FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Feed the Future Innovation Lab for Fish

Annual Report October 1, 2020 – September 30, 2021

Cooperative Agreement 7200AA18CA0030

USAID
FROM THE AMERICAN PEOPLE

MISSISSIPPI STATE UNIVERSITY
GLOBAL CENTER FOR AQUATIC FOOD SECURITY

Feed the Future Innovation Lab for Fish

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November 30, 2021

Prepared for:

Agreement Officer's Representative (AOR)

Feed the Future Innovation Lab for Fish (Fish Innovation Lab)

Bureau for Resilience and Food Security (RFS)

United States Agency for International Development (USAID)

Prepared by:

Mississippi State University

Global Center for Aquatic Food Security

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Management Entity Information

The Feed the Future Innovation Lab for Fish (Fish Innovation Lab) is managed by Mississippi State University (MSU) and is housed in the MSU Global Center for Aquatic Food Security, which is affiliated with the College of Veterinary Medicine.

Members of the Management Entity

- Mark L. Lawrence, Director (88%)
- Peter Allen, Productivity Frontier Specialist (8%)
- Jared Dees, Grants and Contracts Manager (90%)
- Alaina Dismukes, Communications Specialist (100%)
- Shauncey Hill, Program/Finance Manager (100%)
- Mark Peterman, Capacity Development Associate (20%)
- Kathleen Ragsdale, Gender and Youth Equity Specialist (20%)
- Mary Read-Wahidi, Gender and Youth Equity Co-Specialist (15%)
- Stephen Reichley, Risk Mitigation Specialist (25%)
- Laura Zseleczky, Communications Manager (100%)

External Advisory Board

The Fish Innovation Lab Management Entity (ME) is advised by the Fish Innovation Lab External Advisory Board (EAB), who provides strategic direction for Fish Innovation Lab goals and objectives, gives scientific oversight for Fish Innovation Lab activities, and monitors progress toward Fish Innovation Lab objectives.

Members of the External Advisory Board

- Bryan McCoy, Director of FirstWave Group
- Michael Phillips, Director of the CGIAR Research Program on Fish Agri-Food Systems and WorldFish Director of Aquaculture and Fisheries
- Melba B. Reantaso, Team Leader (NFIMF: Food Safety, Nutrition and Health), Fisheries and Aquaculture Division (NFI), Food and Agriculture Organization of the United Nations (FAO)
- Rohana Subasinghe, Technical Lead, WorldFish Nigeria
- Karen Veverica, Former Director, Auburn University E.W. Shell Fisheries Research Center

Countries Where the Fish Innovation Lab Works

In federal fiscal year (FY) 2021, the Fish Innovation Lab implemented activities in Bangladesh, Nigeria, Kenya, Zambia, Cambodia, Ghana, and Malawi (Figure 1).

Figure 1: Location of Fish Innovation Lab Activities

Fish Innovation Lab Management Entity Partners

University of Rhode Island (URI)

- Elin Torell, Deputy Director (40%)
- Austin Humphries, East Africa Specialist (25%)
- Karen Kent, West Africa Specialist (9%)
- Glenn Ricci, Capacity Development Specialist (33%)
- Laura Skrobe, Fisheries and Program Management (30%)

Research Triangle Institute (RTI) International

- Rebecca Jeudin, Monitoring, Evaluation, and Learning Advisor (70%)
- Joanna Springer, Resilience Specialist (7%)

Washington University in St. Louis (WUSTL)

- Lora Iannotti, Nutrition Specialist (8%)

Texas State University (TSU)

- Madan Dey, Asia Specialist (25%)

Regional Coordinators

- Md. Gulam Hussain, Asia Coordinator (50%)
- Sunil Siriwardena, West Africa Coordinator (50%)
- Andrew Wamukota, East Africa Coordinator (50%)

Abbreviations and Acronyms

AOR	Agreement Officer's Representative
BC	Bighead Catfish
BMP	Better Management Practice
BMU	Beach Management Unit
BSF	Black Soldier Fly
CIRDAP	Center on Integrated Rural Development for Asia and the Pacific
ComFA+Fish	Complementary Food for Africa + dried fish powder
DWF	Distance Water Fleet
EAB	External Advisory Board
EMMP	Environmental Management and Mitigation Plan
ESBL	Extended Spectrum Beta Lactamase
FAO	Food and Agriculture Organization of the United Nations
FY	Fiscal Year
G3	Generation 3
GIFT	Genetically Improved Farmed Tilapia
GRADA-FIL	Gender Responsive Aquaculture/Fisheries Development Assessment
HC	Host Country
HDDS	Household Dietary Diversity Score
HFIES	Household Food Insecurity Experience Scale
HICD	Human and Institutional Capacity Development
IACUC	Institutional Animal Care and Use Committee
IMC	Indian Major Carp
LSME	Lean Subject Matter Expert
MDD-IYC	Minimum Dietary Diversity-Infants & Young Children
MDD-W	Minimum Dietary Diversity-Women
MDD-WRA	Minimum Dietary Diversity-Women of Reproductive Age
ME	Management Entity
MEL	Monitoring, Evaluation, and Learning
MSU	Mississippi State University
NGO	Nongovernmental Organization
PCR	Polymerase Chain Reaction
PHFL	Post-Harvest Fish Loss
PI	Principal Investigator
RTI	Research Triangle Institute
RUA	Royal University of Agriculture
TSU	Texas State University
UI	University of Ibadan
URI	University of Rhode Island
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USG	United States Government
WEFI-FFZ	Women's Empowerment in Fisheries Index - FishFirst! Zambia
WUSTL	Washington University in St. Louis

Glossary

Aquaculture: “The farming of aquatic organisms, including fish, mollusks, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated” (FAO, 1988).

Gender Integration: Strategies employed to ensure women’s and men’s attitudes, roles, responsibilities, concerns, and experiences are an integral dimension of the design, implementation, monitoring, and evaluation of research and extension. Differences are recognized and routinely addressed for all activities.

Gender Equality: Norms, values, attitudes, and perceptions required to attain equal status between women and men without neutralizing the biological differences between women and men.

Small-Scale Fisheries: Also referred to as artisanal fisheries. Characteristics differ among countries, but the term generally means “traditional fisheries involving fishing households (as opposed to commercial companies), using a relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption” (FAO, 2014). “Women are significant participants in the sector, particularly in postharvest and processing activities. It is estimated that about 90% of all people directly dependent on capture fisheries work in the small-scale fisheries sector. As such, small-scale fisheries serve as an economic and social engine, providing food and nutrition security, employment and other multiplier effects to local economies while underpinning the livelihoods of riparian communities” (FAO, SSF Guidelines, 2015).

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Executive Summary

The Feed the Future Innovation Lab for Fish (Fish Innovation Lab) began in September 2018 and has completed three years. FY 21 was the first full year for the 13 competitively awarded research activities in Bangladesh, Cambodia, Kenya, Nigeria, and Zambia. In FY 21, the Fish Innovation Lab also commissioned six activities that were designed to address areas of need, complement ongoing work, foster strategic partnerships, and address the Fish Innovation Lab theory of change. The six commissioned activities also expand the geographic coverage to include Malawi and Ghana.

Fish Innovation Lab accomplishments in advancing productivity (Area of Inquiry 1) include improving efficiency of aquaculture production, feed production, and fish processing in Nigeria; implementing integrated rice-fish farming experimental plots in Nigeria; and supporting improved genetics of carp species in Bangladesh through family selection and sperm cryopreservation. Fisheries productivity was also advanced by launching community-led fish landing monitoring activities in Kenya and developing a searchable photo identification catalog of freshwater fishes harvested in Cambodia.

The Fish Innovation Lab addressed reducing and mitigating risks (Area of Inquiry 2) by conducting epidemiologic surveys and analyzing biological samples from private fish farms in Nigeria and completing surveillance for foodborne pathogens in fish processors in Dhaka City.

Human outcomes (Area of Inquiry 3) were addressed by conducting a census of aquaculture households, farmers, fish traders, and input suppliers in Bangladesh and developing an Aquaculture TV YouTube channel; launching a nutrition and food safety training for fish processors in Nigeria; surveying fishers, processors, and traders for assessing equitable access to fish and nutrition in Zambia; and implementing a social marketing campaign in Kenya about child nutrition, diet diversity, and sustainable fishing practices targeting caregivers and fishers.

The Fish Innovation Lab subawardees and Management Entity (ME) worked to achieve impacts within four cross-cutting themes: capacity development, gender equity and youth engagement, nutrition, and resilience. Capacity development activities included recruiting and working with graduate students and implementing trainings for field research teams, community members (particularly for citizen monitoring of fisheries), and end-users. The gender and youth equity specialists implemented an online Gender Responsive Aquaculture/Fisheries Development Assessment (GRADA-FIL) to Fish Innovation Lab implementing partners, and they supported the research teams implementing activities aiming to address gender disparities in resource use, improve access to nutrition, and increase the involvement of women and youth in aquaculture and fisheries value chains. The Fish Innovation Lab collaborated with Advancing Nutrition on outreach and development of social marketing materials. Multiple activities strived to increase the availability and affordability of fish to improve household food and nutritional security. Ecologically, resilience was addressed for fisheries in Cambodia and Kenya, and in terms of biosecurity, resilience is an activity theme for aquaculture systems in Nigeria and Bangladesh.

The Fish Innovation Lab ME implemented several activities aiming to encourage cross-activity learning. This included quarterly virtual platform meetings/learning sessions, the annual principal investigator (PI) meeting, and meetings to finalize and plan for the implementation of the research strategy. The Fish Innovation Lab also received its first buy-in award to support the ongoing USAID Distant Water Fleet Research Agenda.

The Fish Innovation Lab experienced some COVID-19 related setbacks due to local and international travel restrictions and lockdowns. While only two teams were able to travel to the field, all the research teams adapted and accomplished milestones by implementing virtual technologies and relying on host country team members to conduct on-the-ground research and capacity development.

Regional and Country-Level Accomplishments

The Fish Innovation Lab implements activities in West Africa (Nigeria and Ghana), Eastern and Southern Africa (Kenya, Zambia, and Malawi), and Asia (Cambodia and Bangladesh). A list of the activities funded through the Fish Innovation Lab is shown in Appendix 1.

West Africa: Five competitively awarded research-for-development activities are implemented in Nigeria – farming insects as a cost-effective aquaculture feed, developing integrated rice and fish aquaculture, implementing Lean technologies for improved value-chain efficiency, improving biosecurity by building capacity to reduce risks of disease outbreaks in catfish and tilapia, and improving nutrition by strengthening the capacity of fish processors. A new activity in Ghana studies the impacts of oysters in the diet of women shellfishers.

Notable FY 21 accomplishments include

- Established adaptive integrated rice-fish research plots in Nigeria and developed a study to assess formulated fish feed.
- Measured the effectiveness of Lean management principles applied to 12 fish production projects, three fish processing projects, and three fish feed production projects in Nigeria. Improvements were found in all measured areas, including cost effectiveness, resource use, and waste reduction.
- Developed an open-source Android app for mobile collection of survey-based data and a fish sampling for disease diagnostics course, which were made available online on the Learn.ink platform. Implemented 399 epidemiology surveys and collected 115 biological samples in Nigeria.
- Launched a training program for fish processors in Nigeria. The training program used a seven-module nutrition and food safety curriculum that covered general nutrition education, food safety, and fish handling practices.
- Conducted a 24-hour dietary recall study among 504 women shellfishers in Ghana. Collected and analyzed 915 oyster samples.

Eastern and Southern Africa: Expanding its coverage to include two new activities in Zambia, the Fish Innovation Lab is developing a multivalent bacterial fish vaccine and studying the population ecology and current distribution of the introduced invasive crayfish in the Kafue Floodplain and Lake Kariba. These activities complement the ongoing FishFirst! Zambia activity, which aims to identify opportunities to upgrade the fish value chain to reduce postharvest loss and improve food security in Zambia. The Fish Innovation Lab has also expanded to Malawi, where a team of U.S. and Malawian researchers are piloting integrated insect-to-fish farming systems. Two activities implemented in Kenya focus on improving the sustainability of fisheries by piloting modified traps and improving the management capacity of communities to monitor fisheries and habitats, which informs adaptive management. One of the funded activities in Kenya is also implementing a social marketing campaign to improve nutrition and reduce the catches of undersized fish.

Specific accomplishments in FY 21 include

- Conducted a participatory resource mapping exercise, which resulted in hand-drawn and digitized maps outlining fishing landmarks and fishing gear zones along the south coast of Kenya. Launched community-led fish landing monitoring activities, involving seven community members and two government fisheries officers in data collection using mobile technologies.
- Enumerated surveys among 451 men and women fishers, processors, and traders at Lake Kariba, Zambia. The survey included the following components: (1) Women's Empowerment in Fisheries Index - FishFirst! Zambia, (2) Household Hunger Scale II, (3) Post-Harvest Fish Loss Assessment for Small-scale Fisheries; (4) Minimum Dietary Diversity-Women of

Reproductive Age Questionnaire; and the (5) Minimum Dietary Diversity-Infants & Young Child Module (ages 6-23 months).

- Implemented a social marketing campaign that targets caregivers and fishers with information about child nutrition, health, diet diversity, and importance of catching mature fish for fisheries sustainability and improved income. Conducted 100 home visits and provided 100 modified traps with escape gaps to half of the intervention households/fishers.
- Trapped 250 crayfish in Kafue town, Zambia to provide initial measurements of the carapace and total length to gain a better understanding of the reproductive potential.

Asia: Five diverse research activities are implemented in Bangladesh. Three research activities focus on strengthening value chains by 1) determining behavior practices associated with fish contamination by foodborne pathogens, 2) using machine learning to estimate aquaculture production and identify innovative practices that enhance adoption and productivity, and 3) analyzing market access, trade, and consumption patterns. Two activities aim to improve aquaculture production via cryogenic sperm banking and carp genetic improvement.

FY 21 accomplishments in Asia include

- Developed a cryogenic sperm bank and cryopreserved sperm of rohu, mrigal, silver carp, and bighead carp in government and private hatcheries in Bangladesh. Conducted genetic characterization of brood fish using DNA microsatellite markers.
- Developed a harvest database and searchable photo identification catalog containing thousands of photographs, each with a unique code matching the harvest database in Cambodia. Developed the iFISH Community Fisheries Assessment Tool, which compiles the data collected by fishers into easy-to-understand fisheries graphical analyses.
- Distributed genetically improved rohu families to hatcheries and nurseries in Bangladesh. The nurseries commenced selling seed to farmers. Successfully completed spawning the next generation of improved catla and rohu, which are expected to grow 10% more rapidly than the previous generation.
- Completed surveillance of foodborne pathogens in tilapia and pangas at 28 retail wet-markets and 19 super shops in Dhaka City, Bangladesh. Completed a survey of fish vendors to assess behaviors associated with increased microbial contamination.
- Conducted a census of 3,554 aquaculture households in 36 villages and 1,319 traders in 50 markets and followed up by conducting surveys with over 1,000 farmers, fish traders, and aquaculture input suppliers in Bangladesh. Developed a database and interactive geographic information system (GIS) platform that distinguish between aquaculture waterbody types identified through machine learning. Developed an Aquaculture TV YouTube channel and developed and disseminated three short films promoting innovative practices in aquaculture.

A summary of the FY 21 accomplishments per country and Fish Innovation Lab indicator is presented in Table 1. A full list of indicator results is shown in Appendix 2. Three Fish Innovation Lab success stories are presented in Appendix 3.

Table 1: Summary of FY 21 Country Accomplishments

Country	Nigeria		Bangladesh		Cambodia		Kenya		Zambia	
Indicator	**Total**	**Gender**	**Total**	**Gender**	**Total**	**Gender**	**Total**	**Gender**	**Total**	**Gender**
Number of individuals trained	590	377 M 213 W	32	29 M 3 W	26	22 M 4 W	113	79 M 34 W	17	9 M 8 W
Number of individuals participating in food security programs*	999	628 M 371 W	228	199 M 29 W	26	22 M 4 W	503	314 M 189 W	17	9 M 8 W
Number of individuals who have applied improved management practices or technologies	0	0	17	16 M 1 W	15	15 M 0 W	124	114 M 10 W	0	0
Number of Technologies	15		4		3		3		0	
Phase 1: Under Research	*6*		*1*		*2*		*0*		*0*	
Phase 2: Under Field Testing	*8*		*2*		*1*		*3*		*0*	
Phase 3: Made Available for Transfer	*1*		*1*		*0*		*0*		*0*	

*Includes number of individuals trained

Fish Innovation Lab Overview and Structure

Funded by USAID, the Fish Innovation Lab aims to reduce poverty and improve nutrition, food security, and livelihoods in developing countries by supporting the sustainable development of aquaculture and fisheries. To achieve these goals, the Fish Innovation Lab supports research and capacity-building activities targeting three program areas:

1. **Advancing productivity:** The Fish Innovation Lab works to identify and develop scalable technologies and practices that enhance opportunities for prosperity, nutrition, and resilience in aquaculture and fisheries, with the overarching objective to enhance food and nutrition security. This includes developing innovations to increase achieved yield of fish in aquaculture, improving availability and nutritional quality of feed (especially removal of fish meal and fish oil), improving genetics and reliability of fish seed, and enhancing sustainable fisheries management to improve harvest yields and increase reliability.
2. **Reducing and mitigating risks:** These Fish Innovation Lab activities identify and develop scalable technologies and practices that promote resilience and mitigate food security risks, especially through improved fish and environmental health. This includes increasing the tolerance of fish to biotic and abiotic stresses (including ecological resilience), improving diagnostic capabilities, maintaining healthy and bio-secure production environments, and reducing pre- and postharvest losses (including ensuring food safety).
3. **Improving human outcomes:** This Fish Innovation Lab program area generates evidence on how to sustainably and equitably improve economic opportunity, nutrition, and resilience in aquaculture and fisheries value chains, households, and communities. This includes identifying how aquaculture and fisheries can help improve nutrition and market

opportunities (especially for vulnerable populations), equitable access to production assets (especially for women and youth), and establishment of an enabling environment for fish production.

Rationale for Aquaculture and Fisheries

Fish are a nutrient-rich and highly traded food commodity; as such, they are a unique global resource that offers opportunity for the Feed the Future Initiative to accomplish the goals of the Global Food Security Strategy for sustainable and equitable agriculture-led economic growth, strengthened resilience in people and systems, and improved nutrition—particularly for women and children. In the developing world, more than 2.6 billion people depend on aquaculture products and captured fish for more than 20% of their total animal protein — and in the Feed the Future countries of Bangladesh, Cambodia, Ghana, Sierra Leone, and Indonesia, fish constitute over 50% of animal protein intake (FAO, 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. License: CC BY-NC-SA 3.0 IGO). To meet the growing demand for food and quality protein (especially animal source protein), reduce potential conflicts over natural resources, and ensure equitable access to fish in developing countries, innovations are needed in both aquaculture and fisheries to foster sustainable, resilient, inclusive, and profitable production and marketing systems.

The aquaculture and fisheries sectors are important to global food security because:

1. **Fish provide high-quality animal protein and micronutrients**, including vitamins A, B12, zinc, iron, and selenium. In many of the Feed the Future countries (examples listed above), fish are the primary source of animal protein; thus, increased consumption of fish and/or fish products has potential to reduce childhood stunting and improve brain development and function.
2. **Fish are one of the most widely traded agricultural commodities worldwide**; increased trade (local and regional) has potential to improve livelihoods and increase incomes.
3. **Aquaculture and fisheries provide formal and informal employment opportunities** for women and youth.
4. **Aquaculture enables diversification of farming systems** through opportunities such as integrated aquaculture, providing increased economic resilience for producers.

Fish Innovation Lab Pillars

The Fish Innovation Lab funds **research for development**, which generates knowledge, innovations, and technologies and transfers information and innovations to stakeholders for achievement of impacts. Research for development requires scientific rigor, awareness of local context, and building of relationships to enable adoption and scaling. It is not an abstract quest for fundamental knowledge or the improvement of scientific theories, nor is it the straightforward delivery of goods and services associated with development work.

Fish Innovation Lab strategies are based on these pillars:

1. **Technology Innovations:** Innovative technologies to advance aquaculture and fisheries production result from productive collaborations among universities, private industry, government research agencies, and producers.
2. **Behavior Change:** Effective implementation of sustainable aquaculture and fisheries often requires voluntary behavioral changes among producers and fishers to comply with best practices. Socioeconomic research, therefore, is often required to determine the best methods to change behaviors.
3. **Value Chain Linkages:** Small-, medium-, and large-scale farms require linkages and support from private investors and industries up and down the value chain. Infrastructure development for industries to support producers (e.g., feed mills, seed stock production,

harvesting and hauling equipment and services, and processing plants) is necessary for sustainable aquaculture development.

4. **Local Capacity Development:** Ensuring local institutional capacity that endures beyond Fish Innovation Lab-sponsored activities is achieved most effectively by building capacity in partner organizations. One of the Fish Innovation Lab's goals is to build cooperative learning programs that foster two-way learning and the exchange of ideas and expertise between U.S. universities and international partners.

Theory of Change and Results Framework

The Fish Innovation Lab theory of change posits that: ***If*** innovative technologies from universities and nongovernmental organizations (NGOs) are more effectively developed and transferred to aquaculture producers and commercial support industries (particularly in feed and seed production), aquatic animal health and biosecurity capacity is effectively engaged to support aquaculture, behavior changes in producers and fishers are adopted to use sustainable practices, and equitable access to fish markets is enabled for fish producers and consumers, ***then*** goals of improved profitability and sustainability in fish production, increased resilience to cope with disease outbreaks and other threats, and more nutritious diets for vulnerable individuals (especially children and women) can be realized.

All Fish Innovation Lab activities connect to this theory of change and include three approaches, as specified in the Fish Innovation Lab results framework:

1. **Research for development.** Increased end-user aquaculture and fisheries research results promote sustainable, resilient intensification of production systems, enhance food safety and nutrition, increase trade and domestic market opportunities, and contribute to responsible aquatic resource management.
2. **Capacity building.** Activities result in increased capacity of local partners to independently generate and transfer fish-related knowledge, technologies, and practices to beneficiaries.
3. **Adoption of innovation and scaling.** Activities yield increased adoption of new technologies and practices, as well as other innovations.

Goals and Objectives

The overarching goal of the Fish Innovation Lab is to alleviate poverty and improve nutrition through reliable provision of fish, a nutrient-rich animal source food. Like all Feed the Future Innovation Labs funded by USAID, the Fish Innovation Lab will reach its goal by supporting a research-for-development program that will be composed of competitive subawards, commissioned research, and collaborations with international partners (universities, NGOs, private sector, and governmental research agencies). Buy-ins and associate awards will be used to extend Fish Innovation Lab activities and expand countries that are reached. The Fish Innovation Lab ME will implement activities that align to the following three objectives:

1. Advance aquaculture and fisheries productivity
2. Reduce and mitigate risks to aquaculture and fisheries
3. Improve human outcomes from the aquaculture and fisheries sector

These three objectives align with Fish Innovation Lab's three areas of inquiry, which are the focus of the Fish Innovation Lab research for development and capacity building programs. The activities undertaken within these objectives were implemented in three phases:

1. Quick Start activities (short activities implemented in FY 19)
2. Competitively awarded activities (two- or three-year activities implemented in FY 20)

3. Direct commissioned activities (one- or two-year activities implemented in FY 21)

Research Strategy Development

The Fish Innovation Lab research strategy provides a framework for the cumulative contributions of the diverse set of research activities currently being implemented. The research strategy will enable the ME and ME Partners to leverage the potential for comparative analysis between country contexts. It will also help ensure complementary research across the three areas of inquiry in support of Fish Innovation Lab intended results.

The research strategy was developed using a participatory approach in FY 21. The ME and ME Partners (cross-cutting theme leaders and regional leaders) developed an overarching research strategy for the Fish Innovation Lab based on its activities. From this, the Fish Innovation Lab research teams, ME Partners, and EAB selected three priority questions that are relevant across multiple research activities/countries:

1. How can improved technologies and practices identified in the Fish Innovation Lab be effectively promoted for adoption by aquaculture producers and hatchery owners? *(Area of Inquiry 1)*
2. How can improved technologies and practices identified in the Fish Innovation Lab be incentivized for adoption to mitigate pre- and postharvest losses in aquaculture and fisheries? *(Area of Inquiry 2)*
3. How can increased availability through production and access to fish across the value chain address barriers to food, nutrition, and women's economic opportunity? *(Area of Inquiry 3)*

At the FY 21 annual meeting, the teams began identifying potential activities and products that they can implement in FY 22 to address the research strategy questions.

Research Activity Reports

Objective 1: Advance aquaculture and fisheries productivity

Activity 1.1: Aquaculture and rural communities: Farm diversification strategy through integrated agriculture-aquaculture systems and nutrition-sensitive value chains for better nutrition outcomes (Aquaculture Diversification in Rural Communities)

Location: Nigeria

Lead PI: Matthias Halwart, PhD, Food and Agricultural Organization of the United Nations
Lead Co-PI: Yuan Xinhua, PhD, Food and Agricultural Organization of the United Nations
U.S. PI: Esendugue G. Fonsah, PhD, University of Georgia
U.S. Co-PI: Gary J. Burtle, PhD, University of Georgia
Host Country (HC) PI: E.K. Ajani, PhD, University of Ibadan
HC Co-PI: B.O. Omitoyin, PhD, University of Ibadan

Objectives: The activity goal is to secure supply and access to rice and fish, improve nutrition-sensitive diets, promote resource use efficiency, and generate employment and better livelihood options in the selected communities. Present challenges relevant for future needs of vulnerable populations will be addressed through appropriate research and targeted interventions. The activity will demonstrate the importance of technology innovations for enhancing and sustaining aquaculture production, economic opportunities for youth and women, and resilience of rural communities to food and nutrition security challenges. The objectives are:

1. The activity will consider the technologies that are accessible to local farmers and analyze how integrated agriculture-aquaculture systems influence the resilience, dietary diversity,

livelihood options, rural employment (especially for youth and women), use of resources, and the role of institutional and policy innovations.

2. The activity will study how diversification of farming systems through integrated agriculture-aquaculture systems can contribute to producing more diversified and nutritious food for the local market and rural communities with consideration for all demographic strata (women, men, and youth).
3. The activity will study value chain enhancement through market access facilitation and marketing management.
4. The activity will study sustainability and long-term support of capacity development of farmers, extension workers, university students, and value-chain actors for activity goals within and beyond activity locations.

Outcomes:

1. Suitable integrated rice-fish production technology will be developed through participatory research actions.
2. Understanding of convenient market access approaches and nutrition contributions of rice-fish farming products will be achieved.
3. Capacity development and enhancement of co-learning among all stakeholders (farmers, value-chain actors, and extension workers) will be accomplished.

Achievements: To accomplish Objective 1, the team implemented a wetland mapping exercise to identify wetland areas in Kebbi and Ebonyi states. This information was used to establish on-farm adaptive research plots in three locations in each of the two activity states. The adaptive research plots have been stocked with fish (*Clarias gariepinus*) and planted with rice seedlings. In addition, 200 farmer beneficiaries were selected as well as 6 MS and 2 PhD students. Students have been mobilized for data collection on various research activities conducted on the adaptive research plots. Data on key parameters for the integrated rice-fish farming system (water balance, nutrient flow, key elements of fish integration into rice-fields, feeding practice) commenced. Three stakeholders' meetings were organized.

To satisfy Objective 2, the activity team conducted surveys on market access analyses and nutrition (Household Dietary Diversity Score [HDDS], Minimum Dietary Diversity-Women [MDD-W], and Household Food Insecurity Experience Scale [HFIES]). Baseline data on rice-fish profitability, consumer preference, HDDS, MDD-W, and Household Food Insecurity Access Scale were obtained. This data will be utilized to understand market access approaches and nutrition contributions of rice-fish farming products by an agricultural economics PhD student as part of the dissertation research.

Finally, to accomplish Objective 3, the activity team developed a study to assess formulated fish feed. An assessment of locally available rice bran and fish offal, which are suitable ingredients in fish feeding, was initiated. To support this activity, an MS student was trained and is being supported to conduct a digestibility study of these feedstuffs.

Lessons learned: Youth remain a formidable force in improved integrated rice and fish farming. Training them on the design and construction of rice-fish ponds will help ensure the sustainability of the activity. This activity aims to ensure equitable engagement of men and women (including youth) in income-generating activities, and it works to reduce gender-based vulnerability. The team has determined that capacity building is crucial in the identification of beneficiaries and for gaining stakeholder support. Use and strengthening of existing frameworks and structures should enhance proper identification, smooth implementation, ownership, and sustainability of interventions.

Presentations and publications:

Burtle, G.J. (2021, August). *Feeding fish in rice-fish systems*. [Presentation]. University of Ibadan seminar, Ibadan, Nigeria.

Fonsah, E. (2021, August). *Revolutionizing agriculture in Africa*. [Presentation]. University of Ibadan seminar, Ibadan, Nigeria.

Ajani, E. K., Omitoyin, B. O., & Kareem, O. K. *Preliminary reports on the activities towards achieving milestone 1 (Study and assessment of locally available feedstuffs) and milestone 2 (Analysis of parameters for integrated rice-fish farming system)*.

Ajani, E. K., Omitoyin, B. O., & Kareem, O. K. *Situational analysis of the selected communities in Ebonyi and Kebbi States*.

Ajani, E. K., Omitoyin, B. O., & Kareem, O. K. *Wetland mapping of Ebonyi and Kebbi States*.

Activity 1.2: No longer bugged by feed costs: Farming insects as sustainable and scalable aquaculture feedstock to improve catfish (*Clariidae*) producers' and consumers' livelihoods towards food security in Nigeria (Farming Insects in Nigeria)

Location: Nigeria

Lead and U.S. PI: Jennifer Pechal, PhD, Michigan State University
U.S. Co-PI: Simone Valle de Souza, PhD, Michigan State University
HC PI: Bolarin T. Omonona, PhD, University of Ibadan

Objectives: This activity will evaluate integrated insect-to-fish farming systems: 1) costs and conversion ratios of propagating black soldier fly (BSF) and processing into aquaculture feed; 2) feasibility and cost-effectiveness of organic waste streams (e.g., market waste) for BSF farming; 3) changes in pond yield and productivity resulting from BSF meal replacement in fish feed; 4) changes in nutrient profiles of farmed fish resulting from partial BSF meal substitution in fish feed; 5) economic viability and impacts of female-led small-scale BSF production enterprises; and 6) effects of BSF meal production and processing on labor, time allocation, and household income for the BSF farmers and fish farmers. The team expects fish farmers to willingly learn about and adopt BSF meal because it is a low-cost, local-input, nonmechanized technology that will produce a substantial part of the animal protein needs of fish.

Outcomes: These activities are expected to produce the following evidence and service delivery: 1) BSF-based aquaculture feed will be developed that is noncompetitive with human food production to improve sustainability of the aquaculture industry; and 2) capacity of private sector, academic, and NGO stakeholders will be enhanced via training seminars and workshops. Ultimately, achievement of these outcomes should result in increased food and job security for vulnerable populations in Nigeria.

Achievements: Despite the COVID-19 challenges that delayed on-the-ground research activities, the team has made progress by contacting subject matter specialists in Ebonyi and Cross River states' Agricultural Development Programs; they are assisting in locating fish farmers to participate in the activity. The University of Ibadan team communicated with contacts in each site to understand the relevant population and develop survey sampling methods. The team contacted the program managers of the Ebonyi and Cross River Agricultural Development Programs based on the need to provide an understanding of the way fish farmers are organized in the states. Ongoing literature reviews are being performed to achieve Objectives 1, 2, and 4. Submission of these reviews is anticipated by the end of the calendar year. A questionnaire needed for the achievement of Objectives 3 and 4 was finalized. The instrument (over 700 potential questions) is being programmed into the Kobo ToolBox, which can work with Android-based tablets for computer aided personal interview of participants in the study sites. Procurement of the necessary tablets that will be used for the data collection is in process. Additionally, the activity team continues to hold meetings every 1-2 weeks to discuss ongoing progress, results, and challenges faced thus far.

Lessons learned: The COVID-19 pandemic and financial barriers stalled activities. The closest airport to the study area did not open when the restrictions on air travel were lifted. In addition, Nigeria experienced a second wave of the pandemic. The activity team could not travel to the study

area due to the lockdown; however, travel is gradually getting easier. The activity team is expecting to be in the field soon after resolving permission and in-country funding allocation issues. Through this situation the team learned the importance of ensuring that the financial channels have been properly established between all institutions.

Presentations and publications:

Pechal. J. L. (2021, February). *Applications of insect-microbiome interactions*. [Invited seminar, virtual]. Texas A&M University, College Station, TX.

Sheikh, S. (2021, April 8). *MSU researchers study insects to help globally improve human diets*. WLNS. https://www.wlns.com/digital-exclusives/msu-researchers-study-insects-to-help-globally-improve-human-diets/

Activity 1.3: Improving efficiency in the Nigerian aquaculture sector by employing Lean production systems (Lean Production Systems)

Location: Nigeria

Lead and HC PI: Rohana Subasinghe, PhD, WorldFish
HC Co-PI: Sunil Siriwardena, PhD, WorldFish
U.S. PI: Julius Nukpezah, PhD, Mississippi State University
U.S. Co-PI: Joe Steensma, EdD, Washington University in St. Louis

Objectives: The research objective is to improve operational efficiency, reduce postharvest losses, improve waste management, and decrease the cost of production of catfish and tilapia in Nigerian aquaculture through application of Lean production systems. The goal is to explore how Lean technology can be used in a developing country context, specifically in Nigeria, to identify benefits that are conferred to small-scale fish farmers as well as larger corporate aquaculture operations and processors. In short, the goal is to prevent the loss of value along the value chain and economize the process of raising fish and bringing them to market using Lean technology.

Outcomes: Tilapia and catfish industries in Ogun and Delta states of Nigeria will adopt and apply science-based Lean production system management concepts to increase efficiency by reducing production costs, waste, and postharvest losses. Application of these strategies will increase financial and social benefits to small-scale farmers and their families. If successful, the activity will implement a scaling program to drive down the costs of production within the sector, which has potential to decrease costs to consumers.

Achievements: To achieve its research objective, the activity team aims to improve operational efficiency, reduce postharvest losses, improve waste management, and decrease the cost of production of catfish and tilapia in Nigerian aquaculture through application of Lean production systems. Forty fish farmers, processors, and extensionists, 20 each in Delta and Ogun States of Nigeria, were trained on the application of Lean management tools to identify waste streams in the aquaculture value chain, which prepared them to function as Lean Subject Matter Experts (LSMEs).

In preparation of the LSMEs, the effectiveness of Lean management principles and tools were measured in a total of 12 fish production, three fish processing, and three fish feed production projects. In fish production projects, there were improvements to the extent of approximately 29% cost reduction, 80% improved resource use, 49% reduced motion waste, 50% improved product quality, 40%-65% reduced fuel use, 33% reduced feeding time, 13% reduced feed waste, 50% reduced farm personnel, and 22% reduced water pumping rate.

In feed production, there was approximately 91% improvement in feed quantity production, 68% reduction in walk steps, and 67% reduced walk time. In fish processing, there was a reduction of 67% in walk time and 71% reduction in walk steps. LSMEs have embarked on a program in Delta and Ogun to sensitize other farmers in the application of Lean management principles and tools.

Lessons learned: The lessons learned through this activity were primarily on the use of alternative strategies to implement training, which included renting a facility in Nigeria and delivering the

training virtually from the US. The team learned how to manage without international travel, using local expertise and conducting guided workshops.

Presentations and publications: None to report

Activity 1.4: Development of bighead catfish (*Clarias macrocephalus*) culture for sustainable aquaculture in Cambodia (Bighead Catfish)

Location: Cambodia

Lead PI: Lyda Hok, PhD, Center of Excellence on Sustainable Agricultural Intensification and Nutrition, Royal University of Agriculture
HC PI: Rodrigue Yossa, PhD, WorldFish
U.S. PI: Manuel 'Manny' Reyes, PhD, Kansas State University
U.S. Co-PI: Delbert Gatlin, PhD, Texas A&M University

Objectives: The goal of the activity is to develop and apply new technologies on formulated sustainable feeds for bighead catfish (BC) (*Clarias macrocephalus*) culture that will increase income, promote gender equality, empower youth, provide nutritious food, and strengthen resilience in Cambodia, while building the capacity of local institutions to expand the farming of this species. The objectives are:

1. To develop and scale cost-effective feeds for sustainable culture of BC in Cambodia.
2. To strengthen the infrastructural and human aquaculture research capacities of local institutions.

Outcomes:

1. Sustainable fish culture technology to meet increasing demand of local catfish (*Clarias macrocephalus*) for local and regional markets will be developed.
2. The overfishing of local catfish (*Clarias macrocephalus*) and the use of underrated fish in BC feed will be reduced.
3. Knowledge and human capacity on aquaculture in Cambodia will be improved.

Achievements: To achieve Objective 1, the activity team organized regular coordination meetings between the key partners (Kansas State University, Texas A&M University, WorldFish, and the Faculty of Fishery of Royal University of Agriculture [RUA]) to discuss activities and research plans for the installation of the wet lab in RUA. Location selection of the wet lab was completed as well as development of the blueprints. About 80% of materials to start the wet-lab installation have been purchased.

To satisfy Objective 2, the activity team conducted two trainings: (1) Formulating and preparing aquaculture feeds and (2) Managing a research facility to build the capacity of local institutions. These trainings were conducted virtually by key partners in response to the COVID-19 pandemic. There were nine RUA participants (all males) for each training, including one activity staff, two faculty members, and six students. Dr. Rodrigue Yossa, HC PI and WorldFish scientist on fish feeds and nutrition, facilitated the trainings.

Lessons learned: Nothing to report at this time

Presentations and publications:

Yossa, N. R. & Fatan, N. A. *Formulating and preparing aquafeeds*.

Yossa N. R., Fatan, N. A., & Bakar, K. A. *Recirculating aquaculture system facility at WorldFish Penang, Malaysia*.

Activity 1.5: Achieving coral reef fishery sustainability in the Kenyan biodiversity and climate refugia center (Coral Reef Fishery Sustainability)

Location: Kenya

Lead and U.S. PI: Timothy McClanahan, PhD, Wildlife Conservation Society
U.S. Co-PI: Nyawira Muthiga, PhD, Wildlife Conservation Society
HC PI: Emmanuel Mbaru, PhD, Kenya Marine and Fisheries Research Institute
U.S. Co-PI: Austin Humphries, PhD, University of Rhode Island

Objectives:

1. Determine the yield potential for coral reef climate refugia to support improved fisheries management.
2. Determine the best metrics for measuring sustainability to enhance the likelihood of sustainable management.
3. Improve the management capacity of communities to monitor fisheries and habitats and use this information for adaptive management.
4. Measure perceptions about natural resource use and sustainability among dependent communities and encourage realistic expectations.

Outcomes:

1. Estimations of sustainable yields specific for coral reefs at activity sites will be determined, and community knowledge will be improved.
2. The best metric for estimation of sustainability of fisheries will be determined, and community knowledge will be improved.
3. Community capacity will be improved through training in monitoring coral reef fisheries and ecology.
4. Perception by communities of resource use and sustainability will be changed, resulting in improved management practices.

Achievements: In FY 21, the team completed a two-year work plan and launched the activity. The team communicated its objectives and anticipated results to 217 community members and relevant partners to incorporate their views into the activity.

Socioeconomic and ecological survey tools were developed, translated into Swahili, piloted, and administered. A total of 193 household surveys were conducted with local community members. The surveys aimed to help the team understand perceptions on marine resource use and sustainability. In addition, 110 volunteers were tested on their literacy levels, and the 15 highest scoring candidates were trained on the Wildlife Conservation Society data-collection protocols and mobile phone data collection procedures.

Community training on fisheries resources mapping was conducted in all sites with a total of 92 individuals representing fishers using different gears, boat operators, seaweed farmers, beach management units (BMUs), community leaders, county government fisheries officers, and Kenya Wildlife Service officers. The activity resulted in the production of both hand-drawn and digitized maps outlining fishing landmarks and fishing gear zones.

Community fish-landing monitoring activities were launched in all activity sites with seven individuals from the BMUs and two government fisheries officers. Mobile phones and monthly data bundles were provided for communication and sharing catch monitoring data at each landing site.

Household data collection and entries were completed in all activity sites with 80% of data cleaning complete, and partial analysis was done to assess the sustainability scenarios, access to loans by gender, and fish consumption by household type/education. Results were presented at the Fish Innovation Lab annual meeting.

Lessons learned: The COVID-19 pandemic and failure by community members to follow the Ministry of Health regulations and guidelines led to failure in organizing an inception meeting during the activity launch. This also limited the movement of enumerators during the socioeconomic surveys, which necessitated holding smaller meetings and the engagement of local community guides to assist with identification of participants to be interviewed at specific centers, further creating awareness of the disease.

Most local communities have no access to smartphones and internet connectivity, which slowed down access to the fisheries stock assessment training. The activity team helped the community data enumerators create an email account for sending information on fisheries stock assessment to their BMUs and other community members to facilitate the information flow and to bridge the knowledge gap. The team observed that some community data collectors were replicating efforts, having difficulty in fish group identification, and those on the island had no access to electricity connections, which might affect their work.

During resource mapping ground-truthing exercises, it was realized that the lines were blurry between government marine protected areas and locally managed marine areas. Resource boundaries between Kenya and Tanzania were also unclear, and sometimes the same fishing area had multiple names. This led to an awareness by the participants about the need to demarcate locally managed marine areas and marine protected areas, communicate this to relevant authorities, and recognize the multiple naming of fishing areas. It was decided that a similar harmonization needed to be done during future stakeholder meetings. Data collectors conducting community fish-landing monitoring activity had difficulties in identifying fish categories, and they sometimes missed the zero landing recordings. Fluctuating fish landing by foreign fishers also caused difficulty for data collectors. The team realized that there is a need to conduct more training and practice with the community data collectors, and close monitoring of data collectors is needed. In response, a list of names for the same fishing area was developed, and the team determined that recording landings for foreign fishers was not necessary. Delay on socioeconomic data cleaning completion was counteracted by more time being allocated to the activity.

Presentations and publications: None to report

Activity 1.6: Cryogenic sperm banking of Indian major carps (*Labeo catla*, *Labeo rohita*, and *Cirrhinus cirrhosis*) and exotic carps (*Hypophthalmichthys molitrix*, *Hypophthalmicthys nobilis*, and *Ctenopharyngodon idella*) for commercial seed production and brood banking (Cryogenic Sperm Banking)

Location: Bangladesh

Lead and HC PI: Md. Rafiqul Islam Sarder, PhD, Bangladesh Agricultural University
HC Co-PI: Mohammad Matiur Rahman, PhD, Bangladesh Agricultural University
U.S. PI: Terrence Tiersch, PhD, Louisiana State University

Objectives: The overall objective is to increase production of Indian major carps (IMCs) and exotic carps by improving broodstock quality and seeds through establishing a national genetics program based on cryogenic sperm banking. The specific objectives are:

1. To develop donor broodstocks of IMCs and three exotic carps.
2. To cryopreserve sperm of IMCs and exotic carps and develop a cryogenic sperm bank.
3. To produce seeds of carps in hatcheries using cryopreserved sperm and characterize and assess their quality through growth studies and DNA microsatellite analysis.
4. To assess the performance of cryopreserved sperm for establishment of sperm banks in different regions.
5. To evaluate the adoptability of technology by the stakeholders.

Outcomes:

1. Donor broodstocks (male and female) of IMCs from different river origins and three exotic carps will be developed.
2. Sperm of IMCs and exotic carps will be cryopreserved, and a cryogenic sperm bank will be developed.
3. Seeds of IMCs and exotic carps in public and private hatcheries using cryopreserved sperm will be produced, and quality will be characterized and assessed through growth studies and DNA microsatellite markers.
4. Performance of cryopreserved sperm will be assessed, and the feasibility of establishing sperm banks in additional regions will be evaluated.
5. Seeds produced with cryopreserved sperm will be supplied to 24 hatcheries (technology adoption) beyond the 22 selected (pioneer) hatcheries in four regions, and the growth and survivability of the seeds will be compared.

Achievements: MS and PhD students were recruited in FY 21. A day-long consultation and training workshop was conducted for high-level officials and selected government hatchery managers of the Department of Fisheries, and a Memorandum of Understanding between the Department of Fisheries and Bangladesh Agricultural University was signed for using the hatchery and nursery facilities. An informative video on sperm cryopreservation techniques and use of cryopreserved sperm in seed production was produced for the stakeholders' training workshop**.**

The basic parameters of cryopreservation protocols such as activation of sperm motility, cryoprotectant concentration, dilution of milt (sperm concentration), equilibration period, cooling rate for freezing of sperm, thawing of sperm, and techniques for fertilization of eggs using thawed sperm were standardized.

Sperm of rohu, mrigal, silver carp, and bighead carp were cryopreserved, and a cryogenic sperm bank was developed. Breeding of rohu, mrigal, silver carp, and bighead carp was conducted using cryopreserved sperm in government and private hatcheries in Mymensingh, Jashore, Faridpur, and Barishal regions, and seeds were produced. Seeds of the experimental fish are being reared in ponds in respective hatcheries. In addition, genetic characterization of brood fish using DNA microsatellite markers was conducted.

Lessons learned: The team faced several difficulties throughout the reporting period due to the outbreak of COVID-19 and the second wave of the Delta variant. Since the outbreak in March 2020, Bangladesh Agricultural University remained closed, reopening at the end of September 2021. During the closing, no students were allowed to stay in university dormitories. This delayed recruitment of MS and PhD students, and one additional MS and PhD student each still need to be recruited.

In addition, the university was running with minimum manpower and for limited working hours, so processing and getting approval of necessary financial and other documents from authorities took more time.

Visits to hatcheries located in four regions was risky due to COVID-19; however, the team was able to successfully visit hatcheries and select participants through discussion and observation of fish breeding and nursing facilities. Similarly, the hands-on training workshop for selected hatchery operators and other stakeholders was difficult to arrange, but four training workshops in four regions were conducted while maintaining proper safety measures. The in-person inception workshop was also arranged, though it was difficult due to safety concerns. A few breeding trials in government and private hatcheries were conducted in the Mymensingh region by obtaining a movement pass from police authorities. After the lifting of lockdown measures in the middle of August 2021, the team was able to conduct a few breeding trials in Jashore, Faridpur, and Barishal regions and produced fish seeds. However, when breeding trials were finally conducted, the breeding season was almost over, and most of the hatcheries had stopped their hatchery production.

Presentations and publications: None to report

Activity 1.7: Increasing sustainability of fisheries for resilience of Cambodian communities (Cambodian Fisheries and Food Processing)

Location: Cambodia

Lead and U.S. PI: Sandra Correa, PhD, Mississippi State University
U.S. Co-PI: Wes Neal, PhD, Mississippi State University
U.S. Co-PI: Peter Allen, PhD, Mississippi State University
U.S. Co-PI: Thu Dinh, PhD, Mississippi State University
U.S. Co-PI: Wes Schilling, PhD, Mississippi State University
HC PI: Som Sitha, MS, Wildlife Conservation Society
HC Co-PI: Simon Mahood, MS, Wildlife Conservation Society

Objectives:

1. Improve sustainable fisheries management by assessing changes in the existing fishery through the development of a protocol to monitor fish populations and implement a citizen science digital platform for documentation and analysis of harvest.
2. Educate and train villagers in standardized food processing and preservation techniques to reduce fish waste.

Outcomes:

1. Community and regional knowledge of fisheries management and postharvest food processing techniques will be increased in youth, women, and men.
2. A long-term dataset will be developed on artisanal fisheries diversity, abundance, size distributions, and reproductive stage, which will inform ongoing and future community-based management efforts.
3. Training of villagers in fisheries data collection and analysis will be done, which will allow successful transfer of the program to the Community Fisheries Council upon activity completion.
4. Postharvest training will be provided, which will add capacity to develop fish processing and preservation techniques for family-scale to village-scale fish handling.

Achievements: To accomplish Objective 1, the team launched the Citizen Science Program to collect fisheries harvest data in the Sre Ambel River. To date, 15 fishers from villages along the river were trained, and they collected data on their harvest for six months. This effort resulted in more than 12,800 entries for 29,450 fish individuals representing what, when, and where fish are harvested in the Sre Ambel River. Along with the harvest database, a searchable photo identification catalog of the harvested fish was created to confirm fish taxonomy, train fishers in taxonomic identification, and verify the size of exploited fish. To date, the visual catalog contains thousands of photographs, each labeled with a unique code matching the Sre Ambel River Citizen Science Fisheries Harvest database. The taxonomic identity of the fish species was curated by a federal ichthyologist collaborating with the program. To facilitate data interpretation and fisheries monitoring, the iFISH Community Fisheries Assessment Tool for the Sre Ambel River Fishery was developed. iFISH compiles data collected by fishers participating in the program into easy-to-understand fisheries graphical analyses. It produces simple graphs and maps that show which species are captured, how capture changes between seasons, and the main fishing zones.

To satisfy the second objective, a video was produced to train the Cambodia personnel on sensory evaluation. This video allows activity personnel to properly cook samples, randomize serving order, maintain sample integrity, properly instruct consumers, and properly collect data. A survey instrument and consent form for community surveys was completed, translated to Khmer, and printed for future surveys. The team also completed a focus group questionnaire, and video and audio consent forms (translated to Khmer) were submitted to the MSU Office of Research Compliance.

Two graduate students in Cambodia were recruited, and collaboration with two Cambodian professors (Center of Biodiversity Conservation and Development Studies) from the Royal University of Phnom Penh was established.

Fish samples for nutritional composition analysis were collected, including proximate composition and fatty acid composition. The majority of samples were caught in the Sre Ambel River except for two samples that were purchased at markets. Samples were processed by removing the head and gut, and then they were vacuum-packaged. Measurements of fish length and weight were collected.

Lessons learned: COVID-19 imposed major challenges by restricting international travel for MSU-Co-PIs. The team adapted to this challenge by developing video training and online courses, and they adapted a remote train-the-trainers approach. The travel restrictions required a shift from the planned activities; therefore, the production of educational materials was moved to the forefront while waiting for the travel restrictions to be lifted. Training of the Cambodian partners will be performed virtually to conduct sensory evaluation and focus groups.

Presentations and publications: None to report

Activity 1.8: Advancing aquaculture systems productivity through carp genetic improvement (Carp Genetic Improvement)

Location: Bangladesh

Lead PI: Matthew Hamilton, PhD, WorldFish, Malaysia
Lead Co-PI: John Benzie, PhD, WorldFish, Malaysia
U.S. PI: Terrence Tiersch, MS, PhD, Louisiana State University Agricultural Center
HC PI: Mohammed Yeasin, WorldFish, Bangladesh
HC Co-PI: Mostafa Hossain, PhD, Bangladesh Agricultural University

Objectives:

1. Ensure capacity in private hatcheries and nurseries for business plan implementation and commercial delivery of improved carps.
2. Conduct assessments of farm performance of genetically improved carps, providing data to strengthen marketing and business analysis.
3. Secure and genetically improve core populations of rohu, catla, and silver carp, and develop and apply tools for genetic management of these three species that can be operated under a commercially oriented model of carp genetic improvement and dissemination in Bangladesh.

Outcomes:

1. Partner hatcheries and nurseries will have improved capacity for management of carp genetics and improved carps for optimal impact.
2. Pond productivity will be improved, and farmers' incomes will be increased through adoption of genetically improved rohu. Documentation of the substantial gains in growth will also provide a powerful marketing tool for dissemination at scale by private sector hatcheries.
3. Long-term genetic management of carp in commercial hatchery operations will be based on fully pedigreed and genetically diverse carp breeding populations with increased growth rate, and management will be supported by adoption of pedigree assignment and cryopreservation methods.

Achievements: During this reporting period, the team developed impact metrics for the activity through consultation with the Fish Innovation Lab. To satisfy Objectives 1 and 2, a subset of highly ranked and genetically improved (Generation 3; G3) rohu families were distributed to three Bangladeshi hatcheries and 19 nurseries. These families were equivalent in genetic quality to G3 families released in 2020. The nurseries have commenced selling seed to farmers for grow out. Three of the nurseries in Kulna District also operate as hatcheries and intend to grow out fish as

broodstock to produce spawn for sale to nurseries and farmers beginning in mid-2023. In addition, a subset of highly ranked G3 rohu families spawned in 2020 were distributed to the 19 farms to benchmark growth performance under 'real-world' conditions against currently available strains.

To fulfil Objectives 3 and 4, spawning of the next generation of genetically improved catla (initiation of G1; 122 families) and rohu (completion of G3; 228 families) was successfully completed. Each generation is expected to result in a population of fish that grows approximately 10% more rapidly than the previous generation. Tissue sampling of fish for genotyping the development of a pedigree assignment tool was delayed due to an extended COVID-19 lockdown.

Lessons learned: Nothing to report beyond substantial COVID-19 challenges.

Presentations and publications: None to report

Activity 1.9: Piloting integrated insect-to-fish farming systems in Malawi (Black Soldier Fly in Malawi)

Location: Malawi

Lead and U.S. PI: Jennifer L. Pechal, PhD, Michigan State University
U.S. Co-PI: Simone Valle de Souza, PhD, Michigan State University
U.S. Co-PI: Marjatta Eilittä, MS, PhD, Cultivating New Frontiers in Agriculture
HC PI: Jeremiah Kang'ombe, PhD, Lilongwe University of Agriculture and Natural Resources
HC Co-PI: Ari Magnus Mathiesen, LM Aquaculture Limited

Objectives: Black soldier fly (BSF) farming represents a viable option for enhancing productivity of aquaculture value chains in Malawi. This activity's focus on fish feed production will integrate efforts to promote smaller scale BSF production (targeting small- and medium-scale fish farmers) with BSF production advancing larger scale production in Africa. Key parameters, such as optimal BSF-suitable waste streams, feed ratios, cost-effectiveness for fish meal replacement ratios, potential effects on fish production yield, and value-chain linkages between BSF and aquaculture production have not been tested in the field for small- and medium-scale producers in Feed the Future target and aligned countries. The goal of this activity is to fill the empirical knowledge gaps that currently preclude effective implementation of BSF as affordable aquaculture feed in sustainable, nutrition-sensitive aquaculture value chains, while developing a network to expand knowledge dissemination and collaborative partnerships from small- to large-scale BSF production to benefit fish sectors. To achieve this goal, the activity will couple work with small- and medium-scale farmers, a medium-scale fish farmer, and BSF producers (targeting female and youth producers) to conduct experiments that will evaluate

1. Costs and conversion ratio of propagating BSF and processing into aquaculture feed.
2. Feasibility and cost-effectiveness of waste streams (spent grain, market waste) for BSF farming.
2. Changes in pond yield and productivity resulting from different mixes of BSF meal in fish feed.
3. Existing aquaculture value chains and potential income gains from increased aquaculture cost-efficiency.

Outcomes: These activities will lead to the following changes:

1. Defining a low-input system to increase production of BSF-meal and related products (e.g., compost).
2. Creation of three small-scale BSF farms led by women and youth to produce BSF larvae meal for both domestic use and commercialization as fish meal replacement in aquaculture operations.

3. Development of insect farms to work in synchrony with local fish farmer volunteers (e.g., collaboration with the Farmer-to-Farmer program) to teach the community how to mass rear BSF.
4. Establishment of collaborations between fish and insect farmers by integrating BSF larvae meal to replace current fish meal used in fish feed.

Achievements: Activities have not yet begun (start date Aug 2021). Subawards to PI institutions are being processed and issued by the Fish Innovation Lab ME.

Lessons learned: Activities have not yet begun.

Presentations and publications: None to report

Objective 2: Reduce and mitigate risks to aquaculture and fisheries

Activity 2.1: Improving biosecurity: A science-based approach to manage fish disease risks and increase the socioeconomic contribution of the Nigerian catfish and tilapia industries (Improving Biosecurity)

Location: Nigeria

Lead PI: Mohan Chadag, PhD, WorldFish
Lead Co-PI: Jerome Delamare-Debouttеville, PhD, WorldFish
Lead Co-PI: Rohana Subasinghe, PhD, WorldFish
U.S. PI: Larry Hanson, PhD, Mississippi State University
U.S. Co-PI: Robert Wills, PhD, Mississippi State University
HC PI: Olanike K. Adeyemo, PhD, University of Ibadan
HC Co-PI: Oluwasanmi O. Aina, PhD, University of Ibadan

Objectives:

1. Understand epidemiology and health economics of catfish and tilapia aquaculture in Ogun and Delta states, Nigeria.
2. Understand health status of catfish and tilapia in a regional model by employing presumptive field and laboratory diagnostics.
3. Identify pathogens of economic significance circulating in Nigerian catfish and tilapia aquaculture using whole genome sequencing.
4. Develop better management practices (BMPs) and build capacity to reduce risks of disease outbreaks in catfish and tilapia aquaculture in Nigeria.
5. Develop science-based policies and strategies for reducing fish disease risks in Nigerian aquaculture for longer-term development beyond the three years of the activity.

Outcomes:

1. Risk factors for disease emergence, outbreaks, and spread, including seasonality issues with respect to environmental and climate change associated risks, will be identified.
2. Endemic, emerging, and exotic pathogens will be identified, and economic impacts will be quantified in regional models.
3. Whole genomes of key pathogens isolated from farming systems and seed supply networks will be sequenced by next generation sequencing.
4. Health management interventions for fish farming systems and fish seed supply chains that reduce fish disease risks, in the form of BMPs and capacity building activities tailored to the needs of various stakeholders, will be developed and implemented.

5. Research findings and capacity development activities will support development and operationalization of a simple and practical national aquatic animal health and biosecurity strategy for implementation by the national competent authorities.

Achievements: In FY 21, 10 online meetings were conducted between activity team members to plan and implement activity objectives. The PIs and Co-PIs from MSU and WorldFish received official invitation letters from the University of Ibadan (UI) to be part of the supervisory panel of two master's students. The WorldFish Fish Epidemiology and Health Economics survey-based tool ODK Collect[1] course was finalized and implemented in Ogun and Delta states. WorldFish developed two online teaching courses on the Learn.ink platform: (1) the ODK Collect course and (2) a fish sampling for disease diagnostics course. UI's project manager, enumerators, and master's students completed the ODK Collect course. Seven quick fish-sampling protocols for disease diagnostics were completed. The UI team led an initiative to engage with resident veterinarians to assist farm and hatchery operators during disease outbreaks within Ogun and Delta states. This will allow flow of information between farmers and the UI team. Two additional universities within activity states were approached for collaboration: Federal University of Agriculture in Abeokuta, Ogun State and Delta State University in Delta State. They will provide oversight and support through biological sample handling, storage, and/or preliminary processing and transportation to UI for further analysis. Implementation of the field epidemiology surveys and biological sample collection (phase I) was completed. The activity team attended the Fish Innovation Lab annual meeting August 9-11, 2021, and gave a video presentation on activity updates. Master's students presented posters at the annual meeting.

Lessons learned: Due to international travel restrictions caused by the COVID-19 pandemic and some local strike events in Oyo state, alternative methods such as online learning/platforms were utilized. A single meeting venue near the UI main campus was arranged that had a stable power supply with improved internet, audio, and video connectivity. This allowed the project manager, PI/Co-PIs, enumerators, and master's students from Nigeria to attend the training face-to-face with safe social distancing in one location with virtual attendance by other PIs and Co-PIs from WorldFish and MSU (located in UK, Malaysia, and the US). All the preparations for this event were facilitated by regular communications between the project manager based in Nigeria and other PIs and Co-PIs.

To access individual small-scale farmers and farming units, the UI team first conducted community entry meetings with the leadership of different farm clusters in Ogun and Delta states. The activity team learned of the need to build trust and confidence amongst farmers so they would share information and biological samples. In return, the farmers were provided with feedback and advice that could improve their farming practices, overall productivity, and livelihoods. Thanks to an initiative led by the UI team, collaborations with resident veterinarians and local universities have been established. These will speed up farm visits during disease outbreaks and facilitate investigations, including sample collection/transport/storage before being sent to UI for further analyses.

Presentations and publications:

Khor, L. (2021). *Aquatic animal health package of practices: Fish epidemiology and health economics*. [Guidance Note]. https://hdl.handle.net/20.500.12348/4900

Khor, L. (2021). *Aquatic animal health package of practices: Fish sampling for disease diagnostics*. [Guidance Note]. https://hdl.handle.net/20.500.12348/4898

Khor, L., Delamare-Deboutteville, J., Ali, S., & Mohan, C. V. (2021). *Aquatic animal health package of practices: Syndromic surveillance and disease outbreak characterization*. [Guidance Note]. https://hdl.handle.net/20.500.12348/4895

[1] ODK Collect is an open-source Android app for mobile collection of survey-based data.

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Activity 2.2: Identifying the major sources of fecal pathogens in Bangladeshi aquaculture value chains and evaluating the effectiveness of various risk reduction strategies (Sources of Fecal Pathogens)

Location: Bangladesh

Lead and U.S. PI: Mohammad Aminul Islam, PhD, Washington State University
U.S. Co-PI: Clare Narrod, PhD, University of Maryland
U.S. Co-PI: Salina Parveen, PhD, University of Maryland Eastern Shore
HC PI: Mohammed Badrul Amin, PhD, International Centre for Diarrheal Disease Research, Bangladesh

Objectives:

1. Determine the prevalence of pathogens on pangas catfish and tilapia at retail markets.

2. Understand behavioral practices of fish value-chain actors that can impact microbial contamination of fish.
3. Assess fish value chain for microbial contamination and develop quantitative microbial risk assessment models characterizing exposure to pathogens along the fish value chain.
4. Conduct sensitivity analysis using quantitative microbial risk assessment models to identify critical points for implementing future intervention strategies.

Outcomes: This study will provide data on microbiological quality of fish at retail markets and along the supply chain. The study will provide an understanding of how behavioral practices among different value-chain actors impact the load of microbial pathogens on fish and the key players to train in a future intervention study. Results and data from this study will support science-based decisions on the most effective methods and key actors/locations where interventions can reduce microbial contamination of fish in informal markets of Bangladesh. Training of local laboratories on microbial methods and risk analysis will be useful not only for this study, but for expanded monitoring of the microbial quality of fish at sale.

Achievements: In FY 21, surveillance of foodborne pathogens in tilapia and pangas at point-of-delivery to consumers at retail fish markets in Dhaka was accomplished through the sampling of 28 retail wet markets and 19 super shops in Dhaka City. A total of 344 fish samples were collected from the wet markets, of which 97% tested positive for *Escherichia coli* and 60% were positive for extended spectrum beta lactamase (ESBL)-producing *E. coli*. Around 26% and 54% of the samples tested positive for *Salmonella* spp. and *Vibrio cholerae*, respectively. None of the fish samples (n=150) were found contaminated with *Cryptosporidium* spp. Of the 75 fish samples collected from the 19 super shops, 62% were positive for *E. coli* and 10% were positive for ESBL-producing *E. coli*. Around 5% and 65% samples were positive for *Salmonella* spp. and *Vibrio cholerae*, respectively. None of the fish samples from wet markets or super shops were positive for *Shigella* spp. and *V. parahaemolyticus*. Collection and testing of 84% of the target samples in retail markets have been completed.

To capture behavioral practices of different players and conditions in retail markets associated with increased microbial contamination of fish at retail sale, the activity team has completed the questionnaire-based surveys of all vendors in the wet market (n=344) and super shops (n=75) during sample collection. However, focus group discussions and structured observations in the markets were not conducted due to ongoing restrictions from the local institutes and from the government.

Lessons learned: There is no standardized method for detection of the parasite *Cryptosporidium* spp. in fish samples, or the available methods are not feasible to set up in the field laboratory. The team discovered, as they conducted testing of samples for other pathogens, that the prevalence of *Cryptosporidium* in those samples was missed. They are following polymerase chain reaction (PCR)-based detection of *Cryptosporidium* spp.-specific genes but had difficulties in setting up the initial volume of fish samples to isolate the oocysts for DNA extraction. In addition, extraction of DNA from homogenized fish samples or whole fish wash samples was a challenge. Therefore, to address the problem with detection of *Cryptosporidium* in fish samples, the team is trying multiple filtration steps to concentrate the oocysts from a large volume of homogenized fish samples. In addition, it was not possible to store all these samples for testing in the future. To address this inconsistency, re-sampling of the same vendors in retail markets and *Cryptosporidium*-only testing was conducted, which incurred additional costs.

Challenges were faced when transferring financial support to the collaborator at the Center on Integrated Rural Development for Asia and the Pacific (CIRDAP), who is responsible for conducting focus group discussions and interviews among various actors in fish value chain. The current agreement did not allow the International Centre for Diarrheal Disease Research, Bangladesh (icddr,b) to make a subcontract agreement with CIRDAP; therefore, icddr,b made a vendor service agreement with CIRDAP to facilitate the fund transfer process.

Presentations and publications: None to report

Activity 2.3: Development and investigation of the delivery mode of a multivalent bacterial fish vaccine in Zambia (Vaccines for Tilapia)

Location: Zambia

Lead and HC PI: Bernard Hang`ombe, BVM, MS, PhD, University of Zambia
U.S. PI: Stephen Reichley, DVM, PhD, Mississippi State University
HC Co-PI: John Yabe, BVM, MS, PhD, University of Zambia
HC Co-PI: Mwansa Songe, BVM, MS, PhD, Central Veterinary Research Institute
HC Co-PI: Patricia Bwalya, BVM, Zambia Ministry of Fisheries and Livestock

Objectives:

1. Identify *Lactococcus garviae, Streptococcus iniae, Streptococcus agalactiae, Aeromonas hydrophila*, and *Aeromonas veronii* associated with fish mortalities in aquaculture establishments of Lake Kariba.
2. Confirm pathogenicity and disease causation through development of experimental infection methods in tilapia.
3. Develop and test autogenous vaccines for the *L. garviae*, *S. iniae*, and/or *S. agalactiae*.
4. Devise methods of administering autogenous vaccines to the fish on the farms.
5. Improve the administration of the already developed *L. garviae* vaccine through various methods.

Outcomes:

1. Characterization of pathogenic bacteria responsible for fish mortalities.
2. Development of environmentally friendly vaccines leading to a decreased need to use antimicrobials and chemical treatments.
3. Adoption of improved methods to administer fish vaccines.
4. Reduction of stress during handling of fish.

Achievements: This activity was approved on May 1, 2021. Following approval, required documentation for funding has been completed, and the subaward has been issued for activity implementation. Three students have been incorporated (two master's and one PhD) in the activity for implementation and attainment of objectives. The wet laboratory for fish experiments has been renovated.

Lessons learned: Nothing to report at this time

Presentations and publications: None to report

Objective 3: Improve human outcomes from the aquaculture and fisheries sector

Activity 3.1: Harnessing machine learning to estimate aquaculture production and value chain performance in Bangladesh (Harnessing Machine Learning)

Location: Bangladesh

Lead and U.S. PI: Ben Belton, PhD, Michigan State University
U.S. Co-PI: Amirpouyan Nejadhashemi, PhD, Michigan State University
HC PI: Mohammad Mahfujul Haque, PhD, Bangladesh Agricultural University
HC Co-PI: Khondker Murshed-e-Jahan, PhD, WorldFish

Objectives:

1. Identify emerging technologies and innovative practices in aquaculture value chains and pilot digital extension approaches that accelerate their adoption to enhance productivity, resilience, and human nutrition, while reducing the transaction costs and time associated with traditional forms of technical research and extension.
2. Use machine learning to automate extraction of data on ponds from satellite images and integrate with georeferenced survey data to accurately estimate fish production, employment, and economic value; improve the accuracy of official statistics; and enhance capacity to target investments and regulation.
3. Build organizational and individual capacity in Bangladesh for conducting state-of-the-art research on socioeconomic and spatial dimensions of aquaculture development and contribute to societal capacity to create a more enabling environment for fostering sustainable aquaculture development.

Outcomes:

1. Information on new technologies, practices, and innovations in Bangladesh aquaculture value chains will be received by government, development partners, and researchers.
2. Bottlenecks in adoption and scaling of innovative technologies and practices will be reduced.
3. Institutional capacity will be increased to independently generate accurate spatialized information on aquaculture area, production, women and youth participation, and contributions to the economy in Bangladesh and beyond.

Achievements: During this reporting period, the activity team conducted a census of 3,554 aquaculture households in 36 villages, and 1,319 traders in 50 markets. Using the results, survey sample frames were designed. Questionnaires for farms, traders, and input providers were designed, field tested, digitized, and finalized as well as key informant survey questionnaires of farming communities and markets. A one-week training for 12 data enumerators was conducted in December. Interviews with 721 farms, 329 fish traders, 79 aquaculture input suppliers, 36 farming communities, and 15 markets were conducted, quality checked, and uploaded. The activity team began reshaping, cleaning, and analyzing all survey datasets.

Activity staff were trained in using Google Earth Engine to create boundary polygons for delimiting waterbodies, and then GPS coordinates were collected and used to create a database of boundary polygons using Google Earth Engine for 1,822 individual waterbodies. The collected GPS coordinates and polygons were then used to train the machine learning algorithm to detect and distinguish between aquaculture waterbody types. Two alternative models for waterbody detection were developed, validated, and compared: a logistic regression model and a decision tree model. To further refine the decision tree model, a typology of aquaculture and non-aquaculture waterbodies was developed.

A virtual stakeholder consultation workshop was convened with 26 participants from Bangladesh to elicit feedback on development of a wireframe for the interactive GIS platform containing activity data. Using Google Forms, feedback from the 20 workshop participants was received. A Bangla language YouTube channel “Aquaculture TV” was established for dissemination of extension videos, and a pilot video was created. Three short films were filmed and edited for dissemination via social media. In addition, an article on “Harnessing machine learning techniques for large-scale mapping of aquaculture in Bangladesh” was submitted to the journal *Remote Sensing*.

Lessons learned: Most of the recruited data enumerators had to participate in Bangladesh Civil Service entry exams in March to apply for government jobs. This slowed survey implementation because fewer enumerators than anticipated were able to participate. Difficulties recruiting qualified data analysts have also slowed down production of research outputs.

Presentations and publications: Submitted article “Harnessing machine learning techniques for large-scale mapping of aquaculture in Bangladesh” to *Remote Sensing*.

Activity 3.2: Nourishing nations: Improving the quality and safety of processed fish products in Nigeria (Nourishing Nations)

Location: Nigeria

Lead PI: Lauren Pincus, PhD, WorldFish
U.S. PI: Terezie Tolar-Peterson, EdD, MS, RDN, LDN, FAND, Mississippi State University
HC PI: Henrietta Ene-Obong, PhD, University of Calabar, Cross River State

Objectives:

1. Develop cost-per-nutrient guides by analyzing the nutrient and contaminant profile of select processed fish products and their respective prices in comparison to other animal source foods available in Delta state, Nigeria.
2. Build capacity among women and youth fish processors in Delta state to produce high quality, safe, and nutritious processed fish products for local consumption.
3. Educate women and youth fish processors in Delta state about the benefit of fish in the human diet and develop a low-literacy tool to help them better market their product.

Outcomes:

1. Two MS students will be trained in research design, implementation, data analysis and interpretation, and manuscript writing.
2. One PhD student will be trained in development and implementation of a low-literacy tool to teach about the benefits of fish in the diet.
3. Two datasets about fish contaminant levels and the cost per nutrient of processed fish products will be gathered from fish markets in Delta state.
4. Three scientific articles will be published in peer reviewed journals: 1) Cost per nutrient of processed fish products in comparison to other animal source foods in Nigeria, 2) Food safety concerns of processed fish products in Nigeria, and 3) Development and testing of a low literacy tool to promote fish consumption.
5. Women and youth fish processing cooperative members will be trained in the benefits of fish for human consumption, how to use low-literacy tools, fish handling and processing techniques, and business and marketing skills.

Achievements: During this reporting period, the activity team launched its training program for fish processors. In anticipation of the training, the team prepared a Nutrition and Food Safety curriculum that covered general nutrition education, food safety, and fish handling practices. A facilitator's guide to accompany each lecture was also developed. The team prepared a baseline survey and post-education survey to capture changes in knowledge, attitudes, and practices surrounding key nutrition and food safety concepts. Each of the seven modules included pre- and post-tests that were developed and designed in Qualtrics.

Prior to the training launch, the team held a stakeholders' meeting in Nigeria with local officials representing Delta State Ministry of Agriculture and Natural Resources, Delta Agricultural and Rural Development Authority, and Delta State Primary Health Care Development Agencies. This meeting informed local officials of the proposed activities and solicited feedback on important topics and considerations to be included in the activities, including the identification of women and youth fish processors for the baseline survey and training programs. The University of Calabar team conducted a familiarization tour of Delta State to identify possible markets to conduct the market survey and collect fish samples. The team completed baseline data collection and launched the Nutrition and Food Safety training program. The training was held from August 18-24 in Asaba and Warri towns in Delta state. Participants came from the north, south, and central zones of Delta state. In total, 122 fish processors (78% female) were trained.

University of Calabar MS students began to develop their research tools. Notably, one MS student has developed a questionnaire that investigated use of fish and fish products by about 300 mother-

infant pairs in Delta State. Both MS students will undertake a market survey in November 2021. PhD candidate Grace Adegoye (Nigerian nationality) completed her dissertation research proposal and will defend her proposal on April 20th, 2021, as part of her preliminary exams.

Lessons learned: The biggest challenge was the inability to travel to Nigeria due to COVID-19 restrictions. Unfortunately, the PI and U.S. Co-PI were unable to attend the activity training. Another serious challenge was access to funds. Although a subaward was issued to University of Calabar from the Fish Innovation Lab ME, the host country team was not able to access funds, which affected the training activity.

Presentations and publications:

Tolar-Peterson, T. & Adegoye, G. A. *Nutrition education, food safety, and safe fish handling, and practice guide for fish processors in Nigeria*. [Facilitator's Guide].

Activity 3.3: FishFirst! Zambia: Research for development and scaling staple fish products for enhanced nutrition in the first 1,000 days of life (FishFirst! Zambia)

Location: Zambia

Lead and U.S. PI: Kathleen Ragsdale, PhD, Mississippi State University
U.S. Co-PI: Mary Read-Wahidi, PhD, Mississippi State University
HC PI: Pamela Marinda, PhD, University of Zambia
HC PI; Netsayi Mudege, PhD, WorldFish

Objectives: FishFirst! Zambia aims to increase quality/quantity of fish benefitting nutrition and food security in Zambia, especially for women of reproductive age (ages 15-49 years) and children in the first 1,000 days of life (under two years). The objectives of FishFirst! Zambia are to

1. Assess the current state of small pelagic fish harvesting, processing, and trading activities from point of catch through processing to local and distant markets for sale in rural and urban areas.
2. Identify social and gender barriers to entry and/or participation in these value-chain activities for different actors, particularly women and youth.
3. Assess how small pelagic fish are accessed by different consumer groups and household consumption.
4. Explore potential of upgrading the small pelagic fish value chain via improving processing, storage, and trading methods to reduce postharvest losses and improve food safety.
5. Develop and test nutrient-enhanced Complementary Food for Africa + dried fish powder (ComFA+Fish) products/recipes for enhanced nutrition particularly benefiting women of reproductive age and children under two years in vulnerable households.
6. Explore options to scale the production and dissemination of ComFA+Fish products/recipes with private and public sector actors, particularly women and youth entrepreneurs.

Outcomes: To meet Objectives 1-3, FishFirst! Zambia outputs include 1) an assessment of existing fisheries enterprises disaggregated by key actors' gender and age to assess existing barriers and bridges to women- and youth-led fisheries development and pinpoint leverage points for growing this sector, and 2) a fish-flow study of actors' engagement across the fish value chain (i.e., as producers, processors, marketers, and consumers). To meet Objective 4, FishFirst! Zambia outputs include a multi-stakeholder workshop to explore potential of upgrading the small-fish value chain via improving processing, storage, and trading methods to reduce postharvest losses and improve food safety. To meet Objectives 5-6, FishFirst! Zambia outputs include 1) development and testing of nutrient-enhanced ComFA+Fish products/recipes for enhanced nutrition particularly benefiting women of reproductive age and children under two years in vulnerable households, and 2) exploration of options to scale the production and dissemination of the ComFA+Fish products/recipes with private and public sector actors, particularly women and youth entrepreneurs.

FishFirst! Zambia contributes to Feed the Future objectives to understand why many Zambians, particularly women of reproductive age and children under two years, continue to lack dietary diversity and remain vulnerable to food insecurity and malnutrition.

Achievements: During this reporting period, the activity team selected two graduate interns from the University of Zambia to assist with data collection at Lake Kariba and literature reviews. Weekly meetings to monitor work progress and collaborate on the development of the survey instruments were implemented.

Protocols for ethical approval were submitted to the WorldFish Protocol Review Committee. The process of preparing the FishFirst! Zambia protocol documentation was initiated for submission to the University of Zambia Ethics Review Committee.

Instruments for Phase I were finalized, which included: (1) Women's Empowerment in Fisheries Index - FishFirst! Zambia (WEFI-FFZ); (2) Household Hunger Scale II: this tool was used to collect individual-level and household-level data for three hunger events to categorize individual- and household-level hunger as occasional, moderate, or severe, and it disaggregated the findings by gender; (3) Post-Harvest Fish Loss Assessment for Small-Scale Fisheries (PHFL); (4) Minimum Dietary Diversity-Women of Reproductive Age Questionnaire (MDD-WRA), which was modified for Tonga and Nyanja speakers; (5) Minimum Dietary Diversity-Infants & Young Children Module (ages 6-23 months) (MDD-IYC), which was modified for Tonga and Nyanja speakers.

The instruments were uploaded to the KoBoToolbox in preparation for fieldwork and pretested prior to data collection. The team purchased ten tablets to be used for fieldwork, and 14 enumerators were identified for data collection.

Two literature review protocols on 1) postharvest losses and 2) fish consumption patterns and nutrition were drafted and circulated for internal and external review. A two-day enumerator training workshop was conducted in Lusaka, Zambia. Fourteen male and female enumerators attended the two-day training. The training included hands-on practice administering the instruments identified above (WEFI-FFZ, Household Hunger Scale II, PHFL, MDD-WRA, and MDD-IYC). The WEFI-FFZ, Household Hunger Scale II, PHFL, MDD-WRA, and MDD-IYC were uploaded onto tablets using KoBoCollect. Survey practice sessions were held during the enumerator training workshop.

Phase I was conducted, which included enumerating the survey tools among 451 men and women fishers, processors, and traders at Lake Kariba, Zambia. The MSU team members began collaborating with WorldFish to clean the data collected during Phase I and conduct preliminary analysis of the Household Hunger Scale II results for individuals and their households.

Lessons learned: Nothing to report

Presentations and publications:

Ragsdale, K., Torell, E. C., Read-Wahidi, M., Pincus, L., Marinda, P., & Kolbila, R. (Under Review). Adapting the WEAI to explore gender equity among fishers, processors, and sellers/traders at Zambia's Lake Bangweulu. *World Development*.

Ragsdale, K., Torell, E. C., Read-Wahidi, M., Pincus, L., Marinda, P., & Kolbila, R. (2020 December 7-9). *Fish4Zambia: Exploring food insecurity among fishing value chain actors at Lake Bangweulu*. Presentation at Fourth International Conference on Global Food Security, Virtual.

Ragsdale, K., Torell, E. C., Read-Wahidi, M., Pincus, L., Marinda, P., & Kolbila, R. (2021 February 23-26). *Using the Household Hunger Scale to explore food insecurity among smallscale fishers, processors, and traders at Zambia's Lake Bangweulu: Fish4Zambia Results*. Presentation at 2021 Women and Gender in International Development Conference, Virtual.

Activity 3.4: Samaki Salama: Securing small-scale fisheries in Kenya for healthy nutrition and ecosystems (Samaki Salama)

Location: Kenya

Lead and U.S. PI: Lora Iannotti, PhD, Washington University in St. Louis
U.S. Co-PI: Austin Humphries, PhD, University of Rhode Island
HC PI: Andrew Wamukota, PhD, Pwani University
HC Co-PI: Elizabeth Kamau-Mbuthia, PhD, Egerton University

Objectives:

1. Determine the effects of a multi-tiered social marketing campaign to promote fish nutrition, dietary diversity, and food safety on child growth.
2. Measure the impact of fishing gear cooperatives on gear modification and diversification as well as catch dynamics and earnings.
3. Describe fish access, safety, and consumption in a representative inland county with a view towards potential future application of the *Samaki Salama* intervention package.

Outcomes:

1. The effectiveness of a bundled, integrated intervention on healthy nutrition, income growth, and sustainable fisheries in coastal communities of Kenya will be examined.
2. Model socioenvironmental program framework for adaptation and replication in other small-scale fisheries and aquaculture communities in Kenya and globally will be developed.
3. Longitudinal difference-in-difference analyses will be completed for nutrition parameters during the first 1,000 days of life: dietary diversity, fish food intake, stunting prevalence, and height-for-age Z-scores.
4. Other impacts will be monitored, specifically household wealth and expenditures, women's decision making and empowerment, fisheries yield, fishable biomass, fish spawning potential ratio, and fisher income and earnings.

Achievements: In FY 21, development of the household survey and other tracking tools was completed. These tools will measure the effects of the social marketing campaign; track the degree to which nutrition messaging is being received, understood, and used by mothers/caregivers and fishers over the course of the activity; and elucidate gender norms and household decision-making power dynamics that may impact social marketing delivery. The team is in the process of finalizing the fisheries data collection protocol, and the surveys and tools were approved by the WUSTL Institutional Review Board and the Pwani University Ethics Committee.

Baseline data collection was completed in all intervention sites, and the activity team started implementing the social marketing campaign that targets caregivers and fishers with information about child nutrition, health, diet diversity, and the importance of catching mature fish for fisheries sustainability and improved income. The social marketing campaign includes home visits, cooking classes, workshops with fishers, health/diet-focused calendars, health/diet-focused posters, and t-shirts printed with the Samaki Salama visual identifier. To date, 100 home visits were completed. Social marketing materials are being printed. Half of the intervention households/fishers (n=100) received modified traps with escape gaps; each fisher received two traps.

Lessons learned: During recruitment, it was determined that there were not enough trap fishers with children under the age of 5 to reach the needed sample size. This limitation necessitated a change of design from a cluster-randomized study to a matched intervention control study. The intervention group was divided into a social marketing only group and a social marketing plus fisher gear modification group. Splitting the intervention group will allow the activity team to explore the impacts of the fisher component of the intervention while maintaining a sample size of 200 that receive the full social marketing.

Presentations and publications:

Humphries, A., Iannotti, L., Wamukota, A., Kamau-Mbuthia, E., Lesorogol, Blackmore, I., Sarange, C., Mbeyu, R., Cheupe, C., Cheupe, J., & Nunez-Garcia, A. (Under Review). Child nutrition in fishing versus non-fishing households of coastal Kenya. *Maternal & Child Nutrition*

Humphries, A., Iannotti, L., Wamukota, A., Kamau-Mbuthia, E., Lesorogol, Blackmore, I., Sarange, C., Mbeyu, R., Cheupe, C., Cheupe, J., & Nunez-Garcia, A. (2021 June 7-10). *Fish and complementary feeding practices for young children: Qualitative research findings from coastal Kenya*. [Conference Presentation]. American Society for Nutrition, Virtual. http://doi.org/10.1093/cdn/nzab045_014

Humphries, A., Iannotti, L., Wamukota, A., Kamau-Mbuthia, E., Lesorogol, Blackmore, I., Sarange, C., Mbeyu, R., Cheupe, C., Cheupe, J., & Nunez-Garcia, A. (Under Review). Fish and complementary feeding practices for young children: Qualitative research findings from coastal Kenya. *PLOS One*.

Activity 3.5: Population ecology and current distribution assessment of the introduced invasive crayfish in the Kafue floodplain and Lake Kariba, Zambia (Zambia Crayfish)

Location: Zambia

Lead and U.S. PI: Michael Rice, MS, PhD, University of Rhode Island
HC PI: Eva Nambeye-Kaonga, MS, University of Zambia
HC Co-PI: Marjatta Eilittä, MS, PhD, Cultivating New Frontiers in Agriculture

Objectives: The general objective of this study is to investigate the biology, ecology, and population of the invasive crayfish in the Kafue Floodplains and Lake Kariba. The specific objectives are

1. To assess the current biology, ecology, and environmental situation of the invasive crayfish through understanding the reproductive rates, spread, and distribution throughout the Kafue Floodplains and Lake Kariba in Zambia.
2. To determine growth parameters and growth performances of crayfishes in the two water bodies.
3. To determine the prolific breeding and reproduction of crayfishes in both rainy and dry seasons.
4. To assess relative abundance of crayfishes in the two water bodies and from crayfish farming.
5. To determine the relative distribution and invasion of crayfishes in both water bodies, throughout the floodplain, and in connected waterways.

Outcomes: The activity will have the following outcomes:

1. Assess the population structure of the introduced invasive crayfish population through increased knowledge of the crayfish in target water bodies. Monthly length and weight measurement in different locations will help understand growth, reproduction, and distribution of the introduced invasive species throughout the connected waterways.
2. Assess effects of the natural aquatic environment on crayfish population distribution and abundance. Data on physical and chemical water parameters will allow analysis of their effects on these factors.
3. Determine current harvest volumes from fished and farmed crayfish by analyzing existing postharvest utilization.
4. Assess the likelihood of potential trans-watershed boundary spread of the invasive crayfish by survey of rate of crayfish spread into the adjacent Cuando/Chobe sub-basin of the Zambezi that has a boundary with the ecologically critical Okavango Delta watershed.

5. Updated crayfish distribution data assessment in Zambia following protocols established by Douthwaute et al. [African J. Aquatic Sci. (2018) 43:353-366)] determining rates of natural spread vs. likely human mediated intentional stocking.

Achievements: In FY 21, the three-partner team revised the activity concept after feedback from USAID, developed a work plan, and started regular meetings in May, which are held on a weekly basis. Research activities will initiate in FY 22. However, two activities were conducted that allowed for improved planning of the FY 22 activities. Pilot trapping of 250 crayfish in Kafue town in September allowed for initial measurements of carapace and total length for calibration purposes and better understanding of reproductive potential through counting of egg numbers. Additionally, one interview conducted by the Zambia-based researchers of a crayfish entrepreneur allowed for improved initial understanding of the harvesting patterns and volumes.

Lessons learned: Based on feedback from USAID, the activity was revised to focus on understanding harvest volumes and setting up of a monitoring mechanism for the spread of the crayfish. The revised objectives were rapidly adopted by the activity team, and planning was adjusted as a result. Because the subaward for the University of Zambia was not made in FY 21, field activities were delayed to FY 22. Despite this, the team continued to meet on a weekly basis and conducted initial activities that allowed for improved planning of the future activities.

Presentations and publications:

Rice, M. A. (Under Review). Intensive fishing effort as a tool for managing invasive aquatic species. *Asian Fisheries Science*.

Rice, M. A. (2021 September 20-21). *Intensive fishing effort as a tool for managing invasive aquatic species*. Presentation at International Conference on Fisheries and Marine Science, Kayu Tangi, Banjarmasin, Indonesia.

Activity 3.6: Strategies for inclusive aquaculture value chain in Bangladesh: Analysis of market access, trade, and consumption pattern (Market Analysis)

Location: Bangladesh

Lead and U.S. PI: Madan Dey, PhD, Texas State University
U.S. Co-PI: Prasanna Surathkal, PhD, Texas State University
HC PI: Md. Akhtaruzzaman Khan, PhD, Bangladesh Agricultural University
HC Co-PI: Md. Takibur Rahman, PhD, Patuakhali Science and Technology University

Objectives: The overall goal of this activity is to analyze economic implications of aquaculture value chain development in Bangladesh in terms of food security and market access, and thus to improve market access for consumers and producers. Specific objectives are as follows:

1. Analyze the food and nutritional security impacts of increased aquaculture production.
    a. Can inland aquaculture continue to contribute to food and nutritional security of poorer households, as measured by nutritional elasticities?
    b. How do poorest households' expenditures on fish, as disaggregated by species and/or source of production, differ from richer households as measured by the income elasticity?
    c. How does the expenditure on fish compare to expenditure on other major food items across households of different income levels? How true and/or strong is status bias in fish consumption?
2. Evaluate constraints in the aquaculture input markets that influence domestic market access for aquaculture producers.
    a. Determine availability of trade credits to fish farmers.

b. How does volatility in input prices (corn price, soybean price, etc.) influence prices of farmed fish?

c. What are the impacts of COVID-19 on aquaculture business operations, particularly small and marginal farmers, and on market prices of major aquaculture species at different geographical markets?

3. Analyze the export market competitiveness of major aquaculture products of Bangladesh (such as pangasius, tilapia, shrimp, and major carps) for different scale and intensity of farming operations.

Outcomes: The activity will lead to a better understanding of aquaculture value-chain development and its impacts on

- Food and nutritional security of vulnerable households
- Market access for small and marginal farmers
- Linkages with input markets
- Export market competitiveness of major aquaculture products by scale of operation

At the end of the activity, a conference will be held for stakeholders, including policymakers, to discuss the research outcomes and their policy implications. This will facilitate development of action plans to make the aquaculture value chain more inclusive and accessible to vulnerable households. Dr. Shamsul Alam of the Planning Commission of Bangladesh has kindly agreed to be an adviser for the activity, and his participation will increase the relevance of activity outcomes to the promotion of inclusive aquaculture value chains.

Achievements: The action plan was validated, and consent of the institutional research ethics committee was completed. Time-series data collection on input price, fish price, and imported ingredients of commercial feeds are progressing. Household Income Expenditures Survey data collection is also in progress. A survey questionnaire for primary data on producers and other value-chain actors has been drafted and is ready for piloting. One scientific article has been drafted on COVID-19 impacts on the fish value chain, and one more article on trade credit is in progress. The activity team has visited potential sampling areas for piloting the questionnaire.

Lessons learned: Nothing to report at this time

Presentations and publications: Draft article on COVID-19 impacts on the fish value chain.

Activity 3.7: Micronutrient impact of oysters in the diet of women shellfishers (Micronutrient Impact of Oysters)

Location: Ghana

Lead and U.S. PI: Brietta Oaks, University of Rhode Island
HC PI: Seth Adu-Afarwuah, University of Ghana

Objectives:

This research will

- Determine the contribution of oyster consumption to iron and zinc intakes of women shellfishers.
- Determine whether there is any variation in iron and zinc content of oysters across the three study sites in Ghana.
- Investigate whether heavy metal contamination is a concern in the three study sites in Ghana.
- Provide guidance for public health authorities, women's shellfish associations, and other stakeholders.

Outcomes: This research will test the hypothesis that oysters are the primary food source for iron and zinc among women shellfishers in West Africa using Ghana as a case study. It will also measure heavy metal contamination in oysters to evaluate health risks of oyster consumption. This research has the potential to identify oysters as a key contributor of iron and zinc in the diet of women shellfishers, reducing the risk of anemia and micronutrient deficiencies. Results from this study will inform relevant stakeholders whether oysters should be recommended to women of reproductive age to reduce anemia prevalence or avoided because of heavy metal contamination. If it is determined that oysters are providing a critical micronutrient contribution to the diet but are also contaminated with heavy metals, this research may be used as a call for action to address heavy metal contamination in the environment.

Specific outcomes of this work will include

- A stronger evidence-base of the nutritional benefit of oysters for women of reproductive age will be provided.
- Heavy metal contamination levels will be identified for oysters from the three study sites in Ghana.
- Results will be provided to health authorities and other stakeholders in Ghana.
- Findings will result in one or more publications in a peer-reviewed journal.
- Findings will be integrated into the Women Shellfishers and Food Security project multivariate analysis research report and stakeholder toolkit for dissemination to women shellfishers, government, and academic stakeholders in coastal West Africa from Senegal to Nigeria.

Achievements: During this reporting period, the activity team completed all field data collection. In total, 504 women shellfishers were enrolled, including 200 from the Densu estuary, 166 from the Narkwa Lagoon area, and 138 from the Whin estuary. These women comprised nearly all of the women shellfishers in the target age group (women of reproductive age, 15-49 years of age) available for enrollment at the three study sites.

At each of the three sites, information on women's background socioeconomic characteristics was collected, and two nonconsecutive 24-hour dietary recalls were conducted; the first on the day of enrollment and the second within seven days of enrollment. The dietary data includes the type, ingredients, and quantities of foods the women shellfishers consumed.

A total of 305 oyster samples were collected from each of the three study sites (total n = 915) based on procedures described by the Food and Agriculture Organization of the United Nations (FAO). At each study site, the main oyster harvesting locations were identified, and the team proportioned the 305 oysters per study site to the number of known harvesting locations at the site. At each oyster harvesting location, the activity team earmarked an estimated quadrant of 20 m squared from where a local guide randomly collected the quota number of oysters.

All 24-hour dietary data collection and oyster samples collection have been completed. The oyster samples collected are currently being stored at the University of Ghana pending analysis starting October 2021.

Much of the data cleaning was completed, and preliminary analysis of key variables was performed. For the analysis of women's nutrient intakes (iron and zinc), a food composition table was compiled, which was supplemented with data from the FAO and the United States Department of Agriculture (USDA).

Lessons learned: Finding a reliable food composition table to determine the women’s nutrient intakes and the contribution of oyster consumption to iron and zinc intakes is a major challenge. The activity team is currently compiling a food composition table based on a previous version, which will be supplemented with data from two additional sources including the FAO and the USDA.

Presentations and publications:

Oaks, B. (2021 July 20). *Innovations in shellfish harvesting to increase entrepreneurship for women*. Presentation at Global Agriculture Innovation Forum, Online.

Associate and Buy-in Awards

The Fish Innovation Lab received its first buy-in award at the end of FY 21. The $200,000 buy-in from the Bureau for Development, Democracy, and Innovation will support the ongoing USAID Distant Water Fleet (DWF) Research Agenda on responsive actions related to the drivers and impacts of DWF on national fisheries and fisherfolk in priority USAID geographies. The final deliverables of the DWF activity will be defined in the annual work plans but are expected to include communications materials related to transparency and sustainability in licensing and supply chains associated with DWF activity, a summary communications product comparing licensing in priority countries, a project report related to the socioeconomic impacts of DWF on national fisheries and fisherfolk, and mission level-briefs and presentations. The DWF activity fits within the Fish Innovation Lab's theory of change and its three areas of inquiry.

Human and Institutional Capacity Development

Human and Institutional Capacity Development Activities

Human and institutional capacity development (HICD) is a critical component of the Fish Innovation Lab, which strives to catalyze local leadership, research excellence, and capacity. All Fish Innovation Lab-funded subawards include activities to strengthen local partner, student, extension, and broader stakeholder capacity. The strategy includes traditional classroom and online training, mentoring, partnering, and "learning by doing" models founded in collaborative research. Notable HICD accomplishments in FY 21 include:

- To better understand the interest, needs, and format of a Fish Innovation Lab student network, an online survey was conducted in April 2021. The survey was sent out to Fish Innovation Lab collaborators, who shared it with their students. A total of 42 responses were received. The survey analysis showed that almost all respondents would like to join a Fish Innovation Lab-led student network, though they want it to be well managed, easily accessible, and have faculty engaged. In return, the students said they can offer sharing of research and peer reviews. Based on these findings, a student network will be established in FY 22 Quarter 1.
- The **Cambodian Fisheries and Food Processing activity** continued training and providing feedback to the fishers participating in the activity's citizen science program, collecting fisheries harvest data in the Sre Ambel River. In addition to the 15 local fishers, the activity is training one Cambodian graduate student and one local program coordinator in fisheries management. The team is collaborating with a faculty member of the Royal University of Phnom Penh as well as a federal ichthyologist.
- The **Sources of Fecal Pathogens activity** provided intensive training to the laboratory personnel from the fisheries and food safety laboratories operated by the government in Bangladesh. The fisheries laboratory is primarily responsible for testing all types of fish destined for export. Increasingly, they are also involved in conducting surveillance of fish samples from local markets. The Sources of Fecal Pathogens activity training has increased the capacity of these laboratory analysts to test microbial prevalence in fish and environmental samples following standard methods as well as detection of foodborne pathogen-specific genes by PCR. The analysts will contribute to improving aquaculture and fishery operations by applying their knowledge and skills in existing surveillance of fish samples. This will include PCR-based technologies that will facilitate rapid detection of

foodborne pathogens in fish for both local and export markets. The team is sharing fish samples with the Department of Fisheries laboratory, which will test at least 10% of the samples in the Sources of Fecal Pathogens study. Comparing the results with those of the icddr,b laboratory will provide a results-based evaluation of the training and continue to grow the capacity of the public laboratory.

- The social marketing strategy and home visits implemented by **Samaki Salama** are increasing caregivers' and fishers' capacities to care for their young children and improve household diet and nutrition. The field team will also train local community health volunteers to conduct home visits so that caregivers have a reliable source of information and support even after the activity is completed.
- During each of the stakeholder training workshops implemented by the **Cryogenic Sperm Banking activity**, basic principles of sperm cryopreservation were presented via PowerPoint presentations. In addition, a video on cryopreservation of sperm and its use in egg fertilization was demonstrated. The hatchery operators also took part in breeding trials in hatcheries using cryopreserved sperm and received hands-on training on how to fertilize eggs with cryopreserved sperm. They are also rearing the seeds in their hatcheries for production of broods. These activities have increased the hatchery operators' capacity and confidence to use the cryopreservation technology for production of quality broods and seeds.
- The **Improving Biosecurity activity** provided mentoring and supervision support to two master's students who finalized their research topics, research designs, and abstracts and posters for the Fish Innovation Lab annual meeting. To strengthen the capacity of enumerators and master's students, the team developed two online courses on the Learn.ink platform. Enumerators learned about digital data collection through practical application of ODK Collect mobile data in the field survey. This was useful in places with limited internet connectivity. The team engaged resident veterinarians in the study locations to interact with farmers/farms to report mortality and collect samples for diagnostics. This created a foundation for local aquaculture morbidity and mortality reporting and created a diagnostic sample delivery network. The team also developed seven quick fish-sampling guides for disease diagnostics, which were published and disseminated to partner universities. The team has received positive feedback from public and private institutions in southeast Asian and sub-Saharan African countries on the usefulness of these vocational training resources.
- The **Lean Production Systems** team organized virtual meetings and training sessions followed by in-country hands-on training workshops for 40 Lean Subject Matter Experts (LSMEs). The trained LSMEs learned to launch a sensitization program to train other farmers and processors in Delta and Ogun states to adopt the Lean production technology. After the sensitization program, each LSME has commenced working with at least six fellow farmers and processors to apply Lean management tools to identify waste management streams and apply correction measures.
- The **Aquaculture Diversification in Rural Communities** team trained farmers in rice-fish farming practices, including record keeping and data collection, conducted participatory implementation of six adaptive rice-fish farming research plots, and offered hands-on training to farmers. The team also supported capacity development and enhancement of co-learning among all stakeholders, including academics, farmers, extension workers, and other development partners.
- **Nourishing Nations** conducted two training workshops on nutrition education, food safety, and safe fish handling. The team implemented the following modules: 1) Nutrition Education; 2) Animal Source Proteins; 3) Food Safety; 4) Fish Processing Techniques; 5) Fish Poisoning and Contamination; 6) Hygiene Rules and Good Practices; and 7) Economic and Nutrition Benefits of Quality Fish Products. Implementing good practices has helped improve the farmers' and processors' knowledge of nutrition, including the importance of fish and fish

products in human diets. A total of 135 farmers and fish processors (66% female) participated in the two trainings.

- The **Coral Reef Fishery Sustainability activity** conducted a training on Wildlife Conservation Society data-collection protocols and installed the Atlan Collect application on mobile phones. The mobile technology will improve the capacity of beach management units and fisheries officers to record fish weights by different fish groups and fishing efforts.

Short-Term Trainings

Fish Innovation Lab subawardees held 28 short-term trainings in FY 21, reaching 778 beneficiaries, including 516 males and 262 females as shown in Table 2.

Table 2: Short-Term Trainings

Country of Training	Activity	Brief Purpose of Training	Number Trained		
			M	F	Total
Bangladesh	Belton - Machine Learning	Training for data enumerators entitled "Harnessing Machine Learning to Estimate Aquaculture Production and Value Chain Performance in Bangladesh;" orient enumerators to purpose of activity surveys, familiarize enumerators with contents of questionnaire and interview protocols, conduct field practice	12	0	12
Bangladesh	Islam - Fecal Pathogens	Sampling, isolation, and identification of pathogenic microbes and bacteria from fish and water samples	8	1	9
Bangladesh	Islam - Fecal Pathogens	Training at Department of Fisheries lab on "Isolation and Identification of Pathogenic Microbes from Fish Samples"	3	2	5
Bangladesh	Sarder - Cryogenic Sperm Banking	Interactive training workshop between host institution (Bangladesh Agricultural University) and Louisiana State University	6	0	6
Cambodia	Correa - Cambodian Fisheries & Food Processing	A training workshop on data collection for the fishers selected to participate in the citizen science fisheries data collection program	16	2	18
Cambodia	Correa - Cambodian Fisheries & Food Processing	Training on human subject research issues; participants must acquire this certificate to participate in human-related research activities	0	2	2
Cambodia	Hok - Bighead Catfish	"Formulating and Preparing Aqua Feeds" to build and strengthen capacity of Royal University of Agriculture faculty, students, and staff	6	0	6
Kenya	McClanahan - Coral Reef Fishery	Data collection protocols and procedures training for community members and county fisheries officers on Wildlife Conservation Society data-collection protocols and mobile-phone data collection procedures to help improve their knowledge of fisheries measurements and fish group identification	11	6	17

Country of Training	Activity	Brief Purpose of Training	Number Trained		
			M	F	Total
Kenya	McClanahan - Coral Reef Fishery	Fisheries mapping training about the marine resources found within community fishing areas; assistance in the production of hand-drawn and digitized maps	44	19	63
Kenya	McClanahan - Coral Reef Fishery	Stock-assessment training, which is an online activity that involves sending fish species identifications with some key facts to a group of individuals within various institutions to print and discuss with their teams	3	1	4
Kenya	McClanahan - Coral Reef Fishery	Training for members of the BMUs in Kibuyuni and Wasini sites on the marine resources found within their areas, and enhancement of their knowledge of artwork in the production of hand-drawn resource maps	21	8	29
Nigeria	Chadag - Biosecurity	Training on aquatic disease diagnostic procedures (water quality, bacteriology, hematology, biochemistry, and histology)	12	9	21
Nigeria	Chadag - Biosecurity	Aquatic epidemiology and health economics survey tool (ODK) and fish-sampling virtual training	12	9	21
Nigeria	Chadag - Biosecurity	Field-level training with catfish and tilapia farmers on farming practices, biosecurity, and health management	269	80	349
Nigeria	Halwart - Farm Diversification	Training of enumerators on the socioeconomic questionnaires for respondents' survey	14	6	20
Nigeria	Halwart - Farm Diversification	Graduate student training on research design, sample-collection techniques, data analysis, and development of research plans on adaptive research platforms; research proposal development	3	4	7
Nigeria	Halwart - Farm Diversification	University of Ibadan survey enumerators' training on field-data collection procedure; familiarization with specific activity survey questionnaires, methodology, and expectations	6	2	8
Nigeria	Pincus - Nourishing Nations	Research-proposal development training of two MS students from Nigeria	1	1	2
Nigeria	Subasinghe - Lean Production Systems	Training on improving efficiency in the Nigeria aquaculture sector by employing Lean production systems	33	7	40
Nigeria	Pincus - Nourishing Nations	Training workshop on nutrition education, food safety, and safe fish handling and practices	27	95	122

Country of Training	Activity	Brief Purpose of Training	Number Trained		
			M	F	Total
Zambia	Ragsdale - FishFirst! Zambia	FishFirst! Zambia enumerator training workshop on implementing three data collection tools: 1) Women's Empowerment in Fisheries Index tool, 2) Minimum Dietary Diversity tool for Women of Reproductive Ages (18-49), and 3) the Post-Harvest Fish Loss Assessment for Small-Scale Fisheries tool.	9	8	17

Long-Term Trainings

The Fish Innovation Lab has 31 individuals/students (14 females and 17 males) who are currently enrolled in or have graduated from a bachelor's, master's, or PhD program receiving long-term training, mentorship, or apprenticeship in our aquaculture, fisheries, resilience, and food-system activities in FY 21, as shown in Table 3.

Table 3: Long-Term Trainings

PI and Student Number	Sex	University	Degree	Major	Program End Date	Degree Granted Yet?	Student's Home Country
Belton	M	Bangladesh Agricultural University	PhD	Aquaculture Systems and Development	2022/23	No	Bangladesh
Chadag 1	M	University of Ibadan	Master, Veterinary Public Health (MVPH)	Fish Epidemiology	2022/2023	No	Nigeria
Chadag 2	F	University of Ibadan	Master, Veterinary Public Health (MVPH)	Fish Epidemiology	2022/2023	No	Nigeria
Correa 1	M	Royal University of Phnom Penh	Master of Science (MS)	Center of Biodiversity Conservation Program	2023	No	Cambodia
Correa 2	F	Royal University of Phnom Penh	MS	Food Science and Technology	2023	No	Cambodia
Halwart 1	M	University of Ibadan	PhD	Agricultural Economics	2023	No	Nigeria
Halwart 2	F	University of Ibadan	PhD	Fisheries Management	2023	No	Nigeria
Halwart 3	M	Usmanu Danfodiyo University, Sokoto	MS	Fisheries Ecology	2021	No	Nigeria
Halwart 4	F	University of Ibadan	MS	Fish Nutrition	2022	No	Nigeria

PI and Student Number	Sex	University	Degree	Major	Program End Date	Degree Granted Yet?	Student's Home Country
Halwart 5	F	University of Ibadan	MS	Fish Nutrition	2022	No	Nigeria
Halwart 6	F	University of Ibadan	MS	Fish Nutrition	2022	No	Nigeria
Halwart 7	M	Federal University of Technology Owerri	MS	Fish Nutrition	2021	No	Nigeria
Halwart 8	M	University of Ibadan	MS	Fish Nutrition	2022	No	Nigeria
Hok	M	Royal University of Agriculture	PhD	Agricultural Science	TBD	No	Cambodia
Iannotti 1	M	Pwani University	NA – postdoc	NA – postdoc	NA – postdoc	NA – postdoc	Kenya
Iannotti 2	F	University of Rhode Island	PhD	Environment and Life Sciences	TBD	No	USA
Iannotti 3	F	Washington University in St Louis	NA – postdoc	NA – postdoc	NA – postdoc	NA – postdoc	USA
Iannotti 4	F	Washington University in St Louis	MPH	Global Health	2019	Yes	USA
McClanahan 1	F	University of Rhode Island	PhD	Biological and Environmental Sciences	2024	No	USA
Pincus 1	F	Mississippi State University	PhD	Food Science, Nutrition and Health Promotion – concentration Nutrition	2021	No	Nigeria
Pincus 2	F	University of Calabar	MS	Nutrition and Food Science	2022/2023	No	Nigeria
Pincus 3	M	University of Calabar	MS	Nutrition and Food Science	2021/2022	No	Nigeria
Ragsdale 1	M	University of Zambia	MS	Agricultural Economics	TBD	No	Zambia
Ragsdale 2	F	University of Zambia	MS	Human Nutrition	TBD	No	Zambia
Rice 1	F	University of Zambia	MS	Research Training	2022	No	Zambia
Sarder 1	M	Bangladesh Agricultural University	PhD	Fish Breeding and Biotechnology	2024	No	Bangladesh
Sarder 2	M	Bangladesh Agricultural University	M.S	Fish Breeding and Biotechnology	2021	No	Bangladesh

PI and Student Number	Sex	University	Degree	Major	Program End Date	Degree Granted Yet?	Student's Home Country
Sarder 3	M	Bangladesh Agricultural University	MS	Fish Breeding and Biotechnology	2021	No	Bangladesh
Sarder 4	M	Bangladesh Agricultural University	PhD	Fish Breeding and Biotechnology	2024	No	Bangladesh
Sarder 5	M	Bangladesh Agricultural University	MS	Fish Breeding and Biotechnology	2022	No	Bangladesh
Sarder 6	M	Bangladesh Agricultural University	PhD	Fish Breeding and Biotechnology	2024	No	Bangladesh

Implementation of Other Cross-Cutting Themes

The Fish Innovation Lab has four cross-cutting themes: gender equity and youth engagement, nutrition, resilience, and capacity development. The importance of integrating cross-cutting themes is gaining increasing acknowledgement within the broader Feed the Future Innovation Lab community. The Fish Innovation Lab participated in the Innovation Lab Community of Practice on cross-cutting themes (gender and capacity development). Fish Innovation Lab deputy director Elin Torell participated in the Community of Practice steering committee, and Fish Innovation Lab gender and youth equity specialists Kathleen Ragsdale and Mary Read-Wahidi engaged in the gender affinity group. FY 21 highlights related to capacity development were summarized above; highlights related to gender and youth, nutrition, and resilience are summarized below.

Gender Equity and Youth Engagement

The Fish Innovation Lab gender equity and youth engagement theme is led by experts Kathleen Ragsdale and Mary Read-Wahidi. They support subaward activities by providing overall guidance and individualized support. In FY 21, the gender and youth equity specialists implemented the online Gender Responsive Aquaculture/Fisheries Development Assessment (GRADA-FIL) to Fish Innovation Lab implementing partners and produced several technical reports, including

- GRADA-FIL Results at a Glance: Fish Innovation Lab Research. https://www.fishinnovationlab.msstate.edu/sites/www.fishinnovationlab.msstate.edu/files/2021-08/GRADA-FIL_Results%20at%20a%20Glance_2_FINAL.pdf
- GRADA-FIL Results at a Glance: Fish Innovation Lab Quick Start Successes and Challenges. https://www.fishinnovationlab.msstate.edu/sites/www.fishinnovationlab.msstate.edu/files/2021-03/GRADA-FIL%20Results%20at%20a%20Glance_1_Quick%20Start_03-08-21%20%283%29_FINAL.pdf

The Fish Innovation Lab collaborated on a series online courses led by the Soybean Innovation Lab. The first course called "How to Increase Your Gender Responsive Agricultural Development Capacity" is available online: https://www.tropicalsoybean.com/. This course featured input from Fish Innovation Lab ME Partners including Elin Torell, deputy director and human outcomes specialist, and Lora Iannotti, nutrition specialist. It also featured examples from the Fish Innovation Lab-supported Fish4Zambia Quick Start activity. The course had 220 enrollees and issued 45 certificates of completion between January 14, 2021 (launch date) and January 27, 2021. As of September 2021, the course has had 376 enrollees and issued 113 certificates of completion. The Fish Innovation Lab gender and youth equity specialists also began to develop three new online open access certificate courses:

- How to Build Your Own GRADA (Gender Responsive Agricultural Development Assessment)
- How to Plan and Conduct Gender Responsive Enumerator Trainings
- Gender and Resiliency

The gender and youth equity specialists contributed to several communications and outreach initiatives. These included collaborating across seven Innovation Labs to develop and submit a panel session abstract that was accepted for presentation at the CGIAR-supported Cultivating Equality Conference 2021: Advancing Gender Research in Agriculture and Food Systems. Other communication pieces include blog posts for Agrilinks and the Fish Innovation Lab website:

- "Advancing Gender-Responsive Aquaculture and Fisheries Development Starts with Identifying Common Gender Barriers" https://www.fishinnovationlab.msstate.edu/newsroom/2021/08/advancing-genderresponsive-aquaculture-and-fisheries-development-starts
- "Fish4Zambia: Research Among Men and Women Fishers, Processors, and Sellers". https://agrilinks.org/post/fish4zambia-research-among-men-and-women-fishers-processors-and-sellers
- "Gender Mainstreaming in Fisheries and Aquaculture Sectors" https://www.agrilinks.org/post/gender-mainstreaming-fisheries-and-aquaculture-sectors
- "Free Online Course Explains the Role of Gender in Agricultural Development" https://agrilinks.org/post/free-online-course-explains-role-gender-agricultural-development
- "Quick Start Projects Yield Lessons for Gender-Responsive Aquaculture and Fisheries Activities" https://www.fishinnovationlab.msstate.edu/newsroom/2021/03/quick-start-projects-yield-lessons-genderresponsive-aquaculture-and-fisheries
- "Addressing Inequalities at Home and Abroad: How the Gender Impacts Lab's Work Covers Continents" https://ssrc.msstate.edu/2020-annual-report/
- "Researchers Present at International Conference on Global Food Security" https://www.fishinnovationlab.msstate.edu/newsroom/2020/12/researchers-present-international-conference-global-food-security

Gender results associated with the Fish Innovation Lab research activities include:

- **FishFirst! Zambia** conducted a survey that included the novel "Post-Harvest Fish Loss Assessment for Small-scale Fisheries" (PHFL) tool to explore differences in postharvest loss experienced by lake fishers (predominantly male), shore fishers (predominantly female), fish processors (predominantly female), and fish sellers (predominantly female). The data will provide a better understanding of any inequalities that exist across the three different nodes of the small-scale fisheries value chain. The survey also included the adapted "Household Hunger Scale II," which was adapted to explore whether males and females experience food insecurity differently at the individual level and whether males and females perceive food insecurity differently at the household level. These gender-disaggregated results will allow the team to better tailor activities to address gender equity and related challenges.
- **The Aquaculture Diversification in Rural Communities activity** addressed gender disparities in resource use and access to nutrition, and it has the potential to bring multiple benefits, including higher fish and rice productivity and household incomes as well as positive nutritional outcomes. The activity addressed gender inequity through the collection and analysis of sex-disaggregated data and qualitative information to understand the roles and needs of women and men. Interventions are directed toward robust youth engagement in the aquaculture value chain, and they are tailored to ensure youth access to knowledge, information, and education related to productive land use, extension services, and mentorship.

- **The Sources of Fecal Pathogens activity** aimed to enroll women fish vendors at retail markets. Despite collecting samples from most of the major food markets in Dhaka City, the team was unable to find any women fish vendors. However, the team successfully engaged youth, as over 50% of the vendors are below 35 years of age. The team also found that many young adults are engaged in fish processing in the retail market. As the fish processing stations interact with consumers, it is one of the most vulnerable points of microbial contamination. Hence, training youth vendors and processors will make a significant impact on the safety and quality of fish for the consumers.
- The **Farming Insects** team's preliminary discussions with the aquaculture entrepreneurs in the two Nigerian pilot sites showed that most fish farmers are men, while more women are involved in processing and marketing of fish. The research team decided that all interested female fish farmers will participate in the activity, and they will be given equal voice to men.
- **Samaki Salama** conducted baseline data collection, which included a series of questions on differences in health and nutrition-related decision making between caregivers (predominantly female) and fishers (predominantly male). The data will provide a better understanding of any inequalities that exist in household-level decision making. This will allow the team to better tailor the intervention to address gaps and challenges. Both fathers and mothers of young children are targeted for the social marketing around the importance of fish nutrition and sustainable fisheries. Youth are also among the small-scale fishers and mothers of young children.
- **The Cryogenic Sperm Banking** team surveyed 46 fish-breeding and technology-adoption hatcheries in both public and private sectors in Mymensingh, Jashore, Faridpur, and Barishal regions. While over 30% of the hatchery operators are youth, the team did not find any female hatchery owners. However, the team prioritized selecting female and youth participants for the training workshops organized in the four regions.
- The **Cambodia Fisheries and Food Processing activity** is contributing indirectly to address gender inequalities in the fish value chain. The team implemented participatory information meetings and training workshops in villages along the Sre Ambel River. As a result of the process, the team selected 14 fishers and one Wildlife Conservation Society local staff member to participate in fisheries citizen science research. Although no women were selected to directly participate in data collection, the wives of some fishers took part in the citizen science training workshops together with their husbands.
- **The Coral Reef Fishery Sustainability activity** ensured that both women and men, young and old, were invited to inception meetings and engaged as community data collectors. All genders and age groups were invited to participate in participatory fisheries resource mapping, community literacy testing, and monthly fish-landing monitoring activities. The team also implemented survey sampling methods that aimed to reduce bias and reach both women and men.
- **Nourishing Nations** addressed gender inequity in the fish value chain by targeting fish processing, which is a women-dominated sector. As women (and men) involved in fish processing lack access to information and resources, the training program aims to provide fish processors with foundational knowledge about nutrition and food safety so that they may improve the quality of their products and thus improve the income generated from fish processing.
- Youth are important resource persons in the **Bighead Catfish activity**. Empowered and innovative youth are essential to the future of small-scale fisheries and aquaculture. Thus, it is crucial to understand how youth can engage with the sector to access decent and meaningful livelihood opportunities. Hence, the team strongly encouraged youth involvement in the implementation of different interventions.

Human Nutrition

Nutrition is an essential theme within the Fish Innovation Lab as both a cross-cutting issue and part of the human outcomes Area of Inquiry. One particular emphasis is identifying and supporting the most nutritionally vulnerable groups. Globally, evidence points to the first 1,000 days of life (from conception to a child's second birthday) for the highest risk of malnutrition and need for nutrient-dense animal source foods such as fish. Thus, the Fish Innovation Lab targets downstream access to fish foods for pregnant and lactating women, infants, and young children. Nutrition data sources (e.g., Demographic and Health Surveys, United Nations Children's Fund Multiple Indicator Cluster Surveys) were recommended to Fish Innovation Lab-funded activities to target the most vulnerable by sociodemographic and economic factors. Small-scale fisher households are among those at high risk and are a sample population across several Fish Innovation Lab activities. Lora Iannotti at WUSTL provides expertise and leadership for the nutrition theme in the Fish Innovation Lab. In FY 21, Iannotti and her colleague Elizabeth Hahn supported the ME by reviewing proposals and discussing opportunities for nutrition-sensitive inputs across Fish Innovation Lab-funded activities. Iannotti reached out to the PIs to assess interest levels. Together with Hahn she met with teams working in Cambodia, Bangladesh, Nigeria, and Zambia. Relevant nutrition resources and inputs (e.g., survey development, proposal inputs, relevant literature, and relevant nutrition data) were provided.

The Fish Innovation Lab is in the process of developing an online course on fish and nutrition. Several meetings were held with Glenn Ricci, Fish Innovation Lab capacity development specialist. Iannotti and her colleague Vanessa Chen are developing the learning objectives, modules, and case studies.

A meeting between the Fish Innovation Lab, WorldFish, and Advancing Nutrition was held to plan for dissemination efforts around fish in human nutrition, highlighting Fish Innovation Lab activities. Panels and presentations are planned for the Agriculture, Nutrition and Health Academy (July 2021); World Food Prize Foundation's 2021 Borlaug International Dialogue (October 2021); Nutrition and Growth Conference (December 2021); and the International Congress on Nutrition (December 2022).

Iannotti contributed to communication efforts related to nutrition, including the article: "More Bites of Fish Recommended in the Dietary Guidelines for Americans 2020-2025" and brief stories on fish recipes. The Fish Innovation Lab was also featured in a podcast on fisheries and food policy organized by the Duke University World Food Policy Center: https://wfpc.sanford.duke.edu/podcasts/fisheries-need-stronger-role-food-policy-and-food-security-planning

Activity-specific nutrition results include:

- **The Aquaculture Diversification in Rural Communities activity** recognizes that the contribution of fish to household food and nutrition security depends upon availability, access, and cultural and personal preferences. The activity goal and objectives ensure that improved access to fish-based sources of nutrition for the poorest and most vulnerable groups are explored with reference to integrated rice-fish farming and the accompanying technical and policy innovations needed to ensure that fish farming actively contributes to meeting Nigeria's food and nutrition needs.
- The **Sources of Fecal Pathogens activity** works with tilapia and pangas, two of the most available and affordable cultured fish varieties in Bangladesh. In FY 21, the team conducted an observational study to understand the level of microbial contamination of fish for human consumption. The team is assessing behavioral practices of fish value chain actors, including fish vendors, processors, and consumers. One of the assessment components is fish consumption patterns at the household level and the factors that contribute to decisions related to fish consumption. The assessment will identify barriers to delivering microbiologically safe fish to the poorest and most vulnerable consumers.

- **Samaki Salama** is promoting dietary diversity and increased consumption of fish among vulnerable groups, including infants and young children and women of reproductive age. An anticipated increase in catch of mature fish associated with the modified traps promoted through the activity should improve incomes and access to fish and other higher quality foods. As part of the Samaki Salama activity, Iannotti held regular biweekly meetings with USAID Advancing Nutrition to develop social marketing materials that could be used more widely by Fish Innovation Lab grantees. Relatedly, Iannotti and postdoc Ivy Blackmore are working with a USAID project led by John Snow International to inform the Samaki Salama marketing healthy diets activity.
- **Cambodia Fisheries and Food Processing** collected samples of five fish species for nutrient composition analyses. These data will be used to inform the nutritional profile of the most harvested and consumed fish species. The collected samples will also show to what extent the nutrient content changes during food processing.
- **The Coral Reef Fishery Sustainability activity** gathered information via socioeconomic surveys, which will assist in understanding the rate of fish consumption within the surveyed households in each site and within a given time. Preliminary results indicate that over 50% of households consume fish more than once a day. The ongoing community data collection will help create awareness of the types and quantity of fish caught and landed in each site. This will generate data for discussion and recommendations for inclusion in beach management unit bylaws, developed to conserve species that are critical to the ecosystem and are at risk of decline or extinction.
- **Nourishing Nations** works to strengthen capacity among women and youth fish processors in Delta State, Nigeria to produce high quality, safe, and nutritious processed fish products for local consumption. The activity also educates women and youth fish processors in Delta State about the benefit of fish in human diets, and it is developing a low-literacy tool to help processors better market their product. Trainings conducted in FY 21 have helped improve processors' knowledge of nutrition and the importance of fish and fish products in human diets. They are designed to improve the quality of fish products rather than access. By improving the quality and safety of fish products, the team hopes to address reasons for malnutrition beyond dietary quality, such as the nutritional impact of food-related illnesses. Hence, the trainings exposed some of the detrimental practices in fish processing and alternate ways of handling fish to yield quality products. Both the aquaculture and fishery operators gained knowledge of various ways fish could be contaminated during processing and safer ways to process and dry their fish. They were also exposed to the qualities that would make their processed fish products acceptable in better markets. The team developed a nutrition curriculum and pre- and post-program quizzes to test information acquisition and retention. The team also developed and provided participants with incentives such as aprons, bracelets, and fans that all included messages to encourage fish consumption.
- **The Vaccines for Tilapia activity** addresses aquaculture production, where disease management is expected to improve aquaculture yield. Improved productivity may also reduce the pricing of fish, thus benefiting vulnerable individuals (children and women). This will in turn lead to improved revenue, nutrition, and well-being.

Resilience of Value Chains/Households

Improving resilience in aquaculture and fisheries relies upon strengthening adaptive capacity and reducing the risks of recurrent crises, shocks, and stresses. Joanna Springer from RTI International provides expertise in resilience for the Fish Innovation Lab and the ME Partners. She identified four subaward activities that address resilience at the systems level. Ecologically, resilience is addressed for fisheries in Cambodia and Kenya, and in terms of biosecurity, resilience is an activity theme for aquaculture systems in Nigeria and Bangladesh. Springer wrote a blog post describing how Fish Innovation Lab activities are contributing to system resilience and the importance of

measuring shocks and stress trends when designing and piloting development interventions in the aquaculture and fishery sectors.

Additionally, Springer developed a training on USAID's resilience framework tailored for aquaculture and fisheries, with an emphasis on systems level resilience. The training includes an example set of aquaculture and fisheries system resilience capacities for activities to refer to when applying their results and findings to USAID's resilience approach. The interactive training is four modules long and includes one in-depth exercise on system resilience built around a hypothetical case study. The goal of the training is for ME Partners and PIs to align their resilience work with USAID's framework and to grow their awareness of resilience. The resilience training will be implemented in Quarter 1 of FY 22 and will be followed by interactive learning activities led by teams that champion applying a resilience focus to their activity reporting, scaling, and adoption plans. Springer also advised the Fish Innovation Lab on the climate resilience component of the Initial Environmental Examination and Environmental Management and Mitigation Plan to identify key activities for further consultation to align with USAID's climate risk management framework.

Activity-related achievements related to climate resilience include:

- **The Coral Reef Fishery Sustainability activity** is supporting fishing livelihoods in climate refugia that are predicted to be less exposed to climate change impacts. The livelihood improvements resulting from the activity will therefore be sustainable in the face of climate change because coral reefs in the climate refugia are unlikely to be affected by rising sea temperatures.
- **The Samaki Salama activity** is working to make current livelihoods more resistant to climate change by modifying a fishing gear to target a climate-resilient fish species (rabbitfish) and reduce the catch of juveniles. Fisher livelihoods can therefore be sustained in the face of rising sea temperatures since rabbitfish depend more on seagrasses than coral reefs.
- **The Harnessing Machine Learning** team added a module on climate risk, exposure, and adaptation to their farm-level survey (720 farming households) as well as their community survey (7 districts, 37 communities) conducted in December 2020–January 2021. The activity will train local extension agents on action research, with the potential to continue tracking climate risk, exposure, and adaptation. The extension agents could use the information gleaned about climate effects to prepare new digital or in-person trainings on climate adaptation and disaster preparedness techniques.
- **The Aquaculture Diversification in Rural Communities activity** is using a technology with potential to contribute to biodiversity conservation and make efficient use of scarce land and water resources, and generally minimize the environmental impacts of livelihoods.

Innovation Transfer and Scaling Partnership

Innovation Transfer

As presented in the country summary (Table 1) and in Appendix 2, the Fish Innovation Lab has 25 innovations that are at different stages of research, field testing, transfer, and uptake.

Innovations **under research** include

- Fish feed development (Aquaculture Diversification in Rural Communities). Development of inexpensive and good quality fish feed using locally available ingredients.
- Technology for fish seed production within integrated rice-fish farming systems (Aquaculture Diversification in Rural Communities). This will lead to the provision of good employment opportunities, especially for youth and women, in the areas of hatchery operation and seed

production, and it will support availability of good fish seed to farmers for increased yield, food security, and improved income.

- Feed nutrition and feed development under integrated rice-fish farming (Aquaculture Diversification in Rural Communities). Innovative template for the use of locally produced feed ingredients ensuring the sustainability of production and leading to increased employment.
- Rice-fish farming (Aquaculture Diversification in Rural Communities). The process of successfully introducing fish into rice fields for optimum production output/yield and resource-use efficiency.
- Improvement of seeds and broods of experimental fish (Cryogenic Sperm Banking). Quality of seeds of both Indian major carps and exotic carps produced by cryopreserved sperm will be improved, and the hatchery operators will be able to produce good quality broods with faster growth.
- Sensory Evaluation of Fish Product training (Cambodian Fisheries and Food Processing). Video to train personnel in sensory evaluation technique for fish products to provide the knowledge base for product research and development.
- Sre Ambel River Fisheries application (Cambodian Fisheries and Food Processing). Computer application to analyze and visualize data on the Sre Ambel River fisheries developed in the R Shiny program.
- Insects as fishmeal replacement (Farming Insects in Nigeria). Engaging local stakeholders to develop small-scale backyard black soldier fly and fish farms to support both subsistence and income generation.
- Fishing gear modification (Samaki Salama). Traps are modified through the addition of escape gaps to improve harvest efficiency and promote sustainable fish populations.
- Lean management tools (Lean Production Systems). Designed to identify inefficiencies in the aquaculture value chain for improved practices and productivity.

Technologies that are **under field testing** include

- Production of quality fish seeds and broods using cryopreserved sperm (Cryogenic Sperm Banking). Seeds of three Indian major carps and exotic carps are being produced using cryopreserved sperm in government and private hatcheries for quality improvement.
- Standard operating procedures on fish sampling techniques for disease diagnostics (Improving Biosecurity). Seven discrete standard operating procedures were developed and contextualized for specific uses related to collecting and analyzing biological samples from catfish and tilapia production systems.
- Data visualization tools for fishpond identification (Harnessing Machine Learning). Techniques for extracting information on aquaculture pond location, area, and type from remotely sensed images using machine learning algorithms for stakeholder availability.
- Nutrition social marketing (Samaki Salama). Social marketing campaign utilizing multiple platforms targeting various stakeholders.
- Fisheries harvest and recovery monitoring protocol (Cambodian Fisheries and Food Processing). A protocol to document, visualize, and analyze artisanal fisheries data implemented through a participatory approach for successful transfer of the program to the local Community Fisheries Council upon activity completion.
- Training course for fish processors on nutrition and food safety and fish processing/handling (Nourishing Nations). Marketing strategy that incorporates nutrition information as a new method to boost sales among potential customers.

- Atlan Collect application (Coral Reef Fishery Sustainability). This application, installed on mobile phones and laptops, is being used by community data collectors and local fisheries to monitor fish landings.

Innovations that have reached the point of **technology transfer** include

- Fish epidemiology and health economics survey tool (Improving Biosecurity). Online Android mobile data collection tool for farmer surveys to generate data on fish epidemiology and health economics.
- Extension video trainings (Harnessing Machine Learning). A dedicated Bangla language YouTube channel established to build capacity for the adoption of new technologies and speed up the uptake of improved practices among farmers and other value chain actors.

Scaling Partnerships

As part of an agreement between the Government of Nigeria and WorldFish on transfer of Genetically Improved Farmed Tilapia (GIFT) from Malaysia to Nigeria, a new local partnership with the private sector to set up a GIFT multiplication and seed dissemination program in Nigeria is being developed under a Bill and Melinda Gates Foundation project. Capacity development of private sector partners on biosecurity, including sampling and testing for diseases, is being supported under this project, which is connected with the Fish Innovation Lab-funded Improving Biosecurity activity.

Environmental Management and Mitigation Plan

The Fish Innovation Lab Environmental Management and Mitigation Plan (EMMP) was originally approved by the Bureau of Resilience and Food Security environmental officer on July 8, 2019. After completing the competitive awards process and commissioning the final awards, the Fish Innovation Lab supported USAID in revising the Initial Environmental Examination. The team also revised the EMMP, which included addition of climate risk screening and management. Both documents were submitted and approved in FY 21.

Environmental Management and Mitigation Reports are presented in Appendix 4, and Climate Risk Screening and Management Reports are presented in Appendix 5.

Open Data Management Plan

The Fish Innovation Lab ME worked with all research teams to explain, advise, and support the data management plan. All teams submit their data upon completion of data collection, analysis, and publication of results. Teams use Piestar as the Fish Innovation Lab's data management platform for information management, monitoring, data visualization, and routine reporting, including updates to the to the USAID Development Experience Clearinghouse and the Development Data Library.

Management Entity and Management Entity Partner Activities

The Fish Innovation Lab ME implements its research portfolio to achieve knowledge and technology adoption, scaling, and impact. The Fish Innovation Lab launched a competitive request for applications in April 2019. After screening and reviewing the 243 concept notes received, the Fish Innovation Lab invited 41 teams to submit full proposals. Thirteen research-for-development activities were awarded in FY 20, and six new commissioned studies were awarded in FY 21. This section describes the activities the ME implemented in FY 21 to support the new and ongoing research activities.

Support the competitively awarded Fish Innovation Lab research-for-development activities

In FY 21, the Fish Innovation Lab ME and its partners provided technical assistance to the funded research-for-development activities through the regional coordinators and specialists as well as the cross-cutting theme specialists. The ME conducted virtual trainings on finance and administration; communications; and monitoring, evaluation, and learning for the new grantees. Upon request, the cross-cutting theme and country specialists reviewed and provided feedback on research protocols, survey tools, and the development of capacity-building strategies. The ME also supported the sharing of lessons learned via blogs, success stories, and joint conference and workshop panels. The country coordinators and specialists met regularly with in-country partners and provided technical support to activity implementation.

The Fish Innovation Lab ME maintained communication with the ME Partners via monthly virtual ME partner meetings. These meetings included a mix of activity administration and technical updates, and they provided a forum for quick updates and sharing of lessons learned. When deemed necessary, the ME also conducted individual virtual meetings with PIs as needed to brainstorm and problem solve.

Early in FY 21, the ME organized a virtual meeting to showcase the results and impacts of the Fish Innovation Lab Quick Start activities. The Fish Innovation Lab ME also worked with the Fish Innovation Lab AOR to identify opportunities to engage with USAID Missions, including the dissemination of findings and accomplishments. A virtual annual meeting was conducted in August 2021; it included the Fish Innovation Lab ME, ME Partners, EAB, AOR, and activity PIs.

Commission or competitively award complementary research studies

In FY 21, the Fish Innovation Lab commissioned six activities that were designed to complement ongoing work, foster strategic partnerships, and address the Fish Innovation Lab theory of change. The six research activities (presented in Objectives 1-3) allowed the Fish Innovation Lab to expand its work to Ghana and Malawi. They also enabled the Fish Innovation Lab to initiate a new collaboration with the Farmer-to-Farmer Program.

Implement Knowledge Management Plan

The Fish Innovation Lab ME implemented several internal and external communications activities to 1) continue building awareness of the lab and its research results and 2) facilitate internal communication among new and existing stakeholders to drive learning and networking (see Communications section below for full details).

Monitoring, evaluating, and learning from research findings

The Fish Innovation Lab ME ensures accountability for implementation of the Fish Innovation Lab research portfolio using the Fish Innovation Lab monitoring, evaluation, and learning (MEL) plan, which was approved in March 2019. In FY 21, ME Partner RTI International coordinated Fish Innovation Lab MEL activities described below.

Indicators: All Fish Innovation Lab grantees completed online trainings on indicator target setting and designing custom indicators, and they completed target-setting forms in Piestar. The MEL advisor followed up with each team to finalize their indicators, targets, and data-management practices for inclusion in a revised MEL plan. This included targets for the six activities that began mid-FY 21. The revised and updated MEL plan, including updated performance indicator reference sheets, target descriptions for each subaward, and actuals to date will be submitted for USAID's review and approval as a follow-up to the submission of the annual report in Quarter 1 of FY 22.

Learning agenda: The Fish Innovation Lab has developed a learning agenda that has four primary purposes: 1) Facilitate sharing of best practices and findings related to cross-cutting themes and other questions prioritized by activities; 2) Promote best development practices, particularly related to gender and youth inclusion, capacity building, resilience, and nutrition outcomes; 3) Provide a

structure for sustained engagement between teams to promote collaboration; and 4) Harvest and communicate lessons learned related to development best practices. In FY 21, the ME organized two separate learning agenda meetings with the Africa aquaculture group, the Asia aquaculture group, and the Africa and Asia fisheries group. The virtual semiannual regional learning meetings were designed to allow the grantees to share lessons learned related to the Fish Innovation Lab areas of inquiry and strengthen integration of cross-cutting themes into programming.

The learning event in February 2021 concentrated on questions related to COVID-19-related adaptations. Teams discussed approaches to hands-on training to respond to COVID-19 restrictions, effective ways for activities to leverage and strengthen local expertise to mitigate effects of COVID-19 travel restrictions, tools and methods to disseminate new technologies to stakeholders, and methods and approaches for scaling and integrating networks during COVID-19. The learning event in July 2021 concentrated on questions related to women and youth engagement. Discussions focused on effective ways for activities to leverage local partners and NGOs to reach vulnerable women, how activities are making a business or career case to youth to incentivize sustained engagement in training, and successful strategies for activity teams and extension workers to reach women doing household-level aquaculture. The meetings included formal presentations, facilitated dialogue, and group discussions as well the development of next steps to infuse lessons learned into their interventions.

Research strategy: The research strategy, distinct from the learning agenda, lays out the key research questions that will be addressed across regions and impact pathways by subaward research findings and development outcomes. In early FY 21, Fish Innovation Lab research award teams, the ME Partners, and the EAB deliberated upon a set of 13 possible research questions that cut across multiple teams. While there was a consensus that the research strategy questions have merit and are relevant to the Fish Innovation Lab theory of change and funded research activities, three priority questions were identified for their relevance across multiple research activities/countries and inclusion of some of the narrower questions:

1. How can improved technologies and practices identified in the Fish Innovation Lab be effectively promoted for adoption by aquaculture producers and hatchery owners? *(Area of Inquiry 1)*
2. How can improved technologies and practices identified in the Fish Innovation Lab be incentivized for adoption to mitigate pre- and postharvest losses in aquaculture and fisheries? *(Area of Inquiry 2)*
3. How can increased availability through production and access to fish across the value chain address barriers to food, nutrition, and women's economic opportunity? *(Area of Inquiry 3)*

During the annual meeting, the ME organized a group session where the research teams identified which research strategy questions they were interested in. They also developed simple action plans for how to tackle the questions and present results in FY 22.

Management Entity – MSU

The ME led and supported the Fish Innovation Lab management and research-for-development activities in a comprehensive manner. Summarized activities of each member are highlighted below.

Mark Lawrence provided direction and oversight for all Fish Innovation Lab activities. Lawrence coordinated the Fish Innovation Lab ME and ME Partners. He served as the primary contact for the Fish Innovation Lab AOR and represented the Fish Innovation Lab at meetings and activities. Lawrence facilitated collaboration with current and potential research partners. The following meetings and activities were attended:

1. Participated in Feed the Future Innovation Labs Community of Practice on Cross-Cutting Themes events and workshops (November 2020, December 2020, April 2021, and July 2021)
2. Participated in Innovation Lab Directors quarterly meetings (November 2020, February 2021, April 2021, and July 2021)
3. Conducted a meeting with USAID Malawi to provide an update on Fish Innovation Lab activities and receive an update on the response to the Epizootic Ulcerative Syndrome outbreak with Shivaun Leonard and Bruce Sosola (November 2020)
4. Held meetings to discuss potential Fish Innovation Lab participation in WorldFish project on fish powder to improve nutrition in India with Shivaun Leonard and Shakuntala Thilsted (November 2020, December 2020, and May 2021)
5. Participated in discussions with USAID Bureau for Development, Democracy, and Innovation on collaborations to advance distant water fishing research with Shivaun Leonard and Heidi Schuttenberg (February and March 2021)
6. Participated in six WorldFish Learning Sessions for Bill and Melinda Gates Foundation-funded activities in Bangladesh and Nigeria (March, April, and May 2021)
7. Organized a Fish Innovation Lab response to RFI no. 72047221RFI00001 USAID/Timor-Leste's Nutritious Agriculture Market Systems activity (April 2021)
8. Organized discussions on potential Fish Innovation Lab activities to support Nigeria inland fisheries with Rohana Subasinghe, Sunil Siriwardena, Sandra Correa, and Peter Allen (April and May 2021)
9. Participated in introduction of the Product Life Cycle to the Fish Innovation Lab with Shivaun Leonard and James Gaffney (May 2021)
10. Participated in Innovation Lab Directors Council Regional Meeting (virtual; May 2021)
11. Held discussions on potential collaboration between Fish Innovation Lab and Norad to support WorldFish initiative for aquaculture feeds development in Africa with Rodrigue Yossa and Magnus Petersen (July 2021)
12. Discussed continued collaborations between Fish Innovation Lab and WorldFish with Faridah Ibrahim (July 2021)
13. Facilitated a meeting between WorldFish Zambia scientist Rose Komugisha Basiita and Zambezi District fisheries and livestock coordinator Moses Chama (August 2021)
14. Facilitated collaborations with WorldFish to share WorldFish resource materials on the Fish Innovation Lab Resource Center web page with Michael Phillips and Alexandra Pounds (ThinkAqua) (August and September 2021)
15. Participated in a panel discussion on USAID funding for the University of Sydney (August 2021)
16. Participated in the Innovation Lab Directors Council annual meeting and gave a presentation on the importance of fish as an animal-source food (September 2021)
17. Conducted various check-in meetings with project team leaders throughout the year addressing administrative needs, programmatic adjustments, and/or financial issues

Lawrence also serves on the Technical Working Group for the United Nations Food and Agriculture Organization program "Progressive Management Pathway for Improving Aquaculture Biosecurity". He participated in Technical Working Group meetings in FY 21 and is collaborating with Melba Reantaso and Madan Dey to organize a technical committee for initiating Bangladesh as a pilot country for the program. Lawrence was a speaker for a Food and Agriculture Organization webinar entitled "Understanding AMR in Aquaculture" on April 13-14, 2021.

Peter Allen assisted the Fish Innovation Lab ME as needed to achieve Fish Innovation Lab goals by facilitating activities. He attended virtual meetings and served as a moderator. This included participating and moderating learning meetings for the Asia aquaculture, Africa aquaculture, and fisheries learning agenda groups. Allen assisted with Fish Innovation Lab Aquaculture and Fisheries Resource Center creation, and he reviewed documents and provided technical expertise as needed.

Jared Dees worked with all competitively awarded activities to issue subawards, which required review to ensure financial compliance with USAID and MSU rules and regulations, establishment of milestones, and coordinating subaward management with the MSU Office of Sponsored Projects. Dees also managed all subawards issued to ME Partners, and he supported Fish Innovation Lab virtual meetings.

Alaina Dismukes supported Fish Innovation Lab communications with a focus on activity-level communications (see Communications below).

Shauncey Hill assisted the director and ME Partners in planning, organizing, and managing Fish Innovation Lab activities. She oversaw establishment of subawards for competitively awarded activities, ensured compliance with USAID and MSU rules and regulations, and coordinated programmatic support for the activities.

Kathleen Ragsdale and **Mary Read-Wahidi** supported the Fish Innovation Lab as the gender and youth equity specialist and co-specialist. In addition to implementing the online Gender Responsive Aquaculture/Fisheries Development Assessment (GRADA-FIL) to Fish Innovation Lab implementing partners via Qualtrics, they are currently developing a GRADA-FIL brief that focuses on results from the FY 20 competitively awarded activities and the FY 21 commissioned activities. To achieve implementation, the GRADA-FIL data was cleaned, and descriptive analyses conducted. Two 2-page “GRADA-FIL Results at a Glance” briefs based on the Fish Innovation Lab results were produced in March 2021 and August 2021.

Stephen Reichley attended virtual meetings and served as a moderator. This included participating and moderating learning meetings for the Asia aquaculture, Africa aquaculture, and fisheries groups. He provided technical expertise as needed. Reichley facilitated the creation of the Fish Innovation Lab Aquaculture and Fisheries Resource Center on the website. He supported document formation and review for reports, plans, etc.

Laura Zseleczky supported the Fish Innovation Lab extensively through internal and external communications (see Communications below).

ME Partner – URI

During FY 21, the URI ME Partner team (Elin Torell, Austin Humphries, Glenn Ricci, Karen Kent, Laura Skrobe, and Rachel Cohn) continued to support the implementation of the Fish Innovation Lab-funded research-for-development activities as regional and cross-cutting theme specialists.

- Austin Humphries monitored and assisted all the East Africa activity teams in accomplishing their goals for this period of performance, including COVID-19 modifications. He has also taken on three new activities in East Africa.
- Glenn Ricci developed a Fish Innovation Lab student survey, which is the first step towards creating a Fish Innovation Lab student network. He is collaborating with Lora Iannotti to develop an online nutrition course.
- Karen Kent coordinated with Sunil Siriwardena on the West Africa activities.
- Elin Torell led the development of a research strategy and supported the ME in organizing research strategy, ME Partner, and ME core team meetings. This included the virtual three-day annual meeting. She also supported Fish Innovation Lab strategies on development of associate awards and selection of six commissioned activities awarded in FY 21, out of

which two are led by URI (Mike Rice, Brietta Oaks). Torell supported the FishFirst! Zambia activity in developing a postharvest loss research protocol.

- In collaboration with Laura Skrobe, Torell also supported the development of Fish Innovation Lab documents and blogs, including a summary document about lessons learned from implementing the Quick Start activities. Torell represented the Fish Innovation Lab in the Innovation Lab cross-cutting theme community of practice, where she serves as a steering committee member.
- Humphries and Torell supported the USAID learning agenda on fisheries distant water fleets (DWFs) by developing a plan for how to investigate transparency and sustainability in licensing and supply chains associated with DWF activity in national exclusive economic zones. This work led to the Fish Innovation Lab's first buy-in award of $200,000, which was finalized on September 29, 2021.
- One notable achievement in FY 21 is that URI led the development of a small research award that is implemented in Ghana. The Micronutrient Impact of Oysters activity is the first Fish Innovation Lab activity approved for implementation by USAID Ghana.

ME Partner – RTI International

RTI International supported the Fish Innovation Lab team in monitoring, evaluation, and learning (Rebecca Jeudin) as well as resilience (Joanna Springer). Notable FY 21 activities included:

- Nine interactive learning sessions were held: three in October to establish the learning agenda, three in February, and three in July to provide opportunities for Fish Innovation Lab researchers to connect with one another. Fish Innovation Lab subwardees were divided into three learning teams: those focused on aquaculture research in Africa, those focused on fisheries research, and those focused on aquaculture research in Asia. Three learning themes were discussed in FY 21: COVID-19, women and youth engagement, and stakeholder engagement. Each team established specific subquestions under the learning themes during the October meetings. They met in February to present and discuss their progress around the first theme, adaptations due to COVID-19, and they met in July to discuss their progress around the second and third themes, women and youth engagement and stakeholder engagement.
- FY 21 indicator and narrative reporting was completed through the new Development Information System in addition to the Research Rack-Up reporting. Rebecca Jeudin also developed data entry videos instructing subawardees on proper reporting for the indicators and short-term training information through Piestar.
- Joanna Springer provided additional support to the Fish Innovation Lab through the resilience cross-cutting theme by publishing a blog, "Building Resilience of Fishery and Aquaculture Systems", which was highlighted in the Agrilinks newsletter in December 2020. She developed a resilience cross-cutting theme scope that detailed how she will support the Fish Innovation Lab to provide awareness and training to subawardees on resilience as well as to conduct more focused resilience work within a few of the activities. Virtual communications training for Fish Innovation Lab subawardees was finalized in November 2020 with support from RTI International and made available on Piestar with best practices, tips, and tricks on good communications.
- Springer developed a training on USAID's resilience framework tailored for aquaculture and fisheries, with an emphasis on the systems level. Springer developed a set of aquaculture and fisheries system resilience capacities for activities to refer to when applying their results and findings to USAID's resilience approach. Springer also provided advice on the climate resilience component of the Fish Innovation Lab Initial Environmental Examination and Environmental Mitigation and Management Plan to identify key activities for further consultation to align with USAID's climate risk management framework.

- Rebecca Jeudin took over as the MEL lead from Joanna Springer in March 2021.

ME Partner – TSU

Madan Dey coordinated various activities for the Fish Innovation Lab in Bangladesh and collaborated with the Asia regional coordinator, M. Gulam Hussain. During this reporting period, TSU conducted the following activities:

- Contributed to the development of the 8th Five Year Plan of the Government of Bangladesh (national plan), establishing stronger linkages between the Fish Innovation Lab and the Government of Bangladesh priorities.
- Contributed to the successful initiation of five Fish Innovation Lab activities in Asia.
- Informed the ME about issues and priorities from aquaculture and fisheries in Bangladesh and Cambodia, including keeping the ME abreast of COVID-19-related issues.
- Prepared and submitted monthly, semi-annual, and annual progress reports, including any other technical reports assigned by the ME for Bangladesh and Cambodia.

ME Partner – WUSTL

As a Fish Innovation Lab ME Partner, Lora Iannotti primarily provided technical inputs regarding nutrition and food security, a cross-cutting theme of the Fish Innovation Lab activities. During FY 21, she supported the ME in the following ways:

- Iannotti regularly attended and participated in calls convened for the Fish Innovation Lab ME. She provided brief reports of progress made for activities under the nutrition cross-cutting theme.
- Iannotti and Elizabeth Hahn reviewed the activity proposals and met with Mark Lawrence and Elin Torell to discuss opportunities for nutrition-sensitive inputs across Fish Innovation Lab activities. After specific activities were identified, Iannotti reached out to the PIs to assess interest levels. Together with Hahn, she met with teams from activities in Cambodia, Bangladesh, Nigeria, and Zambia. Relevant nutrition resources and inputs (e.g., survey development, proposal inputs) were provided. Ongoing nutrition inputs were made as PI on the Samaki Salama activity.
- Iannotti contributed to communication efforts of the Fish Innovation Lab related to nutrition during FY 21, including the article “More Bites of Fish Recommended in the Dietary Guidelines for Americans 2020-2025” as well as brief stories on fish recipes.
- Panels and presentations are planned for the Agriculture, Nutrition and Health Academy (July 2021); World Food Prize Foundation’s 2021 Borlaug International Dialogue (October 2021); Nutrition and Growth Conference (December 2021); and the International Congress on Nutrition (December 2022).
- Iannotti held regular biweekly meetings with USAID Advancing Nutrition to develop social marketing for Samaki Salama with a goal towards adapting the social marketing approach to other Fish Innovation Lab activities. Relatedly, Iannotti and postdoc Ivy Blackmore are working with the USAID-John Snow International project to inform their marketing healthy diets activity. The “Aquatic Animal Foods for Nutrition Security and Child Health” manuscript was submitted to *Food & Nutrition Bulletin*, and Iannotti and colleagues have now responded to the first round of comments by reviewers in the revise and resubmit phase. Iannotti has had several meetings with Glenn Ricci, Fish Innovation Lab capacity development specialist, to initiate collaboration on development of a Fish Innovation Lab nutrition course. Iannotti and her colleague Vanessa Chen are developing the learning objectives, modules, and case studies.

Regional Coordinators and Regional Specialists

The three regional coordinators (M. Gulam Hussain, Andrew Wamukota, and Sunil Siriwardena) and regional specialists (Madan Dey, Austin Humphries, and Karen Kent) supported Fish Innovation Lab research activities in their respective regions. The regional teams are responsible for coordinating, monitoring, and technically advising all research activities by the Fish Innovation Lab in their respective regions. The coordinators were particularly valuable this year as a critical link between the Fish Innovation Lab ME and the research teams during times of restricted international travel due to COVID-19. FY 21 activity highlights include:

1. **Supported Fish Innovation Lab-funded research activities**. The Asia regional coordinator made several field visits to Fish Innovation Lab-funded activity sites in Bangladesh and regularly contacted all lead/country PIs in Bangladesh and Cambodia via email and phone. Hussain provided aquaculture/fisheries support to teams in both Bangladesh and Cambodia, which included discussions regarding possible adaptation measures and resilience related to the COVID-19 pandemic. The East Africa team communicated with subawardees in Kenya and Zambia monthly, and the West Africa team continued supporting the subawardees in Nigeria and the new team in Ghana.
2. **Connected with local stakeholders**. The East Africa team had engaging discussions with the Kenya Fisheries Service, Kenya Wildlife Service, and leaders and fishers in multiple beach management units along the coast in Kilifi and Kwale Counties. The Asia coordinator communicated regularly with in-country public sector organizations and institutions, such as the Department of Fisheries, the Bangladesh Fisheries Research Institute, universities, WorldFish, NGOs, and other stakeholders. The Asia coordinator kept the Fish Innovation Lab abreast of issues and priorities related to aquaculture and fisheries in Bangladesh and Cambodia. The West Africa coordinator facilitated connections between Fish Innovation Lab activities and local aquaculture producer organizations. He also connected the Fish Innovation Lab with the broader WorldFish activities in Nigeria.
3. **Engaged in broader stakeholder outreach**. All of the coordinators participated in local meetings and workshops, where they represented the Fish Innovation Lab and made connections to local stakeholders and programs.
4. **Acted as members of the Fish Innovation Lab ME Partner team**. As ME Partners, the regional coordinators and specialists attended monthly ME Partner virtual meetings, learning and research agenda sessions, the annual meeting, and other meetings. They prepared and submitted monthly, semiannual, and annual progress reports as well as other technical reports assigned by the Fish Innovation Lab ME.
5. Andrew Wamukota, East Africa coordinator, provided **technical assistance** to the development of Institutional Review Board protocols and survey instruments implemented in Kenya.
6. **Produced technical reports and publications** relevant to the region. M. Gulam Hussain authored two peer-reviewed publications:

   Hussain, M.G. (2021). Biological diversity status of fish genetic resources at Tanguar Haor Wetland in Bangladesh. *Bangladesh Maritime Journal*, *5*(1).

   AftabUddin, S., Hussain, M. G., Al, M. A., Failler, P., & Drakeford, B. M. (2021). On the potential and constraints of mariculture development in Bangladesh. *Aquaculture International*, *29*. https://doi.org/10.1007/s10499-020-00643-9

Communications

In FY 21, the Fish Innovation Lab ME implemented several internal and external communications activities connected to its Knowledge Management Plan:

Internal Communications

1. New stakeholders and subawardees were oriented to the communications strategy and expectations, branding requirements, and ethical standards for photography and videography. A communications training module in Piestar was introduced.
2. Virtual workspaces were facilitated and managed for internal communication and teambuilding.
3. Digital communications were used to drive awareness of the Fish Innovation Lab brand and resources and to drive organization of content on platforms.

External Communications

1. Executive summaries from all Quick Start activities were developed to be included in the Fish Innovation Lab promotional toolkit. Videos of Quick Start presentations to the EAB were posted on the website.
2. Five Fish Innovation Lab newsletters were distributed.
3. Lessons learned from the Quick Start activities were communicated via print and digital media.
4. Materials such as success stories and briefs were developed and launched to showcase methods, technologies, and activities' progress.
5. Key milestones were amplified via press releases, events, social media, website, and other channels.
6. An overview video about the Fish Innovation Lab was developed.
7. USAID-led learning and sharing opportunities were tracked, and contributions were made to them as needed.

The Fish Innovation Lab uses its website as a conduit for distributing news releases and communications materials. All videos produced are available at https://www.fishinnovationlab.msstate.edu/media/videos. All blogs and news items are available at https://www.fishinnovationlab.msstate.edu/newsroom and https://www.agrilinks.org/activities/feed-future-innovation-lab-fish. The Fish Innovation Lab continued to use the Piestar platform for collecting and organizing monitoring data from research activities as well as subawardee activities and achievements.

Five newsletters were distributed through the Fish Innovation Lab email list and website. A structured social media campaign was also implemented to distribute success stories, briefs, and ad hoc material generated from subaward activities and partners. Results and success stories from the Fish Innovation Lab were regularly submitted for publication on the Feed the Future Agrilinks online community, which picked up the following stories in FY 21 (all stories available at https://www.agrilinks.org/activities/feed-future-innovation-lab-fish):

- Improving the Efficiency of Aquaculture Farms in Nigeria
- Emerging Technologies Improve Aquaculture Data Systems in Bangladesh
- Gender Mainstreaming in Fisheries and Aquaculture Sectors
- Rohu Carp Genome Sequencing to Improve Food Security in Bangladesh
- Detecting Fecal Pathogens in Aquaculture: Improving Capacity in Bangladesh
- Fish4Zambia: Research Among Men and Women Fishers, Processors, and Sellers
- Addressing Food Safety in Aquaculture Systems in Developing Countries
- Ground-Truth Visits Inform Efforts to Promote Aquaculture
- The Learning Agenda Meeting: Providing Innovation Through Collaboration
- Fish Innovation Lab's 2021 Virtual Annual Meeting

Issues

This section reports on issues and lessons learned by the Fish Innovation Lab ME. Issues encountered by individual activities are reported in their respective sections.

COVID-19

COVID-19 and associated travel restrictions required the Fish Innovation Lab to cancel in-country visits for the Fish Innovation Lab ME and ME Partners. COVID-19 impacts were discussed in several Fish Innovation Lab learning meetings, and while the impacts differed among and within countries, COVID-19 slowed down implementation as investigators were limited in their ability to accomplish site visits and interact as a team. The ME took the following steps to address the COVID-19-related issues:

- As COVID-19 restricted travel and field activities, the ME supported teams adapting by implementing activities virtually (such as a digital survey of fish traders in the Harnessing Machine Learning activity). The teams also relied heavily on the host country team members to accomplish on-the-ground activities.
- Protocols regarding social distancing, face masks, and hand sanitizer to help prevent the spread of COVID-19 were put into place for enumerator trainings and site visits.
- The Fish Innovation Lab ME helped teams reconsider field work plans and implementation, including rebudgeting travel money to cover other expenses. For example, in the Cryogenic Sperm Banking activity, funds were reallocated to establish field trials at the Bangladesh Fisheries Research Institute instead of conducting trials at originally planned sites farther from the host-country research team.
- The Fish Innovation Lab annual meeting was held virtually instead of in person. The agenda was developed to maximize networking and interactive opportunities in the virtual space, and activities were designed to gather feedback on the research strategy. Learning agenda activities were also conducted virtually instead of in country. Unfortunately, this meant that team participation was not as broad as intended, and as a result, networking opportunities were limited. However, the Fish Innovation Lab pivoted seamlessly to the virtual space, maximizing the time in virtual sessions, and using online platforms, such as Mural, for interaction and input.

Other ME-Related Challenges

Several of the Fish Innovation Lab-funded activities in Nigeria experienced issues related to funding flow from the host Nigerian universities to the research teams. Some activities were delayed as the in-country teams were unable to access funds. To resolve this issue, the Fish Innovation Lab ME met with the respective universities' offices of sponsored projects to determine how to make funding available to host country subawardees.

The Fish Innovation Lab had the opportunity to fund a research activity related to invasive crayfish in Zambia (Activity 3.5.). The activity was built on a strong proposal that included collaboration with the Farmer-to-Farmer Program; however, the topic of invasive species is very sensitive. Therefore, the ME had to be very careful not to support any activities that could be perceived as promoting invasive species. To resolve this issue, the ME sought and received good feedback from the USAID AOR and the Bureau for Resilience and Food Security environmental officer, and the ME worked with the PI to adjust the activity focus.

Future Directions

The next steps for the competitively awarded research-for-development activities are listed in Table 4.

Note: some of these activities are dependent on an improvement of the COVID-19 pandemic situation and may not occur if the spread continues or if COVID-19 restrictions are not lifted.

Table 4. FY 22 Research Activities

Research Activities
1.1. Aquaculture Diversification in Rural Communities activity ● Continue data collection on the adaptive research pilot plots for rice-fish farming. ● Study and assess locally available feedstuffs as suitable supplemental feeding for selected species in the integrated agriculture-aquaculture system. ● Analyze parameters for integrated rice-fish farming system (water balance, nutrient flow, key elements of fish integration into rice fields, feeding practices, etc.). ● Conduct mid-project surveys on fish consumption, nutrition, market access analyses (food and fish inclusive of Household Dietary Diversity Score, Minimum Dietary Diversity - Women, Household Food Insecurity Access Scale). ● Enhance the effectiveness of integrated agriculture-aquaculture innovation platform. ● Prepare peer-reviewed journal article on fish feed assessment. ● Develop training materials for farmer-group workshops. ● Prepare peer-reviewed journal article on wetland maps.
1.2 Farming Insects in Nigeria activity ● Conduct reconnaissance survey. ● List fish farmers in the study location. ● Conduct baseline survey. ● Perform preliminary modeling of fish farms' production systems. ● Start intervention by setting up the demonstration plots for the black soldier fly larvae production, processing, and mixing with feed ingredients for making fish feed. ● Set up two plots to demonstrate to the farmers how catfish fed with feed made with black soldier fly larvae as a source of animal protein will perform against those that will be fed with the conventional fish feed popularly used in the area. ● Conduct collaborative work on the distribution of the survey. ● Process data. ● Develop catfish production model.
1.3 Lean Production Systems activity ● Identify 20 farmers/processors to be "Lean Subject Matter Experts." ● Travel to Nigeria to conduct in-country training. ● Analyze initial data on Lean management training. ● Engage stakeholders virtually. ● Lean Subject Matter Experts will continue to train farmers and processors.

Research Activities
● Apply Lean management principles and tools with the other farmers and processors to identify the waste streams at different nodes of the aquaculture value chain and apply correction measures. ● Conduct data collection and analysis of the improvement in production efficiencies (quantitative analysis process).
1.4 Bighead Catfish activity ● Coordinate meetings among activity team, Royal Univeristy of Agriculture (RUA), Kansas State University, Texas A&M University, and WorldFish team to discuss plans and provide progress updates. ● Process quotation to purchase materials for the wet lab for aquaculture feed nutrition research. ● Install wet lab for aquaculture feed nutrition research at RUA. ● Conduct training of RUA personnel on the operation of a wet lab, including pelleted (sinking) feed formulation, preparation, and management, and visit WorldFish Malaysia (if travel is allowed). ● Maintain and initiate aquaculture feed nutrition research. ● Conduct ongoing activity monitoring and documentation. ● Install materials to operationalize a wet lab for aquaculture feed nutrition research at RUA. ● Provide maintenance to the wet lab for aquaculture feed nutrition research. ● Conduct training of RUA personnel on feed manufacture through a study visit to the US (if travel is allowed). ● Conduct training of farmers and peers in Cambodia on the operation of a wet lab and feed formulation and manufacture by RUA staff. ● Conduct annual meeting with activity team and other key relevant partners.
1.5 Coral Reef Fishery Sustainability activity ● Continue fisheries mapping in the two remaining sites and the training on stock assessment with anticipation of bringing on board additional members of the community to participate in the ongoing process. ● Monitor data collectors to continue to help minimize issues of effort duplication and the challenges with fish group identification as earlier reported. ● Initiate data entry and analysis. ● Continue community fisheries monitoring in all activity sites with minimal supervision by the activity team and training on stock assessment. ● Continue ecological and socioeconomic data compilation and analysis. ● Conduct stakeholder engagement and training on estimate yields, sustainability, fisheries and ecology monitoring, and socioeconomic post-surveys. ● Perform analysis of the earlier pre-surveys. ● Test community data collectors and county fisheries officers' skills on fish identification.
1.6 Cryogenic Sperm Banking activity ● Collect additional Indian major carps and exotic carps for broodstock development. ● Conduct genetic characterization of broods. ● Conduct breeding trials using cryopreserved sperm in selected hatcheries in four regions. ● Recruit one more PhD student and a MS student. ● Collect data on growth of cryopreserved-sperm-originated and control fry/fingerlings being reared in ponds in different hatcheries of four regions.

Research Activities
● Conduct training workshops for stakeholders in four regions on cryopreservation of sperm and dissemination of the technology. ● Perform genetic characterization of broods of six species using DNA microsatellite markers.
1.7 Cambodian Fisheries and Food Processing activity ● Finalize contracts for all 14 fishers by Wildlife Conservation Society Cambodia. ● Conduct field checks on new adjusted data collection protocols with all contracted fishers. ● Conduct field checks and training to contracted fishers to ensure the correctness of the fisheries data record. ● Conduct training to Wildlife Conservation Society staff about data management, data entry, and data storage. ● Enter in weekly fisheries data onto the computer (data will be stored on the activity's computer, external hard drives, and online cloud). ● Conduct fish species identification by ichthyologist. ● Design preliminary survey instrument for focus group sensory panel. ● Conduct focus group surveys with at least six villages. ● Conduct pilot survey and sensory panels. ● Develop FY 22 approaches for assessment and training. ● Complete sample collection for stable isotopes analyses for 30 fish species dominating the harvest in the Sre Ambel River. ● Train activity personnel in Cambodia via an online course on fisheries data management and analysis using iFISH web application. ● Monitor the spatial extent of fishing areas using iFISH Sre Ambel data visualization application. ● Complete proximate analysis and fatty acid composition analysis. ● Complete sensory evaluation and survey of fish processing knowledge. ● Complete video production for training workshops. ● Complete shelf-life study of fresh fish in Cambodian markets.
1.8 Carp Genetic Improvement activity ● Obtain and prepare rohu samples (>1,500 fin-clips) for shipping. ● Conduct rohu (2020) progeny testing and harvest measurements for a dataset comprised of growth data for all (~3,000) fish. ● Analyze to generate estimated breeding values and identify ~600 individuals to be retained for broodstock development. ● Tag catla and rohu (2021) for progeny testing and population backup (~21,600 [60 individuals per family from 360 families]).
1.9 Black Soldier Fly in Malawi activity ● Identify the costs for black soldier fly production and develop prototype equipment using locally sourced materials. ● Initiate black soldier fly production, including recruitment of black soldier fly farmers. ● Identify metrics of black soldier fly production, such as native insect species availability, generation time, output capacity (wet and dried prepupal weight), and input black soldier fly diet needs (organic material type). ● Determine the costs to make black soldier fly feed for aquaculture.

Research Activities
● Determine the feasibility and cost-effectiveness of waste streams, which includes identifying costs of waste streams and modeling waste stream costs necessary to rear and maintain black soldier fly colonies.
2.1 Improving Biosecurity activity ● Train project manager to access and manage ODK survey data submitted by enumerators using the ODK Kobo Toolbox dashboard. ● Enumerators pilot epidemiology survey tools on 5-10 farms. ● Enumerators use the survey questionnaires to interview up to 320 tilapia and catfish farmers and up to 30 tilapia and catfish hatchery owners across Ogun and Delta states. ● Complete epidemiology work and analyze risk factors in consultation with local scientists, veterinarians, competent authorities, and fish associations. ● Collect biological samples on up to three selected intensive catfish and tilapia farms, up to three river-based farms for each species along the Ogun River, and up to nine inland-based farms for each species (total of 15 different farm sites per species and up to three to five hatcheries for each species). ● Develop new teaching modules on fish-sampling techniques for laboratory diagnostics on the Learn.ink platform. ● Perform biosecurity checklist for farmers and hatchery operators in Ogun and Delta states. ● Develop tilapia and catfish clinical sign posters. ● Conduct bacteriology analyses from first batch of biological samples. ● Finalize first report on water quality parameters, hematology, and biochemical and disease diagnostic laboratory analyses. ● Continue analysis of epidemiological raw data using specialized software from MSU. ● Finalize interim first report on epidemiology data for risk factor identification. ● Develop draft list of risk factors and management interventions as identified by University of Ibadan team during the epidemiology survey, biological sample collection field visits, and interactions with farmers. ● Produce network report (competent authorities, universities, private sector, farmer communities). ● Conduct review of existing better management practices (BMPs) produced by WorldFish and others and organize focus group discussion to produce contextualized BMPs for Nigerian aquaculture.
2.2 Sources of Fecal Pathogens activity ● Collect and analyze the remaining 81 cut-fish samples from retail markets and super shops. ● Enroll two MS students from Fisheries Department, University of Dhaka. ● Conduct focus group discussions and structured observation of different stakeholders in the retail markets. ● Conduct focus group discussion and questionnaire survey with the key actors involved in fish value chains. ● Organize virtual stakeholders meeting.
2.3 Vaccines for Tilapia activity ● Orient students on biosafety and biosecurity procedures and good laboratory practices. ● Develop experimental protocols for student sampling and experimentation. ● Conduct sample collection and analysis through bacterial identification procedures.

Research Activities
● Grow and acclimatize fish to laboratory conditions for experimentation.
3.1 Harnessing Machine Learning activity ● Complete interviews with fish traders, key informant interviews at markets, and input supplier survey. ● Conduct virtual data analytics capacity-building workshop for activity team members. ● Clean and analyze farm, trader, and farming community datasets and produce initial descriptive statistics. ● Refine and finalize the algorithm for identifying waterbodies used for aquaculture. ● Map and summarize data extracted from remotely sensed satellite images. ● Organize virtual stakeholder consultation workshop on features for inclusion in the GIS interface. ● Conduct comparative analysis of 2013 and 2020 datasets. ● Produce reports and research briefs. ● Produce and disseminate extension videos on emerging trends via social media.
3.2 Nourishing Nations activity ● MSU PhD student will defend research proposal. ● Organize key stakeholders' meeting with the activity team, fisheries policymakers, and fish processors in Delta state. ● Hire and train enumerators to administer a pre-project questionnaire and commence data collection. ● Finalize recruitment of fish processors for training program. ● Complete low-literacy nutrition education tool and business plan curriculum for training program. ● Complete development of survey and experimental protocols by MS students at University of Calabar. ● Initiate market survey and fish-sample collection for analysis. ● Initiate first phase of training program. ● Evaluate and prepare data on the development and validation of low-literacy training for fish processors for publication.
3.3 FishFirst! Zambia activity ● Develop and finalize fieldwork logistic plans, fieldwork protocol plans, and enumerator training protocols. ● Finalize two literature review protocols and inception of the literature reviews by the FishFirst! Zambia graduate interns. ● Train enumerators in implementing the Women's Empowerment in Fisheries Index – FishFirst! Zabmia, Minimum Dietary Diversity - Women of Reproductive Age questionnaire, and Minimum Dietary Diversity – Infants & Young Children questionnaire. ● Collect and clean data and begin data analysis. ● Collect dried fish powder in Lusaka and ship to the US for laboratory analysis of nutritional content.
3.4 Samaki Salama activity ● Recruit fishers with children under the age of five. ● Refine and pilot data-collection tools and social marketing materials. ● Collect baseline data from intervention and control households. ● Conduct home visits with intervention households in Kuruwitu.

Research Activities
● Distribute social marketing materials to all intervention households. ● Implement cooking demonstration and workshops with fishers. ● Conduct meetings with fishers to discuss usage/issues/challenges of modified traps. ● Collect baseline data collection in control communities.
3.5 Zambia Crayfish activity ● Initiate the main phase of the trapping studies. ● Initiate the survey. ● Perform first reconnaissance visit to the Kwando River area, a tributary of the Okavango Delta.
3.6 Market Analysis activity ● Conduct secondary data analysis. ● Conduct primary data analysis. ● Publish two scientific articles that have been drafted. ● Draft two more articles.
3.7: Micronutrient Impact of Oysters ● Complete data cleaning. ● Conduct iron, zinc, and trace/heavy metals analysis of the collected oyster samples. ● Complete data analysis.

The next steps for the ME and ME Partners in implementing the FY 22 annual work plan are listed in Table 5.

Table 5. Upcoming activities for the ME and ME Partners

Management Activities
Management Entity – MSU 1. Ensure financial accountability of research subawards and coordinate with the MSU Office of Sponsored Projects to manage subawards to institutions funded through the competitive Request for Applications and direct commission process. 2. Depending on COVID-19 travel restrictions, the ME will support Fish Innovation Lab activities in FY 22 by travelling to countries to attend Fish Innovation Lab-related stakeholder and implementation meetings, meet with PIs and team members, and visit research sites. 3. Conduct virtual meetings with all PIs and Co-PIs for all activities. 4. Conduct an annual meeting in the US. The ME, ME Partners, AOR, EAB, and all subaward PIs will be invited. Subaward PIs are required to include a travel budget to attend the annual meeting in their subaward budgets. 5. Continue leading the Fish Innovation Lab communications efforts with website and social media maintenance, content generation and dissemination for quarterly newsletters, and feature articles. The ME also will maintain templates and other internal communications documents and will provide subawardees and ME Partners in-depth virtual communications training on rules and regulations related to communications, including those related to branding and marking, success stories, and ethical photography. 6. Members of the ME will continue to provide technical aquaculture expertise, support Institutional Animal Care and Use Committee (IACUC) regulatory compliance of activities,

Management Activities
work to provide technical assistance to ensure productivity of activities, provide gender impacts and youth engagement expertise, support the research agenda and activities, and assist the director with document and presentation preparation. 7. Organize mission meetings to increase awareness of Fish Innovation Lab activities and to explore opportunities for associate awards and buy-ins 8. Visit minority-serving institutions and host webinars to strengthen relationships and build capacity. 9. Continue supporting the Fish Innovation Lab's implementation of activities related to gender equity and youth engagement. This will include Wave II of the Gender Responsive Aquaculture/Fisheries Development Assessment–Fish Innovation Lab; offering additional open-access courses; developing outreach materials for Agrilinks and other platforms; and presenting the gender equity and youth engagement work at international conferences and meetings.
ME Partner – URI 1. Provide individualized support to the research activities in East and West Africa through periodic consultations and technical assistance, including field visits as soon as international travel is possible. 2. Participate in the Innovation Lab cross-cutting theme community of practice. 3. Develop Fisheries, Aquaculture, and Human Nutrition online course. 4. Establish and support Fish Innovation Lab student network. 5. Cross-cutting theme and country specialists conduct quarterly informal check-ins with teams. 6. Support and participate in monthly ME partner meetings, PI meetings, learning agenda meetings, annual meeting, etc. 7. Support and participate in mission meetings starting with Nigeria and Bangladesh, followed by Ghana, Zambia, Kenya, Malawi, and Cambodia. 8. Support the startup and implementation of the six commissioned studies initiated in FY 21. 9. Implement DWF buy-in activity. 10. Attend and showcase the Fish Innovation Lab at virtual and in-person conferences and workshops. 11. Communicate innovations, success stories, and lessons learned via technical briefs, fact sheets, success stories, etc. 12. Lead research strategy implementation, including overseeing the implementation of Area of Inquiry-specific research questions.
ME Partner – RTI International 1. Launch online resilience training, followed by resilience-focused discussions during the February learning meeting. 2. Conduct climate resilience consultations with regional/technical team leads and selected activities; follow-up with activity-level support on reporting and climate-aware analysis. 3. Engage activity teams with potential for contributing to system resilience in scaling and adoption; follow-up with activity-level support on reporting and resilience-aware scaling and adoption planning a. Two biosecurity- and aquaculture-focused (Nigeria and Bangladesh) b. Two fisheries with community-level work (Cambodia and Kenya)

Management Activities
4. Facilitate the development of the learning agenda question development based on the USAID priority areas of innovation adoption and scaling and health and nutrition in Quarter 1. 5. Organize and facilitate two separate learning agenda meetings with the Africa aquaculture group, the Asia aquaculture group, and the Africa and Asia fisheries group as a virtual webinar meeting in Quarter 2 and Quarter 4. 6. Support the application of learning agenda lessons into the development of research agenda activities. 7. Facilitate a review of Fish Innovation Lab activity performance based on the FY 21 indicator results. 8. Draft/review Fish Innovation Lab communications, presentations, and other external materials related to the resilience cross-cutting theme 9. Contribute to semiannual and annual reporting on progress related to the resilience cross-cutting theme and climate resilience reporting
ME Partner – TSU 1. Prepare articles based on the Bangladesh Quick Start activity. 2. Participate in future sessions of the Asia aquaculture and Africa/Asia fisheries learning agenda meetings. 3. Communicate with lead/host country PIs in Bangladesh and Cambodia to ensure successful implementation of activities. 4. Coordinate and monitor Fish Innovation Lab-funded activities in Bangladesh and in Cambodia (support Center of Excellence on Sustainable Agricultural Intensification and Nutrition technically in aquaculture). 5. Participate in Fish Innovation Lab ME Partners monthly meetings and any other Fish Innovation Lab virtual meetings. 6. Facilitate planning of virtual MEL reporting. 7. Prepare and submit blog posts on aquaculture, youth, and women's engagement. 8. Submit monthly reports, quarterly activity updates, and annual progress reports. 9. Prepare and submit five technical reports on COVID-19 impacts in Bangladesh and Cambodia and on Fish Innovation Lab-funded activities in these countries. 10. Participate in West Africa, East Africa, and Asia regional PI meetings. 11. Participate in the Fish Innovation Lab annual meeting. 12. Participate in the Bangladesh mission planning meeting.
ME Partner – WUSTL 1. Support proposal development with the FishFirst! Zambia team (e.g., fish powder in school feeding). 2. Conduct fish food composition analyses with the Cambodian Fisheries and Food Processing activity. 3. Support survey development with the Sources of Fecal Pathogens activity. 4. Hold targeted meetings with Nourishing Nations team. 5. Together with the USAID Advancing Nutrition team, continue to organize opportunities for dissemination. 6. Conduct Fish Innovation Lab symposium planning on the nutrition theme. 7. Explore funding opportunities that would facilitate nutritional analysis of the data collected in the Sources of Fecal Pathogens activity.

Management Activities
8. Analyze the nutrient composition of catfish fed black soldier fly vs standard feed (Feeding Insects activity). 9. Provide technical guidance on nutrition as well as dissemination strategies for the Micronutrient Impact of Oysters activity. 10. Travel to two of the four Fish Innovation Lab countries to provide technical assistance and oversight of nutrition-related activities ongoing in the aquaculture and fisheries research. 11. Present at the Feed the Future Innovation Lab for Fish virtual side event during the World Food Prize Foundation's 2021 Borlaug International Dialogue in October. 12. Conduct further planning for the nutrition course, Borlaug International Dialogue side event, and Fish Innovation Lab symposium.
Regional Coordinators 1. Participate in virtual platform meetings, research agenda meetings, and learning agenda sessions. 2. Communicate with lead/host country activity PIs to ensure successful implementation of activities, including monthly reporting. 3. Help facilitate and problem solve when issues arise related to activity implementation, particularly related to COVID-19. 4. Perform coordination and monitoring of Fish Innovation Lab-funded activities in their respective countries/regions. 5. Participate in Fish Innovation Lab ME Partners monthly and quarterly meetings and any other Fish Innovation Lab virtual meetings and webinars, such as EAB meetings. 6. Facilitate planning of virtual MEL reporting. 7. Prepare and submit monthly and quarterly progress reports. 8. Reach out to relevant government entities to share activity information and connect the activities to policymakers and other local stakeholders.

Appendices

Appendix 1: List of Fish Innovation Lab Awarded Activities

Bangladesh

- Cryogenic Sperm Banking of Indian Major Carps and Exotic Carps for Commercial Seed Production and Brood Banking. Lead PI: Md. Rafiqul Islam Sarder, Bangladesh Agricultural University. Award: $499,999
- Harnessing Machine Learning to Estimate Aquaculture Production and Value Chain Performance in Bangladesh. Lead PI: Ben Belton, Michigan State University. Award: $499,903
- Identifying Major Sources of Fecal Pathogens in Bangladeshi Aquaculture Value Chains and the Most Cost-Effective Risk Reduction Strategies. Lead PI: Mohammad Aminul Islam, Washington State University. Award: $485,150
- Advancing Aquaculture Systems Productivity Through Carp Genetic Improvement. Lead PI: Matthew Hamilton, WorldFish. Award: $494,885
- Strategies for an Inclusive Aquaculture Value Chain in Bangladesh: Analysis of Market Access, Trade, and Consumption Patterns. Lead PI: Madan M. Dey, Texas State University. Award: $149,956
- Genome Sequencing and Development of Single Nucleotide Polymorphism (SNP) Markers from Rohu in Bangladesh. Lead PI: Attila Karsi, Mississippi State University. Award: $99,999

Cambodia

- Development of Bighead Catfish Culture for Sustainable Aquaculture in Cambodia. Lead PI: Lyda Hok, Center of Excellence on Sustainable Agricultural Intensification and Nutrition, Royal University of Agriculture. Award: $500,000
- Increasing Sustainability of Fisheries and Aquaculture for Resilience of Cambodian Communities. Lead PI: Sandra Correa, Mississippi State University. Award: $424,615

Ghana

- Micronutrient Impact of Oysters in the Diet of Women Shellfishers. Lead PI: Brietta Oaks, University of Rhode Island. Award: $114,588

Kenya

- Achieving Coral Reef Fishery Sustainability in East African Biodiversity and Climate Refugia Centers. Lead PI: Timothy McClanahan, Wildlife Conservation Society. Award: $380,437
- Samaki Salama: Securing Small-Scale Fisheries in Kenya for Healthy Nutrition and Ecosystems. Lead PI: Lora Iannotti, Washington University in St. Louis. Award: $499,985
- SecureFish: Improved Nutrition Security in Kenya Through Increased Access to and Consumption of Coastal Marine Fish. Lead PI: Lora Iannotti, Washington University of St. Louis. Award: $100.000

Malawi

- Piloting Integrated Insect-to-Fish (ITF) Farming Systems in Malawi. Lead PI: Jennifer L. Pechal, Michigan State University. Award: $100,000

Nigeria

- Aquaculture and Rural Communities: Integrated Agriculture-Aquaculture as Farm Diversification Strategy. Lead PI: Matthias Halwart, Food and Agriculture Organization of the United Nations. Award: $498,593
- Improving Biosecurity: A Science-Based Approach to Manage Fish Disease Risks and Increase the Socioeconomic Contribution of the Nigerian Catfish and Tilapia Industries. Lead PI: Mohan Chadag, WorldFish. Award: $623,143
- Improving Efficiency in the Nigerian Aquaculture Sector by Employing Lean Production Systems. Lead PI: Rohana Subasinghe, WorldFish. Award: $533,924

- No Longer Bugged by Feed Costs: Farming Insects as Sustainable and Scalable Aquaculture Feedstock to Improve Catfish (*Claridae*) Producers' and Consumers' Livelihoods Towards Food Security in Nigeria. Lead PI: Jennifer L. Pechal, Michigan State University. Award: $400,000
- Nourishing Nations: Improving the Quality and Safety of Processed Fish Products in Nigeria. Lead PI: Lauren Pincus, WorldFish. Award: $396,398
- From Harvest to Plate: An Analysis of the Aquaculture Post-Harvest Chain in Nigeria. Lead PI: Julius A. Nukpezah, Mississippi State University. Award: $99,964

Zambia

- FishFirst! Zambia: Research for Development and Scaling Staple-Fish Products for Enhanced Nutrition in the First 1,000 Days of Life. Lead PI: Kathleen Ragsdale, Mississippi State University. Award: $500,403
- Development and Investigation of the Delivery Mode of a Multivalent Bacterial Fish Vaccine in Zambia. Lead PI: Bernard Hang`ombe, University of Zambia. Award: $144,846
- Fish4Zambia: Assessing Facilitators and Barriers to Aquaculture and Fish Consumption in Zambia. Lead PI: Kathleen Ragsdale, Mississippi State University. Award: $99,879
- Population Ecology and Current Distribution Assessment of the Introduced Invasive Crayfish in the Kafue Floodplain and Lake Kariba, Zambia. Lead PI: Michael Rice, University of Rhode Island. Award: $140,453
- Replacing Fishmeal with Single Cell Proteins in Tilapia *Oreochromis niloticus* Diets in Zambia. Lead PI: Delbert Gatlin, Texas A & M University. Award: $98,883

Appendix 2: FY 21 Indicator Results Tables

Publications & Presentations Module:					
STIR-12: Book	**2020**	**2021**		**2022**	**2023**
	Actual	**Target**	**Actual**	**Target**	**Target**
Peer-Reviewed Publications (Books)	0	0	0	1	3
STIR-12: Book Chapter	**2020**	**2021**		**2022**	**2023**
	Actual	**Target**	**Actual**	**Target**	**Target**
Peer-Reviewed Publications (Book Chapters)	0	0	0	3	2
STIR-12: Journal Article	**2020**	**2021**		**2022**	**2023**
	Actual	**Target**	**Actual**	**Target**	**Target**
Peer-Reviewed Publications (Journal Articles)	0	0	6	2	5

EG.3.2-1: Number of individuals who have received USG-supported short-term agricultural sector productivity or food security training					
EG.3.2-1 Producers: Number of producers who have received USG-supported short-term agricultural sector productivity or food security training	**2020**	**2021**		**2022**	**2023**
	Actual	**Target**	**Actual**	**Target**	**Target**
Gender					
Male	0	386	516	320	168
Female	0	142	262	159	100
Disaggregation not available	0	0	0	0	0
Totals	**0**	**528**	**778**	**479**	**268**
Participant Type (multiple choices allowed)					
Household Members	0	0	0	0	0
People in Government	0	0	47	25	25
USG-Assisted Private Sector Firms	0	0	4	25	10
People in Civil Society	0	0	107	79	33
Producers	0	0	620	350	200
Not Applicable	0	0	0	0	0
Totals	**0**	**0**	**778**	**479**	**268**

Indicator Result Narrative	FY 21 results for EG.3.2-1 reflect 28 short-term trainings conducted by activities in FY 21, reaching 778 beneficiaries (516 males and 262 females). These results reflect activities led by 11 research teams. These include training on data-collection tools for enumerators, diagnostic procedures, identification of pathogenic microbes from fish and water samples, and a training workshop on nutrition education, food safety, and safe fish handling practices.

Deviation From Target	Targets for FY 21 were set based on FY 20 results, which assumed delays to the implementation of activities due to the ongoing COVID-19 pandemic. However, research teams were able to implement adaptations to accomplish trainings through reliance on host-country expertise, responsible use of digital technology for virtual trainings, and some targeted travel for specific experts. In addition, some trainings had higher numbers of qualified host-country participants enroll than was originally anticipated. As a result, FY 21 actual results surpassed the projected targets.

EG.3-2: Number of individuals participating in USG food security programs

EG.3-2: Other project participants	2020	2021		2022	2023
	Actual	Target	Actual	Target	Target
Gender					
Male	0	497	1,172	680	400
Female	0	257	601	364	238
Totals	**0**	**754**	**1,773**	**1,044**	**638**
Age					
15-29	0	236	442	200	200
30+	0	518	523	844	438
Disaggregation not available	0	0	808	0	0
Totals	**0**	**754**	**1,773**	**1,044**	**638**
Participant Type (multiple choices allowed)					
Parents/Caregivers	0	26	122	50	60
Household Members	0	0	30	25	25
People in Government	0	20	213	125	75
USG-Assisted Private Sector Firms	0	22	54	100	0
People in Civil Society	0	57	311	75	55
Laborers	0	20	20	44	23
Producers	0	597	1,023	625	400
Not Applicable	0	12	0	0	0
Disaggregation Not Available	0	0	0	0	0
Totals	**0**	**754**	**1,773**	**1,044**	**638**

Indicator Result Narrative	FY 21 results for EG.3-2 reflect 13 research activities. These include stakeholder consultation meetings, community entry meetings for project sensitization, stakeholder engagement and awareness creation, fish-landing monitoring, and beneficiaries reached through short-term trainings.

Deviation From Target	Based on FY 20 results, FY 21 targets assumed ongoing delays to implementation due to the ongoing COVID-19 pandemic. However, research teams implemented adaptations, which included dissemination of new and adapted approaches through virtual and on-the-ground methods, as well as sensitization of key stakeholders through webinars and virtual workshops. As a result, the Fish Innovation Lab FY 21 actual results surpassed the projected targets.

EG.3.2-7: Number of technologies or management practices under research, under field testing, or made available for transfer as a result of USG assistance

EG.3.2-7: Plant and Animal Improvement Research	2020	2021		2022	2023
	Actual	Target	Actual	Target	Target
Phase 1: Under Research	1	1	4	1	0
Phase 2: Under Field Testing	0	0	1	1	1
Phase 3: Made Available for Transfer	0	0	0	1	0
Phase 4: Demonstrated Uptake by the Public and/or Private Sector	0	0	0	0	0
Totals	**1**	**1**	**5**	**3**	**1**

EG.3.2-7: Production Systems Research	2020	2021		2022	2023
	Actual	Target	Actual	Target	Target
Status					
Phase 1: Under Research	1	4	4	0	2
Phase 2: Under Field Testing	0	7	10	6	1
Phase 3: Made Available for Transfer	0	1	0	3	0
Phase 4: Demonstrated Uptake by the Public and/or Private Sector	0	0	0	1	0
Totals	**1**	**12**	**14**	**10**	**3**

EG.3.2-7: Social Science Research	2020	2021		2022	2023
	Actual	Target	Actual	Target	Target
Status					
Phase 1: Under Research	0	2	1	0	1
Phase 2: Under Field Testing	1	1	3	2	0
Phase 3: Made Available for Transfer	0	1	2	3	0
Phase 4: Demonstrated Uptake by the Public and/or Private Sector	0	0	0	0	0
Totals	**1**	**4**	**6**	**5**	**1**

Indicator Result Narrative	FY 21 results for EG.3.2-7 reflect activities conducted by 10 research teams. This included five technologies in plant and animal improvement research, 14 in production systems research, and 7 in social science research.

Deviation From Target	With limits to on-the-ground activity implementation due to the ongoing COVID-19 pandemic, many of the Fish Innovation Lab research teams adapted and modified the timeframe for development of their technologies, approaches, and practices. For several teams, this was accomplished through modifications and improvements of existing technologies and approaches. In particular, the Improving Biosecurity activity in Nigeria developed seven Standard Operating Procedures (SOPs) on fish sampling techniques for disease diagnostics. These SOPs will allow beneficiaries to improve their practices in disease surveillance and fish sampling methods for diagnostic sample collection. As a result of these innovative approaches, the Fish Innovation Lab exceeded its planned targets for FY 21.

EG.3.2-24: Number of technologies, practices and approaches under various phases of research, development, and uptake as a result of U.S. government (USG) assistance

EG.3.2-24: Applied Technology	2020	2021		2022	2023
	Actual	Target	Actual	Target	Target
Gender					
Male	0	236	145	13,500	9,555
Female	0	40	11	6,713	5,779
Totals	**0**	**276**	**156**	**20,213**	**15,334**
Age					
15-29	0	51	45	6,000	5,334
30+	0	225	104	14,213	10,000
Not Applicable	0	0	7	0	0
Totals	**0**	**276**	**156**	**20,213**	**15,334**
Technology Type (multiple choices allowed)					
Cultural Practices	0	0	0	0	0
Wild-Fishing Technique/Gear	0	0	115	0	0
Aquaculture Management	0	0	21	0	0
Disease Management	0	0	3	0	0
Soil-Related Fertility and Conservation	0	0	0	0	0
Water Management-Non-Irrigation based	0	0	0	0	0
Climate Mitigation	0	0	17	0	0
Climate Adaptation	0	0	0	0	0
Marketing and Distribution	0	0	0	0	0
Postharvest - Handling and Storage	0	0	0	0	0
Value-Added Processing	0	0	0	0	0
Other	0	276	0	20,213	15,334
Totals	**0**	**276**	**156**	**20,213**	**15,334**

Participant Type (multiple choices allowed)					
Parents/Caregivers (Other)	0	0	2	20	0
Household Members	0	0	0	0	0
People in Government	0	9	8	11	0
USG-Assisted Private Sector Firms	0	42	10	40	0
People in Civil Society	0	11	3	1	0
Laborers	0	0	0	0	0
Producers	0	214	133	20,000	15,155
Not Applicable	0	0	0	213	179
Totals	**0**	**276**	**156**	**20,213**	**15,334**

Indicator Result Narrative	FY 21 results for EG.3-2-24 reflect activities conducted by research teams in the process of developing, testing, and making available for adoption new and improved technologies, approaches, and practices.
Deviation From Target	In FY 21, most Fish Innovation Lab technologies were under phase 1 of research or phase 2 of field testing. Delays due to COVID-19 in FY 21 affected the ability of teams to generate data and to travel to implementation sites, which slowed the ability of teams to move innovative technologies and approaches from phase 1 or 2 into the transfer or uptake phases, which would allow beneficiaries to apply these approaches. As a result, the actual results from FY 21 deviate from the target for this indicator.

Custom: Number of individuals who have received USG-supported long-term agricultural sector productivity or food security training

EG.3.2-24: Applied Tech	2020	2021		2022	2023
	Actual	Target	Actual	Target	Target
Gender					
Male	0	0	17	4	3
Female	0	0	14	2	2
Totals	**0**	**0**	**31**	**6**	**5**

Indicator result narrative	The Fish Innovation Lab had 31 individuals/students (14 females and 17 males) who are currently enrolled in or have graduated from a bachelor's, master's, or PhD program receiving long-term training, mentorship, or apprenticeship in aquaculture, fisheries, resilience, and food system activities in FY 21. This is a new custom indicator developed for the Fish Innovation Lab during FY 21 which does not have set targets for the year.
Deviation From Target	NA

Appendix 3: Success Stories

Three Fish Innovation Lab success stories from FY 21 are presented here.

1. Activity title: Increasing Sustainability of Fisheries and Aquaculture for Resilience of Cambodian Communities

   Lead PI: Sandra Correa, Mississippi State University

   Story title: Fishers in Cambodia Use Citizen Science Program to Improve their Fishery

   Story link: https://www.fishinnovationlab.msstate.edu/sites/www.fishinnovationlab.msstate.edu/files/inline-files/FY21%20Increasing%20Fisheries%20Sustainability%20for%20Resilience%20-%20Success%20Story.pdf

2. Activity title: Advancing Aquaculture Systems Productivity Through Carp Genetic Improvement

   Lead PI: Matthew Hamilton, WorldFish

   Story title: Genetically Improved Rohu Carp Is Now in the Hands of Bangladeshi Farmers

   Story link: https://www.fishinnovationlab.msstate.edu/sites/www.fishinnovationlab.msstate.edu/files/inline-files/Advancing%20Aquaculture%20Systems%20Productivity%20Through%20Carp%20Genetic%20Improvement%20project%20Success%20Story%20FY21-final-draft.pdf

3. Activity title: Achieving Coral Reef Fishery Sustainability in East African Biodiversity and Climate Refugia Centers

   Lead PI: Timothy McClanahan, Wildlife Conservation Society

   Story title: Increasing the Capacity for Achieving Sustainable Fisheries Management in Kenya

   Story link: https://www.fishinnovationlab.msstate.edu/sites/www.fishinnovationlab.msstate.edu/files/inline-files/Achieving%20Coral%20Reef%20Fishery%20Sustainability%20project%20Success%20Story%20FY21_final-draft.pdf

Appendix 4: Environmental Management and Mitigation Reports

Initial environmental examination (IEE) condition	Proposed actions to mitigate risk	How to monitor that mitigation has been undertaken	Reporting for October 1, 2020, to September 30, 2021
Activity Name: Aquaculture and Rural Communities: Farm diversification strategy through integrated agriculture-aquaculture systems and nutrition-sensitive value chains for better nutrition outcomes **Sub-Activity:** Development of suitable integrated rice-fish production technology through participatory research actions **PI: Halwart**			
IEE Condition Category: controlled experimentation exclusively for the purpose of research and field evaluation which are confined to small areas and carefully monitored. Activities should be evaluated to ensure that there are no risks related to: • Poor siting and improper pond construction • Aquaculture operations, which can cause water contamination, sedimentation; farmed animal escape; unhealthy fish in the aquaculture ponds due to overcrowding; and overharvesting of wild eggs, larvae, juveniles, and adults for aquaculture production.	**Mitigation** Implementation of environmental best management practices for agriculture and aquaculture. Training provided to staff to ensure adherence to the regulations. Use already cleared land and reuse existing ponds or rice paddies whenever possible. When possible, select native versus exotic species. Use hatcheries to provide eggs, larvae, etc. for aquaculture operations. Protect against escapes of farmed animals. Implement protocols for maintaining fish health.	**Monitoring** Documented staff training. Documented adherence to the appropriate protocols. Documented approval by the IACUC and environmental health and safety (EH&S) office or equivalent, as appropriate.	**Reporting** In consultation with the host community, the team has cleared land in rice paddy areas, which were selected for the on-site adaptive plots. University of Ibadan PI facilitated training and guidance for proper construction of the on-site adaptive plot.
Activity Name: Cryogenic sperm banking of Indian major carps (*Catla*, *Labeo rohita* and *Cirrhinus cirrhosus*) and exotic carps (*Hypophtalmichthys molitrix*, *Hypophthalmichthys nobilis* and *Ctenopharyngodon idella*) for commercial seed production and brood banking **Sub-Activity:** Development of donor broodstocks of Indian major carps (IMCs) and three exotic carps **PI: Sarder**			

IEE Condition	Mitigation	Monitoring	Reporting
Category: controlled experimentation exclusively for the purpose of research and field evaluation which are confined to small areas and carefully monitored. Precautions must be taken to avoid overharvesting of fry for the broodstock.	• A small amount of larvae/fry will be collected from rivers, so there will be no negative impact on natural stocks. • The three exotic carps are being cultured along with IMCs in Bangladesh for about the last three decades in a polyculture fashion and there is no negative effect of the exotic carps on IMCs. • The exotic carps do not breed in natural water bodies and the seeds of them are always artificially produced in hatcheries.	Documented staff training. Documented adherence to the appropriate protocols. Documented approval by the IACUC and EH&S office or equivalent, as appropriate.	For broodstock development, both IMCs (catla, rohu and mrigal) and exotic carps (silver carp, bighead carp and grass carp) are reared together in ponds. All the fish species grew well and there were no mortalities. No negative effects of communal rearing have been observed. The brood ponds are properly prepared, and the embankments are well constructed, so there is very low risk of fish escaping from the ponds even during flooding (if any).

Activity Name: Cryogenic sperm banking of Indian major carps (*Catla*, *Labeo rohita* and *Cirrhinus cirrhosus*) and exotic carps (*Hypophtalmichthys molitrix*, *Hypophthalmichthys nobilis* and *Ctenopharyngodon idella*) for commercial seed production and brood banking

Sub-Activity: Production of seeds of carps in hatcheries by use of cryopreserved sperm and assessment of their quality through growth and DNA microsatellite analysis

PI: Sarder

IEE Condition	Mitigation	Monitoring	Reporting
Category: controlled experimentation exclusively for the purpose of research and field evaluation which are confined to small areas and carefully monitored. Precautions must be taken to avoid exotic species escaping to natural waters.	The team will adhere to good laboratory and biosafety practices. Seeds will be produced using cryopreserved sperm in hatcheries and will be reared very carefully in confined conditions (ponds). So, there will be no chance of escape of exotic carps to natural waters. However, if they escape to natural waters during flooding (if any), it will have no negative effects on indigenous species.	Documented staff training. Documented adherence to the appropriate protocols. Documented approval by the IACUC and EH&S office or equivalent, as appropriate.	Due to a second wave of COVID-19 and strict lockdown in Bangladesh during most of the breeding season, a very short time period was available to conduct breeding trails in hatcheries. However, in Mymensingh region, breeding of rohu, mrigal, silver carp, and bighead carp was conducted in four public and private hatcheries using cryopreserved sperm, and seeds were produced of those species. Similarly, breeding of rohu, mrigal, silver carp, and bighead carp was done in Jashore, Faridpur, and Barishal regions in four private hatcheries using cryopreserved sperm, and seeds were produced of those species. The produced seeds are being reared in ponds in the respective hatcheries with supplemental feeding.

			The length and weight of fry/fingerlings are being taken at a regular basis (monthly) to assess their growth performance.
Activity Name: Cryogenic sperm banking of Indian major carps (*Catla*, *Labeo rohita* and *Cirrhinus cirrhosus*) and exotic carps (*Hypophtalmichthys molitrix*, *Hypophthalmichthys nobilis* and *Ctenopharyngodon idella*) for commercial seed production and brood banking **Sub-Activity:** Evaluation of the adoptability of technology by the stakeholders **PI: Sarder**			
IEE Condition	**Mitigation**	**Monitoring**	**Reporting**
Category: analyses, studies, academic or research workshops and meetings. Precautions must be taken to avoid exotic species escaping to natural waters.	Growth performance of seeds of exotic carps produced using cryopreserved sperm will be carried out in ponds that are not flood-prone. However, if they escape to natural waters during flooding (if any), it will have no negative effects on the indigenous species.	Documented staff training. Documented adherence to the appropriate protocols. Documented approval by the IACUC and EH&S office or equivalent, as appropriate.	Cryopreserved sperm-originated seeds are being reared in ponds in most of the seed-producing hatcheries. However, to evaluate the adoptability of the technology, seeds of rohu and mrigal are being reared in a fish farm in Mymensingh region, and their growth performances (increment of length and weight) are being evaluated at a regular basis (monthly).
Activity Name: No longer bugged by feed costs: Farming insects as sustainable and scalable aquaculture feedstock to improve catfish (Clariidae) producers' and consumers' livelihoods towards food security in Nigeria **Sub-Activity:** Co-optimize integrated insect to feed farming system infrastructure to increase local production of fish while minimizing costs of production **PI: Pechal**			

IEE Condition	Mitigation	Monitoring	Reporting
Category: controlled experimentation exclusively for the purpose of research and field evaluation which are confined to small areas and carefully monitored. However, activities should be evaluated to ensure that there are no risks related to: • Poor siting and improper pond construction. • Aquaculture operations, which can cause water contamination, sedimentation; farmed animal escape; unhealthy fish in the aquaculture ponds due to overcrowding; and overharvesting of wild eggs, larvae, juveniles, and adults for aquaculture production.	• Implementation of environmental best management practices for agriculture and aquaculture. • Training provided to staff to ensure adherence to the regulations. • Use already cleared land and reuse existing ponds whenever possible. • Use lower stocking densities and less intensive production systems. • When possible, select native versus exotic species. • Use hatcheries to provide eggs, larvae, etc. for aquaculture operations. • Protect against escapes of farmed animals. • Implement protocols for maintaining fish health.	Documented staff training. Documented adherence to the appropriate protocols. Documented approval by the IACUC and EH&S office or equivalent, as appropriate.	Nothing to report. The activity is yet to start implementation on the ground.
Activity Name: Development and Investigation of the Delivery Mode of a Multivalent Bacterial Fish Vaccine in Zambia" (NEW in 2021) **Sub-Activity:** Clinical trials **PI: Hang'ombe**			
IEE Condition	**Mitigation**	**Monitoring**	**Reporting**
Category: controlled experimentation exclusively for the purpose of research and field evaluation which are confined to small areas and carefully monitored. • Precautions must be taken to ensure biosafety and avoid accidental water contamination and spread of bacteria.	The team will adhere to standard laborator and biosafety practices. PIs should be trained in biosafety and standard procedures for conducting research with bacterial pathogens. Use of technical staff trained to handle biological and hazardous materials.	Documented staff training. Documented adherence to the appropriate protocols. Documented approval by the IACUC and EH&S office or equivalent, as appropriate.	Nothing to report. The activity is yet to start implementation on the ground.

Use of secured laboratories for pathogen isolation and animal experimentation.	Training provided to staff to ensure adherence to the regulations.		
Activity Name: Piloting integrated insect-to-fish farming systems in Malawi (NEW in 2021) **Sub-Activity:** Evaluate changes in pond yield and productivity resulting from different mixes of black soldier fly meal in fish feed. **PI: Pechal**			
IEE Condition Category: controlled experimentation exclusively for the purpose of research and field evaluation which are confined to small areas and carefully monitored. However, activities should be evaluated to ensure that there are no risks related to: • Poor siting and improper pond or cage construction. • Aquaculture operations, which can cause water contamination, sedimentation; farmed animal escape; unhealthy fish in the aquaculture ponds or cage due to overcrowding; and overharvesting of wild eggs, larvae, juveniles, and adults for aquaculture production.	**Mitigation** • Implementation of environmental best management practices for agriculture and aquaculture. • Training provided to staff to ensure adherence to the regulations. • Use already cleared land and reuse existing ponds whenever possible. • Use lower stocking densities and less intensive production systems. • When possible, select native versus exotic species. • Use hatcheries to provide eggs, larvae, etc. for aquaculture operations. • Protect against escapes of farmed animals (e.g., insects). • Implement protocols for maintaining fish health.	**Monitoring** Documented staff training. Documented adherence to the appropriate protocols. Documented approval by the IACUC and EH&S office or equivalent, as appropriate.	**Reporting** Nothing to report. The activity is yet to start implementation on the ground.
Activity Name: Advancing Aquaculture Systems Productivity Through Carp Genetic Improvement (NEW in 2021) **Sub-Activities:** Output 1: Performance analysis from dissemination of genetically improved rohu at scale to hatcheries and farmers; Output 3: New generations of improved carps **PI: Hamilton**			

IEE Condition	Mitigation	Monitoring	Reporting
Negative determination with conditions: Activities should be evaluated to ensure that there are no risks related to: • Biosafety might be disrupted if invasive alien species are introduced. • Fish seed adulteration may take place. Food safety might be disrupted if harmful inputs/chemicals are used and/or appropriate cleaning, disinfection, and waste management, are not followed.	• Introduction of invasive alien fish species will be avoided. • Maintaining broodstock purity will be promoted, and inbreeding or other causes of seed adulteration will be avoided • Using inputs in seed production that are not approved by the Fish Hatchery Rules, 2011, and U.S. Food and Drug Administration will be avoided Appropriate cleaning, disinfection, and waste management will be followed.	• List of approved fish species to be promoted developed. • Guidelines for maintaining the purity of broodstock developed. • Number of hatcheries that follow the guidelines for maintaining the purity of broodstock. • Guidelines for cleaning, disinfection, and waste management for hatchery developed. • Log sheets for recording day-to-day hatchery operations developed. • Monitor the number of hatcheries that use only approved inputs and follow appropriate cleaning, disinfection, and waste management procedures. • Number of hatcheries that update the log sheets for recording day-to-day operations including waste management.	• For catla (*Labeo catla*), rohu (*Labeo rohita*), and silver carp (*Hypophthalmichthys molitrix*), parents of all families were generated, recorded, and progeny tracked in a data management system: Hamilton, M. G. (2021). *WorldFish Carp Genetic Improvement Program data management system (version 3): Data input*. WorldFish. https://doi.org/20.500.12348/4869 • Activities were conducted according to WorldFish internal best management practices, including Hamilton, M. G., Rajts, F., Alam, M. B., Yossa, R., Delamare-Debouteville, J. R. M., Chadag, V. M., & Collis, B. (2020). *WorldFish carp genetic improvement program pond and fish management manual*. • Electronic pond books were used: Hamilton, M., Rajts, F., Collis, W., Shanta, S., Alam, M., & Kabir, M. (2020). *WorldFish carp genetic improvement program electronic pond book guide*. https://doi.org/10.7910/DVN/DBN1UD • All 2020/21 genetic improvement activities undertaken at one facility managed by WorldFish. Inputs and outputs of private hatcheries with disseminated genetically improved rohu were not monitored.

Activity Name: Increasing sustainability of fisheries for resilience of Cambodian communities**.**

Sub-Activity: Improve sustainable fisheries management by implementing a citizen science harvest-monitoring program and digital platform for documentation and analysis of harvest to assess change. Potential adverse environmental impacts of this activity include the unexpected promotion of unsustainable fishing practices.

PI: Correa

IEE Condition	Mitigation	Monitoring	Reporting
Category: analyses, studies, academic or research workshops and meetings. Research, extension, and capacity building should integrate and promote general awareness of the environmental, health and safety risks presented by fishing and coastal economic activities and make appropriate choices and measures to manage these risks.	Fishers will be trained to monitor how fish populations change after the implementation of community fisheries agreements. The research team will review and screen all policy documents, advocacy materials, and training curricula to ensure that they are environmentally sound and promote sustainable fishing practices. They will teach fisheries management concepts and emphasize the importance of keeping fishing within the maximum sustainable yield to ensure fish for future generations.	In addition to ensuring that training materials do not promote unsustainable practices, the team will monitor unexpected changes in harvesting practices (e.g., increase in yield of currently overharvested species and fishing activities in locations banned per community-based fishing agreements).	Train-the-trainer activities have emphasized that the selection of fishers to participate in the Citizen Science data-collection program must not lead to changes in fishers' behavior in terms of fishing location and frequency. The team discussed the potential for such behavioral change during training sections and requested the Cambodian team to discuss it with fishers during field training sections and community meetings. The team is using the iFish Sre Ambel data visualization application to monitor the spatial extent of fishing areas. This will allow the team to create a visual spatial analysis of fishing practices and detect unexpected changes in harvesting practices.

Activity Name: Samaki Salama: securing small-scale fisheries in Kenya for healthy nutrition and ecosystems

Sub-Activity: Measure the impact of fishing gear cooperatives on gear modification and diversification, as well as catch dynamics and earnings

PI: Iannotti

IEE Condition	Mitigation	Monitoring	Reporting
Category: analyses, studies, academic or research workshops and meetings. Research, extension, and capacity building should integrate and promote general awareness of the environmental, health and safety risks presented by fishing and coastal economic activities and	Fishers will be trained in sustainable fisheries management. The importance of keeping fishing within the maximum sustainable yield will be emphasized.	Review of training curricula.	• Modified traps with escape gaps have been distributed. • The field team is holding monthly meetings with fishers who have received traps to ensure proper use.

make appropriate choices and measures to manage these risks.			
Activity Name: Achieving coral reef fishery sustainability in the Kenyan biodiversity and climate refugia center **Sub-Activity:** Improve the management capacity of communities to monitor fisheries and habitats and use this information for adaptive management **PI: McClanahan**			
IEE Condition Category: education, technical assistance, or training programs. Research, extension, and capacity building should integrate and promote general awareness of the environmental, health and safety risks presented by fishing and coastal economic activities, and appropriate choices and measures to manage these risks.	**Mitigation** Co-production of information and management intended to reverse the current downward trends and reduce environmental impacts.	**Monitoring** • Generated knowledge by targeted fisheries communities through participatory fisheries measurements and management. • Conservation of marine resources and expected increase in fish production and incomes. • Benefits sharing from sustainable use of fisheries resources.	**Reporting** • The literacy testing survey with 81 participants showed that communities are knowledgeable and quick to adapt to new technologies due to previous interactions in various forums and collaborations with government and NGOs working in the area. • 15 community members and two fisheries officers from government trained on the Wildlife Conservation Society and mobile phone data-collection protocols and procedures. • Participatory fisheries mapping helped in the production of hand-drawn and digitized maps of fishing ground landmarks and fishing zones and validation in all activity sites. During the ground-truthing exercise, the team realized that there was some overestimation of fishing areas, while some fishers were still fishing within locally Marine Managed Areas coupled with poaching within Marine Protected Areas, use of illegal gears, no clear government and locally managed areas, and marine closures and fishing boundaries between Kenya and Tanzania. The field team had to inform the immediate beach management units and the local wardens for follow up on most of these issues since it was clear that the community members are always aware of the patrol timings to avoid arrest, hence the need to work closely with the government institutions and community to help identify the lawbreakers and need for more awareness creation activities. • Community fish-landing monitoring helps in recording monthly fish-catch data, but there

			have been some challenges of fish categories identification, multiple naming of some fishing areas, failure to record zero landing, and resistance by some fishers to allow their catch to be recorded. This was resolved by continuous reminders to data collectors on fish categories, creation of a list of names from the same landing sites, and closer basic data checking by more than two people to ensure data quality.
Activity Name: FishFirst! Zambia: Research for development and scaling staple-fish products for enhanced nutrition in the first 1,000 days of life **Sub-Activity:** Explore potential of upgrading the small pelagic fish value chain via improving processing, storage, and trading methods to reduce postharvest losses and improve food safety **PI: Ragsdale**			
IEE Condition	**Mitigation**	**Monitoring**	**Reporting**
Category: analyses, studies, academic or research workshops and meetings. Training and extension activities promoting postharvest loss and fish processing technologies may result in unsustainable use of fish and other natural resources (e.g., fuelwood) if message is poorly conceived and conveyed.	Research, extension, and capacity building will integrate and promote general awareness of the environmental, health, and safety risks presented by fishing, onboard handling, and postharvest processing. It will integrate appropriate choices and measures to manage associated risks.	Review and screening of research protocols, advocacy materials, and training curricula to ensure that they are environmentally sound.	Nothing to report. Data collection using a survey tool was undertaken in May 2021. Use of this survey did not have a negative environmental impact.
Activity Name: Nourishing Nations: Improving the quality and safety of processed fish products in Nigeria **Sub-Activity**: Build capacity among women and youth fish processors to produce high quality, safe and nutritious processed fish products for local consumption **PI: Pincus**			

IEE Condition	Mitigation	Monitoring	Reporting
Category: education, technical assistance, or training programs. Training and extension activities promoting postharvest loss and fish processing technologies may result in unsustainable use of fish and other natural resources (e.g., fuelwood) if message is poorly conceived and conveyed.	Trainings with fish processors will include recommendations to keep fishing at maximum sustainable yield, although the participants themselves will not be the individuals conducting any fishing activities.	The activity will include a MEL indicator confirming that the activity recommended that fishers not fish above maximum sustainable yields.	A participatory training was successfully conducted in August 2021. Trainings included information about fuel-efficient stoves for smoking fish products. Trainings also promoted other storage and processing methods to reduce postharvest loss of fish. Participants were receptive and enthusiastic about the training. There is a willingness to have a positive behavioral change towards fish processing, and safe handling to produce quality, safe, and nutritious processed fish products for local consumption

Appendix 5: Climate Risk Screening and Management Reports

Climate Risk Screening and Management Report

Defined or Anticipated Activity Elements	Climate Risks	How Risks are Addressed at Activity Level	Further Analysis and Actions for Activity Design/ Implementation	Reporting for October 1, 2020, to September 30, 2021
Integrated rice-fish technology (Nigeria)	Extreme weather events (e.g., storms) could disrupt integrated rice-fish ponds.	Climate risks, such as storms and flooding, must be accepted and mitigated through working with rice growing systems that have the capacity to minimize negative impacts.	Researchers will monitor extreme weather events and implement risk mitigation measures prior to the close of the activity.	Two activities in Nigeria were affected by climate-related shocks in FY 21. The Aquaculture Diversification in Rural Communities activity responded to severe weather events, severe flooding, and severe drought by supporting producers in the use of tube wells to aid pond impoundment and using sandbags to reinforce pond embarkment. The Lean Production Systems activity responded to severe flooding, an exceptionally high water table, climate-related storms, and acid rain by providing advice to farmers on the importance of reinforcing pond dikes and guidance on new pond construction to avoid obstructing pathways of surface runoff to flood detention and retention areas.

Defined or Anticipated Activity Elements	Climate Risks	How Risks are Addressed at Activity Level	Further Analysis and Actions for Activity Design/ Implementation	Reporting for October 1, 2020, to September 30, 2021
Insects as aquaculture feed (Nigeria and Malawi)	Natural weather patterns such as El Niño, hurricanes, floods, droughts, hail, and extreme heat and cold threaten aquaculture. Slowly changing weather patterns and temperatures can impact the production area of a given standing crop of fish or crops of raw materials for fish feed.	Some stages in raw material crop research for fish feed are amenable to controlled greenhouse research. Other stages require a scaled-up effort in open fields. For research purposes, irrigation can be installed at selected sites to combat drought. Other climate risks, such as flooding, extreme temperatures, hail, etc. must be accepted and mitigated through trials over multiple seasons and at several locations.	No other measures are anticipated.	Nothing to report.
Develop genetic improvements and donor broodstock of Indian major carps and exotic carps (Bangladesh)	Changes in water body temperatures may impact fish stocks and hence the availability of fish for broodstock.	The broodstock will be developed in 2020, and it is not likely that the risks will occur within the timeframe where the broodstock will be developed. In the long-term, development of a cryogenic sperm bank for carp broodstock will enable climate resilience by allowing selection for temperature tolerance or other environmental stressors.	None	Nothing to report.

Defined or Anticipated Activity Elements	Climate Risks	How Risks are Addressed at Activity Level	Further Analysis and Actions for Activity Design/ Implementation	Reporting for October 1, 2020, to September 30, 2021
Increased understanding of how to manage fish disease risks (Nigeria)	Temperature increases and changes in rainfall patterns have the potential to increase the occurrence of fish disease outbreaks.	All climate risks are accepted because the research aims to understand how to manage disease risks.	None	Nothing to report.
Increased understanding of nutritional value of fish products (Nigeria, Zambia)	Increased nutrition understanding primarily comes from a clinical laboratory setting that is primarily independent of climate.	All climate risks are accepted as they are deemed to be non-impactful to this research area.	None	Nothing to report.
Increased understanding of preferences, needs, and priorities along the fish value chain by gender, age group, or other disadvantaged groups, and application of that understanding to activity design and implementation (Nigeria, Kenya, Bangladesh)	Priorities may be biased during surveys based on current raw material and seasonal needs.	This is an acceptable risk because it still highlights the priorities of producers. Researchers need to be cognizant of the challenges and limitations of this type of research and inherent bias.	Researchers in this field should be fully cognizant of their area of specialty; the research activities will receive technical assistance from the Fish Innovation Lab's resilience technical advisor.	Nothing to report at this time, pending further discussion on the relevance of climate change to seasonal factors that may affect the preferences, needs, and priorities of the research participants.

Defined or Anticipated Activity Elements	Climate Risks	How Risks are Addressed at Activity Level	Further Analysis and Actions for Activity Design/ Implementation	Reporting for October 1, 2020, to September 30, 2021
Increased and inclusive value-added gains along the value chain, including bottlenecks in innovation adoption and scale-up and where these bottlenecks may be gender-related or affect youth in particular (Nigeria, Bangladesh, Zambia, Cambodia)	Natural weather patterns and slowly changing weather patterns and temperatures can impact the production area of a given standing crop of fish, or crops of raw materials for fish feed.	Risks must be addressed on an individual basis.	Researchers will discuss potential climate risks with the resilience technical advisor using USAID's Climate Risk Screening and Management Framework and adjust research as necessary.	Consultations with regional teams indicate that climate-related changes in weather patterns do not affect fish supply or the availability of raw materials for fish feed for current activities. Severe weather events pose a risk for aquaculture production specifically in Nigeria as previously addressed in this table.
Improve sustainable fisheries management (Cambodia, Kenya)	Changes in sea or river temperatures may impact fish stocks and cause coral bleaching, which could offset gains made by the activity on sustainable fisheries management. Coral may also be impacted by ocean acidification. Extreme weather events, such as storms, can damage coral and cause declines in fish stocks as well as destroy boats used by fishers.	Capacity-building efforts and related research on developing sustainable fisheries management activities will consider relevant climate risks. .	Researchers will discuss potential climate risks with the resilience technical advisor using USAID's Climate Risk Screening and Management Framework and adjust research as necessary.	Consultations with regional and activity teams indicate that climate-related changes in water temperatures will only affect the participants in the Samaki Salama activity and the Micronutrient Impact of Oysters activity. The Samaki Salama team identified a climate-resilient fish species (rabbitfish) and is strengthening sustainable fishing systems for rabbitfish. With coral bleaching due to rising water temperatures, these communities are likely to be more affected by extreme weather events. However, transitioning livelihoods to greater reliance on rabbitfish, which do not depend on coral reefs, is an adaptive capacity

Defined or Anticipated Activity Elements	Climate Risks	How Risks are Addressed at Activity Level	Further Analysis and Actions for Activity Design/ Implementation	Reporting for October 1, 2020, to September 30, 2021
				in the face of climate change. The Micronutrient Impact of Oysters activity is part of a larger scale effort to contribute to improving the health of vulnerable coastal mangrove ecosystems to adapt to climate change.
Human and Institutional Capacity Development (HICD; Nigeria, Zambia, Kenya, Cambodia, Bangladesh)	Catastrophes due to fire, flood, hurricanes, etc. would interrupt many HICD activities temporarily. Structures that may be depended upon to provide research services could be damaged by climate-related events.	Adaptive management strategies will be used to respond to these unexpected events if necessary.	None	Nothing to report.

Climate-related shocks affecting activities in Nigeria and team response

Activity Name	Climate-Related Shocks	States & Local Government Areas Affected	Team Response
Aquaculture Diversification in Rural Communities	Severe flooding, severe weather events, and severe drought (only in Jega and Ngaski)	Kebbi State (Arugungu, Jega, Ngaski), Sokoto State (Usmanu Danfodiyio University), Ebonyi State (Ikwo), Ibadan State (University of Ibadan)	Use of tube wells to aid pond impoundment and use of sandbags to reinforce the pond embarkment.
Lean Production Systems	Severe flooding, fluctuating temperature and incessant rainfall pattern, exceptionally high water table, climate-related storms, unusually high tides, and acid rain (only in Warri South, Okpe, and Ovwie)	Delta State (Ughelli North, Ughelli South, Ethiope East, Warri South, Okpe, Ovwie)	Advice given to farmers on the importance of reinforcing the pond dikes and not to obstruct the pathway of surface runoff to flood detention and retention areas when constructing the new ponds.
Lean Production Systems	Fluctuating temperature and rainfall pattern, length of seasons, exceptionally high water table, climate-related storm and disease occurrence, and severe flooding (only in Odogbolu, Sagamu Ijebu East, and Ijebu North)	Ogun State (Odogbolu, Ijebu- East, Sagamu, Odeda, Ijebu-North, Yewa-North)	Nothing to report.