

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

AQUAFISH NINTH ANNUAL REPORT

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AQUAFISH
INNOVATION LAB



AQUAFISH INNOVATION LAB NINTH ANNUAL REPORT

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Cover Photo

Farmers in Bangladesh carry recently harvested *Pangasius* catfish (photo courtesy of Dr. Lokman Ali).

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 staff are listed below.

AQUAFISH MANAGEMENT OFFICE

| | |
|------------------|---|
| Dr. Hillary Egna | Director and Lead Principal Investigator, AquaFish Innovation Lab |
| Dr. Ford Evans | Administrative Officer, AquaFish Innovation Lab |
| Jenna Borberg | Research & Communications Manager, AquaFish Innovation Lab |
| Kathryn Goetting | Outreach & Communications Manager, AquaFish Innovation Lab |

TECHNICAL AND ADVISORY COMMITTEE INFORMATION

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

DEVELOPMENT THEMES ADVISORY PANEL (DTAP)

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 FY15 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. Taking an active role in integrating Associate Award partners into the portfolio, Lead Coordinators manage Associate Awards that fall under their purview. Lead Coordinators also assist the Director in cases where a screening process is required in advance of an Initial Environmental Examination. The RCE Coordinators for FY15 included:

RCE – Africa: *Charles Ngugi (Kenya) & Héry Coulibaly (Mali)*

RCE – Asia: *Remedios Bolivar (Philippines) & Yuan Derun (Thailand)*

RCE – Latin America & Caribbean: *Wilfrido Contreras-Sanchez (Mexico) & Maria Célia Portella (Brazil)*

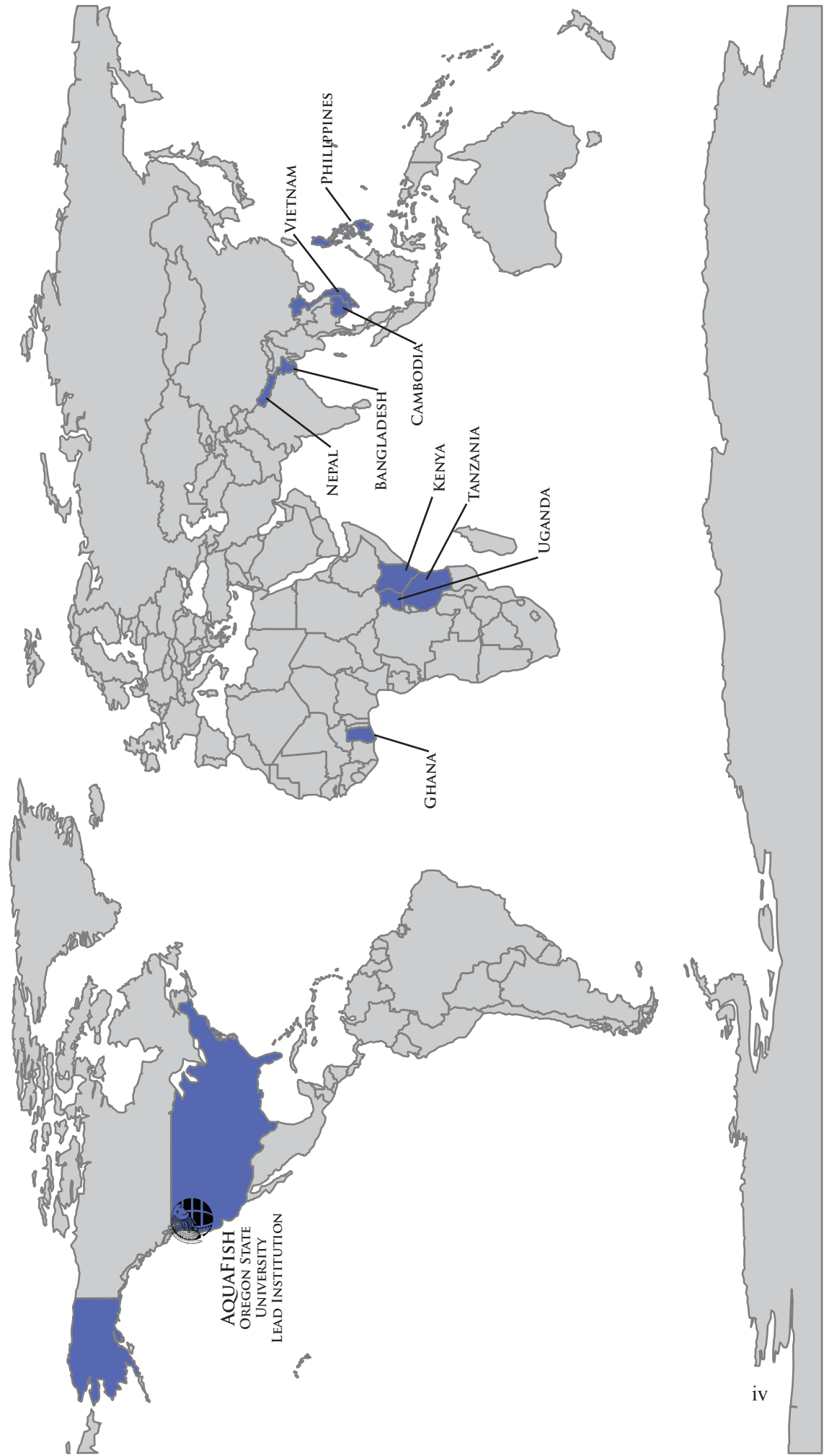
EXTERNAL PROGRAM ADVISORY COUNCIL (EPAC)

The EPAC provides advice to the MT on global program direction and annual critiques of research projects during annual or regional meetings to assist the MT in gauging 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, Borlaugh Higher Education for Agricultural Research and Development, and others. EPAC members for FY15 included:

Africa: *Nancy Gitonga*

Asia: *Liping Liu*

AQUAFISH PROJECT COUNTRIES FY15



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 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 formally funded partnerships as well as non-funded collaborations.

Funded Project Partners in FY15

(The list below includes all institutions in formally funded partnership with AquaFish during FY15.)

Bangladesh

Bangladesh Agricultural University
Hajee Mohammad Danesh Science &
Technology University
Khulna University
Patuakhali Science and Technology University
Shushilan NGO
University of Dhaka

Cambodia

Inland Fisheries Research and Development
Institute

Ghana

FarmerLine
Kwame Nkrumah University of Science and
Technology
University for Development Studies

Kenya

Kenya Ministry of Fisheries Development
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

Gulu University
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-FY15)

(This is a comprehensive list of AquaFish linkages from inception in 2006 through FY15.)

Australia

Monash University (Melbourne)

Bangladesh

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

Argentina

Universidad Nacional del Comahue

Australia

Australian Center for International Agricultural
Research
University of Tasmania

Brazil

Embrapa Meio Ambiente
Sao Paulo State University
Universidade Estadual Paulista, Centro de
Aqüicultura, Jaboticabal
Universidade 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 Co.

Shanghai Ocean University

Sichuan Aquacultural Engineering Research
Center

Southwest University

Tongwei Co. Ltd.

Wuhan University

Xiamen University

Zhanghe Reservoir Fisheries Management Co.

Zhejiang University

Colombia

Centro Internacional de Agricultura Tropical

Costa Rica

University of Costa Rica

Ecuador

Ecotas

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 Co.
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
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

Kenya Business Development Services
Kenya Marine & Fisheries Research Institute
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
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
Kenya Ministry of Fisheries Development
University of Eldoret

Lebanon

American University of Beirut

Malawi

Bunda College, Lilongwe

Malaysia

WorldFish Center

Mali

Assemblée Permanente des Chambres
d'Agriculture du Mali
Direction Nationale de la Pêche
Ministère de L'Élevage et de la Pêche
Rural Polytechnic Institute for Training &
Applied Research
The Permanent Assembly of Chambers of
Agriculture
USAID Mali

Mexico

Centro de Investigación de Alimentación y
Desarrollo (Research Center for Food &
Development)
Centro de Transferencia Tecnológica Para La
Acuicultura
Comité Estatal de Sanidad Acuícola 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 Acuicultura
Instituto Tecnológico 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 –
Culiacán
The Autonomous University of Sinaloa –
Mazatlán
Universidad Autónoma de Sinaloa – Culiacán
Universidad Autónoma de Sinaloa – Mazatlán
Universidad Autónoma de Tamaulipas
Wetlands Conservation Program
Universidad Juárez 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 Co.
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 Co.

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 Fish |
| AFU | Agriculture and Forestry University |
| AOR | Agreement Officer's Representative |
| AquaFish | The Feed the Future Innovation Lab for Collaborative Research on Aquaculture & Fisheries (Formerly Aquaculture & Fisheries CRSP) |
| BAU | Bangladesh Agricultural University |
| BFS | Bureau for Food Security |
| BMA | Production System Design and Best Management Alternatives |
| CRSP | Collaborative Research Support Program |
| DTAP | Development Theme Advisory Panel |
| EPAC | External Program Advisory Council |
| FAO | Food and Agriculture Organization of the United Nations |
| FSV | Food Safety, Post Harvest, and Value-Added Product Development |
| FTF | Feed the Future |
| GMO | Genetically Modified Organism |
| HC | Host Country |
| HHI | Human Nutrition and Human Health Impacts of Aquaculture |
| HICD | Human and Institutional Capacity Development |
| IFReDI | Inland Fisheries Research and Development Institute |
| IMS | Institute of Marine Sciences |
| IND | Climate Change Adaptation: Indigenous Species Development |
| KNUST | Kwame Nkrumah University of Science and Technology |
| LAC | Latin America and Caribbean |
| ME | Management Entity |
| MER | Marketing, Economic Risk Assessment, and Trade |
| MNE | Mitigating Negative Environmental Impacts |
| MT | Management Team |
| NACA | Network of Aquaculture Centres in Asia-Pacific |
| NCE | No-Cost Extension |
| NGO | Non-Governmental Organization |
| OSU | Oregon State University |
| PDV | Policy Development |
| PI | Principal Investigator |
| PoC | Point of Contact |
| QSD | Quality Seedstock Development |
| RCE | Regional Center of Excellence |
| SARNISSA | Sustainable Aquaculture Research Networks in Sub-Saharan Africa |
| SFT | Sustainable Feed Technology and Nutrient Input Systems |
| SIRTD | Strategic Investment in Rapid Technology Dissemination |
| SIS | Small Indigenous Species (of fish) |
| SNP | Single Nucleotide Polymorphism |
| SUA | Sokoine University of Agriculture |
| UJAT | Universidad Juárez Autónoma de Tabasco |
| US | United States |
| USAID | United States Agency for International Development |
| WAS | World Aquaculture Society |
| WIZ | Watershed and Integrated Coastal Zone Management |

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I. EXECUTIVE SUMMARY

The mission of the *Feed the Future Innovation 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 on 31 March 2013 for an additional five years (Phase II) through 29 March 2018.

The AquaFish Ninth Annual Report describes activities and accomplishments of the AquaFish Innovation Lab from 1 October 2014 to 30 September 2015 (FY15). During this reporting period, 24 Host Country (HC) institutions and 12 US universities in 10 countries engaged in collaborative research focused on improving the health and livelihoods of the poor and building human and institutional capacity through research, technology development, and training students and stakeholders at all levels. Five research projects under [*Implementation Plan 2013-2015*](#) 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

Building on AquaFish Phase I (2006-2013) accomplishments, Phase II efforts are strengthening longstanding collaborative partnerships, establishing new connections, expanding promising research, and maintaining alignment with the US Government’s Feed the Future (FTF) Initiative. In 33 investigations across the five projects, Phase II research focuses on improving the sustainability of aquaculture and fisheries through the development of innovative technologies and outreach techniques that enhance the sustained well-being of the poor.

As part of the 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. Inherent to the programmatic mission, human nutrition is a unifying thread in AquaFish research and the human nutrition focus allows for a more deliberate emphasis on connecting AquaFish research to the nutrition needs of rural and vulnerable families and broader nutrition goals. For example, research in Nepal established demonstration fish pond prototypes at four elementary schools in rural communities to help improve overall health and nutrition, as well as to integrate STEM knowledge with lessons in fish farming for schoolchildren in a new course of study. Newly developed women’s groups are also involved in this effort as a way to help build capacity throughout the whole community and bring aquaculture knowledge and nutrition to the household.

In FY15, AquaFish researchers continued to examine cultivation methods for indigenous fish species in an effort to provide sustainable, local food sources. Studies in Bangladesh are looking at the cultivation of nutrient-rich mola (*Amblypharyngodon mola*) with other aquatic species, such as prawns and carp. AquaFish research found that vegetable production on pond dykes significantly increased when grown in soils enriched with mud from ponds where mola, carp, and prawns were polycultured. This research helps

provide opportunities for farmers to generate additional income streams and increase access to a wider variety of nutritious foods.

AquaFish is dedicated to improving gender equity in the aquaculture and fisheries sectors. Women are involved in all aspects of AquaFish work, as long-term degree students and workshop participants to researchers, educators, and project leaders. Improving gender equity at all levels is central to the long-term benefits of gender integration. Efforts to increase women's involvement in aquaculture production and access to aquaculture technologies and resources during FY15 included workshops and other outreach mechanisms to empower women along the entire aquaculture value chain. For example, a workshop in Zanzibar focused on women's roles in shellfish aquaculture. In Cambodia, women fish farmers participated in on-farm feeding trials of wild and domesticated snakehead (*Channa striata*). Support of women in long-term degree trainings is another component integral to increasing women's participation in the aquaculture and fisheries sectors and in FY15 women represented nearly half of all the long-term students supported by AquaFish. Sustained involvement during formal degree training helps create connections and build networks that can be accessed far into the future.

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, the commercial sector, and non-governmental organizations (NGOs). Eighteen short-term training events were held in FY15, with a total of 661 participants. AquaFish supported 153 students in long-term formal degree programs in a variety of disciplines. Institutional strengthening also arises from successful partnerships that allow institutions to gain valuable experience in managing international grants and research projects. The wide dissemination of programmatic activities and results is critical to capture and ensure the sustained impact of the interdisciplinary and collaborative accomplishments of the AquaFish research community. Toward this effort in FY15, AquaFish researchers made 32 presentations at international scientific conferences and meetings and published 14 articles in peer-reviewed academic journals and trade magazines on AquaFish research, reaching a broad global audience. These activities further complement the AquaFish mission and expand the network of researchers dedicated to sustainable aquaculture and fisheries innovations.



A participating household in the catfish culture project in Bangladesh.



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 FY15 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 at Avery Point, and University of Michigan) were selected in 2013 to partner with OSU to conduct work in nine countries in Africa and Asia. Through funded partnerships with seven other US universities and 24 institutions and organizations in Africa and Asia, AquaFish is conducting 33 investigations using a systems approach that focuses on *Integrated Production Systems*, and *People, Livelihoods, and Ecosystem Interrelationships*.

In FY15, AquaFish successfully completed the Strategic Investment in Rapid Technology Dissemination (SIRTD) Associate Award. This project used evidence-based efforts to decrease poverty and increase food security through the adoption and dissemination of best management practices in Ghana, Kenya, and Tanzania. These practices were developed to help increase aquaculture productivity and profitability while also decreasing environmental impacts. Objectives for the project were met, and a final report was published and submitted to USAID in December 2014. This report can be accessed at: aquafishcrsp.oregonstate.edu/Documents/Uploads/FileManager/SIRTD_FinalReport_30DEC2014_Final.pdf

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 increase the range of available aquaculture feed through the development of improved and more cost-effective feed ingredients and production strategies. In Tanzania, the need to identify and evaluate alternative protein sources for quality and affordable feeds led to research that assessed the suitability of two different invertebrates (earthworms and maggots) as protein sources in tilapia diets. In FY15, this study found that a 35% inclusion of either earthworms or maggots as protein sources in tilapia feed resulted in the highest production and the most cost-effective composition of all the diets studied. Applying previous AquaFish research from the Philippines, research conducted in Bangladesh in FY15 showed that a 50% reduction in daily feed ration in polyculture systems of tilapia and indigenous carp did not significantly affect overall production and resulted in significant cost savings to farmers and minimized nutrient inputs in the environment.

Expanded market access contributes to increased income generation and food security. In FY15, AquaFish projects in Ghana and Uganda addressed challenges in the flow of information in the aquaculture value chain by studying the development and implementation of text-based aquaculture information via cell phones. These studies were preceded by AquaFish research that began in Kenya in 2009 that investigated the potential of including aquaculture market information via text messaging with an already existing platform for wild capture fisheries.

Gender integration and nutrition are cornerstones of the AquaFish mission, and researchers are examining methods to improve gender equity and human health in all projects. In Cambodia, AquaFish researchers

identified fish and other aquatic organisms commonly consumed by women and children less than five years of age to assess aquaculture potential to help alleviate food insecurity. In Nepal, fish ponds located at four schools in two districts are being used to teach school children, their mothers, and teachers about all aspects of aquaculture production. In addition, two Nepalese women's groups have been formed in order to increase women's access to training opportunities and knowledge transfer. These efforts, along with additional standards and benchmarks within the AquaFish research portfolio, are fundamental to achieving effective and sustainable development strategies that benefit and include all genders.



AquaFish researchers and fish farmers transport Pangasius feed in Bangladesh.

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 aquatic resources conferences. As an example, this past year AquaFish students and researchers at University of Eldoret in Kenya developed a low-cost aquaponic system to provide hands-on education to students, faculty, and farmers on a novel aquaculture production technology in that region while concurrently testing the productivity and efficiency of the system. In FY15, AquaFish supported 153 long-term degree students at 21 universities in nine countries, and AquaFish researchers conducted 18 short-term trainings, reaching 661 people. AquaFish researchers at HC institutions continued to strengthen collaborations with national and international institutions. In FY15, AquaFish researchers from the US and Host Countries attended 12 conferences, meetings, and symposia in nine countries, disseminating research results and sharing knowledge with colleagues, further expanding collaborative networks and increasing AquaFish's impact throughout the world.



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 Plan and Feed the Future Indicators and Monitoring System. Key accomplishments in FY15 in the AquaFish Leader Award are highlighted below.

Research and Technology Development

Twenty-five innovative aquaculture technologies were at varying stages of development in Africa and Asia in FY15. In developing these technologies, AquaFish projects involved 26 food security enterprises, producer organizations, women's groups, trade and business associations, and community-based organizations. For example, research in Bangladesh continued to diversify the small-scale aquaculture industry. Farmers were able to enhance their fish yield and economic returns for *Pangasius* in hyposaline culture by stocking fish at a higher density and using locally formulated rather than commercial feeds. In Nepal, AquaFish researchers expanded access of fish to under-represented populations by establishing demonstration fish ponds as a tool for a newly developed course of study on fish farming at four rural secondary schools. Through experiential education, school-age children and newly formed women's groups are introduced to the practice of fish farming as a means to improve health and nutrition. AquaFish also engaged with USAID and other Innovation Labs on topics related to human nutrition – including advising on collaborative work in Bangladesh and Cambodia.

Human and Institutional Capacity Building

Since program inception in 2006, AquaFish has fostered linkages with more than 275 institutions globally. In FY15, AquaFish had a total of 85 active linkages, including formal (funded) institutional partnerships with 42 organizations in 14 countries. AquaFish supported 153 students enrolled in long-term degree programs at US and HC institutions this fiscal year. Eighteen short-term training events were held, with a total of 661 participants, and included workshops, on-farm trainings, and train-the-trainer events to reach a range of audiences. In Kenya, students and fish farmers are gaining exposure to aquaponics by helping develop a low-cost, medium-scale demonstration at the University of Eldoret. The aquaponics demonstration is teaching the basics of growing plants with nutrient-rich effluent water from aquaculture ponds. Cambodian researchers trained community fishers as well as fisheries managers and officers on aquaculture carrying capacity – a concept essential to understanding successful resource management and optimal fish pond management. Carrying capacity is substantially more complex in water, a three-dimensional system, than for managing land-based agriculture systems.

AquaFish continued supporting Regional Centers of Excellence (RCEs) in FY15, with two coordinators each in Africa, Asia, and Latin America and the Caribbean. They assessed regional strengths and challenges, and built linkages for sharing information and technology.

Information Dissemination

AquaFish has disseminated programmatic findings to stakeholders through multiple avenues including the AquaFish website (aquafishersp.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 more than 1,500 recipients in FY15. AquaFish encourages researchers to publish findings in 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 more than 225 peer-reviewed publications on AquaFish-supported

research and data since program inception in 2006, 14 of which were published in FY15. AquaFish is also investigating methods for reducing knowledge gaps along the aquaculture value chain, with research underway in Ghana and Uganda to assess cell phones as a means to disseminate information to fish farmers and others.

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 toward 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 Vietnam, for example, two workshops were held with 60 women fish farmers to train them on small-scale snakehead farming, processing of snakehead products, and to assess their aquaculture needs and challenges.



A farmer in Zanzibar, Tanzania, shows some of her seaweed harvest.



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, and to lead research through scientific inquiry and problem solving.

The overall research context for the projects described in this Annual Report is poverty alleviation and improving food security 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, mentoring, 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 their awards.

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 incorporates 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 TOPIC AREAS

All projects are organized around ten areas of inquiry called topic areas, developed to characterize the research. The ten AquaFish topic areas (described below) cover a broad range of interrelated issues and are coordinated in the project design to address cross-cutting issues. Projects contain investigations, which focus on more than one topic area in describing aquaculture research and activities that will improve diets, generate income for smallholders, manage environments for future generations, and

enhance trade opportunities. These investigations are integrated across two categories: *Integrated Production Systems* and *People, Livelihoods, and Ecosystem Interrelationships*.

Investigations provide a transparent means for evaluating different types of work, be they quantitative, empirical, biologically-based, qualitative, policy-based, or informal. They are designated as experiments, studies, or activities, with experiments and studies generating new information (i.e., they involve traditional research) and activities building capacity and transferring technologies and information through training sessions, workshops, outreach, and other means. Each project includes at least one experiment or study, as well as at least one outreach activity that focuses on women and/or girls.

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, improve overall fish health, and optimize carrying capacity. Interventions for disease and predation prevention must adopt an integrated pest management 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 and Aquaculture Collaborative Research Support Program; 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 results in high quality and safe aquaculture products with healthy nutrition profiles. Complex pond dynamics technologies need to be simplified for use by new farmers; improved applications of pond dynamics technologies for driving non-fed plankton-driven systems are applicable where access to feeds is expensive or unreliable.

- ***Climate Change Adaptation: Indigenous Species Development (IND)***

Aquaculture, like agriculture and other human activities, will feel the effects of long-term climate change. Among the myriad challenges, ocean acidification and sea level rise will affect the world’s coastal aquaculture operations, much of which occur in poorer countries. Temperature changes will test the resiliency of domesticated varieties. 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 Collaborative Research Support Program 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 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 should be given to vulnerable populations, women and children, and underserved populations, and should be assessed as to 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 controls and hazards associated with seafood processing, value-added processing, post-processing, and by-product/waste development are of interest. Consumers and producers alike will benefit from research that contributes to the development of standards and practices that protect fish products from spoilage, adulteration, mishandling, and off-flavors. Processing waste can claim up to 70% by weight of finfish depending on the species and manner processed, and post-harvest losses can claim around 30%. Partnering with other groups and co-developing outreach techniques to reduce post-harvest losses can significantly contribute to the amount of fish available for consumption, thus, contributing to the nutrition goals of USAID's Feed the Future Initiative. Certification, traceability, product integrity, and other efforts to improve fish products for consumer acceptance and international markets are desired. Gender integration is important to consider as women are strongly represented in the processing and marketing sectors and throughout much of the value chains. (Aquaculture-Fisheries Nexus Topic Area)

- ***Policy Development (PDV)***

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

- ***Marketing, Economic Risk Assessment, and Trade (MER)***

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

- ***Watershed & Integrated Coastal Zone Management (WIZ)***

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

- ***Mitigating Negative Environmental Impacts (MNE)***

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

AQUAFISH RESEARCH PROJECTS

Current AquaFish projects contain between six and eight investigations, with 51% of investigations categorized as *Integrated Production Systems* and 49% 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 Plans 2007-2009 and 2009-2011, and additional work that occurred prior to Phase II) and for Phase II (Implementation Plan 2013-2015).

| Systems Approach | Topic Area | Number of Investigations | | | Percent of Total |
|---|--|--------------------------|-------------------------|------------|------------------|
| | | Phase I (2007-2013) | Phase II (2013-2015) | Total | |
| Integrated Production Systems | | | | | |
| | Production System Design & Best Management Alternatives (BMA) | 17 | 6 | 23 | 17% |
| | Sustainable Feed Technology (SFT) | 13 | 8 | 21 | 15% |
| | Climate Change Adaptation: Indigenous Species Development (IND) | 14 | 4 | 18 | 13% |
| | Quality Seedstock Development (QSD) | 7 | 2 | 9 | 6% |
| | <i>Subtotal</i> | <i>51</i> | <i>20</i> | <i>71</i> | <i>51%</i> |
| People, Livelihoods, and Ecosystem Interrelationships | | | | | |
| | Human Nutrition and Human Health Impacts of Aquaculture (HHI) | 7 | 4 | 11 | 8% |
| | Food Safety, Post Harvest, and Value-Added Product Development (FSV) | 4 | 0 | 4 | 3% |
| | Policy Development (PDV) | 11 | 1 | 12 | 9% |
| | Marketing, Economic Risk Assessment, and Trade (MER) | 14 | 6 | 20 | 14% |
| | Watershed and Integrated Coastal Zone Management (WIZ) | 5 | 1 | 6 | 4% |
| | Mitigating Negative Environmental Impacts (MNE) | 14 | 1 | 15 | 11% |
| | <i>Subtotal</i> | <i>55</i> | <i>13</i> | <i>68</i> | <i>49%</i> |
| Total | | 106 | 33 | 139 | |

Thirty-three investigations were underway in FY15 and will continue into FY16 as part of Implementation Plan 2013-2015. A total of 10 countries, 12 US Universities, and 24 HC institutions are involved in formal funded partnerships as part of these investigations, and an additional 5 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 in the USAID request for applications: a systems approach; social, economic, and environmental sustainability; capacity building and institution strengthening; outreach, dissemination, and adoption; and gender integration.

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 GMOs.
- 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.



V. RESEARCH PROJECT REPORTS

Research project reports summarize achievements, capacity building, and lessons learned from FY15, as reported by AquaFish Lead Project Principal Investigators (PIs). Reports present progress made during the second year of Implementation Plan 2013-2015. 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*

Project Description

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)

Project Summary

The Ghana and Tanzania project is examining various facets of aquaculture and its contribution to food supply, nutrition, and health in Ghana and Tanzania. Eight investigations are underway assessing improvements in human nutrition from aquaculture activities, developing fish feed using invertebrates as protein sources to minimize costs, enhancing human health through improvements in the nutritional value of tilapia feed, identifying local strains of tilapia resilient to changing climate conditions, improving shellfish culture in Zanzibar and training women shellfish producers in aquaculture enterprises, value chain analysis of tilapia and catfish, and developing a mobile phone based system of tilapia prices.

Principal Project Personnel

Purdue University, US (Lead US University)
Kwamena Quagrainie – US Lead Project PI

University of Arkansas at Pine Bluff, US
Rebecca Lochmann – US Co-PI

Kwame Nkrumah University of Science & Technology, Ghana (Lead HC Institution)

Stephen Amisah – HC Lead Project PI
Gifty Anane-Taabeah – HC Investigator
Regina Edziyie – HC Investigator
Nelson Agbo – HC Investigator
Reginald Annan – HC Investigator

Virginia Polytechnic Institute & State University, US
Emmanuel Frimpong – US Co-PI

Sokoine University of Agriculture, Tanzania
Sebastian Chenyambuga – HC Co-PI & Tanzania PoC
Nazael Madalla – HC Investigator
Elibariki Emmanuel Msuya – HC Investigator

Institute of Marine Sciences, University of Dar es Salaam, Zanzibar, Tanzania
Narriman Jiddawi – HC Co-PI

FarmerLine, Ghana
Alloysius Attah – HC Co-PI

University of Hawaii-Hilo, US
Maria Haws – US Co-PI

Western Indian Ocean Marine Science Association, Zanzibar, Tanzania
Julius Francis – HC Co-PI

University for Development Studies, Ghana
Akwasi Ampofo-Yeboah – HC Co-PI
Eliot Alhassan – HC Investigator

Achievements

In FY15, the objectives set forth in Implementation Plan 2013-2015 for three investigations were accomplished and progress was made on the remaining five investigations. A study on aquaculture's impact on human nutrition revealed that dietary diversity depended in part on household income and economic status. Thus, increased income from fish farming helps households to diversify their diets and improve nutritional quality. A cell phone based Seafood Market Information System has been developed in Ghana with a focus on tilapia, the predominant species farmed and captured in inland waters. This system will help minimize information gaps along the tilapia value chain, thereby improving efficiencies, reducing post-harvest loss, and increasing market profit. The new technology underwent initial testing with fisheries officers, selected fish farmers, and fish traders at workshops in Kumasi. Surveys were conducted in two regions of Tanzania to characterize and identify areas of improvement in the Nile tilapia and African catfish value chains. Data collected from more than 250 survey participants (including input suppliers, fish farmers, food vendors, processors, and market retailers) are being entered for analysis.

A study conducted in Tanzania to minimize tilapia feed costs by using invertebrates as an alternative protein source found that a 35% inclusion of either earthworms or maggots resulted in the highest production and the most cost-effective composition of all the diets studied. Additional feed research underway in Ghana is analyzing fatty acids and amino acids of tilapia feed ingredients, with the ultimate goal of enhancing nutritional value of tilapia for human consumption. Four sites have been established

along the Volta River in Ghana to locate and identify strains of Nile tilapia resistant to climate change. Additionally, historical data have been acquired and compiled into a geodatabase and ArcGIS for mapping and modeling tilapia distribution along the Volta River.

Capacity Building

Three workshops were held as part of this project in FY15. A workshop in Zanzibar, Tanzania, in July 2015 for Coastal Women's Shellfish Aquaculture Development was organized and hosted by researchers from the University of Dar es Salaam's Institute of Marine Sciences (IMS), the University of Hawaii-Hilo, and Oregon State University. It is notable that, at this workshop, all of the trainers were women, with 37 trainees participating in the workshop, 46% (17) of whom were women. Two workshops were held in Ghana in July 2015, both focusing on the use of mobile phones for sharing aquaculture information. These workshops trained 67 participants, 58% (39) of whom were women. Six long-term students were supported in Ghana and Tanzania in FY15: one Bachelor's student and five Master's students – 33% (2) were women. These students studied at Kwame Nkrumah University of Science and Technology (KNUST) in Ghana and Sokoine University of Agriculture (SUA) in Tanzania.

In FY15, there has been improved collaboration and active involvement with the Ghana Fisheries Commission for ongoing projects at KNUST. In Tanzania, there is improved collaboration between the institutions involved in the AquaFish Innovation lab projects. For example, students attending SUA in Morogoro enroll in a summer field program on aquaculture at IMS in Zanzibar, with AquaFish researchers involved in this exchange.

Presentations and Publications

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- Ndanga, L.Z.B., K.K. Quagraine, C.C. Ngugi, and J. Amadiva. 2015. Application of Porter's Framework to assess aquaculture value chain in Kenya. *African Journal of Food, Agriculture, Nutrition, and Development* 15(3): 10118-10137.

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*

Project Description

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)

Project Summary

The Kenya and Uganda project has six investigations underway, aimed to improve livelihoods, nutrition, and income for fishers, farmers, and vulnerable communities by working to reduce bottlenecks that limit the advancement of fish culture. In Uganda, breeding and hatching technologies for African lungfish species are being assessed to improve nutrition and livelihoods, cell phone technologies are being evaluated to better inform fish farmers, and market opportunities are being assessed for small-scale farmers. In Kenya, feed formulations and growth performance of Nile tilapia are being assessed; low-cost aquaponics systems are under development; and capacity is being built through trainings, formal education, partnerships, and other collaborative activities.

Principal Project Personnel

Auburn University, US (Lead US University)

Joseph Molnar – US Lead Project PI

Claude Boyd – US Investigator

Makerere University, Uganda (Lead HC Institution)

Theodora Hyuha – HC Lead Project PI

Monica Beharo – HC Investigator

University of Arizona, US

Kevin Fitzsimmons – US Co-PI

Kenyatta University, Kenya

Charles Ngugi – HC Co-PI & Kenya PoC

Alabama A&M University, US

James Bukenya – US Co-PI

National Fisheries Resources Research Institute, Uganda

John Walakira – HC Co-PI

Gertrude Atukunda – HC Investigator

University of Eldoret, Kenya

Julius Manyala – HC Co-PI

Achievements

In Uganda in FY15, genetic analyses of African lungfish collected from six lakes revealed that one lake is a good source of broodstock for aquaculture and conservation programs due to high genetic diversity of endemic lungfish. Further, wild caught African lungfish fingerlings were grown successfully to market

size (200g) with an 87% survival rate in aquaculture tanks when cultured with mixed-sex tilapia. A study on mobile phone use by fish farmers revealed that they lack information on various aspects of fish culture, including water quality management. To address this need, a water quality test kit was evaluated and identified as suitable for use by farmers due to its reliability and simplicity. Market opportunities for small-scale catfish farmers in central Uganda were assessed by collecting and analyzing data from more than 250 wholesalers, retailers, and food service outlets from nine districts. Initial results have provided insight into the pricing behavior and actions of players in catfish markets, which is necessary to ensure the transparency required to increase the level of competition in the seafood industry. In Kenya, experiments are underway that will inform the design and implementation of a low-cost, medium-scale aquaponics demonstration facility at the University of Eldoret. Students and fish farmers are gaining exposure to the basics of growing plants with nutrient-rich effluent water from aquaculture ponds, and data are being processed to develop a nutrient dynamics model for the system based on different stocking densities and plant biomass. In response to increasing commercial feed prices, AquaFish researchers are identifying high quality feed formulations and manufacturing those feeds on-site using locally sourced ingredients. These feeds are being tested in on-farm trials that assess the growth of Nile tilapia at different stocking densities in hapas and findings are being disseminated through training workshops with fish farmers and pond construction crews.

Capacity Building

In FY15, three workshops were conducted in Kenya as a part of this project, reaching a total of 146 trainees, including 28 women (19%) and 118 men. These workshops focused on low-cost fish feeds and cage culture of tilapia, pond construction, and best management practices for fish farmers and extension agents. Nineteen long-term students were supported under this project in FY15 in Kenya, Uganda, and the US: two certificate students, one Bachelor's student, 11 Master's students, and five PhD students – 63% (12) were women. These students studied at Egerton University, University of Eldoret, Kenyatta University, Moi University, and the University of Nairobi in Kenya; Makerere University in Uganda; and Auburn University in the US.

Presentations and Publications

- Boyd, C. 2014. Atmosphere pollution affects water quality. *Global Aquaculture Advocate* 17(5): 57-58.
- Bukenya, J.O. and M. Ssebisubi. 2015. Price transmission and threshold behavior in the African catfish supply chain in Uganda. *Journal of African Business* 16(1-2): 180-197.
- Fitzsimmons, K. 2014. *Aquaponics in Arizona and beyond*. [Oral presentation]. Congresso Acuicultura Chile, La Serena, Chile.
- Fitzsimmons, K. 2014. *Status of aquaponics 2014-Auburn*. [Oral presentation]. Aquaculture Course, Auburn, Alabama.
- Manyala, J.O., R.S. Pomeroy, P. Nen, K. Fitzsimmons, M.K. Shrestha, and J.S. Diana. 2015. Low-Cost tilapia production with fertilization and supplementary feeding. *World Aquaculture* 43-46.
- Matuha, M. 2015. *Mobile phone use in Ugandan aquaculture: Farmer experiences and aspirations*. [Oral presentation]. Aquaculture America 2015, New Orleans, Louisiana, US. 19-22 February 2015.
- Ngugi, C.C., E. Oyoo-Okoth, J. Mugo-Bundi, P.S. Orina, E.J. Chemoiwa, and P.A. Aloo. 2015. Effects of dietary administration of stinging nettle (*Urtica dioica*) on the growth performance, biochemical, hematological and immunological parameters in juvenile and adult Victoria Labeo (*Labeo victorinus*) challenged with *Aeromonas hydrophila*. *Fish and Shellfish Immunology* 44(2): 533-541.
- Rono, K. 2015. *Effect of stocking density on growth and survival of Nile tilapia (Oreochromis niloticus) fry reared in an aquaponic system*. [Oral presentation]. University of Eldoret Annual Conference, Kenya. June 2015.
- Walakira, J. 2015. *Guiding captive breeding of African lungfish Protopterus aethiopicus in Uganda: Genetic diversity and sex determination*. [Oral presentation]. Aquaculture America 2015, New Orleans, Louisiana, US. 19-22 February 2015.

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*

Project Description

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)

Project Summary

The Bangladesh project includes a series of investigations aimed at improving aquaculture production efficiency, seafood yield and income, nutrition, and overall livelihoods of rural farming communities. Toward this goal, improved aquaculture management technologies are being tested and developed for better use of resources in polyculture, limiting nutrient/feed inputs, maximizing feed conversion efficiency, promoting production of nutrient rich fishes and vegetables, and increasing resilience to climate change. Specifically, the project is assessing: 1) production parameters and potential economic and environmental benefits of reducing feed inputs for Indian carps (rohu) in the growout of tilapia in earthen ponds; 2) pulsed feeding strategies on growth performance, feed efficiency, and composition of gut flora of tilapia grown in ponds; 3) reduced-feeding strategies for combined polyculture of two major carps (rohu and catla) with shing catfish; 4) the aquaculture potential of *Pangasius* catfish in brackish (hyposaline) waters; 5) production of mola (*Amblypharyngodon mola*) integrated with existing practices of gher-prawn (*Macrobrachium rosenbergii*) and gher-prawn/carp production and the use of pond muds for growing vegetables on dykes of gher/pond systems; 6) production of nutrient-rich small fish, mola, and freshwater prawns using integrated cage-pond carp polyculture in northwest Bangladesh; and 7) nutritional status and livelihoods of mud crab farmers, tilapia polyculture with mud crab, and the crab value chain to help marginalized farmers in southwest Bangladesh. The project provides new technologies and management practices for intensifying seafood production while maximizing use of nutrient inputs and reducing environmental impact through polyculture, improving overall aquaculture production efficiency, and increasing incomes of farmers and the production of seafood for home consumption and better nutrition in Bangladesh.

Principal Project Personnel

North Carolina State University, US (Lead US University)

Russell Borski – US Lead Project PI

Upton Hatch – US Investigator

Southeast Asian Fisheries Development Center, Philippines

Emilia Quinitio – HC Co-PI

Harry Daniels – US Investigator

**Bangladesh Agricultural University, Bangladesh
(Lead HC Institution)**

Md. Abdul Wahab – HC Lead Project PI (until November 2014)

Sharoz Mahean Haque – HC Investigator (until November 2014); HC Lead Project PI (starting November 2014)

Sadika Haque – HC Investigator

Md. Ashraful Islam – HC Investigator

Central Luzon State University, Philippines

Wilfred Jamandre – HC Co-PI & Philippines PoC

Khulna University, Bangladesh

Shak Md. Anisul Huq – 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 Investigator

Patuakhali Science and Technology University, Bangladesh

Md. Lokman Ali – HC Co-PI

Shushilan NGO, Bangladesh

Satchidananda “Sattu” Biswas – HC Co-PI

Achievements

Preliminary results from an experiment on economic benefits of polyculture and reduced feed strategies indicate that inclusion of a major Indian carp (rohu) and a 50% reduction in daily feed ration from that currently used provides significant cost savings to farmers who grow tilapia in ponds. The benefit-cost ratio of tilapia-rohu polyculture combined with reduced feeding is improved by almost 100% relative to current tilapia monoculture practices with little impact on overall fish growth. Semi-intensive polyculture research found that economic and nutritional benefits increase when major Indian carps (rohu and catla) are co-cultured with shing (stinging catfish), a high value air-breathing fish (ABF) that is rich in iron. Another polyculture experiment suggests that the addition of mola, a small indigenous fish species rich in vitamin A, to carp and prawn culture enhanced total fish yields, allowed farmers to generate more income, and increased farmer household consumption of nutrient-rich fish. Additional work compared the performance of aquaculture muds from the mola/carp-prawn ponds and found that they serve as fertile soil for enhancing vegetable yield.

Initial results from an experiment on pulsed feeding strategies for tilapia established that application of feeds on alternate days provides a higher benefit-cost ratio and net return than daily and every third day of feeding in growout in fertilized ponds. As part of this work, sequencing of Nile tilapia fecal microbiome found that the fish fed on alternate days had 20 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). An experiment on *Pangasius* growth in brackish waters indicated that *Pangasius* can easily survive and grow in water up to 10 ppt salinity, and that higher stocking density (3 fish/m² compared to 2 fish/m²) and formulated feeds can provide better economic benefit to farmers. A final investigation aimed to improve the livelihoods of marginalized women-headed households in southwest Bangladesh that traditionally rely on mud crab fattening to make a living. Marketing and value chain data collection has been completed and 45 farmers are now conducting experimental trials incorporating tilapia into their mud crab culture systems. Tilapia-mud crab is a new technology that farmers are excited about both from the perspective of providing feed for mud crab as well for their own consumption or for sale to market.

Capacity Building

An important element to the project is building community, institutional, and individual capacity in the aquaculture and fisheries sectors in Bangladesh. Toward this goal, the project has been successful in the education and training of the next generation of aquaculture and fisheries scientists. During FY15, this

project supported the education of 35 students in Bangladesh and the US: five Bachelor's students, 25 Master's students, three PhD students, and two post-doctorate fellows; 13 (37%) of these were women. These students studied at Bangladesh Agricultural University (BAU), Khulna University, and Patuakhali Science and Technology University in Bangladesh, and North Carolina State University in the US. Students were trained on hypothesis-driven experimental design, various research techniques, data collection and analyses, and other critical features to successfully test, carry out and disseminate technologies for aquaculture and fisheries development.

The project also involved a considerable effort with community capacity building. Four of the investigations tested new technologies with farmers using their aquaculture ponds. More than 100 village households, representative of eight communities and five regions of Bangladesh, participated in the research and learned how to test new ideas, manage and harvest aquaculture ponds, collect and track data, and measure seafood yields. Additionally, four workshops were conducted in Bangladesh as part of this project, reaching a total of 154 trainees, including 49 women (32%) and 105 men. These training events focused on promoting best management practices for integrated tilapia/mud crab culture; *Pangasius* culture in hyposaline water; and shing/koi/carp and tilapia/carp polyculture technologies.

This project works with institutions that encompass a broad geographical range within Bangladesh and within South and Southeast Asia, allowing staff to gain considerable training and knowledge on management of community development projects and innovative aquaculture techniques. In addition, this project was the first in which the BAU Research Office provided contracts to other Bangladesh universities. It is now a model used by BAU, the premier agricultural institution in the country, as a mechanism to promote and administer multi-institutional collaborations within Bangladesh, a feature critical to the country's future development.

Presentations and Publications

- Douros, J., D. Baltzegar, B. Reading, and R. Borski. 2015. *Novel function of leptin as a stimulator of glycolysis*. [Oral presentation]. North American Society of Comparative Endocrinology, Ottawa, Canada. 21-25 June 2015.
- Lokman, A., Md. A. Wahab, and R. Borski. 2015. *Development of Pangasius catfish (Pangasius hypophthalmus) culture in hyposaline waters of Southern Bangladesh*. [Oral presentation]. World Aquaculture Society, Jeju, South Korea. 26-30 May 2015.
- Mankiewicz, J., J. Taylor, J. Douros, D. Baltzegar, and R. Borski. 2015. *In vitro regulation of hepatic leptin – A synthesis and secretion by glucose and stress hormones in tilapia (Oreochromis mossambicus)*. [Oral presentation]. North American Society of Comparative Endocrinology, Ottawa, Canada. 21-25 June 2015.
- Wahab, A., R. Borski, and H. Egna. 2014. *Aquaculture in Bangladesh*. [Oral presentation]. USAID Mission. Dhaka, Bangladesh.

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*

Project Description

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)

Project Summary

The Nepal project has six investigations underway assessing three primary lines of research: 1) the incorporation of small indigenous fish species into polyculture systems to determine if it is a viable means to increase food production for poorer households; 2) evaluating the success of household and school ponds in increasing fish consumption by women and children in poor households, and to then determine if this increased consumption leads to improvements in the nutritional status for children; and 3) the potential for the enhanced production of native species, particularly sahar, a cool water species indigenous to Nepal. Through setbacks and natural disasters in FY15, progress continued toward developing more efficient and environmentally sustainable aquaculture systems for improved health and nutrition. The 25 April 2015 earthquake in Nepal fortunately did not destroy the AquaFish experiment sites; however, it did cause delays in several of the project's research activities resulting from the broad reaching impacts after the event such as school closures, utility and road disturbances, and political unrest. The project research team, under the University of Michigan and the Agriculture and Forestry University (AFU) in Nepal, has adjusted well and remains on track.

Principal Project Personnel

University of Michigan, US (Lead US University)

James Diana – US Lead Project PI

Agriculture and Forestry University, Nepal (Lead HC Institution)

Madhav Shrestha – HC Lead Project PI

Dilip Kumar Jha – HC Investigator

Narayan Pandit – HC Investigator

Sunila Rai – HC Investigator

Directorate of Fisheries Development, Nepal

Rama Nanda Mishra – HC Co-PI

Fisheries Research Center, Nepal

Jay Dev Bista – HC Co-PI

Achievements

Though FY15 was a difficult year for the Nepal project, the team adjusted accordingly and made notable progress. Delays occurred because of school closings and lack of work force following the earthquake. The development of the school pond practices and a fish farming training curriculum is well underway at

four schools in Nepal along with the creation of two associated women's fish farming groups. On-station trials on periphyton-based aquaculture and value of tilapia-sahar-carps polyculture are completed, and on-farm trials are in progress.

Capacity Building

In FY15, the Nepal project continued building institutional and human capacity. The first Nepal Fisheries Society Convention was held in Kathmandu, with faculty members and postgraduate students participating and presenting papers. Additionally, the AquaFish team in Nepal held four fish farming trainings (one at each of the four secondary schools), reaching a total of 131 students, including 69 girls (53%) and 62 boys. The goal of these trainings is to help improve health and nutrition for women and children in rural Nepal through the school system.

During FY15, 42 long-term students were supported by this project in Nepal and the US: 29 Bachelor's students, 12 Master's students, and one PhD student; including 20 women (48%) and 22 men. These students studied at AFU in Nepal and at the University of Michigan in the US. The team in Nepal also made significant strides towards advancing the aquaculture and fisheries program at AFU through improvements in accessibility to ponds and lab resources.

Presentations and Publications

- Ahmed, N. and J.S. Diana. 2015. Threatening "white gold": Impacts of climate change on shrimp farming in coastal Bangladesh. *Ocean & Coastal Management* 114: 42-52.
- Bista, J.D., B. Shrestha, R.K. Shrestha, S. Prasad, A.P. Nepal, A. Baidya, S. K. Wagle, and T.B. Thapa. 2015. *Spawning response of sahar (Tor putitora) in different seasons under pond rear condition in Pokhara, Nepal*. [Oral Presentation]. First NEFIS Convention, Kathmandu, Nepal. 30-31 January 2015.
- Li, Y., X. Guo, L. Chen, X. Bai, X. Wei, X. Zhou, S. Huang, and W. Wang. 2015. Inferring invasion history of red swamp crayfish (*Procambarus clarkii*) in China from mitochondrial control region and nuclear intron sequences. *Journal of Molecular Science* 16: 14623-14639.
- Liu, L., X. Su, T. Chen, K. Li, J. Zhan, H. Egna, and J. Diana. 2015. Evidence of rapid transfer and bioaccumulation of Microcystin-LR poses potential risk to freshwater prawn *Macrobrachium rosenbergii* (de Man). *Aquaculture Research* 1-10.
- Mandal, R.B. and N.P. Pandit. 2015. *Problem assessment of red bloom fish pond*. [Oral presentation]. First NEFIS Convention, Kathmandu, Nepal. 30-31 January 2015.
- Manyala, J.O., R.S. Pomeroy, P. Nen, K. Fitzsimmons, M.K. Shrestha, and J.S. Diana. 2015. Low-cost tilapia production with fertilization and supplemental feeding. *World Aquaculture* 46(1): 43-46.
- Rai, S. 2015. *Substrate-based carp and small indigenous fish polyculture*. [Oral presentation]. First NEFIS Convention, Kathmandu, Nepal. 30-31 January 2015.
- Shrestha, M.K., J.D. Bista, S.P. Dahal, and N.P. Pandit. 2015. *Polyculture of mixed-sex tilapia with pangas and sahar*. [Oral presentation]. First NEFIS Convention, Kathmandu, Nepal. 30-31 January 2015.
- Shrestha, M.K., R.N. Mishra, S.K. Wagle, S. Rai, N. Bhattarai, and L. Karki. 2015. *Small-scale aquaculture to enhance fish production in Nepal*. [Poster presentation]. First NEFIS Convention, Kathmandu, Nepal. 30-31 January 2015.
- Thapa, R.B. 2015. *Value chain analysis of carp polyculture system in Chitwan district, Nepal*. [Oral presentation]. First NEFIS Convention, Kathmandu, Nepal. 30-31 January 2015.

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******Project Description******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)

Project Summary

The goals of the Cambodia and Vietnam project are to help improve nutrition, alleviate poverty, and increase food security through sustainable aquaculture development and aquatic resources management, especially in the context of linking trade and markets with climate change. This project addresses these goals through six separate but complementary investigations focused on fish value chains; development of feeds, feeding strategies, and processed products; improvement of sustainable snakehead aquaculture systems; estimating carrying capacity for aquaculture; enhancing food and nutrition security for vulnerable women and children; and developing policy recommendations and outreach strategies. All six investigations have a strong focus on vulnerable populations and nutrition. Three of the investigations build on the work of the previous AquaFish Collaborative Research Support Program (CRSP) and other research with a focus on snakehead aquaculture, including continued work on development of cost-effective feed for snakehead, development of sustainable snakehead aquaculture in Cambodia, and evaluation of carrying capacity for aquaculture in Cambodia. The other four investigations focus on better understanding the impacts of climate change on food security, nutrition and trade, and fisheries and aquaculture and adaptation strategies. These efforts include examining the fisheries value chain, improving processing for value added products for markets, understanding specific impacts on food security and nutrition for vulnerable populations (women and children), and creating awareness for policy development and outreach to address the impacts on vulnerable populations.

Principal Project Personnel**University of Connecticut, US (Lead US University)**

Robert Pomeroy – US Lead Project PI
Sylvain DeGuise – US Investigator

Inland Fisheries Research and Development Institute, Cambodia (Lead HC Institution)

So Nam – HC Lead Project PI
Nen Phanna – HC Investigator
Hap Navy – HC Investigator
Prum Somany – 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

Touch Bungthang – HC Investigator
 Chheng Phen – HC Investigator
 Phanara Thach – HC Investigator
 SETHA Im – HC Investigator

Achievements

In FY15, project researchers completed a survey of snakehead fishers in Cambodia and snakehead farmers in Vietnam in five provinces on the impacts of climate change and adaptation strategies. Laboratory and on-farm trials on the use of immunostimulant in snakehead diets indicate that supplementing snakehead diets with 0.2% immunostimulant achieved the highest survival. Researchers developed methods for conserving and processing snakehead products, which were transferred to women snakehead farmers at training courses in An Giang province. Successful spawning of snakehead in Cambodia yielded a first generation of hatchery stock adapted to formulated feed, which have been conditioned in hapas at the Freshwater Aquaculture Research and Development Center. The mass balance model for estimating carrying capacity for aquaculture was applied to the Stung Chinit reservoir in Cambodia during training events held this fiscal year. The project identified fish and aquaculture products commonly consumed by women and children in Cambodia in order to determine their micro- and macro-nutrient profiles. Finally, a number of policy briefs and journal articles have been prepared and disseminated with policy recommendations to address the impacts of climate change on aquaculture operations in Cambodia and Vietnam.

Capacity Building

A total of 126 short-term trainees were reached in four trainings in FY15: two in Cambodia and two in Vietnam, including 66 (52%) women and 60 men. These workshops focused on training scientists, regulators, and fisheries officers to estimate carrying capacity in reservoirs in Cambodia; and training women in the Mekong Delta on small-scale farming of snakehead using formulated feed and processing snakehead products in Vietnam. There were 49 long-term students supported by the project in Cambodia and Vietnam in FY15: 35 Bachelor's students, 11 Master's students, and three PhD students – 23 women and 26 men. These students studied at Can Tho University in Vietnam and four institutions in Cambodia: Royal University of Agriculture, Royal University of Law and Economics, Kampong Cham National School of Agriculture, and the Inland Fisheries Research and Development Institute (IFReDI).

Presentations and Publications

- Bengtson, D.A., C. Phen, T. Puthearath, and S. Nam. 2015. Aquaculture carrying capacity of Stung Chinit Reservoir: A pilot project. *Catch and Culture* Volume 21 (2): 58-60.
- Grimm-Greenblatt, J., R. Pomeroy, B. Bravo-Ureta, L.X. Sinh, H.V. Hien, and T. Getchis. 2015. Economic analysis of alternative snakehead *Channa striata* feed. *Aquaculture Economics and Management* 19(2): 192-209.
- Ha, N.T.N., T.T.M. Thu, and T.T.T. Hien. 2014. *A study of processing dried snakehead fish (Channa striata) applying for the small-scale production*. [Oral presentation]. International Fisheries Symposium 2014, Surabaya, Indonesia. 30 October – 1 November 2014.
- Ha, N.T.N., T.T.M. Thu, and T.T.T. Hien. 2015. *Effects of storage temperatures, adding sticky rice wine, and glycerol on chemical, microbial, and sensory attributes of dried snakehead fish (Channa striata)*. [Poster presentation]. World Aquaculture 2015, Jeju, South Korea. 26-30 May 2015.
- Hien, T.T.T., P.M. Duc, N.V. Tien, T.T.M. Thu, and N.M. Ha. 2015. *Research progress report on project meeting*. [Oral presentation]. Project Meeting, Phu Quoc Island, Vietnam. January 2015.
- Hien, T.T.T., T.L.C. Tu, T.M. Phu, and N.V. Tien. 2014. *The use of soy protein in Tra catfish (Pangasionodon hypophthalmus), snakehead (Channa striata) and knife fish (Chitala chitala)*. [Oral presentation]. Regional AquaFeed Forum 6th, Nha Trang University, Nha Trang, Vietnam. 24-29 November 2014.

- Hien, T.T.T., T.L.C. Tu, N.V. Tien, N.B. Trung, T.M. Phu, and D. Bengtson. 2015. *Effects of replacing fishmeal with soy protein concentrate on growth, feed efficiency, and digestibility in diets for snakehead (Channa striata)*. [Poster presentation]. World Aquaculture 2015, Jeju, South Korea. 24-29 November 2015.
- Hien, T.T.T., T.T. Be, C.M. Lee, and D.A. Bengtson. 2015. Development of formulated diets for snakehead (*Channa striata* and *Channa micropeltes*): Can phytase and taurine supplementation increase use of soybean meal to replace fish meal? *Aquaculture* 448: 334-340.
- Pomeroy, R., M.M. Dey, and N. Plesha. 2014. The social and economic impacts of semi-intensive aquaculture on biodiversity. *Aquaculture Economics and Management* 18(3): 303-324.
- Thu, T.T.M., L.T. Diem, N.T.H. Ha, T.L.C. Tu, and T.T.T. Hien. 2015. *Development of techniques for processing of salty fermented fish product from commercial snakehead fish*. [Poster presentation]. World Aquaculture 2015, Jeju, South Korea. 26-30 May 2015.
- Tien, N.V., T.L.C. Tu, N.B. Trung, P.M. Duc, and D. Bengtson. 2014. *Effects of replacing fishmeal with soybean meal protein products on diets on growth, feed efficiency and digestibility of snakehead (Channa striata)*. [Oral presentation]. International Fisheries Symposium 2014, Surabaya, Indonesia. 30 October – 1 November 2014.
- Tuan, T.H., N.T. Loc, H.V. Hien, T.H. Minh, T.N. Hai, and R.S. Pomeroy. 2014. *Assessment on production efficiency and climate change impact on snakehead (Channa striata) grow-out farms in An Giang and Tra Vinh provinces*. [Oral presentation]. Aquaculture and Fisheries Symposium, Ho Chi Minh City, Vietnam. 24-28 November 2014.

LESSONS LEARNED

Lessons learned from FY15 are integrated and compiled below.

- The large volume of reporting required by USAID consumes a substantial amount of Management Team time and energy, especially when policies change midway through a funding cycle (e.g., being told that data management plans are required after contracts and subcontracts are already in place), when frequent information requests go above and beyond grant requirements, and when requests require very quick turn-around times. Unanticipated requests interrupt operations and monopolize time already allocated for other activities, impacting AquaFish's ability to accomplish stated program objectives. AquaFish has learned that best reporting practices for subcontractors provide clear reporting policies and timelines at the beginning of the contractual period; follow contractual agreements; and use information readily available via reports already submitted prior to sending additional requests. AquaFish would benefit from USAID's adoption of this approach to save time and decrease the occurrence of redundant requests.
- Individuals and institutional partners in developing countries often do not have the capital or credit to fund development work upfront, as is required with the cost-reimbursement invoicing process. Submitting invoices regularly as work is conducted (e.g., quarterly) rather than waiting until work is complete, can alleviate some of the financial challenges associated with reimbursement for salary, travel, and services. Although encouraged to invoice at regular intervals throughout the project in order to receive funds in a timely manner, this process is not always clearly understood by all project partners, resulting in infrequent invoicing and associated cash-flow problems. Regular invoicing for work completed is also essential for tracking and reporting an accurate burn rate of program funds.
- The USAID J-1 visa process and TraiNet policies under Automated Directives Systems 252 and 253 are examples of USAID requirements with particularly high transaction costs, discouraging researchers from engaging in activities that support USAID's training goals. These requirements are very time-consuming and onerous, often resulting in potential foreign students being significantly delayed or not enrolling in US-based programs at all. Due to the seasonal nature of aquaculture work, such delays can postpone an experiment for a year or longer. Eliminating redundancies and problematic bureaucratic policies can help increase capacity building and network opportunities while still upholding high standards of accountability.
- AquaFish was reminded that with support, flexibility, and perseverance, project work can withstand natural disasters in spite of tremendous challenges to the personal and professional lives of participants. While fortunately no AquaFish project partners in Nepal were injured during the 2015 Gorkha earthquake and aftershocks, facilities were damaged and project timelines disrupted. The Director was mindful that natural disasters can cause research delays and additional costs, and reached out to the project team in Nepal to offer support. Due to this quick response and action by the Director and Management Team, and because of strong partnerships in Nepal, researchers were able to continue work with little impact on project progress.



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 young 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 participation in short- and long-term trainings.

Each project conducted by AquaFish 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.

Project-Wide Short-Term Summary

During FY15, a total of 18 short-term trainings, reaching 661 trainees, took place in AquaFish Host Countries in Africa and Asia. Women represented 41% of these trainees, with 268 women participants and 393 men (Figures VII-1 and VII-2). There was an increase in women short-term trainees from the previous year, although the percentages of women participants in short-term trainings in FY15 remains under the 50% benchmark.

Project-Wide Long-Term Training Summary

During FY15, the AquaFish Innovation Lab supported 153 long-term trainees at 21 institutions in nine countries (Figures VII-3 and VII-4). Women represented 47% of the long-term degree students, with 72 women and 81 men (53%) enrolled in FY15. There were two students seeking certificates (both women), 71 students seeking Bachelor's degrees (37 women and 34 men), 67 students seeking Master's degrees (30 women and 37 men), 11 students seeking PhD's (3 women and 8 men), and two male post-docs.

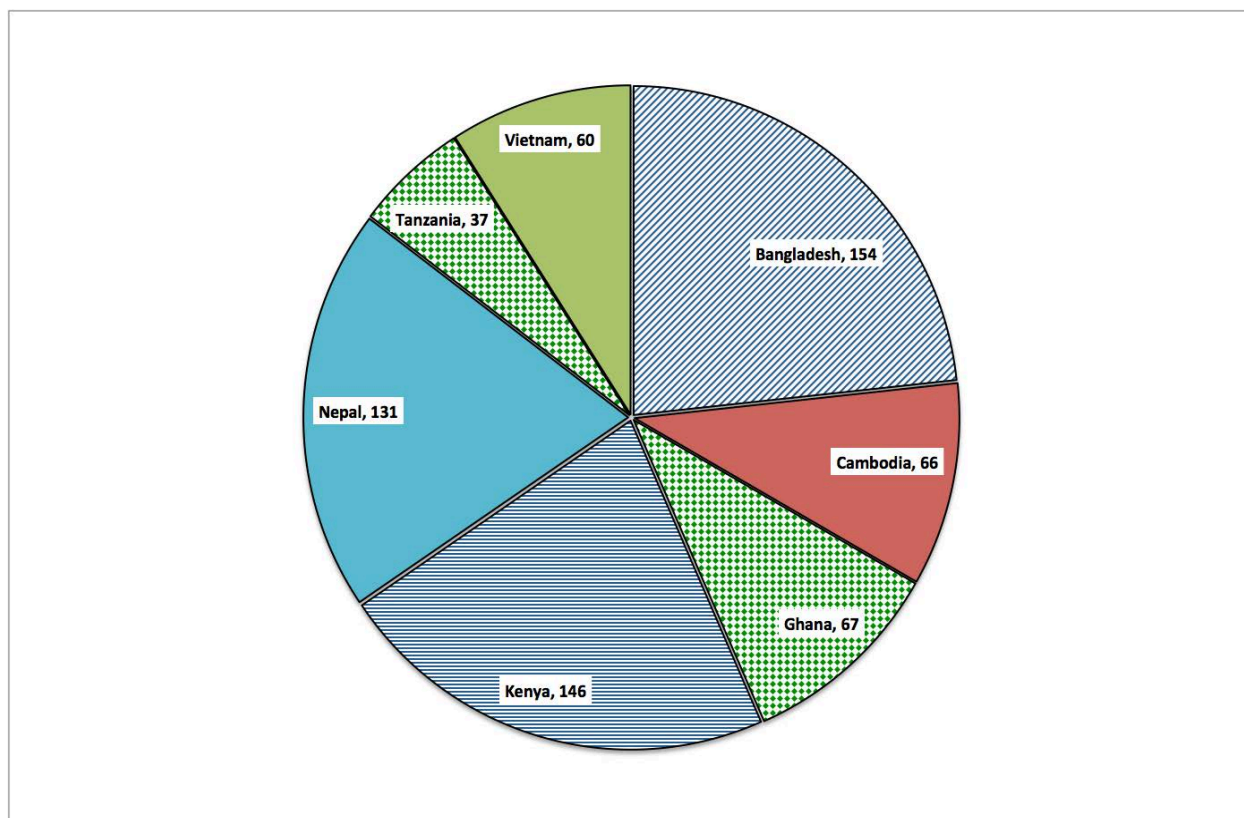


Figure VII-1. Number of short-term trainees by country in FY15.

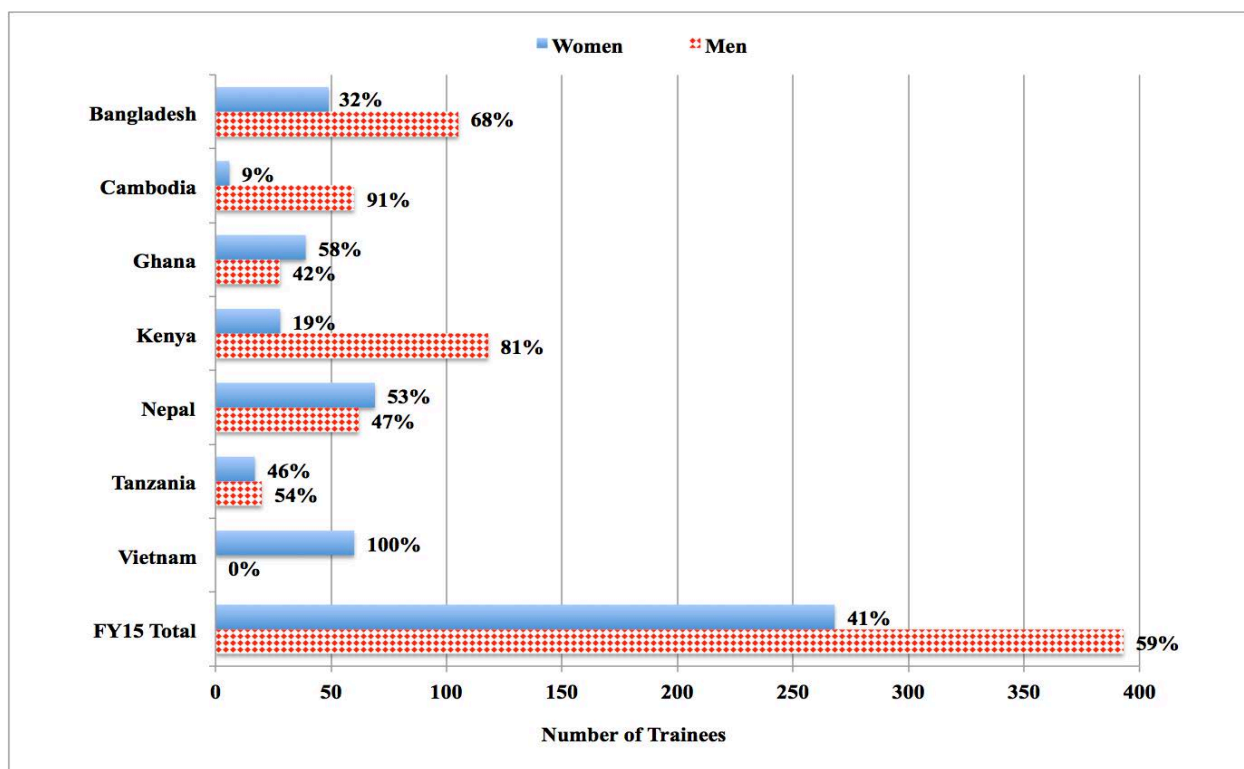


Figure VII-2. Numbers and percentages of short-term trainees by training country and gender in FY15.

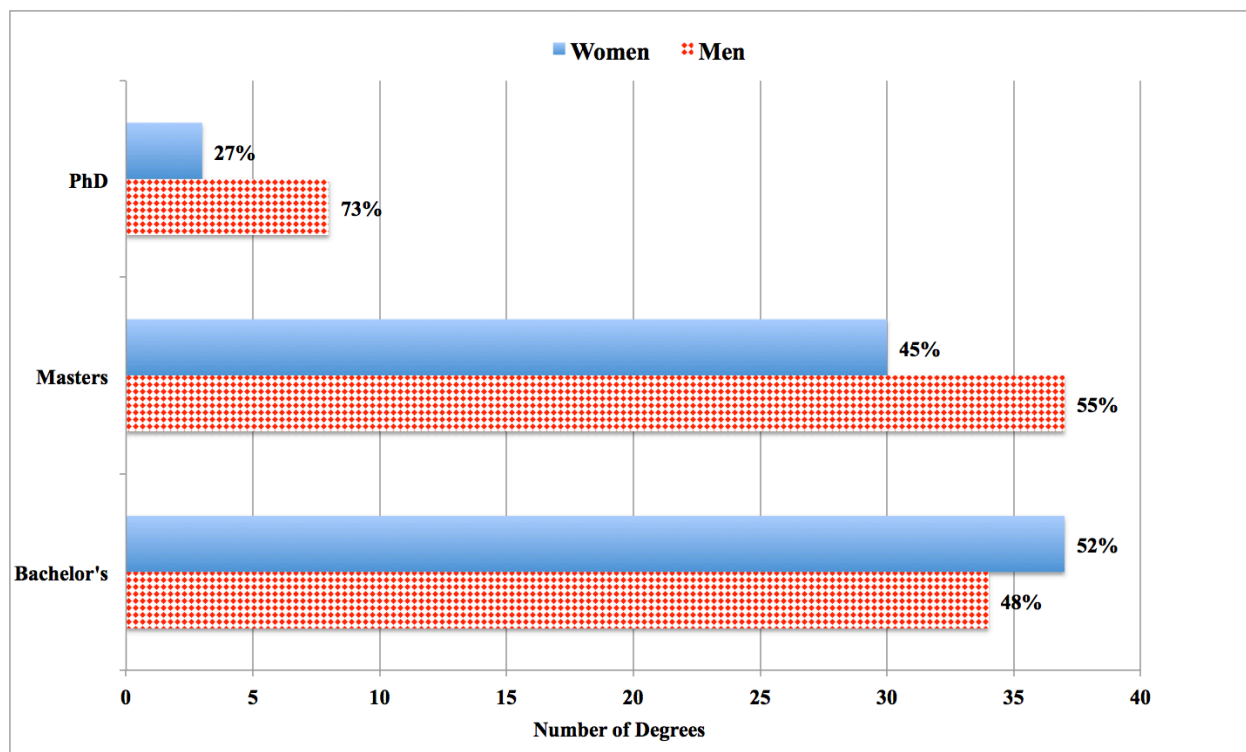


Figure VII-3. Number and percentages of long-term trainees by degree and gender in FY15.

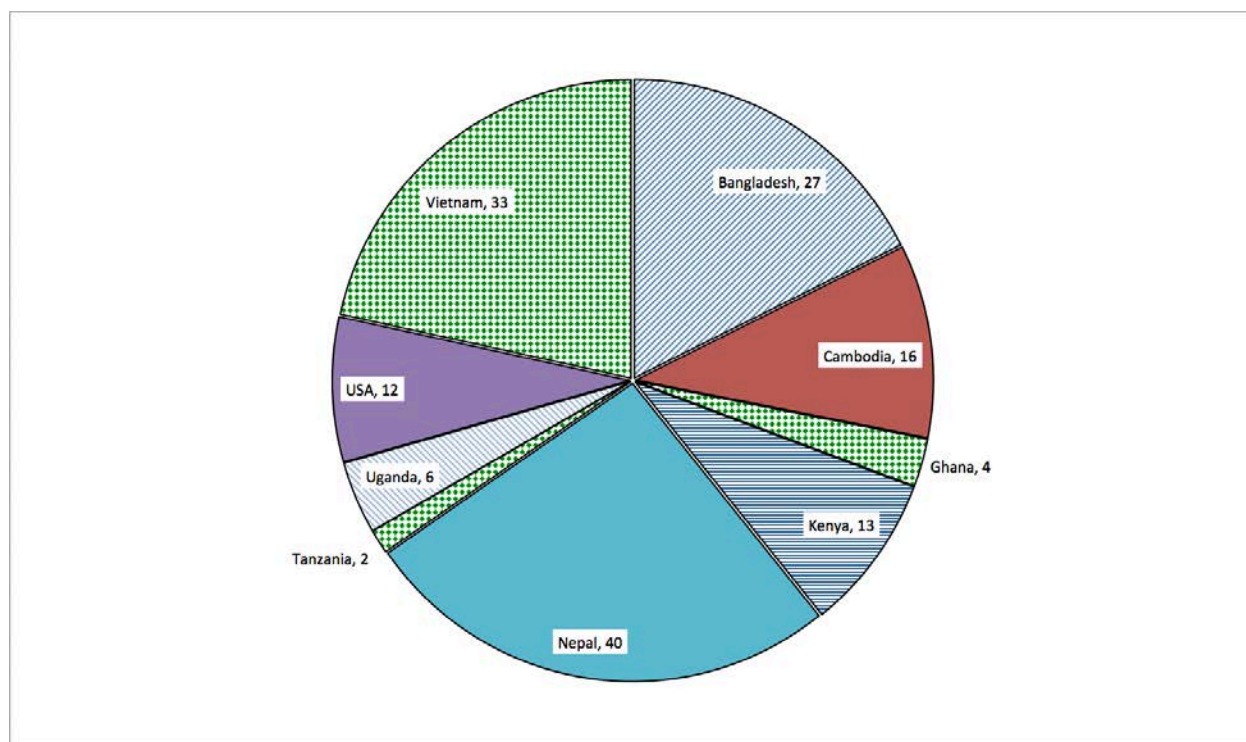


Figure VII-4. Number of long-term trainees by training country in FY15.

TRAINING BY COUNTRY

Bangladesh

Trainings

AquaFish researchers hosted four short-term trainings in Bangladesh in FY15, including 105 men and 49 women, for a total of 154 participants. Trainees learned about best management practices for integrated tilapia/mud crab culture, *Pangasius* culture in hyposaline water, and shing/koi/carp and tilapia/carp polyculture technologies. AquaFish supported 27 long-term students in Bangladesh: one Bachelor's student, 25 Master's students, and one PhD student, including 10 women and 17 men. These students studied at BAU, Khulna University, and Patuakhali Science and Technology University in the following three disciplines: 1) Aquaculture, 2) Aquaculture Physiology, and 3) Horticulture.

Cambodia

Trainings

In FY15 in Cambodia, 66 trainees, including 60 men and six women, participated in two short-term training events. The workshops focused on modeling aquaculture carrying capacity in reservoirs. Sixteen long-term students were supported by AquaFish in Cambodia in FY15: 11 Bachelor's students and five Master's students, including four women and 12 men. These students studied at the Royal University of Agriculture, Royal University of Law and Economics, IFReDI, and Kampong Cham National School of Agriculture in the following four disciplines: 1) Aquaculture, 2) Economics, 3) Nutrition, and 4) Fisheries Science.

Ghana

Trainings

In FY15, two short-term trainings were conducted in Ghana with 67 participants, including 39 women and 28 men. The workshops focused on training fish farmers; artisanal fishermen; and women fish processors, marketers, and traders in the use of the newly developed Seafood Market Information System. Four long-term students were supported in Ghana in FY15: one Bachelor's student and three Master's students, including one woman and three men. These students studied at KNUST in Aquaculture.

Kenya

Trainings

In FY15, three short-term trainings were conducted in Kenya, reaching a total of 146 trainees, including 118 men and 28 women. These workshops focused on low-cost fish feeds and cage culture of tilapia, pond construction, and best management practices for fish farmers and extension agents. AquaFish supported 13 long-term students in Kenya under the Leader Award and the Associate Award in FY15: two Certificate students, one Bachelor's student, eight Master's students, and two PhD students, including eight women and five men. These students studied at Egerton University, University of Eldoret, Kenyatta University, Moi University, and the University of Nairobi in the following three disciplines: 1) Allied Aquaculture, 2) Fisheries Science, and 3) Aquaculture Environment.

Nepal

Trainings

In FY15, four short-term trainings were conducted in Nepal, reaching 131 trainees, including 69 women/girls and 62 men/boys. The events were fish farming training sessions held at four different secondary schools in rural Nepal as a part of a larger effort to establish school demonstration ponds for fish farming and education. There were 40 long-term students supported in Nepal in FY15: 29 Bachelor's students, 10 Master's students, and one PhD student, including 19 women and 21 men. These students studied at the AFU in two separate disciplines: 1) Aquaculture and 2) Fisheries Science.

Tanzania***Trainings***

One training reaching 37 trainees (including 20 men and 17 women) was conducted in Tanzania at the Institute of Marine Sciences in Zanzibar during FY15. This workshop focused on women's shellfish aquaculture development for coastal communities. Two long-term Master's students were supported in Tanzania in FY15 (one woman and one man). These students studied at SUA in Aquaculture.

Uganda***Trainings***

No short-term trainings occurred in Uganda during FY15. Four students were supported in Uganda in FY15: three Master's students and one PhD student, including two women and two men. All four students studied at Makerere University in the disciplines of 1) Agricultural Economics and 2) Aquaculture Economics.

US***Trainings***

There were no short-term trainings scheduled in the US in FY15. Fourteen long-term students were supported in the US in FY15: four Bachelor's students, five Master's students, three PhD students, and two post-docs, including eight women and six men. These students studied at Auburn University, North Carolina State University, Oregon State University, and the University of Michigan, in eight disciplines, including: 1) Aquaculture, 2) Fish Physiology and Genomics, 3) Biology, 4) Environmental Sciences, 5) Fisheries and Wildlife, 6) Fisheries and Allied Aquaculture, 7) Marine Resource Management, and 8) Natural Resources.

Vietnam***Trainings***

Two short-term trainings occurred in Vietnam during FY15, reaching a total of 60 participants, all of whom were women. The workshops focused on training women in the Mekong Delta on small-scale farming of snakehead using formulated feeds and processing snakehead products. There were 33 long-term AquaFish-supported students in Vietnam in FY15: 24 Bachelor's students, six Master's students, and three PhD students, including 19 women and 14 men. All students in Vietnam studied at Can Tho University in Aquaculture.

INSTITUTIONAL DEVELOPMENT

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 aquaculture, fisheries, aquatic ecology, economics, engineering, and many other degree programs. 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.

Since 2006, AquaFish has helped HC institutions develop specialized curricula and institutional infrastructure 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. The curricula for these programs continues to be developed, with new aquaculture and water resources management courses added in FY15. These accomplishments, aided by AquaFish support and collaboration, 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.

In addition to curriculum development, HC colleagues and their associated institutions build institutional capacity through the management of international grants and contracts. Universities in developing nations often require external guidance and training to facilitate intake and administration of international research awards. The capacity to process awards from US universities tends to be underdeveloped and basic research structures are seldom in place. The Research Office at BAU, the premier agricultural institution in Bangladesh, now has a mechanism to promote and administer multi-institutional collaborations within Bangladesh. AquaFish's collaboration with HC institutions allows these universities to build the administrative infrastructure necessary to be competitive for future international awards and enables the development of multi-institutional collaborations within the host country.

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. Below is a list of universities where AquaFish-supported long-term trainees were enrolled in FY15 (for a complete list of our 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 Kenyatta University Moi University University of Eldoret University of Nairobi | Nepal Agriculture and Forestry University Tanzania Sokoine University of Agriculture Uganda Makerere University US Auburn University North Carolina State University Oregon State University University of Michigan Vietnam Can Tho University |
|--|---|



VII. TECHNOLOGY TRANSFER AND SCALING PARTNERSHIPS

In FY15, AquaFish continued building on previous successes to make significant global and regional technological advances. Collaborative research remained focused on improving sustainable aquaculture productivity through the development and transfer of innovative technologies and management practices that address 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 development of sustainable practices. AquaFish focuses on research that creates a multiplier effect for farm-level income and works with partners to scale up technologies to have broader impacts. Supporting and partnering with HC research institutions allows AquaFish researchers to tailor 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, by forging connections with other projects, and by growing the local institutional infrastructure. Additionally, the AquaFish training effort focuses on local researchers, technicians, and students as a way to develop and build human capacity. AquaFish efforts target small-scale producers and prioritize the development and transfer of low-cost technologies and best management practices. Increasing access to inputs is coupled with training on innovative strategies to help ensure safety and environmental sustainability. AquaFish investments aim to give women equal access to affordable inputs and improved technologies through training opportunities and by emphasizing equitable participation in aquaculture development in project goals.

Efforts have been made to streamline successful technology development at key sites and to highlight human nutrition and systems research. AquaFish researchers use a variety of methods, including the on-farm and on-station trials, baseline surveys, and stakeholder engagement to fine-tune appropriate technologies for transfer, to identify and verify parameters for scaling up, and for capacity building efforts that aim to create successful and sustained diffusion into local communities. The tables below list the AquaFish-supported scalable technologies in various stages of development in FY15, as part of Implementation Plan 2013-2015.



Tilapia farmer feeds his fish on Lake Taal, Philippines.

Asia Project: Bangladesh**Project Partners and Collaborators**

North Carolina State University (Lead US University); Bangladesh Agricultural University (Lead HC Institution); Hajee Mohammed Danesh Science & Technology University; 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 |
|--|--|--|
| <i>Pangasius</i> 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 <i>Pangasius</i> 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. |
| Semi-intensive polyculture with air-breathing fish (ABF) species and carp in Bangladesh | Culturing shing with carps represents a novel polyculture technology in Bangladesh. This system involves two indigenous ABF fish 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 CRSP 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 in 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 | Tilapia cultured with mud crab can provide increases in seafood yields, an additional source of protein for consumption or sale, and a source of 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 <i>Pangasius</i> culture in hyposaline waters | Increasing stocking density by 50% and application of formulated feeds enhances fish yields and reduces feed costs for growing <i>Pangasius</i> in hyposaline waters. | Farmers can enhance their fish yield and economic returns for <i>Pangasius</i> culture in hyposaline culture by stocking fish at a higher density and using formulated rather than commercial feeds. |

| | | |
|---|---|---|
| Pond mud soils for more effective spinach cultivation than dyke soils | The utilization of nutrient-rich pond mud produces greater yields of vine spinach than dyke soils. | 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 gut microbiome for improved tilapia production | Identification of beneficial gut microflora 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 feeds, which may lead to better vitamin synthesis and enhanced nutrient absorption, ultimately leading to the promotion of enhanced food security in Bangladesh. |



Researchers in Bangladesh prepare Pangasius for stocking ponds.

Asia Project: Cambodia & Vietnam***Project Partners and Collaborators***

University of Connecticut-Avery Point (Lead US University); University of Rhode Island; Inland Fisheries Research and Development Institute (Lead HC Institution); Can Tho University; Mekong River Commission; and Cambodia Helping Address Rural Vulnerabilities and Ecosystem Sustainability (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. | The successful implementation of these technologies will lead to broader scale improvements in the snakehead value chain. |
| Feed formulation and processing with soy protein concentrate for snakehead diets | Continues the 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 will help overcome the use of small-size fish for fishmeal, improving the sustainability of snakehead aquaculture and reducing pressures on wild caught small-size fish. |
| Techniques of snakehead (<i>Channa striata</i>) culture transferred from Can Tho University (Vietnam) to IFRDI/FARDeC (Cambodia) | Technology and knowledge transfer of successful research in Vietnam to Cambodia as a way to make the culture of snakehead more sustainable in the region. The technology consists of snakehead breeding, domestication, weaning, and grow out involving successful induced spawning and weaning. | Development and transfer of successful domestication and breeding, weaning, and rearing/growout practices for snakehead in Cambodia will help support the large population of snakehead fish farmers in the region. |
| Development of an aquaculture carrying capacity estimate for a Cambodian water way | 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 for a more sustainable aquaculture industry. |
| Climate change vulnerability assessment | Developing an improved understanding of the vulnerability of actors in the fish value chain to the key drivers of climate change through this assessment. | 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. |

Asia Project: Nepal**Project Partners and Collaborators**

University of Michigan (Lead US University); Agricultural and Forestry University (Lead HC Institution); Nepal Agricultural Research Center; Directorate of Fisheries Development; Janata Higher Secondary School; Kathar Higher Secondary School; Nepal Higher Secondary School; and Prithivi Secondary School.

| Technology | Description | Key Impact |
|---|---|---|
| Sahar reproduction in warm water – Chitwan, Nepal | Large-scale production of sahar fry and more accessible nursing and rearing techniques in warm water – developed in Pokhara and ready for transfer to Chitwan. | The promotion of sahar, indigenous to Nepal, increases pond production, harvest, and income for local fish farmers. It also provides fry for restocking natural waterways to help mitigate population declines in Chitwan. |
| Controlled introduction of small indigenous species (SIS) of fish to household ponds in Nepal | The inclusion of SIS in carp polyculture systems introduces a new source of protein for household consumption without changing sales generated from carp production. This work specifically investigates the most effective stocking density of SIS for establishing a breeding population. | It is anticipated that the successful introduction of SIS will increase yield in the Terai region of Nepal without reducing carp production. The addition of 'SIS' to household diets is also expected to enhance the nutritional options for farmers and their families. |
| Sahar-tilapia polyculture | Sahar (<i>Tor putitora</i>) is cultured with Nile tilapia (<i>Oreochromis niloticus</i>) to increase harvests opportunities for tilapia and improve sahar production. | Cultured sahar is now available for human consumption and tilapia production has improved. This is a positive impact on smallholder farmers in Nepal and the region. |
| School ponds for fish farming development and education | Demonstration fishponds were established at four secondary schools in rural Nepal, where protocols are being implemented in a new course of study to a unique, younger population. | Through experiential education, school-aged children and women are exposed to the practice of fish farming as a way to improve health and nutrition and to integrate STEM knowledge with agricultural practices. |
| Carp-SIS polyculture system with periphyton | This technology in Nepal will provide a cost-effective improvement in production of carp-SIS polyculture with periphyton enhancement. | A more sustainable carp-SIS polyculture system suitable for small-scale fish farmers in Nepal is anticipated to increase fish yield, improving family income and household fish consumption. |

Africa Project: Ghana & Tanzania***Project Partners and Collaborators***

Purdue University (Lead HC University); University of Arkansas at Pine Bluff; Virginia Polytechnic Institute and State University; University of Hawaii at Hilo; FarmerLine; University of Development Studies, Tamale; 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; and University of Dar es Salaam.

| Technology | Description | Key Impact |
|--|--|--|
| Invertebrates as a protein source in fish feeds | Evaluate the suitability of selected invertebrates (earthworms and maggots) as protein sources for Nile tilapia diets. Through this investigation, feeding packages based on the selected invertebrates will be developed and promoted for adoption by small-scale fish farmers. | Through the use of these diets, farmers can improve tilapia production and reduce the cost of feeds, thereby increasing the profitability of fish farming in Tanzania. Income increases may improve the purchasing power of rural farmers, reducing the risks of food insecurity at the household level. |
| Cell phone marketing tool in Ghana | A cell phone-based information exchange technology platform and algorithms for fish producers, fishers, seafood marketers, and consumers involved in the tilapia market is being developed. | Development and scaling of this technology will enhance the trade and profitability of tilapia in Ghana and the region. It will provide a transparent and fair fish trading system. |
| Enhancing the nutritional value of tilapia through innovative feed formulation | The study will produce information useful for practical diet development for Nile tilapia in Ghana that will result in production of a fish with a healthier lipid profile (enriched in omega-3/n-3 fatty acids) compared to conventionally grown fish. | Production of healthier tilapia is part of a larger strategy to improve the nutritional status of people in developing countries. The study will also emphasize the importance of using environmentally sustainable and cost-effective ingredients to accomplish the nutrient enhancement of tilapia. |

Africa Project: Kenya & Uganda***Project Partners and Collaborators***

Auburn University (Lead US University); Alabama A&M University; University of Arizona; University of Eldoret; Kenya Ministry of Fisheries Development; Makerere University (Lead HC Institution); National Fisheries Resources Research Institute; Grameen Foundation; Sustainable Aquaculture Research Networks in Sub-Saharan Africa (SARNISSA); and the Bidii Fish Farmers Cooperative.

| Technology | Description | Key Impact |
|--|--|---|
| Cell phone marketing tool in Uganda | This study develops baseline information about the needs and interest of fish farmers in order to encourage public agencies, NGOs, and cellular providers to facilitate the use of cell phones as a means to guide, coordinate, and instruct fish farmers. | This technology may improve livelihoods by networking and informing previously unconnected portions of the population. |
| Formulation and manufacture of practical feeds for Western Kenya | This work involves increasing the stability of pelleted feeds in water, testing newly formulated feeds with more readily available ingredients, and reducing the overall cost of feeds. | Feed can represents more than 50% of the production costs in Western Kenya. Often commercial feed quality can vary, which can have negative impacts on fish growout. This technology may increase fish production and improve feed conversion ratios. |
| Diversity and putative novel single nucleotide polymorphisms (SNPs) for African lungfish | The development of a SNP panel guide for the domestication of African lungfish, an ABF found in six sources in Ugandan waters. | Information generated here will enhance strategies to improve the development of African lungfish broodstocks in the future. |
| Early maturity of lungfish males in captivity | This technology is a component of the overall effort to understand the reproductive biology of African lungfish. | The full development of this technology will aid in the domestication of the African lungfish and ensure the environmentally sustainable supply of lungfish seed to small-scale fish farmers. |



VIII. GOVERNANCE AND MANAGEMENT ENTITY ACTIVITY

Oregon State University (OSU) serves as the ME of the AquaFish Innovation Lab, responsible for the programmatic, technical, and fiscal performance of the program. In support of the overall AquaFish mission and to further expand the reach of the program, the AquaFish Management Team (MT) engages in research, education, outreach, and capacity building activities related to sustainable aquaculture and fisheries strategies.

AquaFish is one of 24 USAID Feed the Future Innovation Labs working with US and Host Country institutions to address food security challenges through agriculture research and development, technology transfer, and capacity building. Collaboration within the FTF Initiative and other international research programs further expands AquaFish's scope and supports its research efforts and capacity building, contributing to the enhancement of food security and improved livelihoods. The AquaFish MT continued to strengthen collaboration on research and development in FY15 through:

- Continued collaboration on a nutrition project in Bangladesh with other Innovation Labs;
- Participation in the FTF Innovation Labs Partners Meeting in Lilongwe, Malawi, and meeting with WorldFish staff in Zomba, Malawi; and
- Regular conference calls and correspondences with the AquaFish Activity Manager, Shivaun Leonard, and Agreement Officer's Representative (AOR), Maura Mack, to discuss ongoing research progress, funding timelines, and other items.

Successful program management requires regular communication and strategic guidance. Such activities include site visits, data synthesis and analysis, publication of programmatic reports, and consistent communication with project partners to measure progress. The AquaFish MT worked in support and service to its mission and partners in FY15 through the following activities:

- Conducted quarterly conference calls with Project PIs to discuss progress of AquaFish work related to reporting, funding, upcoming opportunities, and challenges;
- Participated in Visa and TraiNet workshop for training in compliance, policies, and procedures related to long- and short-term trainings in the US and Host Countries;
- Consulted with advisory groups (e.g., RCE, EPAC) to strengthen linkages and promote networking opportunities;
- Published the AquaFish Eighth Annual Report, SIRTDA Associate Award Final Report, seven posters at international scientific conferences, four issues of *AquaNews* newsletter, and 12 monthly employment opportunity newsletters (*EdOpNet*);
- Maintained programmatic website and responded to public inquiries about AquaFish activities and opportunities, both internationally and in the US; and
- Met with partners at the following project institutions and organizations: Bangladesh Agricultural University, Central Luzon State University, Sokoine University of Agriculture, Institute of Marine Sciences (University of Dar es Salaam), and Western Indian Ocean Marine Science Association.

AquaFish also met with the following institutional and organizational leaders to discuss opportunities for strengthening institutional capacity and collaboration:

- WorldFish Bangladesh Director;
- CARE and other NGOs, Bangladesh
- President and Vice President of Research of Bangladesh Agricultural University

- President and Vice President of Academic Affairs at Central Luzon State University, Philippines
- Deputy Vice Chancellor of Lilongwe University of Agriculture and Natural Resources, Malawi
- Deputy Chief of Party of Fisheries Integration of Society and Habitat (University of Rhode Island), Malawi
- Project Manager of Aquaculture Enterprises Malawi
- Vice Chancellor of Sokoine University of Agriculture, Tanzania
- Director and Associate Director of Institute of Marine Sciences, University of Dar es Salaam, Tanzania
- Director of the Innovative Agricultural Research Initiative, Sokoine University of Agriculture, Tanzania

AquaFish assists in chairing and organizing conferences, and sponsors awards for students and young scientists to present papers at academic and scientific conferences and symposia. These activities build and strengthen networks, provide opportunities for research to be disseminated to international audiences, and support innovative researchers who will carry on the message of sustainable aquaculture and fisheries practices well into the future. In FY15, the AquaFish Director and MT helped organize sessions and awards for the following conferences, many of them scheduled to take place in 2016:

- Global Conference on Inland Fisheries (January 2015)
- Asian-Pacific Aquaculture Conference (April 2016)
- International Symposium on Tilapia in Aquaculture (April 2016)
- International Institute of Fisheries Economics & Trade (July 2016)
- Asian Fisheries and Aquaculture Forum (August 2016)
- Gender in Aquaculture and Fisheries (August 2016)

In addition to AquaFish PIs and partners' publications and presentations, the AquaFish MT continued to reach out to various stakeholder groups and disseminate information via publications, presentations, and exhibitions at conferences and community events, including:

- Borberg, J., P. Edwards, B. Chavan, and H. Egna. 2015. *Addressing hunger and undernutrition through sustainable aquaculture*. [Poster]. World Aquaculture Society – Aquaculture America, New Orleans, Louisiana, US. 19-22 February 2015.
- Chow, M. and H. Egna. 2015. *Gender dimensions in disaster management: Implications for coastal aquaculture and fishing communities in the Philippines*. [Poster]. American Fisheries Society 145th Annual Meeting, Portland, Oregon, US. 16-20 August 2015.
- Egna, H. 2015. *Linking human nutrition and sustainable aquaculture: AquaFish Innovation Lab strategies from Africa and Asia*. [Oral presentation]. Coastal Women's Shellfish Aquaculture Development Workshop, Zanzibar, Tanzania. 29 July 2015.
- Egna, H. 2015. *Pond to platter: Linking human nutrition and sustainable aquaculture in Africa* [Oral presentation]. USAID Feed the Future Innovation Labs Annual Partners Meeting, Lilongwe, Malawi. 20-23 April 2015.
- Goetting, K., M. Chow, C. Price, and H. Egna. 2015. *Adapting best management practices for enhancing the profitability of small-scale aquaculture in Ghana, Tanzania, and Kenya*. [Poster]. World Aquaculture Society – Aquaculture America, New Orleans, Louisiana, US. 19-22 February 2015.
- Ichien, S., J. Borberg, J. Hawkins, and H. Egna. 2015. *The potential role of air-breathing fish in enhancing climate resilience for small-scale fish farmers*. [Poster]. American Fisheries Society 145th Annual Meeting, Portland, Oregon, US. 16-20 August 2015.
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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 the US Government’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.

Gender disaggregated data show that women represent 42% and 48% of the AquaFish short- and long-term trainees, respectively, earning specialized skills, adopting best management practices and new technologies, and earning professional degrees. Evidence suggests that these types of experiences help to strengthen their ability to earn income, improve household nutrition, and contribute to aquaculture development in their respective communities. Improving gender equity at the institutional level and ensuring that women are included in leadership is central to the long-term benefits of gender integration. During FY15, AquaFish made significant progress toward including women as beneficiaries in the processes and outcomes of aquaculture research. Social and cultural barriers can pose challenges to meeting the 50% gender benchmark, and AquaFish works with US and Host Country researchers, extension agents, and others to overcome these obstacles.

Gender Integration Initiatives

FY15 accomplishments toward AquaFish’s Gender Integration Initiatives (highlighted in green) 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- 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 <i>VI. Human and Institutional Capacity Development</i> of this report for more information). To help facilitate success, women’s participation is integrated at the |

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| planning stage for all sponsored projects, utilizing context-based circumstances and information to anticipate and overcome obstacles on the ground. In FY15, 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 is a cross-cutting issue for all AquaFish projects. Gender Inclusiveness Strategies identify specific project approaches. Each investigation focusing on women involves forethought, including a tailored approach that considers conditions on the ground to help ensure success. PIs and researchers in the US and Host Countries are involved in monitoring and evaluation. |
| Focus one component of a lessons learned and synthesis assessment specifically on the social context and impact of AquaFish research and outreach activities on the lives of women. |
| AquaFish communicates gender activities and accomplishments through conference presentations, posters, AquaNews articles, and other media. In FY15, AquaFish produced and presented two gender-focused posters at national conferences. The first poster, titled <i>Addressing hunger and undernutrition through sustainable aquaculture</i> , was presented at the annual meeting of the World Aquaculture Society in New Orleans, Louisiana, US, in February. The second poster, titled <i>Gender dimensions in disaster management: Implications for coastal aquaculture and fishing communities in the Philippines</i> , was presented at the annual meeting of the American Fisheries Society in Portland, Oregon, US, in August. Both posters examined issues relating to food and income security through a gender lens. |
| 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 FY15, AquaFish researchers held two separate workshops in Vietnam that focused on small-scale aquaculture of snakehead using formulated feeds, reaching a total of 60 women participants. |
| 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 were made to ensure women farmers were welcome at trainings. In FY15 in Tanzania, for example, AquaFish personnel directly engaged with several women fisheries extension specialists to discuss strengths and challenges of fish ponds in their districts. Additionally, each AquaFish project makes an effort to include women in key positions with roles such as investigators, research collaborators, and workshop leaders. |
| Promote the participation of women in formal and informal education and training opportunities provided through AquaFish. AquaFish has set a 50% benchmark for training women in formal and informal education. In addition, the 50% benchmark applies to attracting and retaining women scientists and administrators in all AquaFish activities, as project researchers, advisory group members, and managers. |
| AquaFish continues to set a 50% benchmark for the involvement of women in all programmatic activities. During FY15, AquaFish supported 268 women in short-term trainings and 71 women in long-term training degree programs. Women are represented as key personnel on AquaFish projects, in 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 FY15 gender-focused investigations for the five AquaFish projects are included below.

Africa Project: Ghana & Tanzania

Assessing the Nutritional Impact of Aquaculture Policy in Fish Farming Districts in Tanzania and Ghana (13HHI01PU)

- A two-day workshop was held in Zanzibar, Tanzania, in July 2015 called Coastal Women's Shellfish Aquaculture Development. This event focused on community-based aquaculture in Tanzania, empowering women through mariculture activities, reflecting on experiences from local communities, marketing strategies and challenges, pearl oyster seeding, and sustainable bivalve farming using no-take zones.

Africa Project: Kenya & Uganda

New Approaches to Inform, Motivate, and Advance Small- and Medium-scale Fish Farmers: Building Industry Networks through Cell Phone Networks, Training, and Market Participation (13BMA04AU)

- Results from five focus group interviews provided information about the needs and interests of fish farmers as they relate to mobile phone use. Factors influencing mobile phone use included lack of electricity, poor network coverage, high calling credit and maintenance costs, and lack of awareness and promotion. These findings, among others, will enable public agencies, NGOs, and telephone service providers to address barriers to mobile phone use and support women's roles in the fisheries value chain.

Asia Project: Bangladesh

Improving Nutritional Status and Livelihoods for Marginalized Women Households in Southwest Bangladesh through Aquaculture and Value Chain Analysis (13MER04NC)

- A regional stakeholder workshop was organized on mud crab and tilapia polyculture in Munshiganj, Shyamnagar in the Satkhira district, and a two-day women farmers' training on mud crab and tilapia polyculture (follow-up session) was also conducted in the same region. Diversifying the outreach mode, this training also included a courtyard knowledge sharing meeting and farmers plot visit.

Asia Project: Cambodia & Vietnam

Enhancing Food Security and Household Nutrition of Women and Children with a Focus on Nutrient Dense Commonly Consumed Fish from Capture Fish and Aquaculture in Cambodia (13HHI02UC)

- Data on food and nutrient intakes among women and children under 5 years old were collected and summarized, and the nutritional composition of commonly consumed fish was analyzed.
- Two workshops were held in Vietnam to train women on small-scale farming of snakehead using formulated feed and processing snakehead products.

Asia Project: Nepal

Establishing School Ponds for Fish Farming and Education to Improve Health and Nutrition of Women and Children in Rural Nepal (13HHI04UM)

- Two women's groups were formed in Nepal in association with school pond development and training at secondary schools: one in the Chitwan district and one in the Nawalparasi district, as a way to get them involved in fish farming education. Student training in the secondary schools is ongoing, and two sets of trainings have been completed at each of the four schools. Furthermore, a course of study for teacher and student education on fish culture is in development.

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.

RCE – Africa Annual Report

Charles Ngugi & Steve Amisah

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

Many African countries are in need of food security assistance, with some war-torn or disease-stricken African nations having heightened need for support. Several constraints exist for aquaculture development and transfer of technology in African regions, including lack of national government recognition of the contribution of aquaculture and fisheries to GDP, lack of clearly defined plans for development of the sector, and lack of record keeping that can prevent fish farmers from having access to credit. In addition, constraints continue to exist in access to good quality information (via outreach and extension, for example) and to land and water rights. Fish feed shortages also limit the growth of the industry in many African countries. There is a disparity in availability of fish feed between nations within the same region, due in part differences in investment in commercial aquaculture development between African states.

Activities that Support Women's Involvement in Aquaculture and Fisheries

The RCE will continue to extend partnerships with women's groups and youth. The RCE is in contact with Women in Agriculture Development in Ghana to explore the training and integration of women into mainstream aquaculture production and also to provide further education on fish processing under more hygienic conditions.

Capacity Building and Information Dissemination

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

- Developing and maintaining an Africa RCE webpage (<http://rceafrica.com/>) – the network is also accessible on Facebook and Twitter).
- Collaborative research and institutional linkages (e.g., International Livestock Research Institute, WorldFish, CGIAR).
- Facilitating networking with global scientists interested in African aquaculture through the International Symposium on Tilapia in Aquaculture, SARNISSA, World Aquaculture Society (WAS), New Partnership for Africa's Development, Aquaculture Network for Africa, and other meetings and conferences.
- Networking at professional conferences (e.g., a two-day regional aquaculture meeting in Arusha, Tanzania, that took place in September 2015). It was well attended with participants from Kenya, Uganda, and Tanzania making oral presentations and subsequently participating in a panel discussion. Members were encouraged to join WAS and form an African chapter of WAS.
- 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. Key among the organizations and governments include FAO, the German and Israeli government under a trilateral arrangement in Kenya, and Kenya Marketing Trust. FAO has committed funds under a three-year program to train youth in aquaculture at the Mwea Aquaculture Farm in Kenya. Efforts have been made to bring in floating feeds from Norway, Denmark,

and Israel, and discussions are underway with Norwegian AllerAqua regarding importation of floating feeds and distribution to fish farmers in Kenya.

RCE – Asia Annual Report

Yuan Derun & Remedios Bolivar

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

New challenges in aquaculture development in Asia are emerging, including increasingly stringent production practice requirements to meet food quality and safety standards for dynamic markets and consumer preferences, improving traceability along production/value chains, minimizing environmental impacts, maintaining and increasing access to high quality feeds, and ensuring inclusiveness concerning small-scale operators. Persistent issues include low investment in research and development and capacity building; low efficiency of farming systems with regards to resource use and profitability; use of improper farming technologies that frequently result in disease and negative environmental impacts and, in some cases, lead to issues with food safety and labor; and under-recognition of women's roles and contribution to the aquaculture sector.

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 conducting advocacy for more gender sensitive policies and mainstreaming gender in institutional settings; conducting training needs assessments among women throughout the aquaculture value chain; developing women-focused training courses on farm management, record keeping, and accounting; supporting the development of gender sensitive curricula in educational institutions, and training trainers for gender outreach and mainstreaming efforts. One activity involving NACA is the "Coordination of the Thematic Studies on Gender in Aquaculture in Cambodia, Lao PDR, Thailand, and Vietnam" project, which is a joint activity of NACA and the USAID-funded MARKET program. The project is a joint activity of NACA and USAID-funded MARKET project.

Capacity Building and Information Dissemination

The Asia RCE coordinators were involved in the following outreach and dissemination activities in FY15:

- Training focused on developing culture-based fisheries in Cambodia and Lao, including exchange visits of professionals between the two countries.
- Hosting an international symposium on small-scale aquaculture extension and development of a guidebook to assess and promote the farmer-to-farmer extension approach.
- Participation in a FAO workshop organized and attended by professionals from 17 countries focused on developing strategies and an action plan for sustainable intensification of aquaculture in Asia-Pacific.

Leveraged Activities

An Australian Centre for International Agricultural Research funded project on culture-based fisheries development in Southeast Asia built upon previous ACIAR projects in the region.

RCE – Latin America and the Caribbean (LAC) Annual Report

Wilfrido Contreras-Sánchez & Maria Célia Portella

In Phase II (2013 – 2018), USAID requested that AquaFish focus on Africa and Asia. As a result, there are currently no funded projects in LAC, but AquaFish hopes to continue assisting in the region informally through an 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

There remains a significant gap in development in the aquaculture sector between North/South America and Central America. Research is perhaps the most significant need for the industry in this region, with a focus on developing culture of marine species. Currently, most aquaculture in the LAC is focused on shrimp and tilapia, and the shrimp industry is experiencing severe challenges from outbreaks of Early Mortality Syndrome, which is responsible for mortality rates up to 70% on some farms. Technology transfer for improving disease control in shrimp culture is a pressing need, in light of the recent economic hardships experienced by producers in that sector. Tilapia culture is continuing to grow, and major advances have occurred, including improvements in infrastructure and incorporating solar power technology and bioflocs into commercial tilapia culture systems. Nevertheless, there is a need for reliable access of quality feed at reasonable prices, stocks of disease-resistant culture species, and consistent, dependable sources of high quality fingerlings.

Activities that Support Women's Involvement in Aquaculture and Fisheries

Women's involvement in aquaculture in LAC is limited almost exclusively to fish processing. Despite incentives, there has been little involvement in other aquaculture activities by women in this region. Though all countries in this region have programs designed to support women in education and industry, none of them are focused specifically on aquaculture, and realizing gender equity in this field is still a work in progress.

Capacity Building and Information Transfer

The LAC RCE has 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.
- In the wake of the Brazilian Government's recent decision to abolish the Ministry of Fisheries and Aquaculture (MPA) and fold the activities into the Ministry of Agriculture and Livestock (MAPA), Dr. Portella is serving on a committee that will discuss the issue with the Minister of MAPA in order to maintain the projects and programs established by the MPA.
- Dr. Portella is serving as the President of LACQUA 15 in Brazil, is the chair of the steering committee, and has participated on the board of directors of the LAC chapter of the World Aquaculture Society.
- Mentor long-term students – during the last two years, RCE coordinators have advised 13 graduate students and two undergraduate students in research related to fish larviculture and hatchery production.
- Dr. Contreras-Sánchez chaired a session at the 2015 Aquaculture America meeting, titled "Recent Advances in Snook Aquaculture", which built upon earlier AquaFish CRSP work. This session hosted 17 talks and represented a major step forward for disseminating research results and providing networking opportunities snook researchers in LAC and the Americas in general.
- A former AquaFish participant and faculty at Universidad Juárez Autónoma de Tabasco (UJAT), Rafael Martínez, recently conducted a one week visit to Haiti to promote aquaculture to improve food security among the poor. Since the devastating earthquake in Haiti in 2010, Mexico has been sending missions every month, and recently UJAT had the opportunity to lead and organize a mission.

Leveraged Activities and Associate Awards

In Mexico, the National Council for Science and Technology implemented a program focused on developing innovations in all sectors of the industry. Researchers from UJAT submitted proposals to support fish farms that are incorporating solar energy, utilizing new culture species, and/or implementing new culture methods on-farm. Results will be provided in February next year. The National Commission for Knowledge and Use of Biodiversity project for recovery of native fish populations in lagoons and rivers is concluding, and the reports are anticipated in 2016.

The RCE Lead Coordinator and his colleagues are closing a project reported in the previous year, funded by the national oil industry, and have simultaneously initiated a new study from the same funder, entitled “Immediate actions for sustainable development in fishermen communities of Campeche: Phase I.” A second phase is anticipated in the future and UJAT will continue its participation in this study.



Participants at the Coastal Women's Shellfish Aquaculture Development Workshop in Zanzibar, Tanzania.



X. ISSUES AND CHALLENGES

- A recurring issue at OSU stems from continued rapid growth in student enrollment and capital investment in buildings. Although growth is generally considered positive, the University must, during periods of construction and remodeling, relocate displaced staff and/or entire departments or colleges. During this growth period for OSU, AquaFish has been forced to relocate in its entirety four times in less than four years. The challenges faced by these moves can not be overstated. The AquaFish office moved twice in FY15, with the second move occurring late in the Fall, just prior to the fiscal year's end. Planning and conducting these large-scale moves has had a negative impact, especially during times of heavy reporting. Although forward-thinking management decisions were made to operate as efficiently as possible during the moves, the AquaFish MT is thankful that these disruptions are in the past.
- During FY15 several new reporting requirements were introduced to the Innovation Labs. These requirements included adhering to new data management plan guidelines, new due date and formatting for the Annual Work Plan, and changes to the organization of the Annual Report. In addition, discussion around the development of new branding and marking guidelines resulted in more questions than answers. While these may be seen as growing pains while USAID embraces the management challenges of an expanded Innovation Lab portfolio, the absence of clear operational policies handed down to implementing partners presents confusion and consumes valuable time and other resources for all parties involved.
- The AquaFish MT has enjoyed a successful working relationship with OSU's Office for Sponsored Research and Award Administration (OSRAA). A challenge that surfaced this Fiscal Year was communicating to OSRAA how important timely subaward amendments are to the AquaFish Innovation Lab. Much of the success that AquaFish has enjoyed in achieving grant objectives and impacting the most needy in developing countries is due to the efforts of subcontracting (and sub-subcontracting, etc.) partners. It is therefore critical for subcontract amendments to provide not only the necessary funding, but also the necessary period of performance to ensure success all along the contractual "pipeline." AquaFish has communicated this concern to OSU, and OSU is making progress towards issuing more timely subaward amendments to project partners that encompass a multi-year period of performance, thereby maximizing continuity and momentum, and minimizing stoppages due to amendment delays.
- Communicating an accurate annual burn rate to USAID has proven to be a challenge this year. USAID requires that burn rate be computed from inception to date. Unfortunately, this formulaic approach – allocating future funds based on monthly burn rate over the life of the award – prevents AquaFish from spending at USAID-approved budgeted levels. It is important to note that any departure from agreed-upon annual allocations prevents the ME from making long-term strategic funding decisions. AquaFish's annual budget nearly doubled from Phase 1 (2006-2013) to Phase 2 (2013-2018) in support of a greatly expanded scope of work. In this context, incorporating historic (Phase 1) spending to estimate the current burn rate, will inevitably result in an underestimate of future AquaFish spending and, ultimately, may result in underallocation of annual funding to AquaFish from USAID.
- Increasing Management Office staffing to administer Associate Awards and assimilating such projects more completely into the overall AquaFish program are two ways to improve the management of Associate Awards in the future. The consensus among AquaFish management and advisory groups at the 2009 Annual Meeting was that future Associate Awards must be treated more similarly to core research projects, adhering to technical peer-review, organizational, and reporting requirements. With this SIRTDA Associate Award, AquaFish heeded this lesson by requiring all tasks to be written as

“investigations” that undergo peer-review; to add to the overall AquaFish metrics/indicators; and to conform with core program guidelines and policies. Integration and alignment require extra planning time. Quick turnaround task-order USAID request for applications do not typically allow for this. Another method for promoting integration of Associate Award personnel is for them to provide service on core AquaFish advisory groups. The East and West Africa RCE Leaders on the core program were involved in the Associate Award from the beginning; however, due to changes in their work responsibilities they were unable to devote the necessary time for integrating project activities across East and West Africa. A re-evaluation of the role of RCEs on Associate Awards will be taken up at a future advisory meeting.

- Timely information from USAID regarding project extensions is required for the AquaFish Management Office to make effective programmatic and funding decisions as awards close down. The AquaFish Management Office requested a three-month no-cost extension (NCE) to its SIRTH Associate Award in June 2014, to avoid simultaneously closing down the prime Associate Award from USAID and subawards to project partners on the same date. This untenable situation would not have provided the Management Office adequate time to synthesize data/information across the two projects and three countries in a meaningful way. The NCE was fully executed on 29 September 2014 – one day before the Associate Award was slated to close down. AquaFish appreciated receiving the NCE; however, it came at the 11th hour and thus presented program management challenges due to the uncertainty of whether or not an NCE would ultimately be granted.
- AquaFish experienced a hiatus in AOR leadership from USAID BFS in FY13-14, during which a transition from AquaFish’s longtime AOR (Harry Rea) occurred. The transition involved a lengthy regrouping period when institutional memory was unfortunately lost. As of the very end of FY14, the transitional period appears to be coming to a close – the new Activity Manager recently received clearance and a USAID email address and phone number, along with some administrative and operational training, although AOR training still awaits. Looking back, the transition in AORs was probably made more challenging due to changes occurring in tandem at BFS. The learning curve for anyone coming into such a situation can be very steep. While AquaFish has made mentoring its new USAID AORs a priority, the additional information-sharing burden has at times been high. Although USAID tried to overlap AORs, ensuring success during the transition depended heavily on having an experienced Director and management team in place. Had both sides (USAID and the MT) been in a period of transition, serious problems could easily have ensued.
- The cost of doing business has increased considerably over the past few years. New and additional regulations, increased risk aversion, and heightened security issues mean more effort must be put into management, compliance, and oversight. These factors, along with rising personnel and health care costs, have increased management costs at US universities even in the short period since the start of Phase II. Overseas, many of these same costs are causing budgets to go less far. AquaFish field projects have encountered steep price increases for feed, labor, and other research inputs. The cost sharing and leveraging AquaFish has raised in the past is very meaningful for success of its collaborative research projects; however, these streams are harder to come by. The ability to manage Associate Awards will become increasingly difficult as core funds are worth less and less. USAID correctly recognized these challenges when it increased the core annual budget of the most recent Innovation Lab to the highest of any Innovation Lab fashioned in the CRSP vein (i.e., Sustainable Intensification at Kansas State, core funding of \$25M over 5 years, with a \$25M additional ceiling to \$50M total). The AquaFish ceiling and, thus, its ability to take on Associate Awards without infringing on its core performance and funding, is very low at \$1M. Without a higher ceiling, any Associate Award would need to absorb the heavier management costs so as not to jeopardize core research and field projects. A recommendation would be to increase the ceiling of AquaFish in the next modification.



XI. FUTURE DIRECTIONS

The *Feed the Future Innovation Lab for Collaborative Research on Aquaculture & Fisheries* (AquaFish Innovation Lab) at 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. Moving forward, AquaFish will continue to monitor project progress through various mechanisms, including Feed the Future Monitoring System metrics, disaggregated short- and long-term training data, and benchmarks.

AquaFish 2013-2015 Implementation Plan

Current AquaFish projects were funded over a two-year Implementation Plan from 2013-2015 (<http://aquafishcrsp.oregonstate.edu/page/implementation-plans>) and are taking place in the following countries in Asia and Africa: Bangladesh, Nepal, Cambodia, Vietnam, Ghana, Tanzania, Uganda, and Kenya, with additional key project personnel in the Philippines. The AquaFish Innovation Lab is managed at OSU, and individual projects are led by investigators at the following five US Universities: Auburn University, North Carolina State University, Purdue University, University of Connecticut, and University of Michigan. Projects have been underway for almost two years, and are continuing work in FY16.

2016-2018 Continuing Projects

As planned by AquaFish and approved by USAID, existing projects will undergo a mid-term review in FY16, and work that builds on and adds value to previous AquaFish work will be continued. As Burma remains an area of interest for USAID, AquaFish plans to undertake an assessment of aquaculture in that region.

Assessing Programmatic Impacts

AquaFish has initiated planning for a program-wide Impact Assessment project to assess the efficacy of various long-term training practices. A workshop or webinar will be held in FY16 to develop methodologies. The work will focus on long-term graduate student training by looking at strategies employed by AquaFish CRSP and AquaFish Innovation Lab.

Regional and Global Work

The AquaFish MT will stay informed of emerging development and technical issues through open dialogue with three established external and internal advisory groups: DTAP, RCE, and EPAC.



APPENDIX A: SUCCESS STORIES

INVERTEBRATES ARE A BOON TO AQUACULTURE IN TANZANIA

Aquaculture in Tanzania has mostly been relegated to rural areas, where fish are grown in small ponds as a secondary activity for farmers wanting to supplement their income and diet. This type of small-scale aquaculture is often not economically sustainable due to a number of factors, including high production costs. Perhaps the most significant barrier to growth of the aquaculture industry in Tanzania is the high cost and relative scarcity of quality fish feed. There is competition between agriculture sectors for protein sources, such as fishmeal, that are necessary to produce quality feed. Consequently, high quality fish feed is often hard to find, and expensive when available.

Recognizing the bottleneck created for the growth of Tanzanian aquaculture by this widespread lack of quality feed, AquaFish Innovation Lab researchers at Sokoine University of Agriculture (SUA) in Morogoro, Tanzania, investigated the potential of invertebrates as an affordable alternative protein source for fish feeds. Specifically, two common invertebrates were studied – housefly larvae and earthworms – both of which are good candidates because of their relatively short life-cycles and high fecundity.

Scientists first tested the effects of different substrates on the yield and protein composition of the earthworms and maggots. They found that the type of substrate used affected the quality of protein produced, depending on the invertebrate. For earthworms, the highest quality protein was achieved using cow manure as the culture media, while chicken manure yielded the highest quality protein in housefly larvae.

The second objective of this research was to evaluate the growth performance of juvenile tilapia (*Oreochromis niloticus*) fed diets containing protein meal made from earthworms and housefly larvae. Researchers designed an experiment to test five treatments of formulated fish feed in a controlled grow-out trial, where each treatment diet contained an incremental level of crude protein derived from the two invertebrate meals. Fish were grown in controlled conditions in the wet laboratory at SUA for eight weeks.

Results of the grow out trial indicate that the fish fed diets containing between 25% and 35% housefly meal gained more weight compared to those fed a control diet. Diets containing housefly meal out-performed those made with earthworm meal, and feed conversion ratios were the best for fish fed the 35% diets – which were also the most cost-effective treatment for producing a unit of fish.

This investigation highlights the potential for producing and using locally sourced ingredients as low-cost alternatives to traditional sources of protein meal in fish feed production. Formulating fish feed using high quality protein from invertebrates can reduce overhead costs, improve the sustainability of small-holder aquaculture systems, and increase food security at the household level



Testing different substrates on the yield and protein composition of earthworms for use in fish feed.

NOVEL METHOD FOR GROWING PANGASIOUS IN HYPOSALINE PONDS UNLOCKS THE AQUACULTURE POTENTIAL OF SOUTHERN BANGLADESH

In Bangladesh, a poor nation situated almost entirely on a low-elevation river delta, sea level rise is inundating many freshwater systems in coastal areas with hyposaline water. This salt-water intrusion has presented an ongoing challenge to expanding freshwater pond aquaculture in the region, as many freshwater culture species cannot tolerate the elevated salinity.

The southern, low-lying regions of Bangladesh have traditionally relied on fishing or aquaculture of marine species like shrimp for both nutrition and income. However, overfishing, increased frequency of damaging storms, and disease epidemics in shrimp culture have left the communities of coastal Bangladesh with more than half a million fishers living in severe poverty in the Barisal region of southern Bangladesh alone. The result is thousands of displaced fishers and people whose livelihoods depended on that industry to survive.

Maintaining sustainable growth in aquaculture is critical for meeting the demand for seafood in a nation that sources up to sixty percent of its animal protein from the fisheries sector. Aquaculture of Indian carps, non-native carps (such as silver, common and grass carp species), tilapia, and *Pangasius* catfish account for the lion's share of fish farming in Bangladesh. Shrimp farming is still the leading aquaculture product by value in the nation, though it remains an industry with significant challenges to sustainability.

The river catfish *Pangasius hypophthalmus*, a freshwater species well suited for aquaculture, was introduced to Bangladesh in the 1990s. Since then, *Pangasius* aquaculture has grown rapidly, yielding over 300,000 tons of product every year. Farmers have achieved economic success in culturing this species in the northern parts of the country. However, expanding aquaculture to the southern regions of the country is more challenging, since pond water is becoming increasingly saline due to rising sea levels.

Recognizing the potential of southern coastal areas for *Pangasius* farming, and aware of the challenge of seawater incursion, AquaFish researchers from the US and Bangladesh wanted to test whether these fish could be cultured in higher salinity water. Working with local fish farmers in the Barisal region of coastal



A fish farmer shows off his successful catfish harvest from a pond in Bangladesh.

Bangladesh, *Pangasius* catfish were stocked in ponds with two salinity ranges – 2-5 ppt and 5-8 ppt – and reared for a period of 180 days to evaluate growth performance. The results of the experiment demonstrate for the first time that *Pangasius* catfish can be successfully grown in hyposaline waters.

This study has important implications for the future of aquaculture in the southern regions of Bangladesh, and further afield in southeast Asia. To date, aquaculture of this species has been limited to freshwater systems along the Mekong Delta region in Vietnam and Cambodia, and to locations in Thailand and the central and northern regions of Bangladesh.

“Opportunities exist to expand its culture to coastal regions impacted by seawater incursion and in communities impacted by overfishing and inadequate food security,” said Host Country Co-PI Dr. Md. Lokman Ali of Patuakhali Science and Technology University. The coastal areas along the Ganges River Delta in Bangladesh and the Mekong River Delta in Vietnam will continue to be impacted by rising sea levels, where freshwater bodies along inland coastal areas are already experiencing salinization. This project provides a precedent for culturing *Pangasius* in areas of higher salinity, expanding the potential for aquaculture to contribute to food security and fish protein production throughout the region.

RESEARCHERS IN NEPAL REPEAT SUCCESS WITH BREEDING NATIVE SAHAR IN NEW LOCATION

The sahar (*Tor putitora*) is an endangered cyprinid endemic to Asia. Also called “mahseer”, it is a popular game fish and an economically important food fish in several countries across the Himalayan plateau. In Nepal, as in many places throughout its native range, overfishing and habitat alterations have caused widespread declines in sahar populations. Management efforts to reverse population declines, such as restoring habitat and curbing fishing pressure with government regulations, offer possible solutions. Another approach is to supplement the capture fishery by increasing supply from aquaculture production, which could allow for an enhanced market presence.

AquaFish researchers in Nepal are improving breeding techniques for sahar to support conservation and improve food security. Building upon past findings, AquaFish researchers at the Agriculture and Forestry University (AFU) developed artificial breeding techniques for sahar. Ultimately, the goal is to scale up seed production technologies. Many current hatchery operations use reproductive hormones to artificially induce the development of ova in female fish. Though effective, these techniques can have negative environmental effects that reduce the sustainability of the aquaculture operation.

Dr. Jay Dev Bista, AquaFish Host Country Co-PI, worked with colleagues at AFU and the Fisheries Research Center in Pokhara to establish a method that allows the fish to “ripen” (become sexually mature) more frequently than in the wild without the use of reproductive hormones. By controlling for temperature and stocking density in culture ponds, Dr. Bista and his team were able to create conditions that allowed nearly 100% of females to become sexually mature in February and March 2015, and achieved hatch rates between 75 and 95% after spawning and incubation.

The sahar, as with most other cyprinids (such as carps, minnows, and barbs), is capable of spawning multiple times per year. Replicating the same spawning frequencies at different hatcheries throughout Nepal will increase sahar seed production for grow-out farms, reducing the need for fishing bans and tighter regulations.

Although initial attempts to spawn sahar in Chitwan were unsuccessful, researchers achieved breeding success in the springtime, once water temperatures began to rise. These results are an encouraging step towards accomplishing the research objective of scaling up production of sahar seed for grow out operations at fish farms throughout the country.

In Nepal, where there are very few experts working in the field of aquaculture, knowledge transfer and extension activities are critically important for building capacity in the aquaculture industry, which relies heavily on government subsidies to keep fish farms running. By innovating methods for efficient, reliable seed production of sahar, Dr. Bista and his team hope their efforts will spur sustainable growth of the aquaculture industry in Nepal.

Culturing indigenous species helps avoid invasive species introductions, aligns with local cultural needs, and increases the available options for aquaculture production. AquaFish researchers in Nepal are paving the way for producing large volumes of sahar seed, as well as developing nursing and rearing techniques. The results of this research could ultimately kick-start a new sector of the industry that can help contribute to food security and promote conservation of this important yet threatened fishery.



AquaFish researchers check the maturity of a sahar brood fish to determine its readiness to spawn.



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 2015, there have been 229 publications.

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