-1. SIRTD Associate Award workshops held in Ghana.

Event Name	Location	Start Date	End Date	# of Trainees	# of Women
FTF Ghana BMP Training of Trainers workshop	KNUST, Kumasi	11-Jan-2011	11-Jan-2011	13	4
FTF Ghana BMP Training Workshop #1	KNUST, Kumasi	12-Jul-2011	15-Jul-2011	155	21
FTF Ghana BMP Training Workshop #2	Sunyani	12-Jun-2012	14-Jun-2012	125	19
Women's Training Program for Commercial Aquaculture	Kumasi & Akosombo	08-Jan-2013	11-Jan-2013	87	79
FTF Ghana BMP Training Workshop #3	Tarkwa	02-Jul-2013	05-Jul-2013	165	17
TOTAL:				**545**	**140**

Eight farms served as BMP demonstration and testing sites in Ghana, with four in the Ashanti region, and two each in Western and Brong Ahafo regions.

The project generated extension publications, presentations, manuscripts, survey tools, and outreach products, with the aim of extending best management practices to fish farmers throughout the country. Outreach products included posters; leaflets written in English and Akan, a prominent Ghanaian language; and radio scripts that will be broadcast throughout the country.

Metrics [*]

BMP Adoption Rates

BMP adoption rates were quantified by analyzing results from baseline and follow-up surveys. In total, 393 unique farmers were surveyed, of which 286 were surveyed once, 160 were surveyed twice, and 66 were surveyed three times.

The SIRTD project successfully introduced Ghanaian fish farmers to water reuse, which was not practiced in the country at the inception of the project. Over the life of the project, water reuse increased

[*] Data are reported as provided by Co-PIs.

from 0 to approximately 25% and floating feed use increased from approximately 49% to 80%, among farmers surveyed.

Number of Beneficiaries

An estimated 40% of farmers representing 2,400 farm owners adopted one or both technologies. The average fish farm household size estimated from the surveys was 7.2, with 3.6 females per family. The total number of beneficiaries in Ghana (farmers and their families) from the adoption of the BMPs alone is 17,280, with half being women. Additional beneficiaries include short- and long-term trainees (see *Summary of Short- and Long-Term Trainings* on pg. 14).

Increase in Household Income

The predominant use of farm-made sinking feeds can often lead to pond-based tilapia farms running at a loss; furthermore, farm operators are often unaware that they are operating at a loss because they do not account for personal or family labor. Project personnel in Ghana used enterprise budgeting to assess profitability of fish farms that adopted BMPs versus those that did not. Results of the enterprise budgets indicated that with proper accounting for labor and other sources of additional cost, a household adopting the floating feed BMP would increase fish-farming income by US $8,498/ha/year when not borrowing any capital and by US $7,665/ha/year with a 50% loan. For the typical small fish farm in Ghana, which is about 0.1 ha, the increase in household income with the adoption of floating feed BMP would be US $849/year and US $767/year without and with a loan, respectively.

Improvement in Water Quality

The Tradeoff Analysis-Minimum Data (TOA-MD) technique was used to consider other models of adoption that are not primarily statistical. This technique bases adoption projections on the opportunity cost of switching from one technology to another. TOA-MD also allowed the combination of the water quality data from the experiments to project reductions in pollution. The TOA-MD model predicted an adoption rate of 38% for floating feed, in the absence of any subsidy provided to farmers. This analysis was not performed for water reuse because accurate production cost numbers for water reuse were lacking. The 38% adoption rate of floating feed would result in significant projected improvements in receiving water quality due to reductions in phosphorus, suspended solids, and oxygen demand, which would constitute at least a 20% reduction in annual loadings from ponds to receiving streams (Table IV-2).

Table IV-2. Predicted annual amounts of pollution reduction resulting from the adoption of floating feed.

Water Quality Parameter	Description	Predicted Reduction Under BMP
PO_4 (kg/ha/year)	Orthophosphates	0.73
$PO4^{-3}$ (kg/ha/year)	Total phosphates	1.53
SusSol (kg/ha/year)	Suspended solids	78.48
SetSol (l/ha/year)	Total settleable solids	496.45
BOD_5 (kg/ha/year)	Biochemical oxygen demand	0.57
DIN (kg/ha/year)	Dissolved inorganic nitrogen	-0.92
DON (kg/ha/year)	Dissolved organic nitrogen	3.67
TDN kg/ha/year)	Total dissolved nitrogen	2.75

Area of Land Improved

Based on the estimate of 1,000 hectares of land currently in ponds in Ghana, the estimated adoption rates constitute approximately 310 hectares of land affected by the improved feed BMP and 250 hectares affected by the water reuse BMP.

KENYA

Outreach

Five workshops were held in Kenya throughout the course of this project (Table IV-3). The first of these workshops focused on training project personnel on BMP technologies, and on methods for extension and outreach. The subsequent four workshops focused on extending best management practices to fish farmers in three distinct regions in Kenya – the Rift Valley, Western, and Central provinces. The last workshop held in Kenya in August 2014 focused specifically on women's roles in aquaculture and included two women trainers from Kenya to lead sessions.

Table IV-3. SIRTD Associate Award workshops held in Kenya.

Event Name	Location	Start Date	End Date	# of Trainees	# of Women
FTF Kenya BMP Training of Trainers workshop	Rift Valley Province	21-Sep-2011	23-Sep-2011	23	6
FTF Kenya BMP Training Workshop #1	Western Province	09-May-2012	11-May-2012	38	7
FTF Kenya BMP Training Workshop #2	Central Province	12-Jun-2012	13-Jun-2012	71	14
FTF Kenya BMP End of Cycle Workshop	Nakuru	02-Dec-2013	03-Dec-2013	19	5
Women in Aquaculture - BMP Review Workshop	Mwea AquaFish Farm, Kinyaga	22-Aug-2014	23-Aug-2014	21	16
TOTAL:				**172**	**48**

Kenya used seven different farms in three provinces as sites to demonstrate the implementation of BMPs. Three sites were in Central province, and two each were in the Rift Valley and Western provinces.

Project personnel for Kenya produced extension publications, presentations, manuscripts, survey tools, and outreach products, with the aim of extending best management practices to fish farmers throughout Kenya. Outreach products included calendars and leaflets with BMP messages written in English and Swahili, a local language of East Africa, to be distributed to local extension agents and fish farmers.

Metrics [*]

BMP Adoption Rates

The data used to estimate adoption rates were collected by two surveys: one in 2012 and one in 2014. These surveys were issued to fish farming households in Kenya, selected by a multi-stage sampling procedure. The first stage involved a sampling of the regions where fish farming is predominantly practiced. In Kenya, the Western, Central, and Rift Valley provinces have high pond fish production and the most fish farming sites in the country. The households from these regions were randomly sampled to interview. The 2012 survey covered all three provinces with a total of 100 households sampled. In 2014 however, only Western and Rift Valley provinces were sampled, with a total of 205 households interviewed.

Adoption of improved feeds and water reuse technologies increased over the project period from 2012 to 2014. The adoption of improved feeds was almost equally distributed across the two regions in 2014, while water reuse had more adopters in the Rift Valley province than in Western province (Table IV-4).

[*] Data are reported as provided by Co-PIs.

The annual adoption rate is calculated as the percent increase in adoption during the project period (2012 - 2014) divided by the number of years.[1] The percentage of sampled farmers adopting improved feeds in 2012 was 33%, while the percentage of sampled farmers adopting improved feed in 2014 was 56%, indicating an improved feed annual adoption rate of 23% among the representative farmers. The adoption of water reuse technologies increased from 26% in 2012 to 47% in 2014, resulting in an annual adoption rate of 27%.

Table IV-4. Percent of adopters for two BMPs across provinces from the 2014 survey.

		Improved Feeds		Water Reuse	
Province	**Total Sample**	**Non-Adopters (%)**	**Adopters (%)**	**Non-Adopters (%)**	**Adopters (%)**
Rift Valley	92	46	54	35	65
Western	108	43	57	69	31

Number of Beneficiaries

The project targeted as many farmers as possible to expand exposure to BMPs. This was accomplished through the demonstration farms, outreach through regional extension officers, and farmer-to-farmer communications. Communications media in Swahili and English, the official languages of Kenya, were used to spread awareness targeting the Western, Central, and Rift Valley provinces where fish farms were concentrated. Preliminary estimates using the adoption rate and the farmers sampled in 2014 indicate that about 534 farmers benefited from the adoption of water reuse while 472 benefited from improved feeds bringing the total beneficiaries to 1,006 farmers.

Increase in Household Income

Gross household income consists of earnings from land and non-land income (e.g., livestock earnings, labor income, fish income, crop income) and off-farm income (agricultural and non-agricultural income). A survey instrument was developed to collect data on income and included questions about fish farming, off-farm, and crop and livestock incomes. The survey was implemented at the start of the project in 2012 and at the end in 2014 to assess project impacts. From 2012 to 2014, gross income and fish income of adopters of improved feeds were significantly higher than that of non-adopters, and there was a slight increase in household income (Table IV-5).

Table IV-5. Income effects on feed technology adoption across years (KSh=Kenyan Shillings).

2012 Survey	**Non-Adopters**	**Adopters**	**Difference**	**p-value**
Fish income	43,202	97,192	53,990	0.05
Total household income	187,880	293,545	105,665	0.09
2014 Survey	**Non-Adopters**	**Adopters**	**Difference**	**p-value**
Fish income	67,630	129,606	61,975	<0.01
Total household income	208,188	274,663	66,475	0.09

[1] The percent increase in adoption [(percent 2014 adopters – percent 2012 adopters)/percent 2012 adopters] is divided by the project period, 3 years.

Profitability Analysis of Improved Feeds Technology

Profitability analysis distinguished between two types of profits: (1) the total costs of production (variable and fixed costs) and (2) the variable costs of production. When examining the total costs of production, the share of the cost of commercially formulated pelleted floating feeds in total feed cost was estimated to be 75%. Furthermore, the share of feed cost for adopters' total variable cost of production was about 52%, while for non-adopters it was approximately 42%. Tilapia is the main species produced in Kenya and therefore accounts for a majority of the total revenue from fish farming. On average, adopters of pelleted floating feeds had significantly more net return over fixed cost than non-adopters (Table IV-6).

When considering only the variable costs of production, adopters of commercially formulated pelleted floating feeds had significantly higher profit ($p<0.05$) (94,091 Kenyan Shillings or $1,079 US dollars) than non-adopters in a given production period (usually six months). This profit may be attributed to the difference in tilapia output (and yield) between the adopters and non-adopters, since there was not much variation in fish price. These results demonstrate that the improved feeds technology was profitable, assuming all other production and stochastic factors were constant.

Table IV-6. Comparison of profits of improved feed use in a production period (KSh).

Variable	Non-Adopters	Adopters	Difference	p-value
Total revenue from fish	117,666	231,073	113,407	<0.01
Total variable cost	49,168	68,484	19,316	0.34
Total fixed cost	108,230	73,969	-34,262	0.45
Total cost	157,399	142,453	-14,946	0.76
Profit with fixed and variable cost	-39,732 (-US $456)	88,620 (US $1,016)	128,353 (US $1,472)	0.04
Profit with only variable cost	68,498 (US $786)	162,589 (US $1,865)	94,091 (US $1,079)	0.03

Improvement in Water Quality

Water quality values obtained from samples collected from farm ponds that were under BMPs varied with the level of management. Higher concentration of nutrients and suspended solids were observed from ponds that reused water and locally formulated feeds. Changes in the water quality values obtained from ponds that reused water showed a general decreasing trend in oxygen levels especially in the early morning. Water reuse reduced effluent discharges and the environmental impact and still allowed production to be conducted in an economically efficient manner.

With regards to improving water quality in receiving waters, it was recommended to farmers that where it became necessary to discharge water from ponds, the effluent should be treated by passing it through a constructed natural wetland before discharge into public water systems. Farmers could also retain water released from ponds in a larger pond and reuse it for irrigation on crops such as vegetables. These are effective measures for reducing the ecological effects of effluents. Preliminary observations of farms adopting these practices have shown promising results in improving water quality.

Area of Land Improved

The area of land improved was measured as the total pond area subjected to one or both of the BMP technologies. If a household implemented both technologies, their pond area was still only counted once. The total area under pelleted floating feeds increased from 7.9 hectares in 2012 to 8.6 hectares in 2014. However, the total pond area under water reuse only decreased from 5.7 hectares in 2012 to 5.4 hectares in 2014. This led to the total area under either technology decreasing from 10.8 hectares to 10.5 hectares

over the same period. The average land area under fish production is higher for adopters than non-adopters of pelleted floating feeds, though it is more or less equal in the case of water reuse technology.

TANZANIA

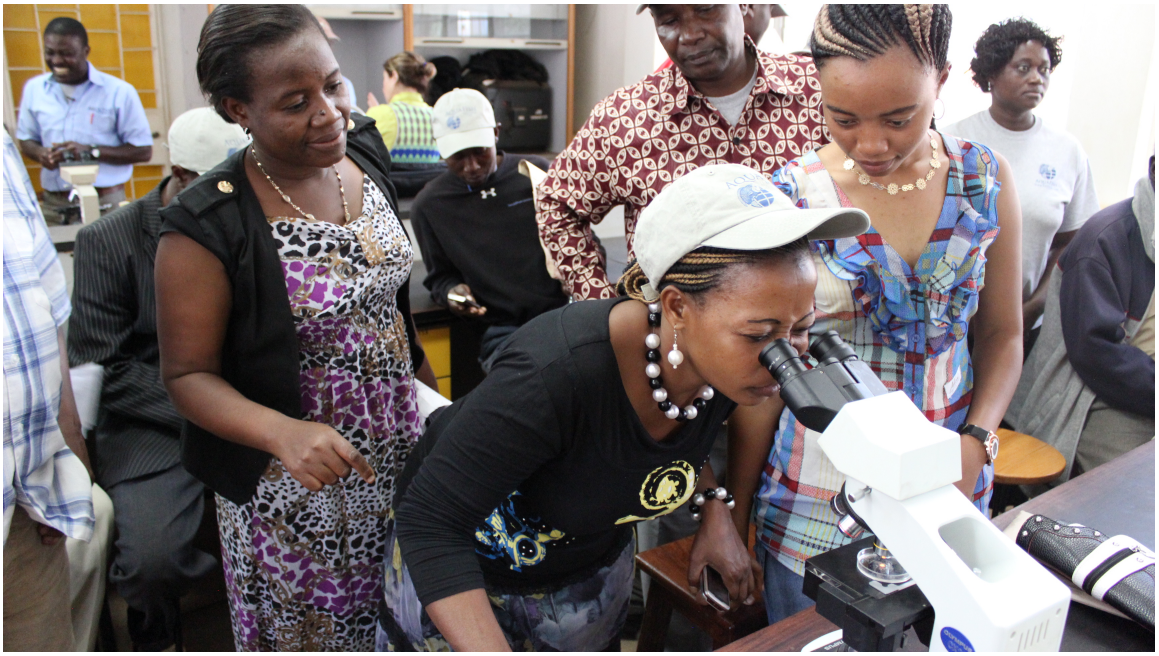
Outreach

Four workshops were held in Tanzania (Table IV-8). The first three focused largely on generating awareness of best management practices for fish farmers. The final workshop included project personnel from Tanzania, Ghana, Kenya, and the US as trainers and facilitators and focused chiefly on introducing farmers to BMP concepts, such as education on the basics of record keeping on farms, feeding efficiency, feed production, fingerling transport, and pond fertilization.

Table IV-8. SIRTD Associate Award workshops held in Tanzania.

Event Name	Location	Start Date	End Date	# of Trainees	# of Women
Fish Farmers Training Workshop	Mpwapwa	23-Apr-2013	24-Apr-2013	21	2
Farmers Training on Fish Farming	Kilosa	25-Apr-2013	26-Apr-2013	41	11
Fish Farming Training Workshop	Mafinga	13-Nov-2013	14-Nov-2013	15	5
Pond Aquaculture Best Management Practices Workshop	Morogoro	05-Aug-2014	06-Aug-2014	48	8
TOTAL:				**125**	**26**

Project personnel for Tanzania produced outreach materials, including a BMP calendar in Swahili, an official language of Tanzania, to be distributed to local extension agents and fish farmers.



Women examine water samples under a microscope at Sokoine University of Agriculture during a BMP workshop in Morogoro, Tanzania.

SUMMARY OF SHORT- AND LONG-TERM TRAININGS

Over the life of the SIRTD project, 14 short-term training events were held, five each in Ghana and Kenya, and four in Tanzania (Tables IV-1, 3, & 8). Of the 842 training participants, 214 (25%) were women and 628 (75%) were men. The five trainings in Ghana brought together 545 people, with 140 (26%) women and 405 (74%) men. In Kenya, 172 people attended five trainings, with 48 (28%) women and 124 (72%) men, and Tanzania had 125 participants at four trainings, with 26 (21%) women and 99 (79%) men.

There were 17 long-term students trained under the SIRTD Associate Award over the life of the project, including seven men and ten women (59%). These students studied at four universities in Kenya, one university in Ghana, and two universities in the US (Table IV-9).

Table IV-9. SIRTD Associate Award long-term trainees by gender, degree, country, and institution.

Training Country and Institution	Women			Men		Total
	BS	MS	PhD	MS	PhD	
Ghana						
Kwame Nkrumah University of Science and Technology		2		1		3
Kenya						
Eldoret University	3				1	4
Kenyatta University		1		1	1	3
Moi University		1		1		2
University of Nairobi		1				1
US						
Purdue University			1		1	2
Virginia Tech University		1			1	2
TOTAL:	**3**	**6**	**1**	**3**	**4**	**17**

COMMUNICATIONS & NETWORKING ACTIVITIES

Five SIRTD project meetings were held during the span of the project. These meetings provided opportunities for investigators to discuss progress, plan for future activities, and address any challenges they might have encountered. Many of the meetings were held in conjunction with AquaFish annual and regional meetings, SIRTD workshops, and international aquaculture conferences. Three SIRTD annual reports were published, and metrics were submitted annually via the FTF Monitoring System (FTFMS). In addition, project personnel presented results and information on BMP technologies at several academic conferences.

- AquaFish Annual Meeting – April 2011
- SIRTD Project Meeting – July 2012
- AquaFish Africa Regional Meeting – July 2013
- AquaFish Annual Meeting – February 2014
- SIRTD Closeout Meeting – August 2014

V. GENDER INTEGRATION

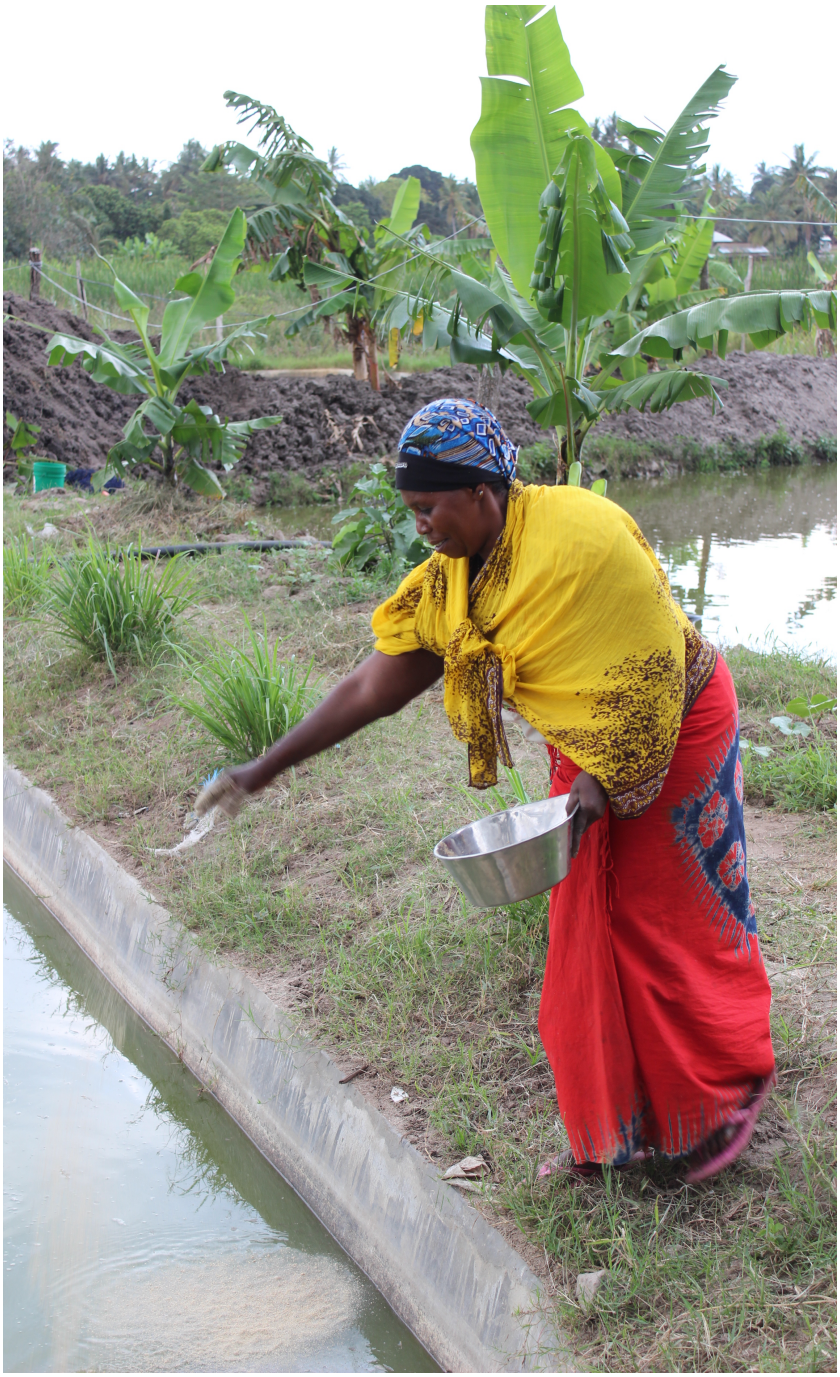
Gender equity and female empowerment are core development objectives of the USAID research agenda and are fundamental to accomplishing effective and sustainable development outcomes. Gender integration, a strategy used to improve equity, involves identifying and addressing differences and inequalities due to gender. These differences are anticipated and addressed during all stages of the project, from the design process and throughout implementation, monitoring, and evaluation. Gender integration incorporates efforts like capacity building, economic development, agricultural development, food security, and poverty alleviation – key issues targeted by USAID's FTF initiative.

Women participate extensively and actively in all phases of work performed on fish farms throughout Africa, but many barriers to participation in aquaculture value chains still exist and result in underrepresentation by women. Women often lack access to basic education, land ownership and associated water rights, credit, training, and extension services. A compounding issue is the reported lack of knowledge among women about targeted outreach programs and other opportunities.

AquaFish takes a holistic approach to integrating women into all programmatic activities, with a goal of extending gender equity beyond the life of any given project and of the entire AquaFish program. AquaFish involved women in the design, management, and leadership of the SIRTD project, and made efforts to recruit women trainees and create relevant trainings. The SIRTD project utilized similar strategies to those of Leader Award activities to encourage women's participation. These included collecting and analyzing gender disaggregated data for short- and long-term trainings to inform project management and future capacity building needs, tailoring extension and technical services related to BMPs and sustainable aquaculture practices to women producers, and engaging extension specialists that are sensitive to diversity issues to help enhance women's participation.

The SIRTD project provided training opportunities to women and men, alike. Ten of the 17 long-term trainees were women, making up over half (59%) of students earning undergraduate and graduate degrees. Short-term trainings involved 214 women out of the total 842 participants (25%), and two of the 14 trainings were specifically designed for women participants, focusing on women's roles in aquaculture enterprises.

In addition to participating in short- and long-term training activities, women served as trainers and key project personnel. In Ghana, 11 women were involved in project activities under various affiliations, including NGOs, universities, and government agencies. Six women in Kenya and seven in Tanzania participated in project activities, representing universities, private fish farms, and regional and national government councils and ministries. Women owned two of the seven demonstration farms used for this project in Kenya, and it is estimated that over 9,000 women benefitted from the SIRTD project. Representing women in all aspects of research projects, particularly in leadership and management roles, enhances recruitment of women, strengthens the foundation needed to mainstream women's participation in the aquaculture sector, and provides examples of what women can achieve when given access to opportunities.



A woman spreads feed at a fish pond outside of Dar es Salaam, Tanzania.

VI. SUCCESS STORIES

SPENDING MORE ON FEEDS MEANS GREATER PROFITS FOR FISH FARMERS IN KENYA

In Kenya, aquaculture has been growing rapidly since a government economic stimulus program helped breathe new life into the industry in 2010. Since then, fish farming has become an increasingly popular option for entrepreneurs looking to get into the business of aquaculture, which has been gaining legitimacy in the Kenyan agricultural sector as a significant contributor to food security and income. National aquaculture production in Kenya increased to 12,000 metric tons (MT) per year in 2010 (up from about 1,000 MT per year in 2000), and is projected to increase to around 20,000 MT per year within the decade.

Though such development is beneficial in many ways, it also presents significant challenges. People new to fish farming may be aware of the potential for making a profit, but lack the proper knowledge necessary to run a successful business. One of the most common pitfalls that new or beginning farmers encounter is the temptation to use cheaper traditional feeds, such as agricultural byproducts or sinking fish feed. These feeds may save on upfront costs, but can also suppress the growth of a fish crop and ultimately eliminate the profits of the fish farmer.

The problem arises because sinking feeds, which are often made from on-farm sources, can be nutritionally unreliable, meaning fish cannot achieve optimal growth when fed this diet. Furthermore, the feed sinks quickly to the bottom of the fish pond, where it becomes unavailable for consumption, and instead fuels algae growth, which increases oxygen demand and causes water quality complications.

Convincing fish farmers to abandon this practice and instead purchase more expensive, commercially produced floating feeds is a hard sell, in spite of evidence about the drawbacks of sinking feeds. Partners at Oregon State University, Virginia Tech, and Purdue University in the US; Kwame Nkrumah University of Science and Technology (KNUST) in Ghana; the Department of Fisheries in Kenya; and Sokoine University of Agriculture in Tanzania worked together to distribute knowledge of best management practices (BMPs) to fish farmers in Kenya, Ghana, and Tanzania between 2011 and 2014 under the AquaFish Strategic Investment in Rapid Technology Dissemination (SIRTD) Associate Award. One of the objectives of this project was to determine the profitability of fish farms operating under different scenarios, including those using commercial floating feeds versus those using traditional sinking feeds.

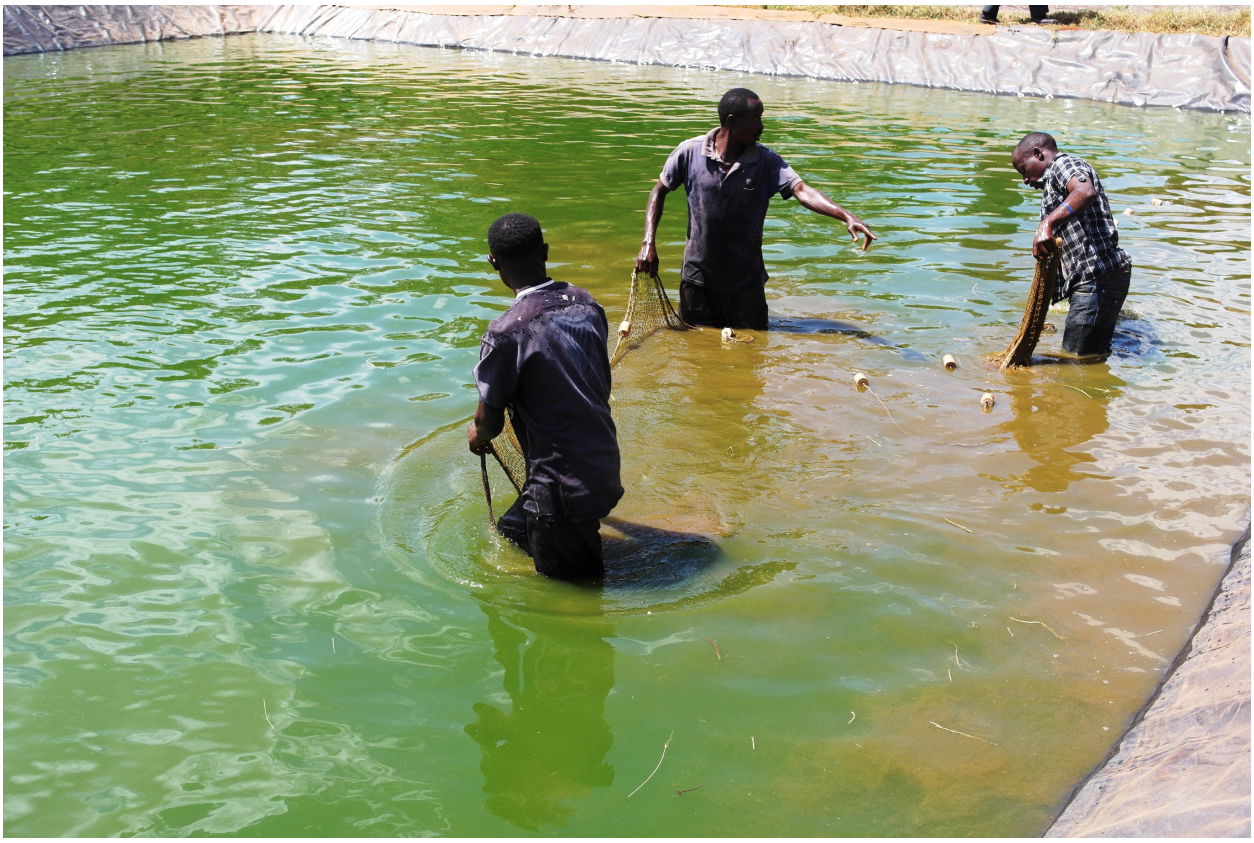
AquaFish researchers held a series of workshops for fish farmers in Kenya that focused on teaching the BMP technology of improved feeds. In addition to these workshops, a survey of fish farming households in various regions of the country was conducted to determine the adoption rate of these technologies, as well as the effects of adoption on the operation and profitability of fish farms. The results of the study demonstrate that using improved feeds is an investment that pays big dividends when it comes time to harvest the crop.

“The benefits from floating feeds especially accrue to less experienced farmers who don’t yet have knowledge of fish feeding behaviors and pond carrying capacity,” says Dr. Hillary Egna, Lead PI for the SIRTD project.

The study quantified the adoption rate of the improved feed technology among fish farmers in Kenya in 2012 and 2014. Research determined that, among the representative farmers, there was an adoption rate of 23% annually over the project period for the improved feed technology. For fish farmers in Kenya, where high-quality feeds are widely available, this increase in adoption of the improved feed technology translates directly to increased profits and higher household incomes for adopters.

"The share of feed in total variable cost of production for adopters is about 52%, while that of non-adopters is about 42%," observes Dr. Kwamena Quagrainie, the US Co-PI for the SIRTD project in Kenya and Tanzania, on the profitability of adopting BMPs. "The improved feed technology may be costly, but increased production from its use could offset the cost if market premiums can be obtained for the harvested fish."

Though the project came to an end in December 2014, the effects of the outreach efforts and workshops are anticipated to continue to provide benefits for small-scale aquaculture in Kenya. Farmer-to-farmer transfer of BMP technologies is an effective channel for dissemination of knowledge, as farmers learn quickly from each other and they often choose to emulate operations of successful farms. By diffusing knowledge of BMPs through farmer networks, the legacy of this research will continue to provide benefits to fish farmers in Kenya well beyond the life of this project.



Seining a BMP demonstration pond at the Mwea Aquafish Farm in Kenya.

ADOPTING BEST MANAGEMENT PRACTICES FOR MORE PROFITABLE AND SUSTAINABLE FISH FARMING IN GHANA

Ghana is a country rich in water resources, hosting two major rivers and the world's largest reservoir by surface area, Lake Volta. This vast abundance of freshwater holds great potential for expanding the aquaculture industry to meet a growing shortfall in the national fish supply. However, as aquaculture operations continue to grow, water bodies can be negatively impacted by eutrophication resulting from nutrient-rich runoff from fish farms. If eutrophication escalates to cause pollution, it could trigger top-down regulation of the industry, which discourages potential farmers from starting fish farms, hampers growth, and weakens food security.

In 2010, the AquaFish Strategic Investment in Rapid Technology (SIRTD) Associate Award project was initiated to identify, develop, and disseminate aquaculture best management practices (BMPs) to fish farmers in Ghana, Kenya, and Tanzania. The project was launched with a "training-of-trainers" workshop in Ghana to equip a cohort of aquaculture professionals with the necessary knowledge to disseminate the selected BMPs to local fish farmers.

One of the chief objectives of this project was to take an anticipatory approach to lessen water pollution by addressing the problem at the source. In Ghana, fish farmers traditionally drain their ponds after they harvest a crop of fish, about every six months. The prevailing belief among many fish farmers is that fish benefit from pond draining because it brings clean water to the pond, reduces parasite loads, and flushes out "dirty water."

Based on research results, the SIRTD project brought a different message to fish farmers about draining ponds. "When fertilization and feeding in one production cycle results in abundant plankton at the end of production, why drain water out and squander that investment and start all over again?" asks Dr. Emmanuel Frimpong, the US Co-PI for the SIRTD project in Ghana.

"Pond fertilization strategies – green water technology – were already developed and tested worldwide when this project began in 2010. We wanted to use what we knew would work, and has worked in Asia and Latin America, in Ghana. Then we wanted to transfer successful behavior communication strategies from Ghana to the other two countries involved in this project – Kenya and Tanzania," says Dr. Hillary Egna, Lead PI for the SIRTD project.

By reusing water from a previous production cycle, farmers can reduce the amount of feed they need to purchase to grow fish to market size, which decreases their cost of operation, and ultimately makes their businesses more profitable.

Project researchers knew the challenges of promoting BMPs in Ghana from the onset of this project. Recognizing the issues with draining ponds was a step in the right direction, but convincing fish farmers to adopt water reuse technology was not as straightforward, despite the potential to improve profits and environmental sustainability of fish farms.

"Considering that freshly filled and fertilized ponds stocked with tilapia fingerlings take anywhere from four to six weeks to achieve the desired plankton levels found in old water, new water is clearly not the most optimal environment to start growing [fish], from a food availability standpoint," says Dr. Frimpong.

Water reuse adoption is hampered by the abundance of water resources in the country. Because Ghana has so much freshwater, draining and re-filling ponds is easily accomplished at little cost, which provides

no real incentive for farmers to reuse their pond water, especially when they are unaware of the benefits of water reuse.

Despite this apparent challenge to adoption, the timing was right for changing people's opinions about water reuse in pond aquaculture in Ghana. With the help of several researchers and graduate students from Virginia Tech, Oregon State University, and Purdue University in the US; Kwame Nkrumah University of Science and Technology (KNUST) in Ghana; the Department of Fisheries in Kenya; and Sokoine University of Agriculture in Tanzania, the project increased awareness of this BMP technology through a series of workshops and field demonstrations. By using innovative outreach initiatives, such as radio broadcasts and posters, the AquaFish researchers disseminated knowledge of water reuse technology for the first time in Ghana.

Four years after the inception of this effort, with the project coming to a close, the project team found that water reuse, which was not practiced in Ghana before the project, was adopted at a rate of 25% over the life of the project.

The project team is optimistic that farmers will continue to use the BMPs on their farms and encourage others to adopt as well. "The concept of water reuse is intuitively simple, but the practice of draining water at the end of every production cycle is a learned habit that will take continuing farmer education [to reverse]," says Dr. Frimpong.

Ultimately, the technologies promoted by the SIRTD project will encourage sustainable growth of small-scale fish farming in Ghana, while also creating food security and increasing the profitability of aquaculture operations.

Deploying a fish net at a BMP demonstration pond in Ghana.

VII. LESSONS LEARNED

1. Outreach and training tools such as on-farm trials, demonstrations, and workshops are highly effective for sharing critical information and providing hands-on, practical experiences needed for effective learning. In the SIRTD Associate Award, participants involved in these trainings were enthusiastic, actively engaged, and excited about the material at the end of each activity. Lessons learned from previous work led to follow up trainings with subsets of outreach participants. Information was assimilated and utilized, and participants were often able to help other farmers and producers who were not initially reached by the SIRTD (BMP) sponsored events.

2. Coordinating a collaborative effort involving partners from three African countries and three US universities requires considerable effort. Although at times administratively burdensome, the Associate Award provided AquaFish with an opportunity to contribute to aquaculture development through a greater presence in Africa. Many project tasks, although similar to those necessary to run the core AquaFish program, had to be handled independently and thus required extra resources and effort. When all partners are already involved in high-level programs of their own, it becomes even more difficult to make timely decisions and keep the collective activities moving ahead on schedule. This lesson became even more apparent this past year when over half of the Associate Awards' researchers were unable to attend meetings or contribute as planned due to illnesses, injuries, or employment changes. The lesson learned is to create and involve a deeper and broader cadre of researchers and managers, which requires additional funding and time, or to downscale anticipated outputs to better factor in risks.

3. Synchronizing Associate Award projects with AquaFish requires considerable coordination. There are independent demands on timeframes, deliverables, reporting, and networks. These alignment issues can be reduced if the Associate Awards do not have independent technical or performance reporting requirements, if adequate funding is given for management and administration, if time is allotted up front for coordination among partners, and if the awarding unit at USAID understands that the project will be fitting into an organization that operates under a University system that has its own sets of rules and cultural norms. In this Associate Award, independent reporting was required for FTFMS and performance reports; even though the SIRTD project overlapped with core country locations, there were substantial additional reporting burdens to core projects and to management. Fortunately, previous lessons learned anticipated extra costs and planning time associated with these reporting burdens, and thus the core award and core projects were not parasitized or negatively affected.

4. Third-country training can provide exceptionally good benefits for stakeholders. In-person observations of successes and failures in other countries, complemented with face-to-face discussions with practitioners in those countries, often provide a richer educational experience than reading reports or listening to conference presentations from afar. This truth has been demonstrated in other AquaFish Associate Award projects as well as this one.

5. Aquaculture trainings disproportionately reached men, as was predicted yet unfortunately not easily prevented. The Lead PI understood this possibility and intentionally organized workshops with a focus on including women. However, a breakdown in reaching equal numbers of men and women occurred for a number of reasons. The effort to recruit and retain underrepresented groups was far greater than anticipated. Even forearmed with knowledge regarding barriers to participation, a lesson learned is that more time was needed to effectively reach these groups. Additionally, inherent bias and lack of

comprehension regarding gender inclusiveness by many of the researchers themselves resulted in less effective planning and interventions. This indicates that training on gender and diversity should be provided at all levels of the enterprise, including researchers and graduate students who do the trainings in the field.

6. More timely information and feedback from USAID regarding project extensions is required. The organizations involved are large and complex and require substantial lead time for closedown. Management discussed the need for extension with USAID managers in Winter 2014 and submitted paperwork in Spring 2014. Until late September, the project was planning to closedown on 30 September. The lead institution and its partner subagreements were ending and contract offices were beginning layoffs and closedown procedures. While the no-cost extension was eventually granted, it came only one day before the overall project was to terminate.

7. This Associate Award project has benefitted substantially from the cumulative effect of previous AquaFish-sponsored activities in Ghana and Kenya, and to some extent Tanzania. AquaFish's well-patronized training programs play a vital role in extension and in farmer-to-farmer networking. Overall extension services for fish farming are weak to non-existent in many parts of the world, with Africa being no exception. Adoption of aquaculture, a knowledge-driven activity, depends on reliable information being distributed among many stakeholders, including farmers, marketers, processors, extension agents, government specialists, and feed mills. Lead SIRTD project principal investigators understood this research-extension-implementation bottleneck at the outset and designed outreach and training activities accordingly. The project was highly successful in providing access to good quality information on a consistent basis. At the end of the project, those trained are responsible for knowing how to seek out reliable information, and can build upon basic good practices. There is unfortunately much technical misinformation on aquaculture provided by the government and private sector. Examples of unreliable advice were found in all three countries. A government-financed hatchery in Tanzania recommended buying fry and stocking at 20 fish/m^3 for a new small-scale grower when the actual recommendation is 3-4 fish/m^3; the fish farmer in this case would lose money. Another example occurred when feed distributors recommended feeding at unnecessarily high levels to sell more product. There is an opportunity for our partners in Ghana, Kenya, and Tanzania to continue to help develop extension services and information, whether they end up in public or private hands, or both. Follow-up activities after the project ends could involve HC partners working with private groups, such as FarmerLine in Ghana, the Kenya government, or feed mills such as Ranaan, to help accredit them so as to improve the reliability of information being disseminated, and reduce implications of conflicts of interest.

VIII. LIST OF SIRTD PUBLICATIONS & PRESENTATIONS

Agbo, N.B., S. Amisah, E. Tettey, and E. Frimpong. 2014. Effects of dietary protein levels on growth performance of Claroteid catfish, *Chrysichthys nigrodigitatus*, fingerlings. Annals of Biological Research 5(4): 17-22.

Ansah, Y.B. 2012. *Adoption of environmental BMPs in small-scale fish farming.* [Oral presentation] International Water Management Institute, Ghana. 27 June 2012.

Ansah, Y.B. and E.A. Frimpong. 2014. *Profitability and adoption of two pond aquaculture best management practices in Ghana.* [Oral presentation] World Aquaculture Society -- Aquaculture America, Seattle, Washington, USA. 9-12 February 2014.

Ansah, Y. B. and E.A. Frimpong. 2012. *Comparison of the performance of growth models for farmed tilapia.* [Oral presentation] 142nd Annual meeting of the American Fisheries Society, Minneapolis -- St. Paul, Minnesota, USA. 19-23 August 2012.

Ansah, Y.B., E.A. Frimpong, S. Amisah, and D. Adjei-Boateng. 2012. *Effects of two aquaculture best management practices on tilapia growth.* [Oral presentation] World Aquaculture Society -- Aquaculture America, Las Vegas, Nevada, USA. 29 February – 02 March 2012.

Ansah, Y.B., E.A. Frimpong, S. Amisah, and D. Adjei-Boateng. 2012. *Effects of two aquaculture best management practices on tilapia growth.* [Oral presentation] Virginia Tech Graduate Research Symposium, Blacksburg, Virginia, USA. 28 March 2012.

Ansah, Y.B., E. Frimpong, and R. Namarab. 2013. *Characteristics of adopters of environmental best management practices in small-scale pond aquaculture.* [Oral presentation] World Aquaculture Society -- Aquaculture America, Nashville, Tennessee, USA. 22-25 February 2013.

Chenyambuga, S., N. Madalla, and B.V. Mnembuka. 2012. *Management and value chain of Nile tilapia cultured in ponds of small-scale farmers in Morogoro region, Tanzania.* [Oral presentation] International Institute of Fisheries Economics & Trade Conference, Dar es Salaam, Tanzania. 16-20 July 2012.

Egna, H. 2011. *Training activities planned in Africa.* [Oral presentation] AquaFish CRSP project-level coordination meeting, Shanghai, China, 18 April 2011.

Evans, F., S. Ichien, and H. Egna. 2012. *Enhancing economic and trade opportunities in aquaculture markets to alleviate poverty and increase food security in Africa, Asia, and Latin America.* [Poster] World Aquaculture Society -- Aquaculture America, Las Vegas, Nevada, USA. 29 February – 02 March 2012.

Frimpong, E.A., Y.B. Ansah, S. Amisah, D. Adjei-Boateng, N.W. Agbo, and H. Egna. 2014. Effects of two environmental best management practices on pond water and effluent quality of growth of Nile tilapia, *Oreochromis niloticus.* Sustainability 6: 652-675.

Frimpong, E.A. and I.E.M. Fynn. 2014. Tilapia aquaculture in Ghana: ponds can contribute more to overall production, food security. Global Aquaculture Advocate 17(4): 18-21.

Goetting, K., C. Price, M. Chow, S. Ichien, and H. Egna. 2014. *Identifying and implementing best management practices for small-scale aquaculture in sub-Saharan Africa.* [Poster] World Aquaculture Society – Aquaculture America, Seattle, Washington, USA. 9-12 February 2014.

Ichien, S. and H. Egna. 2012. *Evaluating technology adoption by the small-scale aquaculture operations in developing countries for improved productivity and profitability.* [Poster] International Institute of Fisheries Economics & Trade Conference, Dar es Salaam, Tanzania. 16-20 July 2012.

Ichien, S. and H. Egna. 2012. *Evaluating value chains and consumer preferences in Asian and African aquaculture to help overcome unemployment and poverty.* [Poster] International Institute of Fisheries Economics & Trade Conference, Dar es Salaam, Tanzania. 16-20 July 2012.

Ichien, S., C. Stephen, and H. Egna. 2011. *Addressing the goals and objectives of the Feed the Future Initiative: enhancing the profitability of small aquaculture operations in Ghana, Kenya, and Tanzania.* [Poster] The Ninth International Symposium on Tilapia in Aquaculture, Shanghai, China. 22-25 April 2011.

Macharia, S. and J. Amadiva. 2012. *Developing aquashops in Kenya*. [Oral presentation] International Institute of Fisheries Economics & Trade Conference, Dar es Salaam, Tanzania. 16-20 July 2012.

Manyala, J., J. Amadiva, C. Ngugi, and K. Quagrainie. *Review of status and opportunities in farmed fish marketing in Kenya.* [Oral presentation] International Institute of Fisheries Economics & Trade Conference, Dar es Salaam, Tanzania. 16-20 July 2012.

Price, C. and H. Egna. 2014. Strategies for reducing feed costs in small-scale aquaculture. Global Aquaculture Advocate 17(3): 24-26.

Price, C., S. Ichien, and H. Egna. 2014. *Strategies for reducing feed costs in smallholder tilapia aquaculture.* [Poster] World Aquaculture Society – Aquaculture America, Seattle, Washington, USA. 9-12 February 2014.