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

AQUAFISH TENTH ANNUAL REPORT

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USAID FROM THE AMERICAN PEOPLE

OSU Oregon State University

AQUAFISH INNOVATION LAB

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TENTH ANNUAL REPORT

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Cover Photo
A hapa containing fish in a pond in Tanzania. Credit: Dr. Hillary Egna

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 two internal and one external advisory groups: Development Themes Advisory Panel, Regional Centers of Excellence, and External Program Advisory Council.

DEVELOPMENT THEMES ADVISORY PANEL (DTAP)

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 identified by USAID, including emphases on gender; human institutional and capacity development; biodiversity; aquatic ecosystem health; poverty; soil and water quality; biotechnology; and nutrition. Coordinators also review 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 FY16 were as follows:

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 FY16 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 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 Food and Agriculture Organization of the United Nations (FAO), World Bank, non-governmental organizations, CGIAR, Borlaug Higher Education for Agricultural Research and Development, and others. EPAC members for FY16 were:

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

AquaFish Project Countries FY16

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 250 institutions globally. AquaFish builds and maintains its network through formal funded partnerships as well as through non-funded collaborations.

Funded Project Partners in FY16

(The list below includes all institutions in formally-funded partnership with AquaFish during FY16.)

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

Philippines
Central Luzon State University
Southeast Asian Fisheries Development Center - Aquaculture Division

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-FY16)

(This is a comprehensive list of AquaFish linkages from inception in 2006 through FY16.)

Australia
Monash University (Melbourne)

Bangladesh
Bangladesh Agricultural University
Bangladesh Department of Fisheries
CGIAR-WorldFish, South Asia & Bangladesh
Chanchal Hatchery (WorldFish 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 Fish 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
AFU	Agriculture and Forestry University
AquaFish	The Feed the Future Innovation Lab for Collaborative Research on Aquaculture & Fisheries (Formerly Aquaculture & Fisheries CRSP)
AOR	Agreement Officer's Representative
ASEAN	Association of Southeast Asian Nations
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
DAI	Development Alternatives Incorporated
DTAP	Development Theme Advisory Panel
EdOpNet	Educational Opportunities Network
EPAC	External Program Advisory Council
FAO	Food and Agriculture Organization of the United Nations
FARDeC	Freshwater Aquaculture Research and Development Center
FCR	Feed Conversion Ratio
FFA	Future Farmers of America
FSV	Food Safety, Post Harvest, and Value-Added Product Development
FTF	Feed the Future
FTFMS	Feed the Future Monitoring System
FY14	Fiscal Year 2014 (01 October 2013 – 30 September 2014)
GIS	Geographic Information System
GMO	Genetically Modified Organism
GTIS	Guyana Trade and Investment Support
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
iAGRI	Innovative Agriculture Research Initiative
IFReDI	Inland Fisheries Research and Development Institute
IIFET	International Institute of Fisheries Economics & Trade
IMS	Institute of Marine Sciences
IND	Climate Change Adaptation: Indigenous Species Development
IPM	Integrated Pest Management
ISTA	International Symposium on Tilapia in Aquaculture
KMFD	Kenya Ministry of Fisheries Development
KMT	Kenya Marketing Trust
KNUST	Kwame Nkrumah University of Science and Technology
LLC	Limited Liability Company
LWA	Leader-with-Award

M&E	Monitoring and Evaluation
MER	Marketing, Economic Risk Assessment, and Trade
ME	Management Entity
MNE	Mitigating Negative Environmental Impacts
MOU	Memorandum of Understanding
MT	Management Team
NaFIRRI	National Fisheries Resources Research Institute
NCE	No Cost Extension
NCSU	North Carolina State University
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OSU	Oregon State University
PD/A	Pond Dynamics/Aquaculture
PDV	Policy Development
PI	Principal Investigator
PoC	Point of Contact
QSD	Quality Seedstock Development
RCE	Regional Center of Excellence
RFP	Request for Proposals
SARNISSA	Sustainable Aquaculture Research Networks in Sub-Saharan Africa
SIS	Small Indigenous Species (of fish)
SFT	Sustainable Feed Technology and Nutrient Input Systems
SMIS	Seafood Market Information System
SOU	Shanghai Ocean University
SUCCESS	Sustainable Coastal Communities and Ecosystems Program
TIES	Training, Internships, Education and Scholarships Program
UK	United Kingdom
UN	United Nations
US	United States
USAID	United States Agency for International Development
USG	United States Government
VCA	Value Chain Assessment
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) and was extended for an additional five years (Phase II) from 31 March 2013 to 29 March 2018.

The AquaFish Tenth Annual Report describes activities and accomplishments of the AquaFish Innovation Lab from 01 October 2015 to 30 September 2016 (FY16). FY16 was a transitional year that included research on investigations from *Implementation Plan 2013-2015* (*IP 2013-2015*) and *IP 2016-2018*. During this reporting period, 20 Host Country institutions in nine 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 maintaining alignment with the US Government's Feed the Future (FTF) Initiative. In investigations across five projects, Phase II research focuses on improving sustainability of aquaculture and fisheries through the development of innovative technologies and outreach techniques that enhance the sustained well-being of the poor. In FY16, AquaFish led 33 investigations as part of *IP 2013-2015* and continued successful lines of research to maximize impacts through 24 investigations under *IP 2016-2018*.

As part of USAID's Bureau for Food Security (BFS) *Feed the Future Food Security Innovation Center*, AquaFish operates under the *Program for Research on Nutritious and Safe Foods*. AquaFish has adapted its research portfolio to include the impacts of sustainable aquaculture and fisheries on human nutrition while maintaining a focus on food security and safety. Human nutrition is a unifying thread in AquaFish research and we are continuously helping meet nutrition needs and increase food security for rural and vulnerable families by promoting sustainable aquaculture technologies and practices. In FY16, AquaFish research in Bangladesh and Nepal found that polyculture of two or more fish species not only led to an increase in profits and fish production, but also led to higher consumption of nutrient-dense fish species, such as mola and mud crab. Household nutrition surveys in Ghana revealed that fish farming households have higher dietary diversity and food security than non-fish farming households. Research projects like these help inform the potential impacts that 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.

In FY16, a more than 10-year-long ban on snakehead culture in Cambodia was lifted and AquaFish played a large role. Through the development of sustainable feeding strategies that focused on plant-based pelleted feeds for the highly carnivorous fish, as well as successful hatchery technology, AquaFish research in Cambodia and Vietnam continued to refine and expand research to ensure an economically- and ecologically-sustainable snakehead aquaculture sector. The lifting of this ban has the potential to increase food security and well-being for millions of disadvantaged people in the region who depend on fisheries and other ecosystem services for food, income, and livelihoods.

AquaFish is dedicated to improving gender equity and equality in the aquaculture and fisheries sectors. AquaFish strives to involve women throughout the aquaculture value chain. As a result of an AquaFish project in Zanzibar that taught women spat collection and nursery methods for shellfish culture, women from two villages are earning income through the sale of pearl jewelry. These women have been able to take this extra income and invest in the building of houses, purchasing of a fishing boat, and paying of school fees for their children. In addition, they have started to make and sell non-shell handicrafts and necessities, such as soap, paper bags, and food. AquaFish sets a benchmark of 50% participation by women in all types of training activities, whether it be as a trainee at a one-day workshop or a student enrolled in a long-term, formal degree program. Overall, in FY16, AquaFish achieved this benchmark, with equitable participation by men and women in short- and long-term training activities. Short-term trainings addressed a variety of innovative aquaculture strategies, including impacts of climate change on the fish value chain, polyculture systems, and expansion of market information via cell phone technologies. Providing support to women through long-term educational training increases their involvement in aquaculture early in their academic careers, helps create connections and build networks that can be accessed far into the future, and prepares them to serve in lead research and administrative positions to contribute to long-lasting gender equity.

Human and institutional capacity development (HICD) underpins the AquaFish research mission. 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 FY16, seventeen short-term training events were held, reaching a total of 526 participants. In addition, AquaFish supported and mentored 158 students in long-term formal degree programs at 22 institutions in nine countries. AquaFish researchers also helped build community capacity by working with fish farmers to test new technologies using their own aquaculture ponds and to engage with regional stakeholders at symposia and conferences. For example, the Annual Fish Farmers Symposium and Trade Show in Uganda allowed hundreds of participants, including current and potential fish farmers, to share ideas and experiences and learn about innovative, emerging technologies that can help reduce operational costs and increase profits.

Additional AquaFish HICD efforts include sponsorship and coordination of international aquaculture conferences, mentorship of students and scientists, and institutional strengthening. In FY16, AquaFish and its Director Dr. Hillary Egna served as sponsor, organizer, and session chair at the Asian-Pacific Aquaculture 2016 (APA16) conference, the 11th Asian Fisheries and Aquaculture Forum (AFAF), and the 6th Global Symposium on Gender in Aquaculture and Fisheries (GAF6). While at AFAF, two early-career scientists received AquaFish-sponsored Yang Yi Young Scientist Fellowships. AquaFish also presented three awards for best papers at the 18th Biennial International Institute of Fisheries Economics and Trade (IIFET) 2016 conference. AquaFish's support of these conferences and emerging scientists showcases a commitment to building human capacity in research, education, and outreach.

2016 Yang Yi Young award recipients, Isagani P. Angeles Jr. (left) and Laila M. Gallego (right) with AquaFish Innovation Lab Director, Dr. Hillary Egna (center).

Capacity at AquaFish Host Country institutions continued to strengthen in FY16. Long-standing AquaFish partner institution Kwame Nkrumah University of Science and Technology (KNUST) received the National Best Pond Fish Farmers Award and a Certificate of Merit for contributing to the development of sustainable aquaculture in Ghana. At the Inland Fisheries Research and Development Institute (IFReDI) in Cambodia, staff were taught complex mathematical and scientific concepts regarding aquaculture carrying capacity and modeling. Efforts to increase capacity, demonstrated by these examples, enable researchers to understand complex concepts necessary for the development of adaptable and efficient technologies that support sustainable aquaculture practices.

In FY16, AquaFish and Dr. Egna received external recognition of the program's value and commitment to sustainable aquaculture development. In August 2016, the Asian Fisheries Society (AFS) honored AquaFish and Dr. Egna with Gold Medal awards for longtime support of AFS, as well as Dr. Egna's decades-long commitment to mentor and support many early-career scientists from the Asia-Pacific region. In September 2016, Dr. Egna was highlighted as the Woman of the Month by Aquaculture without Frontiers (AwF) for her legacy of aquaculture research programs. These acknowledgements highlight Dr. Egna and AquaFish as leaders in capacity building and international development.

AquaFish engages in outreach and dissemination activities to communicate results to stakeholders globally and to increase awareness of the development of innovative and sustainable aquaculture technologies. In FY16, 36 presentations were made by AquaFish researchers at international scientific conferences and meetings and 15 articles were published in peer-reviewed academic journals and trade magazines. Since 2006, nearly 250 peer-reviewed manuscripts were published on AquaFish-related research. AquaFish also continued to increase its national and international audience as an exhibitor at international conferences such as APA16 and AFAF, as well as at OSU-sponsored events, including Earth Day and University Day. AquaFish continued to produce newsletters like *AquaNews* and *EdOpNet*, while also answering public inquiries about AquaFish opportunities and aquaculture production strategies. Through these outreach activities, AquaFish is able to fulfill its mission by sharing reliable research results, expanding the network of researchers dedicated to sustainable aquaculture practices, and staying informed on the latest innovations and technologies in aquaculture and fisheries.

II. PROGRAM ACTIVITIES AND HIGHLIGHTS

The AquaFish mission is built around sound science, education, and outreach that improve the health and well-being of vulnerable communities through aquaculture and fisheries research. Toward this goal, in FY16 AquaFish conducted research with leading scientists in developing countries and the US, continued building and strengthening international multidisciplinary partnerships, and disseminated research results at international conferences and in scientific journals and trade magazines.

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 24 institutions and organizations in Africa and Asia in FY16. AquaFish researchers worked on 33 investigations and began to focus research on 24 of those investigations to last until the program's end in March 2018. All of these investigations center around two main themes: *Integrated Production Systems*, and *People, Livelihoods, and Ecosystem Interrelationships*.

A primary objective of AquaFish is to conduct sound scientific aquaculture and fisheries research that creates innovative and sustainable technologies and production practices to help increase food security and safety in environmentally responsible ways. Notable research includes efforts to generate additional income and increase access to a wider variety of nutritious foods through polyculture systems. Research in Bangladesh and Nepal found that culturing two or more species in one aquaculture system not only reduced operational costs while maintaining profitable yields, but also increased income and household fish consumption. AquaFish feeds research also helped reduce operational costs and increase environmental sustainability by testing alternative protein ingredients in commercial feeds. In Tanzania, researchers produced feeds using maggot meal and worm meal. They found that feeds comprised of 35% of either of these ingredients are more cost-effective at producing a unit of fish than their more expensive commercial fish-meal counterparts.

Expanded market access contributes to increased income generation and food security. In Ghana and Uganda, AquaFish researchers developed and tested cell phone applications that supply market information to both sellers and buyers. These innovative technologies can help expand the flow of information throughout the value chain, leading to reductions in post-harvest losses and marketing costs. The system in Ghana, called the Fisheries Market Information System (FMIS), already has close to 500 users as of September 2016, with that number expected to rise exponentially to over 5,000 in 2017.

Climate-smart aquaculture strategies are essential to address changing climates that can have negative impacts on vulnerable populations. In Bangladesh, a poor nation situated almost entirely on a low-elevation river delta, saltwater intrusion has presented an ongoing challenge to expanding freshwater aquaculture in the region. In FY16, AquaFish researchers successfully raised *Pangasius* catfish in hyposaline conditions, potentially enhancing *Pangasius* production in Bangladesh by 60,000 tons. In Kenya in FY16, AquaFish researchers assisted a school in Eldoret to develop a small-scale aquaponics system for demonstration. AquaFish partners used a previously-tested system that successfully grew multiple crops under differing fish densities. This is effective technology for tropical regions where drought conditions often prevail.

The AquaFish research portfolio includes activities that provide equal access for women and men and address the marginalization of women throughout the value chain. In Uganda, AquaFish partners participated in two events in FY16 that helped foster women's roles in the aquaculture value chain. The 6th Africa Day for Food and Nutrition Security centered on women's empowerment through successful involvement in agribusiness, and included presentations by AquaFish partners on important research innovations. An AquaFish partner in Uganda helped coordinate the Uganda Fisheries & Aquaculture Conference, which focused on involving women and youth to help transform the aquaculture and fisheries sectors. In order for the aquaculture and fisheries sectors to grow in the region, all stakeholders must benefit across the value chain. This conference provided an opportunity to plan the way forward, including and empowering women and men in equal measure in the decision-making and technology development for these important resource sectors.

Strengthening human and institutional capacity is a primary objective for AquaFish and is accomplished through collaboration with personnel at universities, resource and facility sharing, support of degree-seeking students, curriculum development, short-term training courses, and recognition of outstanding achievements at international aquaculture and fisheries conferences. In FY16, AquaFish supported and mentored 158 long-term degree students at 22 universities in nine countries, with women representing 50% of the total students and conducted 17 short-term trainings, reaching 526 people. Fifty percent of short- and long-term trainees were women, which was an increase from last year and also met the 50% AquaFish programmatic benchmark for women's participation in trainings.

AquaFish partners in Ghana, Kenya, and Nepal strengthened institutional capacity through the development and enhancement of on-campus teaching and demonstration tools in FY16. These tools helped teach students and trainees about aquaponics and earthen pond production systems. AquaFish was a sponsor of three international aquaculture conferences and symposia in FY16 – APA16, AFAF, and GAF6 – and also recognized emerging scientists through the Yang Yi Young Scientist Fellowships at AFAF and three awards for best papers at IIFET 2016.

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 FY16, AquaFish researchers attended six conferences, meetings, and symposia in four countries, and published 15 articles. Since 2006, AquaFish researchers have published nearly 250 peer-reviewed articles on program-related research. These types of outreach and dissemination approaches further expand collaborative networks and increase AquaFish impacts throughout the world.

AquaFish and its Director, Dr. Egna, were honored with Gold Medal awards by the AFS for advancing the AFS mission and for Dr. Egna's continued and long-standing support and mentorship of emerging scientists from the Asia-Pacific region. AwF also featured Dr. Egna as the Woman of the Month in September 2016, recognizing her commitment and achievements toward increasing aquaculture capacity and sustainability for people and institutions in developing countries for almost three decades.

III. KEY ACCOMPLISHMENTS

AquaFish outputs and achievements in research, capacity building, information dissemination, and gender integration are measured relative to qualitative and quantitative targets identified in the USAID-approved Monitoring and Evaluation (M&E) Plan and Feed the Future Indicators and Monitoring System (FTFMS). Key accomplishments in FY16 under the AquaFish Leader Award are highlighted below.

Research and Technology Development

Twenty-nine innovative aquaculture technologies were at varying stages of development in Africa and Asia in FY16. In developing these technologies, AquaFish projects involved 126 food security enterprises, producer organizations, women's groups, trade and business associations, and community-based organizations. In Uganda and Ghana, AquaFish researchers worked with fish farmers to develop cell phone information networks to address aquaculture information needs, improve efficiencies in the value chain, and reduce post-harvest loss. This text-based cell phone information system, completed in FY16, laid the foundation for development and implementation of a mobile application in Uganda. To improve production efficiency of tilapia, AquaFish researchers in Bangladesh are building on past research that successfully reduced feeds by identifying gut microflora needed for optimal nutritional absorption, and 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.

Human and Institutional Capacity Building

Since program inception in 2006, AquaFish has fostered linkages with over 250 institutions globally. In FY16, AquaFish had a total of 78 active linkages, including formal (funded) institutional or individual partnerships with 37 organizations in 10 countries, and an additional 41 informal (unfunded) collaborators. AquaFish supported 158 students enrolled in long-term degree programs at US and HC institutions this fiscal year. Thirteen short-term training events, including workshops, on-farm trainings, and train-the-trainer events, were held with a total of 526 participants covering a range of audiences. In Nepal, school ponds were established to train teachers and students about carp culture best management practices, and associated women's fish farmer groups received additional training on how to increase household food security by incorporating small indigenous fish. AquaFish researchers in Kenya also conducted a youth training, focusing on several aspects of pond culture from site selection and construction to production, management, and business practices. The Kwame Nkrumah University of Science and Technology (KNUST) in Ghana, received a Certificate of Merit in recognition of its role in the development of aquaculture in the country. KNUST partners shared credit with AquaFish for the Innovation Lab's substantial contributions towards human and institutional capacity building in Ghana.

Information Dissemination

AquaFish has disseminated programmatic findings to stakeholders through multiple avenues including the AquaFish website (aquafish.oregonstate.edu), social media sites, newsletters, conference presentations, and trade magazines/publications. Additionally, 12 issues of *EdOpNet* (education opportunities in aquaculture and fisheries-related fields) reached over 1,500 recipients in FY16. AquaFish encourages researchers to publish findings in trade magazines and peer-reviewed journals in order to reach the broader research

community and to advance aquaculture science. AquaFish's scientific strengths and accomplishments are evidenced by over 250 publications on AquaFish-supported research and data since program inception in 2006, 15 of which were published in FY16. Information is also being shared among AquaFish project partners, for example, a south-south collaboration resulted in technology and knowledge transfer of successful research in Vietnam on snakehead breeding, weaning, and feed development to Cambodia, resulting in more sustainable snakehead aquaculture in the region.

AquaFish researchers training Nepali women on the importance of aquaculture for nutrition and food security.

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 FY16, AquaFish met this 50% benchmark for long-term and short-term trainings. In Zanzibar, Tanzania, AquaFish researchers trained community members on spat collection techniques and growing of pearl oysters with a goal of providing much needed alternative income in a sustainable way. As women play a significant role in the pearl culture industry, they were involved in experiments and were provided training on entrepreneurship skills. In Uganda, AquaFish researchers partnered with the Women Fish Farming Network to provide training on new approaches to technical assistance in aquaculture. Seventy-six of the 111 participants in the training were women.

IV. RESEARCH PROGRAM OVERVIEW AND STRUCTURE

AquaFish is managed to achieve maximum program impacts, particularly for small-scale farmers and fishers, in Host Countries 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.

GLOBAL AQUAFISH PROJECT THEMES (GOALS)

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

Each project focuses on one primary AquaFish theme, yet integrates all four themes to achieve a systems approach. The global themes of AquaFish are cross-cutting and address several specific USAID policy documents and guidelines.

AQUAFISH RESEARCH PROJECTS

All projects are organized 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, Post Harvest, 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 takes a systems approach, with 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**	

In FY16, 33 investigations were underway as part of the 2013-2015 Implementation Plan, 24 of which continued as areas of focus for the 2016-2018 Implementation Plan. A total of 10 countries, 12 US Universities, and 20 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.

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. 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.

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.

AquaFish working with coastal farmers in Bangladesh to demonstrate Pangasius catfish can be grown in hyposaline waters.

- ***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)

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 FY16, as reported by AquaFish Lead Project PIs. Reports present progress made during the second year of the 2013-2015 Implementation Plan and the continuation of work into the 2016-2018 Implementation Plan. The five lead 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 & the Philippines 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

2013-2015 Implementation Plan Investigations

1. Assessing the Nutritional Impact of Aquaculture Policy in Fish Farming Districts in Tanzania and Ghana (13HHI01PU)
2. Development of a Cell Phone Based Seafood Market Information System (SMIS) in Ghana: Application to Tilapia (13MER01PU)
3. Value Chain Analysis of Farmed Nile Tilapia (*Oreochromis niloticus*) and African Catfish (*Clarias gariepinus*) in Tanzania (13MER02PU)
4. Spat Collection and Nursery Methods for Shellfish Culture by Women (13QSD01PU)
5. Coastal Women's Shellfish Aquaculture Development Workshop (13BMA01PU)
6. Identifying Local Strains of Nile Tilapia (*Oreochromis niloticus)* that are Adapted to Future Climate Conditions (13IND01PU)

7. Evaluation of Invertebrates as Protein Sources in Nile Tilapia (*Oreochromis niloticus*) Diets (13SFT01PU)
8. Enhancing the Nutritional Value of Tilapia for Human Health (13SFT02PU)

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)

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 Gifty Anane-Taabeah – HC Investigator Reginald Annan – 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 for Development Studies, Ghana** Akwasi Ampofo-Yeboah – HC Co-PI Eliot Alhassan – HC Investigator	**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 Elibariki Emmanuel Msuya – HC Investigator **Farmerline, Ghana** Alloysius Attah – HC Co-PI **Western Indian Ocean Marine Science Association, Zanzibar, Tanzania** Julius Francis – HC Co-PI

Achievements

Research objectives from the 2013-2015 Implementation Plan were completed, and results informed research lines to carry progress forward in Ghana and Tanzania for the 2016-2018 Implementation Plan. Results from fish feed studies in Tanzania indicate that housefly maggot and earthworm meals are good protein sources in diets of Nile tilapia (*O. niloticus*) juveniles. These feeds developed from local and alternative protein sources are more cost effective in producing a unit of fish than traditional fish-based feeds, particularly for small- to medium-scale fish farmers. In Ghana, tilapia feeds are being developed with alternative plant-based protein sources (such as seeds from locust, egushi, eggplant, calabash, cucumber, neri, and sesame) and tested for their effectiveness in enhancing the nutritional value of tilapia

for human consumption, while considering the cost-effectiveness and environmental footprint of those ingredients. A related but separate line of research on fish consumption and human nutrition suggests that in Ghana, fish farming households have higher dietary diversity and food security than non-fish farming households, and that household income and mother's education positively affect household dietary diversity and nutritional quality in both Ghana and Tanzania.

Training activities on spat collection and nursery methods for pearl oyster culture in Zanzibar have helped to empower women in building the economies of the Bweleo and Nyamanzi villages. The women involved in this work earned extra income from pearl sales, allowing them to further improve their household livelihoods by building houses, purchasing a fishing boat, and paying children's school fees. In Ghana, a Seafood Market Information System was developed to help open market communication pathways, thereby minimizing the information gaps along the fish value chain. This greatly improved efficiencies in fish marketing and the value chain as a whole. Researchers in Ghana also conducted a comparative analysis of wild tilapia populations in the Volta basin and the eighth generation of selected bred Akosombo strain under current and future climate conditions. Results showed no evidence of superior performance of the Akosombo strain of Nile tilapia over the wild strains, and at least one wild population from the Oti River (Sabare) may be tolerant to climate change impacts with traits for superior performance under high temperature and low dissolved oxygen conditions.

AqauFish training workshop informing women of Ghana on the benefits of the Seafood Market Information System.

Capacity Building

Women from two villages in Zanzibar, Tanzania, have earned extra income (US$160-$220/month) selling oyster shell and pearl jewelry using oysters that they cultured and harvested themselves using techniques they learned from AquaFish short-term trainings. This additional income has increased these women's capacities as producers and managers of their own businesses and has helped them pay for expenses, such as school fees, that will improve the lives of their families in the long term.

In addition to the community capacity development, 10 long-term students were supported in pursuit of Bachelor's (1), Master's (7), and PhD (2) degrees. These students studied at Kwame Nkrumah University of Science and Technology (KNUST) in Ghana, Sokoine University of Agriculture (SUA) in Tanzania, and Purdue University in the US.

In the last five years, AquaFish and KNUST have helped develop new programs and curricula in aquaculture and fisheries, building KNUST into a leading aquaculture research program in the region. In FY16, KNUST won the National Best Pond Fish Farmer Award by the Ministry of Fisheries and Aquaculture Development. The farm has evolved into more than a training and research facility for undergraduate and graduate students; after commercialization in 2011, the farm began generating income from fish sales to maintain and improve facilities as the need arises. AquaFish collaborations with KNUST have strengthened the capacity of fish farmers throughout Ghana, teaching best management practices such as water re-use, record keeping, and fertilizer reduction.

Presentations and Publications

Akuffo, A., and K. Quagrainie. 2016. Determinants of household food security in Tanzania. [Oral presentation]. Aquaculture 2016, Las Vegas, Nevada, US, 22–26 February 2016.

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Anane-Taabeah, G., K. Quagrainie, and S. Amisah. 2015. Assessment of farmed tilapia value chain in Ghana. Aquaculture International. DOI 10.007/s10499-015-9960-1.

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Chenyambuga, S.W., E.E. Msuya, and N.A. Madalla. 2016. Assessment of value chain of farmed Nile tilapia (*Oreochromis niloticus*) in coastal and lake zones of Tanzania. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Darko, F.A., K. Quagrainie, and S.W. Chenyambuga. 2016. Consumer preferences for farmed tilapia in Tanzania: A choice experiment analysis. Journal of Applied Aquaculture, 28:3.

Jiddawi, N.S., and M.C. Haws. 2016. Sustainable pearl farming in Africa using new spat collection techniques. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Madalla, N.A., T. Ally, and S.W. Chenyambuga. 2016. Evaluation of housefly *Musca domestica* maggot meal as protein source in Nile tilapia *Oreochromis niloticus* diets. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Quagrainie, K., and A. Akuffo. 2016. An assessment of household food security in fish farming communities in Ghana. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

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
2013-2015 Implementation Plan Investigations
1. Development of Low-Cost Captive Breeding and Hatching Technologies for Two African Lungfish (*Protopterus aethiopicus* and *P. amphibius*) to Improve Livelihoods, Nutrition, and Income for Vulnerable Communities in Uganda (13IND03AU)
2. New Approaches to Inform, Motivate, and Advance Small and Medium-Scale Fish Farmers: Building Industry Capacity through Cell Phone Networks, Training, and Market Participation (13BMA04AU)
3. Assessment of Market Opportunities for Small-Scale Fishers and Farmers in Central Uganda (13MER05AU)
4. 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)
5. Formulation and Manufacture of Practical Feeds for Western Kenya (13SFT07AU)
6. Development of Low-Cost Aquaponics Systems for Kenya (13BMA05AU)

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)

Principal Project Personnel

Auburn University, US (US Project University) Joseph Molnar – US Project PI Claude Boyd – US Investigator Jeffrey Terhune – US Investigator **Makerere University, Uganda (Lead HC Institution)** Theodora Hyuha – HC Project PI (to May 2016) & HC Co-PI (from May 2016 to present) Monica Beharo – HC Investigator **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 Co-PI (to May 2016) & HC Project PI (from May 2016 to present) Gertrude Atukunda – HC Investigator Moureen Matuha – HC Investigator **University of Eldoret, Kenya** Charles Ngugi – HC Co-PI & Kenya PoC Julius Manyala – HC Investigator **Fisheries Training Institute, Uganda** Gertude Abalo – HC Co-PI

Achievements

In FY16, research in Kenya and Uganda focused efforts on analyzing data and completing objectives from the 2013-2015 Implementation Plan with an aim to improve livelihoods, nutrition, and income for fishers, farmers, and vulnerable communities by working to solve or clarify bottlenecks that limit the advancement of fish culture. Results are informing continuing research in the region. A study on mobile phone use by aquaculture farmers in Uganda found that farmers prioritized information on pond management, feeds, broodstock and water quality management, stocking and harvesting, and most importantly, market price. These findings are being used in the development of a mobile phone application to address fish farming information gaps and to provide farmers with current market information. Economic analyses of fish markets showed that: (1) mark-up pricing, competitors prices and price haggling were the most used pricing strategies by fish farmers; (2) retailers are the price leaders in the Uganda catfish supply chain; (3) participants in the wholesale market channel realized higher absolute margins compared to participants in the retail market channel; and (4) the most pressing concerns were common to both retailers and wholesalers, including high cost of fish supply, low sales price, low fish supplies, and arrests for selling immature fish. Grow-out and reproductive experiments guided the development of low-cost technologies for propagating and producing cultured African lungfish to improve household nutrition, food security, and income.

Research in Kenya made an important step forward in demonstrating practical approaches to fish culture using aquaponics. Another study showed there is a high potential for on-farm fish feed formulation and processing, and the present knowledge will benefit fish farmers in formulating nutritionally balanced diets to improve growth and production of tilapia in Western Kenya.

Capacity Building

For FY16, capacity building efforts in Kenya and Uganda featured partnerships with farmer organizations to help amplify and disseminate the insights and recommendations coming from AquaFish research. In Uganda, the Annual Fish Farmers Symposium and Trade Show drew hundreds of participants, including existing and prospective fish farmers and aquaculture stakeholders. In addition, AquaFish worked with the Women Fish Network to organize and run the Uganda Fisheries & Aquaculture Conference, focusing on involving women and youth in developing and disseminating fisheries and aquaculture innovations.

Seven short-term training events were held in Kenya and Uganda in FY16, reaching a total of 306 trainees, 136 (44%) of whom were women. Uganda hosted four trainings, which mainly focused on designing methods to deliver aquaculture and fisheries information via cell phone technology. In Kenya, two of the three workshops trained youth on the use of cages in aquaculture systems, while the third training addressed best management practices and culture techniques for tilapia and catfish. Twenty-four long-term students (12 women and 12 men) were supported and mentored in FY16 at Makerere University in Uganda; Kenyatta University, Egerton University, Karatina University, and University of Eldoret in Kenya; and Auburn University and University of Arizona in the US. These students were pursuing Certificates (2), Bachelor's (12), Master's (6), and PhD (4) degrees.

AquaFish showcased low cost feed manufacturing and processing alternatives at the Annual Agribusiness and Trade Fair at the University of Eldoret in Kenya.

Presentations and Publications

Boyd, C. 2015. Efficiency of mechanical aeration. Global Aquaculture Advocate 17(4): 31-33.

Matuha, M., J. Molnar, C.E. Boyd, and J.S. Terhune. 2016. The role of mobile phones in facilitating aquaculture development in Uganda. World Aquaculture 47(1): 39-46.

Molnar, J., M. Matuha, G. Atukunda, J. Walakira, J. Terhune, J. Bukenya, and S. Naigaga. 2016. Implementing mobile marketing and technical support for fish farmers: Uganda grower experiences and aspirations. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Ngugi, C.C., E. Oyoo-Okoth, and M. Muchiri. 2016. Effects of dietary levels of essential oil (EO) extract from bitter lemon (*Citrus limon*) fruit peels on growth, biochemical, haemato-immunological parameters and disease resistance in juvenile *Labeo victorianus* fingerlings challenged with *Aeromonas hydrophila*. Aquaculture Research 1–13.

Walakira, J., J. Kiburara, A. Idrifua, J. Molnar, E. Ganda, G. Kityo, and C. Aruho. 2016. Understanding sex change and hermaphroditism in African lungfish (*Protopterus aethiopicus*) and its

implication to aquaculture: Preliminary findings. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

THEME C: ENVIRONMENTAL MANAGEMENT FOR SUSTAINABLE AQUATIC RESOURCES USE

Asia Project: Bangladesh & the Philippines

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

Location

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

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

Project Description

2013-2015 Implementation Plan Investigations

1. Economic and Environmental Benefits of Reduced Feed Inputs in the Polyculture of Tilapia and Major Indian Carps (13SFT04NC)
2. Pulsed Feeding Strategies to Improve Growth Performance, Gastrointestinal Nutrient Absorption Efficiency, and Establishment of Beneficial Gut Flora in Tilapia Pond Culture (13SFT05NC)
3. Novel Approach for the Semi-Intensive Polyculture of Indigenous Air-Breathing Fish with Carp for Increasing Income and Dietary Nutrition while Reducing Negative Environmental Impacts (13MNE01NC)
4. The Culture Potential of *Pangasius* Catfish in Brackish (Hyposaline) Waters of the Greater Barisal Regions in Southern Bangladesh (13BMA02NC)
5. Integrated Mola Fish and Gher/Freshwater Prawn Farming with Dyke Cropping to Increase Household Nutrition and Earnings for Rural Farmers in Southwest Bangladesh (13HHI03NC)
6. Production for Nutrient-Rich Small Fish Mola and Freshwater Prawn Using Integrated Cage-Pond Carp Polyculture for Northwest Bangladesh (13BMA03NC)
7. Improving Nutritional Status and Livelihoods for Marginalized Women Households in Southwest Bangladesh through Aquaculture and Value Chain Analysis (13MER04NC)

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 Upton Hatch – US Investigator Harry Daniels – US Investigator Peter Ferket – 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 **Central Luzon State University, Philippines** Wilfred Jamandre – HC Co-PI & Philippines PoC **Khulna University, Bangladesh** Khandaker Anisul Huq – HC Co-PI	**Southeast Asian Fisheries Development Center, Philippines** Emilia Quinitio – HC Co-PI **University of Dhaka, Bangladesh** Abu Torab M.A. Rahim – HC Co-PI Nazma Shaheen – HC Investigator **Hajee Mohammad Danesh Science & Technology University, Bangladesh** Rezoanul Haque – 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 FY16, research in Bangladesh provided new technologies and management practices for intensifying seafood production while maximizing utilization of nutrient input and reducing environmental impact through polyculture, improving overall aquaculture production efficiency, and increasing incomes and nutrition of farmers. Polyculture research demonstrated that inclusion of two major Indian carp, Rohu and Catla, either alone or in combination, has little impact on tilapia growth but provides a means for farmers to enhance their income by providing additional fish (carps) for consumption or sale at local markets. Further, Rohu and Catla can be co-cultured with Koi with little impact on its production.

Sequencing of Nile tilapia fecal microbiome found that fish fed on alternate-days had twenty unique species of bacteria compared to other treatment groups, raising the possibility that this may contribute to improved performance of these fishes (e.g., better feed efficiency). This work leveraged additional funds from the National Science Foundation on endocrine control of metabolism in tilapia to further enhance the culture of this species. Research aimed at increasing resilience to climate change discovered that *Pangasius* can easily survive and grow in saline water up to 12 ppt and that higher stocking density (3 fish/m^2) and formulated feeds can provide better economic benefit to farmers.

Two studies focused on improving household nutrition, income generation, and livelihoods. Stocking densities of Mola (*A. mola*), a small indigenous species rich in vitamin A, were evaluated in gher-prawn-Rohu polyculture in the Khulna region of Southwest Bangladesh. This study demonstrated that the addition of Mola results in improved prawn production, enhances total fish yields, increases farmer fish consumption, and allows farmers to generate more income. Further analyses found that household members consumed over 50% of the Mola produced in their systems and suggest that dyke cropping can provide farmers additional opportunities for generating income and for consuming nutritious foods. Work in Southwest Bangladesh aimed at improving the livelihoods for marginalized women households that traditionally rely on mud crab fattening to make a living. This pilot study determined that integration of tilapia into current mud crab fattening and culture practices can boost total mud crab production. It was

also found that the women and their household members had a higher income, consumed more high quality protein in their diets, and were less malnourished.

Capacity Building

During FY16, work in Bangladesh focused capacity-building efforts on strengthening community, institutional, and individual partnerships and capacities. Toward this goal, the project partnered with 10 Host Country university faculty at five regional universities in Bangladesh and one in the Philippines, and with three senior project scientists from the Southeast Asian Fisheries Development Center, WorldFish, and Shushilan, an NGO. These partners and their respective staff received training in managing community development projects, conducting research trials, and understanding the importance of reporting project results and impacts.

This project also supported the education of 28 (13 women and 15 men) students including four Bachelor's, 20 Master's, three PhD's, and one post-doctoral fellow. These students studied at Bangladesh Agricultural University (BAU), Patuakhali Science and Technology University, and Khulna University in Bangladesh, and North Carolina State University (NCSU) in the US. Fourteen of these students graduated in FY16, many of whom advanced on to various jobs in their fields at non-profit research organizations and universities.

Additionally, community capacity was strengthened in Bangladesh in FY16 through collaboration with farmers testing new technologies on their individual fish ponds. This type of hands-on training allows farmers to participate in the research and teaches them valuable skills such as pond management, record keeping, and yield calculation. Nearly 100 village households participated in FY16, representing eight communities and four regions in Bangladesh. These types of activities have promoted entrepreneurship among participants and improved their aquaculture production capacity.

Presentations and Publications

Ali, M.L., S.M. Haque, M.A. Wahab, and R.J. Borski. 2016. Impact of stocking density and feeds on yield of *Pangasius* catfish (*Pangasius hypophthalmus*) in hyposaline waters. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Borski, R.J., S. Salger, D. Baltzegar, J. Reza, and M.A. Wahab. 2016. Effect of pulsed feeding on growth, gut metagenome, and intestinal nutrient transporters of tilapia in pond culture. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Fatema, M.K. 2016. An overview of women in aquaculture and fisheries in Bangladesh. [Oral presentation]. 6th Global Symposium on Gender in Aquaculture and Fisheries, Bangkok, Thailand, 3–7 August 2016.

Fatema, M.K., M.A. Wahab, S.A.S.A. Tahmid, A. Pandit, S.M.M. Rana, S.M. Haque, and R.J. Borski. 2016. Production and economic benefits of reduced feed inputs and addition of Indian carp (rohu) on Nile tilapia growout in ponds. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Haque, S.M., I. Kaiser, M. Dutta, M.A. Wahab, and R.J. Borski. 2016. Effects of reduced feeding strategies for combined polyculture of two major carps (rohu and catla) with shing catfish (*Heteropneustes fossilis*). [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Haque, S.M., M. Rahman, S.B. Satu, R.J Borski, and H.S. Egna. 2016. Improving nutritional status and livelihoods for marginalized women households in southwest Bangladesh through aquaculture. [Oral presentation]. 6th Global Symposium on Gender in Aquaculture and Fisheries, Bangkok, Thailand, 3–7 August 2016.

Jamandre, W., U. Hatch, S. Biswas, E. Quinitio, M.A.Wahab, S. Haque, and R.J. Borski. 2016. Improving the well-being of Bangladeshi women mud crab culturist using a value chain analysis. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Won, E.T., J.D. Douros, D.A. Hurt, and R.J. Borski. 2016. Leptin stimulates hepatic growth hormone receptor and insulin-like growth factor gene expression in a teleost fish, the hybrid striped bass. General and Comparative Endocrinology 229: 84–91.

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, Bhairahwa, Dayanagar, and Terai Region

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

Project Description

2013-2015 Implementation Plan Investigations

1. Reproduction and Seed Production of Sahar (*Tor putitora*) in Chitwan, Nepal (13QSD02UM)
2. Production of Periphyton to Enhance Yield in Polyculture Ponds with Carps and Small Indigenous Species (13SFT08UM)
3. Household Fish Ponds in Nepal: Their Impact on Fish Consumption and Health of Women and Children and their Constraints Determined by Value Chain Analysis (13MER06UM)
4. Two Small Indigenous Species to Improve Sustainability in Typical Polyculture Systems in Nepal (13IND04UM)
5. Demonstrating the Value of Tilapia and Sahar Production in Polyculture Ponds Using Government Farm and On-Farm Trials (13BMA06UM)
6. Establishing School Ponds for Fish Farming and Education to Improve Health and Nutrition of Women and Children in Rural Nepal (13HHI04UM)

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 successfully completed objectives from the 2013-2015 Implementation Plan with research focused on polyculture, household nutrition, and enhanced production of native species, contributing to technology development and capacity building. Small indigenous fish species (SIS) were incorporated into polyculture systems, demonstrating that SIS colonization from natural waters was sufficient to establish viable populations in ponds, and that bird predation appeared to reduce yield by 20% in ponds far from human disturbance. On-farm experiments showed increased profit of 51.7% by using periphyton enhancement structures and reducing feeding to 50% of maximum levels. A study on household fish ponds showed households with fish ponds consumed about 120% more fish than those without ponds and that children in those households exceeded country-wide levels for growth and weight. The Nepal project's work with school ponds also proved successful. Testing indicated that students scored less than 40% in pre testing but 61-80% in tests after completing an aquaculture course at their school. These students also showed increased household consumption of fish after taking the course. In another study, approximately 5,000 sahar fry were successfully raised in Rampur, and induced maturation showed some success in producing final maturation for the fish. Finally, the addition of tilapia and sahar to farm ponds resulted in a 79% increase in gross margin compared to traditional carp polyculture.

Capacity Building

In FY16, AquaFish work in Nepal continued to strengthen human and institutional capacity through trainings and collaborations. AquaFish researchers hosted five short-term trainings, including 123 women and 63 men, for a total of 186 trainees. Two of the trainings were on nutrition and income generation for women's fish farming groups in Nawalparasi and Chitwan and the additional three trainings covered polyculture management and Sahar seed production. US and Nepalese AquaFish partners mentored 55 students in pursuit of Bachelor's (45), Master's (9), and PhD (1) degrees. These students were enrolled at Agriculture and Forestry University (AFU) in Nepal and University of Michigan in the US. Twenty-seven of these students (49%) were women and 28 were men (51%).

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 FY16, 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

Ahmed, N., and J.S. Diana. 2016. Does climate change matter for freshwater aquaculture in Bangladesh? Reg. Environ. Change 16: 1659.

Bhandari, M., R.N. Mishra, M.K. Shrestha, and J.S. Diana. 2016. Inclusion of Nile tilapia *Oreochromis niloticus* and sahar *Tor putitora* improves reproductivity in carp-polyculture system. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Bista, J.D., N.P. Pandit, M.K. Shrestha, and J.S. Diana. 2016. In-situ and ex-situ conservation of sahar (*Tor putitora*) in Nepal. [Oral presentation]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand, 3–7 August 2016.

Gharti, K., G.P. Lamasal, and S.K. Wagle. 2016. Observation of the performance of wild jalkapur fry (*Pseueutropius murus batarensis)* in ponds in Trishuli, Nuwakot. [Poster presentation]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand, 3–7 August 2016.

Jha, D.K., R. Bhujel, and A.K. Anal. 2016. Carp brood stock management in private hatcheries of Nepal. [Poster presentation]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand, 3–7 August 2016.

Jha, D.K., N.P. Pandit, I.S. Mahato, M. Shrestha, and J.S. Diana. 2016. Establishing school ponds for educating students to improve health and nutrition of children and women in rural Nepal. [Oral

presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Jha, S., S. Rai, M.K. Shrestha, and J.S. Diana. 2016. Growth and production of carp and SIS in periphyton enhanced system. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Jha, S.K, J. Bista, N.P. Pandit, M.K. Shrestha, and J.S. Diana. 2016. Spawning response of sahar *Tor putitora* in Terai region of Nepal. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Khanal, N., and M.K. Shrestha. 2016. Status of *Pangasius* (*Pangasiondon hypopthalamus*) aquaculture in Nepal. [Poster presentation]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand, 3–7 August 2016.

Mandal, R.B., S. Rai, M.K. Shrestha, D.K. Jha, and N.P. Pandit. 2016. Dynamics of red bloom algae in fishponds in three different region of Nepal. [Poster presentation]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand, 3–7 August 2016.

Mishra, R.N. 2016. Strategies to attract private sector investment in aquaculture for self-sufficiency in Nepal. [Oral presentation]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand, 3–7 August 2016.

Pandit, N.P., and M.K. Shrestha. 2016. Status of tilapia culture in Nepal. [Poster presentation]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand, 3–7 August 2016.

Rai, S., M.K. Shrestha, and J.S. Diana. 2016. Participation of women farmers in an on farm training of sustainable periphyton enhanced system. [Oral and poster presentations]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand, 3–7 August 2016.

Ranjan, R., N.P Pandit, N.B. Khanal, M.K. Shrestha, and J.S. Diana. 2016. Efficacy of common carp *Cyprinus carpio* testis inducing sex reversal of Nile tilapia *Oreochromis niloticus*. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

Shrestha, M.K., K.K. Amatya, and J.D. Bista. 2016. Women-led river bank aquaculture for livelihoods of rural poor community in foot hills of Nepal. [Oral and poster presentations]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand, 3–7 August 2016.

Shrestha, M.K., and J.S. Diana. 2016. Role of the AquaFish Innovation Lab in university capacity building and aquaculture development in Nepal. [Oral presentation]. Asian-Pacific Aquaculture Conference 2016, Surabaya, Indonesia, 26–29 April 2016.

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, and Kratie province

Vietnam: An Giang province and Tra Vinh province

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

Project Description

2013-2015 Implementation Plan Investigations

1. Impacts of Climate Change on Fish Value Chains in the Lower Mekong Basin of Cambodia and Vietnam (13MER03UC)
2. Alternative Feeds and Processing for Freshwater Aquaculture Species (13SFT03UC)
3. Sustainable Snakehead Aquaculture Development in the Lower Mekong River Basin of Cambodia (13IND02UC)
4. Estimating Carrying Capacity for Aquaculture in Cambodia (13WIZ01UC)
5. Enhancing Food Security and Household Nutrition of Women and Children with a Focus on Nutrient Dense Commonly Consumed Fish from Capture Fisheries and Aquaculture in Cambodia (13HHI02UC)
6. Policy Recommendations to Improve Food Security and Household Nutrition through Sustainable Aquaculture and Aquatic Resource Management in Cambodia and Vietnam (13PDV01UC)

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 **Inland Fisheries Research and Development Institute, Cambodia (Lead HC Institution)** So Nam – HC Project PI Nen Phanna – HC Investigator Hap Navy – HC Investigator Prum Somany – HC Investigator Touch Bunthang – HC Investigator Chheng Phen – HC Investigator Phanara Thach – HC Investigator Setha Im – 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 Thi Nhu Ha Nguyen – HC Investigator Pham Minh Duc – HC Investigator Duong Thuy Yen – HC Investigator

Achievements

In FY16, this project led research in Cambodia and Vietnam that supported the development of sustainable snakehead aquaculture in Cambodia, informed climate change adaptation strategies for fish farming, and evaluated fish consumption and nutrition. A major accomplishment in Cambodia was the lifting of the snakehead culture ban in April 2016, resulting in part from 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. To address this, researchers developed and refined a formulated, pelleted snakehead feed that reduces the use of small-sized fish and fishmeal without decreasing growth performance and marketability. Both Vietnamese hatchery snakehead (domesticated) and Cambodian indigenous wild snakehead (non-domesticated) can accept formulated feed with similar product quality. The lifting of the snakehead farming ban and adoption of sustainable feed practices will allow for enhanced trade opportunities for Cambodian farmers as snakehead is in demand both domestically and regionally, and there will be increased investment in feed mills, grow-out operations, processing, and other post-harvest activities.

Perceived impacts of climate change on various actors in the fish value chain in Cambodia were identified, as well as adaptation strategies currently being utilized and planned for the future. A nutritional survey on women and preschool-children found that low intakes of iron, zinc, calcium and vitamin A put Cambodian women and children at risk of micronutrient deficiencies. Another study on fish consumption of demonstrated processing techniques that allow safe consumption of snakehead for up to four weeks of storage, based on sensory, chemical, and microbiological parameters.

Capacity Building

FY16 saw the lifting of a more than 10-year long ban on snakehead farming in Cambodia. The development of sustainable snakehead feed comprised of 40% plant protein (rather than the more resource-intensive fishmeal protein), and a focus on ecologically-friendly rearing methods – both lines of research implemented by AquaFish researchers in Cambodia, Vietnam, and the US – have helped inform the decision to allow the culture of snakehead in Cambodia. This lift will increase the capacity of fish farmers in Cambodia, a country where the majority of the population relies on aquatic resources for income and nutrition.

This project supported the education of 40 long-term students at all degree levels in FY16; 58% (23) of these were women. These students studied at Can Tho University (CTU) in Vietnam, and Inland Fisheries Research and Development Institute (IFReDI), Kampong Cham National School of Agriculture, Royal University of Agriculture, and Royal University of Law and Economics, all in Cambodia.

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Nam, S., S. Phommakone, L. Vuthy, T. Samphawamana, N.H. Son, M. Khumsri, N.P. Bun, K. Sovanara, P. Degen, and P. Starr. 2015. Economic value of Lower Mekong fisheries: Lower Mekong fisheries estimated to be worth around $17 billion a year. Mekong River Commission Catch and Culture, 21(3): 4–7.

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LESSONS LEARNED

The lessons learned highlighted below are a compilation of FY16 experiences communicated by subcontracting partners.

- **Negative results can be just as valuable as expected results, and AquaFish ME was reminded to encourage researchers to report on all findings – positive or negative.** A common fallacy in the scientific arena is that experiments are only successful when data prove the expected or desired results. This leads to a "positive bias" in scientific and grey literature as researchers and journals are more apt to publish findings that support predictions and many experimental results are never revealed. Among others in the scientific community, AquaFish is well aware of this bias and has a policy of accepting experiments as completed even when data are unexpected, controversial, or show that there are no significant differences (e.g., a comparison of two feeds on fish production results in the same growth rate) so long as good scientific practices are followed. Even with this standing policy, some AquaFish researchers were hesitant to submit reports that highlighted what they considered "failed" experiments.
- **Research plans need to consider and adapt to physical and administrative barriers, particularly when working with youth.** AquaFish researchers in Nepal have developed a youth education program using aquaculture ponds in local schools and are expanding upon this work as a result of early successes. This practical, hands-on educational approach has the potential to help local people with food production and better household nutrition. While the program is highly supported by students, teachers, and school administrators alike, building and managing ponds on school properties presents some difficulties. Schools in Nepal have walls surrounding their facilities for security. Those schools that have large enough areas to establish ponds within the school walls prevent theft of fish being grown, but administrators are concerned about student safety due to the accessibility of the ponds. Alternatively, some schools do not have space for a pond within school walls and instead have ponds on adjacent land. As a result, pond locations were generally established away from normal student activities.
- **There is no replacement for spoken dialogue.** In an era of electronic communication, email is often the go-to means for communication. Email can be especially useful when communicating on a global scale with partners in many time zones, conducting fieldwork, and with frequent travel. While convenient and seemingly time effective to communicate almost exclusively via email, research partners at Auburn University and elsewhere experienced first hand that calls were more interactive and helped resolve project issues faster. Communicating via phone, Skype, or in-person can be particularly important to avoid misunderstandings when working across many cultures and languages.
- **Transferring knowledge on complex mathematical and scientific concepts takes time, but this investment can pay off exponentially.** Investing time to train host country researchers on complex concepts can be a critical step in building institutional capacity. A US investigator spent three days teaching five IFReDI staff members about aquaculture carrying capacity and phosphorus mass-balance modeling to limit impacts on water quality as freshwater aquaculture expands in Cambodia. While it was challenging to introduce this mathematically complex concept, it is important for Cambodian researchers to understand carrying capacity and phosphorous modeling in order to develop sustainable aquaculture in the country. Resulting from the training, IFReDI staff were able to learn this new concept and effectively brief a larger audience on the limits of aquaculture production in freshwater.

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 and farmers 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 development gaps. 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 FY16, a total of 17 short-term trainings took place in five AquaFish Host Countries in Africa and Asia, reaching 526 trainees. Women represented 50% of these trainees, with 265 women participants and 261 men (Figure 1 and Table 1). Women's participation in short-term trainings increased from the previous fiscal year and the 50% benchmark for women trainees was met.

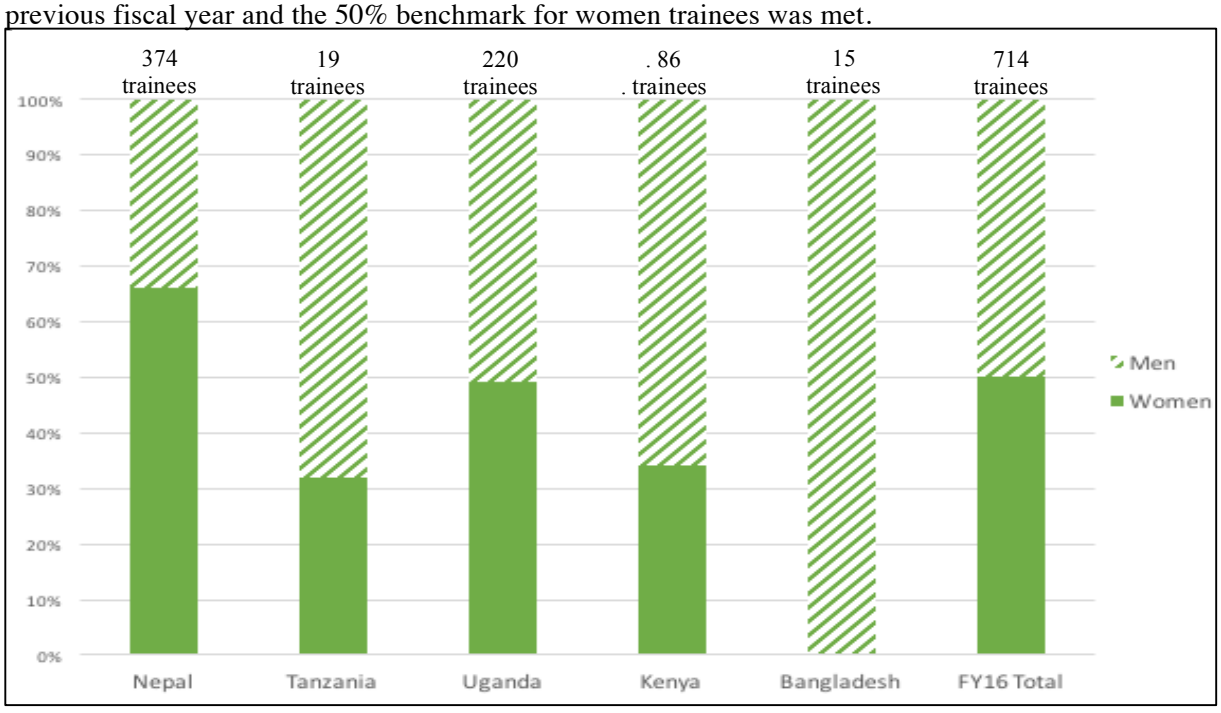

Figure VI-1. Percent of women and men short-term trainees by country for FY16.
Table 1. Short-term trainings by country.

Country of Training	**Brief Purpose of Training**	**Who was Trained**	**Number Trained**		
			M	**F**	**Total**
Bangladesh	On-farm training for production of nutrient-rich small fish Mola and freshwater prawn using integrated cage-pond/carp polyculture for the Northwest Bangladesh	Producers	15	0	15
Nepal	Sahar seed production technology farmer training workshop	Producers and government	15	2	17
Nepal	Carp-SIS - periphyton polyculture culture workshop	Producers	7	28	35
Nepal	Carp-tilapia-sahar polyculture demonstration project	Producers and government	33	9	42
Nepal	Workshop on nutrition and income generation for women's fish farming groups in Nawalparasi	Producers and civil society	3	19	22
Nepal	Workshop on nutrition and income generation for women's fish farming groups in Chitwan	Producers	2	25	27
Nepal	Carp-tilapia-sahar polyculture on-farm trials	Producers	3	3	6
Nepal	Carp-SIS - periphyton polyculture on-farm trainings	Producers	0	15	15
Nepal	Carp-SIS - periphyton polyculture on-farm trainings	Producers	0	22	22
Tanzania	Stakeholder training on fishmeal results	Civil society	13	6	19
Uganda	Conference on designing and delivering cell-based information	Civil society	40	6	46

Uganda	Conference on designing and delivering cell-based information	Disaggregated data not available	10	7	17
Uganda	Conference on designing and delivering cell-based information	Civil society	28	18	46
Uganda	Technical symposium on new approaches to technical assistance in aquaculture (preceding Annual Fish Farming Conference)	Government, private sector, civil society	35	76	111
Kenya	Youth Cage Culture Workshop	Producers and government	8	8	16
Kenya	Training Youth on Cage Culture Systems Workshop	Producers, government, and civil society	32	13	45
Kenya	Training in Tilapia and Catfish Commercial Farming and Best Management Practices	Disaggregated data not available	17	8	25
Total			261	265	526

Long-Term Trainings

Building human and institutional capacity in partner countries is a hallmark of the AquaFish collaborative research program. AquaFish provides financial 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 move on to careers in government, academia, and private enterprise upon graduation.

In FY16, AquaFish partners in nine countries supported and mentored 158 long-term students at 22 different institutions. AquaFish met its 50% benchmark for women's participation in long-term trainings, with an even split of 79 women and 79 men.

These students were in various phases of their degree programs, with 30 (19%) graduating in FY16 and 41 (26%) just starting their programs in FY16. The majority of the students (55%) were enrolled prior to FY16 and are expected to complete their degrees before AquaFish ends in March 2018. Many of the graduate students who graduated in FY16 have gone on to careers in their field of study with non-profits, private industries, and NGOs.

The degree breakdown for long-term trainees in FY16 is as follows: two in a Certificate program; 89 (56%) in a Bachelor's program; 53 (34%) in a Master's program; 13 (8%) in a PhD program; and one post-doctoral fellow.

INSTITUTIONAL DEVELOPMENT

Since 2006, AquaFish has helped HC institutions develop specialized curricula and strengthen institutions for building local capacity. A few years ago, AquaFish played a pivotal role in the establishment of Master's and PhD programs at KNUST in Ghana. In FY16, KNUST received the National Best Pond Fish Farmer Award. With the help of AquaFish guidance, KNUST is equipped with resources to accommodate multiple levels of scientific testing and attract students and extensionists for training purposes. KNUST has trained more than 400 Ghanaians and West African nationals at undergraduate and graduate degree levels, making KNUST a leading aquaculture institution in Ghana.

In FY16, progress was made by University of Eldoret in Kenya in demonstrating practical approaches to fish culture using aquaponics. An aquaponics system was developed at Eldoret to demonstrate a basic design for small-scale production of lettuce and other crops with tilapia. This system will continue to be used as an on-campus teaching and demonstration tool.

AFU in Nepal continued to improve resources for its aquaculture program in FY16 to help facilitate workshops, training sessions, and experimental research for both students and fish farmers.

These accomplishments, aided by AquaFish support, collaboration, and expertise, increase the capacity for institutions to train more students and help establish these 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 FY16 (for a complete list of AquaFish institutional affiliations, see *List of Program Partners*).

Bangladesh Bangladesh Agricultural University Khulna University Patuakhali Science and Technology University **Cambodia** Inland Fisheries Research and Development Institute Kampong Cham National School of Agriculture 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 Arizona University of Michigan **Vietnam** Can Tho University

VII. INNOVATION TRANSFER AND SCALING PARTNERSHIPS

In FY16, AquaFish 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, enhance food security, consider environmental impacts, and advance 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 Host Country (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 efforts target 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 in 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.

Efforts have been made to streamline successful technology development in a systems approach at key sites with a focus on human nutrition. AquaFish ruses 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 uses 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 FY16.

Asia Project: Bangladesh

Project Partners and Collaborators

North Carolina State University (US Project University); Bangladesh Agricultural University (Lead HC Institution); Khulna University; University of Dhaka; Shushilan NGO; Central Luzon State University; South East Asian Fisheries Development Center; Patuakhali Science and Technology University; Bangladesh Department of Fisheries; WorldFish; and WorldFish Aquaculture Income & Nutrition Project.

Technology	Description	Key Impact
Reduced feed strategies for semi-intensive tilapia monoculture and polyculture with the major Indian carp, Rohu.	Evaluate the potential economic and environmental benefits of reducing feed inputs with the addition of carp (Rohu) in tilapia culture.	Feeding at half ration combined with pond fertilization substantially increases the net return and benefit-cost ratio for growing tilapia whether in monoculture or in polyculture with Rohu. This strategy is useful for enhancing utilization of costly nutrients while limiting their impacts to the environment. The polyculture of carp with tilapia allows additional production of fish that can enhance incomes of small scale farmers.
Semi-intensive culture of tilapia with two major Indian carps (Rohu and Catla)	Polyculture of tilapia with Rohu alone, Catla alone, or a combination of the two carps was tested to determine if tilapia-carp polyculture might be improved with a particular carp species or a combination of the two	Tilapia grown with either Catla or Rohu had nominally better cost:benefit ratios and is more economical than tilapia grown with both carp species. This technology shows farmers have greater flexibility in the carp species used in tilapia-carp polyculture systems.
Pangasius culture in brackish water	This technology will help farmers adapt to saline water encroachment on the freshwater environment and make use of large areas of abandoned or underused land by developing *Pangasius* catfish culture in brackish waters.	Farmers may be able to make more productive use of encroached hyposaline waters in the coastal Southern region of Bangladesh.
Mola and gher-rice culture of prawns	Improving current practices to increase production yields using polyculture and integrated aquaculture techniques by incorporating mola and vegetables into gher (rice field)/prawn culture.	Improved access to income and highly nutritious mola fish may help address widespread nutritional deficiencies.
Pulse feeding for improved nutrient absorption in tilapia pond culture	Reduced feed costs can be achieved through reduced ration size or pulsed feeding. Pulsed feeding makes semi-intensive aquaculture more accessible and may increase the nutrient absorption efficiency of fish.	Feed costs could be reduced by up to 66% with the added benefit of increased household income, fish consumption, and improvements in water quality through better management of inputs.
Semi-intensive polyculture with air-breathing fish species and carp in Bangladesh	Culturing shing with carps represents a novel polyculture technology in Bangladesh. This system involves two indigenous air-breathing fish (ABF) and will increase yield and diversify aquaculture products available for consumption in Bangladesh, currently dominated by carps.	ABF species provide an advantage, as they can be resilient to harsh conditions. The mixed-trophic level nutrient utilization may make semi-intensive culture of shing catfish and carp more feasible for greater adoption among farmers while also mitigating the environmental impacts of nutrient loading.

Reduced feeding strategies for semi-intensive polyculture of shing and carp	Previous AquaFish studies have shown that equivalent production yields of tilapia can be achieved with 50% less feed, significantly improving feed conversion and reducing costs. This study will evaluate these techniques specifically for shing/carp production.	Successful implementation of feed-reduced strategies will decrease feed costs by as much as 50%, thereby increasing profits and making fish farming more accessible to low-income farmers.
Tilapia and mud crab polyculture	A pilot study was conducted to demonstrate the potential benefits of integrated tilapia and mud crab culture to practicing women aquaculturists who utilize mud crab-fattening as a source of income.	Tilapia cultured with mud crab can provide increases in seafood yields and an additional source of protein for consumption or sale and as food for mud crab. Farmers can enhance income, nutrition, and sustainability of mud crab culture by limiting use of wild caught small fish as feed for mud crab.
Formulated feeds and higher stocking density for *Pangasius* culture in hyposaline waters	Development of this technology determined if increasing stocking density by 50% and application of formulated feeds enhances fish yields and reduces feed costs for growing *Pangasius* in hyposaline waters.	Farmers can enhance their fish yield and economic returns for *Pangasius* culture in hyposaline culture by stocking fish at a higher density and using feeds formulated on-farm rather than commercial feeds.
Using dyke soils for growing spinach and snake gourd	Farmers often excavate mud for preparation of ponds prior to the start of a production cycle. These mud soils have greater nutrient content than adjacent land soil and can be used for enhancing production of nutrient-rich vegetables for household consumption and to improve family nutrition.	The utilization of nutrient-rich pond mud produces greater yields of vine spinach and snake gourd than dyke soils.
Characterizing the gut microbiome for improved tilapia production	This technology identified beneficial gut microflora in tilapia needed for optimal nutritional absorption and to generate a greater understanding of how gut microbial diversity changes in response to alternate-feeding strategies.	This technology will allow for the development of probiotic bacterial supplements for tilapia feeds, which may lead to better vitamin synthesis and enhanced nutrient absorption.

Asia Project: Cambodia & Vietnam

Project Partners and Collaborators

University of Connecticut-Avery Point (US Project University); University of Rhode Island; Inland Fisheries Research and Development Institute (Lead HC Institution); Can Tho University; Mekong River Commission; and Cambodia HARVEST Project.

Technology	Description	Key Impact
Value-added processing of farmed snakehead	Snakehead can yield many value-added processed products that improve the shelf life of the fish. This work improves the use of two major value-added products: dried and fermented snakehead.	This investigation has led to development of a manual of the processes of dried and fermented snakehead (*C. striata*) that cut processing time for both salted and fermented snakehead. Results demonstrated processing techniques that allow safe consumption of snakehead for up to 4 weeks of storage, based on sensory, chemical and microbiological parameters.
Feed formulation and processing with soy protein concentrate for snakehead diets	Development of cost-effective alternative feeds for small-scale farming of snakehead, replacing fishmeal with plant-based protein (soy protein concentrate).	Success of this technology is helping overcome the use of small-size fish for fishmeal, improving the sustainability of snakehead aquaculture and reducing pressures on wild caught small-size fish.
Sustainable snakehead breeding, weaning, and rearing in Cambodia	Development and knowledge transfer of successful breeding, weaning, and rearing/growout practices for snakehead in Cambodia	This work has helped lift the 2005 ban on snakehead farming, helping to support the large population of snakehead fish farmers in the region.
Sustainable aquaculture development in Cambodia through carrying capacity models and estimates	This study develops a planning tool for sustainable aquaculture in Cambodia by training Cambodian scientists, regulators/managers, and officers in the use of models to estimate the amount of aquaculture waste that an ecosystem can assimilate.	This work has initiated the development of aquaculture carrying capacity estimates for Cambodian waterways as part of a regional planning effort to build a more sustainable aquaculture industry.
Climate change vulnerability assessment on snakehead value chain in the Lower Mekong Basin	This assessment develops an improved understanding of the vulnerability of actors in the fish value chain to the key drivers of climate change. Assessment of vulnerability of snakehead fishers in Cambodia and Vietnam will provide evidence-based policy recommendations for the sustainable development of aquaculture and fisheries in the Lower Mekong River basin.	Recommendations are suggested to contribute to assisting snakehead farmers and fishers in adapting and preparing for the impacts of climate change.

Asia Project: Nepal

Project Partners and Collaborators

University of Michigan (US Project 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; and Prithivi Secondary School.

Technology	Description	Key Impact
Sahar reproduction in warm water – Chitwan, Nepal	Adapting reproduction technology from cool to warm water site to increase the amount of sahar fry available.	5,000 fry were produced in Rampur and used in stocking aquaculture ponds or natural waters.
Reducing bird predators and poaching for ponds in Nepal	Isolation of ponds from human disturbance allows more bird occupation and reduces fish production. This study assessed periphyton substrate as shelter and cover to protect fish from predators like birds and also hindered poaching.	The periphyton substrate was successful in reducing bird occupation and increasing fish production by about 20%.
Sahar-tilapia polyculture	This project determined whether or not Sahar (*Tor putitora*) and Nile tilapia (*Oreochromis niloticus*) cultured with carps increases fish production compared to existing carp polyculture systems.	Cultured sahar is now available for human consumption. Carp production increased when the two species were added. Tilapia production has improved by 30%. This is a positive impact on smallholder farmers in Nepal and region.
Establishment of school ponds and curriculum for teaching children and women about aquaculture and fish.	A pond and new aquaculture curriculum was used to train students on aquaculture technology.	STEM knowledge was integrated with agriculture education. 117 students were trained, and knowledge for them improved from less than 40% to 60-82% on standard tests. 45 women received training and knowledge on fish and its role in household health. Consumption of fish in the household also increased.
Carp-SIS polyculture system with periphyton	This project compared fish production between carp-SIS polyculture and periphyton-based carp-SIS polyculture in order to develop a cost-effective means to increase fish production.	This technology led to a 74% increase in gross margin for carp polyculture due to reduced feeding costs and increased fish production. Farmers can earn income through carp sales and improve family health and nutrition through consumption of SIS from their ponds. This technology is suitable to rural farmers, as it is cost-effective, simple, and supports family nutrition.

Africa Project: Ghana & Tanzania

Project Partners and Collaborators

Purdue University (US Project 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); Ministry of Agriculture, Livestock, and Fisheries; Sokoine University of Agriculture; Western Indian Ocean Marine Sciences Association (WIOMSA); and University of Dar es Salaam.

Technology	Description	Key Impact
Invertebrates as a protein source in fish feeds	Evaluation of the composition of housefly maggots and earthworms from different substrates to determine their suitability as protein sources in Nile tilapia diets in Tanzania showed promise. Chicken manure was the best substrate for production of housefly maggots in terms of yield and protein content, while cow manure was the best substrate for producing earthworm.	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 poor-resourced fish farmers.
Cell phone marketing tool in Ghana	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. The technology is a cellphone based Fish Market Information System (FMIS) with a focus on tilapia and catfish.	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.
Spat collection and nursery methods for shellfish culture and training in Zanzibar	Spat collection is one of the most sustainable and cost-effective methods to obtain stock for shellfish farms, hence methods will be tested to determine the best materials and timing for spat collectors, and test nursery methods to rear the collected spat. This work addresses one of the primary obstacles to further development of the small shellfish farms - how to obtain stock in a sustainable manner for the farms.	The extension of this technology has helped to build the economy of women along the villages of Bweleo and Nyamanzi. They have reported earning supplementary incomes from $160-$220 per month from pearl farming, which has helped them to build houses, purchase fishing boats, and pay school fees for children.

Africa Project: Kenya & Uganda

Project Partners and Collaborators

Auburn University (US Project University); Alabama A&M University; University of Arizona; University of Eldoret; Kenyatta University; Makerere University (Lead HC Institution); National Fisheries Resources Research Institute (NaFIRRI); Grameen Foundation; SARNISSA; and the Bidii Fish Farmers Cooperative.

Technology	Description	Key Impact
Low-Cost captive breeding and hatching of African Lungfish	Investigation of lungfish reproductive cycle to facilitate farm-based spawning.	The full development of this technology is contributing to the domestication of the African lungfish and is helping to ensure the environmentally sustainable supply of lungfish seed for a new culture industry.
Cell Phone Network for Small & Medium Scale Fish Farmers	Marketing and information tool: Develop a program of technical collaboration among researchers, government technical staff, and cellular providers to advance aquacultural development.	Through the availability of a text-based system, farmers have access to fish market and fingerling supply information. This results in better prices, less risk, better information, and facilitates access to key inputs.
Market Strategy for Small-Scale Fishers and Fish Farmers	Generating information to support the development of marketing strategies for fishers and aquaculturists producing products for the reseller markets in Uganda.	Results can be used by relevant authorities to harmonize marketing strategies and to develop guidelines through which price distortions can be removed to promote free market practices.
Low-cost Aquaponics unit in Kenya	One option to increase fish productivity and at the same time provide an additional revenue stream is to integrate the fish culture more directly with vegetable production.	The prototype 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	Producing 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.	Results showed diets supplemented with the amino acid, lysine, resulted in faster tilapia growth rates. All experimental feeds containing EAAs supported faster tilapia growth than the readily-available but expensive commercial feeds. Farmers can incorporate these new feeds with minimal investment.

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.

The AquaFish Open Access Policy should be implemented by AquaFish Lead Project PIs 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.

Improving the accessibility of AquaFish data and results can more effectively bring the program, its partners, and other stakeholders a more complete and timely understanding of development programs. 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 project developed a plan that outlines 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 Data Management Plans (DMP), approved by USAID AOR 30 August 2016. As AquaFish 2016-2018 continuing work is just getting underway, projects reported that no data was made public in FY16.

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 poorer societies 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 the US and Host Countries to ensure efficient and effective administration of program objectives. 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.

In FY16, the MT continued to monitor all program activities and deliverables, establishing research accountability and evaluating achievements. As planned, the MT performed a comprehensive mid-term review of the 2013-2015 research portfolio and Host Country field sites to identify successful lines of research to continue forward. The MT reviewed deliverables and final reports for the 33 investigations that were carried out under the 2013-2015 Implementation Plan to determine if research was completed and objectives were met. The five research projects (Bangladesh, Cambodia & Vietnam, Nepal, Ghana & Tanzania, and Uganda & Kenya) were invited to propose continuing investigations to build on successful lines of research for the 2016-2018 Implementation Plan. In preparation for closedown in 2018 and to position projects for the future, the MT led discussions at the AquaFish Annual Meeting in April 2016 to ensure projects were planning for graceful exits from host countries. After an external proposal review process, with assistance from external expert reviewers, AquaFish sanctioned work on 24 investigations for the final phase of the award.

The MT continued regular communication with program partners in FY16, including conference calls, in-person meetings, and site visits in order to support, monitor, and evaluate projects. More than 40 AquaFish partners from 13 countries attended the AquaFish Annual Meeting in Indonesia to exchange ideas, share achievements, and discuss strategies for advancing aquaculture research technologies while continuing to build capacity in communities and at host country institutions. Quarterly PI conference calls provided regular check-ins to discuss progress of AquaFish work related to reporting, funding, upcoming opportunities, and challenges. MT staff conducted visits in FY16 with US project partner institutions to evaluate financial and contractual processes. The MT also continued to monitor and evaluate project success via online reporting and the FTF monitoring system. In an effort to identify outputs and outcomes of AquaFish research, an Impact Assessment workshop was held in FY16 with program partners and advisory team members. The half-day workshop, organized and chaired by the Director, was held to discuss AquaFish program-wide impacts and to develop a strategy to communicate 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 provided guidance for implementing protocols for future data synthesis and

storage beyond what was already included in the original 2013 extension award. The MT also maintained regular communication with the AquaFish Agreement Officer's Representative at USAID, Dr. Shivaun Leonard, and fielded information and data requests, serving as an effective liaison for our partners, allowing them to devote their time and expertise to ensure research integrity.

AquaFish focuses on research and works with partners to scale up technologies to maximize impacts. This includes fostering existing partnerships and creating new ones. In FY16, the MT developed a new partnership with Yangon University in Burma and engaged with personnel at both the Asian Institute of Technology in Thailand and the Institute for Mariculture Research and Development in Indonesia to promote aquaculture development. The MT worked with EPAC and RCE coordinators to review priorities and methods that will ensure successful closedown in 2018. In addition, as one of 24 FTF Innovation Labs, AquaFish recognizes the importance of inter-lab relationships and communication in tackling root causes of global hunger and poverty by employing proven strategies for achieving large scale and lasting impact. To this end, AquaFish continued collaborative partnerships with other Innovation Labs, including Horticulture and Nutrition, on a nutrition project in Bangladesh. Dr. Egna maintained ongoing communication with USAID about expanding a similar collaborative Innovation Lab project in Cambodia in the future. AquaFish MT staff also participated in the Innovation Labs Council Meeting and the World Food Prize, allowing AquaFish to connect with other programs and foster new international development relationships 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 FY16, the MT honored two early career scientists with *Yang Yi Young Scientists Fellowships* at 11th Asian Fisheries and Aquaculture Forum and sponsored three awards for best aquaculture economic papers at the International Institute of Fisheries Economics & Trade's 18th Biennial Conference. 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 MT is responsible for engaging in outreach and dissemination activities that facilitate communication, publicize results and technologies, and create new linkages. In FY16, the AquaFish MT assisted in chairing and organizing four international aquaculture conferences and symposia. The MT served as an exhibitor at four events in FY16, including two international conferences and two OSU events. These activities are opportunities to educate and engage the scientific community and the wider public, both in the US and internationally, on AquaFish activities and accomplishments, and open doors to new partnerships. AquaFish disseminated information widely in FY16 through flagship newsletters and publications, including the AquaFish Ninth Annual Report, AquaFish Technical Report, 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 responded to public inquiries about AquaFish activities and opportunities, both internationally and in the US. The AquaFish MT began, in FY16, to archive past documents that were previously not available to the public. These publications and resources demonstrate decades of experience and knowledge, and highlight the value and impact of long-standing and successful programs like AquaFish. The AquaFish Director also provided interviews with a wide array of private sector organizations, including the American Association of the Advancement of Science, Monterey Bay Aquarium, and the Conservation X Labs. 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.

In addition to AquaFish PIs and partners' publications and presentations, 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., B. Goodwin, M. Chow, S. Ichien, and H. Egna. 2016. A multifaceted approach to closing the gender gap in aquaculture for improving global nutrition. [Poster]. 6th Global Symposium on Gender in Aquaculture and Fisheries, Bangkok, Thailand, 3-7 August 2016.
- Chow, M. and H. Egna. 2016. Gender dimensions of disaster management: Building resilience for coastal aquaculture and fishing communities in the Philippines. [Poster]. - 6th Global Symposium on Gender in Aquaculture and Fisheries, Bangkok, Thailand, 3-7 August 2016.
- Chow, M., B. Goodwin, S. Ichien, K. Goetting, and H. Egna. 2016. Improving feed quality, availability, and cost with alternative feeds and feeding regimes for smallholder aquaculture operations. [Poster]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand. 3-7 August 2016.
- Chow, M., J. West, and H. Egna. 2016. Examining gender authorship in aquaculture journals. [Poster]. 6th Global Symposium on Gender in Aquaculture and Fisheries, Bangkok, Thailand. 3-7 August 2016.
- Egna, H., M. Chow, and J. West. 2016. Examining gender authorship in aquaculture journals. [Oral]. 6th Global Symposium on Gender in Aquaculture and Fisheries, Bangkok, Thailand. 3-7 August 2016.
- Goetting, K, M. Chow, and H. Egna. 2016. Development of innovation feed technologies and strategies for small-holder aquaculture operations. [Poster]. World Aquaculture Society – Aquaculture America 2016, Las Vegas, Nevada, US. 22-26 February 2016.
- Ichien, S. and H. Egna. 2016. At the nexus of food water: Fish for a food secure future. [Poster]. The Food-Energy-Water Nexus – 16th National Conference and Global Forum on Science, Policy, and the Environment, Washington, DC, US. 19-21 January 2016.
- Ichien, S., K. Goetting, C. Price, and H. Egna. 2016. Aquaculture education for development: Empowering a diverse community of aquaculture researchers and professionals. [Poster]. World Aquaculture Society – Aquaculture America 2016, Las Vegas, Nevada, US. 22-26 February 2016.
- Ichien, S., M. Chow, and H. Egna. 2016. Integrating the culture of indigenous species with climate-smart aquaculture. [Poster]. 11th Asian Fisheries and Aquaculture Forum, Bangkok, Thailand. 3-7 August 2016.
- OSU Earth Day Fair in Corvallis, OR, US (April 2016) – exhibitor on sustainable aquaculture and fisheries practices.
- OSU University Day in Corvallis, OR, US (September 2016) – exhibitor.
- Price, C., S. Ichien, and H. Egna. 2016. Cell phone fish marketing networks in Kenya, Ghana, and Uganda. [Poster]. World Aquaculture Society – Aquaculture America 2016, Las Vegas, Nevada, US. 22-26 February 2016.

FY16 also included accolades for AquaFish and its Director. In recognition of her decades-long efforts to mentor and support the work of many young scientists from the Asia-Pacific region, the Asian Fisheries Society (AFS) honored Dr. Egna with a Gold Medal award. AquaFish received a separate, all-team Gold award for its support to AFS. Additionally, Dr. Egna was named Aquaculture Without Frontiers' Woman of the Month for September 2016, recognizing the legacy she has built over the years through various aquaculture research programs. These awards distinguish Dr. Egna as a leader in her field and showcase her commitment to research and capacity building efforts that improve livelihoods and food security for vulnerable populations.

In FY16, the MT continued to effectively manage a large cooperative agreement, ensure compliance and transparency in research, and work in concert with USAID's objectives. The productivity for FY16 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

IX. OTHER TOPICS

GENDER INITIATIVES AND ACCOMPLISHMENTS

Gender equality and female 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 aquaculture 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 FY16 the AquaFish gender disaggregated data show that women represent 50% of the AquaFish short and long-term trainees, 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 long-term 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. During FY16, women in Nepal were trained on polyculture systems to increase household income and nutrition.

Gender Integration Initiatives

FY16 accomplishments towards AquaFish's Gender Integration Initiatives (highlighted with the green background) are presented in the table below. These gender initiatives are a component of AquaFish's 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 project.
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 *XII. 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. In FY16, AquaFish researchers successfully increased the number and proportion of women involved in short-term trainings by holding several workshops focused on involving women.
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. Investigations involve a tailored approach that considers 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 assesses and synthesizes impacts of our activities on women and communicates that information through conference presentations, posters, AquaNews articles, and other media. In FY16, AquaFish produced and presented three gender-focused posters at the 6th Global Symposium on Gender in Aquaculture and Fisheries in Bangkok, Thailand in August. The posters were titled: • *Gender Dimensions of Disaster Management: Building Resilience for Coastal Aquaculture and Fishing Communities in the Philippines* • *Examining Gender Authorship in Aquaculture Journals* • *A Multifaceted Approach to Closing the Gender Gap in Aquaculture for Improving Global Nutrition*
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 FY16, AquaFish researchers in Uganda held three workshops on designing and delivering cell-based information, reaching a total of 31 women to address their specific needs and barriers.
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 that women farmers have equitable opportunities to participate in trainings. In FY16, two trainings on nutrition and income generation for women's fish farming groups were held in Nepal, reaching 44 women. Additionally, each AquaFish project includes women in key positions, serving in roles such as investigators, research collaborators, mentors, and workshop leaders. All project participants are encouraged to attend trainings, conferences, and special sessions that build on their gender awareness in fisheries and aquaculture. In FY16, the Gender in Fisheries and Aquaculture (GAF) group held the *GAF101 Training Workshop: Theorizing Gender in Aquaculture and Fisheries Research,* which was attended by several AquaFish researchers. This session was held within the GAF6 Symposium sponsored by AquaFish..
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 FY16, women represented 50% of the AquaFish short and long-term trainees, with program efforts reaching 265 women in short-term trainings and 79 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 FY16 gender-focused work for the five AquaFish projects are included below.

Africa Project: Ghana & Tanzania

- AquaFish researchers are working with pearl oyster shellfish farmers in Zanzibar to obtain stock in a sustainable manner - a primary obstacle in the further development of small-scale shellfish farms. Spat collection is one of the most sustainable and cost-effective methods to obtain stock for shellfish farms, so different methods were tested to determine the best materials and timing for pearl oyster spat collectors. Women involved in the project have also learned to create pearl crafts, market products, and develop business plans. By selling pearl crafts, these women reported earning $160 to $220 per month in supplemental income from pearl farming (equivalent to the lowest salary earned by an employed person in Tanzania).

Africa Project: Kenya & Uganda

- In FY15, researchers identified challenges and limitations to cell phone usage by fish farmers in Uganda, with a goal of informing new approaches to communicate fish farming best practices, provide farmers with current market rates, and better connect fish producers and fish buyers. In FY16, researchers are building on this work to develop and implement a mobile application for fish farmers.

Asia Project: Bangladesh

- Women were integrated in all levels of AquaFish work in Bangladesh in FY16. Three women host country researchers from the Bangladesh Agricultural University played key roles in conducting research and outreach, with one serving as the HC Project PI. One experiment showed that *Pangasius* can be grown in brackish water, which provides fish farmers in areas of saltwater incursion the opportunity to continue farming. On-farm trials were used to test and apply these findings while also training the farmers involved, and over half of the farms conducting trials were owned by women.

Asia Project: Cambodia & Vietnam

- In FY15, researchers found fish and 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 began to expand on this work in FY16 to establish food consumption patterns in Cambodia and Vietnam during the *dry* season. Results of this continuing study will allow for seasonal nutrition comparisons to inform recommendations on improving food security and household nutrition.

Asia Project: Nepal

- Research led by a host country investigator in Nepal who received her PhD with Aquaculture Collaborative Research Support Program support worked with 37 women fish farmers to evaluate the impact of periphyton enhancement on carp and small indigenous fish species (SIS) polyculture yields. Fish production and gross margin were found to be higher in carp-SIS polyculture with periphyton enhancement. Training on carp-SIS polyculture systems was provided to 35 farmers, including 28 women.

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. 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, 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 and socio-cultural status of women. Youth un- and under-employment 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 correlated with the socio-cultural roles of women in the specific regions. Women and youth are tied by their barriers to participation in the agriculture sector, including inadequate access to education, employment, and decision-making. In Kenya, the RCE leveraged funds to train 51 youth, including 21 girls, on sustainable pond aquaculture. RCE coordinators have encouraged HC PIs to offer more scholarships for women and organize women-specific trainings.

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 (http://rceafrica.com/; the network is also accessible on Facebook and Twitter)
- Fostering intra-Africa collaboration – The RCE is currently collaborating with Kenyatta University, Malawi University, Kwame Nkrumah University of Science and Technology, and University of Stirling on a grant application to the Africa Union to support cage aquaculture.
- Collaborative research and institutional linkages (e.g., International Livestock Research Institute [ILRI], Worldfish, CGIAR)
- 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, a two-day Regional Aquaculture meeting in Arusha, Tanzania that took place in September 2016. At the meeting, a constitution for the Aquaculture Network of East Africa was discussed and a progress update was provided on the World Aquaculture Society Africa 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 organize an international conference on animal nutrition. The two-day conference was held in Ghana on August 8-9, 2016 and was attended by several current and past AquaFish HC investigators. The

Fisheries and Agriculture Organization of the United Nations (FAO) program to enhance youth employment continues, including training youth in pond aquaculture.

RCE – Asia Annual Report

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

The main aquaculture research needs in the region are new and improved technologies; specifically, to optimize farming systems for increase ecological efficiency, reduce environmental impacts, and increase profitability. Additionally, more effort is needed to better understand how to monitor for and manage fish health. Countries with less developed aquaculture industries need more effort put into fish feeds and seed production. The challenge remains of increasingly stringent production practice requirements to meet food quality and safety standards. Finally, there is a need to address climate change mitigation and adaption.

Activities that Support Women's Involvement in Aquaculture and Fisheries

The Network of Aquaculture Centres in Asia-Pacific (NACA) is an intergovernmental organization affiliated with the RCE Asia 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 and audit; policy advocacy for more gender sensitive policies; assessment of gender policies and programs for aquaculture; and conducting a training needs assessment 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 FY16:

- Continued training focused on developing culture-based fisheries in Cambodia and Lao People's Democratic Republic, and more than 100 professionals have been trained on fish breeding techniques and hatchery management.
- Building regional capacity for aquaculture development through training and education with several partner institutions, including conducting a training needs assessment.

Leveraged Activities

An ACIAR (Australian Centre for International Agricultural Research) funded project on Culture Based Fisheries (CBF) development in southeast Asia built upon previous ACIAR projects in the region.

RCE – Latin American and Caribbean Annual Report

In Phase II (2013 – 2018), USAID requested that AquaFish focus on Africa and Asia. As a result, there are currently no funded projects in Latin American and Caribbean region (LAC), but AquaFish hopes to continue assisting in the region informally through its established network and previous relations. The LAC RCE, thus, plays an important role in maintaining communication with past and present AquaFish collaborators, building capacity, and leveraging resources.

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

The aquaculture industry in the LAC is being impacted by economic hardships, causing increases in the cost of equipment and feed ingredients. A major concern in Brazil is the bureaucracy and delay in receiving environmental licenses for cage farming in public waters. These issues have lead to farms operating illegally, ultimately disqualifying them from access to credit.Continuing research remains the greatest need in the LAC, specifically on incorporating marine species into the aquaculture industry, identifying new ingredients to improve diets, 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
Women's involvement in aquaculture in LAC continues to be limited almost exclusively to fish processing. Many countries in the region have programs to support women; however, none are specific to aquaculture or fisheries. In 2016, FAO supported a study entitled "The Role of Women in Fisheries and Aquaculture in Chile, Colombia, Paraguay, and Peru." The AquaFish RCE Coordinator for South America, Maria Portella, serves as a role model for women in aquaculture. She has served as president of LACQUA, teaches two courses in aquaculture, and is currently advising seven students.

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

- Regional and international conference participation including, serving as program chair, meeting organization, chairing and moderating sessions, and presenting.
- Leveraging funds to support long-term students
- Participating in calls for proposals to leverage funds and increase capacity
- Dr. Portella is serving as the President of LACQUA 16 in Brazil, and also is the chair of the steering committee, and has participated on the board of directors of The Latin American and Caribbean Chapter of the World Aquaculture Society
- Dr. Contreras chaired a session at LACQUA 2015, titled "Fish Larviculture"

Leveraged Activities and Associate Awards
RCE Coordinators in LAC leveraged funds for 13 separate grants, including funding for student support, professional networking, and lab expansions. Dr. Portella secured leveraged RCE funds to obtain three scholarships for students from the National Council for Scientific and Technological Development (CNPq). Funds were also secured through B.BICE+ and CNPq to support a visiting professor from Germany. Dr. Contreras-Sánchez secured a grant from the National Fisheries Institute (INAPESCA) to support cryopreservation of germplasm from aquatic organisms.

Zanzibar woman using pearls farmed from shellfish aquaculture to make jewelry.

XII. ISSUES AND CHALLENGES

- AquaFish typically receives annual funding prior to the start of each fiscal year, although sometimes at the "11th hour." Receiving funding before the start of each fiscal year allows the ME to program funds responsibly, prevent subaward termination, and if needed, modify the work plan to accommodate changes in funding levels. Unfortunately, AquaFish did not receive funding, or any information on funding levels, prior to the start of FY2017. Uncertainty regarding funding level and when the funds will arrive impacts the ability of AquaFish to program funds effectively and meet grant objectives within the proposed timeline.

- The AquaFish Management Team (MT) continues to enjoy productive relationships with OSU's Office of Sponsored Research and Award Administration (OSRAA) and the Agricultural and Marine Sciences Business Center (AMBC) to handle aspects of award administration that the MT is not trained or legally authorized to do (e.g., signing contracts, managing payroll, and maintaining infrastructure). Unfortunately, recent high staff turnover at both OSRAA and AMBC has resulted in delays in providing critical services to AquaFish. Delays in processing subcontract amendments and paying subcontract invoices were especially noticeable as seasoned personnel left OSRAA and new staff brought on board. The AquaFish MT was vigilant in monitoring OSU's progress in processing subaward amendments to minimize the impact of these institutional slow-downs on program activities and our ability to move funding through the pipeline to our project partners. With experience and training, we are confident that new personnel within OSU's OSRAA and AMBC will soon be back to providing AquaFish with the support needed to meet award objectives in a timely and efficient manner.

- The 2015 earthquakes and aftershocks in Nepal killed and injured thousands of people and destroyed buildings throughout the country. Fortunately the Nepal AquaFish team and their families were not injured, however, AquaFish research encountered delays due to redirected efforts and damage to experimental units. As expected with disruptions of this nature, impacts extended into FY2016, primarily in the form of delayed work and infrastructure concerns. In FY2016, additional support was provided to AquaFish researchers in Nepal to assist them in overcoming challenges that the earthquake presented. As of the end of FY16, researchers were well on their way to bringing AquaFish work back on schedule.

- The security situation in Kenya and Bangladesh, two of our partnering host countries, has deteriorated considerably over the last several years. While AquaFish partnerships remained strong in these countries allowing work to continue, additional precautions must be given to personal safety. In Bangladesh, the U.S. government determined that the terrorist threat was "real and credible," with high-profile terrorist attacks occurring in July 2016 at a restaurant frequented by foreigners in Dhaka and elsewhere throughout Bangladesh against religious minorities, bloggers, publishers, and others. Travel warnings were also issued by the U.S. Department of State warning U.S. citizens to avoid travel to certain areas of Kenya due to threats by the terrorist group al-Shabaab. The travel warning continued into 2016, although the deadliest attacks occurred in April 2015 at Garissa University College, Garissa, and in September 2013 at the Westgate Mall, Nairobi.

- FY2016 started amid considerable confusion regarding USAID's position on J-1 Visa requirements for Exchange Visitors in the US. In early October 2015, Innovation Labs were contacted by BIFAD to provide feedback on a letter and policy brief prepared by a number of US universities concerning the burdensome and costly nature of USAID's Visa and TraiNet policies. These discussions and feedback resulted in an Exchange Visitor exemption for the Innovation Labs, meaning that requirements of ADS 252 and 253 applicable to Exchange Visitors (including use of USAID-sponsored J-1 visas and reporting in TraiNet) do

not apply to IL-supported individuals. The exemption eliminated a cumbersome process that posed a significant deterrent to supporting HC students at US universities.

- Associate Awards are intended to allow Missions or Bureaus within USAID to support work related to the Leader program. AquaFish has received two Associate Awards since inception, the first in 2007 and the second in 2010. Unfortunately, no Associate Awards have been received since. The AquaFish MT is restricted from actively seeking out Associate Awards, and therefore relies on USAID Mission and DC personnel to highlight award opportunities. In ongoing discussions with USAID, AquaFish has expressed interest in Associate Award opportunities for scaling and stretching results, technologies, and impacts beyond what is currently done. It is regretful that no Associate Award opportunities have materialized from these interactions. This issue is compounded by the relatively low ceiling on the AquaFish award for Mission buy-in of $1 million, restricting opportunities to smaller efforts. With the understanding that Associate Award performance periods can extend beyond the Leader award end date, AquaFish remains hopeful that an opportunity to secure an Associate Award will arrive soon.

XI. FUTURE DIRECTIONS

The *Feed the Future Innovation Lab for Collaborative Research on Aquaculture & Fisheries* (AquaFish Innovation Lab) at Oregon State University (OSU) 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 (FTFMS) metrics, disaggregated short- and long-term training data, and benchmarks. Moving forward, AquaFish will have a greater focus on outreach and dissemination to enable host countries to continue to implement best aquaculture practices and to build on existing work.

2016-2018 Continuing Projects
AquaFish Phase II projects were initially funded over a two-year Implementation Plan from 2013-2015 (http://aquafishcrsp.oregonstate.edu/page/implementation-plans), and after a mid-term review in FY16, successful lines of research that build on and add value to previous work are being continued through 24 investigations under the 2016-2018 Implementation Plan. Projects are taking place in the following countries in Asia and Africa: Bangladesh, Nepal, Cambodia, Vietnam, Ghana, Tanzania, Uganda, and Kenya. As Burma has remained an area of interest for USAID, AquaFish also intends to initiate an assessment of aquaculture in that region. Moving forward, AquaFish activities will continue progress toward the overall goal of enriching livelihoods and promoting health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquatic resources. Bringing together resources from Host Country institutions and US universities, AquaFish emphasizes sustainable solutions in aquaculture and fisheries.

Planning for Graceful Exits
During this final Implementation Plan, it is a high priority to ensure that almost 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 host country researchers, extension agents, farmers, industry personnel, and other stakeholders, managers, and policy makers. Each project developed an Exit Strategy in FY16 describing a plan for a graceful exit after the AquaFish program ends in March 2018. All project partners, as well as external advisory groups, contributed to these plans during a dedicated session at the AquaFish 2016 Annual Meeting in Surabaya, Indonesia.

Adding Value Through an Associate Award
An Associate Award would enable AquaFish to scale and stretch our results, technologies, and impact beyond what we already do. Focusing work in one of our current host countries, where we already have effective partners, would lead to the highest success. Results could also be adapted for regional application. An Associate Award would provide the opportunity for AquaFish to add value for the Bureau of Food Security and Missions in the areas of nutritious foods, climate smart agriculture, diversifying farm enterprises, gender, innovative market solutions, and water quality and use.

Assessing Programmatic Impacts
AquaFish partners met for a half-day workshop to discuss a program-wide assessment of impacts in conjunction with the AquaFish 2016 Annual Meeting. Due to difficulty of gathering good longitudinal

data to conduct an Impact Assessment on long-term training (as initially intended), the collective decision was to instead focus on feed technologies. 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. Reviewing past and present work can help inform future aquaculture research on feeds. The assessment will thus include a review of AquaFish Collaborative Research Support Program and AquaFish Innovation Lab research on feed ingredients and feed strategies and on resulting technologies and their adoption, transfer, and scalability.

APPENDIX A: SUCCESS STORIES

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY FISH FARM NETS NATIONAL AWARD FOR AQUACULTURAL EXCELLENCE

Poverty reduction, improved nutrition, and greater food security are the focal points of development efforts by many African governments. Because fish is an important source of protein and essential micronutrients in African households, supporting the growth and sustainability of aquaculture on the continent, particularly in sub-Saharan Africa, provides a means to address income and nutrition concerns.

AquaFish Innovation Lab researchers in Ghana, including those at Kwame Nkrumah University of Science and Technology (KNUST), are working towards the overarching goal of improving food security and human nutrition in fish-farming and nonfish-farming households by increasing tilapia's nutritional value through innovative tilapia feeds. Additionally, the development of a market information system is helping close gaps in the fish value chain.

It's part of the AquaFish longtime effort to support fish farmers around the globe — through advancement of aquaculture systems that promote and model small-scale fish farming, development of feeding strategies that reduce operating costs while maintaining optimal fish growth, and promoting environmentally sustainable technologies.

Over the last 10 years, AquaFish partners in the US and at KNUST have developed new programs and curricula in aquaculture and fisheries, establishing KNUST as a leading aquaculture research program in Ghana. The program includes a fish farm operated by the university's Department of Fisheries and Watershed Management.

In December 2015, the fish farm was recognized by Ghana's Ministry of Fisheries and Aquaculture Development with a National Best Pond Fish Farmer Award during the country's 31st National Farmers' Day, which acknowledges the vital role farmers and fish farmers play in Ghana's socio-economic development.

"Aboboyaa," the 200-horse power farm tricycle awarded to KNUST as part of the National Best Pond Fish Farmer Award at National Farm Day in Ghana.

The national award further shines a spotlight on KNUST and positions its fish farm as a center of aquacultural excellence based on its research, teaching and outreach efforts, training and extension programs, and farm infrastructure.

KNUST received the award based on its use of best management practices (e.g., water reuse, record keeping, and fertilizer reduction) and its contributions to aquaculture development in Ghana.

Another criterion for the honor was KNUST's commitment to environmental safety without

compromising economic gains. KNUST accomplished this by adapting earlier Aquaculture Collaborative Research Support Program (CRSP) and AquaFish CRSP fish production methodologies that recycle benthic nutrients for vegetable crop production.

Over time, KNUST has scaled its farm up from a simple training and research facility for undergraduate and graduate students into a commercialized operation that includes 18 fish ponds of various sizes. The farm now generates income from fish sales, allowing it to maintain and improve facilities as the need arises. It also continues to be used for educational and training purposes, further building capacity around aquaculture in Ghana.

In addition to the farm, KNUST is poised to continue its contributions to aquaculture development in Ghana through AquaFish-support, research and capacity-building efforts, including training, professional development, and exposure at international conferences for KNUST students and faculty.

STUDY OF TILAPIA'S GUT MICROBIOME YIELDS INSIGHTS TO HELP BOOST FEED EFFICIENCY AND LOWER FEED COSTS TO SMALL-SCALE FARMERS

One of the challenges facing poor, small-scale farmers in coastal Bangladesh is how to improve aquaculture production in a sustainable way that also lowers costs and environmental impacts.

One target for cost reduction is in the area of feeds. Aquaculture growth for small-scale farms is often limited by a lack of access to affordable, high-quality feeds. For tilapia, feed can account for 60%–85% of total production costs.

A means of lowering production costs is to develop aquaculture strategies and systems that increase feed efficiency among cultured species, thereby reducing reliance on expensive feeds.

In previous investigations, AquaFish Collaborative Research Support Program researchers showed that alternate-day feeding results in higher benefit-to-cost ratios and net returns than daily and every-third-day feeding strategies in terms of tilapia grow-out in fertilized ponds. For example, tilapia and milkfish were grown to market size in the Phillippines using alternate-day feeding with significant cost savings (50% feed reduction) compared to daily feeding.

Analysis of Nile tilapia gut microbiome indicates that alternate-day feeding and weekly pond fertilization in tilapia culture can aid fish farmers.

Building on this past work, AquaFish partners from North Carolina State University (NCSU) and Bangladesh Agricultural University (BAU) conducted experiments on feed efficiency in Nile tilapia that characterized tilapia's gut microbiome and explored how alternate-day (or pulsed) feeding strategies affect nutrient absorption in this species.

Similar to the human gut microbiome, the community of microbes living in a fish's digestive tract can aid in the absorption of nutrients, maintain energy balance, and increase immunity. These functions make the microbes essential to fish health and grow-out.

To explore the tilapia gut microbiome, NCSU and BAU researchers analyzed tilapia fecal material and microbial communities.

The researchers found that fish fed on alternate days (every other or every third day) with pond fertilization had a greater diversity of microbes in their guts and that pulse-fed fish also had 20 unique species of bacteria compared to other treatment groups, such as extensive culture (using fertilization only) and semi-intensive culture (fertilization plus daily feeding).

They also found that fish fed on alternate days may experience a more balanced and efficient uptake of nutrients, resulting in better feed efficiency.

Ultimately, characterizing the gut microbiome of tilapia could aid in the development of probiotic supplements that support efficient and sustainable tilapia grow-out. Studies elsewhere have shown that probiotic maintenance of beneficial gut flora in cultured finfish can promote growth, greater nutrient availability, and better stock health. Additionally, supporting healthy gut flora in tilapia could allow

beneficial microbes to outcompete pathogens, such as fecal coliform bacteria, which can be passed on to human consumers through improper storage and handling of fish.

AquaFish researchers are continuing to build on their work by studying how nutrients received in the early stages of growth impact the health of mature tilapia, which could improve the environmental sustainability of tilapia farming practices in the US and globally. This research aims to help fill a gap in knowledge about fish nutrition and to further develop efficient feed strategies for fish farmers that can help boost yields, income, and human nutrition.

AQUAFISH RESEARCH ON FEEDS CONTRIBUTES TO LIFTING OF CAMBODIAN SNAKEHEAD BAN, OPENS DOOR TO ECONOMIC OPPORTUNITIES

Fisheries of the Lower Mekong Basin provide the means to create food security and nutrition for 60 million people in Cambodia and Vietnam. While aquaculture of snakehead (*Channa striata*) in Vietnam has been gaining in popularity because of its high market value, snakehead farming was banned in neighboring Cambodia in 2004 in an effort to alleviate pressure on wild populations of small, low-value, freshwater fish that were being harvested for snakehead feed.

AquaFish Innovation Lab researchers — at the Inland Fisheries Research and Development Institute in Cambodia, Can Tho University in Vietnam, and the University of Connecticut–Avery Point, University of Rhode Island, and Oregon State University in the US — have been working in the region since the ban to develop technologies and strategies to create a sustainable snakehead aquaculture program that can meet consumer demand.

These efforts have focused on domestication of snakehead, formulating alternative protein commercial feeds, and developing protocols for weaning and grow-out of hatchery-reared snakehead on formulated feeds.

Traditional methods of culturing snakehead involve catching juvenile striped snakehead (*Channa striata*) from the wild, holding them in ponds or cages, and feeding them wild-caught low-value fish.

AquaFish research in Vietnam first developed a pelleted snakehead feed that contained 40% plant (soy) protein — a far more sustainable protein source than that found in typical fish feed. Mannan oligosaccharide (MO), an immune stimulant, was tested as a feed supplement in the same study. Incorporating a 0.2% to 0.4% level of MO in snakehead diets yielded better growth performance and higher immune response in the fish.

A farmer poses next to a bag of alternative protein feed developed by AquaFish researchers.

Once the feed was successfully adopted by feed mills and farmers in Vietnam, AquaFish researchers compared the weaning and grow-out performance of wild, indigenous snakehead in Cambodia to that of domesticated snakehead from Vietnamese hatcheries using pelleted diets that contained a combination of soybean and fish meal. The Vietnamese hatchery fish showed a higher growth rate than that of wild Cambodian snakehead.

Outreach to spread information about the technology has already begun in the form of trainings about sustainable, small-scale snakehead culture for women in the Lower Mekong. Today, more than 90 percent for snakehead farmers use a pelleted feed that combines fish and soybean meals.

Cambodia's Fisheries Administration ultimately relied on information from AquaFish researchers regarding their investigations of snakehead domestication and breeding, weaning, and grow-out in considering a change to Cambodia's snakehead policy.

The ban on snakehead farming in Cambodia was lifted earlier this year, in April 2016. AquaFish-supported research played a critical role by informing the design and implementation of a successful and sustainable snakehead aquaculture policy.

Success in ending the ban not only opens the door for improved economic opportunities and better nutrition and food security for Cambodians but also promises to alleviate the environmental impacts of overfishing in the Lower Mekong Basin.

APPENDIX B: AQUAFISH PUBLICATIONS

The following 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. As of October 2016, there have been 244 publications.

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