FEED THE FUTURE INNOVATION LAB FOR COLLABORATIVE RESEARCH ON AQUACULTURE AND FISHERIES (AQUAFISH INNOVATION LAB)

AQUAFISH ELEVENTH ANNUAL REPORT

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Oregon State University
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USAID FROM THE AMERICAN PEOPLE

Oregon State University

AQUAFISH INNOVATION LAB

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ELEVENTH ANNUAL REPORT

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Tilapia fry in hands. Credit: Jim Bowman.

Photos
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MANAGEMENT ENTITY INFORMATION

The Management Entity (ME) for the AquaFish Innovation Lab is headquartered at Oregon State University (OSU) in Corvallis, Oregon.

AQUAFISH MANAGEMENT OFFICE

Hillary Egna	Director and Lead Principal Investigator, AquaFish Innovation Lab
Ford Evans	Associate Director, AquaFish Innovation Lab
Jenna Borberg	Assistant Director – Research, AquaFish Innovation Lab
Kathryn Goetting	Assistant Director – Outreach, AquaFish Innovation Lab

TECHNICAL AND ADVISORY COMMITTEE INFORMATION

The AquaFish Innovation Lab receives information on emerging developments and technical issues through open dialogue with one external and two internal advisory groups: Development Themes Advisory Panel, Regional Centers of Excellence, and External Program Advisory Council.

DEVELOPMENT THEMES ADVISORY PANEL (DTAP)

The DTAP provides technical advice on emerging issues and gaps in the portfolio from a thematic perspective. The DTAP recommends policies for technical issues and is aligned with the four themes listed below. Coordinators of the thematic panels assist the Management Team (MT) in integrating cross-cutting needs, including emphasis on gender; human institutional and capacity development; biodiversity; aquatic ecosystem health; poverty; soil and water quality; biotechnology; and nutrition. Coordinators also review work plan modifications in cases where research is curtailed for various reasons (e.g., laboratory equipment malfunction, poaching, etc.) and work together to provide quality information for thematic synthesis and reporting on lessons learned.

The DTAP Coordinators for the four themes for FY17 were:

DTAP A: Improved Human Health and Nutrition, Food Quality, and Food Safety
Lead Coordinator: Kwamena Quagrainie (Purdue University)

DTAP B: Income Generation for Small-Scale Fish Farmers and Fishers
Lead Coordinator: Joe Molnar (Auburn University)

DTAP C: Environmental Management for Sustainable Aquatic Resources Use
Lead Coordinator: Jim Diana (University of Michigan)

DTAP D: Enhanced Trade Opportunities for Global Fishery Markets
Lead Coordinator: Bob Pomeroy (University of Connecticut – Avery Point)

REGIONAL CENTERS OF EXCELLENCE (RCE)

The RCEs provide technical advice on emerging issues and gaps in the portfolio from a regional perspective. Centers develop useful materials for Missions and other regional stakeholders and end-users, and gauge opportunities for collaboration based on regional and national needs. RCE Coordinators assist the Director in cases where a screening process is required in advance of an Initial Environmental Examination. The RCE Coordinators for FY17 were:

RCE – Africa: *Charles Ngugi (East Africa) & Steve Amisah (West Africa)*
RCE – Asia: *Yuan Derun (Southeast Asia)*
RCE – Latin America & Caribbean: *Wilfrido Contreras-Sanchez (Central America and the Caribbean) & Maria Célia Portella (South America)*

EXTERNAL PROGRAM ADVISORY COUNCIL (EPAC)

The EPAC provides advice on global program direction and annual critiques of research projects during annual or regional meetings to assist the Director in gauging project performance; participates in the programmatic review process for proposals on an as-needed basis, provided there are no conflicts of interest; and helps the Director network and link AquaFish with non-governmental organizations, internal organizations (e.g., CGIAR), and others. The EPAC members for FY17 were:

Africa: *Nancy Gitonga*
Asia: *Liping Liu*

AquaFish Research Project Countries FY17

PROGRAM PARTNERS

The AquaFish Innovation Lab partners and collaborates with institutions around the world to maximize the benefits of aquaculture and fisheries research, technology development, and capacity building. AquaFish US and Host Country (HC) participants accomplish this by sharing expertise, conducting collaborative research, engaging and educating stakeholders, and leveraging opportunities through a strong and growing aquaculture network.

Since inception in 2006, AquaFish has fostered linkages with more than 300 institutions globally. AquaFish builds and maintains its network through formal funded partnerships as well as through non-funded collaborations.

Funded Project Partners in FY17

(The list below includes all institutions in formally-funded partnership with AquaFish during FY17.)

Bangladesh
Bangladesh Agricultural University
Khulna University
Patuakhali Science and Technology University
Shushilan NGO

Cambodia
Inland Fisheries Research and Development Institute

Ghana
Farmerline
Kwame Nkrumah University of Science and Technology

Kenya
Kenyatta University
University of Eldoret

Nepal
Agriculture and Forestry University
Directorate of Fisheries Development
Nepal Agricultural Research Council

Tanzania
Institute of Marine Sciences, University of Dar es Salaam
Sokoine University of Agriculture
Western Indian Ocean Marine Science Association

Uganda
Makerere University
National Fisheries Resources Research Institute-Aquaculture Research and Development Center

US
Alabama A&M University
Auburn University
North Carolina State University
Oregon State University
Purdue University
University of Arizona
University of Arkansas at Pine Bluff
University of Connecticut at Avery Point
University of Hawaii at Hilo
University of Michigan
University of Rhode Island
Virginia Polytechnic Institute and State University

Vietnam
Can Tho University

Current and Former AquaFish Linkages (FY06-FY17)

(This is a comprehensive list of AquaFish linkages from inception in 2006 through FY17.)

Australia
Monash University (Melbourne)

Bangladesh
Bangladesh Agricultural University
Bangladesh Department of Fisheries
CGIAR-WorldFish, South Asia & Bangladesh
Chanchal Hatchery (World Fish Supported)
Hajee Mohammad Danesh Science & Technology University
Institution of Nutrition and Food Science (University of Dhaka)
Khulna University
Patuakhali Science and Technology University
Shushilan NGO
University of Dhaka
WorldFish Aquaculture Income & Nutrition
WorldFish Farmer's Group

Argentina
Universidad Nacional del Comahue

Australia
Australian Center for International Agricultural Research
University of Tasmania

Brazil
Embrapa Meio Ambiente
Sao Paulo State University
Universidad Estadual Paulista, Centro de Acüicultura, Jaboticabal
Universidad Federal do Amazonas

Cambodia
Cambodia Department of Conservation
Cambodia HARVEST Project, USAID
Cambodia Molecular Genetic Group, Health Scientific Research Centre University Health Sciences
Department of Aquaculture Development
Department of Fisheries, Post-Harvest Technologies & Quality Control of Fisheries Administration
Fisheries Administration in Cambodia
Freshwater Aquaculture Research & Development Center
Hun Sen Aquaculture Institute
Inland Aquaculture Extension & Productivity Improvement Project
Inland Fisheries Research and Development Institute
Institution for Research in Food and Development
Kampong Cham National School of Agriculture
Kandal Fisheries Administration
Marine Aquaculture Research and Development Center
Mekong River Commission
Ministry of Agriculture, Forestry, and Fisheries
Phnom Penh Fisheries Administration
Prek Leap National School of Agriculture
Royal University of Agriculture
Royal University of Law and Economics
WorldFish Center, Cambodia

Canada
International Development Research Centre

Chile
Foundation Chile

China
China Aquatic Products Processing & Marketing Association
Guizhou Normal University
Hainan University
Haoshideng Shrimp Farm
Huazhong University
Huiting Reservoir Fisheries Management Company
Shanghai Ocean University
Sichuan Aquacultural Engineering Research Center
Southwest University
Tongwei Co. Ltd.
Wuhan University
Xiamen University
Zhanghe Reservoir Fisheries Management Company
Zhejiang University

Colombia
Centro Internacional de Agricultura Tropical

Costa Rica
University of Costa Rica

Ecuador
Ecostas

Egypt
Academy of Scientific Research & Egyptian Universities
Central Laboratory for Aquaculture Research
Egyptian Society of Agribusiness
Ministry of Agriculture & Land Reclamation

Ethiopia
Ethiopian Institute of Agricultural Research

Ghana
FAO-Ghana (not FAO Regional Office)
Farmerline
Fisheries Department, Ministry of Food & Agriculture
Kwame Nkrumah University of Science and Technology
Ministry of Agriculture Fisheries Directorate
Pilot Aquaculture Center
University for Development Studies
Water & Sewage Company
Water Research Institute's Aquaculture Research Development Center

Guatemala
San Carlos University

Guyana
Anna Regina Fish Culture Station
Guyana Department of Fisheries
Guyana School of Agriculture
Maharaja Oil Mill
Mon Repos Aquaculture Center, Department of Fisheries
National Aquaculture Association of Guyana
Trafalgar Union Women's Cooperative
University of Guyana
USAID Farmer-to-Farmer Program
USAID/GTIS Program
Von Better Aquaculture

Honduras
Centro Nacional de Investigación Piscícola El Carao
Escuela Agrícola Panamerican
Laboratorio de Calidad de Agua La Lujosas
Secretaría de Agricultura y Ganadería
Zamorano University

Indonesia
Indonesian Department of Fisheries
Ladong Fisheries College
Ujung Batee Aquaculture Center

International
Asian Fisheries and Aquaculture Forum
Heifer International
International Water Management Institute of the Consultative Group on International Agriculture Development (CGIAR)
Food & Agriculture Organization of the United Nations
Gender in Aquaculture and Fisheries for the Asian Fisheries Society
International Symposium on Tilapia in Aquaculture
The International Institute of Fisheries Economics & Trade
Sustainable Aquaculture Research Networks in Sub Saharan Africa
World Aquaculture Society
The World Bank

Kenya
Egerton University
Karatina University
Kenya Business Development Services
Kenya Marine & Fisheries Research Institute
Kenya Ministry of Fisheries Development
Ministry of Agriculture, Livestock, and Fisheries
Moi University
Mwea Aquafish Farm
National Investment Center
Nyanchwa College of Science and Technology
Sagana Aquaculture Center
University of Nairobi
University of Eldoret
Women in Fishing Industry Project Kenyatta University

Kenya, Tanzania, Uganda
Lake Victoria Fisheries Organization (Kenya, Tanzania, Uganda)

Kenya, Tanzania, Uganda, Rwanda, Burundi
Lake Victoria Environmental Management Project (Kenya, Tanzania, Uganda, Rwanda, Burundi)
FishAfrica

Lebanon
American University of Beirut

Malawi
Bunda College, Lilongwe

Malaysia
WorldFish Center

Mali
Assemblee Permanente des Chambres d'Agriculture du Mali
Direction Nationale de la Peche
Ministere de L'Elvage et de la Peche
Rural Polytechnic Institute for Training & Applied Research
The Permanent Assembly of Chambers of Agriculture
USAID Mali

Mexico
Centro de Investigacion de Alimentacion y Desarrollo (Research Center for Food & Development)
Centro de Transferencia Tecnologica Para La Acuicultura
Comite Estatal de Sanidad Acuicola de Sinaloa
Cooperativa Pesquera San Ramon
Federation of Shrimp Cooperatives
Instituto Nacional de Investigaciones Forestales y Agropecuarias
Instituto Nacional de Investigaciones Forestales y Agropecuarias
Instituto Sinaloense de Acuacultura
Instituto Technologico del Mar
Mariano Matamoros Hatchery
Regional Center of Education and Qualification for Sustainable Development
Research Center for Food & Development
Secretariat of Agricultural Development for the State of Tabasco
Sinaloa State Fisheries Department
The Autonomous University of Sinaloa-Culiacan
The Autonomous University of Sinaloa-Mazatlan
Universidad Autónoma de Sinaloa–Culiacán
Universidad Autónoma de Sinaloa–Mazatlán
Universidad Autónoma de Tamaulipas
Wetlands Conservation Program
Universidad Juarez Autónoma de Tabasco
Women's Oyster Culture Cooperatives of Nayarit
Women's Oyster Culture Cooperatives of Puerto Penasco

Nepal
Agriculture and Forestry University
Directorate of Fisheries Development
Institute of Agriculture and Animal Science
Nepal Agricultural Research Council
Rural Integrated Development Society
Rural Integrated Development Society-Nepal
Winrock International
Nepal Fisheries Society
Nepal Fish Farmer's Association
Janata Higher Secondary School
Nepal Higher Secondary School
Kathar Higher Secondary School
Prithivi Secondary School

Nicaragua
Center for Research for Aquatic Ecosystems and Aquaculture/Central American University
Nicaraguan Ministry of the Environment

Peru
Fondo Nacional del Desarrollo Pesquero
Instituto de Investigaciones de la Amazonia Peruana
Universidad Nacional Mayor de San Marcos

Philippines
Bureau of Fisheries and Aquatic Resources
Central Luzon State University
Department of Agriculture
Genetically Improved Farmed Tilapia Foundation International, Inc.
Mindanao State University
Southeast Asian Fisheries Development Center - Aquaculture Division
University of the Philippines Visayas (Institute of Fish Processing Technology)
West Visayas State University

Puerto Rico
University of Puerto Rico

South Africa
Department of Water Affairs & Forestry
Stellenbosch University
Water Research Commission

Tanzania
Institute of Marine Sciences, University of Dar es Salaam
Kingorwila National Fish Center
Mbegani Fisheries Development Centre
Ministry of Natural Resources and Tourism-Aquaculture Division
Nyegezi Fisheries Institute
Sokoine University of Agriculture
Tanzania Fisheries Research Institute
University of Dar es Salaam
Western Indian Ocean Marine Science Association

Thailand
CNN Aquaculture and Supply Company
Department of Fisheries
FAO in Asia-Pacific
Kasetsart University
Network of Aquaculture Centers in Asia

The Netherlands
Intervet-Schering Plough Animal Health
Tilapia International Foundation

Uganda
Bidii Fish Farmers
Blessed Investment Fish Farm
Grameen Foundation
Gulu University
Jinja United Group Initiative for Poverty Alleviation & Economic Development
Makerere University
Namuyenge Mixed Farmers Ltd
National Fisheries Resources Research Institute-Aquaculture Research and Development Center
Source of the Nile Fish Farm
Walimi Fish Cooperative Society Ltd.

United Kingdom
Forum for the Future
UK Department for International Development
University of Stirling

US
American Soybean Association
AmeriSci International
Aquaculture without Frontiers
Bemidji State University
Brooklyn College
Coastal Resources Center-University of Rhode Island
Cornell University
Cultural Practice LLC
Delaware State University
Feed the Future Innovation Labs
Fish Farmacy
Fisheries Industry Technology Center-University of Alaska
Florida International University
Global Aquaculture Alliance
Goldman Sachs
Goosepoint Oyster Inc.
Institute for Agriculture and Trade Policy, Minnesota
Louisiana State University
Michigan State University
Montana State University
National Oceanic and Atmospheric Administration – International Sea Grant
National Sea Grant Program Extension Office
Nutrition Innovation Lab, Tufts University
Ohio State University
Oxfam America
Pacific Shellfish Growers Association
Partners of the Americas
Peanut CRSP
Shrimp Improvement Systems
Southern Illinois University at Carbondale
Sustainable Management of Watershed CRSP
Texas A&M University
Texas Parks & Wildlife Department
Texas Sea Grant
Texas Tech University
U.S. Food & Drug Administration
University of California, Davis
University of Delaware
University of Georgia
University of Hawaii at Manoa
University of Oklahoma
University of Tennessee
University of Texas
University of the Virgin Islands

US Department of Agriculture
US Department of Commerce-NOAA
US Geological Survey
US-Mexico Aquaculture TIES Program
USAID Sustainable Coastal Communities & Ecosystems Program (SUCCESS)
USAID-Micro, Small & Medium Enterprises-Aquaculture-DAI
World Wildlife Fund

Venezuela
BIOTECMAR C.A.

Vietnam
An Giang Department of Agriculture and Rural Development
Can Tho University
Dong Nai Fisheries Company
Nong Lam University (University of Agriculture and Forestry)
Research Institution for Aquaculture No. 1
University of Agriculture and Forestry (Nong Lam University)
World Wildlife Fund in Asia

ACRONYMS

ABF	Air-Breathing Fishes
ACRSP	Aquaculture Collaborative Research Support Program
AFS	Asian Fisheries Society
AFU	Agriculture and Forestry University
AIARD	Association for International Agriculture & Rural Development
ANAF	Aquaculture Network for Africa
AquaFish	The Feed the Future Innovation Lab for Collaborative Research on Aquaculture & Fisheries (Formerly Aquaculture & Fisheries CRSP)
AU	Auburn University
BAU	Bangladesh Agricultural University
BFS	Bureau for Food Security
BMA	Production System Design and Best Management Alternatives
BMP	Best Management Practice
CGIAR	Consultative Group on International Agricultural Research
CRSP	Collaborative Research Support Program
CTU	Can Tho University
DTAP	Development Theme Advisory Panel
EdOpNet	Educational Opportunities Network
EPAC	External Program Advisory Council
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Ratio
FMIS	Fish Market Information System
FSV	Food Safety, Post-Harvest, and Value-Added Product Development
FTF	Feed the Future
FTFMS	Feed the Future Monitoring System
FY17	Fiscal Year 2017 (01 October 2016 – 30 September 2017)
GAF	Gender in Aquaculture and Fisheries
GMO	Genetically Modified Organism
HACCP	Hazard Analysis and Critical Control Point
HARVEST	Helping Address Rural Vulnerabilities and Ecosystem Stability
HC	Host Country
HHI	Human Nutrition and Human Health Impacts of Aquaculture
HICD	Human and Institutional Capacity Development
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome
IA	Impact Assessment
IFReDI	Inland Fisheries Research and Development Institute
IMS	Institute of Marine Sciences
IND	Climate Change Adaptation: Indigenous Species Development
IPM	Integrated Pest Management
ISTA	International Symposium on Tilapia in Aquaculture
KNUST	Kwame Nkrumah University of Science and Technology
LWA	Leader-with-Award
M&E	Monitoring and Evaluation
MER	Marketing, Economic Risk Assessment, and Trade
ME	Management Entity
MNE	Mitigating Negative Environmental Impacts
MT	Management Team
NACA	Network of Aquaculture Centres in Asia-Pacific

NaFIRRI	National Fisheries Resources Research Institute
NCE	No Cost Extension
NCSU	North Carolina State University
NEPAD	New Partnership for Africa's Development
NOAA	National Oceanic and Atmospheric Administration
NGO	Non-Governmental Organization
OSU	Oregon State University
PD/A	Pond Dynamics/Aquaculture
PDV	Policy Development
PEEL	Program Evaluation for Effectiveness and Learning
PI	Principal Investigator
PoC	Point of Contact
PU	Purdue University
QSD	Quality Seedstock Development
RCE	Regional Center of Excellence
SARNISSA	Sustainable Aquaculture Research Networks in Sub-Saharan Africa
SIS	Small Indigenous Species (of fish)
SFT	Sustainable Feed Technology and Nutrient Input Systems
SSA	Sub-Saharan Africa
UC	University of Connecticut – Avery Point
UM	University of Michigan
US	United States
USAID	United States Agency for International Development
WAS	World Aquaculture Society
WIOMSA	Western Indian Ocean Marine Science Association
WIZ	Watershed and Integrated Coastal Zone Management

I. EXECUTIVE SUMMARY

The mission of the *Feed the Future Lab for Collaborative Research on Aquaculture & Fisheries* (*AquaFish Innovation Lab*) is to enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquaculture and fisheries. The United States Agency for International Development (USAID) looks to AquaFish to "develop more comprehensive, sustainable, ecological and socially compatible, and economically viable aquaculture systems and innovative fisheries management systems in developing countries that contribute to poverty alleviation and food security." AquaFish began on 30 September 2006 at Oregon State University (OSU); was in hiatus while under a delayed agency review cycle from October 2011 to March 2013; and was invited to propose a 5-year Phase II program, which was awarded on 27 March 2013.

The AquaFish Eleventh Annual Report describes activities and accomplishments of the AquaFish Innovation Lab from 01 October 2016 to 30 September 2017 (FY17). During this reporting period, 18 Host Country institutions in eight countries and 12 US universities engaged in collaborative research focused on increasing food security, income, and household health of poor and vulnerable populations and building human and institutional capacity through research, technology development, and training students and stakeholders at all levels. Five research projects are integrated across four interrelated themes:

A. Improved Human Health and Nutrition, Food Quality, and Food Safety
B. Income Generation for Small-Scale Fish Farmers and Fishers
C. Environmental Management for Sustainable Aquatic Resources Use
D. Enhanced Trade Opportunities for Global Fishery Markets

The AquaFish Innovation Lab builds upon successes from Phase I (2006-2013), when it was known as the AquaFish Collaborative Research Support Program (AquaFish CRSP), by strengthening longstanding collaborative partnerships, establishing new connections, expanding promising research, and aligning with the US Government's Feed the Future (FTF) Initiative. In investigations across five projects, Phase II research focuses on improving sustainability of aquaculture through the development of innovative technologies and outreach techniques that enhance the sustained well-being of the poor. In FY17, AquaFish led 24 investigations under Implementation Plan 2016-2018, and continued work on six investigations under Implementation Plan 2013-2015, focusing on maximizing impacts and building capacity in host countries.

As part of USAID's Bureau for Food Security (BFS) *Feed the Future Food Security Innovation Center*, AquaFish Phase II operates under the *Program for Research on Nutritious and Safe Foods*. AquaFish has adapted its research portfolio to emphasize the importance of sustainable aquaculture and fisheries on human nutrition while maintaining a focus on broader food security issues. Human nutrition is a unifying thread in AquaFish research and partners are helping meet nutrition needs and increase food security by developing sustainable aquaculture technologies and practices. In FY17, AquaFish research in Vietnam and Cambodia enhanced fish feed with vitamin C to improve fish growth and fish health. The benefits of this research have the potential to improve both the income and the nutrition of fish-farming households by increasing fish production. AquaFish researchers in Tanzania are continuing experiments on invertebrates and insects in fish feeds to create locally-sourced, high quality, and more cost effective protein sources as alternatives to commercial fishmeal. Research projects like these show the impacts that improved aquaculture production systems can have on rural households and support the need for further

studies focused on sustainable aquaculture practices, including efforts to lower environmental footprints while minimizing operational costs and maintaining profitable yields.

AquaFish is dedicated to improving gender equity and equality in the aquaculture and fisheries sectors. In FY17, AquaFish helped support the establishment of the Gender in Aquaculture and Fisheries Section of the Asian Fisheries Society. In addition, gender equity and integration efforts are evident within AquaFish research projects. For example, researchers in Zanzibar, Tanzania, continued to train women on oyster spat collection techniques and nursery methods. These women have already increased household incomes through the sale of pearl jewelry and other products from oysters. AquaFish sets a benchmark of 50% participation by women in all types of training activities, whether it be as trainees at a one-day workshop or a student enrolled in a long-term, formal degree program. For FY17 long-term trainings, AquaFish met this 50% benchmark; 45% of short-term training participants in FY17 were women. Providing support to women through long-term educational training increases their involvement in aquaculture early in their academic careers, creating connections and building networks that can be accessed far into the future, and prepares them to serve in lead research and administrative positions for long-lasting gender equity.

AquaFish collaborates with international partners and institutions in order to build human and institutional capacity in developing countries and to ensure sustainable solutions that are appropriate and applicable to regional conditions. AquaFish's HICD work focuses on short- and long-term trainings; institutional strengthening; and collaborative partnerships with governmental research institutions, public and private sectors, and non-governmental organizations (NGOs). In FY17, fifteen short-term training events were held, reaching a total of 512 participants. In addition, AquaFish supported and mentored 175 students in long-term formal degree programs at 21 institutions in nine countries, and awarded five African students a Best Abstract Award for World Aquaculture 2017. In collaboration with the World Aquaculture Society (WAS), AquaFish offered its first ever African Professional Fellowships, providing networking and collaboration opportunities for African scientists. AquaFish has also helped build community and institutional capacity in its project countries. In Bangladesh, approximately 35 village households, representing six communities and two regions, participated in research and learned how to evaluate new techniques, collect and track data, and measure yields. Over 1,000 tilapia farmers in western Kenya benefited from the AquaFish-developed feed formulation that was produced at the University of Eldoret. The University of Eldoret has now implemented a protocol to produce fingerlings in the region, possibly further improving aquaculture potential for farmers in the area and beyond. AquaFish cell phone research in Uganda is expanding by training National Fisheries Resources Research Institute (NaFIRRI) personnel how to use the platform and to verify the information that will be available on the cell phone app. NaFIRRI personnel and District Fisheries Officers in central Uganda will be essential in strategically and effectively implementing the app by leveraging their connections to fish farming networks. Collaboration amongst communities, institutions, and government agencies promotes sustainable aquaculture technologies and ensures that there is capacity within project countries to maximize impacts in the future.

Although progress was made towards AquaFish research objectives in FY17, AquaFish also experienced delays in experiments and on-farm trials due to unforeseen circumstances. An unusually heavy monsoon season in Nepal and Bangladesh caused major flooding, damaging irrigation canals and impacting on-farm trials. AquaFish research sites in east Africa experienced severe droughts that postponed field work in Kenya and Uganda, and subsequent flash flooding limited access to research sites in Tanzania. Additionally, institutional strikes in Kenya and Uganda caused delayed invoicing and contract actions. AquaFish anticipates challenges and has strived to promote strong and resilient projects that can survive such disruptions. However, these kinds of major research delays in the final year of the project are much more difficult to manage while still meeting research objectives and deadlines.

Despite these delays, AquaFish researchers disseminated results to stakeholders globally in many ways, including presentations and publications. In FY17, AquaFish participants at international scientific conferences and meetings made 83 presentations and published 24 articles in peer-reviewed academic journals, books, and trade magazines. At the World Aquaculture 2017 conference in Cape Town, South Africa, AquaFish Director Dr. Hillary Egna chaired an all-day technical session focusing on AquaFish research results, covering topics such as fish marketing and trade strategies, development of alternative feed ingredients, and impacts of fish farming on household nutrition. AquaFish also held two regional meetings in FY17 (one in Africa and one in Asia) to gather partners together to discuss progress and exit strategies. These activities further complement the AquaFish mission and expand the network of researchers dedicated to sustainable aquaculture and fisheries innovations.

II. PROGRAM ACTIVITIES AND HIGHLIGHTS

In FY17, AquaFish conducted research in developing countries and the US, continued building and strengthening international multidisciplinary partnerships, and disseminated research results at international conferences and workshops, in scientific journals, books, and trade magazines, and through public media, including interviews.

Five US universities (Auburn University, North Carolina State University, Purdue University, University of Connecticut – Avery Point, and University of Michigan) were selected in 2013 to partner with OSU to conduct work in nine countries in Africa and Asia. Under these five projects, AquaFish partnered with seven additional US universities and 18 institutions and organizations in Africa and Asia in FY17 to work on a total of 30 investigations (24 from IP 2016-2018 and six continuing from IP 2013-2015) focusing on two main themes: *Integrated Production Systems* and *People, Livelihoods, and Ecosystem Interrelationships*.

Notable research in FY17 included efforts to increase household income and availability of nutritious foods. Researchers in Bangladesh and Nepal found polyculture effectively reduced operational costs while maintaining profitable yields. These polyculture systems also offer a wider range of fish species for household consumption, improving nutritional diversity. In Kenya, results on low-cost feed research and best management practices for pond-based aquaculture are being disseminated through trainings and outreach documents. This research developed technologies and methods to produce feeds using locally-sourced and affordable ingredients that maintain profitability for farmers.

Availability of high-quality seed and broodstock is essential to support a sustainable aquaculture industry. After the decade-long ban on snakehead (*Channa* spp.) culture was lifted in Cambodia in 2016, AquaFish researchers have been working on domestication by studying the breeding of wild and hatchery-raised snakehead. The second generation from the breeding experiments are now being raised as future broodstock; additional studies on pelleted feeding will inform policy recommendations on sustainable snakehead aquaculture in Cambodia. Grow-out and reproduction experiments on the African lungfish (*Protopterus aethiopicus*), an air-breathing indigenous fish popular in Uganda, are informing the development of a sustainable culture system in the region. This new culture species has potential to provide a protein-rich food source that is less vulnerable to a changing climate than many non-native species.

The AquaFish research portfolio includes activities that promote equal access to training opportunities and involvement in the program; it also includes specific activities to remove barriers to equal access. In FY17, for example, AquaFish workshops in Zanzibar, Tanzania, trained women in spat collection and nursery techniques for shellfish culture. Many of these women have been involved in the culture and sale of pearl products in the past and now know how to maintain and grow shellfish spat to a size that can be used to seed pearls. They are also ready to train others, increasing the knowledge-base of the community and supporting the sustainability of the culture system.

Strengthening human and institutional capacity is a primary objective for AquaFish and is accomplished through a variety of ways, including collaborative partnerships, resource and facility sharing, support of degree-seeking students, curriculum development, recruitment and retention of students and faculty, short-term training courses, recognition of outstanding achievements, and professional development

opportunities at international aquaculture and fisheries conferences. In FY17, AquaFish supported 175 long-term degree students at 21 universities in nine countries, with women representing 51% of the total. AquaFish conducted 15 short-term trainings, reaching 512 people, with 45% women's participation. AquaFish chaired an all-day technical session at World Aquaculture 2017 in Cape Town, South Africa, and offered the first ever AquaFish/World Aquaculture Society African Professional Fellowships to African aquaculture scientists representing five countries. AquaFish also recognized student research through the AquaFish Best African Student Abstract awards at World Aquaculture 2017.

Two AquaFish partner institutions were recognized nationally in FY17 for their commitments and achievements in research. Bangladesh Agricultural University was ranked first among all Bangladesh universities. AquaFish researchers at Kwame Nkrumah University of Science and Technology in Ghana were recognized for their leadership in increasing fish production to address household food security and income. Collaborations with AquaFish have helped these institutions build administrative infrastructure to make them competitive national and international leaders in science.

To further support and expand collaborative networks and partnerships, AquaFish facilitated the establishment of the Africa Chapter of the World Aquaculture Society. This chapter will provide a much needed forum to address Africa's diverse and growing aquaculture sector. In FY17 in Asia, the Asian Fisheries Society (AFS) proudly launched, with AquaFish support, the AFS Gender in Aquaculture and Fisheries Section (GAFS), marking the first formal gender-affiliated section within a professional aquaculture or fisheries society. This milestone showcases AFS and AquaFish's long-standing commitment to gender integration in fisheries and aquaculture.

Many gather in anticipation of the launch of the World Aquaculture Society Africa Chapter in Cape Town, South Africa.

AquaFish continued to disseminate research results and recommendations through presentations at national and international conferences as well as in peer-reviewed and trade publications. In FY17, AquaFish had 83 presentations at scientific and professional conference and produced 24 publications for journals, books, and trade magazines. Since 2006, AquaFish researchers have published more than 265 peer-reviewed articles on program-related research. These outreach activities further expand collaborative networks and increase AquaFish impacts throughout the world.

III. KEY ACCOMPLISHMENTS

AquaFish outputs and impacts in research, capacity building, outreach, and gender integration are measured relative to qualitative and quantitative targets identified in the USAID-approved Monitoring and Evaluation Plan and Feed the Future Monitoring System. Key accomplishments in FY17 under the AquaFish Leader Award are highlighted below.

Research and Technology Development

Twenty-three innovative aquaculture technologies were at varying stages of development in Africa and Asia in FY17. In developing these technologies, AquaFish projects involved 45 food security enterprises, producer organizations, women's groups, trade and business associations, and community-based organizations. In Uganda and Ghana, AquaFish worked with fish farmers to continue developing mobile phone applications and information networks to address aquaculture information needs, improve efficiencies in the value chain, and reduce post-harvest loss. This mobile phone information system in Ghana, first developed in FY16 with a focus on tilapia and catfish, is now being expanded to reach new markets and users in the marine fisheries sector. This earlier work also laid the foundation for development and implementation of a mobile application in Uganda available on three platforms—smartphones, basic cell phones, and on the internet.

Research and technology development in FY17 has also continued on the development of alternative feeds and feeding practices. To improve production efficiency of tilapia, AquaFish researchers in Bangladesh are building on past research that successfully reduced feed costs by testing the effectiveness of nutritional conditioning for optimal nutritional absorption and growth. Results from this work indicate that tilapia fry that are fed on a reduced protein diet from days 7-14 may have improved growth rates later in life. Work is also continuing towards understanding how gut microbial diversity changes in response to reduced feeding strategies. This research has the potential to lead to the development of probiotic bacterial supplements for feeds to improve fish health and growth, and contribute to food security. In Vietnam and Cambodia, AquaFish is working to improve cost-effective feeds by incorporating optimal levels of vitamin C to maximize growth. In Tanzania, researchers are building on FY16 work in developing affordable, locally-sourced fish-feeds from insects and invertebrates and determining the optimal substrates for growing them.

Human and Institutional Capacity Building

Since program inception in 2006, AquaFish has fostered linkages with approximately 300 institutions globally. In FY17, AquaFish had a total of 74 active linkages, including formal (funded) institutional or individual partnerships with 36 organizations in 14 countries, and an additional 38 informal (unfunded) collaborators. AquaFish mentored 175 students in long-term degree programs at US and HC institutions this fiscal year. Fifteen short-term training events were held, with a total of 512 participants, and included workshops, on-farm trainings, and train-the-trainer events to target a range of audiences.

In FY17, AquaFish also helped build the capacity of partnering HC institutions, their local communities, and more broadly, the aquaculture sector in their regions. In Tanzania, AquaFish researchers at the Sokoine University of Agriculture (SUA) partnered with researchers from the Kwame Nkrumah University of Science and Technology in Ghana to conduct an experimental pond unit assessment. A primary goal of this collaborative effort was to train SUA faculty and students about best pond management practices, thereby taking a "learn by doing" approach. Researchers at Nepal's Agriculture

and Fisheries University helped build capacity of their surrounding community by facilitating farmer-to-farmer exchange of information, training teachers and students about carp culture in ponds located at secondary schools, and through collaboration with women's fish farmer groups. In Kenya, AquaFish researchers from the University of Eldoret undertook work on developing on-farm fish feed using locally available and more affordable ingredients, and the resulting feed formulation benefited over 1,000 tilapia farmers in Western Kenya. As part of this work, they developed a protocol to produce quality fingerlings at the University of Eldoret hatchery, building aquaculture capacity in the region as fingerlings are often cited as a limiting factor in production. In Bangladesh, approximately 35 village households, representing six communities and two regions of Bangladesh, participated in AquaFish research and learned how to test new ideas, manage and harvest aquaculture ponds and dyke vegetable farming, collect and track data, and measure seafood yields. The activities have greatly promoted the entrepreneurship of the communities as well as improved their capacity to farm fish. Researchers based at Michigan State University utilized existing data sets and began to explore the importance of inland fisheries in Burma, both wild-capture and aquaculture, in supplying micronutrients to the Burmese diet and their role in food security across the country.

Information Dissemination

AquaFish has disseminated findings to stakeholders through multiple avenues including the AquaFish website (aquafish.oregonstate.edu), social media sites, newsletters, conference presentations, scientific journals, public conversations, media interviews, and trade magazines and publications. Additionally, 12 issues of *EdOpNet* (education opportunities in aquaculture and fisheries-related fields) reached over 1,650 recipients in FY17. The scientific strength and accomplishments of AquaFish are evidenced by over 265 publications on AquaFish-supported research and data since program inception in 2006, twenty-four of which were published in FY17. Information was also shared among AquaFish project partners in FY17 through two regional meetings (one in Nepal and one in Uganda), through an all-day technical session at the World Aquaculture 2017 Conference in Cape Town, South Africa, and via 83 oral and poster presentations throughout the year. These venues provided opportunities to showcase AquaFish work and to improve upon research and capacity building efforts through peer feedback.

Gender Integration

AquaFish continues to collect and analyze gender-disaggregated data in order to gauge gender inclusiveness and success. Strategies for engaging women are adapted, as needed, as AquaFish works towards the 50% benchmark for training women in formal and informal education, and for retaining women scientists and administrators in all facets of AquaFish operations. In FY17, AquaFish met this 50% benchmark for supporting long-term trainees at degree granting institutions in the US and HCs. Women represented 45% of participants in AquaFish-sponsored short-term trainings. Beyond the formal capacity building effort, gender integration continues to be a cross-cutting theme of the AquaFish research portfolio. In Zanzibar, work continued to empower coastal communities through spat collection experiments. As women play a significant role in the pearl culture industry, they were involved in experiments and were provided training on entrepreneurship skills. These activities continue to help empower women in building the economies of the Bweleo and Nyamanzi villages and further improve their household livelihoods. In Nepal, 15 women from the Sunderdeep Women's Fish Farmer's Cooperative joined 12 men and three additional women from the Mishrit Cooperative to participate in a periphyton enhancement study. The group tested five different substrates for boosting periphyton growth and improving in-pond productivity. AquaFish has also empowered a woman professor at Yangon University in Burma to lead efforts towards evaluating and enhancing faculty and institutional capacity in aquaculture. Given that over 90% of professors at Yangon University are women, faculty development has the potential to reach many women in Burma and to more broadly improve gender integration in the aquaculture sector in Southeast Asia.

IV. RESEARCH PROGRAM OVERVIEW AND STRUCTURE

AquaFish is managed to achieve maximum program impacts, particularly for small- to medium-scale farmers and fishers, in Host Countries (HCs) and more broadly. AquaFish program objectives address the need for world-class research, capacity building, and information dissemination. Specifically, AquaFish strives to:

- Develop sustainable end-user level aquaculture and fisheries systems to increase productivity, enhance international trade opportunities, and contribute to responsible aquatic resource management;
- Enhance local capacity in aquaculture and aquatic resource management to ensure long-term program impacts at community and national levels;
- Foster wide dissemination of research results and technologies to local stakeholders at all levels, including end-users, researchers, and government officials; and
- Increase Host Country capacity and productivity to contribute to national food security, income generation, and market access.

The overall research context for the projects described in this Annual Report is poverty alleviation and food security improvement through sustainable aquaculture development and aquatic resources management. Discovery through research and technology development forms the core of projects. Projects also integrate institutional strengthening, gender, outreach, and capacity building through activities such as training, formal education, workshops, extension, and conferences to support the scientific research being conducted.

Projects focus on one or two USAID-eligible countries within a region, and may include activities in nearby countries within the same region. All projects received USAID country-level concurrence prior to award.

AQUAFISH RESEARCH PROJECTS

Each project focuses on one of AquaFish's primary global themes (or goals), and integrates all four themes in a systems approach. The global themes, listed below, are cross-cutting and address several specific USAID policy documents and guidelines:

A. Improved Human Health and Nutrition, Food Quality, and Food Safety
B. Income Generation for Small-Scale Fish Farmers and Fishers
C. Environmental Management for Sustainable Aquatic Resources Use
D. Enhanced Trade Opportunities for Global Fishery Markets

In addition to the global themes guiding project development, projects were formed around *core program components*, as identified by USAID: a systems approach; social, economic, and environmental sustainability; capacity building and institution strengthening; outreach, dissemination, and adoption; and gender integration. USAID also encourages AquaFish to address biodiversity conservation and non-GMO biotechnology solutions to critical issues in aquaculture.

Each overall project describes a comprehensive development approach to a problem and revolves around ten specific areas of inquiry called Topic Areas. Current projects contain between four and eight investigations. Project investigations focus on more than one topic area in describing aquaculture research that will improve diets, generate income for smallholders, manage environments for future generations, and enhance trade opportunities.

A systems approach requires that each AquaFish project integrate topic areas (listed below and described later in this Section) from the following two categories:

Integrated Production Systems

- Production System Design & Best Management Alternatives (BMA)
- Sustainable Feed Technology (SFT)
- Climate Change Adaptation: Indigenous Species Development (IND)
- Quality Seedstock Development (QSD)

People, Livelihoods, and Ecosystem Interrelationships

- Human Nutrition and Human Health Impacts of Aquaculture (HHI)
- Food Safety, Postharvest, and Value-Added Product Development (FSV)
- Policy Development (PDV)
- Marketing, Economic Risk Assessment, and Trade (MER)
- Watershed and Integrated Coastal Zone Management (WIZ)
- Mitigating Negative Environmental Impacts (MNE)

RESEARCH PROJECT STATISTICS

AquaFish has 52% of investigations categorized as *Integrated Production Systems* and 48% as *People, Livelihoods, and Ecosystem Interrelationships* for Phase I and II research projects (Table IV-1).

Table IV-1. AquaFish research project investigations by Systems Approach and Topic Areas for Phase I (includes work conducted under Implementation Plan 2007-2009 and 2009-2011 plus additional work that occurred prior to Phase II) and for Phase II (Implementation Plan 2013-2015 and 2016-2018).

		Number of Investigations					
		Phase I		Phase II			
Systems Approach	**Topic Area**	**2007-2009**	**2009-2012**	**2013-2015**	**2016-2018**	**Total**	**Percent of Total**
Integrated Production Systems							
	Production System Design & Best Management Alternatives (BMA)	4	13	6	5	28	17%
	Sustainable Feed Technology (SFT)	6	7	8	3	24	15%
	Climate Change Adaptation: Indigenous Species Development (IND)	4	10	4	3	21	13%
	Quality Seedstock Development (QSD)	2	5	2	2	11	7%
	Subtotal	***16***	***35***	***20***	***13***	***84***	***52%***
People, Livelihoods, and Ecosystem Interrelationships							
	Human Nutrition and Human Health Impacts of Aquaculture (HHI)	5	2	4	4	15	9%
	Food Safety, Post Harvest, and Value-Added Product Development (FSV)	1	3	0	2	6	4%

Policy Development (PDV)	3	8	1	1	13	8%
Marketing, Economic Risk Assessment, and Trade (MER)	4	10	6	2	22	13%
Watershed and Integrated Coastal Zone Management (WIZ)	2	3	1	0	6	4%
Mitigating Negative Environmental Impacts (MNE)	7	7	1	2	17	10%
Subtotal	***22***	***33***	***13***	***11***	***79***	***48%***
Total	**38**	**68**	**33**	**24**	**163**	

Twenty-four investigations were underway as part of the 2016-2018 Implementation Plan, plus six additional investigations that were continued from the 2013-2015 Implementation Plan. Despite research delays due to natural disasters and political unrest, these investigations proceeded in FY17. A total of eight countries, 12 US Universities, and 18 HC institutions are involved in formal funded partnerships as part of these investigations, and an additional three HC partners are involved through AquaFish advisory panels.

AQUAFISH TOPIC AREAS

Topic areas pertain to aquaculture and the nexus between aquaculture and fisheries. Some of the following topic areas overlap and are interconnected. Each investigation identifies a single topic area that best describes it. The text under each topic area is provided for illustrative purposes and is not prescriptive.

Integrated Production Systems

- ***Production System Design & Best Management Alternatives (BMA)***
  Aquaculture is an agricultural activity with specific input demands. Systems need to be designed to improve efficiency and/or integrate aquaculture inputs and outputs with other agricultural and non-agricultural production systems. AquaFish research must benefit smallholder or low- to semi-intensive producers, and should focus on low-trophic species for aquaculture development. Design systems to limit negative environmental impacts, to improve overall fish health, and optimize carrying capacity. Interventions for disease and predation prevention must adopt an integrated pest management (IPM) approach and be careful to consider consumer acceptance and environmental risk of selected treatments. Innovative research is encouraged on: recirculating and aquaponics systems for supplying aquatic products to denser marketplaces in urban and peri-urban areas; integrated systems using shellfish, seaweeds, or other plants and animals; and new solutions for aeration, cold storage, and pond operations involving solar or other novel energy sources.

- ***Sustainable Feed Technology and Nutrient Input Systems (SFT)***
  Methods of increasing the range of available ingredients and improving the technology available to manufacture and deliver feeds are critical research themes. Better information about fish nutrition can lead to the development of less expensive and more efficient feeds. Investigations on successful adoption, extension, and best practices for efficient feed strategies that reduce the "ecological footprint" of a species under cultivation are encouraged. Research on soil-water dynamics and natural productivity to lessen feed needs were fundamental to the Pond Dynamics/Aquaculture (PD/A) and Aquaculture Collaborative Research Support Program (ACRSP); critical new areas of research may be continued, along with outreach to poor farmers using low-cost, no/low-feed technologies. Feed research that lessens reliance on fishmeal/proteins/oils and lowers feed conversion ratios is desired, as is research on feeds (ingredients, sources, regimes, formulations) that result in high quality and safe aquaculture products with healthy nutrition profiles. Complex pond dynamics technologies need to be simplified for use by new farmers; improved applications of pond dynamics technologies for driving non-fed plankton-driven systems are applicable where access to feeds is expensive or unreliable.

- ***Climate Change Adaptation: Indigenous Species Development (IND)***
  Aquaculture, like agriculture and other human activities, will feel the effects of long-term climate change. Among the myriad challenges, ocean acidification and sea level rise will affect the world's coastal aquaculture operations, much of which occur in poorer countries. Temperature changes will test the resiliency of domesticated varietals. Research challenges involve understanding the adaptive range of these species, and developing cultivation techniques for new species, such as air-breathing fishes. The shifting distribution of global freshwater supplies will pose challenges for the aquaculture industry, small farmers, and the marketplace. Genomics tools may be used to characterize candidate air-breathing species already being evaluated through previous CRSP research. Domestication of indigenous species may contribute positively to the development of local communities as well as protect ecosystems. At the same time, the development of new native species for aquaculture must be approached in a responsible manner that diminishes the chance for negative environmental, economic, and social impacts. Research that investigates relevant policies and practices is encouraged while exotic species development and transfer of non-native fishes are not encouraged. A focus on biodiversity conservation and biodiversity hotspots, as related to the development of native species for aquaculture, is of great interest. Aquaculture, done sensitively, can be a means to enhance and restock small-scale capture and wild fisheries resources. (Aquaculture-Fisheries Nexus Topic Area)

- ***Quality Seedstock Development (QSD)***
  Procuring reliable supplies of high quality seed for stocking local and remote sites is critical to continued development of the industry, and especially for small-holder private farms. A better understanding of the factors that contribute to stable seedstock quality, availability, and quantity for aquaculture enterprises is essential. Genetic improvement (e.g., selective breeding) that does not involve genetically-modified organisms (GMOs) may be needed for certain species that are internationally traded. All genetic improvement strategies need to be cognizant of marketplace pressures and trends, including consumer acceptance and environmental impacts. Augmentation of bait fisheries through aquaculture to support capture fisheries is an area of interest, provided there are no net negative environmental effects.

People, Livelihoods, and Ecosystem Interrelationships

- ***Human Nutrition and Human Health Impacts of Aquaculture (HHI)***
  Aquaculture can be a crucial source of protein and micronutrients for improved human health, growth, and development. Research on the intrinsic food quality of various farmed fish for human consumption is needed—this might include science-based studies of positive and negative effects of consuming certain farmed fishes. Patterns of fish consumption are not well understood for many subpopulations. Human health can be negatively impacted by aquaculture if it serves as a direct or indirect vector for human diseases. There is interest in better understanding the interconnectedness of aquaculture production and water/vector-borne illnesses such as malaria, schistosomiasis, and Buruli ulcer and human health crises such as HIV/AIDS and avian flu. Focus on vulnerable populations, women and children, and underserved populations, and assess how any given technology will affect or improve the welfare of these groups. Research or field-testing with schools and nutrition centers is encouraged. (Aquaculture-Fisheries Nexus Topic Area)

- ***Food Safety, Post-Harvest, and Value-Added Product Development (FSV)***
  Ensuring high quality, safe, and nutritious fish products for local consumers and the competitive international marketplace is a primary research goal. Efforts that focus on reducing microbial contamination, hazard analysis and critical control point (HACCP) controls and hazards associated with seafood processing, value-added processing, post-processing, and by-product/waste development are of interest. Consumers and producers alike will benefit from research that contributes to the development of standards and practices that protect fish products from spoilage, adulteration, mishandling, and off-flavors. Processing waste can claim up to 70% by weight of finfish depending

on the species and manner processed, and post-harvest losses can claim around 30%. Partnering with other groups and co-developing outreach techniques to reduce post-harvest losses can significantly contribute to the amount of fish available for consumption, thus, contributing to the nutrition goals of USAID's Feed the Future Initiative. Certification, traceability, product integrity, and other efforts to improve fish products for consumer acceptance and international markets are desired. Gender integration is important to consider as women are strongly represented in the processing and marketing sectors, and throughout much of the value chains. (Aquaculture-Fisheries Nexus Topic Area)

- ***Policy Development (PDV)***
  Policy initiatives that link aquaculture to various water uses to improve human health are needed. Areas of inquiry can include institutional efforts to improve extension related to aquaculture and aquatic resources management; science-based policy recommendations targeting poor subpopulations within a project area, or more broadly (e.g., national aquaculture strategies); methods of improving access to fish of vulnerable populations including children (e.g., school-based aquaculture programs); science-based strategies for integrating aquaculture with other water uses to improve well-being, such as linkages with clean drinking water and improved sanitation. Additionally, social and cultural analyses regarding the impacts of fish farming may yield critical information for informing policy development.

- ***Marketing, Economic Risk Assessment, and Trade (MER)***
  Aquaculture is a rapidly growing industry and its risks and impacts on livelihoods need to be assessed. Significant researchable issues in this arena include cost, price, and risk relationships; domestic market and distribution needs and trends; the relationships between aquaculture and women/underrepresented groups; the availability of financial resources for small farms; and the effects of subsidies, taxes, and other regulations. Understanding constraints across value chains in local, regional, and international markets is of interest, especially as constraints affect competitiveness, market demand, and how to link producers to specific markets. (Aquaculture Fisheries Nexus Topic Area)

- ***Watershed & Integrated Coastal Zone Management (WIZ)***
  Aquaculture development that makes wise use of natural resources is at the core of the AquaFish program. Research that yields a better understanding of aquaculture as one competing part of an integrated water use system is of great interest. The range of research possibilities is broad—from investigations that quantify water availability and quality to those that look into the social context of water and aquaculture, including land and water rights, national and regional policies (or the lack thereof), traditional versus industrial uses, and the like. Water quality issues are of increasing concern as multiple resource use conflicts increase under trends toward scarcity or uneven supply and access, especially for freshwater. Ecoregional analysis is also of interest to explore spatial differences in the capacities and potentials of ecosystems in response to disturbances. Innovative research on maximizing water and soil quality and productivity of overall watersheds is of interest. Pollution is a huge concern, as over 50% of people in developing countries are exposed to polluted water sources. Additionally, aquatic organisms cannot adequately grow and reproduce in polluted waters, and aquaculture may not only be receiving polluted waters, but adding to the burden. Rapid urbanization has further harmed coastal ecosystems, and with small-scale fisheries and aquaculture operations in the nearshore, integrated management strategies for coastal areas are also important. (Aquaculture Fisheries Nexus Topic Area)

- ***Mitigating Negative Environmental Impacts (MNE)***
  With the rapid growth in aquaculture production, environmental externalities are of increasing

concern. Determining the scope and mitigating or eliminating negative environmental impacts of aquaculture—such as poor management practices and the effects of industrial aquaculture—is a primary research goal of this program. A focus on biodiversity conservation, especially in biodiversity "hotspot" areas, as related to emerging or existing fish farms is of great interest. Therefore, research on the impacts of farmed fish on wild fish populations, and research on other potential negative impacts of farmed fish or aquaculture operations are needed, along with scenarios and options for mitigation. (Aquaculture-Fisheries Nexus Topic Area)

ENVIRONMENTAL COMPLIANCE

The following USAID environmental restrictions apply to the projects and the overall program:

- Biotechnical investigations will be conducted primarily on research stations in Host Countries.
- Research protocols, policies, and practices will be established prior to implementation to ensure that potential environmental impacts are strictly controlled.
- All training programs and outreach materials intended to promote the adoption of AquaFish-generated research findings will incorporate the appropriate environmental recommendations.
- All sub-awards must comply with environmental standards.
- AquaFish Projects will not procure, use, or recommend the use of pesticides of any kind. This includes but is not limited to algaecides, herbicides, fungicides, piscicides, parasiticides, and protozoacides.
- AquaFish Projects will not use or procure genetically modified organisms.
- AquaFish Projects will not use, or recommend for use, any species that are non-endemic to a country or not already well established in its local waters, or that are non-endemic and well established but are the subject of an invasive species control effort.

TERMINOLOGY FOR INVESTIGATIONS

Investigations that generate new information form the core of projects. Each investigation is clearly identified as an experiment, study, or activity, based on the following definitions:

Experiment	A scientifically sound investigation that addresses a testable hypothesis. An experiment implies collection of new data by controlled manipulation and observation.
Study	A study may or may not be less technical or rigorous than an experiment and may state a hypothesis if appropriate. Studies include surveys, focus groups, database examinations, most modeling work, and collection of technical data that do not involve controlled manipulation (e.g., collection and analysis of soil samples from sites without having experiments of hypothesized effect before collection).
Activity	An activity requires staff time and possibly materials but does not generate new information like an experiment or a study. Conference organization, training sessions, workshops, outreach, and transformation and dissemination of information are examples of activities.

Investigations provide a transparent means for evaluating different types of work under AquaFish, be they quantitative, empirical, biologically-based, qualitative, policy-based, or informal. Each project is required to include at least one experiment or study, and at least one outreach activity that focuses on women and/or girls.

GENERAL RESEARCH PRIORITIES

All projects address the following general research priorities:

- Priority Ecosystems
  Inland and coastal ecosystems for aquaculture and aquaculture-fishery nexus topic areas.

- Priority Species
  Low-trophic level fishes, domesticated freshwater fishes, non-finfishes (e.g., bivalves, seaweeds), aquatic organisms used in polyculture and integrated systems, and native species. Food fishes are a priority but species used for non-food purposes (e.g., ornamental, pharmaceutical) may also be included as a priority if they are a vital part of an integrated approach towards food security and poverty alleviation.

- Target Groups
  Aquaculture farms (small- to medium-scale, subsistence, and commercial) and aquaculture intermediaries, policy makers, and others in host countries.

- Key Partners
  Universities, HC and US government, non-government organizations, private sector, CGIAR, and the USAID Food Security Innovation Center.

V. RESEARCH PROJECT REPORTS

Research project reports summarize achievements, capacity building, and lessons learned from FY17, representing progress made towards objectives of the 2016-2018 Implementation Plan. The five lead research projects address four global themes in an integrated systems approach but primarily focus on one theme as part of the overall AquaFish research portfolio.

Theme A – *Improved Human Health and Nutrition, Food Quality, and Food Safety*
Africa Project: Ghana & Tanzania

Theme B – *Income Generation for Small-Scale Fish Farmers and Fishers*
Africa Project: Kenya & Uganda

Theme C – *Environmental Management for Sustainable Aquatic Resources Use*
Asia Project: Bangladesh
Asia Project: Nepal

Theme D – *Enhanced Trade Opportunities for Global Fishery Markets*
Asia Project: Cambodia & Vietnam

THEME A: IMPROVED HUMAN HEALTH AND NUTRITION, FOOD QUALITY, AND FOOD SAFETY

Africa Project: Ghana & Tanzania
Project Title: ***Aquaculture Development and the Impact on Food Supply, Nutrition, and Health in Ghana and Tanzania***

Location
Ghana: Accra, Eastern Ashanti, and Volta Basin
Tanzania: Mbeya, Morogoro, and Zanzibar

For more details on research locations, see the AquaFish Site Descriptions**.**

Project Description
2016-2018 Implementation Plan Investigations
1. Experimental Pond Unit Assessment in Tanzania (16BMA01PU)
2. Increasing Productivity of Nile Tilapia (*Oreochromis niloticus*) through Enhanced Feeds and Feeding Practices (16SFT03PU)
3. Optimizing the Use of Commercial Feeds in Semi-intensive Pond Production of Tilapia in Ghana; From Nursery to Grow-out (16BMA02PU)
4. Fish Consumption and Implications for Household Nutrition and Food Security in Tanzania and Ghana (16HHI02PU)
5. Enhancing the Functionality and Applicability of Fish Market Information System (FMIS) to Marine Artisanal Fisheries in Ghana (16MER01PU)

Continuing Investigations from the 2013-2015 Implementation Plan

1. Spat Collection and Nursery Methods for Shellfish Culture by Women (13QSD01PU)
2. Coastal Women's Shellfish Aquaculture Development Workshop (13BMA01PU)
3. Enhancing the Nutritional Value of Tilapia for Human Health (13SFT02PU)

Principal Project Personnel

Purdue University, US (US Project University) Kwamena Quagrainie – US Project PI **Kwame Nkrumah University of Science & Technology, Ghana (Lead HC Institution)** Stephen Amisah – HC Project PI Daniel Adjei-Boateng – HC Investigator Nelson Agbo – HC Investigator Regina Edziyie – HC Investigator Kwasi Obirikorang – HC Investigator **Institute of Marine Sciences, University of Dar es Salaam, Zanzibar, Tanzania** Narriman Jiddawi – HC Co-PI **University of Hawaii-Hilo, US** Maria Haws – US Co-PI	**University of Arkansas at Pine Bluff, US** Rebecca Lochmann – US Co-PI **Virginia Polytechnic Institute & State University, US** Emmanuel Frimpong – US Co-PI **Sokoine University of Agriculture, Tanzania** Sebastian Chenyambuga – HC Co-PI & Tanzania PoC Hieromin Lamtane – HC Investigator Nazael Madalla – HC Investigator Renalda Munubi – HC Investigator **Farmerline, Ghana** Alloysius Attah – HC Co-PI **Western Indian Ocean Marine Science Association, Zanzibar, Tanzania** Julius Francis – HC Co-PI

Achievements

In FY17, this project continued to take a multifaceted approach to increasing productivity of tilapia. AquaFish addressed challenging issues at both the supply-side and demand-side of aquaculture in Ghana and Tanzania. Investigations at the supply-side examined productivity in ponds, alternative fish feed ingredients, and feed management. The demand-side examined market information systems and technology, and demand for seafood. This is a holistic approach that, when completed and findings are adopted, will help put the aquaculture industry in the two Host Countries on a sustainable productive path.

In Tanzania, a study on replacing fishmeal in feeds with housefly maggot meal, a locally-sourced alternative protein source in fish feed, resulted in successful feed utilization efficiency, cost competitiveness, and similar growth performance of Nile tilapia (*O. niloticus*) when compared to more costly, traditional feeds. Results from a comparison of five substrates to determine the most appropriate substrate for production of these insects indicate that they grow best in cattle intestine and poultry dung. While alternative feeds were explored in Tanzania, a study in Ghana focused on optimizing the utilization of commercial feeds by evaluating the effect of varying crude protein levels. Initial results suggest that there is no significant difference in growth of tilapia with feeds that contain 25%, 28%, and 30% crude protein. This research experienced delays in the last quarter of FY17 due to the breakdown of the solar powered tank system necessary to conduct the research.

On the demand-side of the aquaculture value chain, a Fish Market Information System was developed in Ghana to help open market communication pathways. As a mobile phone-based system, this evolving technology minimizes the information gaps along the fish value chain and improves efficiencies in fish

marketing and the value chain as a whole. Currently, researchers are attempting to expand the system to incorporate marine fishes and markets. A related but separate line of research explores household food security improvements through fish farming and seafood consumption in Ghana and seafood accessibility in Tanzania. Results in Ghana reveal the potential reasons, including price, taste, education levels, and religion, for the substitutability of fish over other protein sources. In Tanzania, accessibility to seafood was evaluated through the impact of infrastructural features such as electricity, communication networks, and transportation.

In Zanzibar, spat collection experiments involving women were conducted from May 2016 to June 2017 and produced a total of 3,354 *Pinctada margaritifera* spat and 3,861 *Pteria* species spat at Bweleo and Nyamanzi, respectively. The community has welcomed trainings on growing and maintaining spat because this technique helps women, who are the traditional spat collectors, avoid going out in deeper waters to collect the large shells and alleviate dependence on men. Community members are also ready to train others to make this activity sustainable and feasible by increasing the potential for shells to seed. These activities continue to help empower women in building the economies of the Bweleo and Nyamanzi villages and further improve their household livelihoods.

Capacity Building

In Zanzibar, the AquaFish team brought together villagers from Nyamanzi, Fumba Bondeni, Fumba Chaleni, Bweleo, Unguja Ukuu, and Kizingo in pearl farming, jewelry making, and mariculture activities (seaweed and sea cucumber farming) to discuss the development of shellfish aquaculture. The village head of Bweleo officially opened the event. Facilitators then addressed how to help improve the packaging of their products and marketing in order to provide sustained benefits throughout the community. Leaders also aimed to strengthen the collaborations between the various villages.

Seventeen long-term students (nine women and eight men) were supported under this project in FY17: one BS student, 14 MS students, and two PhD students. They were enrolled at Kwame Nkrumah University of Science and Technology in Ghana, Sokoine University of Agriculture in Tanzania, and Purdue University and Virginia Tech University in the US. Three workshops were organized in Ghana to disseminate project findings to stakeholders. Participants included fish farmers, students, regional fisheries officers, and artisanal fishermen.

Furthering the capacity of project participants, nine faculty members and six students from Host Countries attended World Aquaculture 2017 conference in South Africa. This was a first time for students from Ghana and Tanzania to present at an international conference.

Presentations and Publications

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gariepinus). [Oral Presentation]. AquaFish African Regional Meeting, Kampala, Uganda, 9-12 January 2017.

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THEME B: INCOME GENERATION FOR SMALL-SCALE FISH FARMERS AND FISHERS

Africa Project: Kenya & Uganda
Project Title: ***Aquaculture Development in Kenya and Uganda: Advancing Cost-Effective Technology, Market Assessment, and End-User Engagement***

Location
Uganda: Kajjansi, Gulu, Jinja, Kampala, Kayunga, Mukonno, Buikwe, Wakiso, Luweero, Mpigi, and Nakasongola

Kenya: Kirinyaga, Nairobi, and Uasi Gishu/Rift Valley

For more details on research locations, see the AquaFish Site Descriptions**.**

Project Description
2016-2018 Implementation Plan Investigations
1. Development of Captive Breeding, Larval Rearing Technologies and Management Practices for African Lungfish (*Protopterus aethiopicus*) (16IND03AU)
2. Implementing and Assessing Cell-Based Technical and Marketing Support Systems for Small- and Medium-scale Fish Farmers in Uganda (16FSV02AU)
3. Assessment of Price Volatility in the Fish Supply Chain in Uganda (16MER02AU)
4. Women in Uganda Aquaculture: Nutrition, Training, and Advancement (16HHI04AU)
5. Water, Water Quality, and Pond Bottom Soil Management in Ugandan Aquaculture (16BMA05AU)

Continuing Investigations from the 2013-2015 Implementation Plan
1. Assessment of Growth Performance of Monosex Nile Tilapia (*Oreochromis niloticus*) in Cages Using Low-Cost, Locally Produced Supplemental Feeds and Training Fish Farmers on Best Management Practices in Kenya (13SFT06AU)
2. Formulation and Manufacture of Practical Feeds for Western Kenya (13SFT07AU)
3. Development of Low-Cost Aquaponics Systems for Kenya (13BMA05AU)

Principal Project Personnel

Auburn University, US (US Project University) Joseph Molnar – US Project PI Claude Boyd – US Investigator Patricia James – Research Assistant Jeffery Terhune – US Investigator **Makerere University, Uganda (Lead HC Institution)** Theodora Hyuha – HC Co-PI **University of Arizona, US** Kevin Fitzsimmons – US Co-PI **Alabama A&M University, US** James Bukenya – US Co-PI	**National Fisheries Resources Research Institute, Uganda** John Walakira – HC Project PI Gertrude Atukunda – HC Investigator Moureen Matuha – HC Investigator **University of Eldoret, Kenya** Julius Manyala – HC Co-PI Charles Ngugi – HC Investigator & Kenya PoC **Fisheries Training Institute, Uganda** Gertrude Abalo – HC Co-PI **North Carolina State University, US** Benjamin Reading – US Co-PI Russell Borski – US Investigator

Achievements

In FY17, research in Kenya and Uganda continued efforts focused on improving livelihoods, nutrition, and income for fishers, farmers, and vulnerable communities by working to solve and clarify bottlenecks that limit the advancement of fish culture. Many achievements were accomplished in spite of drought from October 2016 through March 2017, strikes at all public universities in Kenya from January to March 2017, and closure of Makerere University in Uganda from November 2016 to January 2017 due to strikes.

As part of a study on mobile phone use by fish farmers in Uganda, researchers continued to develop and test eight modules accessed on three platforms (basic phones, smartphones, and the internet) for farmers based on previously identified needs, including pond management, feeds, broodstock, water quality management, stocking, harvesting, and market price. The development of a mobile phone application to address fish farming information gaps and to provide farmers with current market information is nearing completion. Researchers led a training workshop to begin testing the application and are working with the Directorate of Fisheries Resource on how they can benefit from this technology. Additional market-side research built on previous work in Kenya and Uganda that showed seasonal variation in fish prices. Current research has led to the development of a forecasting model based on historic price information to help farmers manage market-specific fish price volatility at the farm-gate level.

Grow-out and reproduction experiments have continued to guide the development of low-cost technologies for propagating and producing cultured African lungfish to improve household nutrition, food security, and income. Through this study, AquaFish is generating valuable information on lungfish feeding; the reproduction studies will help determine the best method to spawn fish in captivity. Prolonged droughts delayed the rearing process and further collection of broodstock.

AquaFish researchers and Makerere University students learn about lungfish anatomy at the NaFIRRI field station.

Research in Kenya continued to take important steps forward in demonstrating practical approaches to fish culture using aquaponics on small- and medium-scales. Another study continued to train fish farmers in Kenya on best management practices (BMPs) to enhance small aquaculture operations. The BMPs

highlighted in project trainings included tilapia sex-reversal techniques, low-cost feed use, methods of suspending cages in ponds, and commercialization practices.

Capacity Building

For FY17, capacity building efforts in Kenya and Uganda built on partnerships with farmer organizations to continue amplifying and disseminating the insights and recommendations coming from AquaFish research. In Uganda, AquaFish co-sponsored the Uganda National Aquaculture Show, 10-14 July, where the AquaFish team displayed information on lungfish research and the mobile phone application. The team also joined the Uganda Women Fish Network at the show to support them in selling their farmed tilapia products and welcoming new farmers into the network.

Thirty long-term students (11 women and 19 men) were supported and mentored under this project in FY17 at Makerere University in Uganda; Kenyatta University, Egerton University, Karatina University, and University of Eldoret in Kenya; and Auburn University in the US. These students were pursuing Certificates (1), Bachelor's (14), Master's (12), and PhD (3) degrees.

Presentations and Publications

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THEME C: ENVIRONMENTAL MANAGEMENT FOR SUSTAINABLE AQUATIC RESOURCES USE

Asia Project: Bangladesh
Project Title: ***Enhancing Aquaculture Production Efficiency, Sustainability, and Adaptive Measures to Climate Change Impacts in Bangladesh***

Location
Bangladesh: Bagerhat, Barisal, Khulna, Mymensingh, Patuakhali, and Satkhira

For more details on research locations, see the AquaFish Site Descriptions**.**

Project Description
2016-2018 Implementation Plan Investigations
1. Advancing Semi-intensive Polyculture of Indigenous Air-breathing Fishes, Koi and Shing, with Major Indian Carps for Enhancing Incomes and Dietary Nutrition while Reducing Environmental Impacts (16MNE01NC)
2. Nutritional Conditioning during Larval Development to Improve Feed Efficiency and Identify Beneficial Gut Flora in Tilapia (16SFT02NC)
3. Better Management Practices for *Mola*-Prawn-Carp Gher Farming Integrated with Pond Dyke Cropping for Increased Household Nutrition Earnings of Rural Farmers in Southwest Bangladesh (16HHI01NC)
4. Tilapia and Koi (climbing perch) Polyculture with *Pangasius* Catfish in Brackish (hyposaline) Waters of Southern Bangladesh (16IND02NC)
5. Dissemination of AquaFish Innovation Lab Technologies for Improving Food Production Efficiency and Livelihoods of the People of Bangladesh (16MNE02NC)

Principal Project Personnel

North Carolina State University, US (US Project University) Russell Borski – US Project PI Peter Ferket – US Investigator Scott Salger – US Investigator **Bangladesh Agricultural University, Bangladesh (Lead HC Institution)** Sharoz Mahean Haque – HC Project PI Mst. Kaniz Fatema – HC Investigator Sadika Haque – HC Investigator Md. Ashraful Islam – HC Investigator	**Khulna University, Bangladesh** Khandaker Anisul Huq – HC Co-PI **Patuakhali Science and Technology University, Bangladesh** Md. Lokman Ali – HC Co-PI Zahid Parvez Sukhan – HC Investigator **Shushilan NGO, Bangladesh** Sattyananda Biswas – HC Co-PI

Achievements
In FY17, research in Bangladesh continued testing novel technologies and management practices for intensifying seafood production while maximizing utilization of nutrient input and reducing environmental impacts through polyculture. This research has added benefits of improving overall aquaculture production efficiency and increasing incomes of farmers in Bangladesh. Previous polyculture research demonstrated that inclusion of two major Indian carp, rohu and catla, either alone or in combination, has little impact on koi production but provides a means for farmers to enhance their income by providing additional fish (carps) for home consumption or sale at local markets. Collectively, preliminary analyses indicate that: 1) koi polyculture with major Indian carps provides the opportunity to produce additional fishes while improving koi production, and 2) reductions in feed ration along with

pond fertilization can provide further cost savings in koi-carp polyculture without negatively impacting fish production.

After a challenging start due to low and fluctuating temperatures at hatcheries, followed by flooding, results thus far from research on increasing resilience show that polyculture with tilapia and/or koi has minimal effects on *Pangasius* production in brackish waters, waters which are typically heavily used in shrimp aquaculture. The ability to utilize hyposaline waters for the polyculture of *Pangasius* and tilapia, or *Pangasius* and koi, has potential to enhance efficiency and economic return of these systems for coastal farmers in Bangladesh.

Two investigations focused more specifically on improving household nutrition, income generation, and livelihoods. In mola-prawn-carp gher (seasonal rice/paddy fields) farming systems, researchers evaluated the effects of three fertilization regimes: molasses and yeast (organic fertilizer), phosphate and urea (inorganic fertilizer), and a combination of both fertilizers. This study demonstrated that the addition of either organic or inorganic fertilizer enhances total fish yields, while a combination of both fertilizers enables the highest production of prawn and fishes. Further analyses suggest that dyke cropping can provide farmers and their families additional opportunities to generate income and consume nutritious foods. Results from this work suggest that the addition of black polythene (substrate) to pond muds derived from mola-prawn-carp polyculture increased vegetable yields. To increase household income, researchers sought to improve nutrient uptake and utilization along with production efficiency of tilapia culture. To do so, researchers assessed the effects of limited-term reduced protein diets for post-yolk sac Nile tilapia fry on long-term growth, intestinal gene expression, and fecal microbiome. Growth data indicate that tilapia fry fed reduced protein diets for 7 or 14 days may improve overall growth of fish later in life. Further metagenomics analyses of the tilapia gut microbiome are currently in progress.

Capacity Building

During FY17, capacity-building efforts focused on strengthening community, individual, and institutional partnerships and capacities. Toward this goal, the project partnered with seven host-country university faculty at three regional universities in Bangladesh, and with one senior project scientist from an NGO, Shushilan. These institutions encompass a broad geographical range within Central, South, and Southwest Bangladesh. Through trainings, faculty, students, and staff gained considerable knowledge on community management of development projects, conduct of research trials, and an improved understanding of the importance of reporting project outcomes and impacts. University undergraduate coursework and associated field laboratory experiences on water quality and pond management also benefited from the project as experimental ponds supported by AquaFish were used for teaching and training. The project was successful in the education and training of the next generation of aquaculture and fisheries scientists. During this fiscal year, 26 (13 women and 13 men) students including three Bachelor's, 18 Master's, three PhD's, and two post-doctoral fellows were supported and mentored at Bangladesh Agricultural University, Khulna University, and North Carolina State University. Students were trained on hypothesis-driven experimental design, various research techniques, data collection and analyses, and other critical features to successfully test, carry-out, and disseminate technologies for aquaculture and fisheries development.

Presentations and Publications

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Huq, K.A., W. Sabbir, S.S. Islam, J. Bir, S.M. Haque, M.A. Wahab, and R. Borski. 2017. Brood Mola Stocking Density in Prawn and Carp Farming to Increase Household Nutrition for Rural Farmers in Southwest Bangladesh. [Oral Presentation]. World Aquaculture 2017, Cape Town, South Africa, 26-30 June 2017.

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THEME C: ENVIRONMENTAL MANAGEMENT FOR SUSTAINABLE AQUATIC RESOURCES USE

Asia Project: Nepal
Project Title: ***Development of More Efficient and Environmentally Sustainable Aquaculture Systems for Nepal***

Location
Nepal: Rampur, Chitwan, Majhui, Kawasoti, Nawalparasi, Kathar, and Terai Region

For more details on research locations, see the AquaFish Site Descriptions**.**

Project Description
2016-2018 Implementation Plan Investigations
1. A Comparison of Monoculture and Polyculture of Tilapia with Carps for Pond Production Systems in Nepal (16BMA03UM)
2. Developing New Systems for Periphyton Enhancement in Farmers' Ponds (16BMA04UM)
3. Improving Seed Production of Sahar (*Tor putitora*) in Chitwan, Nepal (16QSD02UM)
4. Outreach to Increase Efficiency of Aquaculture in Nepal (16HHI03UM)

Principal Project Personnel

University of Michigan, US (US Project University) James Diana – US Project PI **Agriculture and Forestry University, Nepal (Lead HC Institution)** Madhav Shrestha – HC Project PI Dilip Kumar Jha – HC Investigator Narayan Pandit – HC Investigator Sunila Rai – HC Investigator Kamala Gharti – HC Investigator Nabin Babu Khanal – HC Investigator	**Directorate of Fisheries Development, Nepal** Rama Nanda Mishra – HC Co-PI **Fisheries Research Center, Nepal** Jay Dev Bista – HC Co-PI **Nepal Agriculture Research Council, Nepal** Suresh Kumar Wagle – HC Co-PI

Achievements
AquaFish research in Nepal focused on polyculture, household nutrition, enhanced production of native species, technology development, and capacity building. Researchers aimed to improve seed production of sahar, a native and economically important fish, yet difficult to raise in captivity. In breeding experiments, 20 females successfully released eggs, though timing of maturity proved difficult. Sahar fry rearing has begun and researchers have started to evaluate optimum fry stocking densities. With the hopes of utilizing sahar and increasing farmers' profits, researchers also have begun to compare monoculture and polyculture of tilapia with carps and sahar through on-farm trials. Heavy flooding from July 2017 through October 2017, however, damaged the main irrigation canal from the river for on-farm trials. Now that farms have found alternate water sources, trials are continuing.

To increase the growth of periphyton in ponds and therefore reduce the need for expensive commercial feed, on-farm experiments tested the utility of four substrates that were recommended by farmers to enhance periphyton growth at previous AquaFish workshops: split bamboo mats, whole bamboo, plastic bottles, and the midrib of banana leafs. On-farm trials have begun with 15 women farmers from a women's cooperative in Majhui and 15 farmers (12 men and three women) from a cooperative in Seri.

Heavy floods completely inundated ponds for several months in FY17, however, causing delays in one region. Where possible, weekly water quality testing and trials continue.

AquaFish work with local schools to establish ponds for enhancing the science and agriculture curriculum and also for training women's groups on fish production and the nutritional value of consuming fish proved successful. In FY17, AquaFish expanded to two more secondary schools in Nawalparasi and Chitwan, reaching an additional 83 students.

Capacity Building

In FY17, AquaFish work in Nepal continued to strengthen human and institutional capacity, in part via trainings and collaborations. Through expansion of the school ponds project, researchers are training an additional 83 secondary school students, 53% (44) of which were girls. Those 83 students participated in a survey to gather baseline data on their knowledge of aquaculture prior to intervention, and they now participate in weekly seminars and gain knowledge from experiential learning. AquaFish hosted two workshops to discuss types and importance of substrates for the production of periphyton in aquaculture. Fifty-nine farmers and students (37% were women and girls) participated in these workshops. In formal long-term training programs, US and Nepalese AquaFish partners mentored 65 degree-seeking students in pursuit of Bachelor's (51), Master's (13), and PhD (1) degrees. These students were enrolled at Agriculture and Forestry University (AFU) in Nepal. Thirty-one of these students (48%) were women and 34 were men (52%).

AquaFish researchers meet students from Agriculture and Forestry University in Nepal at the 2017 AquaFish Asia Regional Meeting.

With AquaFish support and partnership over many years, AFU has developed innovative aquaculture and fisheries curricula, programs, and courses to further enhance AFU's reputation in Nepal as a leading research institution. In FY17, AquaFish partners at AFU continued to expand and improve resources for its aquaculture program, including those that support teaching, experimentation, and hatchery activities.

Presentations and Publications

Alfaro, J. 2017. Using Small-Scale Aquaculture to Promote Sustainability – The Sustainability Without Borders Program at Michigan. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.

Diana, J.S. 2017. Why Do So Many Americans React Negatively to Increasing Aquaculture in the US? [Oral Presentation]. National Aquaculture Extension Conference, Boise, Idaho, USA, 5-9 June 2017.

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Jha, D.K., N.P. Pandit, I.S. Mahato, M.K. Shrestha, and J.S. Diana. 2017. Establishing School Ponds for Educating Students to Improve Health and Nutrition of Children and Women in Rural Nepal. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.

Mandal, R.B., S. Rai, M.K. Shrestha, D.K. Jha, N.P. Pandit, and S.K. Rai. 2016. Water Quality and Red Bloom Algae of Fish Ponds in Three Different Regions of Nepal. Our Nature 14(1):71–77. [Peer-reviewed].

Pandit, N. P., R. Wagle, and R. Ranjan. 2017. Alternative Artificial Incubation System for Intensive Fry Production of Nile Tilapia (*Oreochromis niloticus*). International Journal of Fisheries and Aquatic Studies 5(4):425–29. [Peer-reviewed].

Rai, S. 2017. AquaFish Innovation Lab Nepal Project. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.

THEME D: ENHANCED TRADE OPPORTUNITIES FOR GLOBAL FISHERY MARKETS

Asia Project: Cambodia & Vietnam
Project Title: ***Improving Food Security, Household Nutrition, and Trade through Sustainable Aquaculture and Aquatic Resource Management in Cambodia and Vietnam***

Location
Cambodia: Kandal province, Kampong Chnang province, Kampong Thom province, Siem Reap province, Phnom Penh, Prey Veng province, Tonle Sap region, Kampong Cham province, Preah Sihanouk province, Battambang province, Pursat province, Kandal province, and Kratie province

Vietnam: An Giang province, Dong Thap Province, Can Tho province, Hau Giang, Camau, Longan, Vinh Long, and Tra Vinh province

For more details on research locations, see the AquaFish Site Descriptions***.***

Project Description
2016-2018 Implementation Plan Investigations
1. Genetic Diversity of Striped Snakehead (*Channa striata*) in Cambodia and Vietnam (16QSD01UC)
2. Guidance and Policy Recommendations for Sustainable Snakehead Aquaculture and Aquatic Resource Management in Cambodia and Vietnam (16PDV01UC)
3. Sustainable Snakehead Aquaculture in Cambodia (16IND01UC)
4. Pellet Feed Improvements through Vitamin C Supplementation for Snakehead Culture (16SFT01UC)
5. Enhancing Food Safety and Household Nutrition of Women and Children through Aquaculture and Capture Fisheries in Cambodia and Vietnam in the Dry Season (16FSV01UC)

Principal Project Personnel

University of Connecticut, US (US Project University) Robert Pomeroy – US Project PI Sylvain DeGuise – US Investigator Marta Gomez-Chiarri – US Investigator **Inland Fisheries Research and Development Institute, Cambodia (Lead HC Institution)** Nam So – HC Project PI Phanna Nen – HC Investigator Navy Hap – HC Investigator Bunthang Touch – HC Investigator Phen Chheng – HC Investigator	**University of Rhode Island, US** David Bengtson – US Co-PI **Can Tho University, Vietnam** Tran Thi Thanh Hien – HC Co-PI & Vietnam PoC Tran Ngoc Hai – HC Investigator Truong Hoang Minh – HC Investigator Pham Minh Duc – HC Investigator Duong Thuy Yen – HC Investigator

Achievements
In FY17, the AquaFish Cambodia and Vietnam project led research that supported the development of sustainable snakehead aquaculture, informed climate change adaptation strategies for fish farming, and evaluated fish consumption and nutrition. FY16 saw the lifting of a more than 10-yearlong ban on snakehead farming in Cambodia. The lifting of the ban was in part because of AquaFish research and policy development on sustainable snakehead aquaculture practices. A primary reason for the ban was due to concerns about the environmental impact of capturing wild small-sized fish in Cambodia for the culture of snakehead and hence, AquaFish developed pelleted feed for snakehead production. In FY17, AquaFish researchers built upon this success and continued the complex work of developing sustainable

snakehead feed in the context of ecologically-friendly rearing methods. Both lines of research have great potential to enable ecologically and economically sustainable culture of snakehead in Cambodia.

One experiment showed that both Vietnamese hatchery snakehead (domesticated) and Cambodian indigenous wild snakehead (non-domesticated) can accept formulated pelleted feed, and that domesticated broodstock of Vietnam origin grew more than twice as fast as fish reared from wild Cambodian broodstock on pelleted feed. The second generation from this study is being raised as future broodstock in efforts to increase domestication of Cambodian snakehead. Although snakehead accepted pelleted feed, anecdotal reports from farmers suggested fish fed on these diets suffer from lordosis and scoliosis, issues associated with vitamin C deficiency. Initial research that incorporated vitamin C into the pelleted feed proved highly successful, and current research is underway to determine the optimal vitamin C requirements for snakehead. To further increase the sustainability of snakehead aquaculture, one study began to characterize and compare the genetic diversity of domesticated and non-domesticated strains of snakehead. Researchers have sequenced approximately 700 samples and have started to analyze the data. Researchers are also actively analyzing cost-profit efficiencies of different snakehead farming models with the hope of guiding policy.

To help improve household food security of women and children, one study has started to analyze the nutrient density of commonly consumed fish and other aquatic animals from both capture fisheries and aquaculture and its products through face-to-face surveys. Once surveys are complete, researchers will make nutritional recommendations.

An interviewer conducts a 24-hour food recall survey in Dangkor village, Cambodia.

Capacity Building

In FY17, AquaFish built capacity through support of students and numerous workshops for various stakeholders. This project supported the education of 27 long-term students at all degree levels in FY17; 59% (16) of these were women. These students studied at Can Tho University (CTU) and Nha Trang University in Vietnam, and Inland Fisheries Research and Development Institute (IFReDI), Royal University of Agriculture, and Royal University of Law and Economics, in Cambodia. Researchers held nine short-term trainings, reaching nearly 400 stakeholders, 195 (49%) of which were females. Two of these trainings covered DNA analysis techniques and dietary assessments for government and university employees, while other trainings focused on disseminating successful and sustainable culturing technologies for snakehead. AquaFish research on sustainable snakehead production in Cambodia and

Vietnam is also increasing the capacity of fish farmers, particularly in Cambodia, a country where the majority of the population relies on aquatic resources for income and nutrition.

Presentations and Publications

Touch, B., R. Pomeroy, N. So, P. Chheng, and T.T.T. Hien. 2017. Enhancing Food Security and Household Nutrition Vulnerability of Women and Children through Aquaculture and Capture Fisheries in Cambodia and Vietnam. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.

Hien, T.T.T., B.M. Tam, T.L.C. Tu, and D.A. Bengtson. 2017. Weaning Methods Using Formulated Feeds for Snakehead (*Channa striata* and *Channa micropeltes*) Larvae. Aquaculture Research 48(9):4774–4782. [Peer-reviewed].

Hien, T.T.T., D.A. Bengtson, R. Pomeroy, N. So, P. Chheng, and H. Navy. 2017. Improved Snakehead (*Channa striata*) Health Status through Vitamin C. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.

Navy, H., P. Chheng, Touch, B, N. So, T.T.T. Hien, P.M. Duc, T.M. Phu, R. Pomeroy, and D.A. Bengtson. 2017. Outreach Activities in Cambodia. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.

Navy, H., T.H. Minh, and R. Pomeroy. 2016. Assessing the Impacts of Climate Change on Snakehead Fish Value Chains in the Lower Mekong Basin of Cambodia and Vietnam. World Aquaculture 47(4): 53-55.

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Pomeroy, R., D. Bengtson, T.T.T. Hien, D.T. Yen, T.H. Minh, and P.M. Duc. 2017. Improving Food Security, Household Nutrition and Trade through Sustainable Aquaculture in Cambodia and Vietnam. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.

Pomeroy, R.S., H. Navy, A.J. Ferrer, and A.H. Purnomo. 2017. Linkages and Trust in the Value Chain for Small-Scale Aquaculture in Asia. Journal of the World Aquaculture Society 48(4):542–554. [Peer-reviewed].

Sophorn, U. and P. Chheng. 2017. Genetic Diversity of Striped Snakehead (*Channa striata*) in Cambodia and Vietnam. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.

LESSONS LEARNED

The lessons learned highlighted below are a compilation of FY17 experiences communicated by subcontracting partners.

- **Diffusion of Innovations: The power of farmer-to-farmer interactions in expanding aquaculture.** AquaFish has conducted numerous experiments at universities, at field stations, and in farmers' ponds; has developed technologies and practices to enhance aquaculture production; and has trained over 10,000 academic faculty and students, farmers, extension agents, and other stakeholders on best practices. These efforts have improved aquaculture practices and built capacity in the countries and the regions in which AquaFish operates. An effective way to expand sustainable aquaculture throughout a region is through farmer-to-farmer interactions. Farmer-to-farmer engagement is exemplified by AquaFish's household pond program in Nepal. This program assisted poor households in establishing 26 small ponds to be used in fish production for household fish consumption in the Kathar area. Subsequently, a local group formed that worked cooperatively with neighbors to build ponds and extend fish rearing techniques to households in the area, with the intent that new pond owners would also work to help others develop ponds. This group was extremely successful, and we now believe there to be over 100 ponds developed largely through neighborhood groups. The trust of locals in their neighbors and the success shown by neighbors in growing fish in the area were influential in the establishment and expansion of fish ponds. This farmer-to-farmer exchange resulted in strong growth of aquaculture in the area, even among very poor farmers. Similar results have been found in the Nepal school ponds work, and in other AquaFish project countries. It is indeed encouraging that the results of AquaFish work may continue to be extended long after our initial intervention occurred.

- **Connecting FTF and non-FTF countries can improve research quality, maximize capacity building, and result in broader regional benefits.** At inception of the AquaFish program in 2006, the director had the foresight to initiate a South-South research partnership between Cambodia and Vietnam so that Cambodia's less developed aquaculture sector could benefit from the more advanced Vietnamese sector. A principal goal of this project has been to transfer Vietnamese research and technologies on sustainable snakehead culture to Cambodia in order for the snakehead ban in Cambodia to be lifted. Vietnamese scientists on this project from CTU trained Cambodian colleagues from IFReDI in the hatchery breeding and rearing of snakehead, and the project team successfully developed a feed using soy protein, subsequently commercialized by the private sector, thereby reducing reliance on low-value fish for feed. As a result, the ban on snakehead farming in Cambodia was lifted in April 2016. AquaFish has continued to develop and improve upon alternative cost-effective feeds. This partnership has resulted in substantial social, economic, and environmental benefits to Cambodia. In turn, Vietnam's industry, as well as the Lower Mekong Basin more broadly, has benefited from the domestication (breeding and raising fish in captivity) of snakehead from over a decade of research and information exchange, and from the scaling of AquaFish technologies into the private sector feed industry.

- **Research delays in the final project year are challenging to absorb: Impacts of drought in East Africa and floods in South Asia in FY17.** While it is not uncommon for weather and natural disasters to cause disruptions to field research, due to the highly seasonal nature of fish farming, isolated events can postpone research experiments by an entire year. Animal production research faces different challenges than plant-based systems; external factors have a compounding effect. For example, heavy rain can directly affect fish production through pond flooding and can also have indirect effects by flooding a nearby field where rice bran is being harvested as a feed ingredient for fish. AquaFish anticipates risks and has strived to promote strong and resilient projects that can survive such disruptions. That said, major research delays in the final project year are more

challenging to overcome. Early in FY17, East Africa experienced a significant drought (from January through March of 2017), delaying and altering AquaFish field work in Kenya and Uganda. This drought was followed by heavy rains and flash flooding in May, which prevented access to experimental sites in Tanzania. More recently, South Asia was inundated with heavy rains and devastating floods in August 2017, delaying initiation of a second series of experiments in Bangladesh, and damaging irrigation canals and causing pond flooding in Nepal.

Through careful planning, AquaFish projects in Africa and Asia have been able to adapt to many of these challenges by delaying harvest, finding alternative sources of water to respond to irrigation issues, and on-the-ground ingenuity of AquaFish's well-trained researchers and participants. However, although projects adapted and are working diligently to complete the proposed research, the refining of and transferring findings and technologies will suffer in many cases without additional time. With more time, more comprehensive dissemination of results to a wide range of stakeholders increases, including through publication in scientific literature, and partnerships with market linkages.

- **Closing down a large and long-lived research program takes time and diligence.** The AquaFish Innovation Lab Leader with Associates Award is a long-lived collaborative research program that has involved complex coordination of many partnering individuals and institutions. In its decade of operation, the Management Entity (ME) at OSU has been responsible for leading and implementing all elements of the program. Over the course of the award, AquaFish has managed up to eight lead subcontracting partners at a given time, which in turn subcontract to other US and HC partner institutions. The ME is responsible for ensuring that all levels of subcontractors are in compliance with federal, state, and university regulations and policies. The Director, Dr. Egna, also serves as the Lead Principal Investigator and in that role has been the driver of the research portfolio, initiating 163 unique investigations since program inception in 2006. Managing this large program has taken substantial time and dedication, and as the program approaches closedown the intensity of the work is amplified. AquaFish began planning for closedown years in advance. Each lead project was required to create an exit strategy at the start of the final Implementation Plan (2016-2018), with the goal of building the capacity of HC partners so that they can carry forward and initiate new lines of research once the program ends. With many layers of subcontractors, the ME has been diligently tracking on contract compliance to ensure that cost share requirements are met; that project spending is allowable, allocable, and consistent; and that policies have been followed, such as USAID's open data policy. The AquaFish ME has proactively taken steps during its final phase towards a smooth closedown process, including: initiating meetings with the five current US lead partner institutions, discussing research and administrative closedown with US and HC partners at regional meetings in Asia and Africa, hosting a closedown meeting with US PIs and their fiscal officers, and holding quarterly conference calls with US PIs and Skype calls with HC partners to gain visibility on pipeline spending and to help resolve any invoicing and contractual challenges.

VI. HUMAN AND INSTITUTIONAL CAPACITY DEVELOPMENT

HUMAN CAPACITY DEVELOPMENT

The capacity building efforts of AquaFish help benefit stakeholders in Host Countries and the US, and regionally through the transfer of knowledge and technology. AquaFish supports trainees in both short- and long-term trainings and provides opportunities for early-career scientists, farmers, and others to make connections and strengthen networks. AquaFish understands that women's participation is essential to the successful growth and development of the aquaculture and fisheries sectors. To ensure that women are included in the development agenda in meaningful and equitable ways, AquaFish has set benchmarks to track the inclusion of women and men in projects funded by AquaFish. Some key capacity building strategies include: collecting and analyzing disaggregated gender data from individual research and outreach projects, tailoring specific extension and technical services to women, gender mainstreaming throughout all aspects of the research and development enterprise, engaging outreach specialists who are sensitive to challenges facing underrepresented groups, and setting a 50% benchmark for women's participation in short- and long-term trainings.

Each of the five AquaFish projects is designed to address country-specific research and development. The overall capacity building effort is one of the cross-cutting elements of the program as a whole and is a fundamental component towards addressing the AquaFish mission.

Short-Term Training

During FY17, a total of 15 short-term trainings took place in five AquaFish Host Countries in Africa and Asia, reaching 512 trainees. Women represented 45% of these trainees, with 232 women participants and 280 men (Figure VI-1 and Table VI-1). Thirty-six trainings still remain to be completed under the 2016-2018 Implementation Plan, due in part to research delays.

AquaFish training participants at a FMIS workshop in Elmina, Ghana.

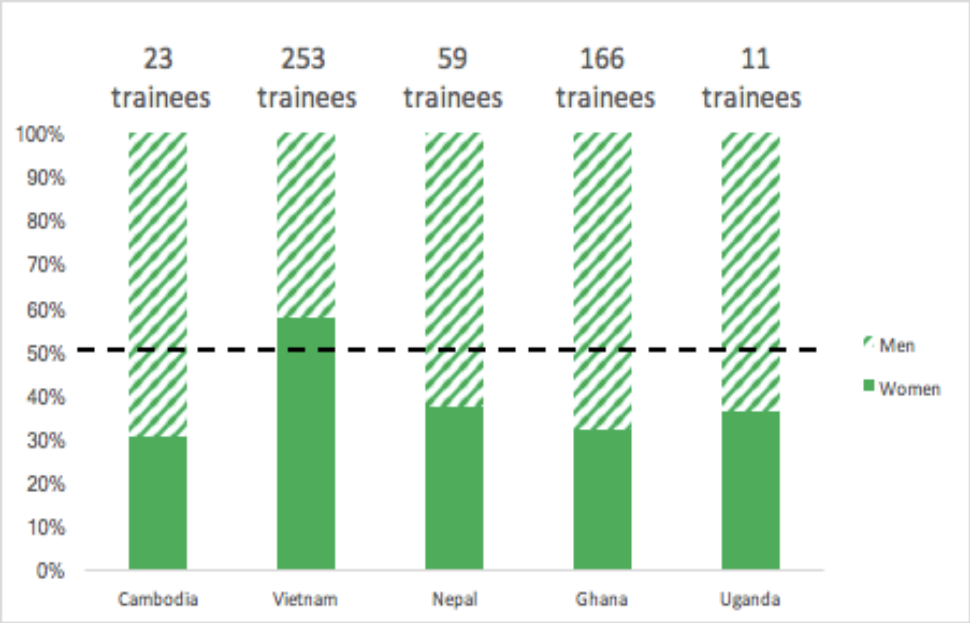

Figure VI-1. Percent of women and men short-term trainees by country in FY17.

Table VI-1. Short-term trainings by country in FY17.

Country of Training	**Brief Purpose of Training**	**Who was Trained (e.g., producers, government)**	**Number Trained**		
			M	**F**	**Total**
Vietnam	Training of IFReDI staff members on practical skills on DNA lab work, genetic data analysis and reporting	Government, University	1	1	2
Cambodia	Training for IFReDI and Can Tho University staff on dietary assessment by using the 24-hour food recall, fish species, food safety, nutrition, and data cleaning and entry	Government, University	5	4	9
Ghana	Workshop to train tilapia farmers in optimal production techniques	Producers	44	15	59
Ghana	Training program on using mobile phones for market info for artisanal fishermen	Producers, University, Private Sector	40	18	58
Ghana	Training program on using mobile phones for market info for artisanal fishermen	Producers, University, Private Sector	29	20	49

Nepal	Workshop in Majhui on alternatives for periphyton substrates	Producers, University, NGO	13	19	32
Nepal	Workshop in Kawasoti on alternatives for periphyton substrates	Producers, University, NGO	24	3	27
Uganda	Demonstration on lungfish during regional meeting	University	7	4	11
Vietnam	Women's workshop on snakehead culture in An Giang	Farmers	0	30	30
Vietnam	Workshop on snakehead culture development sustainability based on audience analysis in An Giang, Province	Farmers, University	27	18	45
Vietnam	Workshop on snakehead culture development sustainability based on audience analysis at Can Tho University	Farmers, University	40	30	70
Vietnam	Workshop on snakehead culture development sustainability based on audience analysis in	Farmers, University	23	7	30
Vietnam	Women's workshop on snakehead culture	Farmers	16	29	45
Vietnam	Women's workshop on snakehead culture in Tra Vinh	Farmers	0	31	31
Cambodia	Training for fish farmers and government fisheries officers on domestication breeding, weaning, grow-out and feed formulation technologies of the striped snakehead	Farmers, Government	11	3	14
Total			280	232	512

Long-Term Trainings

Building human and institutional capacity in partner countries is a hallmark of the AquaFish collaborative research program. AquaFish provides support, research mentoring, and academic guidance for students in undergraduate and graduate programs in a wide array of disciplines including aquaculture, fisheries, aquatic ecology, economics, and engineering. Long-term degree students constitute a pipeline of educated professionals who are positioned to enter careers in government, academia, and private enterprise upon graduation.

In FY17, AquaFish partners in nine countries supported and mentored 175 long-term students at 21 different institutions (6 in the US and 15 in Host Countries). AquaFish met its 50% benchmark for women's participation in long-term trainings, with 90 (51%) women and 85 (49%) men.

The degree breakdown for long-term trainees in FY17 is as follows: one in a Certificate program; 89 (51%) in a Bachelor's program; 70 (40%) in a Master's program; 13 (7%) in a PhD program; and two post-doctoral fellows.

INSTITUTIONAL DEVELOPMENT

Since 2006, AquaFish has helped HC institutions develop specialized curricula and institutional proficiency for building local capacity. AquaFish is expanding capacity in our Host Countries by collaborating with faculty and researchers, supporting degree-seeking students, developing aquaculture-related curriculum, and building partnerships with local aquaculture and fisheries organizations. In FY17, partners at Agriculture and Forestry University (AFU) in Nepal continued to improve faculty capacity for its aquaculture program and began organizing a workshop to connect students with industry and government officials in order to increase job placement of graduating students. The goal is to incorporate these types of workshops into the AFU aquaculture curriculum moving forward.

Long-time AquaFish partner and collaborator, Dr. Steve Amisah, was appointed Provost of the College of Agriculture and Natural Resources at Kwame Nkrumah University of Science and Technology (KNUST) in Ghana. Dr. Amisah has dedicated over 20 years of his career to KNUST, where he has served as the Dean of Faculty of Renewable Resources, professor, and mentor, including to faculty now in the US who are serving as project PIs and Co-PIs on the AquaFish award. Dr. Amisah and many other AquaFish partners at KNUST were recognized for their leadership in increasing fish production to address household food security and income in FY17. Since 2006, AquaFish collaborations have strengthened research and institutional capacity at KNUST, establishing KNUST as a leading aquaculture research program in Ghana.

In FY17, Bangladesh Agriculture University (BAU) was ranked first among all Bangladesh universities for its leadership and overall visibility and impact of web publications. Collaboration with AquaFish over the years has contributed to visibility of their research and enabled BAU to build necessary administrative capacity to develop multi-institutional collaborations within Bangladesh.

These accomplishments, aided by AquaFish support, collaboration, and expertise, increase the capacity of institutions as leaders in higher education and research in aquaculture and fisheries sciences.

Partners

Fostering connections with institutions around the world is a primary component of AquaFish HICD efforts. These networks help create long-lasting collaborations and provide both trainees and organizations with resources that they can access and build upon throughout their careers. The following is a list of universities where AquaFish supported long-term trainees were enrolled in FY17 (for a complete list of AquaFish institutional affiliations, see *List of Program Partners*).

Bangladesh Bangladesh Agricultural University Khulna University **Cambodia** Inland Fisheries Research and Development Institute Royal University of Agriculture Royal University of Law and Economics **Ghana** Kwame Nkrumah University of Science and Technology **Kenya** Egerton University Karatina University Kenyatta University University of Eldoret	**Nepal** Agriculture and Forestry University **Tanzania** Sokoine University of Agriculture **Uganda** Makerere University **US** Auburn University North Carolina State University Oregon State University Purdue University University of Michigan Virginia Tech **Vietnam** Can Tho University Nha Trang University

VII. INNOVATION TRANSFER AND SCALING PARTNERSHIPS

In FY17, AquaFish researchers continued building on previous successes to make significant global and regional technological advances. Collaborative research remained focused on improving sustainable aquaculture production through the development and transfer of innovative technologies and management practices that address human health and nutrition, food security, environmental impacts, and market development.

An underlying theme of the AquaFish research agenda has been the development of responsible aquaculture technologies and systems through a forward-thinking approach for the implementation of sustainable practices. AquaFish focuses on research that creates a multiplier effect for farm-level income and works with partners to scale up technologies for broader impacts. Supporting and partnering with HC research institutions allows AquaFish researchers to customize technologies to local conditions and on-the-ground needs as part of this effort to create sustained impacts and effective technology transfer. These linkages play a critical role in the scaling process by increasing local buy-in, forging connections with other projects, and growing the institutional infrastructure. Additionally, AquaFish training efforts focus on local researchers, technicians, and students as a way to develop and build human capacity. AquaFish includes small- and medium-scale producers, prioritizing the development and transfer of low-cost technologies and best management practices. Efforts to increase access to inputs are coupled with trainings on innovative strategies to help ensure safety and environmental sustainability. AquaFish investments aim to give women equal access to affordable inputs and improved technologies through training opportunities and by emphasizing equitable participation in aquaculture development in project goals.

Participants harvest a pond at an aquaculture best management practices (BMPs) workshop in Kenya.

Efforts have been made to streamline successful technology development in a systems approach at key sites with a particular focus on human nutrition. AquaFish researchers use a variety of methods, including on-farm and on-station trials, baseline surveys, and stakeholder engagement to fine-tune appropriate technologies for transfer. Towards the goal of successful and sustained diffusion of innovation into local communities, AquaFish researchers use the research and outreach process to identify and verify parameters for scaling up with extensive capacity building efforts. The tables below list the AquaFish-supported new and continuing scalable technologies in various stages of development in FY17.

Asia Project: Bangladesh

Project Partners and Collaborators

North Carolina State University (Lead US University); Bangladesh Agricultural University (Lead HC Institution); Khulna University; Shushilan NGO; and Patuakhali Science and Technology University.

Technology	Description	Key Impact
Tilapia, Koi, *Pangasius* polyculture in brackish water	Koi and tilapia can be grown with Pangasius in hyposaline waters with little impact on growth.	Farmers can polyculture higher value koi and/or tilapia with *Pangasius* catfish making more productive use of waters facing increases in salinity from sea level rise. More value may also be obtained with the *Pangasius* polycultured with tilapia or koi than in monoculture.
Semi-intensive polyculture with air-breathing fish species and carp in Bangladesh	Culture of koi (climbing perch), an air-breathing fish, with carps does not impact koi growth, but may actually improve it. The new polyculture technology could increase fish yields, compared with koi monoculture alone, increasing the diversity of fish produced for income generation.	Koi is predominantly grown in monoculture, but its culture with major Indian carps allows farmers to produce more fish for consumption and sale.
Reduced feeding strategies for semi-intensive polyculture of koi and carp	Reducing feed inputs by 50% has no negative impacts on polyculture production of koi or carps.	Farmers can produce koi and major Indian carps with 50% less feed providing considerable cost savings to farmers.
Nutritional conditioning during larval development to improve production and feed efficiency in tilapia	Reducing protein in the diet of post yolk-sac tilapia fry for 14 days can enhance growth of tilapia later in life.	Conditioning tilapia early in life with a low protein diet may improve their capacity to utilize protein and improve growth during subsequent growout. This could enhance the efficiency of tilapia production
Fertilizers for improved polyculture of prawn-mola-carp in gher (rice)-pond systems	A combination of organic (molasses and yeast) and inorganic (urea and phosphate) fertilizers enhances prawn, mola, and carp in gher-pond polyculture.	Farmers can increase production of mola, prawn, and carps for home consumption or for domestic or export markets by utilizing a combination of organic and inorganic fertilizers. This could enhance income and nutrition of farmer household members and livelihoods.
Improved management of vegetable cropping on aquaculture pond dykes	Aquaculture farmers can increase tomato production by utilizing pond muds in combination with mulch and inorganic fertilizer.	Farmers can readily utilize muds from their aquaculture ponds to grow tomatoes, with mud, mulch and inorganic fertilizers enhancing plant growth and fruit yield. This could allow for greater vegetable production to increase household nutrition.

Koi (climbing perch) culture in brackish waters	Koi is a high value fish that can be grown in coastal regions where water bodies and ponds are faced with increased salinization from sea level rise and have been underutilized or abandoned	Farmers may be able to make more productive use of encroached hyposaline waters in the coastal southern region of Bangladesh.

Asia Project: Cambodia & Vietnam

Project Partners and Collaborators

University of Connecticut-Avery Point (Lead US University); University of Rhode Island; Inland Fisheries Research and Development Institute (IFReDI, Lead HC Institution); Can Tho University; Mekong River Commission; Cambodia HARVEST Project; Cambodia Ministry of Agriculture, Forestry, and Fisheries, Kampong Cham National School of Agriculture; Royal University of Law and Economics; Royal University of Agriculture; Department of Aquaculture Development; WorldFish Center, Cambodia; and Fisheries Administration in Cambodia.

Technology	Description	Key Impact
Sustainable snakehead breeding, weaning, and rearing in Cambodia	Fish farmers and fisheries officers including students were trained on artificial breeding, weaning and growing out of snakehead regarding to formulated feed use.	Development and transfer of successful domestication and breeding, weaning, and rearing/growout practices for snakehead in Cambodia helped to lift the 2005 ban on snakehead farming, helping to support the large population of snakehead fish farmers in the region. After the first on-station training, farmers have successfully produced snakehead.
Snakehead pellet feed improvements through vitamin C supplementation	The development of this technology is working to provide cost-effective feeds for snakehead aquaculture in Vietnam and Cambodia. Supplementation of vitamin C into snakehead pelleted feed has been shown to enhance growth performance and increased resistance to diseases.	The results of this study will further define optimal pelleted diets for snakehead in Vietnam, helping to reduce production costs, increase survival rate, lower feed conversion ratios, reduce environmental pollution, and improve resistance to disease. Perhaps more importantly, it will provide further demonstration to the Cambodian government that snakehead culture based on pelleted feed should be allowed in Cambodia. Finally, it will train IFReDI personnel to be able to conduct their own future studies in fish nutrition and feeding for snakehead and other species of interest.
Domestic snakehead genetic resource	This work seeks to characterize and compare genetic diversity of (1) wild (non-domesticated) snakehead populations collected from different natural water bodies in Cambodia, and (2) Cambodia wild (non-domesticated) striped snakehead and Vietnamese domesticated striped snakehead (Channa striata) collected from different hatcheries in the Mekong Delta inferred from mitochondrial DNA markers. Two short-term trainings on fish population genetics and DNA lab work were designed to provide trainings for Cambodian colleagues by CTU team.	The results of this work provide basic information and wise recommendations for striped snakehead domestication and selection breeding and farming in Cambodia. Further, information exchange between Cambodia and Vietnam offers the growth of knowledge on basics of fish population genetics.

Asia Project: Nepal

Project Partners and Collaborators

University of Michigan (Lead US University); Agricultural and Forestry University (Lead HC Institution); Nepal Agricultural Research Center; Directorate of Fisheries Development; Janata Higher Secondary School; Kathar Higher Secondary School; Nepal Higher Secondary School; Prithivi Secondary School; Rural Integrated Development Society in Nepal; Shree Chadeswory Secondary School; Annapurna Higher Secondary School; Center for Aquaculture Research and Production; Sundardeep Women Fish Farmer's Cooperative; and the Mishrit Cooperative.

Technology	Description	Key Impact
Sahar fry production	This technology develops and will refine protocols for the use of hormone induction to mature and breed sahar in captivity.	This technology opens up the possibility of rearing sahar on a commercial scale for restocking of natural waters and for culture in ponds.
Carp-sahar-tilapia polyculture	This technology tests the use of tilapia in Nepal aquaculture, alone or in combination with other carp species.	Tilapia are widely cultured and can add economic growth to Nepal's aquaculture industry.
Expansion of school ponds and aquaculture curriculum in Nepal	This technology was developed and established to use school ponds in the training of students and adult women in aquaculture and fish consumption. In the current state, the technology is expanding to additional schools.	Students have learned new ideas about aquaculture, which they can apply to their adult lives. Women in the same households have also learned more about using fish for additional nutrition for their families.
New systems for periphyton enhancement in fish ponds	The development of this technology is testing new ways to grow periphyton besides bamboo mats. Previous studies showed that bamboo mats worked very well for fish growth but were hard to manage in the pond culture system.	Periphyton growth is consumed by fish, which can allow reduction in feed applications to polyculture ponds without significantly impacting production of fish for consumption and sale.

Africa Project: Ghana & Tanzania

Project Partners and Collaborators

Purdue University (Lead US University); University of Arkansas at Pine Bluff; Virginia Polytechnic Institute and State University; University of Hawaii Hilo; Farmerline; Kwame Nkrumah University of Science and Technology (Lead HC Institution); Sokoine University of Agriculture; Western Indian Ocean Marine Sciences Association (WIOMSA); University of Dar es Salaam; Ministry of Fisheries and Aquaculture Development; and Pilot Aquaculture Center.

Technology	Description	Key Impact
Invertebrates as a protein source in fish feeds in Tanzania	Two invertebrates are being evaluated as alternative source of protein in Nile tilapia diet, namely housefly maggot meal (HFM) and earthworm meal (EWM). Current research evaluates the most efficient substrate for growing the insects.	Fish diets of household fly maggots and earthen worm meal at 35% protein had overall superior performance. These diets are more cost effective in producing a unit of fish and will be very affordable to resource-poor fish farmers.
Optimization of a cell phone marketing tool in Ghana	The technology is a cellphone based Fish Market Information System (FMIS) with a focus on tilapia and catfish, and further inclusion of marine fish. For small-scale fish producers and artisanal fishermen in Ghana, readily available market information on prices and demand for fish at different fish markets helps inform production and harvesting decisions.	Minimizing the information gaps along the fish value chain greatly improves efficiencies and reduces post-harvest losses in fish marketing and the value chain as a whole.
Optimizing the use of commercial feeds in semi-intensive tilapia production in Ghana	A lower protein (25%) version of a commercial feed that is already on the market was developed in collaboration with a feed manufacturer in Ghana and is being tested for tilapia production..	The key impact is a reduction in the production cost by lowering feed cost; this will ultimately increase the profitability of semi-intensive pond tilapia farms.
Experimental diets to help improve feed efficiencies in tilapia production in Ghana.	Three experimental diets have been developed, primarily made from agro-industrial by-products that were fermented to improve the nutritional quality of the ingredients. Two of the diets will be further optimized for fingerling production.	The key impact is a reduction in the production cost by lowering feed cost; this will ultimately increase the profitability of semi-intensive pond tilapia farms.

Africa Project: Kenya & Uganda

Project Partners and Collaborators

Auburn University (Lead US University); Alabama A&M University; University of Arizona; University of Eldoret; Kenyatta University; Makerere University (Lead HC Institution); National Fisheries Resources Research Institute (NaFIRRI); AgroMarketDay; Fisheries Training Institute; Gulu University; Kenya Ministry of Agriculture, Livestock, and Fisheries; Mwea Aquafish Farm; Egerton University; Karatina University; Kenyan Marine and Fisheries Research institute; County Government of Kirinyaga,; and Walimi Fish Cooperative Society Ltd.

Technology	Description	Key Impact
Low-cost captive breeding and hatching of African lungfish in Uganda	This technology will develop a breeding procedure and protocols for wild-caught broodstock of African lungfish.	Successful breeding of lungfish would help supply local demand and reduce pressure on wild stocks. There is a significant baitfish market for lungfish fingerlings and potential to develop a grow-out industry.
Cell phone application for small & medium scale fish farmers	This is a cell-based system that will enable fish farmers to access fish production and market information. To date researchers have developed three platforms for a mobile phone application for smartphones, Unstructured Supplementary Service Data for basic phones, and a website.	Through this technology, farmers will have access to an aquaculture information system. The technology will offer fish market and fingerling supply information, resulting in improved marketing and price discovery, timely access to production protocols and disease diagnoses, and improved access to key inputs.
Low-cost aquaponics for a mediums scale unit in Kenya	This technology integrates fish culture more directly with vegetable production. The aquaponics system has been adapted to use both gravel bed and floating rafts.	The medium-scale aquaponics system developed in this study can be used to raise both fish and crops within the tropical climate and especially in water deficient East Africa.
Practical fish feeds for Western Kenya	This technology produced formulated diets using locally available ingredients that provide balanced essential amino acids (EAAs) to enhance both the physical quality and the nutritive value of the fish feed.	Farmers can incorporate these new feeds with minimal investment, while increasing the quality of fish produced.
Best management practices for pond based aquaculture in Kenya	The development of low cost quality feed, pond design and construction, and fertilizer applications has allowed researchers to give guidance on: low cost feeds; fertilizer applications and their impact on the environment; managing monosex tilapia in ponds.	This technology offers benefits that include increased pond stocking, increased use of monosex fingerlings, and increased use of fertilizer in ponds/ reduced reliance on commercial feeds.

VIII. ENVIRONMENTAL MANAGEMENT AND MITIGATION (EMMP)

Excerpted from RFA # M/OAA/EGAT-06-1395, Initial Environmental Examination (IEE); and amended in March 2013

The AquaFish Innovation Lab leads innovative research, training, and capacity building activities designed to develop and disseminate technologies, tools, practices, methodologies and policies that will sustainably increase aquaculture production; maintain and restore capture fisheries productivity; prevent and reduce poverty among subsistence and small-scale farmers and fishers; help prevent further degradation of aquatic ecosystem health; and protect valuable aquatic biodiversity. The AquaFish ME ensures that environmental issues are considered and incorporated into research, training and outreach activities. To this end, USAID determined that a categorical exclusion (under 22 CFR 216) was appropriate for all activities implemented under the AquaFish Leader Award given that projects and the overall program comply with the environmental restrictions listed below. These restrictions are included in all AquaFish solicitations for research and resulting subcontracts.

Environmental Restrictions:

- Biotechnical investigations will be conducted primarily on research stations in host countries.
- Research protocols, policies, and practices will be established prior to implementation to ensure that potential environmental impacts are strictly controlled.
- All training programs and outreach materials intended to promote the adoption of AquaFish-generated research findings will incorporate the appropriate environmental recommendations.
- All sub-awards must comply with environmental standards.
- AquaFish Projects will not procure, use, or recommend the use of pesticides of any kind. This includes but is not limited to algaecides, herbicides, fungicides, piscicides, parasiticides, and protozoacides.
- AquaFish Projects will not use or procure genetically modified organisms (GMO).
- AquaFish Projects will not use, or recommend for use, any species that are non-endemic to a country or not already well established in its local waters, or that are non-endemic and well established but are the subject of an invasive species control effort.

Further, it was determined that a negative environmental threshold determination with conditions was appropriate. These conditions relate to the use of pesticides, GMO, and non-indigenous or non-endemic non-established species.

IX. OPEN DATA MANAGEMENT PLAN

Open Data Policy
In accordance with the Office of Management and Budget (OMB) Open Data Policy (M-13-13) pursuant to Executive Order 13642 issued by the President on 9 May 2013 (*Making Open and Machine-Readable the New Default for Government Information*) and the Office of Science and Technology Policy's (OSTP) 22 February 2013 memo (*Increasing Access to the Results of Federally Funded Scientific Research*), the AquaFish Innovation Lab developed an Open Access Policy to increase access to data and results of federally funded scientific research.

AquaFish implements its Open Access Policy with the intention of providing opportunities for leveraging existing data, fostering public-private partnerships, improving the public's ability to locate and access data from federally-funded scientific research, and ensuring the long-term stewardship of these data. The policy aims to provide broader public access and improve the impact and accountability of the federal research investment in AquaFish. By making data and results available through user-friendly platforms in machine-readable formats, host countries, scientists, and communities can propel research forward in solving the complex development problems of our time.

Data Management Plan
In FY16, each AquaFish research project developed a plan outlining research datasets that are expected to be of sufficient quality to produce *intellectual work*, defined here as a scholarly peer-reviewed publication, during the 2016-2018 Implementation Plan. These individual plans were combined to comprise the AquaFish FY17 and FY18 Data Management Plans, approved by USAID AOR.

In FY17, the AquaFish MT continued to track on USAID's data policy, and established a process and mechanisms for subcontractors to comply with the policy. The MT built an online AquaFish data repository using Dataverse to aid AquaFish researchers in submitting their completed datasets. While subcontractors had been notified of USAID's data policy and their responsibility to comply with this policy on numerous occasions, it is a complex policy and challenging to implement, and thus necessitated the MT to dedicate additional time at AquaFish meetings in FY17. At the two Regional Meetings in Asia and Africa and at the Closeout Business Meeting in Oregon, the MT presented on and discussed the Open Access Policy with all US and HC project partners.

AquaFish projects reported that no resulting data were made public in FY17 because data collection remains underway for the 2016-2018 Implementation Plan. As noted, all project partners have been informed of USAID's data requirements and are aware that qualifying data must be uploaded to a public repository and metadata reported to the USAID Data Development Library no later than upon award closeout.

X. GOVERNANCE AND MANAGEMENT ENTITY ACTIVITY

Oregon State University (OSU) serves as the Management Entity (ME) of the AquaFish Innovation Lab. The vision and leadership for the programmatic, technical, and fiscal performance of the program is set by AquaFish's Director and Lead Principal Investigator, Dr. Hillary Egna. This vision is consistent with USAID's goals to create and nurture strong global partnerships for promoting lasting development that improves health, builds wealth, conserves natural environments for future generations, and strengthens the ability of host countries to self-govern in a way that respects the sanctity of all. The ME houses the AquaFish Management Team (MT) comprised of the Director and her staff, which is responsible for AquaFish operations, management, reporting, and communications among its partners, stakeholders, and the interested public. In support of the overall AquaFish mission and to expand the reach of the program, the MT engages in research, education, outreach, and capacity building activities related to sustainable aquaculture and fisheries with core funds designated by USAID for aquaculture.

In FY17, the MT continued to monitor all program activities and deliverables, establishing research accountability and evaluating achievements. In preparation for closedown in 2018 and to position projects for the future, the MT held two regional meetings (one in Africa and one in Asia). At these meetings, the MT led discussions to ensure projects were planning for graceful exits from host countries, in addition to learning about project progress and unforeseen circumstances that were causing delays (e.g., droughts, flooding, employee strikes). The MT also held a Closeout Business Meeting for US PIs and their university's fiscal staff to review compliance issues related to data management, travel, personnel and students, and to ensure timely invoicing in the last months of the project. Quarterly US PI conference calls and HC PI Skype calls provided regular check-ins to discuss progress of AquaFish work related to reporting, funding, upcoming opportunities, and challenges. The MT further monitored and evaluated project success via quarterly and annual reporting and the FTF monitoring system, and began compiling project findings on the impacts of AquaFish research and technology development related to aquaculture feeds.

The AquaFish MT communicated with USAID regularly and passed along policy and protocol changes to partners to ensure compliance. Projects were informed of exchange visitor and data management requirements and the MT also maintained regular communication with the AquaFish Agreement Officer's Representative at USAID, Dr. Shivaun Leonard, and fielded information and numerous data requests, serving as an effective liaison for our partners to reduce administrative burden and allow partners the time to work towards program objectives. A meeting organized by the MT brought together EPAC and RCE coordinators to review priorities and methods to ensure successful closedown in 2018.

The AquaFish website had to be rebuilt in FY17 on OSU's Drupal platform. Although it was an unexpected event that required quick action and significant staff time, the rebuild provided an opportunity for the MT to ensure that documents and publications can serve as resources after the program ends by creating an archivable website that will retain links to program materials. Developing the new website on the Drupal platform caused delays and introduced challenges for subcontract reporting. Unlike AquaFish's original website, this new platform was not suitable for having unique login access for AquaFish's many reporting partners. This type of access on the original website allowed for a transparent reporting system in which PIs could directly enter training data and submit reporting materials while also giving them access to view their research progress. Given this loss, the AquaFish MT had to create and implement alternative reporting strategies for the remainder of the program. The AquaFish MT worked

diligently to get a new website functional and an alternative online reporting system operational within a month of the rebuild initiation.

As one of 24 FTF Innovation Labs, AquaFish recognizes the importance of inter-lab relationships and communication in tackling root causes of food insecurity and poverty by employing proven strategies for achieving large scale and lasting impacts. To this end, AquaFish continued collaborative partnerships with other Innovation Labs, including Horticulture and Nutrition. A joint workshop on fish consumption and nutrition was planned in Uganda. The MT also completed the Sustainable Intensification survey on technology transfer and scaling and participated in two Innovation Labs Council Meetings and the World Food Prize, allowing AquaFish to connect with other programs and foster new international development relationship that further expand its collaborative network.

Capacity building is a cross-cutting effort for AquaFish and an element that strengthens long-term program impacts at community and national levels. In addition to programmatic and project-level support of short- and long-term trainees, the AquaFish MT engages in mentorship and support of scientists, both during school and after graduation. In FY17, the MT honored five aquaculture scientists with the first ever *AquaFish/World Aquaculture Society African Professional Fellowship* at World Aquaculture 2017 conference in Cape Town, South Africa. At the same conference, AquaFish sponsored five awards for *Best African Student Abstract* to promote academic excellence and high-quality research endeavors. Dr. Egna served on the awards committee at the Association for International Agriculture & Rural Development (AIARD) 53rd Annual Conference and AquaFish provided sponsorships for students at AIARD. Students and alumni continued to be added to the Student Legacy webpage, an MT effort that showcases decades of student support and mentorship by AquaFish and earlier, similar programs (i.e., ACRSP, PD/A CRSP). The AquaFish Director was an invited panelist at the SeaWeb Seafood Summit and at the FTF Innovation Labs West Africa Regional Partners Meeting. By sharing her expertise and knowledge, Dr. Egna highlighted AquaFish achievements and raised awareness about the importance of sustainable aquaculture as a tool to combat global food insecurity and hunger. AquaFish also promoted gender equity and integration in FY17, including supporting the creation of the Gender in Aquaculture and Fisheries Section of the Asian Fisheries Society.

AquaFish helped support the establishment of the Gender in Aquaculture and Fisheries Section of the Asian Fisheries Society.

The MT is responsible for engaging in outreach and dissemination activities that facilitate communication, publicize results and technologies, and create new linkages. In FY17, the AquaFish Director organized an all-day technical session on AquaFish research at World Aquaculture 2017. The conference, attended by approximately 1,500 people from 100 countries, offered an opportunity to showcase AquaFish research that can directly impact the African region, and aligned with the launching of the Africa Chapter of the World Aquaculture Society, an accomplishment facilitated by numerous AquaFish partners and its Director. AquaFish disseminated information widely in FY17 through flagship newsletters and publications, including the AquaFish Tenth Annual Report, Site Descriptions, three issues of the *AquaNews* newsletter, and 12 issues of the employment opportunity newsletter, *EdOpNet*. In addition, the MT continued to update the program website, and respond to public inquiries about AquaFish activities and opportunities.

In addition to AquaFish partners' publications and presentations (see *Section V*), the AquaFish MT continued to reach out to various stakeholder groups and share information via publications, presentations, and exhibitions at conference and community events, including:

- Borberg, J. 2017. Open Access and Data Management. [Oral Presentation]. AquaFish African Regional Meeting, Kampala, Uganda, 9-12 January 2017.
- Borberg, J. 2017. Open Access and Data Management. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.
- Borberg, J., S. Ichien, K. Goetting, A. Hyman, and H. Egna. 2017. Research Investment in Aquaculture Feed Technology Development and Transfer for Global Food Security. [Poster Presentation]. Aquaculture America, San Antonio, Texas, US, 19-22 February 2017.
- Carroll, L., B. Goodwin, K. Goetting, and H. Egna. 2017. Building Human and Institutional Capacity by Supporting Higher Education in Africa. [Poster Presentation]. World Aquaculture 2017, Cape Town, South Africa, 26-30 June 2017.
- Chow, M., L. Cramer, and H. Egna. 2016. Gender Dimensions in Disaster Management: Implications for Coastal Aquaculture and Fishing Communities in the Philippines. In *Responses to Disasters and Climate Change: Understanding Vulnerability and Fostering Resilience*, edited by M. Companion and M.S. Chaiken. Boca Raton, FL: Taylor & Francis, pgs. 159–72. [Peer-reviewed].
- Egna, H. 2017. Alternative Protein Considerations from Farmed Aquatic Animal-Source Foods in Our Diets. [Invited Speaker]. SeaWeb Seafood Summit, Seattle, Washington, US, 5-8 June 2017.
- Egna, H. 2017. Animals in Production Systems: Needs, Challenges, and Opportunities. [Invited Speaker]. Feed the Future Innovation Labs West Africa Regional Partners Meeting: Identifying Agricultural Research Priorities and Strengthening Partnerships, Dakar, Senegal, 6-8 February 2017.
- Egna, H. and J. Borberg. 2017. Impact Assessment on Alternative Feeding Strategies and Feed Ingredients. [Oral Presentation]. AquaFish African Regional Meeting, Kampala, Uganda, 9-12 January 2017.
- Egna, H. and J. Borberg. 2017. Impact Assessment on Alternative Feeding Strategies and Feed Ingredients. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.
- Egna, H., J. West, and M. Chow. 2017. Assessing the Authorship Gender Gap in Aquaculture-Related Publications. [Oral Presentation]. World Aquaculture 2017, Cape Town, South Africa, 26-30 June 2017.
- Goetting, K. 2017. Empowering Women and Strengthening Communities: Gender Integration in Aquaculture. [Oral Presentation]. Aquaculture America, San Antonio, Texas, US, 19-22 February 2017.

- Goetting, K., J. Borberg, F. Evans, and H. Egna. 2017. Research and Technology Innovations in Mobile Phone-Based Fish Information Systems in Ghana, Kenya, and Uganda. [Poster Presentation]. World Aquaculture 2017, Cape Town, South Africa, 26-30 June 2017.
- Goetting, K., L. Carroll, B. Goodwin, S. Bodman, and H. Egna. 2017. Building Human Capacity and Gender Equity among Global Aquaculture Stakeholders. [Poster Presentation]. Aquaculture America, San Antonio, Texas, US, 19-22 February 2017.
- Goodwin, B., A. Hyman, J. Borberg, S. Ichien, and H. Egna. 2017. Empowering Women and Youth Can Advance Sustainable Aquaculture and Increase Food Security. [Poster Presentation]. World Aquaculture 2017, Cape Town, South Africa, 26-30 June 2017.
- Goodwin, B., J. Borberg, S. Ichien, and H. Egna. 2017. Training Women and Youth to Enhance Sustainable Aquaculture and Increase Food Security. [Poster Presentation]. Aquaculture America, San Antonio, Texas, US, 19-22 February 2017.
- Goodwin, B. and L. Carroll. 2016. Fish Fill Ponds, Plates, and Pocketbooks in Nepal. Feed the Future Newsletter, Issue 56, November 2016.
- Hyman, A., S. Bodman, K. Goetting, and H. Egna. 2017. Research Informs Policy to Lift Cambodian Snakehead Farming Ban. [Poster Presentation]. Aquaculture America, San Antonio, Texas, US, 19-22 February 2017.
- Ichien, S., A. Hyman, B. Goodwin, J. Borberg, and H. Egna. 2017. Exploring Climate-Resilient Adaptations of Farmed Fish for Climate-Smart Aquaculture in Africa. [Poster Presentation]. World Aquaculture 2017, Cape Town, South Africa, 26-30 June 2017.
- Ichien, S., B. Goodwin, J. Borberg, and H. Egna. 2017. Exploring Climate-Resilient Adaptations of Farmed Fish for Climate-Smart Aquaculture. [Poster Presentation]. Aquaculture America, San Antonio, Texas, US, 19-22 February 2017.
- OSU Earth Day Fair in Corvallis, Oregon, US (April 2017) – Exhibitor on Sustainable Aquaculture and Fisheries Practices.
- OSU University Day in Corvallis, Oregon, US (September 2017) – Exhibitor
- World Aquaculture 2017, Cape Town, South Africa, 26-30 June 2017 - organizer and chair of all-day technical session, entitled *Sustainability Practices for African Smallholder Aquaculture*

In FY17, the MT continued to effectively manage a large cooperative agreement, ensure compliance and transparency in research, and work in concert with objectives of FTF. The productivity for FY17 highlighted above shows examples of how AquaFish has fulfilled its obligations to provide programmatic, technical, and fiscal leadership and to disseminate research results and programmatic information to global audiences.

XI. OTHER TOPICS

GENDER INITIATIVES AND ACCOMPLISHMENTS

Gender equality and women's empowerment are core development objectives of the USAID research agenda and are fundamental to accomplishing effective and sustainable development outcomes. Gender integration involves identifying and addressing inequalities due to gender. These inequalities are addressed during the project design process and throughout the implementation, monitoring, and evaluation processes. AquaFish integrates women into research and outreach through cross-cutting efforts in capacity building, economic development, agricultural development, food security, and poverty alleviation—key issues targeted by USAID's Feed the Future initiative.

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 AquaFish program itself. Each AquaFish project includes a Gender Inclusiveness Strategy and at least one outreach activity that focuses specifically on women or girls. Gender equity is a major focus of AquaFish capacity building efforts, with a goal of involving equal numbers of men and women in training activities such as formal education, workshops, and conferences; as well as in institutional strengthening efforts and as project investigators. Gender disaggregated data have been collected by predecessors of the AquaFish program at OSU, and AquaFish has continued to collect and analyze gender data to inform project management and future capacity building needs.

In FY17 the AquaFish gender disaggregated data showed that women represent 45% and 51% of the AquaFish short- and long-term trainees, respectively, earning specialized skills, adopting best management practices and new technologies, and earning professional degrees. Evidence suggests that these types of experiences help to strengthen their ability to earn income, improve household nutrition, and contribute to aquaculture development in their respective communities. Improving gender equity at the institutional level and ensuring that women are included in leadership is central to the enduring benefits of gender integration. Social and cultural barriers can pose challenges to meeting the 50% gender benchmark, and AquaFish works with US and Host Country researchers, extension agents, and others to overcome these obstacles.

Gender Integration Initiatives

FY17 accomplishments towards the AquaFish Gender Integration Initiatives (highlighted with the green background) are presented in the table below. These gender initiatives are a component of the AquaFish USAID-approved Monitoring & Evaluation Plan.

Years 2-5 Initiatives:
Collect disaggregated gender data from individual research and outreach projects funded by AquaFish.
Data collected for short-term and long-term training activities is disaggregated by gender and will continue to be for the life of the projects.
Analyze disaggregated data on an annual basis to gauge gender inclusiveness success and take appropriate action as indicated through data analysis.
Since program inception in 2006, gender disaggregated data have been analyzed annually to gauge gender inclusiveness and success (see section *VI. Human and Institutional Capacity Development* of

this report for more information). To help facilitate success, women's participation is integrated at the planning stage for all sponsored projects, utilizing context-based circumstances and information to anticipate and overcome obstacles on the ground.
Involve field projects in monitoring and evaluating gender integration as the program progresses with time. Evaluate the effects of specific projects on gender and ensure that any possible negative effects due to gender bias are mitigated.
Gender integration is a cross-cutting issue for all AquaFish projects. Gender Inclusiveness Strategies identify specific project approaches at the start of each project, whereby PIs and researchers in the US and Host Countries are involved in monitoring and evaluation throughout the research process. USAID reviewed each project gender integration plan and assisted in tailoring approaches for each investigation that consider conditions on the ground to help ensure success, with particular attention to women's involvement and mitigating any negative effects.
Focus one component of a lessons learned and synthesis assessment specifically on the social context and impact of AquaFish research and outreach activities on the lives of women.
AquaFish communicates gender activities and accomplishments through conference presentations, posters, AquaNews articles, and other media. In FY17, AquaFish produced and presented three gender-focused posters at Aquaculture America and the World Aquaculture Society 2017 Conference. The posters were titled: • *Empowering Women and Youth Can Advance Sustainable Aquaculture and Increase Food Security* • *Building Human Capacity and Gender Equity Among Global Aquaculture Stakeholders* • *Training Women and Youth to Enhance Sustainable Aquaculture and Increase Food Security*
Tailor specific extension and technical services related to sustainable aquaculture and aquatic resource management to women producers.
AquaFish tailors specific interventions to empower women through information and access to networks and resources. For example, in FY17, AquaFish researchers in Vietnam held three workshops on snakehead aquaculture specifically for women, reaching a total of 90 women in three provinces.
Engage extension specialists who are sensitive to diversity issues and access to resources of underrepresented groups and women will be included as an integral part of their delivery team to ensure women farmers and fishers feel welcome in AquaFish training opportunities.
As proposed, efforts are made to ensure women farmers are welcome at trainings. In FY17 researchers in Ghana trained 15 women tilapia farmers on optimal production techniques. Additionally, each AquaFish project includes women in key positions, serving roles such as investigators, research collaborators, and workshop leaders.
Promote the participation of women in formal and informal education and training opportunities provided through AquaFish. AquaFish has set a 50% benchmark for training women in formal and informal education. In addition, the 50% benchmark applies to attracting and retaining women scientists and administrators in all AquaFish activities, as project researchers, advisory group members, and managers.
AquaFish continues to set a 50% benchmark for the involvement of women in all programmatic activities. During FY17, women represented 45% and 51% of the AquaFish short and long-term trainees, respectively, with program efforts reaching 232 women in short-term trainings and 90 women in long-term training degree programs. Women are represented as key personnel on AquaFish projects, Advisory Groups, and in program management. Yet work remains in attracting and retaining women in lead research positions and in better involving women stakeholders in short-term trainings.

Gender-Focused Research and Outreach

Highlights of FY17 gender-focused work for the five AquaFish projects are included below.

Africa Project: Ghana & Tanzania

- AquaFish researchers in Ghana developed a service called the Fish Market Information System (FMIS), a web-based tool that provides tilapia market information online as well as via voice and text messaging. The database is populated with the prices at which fish are sold by the farms (farm-gate pricing) and market data for tilapia from several locations throughout the country. In FY17, researchers provided two trainings on the FMIS tool, reaching 38 women. The trainings were used to gather feedback from women to make the tool more user-friendly.

Africa Project: Kenya & Uganda

- In FY17, researchers in Uganda have been developing and strengthening relationships with local partners to increase the capacity of partner organizations to address women-specific issues in aquaculture. These groups include fish farmer cooperatives, women's aquaculture organizations, the Nutrition Innovation Lab, and more. This project also facilitated and supported the involvement of women graduate students in regional and international meetings in Uganda and South Africa. The objectives of this work are to increase the number of training and outreach events held for women and to improve women-specific trainings in aquaculture. A future objectives is to hold a capstone symposium on Advancing Nutrition and the Status of Women through Uganda Aquaculture.

Asia Project: Bangladesh

- Women continued to be integrated in all levels of AquaFish work in Bangladesh in FY17. Three women HC researchers from the Bangladesh Agricultural University played key roles in conducting research and outreach, with one serving as the HC Project PI. Under this project, researchers in Bangladesh found that the addition of mola in prawn gher farming systems shows no negative impact on the production of prawn, but enhances the total production of fishes. Integration of mola allows continuous consumption of this nutrient dense fish, helping to mitigate nutritional deficiencies and increase food security of households.

Asia Project: Cambodia & Vietnam

- During previous AquaFish efforts, researchers found aquatic animals to be the second largest staple food for women and children during the wet season in Cambodia. As the wet and dry seasons are vastly different in this region, researchers continued to expand on this work in FY17 to establish food consumption patterns in Cambodia and Vietnam during the dry season. Towards this effort, they trained nine staff from IFReDI and Can Tho University, including four women, on dietary assessment by using a 24-hour food recall assessment. Results from this work will allow for seasonal nutrition comparisons to inform recommendations on improving food security and household nutrition, particularly for women and children.

Asia Project: Nepal

- Research led by a HC investigator in Nepal who received her PhD under the Aquaculture Collaborative Research Support Program continued her work with women fish farmers on periphyton enhancement on carp and small indigenous fish species (SIS) polyculture yields. The use of periphyton enhancement has previously been shown to improve water quality discharged from ponds and increase net fish yield and profit in fish polyculture. In FY17, this research involved 21 women, who provided input on new periphyton enhancement structures and subsequently helped to test and evaluate the options.

REGIONAL CENTERS OF EXCELLENCE (RCE) ANNUAL REPORTS

The AquaFish Regional Centers of Excellence (RCEs) in Africa, Asia, and Latin America and the Caribbean have continued to strengthen community among AquaFish participants; identify potential new partnerships with the public and private sector, NGOs, USAID, and others; and bridge the knowledge gap from local and regional perspectives to global development outcomes. With a focus on graceful exits as AquaFish approaches closedown, the external advisors provided invaluable input through their participation at regional meetings and while in Cape Town, South Africa, in FY17. The following information was provided by RCE Coordinators, listed under *Technical and Advisory Committee Information*.

RCE – Africa Annual Report

Regional Needs for Aquaculture Development and Gaps in Technology Transfer and Adoption

Aquaculture development continues to be hindered in several African countries due to limited access to feeds, lack of quality seed, a focus on capture fisheries, inadequate infrastructure, and limited access to extension services. There are several country-specific constraints for aquaculture, such as political instability, unsustainable mining techniques, and the socio-cultural status of women. Youth unemployment and underemployment are critical issues facing Sub-Saharan Africa (SSA). In spite of urbanization and industrialization, agriculture including aquaculture remains the principal employer and producer throughout SSA. Thus, a more modern and profitable agriculture sector (including aquaculture, fisheries, forestry, and livestock) is required to generate much needed decent employment opportunities for the continent's youth.

Activities that Support Women's Involvement in Aquaculture and Fisheries

Women's roles in aquaculture vary throughout Africa and are often related to the socio-cultural roles of women in the specific regions. Women and youth experience barriers to participation in the agriculture sector, including inadequate access to education, employment, information, and power. RCE coordinators have encouraged HC PIs to offer more scholarships for women and organize women-specific trainings. The RCE coordinator for East Africa trained young women and men in pond aquaculture technologies in a collaborative effort with the Food and Agriculture Organization (FAO) (see details on this project in the Leveraged Activities section). Forty-five percent of the trainees were women.

Capacity Building and Information Dissemination

The RCE reached a range of audiences in its dissemination strategy, each requiring varying levels of investment and different approaches for effective communication. Specific approaches included:

- Maintaining an Africa RCE Web Page and an active presence on Facebook and Twitter.
- Facilitating networking with global scientists interested in African aquaculture through ISTA, SARNISSA, WAS, NEPAD, ANAF, and other meetings and conferences.
- Networking at professional conferences - for example, the RCE coordinators attended and presented at the World Aquaculture 2017 conference held in Cape Town from June 26-30, 2017. At the meeting, the African Chapter of the World Aquaculture Society was launched; the RCE and AquaFish MT supported a former AquaFish CRSP colleague in initiating this chapter.
- Engaging stakeholders in the region to develop and adopt new aquaculture technologies.

Leveraged Activities

The Africa RCE has been an active participant in engaging various organizations and governments to leverage aquaculture development.

- Funds were leveraged from the Danish International Development Agency to support several graduate students at KNUST.
- The Ministry of Agriculture, Livestock and Fisheries (Kenya) partnered with FAO to implement a three-year program from October 2014 to December 2017. This program aimed to create

employment opportunities for young women and men in aquaculture to improve their income and access to food, including fish products in the local markets.
- RCE Coordinators applied for a grant with the World Bank Agritech Challenge on use of software to assist farmers with record keeping and improve their pond production.
- To build upon AquaFish research, the RCE Coordinators have combined efforts with Ghana, Kenya, and Malawi and have applied for an African Union Grant.
- The RCE Coordinators partnered with research funding agencies in Norway, the Netherlands, Ghana, and Kenya to apply for a request for applications for aquaculture projects through LEAP-Agri.

RCE – Asia Annual Report

Regional Needs for Aquaculture Development and Gaps in Technology Transfer and Adoption

The main aquaculture research needs in the Asia region are improved technologies for optimizing farming systems for increased ecological efficiency, reducing negative environmental impacts, improving food safety, and increasing profitability. Additionally, more effort is needed to better understand how to monitor and manage fish health. Countries with less developed aquaculture industries require additional effort in fish feeds and seed production. Finally, there is a need to address climate change mitigation and adaptation.

Activities that Support Women's Involvement in Aquaculture and Fisheries

The RCE Asia is affiliated with the Network of Aquaculture Centres in Asia-Pacific (NACA), an intergovernmental organization that promotes rural development through sustainable aquaculture. Currently NACA is carrying out several activities that support women's involvement in aquaculture and fisheries, including training on gender assessment, policy advocacy for more gender sensitive policies, assessment of gender policies and programs for aquaculture, and assessment of training needs among women in the aquaculture value chain.

Capacity Building and Information Dissemination

The Asia RCE coordinator was involved in the following outreach and dissemination activities in FY17:
- Continuing training focused on developing culture-based fisheries in Cambodia.
- Aiding in the development and translation of guidebooks in English to local languages for farmers of small-scale aquaculture.
- Presenting at the AquaFish Regional Meeting and attending the World Aquaculture Society conference in South Africa.
    - Derun, Y. 2017. Shifting Dynamics of Aquaculture in Asia and Inclusion of Small Scale Farmers. [Oral Presentation]. AquaFish Asia Regional Meeting, Bharatpur, Nepal, 28 February – 4 March 2017.

Leveraged Activities

The Asia RCE coordinator leveraged funds to build regional capacity for aquaculture and continued aquaculture research.
- With NACA support, the RCE coordinator helped build regional capacity for aquaculture development through training and education with several partner institutions, including conducting an assessment of training needs.
- Several NACA and FAO projects continue to document successful farming cases in sustainable intensification of aquaculture and to review the current situation of aquaculture feed production and use in NACA member countries.

RCE – Latin American and Caribbean Annual Report

While current AquaFish work is focused principally in Africa and Asia, the LAC RCE plays an important role in maintaining communication with past and present AquaFish collaborators, building capacity, and leveraging resources in the region.

Regional Needs for Aquaculture Development and Gaps in Technology Transfer and Adoption

The aquaculture industry in the LAC is affected by economic hardship, resulting in increases in the cost of equipment and feed ingredients. A major concern in Brazil centers on inefficient bureaucracy and delays in receiving environmental licenses. These issues have led to farms operating illegally, ultimately disqualifying them from access to credit. Continuing research remains the greatest need in the LAC, specifically on understanding public policy barriers, incorporating marine species into the aquaculture industry, managing the spread of shrimp diseases, identifying new ingredients to improve diets, developing technologies that enable small-scale farmers, and focusing on issues that relate to the daily lives of fish farmers. In spite of the need, research funds have become increasingly difficult to secure.

Activities that Support Women's Involvement in Aquaculture and Fisheries

Despite many countries in the region having programs to support women, women's involvement in aquaculture in LAC continues to be limited almost exclusively to fish processing. One of the RCE coordinators has begun collaborating with FAO-Nicaragua and has proposed a major role for women in the new project. The AquaFish RCE Coordinator for South America, Dr. Maria Portella, serves as a role model for women in aquaculture. She is the current president of World Aquaculture Society and Dr. Portella has given lectures addressing women in science and aquaculture more specifically.

Capacity Building and Information Transfer

The LAC RCE coordinators have been involved in the following capacity building and dissemination efforts:

- Participating in regional and international conferences including serving as program chair, conference organizers, and presenters.
- Serving leadership roles - Dr. Portella was elected as the President of the World Aquaculture Society.
- Offering expertise to hatcheries for native species reestablishment in Guatemala and Nicaragua.
- Guiding policy and management by fostering global collaboration - LAC RCE coordinator is a principal investigator for LARVAplus, an integrative research network for promoting fish larviculture in Ibero-America.

Leveraged Activities and Associate Awards

The RCE Coordinators in LAC leveraged funds for student support, professional networking, and lab expansions.

- Facilitated collaboration within Central and South America - Worked with FAO-Nicaragua on a governmental project for building a marine hatchery to produce common snook fingerlings. Dr. Contreras-Sánchez secured a grant from FAO to support training on snook aquaculture in Nicaragua and supported several undergraduate students.
- Dr. Portella secured leveraged RCE funds to obtain scholarships for students, one specifically for a student to study at Purdue University on aquaponics systems.
- Dr. Portella received a Productivity Fellowship through CNPq support.

XII. ISSUES AND CHALLENGES

Since inception, AquaFish has utilized an innovative web-based platform to manage and communicate with subcontracting partners. The platform evolved over the life of the award into a well-established, secure website, where project participants could enter data, track the status of their projects, and submit project materials. The utility of this website was enhanced by employing password-protected access, individualized for each project participant. The resulting platform allowed transparency between the MT and our partners in project management from tracking proposal submissions, all the way through to submitting deliverables toward meeting their subcontract requirements. This tool also allowed the MT to integrate detailed project information into program-wide databases, and proved essential for efficient and timely monitoring and evaluation, research synthesis, and project reporting to USAID. Unfortunately, in FY17 the AquaFish website was compromised and required a complete rebuild. All materials were eventually recovered (thanks to routine website back-ups) and the MT worked around the clock to rebuild a public (non-secure) website. The MT concluded that it would not be worth the resources to rebuild the complex, non-public/restricted side of the website for tracking project progress because of the short time period remaining on the award and the website host's (OSU's) new mandatory Drupal website format. Instead, the MT was able to develop a new system to securely track and communicate with project partners with the resources and limited time available Although this new mechanism has been effective, the process of redesigning and building a secure communications system has been burdensome, absorbing already limited resources as we entered into the reporting and compliance-intensive closedown period of this award.

AquaFish received official notification of a USAID external evaluation of the program in February 2017, to be conducted by a panel convened under the Program Evaluation for Effectiveness and Learning (PEEL) task order contract to Mendez England & Associates. The MT communicated to USAID an interest in a collaborative review process, timely notification of the evaluation schedule to share with HC partners, and an understanding of the PEEL team's membership and expectations. The MT recognizes the importance of these evaluations to USAID, however, several false starts, changes in the evaluation team membership, and changes in the evaluation team's methodology have resulted in considerable uncertainty as to the timeline and substance of the evaluation. HC partners are interested in assisting with the evaluation, but have been on "alert" for over 8 months and some partners had set aside time for anticipated site visits by the review team. Contact information for key partners has been requested directly by the evaluation team, but none have occurred to date. Due to evaluation team restructuring, several opportunities were missed to engage with project partners in-person, including well-attended AquaFish meetings in Nepal and South Africa. It has been a challenge to communicate clear evaluation timelines, methodologies, and objectives to our US and HC partners in a manner that allows them to meaningfully engage and participate in the evaluation process.

During the final years of this award, the Management Team has actively engaged with partners–through visits to US and HC institutions, regional meetings, and regular conference calls directly with US and HC researchers–to facilitate project progress. Despite this effort, delays have occurred for a variety of reasons, including due to the effects of natural disasters (such as recent drought in East Africa, severe flooding in Bangladesh and Nepal, and lingering effects of the devastating 2015 earthquake in Nepal) and limited/unreliable access to inputs (e.g., fish feeds, fingerlings, etc.) that resulted in missed growing

seasons. Travel delays have also resulted from efforts to maintain personnel safety overseas. For example, the US State Department issued several travel warnings for AquaFish Host Countries during this fiscal year, which caused site visits by US researchers to be rescheduled. In addition, personnel turnover, retirements, and administrative restructuring have caused delays in contractual and accounting/financial functions (including processing invoices, executing contracts, etc). Further, political unrest within host countries and issues at HC institutions (such as prolonged university closures and strikes, personnel turnover, and student protests) have also contributed to delays. AquaFish has successfully developed a network of strong and resilient projects that are equipped to survive these kinds of disruptions. However, it has been noted that major research delays in the final year of the project are much more difficult to manage around while still meeting contractual deadlines.

The AquaFish Innovation Lab received email notification from BFS's Office of Agricultural Research & Policy regarding uncertain and delayed funding levels for global food security efforts. While the Management Team appreciates early notification of funding delays, it is only when the award modification is received by the ME and fully executed that funds can be responsibly programmed. Last year's funds arrived on 20 December 2016, three months late. Again, this year, USAID noted that new funding will likely not be available earlier than the first quarter of FY18 and advised Innovation Labs to manage current funds prudently. AquaFish typically receives annual funding prior to the start of each fiscal year, allowing the ME time to program funds effectively, prevent subaward termination, and if needed, modify the work plan to accommodate changes in funding levels. Uncertainty regarding funding levels and timing impacts the ability of AquaFish to program funds responsibly and meet grant objectives within the proposed timeline – especially when delays occur within the last 6 months of the award.

XIII. FUTURE DIRECTIONS

The AquaFish Innovation Lab prioritizes research to improve sustainable aquaculture practices and transfer technologies to individuals and institutions through capacity building efforts, such as training events, long-term educational support, curriculum development, as well as establishing and strengthening institutional partnerships within and between countries. AquaFish will continue to monitor project progress through various mechanisms, including Feed the Future Monitoring System metrics, disaggregated short- and long-term training data, and benchmarks. With the award coming to a close, AquaFish will be finalizing all lines of research and focusing efforts more heavily on outreach, dissemination, and capacity building to enable host countries to continue to independently implement best aquaculture practices and to build on existing work.

2016-2018 Research and Capacity Building

Research and capacity building efforts that are underway as part of the AquaFish 2016-2018 Implementation Plan (http://aquafishcrsp.oregonstate.edu/page/implementation-plans) will come to a conclusion in FY18 with termination of the AquaFish Innovation Lab award. Current projects in Bangladesh, Nepal, Cambodia, Vietnam, Ghana, Tanzania, Uganda, and Kenya, as well as a US-based desk study focused on Burma, will be finalizing all lines of research and disseminating findings. The AquaFish Management Entity at OSU will be working with its lead US investigators at Auburn University, Michigan State University, North Carolina State University, Purdue University, University of Connecticut, and University of Michigan towards research completion and to maximize program outputs.

Information and Technology Dissemination

With a focus on outreach and dissemination during the final award period, AquaFish will continue to increase efforts in FY18 towards ensuring that research findings and technologies developed are transferred to relevant stakeholders. As part of this effort, the Management Team (MT) has undertaken a process to archive the AquaFish website so that key reports, publications, and outreach materials produced over the duration of the award remain accessible once the program closes down in FY18. With all lines of research scheduled to be completed in FY18, researchers will be producing final technical reports as well as peer-reviewed publications to disseminate findings to the scientific community. In turn, the MT will be working with AquaFish researchers to upload their qualified datasets to public data repositories as required under ADS 579. AquaFish will also be holding an Annual Meeting in in conjunction with the Aquaculture America 2018 Conference in Las Vegas, Nevada, in February, and will also be hosting a full-day technical session at the conference to highlight AquaFish research successes.

Planning for a Graceful Exit

During this final period, it is a high priority to ensure that over a decade of AquaFish-supported research and capacity building is transferred to host countries so that they can continue to build on and carry work forward. To accomplish this, AquaFish will have a greater focus on outreach and dissemination to transfer knowledge and technologies to HC researchers, extension agents, farmers, industry personnel, managers, policy makers, and other stakeholders. Each project developed an Exit Strategy in FY16 describing a plan for a graceful exit after the AquaFish program ends in March 2018. The AquaFish MT will be working with our partners to monitor progress towards these strategies to assist with seamless transitions to our HC partners.

Assessing Programmatic Impacts
The development of sustainable feeds and feed strategies is a cross-cutting area of AquaFish research that is critical to successful aquaculture development regionally and globally. In FY17, AquaFish initiated a review of research conducted since program inception in 2006 on feed ingredients and feed strategies and on resulting technologies and their adoption, transfer, and scalability. AquaFish will compile findings from the review and will release this program-wide "impact assessment" report in FY18, thereby helping inform future aquaculture research on feeds.

No-Cost Extension Request
Several lines of research were delayed in FY17 due to natural disasters (e.g., drought in East Africa and flooding in Nepal in Bangladesh), limiting resources (e.g., feed and seed), and political challenges, among other reasons. AquaFish thus requested a no-cost extension (NCE) from USAID to enable the program to more comprehensively accomplish research and capacity building objectives. With nearly 40 training activities still planned and less than five months remaining of the AquaFish award, information dissemination and technology transfer would benefit from additional time. An NCE would thus enable AquaFish to maximize program impacts by more comprehensively transferring and scaling our results and technologies in FY18.

APPENDIX A: SUCCESS STORIES

SCHOOL PONDS ENHANCE HIGH SCHOOL CURRICULUM AND IMPROVE HOUSEHOLD NUTRITION AND FOOD SECURITY IN NEPAL

In Nepal, where 8% of the population is undernourished, AquaFish is working to improve food security and household nutrition by partnering with students, teachers, and women's groups while mentoring and teaching them about sustainable aquaculture production and health benefits of consuming fish. AquaFish researchers from the Agriculture and Forestry University in Nepal, the University of Michigan, and Oregon State University in the US created school pond programs at public schools in the Chitwan and Nawalparasi districts. Four ponds were established and used to train teachers and school-age children from grades 8 to 10 on how to manage pond water levels; fertilize, feed, and harvest fish; and prepare fish for household consumption.

To create linkages with the community, AquaFish organized two women's fish farming groups in the school communities. Members learned about the importance of household aquaculture for nutrition and income generation. Connecting the local women's groups to the school pond project spread the value of fish production and consumption among households and ensured long-term school pond sustainability.

The first phase of the school pond program project trained 121 students (64 girls and 57 boys) and eight teachers and engaged with 44 women through women's groups. To measure knowledge transfer, students were given pre- and post-tests. For each school, median grades for pre-tests were <40%, increasing to post-test medians ranging from 61-80%. Only 4% of students scored 60% or better on the pre-test, but after participating in the curriculum and hands on training, 85% of students scored higher than 60%.

Results indicate that the school pond program is contributing to the knowledge of science-based aquaculture in the curriculum, with the added bonus of after school interest in aquaculture for family ponds. After the first year, pond ownership by the households of students increased by 4% and the number of times per year student households consumed fish increased by 47%. Surveys reveal that women and children living in homes with household ponds consume more than twice as much fish as homes without ponds. Most fish cultured in Nepal are consumed in the home; otherwise, pond owners share fish with friends, further contributing to improved nutrition and health among families in local communities.

Student participant of the school pond curriculum at Janta Higher Secondary School in Kawasoti poses with his mother in front of a pond they constructed within a few months of receiving AquaFish training (Photo courtesy of AquaFish Innovation Lab).

In response to the community's increased interest, AquaFish expanded the project to include two additional schools, mentoring 83 more students (44 girls and 39 boys).

Community members recognize the role of the school ponds in improving their community and are seeing the added value among their villages. This project confirms that schools can serve as a foundation to empower women and youth with knowledge and skills on aquaculture to positively impact household nutrition and food security.

OPTIMIZATION OF VITAMIN C IN FEED FOR SNAKEHEAD FISH (*CHANNA STRIATA*) CULTURE IN VIETNAM

In Vietnam, snakehead (*Channa striata*) is considered one of the most valuable cultured fish due to its high quality meat and reasonable price. As a result, total production of snakehead in the Mekong Delta increased rapidly from 14,478 metric tons in 2006 to 77,682 metric tons in 2016. The growth of snakehead aquaculture increased the need for pelleted diets with alternative protein sources to decrease the traditional use of small, wild-caught fish harvested from the Mekong Delta.

Research collaborations between Can Tho University (CTU) in Vietnam, University of Rhode Island (URI), University of Connecticut (UConn), and Oregon State University, in the US, addressed the need to reduce the reliance on small-sized fish as feed by formulating a pelleted feed with soy protein without compromising the growth performance and marketability of farmed snakehead. AquaFish partnered with private feed mills in the Mekong Delta, leading to over 10 manufacturers committing to making the pelleted feed. In 2011, only 33% of Vietnamese snakehead farmers in 13 southern provinces used pelleted diets, but by 2015 more than 90% of those farmers used the pelleted feeds developed by AquaFish.

Experimental ponds containing hapa cages used during snakehead feeding trials (Photo courtesy: Pham Minh Duc).

Farmers, however, reported that fish fed pelleted feed often had a 'hunchback-like" appearance. Despite the fact that the feed originally contained 80-150 mg/kg vitamin C, on-farm, commercial-scale trials confirmed these reports and revealed that 20% of fish fed pelleted feed developed spinal column abnormalities, such as lordosis and scoliosis, which are commonly associated with vitamin C deficiency.

Vitamin C supplementation has several benefits, such as decreased likelihood of skeletal deformities and increased fish growth, survival, and disease resistance. Therefore, AquaFish incorporated laboratory and on-farm trials into the next phase of research to determine the optimal dietary vitamin C levels.

During laboratory feeding trials, soy-based fish meal (45% protein) was supplemented with varying levels of vitamin C (ranging from 0 to 2000 mg vitamin C per kg feed). Results showed that growth rates and protein efficiency ratios were significantly greater in fish ingesting vitamin C supplemented feed compared to diets without vitamin C. Optimal growth rates of snakehead resulted in fish fed diets supplemented with 500 mg/kg vitamin C. Farm trials confirmed that lab results also apply to on-farm conditions, where soy-based pelleted diets containing vitamin C resulted in significantly lower rates of spinal abnormalities, and greater growth rates and protein efficiency ratios, when compared to fish fed commercial feed.

Overall, AquaFish research revealed that feed supplemented with 500 mg/kg vitamin C, a larger amount than previously thought adequate (80-150 mg/kg), resulted in optimal production costs and fish growth in commercial-scale farms. Improved fish health and fish growth from vitamin C supplemented feed has great potential for increasing farmers' incomes and decreasing negative environmental impacts by reducing reliance on previously declining stocks of wild fish. These findings serve as a fundamental step in building a more sustainable and cost-effective snakehead aquaculture strategy that maximizes fish health and productivity in the Mekong Delta and beyond.

DIGITAL AND MOBILE PHONE-BASED FISH INFORMATION SYSTEMS CONNECTING USERS ACROSS GHANA AND UGANDA

For small-scale aquaculture in Africa, some of the challenges to sectoral growth are due to a limited flow of information along the aquaculture value chain. Addressing these challenges is critical because improving aquaculture productivity and expanding market access for rural farmers can greatly increase income generation and food security in developing nations.

For many farmers, mobile phones serve as the most efficient means of communication, and can contribute to savings in time and money. To help further advance aquaculture, AquaFish Innovation Lab partners in Uganda and Ghana are building on earlier mobile platforms in Kenya, and developing digital and mobile-based support systems to promote information transfer on aquaculture production, marketing, and sales.

In Uganda, AquaFish researchers from Auburn University and Oregon State University (OSU) in the US and Uganda's National Fisheries Resources Research Institute (NaFIRRI) and Makerere University partnered with Likamis Software Limited to develop aquaculture training modules through the Agro Market Day's mobile application (app) (http://www.agromarketday.com/). Within the Agro Market Day app, an automatch algorithm populates market prices and connects buyers with sellers.

Based on a needs assessment survey, eight technical modules were built on pond design, construction, and management; fish stocking, feeding, and harvesting; and overall fish health. The modules were built for both smartphones and basic, text-based mobile phones and the content has been translated into five languages: English, Luganda, Lunyankore, Ateso, and Acholi.

AquaFish researchers in Uganda share Agro Market Day mobile application at a local outreach event (Photo courtesy of Isaac Omiat).

AquaFish is broadly disseminating the application to farmer groups, buyers, input companies, consultants, organizations, and training institutions. Testing is underway via extension agents, students, and end-users in central, eastern, and northern regions of Uganda, as well as with the women's fish farmer network near Kampala. Based on user feedback, project partners will revise the app and plan to launch to a broad audience at the Uganda Fish Farmer Symposium in January 2018.

In Ghana, AquaFish researchers from Purdue University and OSU in the US and Ghana's Kwame Nkrumah University of Science and Technology (KNUST) developed a service called the Fish Market Information System (FMIS). FMIS is a web-based tool that provides tilapia market information online as well as via voice and text messaging. AquaFish researchers collaborated with officers from the Ghana Fisheries Commission and a local programming company, Farmerline, to create and populate a central database hosted by researchers at KNUST. Once new market information is uploaded, the system distributes this data in near real-time to users. Already, Farmerline has reported over 320 registered users. At the end of the project in 2018, Dr. Steve Amisah, AquaFish researcher from KNUST, said "We are hopeful to have 5,000 registered users, including fish marketers and processors from across the southern [region] of Ghana." A new version of FMIS was recently piloted at workshops with 107 local fishers in Elmina and Accra in Ghana. "The Chief Fisherman expressed satisfaction of the relevance of the training," said Dr. Amisah.

Given the parallel development of these technologies in Uganda and Ghana, and previous research in Kenya, AquaFish partners were able to share best practices, successes, and challenges across projects. A challenge that both projects faced and overcame was obtaining short-code – code that is often expensive and requires technical expertise, but enables cell-based systems to be more broadly adopted. In both cases, industry partnerships have strengthened the end product by helping overcome technical challenges and by transferring and scaling the mobile technologies once developed.

As access to and use of mobile phones in Africa continues to grow, so does the importance of mobile phone technologies for increasing capacity and data sharing among all key players along the fish value chain. Timely and verified information provided through AquaFish mobile phone technologies in Uganda, Ghana, and Kenya are empowering fish farmers, buyers, and other stakeholders, and can serve as a building block for future innovative technologies that address food security challenges.

APPENDIX B: AQUAFISH PUBLICATIONS

The following is a list of publications and peer-reviewed articles by AquaFish Innovation Lab (formerly AquaFish CRSP) investigators on their AquaFish-sponsored research. Some of the publications before 2009 may be attributable in part to the Aquaculture CRSP. For nearly two years, from 2006-2008, the Aquaculture CRSP overlapped with AquaFish CRSP.

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Ahmad, S.A.S., A.N. Bart, Y. Yi, J.E. Rakocy, and J.S. Diana. 2009. The Effect of the Introduction of Nile Tilapia (*Oreochromis niloticus*, L.) on Small Indigenous Fish Species (Mola, *Amblypharyngodon mola*, Hamilton; Chela, *Chela cachius*, Hamilton; Punti, *Puntius sophore,* Hamilton). Aquaculture Research 1–9:904–912.

Ahmed, N. and J.S. Diana. 2016. Does Climate Change Matter for Freshwater Aquaculture in Bangladesh? Regional Environmental Change 16(6):1659–1669.

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