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

Feed the Future Innovation Lab for Fish

Semi-Annual Report October 1, 2021 – March 31, 2022

Cooperative Agreement 7200AA18CA0030

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MISSISSIPPI STATE UNIVERSITY
GLOBAL CENTER FOR AQUATIC HEALTH AND FOOD SECURITY

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Feed the Future Innovation Lab for Fish (Fish Innovation Lab)
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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 team completed the first cycle of on-farm adaptive research. Seven on-farm adaptive research plots were operationalized to obtain information on the cost of production, rice and fish yield, resource use, and fish performance under different feeding regimes. Fish from the first cycle of rice-fish adaptation was harvested. An analysis of parameters for integrated rice-fish farming systems is ongoing and includes 12 farmers trained in on-field data collection and recording. Preparation for black soldier fly production as low-cost feed is underway. The team collected preliminary quantitative and qualitative data on household food security, fish consumption, and utilization of rice field aquatic resources. An assessment of locally available feedstuffs as suitable supplemental feeding for selected species in integrated agriculture-aquaculture systems is ongoing as well as the development of a feeding model and formulation for sustainable fish production under integration. An analysis of growers' profitability margins and acceptability, as well as consumer purchasing behavior and willingness to pay for high-value locally grown aquaculture products, was concluded.

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 undertook a reconnaissance survey of the study area and found that the area does not have a functional feed mill. As a result, the study was substantially redesigned, and the new plan is to produce the fish feed in Ibadan and transport it to Ebonyi and Cross River states instead of producing in the study area.

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

The research activity works to apply lean management practices and lean tools to increase fish farm and fish processing efficiency. This will help increase the productivity and availability of fish in the local markets. A total of 112 farms/farmers in both Ogun and Delta states have adopted the lean technology and are applying lean management principles and tools. A total of 209 mini activities to address the waste streams have been completed.

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

The bighead catfish (BC) team has strengthened the institutional and human aquaculture research capacity of the Royal University of Agriculture (RUA) in Cambodia. The team purchased and installed materials needed to operate a wet lab for aquaculture feed nutrition research. It trained farmers and RUA personnel in applied aquaculture research, the operation of a wet lab, and feed formulation and manufacture. The team made progress on developing cost-effective feeds by estimating the protein and lipid requirements of BC at the grow-out stage under laboratory conditions. The team is also working with a local feed company and partners to substitute fish meal with soybean in the diet of BC.

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

A fisheries stock assessment training was conducted in eight sites within the Shimoni-Vanga seascape area. The training involved estimating fish biomass in 25 unique sites, including fishing areas, community closures, and a marine park. The collated information was compared to fisheries data that is collected monthly by trained community members. Films of underwater surveys and interviews with participants were produced and presented to the community during the fish biomass training. The team implemented community fish biomass training workshops in 5 sites, involving 45

individuals. The training involved undertaking an underwater visual census of fish in coral reefs, data entry, interpretation of biomass, and calculating yields data in their fishing areas. The team selected 12 participants who had the capacity to conduct stock assessments in collaboration with the activity team. Monthly fish landing monitoring by community and county fisheries officers continued with one new member trained by one of the field data collectors. The team developed a fish biomass training manual in both English and Swahili.

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)

Broodstocks of Indian major carp and three exotic carp were reared with supplementary feeds in three ponds. Cryopreserved-sperm-originated and control fry of rohu, mrigal, silver carp, and bighead carp were reared in five hatcheries and one fish farm in the Jashore, Faridpur, and Mymensingh regions. Monthly sampling of fry/fingerlings of both cryopreserved-sperm origin and control was conducted to compare their growth performance. Genetic characterization of broodstocks using DNA microsatellite markers is being done. Fourteen regions were amplified through polymerase chain reaction (PCR), and a few of them were used for identifying genetic variations of rohu and bighead broodstocks through polyacrylamide gel electrophoresis. Cryopreservation of sperm of silver carp, bighead carp, and grass carp was conducted for cryogenic sperm banking as well as the standardization of some cryopreservation protocol parameters. Training workshops on dissemination of the cryopreservation technology were conducted for hatchery and nursery operators as well as fish farmers. A cryopreservation technology training workshop for junior faculty members, MS, and PhD students was also held. The team conducted visits to the artificial insemination center in Savar, Dhaka. One MS student completed their MS degree, and a new MS student was recruited. Two MS students completed their research work and are writing their MS theses for submission.

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

The team successfully completed one year of data collection as part of the citizen science fisheries harvest data collection program. This data collection resulted in >20,500 entries for >38,700 fish harvested in the Sre Ambel River. The activity developed a community fisheries assessment tool called iFISH. The tool is available online and allows users to plot length-frequency, species composition, capture location, and distance traveled by fishers. The interactive iFISH tool allows users to change the display by species, gear, and village. Summary statistics for the first six months of fisheries harvest data are visually presented in iFISH. A training session on iFISH was held with in-country collaborators from WCS-Cambodia. The training included a discussion on strategies to improve data management and analysis. A searchable photo identification catalog of the harvested fish was maintained by a graduate student and curated by a federal ichthyologist, who is collaborating with the activity. The team collected 49% of the expected 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). On average, 13 fish samples per species were collected. To prepare for the training workshops, the team produced training videos on fish fileting, fish salting, and fish smoking. A smokehouse tour and explanation video was also produced. A knowledge survey on fish processing and fish nutrition was produced and translated into Khmer. Consumer surveys and sensory rubrics were translated for the sensory panel, and the translation was uploaded for IRB approval.

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

Preliminary analyses of ‘real-world’ performance of the G3 rohu families indicates they are growing 30% more rapidly than other treatments. Final results from these trials will be available in May 2022. Additional hatcheries were supplied with G3 spawn to be grown into broodstock in 2021. Over 1,500 enterprises, comprising hatcheries, nurseries, traders, and farmers, are known to have purchased

G3 rohu, primarily via WorldFish partner nurseries. The 2020 G3 rohu progeny testing was completed, and 2,462 fish were assessed. Initial selection of parental candidates was undertaken. Only the top ~20% of fish from each 2020 G3 rohu family were retained. Tagging of 2021 G1 catla and 2021 G3 rohu was completed. Progeny testing of these fish commenced in February 2022. Monitoring of broodstock indicated that the spawning of >200 G2 silver carp families and >100 G1 catla families can commence as scheduled in April/May 2022. Data related to the 2020 and 2021 rohu and catla families have been backed up at one external site. Rohu samples to be used in the development of a cost-effective pedigree-assignment (parentage assignment) tool were obtained. Transfer of samples to plates was completed in mid-March. In March 2022, the host country PI surveyed hatcheries possessing G3 rohu broodstock to identify current capacities and key training requirements.

Activity 1.9: Piloting Integrated Insect-to-Fish Farming Systems in Malawi (Black Soldier Fly in Malawi)

This activity is yet to start and hence did not report any accomplishments for the first half of FY22.

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)

Video conferencing equipment was installed at the University of Ibadan, and the system was used regularly for activity-related online meetings. The dry season sampling was completed in both Delta and Ogun states. Using the Resident Aquatic Veterinarian (AquaVet) Network established by the team, 56 fish samples were collected in Ogun state, and 79 fish samples were collected in Delta state. Analyses of biological samples collected during the rainy season included hematology and biochemical analyses. Enzymatic and biochemical tests were also completed on bacterial isolates. Several putative “novel” pathogens circulating in the clinically normal population were identified across both states. Data collection from the Fish Epidemiology and Health Economics survey tool was completed in Ogun and Delta states. Descriptive statistics were generated and are being used to identify farm characteristics and potential risk factors. Work has been initiated to develop a web-based GIS map for display of data from the Fish Epidemiology and Health Economics survey. A new online tool was developed together with simple instructions for fish disease outbreak investigation.

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

Samples were collected from pangas and tilapia fish at wet markets and super shops in Dhaka city. Together with previously collected data, the team has collected a total of 84 samples from retail markets and 24 samples from super shops. All samples were analyzed for major foodborne pathogens, and the isolates were banked for future analysis. The team completed an antibiotic susceptibility test of 458 *E. coli*, including 239 extended-spectrum beta-lactamase (ESBL) producing *E. coli*, 121 *Salmonella* spp., and 298 *Vibrio cholerae* against a catalog of clinically important antibiotics. All 458 *E. coli* isolates were tested for virulence genes by PCR. Results were compiled, and an abstract was submitted and accepted for presentation at the 2022 annual meeting of the International Association for Food Protection. Collection of whole fish, ice/water, and swab samples from fish cutting boards at retail and wholesale markets was initiated. During the reporting period, sampling of two retail markets and two wholesale markets was conducted with a total of 58 whole fish samples, 12 cutting board swab samples, and 12 fish tank water samples collected. Samples were tested for *E. coli*, ESBL-*E. coli*, *Salmonella* spp., and *Vibrio cholerae*. Short term hands-on and follow-up training was provided to Department of Fisheries staff. Two MS students from the Department of Fisheries were enrolled at the University of Dhaka. Questionnaire surveys and focus group discussions (FGDs) with key actors in pangas and tilapia fish value chains were initiated. Short interviews of vendors from wet markets and super shops were completed as well as FGDs and structured observations in 15 retail markets.

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

The US PI visited the team in Zambia and participated in kick-off meetings. Postgraduate students (two MS and one PhD) were recruited. They have finalized their research proposals, which were approved by the University of Zambia. The proposals have been submitted to the National Ethics Review Committee for ethical consideration. Once approved, the research activities will start in earnest. Farms that will participate in the study have been identified; some of the farms have signed a memorandum of understanding to participate in the activity. The team has identified farms not located in the study area as sources to supply experimental fish. Among these, the Kalimba and Mukasa fish farms have agreed to supply fish for experimental studies.

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

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

The team successfully hosted a training on how to use remote sensing methodologies to identify fishponds. The training was organized as an online course comprising six 45-minute recorded tutorials and four live question and answer sessions. The training was attended by 91 participants from Bangladesh and 45 international participants. Three short extension videos on innovative practices in the aquaculture value chain in southwest Bangladesh were produced and disseminated. A paper was published in the leading field journal *Remote Sensing* on the remote sensing fish pond detection method developed by the activity. Initial descriptive analysis of farm, trader, and input supplier survey datasets was completed. Development of an interactive website, Southwest Bangladesh Aquaculture Data Portal, to display farm survey results was initiated. A data visualization tool for fish pond identification is under development.

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

Following a previously conducted training, the team implemented a post-education survey to evaluate the participants' knowledge, attitude, and perceptions related to the role of fish in human nutrition and health. The survey also assessed the respondents' use of the low-literacy tools developed and distributed to fish processors. In total, 92 participants (all fish processors), 73 women and 19 men, were surveyed, with the majority reporting positive use of the tools. The MS students have finalized their research proposal, and the PhD candidate defended her dissertation. Two market surveys were completed, collecting data on the prices and seasonal price variability of fish species sold in Delta state.

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)

The team engaged in a total of 27 activities, including mentorship of students (11), showcasing research activities through media outlets (4), and the production of technical reports and other documents (1). The team organized and facilitated a seminar on "Confronting Hidden Hunger: How Fish Can Help Fill Heath Gaps." In addition, a total of eight presentations were delivered. The team also published a journal article in the journal *World Development* as well as a tool called "Post-Harvest Fish Loss Assessment for Small-Scale Fisheries (PHFLA): An Open-Access Customizable Tool."

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

All social marketing materials were finalized and are now in use. Materials include a home visit guide, fisher workshop guide, fisher commitment document, letter to fathers/fishers, reminder poster for caregivers, growth chart/calendar, menu game, t-shirt design, sticker design, banners for beach management unit (BMU) offices, and community health volunteer (CHV) training. The first round of home visits to all intervention households (n=200) has been completed, and the second round is ongoing. Distribution of printed social marketing material to participants in the intervention groups is

ongoing. CHVs in the intervention sites were trained to conduct future home visits and support other social marketing events. A total of 15 cooking demonstrations and 10 fisher workshops were conducted in arm 1 and arm 2 of the study. The team collected pre/post data from the cooking demonstrations and fisher workshops. All modified basket traps (n=400) have been made and distributed; fishers in the intervention group (n=100) have each received four modified basket traps with escape gaps. A process monitoring plan and data collection tools have been designed, and the landing site data collection protocol was finalized and is currently in use. There have also been multiple follow-up meetings with fishers to gather feedback on trap usage.

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 developed and tested a crayfish harvest and utilization survey and finished initial field testing among fishers in Siavonga. Focus group discussions and key informant interviews were conducted. An online poll was developed to assess presence or absence of crayfish in Zambia's water bodies. The trap design and methodology for the crayfish population study was finalized. Seasonal preliminary crayfish trapping data was collected at Kafue River, near the Kafue Road bridge, in November, December, January, and April, and at Lake Kariba, near Siavonga, in March. Crayfish size-frequency data was also collected for a few weeks from two trapping sites. A workshop at the University of Zambia was conducted with the Department of Fisheries, Department of Environment, and environmental nongovernmental organizations based in Zambia. Through the workshop, contacts were made and partnerships built for the data-gathering phase.

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

The team completed secondary data collection from the Household Income Expenditure Survey. To investigate constraints in the aquaculture input markets, the team trained enumerators and surveyed a total of 820 fish farmers from nine districts of Bangladesh. Two capacity-building training programs on scientific and business management practices were conducted for fish farmers and hatchery owners. Secondary data on shrimp export and import markets was collected. Questionnaire pre-testing and farm surveys were conducted. Both the primary and secondary data analyses were partially completed. Two papers have been submitted to journals and are under review.

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

Ethics approval from the Ghana Health Service Ethics Review Committee was obtained, and field data collection was completed. In total, 504 women shellfishers were enrolled, including 200 from the Densu estuary (Bortianor, Tsokomey, and Tetegu communities), 166 from the Narkwa Lagoon area (Ekumfi Narkwa community), and 138 from the Whin estuary (New Amanful, Apremdo, and Beaho communities). These women comprised all or nearly all of the women shellfishers in the target age group (women of reproductive age, 15-49 years of age) available for enrollment at the three selected sites. At each site, information on women's background and socioeconomic characteristics was collected. Two non-consecutive 24-hour dietary recalls were conducted; the first on the day of enrollment and the second within seven days after enrollment. Each of 915 oyster samples collected from the three sites were analyzed (i.e., 305 samples per site) for 15 minerals, including five macrominerals (calcium, magnesium, phosphorus, potassium, and sodium), seven trace minerals (chromium, cobalt, copper, iron, manganese, nickel, and zinc), and three heavy metals (cadmium, mercury, and lead).

Associate Awards and Buy-ins

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

The 18-month Distant Water Fleets (DWF) activity started on October 1, 2021. In the first quarter, the DWF Activity team held several meetings with USAID and the University of British Columbia, which is in the process of finalizing a precursor study. Based on these meetings, the team refined the scope of work and geographical coverage and hired a University of Rhode Island postdoctoral researcher. After narrowing the geographical scope to Peru, Madagascar, the Philippines, and Micronesia, the team held a series of informational meetings with the respective USAID missions and other relevant stakeholders. Following the submission of formal mission concurrence forms, the Fish Innovation Lab received concurrence to implement the DWF activity in the four countries/regions. The team outlined the processes for determining the extent to which DWF currently impacts fish availability, access, and potential utilization and estimating the optimal catch allocations to DWF to provide resilience to future domestic catches. The team also outlined the methods to be used for examining the characteristics and impact of existing DWF fishing access agreements within priority geographies.

Issues or Concerns Encountered During the Reporting Period

COVID-19 Pandemic-Related Issues

Overall, the COVID-19 pandemic situation has improved, and restrictions have been lifted in many countries. This led to a revitalization of research activities. However, impacts from the pandemic are still being overcome. Notable COVID-19-related issues and how they have been addressed are:

- Most teams experienced delays in implementation, preventing them from achieving their targets and timelines. The Fish Innovation Lab Management Entity (ME) met with each team to touch base and, when necessary, develop mitigation plans and alternative strategies enabling the teams to reach their objectives.
- Restrictions on travel and social gatherings greatly affected many teams. Travel restrictions prevented the teams from conducting in-person training, workshops, and surveys. The restrictions also prevented many PIs from traveling to the host countries to collaborate on study design, setting up field studies, and data collection. As a result, teams pivoted and held online meetings, conducted remote trainings, and pursued other alternatives for activity planning and implementation. For example, the Biosecurity team used funds to purchase new video conferencing equipment that is being utilized for regular online planning meetings. The Cambodian Fisheries and Food Processing team adapted to the COVID-19 restrictions by creating an online depository (through Canvas), which can be used in training.
- Universities and other organizations were either shut down or ran at a minimized capacity during the peak of the pandemic. This in turn led to staff shortages for laboratory and field work and analysis. In addition, students could not be enrolled in team activities, which delayed student involvement in field experience activities.
- Due to the restrictions on social gatherings, there was a shift to more individualized interactions in place of group meetings. This required more personnel and supplies than originally budgeted. Teams like Samaki Salama, which held cooking demonstrations and fisher workshops, were able to secure additional funds to help overcome this budgetary obstacle.
- Delays in activities due to COVID-19 resulted in unanticipated expenses. For research teams to adhere to the COVID-19 guidelines, more funds had to be spent for planning and implementation than initially proposed. For example, the Coral Reef Fishery activity had to delay activities until December, when costs were higher due to the holiday season for items such as accommodations, boats, and other rentals.
- Shipping has proved to be an issue for a few activities. Lack of dry ice and delays in shipping time have resulted in samples not being delivered in a timely fashion. In addition to delays in shipping of samples, supplies needed to conduct certain activities were unavailable.

Non-COVID-19 Pandemic-Related Issues

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

- The Farming Insects activity in Nigeria had to restructure the way they will obtain feed because they found out that there are no feed mills in Ebonyi and Cross River states. To resolve this issue, the team decided to produce the fish feed in Ibadan and transport it to Ebonyi and Cross River states.
- The Nourishing Nations in-country team had difficulty accessing funding due to an administrative issue at the university. This led to a delay in the collection and analysis of processed fish products and purchasing of necessary sample preparation and storage equipment.
- The Farm Diversification activity in Nigeria encountered a slowdown in activities related to seasonality. A peak in the dry season resulted in a lull in rice planting and fish-farming activities.
- The Coral Reef Fishery activity was not able to meet their male to female ratio target for the fish biomass training because many of the women in the communities are Muslim and are not allowed to swim, dive, and wear diving suits in the company of men. Some women did attend the training and learned the theory but did not participate in the physical activities.

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

Short-Term Training

The Fish Innovation Lab subawardees held 16 short-term trainings during the reporting period. Overall, 1,120 beneficiaries were reached through short-term training, including 741 males and 379 females.

Country of training	Activity	Brief purpose of training	Number trained		
			M	F	Total
Cambodia	Correa - Cambodian Fisheries & Food Processing	Training workshop on data collection with two new fishers selected to participate in a citizen science fisheries data collection program.	1	1	2
Nigeria	Subasinghe - Lean Production Systems	Training on applying lean management tools to identify waste streams and improve efficiency in production.	310	113	423
Nigeria	Halwart - Farm Diversification	Training of enumerators for socioeconomic and field surveys and training of farmers on on-farm data collection and recording.	19	8	27
Bangladesh	Belton - Machine Learning	Training on machine learning to identify aquaculture waterbodies including water-identifying indices, image thresholding (Otsu Segmentation), and convolution filters.	106	30	136
Bangladesh	Islam - Fecal Pathogens	Follow-up training at Department of Fisheries lab on isolation and identification of pathogenic microbes from fish samples.	2	1	3
Bangladesh	Dey - Market Analysis	Enumerators training to develop capacity to collect reliable and high-quality primary data. Fish farmers training on scientific and business management practices. Hatchery owners training on scientific and business management practices.	73	9	82

Country of training	Activity	Brief purpose of training	Number trained		
			M	F	Total
Kenya	Iannotti - Samaki Salama	Training of community health volunteers to conduct home visits. Cooking demonstrations conducted with mother/caregiver intervention participants. Fisher workshops at local beach management unit offices with fishers.	187	215	402
Kenya	McClanahan - Coral Reef Fishery	Community fish biomass training to help create awareness among the community beneficiaries on the current fisheries status within their areas and enhance their knowledge and skills on how to conduct a stock assessment	43	2	45

Long-Term Training

As of mid FY22, a total of 32 individuals (13 females and 19 males) are enrolled in bachelors, masters, or PhD programs receiving support from the Fish Innovation Lab for long-term training, mentorship, or apprenticeship in our aquaculture, fisheries, resilience, and food-system activities. This includes 26 individuals continuing from FY21 and six new individuals. The total number of individuals who have been supported by the Fish Innovation Lab to undertake long-term training is 37, including five persons who completed their studies in FY21 (see details in table below).

PI and student number	Sex	Home institution name	Degree	Major	Program end date	Degree granted	Student's home country	Status FY22 Q1-Q2
Belton	M	Bangladesh Agricultural University	PhD	Aquaculture Systems and Development	2023	No	Bangladesh	Continuing
Chadag 1	M	University of Ibadan	Master, Veterinary Public Health (MVPH)	Fish Epidemiology	2023	Yes	Nigeria	Complete
Chadag 2	F	University of Ibadan	Master, Veterinary Public Health (MVPH)	Fish Epidemiology	2023	Yes	Nigeria	Complete
Correa 1	M	Royal University of Phnom Penh	Master of Science (MS)	Research training	2023	Yes	Cambodia	Complete
Correa 2	F	Royal University of Phnom Penh	MS	Research training	2023	Yes	Cambodia	Complete
Halwart 1	M	University of Ibadan	PhD	Agriculture Economics	2023	No	Nigeria	Continuing
Halwart 2	F	University of Ibadan	PhD	Fisheries Management	2022	No	Nigeria	Continuing
Halwart 3	M	Usmanu Danfodiyo University, Sokoto	MS	Fisheries Ecology	2022	No	Nigeria	Continuing

PI and student number	Sex	Home institution name	Degree	Major	Program end date	Degree granted	Student's home country	Status FY22 Q1-Q2
Halwart 4	F	University of Ibadan	MS	Fish Nutrition	2022	No	Nigeria	Continuing
Halwart 5	F	University of Ibadan	MS	Fish Nutrition	2023	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	2022	No	Nigeria	Continuing
Halwart 8	M	University of Ibadan	MS	Fish Nutrition	2022	No	Nigeria	Continuing
Hok	M	Royal University of Agriculture	PhD	Agricultural Science	2022	No	Cambodia	Continuing
Iannotti 1	M	Pwani University	NA – postdoc	NA – postdoc	NA – postdoc	NA – postdoc	Kenya	Completed
Iannotti 2	F	University of Rhode Island	PhD	Environment and Life Sciences	2022	No	USA	Continuing
Iannotti 3	F	Washington University in St Louis	NA – postdoc	NA – postdoc	NA – postdoc	NA – postdoc	USA	Completed
Iannotti 4	F	Washington University in St Louis	Master of Public Health (MPH)	Global Health	2022	Yes	USA	Completed
McClanahan 1	F	University of Rhode Island	PhD	Biological and Environmental Sciences	2024	No	USA	Continuing
Pasqualino 1	F	Mississippi State University	PhD	Food Science, Nutrition and Health Promotion – concentration Nutrition	2022	No	Nigeria	Continuing
Pasqualino 2	F	University of Calabar	MS	Nutrition & Food Science	2022	No	Nigeria	Continuing
Pasqualino 3	M	University of Calabar	MS	Nutrition & Food Science	2022	No	Nigeria	Continuing
Ragsdale 1	M	University of Zambia	MS	Agricultural Economics	2022	No	Zambia	Continuing
Ragsdale 2	F	University of Zambia	MS	Human Nutrition	2022	No	Zambia	Continuing
Sarder 1	M	Bangladesh Agricultural University	PhD	Fish Breeding and Biotechnology	2024	No	Bangladesh	Continuing
Sarder 2	M	Bangladesh Agricultural University	MS	Fish Breeding and Biotechnology	2023	No	Bangladesh	Continuing

PI and student number	Sex	Home institution name	Degree	Major	Program end date	Degree granted	Student's home country	Status FY22 Q1-Q2
Sarder 3	M	Bangladesh Agricultural University	MS	Fish Breeding and Biotechnology	2022	No	Bangladesh	Continuing
Sarder 4	M	Bangladesh Agricultural University	PhD	Fish Breeding and Biotechnology	2024	No	Bangladesh	Continuing
Sarder 5	M	Bangladesh Agricultural University	MS	Fish Breeding and Biotechnology	2022	No	Bangladesh	Continuing
Sarder 6	M	Bangladesh Agricultural University	PhD	Fish Breeding and Biotechnology	2024	No	Bangladesh	Continuing
Sarder 7	M	Bangladesh Agricultural University	MS	Fish Breeding and Biotechnology	2023	No	Bangladesh	New
Islam 1	M	University of Dhaka	MS	Fisheries and Biotechnology	2023	No	Bangladesh	New
Islam 2	F	University of Dhaka	MS	Fisheries and Biotechnology	2023	No	Bangladesh	New
Rice 1	F	University Zambia	MS	Research training	2022	No	Zambia	Continuing
Hangombe 1	F	University Zambia	PhD	Research training	2024	No	Zambia	New
Hangombe 2	M	University Zambia	MS	Research training	2023	No	Zambia	New
Hangombe 3	M	University Zambia	MS	Research training	2023	No	Zambia	New

Other Cross-Cutting Theme Accomplishments

Gender Equity and Youth Engagement: Kathleen Ragsdale and Mary Read Wahidi, Fish Innovation Lab gender and youth equity specialists, led or participated in a total of 23 gender/youth-related activities. They made a presentation entitled "Gender Across USAID's Feed the Future Innovation Labs: Lessons and Approaches that Cultivate Gender-Transformative Agricultural Development" at the Cultivating Equality Conference 2021: Advancing Gender Research in Agriculture and Food Systems. They also submitted an abstract in collaboration with Fish Innovation Lab nutrition specialist Lora Iannotti and others to organize a panel entitled "Role of Fish in Mitigating Food Security and Nutrition Gaps among Vulnerable Populations in Developing Countries: Evidence Across Sub-Saharan Africa" to the 150th American Public Health Association annual meeting. The gender equity and youth team's work was highlighted in six blog posts and news releases, including Agrilinks and the Fish Innovation Lab website. The team also produced five technical reports and tools, including two summary documents describing the results of the GRADA-FIL surveys and an open access and customizable tool for a gender-sensitive postharvest fish loss assessment for small scale fisheries.

All of the Fish Innovation Lab activities made an effort to ensure balanced gender and youth representation in meetings and workshops and among the students that are actively engaging in Fish Innovation Lab research. Notable activity accomplishments related to gender equity and youth include:

- **Machine Learning**: Good practices implemented by women and youth were highlighted in blogs, reports, and six short videos.
- **Farm Diversification**: Gender-transformative approaches were integrated in all research components, including a social and gender analysis conducted to identify the norms and power relations that contribute to gender inequalities in development outcomes. The team also designed and tested interventions to transform the norms and power relations, aiming to reduce gender gaps and improve gender relations. The activity works to develop solutions for women and youth by creating and enhancing employment-generating opportunities within the local integrated agriculture-aquaculture value chain system. The activity is also helping empower women and youth by promoting farm diversification systems through farmer self-management strategies, farmer-to-farmer knowledge sharing, and involving them in research design.
- **Biosecurity**: As part of the data analysis, attention will be devoted to understanding the role of gender and youth in aquaculture farming practices, implementation of biosecurity, and disease management. Women leaders in farm clusters have been encouraged to document and report abnormal disease mortalities as well as collect appropriate biological samples in consultation with resident veterinarians and the team from the University of Ibadan.
- **Fecal pathogens**: When sampling from fish vendors at the retail markets in Dhaka city, the team found it difficult to reach women, because it is a male dominated profession. However, as a good proportion of the vendors are young and enthusiastic about participating in the program, the team has focused heavily on working with youth.
- **Farming Insects**: The study will work with all women farmers in the study area who are willing to be part of the activity. Youth, who make up most of the farmers, will also be given priority in participating in activities.
- **Nourishing Nations**: Overall, women and youth fish processors reported frequent use of low literacy tools, including wristbands and fans, which were developed with messages on the benefits of fish in human nutrition. These tools were used by women and youth fish processors to educate customers and the general public about the benefits of fish consumption for health as well as better marketing of their fish products, thereby directly strengthening their engagement with consumers, business skill development, and overall productivity in economic activities in the fish value chain. These tools indirectly addressed gender inequalities by increasing knowledge among women fish processors about proper nutrition and health and empowering their decision-making ability, particularly in relation to their business practices.
- **Micronutrient Impact of Oysters**: Research activities have focused on women shellfishers at three estuary sites in Ghana, including evaluating the extent to which oysters contribute to the micronutrient intakes of women, as well as the potential health risks women face as a result of heavy metal contamination of oysters. Under usual circumstances, women shellfishers in Ghana have received little research attention. As a result, the team anticipates that the research recommendations will be taken aboard by local authorities and help influence the health and nutrition of women shellfishers at the three estuary sites and similar settings.

Human Nutrition: In February 2022, Lora Iannotti, Fish Innovation Lab nutrition specialist, traveled to Mississippi State University (MSU) to meet with the Fish Innovation Lab ME team members and PIs. She presented a seminar titled “Confronting Hidden Hunger: How Fish Can Fill Health Gaps Around the World.” The presentation included a general overview of the importance of fish in human nutrition and details describing the case of Samaki Salama research in Kenya. Iannotti also met with

all the MSU-related activity teams to provide nutrition-related technical assistance and feedback. Iannotti presented at the Feed the Future Innovation Lab for Fish virtual side event during the World Food Prize Foundation's 2021 Borlaug International Dialogue in October of 2021. Other conferences planned for dissemination will be the American Public Health Association (APHA, Boston November 2022), International Union of Nutritional Sciences (IUNS-ICN, Japan December 2022). For APHA, two abstracts were submitted, including one panel, "Role of Fish in Mitigating Nutrition Gaps among Vulnerable Populations in Developing Countries: Evidence from Ghana, Kenya, Nigeria, and Zambia," which will include four Fish Innovation Lab activities with research related to human health and nutrition outcomes. For IUNS, Iannotti joined Gina Kennedy, GAIN, and Shakuntala Thilsted, WorldFish, among others in submitting the abstract titled "Availability, Affordability, Desirability, Convenience, and Sustainability of fish and other aquatic foods in low and middle-income countries." Iannotti and two members of her E3 Nutrition Lab are working with Brietta Oaks (US PI for Micronutrient Impact of Oysters) on a systematic review to examine the evidence base for the effects of mollusks and crustaceans on maternal and young child nutrition and health outcomes. The review team meets bi-weekly and has made substantial progress. A protocol has been registered on PROSPERO, and of the approximately 5,555 articles identified with duplicates removed, approximately half have now been screened.

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

- **Samaki Salama:** The provision of gated traps to fishermen in Kenya coupled with social marketing is an example of how activities have improved access to fish-based sources of nutrition for the poorest and most vulnerable groups. The activity's nutrition social marketing approach is specifically designed to improve access to fish-based sources of nutrition, increase diet diversity, and improve hygiene practices. Messaging and materials are focused on promoting four priority behaviors among infants, young children, and women of reproductive age in small-scale fisheries households: 1) caregivers feed fish to young children 6 months to 5 years daily; 2) caregivers feed an age-appropriate diverse diet, including fish, to children 6 months–5 years daily; 3) caregivers wash hands and child's hands with soap or ash before feeding; 4) fathers reserve and take home a small portion of fish for the child each day. Messaging centered on these four priority behaviors is delivered through diverse channels to mothers/caregivers, fathers, and leaders/members of local institutions. This multi-level approach supports improved feeding and care behaviors through individual, family, and community-level change.
- **Farm Diversification**: Improving the nutrition of individuals, households, and the collective community is one of the major benefits of this activity, with a major focus on reducing malnutrition (undernourishment and undernutrition, typically reflected as stunting, wasting, and underweight in children). Fish/food consumption survey and food security indicators were measured to highlight the linkages between farm diversification strategies and nutrition outcomes using the Household Food Insecurity Experience Scale for community food security, Minimum Dietary Diversity-Women and Household Dietary Diversity Score, and other relevant nutrition assessment tools. These tools and assessment methodologies will be used to measure the activity's impacts on food and nutrition outcomes.
- **Micronutrient Impact of Oysters:** It is unclear at this point if this research has improved access to fish-based sources of nutrition for the most vulnerable groups at the three study sites. However, the study results should allow the team to make recommendations towards sustainable harvesting and consumption of oysters at the study sites (e.g., through sound mangrove ecosystem management and environmental sanitation). Sustainable harvesting of oysters is likely to benefit the poorest and most vulnerable households who depend largely on local fishers for food security, household subsistence, and cash income.
- **Nourishing Nations**: This activity contributes to improving knowledge among smallholder fish processors on nutrition, the importance of fish and fish products in human diets, detrimental practices in fish processing, alternate ways of handling fish to yield quality

products, various ways fish could be contaminated during processing, and safer ways to process and thereby reduce health risks to consumers leading to better human nutrition.

Resilience of Value Chains/Households: The Fish Innovation Lab launched an online resilience training, which is mandatory for all lead PIs and ME partners. The training consists of five parts: 1) introduction, 2) USAID's approach to resilience, 3) USAID's resilience framework, 4) defining and using resilience capacities, and 4) systems resilience for aquaculture and fisheries. The Fish Innovation Lab resilience specialist, Joanna Springer, reached out to three teams for follow-up consultations and had in-depth discussions with the Biosecurity team. As a result of these discussions, the Fish Innovation Lab adapted its framework of resilience capacities to incorporate biosecurity and antimicrobial resistance (AMR) response. The Fish Innovation Lab developed a graphic mapping of seven Fish Innovation Lab activities to USAID's resilience framework. This was done to highlight activities with a strong resilience focus. The resilience specialist and Monitoring, Evaluation, and Learning advisor developed two resilience-focused learning questions and addressed the first during the February learning meeting to allow the teams to apply what they learned during the training. Finally, the resilience specialist contributed to a blog post on Agrilinks showcasing the Fish Innovation Lab's climate resilience activities in Kenya and Bangladesh.

Activity-specific resilience activities include:

- **Farm Diversification**: Integrated agriculture-aquaculture farming practices create household resilience during times of drought. The Farm Diversification activity increases the resilience of rural communities by promoting the diversification of food production systems and empowering stakeholders through inclusion of farmer self-management strategies, farmer-to-farmer knowledge sharing, and involvement in research design.
- **Biosecurity**: This activity creates more resilient systems by improving aquatic health management and enabling producers to prevent biosecurity shocks. The Biosecurity activity contributes to resilience through three pathways. First, improved aquaculture production practices reduce the risk of disease outbreaks. Second, the improved community-level diagnostic capacity contributes to an improved regulatory environment capable of controlling the spread of disease without imposing undue regulatory burdens or costs on smallholder producers. Third, the activity addresses the systemic threat of AMR through its cluster management approach, which facilitates a transition to lower use of antibiotics by producers.
- **Lean Production Systems**: This activity contributes to resilience through improving farm and processing efficiency, which reduces the risk of production loss.
- **Zambia Crayfish**: While the study does not encourage excessive market development of invasive crayfish, which could create incentives for undesirable activities, the team will collect data on the damage caused by crayfish on fisher's nets and catches. Such impacts have a relation to household resilience.
- **Cryogenic Sperm Banking**: The quality of seeds for both indigenous and exotic carps has deteriorated over the years, and fish farmers face issues such as low price, low demand, and high production cost. The growth performance of cryopreserved-sperm-originated seeds is demonstrated to be much better, and they are being reared for brood production. At a later stage, seeds will be produced from those broods, which are expected to show higher growth performance. Thus, the hatchery owners, nursery operators, and fish farmers will get more production and be less susceptible to stresses and shocks.
- **Nourishing Nations**: The market survey completed in March 2022 under the Nourishing Nations activity contributes to creating a cost-per-nutrient guide on fish and other animal source foods, which will establish the relationship between the cost and nutrient composition of foods typically available to and purchased by consumers in Delta state, Nigeria. Such data are helpful in identifying cost-effective ways for individuals and households to move towards dietary patterns that are both affordable and healthy.

Capacity Building: The short- and long-term training accomplishments have been summarized in previous sections. Glenn Ricci, capacity development specialist, launched the Fish Innovation Lab student network, which had its first official gathering. Ricci also began working with Lora Iannotti on an interactive course related to fish and nutrition. Activity-specific capacity building activities include:

- **Farm Diversification**: Capacity building is the backbone of the Farm Diversification activity, which implemented training programs, knowledge sharing, and information dissemination with relevant stakeholders and development of clear strategies for upscaling interventions. Dialogue and learning process discussions involve all stakeholders, including youth and women. The University of Georgia also enhanced the capacity of faculty and staff of the University of Ibadan to undertake field-based research that can feed into academic outputs (publications, student thesis, faculty-postdoc mobility).
- **Machine Learning**: Extension videos were developed by the activity. The videos are disseminated via social media to disseminate information on innovative and emerging practices adopted by farms and other value chain actors. This will speed up the information exchange process and promote adoption of improved and sustainable practices.
- **Fecal Pathogens**: The activity provided training to laboratory personnel from the fisheries and food safety laboratories operated by the Government of Bangladesh. The training has strengthened the capacity of these laboratories in testing fish and environmental samples for various microbiological parameters and detecting pathogen-specific genes. The Department of Fisheries laboratories did not have capacity to run PCR-based detection of foodborne pathogens in fish and environmental samples, although this was a long-standing demand from the consumers' side. After receiving training, they have started implementing PCR detection of major foodborne pathogens. They will contribute to improving aquaculture and fishery operations by applying their knowledge and skills to existing surveillance of fish samples in both local and export markets.
- **Farming Insects**: The farmer school methodology will train farmers to rear and process black soldier fly and incorporate it in the fish feed. This will bring down the cost of production and increase farmers' profitability.
- **Cryogenic Sperm Banking**: Seeds of rohu, mrigal, silver carp, and bighead carp were produced in eight hatcheries in four regions using cryopreserved sperm. Hatchery operators took part in the breeding activities and are now able to produce broods using cryopreserved sperm.
- **Cambodian Fisheries and Food Processing**: Under objective 1, the team continued training and providing feedback to the fishers participating in the citizen science program, collecting fisheries harvest data in the Sre Ambel River. In addition to the 15 local fishers, one Cambodian graduate student and one local program coordinator have been trained in fisheries management. Under objective 2 the team has developed training videos on fish processing, which will be useful to fish value chain actors beyond the grant duration.
- **Coral Reef Fishery**: A fisheries stock assessment video was used to communicate monitoring results to local communities. This information improved the community members' knowledge of local fisheries resources, current management efforts, and the need to conserve fish biodiversity. The community training on fish biomass assessment enhanced the participants' capacity to identify and record fish species.
- **Lean Production Systems**: The team applied a training-of-trainers approach for lean management tools to identify waste streams and improve production efficiency. A total of 423 farmers were trained, out of which 113 were females (27%) and 56 were youth (13%).
- **Nourishing Nations**: The activity works to strengthen capacity among women and youth fish processors in the Delta state. The activity trained 122 fish processors, including 95 females (78%). The fish processors have begun organizing into business cooperatives and will continue learning how to produce high quality, safe, and nutritious processed fish

products for local consumption. They will also continue to hone their business and marketing skills.

- **Zambia Crayfish**: The activity is strengthening the capacity of colleagues at the University of Zambia and the Department of Fisheries by increasing their understanding of the reproductive biology and ecology of crayfishes in their natural habitat areas and ecological impacts of the crayfish. This was the major thrust of the March 17 Crayfish Workshop with various stakeholders at the University of Zambia. Additionally, during the reporting period a masters student started her studies and successfully defended her thesis proposal.

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 met with all of the research teams to take stock of where they are mid-way through their proposed plan, pin-pointing areas of concern and developing adaptive measures and plans where necessary. The ME also supported the teams as they adapted to circumstances caused by the COVID-19 pandemic; implemented the learning agenda and research strategy; organized meetings with USAID missions (Zambia, Bangladesh, 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 Year 5 work planning process and preparing the research teams for close-out. ● 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. ● Organize and implement a Fish Innovation Lab self-assessment. ● Organize an annual meeting and an external advisory board meeting. ● Engage with USAID missions via meetings that showcase the Fish Innovation Lab's work in the respective countries (Ghana scheduled for May, followed by Cambodia). ● Organize country-specific events, including a Bangladesh stakeholder meeting and Nigeria-focused webinar series. ● 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. ● Develop Fisheries, Aquaculture, and Human Nutrition online course. ● Support the Fish Innovation Lab student network. ● Conduct and participate in monthly ME partner meetings, quarterly PI meetings, and semi-annual learning agenda meetings. ● Implement DWF buy-in activity.

Management Entity activities
● Pending concurrence from the Mali USAID mission, support a collaboration between iREACH and the Fish Innovation Lab to replicate the integrated rice and aquaculture activity in Mali. ● Attend and showcase the Fish Innovation Lab at virtual and in-person conferences and workshops. ● Communicate innovations, success stories, and lessons learned via technical briefs, fact sheets, success stories, etc. ● Prepare for the Innovation Lab Council Chair. Dr. Torell will begin this position in September 2022, and the Fish Innovation Lab will provide support.

Appendix 1. Semiannual Progress Summary Table

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 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			
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 completed the first cycle of on-farm adaptive research to assess, evaluate, and develop operational technical packages for the selected rice-fish technology and diagnostics to be disseminated and adopted in each of the participating states. Seven on-farm adaptive research plots were operationalized to obtain information on cost of production, rice and fish yield, resource use, and fish performance under different feeding regimes in each system. The harvesting of fish from the first cycle of rice-fish adaptation was concluded. Preliminary analysis of parameters for integrated rice-fish farming system (water balance, nutrient flow, key elements of fish integration into rice fields, feeding practices, etc.) was initiated and is ongoing. Twelve farmers were trained on on-field data collection and recording. The team collected preliminary quantitative and qualitative data on households through the food security survey, fish consumption survey, and utilization of rice field aquatic resources by rice-fish farmer households and other households in the community. The household data were disaggregated to define roles and access to food by men, women, and children (grouped in different age brackets; infants, young children, adolescents, and young adults). Research studies on the technology to be developed and disseminated were conducted, and the socioeconomic survey and site mapping were completed. Assessment of locally available feedstuffs as suitable supplemental feeding for selected species in integrated agriculture-aquaculture systems is ongoing as well as the development of feeding model and formulation for sustainable fish production under integration. Analysis of the preliminary data on grower's profitability margins, grower's acceptability, and consumer purchasing behavior and willingness to pay for high value aquaculture locally grown products was concluded.
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	Nigeria	Pechal Lead and US PI (MiSU), Souza	The team undertook a reconnaissance survey of the study area and found that the area does not have a functional feed mill. As a result, the study was substantially redesigned by agreeing to

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
production of fish while minimizing costs of production.		US Co-PI (MiSU), Omonona HC PI (UI)	produce the fish feed in Ibadan and transporting to Ebonyi and Cross River states instead of producing in the study area.
1.2.2. Assess the feed safety of black soldier fly (BSF) reared on available organic waste streams via microbiological assays for potential pathogens.			
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 project results through workshops, videos, and factsheets.			

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
Activity 1.3: Improving efficiency in the Nigerian aquaculture sector by employing lean production systems			
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 has engaged fish value chain actors to adopt the technology to apply lean management practices and lean tools to increase fish farm and fish processing efficiency. This will help increase the productivity and availability of fish in the local markets. A total of 112 farms/farmers in both Ogun and Delta states adopted the technology to identify and address 253 waste streams in farming and processing activities by applying lean management principles and tools. A total of 209 mini activities to address the waste streams have been completed.
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.	Cambodia	Hok Lead PI (CE SAIN RUA), Yossa HC Co-PI (WF), Reyes US PI (KSU), Gatlin US Co-PI (TAMU)	Materials for the wet lab for aquaculture feed nutrition research at Royal University of Agriculture (RUA) were purchased and installed. The team trained farmers and RUA personnel on applied scientific aquaculture research including feed manufacture. The RUA staff trained farmers and peers in Cambodia on the operation of a wet lab and feed formulation and manufacture. The protein and lipid requirements of BC at the grow out stage under lab conditions were estimated. The materials and reagents for experiments to conduct research on substitution of fish-meal and "underrated fish" by soybean meal in the diet of BC were secured.
1.4.2. Development and scaling of cost-effective formulated feeds for the sustainable culture of local bighead catfish (*Clarias macrocephalus*) in Cambodia.			
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.	Kenya	McClanahan Lead and US PI (WCS), Muthiga US Co-PI (WCS), Mbaru	Fisheries stock assessment was conducted in eight sites within the Shimoni-Vanga seascape area. The activity involved fish biomass estimation training in fishing areas, community closures, and government closure (marine park). A total of 31 survey transects were done in 25 unique sites within the Shimoni-Vanga seascape. The collated information was compared to the fisheries data collected monthly by trained community persons. In addition, a variety of underwater video clips

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
1.5.2. Determine the best metrics for measuring sustainability to enhance the likelihood of sustainable management.		HC PI (KMFRI) Humphries US Co-PI (URI)	were gathered, and a video presentation on the status of Shimoni-Vanga fisheries and current findings was recorded. The films of underwater surveys and interviews with participants were produced for future reference and presented to the community during the fish biomass training activity. In addition, the video presentation was shared with different stakeholders. Community fish biomass training was completed in all five sites involving 45 individuals including males and females and different age categories. The training provided a biomass data set comprising 19 common fish families. To enhance capacity for monitoring fish biomass and yields in Kenya's coral reefs, the training involved undertaking an underwater visual census of fish in coral reefs, data entry, interpretation of biomass, and yield data in their fishing areas. The team identified 12 participants that gained skills and knowledge and were able to conduct the stock assessment in collaboration with the team. The team communicated feedback results of the data collated over the past year on social and ecological research within the transboundary conservation area. Monthly fish landing monitoring by community and county fisheries officers continued, with one new member trained. Additional data on fish landings was collected, and subsampling of fish length surveys was completed with exploratory analysis. The team developed a fish biomass training manual in both English and Swahili language
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.			
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			
1.6.1. Develop donor broodstocks of Indian major carps and three exotic carps.	Bangladesh	Sarder Lead and HC PI (BAU), Rahman HC Co-PI (BAU), Tiersch US PI (LSU)	Broodstocks of both Indian major carps and three exotic carps were reared with supplementary feeds in three ponds. Cryopreserved sperm-originated and control fry of rohu, mrigal, silver carp, and bighead carp were reared in five hatcheries and one fish farm in Jashore, Faridpur, and Mymensingh regions. Monthly sampling of fry/fingerlings of both cryopreserved-sperm-origin and control carps was conducted to compare their growth performance. Genetic characterization of broodstocks using DNA microsatellite markers is being conducted. Fourteen PCR primers were used to amplify microsatellites, and some of them were used for identifying genetic variations of rohu and bighead broodstocks through polyacrylamide gel electrophoresis. Cryopreservation of sperm of silver carp, bighead carp, and grass carp was conducted for cryogenic sperm banking as well as the standardization of parameters for cryopreservation protocols. Stakeholder training workshops (including hatchery and nursery operators and fish farmers) on dissemination of cryopreservation technology were conducted. A cryopreservation technology training workshop for junior faculty members and MS and PhD students was held. The team conducted visits to the artificial insemination center for cattle in Savar, Dhaka. One MS student completed their MS degree,
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.			

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
1.6.4. Assess the performance of cryopreserved sperm for establishment of sperm banks in different regions.			and a new MS student was recruited. Two MS students completed their research work and are writing their MS thesis for submission.
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), Dinh US Co-PI (MSU), Schilling US Co-PI (MSU), Sitha HC PI (WCS), Mahood HC Co-PI (WCS)	The team successfully completed one year of data collection as part of the Citizen Science Fisheries Harvest data collection program. Data is being collected by 15 trained fishers from five villages in the Sre Ambel River and supervised by the in-country coordinator and a graduate student. This individual-level data resulted in >20,500 entries for >38,700 individual fish harvested in the Sre Ambel River. The activity-developed Community Fisheries Assessment Tool, iFISH, is available online and allows users to plot length frequency, species composition, capture location, and distance traveled by fishers. The interactive app allows users to change the display by species, gear, and village. Summary statistics for the first six months of fisheries harvest data are visually presented in iFISH. Monthly meetings were held with a software developer to advance iFISH. The app's content and Khmer translation were improved, and a training video for end-users was developed. A training session on iFISH was held with in-country collaborators from WCS-Cambodia, which included a discussion on strategies to improve data management and analysis. A searchable photo identification catalog of the harvested fish was maintained by a graduate student and curated by a federal ichthyologist collaborator. Fish data and photos generated from the ongoing Citizens Science Program were periodically uploaded onto shared Google Drive folders. To continue contributing to outcomes, all fishers collected fishing data and regularly submitted all related photos and information to the team. The team frequently visited fishers to ensure they can record fish correctly, and fishers were retrained as necessary. The team collected 49% of the expected 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). On average, 13 fish samples per species were collected. All online materials and tools necessary for sensory evaluation training and IRB training were created. All trainings have been produced, and the team is working on Khmer voice-over. To prepare for the training workshops, the team produced videos on fish fileting, fish salting, and smoking fish. A smokehouse tour and explanation video was produced. A knowledge survey on fish processing and fish nutrition was produced, and the survey was translated into the Khmer language. Consumer surveys and sensory rubrics were translated for the sensory panel, and the translation was uploaded for IRB approval. Videos have been uploaded onto Canvas for the training workshops after the sensory panel.

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
Activity 1.8: Advancing aquaculture systems productivity through carp genetic improvement			
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.** **1.8.4. A cost-effective pedigree assignment tool.** **1.8.5. Practical manuals, tools, and training activities.**	Bangladesh	Hamilton Lead PI (WF), Benzie Lead Co-PI (WF), Tiersch US PI (LSU), Yeasin HC PI (WF), Hossain HC Co-PI (BAU)	Preliminary analyses of "real-world" performance of the G3 rohu families were conducted, indicating that G3 rohu are growing 30% more rapidly than other commercially-grown rohu. The activity supplied additional hatcheries with G3 spawn to be grown into broodstock in 2021. Over 1,500 enterprises, comprising hatcheries, nurseries, traders, and farmers, purchased G3 rohu, primarily via WorldFish partner nurseries. The 2020 G3 rohu progeny testing was completed, and 2,462 fish were assessed. Initial selection of parental candidates was undertaken, and only the top ~20% of fish from each 2020 G3 rohu family were retained. Tagging of 2021 G1 catla and 2021 G3 rohu was completed, and progeny testing commenced. All 2020 and 2021 rohu and catla families have been backed up at one external site. Rohu samples to be used in the development of a cost-effective pedigree-assignment (parentage assignment) tool were obtained, and transfer of samples to plates was completed. Hatcheries possessing G3 rohu broodstock were surveyed to identify current capacities and key training requirements.
Activity 1.9: Piloting integrated insect-to-fish (ITF) farming systems in Malawi			
1.9.1. Costs and conversion ratio of propagating BSF and processing into aquaculture feed. **1.9.2. Feasibility and cost-effectiveness of waste streams (spent grain, market waste) for BSF farming.** **1.9.3. Changes in pond yield and productivity resulting from different mixes of BSF meal in fish feed.**	Malawi	Pechal Lead and US PI (MSU), Souza US Co-PI (MSU), Eilittä US Co-PI (CNFA), Kang'ombe HC PI (LUANAR),	This activity is yet to start and hence did not report any accomplishments for the first half of FY22.

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
1.9.4. Existing aquaculture value chains and potential income gains from increased aquaculture cost-efficiency.			
1.9.5. Engage and collaborate with local community groups (e.g., women and youth) to communicate project results and provide training on the technology.			
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 tilapiaindustries			
2.1.1. To understand epidemiology and health economics of catfish and tilapia aquaculture in Ogun and Delta states, 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)	Video conferencing equipment was installed at the University of Ibadan, and the system was used regularly for online meetings organized between the UI team and MSU and WorldFish colleagues to discuss progress on milestones and planning. Dry season sampling season was completed in both Delta and Ogun states. Using the established Resident Aquatic Veterinarian (AquaVet) Network, 56 fish samples were collected in Ogun state, out of which 41 were blood samples and six were samples originating from fish with clinical signs. In Delta state, 79 fish samples were collected, out of which 56 were blood samples and four were samples originating from fish with clinical signs. Biological samples collected during the rainy season were analyzed. A large number of bacterial isolates have been recovered from biological samples. Information regarding the farms of origin has been matched alongside their source of isolation (i.e., organs). Bacterial isolates have been linked to farm clusters, and the farms will be noted for prevalence calculation. Both hematology and biochemical analyses were completed as well as enzymatic and biochemical tests on bacterial isolates. Several putative “novel” pathogens circulating in “clinically normal” populations have been identified across both states; some of those “pathogens” could represent risks to Nigeria catfish and tilapia aquaculture. Data collection from the Fish Epidemiology and Health Economics survey tool in Ogun and Delta states was completed and provided as a spreadsheet for assessment. The data set was reviewed and prepared for initial analysis for descriptive statistics. Descriptive statistics were generated and are being used to identify farm characteristics and potential risk factors. Work has been initiated to develop a GIS web map for display of data from the Fish Epidemiology and Health Economics survey. A new online tool was developed for fish disease outbreak investigation with
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			

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
disease outbreaks in catfish and tilapia aquaculture in Nigeria.			simple instructions shared with the UI team for future implementations with enumerators and resident veterinarians.
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 project.			
Activity 2.2: Identifying major sources of fecal 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.	Bangladesh	Islam Lead and US PI (WSU), Narrod US Co-PI (UMD), Parveen US Co-PI (UMES), Amin HC PI (icddr,b)	Samples were collected from pangas and tilapia fish at wet markets and super shops in Dhaka city. To achieve the target number of samples, the last batch of samples from six retail markets and six super shops were collected. A total of 84 samples from retail markets and 24 samples from super shops were collected, analysis of all samples for major foodborne pathogens was completed, and the isolates were banked for future analysis. Antibiotic susceptibility test of 458 *E. coli* (including 239 extended-spectrum beta-lactamase (ESBL) producing *E. coli*), 121 *Salmonella* spp., and 298 *Vibrio cholerae* against a catalogue of clinically important antibiotics according to Clinical and Laboratory Standard Institute Guidelines was completed. All 458 *E. coli* isolates were tested for virulence genes by PCR. Results were compiled, and an abstract was submitted and accepted for presentation in the 2022 annual meeting of the International Association for Food Protection. Collection of whole fish, ice/water, and swab samples from fish cut-up boards from retail and wholesale markets was initiated. To date, sampling of two retail markets and two wholesale markets has been conducted, with a total of 58 whole fish samples, 12 cut-up board swab samples, and 12 fish-tank water samples collected and tested for *E. coli*, ESBL-*E. coli*, *Salmonella* spp., and *Vibrio cholerae*. Short-term hands-on and follow-up training was provided to the staff from the Department of Fisheries, and two MS students from the Department of Fisheries were enrolled at the University of Dhaka. Questionnaire surveys and focus group discussions (FGDs) with the key actors in pangas and tilapia fish value chains were initiated. Short interviews of all the vendors from wet markets and super shops were completed as well as FGDs and structured observations in 15 retail markets.
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.			

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
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.	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 US PI visited the team in Zambia and participated in kick-off meetings. Postgraduate students (two masters and PhD) were recruited to undertake the core activities of the program. The students have finalized their research proposals, and the proposals have been approved by the University of Zambia. The proposals have been submitted to the National Ethics Review Committee for ethical consideration, after which the activities will start. Farms have been identified that will participate in the study, and some of the farms have signed a Memorandum of Understanding for involvement in the core activities. Sources to supply experimental fish have been identified. Farms not located in the study area have been approved to supply fish for experimental studies; these farms are Kalimba and Mukasa fish farms.
2.3.2. Bacteria pathogenicity and disease causation confirmation.			
2.3.3. Autogenous vaccine development and challenge studies of the identified pathogen.			
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.	Bangladesh	Belton Lead and US PI (MiSU), Nejadhashemi US Co-PI (MiSU), Haque HC PI (BAU), Murshed-e-Jahan HC Co-PI (WF)	The team successfully completed training on remote sensing methodologies for fish pond identification for 91 registered participants from Bangladesh and 45 registered international participants. The training was conducted through an online course comprised of six 45-minute online tutorials and four live question and answer sessions. Three short extension videos on innovative practices in the aquaculture value chain in southwest Bangladesh were produced and disseminated. A paper was published in the leading field journal *Remote Sensing* on fish pond detection methods. Initial descriptive analysis of farm, trader, and input supplier survey datasets was completed. Development of an interactive website, Southwest Bangladesh Aquaculture Data Portal, to display farm survey results was initiated. Data visualization tool for fish pond identification is under development.
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,			

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
and transfer information to potential users.			
Activity 3.2: Nourishing nations: Improving the quality and safety of processed fish products in Nigeria			
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.	Nigeria	Pasqualino Lead PI (WF), Tolar-Peterson US PI (MSU), Ene-Obong HC PI (UNICAL)	The team implemented a post-education survey as follow-up to a previously conducted training to evaluate the participants' knowledge, attitude, and perceptions related to the role of fish in human nutrition and health. The survey also assessed the respondents' use of the low-literacy tools developed and distributed to fish processors. In total, 92 participants (all fish processors), 73 women and 19 men, were surveyed, with the majority reporting positive use of the tools. The MS students finalized their research proposals, including the methods that will be used to analyze data collected to develop the guide, which contributes to the long-term training goal. Additionally, the PhD candidate defended her dissertation, also contributing to the long-term training goal. Two market surveys, conducted by the MS students, were completed to collect data on the prices of fish species sold in Delta state and assess seasonal variation in prices.
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.			
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.	Zambia	Ragsdale Lead and US PI (MSU), Read-Wahidi US Co-PI (MSU), Marinda HC PI (UNZA),	The team engaged in a total of 27 activities. Activities included the mentorship of students (11), highlighting research activities through media outlets (4), and the production of technical reports and other documents (1). The team organized and facilitated a seminar on "Confronting Hidden Hunger: How Fish Can Help Fill Heath Gaps." A total of eight presentations were delivered, and a journal article was published. In addition, the Post-Harvest Fish Loss Assessment for Small-Scale Fisheries (PHFLA): An Open-Access Customizable Tool was published.

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
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.		Mudege HC PI (WF)	
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.			
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.)	Kenya	Iannotti Lead and US PI (WUSTL), Humphries US Co-PI (URI), Wamukota HC PI (PU), Kamau-Mbuthia HC Co-PI (EU)	All social marketing materials were finalized and are now in use. Materials include a home visit guide, fisher workshop guide, fisher commitment document, letter to fathers/fishers, reminder poster for caregivers, growth chart/calendar, menu game, t-shirt design, sticker design, banners for beach management unit (BMU) offices, and community health volunteer (CHV) training. The first round of home visits to all intervention households (n=200) has been completed, and the second round is ongoing. Distribution of printed social marketing material to participants in the intervention groups is ongoing (t-shirts, stickers, reminder poster, letter to fathers, growth chart/calendar, and BMU banners). CHVs in the intervention sites were trained to conduct future home visits and support other social marketing events. A total of 15 cooking demonstrations and 10 fisher workshops were conducted in arm 1 and arm 2. The team collected pre/post data from the cooking demonstrations and fisher workshops. All modified basket traps (n=400) have been made and distributed; fishers in the intervention group (n=100) have each received four modified basket traps with escape gaps. A process monitoring plan and data collection tools have been designed, and the landing site data collection protocol was finalized and is currently in use. There have also been multiple follow-up meetings with fishers to gather feedback on trap usage.
3.4.2. Fisher Cooperatives (Measure the impact of fishing gear cooperatives on gear modification and diversification as well as catch dynamics and earnings.)			
Activity 3.5: Population ecology and current distribution assessment of the introduced invasive crayfish in the Kafue floodplain and Lake Kariba, Zambia			

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
3.5.1. Characterization of crayfish population growth parameters, including size and age structure, and reproductive rates in Zambian waters.	Zambia	Rice Lead and US PI (URI), Nambeye-Kaonga HC PI (UNZA), Eilittä HC Co-PI (CNFA)	The team developed and tested the crayfish harvest and utilization survey and finished initial field testing among fishers in Siavonga. Focus group discussions and key informant interviews were conducted. An online poll was developed to assess presence/absence of crayfish in Zambia's waterbodies. The poll will be made available and widely distributed to understand the spread of crayfish in Zambia. Trap design and methodology for the crayfish population study was finalized. A pilot crayfish trap design, similar to Australian traps, was developed. Study sites and trapping sites were finalized for crayfish trapping. Seasonal preliminary crayfish trapping data was collected at Kafue River, near the Kafue Road bridge, for the following months: November, December, January, and April, and at Lake Kariba, near Siavonga, in March. This data collection was informal and did not involve use of funds. Crayfish size-frequency data was collected for a few weeks from two trapping sites. A workshop at UNZA was conducted with the Department of Fisheries, Department of Environment, and environmental non-governmental organizations based in Zambia. Through the workshop, contacts were made, and partnerships were built for the data-gathering phase of the activity. Study team members presented at the workshop.
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).			
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.	Bangladesh	Dey Lead and US PI (TSU), Surathkal US Co-PI (TSU), Khan HC PI (BAU), Rahman HC Co-PI (PSTU)	Secondary data collection on the Household Income Expenditure Survey was completed. Training of the enumerators was conducted. A total of 820 fish farmers from nine districts of Bangladesh were surveyed. Two training programs on scientific and business management practices were conducted for fish and hatchery owners for their capacity building. Secondary data on shrimp export and import markets was collected. Questionnaire pre-test and farm survey were conducted. Both the primary and secondary data analysis was partially completed. Two papers have been submitted to journals and are under review.
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.			
Activity 3.7: Micronutrient impact of oysters in the diet of women shellfishers			

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
3.7.1. Determine the contribution of oyster consumption to iron and zinc intakes of women shellfishers.	Ghana	Oaks Lead and US PI (URI), Adu-Afarwuah HC PI (UG)	Ethics approval from the Ghana Health Service Ethics Review Committee was obtained, and field data collection was completed. In total, 504 women shellfishers were enrolled, including 200 from the Densu estuary (Bortianor, Tsokomey, and Tetegu communities), 166 from the Narkwa Lagoon area (Ekumfi Narkwa community), and 138 from the Whin estuary (New Amanful, Apremdo, and Beaho communities). These women comprised all or nearly all of the women shellfishers in the target age group (women of reproductive age, 15-49 years of age) available for enrollment at the three selected sites. At each site, information on women's background socioeconomic characteristics was collected. Two non-consecutive 24-hour dietary recalls were conducted; the first on the day of enrollment and the second within seven days after enrollment. Each of the 915 oyster samples collected from the three sites were analyzed (i.e., 305 samples per site) for 15 minerals, including five macrominerals (calcium, magnesium, phosphorus, potassium, and sodium), seven trace minerals (chromium, cobalt, copper, iron, manganese, nickel, and zinc), and three heavy metals (cadmium, mercury, and lead).
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.			
DWF activity (buy-in): Supporting USAID missions by conducting complementary research and learning related to distant water fleets in fisheries			
Objective 1. Explore transparency and sustainability in licensing and supply chains associated with distant water fleets (DWF) activity in select national exclusive economic zones.	Peru, Madagascar, the Philippines, and Micronesia	Torell Lead and US PI (URI), Humphries US Co-PI (URI)	Orientation meetings with USAID missions and stakeholders were organized. Mission concurrence to implement the research activities in Peru, Madagascar, the Philippines, and Micronesia was obtained. The process was outlined for determining the extent to which DWF currently impacts fish availability, access, and potential utilization and estimating the optimal catch allocations to DWF to provide resilience to future domestic catches. Analysis of data obtained from the University of British Columbia's Sea Around Us database began.
Objective 2. Characterizing the scale, form, and socioeconomic impacts of DWFs on national fisheries and fisherfolk in select geographies.			The methods to be used for examining the characteristics and impact of existing DWF fishing access agreements within priority geographies were outlined. The framework on existing licensing agreements (or lack thereof) was shared in the four priority geographies, and feedback was received.
Objective 4: Effectively manage a portfolio of research for development activities in aquaculture and fisheries and implement a knowledge management plan			

Objectives, Activities and subactivities	Country of activity	Person or institution responsible	FY2022 progress
Activity 4.1: Support the Fish Innovation Lab research-for-development activities.	Bangladesh, Cambodia, Ghana, Kenya, Malawi, Nigeria, Zambia	Lawrence (MSU), Torell (URI), Allen (MSU), Ragsdale (MSU), Read-Wahidi (MSU), Iannotti (WUSTL), Kent (URI), Dey (TSU), Hill (MSU), Zseleczky (MSU), Jeudin (RTI), Springer (RTI), Ricci (URI), Humphries (URI), Wamukota (PU), Hussain (BAC), Siriwardena (WF)	Research activities were supported via quarterly PI and learning meetings and one-on-one meetings. GRADA-FIL results were published via two briefs. 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. The ME participated in the Innovation Lab cross-cutting theme community of practice.
Activity 4.2: Implement plan for engaging missions, attract associate awards, and engage minority-serving institutions.			Meetings were held with USAID missions in Zambia, Nigeria, and Bangladesh, and a request was submitted for a meeting with the Ghana mission. The Fish Innovation Lab received its first buy-in award from the USAID Biodiversity Division, Center for Environment, Energy, and Infrastructure to support its learning agenda on distant water fleets.
Activity 4.3: Implement knowledge management plan.			Online resilience training was launched. Blogs, technical briefs, and other media were developed that highlight Fish Innovation Lab activities and the ME partners' work. A quarterly newsletter was developed and distributed.
Activity 4.4: Monitoring, evaluating, and learning (MEL) from research findings, determining factors that limit adoption of new knowledge/technologies and scaling.			FY21 indicator and narrative reporting was completed through the Development Information System (DIS), Research Rack-Up, and six interactive learning sessions (three in November and three in February). The November discussions focused on establishing the FY22/FY23 learning agenda questions for two new learning themes: innovation/technology adoption and scaling, and health and nutrition. In February, research teams discussed end-user uptake and adoption, stakeholder engagement, and women/youth engagement. The MEL plan was revised and approved by the AOR. The research strategy was facilitated, and the research teams were supported in submitting joint conference session proposals. Semiannual virtual platform meetings were conducted on topics specified in the learning agenda. Fish Innovation Lab research activities were monitored, and quarterly and semiannual indicator data was 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; 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 FY22, 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 1,120 individuals, including 741 males and 379 females.
- **EG.3-2: Number of individuals participating in USG food security programs.** The Fish Innovation Lab reached 739 beneficiaries through activities and events. This included 439 males and 300 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 16 technologies or management practices under the following phases: research (7), field testing (7), being made available for transfer (1), and demonstrated uptake (1).
- **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 1,156 beneficiaries applied improved practices and technologies (789 males, 237 females, and 130 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 32 long-term students (13 females and 19 males), out of which 26 were continuing from FY21 and 6 were new in FY22. Five individuals have completed their long-term training programs.

Publications and presentations module				
STIR-12: Book	**2020**	**2021**	**2022**	**2022 (Q1-Q2)**
	Actual	**Actual**	**Target**	**Actual**
Peer-reviewed publications				
Peer-reviewed publications	0	0	1	0
STIR-12: Book chapter	**2020**	**2021**	**2022**	**2022 (Q1-Q2)**
	Actual	**Actual**	**Target**	**Actual**
Peer-reviewed publications				
Peer-reviewed publications	0	0	3	0
STIR-12: Journal article	**2020**	**2021**	**2022**	**2022 (Q1-Q2)**

Publications and presentations module				
	Actual	**Actual**	**Target**	**Actual**
Peer-reviewed publications				
Peer-reviewed publications	0	6	2	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**	**2021**	**2022**	**2022 (Q1-Q2)**
	Actual	**Actual**	**Target**	**Actual**
Sex				
Male	0	516	320	741
Female	0	262	115	379
Disaggregation not available	0	0	0	0
Totals	**0**	**778**	**435**	**1,120**
Participant type (multiple choices allowed)				
Parents/caregivers		0	0	201
Household members		0	0	12
People in government		47	0	72
USG-assisted private-sector firms		4	0	23
People in civil society		107	0	110
Producers		620	0	702
Totals		**778**	**435**	**1,120**
Indicator result narrative	For the FY22 semiannual reporting period 1,120 beneficiaries were reached through short-term training, including 741 males and 379 females. In Q1, a total of 630 beneficiaries were reached, including 239 males and 191 females. Many participants (423) were reached by the Lean Production Systems activity through short-term training for producers. The training focused on the application of Lean Management tools designed to identify waste streams and improve production efficiency. In Q2, a total of 490 beneficiaries were			

EG.3.2-1: Number of individuals who have received USG-supported short-term agricultural sector productivity or food security training	
	trained, including 302 males and 188 females. Many of these participants (351) were reached by the Samaki Salama activity via a cooking demonstration with mothers/caregivers and a workshop with fishers. The workshop was designed to understand fishers' challenges in providing for their families.

EG.3-2: Number of individuals participating in USG food security programs				
EG.3-2: Other project participants	**2020**	**2021**	**2022**	**2022 (Q1-Q2)**
	Actual	**Actual**	**Target**	**Actual**
Gender				
Male	0	1172	480	439
Female	0	601	221	300
Totals	**0**	**1773**	**701**	**739**
Age				
15-29	0	442	194	237
30+	0	523	507	488
Disaggregation not available	0	808	0	14
Totals	**0**	**1773**	**701**	**739**
Participant type (multiple choices allowed)				
Parents/caregivers	0	122	20	199
Household members	0	30	0	0
People in government	0	213	56	58
USG-assisted private-sector firms	0	54	69	226
People in civil society	0	311	93	86
Laborers	0	20	0	1
Producers	0	1023	459	164

EG.3-2: Number of individuals participating in USG food security programs				
Not applicable	0	0	2	5
Disaggregation not available	0	0	2	0
Totals	**0**	**1773**	**701**	**739**
Indicator result narrative	During the FY22 semiannual reporting period, 739 beneficiaries were reached through activities and events, including 439 males and 300 females. In Q1, 563 beneficiaries were reached, including 318 males and 245 females. The majority (197) were reached by the Samaki Salama activity via home visits focused on nutrition, diagnosing illnesses, and observing child feeding and hygiene habits. Samaki Salama also issued 200 modified traps with escape gaps to 100 fishers. In Q2, 176 beneficiaries were reached, including 121 males and 55 females. The majority were reached through the Cryogenic Sperm Banking activity, which conducted a training workshop to disseminate the cryopreservation technology to stakeholders.			

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**	**2022 (Q1-Q2)**
	Actual	**Actual**	**Target**	**Actual**
Status				
Phase 1: Under research	1	4	1	2
Phase 2: Under field testing	0	1	0	3
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**	**1**	**5**
	2020	**2021**	**2022**	**2022 (Q1-Q2)**

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: Production systems research	**Actual**	**Actual**	**Target**	**Actual**
Status				
Phase 1: Under research	1	4	0	2
Phase 2: Under field testing	0	10	6	4
Phase 3: Made available for transfer	0	0	3	1
Phase 4: Demonstrated uptake by the public and/or private sector	0	0	1	0
Totals	**1**	**14**	**10**	**7**
EG.3.2-7: Social science research	**2020**	**2021**	**2022**	**2022 (Q1-Q2)**
	Actual	**Actual**	**Target**	**Actual**
Status				
Phase 1: Under research	0	1	0	3
Phase 2: Under field testing	1	3	2	0
Phase 3: Made available for transfer	0	2	3	0
Phase 4: Demonstrated uptake by the public and/or private sector	0	0	0	1
Totals	**1**	**6**	**5**	**4**
Indicator result narrative	For the FY22 semiannual reporting period, of the existing five plant and animal improvement technologies or management practices reported in FY21, one moved from Phase 1 to Phase 2. Overall, four new innovations were added, including two from the Biosecurity activity and two from the Carp Genetic Improvement activity. For the production systems technologies or management practices, three out of 14 technologies or management practices moved from Phase 1 to Phase 2. Four new technologies/management practices were added, including one from Farm Diversification, one from Lean Production Systems, one from Cambodian Fisheries and Food Processing, and one from Zambia Crayfish. In terms of social science			

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	
	research, none of the existing six technologies/management practices advanced from one phase to the next. However, four new technologies/management practices were added, including one from Nourishing Nations, one from Market Analysis, and two from Zambia Crayfish.

Indicator #3: Applied technologies/practices module				
EG.3.2-24: Applied technologies	**2020**	**2021**	**2022**	**2022 (Q1-Q2)**
	Actual	**Actual**	**Target**	**Actual**
Gender				
Male	0	145	282	789
Female	0	11	68	237
Did not provide gender				130
Totals	**0**	**156**	**350**	**1156**
Age				
15-29	0	45	88	126
30+	0	104	262	1025
Did not provide age	0	7	0	5
Totals	**0**	**156**	**350**	**1156**
Technology type (multiple choices allowed)				
Wild-caught fisheries management	0	0	0	447
Cultural practices	0	0	0	92
Wild fishing technique/gear	0	115	0	8
Aquaculture management	0	21	0	523
Disease management	0	3	0	55
Soil-related fertility and conservation	0	0	0	0

Indicator #3: Applied technologies/practices module				
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	0	31
Post-harvest—handling & storage	0	0	0	0
Value-added processing	0	0	0	0
Other	0	0	0	0
Totals	**0**	**156**	**350**	**1156**
Participant type (multiple choices allowed)				
Parents/caregivers (other)	0	2	20	4
Household members	0	0	0	1
People in government	0	8	11	66
USG-assisted private sector firms	0	10	40	59
People in civil society	0	3	1	72
Laborers	0	0	0	0
Producers	0	133	278	954
Not applicable	0	0	0	0
Totals	**0**	**156**	**350**	**1156**
Indicator result narrative	For the FY22 semiannual reporting period 1,156 beneficiaries applied various technologies (789 males, 237 females, and 130 who did not define their gender). Overall, in Q1, 941 participants were reached through the application of technologies, including 675 males and 136 females. The genders were not noted for 130 individuals. In Q1, the majority (423) were reached by the Lean Production Systems activity. In Q2, 215 beneficiaries were reached, including 114 males and 101 females. The majority (92) were reached by the Nourishing Nations activity.			

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**	**2022 (Q1-Q2)**
	Actual	**Actual**	**Target**	**Actual**
Gender				
Male	0	17	0	21
Female	0	14	0	16
Totals	**0**	**31**	**0**	**37**
Training status				
Complete	0	0	N/A	5
Continuing	0	31	N/A	26
New	0	0	N/A	6
Totals	**0**	**31**	**N/A**	**37**
Indicator result narrative	For the FY22 semiannual reporting period, the Fish Innovation Lab had 32 individuals/students (13 females and 19 males) who are currently enrolled in a bachelor's, master's, or PhD program receiving long-term training, mentorship, or apprenticeship in Fish Innovation Lab aquaculture, fisheries, resilience, and food-system activities. This includes 26 individuals continuing from FY21 and 6 new individuals, including one from the Cryogenic Sperm Banking activity, two from the Fecal Pathogens activity, and three from the Vaccines for Tilapia activity. Out of the 31 individuals reported in FY 21, five have completed their long-term training.			

Appendix 3. Future Work for Research Activities

Activity	Subactivities planned for April 1 to September 30, 2022
Halwart: Farm Diversification (Nigeria)	1. Finalize training guide on rice-fish farming 2. Set up adaptation plots in Kebbi and Ebonyi ready for second cycle of rice-fish trials 3. Conduct surveys on fish consumption, nutrition, market access analyses 4. Initiate the process to create an instructional video on low-cost integrated rice-fish culture techniques and technological booklet for local government and extension workers 5. Establish platforms for demonstration of the three technological packages (breeding, fish feed, smoking kiln) 6. Commence first phase of series of workshops and seminars on the adoption and benefits of integrated agriculture-aquaculture as a livelihood option for rice-fish farmers and market stakeholders 7. Initiate activities towards the development of production technological packages for sustainable integration of rice-fish farming in the participating states through the adaptive research (i. Locally adoptable fish seed production techniques for African catfish and tilapia; ii. Low-cost and nutrient-dense fish feed production through black soldier fly production)
Pechal: Farming Insects (Nigeria)	1. Recruit and train enumerators for baseline survey 2. Pilot the questionnaire for the baseline survey and conduct the baseline survey 3. Establish demonstration plots in Oyo, Ebonyi, and Cross River states 4. Establish black soldier fly (BSF) colonies in Oyo state to supply BSF larvae for the feed to be compounded for the demonstration plots 5. Select farmers' ponds to be used as demonstration plots/ponds and arrange the necessary inputs (feed, fingerlings, water etc.) 6. Start intervention with the feeding of fish with feeds made from BSF larvae meal
Subasinghe: Lean Production Systems (Nigeria)	1. Continue applying Lean Management technology for farms and processing activities through Lean subject matter experts to identify and manage waste streams to improve efficiency as a means of technology adoption

Activity	Subactivities planned for April 1 to September 30, 2022
Hok: Bighead Catfish (Cambodia)	1. Complete installation of the wet lab and prepare materials and reagents for experiments to conduct research on substitution of fishmeal and “underrated fish” by soybean meal in diet of bighead catfish 2. Provide maintenance to the wet lab and labor for aquaculture feed nutrition research 3. Train Royal University of Agriculture (RUA) personnel on operation of the wet lab including pelleted (sinking) feed formulation, preparation, and management in Malaysia 4. Train RUA personnel on feed manufacture through a study visit to the US. (international travel) 5. Exchange visit and annual meeting with team and partners 6. Start and maintain the aquaculture feed nutrition research 7. Conduct ongoing monitoring and documentation of activities
McClanahan: Coral Reef Fishery (Kenya)	1. Continue with fish landing monitoring and fish length survey activities in all sites 2. Start fish stock assessment by trained community members 3. Produce a preliminary report of results from fish landing, fish length, and ecological surveys done by the Wildlife Conservation Society (WCS) team, including fish biomass surveys to be done by the community 4. Complete data analysis and conduct household governance survey activities in all study sites 5. Write a scientific paper using social science data
Sarder: Cryogenic Sperm Banking (Bangladesh)	1. Conduct breeding of fish in selected hatcheries in four regions 2. Continue ongoing sampling of fingerlings in different hatcheries and fish farms 3. Continue genetic characterization of broodstocks using DNA microsatellite markers 4. Standardize cryopreservation protocols of catla and grass carp, and also some remaining parameters of other four species 5. Conduct cryopreservation of sperm and cryogenic gene banking of all the six target species

Activity	Subactivities planned for April 1 to September 30, 2022
Correa: Fisheries and Food Processing (Cambodia)	1. Continue collecting fisheries harvest data and entering weekly fisheries data onto the computer (data will be stored on the computer, external hard drives, and online cloud) 2. Travel to Cambodia to 1) train WCS personnel on fish photography for identification, 2) take fish photos for a visual catalog to be added to our Community Fisheries Assessment Tool iFISH, 3) train fishers on how to use our Community Fisheries Assessment Tool iFISH, 4) hold workshops on fisheries management with the community fisheries councils in the Sre Ambel River, Koh Kong province, and in Pursat province, 5) discuss the transfer of our Citizen Science Fisheries Harvest data collection program to Sre Ambel Community Fisheries Council after program completion in February 2023 3. Conduct sensory evaluation of fish products, knowledge survey, fish composition analysis, shelf-life study of fresh fish, and training workshops
Hamilton: Carp Genetic Improvement (Bangladesh)	1. Maintain and monitor progeny tests of 2021 G3 rohu and 2021 G1 catla 2. Undertake broodstock development and preparation for spawning in 2022 3. Spawn and commence nursing of >200 G2 silver carp families and >100 G1 catla families 4. Harvest fish from and complete monitoring and assessment of on-farm trials of G3 rohu 5. Undertake analysis and make results available to relevant stakeholders 6. Continue to engage with partner and non-partner hatcheries with G3 rohu 7. Identify and send 2021 G1 catla and G3 rohu (2020 and 2021) to a second backup site 8. Obtain genotype from service provider for development of a pedigree assignment tool and commence analysis and write-up 9. Undertake training of dissemination partners
Chadag: Biosecurity (Nigeria)	1. Finalize epidemiological data analysis by Mississippi State University (MSU) 2. Prepare/conduct mid-term workshop (Better Management Practices National Aquatic Animal Health strategy) 3. Analyze samples collected from dry season and plan upcoming rainy season sampling

Activity	Subactivities planned for April 1 to September 30, 2022
	4. Apply for a permit to import bacteria other than *F. columnare* to MSU for archiving, analyzing on their automated biochemical panel, and conducting antimicrobial sensitivity testing 5. Send key bacterial isolates on transport swabs to MSU for antimicrobial sensitivity testing and in lysis buffer to WorldFish for Next Generation Sequencing 6. Share histology images for further studies and interpretations by WorldFish and MSU pathologists 7. Further develop GIS web map for display of data from the Fish Epidemiology and Health Economics survey
Islam: Fecal Pathogens (Bangladesh)	1. Provide hands-on training on processing and analysis of fish and water samples for various microbiological parameters to the recently enrolled MS students as a part of our plan for building sustainable capacity 2. Collect whole fish samples from different stages of fish value chain including retail markets, wholesale markets, and grower ponds 3. Test whole fish samples for *E. coli*, extended-spectrum beta-lactamase-producing *E. coli*, and predominant foodborne pathogens 4. Complete focus group discussions and structured observations with actors in different stages of the value chain 5. Finalize the datasets with results from retail markets 6. Present study findings at International Association for Food Protection conference
Hang`ombe: Vaccines for Tilapia (Zambia)	1. Study clearance by the ethical committee 2. Procure reagents and materials for the program activities 3. Conduct fish sampling 4. Conduct bacterial culture and isolation 5. Confirm bacteria causing disease 6. Characterize bacteria 7. Develop autogenous vaccine formulations
Belton: Machine Learning (Bangladesh)	1. Finalize interactive Southwest Bangladesh Aquaculture Data Portal web page 2. Disseminate several new extension videos via social media 3. Draft reports summarizing aquaculture value chain survey results

Activity	Subactivities planned for April 1 to September 30, 2022
Pasqualino: Nourishing Nations (Nigeria)	1. Continue the training program with women and youth fish processors 2. Conduct a second training on fish processing techniques and third training on business skill development 3. Conduct pre- and post-activity surveys for the second and third trainings 4. Conduct a quarterly market survey to collect data on fish prices 5. Clean and analyze data collected from market surveys 6. Collect fish product samples and send for analysis 7. Finalize research proposals by The University of Calabar master's students
Ragsdale: FishFirst! Zambia	1. Collect samples of kapenta dried fish in Lusaka and mill into kapenta dried fish powder 2. Ship the kapenta dried fish powder to MSU for nutrient analysis 3. Conduct nutrient analysis of the kapenta dried fish powder, submit report of results to team 4. Conduct multi-stakeholder review to identify nutrient-dense, locally sourced staple foods to combine with kapenta dried fish powder to create the Complementary Food for Africa + drief fish powder (ComFA+Fish) product/recipe prototype 5. Develop the ComFA+Fish prototype 6. Conduct small pilot test of the ComFA+Fish prototype's sensory acceptability (i.e., appearance, texture, flavor) with mothers and infants ages 6-23 months; adjust recipe as necessary 7. Conduct nutritional trainings for mothers and sensory panels for mothers and infants ages 6-23 months at Lake Kariba to determine acceptability of the ComFA+Fish prototype 8. Work to identify potential community-based organizations with whom to partner to train women and youth entrepreneurs on the production of the ComFA+Fish product/recipe as a microenterprise
Iannotti: Samaki Salama (Kenya)	1. Conduct third round of home visits to intervention households 2. Conduct process monitoring interviews with caregivers and fishers 3. Collect endline data 4. Distribute social marketing materials to participants in the control group (after endline data completion)

Activity	Subactivities planned for April 1 to September 30, 2022
	5. Conduct 5-10 key informant interviews with beach management unit leaders, heads of health clinics, etc. as part of process monitoring plan 6. Conduct formative qualitative research in Taita-Taveta
Rice: Zambia Crayfish (Zambia)	1. Continue biweekly crayfish trapping studies to determine population structure in Lake Kariba and Kafue watershed 2. Initiate MS study consisting of monthly trappings and water quality measurements in six sites in Kafue and Kariba 3. Establish and continue contacts across country for reporting presence or absence of crayfish in local waters 4. Convert crayfish poll into an online platform using the Qualtrics site licensed version at University of Rhode Island, and send poll to diverse stakeholders across Zambia 5. Administer the crayfish survey, focus group discussion, and key informant interview instruments using either online or paper versions as appropriate
Dey: Market Analysis (Bangladesh)	1. Conduct secondary and primary data analysis 2. Publish four scientific articles that have been drafted 3. Draft two more articles
Oaks: Micronutrient Impact of Oysters (Ghana)	1. Complete oyster samples analysis for arsenic (and possibly selenium) 2. Complete analysis of the health risks of oyster consumption by calculating the estimated daily intake, target hazard quotient, and hazard index of heavy metals 3. Prepare final report/manuscript
Distant Water Fleets (DWF) Activity (Peru, Madagascar, the Philippines, and Micronesia)	1. Draft blank licensing system evaluation form showing evaluation criteria for strong (sustainable and equitable) DWF licensing procedures 2. Review of draft evaluation form by local experts and stakeholders, resulting in an updated, final blank evaluation form 3. IRB approval for key informant interviews 4. Assembling of initial key informant pools within each of the four geographies

Activity	Subactivities planned for April 1 to September 30, 2022
	5. Conduct four rounds of key informant interviews for licensing system evaluation and fill evaluation forms in each geography using a snowball sampling method 6. Create roadmaps for strengthening licensing systems for each geography considering evaluation results and local context