Feed the Future Innovation Lab for Fish

Semi-Annual Report October 1, 2022 – March 31, 2023

Cooperative Agreement 7200AA18CA0030

Feed the Future Innovation Lab for Fish

Semi-Annual Report
October 1, 2022 – March 31, 2023

Cooperative Agreement 7200AA18CA0030

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 Health and Food Security
Mississippi State, Mississippi 39762

Progress Made by Fish Innovation Lab Activities During the Reporting Period

See Appendix 1 for additional details on activities, sub-activities, and accomplishments.

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 (Farm Diversification)

The activity team conducted a national workshop on rice-fish farming and a training on fish seed production in Kebbi and Ebonyi States. The team completed the laboratory analysis to test the performance of fish feed formulated using rice bran and fish offal. Activity outcomes were disseminated through activity attendance at Aquaculture America 2023, New Orleans, USA. This included presentation of four oral papers and development of four knowledge-based papers for review and possible publication after the conference. In addition, the team conducted the midterm socioeconomic survey including Household Dietary Diversity Score (HDDS) and Food Insecurity Experience Scale (FIES). The survey will be utilized in designing the rice-fish business manual. The activity sponsored five Master of Science (MS) projects submitted for final thesis defense.

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)

The team completed feed trials, making progress towards showing farmers that it is worthwhile to invest in rearing Black Soldier Fly (BSF) to reduce the cost of fish feed. Reducing feed costs reduces the cost of supplying fish, making it a food item more accessible to the poor. The team conducted a training of enumerators, including a refresher course for enumerators, and commenced baseline data collection. The team deployed BSF colonies and trained farmers how to use the colonies to rear the BSF larvae.

Activity 1.3: Improving Efficiency in the Nigerian Aquaculture Sector by Employing Lean Production Systems (Lean Production Systems)

The activity team continued to engage women and young innovators in their training efforts, which can further support dissemination of the Lean applied technologies. Among the 265 overall participants in training activities, 20% were women, and 44% were between 31-43 years old. Other activity outreach and adoption efforts included seminars, farm visits, webinars, and online social groups. In addition, the team is conducting data analysis.

Activity 1.4: Development of Bighead Catfish (*Clarias macrocephalus*) Culture for Sustainable Aquaculture in Cambodia (Bighead Catfish)

The activity team started the trial on bighead catfish in the aquaria of the wet lab using commercial feeds from two companies and two protein levels (i.e., Ocialis 30% and 35%, and Dollar 30% and 35%). Fish growth performance and water quality was recorded to monitor the trial. The technical team finalized the experimental procedures for upcoming experiments. The team surveyed and checked the fingerlings for the upcoming trials with different suppliers and will purchase and transport the fingerlings to the wet lab in April 2023. The activity donated bighead catfish to relevant partners for learning, research, teaching, and hatchery purposes, including a training in which the students hatched three pairs of bighead catfish and produced bighead catfish fry.

Activity 1.5: Achieving Coral Reef Fishery Sustainability in the Kenyan Biodiversity and Climate Refugia Center (Coral Reef Fishery)

The activity team communicated the status of fisheries resources and research findings to six additional Beach Management Units (BMU) within the Diani-Chale area. The meeting brought together a total of 228 BMU members of the communities with a blend of young, old, businesspeople, fishermen, fish vendors, educated, less educated, men, and women. More community members have been equipped with knowledge and skills in mobile phone data collection and use of the Kobo ToolBox application. The team managed and administered literacy tests through written examination and identified 28 BMU members— eight women and 20 men (10 youths

and 18 adults)—who will be trained and engaged in data collection exercises and use of Kobo ToolBox. Community members conducted monthly fish catch monitoring activities, which has resulted in more community members equipped with monitoring skills, improved knowledge of the status of their resources from their locations, and some gaining employment with other institutions. On the socioeconomic aspect of the activity, the team completed Institutional Review Board (IRB) training and initiated the post household-level surveys with 150 questionnaires already administered.

Activity 1.6: Cryogenic Sperm Banking of Indian Major Carps (*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)

The team cryopreserved sperm of all six fish species (rohu, catla, mrigal, silver carp, bighead carp and grass carp) and developed cryogenic sperm banks. Breeding of all six species was conducted in 22 public and private hatcheries in Mymensingh, Faridpur, Jashore, and Barishal regions using cryopreserved sperm. Seeds were produced in 17 hatcheries and stocked in 12 hatcheries and four technology-adoption hatcheries and fish farms. They are being reared along with controls in separate nursery ponds with supplementary feeds. The team conducted monthly sampling of both types of fry. The team conducted genetic characterization of broodstocks and their offspring using DNA microsatellite markers. The team also conducted training workshops on dissemination of cryopreservation technology for stakeholders (hatchery and nursery operators, fish farmers) as well as for junior faculty members and MS and PhD students. One student completed an MS degree; three PhD students and four new MS students are continuing to conduct their research.

Activity 1.7: Increasing Sustainability of Fisheries for Resilience of Cambodian Communities (Cambodian Fisheries and Food Processing)

The team completed the Citizen Science Fisheries Harvest Data Collection Program, which supported 15 fishers (including three women) from four villages along the Sre Ambel River. All fishers recorded individual-level data for 24 months. The data collection resulted in >43,900 entries for >58,500 fish individuals harvested in the Sre Ambel River. The team continued adding content and improving the user experience of the bilingual Community Fisheries Assessment Tool, iFISH. Tabs were added to display data per month and compare among years as well as a tab with photographs of fishing gear and species harvested with scientific names. In addition, the team added the maximum length data per species to contrast the sizes of fish harvested in Sre Ambel with the maximum length a species can achieve. A searchable photo identification catalog of the harvested fish was maintained by a graduate student and curated by a federal ichthyologist collaborating with the program. The team collected 91% of the expected 450 fish muscle samples for Stable Isotope Analysis representing 26 of the 30 selected fish species commonly harvested in the Sre Ambel River in three zones (lower, middle, and upper river) and two seasons (dry and wet). The team conducted a survey of 100 fishermen on processing and nutrition knowledge. The team performed the sensory evaluation of fish products with a total of 100 sensory participants, conducted a shelf-life study on fresh fish using a natural preservative, and conducted nutritional analyses of commonly consumed fish species. The team developed digital education materials and used them to conduct two workshops to transfer knowledge and skills on fish fileting, smoking, and preservation with vinegar solutions. Participants included 36 fishers and fish consumers (21 women) from Sre Ambel communities.

Activity 1.8: Advancing Aquaculture Systems Productivity Through Carp Genetic Improvement (Carp Genetic Improvement)

The activity resulted in approximately 194 kg of genetically improved G3 rohu spawn produced by hatcheries and sold to nurseries and farmers in April 2023. Approximately 2,208 farms were supplied with fish for grow-out from the 2022 spawning. The team conducted two hatchery training workshops on the management and marketing of genetically improved carp. Participants received a manual of the presented slides translated into Bangla.

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 (Biosecurity)

For the epidemiology study, the team conducted descriptive statistics classified by state identity. An unusual level of farm mortality was calculated for production system, biosecurity, management, and other potential risk factors on 220 farms (which only raised table-size catfish). Bacterial isolates were sent for whole-genome sequencing, biochemical analysis, and antibiotic susceptibility tests. The team completed the epidemiology study consolidated report. The activity successfully established a network of cluster leaders, resident veterinarians, researchers, and other stakeholders to offer health management guidance via the E-AquaHealth Network digital platform. The team visited the Mississippi State University College of Veterinary Medicine in Starkville, MS, USA and the Thad Cochran National Warmwater Aquaculture Center in Stoneville, MS, USA to participate in discussions around finalization of epidemiology and microbiology analyses. Using previous workshop findings and epidemiological study risk-factor findings, the team completed a draft set of Best Management Practices (BMP) guidelines for Nigerian catfish farmers. The team also developed a draft document of actions and next steps for a future National Aquatic Animal Health Strategy using the workshop findings, focus group discussions, and stakeholders survey. The team contributed to the Fish Innovation Lab and WorldFish workshop on "Nigerian Aquaculture: Status, Prospects and Future Growth," giving three presentations. The team also participated and presented at the Aquaculture America 2023 conference.

Activity 2.2: Identifying the Major Sources of Foodborne Pathogens in Bangladeshi Aquaculture Value Chains and Evaluating the Effectiveness of Various Risk Reduction Strategies (Sources of Foodborne Pathogens)

The team completed whole fish sample collection from various stages of the supply chain including retail wet markets, wholesale markets, and grower's ponds located in five districts. A total of 574 retail market samples (whole fish, tank water, ice, cutting board swab samples), 100 whole fish samples from wholesale markets, and 120 samples (fish, water samples) from grower ponds were collected. The team processed, analyzed, and tested the samples for the prevalence of predominant pathogens (*Vibrio*, *Salmonella*) along with *E. coli* and extended-spectrum beta-lactamase (ESBL) producing *E. coli*. The activity team performed antibiotic susceptibility tests for 298 ESBL-producing *E. coli*, 180 *Salmonella* spp., and 500 *Vibrio cholerae* isolates against a panel of clinically important antibiotics based on Clinical and Laboratory Standard Institute Guidelines. In addition, the team tested all 298 ESBL-producing *E. coli* isolates for virulence genes and conducted polymerase chain reaction (PCR) and phylogroup analysis. The team completed questionnaire surveys and collected behavioral data by conducting in-depth interviews with the key actors in pangas and tilapia fish value and supply chains. The team collected information on demographics, fish input types, marketing practices, aquaculture challenges, and practices associated with microbial contamination. The team also completed a short-term training on microbial risk analysis in regulatory process for officers from the Bangladesh Food Safety Authority. Two enrolled MSc students from the Department of Fisheries, University of Dhaka completed their thesis as a part of long-term capacity building. The team presented study findings based on the compiled laboratory and survey data from fish value chains at Aquaculture America 2023 in New Orleans, USA.

Activity 2.3: Development and Investigation of the Delivery Mode of a Multivalent Bacterial Fish Vaccine in Zambia (Vaccines for Tilapia)

The team conducted identification of bacteria associated with diseased fish in small-scale aquaculture establishments. The bacteria identified included *Lactococcus*, *Aeromonas*, *Acinetobacter*, and *Klebsiella*. These were isolated at different times of the year. The team completed the confirmation of disease-causing agents and the Minimum Lethal Doses for the isolates in *Oreochromis niloticus*. This provided the tabulations necessary for vaccine trials. The team developed and tested autogenous vaccines for the identified pathogenic bacteria. *Lactococcus* and *Aeromonas* were selected as good candidates for vaccine manufacture and formulation following pathogenicity tests. The bacteria were inactivated using formalin and then subjected to dialysis and purity and sterility tests. Vaccinated fish had an increased leucocyte count. Further

blood profiles are being conducted as the experiment progresses. The team devised methods of administering autogenous vaccines to the fish on the farms. The vaccine trials are focused on the intraperitoneal and immersion methods, which are still being validated before field trials begin. The intraperitoneal route has been adopted so far. Various protocols are being set up in terms of antigen dosage, volume, time of exposure, age, and size of the fish. To conduct the field vaccine trials using real-time setups on the lake, the team identified farms and stocked cages with 5,000 fingerlings, which are currently about 10 grams.

Objective 3: Improve Human Outcomes from the Aquaculture and Fisheries Sector

<u>Activity 3.1: Harnessing Machine Learning to Estimate Aquaculture Production and Value Chain Performance in Bangladesh (Harnessing Machine Learning)</u>

Although this activity ended in September 2022, the activity's online interactive aquaculture database as a decision-making platform/tool has since been tagged on the Department of Fisheries website at http://www.fisheries.gov.bd/ as one of the top navigation bars entitled "Online Fisheries statistics." The Director General of the department played a key role in tagging it on the government website after the activity held the final outreach workshop at the department's conference hall. Government authority acceptance of research outcomes so quickly is rare.

<u>Activity 3.2: Nourishing Nations: Improving the Quality and Safety of Processed Fish Products in Nigeria (Nourishing Nations)</u>

The team completed the activity training program by conducting a final 5-day training on fish processing techniques and business skill development with 75 fish processor attendees and nine facilitators. Topics covered included entrepreneurship, access to financial space and funding for fish, fish business plan development, formation and operation of cooperative societies, fish handling techniques, traditional and modern fish smoking and drying techniques, fish value addition, and fish packaging techniques. Practice sessions were held for participants to get hands-on experience. A self-evaluation assessment form documented an overall increase in knowledge and skills gained. The activity team completed the lab analysis of the nutrient and contaminant profile of commonly available and consumed fish in Delta State, Nigeria. These data will be used along with the market data collected on prices of animal-source foods to develop cost-per-nutrient guides. Once complete, the guides will allow for an informed examination of the food environment in Nigeria and will support government stakeholders as they design nutrition-sensitive programs and policies.

<u>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)</u>

The team engaged in a variety of social media activities, presentations, conference panels, and peer-reviewed publications. Activities included an article on Agrilinks and a two-pager featured on the Fish Innovation Lab website. The team developed a peer-reviewed publication in *Public Health Nutrition*. In addition, three draft technical reports were produced, and presentations were given at the Nutrition 2023 Conference and MSU Undergraduate Research Symposium. The lead PI was an invited participant at the USAID Product Life Cycle (PLC) Framework–Innovation to Impact (i2i) Learning Event hosted by the USAID Bureau for Resilience and Food Security and the Feed the Future Soybean Innovation Lab in Washington DC. As part of this i2i process, the activity identified potential scaling partners for Complementary Food for Africa+Dried Fish Powder (ComFA+Fish). The activity was engaged by Dr. Peter Goldsmith, Director of the Soybean Innovation Lab, to beta test the i2i Station over 60 days for USAID. ComFA+Fish, the protein-micronutrient blend promoted by the activity, was one of the 10 technologies selected to test the i2i Station through a stage-gate process of the product life cycle from product profile to scaling. The process involved 13 technology planning and documenting activities identifying customers, the technology's value proposition, and the critical resources needed to scale the technology.

<u>Activity 3.4: Samaki Salama: Securing Small-Scale Fisheries in Kenya for Healthy Nutrition and Ecosystems (Samaki Salama)</u>

The activity team conducted and accomplished all data collection and activity implementation. The activity accomplished all its objectives in conducting the cluster randomized controlled trial in Kilifi County. The activity strengthened capacity of fishermen through information sharing and provision

of fishing gears to promote sustainable fishing practices. In addition, the team provided nutrition education to caregivers to promote appropriate feeding practices and increase fish consumption. This was aimed at improving the nutritional status of young children. The activity successfully conducted the formative qualitative survey in Taita Taveta County and wrote the survey report. The nutrition team wrote reports on three rounds of home visits conducted in Kilifi County for Intervention Arm 1 and Arm 2. The fish team cleaned the fish value chain data. The research team began data cleaning, coding, and management of the household survey datasets and fisherman survey databases containing the baseline and end-line survey data from in Kilifi County. The nutrition team cleaned the 24-hour dietary recall data and entered the data in an excel template and Nutri-survey Application. The team published one journal article, a study protocol paper detailing the Samaki Salama study procedures and implementation process. The team initiated data analysis of all activity data.

Activity 3.5: Population Ecology and Current Distribution Assessment of the Introduced Invasive Crayfish in the Kafue Floodplain and Lake Kariba, Zambia (Zambia Crayfish)

The team engaged in trap collection of crayfish in areas known to have high numbers of invasive crayfish (Kafue River and Lake Kariba). Considerable descriptive length-frequency data was collected to describe the crayfish population structure in selected Zambian waterways. To enhance the trapping studies, the team purchased crayfish from fishers to supplement measurements and assure a sufficiently large sample size to enable future spawn-class cohort analysis. The Qualtrics survey was completed with approximately 50 responses received and is yielding data on presence or absence of crayfish in water bodies around the country, how the crayfish are perceived to be affecting indigenous fisheries, and how crayfish are being utilized as an alternative fishery catch. The team conducted a survey of 342 fishers affected by crayfish presence in various fishing camps on Lake Kariba (Siavonga and Sinazongwe) and Kafue River (Itezhi tezhi and Kafue town). The survey collected background information on the fishers, including livelihood options, education, household characteristics, type of fish caught, and markets, as well as issues relating to crayfish. It asked whether the crayfish was present in the locations, how the fishers view it, what they think should be done to it, whether they catch it as main or bycatch, and whether they consume it.

Activity 3.6: Strategies for Inclusive Aquaculture Value Chain in Bangladesh: Analysis of Market Access, Trade, and Consumption Pattern (Market Analysis)

The team analyzed the consumption pattern of sources of protein, fish, meat, poultry, and eggs across the different income quantiles and geographic regions, rural and urban. Income was categorized into four quantiles based on the total household expenditure ranging from the most impoverished (quantile 1) to the richest households (quantile 4). The species groups of fish included hilsa, rohu/katla/mrigal, shol/gajar/taki, exotic carps, koi, baila/tapashi, shrimp, sea fish, mala/kachi/chapila (small fishes), dried fish, puti/tilapia, magur/shing, pangasius/boal/air, tangra/eel, and other fishes. Meat included beef, buffalo, and mutton. Poultry consisted of hens and duck. Eggs consisted of hen and duck eggs. The team implemented the quadratic almost ideal demand system (QUAIDS) model to estimate the nutrition elasticity of fish across the species. Using the Household Income Expenditure Survey (HIES) data of 2000, 2005, 2010, and 2016, the activity team drafted a paper on household fish consumption patterns in Bangladesh and a paper on estimating nutrition elasticity of fish in Bangladesh. The team presented numerous papers at Aquaculture America 2023, New Orleans, USA, based on the results of the activity.

Activity 3.7: Micronutrient Impact of Oysters in the Diet of Women Shellfishers (Micronutrient Impact of Oysters)

The team completed analysis of the final element, arsenic, in the 915 oyster samples collected from three estuary sites in Ghana. Technical review of the final activity reporting is ongoing.

Associate Awards and Buy-Ins

Buy-In 1: Distant Water Fleets: Licensing Transparency and Implications for Food Security (DWF Activity)

The activity team finalized data compilation and synthesis on all four research case studies. To do this, the team engaged partners within and outside of USAID Missions to ensure that they had identified the most relevant and appropriate datasets for the work. Quantitative and qualitative analyses exploring the relationships between distant water fleets and food security were also completed. The research team proposed and has been accepted for a full day session on DWF at the 2024 World Fisheries Congress. An expert review process was undertaken to finalize a comprehensive evaluation tool for national systems granting foreign fishing access. Five experts were engaged in a comment period, after which the team revised and finalized the evaluation tool. The team applied the tool in four case studies to conduct evaluations of national licensing and access regimes through input from desktop research and interviews with 12 key informants with relevant expertise for each case study. The team developed a one-page brief for USAID with results, and the USAID/Washington staff will add a section about cross-bureau collaboration. The team developed one-to-two-page Mission-specific briefs with results and policy recommendations.

Issues or Concerns Encountered During the Reporting Period

COVID-19 Pandemic-Related Issues

Fish Innovation Lab teams continued to travel and organize more in-person meetings in the first half of FY23 as COVID-19-specific restrictions and requirements for travel and gatherings have generally been reduced or eliminated in most countries. The in-person workshop on "Nigerian Aquaculture: Status, Prospects, and Future Growth" was attended by 55 participants in October/November 2022, and the first in-person annual meeting in New Orleans was attended by 71 participants in February/March 2023. These meetings emphasized the value added of in-person events in conjunction with virtual platforms. As one PI highlighted, it was an invaluable opportunity to meet, learn, share findings, and identify opportunities with Fish Innovation Lab management entity (ME) leaders, the USAID AOR, team members from all research activities, and other experts.

Non-COVID-19 Pandemic-Related Issues

Non-COVID-19 issues encountered by the research teams include:

- The Farming Insects activity in Nigeria faced further delays implementing its revised plan following previous challenges due to economic and political disruptions in Nigeria. These included lack of financial liquidity because of the government program to replace the currency, fuel scarcity, presidential elections, and insecurity. Activities are expected to be back on track by May 2023. The PI opted to stay in Nigeria and not attend the February Final Annual Meeting in New Orleans to ensure progress in the field.
- The Bighead Catfish activity in Cambodia will continue catfish trials until June 2023 due to earlier delays in setting up their wet lab. The team recently procured two small-scale feed pelleting machines but could not operate them due to lack of experienced trainers. The Asia Regional Coordinator arranged for expertise from Bangladesh to train the activity wet lab technicians next quarter.
- The Cryogenic Sperm Banking activity in Bangladesh faced disruption initiating their carp breeding programs in previous years, so the team will continue targeted breeding and fry/fingerling nursing activities during the next carp breeding season in April–June 2023. The activity conducted breeding of the six target species using cryopreserved sperm collected from the cryogenic sperm bank in 22 government and private hatcheries, but seeds were not produced in five of those hatcheries. This was due to poor egg and sperm quality, water quality such as high iron content, turbidity, and harmful zooplankton, among other reasons. The team has yet to complete genetic characterization of broodstocks due to difficulties such as impurity of chemicals, equipment malfunctions, and disruption of power supply in the laboratory.
- The Bangladesh Carp Genetic Improvement activity delayed submission of a paper on development of parentage assignment tools due to unanticipated anomalies in the data and a need to recode previously developed R functions.

- The Kenya Samaki Salama activity team had some of its participant meetings disrupted by elephants approaching the area and posing a safety risk. The team also faced the challenge of managing community expectations to participate in the activity. All households were made aware of the activity because they had to be inventoried, but the study by its nature was limited to a small sample. The team involved community leaders in explaining to the community.
- The Zambia Crayfish activity did not undertake key informant interviews of crayfish traders, retailers, and consumers within Lusaka to prevent the perception that the activity was conducting supply chain analysis or market promotion of an invasive species. Also, due to unreasonable transportation logistics, the team did not conduct trappings in Cuando to assess the presence of crayfish. Trappings were confined to Lake Kariba and the Kafue River. The team postponed focus group discussions and key informant interviews scheduled for this period until May 2023 based on team member availability.
- The Ghana Micronutrient Impact of Oysters activity identified a mislabeling of units on research results for the mercury content of oysters sampled, resulting in a significant decrease in the mercury levels found and previously shared. The team is revising reports, presentations, and abstracts accordingly.
- The Distant Water Fleet buy-in activity team continued to experience challenges in meeting research goals due to data availability. To ensure useful research results despite this challenge, the team created an overarching framework for the research, then used that framework to tailor the analytical approach for each case study to align with available datasets.
- The two activities scheduled to close out during this reporting period experienced delays in completing all final submissions. Nourishing Nations had an unexpected personal absence. Micronutrient Impact of Oysters requested an extension through June 30, 2023, to revise reports and prepare an outreach brief and publication.
- Two personnel (Shauncey Hill, Program and Finance Manager, and Jared Dees, Contract and Grant Specialist) of the MSU Management Entity accepted promotions within MSU and are leaving positions with the Fish Innovation Lab. MSU has provided interim personnel and expects to replace the positions in the coming quarter.

Human and Institutional Capacity Development, Other Cross-Cutting Themes, and Management Entity-Related Support

Short-Term Training

The Fish Innovation Lab subawardees held 21 short-term trainings during the reporting period. Overall, a total of 823 beneficiaries were reached through short-term training of different categories. Among these beneficiaries, 553 were male and 270 were female. Notably, the highest proportion of trained individuals were producers (73%) who were trained on the innovative practices, approaches, and technologies developed through research activities.

Country of training	Activity	Brief purpose of training	Number trained		
			M	F	Total
Nigeria	Halwart - Farm Diversification	Training on fish breeding and hatchery management in Kebbi State and Ebonyi State	**81**	**26**	**107**
Nigeria	Pechal - Farming Insects	Training on the use black soldier fly larvae meal in catfish production in Ebonyi, Cross River, and Oyo States	130	62	192
Cambodia	Hok - Bighead Catfish	Trainings on water quality monitoring and feeding, fish sampling, and fish stocking and identification	9	5	14
Kenya	McClanahan - Coral Reef Fishery	Fish catch and price monitoring training, Institutional Review Board (IRB) and Kobo Toolbox data collection training for enumerators	181	67	248
Cambodia	Correa - Cambodian Fisheries and Food Processing	Training local fishermen on fish processing and preservation including smoking and dipping fish in vinegar for preservation without refrigeration, and a workshop of fresh fish processing and vinegar preservation	38	32	70
Bangladesh	Hamilton - Carp Genetic Improvement	Training to provide carp hatchery managers with understanding on the WorldFish Carp Genetic Improvement Program, genetic theory, broodfish genetics, and broodfish care in the context of current and future releases of genetically improved carp in Bangladesh	42	9	51
Nigeria	Chadag Biosecurity	Workshop on sequencing and bioinformatics with PhD student from the University of Ibadan	1		1
Bangladesh	Islam – Sources of Foodborne Pathogens	Training to increase capacity on understanding microbial risk assessment to Bangladesh Food Safety Authority (BFSA) under Food Ministry	19	6	25

Country of training	Activity	Brief purpose of training	Number trained		
			M	F	Total
Nigeria	Pasqualino - Nourishing Nations	Training on improving fish processing, value addition and investment opportunities for fish processors in Delta State	21	54	75
Bangladesh	Dey - Market Analysis	Training on technology adoption in aquaculture farms	31	9	40

Long-Term Training

From the reporting period of FY22 to Q1 FY23, 32 individuals from various academic levels—undergraduate, graduate (MS and PhD), and postdoctoral—participated in long-term trainings. By the end of Q2 in FY23, an additional six individuals were added, with four completing their training within the quarter. Of the initial 32 beneficiaries, four have completed their long-term training. The summary shows that as of the end of the FY23 semiannual reporting period, there were two new, 28 continuing, and eight individuals who had completed their training.

PI and student number	Sex	Home institution name	Degree	Major	Program end date	Degree granted	Student's home country	Status FY23 Q1 Q2
Belton	M	Bangladesh Agricultural University	PhD	Aquaculture Systems and Development	2022/23	No	Bangladesh	Continuing
Chadag 1	M	University of Ibadan	Master, Veterinary Public Health (MVPH)	Fish Epidemiology	2022/23	Yes	Nigeria	Continuing
Chadag 2	F	University of Ibadan	MVPH	Fish Epidemiology	2022/23	Yes	Nigeria	Continuing

PI and student number	Sex	Home institution name	Degree	Major	Program end date	Degree granted	Student's home country	Status FY23 Q1 Q2
Correa 1	M	Royal University of Phnom Penh	Master of Science (MS)	Royal University of Phnom Penh	2023	Yes	Cambodia	Continuing
Correa 2	F	Royal University of Phnom Penh	MS	Royal University of Phnom Penh	2023	Yes	Cambodia	Continuing
Halwart 1	M	University of Ibadan	PhD	Agriculture Economics	2023	No	Nigeria	Continuing
Halwart 2	F	University of Ibadan	PhD	Fisheries Management	2023	No	Nigeria	Continuing
Halwart 3	M	Usmanu Danfodiyo University, Sokoto	MS	Fisheries Ecology	2021	No	Nigeria	Continuing
Halwart 4	F	University of Ibadan	MS	Fish Nutrition	2022	No	Nigeria	Continuing
Halwart 5	F	University of Ibadan	MS	Fish Nutrition	2022	No	Nigeria	Continuing
Halwart 6	F	University of Ibadan	MS	Fish Nutrition	2022	No	Nigeria	Continuing
Halwart 7	M	Federal University of Technology Owerri	MS	Fish Nutrition	2021	No	Nigeria	Continuing

PI and student number	Sex	Home institution name	Degree	Major	Program end date	Degree granted	Student's home country	Status FY23 Q1 Q2
Halwart 8	M	University of Ibadan	MS	Fish Nutrition	2022	No	Nigeria	Continuing
Hangombe 1	F	University Zambia	PhD	Research Training	2024	No	Zambia	Continuing
Hangombe 2	M	University Zambia	MS	Research Training	2023	No	Zambia	Continuing
Hangombe 3	M	University Zambia	MS	Research Training	2023	No	Zambia	Continuing
Hok 1	M	Royal University of Agriculture	PhD	Agricultural Science	2023	No	Cambodia	Complete
Hok 2	M	Royal University of Agriculture	Undergrad	Agricultural Science		No	Cambodia	Complete
Hok 3	M	Royal University of Agriculture	Undergrad	Agricultural Science		No	Cambodia	Complete
Hok 4	M	Royal University of Agriculture	Undergrad	Agricultural Science		No	Cambodia	Complete
Hok 5	M	Royal University of Agriculture	Undergrad	Agricultural Science		No	Cambodia	Complete

PI and student number	Sex	Home institution name	Degree	Major	Program end date	Degree granted	Student's home country	Status FY23 Q1 Q2
Islam 1	M	University of Dhaka	MS	Fisheries and Biotechnology	2022/23	No	Bangladesh	Continuing
Islam 2	F	University of Dhaka	MS	Fisheries and Biotechnology	2022/23	No	Bangladesh	Continuing
McClanahan 1	F	University of Rhode Island	PhD	Biological and Environmental Sciences	2023	No	USA	Continuing
Oaks 1	M	University of Ghana	PhD	Research Training	2024	No	Ghana	Continuing
Pasqualino 2	F	University of Calabar	MS	Nutrition & Food Science	2022/23	No	Nigeria	Complete
Pasqualino 3	M	University of Calabar	MS	Nutrition & Food Science	2021/22	No	Nigeria	Complete
Pechal 1	M	University of Ibadan	PhD	Microbial analysis	2025	No	Nigeria	New
Pechal 2	M	University of Ibadan	PhD	Agricultural Economics	2023	No	Nigeria	New
Rice 1	F	University of Zambia	MS	Research Training	2022	No	Zambia	Continuing
Sarder 1	M	Bangladesh Agricultural University	PhD	Fish Breeding and Biotechnology	2024	No	Bangladesh	Continuing

PI and student number	Sex	Home institution name	Degree	Major	Program end date	Degree granted	Student's home country	Status FY23 Q1 Q2
Sarder 2	M	Bangladesh Agricultural University	MS	Fish Breeding and Biotechnology	2021	No	Bangladesh	Continuing
Sarder 4	M	Bangladesh Agricultural University	PhD	Fish Breeding and Biotechnology	2024	No	Bangladesh	Complete
Sarder 7	M	Bangladesh Agricultural University	MS	Fish Breeding and Biotechnology	2023	No	Bangladesh	Continuing
Sarder 8	M	Bangladesh Agricultural University	MS	Fisheries Biology and Genetics	2023	No	Bangladesh	Continuing
Sarder 9	M	Bangladesh Agricultural University	MS	Fisheries Biology and Genetics	2023	No	Bangladesh	Continuing
Sarder 10	F	Bangladesh Agricultural University	MS	Fisheries Biology and Genetics	2023	No	Bangladesh	Continuing
Sarder 11	F	Bangladesh Agricultural University	MS	Fisheries Biology and Genetics	2023	No	Bangladesh	Continuing

Other Cross-Cutting Theme Accomplishments

Gender Equity and Youth Engagement: Kathleen Ragsdale and Mary Read-Wahidi, Fish Innovation Lab gender and youth equity specialists, administered the Gender Responsive Aquaculture/Fisheries Development Assessment (GRADA-FIL) Wave II to 75 Fish Innovation Lab researchers from December 2022–January 2023, analyzed the results, and submitted a draft GRADA-FIL Wave II Results Brief to the Management Entity. They completed the following online course that is in production:

Ragsdale, K., & Read-Wahidi, M. (2022) *Gender Impacts Lab Toolkit: Your Comprehensive Guide to Conducting Focus Groups in Village Settings for Gender Responsive Agricultural*

Development [Online Certification Course]. USAID, Feed the Future Soybean Innovation Lab, Feed the Future Innovation Lab for Fish, Gender Impacts Lab, Mississippi State University.

Ragsdale and Wahidi facilitated the Mainstreaming Gender Equity & Youth Inclusion panel at the Fish Innovation Lab final annual meeting that was followed by a breakout session on this theme. Highlights of the discussion included that women's time burdens were different than men's time burdens, and cultural barriers to women's participation and leadership were important considerations for improving gender equity within research teams and among beneficiary populations.

Notable activity accomplishments related to gender equity and youth include:

- **Bangladesh Cryogenic Sperm Banking:** The activity team conducted nine stakeholders' workshops on the dissemination of sperm cryopreservation technology in Mymensingh, Barisal, Faridpur, and Jashore regions. More than 220 participants attended, about 30% women and more than 40% youth. Among the 25 junior faculty, MS, and PhD students who participated, 52% were women. All the participants, especially the youth and women, expressed their willingness to participate in seed and fish production activities.

- **Bangladesh Sources of Foodborne Pathogens:** Two MS students from University of Dhaka conducted research, and six technicians worked in the lab. All were youth, and 50% were women. Women actors are rare in the traditionally male-dominated fish supply chain. However, at the production level, women family members of pond owners play an important role, especially at hatcheries or fish grower ponds. Twenty-five percent of trainees in the activity's risk assessment training workshop were women. They serve in the Bangladesh Food Safety Authority as food safety monitoring officers, scientific officers, and food safety officers, among other roles. At the retail wet-market level, about 50 percent of the vendors targeted by the activity were from the younger age group (below 35). This is significant as interventions at these retailer points could have a substantial impact on fish quality in terms of microbial contamination. Younger individuals tend to adopt good practices more quickly, which can ultimately improve the sector in Bangladesh.

- **Bangladesh Market Analysis:** Twenty-five percent of the 40 participants at a day-long training workshop on "Technology Adoption in Aquaculture Farms" in February 2023 were women.

- **Cambodia Fisheries and Food Processing:** Thirty-eight percent of the 32 local community participants at a training workshop on fish preservation and fish processing techniques were women. Three women participated in the citizen science fisheries harvest data collection program. Activities continued to address gender inequalities in the fish value chain; for example, participatory information meetings and training workshops in villages along the Sre Ambel River included up to 56% participation of women.

- **Cambodia Bighead Catfish:** The activity strongly encouraged youth involvement in implementation. Four undergraduate students from the Royal University of Agriculture completed a short-term hands-on training. Another 12 students were trained on fish sampling, water quality monitoring and feeding, and fish stocking and identification.

- **FishFirst! Zambia:** The activity has focused on addressing gender inequality in the fish value chain and food insecurity/nutrition (primarily targeting 6- to 23-month-olds and pregnant/lactating women) at the household- and community-levels. A success story entitled, "A community health worker becomes a FishFirst! Zambia Champion and local catalyst for change" describes how a woman activity trainee is spreading the knowledge she gained and working with other women to mobilize resources to conduct another training in their community.

- **Nigeria Nourishing Nations:** The activity addressed gender equity by inviting women and youth fish processors to a training on fish processing techniques and business skills to strengthen women's capacity as strong economic actors in the fish processing sector. Seventy-two percent of participants were women. Many planned to use the knowledge and practical experience gained to develop business plans to enhance productivity and expansion.

Human Nutrition: Lora Iannotti, Fish Innovation Lab nutrition specialist, worked most closely with the Fish Innovation Lab activities addressing Area of Inquiry 3: Human Outcomes, including Samaki Salama in Kenya (serving as the PI), FishFirst! Zambia, Micronutrient Impact of Oysters in Ghana, and Nourishing Nations in Nigeria. All four activities target women and children in the first 1,000 days of life, the most vulnerable period to malnutrition. The activities are also located in very low-resource settings, which heightens the risks for nutrient deficiencies, stunted growth and development, and other adverse outcomes. Dr. Iannotti assisted PIs and other team members to better characterize nutritional problems and fine-tune the targeting and intervention strategies for reaching vulnerable groups. Iannotti also supported activities across different areas of inquiry reaching highly vulnerable groups, most notably Sources of Foodborne Pathogens in Bangladesh, Market Analysis in Bangladesh, and Lean Production Systems in Nigeria. The work has highlighted the need for more research on low- and middle-income countries and nutritional outcomes in the first 1,000 days of life. Iannotti participated in three conferences where she disseminated Fish Innovation Lab research results: the Annual Meeting of the American Public Health Association (APHA), the 22nd IUNS-ICN International Congress of Nutrition in Tokyo, and the Global Health Conference at Washington University in St. Louis. Iannotti facilitated the Advancing Nutrition panel at the Fish Innovation Lab final annual meeting that was followed by a breakout session on this theme. Highlights of the discussion indicated that the Fish Innovation Lab provides an exciting opportunity to address hidden hunger and nutrition deficiencies around the world.

Nutrition-related achievements among the Fish Innovation Lab research activities include:

- **Bangladesh Sources of Foodborne Pathogens:** The activity team interviewed producers, consumers, traders, and market sellers about their fish consumption frequency as a protein source and asked if people are consuming other protein sources in their family.

- **Kenya Samaki Salama:** Formative research in Taita Taveta county provided data on fishing and child feeding habits related to fish. This county is reported to have high malnutrition rates. The county had availability of fish from nearby lakes, but the qualitative survey will determine whether fish was accessible to households for consumption or was sold. Findings will guide interventions to help improve the nutrition status of children and communities.

- **Cambodia Fisheries and Food Processing:** The activity completed nutritional analysis of 11 commonly consumed fish species, six species more than proposed.

- **Bangladesh Market Analysis:** The activity estimated how the fisheries sector contributes to the nutrition of people based on their income, location, and other household demographic characteristics over the period from 2000–2016. The study results provide important insights on the contribution of aquaculture to the nutritional status of the country and support policy for sector development and household nutrition improvement.

- **Zambia Crayfish:** Although value chain analysis is not undertaken by the activity, survey results suggest that fishers are adapting to the presence of crayfish in their waters, and there is some shifting of markets to supply domestic tourism. There is some growing acceptance of crayfish as an alternative food source, including among the fishers.

- **Ghana Micronutrient Impact of Oysters:** The activity investigated the dietary intakes (including oyster consumption) and household food insecurity among vulnerable women shellfishers at three estuarine sites along the coastline of Ghana. Results may serve as an advocacy tool to promote nutrition and food security among women in coastal communities. The activity also found that while oysters from these sites are a rich source of dietary

minerals, concentrations of heavy metals are also a concern, likely due to pollution. These results could serve as an advocacy tool to minimize pollution in estuarine waters in Ghana.

Resilience of Value Chains/Households: In preparing for adoption and scaling, research teams applied resilience thinking, which involves planning and designing for dynamic response to emerging shocks and stresses. The Fish Innovation Lab resilience specialist, Joanna Springer, facilitated a series of collaborative workshops in which teams interacted across technical areas and exchanged ideas and experiences relevant to their countries and sectoral contexts. As an outcome of these consultations, researchers developed resilience strategies for sustaining well-being outcomes in the face of shocks and pressures related to climate change and other stresses that threaten the positive impacts of their innovations. The research teams determined the positive responses to shocks and stresses that will be necessary for effective recovery of aquaculture and fisheries systems, identified resilience capacities needed by aquaculture and fisheries systems and system actors to respond proactively, proposed interventions to strengthen those resilience capacities, and noted the various types of stakeholders who would need to be involved. Notably, the resilience strategies across areas of inquiry and country contexts involved three key elements: 1) dynamic organizing and response capacity of smallholder aquaculture producers, processors, and fishers; 2) government-sponsored infrastructure and organizational capacity to provide services and strategic investment, in partnership with private sector actors; and 3) timely emergency support to vulnerable actors through insurance schemes, cash transfers, or responsive services, etc. Research teams presented their plans for scaling and adoption and engaged in deep-dive discussions on their strategies during the Fish Innovation Lab final annual meeting, including the Strengthening Resilience panel facilitated by Joanna Springer and associated breakout sessions.

Activity-specific resilience activities include:

- **Kenya Samaki Salama**: According to anecdotal information from some of the activity sites, household incomes improved, and households were able to diversify their sources of income as a result of increased catch from gated traps aimed at allowing juvenile fish to escape. This is likely to help manage shocks and stresses in artisanal fishery operations.

- **Nigeria Biosecurity**: The activity team's continued work with the resilience specialist contributed to better understanding of resilience pathways for catfish farming systems through improved biosecurity and farm management.

- **Cambodia Fisheries and Food Processing:** The citizen science program continued training fishers to collect fisheries harvest data to establish baselines for the Sre Ambel River to enhance stock management. The activity also offered fishermen technologies to preserve fish, add value to fish, and prevent product loss through smoking and further processing such as making fish surimi.

- **Zambia Vaccines for Tilapia:** The activity is directly linked to reducing fish losses from production diseases. Vaccinating fish will bring benefits to fish animal welfare, transboundary biosecurity, local farmer and industry economics, food safety, and public health. It also leads to implementation of a locally enabled solution in the local aquaculture industry that addresses the global problem of antimicrobial resistance. The program has highlighted deficiencies in the aquaculture industry such as lack of biosecurity and the need for improved fish health programs.

- **Bangladesh Sources of Foodborne Pathogens:** Questionnaires and in-depth interviews captured the practices of primary producers farming fish intensively, especially biosecurity and mitigation of fish infection during production, which is a major problem for farm owners. There is no standard guideline for the treatment of infected fish in ponds, so farmers tend to use antibiotics indiscriminately as prophylaxis and metaphylaxis. They also use probiotics, which have little or no regulatory oversight by the authorities. Fish farmers are aware of the consequences of such practices, but they have few options to maintain fish production and improve their livelihoods. Initiatives to minimize the negative impact of these stresses on aquaculture and fishery operations in the country are crucial.

- **Kenya Coral Reef Fishery:** The activity informs managers and resource users of the state of fisheries resources. As a result, communities have taken up initiatives to amend by-laws that govern fishing areas, such as setting targets to achieve a fishing effort of four to seven fishers per square kilometer. Patrols by local communities and national government partners to root out illegal activities have increased. Community members are more willing to learn and practice fish catch monitoring to inform resource status and as an employment opportunity.

- **Nigeria Farming Insects:** Lower-cost fish feed using black soldier fly larvae meal enables farmers to better cope with the financial stress of fish production. It may also make fish more accessible to more consumers at a lower cost. The activity is also teaching farmers to rear black soldier fly larvae through farm-based demonstrations, building their capacity for resilience by producing a key feed component locally.

- **Zambia Crayfish**: The research has clarified that the most critical goal of managing invasive crayfish in Zambia is to prevent westward expansion into the Cuando River watershed and other tributaries leading into the ecologically critical Okavango Delta World Heritage Protected Area.

- **Bangladesh Cryogenic Sperm Banking:** The growth of cryopreserved sperm-originated seeds is significantly higher than those produced from fresh sperm of hatchery-origin males. The seeds of six carp species are being reared for quality brood production. It is expected that once the broods produce seeds, they will have higher growth, and hatchery operators will be able to sell them at a higher price, improving the resilience of the hatchery and production nodes of the value chain.

- **Bangladesh Carp Genetic Improvement:** Approximately 194 kg of genetically improved G3 rohu spawn was produced by hatcheries and sold to nurseries and farmers in April 2023. Approximately 2208 farms were supplied with fish for grow out from the 2022 spawning, increasing resilience of productivity in the sector.

Capacity Building: The short- and long-term training accomplishments have been summarized in previous sections. Glenn Ricci, capacity development specialist, continued to support the Fish Innovation Lab student network. Students submitted posters, and some attended the in-person final annual meeting. Ricci facilitated a panel at the meeting on Advancing Human and Institutional Capacity Development, which was followed by a breakout session on this theme. Highlights of the discussion included the critical need for creative solutions for how to reach certain stakeholders, engage them, and motivate those involved to follow through so that capacity development leads to behavior change.

Activity-specific capacity building activities include:

- **Bangladesh Cryogenic Sperm Banking:** Seeds produced using cryopreserved sperm are being reared in hatcheries and in some technology adoption fish farms across four regions to produce broods. Seeds are sampled monthly in all the nursery points with the help of hatchery and farm operators. Seven students (3 PhD and 4 MS) and 22 hatchery operators (8 public and 14 private) took part in the breeding and received hands-on training. This will increase their capacity to produce quality broods by themselves. Seeds produced from the cryopreserved sperm-originated quality broods can be a good source of income.

- **Kenya Samaki Salama:** The activity issued fishermen modified basket traps with escape gates for small fish, enabling fishing households to increase their catch and improve fish consumption at the household level. The fishermen were educated on sustainable fishing practices while caregivers were educated on appropriate child feeding practices. The caregivers also received three follow-up visits to encourage them to continue practicing what they had learned. The visits helped identify households with challenges to offer more educational support.

- **Kenya Coral Reef Fishery:** The activity involved primary stakeholders in resource monitoring, building their capacity and creating enabling conditions for sustainability of the practice and better management of the fishery. Findings showed that if communities are trained and empowered, they can monitor their fisheries resources and produce basic data of comparable or higher quality than fisheries officers. Trained community persons were able to transfer skills to new recruits. Quality data that informs actual status of resources was presented to non-government organizations and government institutions. Feedback of the results of the fisheries monitoring initiated community-driven conversations to improve enforcement of banning illegal fishing gear. Government institutions such as Kenya Wildlife Service and Fisheries Departments are coming on board to help with enforcement.

- **Cambodia Fisheries and Food Processing**: The activity team continued training and providing feedback to the 15 fishers participating in the citizen science program collecting fisheries harvest data in the Sre Ambel River and continued collaborating with one Royal University of Phnom Penh faculty and one federal ichthyologist. A key to the success of the citizen science program has been continuous monthly follow-up on data quality and retraining of fishers as needed. Processing options of smoking, surimi production, and natural preservation with vinegar were provided during workshops, building value chain actors' capacity to increase the value and shelf life of fish. Successful technology transfer is associated with the fact that these processing techniques are simple, inexpensive, and suitable for local markets. Training a graduate student as a mechanism to bridge the gaps in fish processing knowledge is an important factor for success after the end of the activity.

- **Nigeria Farm Diversification**: Fish seed availability is a bottleneck that could limit the adoption of rice-fish farming. The activity trained selected farmers and practitioners in Ebonyi and Kebbi States on fish seed production, but more needs to be done to strengthen the capacity of interested farmers and hatchery operators for catfish and tilapia breeding.

- **Cambodia Bighead Catfish:** The activity coordinator participated in the Cambodian Certification for Aquaculture Professionals (Cam-CAP) training, a joint effort to build more human resources on aquaculture in the country. The activity has strengthened partnerships by providing broodstocks of bighead catfish for teaching, research, and hatching purposes; engaging in training activities; and hosting a visit by various stakeholders to learn about the wet lab's activities.

- **Bangladesh Sources of Foodborne Pathogens:** The activity organized a one-day training at the Bangladesh Food Safety Authority on food safety risk analysis in the regulatory process for food safety officers involved in risk analysis activities at the community level. Trainees were eager for more advanced risk assessment training, motivating the activity team to plan comprehensive training programs on food safety risk assessment that could greatly influence the management of food safety concerns in the country.

- **Nigeria Nourishing Nations:** A key activity achievement was strengthened capacity among women and youth fish processors in Delta State, Nigeria. Fish processors began organizing into business cooperatives with support from training facilitators and activity team members because of the training they received. Processors strengthened their technical skills in producing high-quality, safe, and nutritious processed fish products for local consumption and strengthened their business skills in marketing their products. Women and youth fish processors reported frequent use of the low-literacy tools developed by the activity for educating customers and the general public on the benefits of fish consumption for human nutrition. The tools also increased knowledge among women fish processors about proper nutrition, empowering their decision-making ability, particularly in relation to their business practices.

- **Bangladesh Harnessing Machine Learning:** The Department of Fisheries website has tagged the activity's online interactive aquaculture database as a decision-making platform/tool on its homepage navigation bar (see "Online Fisheries statistics" at http://www.fisheries.gov.bd/).

- **Bangladesh Carp Genetic Improvement:** Sixty men and eight women attended two hatchery training workshops on the management and marketing of genetically improved carp. Participants received a manual of the presented slides translated into Bangla (https://digitalarchive.worldfishcenter.org/handle/20.500.12348/5351).

Management Entity (ME) and Partner Activities

The Fish Innovation Lab ME implements its research portfolio to achieve knowledge and technology adoption, scaling, and impact.

The ME organized the Fish Innovation Lab Annual Meeting February 27–March 1 in New Orleans. This was the Fish Innovation Lab's first in-person annual meeting, and it provided an opportunity for research teams to present their work, interact and learn from one another, and interact with the ME and External Advisory Board. The meeting included sessions on research activity results, successes and challenges related to the four cross-cutting themes, and guidance from the ME on activity closeout and data management processes. Keynote addresses were provided by Stella Williams, Founder of Nigerian Women in Agricultural Research for Development (NiWARD), and Shakuntala Haraksingh Thilsted, Director of the CGIAR Nutrition, Health and Food Security Impact Area Platform and 2021 World Food Prize Laureate. Mississippi State University President Mark Keenum provided an opening video welcome message. A student poster showcase featured 15 posters from undergraduate and graduate students and postdoctoral researchers working with Fish Innovation Lab activities.

The ME hosted a booth and a session at the World Aquaculture Society's Aquaculture America Meeting just prior to the final annual meeting titled "Fish to Feed the World: Advancing Sustainable Solutions for Global Food Security," at which 16 Fish Innovation Lab researchers presented. Five representatives of three ME partner organizations attended the in-person workshop on "Nigerian Aquaculture: Status, Prospects, and Future Growth" October 31–November 2 in Ibadan, Nigeria. The ME met with all the Nigeria research teams to take stock of where they are in the final year of their proposed plans, pin-pointing areas of concern and developing adaptive measures and plans where necessary. The ME developed and communicated close-out procedures to research teams and subawardee organizations.

The ME also supported the teams as many intensified their work to advance activities affected by earlier delays due to the COVID-19 pandemic; implemented the learning agenda and research strategy; organized meetings with USAID missions (Kenya and Nigeria); and communicated results, lessons learned, and success stories related to Fish Innovation Lab-supported activities. Indicator results were collected, and they are presented in Appendix 2.

Future Work

The next steps for the activities in implementing their work plans are as follows:

Research activities
See Appendix 3

Management Entity activities
Provide ongoing technical inputs and support to research activities, including supporting the research teams for close-out. Eleven of the nineteen activities are scheduled to be closed by June 30, 2023.

Management Entity activities

- Provide individualized support to the research activities, especially as it relates to scaling and uptake, through periodic consultations and technical assistance, including field visits when feasible.

- Conduct ME leadership site visit to Mymensingh and Dhaka, Bangladesh, on April 19–22, 2023 and to Cambodia on April 24–29, 2023.

- Engage with USAID missions and programs via meetings that showcase the Fish Innovation Lab's work in the respective countries (DWF webinars to present results are scheduled for April and May with USAID/Washington, Madagascar, Peru, Philippines, and Pacific Islands missions and implementing partners; a follow-on meeting with the Feed the Future Nigeria Agricultural Extension and Advisory Services Activity is scheduled in April).

- Participate in the Feed the Future Innovation Labs Regional Partners Meeting in Nairobi, Kenya in May, including presentations by the Samaki Salama and Coral Reef Fishery activities.

- Update the iReach platform information on all Fish Innovation Lab activities as part of iReach expansion to all USAID Innovation Lab countries to share information and build synergies with stakeholders subscribing to the platform.

- Support the implementation of cross-cutting themes through quarterly informal check-ins with teams and participate in the Innovation Lab cross-cutting theme community of practice.

- Prepare a brief summarizing the resilience strategies across sectors and regions.

- Produce additional GRADA-FIL Wave II brief(s).

- Produce Fisheries, Aquaculture, and Human Nutrition online course.

- Complete systematic review of mollusks' and crustaceans' contribution to nutrition in the first 1,000 days of life.

- Complete a Fish and Food Environment paper.

- Support the Fish Innovation Lab student network.

- Conduct and participate in monthly ME partner meetings, quarterly PI meetings, and a Learning Agenda meeting on Nutrition for Vulnerable Groups in June 2023.

- Attend and showcase the Fish Innovation Lab at virtual and in-person conferences and workshops. The Fish Innovation Lab will host a booth and participate in a tour at the AIM 4 Climate Summit in May 2023 in Washington, D.C.

- Communicate innovations, success stories, and lessons learned via technical briefs, fact sheets, success stories, etc. using social media, website, the bi-monthly newsletter, Agrilinks, and other channels.

Appendix 1. Semiannual Progress Summary Table

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
Objective 1: Improve aquaculture and fisheries productivity			
Activity 1.1: Aquacultural and rural communities: Farm diversification strategy through integrated agriculture-aquaculture systems and nutrition-sensitive value chains for better nutrition outcomes in Nigeria			
1.1.1. Development of suitable integrated rice-fish production technology through participatory research actions. **1.1.2. Understanding convenient market access approach and nutrition contributions of rice-fish farming products.** **1.1.3. Capacity development and enhancement of co-learning among all stakeholders (farmers, value chain actors, and extension workers).**	Nigeria	Halwart Lead PI (FAO), Xinhua Lead Co-PI (FAO), Fonsah US PI (UGA), Burtle US Co-PI (UGA), Ajani HC PI (UI), Omitoyin HC Co-PI (UI)	The team conducted a national workshop on rice-fish farming and a training on fish seed production in Kebbi and Ebonyi States. The activity team completed the laboratory analysis to test the performance of fish feed formulated using rice bran and fish offal. Activity outcomes were disseminated through activity attendance at the 2023 Aquaculture America meeting held in New Orleans, USA. This included the presentation of four oral papers and development of four knowledge-based papers for review and possible publication after the conference. The team conducted the midterm socioeconomic survey including Household Dietary Diversity Score (HDDS) and Food Insecurity Experience Scale (FIES). The survey will be utilized in designing the rice-fish business manual. The activity sponsored five MS projects submitted for final thesis defense.
Activity 1.2: 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			
1.2.1. Co-optimize integrated insect-to-fish (ITF) farming system infrastructure to increase local production of fish while minimizing costs of production.	Nigeria	Pechal Lead and US PI (MiSU), Souza US Co-PI (MiSU),	The team made progress towards showing farmers that it is worthwhile to invest in rearing BSF to reduce the cost of fish feed being used so that fish can be supplied cheaper, making it a more accessible food item for the poor. The team conducted a training of enumerators including a refresher course for enumerators and commencement of data collection. Deployment of the BSF

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
1.2.2. Assess the feed safety of black soldier fly (BSF) reared on available organic waste streams via microbiological assays for potential pathogens.		Omonona HC PI (UI)	colonies and the training of farmers on the use of the colonies to rear BSF was achieved. Finally, the team completed the feed trials.
1.2.3. Design and implement a survey of producers to generate data on the social and institutional context of small-scale fish farming in Nigeria.			
1.2.4. Define and model the relationships among stages of production throughout the ITF farming system, and construct a relational map of optimal profitability points for BSF and catfish production.			
1.2.5. Design and implement semi-structured interviews with key informants for a rich understanding of the social and institutional environment within which small-scale fish farming occurs.			
1.2.6. Engage women and youth representing local community groups and collaborate with academic groups in Nigeria to communicate activity results through workshops, videos, and factsheets.			
Activity 1.3: Improving efficiency in the Nigerian aquaculture sector by employing lean production systems			

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
1.3.1. 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.	Nigeria	Subasinghe Lead and HC PI (WF), Siriwardena HC Co-PI (WF), Nukpezah US PI (MSU), Steensma US Co-PI (WUSTL)	The activity team continued to engage women and young innovators in their training efforts, which can further support dissemination of the Lean applied technologies. Among the 265 overall participants in training activities, 20% were women, and 44% were between 31-43 years old. Other activity outreach and adoption efforts included seminars, farm visits, webinars, and online social groups. In addition, the team is conducting data analysis.
Activity 1.4: Development of bighead catfish (*Clarias macrocephalus*) culture for sustainable aquaculture in Cambodia			
1.4.1. Strengthening the institutional and human aquaculture research capacity of local institutions in Cambodia, especially RUA. **1.4.2. Development and scaling of cost-effective formulated feeds for the sustainable culture of local bighead catfish (*Clarias macrocephalus*) in Cambodia.**	Cambodia	Hok Lead PI (CE SAIN RUA), Yossa HC Co-PI (WF), Reyes US PI (KSU), Gatlin US Co-PI (TAMU)	The activity team started the trial on bighead catfish in the aquaria of the wet lab using commercial feeds from two companies and two protein levels (i.e., Ocialis 30% and 35%, and Dollar 30% and 35%). Fish growth performance and water quality was recorded to monitor the trial. Bighead catfish fed with Ocialis 30% and 35% showed similar growth of the fish, while the Dollar 35% produced significantly higher fish growth compared to those of Dollar 30%. The Dollar 35% obtained higher total feed intake than other treatments. The technical team of the activity finalized the experiment procedures for the upcoming feed experiments using the aquaria in the wet lab and the pond. The activity team surveyed and checked the fingerlings for the upcoming trials with different suppliers and will purchase and transport the fingerlings to the wet lab in April 2023. The activity donated the reserved bighead catfish to relevant partners for learning, research, teaching, and hatchery purposes. The activity coordinator and the graduate research assistant participated in the hatchery production training by Dr. Tam from Can Tho University, Vietnam though the USD-funded CAST Project; the activity bighead catfish were used for the hatchery training. The students hatched three pairs of bighead catfish and produced bighead catfish fry. The activity coordinator also participated in the training program on Cambodian Certification for Aquaculture Professionals (Cam-CAP), a joint effort to build more human resources on aquaculture in the country. The activity team visited the pelletizing floating fish feeding machine at a store to check the quality and expects to have the pelletizing machine ready in April 2023.

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
			To learn about the wet lab facilities, 48 students (24 women) visited the activity wet lab including 33 high school students (17 women) from Veal Renh High School and 15 students (7 women) from RUA Faculty of Fisheries. The activity team completed the design of the hapas in the pond. The hapas are now 70% complete and should be 100% complete by May 2023.
Activity 1.5: Achieving coral reef fishery sustainability in the Kenyan biodiversity and climate refugia center			
1.5.1. Determine the yield potential for coral reef climate refugia to support improved fisheries management. **1.5.2. Determine the best metrics for measuring sustainability to enhance the likelihood of sustainable management.** **1.5.3. Improve the management capacity of communities to monitor fisheries and habitats and use this information for adaptive management.** **1.5.4. Measure perceptions about natural resource use and sustainability among dependent communities and encourage realistic expectations.**	Kenya	McClanahan Lead and US PI (WCS), Muthiga US Co-PI (WCS), Mbaru HC PI (KMFRI) Humphries US Co-PI (URI)	The activity team communicated the status of fisheries resources and research findings to 6 additional Beach Management Units within the Diani-Chale area: Tradewinds, Nyari-Kikadini (Waa), Mwaepe, Mwanyaza, and Gazi. The meeting brought together a total of 228 members of the communities with a good blend of young, old, businesspeople, fishermen, fish vendors, educated, less educated, men, and women, but all members of the local BMUs. The meeting led to the activity team sensitizing the community members on conserving marine resources and conducting monthly fish catch and pricing monitoring activities in those areas. More community members have been equipped with knowledge and skills in mobile phones data collection and use of Kobo ToolBox application. The team managed and administered literacy tests through written examination to help identify the best individuals to be later trained and engaged in data collection exercises and use of Kobo ToolBox. The data will help monitor the fish catch along the Diani-Chale areas as a replicate of project activities in those new areas. Through the administered literacy tests, the activity team generated a list of 28 BMU members: 8 women and 20 men (10 youths and 18 adults). All passed their examinations and received training on WCS data collection protocols and mobile phones in data collection. Community members conducted monthly fish catch monitoring activities, which has resulted in more community members being equipped with monitoring skills, improved knowledge of the status of their resources from their locations, and some gaining employment with other institutions. On the socioeconomic aspect of the activity, the team has completed Institutional Review Board (IRB) training and initiated the post household surveys with 150 questionnaires already administered.
Activity 1.6: Cryogenic sperm banking of Indian major carps (*Catla catla*, *Labeo rohita*, and *Cirrhinus cirrhosus*) and exotic carps (*Hypophthalmichthys molitrix*, *Hypophthalmicthys nobilis*, and *Ctenopharyngodon Idella*) for commercial seed production and brood banking in Bangladesh			

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
1.6.1. Develop donor broodstocks of Indian major carps and three exotic carps. **1.6.2. Cryopreserve sperm of Indian major carps (IMCs) and exotic carps and develop a cryogenic sperm bank.** **1.6.3. Produce seeds of carps in hatcheries using cryopreserved sperm and characterize and assess their quality through growth study and DNA microsatellite analysis.** **1.6.4. Assess the performance of cryopreserved sperm for establishment of sperm banks in different regions.**	Bangladesh	Sarder Lead and HC PI (BAU), Rahman HC Co-PI (BAU), Tiersch US PI (LSU)	The team cryopreserved sperm of all six fish species (rohu, catla, mrigal, silver carp, bighead carp, and grass carp) and developed cryogenic sperm banks. Breeding of all six species was conducted in 22 public and private hatcheries in Mymensingh, Faridpur, Jashore, and Barishal regions using cryopreserved sperm, and seeds from these breedings were produced in 17 hatcheries. Cryopreserved sperm-originated and control seeds were reared in the respective hatcheries. Seeds produced using cryopreserved sperm were stocked in 12 respective hatcheries and in four technology adoption hatcheries and fish farms. They are being reared along with respective controls in separate nursery ponds with supplementary feeds. The team conducted monthly samplings of fry from both treatments. The team conducted genetic characterization of broodstocks and their offspring using DNA microsatellite markers. The team conducted training workshops on dissemination of cryopreservation technology for stakeholders (hatchery and nursery operators, fish farmers) as well as for junior faculty members and MS and PhD students. In addition, one student completed an MS degree, three PhD students are conducting their research, and four new MS students are conducting their research activities.
Activity 1.7: Increasing sustainability of fisheries for resilience of Cambodian communities			
1.7.1. Improve sustainable fisheries management by assessing changes in the existing fishery through the development of a protocol to monitor fish populations and implementation of a citizen science digital platform for documentation and analysis of harvest. **1.7.2. Educate and train in food processing and preservation techniques to reduce fish waste and enhance food security.**	Cambodia	Correa Lead and US PI (MSU), Neal US Co-PI (MSU), Allen US Co-PI (MSU), Schilling US Co-PI (MSU), Sitha HC PI (WCS), Mahood HC Co-PI (WCS)	The team participated in the Feed the Future Innovation Lab for Fish Final Annual Meeting in New Orleans in February 2023 and shared results and lessons learned. A poster and video presentation of "Survey of Fish Processing Techniques and Consumer Preference for Fish Species and Cooking Methods in Sre Ambel Region in Cambodia" was displayed at the meeting. The team completed the Citizen Science Fisheries Harvest Data Collection Program, which supported 15 fishers (including three women) from four villages along the Sre Ambel River. All fishers recorded individual-level data for 24 months. The data collection resulted in >43,900 entries for >58,500 fish individuals harvested in the Sre Ambel River. The team continued adding content and improving the user experience of the bilingual Community Fisheries Assessment Tool, iFISH, which is available online (https://ifish.shinyapps.io/ifish/). Tabs were added to display data per month and compare among years. In addition, the team added the maximum length data per species to contrast the sizes of fish harvested in Sre Ambel versus the maximum length a species can achieve. This information is critical to understanding whether current

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
			fishing practices are sustainable. A new tab was also added for images with photographs of fishing gear and species harvested with scientific names. A searchable photo identification catalog of the harvested fish was maintained by a graduate student and curated by a federal ichthyologist collaborating with the program. One of the graduate students supported by the activity successfully defended his MS thesis at the Royal University of Phnom Penh, Cambodia. Graduate student Chakriya Chum gave an oral presentation on "Consumer Preference for Fish Species and Cooking Methods in Cambodia" at the Aquaculture America 2022 conference in New Orleans. The team collected 91% of the expected (409/450) fish muscle samples for Stable Isotope Analysis representing 26 out of 30 selected fish species that are commonly harvested in the Sre Ambel River in three reaches (lower, middle, and upper river) and two seasons (dry and wet). The team conducted a survey of processing and nutrition knowledge. A total of 100 fishermen were surveyed. The team performed a sensory evaluation of fish products with a total of 100 sensory participants. The team conducted a shelf-life study on fresh fish using a natural preservative and conducted nutritional analyses of commonly consumed fish species. The team developed digital education materials and used them to conduct two workshops to transfer knowledge and skills of filleting fish, smoking fish, and preserving fish using vinegar solutions. Participants included 36 fishers and fish consumers (21 women) from local Sre Ambel communities.
Activity 1.8: Advancing aquaculture systems productivity through carp genetic improvement in Bangladesh			
1.8.1. Produce and validate performance of carp strains exhibiting rapid growth. **1.8.2. Dissemination of additional genetically improved carp species to partner hatcheries to be developed into broodstock.** **1.8.3. New generations of improved carps.**	Bangladesh	Hamilton Lead PI (WF), Benzie Lead Co-PI (WF), Tiersch US PI (LSU), Yeasin HC PI (WF), Hossain HC Co-PI (BAU)	The activity resulted in approximately 194 kg of genetically improved G3 rohu spawn produced by hatcheries and sold to nurseries and farmers in April 2023. Approximately 2,208 farms were supplied with fish for grow out from the 2022 spawning. The team conducted two hatchery training workshops on the management and marketing of genetically improved carp. Participants received a manual of the presented slides translated into Bangla.

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
1.8.4. A cost-effective pedigree assignment tool.			
1.8.5. Practical manuals, tools, and training activities.			
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 and socioeconomic contribution of the Nigerian catfish and tilapia industries			
2.1.1. To understand epidemiology and health economics of catfish and tilapia aquaculture in Ogun and Delta states, Nigeria. **2.1.2. To understand health status of catfish and tilapia in a regional model by employing presumptive field and laboratory diagnostics.** **2.1.3. To identify pathogens of economic significance circulating in Nigerian catfish and tilapia aquaculture using whole genome sequencing.** **2.1.4. To develop better management practices (BMPs) and build capacity to reduce risks of disease outbreaks in catfish and tilapia aquaculture in Nigeria.**	Nigeria	Chadag Lead PI (WF), Subasinghe Lead Co-PI (WF), Hanson US PI (MSU), Wills US Co-PI (MSU), Adeyemo HC PI (UI), Aina HC Co-PI (UI)	For the epidemiology study, the team conducted descriptive statistics classified by state identity, and an unusual level of farm mortality was calculated for production system, biosecurity, management, and other potential risk factors on 220 farms (which only raised table-size catfish). Findings from this study showed that there is plenty of room for improvement in terms of biosecurity in earthen pond production systems rearing catfish in Ogun and Delta States. Risk factor analysis allows a better understanding of the industry and can further inform development of interventions in the form of better management practices, guidelines for national aquatic health strategies, and farm-level biosecurity plans for sustainable aquaculture in the targeted regions. Bacterial isolates were sent for whole-genome sequencing, biochemical analysis, and antibiotic susceptibility tests. The activity successfully established a network of cluster leaders, resident veterinarians, researchers, and other stakeholders to offer health management guidance via the E-AquaHealth Network digital platform. The team visited the College of Veterinary Medicine at MSU and the Thad Cochran National Warmwater Aquaculture Center in Stoneville, MS to participate in discussions around finalization of epidemiology and microbiology analyses. Using previous workshop findings and epidemiological study risk factor findings, the team completed a draft set of Best Management Practices (BMPs) for Nigerian catfish farmers. The team also developed a draft document of actions and next steps for a future National Aquatic Animal Health Strategy (NAAHS) utilizing the workshop findings, focus group discussions, and stakeholders survey.

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
2.1.5. To develop science-based policies/strategies for reducing fish disease risks in Nigerian aquaculture for longer-term development beyond three years of the activity.			The team completed three output documents: Epidemiology study consolidated report, BMP guidelines draft, and NAAHS action plan/steps. The team participated and contributed to the Fish Innovation Lab and WorldFish workshop on "Nigerian Aquaculture: Status, Prospects and Future Growth." Altogether, the team gave three presentations related to the activity. The team also participated and presented at the Aquaculture America 2023 conference and the Feed the Future Innovation Lab for Fish Final Annual Meeting in New Orleans in February 2023.
Activity 2.2: Identifying major sources of foodborne pathogens in Bangladeshi aquaculture value chains and evaluating the effectiveness of various risk reduction strategies			
2.2.1. Determine the prevalence of foodborne pathogens in pangas and tilapia fish at point-of-delivery to consumers at retail fish markets in Dhaka city. **2.2.2. Identify pre-market and at-market practices and conditions associated with increased microbial contamination on fish at sale and key points, actors, and stakeholders for intervention within the value chain.** **2.2.3. Develop quantitative microbial risk assessment models to characterize the exposure to the chosen pathogen from current aquaculture production and marketing practices.**	Bangladesh	Islam Lead and US PI (WSU), Narrod US Co-PI (UMD), Parveen US Co-PI (UMES), Amin HC PI (icddr,b)	The team completed whole fish sample collection from various stages of the supply chain including retail wet markets, wholesale markets, and grower's ponds located in five districts that were mapped during the beginning of Year 2 activities. The final batch of samples were collected from six retail markets and two grower ponds. A total of 574 retail market samples (whole fish, tank water, ice, cutting board swab samples), 100 whole fish samples from wholesale markets, and 120 samples (fish, water samples) from grower ponds were collected. The samples were processed and analyzed for the prevalence of predominant pathogens (*Vibrio*, *Salmonella*) along with *E. coli* and extended spectrum beta-lactamase-producing *E. coli*. In total, the activity team collected samples from 18 retail markets, five wholesale wet markets in Dhaka City, and five grower ponds outside Dhaka to meet the total sample size of 794 including fish samples, environmental samples, and various swab samples at wet-market level. The activity team performed antibiotic susceptibility tests for 298 ESBL-producing *E. coli*, 180 *Salmonella* spp., and 500 *Vibrio cholerae* isolates against a panel of clinically important antibiotics based on Clinical and Laboratory Standard Institute Guidelines. In addition, the team tested all 298 ESBL-producing *E. coli* isolates for virulence genes and conducted polymerase chain reaction and phylogroup analysis. In addition, the team completed questionnaire surveys and collected behavioral data by conducting in-depth interviews with the key actors in pangas and tilapia fish value and supply chains including fish traders in markets and fish farm owners, farm workers, and fish sellers. The team conducted an interviewer-led survey of 60 producers from 16 villages located in four districts to collect information on demographics, fish input types (fish fries, feeds, antibiotics), marketing and selling practices, aquaculture challenges, and practices associated with microbial contamination. To have a better understanding of the wholesaler behaviors, the team selected six wholesale markets and interviewed 72 actors to collect information on demographics, market safety procedures, vehicle types used for transportation of fish, and actions taken to preserve fish quality. Further, 144 retailers

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
			from 26 markets were interviewed on demographics, market safety practices, pathogen loads, transport type, and actions to maintain the fish and water/ice quality, and others hygiene issues. Cut-up table workers were asked about water, sanitation, and environmentally related hygiene (WASH) practices and consumer preferences of fish processing.
			The team presented study findings based on the compiled laboratory and survey data from fish value chains at the Aquaculture America meeting 2023 in New Orleans, USA. The team also attended the Fish Innovation Lab's Annual Meeting at New Orleans, USA, and presented the activity findings, progress, and future directions to the sponsor.
			The team completed a short-term training on microbial risk analysis in regulatory process among the officers from Bangladesh Food Safety Authority. In addition, two enrolled MS students from the Department of Fisheries, University of Dhaka completed their thesis as a part of long-term capacity building.
Activity 2.3: Development and investigation of the delivery mode of a multivalent bacterial fish vaccine in Zambia			
2.3.1. Identify *Lactococcus garviae*, *Streptococcus inae*, *Streptococcus agalactiae*, *Aeromonas hydrophila*, and *Aeromonas veronii* associated with fish mortalities in aquaculture establishments of Lake Kariba. **2.3.2. Bacteria pathogenicity and disease causation confirmation.** **2.3.3. Autogenous vaccine development and challenge studies of the identified pathogen.**	Zambia	Hang`ombe Lead and HC PI (UNZA), Reichley US PI (MSU), Yabe HC Co-PI (UNZA), Songe HC Co-PI (CVRI), Bwalya HC Co-PI (ZAMFL)	The team conducted identification of bacteria associated with diseased fish in small scale establishments. The bacteria that were identified included *Lactococcus*, *Aeromonas*, *Acinetobacter*, and *Klebsiella*. These were isolated at different times of the year. Both the *Acinetobacter* and *Klebsiella* were documented in this study for the first time, and the documentation of *Klebsiella* highlighted the significance of fecal pollution in the lake waters. The team completed the confirmation of disease-causing agents, and the Minimum Lethal Doses for the isolates was concluded. This has led to tabulations necessary for vaccine trials. The team conducted disease causation confirmation of the documented bacteria using infection experiments in *Oreochromis niloticus*. The Minimum Lethal Dose for *Lactococcus* was found to be 6×10^6 Colony Forming Units (CFU) per fish, while for *Aeromonas* it was 6×10^5 CFU per fish. For *Acinetobacter*, it was established to be 9×10^8 CFU per fish and 12×10^8 CFU per fish for *Klebsiella*. The team developed and tested autogenous vaccines for the identified pathogenic bacteria. In this study, *Lactococcus* and *Aeromonas* were selected as good candidates for vaccine manufacture and formulation following pathogenicity tests. The bacteria were inactivated using formalin and then subjected to dialysis, after which purity and sterility tests were conducted. The vaccine was tested, and it was found that the vaccinated fish had an increased leucocyte count. Further blood profiles are being conducted as the experiment progresses.

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
			The activity team devised methods of administering autogenous vaccines to the fish on the farms. The vaccine trials are focused on the intraperitoneal and immersion methods, which are still being validated before field trials begin. The intraperitoneal route has been adopted so far. Various protocols are being set up in terms of antigen dosage, volume, time of exposure, age, and size of the fish.
			To conduct the field vaccine trials using real time set ups on Lake Kariba, the team identified and stocked farms and cages. The cages have been stocked with 5,000 fingerlings, which currently weigh about 10 grams.
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			
3.1.1. Disseminate knowledge via novel pathways to facilitate widespread utilization resulting in positive behavior change and technology adoption. **3.1.2. Generate knowledge on improved technologies and practices and on the contributions of Bangladesh's aquaculture sector to nutrition, women's and youth participation, and access to economic resources.** **3.1.3. Strengthen the ability of partners to independently generate knowledge, use research findings, and transfer information to potential users.**	Bangladesh	Belton Lead and US PI (MiSU), Nejadhashemi US Co-PI (MiSU), Haque HC PI (BAU), Murshed-e-Jahan HC Co-PI (WF)	Although this research activity ended in September 2022, the activity's online interactive aquaculture database as a decision-making platform/tool has since been tagged on the Department of Fisheries website at http://www.fisheries.gov.bd/ as one of the top navigation bars entitled "Online Fisheries statistics." The Director General of the department played a key role in tagging it on the government website after the activity held the final outreach workshop at the department's conference hall. Government authority acceptance of research outcomes so quickly is rare.
Activity 3.2: Nourishing nations: Improving the quality and safety of processed fish products in Nigeria			

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
3.2.1. 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 the Delta State of Nigeria. **3.2.2. Build capacity among women and youth fish processors in the Delta State to produce high quality, safe, and nutritious processed fish products for local consumption.** **3.2.3. Educate women and youth fish processors in the Delta State about the benefit of fish in human diets and develop low-literacy tools to help them better market their product.**	Nigeria	Pasqualino Lead PI (WF), Tolar-Peterson US PI (CSUSB), Ene-Obong HC PI (UNICAL)	The team completed the activity training program by holding a 5-day training on fish processing techniques and business skill development with 75 fish processor attendees and 9 facilitators. Topics covered during the 5-day training workshop included entrepreneurship, access to financial space and funding for fish, fish business plan development, formation and operation of cooperative societies, fish handling techniques, traditional and modern fish smoking and drying techniques, fish value addition, and fish packaging techniques. Practice sessions were held for participants to get hands-on experience. There was an overall increase in knowledge and skills gained due to the training, as assessed through a self-evaluation form. The activity team completed the lab analysis of the nutrient and contaminant profile of commonly available and consumed fish in Delta State, Nigeria. These data will be used along with the market data collected on prices of animal source foods to develop cost-per-nutrient guides. Once complete, the guides will allow for an informed examination of the food environment in Nigeria and will support government stakeholders as they design nutrition-sensitive programs and policies.
Activity 3.3: FishFirst! Zambia: Research for development and scaling staple-fish products for enhanced nutrition in the first 1,000 days of life			
3.3.1. Assess 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. **3.3.2. Identify social and gender barriers to entry and/or participation in these value chain activities for the different actors, particularly women and youth.**	Zambia	Ragsdale Lead and US PI (MSU), Read-Wahidi US Co-PI (MSU), Mudege HC PI (WF)	The team engaged in a variety of social media activities, presentations, conference panels, and peer-reviewed publications. Activities included an article on Agrilinks and 2-pager featured on the Fish Innovation Lab website ("A community health worker becomes a FishFirst! Zambia Champion and local catalyst for change"). The team developed a peer-reviewed publication in *Public Health Nutrition*. In addition, three draft technical reports were produced. Ragsdale was an invited participant at the USAID Product Life Cycle (PLC) Framework–Innovation to Impact (i2i) Learning Event, USAID Bureau RFS, Soybean Innovation Lab, Washington D.C. Presentations were given at the Nutrition 2023 Conference, MSU Undergraduate Research Symposium, and Feed the Future Innovation Lab for Fish 2023 Final Annual Meeting, New Orleans, LA. Team members participated in panels at the Fish Innovation Lab 2023 Final Annual Meeting, New Orleans, LA.

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
3.3.3. Explore options to scale the production of the ComFA+Fish micronutrient powder with private- and public-sector actors, particularly women and youth.			As part of the Innovation to Impact (i2i) process, the activity identified potential scaling partners for Complementary Food for Africa+Dried Fish Powder (ComFA+Fish). FishFirst! Zambia was engaged by Dr. Peter Goldsmith, Director of the Feed the Future Soybean Innovation Lab, to beta test the i2i Station over 60 days for USAID. ComFA+Fish, the protein-micronutrient blend promoted by FishFirst! Zambia, was one of the ten technologies selected to test the i2i Station through a stage-gate process of the product life cycle from product profile to scaling. The process involved 13 technology planning and documenting activities identifying customers, the technology's value proposition, and the critical resources needed to scale the technology.
Activity 3.4: Samaki Salama: Securing small-scale fisheries in Kenya for healthy nutrition and ecosystems			
3.4.1. Nutrition social marketing (Determine the effects of a multi-tiered social marketing campaign to promote fish nutrition, dietary diversity, and food safety on child growth.) **3.4.2. Fisher Cooperatives (Measure the impact of fishing gear cooperatives on gear modification and diversification as well as catch dynamics and earnings.)**	Kenya	Iannotti Lead and US PI (WUSTL), Humphries US Co-PI (URI), Wamukota HC PI (PU), Kamau-Mbuthia HC Co-PI (EU)	The activity team conducted and accomplished all data collection and activity implementation. The activity was able to accomplish all set objectives in conducting the cluster randomized controlled trial in Kilifi County. The activity was able to strengthen capacity of fishermen through knowledge and provision of fishing gears and promote sustainable fishing practices. In addition, the team provided nutrition education to the caregivers to promote appropriate feeding practices and increase fish consumption. This was aimed at improving the nutritional status of the young children. The activity successfully conducted the Formative Qualitative survey in Taita Taveta County and wrote the report on the survey. In addition, the nutrition team wrote reports on Home Visits I, II, and III that were conducted in Kilifi County Intervention Arm 1 and Arm 2. The fish team cleaned the fish value chain data. The research team embarked on data cleaning coding and management of the household survey datasets and fisherman survey databases containing the baseline and end-line survey data that were conducted in Kilifi County. The nutrition team cleaned the 24-hour recall dietary data and entered the data in an excel template and Nutri-survey App. The team published one journal article that was a study protocol paper detailing the Samaki Salama study procedures and implementation process. The team initiated data analysis of all activity data and is continuing to make progress.
Activity 3.5: Population ecology and current distribution assessment of the introduced invasive crayfish in the Kafue floodplain and Lake Kariba, Zambia			
3.5.1. Characterization of crayfish population growth parameters, including size and age structure,	Zambia	Rice Lead and US PI (URI), Nambeye-Kaonga HC PI (UNZA), Eilittä	During the reporting period, the team was engaged in trap collection of crayfish in areas known to have high numbers of invasive crayfish (Kafue River and Lake Kariba). Considerable descriptive length-frequency data was collected to describe the crayfish population structure in selected Zambian waterways. To enhance the trapping studies, the team purchased crayfish from fishers to

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
and reproductive rates in Zambian waters.		HC Co-PI (CNFA)	supplement measurements and assure a sufficiently large sample size to enable future spawn-class cohort analysis.

Additionally, the Qualtrics survey was completed and is yielding data on presence or absence of crayfish in different water bodies around the country, various aspects of how the crayfish are perceived to be affecting indigenous fisheries, and how crayfish are being utilized as an alternative fishery catch. Approximately 50 responses were received. |
| 3.5.2. Assess the rate of natural spread of crayfish in Zambian waters and devise means to prevent spread across watershed boundaries (e.g., into Okavango basin). | | | Finally, the team conducted a survey of 342 fishers affected by crayfish presence in various fishing camps on Lake Kariba (Siavonga and Sinazongwe) and Kafue River (Itezhi tezhi and Kafue town). The survey collected background information on the fishers, including their livelihood options, education, household characteristics, type of fish caught, and markets. It then focused on issues relating to crayfish, asking whether the crayfish was present in the locations, how the fishers view it and what they think should be done to it, whether they catch it as main or bycatch, and whether they consume it. |
| **Activity 3.6: Strategies for inclusive aquaculture value chain in Bangladesh: Analysis of market access, trade, and consumption patterns** | | | |
| 3.6.1. Analyze the food and nutritional security impacts of increased aquaculture production.

3.6.2. Evaluate constraints in the aquaculture input markets that influence domestic market access for aquaculture producers.

3.6.3. 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. | Bangladesh | Dey Lead and US PI (TSU), Surathkal US Co-PI (TSU), Khan HC PI (BAU), Rahman HC Co-PI (PSTU) | The team delved into the consumption pattern of sources of protein, fish, meat, poultry, and poultry eggs across the different income quantiles and the geographic regions, rural and urban. The income quantiles were categorized into four quantiles based on the total expenditure of the households. The households belonging to the first income quantile are the most impoverished ones. The richest households are those in the fourth income quantile. The species groups of fish include hilsa, rohu/katla/mrigal, shol/gajar/taki, exotic carps, koi, baila/tapashi, shrimp, sea fish, mala/kachi/chapila (small fishes), dried fish, puti/tilapia, magur/shing, pangasius/boal/air, tangra/eel, and other fishes. The species of meat include beef, buffalo, and mutton. Poultry consists of hens and duck. Poultry eggs comprise hen eggs and duck eggs.

Key findings from the activity were: Aquaculture contributes to the overall increase in fish consumption; the richest urban households are substituting fish with poultry and poultry eggs, owing to status bias—the rich urban households do not consume cheap aquaculture species like exotic carps; production of tilapia and pangasius has gone up through aquaculture and, as a result, their prices are either stable or decreased as their availability has increased; and production of capture species has remained the same or declined—as the supply is constricted, the prices have increased, affecting the affordability and consumption in poorest and poor households.

The team implemented the quadratic almost ideal demand system (QUAIDS) model to estimate the nutrition elasticity of fish across the species. Most of the households do not consume the same fish |

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
			species every week. There was a sample selection bias created by the presence of zero consumption of the species of fish, meat, poultry, and poultry eggs. A two-step Heckman procedure was used to correct the bias in which the activity team first estimated a probit model for the per capita nutrition consumption of protein sources (fish, meat, poultry, and poultry eggs) across species using demographic variables as explanatory variables and then computed the IMR (Inverse Mills Ratio) (estimated expected error) as a ratio of the normal probability density function to the normal cumulative density function of predicted probabilities in the first step. Using the Household Income Expenditure Survey (HIES) data of 2000, 2005, 2010, and 2016, the activity team drafted a paper on household fish consumption patterns in Bangladesh and a paper on estimating nutrition elasticity of fish in Bangladesh. The team presented numerous papers at the Aquaculture America 2023 conference based on the results of the activity.
Activity 3.7: Micronutrient impact of oysters in the diet of women shellfishers in Ghana			
3.7.1. Determine the contribution of oyster consumption to iron and zinc intakes of women shellfishers. **3.7.2. Determine whether there is any variation in iron and zinc content of oysters across the three study sites in Ghana.** **3.7.3. Investigate whether heavy metal contamination is a concern in the three study sites in Ghana.** **3.7.4. Provide guidance for public health authorities, women's shellfish associations, and other stakeholders.**	Ghana	Oaks Lead and US PI (URI), Adu-Afarwuah HC PI (UG)	The team completed analysis of the final element, arsenic, in the 915 oyster samples collected from three estuary sites in Ghana. Technical review of the final activity reporting is ongoing.
Buy-in activity: Supporting USAID missions by conducting complementary research and learning related to distant water fleets (DWF) in fisheries			

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
Objective 1. Explore transparency and sustainability in licensing and supply chains associated with distant water fleets (DWF) activity in select national exclusive economic zones. **Objective 2. Characterizing the scale, form, and socioeconomic impacts of DWFs on national fisheries and fisherfolk in select geographies.**	Peru, Madagascar, the Philippines, and Pacific Islands	Torell Lead and US PI (URI), Humphries US Co-PI (URI)	The activity team finalized data compilation and synthesis on all four case studies that are part of the research. To do this, the team engaged partners within and outside of USAID Missions to ensure that they had identified the most relevant and appropriate datasets for the work. Quantitative and qualitative analyses exploring the relationships between distant water fleets and food security were also completed during this period. Additionally, the research team organized and was accepted for a full day session on DWF at the 2024 World Fisheries Congress. The team also presented results at the Fish Innovation Lab Final Annual Meeting in New Orleans and engaged in discussion regarding DWF impacts. An expert review process was undertaken to finalize a comprehensive evaluation tool for national systems granting foreign fishing access. This was done through the engagement of five experts in a comment period, after which the evaluation tool was revised and finalized. The tool was applied in four case studies to conduct evaluations of national licensing and access regime through input from desktop research as well as from interviews with twelve key informants with relevant expertise for each case study. The activity team developed a 1-page brief to the bureau home office with results, and the USAID/Washington staff will add a section about cross-bureau collaboration. In addition, the team developed 1- to 2-page Mission-specific briefs with results and policy recommendations. Two peer-reviewed publications or technical reports, one for food security and one for licensing and access, will be developed to ensure methods are documented. A total of three webinars were held, hosted jointly by USAID/Washington and URI to share draft results and gather feedback.
Objective 4: Effectively manage a portfolio of research-for-development activities in aquaculture and fisheries and implement a knowledge management plan			
Activity 4.1: Support the Fish Innovation Lab research-for-development activities. **Activity 4.2: Implement plan for engaging missions, attract associate awards, and engage minority-serving institutions.**	Bangladesh, Cambodia, Ghana, Kenya, Malawi, Nigeria, Zambia	Lawrence (MSU), Reichley (MSU), Allen (MSU), Ragsdale (MSU), Read-Wahidi (MSU), Iannotti (WUSTL), Kent (URI), Dey (TSU), Hill (MSU),	Research activities were supported via quarterly PI and learning meetings and one-on-one meetings. GRADA-FIL Wave II was administered, and a results brief was drafted. Cross-cutting theme specialists provided individualized technical assistance in capacity development, resilience, and nutrition. Country and regional coordinators provided ongoing support to their respective teams virtually and in person. A workshop on "Nigerian Aquaculture: Status, Prospects, and Future Growth" was held in Ibadan, Nigeria on October 31 – November 2, 2022. The Fish Innovation Lab organized the first in-person annual meeting from February 27–March 1, 2023, in New Orleans. Meetings were held with USAID missions in Nigeria and Kenya. The buy-in award from the USAID Biodiversity Division, Center for Environment, Energy, and Infrastructure was implemented to support the Biodiversity Division's learning agenda on distant water fleets, and USAID missions and key informants in Peru, Madagascar, The Philippines, and the Pacific Islands were engaged. The

Objectives, activities and subactivities	Country of activity	Person or institution responsible	FY2023 progress
		Zseleczky (MSU), Jeudin (RTI), Springer (RTI), Ricci (URI), Humphries (URI), Wamukota (PU), Hussain (BAC), Siriwardena (WF)	iREACH platform was expanded to include all Fish Innovation Lab activities and countries. USAID Missions and other subscribers will receive automated quarterly updates through this platform to facilitate synergies.
Activity 4.3: Implement knowledge management plan.			Blogs, technical briefs, and other media were developed that highlight Fish Innovation Lab activities and the ME partners' work. The bi-monthly newsletter was developed and distributed (Nov, Jan, Mar). Three online courses and webinars are under production. Iannotti participated in three conferences: the Annual Meeting of the American Public Health Association (APHA), the 22nd IUNS-ICN International Congress of Nutrition in Tokyo, and the Global Health Conference at Washington University in St. Louis. The Fish Innovation Lab organized an Aquaculture America 2023 session and booth in New Orleans on February 26, 2023, and attended and showcased research at the World Aquaculture Society Conference in Singapore November 29–December 2, 2022.
Activity 4.4: Monitoring, evaluating, and learning (MEL) from research findings, determining factors that limit adoption of new knowledge/technologies and scaling.			FY22 indicator and narrative reporting was completed through the Development Information System (DIS) and Research Rack-Up. Resilience Learning Session 2 was conducted through three interactive learning sessions with the Africa Aquaculture teams on November 15, 2022, and with the Africa/Asia Fisheries and Asia Aquaculture teams on November 16, 2022. Fish Innovation Lab research activities were monitored, and quarterly and semiannual indicator data were collected.

BAC, Blue Aquaculture Consulting; BAU, Bangladesh Agricultural University; CE SAIN RUA, The Center of Excellence on Sustainable Agricultural Intensification and Nutrition in Cambodia's Royal University of Agriculture; CNFA, Cultivating New Frontiers in Agriculture; CSUSB, California State University, San Bernardino; CVRI, Central Veterinary Research Institute; EU, Egerton University; FAO, Food and Agriculture Organization of the United Nations; icddr,b, International Centre for Diarrhoeal Disease Research, Bangladesh; KMFRI, Kenya Marine and Fisheries Research Institute; KSU, Kansas State University; LM Aquaculture Limited; LSU, Louisiana State University; LUANAR, Lilongwe University of Agriculture and Natural Resources; MiSU, Michigan State University; MSU, Mississippi State University; PSTU, Patuakhali Science and Technology University; PU, Pwani University; RTI International, Research Triangle Institute; TAMU, Texas A&M University; TSU, Texas State University; UG, University of Ghana; UGA, University of Georgia; UI, University of Ibadan; UMD, University of Maryland; UMES, University of Maryland Eastern Shore; UNICAL, University of Calabar; UNZA, University of Zambia; URI, University of Rhode Island; WCS, Wildlife Conservation Society; WF, WorldFish; WSU, Washington State University; WUSTL, Washington University in St. Louis; ZAMFL, Zambia Ministry of Fisheries and Livestock

Appendix 2. Semiannual Indicator Results Table

In Quarters 1 and 2 of FY23, the Fish Innovation Lab achieved the following:

- **EG.3.2-1: Number of individuals who have received US Government (USG) supported short-term agricultural sector productivity or food security training.** The Fish Innovation Lab research teams reached 823 individuals, including 553 males and 270 females.

- **EG.3-2: Number of individuals participating in USG food security programs.** The Fish Innovation Lab reached 922 beneficiaries through activities and events. This included 538 males and 324 females.

- **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**. The Fish Innovation Lab's research teams have a total of 54 technologies or management practices under the following phases: research (17), field testing (18), being made available for transfer (17), and demonstrated uptake (2).

- **EG.3.2-24: Number of individuals in the agriculture system who have applied improved management practices or technologies with USG assistance.** A total of 1,440 beneficiaries applied improved practices and technologies (58 males, 61 females, and 1321 who did not define their gender).

- **Publications and Presentations (custom).** The Fish Innovation Lab team members published 10 peer-reviewed journal articles.

- **Number of individuals who have received USG-supported long-term agricultural sector productivity or food security training (custom).** The Fish Innovation Lab had 38 long-term students (13 females and 25 males), out of which 28 were continuing, and two are new. Eight individuals have completed their long-term training programs.

Publications & Presentations					
STIR-12: Book	**2020**	**2021**	**2022**	**2023**	**2023**
	Actual	**Actual**	**Actual**	**Target**	**Actual**
Peer Reviewed Publications					
Peer Reviewed Publications	0	0	0	3	0
STIR-12: Book Chapter	**2020**	**2021**	**2022**	**2023**	**2023**
	Actual	**Actual**	**Actual**	**Target**	**Actual**
Peer Reviewed Publications					
Peer Reviewed Publications	0	0	0	2	0
	2020	**2021**	**2022**	**2023**	**2023**

Publications & Presentations					
STIR-12: Journal Article	**Actual**	**Actual**	**Actual**	**Target**	**Actual**
Peer Reviewed Publications					
Peer Reviewed Publications	0	6	24[1]	5	10

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 short-term agricultural sector productivity or food security training	**2020** **Actual**	**2021** **Actual**	**2022** **Actual**	**2023** **Target**	**2023** **Actual**
Sex					
Male	0	516	1316	0	553
Female	0	262	895	0	270
Disaggregation not available	0	0	0	0	0
Totals	**0**	**778**	**2211**	**0**	**823**
Participant Type (multiple choices allowed)					
Parents/Caregivers	0		388	0	35
Household Members	0	0	14	0	40
People in Government	0	47	221	0	68
USG-assisted Private Sector Firms	0	4	56	0	21
People in Civil Society	0	107	148	0	39
Producers	0	620	1379	0	603
Not Applicable	0	0	5	0	17
Totals		**778**	**2211**	**0**	**823**

---

[1] Three publications in FY22 from Fish Innovation Lab Quick Start activities were not included in the FY22 annual reporting due to an oversight.

EG.3.2-1: Number of individuals who have received USG-supported short-term agricultural sector productivity or food security training	
Indicator result narrative	In the reporting period of FY23 Q1-Q2, a total of 823 individuals were reached through short-term training of different categories. Among these beneficiaries, 553 were male and 270 were female. Notably, the highest proportion of the trained individuals, amounting to 73%, were producers who were trained on the innovative practices, approaches, and technologies developed through our activities.
Deviation From Target	

EG.3-2: Number of individuals participating in USG food security programs					
EG.3-2: Other project participants	**2020**	**2021**	**2022**	**2023**	**2023**
	Actual	**Actual**	**Actual**	**Target**	**Actual**
Gender					
Male	0	1172	2131	0	598
Female	0	601	2050	0	324
Totals	**0**	**1773**	**4181**	**0**	**922**
Age					
15-29	0	442	1302	0	315
30+	0	523	2584	0	607
Disaggregation not available	0	808	295	0	0
Totals	**0**	**1773**	**4181**	**0**	**922**
Participant Type (multiple choices allowed)					
Parents/Caregivers	0	122	1618	0	98
Household Members	0	30	55	0	26
People in Government	0	213	235	0	59
USG-assisted Private Sector Firms	0	54	327	0	122
People in Civil Society	0	311	380	0	246
Laborers	0	20	297	0	5

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

Producers	0	1023	1099	0	360
Not Applicable	0	0	170	0	6
Disaggregation not available	0	0	0	0	0
Totals	**0**	**1773**	**4181**	**0**	**922**
Indicator result narrative	In the first two quarters of FY23, the Fish Innovation Lab reached a total of 922 individuals through various activities and events, including informative and educational workshops. From this outreach, 598 males and 324 females were beneficiaries. Youth aged 15-19 make up the highest proportion of the beneficiaries reached, accounting for 52% of the total number.				
Deviation From Target	NA				

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	2023
	Actual	Actual	Actual	Target	Actual
Status					
Phase 1: Under Research	1	4	5		5
Phase 2: Under Field Testing	0	1	3		4
Phase 3: Made Available for Transfer	0	0	0		0
Phase 4: Demonstrated uptake by the public and/or private sector	0	0	0		0
Totals	**1**	**5**	**8**	**0**	**9**

EG.3.2-7: Production Systems Research	2020	2021	2022	2023	2023
	Actual	Actual	Actual	Target	Actual
Status					
Phase 1: Under Research	1	4	5		4
Phase 2: Under Field Testing	0	10	7		10

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					
Phase 3: Made Available for Transfer	0	0	14		14
Phase 4: Demonstrated uptake by the public and/or private sector	0	0	1		0
Totals	**1**	**14**	**27**		**28**

EG.3.2-7: Social Science Research	2020	2021	2022	2023	2023
	Actual	Actual	Actual	Target	Actual
Status					
Phase 1: Under Research	0	1	7		8
Phase 2: Under Field Testing	1	3	3		4
Phase 3: Made Available for Transfer	0	2	3		3
Phase 4: Demonstrated uptake by the public and/or private sector	0	0	1		2
Totals	**1**	**6**	**14**		**17**
Indicator result narrative	At the end of the second quarter of FY23, the Fish Innovation Lab research efforts have yielded 11 Plant and Animal Improvement Research technologies or management practices, of which 8 were continuing from the previous fiscal year and one was newly initiated in FY23. Furthermore, there are 28 ongoing Production Systems Research approaches, technologies, or practices with one technology moving to Phase 2 and another moving to Phase 3 from the previous year. In addition, there were 17 Social Science Research technologies or management practices underway, including one new technology in Phase 1, one in Phase 2, and another in Phase 4.				
Deviation From Target	NA				

EG.3.2-24: Number of individuals in the agriculture system who have applied improved management practices or technologies with USG assistance.					
EG.3.2-24: Applied Tech	2020	2021	2022	2023	2023
	Actual	Actual	Actual	Target	Actual

EG.3.2-24: Number of individuals in the agriculture system who have applied improved management practices or technologies with USG assistance.

Gender					
Male	0	145	1031		58
Female	0	11	472		61
Not Applicable			270	2179	1321
Totals	**0**	**156**	**1773**	**2179**	**1440**
Age					
15-29	0	45	326		57
30+	0	104	1274		62
Not Applicable	0	7	173	2179	1321
Totals	**0**	**156**	**1773**	**2179**	**1440**
Technology Type (multiple choices allowed)					
Wild-Caught Fisheries Management			732		41
Cultural practices	0	0	184		30
Wild fishing technique/gear	0	115	12		16
Aquaculture management	0	21	575		1321
Disease management	0	3	55		0
Soil-related fertility and conservation	0	0	0		0
Water management- non-irrigation based	0	0	0		0
Climate mitigation	0	17	0		0
Climate adaptation	0	0	0		0
Marketing and distribution	0	0	31		0
Post-harvest—handling & storage	0	0	0		32
Value-added processing	0	0	0		0

EG.3.2-24: Number of individuals in the agriculture system who have applied improved management practices or technologies with USG assistance.					
Pest and Disease Management			84		0
Other	0	0	100	2179	0
Totals	**0**	**156**	**1773**	**2179**	**1440**
Participant Type (multiple choices allowed)					
Parents/Caregivers (Other)	0	2	9		43
Household Members	0	0	106		12
People in Government	0	8	135		3
USG-assisted Private Sector Firms	0	10	99		0
People in Civil Society	0	3	333		0
Laborers	0	0	0		2
Producers	0	133	1091	2000	1380
Not Applicable	0	0	0	179	0
Totals	**0**	**156**	**1773**	**2179**	**1440**
Indicator result narrative	As of Q2 of FY23, Fish Innovation Lab activities reached 1,440 individuals applying technologies, with the majority (1,321) from the Carp Genetic Improvement activity; those individuals (commercial hatcheries, nurseries, and farmers) have adopted the Generation 3 (G3) Genetically Improved Rohu developed by this activity.				
Deviation From Target	NA				

Custom: Number of individuals who have received USG supported long-term agricultural sector productivity or food security training (Custom)					
Long-term Training	**2020**	**2021**	**2022**	**2023**	**2023**
	Actual	**Actual**	**Actual**	**Target**	**Actual**
Gender					
Male	0	17	24		25
Female	0	14	18		13

Custom: Number of individuals who have received USG supported long-term agricultural sector productivity or food security training (Custom)					
Totals	**0**	**31**	**42**	**0**	**38**
Training Status					
Complete	0		10		8
Continuing	0	31	21		28
New	0		11		2
Totals	**0**	**31**	**42**	**0**	**38**
Indicator result narrative	In the first two quarters of FY23, 32 beneficiaries from various academic levels—undergraduate, graduate (MS and PhD), and postdoctoral participated in long-term trainings. By the end of Q2 in FY23, an additional six beneficiaries were included, with four completing their training within the quarter. Of the initial 32 beneficiaries, four have also completed their long-term training. At the end of the FY23 semiannual reporting period, there were two new, 28 continuing, and eight beneficiaries who had completed their training.				
Deviation From Target	NA				

Appendix 3. Future Work for Research Activities

Activity	Subactivities planned for April 1 to September 30, 2023
Halwart: Farm Diversification (Nigeria)	1. Conduct farmer training on value addition through smoked catfish production and on black soldier fly production as alternative fish feed 2. Collect and process field data 3. Develop activity production and business manual
Pechal: Farming Insects (Nigeria)	1. Conduct analysis of feed trials and data 2. Train enumerators on data collection for the endline survey 3. Collect and analyze endline survey
Subasinghe: Lean Production Systems (Nigeria)	1. The activity is scheduled to complete activities in May 2023. The team is planning to work on data cleaning and report writing. The team is also working on adoption and scaling of their efforts.

Hok: Bighead Catfish (Cambodia)	1. Conduct trials:
	
	   Trial 1: Commercial Aquafeed Evaluation for Bighead Catfish Culture in Recirculating Aquaculture System Experiment
	
	   Trial 2: Commercial Aquafeed Evaluation for Bighead Catfish Culture in Pond Net Cage System Experiment
	
	2. Conduct capacity building for feed preparation for research trials on optimizing feed for bighead catfish

McClanahan: Coral Reef Fishery (Kenya)	1. Continue post-ecological and social surveys 2. Monitor and evaluate new community data collectors 3. Analyze length-weight data collected in Shimoni-Vanga seascape 4. Present findings from study in a scientific symposium 5. Collect fish length data from fish landing data in Shimoni-Vanga seascape
Sarder: Cryogenic Sperm Banking (Bangladesh)	1. Conduct rearing of seeds in the selected hatcheries and fish farms in four regions 2. Continue ongoing sampling of seeds in different nursing points 3. Continue genetic characterization of broodstocks and their offspring using DNA microsatellite markers
Correa: Cambodian Fisheries and	1. Train fishers on how to use iFISH community fisheries assessment tool

Activity	Subactivities planned for April 1 to September 30, 2023
Food Processing (Cambodia)	2. Hold workshops on fisheries management with the Community Fisheries Councils in the Sre Ambel River, Koh Kong Province 3. Discuss the transfer of the Citizen Science Fisheries Harvest data collection program with Sre Ambel Community Fisheries Council after program completion 4. Make recommendations for future fisheries management based on the harvest data collected 5. Facilitate peer to peer knowledge transfer by bringing fishers participating in Community-Based Fishing Agreements in the Pursat Province to Sre Ambel 6. Write final report
Hamilton: Carp Genetic Improvement (Bangladesh)	Closes on 04/30/2023
Chadag: Biosecurity (Nigeria)	1. Conduct an advanced molecular diagnostics training program in Malaysia 2. Conduct final stakeholder engagement workshop at the University of Ibadan 3. Finalize all the documents and Piestar final reporting and activity closure
Islam: Sources of Foodborne Pathogens (Bangladesh)	1. Complete the isolated bacterial typing, antibiotic susceptibility testing pattern analysis, and select clinically relevant *Salmonella* and *Vibrio cholerae* for whole genome sequencing 2. Analyze *Salmonella* spp. to identify serotype and virulence genes 3. Perform an agglutination test to detect *V. cholerae* O1 and O139 serogroups 4. Submit first manuscript on the activities conducted in the first year of this activity 5. Develop a Quantitative Microbial Risk Assessment (QMRA) model to characterize exposure to the chosen pathogen from current aquaculture production and marketing practices
Hang`ombe: Vaccines for Tilapia (Zambia)	1. Commence field vaccine trials using intraperitoneal injection 2. Continue with the laboratory vaccine efficacy trials using the immersion route

Activity	Subactivities planned for April 1 to September 30, 2023
	3. Analyze data on the laboratory vaccine efficacy and field injection vaccine trials 4. Finalize data and write final reports for program close out
Belton: Harnessing Machine Learning (Bangladesh)	1. Activity closed on 09/30/2022
Pasqualino: Nourishing Nations (Nigeria)	1. Activity closed on 12/31/2022, and the ME is finalizing administrative and financial closeout processes

Ragsdale: FishFirst! Zambia (Zambia)	1. Capture lessons learned and recommendations for scaling ComFA+Fish products/recipes
	
	2. Finalize journal article and technical reports including:
	
	    Ragsdale et al. (In Revision). Sensory panel results of a dried fish powder supplement among caregivers and young children in Zambia. *Public Health Nutrition*.
	
	    Ragsdale et al. (2023, April). Draft: Nutrient-Dense ComFA+Fish Recipes of Protein-Micronutrient Blends for Nutrition-Insecure Infants, Children, and Families.
	
	    Funduluka et al. (2022, December). Draft: Training Workshop and Cooking Demonstrations Report. FishFirst! Zambia Research for Development and Scaling up Staple-Fish Products for Enhanced Nutrition in the First 1,000 Days of Life.
	
	    Funduluka et al. (2022, December). Draft: Taste-Test Report. FishFirst! Zambia Research for Development and Scaling up Staple-Fish Products for Enhanced Nutrition in the First 1,000 Days of Life.
	
	    Funduluka et al. (2022, December). Draft: Stakeholder Analysis and Environmental Scanning Report. FishFirst! Zambia Research for Development and Scaling up Staple-Fish Products for Enhanced Nutrition in the First 1,000 Days of Life.

Iannotti: Samaki Salama (Kenya)	1. Conduct database entry for health data collected in Interventions Arm 1 and Arm 2 that aimed at monitoring the health, disease occurrence, and health-seeking behaviors in a period of 5 months during the intervention period 2. Continue to analyze various qualitative and quantitative data sets from both the fisheries and nutrition components 3. Outline additional publications

Activity	Subactivities planned for April 1 to September 30, 2023
	4. Organize sessions for feedback and dissemination with participating communities 5. Share results with the relevant stakeholders and other county government authorities for further action and implementation 6. Submit reports with findings and recommendations to the National Commission for Science, Technology and Innovation (NACOSTI) for further dissemination across the country
Rice: Zambia Crayfish (Zambia)	1. Complete the crayfish population sampling 2. Analyze population data 3. Master student will prepare MS thesis and conduct thesis defense (Chibwe Katapa) 4. Analyze Qualtrics survey 5. Begin writing of final report based on all collected data and paper for Africa-based peer-reviewed journal 6. Compile all available data on crayfish populations into a unified Microsoft Excel file that reports crayfish location; data will be maintained at UNZA and made widely available to interested individuals 7. Conduct final workshop presenting results to stakeholders 8. Prepare to close out the activity with the target date of August 31, 2023

Dey: Market Analysis (Bangladesh)	1. Complete two scientific papers:
	
	    Household Fish Consumption Pattern in Bangladesh (descriptive analysis of fish consumption and fish sourced nutrition condition in Bangladesh based on available household data)
	
	    Estimating Nutrition Elasticity of Fish Consumption in Bangladesh (analysis of factors influencing fish consumption and nutrition status including price)
	
	2. Organize the final policy co-creation workshop in Bangladesh in early July 2023 to be attended by key policy stakeholders like the honorable state minister for planning

Oaks: Micronutrient Impact of Oysters (Ghana)	1. Activity was scheduled to close on 03/31/2023; an extension was approved through June 30, 2023, to complete data analysis
Distant Water Fleets (DWF) Activity (Peru,	1. Present results of this research at two venues: (1) the Society for Applied Anthropology in a session on fisheries and food security; and (2) webinars with USAID Missions and other activity partners to

Activity	Subactivities planned for April 1 to September 30, 2023
Madagascar, the Philippines, and Pacific Islands)	solicit feedback on our methods, results, and policy recommendations in April 2023 2. Finalize: (1) a draft of a peer-reviewed publication; (2) a video summarizing the activity; and (3) four 2-page fact sheets summarizing the activity specific to Peru, Madagascar, the Philippines, and the Pacific Islands region 3. Solidify next steps for this research 4. Present results from the licensing and access research objective at a webinar with USAID Missions, other activity partners, and the expert network built through expert review and key informant activities in May 2023 5. Through the webinar, gather feedback on results and discuss implications for future work on the topic of foreign fishing access 6. Develop two peer-reviewed publications or technical reports, one for food security and one for licensing and access, to ensure methods are documented