



Advisory
Services



CGIAR Research Program 2020 Reviews: FISH

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17 November 2020

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CGIAR Research Program 2020

Reviews: FISH

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CAS Disclaimer

By design, the CGIAR Results Dashboard was a key source of data for the 2020 CRP Reviews. During the pilot phase of the CRP Reviews, issues with interoperability and resulting data quality between the management information systems (CLARISA and the Dashboard) and extracts from CRP systems (MARLO and MEL) were discovered. For harmonization, CAS engaged with the MARLO team and the CRP MEL focal points to conduct data cleaning and pre-analysis for CRP review teams. This exercise revealed the limitations of CGIAR's reporting/repository systems for evaluation purposes; these limitations were mostly due to changing reporting requirements and discrepancies in whether CRPs adopted MARLO or MEL systems. Moreover, in the case of peer-reviewed journal articles, the protocol used by the CRP review teams to identify relevant publications differed from the guidance applied by CRPs (the CRP review teams' bibliometric analysis used only publications indexed by International Scientific Indexing [ISI], available through Web of Science). Therefore, CAS acknowledges discrepancies between the CGIAR Results Dashboard, and the data provided to the Review teams for their analysis, which should not be seen as a factor having influenced the analysis by the CRP review teams.

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Table of Acronyms

A4NH	Agriculture for Nutrition and Health
AIGA	alternative income-generating activity
AV	available/ready for uptake (phase)
BMP	Best Management Practice
CBFM	community-based fisheries management
CCAFS	Climate Change, Agriculture and Food Security CRP
CEO	chief executive officer
CFR	community fish refuge
CIRAD	Centre for International Development
COA	cluster of activities
CRP	CGIAR Research Program
FP	Flagship Program
GDP	gross domestic product
GIFT	Genetically Improved Farmed Tilapia
HA	hectare
HLP	High-Level Panel
HLPE	High-Level Panel of Experts on Food Security and Nutrition
HR	human resources
ICLARM	International Center for Living Aquatic Resource Management
IDO	Intermediate Development Outcome
IWMI	International Water Management Institute
JCU	James Cook University
KII	key informant interview
L&F	Livestock and Fish CRP
MEL	monitoring, evaluation, and learning
MT	metric tons
NRI	Natural Resources Institute at University of Greenwich
OICR	Outcome Impact Case Report
PC	proof of concept (phase)
PIL	successful piloting (phase)
PIM	Policies, Institutions and Markets CRP
PMU	Program Management Unit
<i>PNAS</i>	<i>Proceedings of the National Academy of Sciences of the United States of America</i>
POWB	Plan of Work and Budget
QOS	quality of science
ROI	return on investment
RTB	Roots, Tubers and Bananas CRP
SLO	System-Level Outcome
SLU	Swedish University of Agricultural Sciences
SRF	Strategy and Results Framework
SSF	sustainable small-scale fishery
TAAT	Technologies for African Agricultural Transformation
ToC	theory of change
USE	uptake by next user (phase)
W1/W2	Window 1/Window 2
W3	Window 3
WLE	Water, Land and Ecosystems CRP
WUR	Wageningen University

Executive Summary

Background and Context

The FISH CGIAR Research Program (CRP), initiated in 2017, is led by WorldFish together with its managing partners, the International Water Management Institute (IWMI), the Aquaculture and Fisheries Group at Wageningen University (WUR), the Australian Research Council Centre of Excellence in Coral Reef Studies at James Cook University (JCU), and the Natural Resources Institute at University of Greenwich (NRI). The CRP builds upon past research under the Livestock & Fish (L&F) CRP and the CRP on Aquatic Agricultural Systems (AAS) as well legacy research dating to the 1975 founding of WorldFish.

Purpose and Scope of the 2020 Review

The primary purpose of this independent review of the FISH CRP is to assess its quality of science, its effectiveness, and its future orientation. The primary users of the review will be the CGIAR System Council, with recommendations for increased quality of science, effectiveness, and future orientation developed from the review for use by the FISH CRP and the CGIAR System. This review covers Phase II of the CRP (2017 through 2019).

Review Questions

- Q1: To what extent does the CRP deliver quality of science, based on its work from 2017 through 2019?
Q2: Effectiveness: What outputs and outcomes have been achieved, and what is the importance of those identified results?
Q3: What programmatic evidence exists for future effectiveness within the life of the program (through 2021), considering the comparative advantages of the CRP and its Flagship Programs and drawing on their progression according to their corresponding theories of change?

Approach and Methodology of the Review

This review was implemented over an 11-week period by a two-member team composed of a senior evaluator and team leader and a senior subject matter expert. The review team employed a mixed-methods approach to derive findings, which included document review and key informant interviews (KIIs) with members of CRP stakeholder groups. Data analysis was parallel and sequential in order to identify emerging themes and trends for probing in order to strengthen findings as they emerged.

Key Findings and Conclusions

RQ 1: Quality of Science

RQ 1.1 Quality of CRP Scientific Inputs

W1/W2 funding is insufficient to conduct dissemination and impact research in genetics, as well as in other aspects of the FISH CRP, to fully accomplish the theory of change (ToC). Likewise, scientific expertise was of high quality, but output appears quite variable among the team.

- FISH is highly effective in leveraging available funding (4:1) and resources for increased funding, scientific expertise, and facilities access.
- Managing partners are highly supportive of FISH and its comparative advantages, which connect them to resources, research opportunities, outputs, and impacts that they would not otherwise have. They desire a long-term relationship.
- There are shortcomings in the number of WorldFish and managing partner scientists, which are at least partially funded with W1/W2 resources, as well as in facilities and budgets. However, this is overcome by a vast network of high-quality collaborators, a legacy of effectiveness, and a high-quality team.
- In summary, low levels of investments—i.e., small budgets, low numbers of core scientists, and insufficient facilities under FISH direct ownership—represent low-quality inputs, creating significant challenges for the lead center of FISH, WorldFish, and its managing partners and stakeholders.

RQ 1.2 Quality of CRP Scientific Processes

Scientific processes ensure high quality outputs and effectiveness. The director of aquaculture and fisheries supports a workplace that scientists perceive as transparent with good communication.

- Monitoring, evaluation, and learning (MEL) and impact assessment research have implemented processes that are conducive to tracking high-quality outputs and effectiveness.

RQ 1.3 Quality of CRP Scientific Outputs

Germplasm outputs are outstanding, with GIFT tilapia growing 18–200% faster than commonly used Nile tilapia and controls. The CRP has developed high-quality, award-winning tools and technologies.

- Journal articles are of very high quality, including one with 92 citations in three years or less.
- Grey outputs such as reports, manuals, blogs, videos, as well as scholarships, are numerous and of high quality and award winning (29 awards).

RQ Q2: Effectiveness

RQ 2.1 Degree of Achievement of Planned Outcomes

The majority of milestones (76.7%) expected during 2017–29 have been achieved. Both innovations and Output Impact Case Reports (OICRs) are numerous, at 87 and 29, respectively.

RQ 2.2 Extent to Which Outcomes Contributed to Broader Goals and Cross-Cutting Issues

A total of 552,998 people received training in low-income countries, with 69.8% being women. Scientists, farmers, fishers, various members of the value chain, and students have received training.

- Work on climate change has produced extremely high-quality outputs and made progress along the ToC; an increase in fish production resulted in a 37% reduction in water usage and a 22% reduction in greenhouse gases.
- Gender work has significantly increased the participation of women in fisheries and aquaculture (women's engagement in fishing rose from 5 to 75% of women in low-income target countries in FISH CRP projects) and, for example, enhanced women's contributions to intrahousehold decisions about the income generated from processing fish from 45 to 94% in Zambia. This work on gender has produced high-quality and innovative outputs, receiving four awards and recognitions.
- Research on youth has been effective considering the low level of funding and was part of five OICRs.

RQ 2.3 Management and Governance

Management and governance have helped translate research results into meaningful impact.

RQ 2.4 Progress along the Theory of Change

Significant progress has been made along the ToC, and the impact appears to grow each year. Hundreds of thousands of individuals in low-income countries have had their income, empowerment, and nutrition enhanced (the initial 2022 goal was that 3.5 million people would exit poverty and the nutrition of 2.4 million would be improved).

- The System Level Outcome (SLO) 1.1 target was that 5.0 million more farm households would adopt more improved varieties, breeds, and/or management practices; 104,215 have been reached, but assessment is incomplete.
- SLO 1.2 target was 3.5 million people assisted in exiting poverty, of which 50% are women; 350,477 have been assisted to date.
- SLO 2.3 target was 2.4 million more people without deficiencies in one or more essential micronutrients, of which 50% are women; 309,365 are without deficiencies thus far.
- SLO 3.1 target was to increase efficient fish production by 4.8 million metric tons (MT) to reduce water consumption by 5%; thus far 400,000 MT more fish have been produced, decreasing water use by 37%.
- SLO 3.2 target was to increase efficient fish production by 4.8 million MT to reduce greenhouse gas emissions by 5%; thus far 400,000 MT more fish have been produced, decreasing greenhouse gas emissions by 22%.
- SLO 3.3 target was to restore 3.3 million hectares (ha) of land and water ecosystems; 981,771 ha of water ecosystems were restored.
- Market actors and practitioners perceive that FISH has accomplished much that has benefited them greatly, look forward to more interaction, and desire even more future outputs and innovations.
- Policy development and intervention have created an environment and landscape that improves the lives of the poor with respect to benefits from both aquaculture and small-scale fisheries.

RQ 3. Future Orientation

Past and current accomplishments, resources, inputs, networks, and collaborations predict that high quality of science and effectiveness will continue. However, uncertainty of funding and COVID-19 are potential obstacles that could impede high quality of science and effectiveness.

Recommendations***For the CRP*****RQ 1: Quality of Science**

1. Efforts to unify and reduce reporting effort should continue.
2. The interaction of small- and large-scale fisheries should be given more future consideration.
3. Slightly more emphasis on reproduction has the potential to enhance quality of science and effectiveness in both aquaculture and small-scale fisheries.
4. More funding needs to be devoted to research on impact assessment.

RQ 2: Effectiveness

1. The value of various traits differs between countries. To increase impact, the Fish Breeds and Genetics cluster in FP1 (C1 - Fish Breeds and Genetic Cluster) should consider that it is likely different lines will need to be developed for different countries.
2. Development of genetically enhanced tilapia is at a critical juncture. To make a quantum leap forward, FISH needs multiple trait selection or simultaneous use of multiple genetic enhancement.
3. The poor are not always in a position to adopt some of the most effective new technologies. More involvement of medium to large businesses may increase technology transfer to the poor.
4. More manuals and grey outputs should be produced in the native languages of target groups.

RQ 3: Future Orientation

1. Shortcomings in resources and inputs were overcome by partnering with high-quality scientists from universities, research institutions, nongovernmental organizations (NGOs), and other CRPs to create a network.
2. Harnessing Global Fisheries to Tackle Micronutrient Deficiencies was extremely impactful research focused on marine species, and parallel analysis of freshwater fish is underway.
3. Although the FISH CRP is of high quality and effective, small improvements in communication would be beneficial for improving the remaining life of FISH.
4. FISH has been effective at identifying research priorities, and no major changes are needed with regard to the clusters and cross-cutting themes addressed.

CGIAR System-Level Recommendations

1. Quality of science and effectiveness would benefit from avoiding delays in funding and early termination of CRPs.
2. The main objectives of the unfunded FP3 (enhancing the contribution of fish for the nutrition and health of the poor) were integrated into FP1 and FP2. This has been one of the most successful and impactful areas of research and should receive increased support in the future.
3. The FISH CRP, with a relatively small budget, has done an excellent job of leveraging resources (US\$4 per every dollar invested). More support would likely result in good return on investment.
4. More funding needs to be devoted to research on impact assessment.
5. More funding needs to be devoted to the highly impactful work on small-scale fisheries.

1 Background to the CRP 2020 Review

This section provides background on the FISH CGIAR Research Program (CRP) review, including defining the review purpose and audience and detailing an overview of the FISH CRP and its context in development research. Next, it describes the scope of the review and details the review questions. It also provides a description of the methods employed by the review team and a summary of quality assurance procedures. Finally, it describes the organization of the review team and the potential limitations of the review and measures the team took to mitigate these (see **Annex 1: CRP 2020 Review TOR**).

1.1 CRP Overview and Context in Development Research

Fisheries and aquaculture provide 3.1 billion people with 20% of their animal protein. Fish are highly nutritious, providing micronutrients and essential fatty acids essential for cognitive and physical development. Fish is an especially important food in poor countries. Three-quarters of the countries where fish contributes more than one-third of animal protein in the diet are low-income, food-deficit countries. Often fish is the cheapest and most accessible animal-source food in these countries. Additionally, aquaculture and fisheries contribute to livelihoods for 800 million people, providing affordable food as well as income to improve quality of life. Another important attribute of fish is that it can be partially harvested providing meal-size portions without sacrificing a large animal where storage could become problematic.

To meet future demand for fish, particularly in low-income countries, production from aquaculture will need to double by 2030 as global seafood consumption is projected to increase by 46 billion kg by 2030. This increase must come from aquaculture as capture fisheries has been level or declining for the past 50 years. This situation illustrates the importance of preventing overexploitation of natural populations and of building sustainable fisheries to protect and wisely use our natural resources. The scale of these challenges requires research innovations across the whole spectrum of aquaculture and fisheries production systems and associated value chains.

FISH is one of 12 CGIAR CRPs that all aim at (1) reducing poverty, (2) improving food and nutrition security for health, and (3) improving natural resource systems and ecosystem services. To that end, the overarching long-term goal of the FISH CRP is to enhance the contribution of fisheries and aquaculture to reduce poverty and improve food security and nutrition. FISH objectives include:

- Enabling sustainable increases in, and gender- and socially equitable livelihood returns from, aquaculture production without creating adverse socioeconomic or environmental impacts
- Securing and enhancing the contribution of sustainable small-scale fisheries (SSFs) to gender-equitable poverty reduction and food security in priority geographies; and
- Increasing the availability and consumption of safe and nutrient-dense fish, primarily for women of reproductive age, infants, and young children.

FISH conducts research and develops technologies according to its theory of change (ToC) in order to achieve local adoption and dissemination of technologies and management practices, to promote private sector investment and replication of innovative and gender-inclusive business models through small- and medium-scale entrepreneurs, to guide public sector policy improvement and strengthen institutions, and to influence the policies and priorities of civil society and development agencies.

As a stand-alone CRP, FISH was initiated only in 2017 and focuses on fish agri-food systems. Prior to FISH, WorldFish had similar mandates and projects, and developed a strong reputation coupled with a large impact on aquaculture and food security in low-income countries. During 2012–16 FISH was a component of the Livestock & Fish (L&F) CRP, which conducted high-quality research with strong, dedicated research leadership and compensated for limited facility capacity with a large global network of partners including strong collaboration with national partners (CGIAR-IEA, 2016).

The FISH CRP effort is led by WorldFish together with its managing partners, the International Water Management Institute (IWMI), the Aquaculture and Fisheries Group at Wageningen University (WUR), the Australian Research Council Centre of Excellence in Coral Reef Studies at James Cook University (JCU), and the Natural Resources Institute at the University of Greenwich (NRI). Although this is a new CRP, it builds upon previous research under Livestock & Fish (initiated in 2012) and the CGIAR Research Program on Aquatic Agricultural Systems (AAS, initiated in 2011) as well upon legacy research dating back to the founding of WorldFish in 1975 as the International Center for Living Aquatic Resources Management (ICLARM) prior to joining the CGIAR System. Work on variations of the flagship themes of

FISH has been continuous for more than 40 years. WorldFish has a long history of research on genetic enhancement, and its research is ongoing.

Aligned with CGIAR, the FISH CRP addresses cross-cutting themes and collaborates with four global integrative CRPs: (1) Policies, Institutions and Markets (PIM); (2) Climate Change, Agriculture and Food Security (CCAFS); (3) Agriculture for Nutrition and Health (A4NH); and (4) Water, Land and Ecosystems (WLE). Targeted linkages include those between the aquaculture breeding research and CGIAR platforms on Excellence in Breeding, Gender, and Big Data; integrated activities with RICE on integrated rice-fish systems; work with Roots, Tubers and Bananas (RTB) on inputs from cassava waste to novel aquafeeds; and work with Livestock mostly on animal health, including antimicrobial resistance, but also some on feeds.

The FISH CRP has 2 Flagship Programs (FPs): FP1 – Sustainable Aquaculture, and FP2 – Sustainable Small-Scale Fisheries (SSF). A third unfunded FP is FP3 – Enhancing Contribution of Fish to Nutrition and Health of the Poor, which was integrated into FP1 and FP2 and is also related to other cross-cutting themes.¹ Under these FPs are several clusters of activities. Under FP1 the clusters are Cluster 1: Fish breeds and genetics; Cluster 2: Feeds, fish nutrition, and health; and Cluster 3: Aquaculture systems. Under FP 2 the clusters are Cluster 1: Resilient coastal fisheries; Cluster 2: Fish in multifunctional landscapes; and Cluster 3: Fish in regional food systems. The specific activities within FP1 and FP2 for enhancing the contribution of fish to nutrition and health of the poor include nutrition-sensitive fish production, reduction of waste and loss in fish value chains, and fish for nutrition and health of women and children. Although much of the research by the FISH CRP is applicable to many parts of the world, the specific target countries of the research are Bangladesh, Cambodia, Egypt, Myanmar, Nigeria, Solomon Islands, Tanzania, and Zambia. Documented and projected spending on FP1 and FP2 of the FISH CRP for 2017–19 averaged US\$25.9 million per year, with US\$5.4 million (21%) from window 1/2 (W1/W2) funding and US\$20.5 million from W3/bilateral funds consisting of grants, donations, and other funds to supplement funding coming directly from CGIAR.

1.2 Purpose and Audience of the Review

As laid out in the CRP Review Guidelines developed by the CGIAR Advisory Services Shared Secretariat (CAS Secretariat), the primary purpose of this review is to assess the FISH CRP with regard to its quality of science (QoS) and its effectiveness in relation to the FISH CRP theory of change (ToC). It also assesses the future orientation of the CRP. The objectives of this independent review are as follows:

- To fulfill CGIAR’s obligations regarding accountability for the use of public funds and donor support for international agricultural research
- To assess the effectiveness and direction of FISH in its second phase, 2017–21; and
- To provide an opportunity to generate insights about FISH research contexts and programs of work, including lessons for future conduct of CGIAR research to increase quality and effectiveness, if appropriate.

The primary users of the review will be the CGIAR System Council, with recommendations for increased quality of science, effectiveness, and future orientation developed from the review for use by the FISH program and the CGIAR System.

1.3 Scope of the Review

This review is an independent review conducted under the leadership of the CAS Secretariat during 2020 as part of the reviews of the 12 CGIAR CRPs, including FISH. The reviews provide information on QoS (ISDC, 2020); the effectiveness of each CRP, using CGIAR review policy, which is based on criteria from the Organisation for Economic Co-operation and Development (OECD) and the CGIAR Evaluation Policy; and the future orientation of the CRPs. This review covers the Phase II years of 2017 through 2019 with the intent to ascertain positives and negatives to assist with future research pathways. The review includes the work of FISH and its FPs, guided by CGIAR’s quality of science and effectiveness criteria and the ToCs for the FISH FPs. Outcomes and impacts would not be expected to be extensive three years into a five-year program. Thus, outcome-level changes, Intermediate Development Outcomes (IDOs), and

¹ With regard to this topic, the review team noted how the work-around of the nutrition/health outcomes has panned out. This type of work-around has also been required in other CRPs—e.g., Grain Legumes and Dryland Cereals (GLDC), where flagships went unapproved or unfunded, or funding was delayed.

System Level Outcomes (SLOs) were predicted based on the documented outputs of FISH and its Flagship Programs in relation to their ToCs.

Because some of the FPs of the FISH CRP overlap with previous WorldFish research, related CRPs, and legacy research, additional outcomes existed and were relevant for discussion or for prediction of the IDOs, SLOs, and impacts of the current phase of the FISH CRP (2017–2021). The focus of the review was the quality of inputs, activities, processes, and outputs, referred to as “QoS,” and short-term and intermediate outcomes that are expected to lead to a development impact (effectiveness). Productivity and rate of progress were considered. The likelihood that the first users of the research outputs would be the research community or that these outputs would be close to market adoption was also noted. Outputs evaluated by the team included peer-reviewed journal articles, reports and bulletins, media outlets, germplasm, inventions, patents, new technologies, and processes. The team also reviewed impacts related to CRP milestones and its ToC (see Annex 8: FISH Theory of Change).

1.4 Review Questions

This independent review seeks to answer the following review questions and sub-review questions:

Quality of Science: *Q1: To what extent does the CRP deliver quality of science, based on its work from 2017 through 2019?*

1.1: To what extent does the CRP benefit from sufficient high-quality inputs, necessary to deliver planned outputs and outcomes?

1.2: To what extent do the CRP management processes ensure the quality of science, including relevance to next-stage users, scientific credibility, and legitimacy, of the research and operations?

1.3: In what ways are the research outputs, such as germplasm, knowledge tools, and publications, of high quality?

Effectiveness: *Q2: What outputs and outcomes have been achieved, and what is the importance of the identified results?*

2.1: To what extent were planned outputs and outcomes achieved by 2019?

2.2: To what extent have achieved outcomes contributed to broader goals and cross-cutting issues (capacity development, climate change, gender, youth, and partnerships), with consideration for the predictability of funding and legacy time frame for the CRP?

2.3: How have the program’s management and governance supported the CRP’s effectiveness?

2.4: To what extent have the CRP and its Flagship Programs made progress along their ToCs?

Future Orientation: *Q3: What programmatic evidence exists for future effectiveness within the life of the program (through 2021), considering the comparative advantages of the CRP and its Flagship Programs and drawing on their progression according to their corresponding ToCs?*

1.5 Review Methods

The review team employed a mixed-methods approach, building on the initial document review to derive findings (see Annex 2: CRP-specific review methodology). Data collection included FISH CRP management documents and any subsequent modifications, evaluation and strategy documents related to the CRP, peer-reviewed journal articles, reports and bulletins, and background and research documents on topics related to the project themes and context (see Annex 3: List of documents reviewed). It also included key informant interviews (KIIs) with members of all CRP stakeholder groups (see Annex 4: List of persons interviewed). The team used structured interviews guided by interview protocols (guides) developed from a base protocol used for Program Management Unit (PMU) staff and FP leaders, which was modified to reflect the anticipated specialized knowledge of additional stakeholders following initial interviews (see Annex 5: Base data collection tool).

Data collection through document review, stakeholder interviews, and analysis of Outcome Impact Case Reports (OICRs) continued up until the writing of the initial draft report. Subsequently, the team completed analysis of CRP bibliometric and Altmetric data and triangulated data sources (see Annex 6: Bibliometrics). Data analysis was parallel and sequential to identify emerging trends for probing in order to strengthen findings as they emerged, formulate conclusions, and test accuracy.

1.6 Limitations

The review methodology had a number of potential biases and limitations that have implications for the types of findings and conclusions that can be drawn from this review. These, and the steps the review team took to mitigate them, included the following:

- **Positive response (“halo”) bias:** Probing questions regarding progress and outcomes may result in positive response bias—i.e., the tendency of respondents to subjectively focus on positive outcomes. The review team mitigated this bias by probing for both successes and challenges to develop the most holistic picture possible of CRP FISH achievements and challenges relative to the review questions. Responses were triangulated between data sources and against document review.
- **Selection bias:** Selection bias is an inherent risk when implementers help facilitate contact with members of stakeholder groups. The review team worked closely with the CRP PMU to select stakeholders for KIIs. However, there remains a risk that staff selected the most active, responsive, or engaged individuals, meaning that the team heard only from key informants that would report positive experiences. To mitigate the risk of selection bias, prior to launching data collection the team requested a universal list of stakeholders and attempted to contact each group universally. Where a universal sample was not possible, the team identified individuals from the list to contact for interviews, using a snowball approach as applicable within the limited scope of the review.
- **Subjective measurements:** Qualitative approaches can make data analysis dependent on the professional opinions and experience of the review team, which may result in findings, conclusions, and recommendations derived from their subjective experience. The team mitigated this bias through systematic triangulation of findings and by drawing evidence-based conclusions and recommendations based on data. In addition, where possible the team sought the professional opinion of relevant personnel to corroborate findings and conclusions to improve the accuracy and soundness of those conclusions.

2 Findings by Review Questions

This section presents review findings by review questions and sub-questions based on data collection and analysis carried out over the review period.

2.1 Quality of Science

2.1.1 Quality of CRP Scientific Inputs

Findings here are based on the team’s exploration of the extent to which the CRP created a balance (or not) in terms of the right set of skills, gender, and age profile of its researchers, as well as by diversity of nationality and geographic origin. The team also considered, to the extent possible, the availability of research means, including infrastructure and funding.

Based upon the files on personnel and KIIs, we determined that there is a good mixture of senior, mid-career, and young scientists working on the FISH CRP at WorldFish and at the managing partners. These partners included the IWMI, the Aquaculture and Fisheries Group at WUR, the Australian Research Council Centre of Excellence in Coral Reef Studies at JCU, and the NRI at University of Greenwich, with scientists originating from a large number and diverse range of countries. According to respondents and project documents, the scientific team is high quality, extremely hard working, and dedicated, with the appropriate mixture of skills. The team has experience and training in aquaculture, genetics, genomics, feeds, nutrition, fish diseases, fisheries, population dynamics, ecology, policy, social sciences, and economics. Research is enhanced by strong multidisciplinary approaches.

Table 1: FISH CRP research scientists metrics by gender

Role	Current		Left since CRP inception	
	Male	Female	Male	Female
Senior scientist	10	4	1	0
Junior scientist	25	21	8	2
Research assistant	44	21	0	0
TOTAL	79	46	9	2

Percentage (%)	63.2	36.8	81.8	18.2
Leadership and leads	13	7	n/a	n/a
Percentage (%)	65	35	n/a	n/a

Source: WorldFish website and annual reports.

^a The 10 junior scientists were all postdoctoral fellows that left.

Likewise, project documents demonstrated a good gender mix among the scientists, with women currently accounting for 36.8% of scientists and 35.0% of leadership. In general, this is a high number in the aquaculture and fisheries field. However, attempts to obtain global percentages of female senior scientists in aquaculture and fisheries for comparative purposes was difficult to find. Thus, the only basis of comparison was the United States, where approximately 25–30% of senior scientists and faculty are women, with the percentage decreasing as rank increases (see, for example, Oregon State University, 2016; Fishbio, 2018; Arismendi & Penaluna, 2016).

As a whole, the quality of the CRP scientific team is high as demonstrated by the h-index of the 26 most productive authors, which was 2–51 (7–28 for women); 7 (2 women, 5 men) had an h-index greater than 25, indicating a group of highly productive scientists who work is cited often. This is evidence that the CRP's scientific personnel constitute a high-quality input. Not surprisingly, four of the five countries producing the most papers housed WorldFish or managing partners, according to CRP dashboard data. Partnering was conducted with quality scientists in target countries, as evidenced by the fact that three of eight countries with the highest citations per article were from low-income countries. One concern is the apparent variability in productivity. One individual produces more than five papers per year, 20% of the scientists produce three or more papers per year, 27% produce two or more papers per year, and 33% produced no papers in a three-year period. The mean number of papers per scientist per year was 1.22. Based on KIIs, potential explanations from the review team for the relatively low number of papers per WorldFish and managing partner scientists funded partially with W1/W2 funds could be the CRP's emphasis on quality over quantity, excess administrative duties, senior scientists providing leadership without demanding authorship, large numbers of meetings and reporting, extensive time-consuming quality assurance procedures, legacy from earlier CRPs, or scientists' responsibility for bilateral projects, for which emphasis is on grey products and other outputs. This concern is offset by the very high-quality outputs from these scientists, including landmark papers, discussed below (see section 2.1.3: Quality of CRP Scientific Outputs).

Another indicator of the quality of the CRP team is comparative output with the available funds. FISH produced 2.25 journal articles per US\$1 million (calculated from provided budgets), according to annual reports and other documentation. Three other CRPs produced 1.24, 1.83 and 2.75 journal articles (mean = 1.94) per US\$1 million (calculated from provided budgets).² Of course, rate of publication can be affected by many factors, including the field of research. The School of Fisheries, Aquaculture, and Aquatic Sciences at Auburn University produced 5.77 journal articles per US\$1 million invested, but the school does not have the same burden of administrative tasks, the added travel expenses associated with international development research, training and technology transfer, and output of grey products.³ The FISH CRP produced 9.73 grey outputs, including bulletins, videos, blogs, newsletters, briefs, training manuals, and working papers, per US\$1 million. By way of comparison, the Livestock CRP produced 5.86 grey outputs per US\$1 million, according to its 2020 Review.

In addition, the FISH CRP has a smaller budget compared with other CRPs, which makes low numbers of scientific personnel within the current budget problematic. In year 1, FISH received US\$3.4 million in W1/2 funding while other CRPs averaged US\$14.1 million and the Platforms averaged approximately US\$11.2 million in year 1. Flagship 2, SSF, had no W1/W2 funding the first year and received only 40% of the allocated budget the second year. Administrative costs remain constant regardless of budget size, challenging research activities to operate at maximum efficiency, and the CRP cannot afford waste.

However, in KIIs, respondents described the available monies from W1/W2 as well leveraged by FISH, with the budget shortcomings overcome by partnering and leveraging with high-quality scientists from universities, research institutions, nongovernmental organizations (NGOs), and other CRPs (5 KIIs). The low level of W1/W2 funding requires strong support from the lead center as well as management of other partners, all of whom have provided additional staff and facilities beyond the W1/W2 funding provided by

² These figures are from the CAS 2020 Reviews of the GLDC, Livestock, and PIM CRPs.

³ Interview with Joseph Tomasso, director of the School of Fisheries, Aquaculture, and Aquatic Sciences, Auburn University.

the CGIAR and are helping ensure the sustainability of actions beyond the FISH CRP. In fact, the legacy, reputation, and vast network of WorldFish, has allowed them to leverage this investment of W1/W2 funding to obtain significant bilateral funding and partnerships with universities, research institutions, the private sector, and governments that bring resources and funds into the CRP. Thus, according to one respondent, "the spider has spun an enormous, highly effective and high-quality web." Respondents describe the strategy as "to work with the best," an approach and result recognized and admired by all partners interviewed, including all managing partners, several private companies, end users, and country partners. W1/W2 supplies 20% of the budget and bilateral funding the remaining 80%.

Table 2: FISH budget (millions of US dollars)

Year	FP1			FP2			Grand Total
	W1/2	W3/bilateral	Total	W/2	W3/bilateral	Total	
2017	3.4	8.6	12.0	0.0	7.3	7.3	19.3
2018	3.7	10.1	13.8	1.3	8.5	9.8	23.6
2019	4.0	15.8	19.8	1.7	6.3	8.0	27.8
TOTAL	11.1	34.5	45.6	3.0	22.1	25.1	70.7

Source: FISH CRP, "FISH CRP - Introductory Presentation," slide presentation, 2019.

Analysis shows that leveraging of W1/W2 funding is quite high. FISH leveraged each dollar of W1/W2 funding received into US\$4 dollars of W3 funding. During the first year, other CRPs and platforms leveraged each dollar of W1/W2 funding into US\$3.5 and US\$0.44 additional dollars of W3 funding, respectively, according to annual reports. Beyond this, respondents stated in KIIs that FISH has creative funding strategies, in some cases including matching from partners, that leverage available funds even further.

However, the current W1/W2 budget of FISH is half what it was at the time of AAS and L&F. There is an associated bilateral loss of opportunity resulting in the loss of some pre-FISH staff, handicapping some programs, increasing administrative duties, and decreasing research efforts. Additionally, this loss increases the need to spend staff time pursuing bilateral funding, resulting in reduced time for research and has reduced the number of people needed to pursue bilateral funding. In turn, this contributes to additional insecurity and potential turnover of scientists, respondents said in KIIs.

Like the small budget allotment, facilities under the direct control and ownership of WorldFish are minimal. Even in cases with strong partnering, the carp-breeding program is still adversely affected by inadequate evaluation facilities, and this facility problem is exacerbated by the low and unpredictable nature of W1/W2 funding. Molecular facilities are rendered uncompetitive as molecular technology is advancing at a rapid rate. However, this molecular laboratory is used for training, resulting in capacity building and thus contributing to QoS. Molecular genetics and biotechnology are rapidly generating significant science and tools to enhance future genetic enhancement and other applications in multidisciplinary fields. KII respondents agreed that partnerships with research institutions such as the French Agricultural Research Centre for International Development (CIRAD), the Earlham Institute, Norwich, the Roslin Institute, University of Edinburgh, the Swedish University of Agricultural Sciences (SLU), Uppsala, and WUR, Wageningen, have allowed FISH to advance their milestones in genomics, population genetic analysis, and potentially genomic selection. However, facility upgrades or continued strong collaboration will be needed to advance beyond the current CRP and to reach full molecular genetics potential.

In summary, low levels of investment such as small budgets, a low number of core⁴ scientists, and insufficient facilities under FISH direct ownership represent low-quality inputs, creating significant challenges for the lead center of FISH, WorldFish, and its managing partners and in-country stakeholders. However, these impediments are overcome by the high-quality input of highly skilled, motivated, dedicated scientists; high-quality collaboration and leveraging with country partners, other CRPs, universities, and managing partner institutions; effective support teams such as marketing and communications; and other financial and administrative services. Considering the funding obstacles, the approach of partnering with high-quality research institutions, private industry, other CRPs, other NGOs,

⁴ WorldFish and managing partner scientists that are funded at least partially via the W1/W2 resources within the FISH CRP program.

and national agricultural research systems (NARSs) has proven to be a good strategy to overcome personnel, budget, and facilities shortcomings. This has resulted in a highly effective, high-quality, highly productive CRP. The external scientists, especially the managing partners, find this symbiosis beneficial and hope to have a long-term relationship with FISH.

In contrast, one respondent within the FISH CRP suggested that this outsourcing is the wrong approach and that whatever resources are available should be used to build up permanent capacity within the WorldFish core. However, in the absence of a greatly increased investment of W1/W2 funding or a very large investment by donors for internal capacity building, the current partnering and networking strategy is sound and is currently working well for producing high-quality science and effectiveness and setting the stage for the future, as indicated in the following sections.

2.1.2 Quality of CRP Scientific Processes

The review team considered issues such as (1) how CRP partnerships are effectively built and function on the basis of mutual understanding, trust, and commitment, with clear recognition of partners' perspectives, needs, roles, and contribution; (2) research ethics, transparency, and procedures for managing conflicts of interest; (3) internal review mechanisms; (4) mentoring and training of junior research staff; and (5) the scientific credibility of outputs.

Annual reports note that stringent protocols and committees are in place to ensure quality of science. These have been further enhanced and reinforced by the managing partners, which also have highly stringent protocols in place. In KIIs, respondents described FISH and managing partners working together to ensure that experimental design and methodology are credible and legitimate and result in quality outputs. Policies are in place for the ethical conduct of research. Policies and processes of FISH are reasonable and effective and conducted in ways that prevent bias. Ethics policy is administered internally. Animal welfare and human subject approval and protocols are conducted by independent review boards outside of WorldFish, depending on national legislation where the research is conducted. Respondents stated that this system works well and there is no need to change.

Respondents also described monitoring, evaluation, and learning (MEL, initiated in 2018) as having had a large impact on QoS, credibility, legitimacy, and improved operations once it became operational. The MEL and impact assessment research team has executed an operational flowchart and protocols for all scientific outputs, including journal articles, books, book chapters, working papers, manuals, reports, blogs, videos, posters, pictures, and maps. Stakeholders and users are in the feedback loop of this process, and next-stage users and stakeholders are also involved. Research projects undertaken appear highly relevant and with great potential impact on poverty alleviation, nutritional enhancement, aquaculture and fisheries production and policy, climate change, capacity development, and gender/youth equality.⁵

2.1.3 Quality of CRP Scientific Outputs

To derive findings related to the review questions, the team review assessed issues such as (1) quality and quantum of research and technical publications; (2) development of physical products (e.g., germplasm, digital innovations); and (3) communication of research findings.

The outstanding germplasm output from FISH and CRP's legacy is well known in tilapia aquaculture (ADB, 2005). GIFT tilapia and Abassa tilapia, developed via selection for improved growth rates, have been widely distributed in low-income and high-income countries, according to FISH documentation. These varieties usually outperform conspecifics throughout the world (ADB, 2005). This is high-quality output is one of the best examples of genetic enhancement in aquaculture. However, these genetically enhanced tilapia would be of much higher quality if made genetically male. KII respondents note that initial experiments have been conducted to head toward genetically all-male GIFT but are not yet available for evaluation. However, some low-income farmers have been taught how to conduct sex reversal and now have the advantage of both monosex culture and selectively bred tilapia for growth improvement. Research groups outside of CGIAR are also aware of this potential benefit and are taking steps to combine GIFT select lines with monosexing technology (Chen et al., 2018).

Interviewees stated that these fish need to be improved for additional traits, especially resilience traits and disease resistance. Initial experiments have been conducted to determine the inheritance of these

⁵ Review team assessment of FISH CRP peer-reviewed journal articles.

traits, but manuscripts are in preparation, so their quality cannot yet be evaluated. The tilapia germplasm is of high quality but can still be further improved by addressing other traits and combining this selection with other genetic enhancement programs. For example, cold tolerance, disease resistance, and salinity tolerance have equal or greater value than growth rate in Egypt, and breeding for these traits should be addressed, though funding limitations need to be overcome.

The research on the tilapia lake virus is of high quality and will result in future effectiveness (Jansen et al., 2019). According to respondents in KIIs, in some areas of tilapia aquaculture, this virus is not a large problem, but it has the potential to be devastating. With the caveat that this disease could worsen, and that funding and scientific personnel are limited, other diseases that have greater economic impact in some countries should be integrated into the breeding programs, which could perhaps be country or region specific. Of course, this would make outcomes more extensive and more difficult to achieve in the future. A total of 685 authors were included on 159 papers, and the average number of coauthors per paper was 5.97, a strong indicator of collaborative research. Authorship was distributed among scientists from 59 countries, indicating both the collaborative nature of the FISH CRP and its breadth and footprint. Twenty-three of these countries were high-income and 36 were low-income countries, illustrating the partnerships in both the North and South. Average citations per document were 7.6, and per document per year was 2.6. Approximately 30% of scientific papers have 20 or more citations, and 90% of scientific papers have 5 or more citations (Beaulieu, 2015). Twenty-three of 159 papers had 15 or more citations during the first one to three years after publication.

In general, judged by impact factor (a method of evaluation of scientific papers), the journal articles were of very high quality. While it is valuable, impact factor also has certain biases and shortcomings that must be considered. For example, impact factors in aquaculture and fisheries journals are naturally lower as there are fewer individuals working in these fields compared with other disciplines, such as molecular biology. Quality of peer review can also affect whether a poor paper is published in a high-impact journal or a very useful paper is published in a low-impact journal.

The journal *Aquaculture* has an impact factor of 3.2 and is where FISH had the highest number of publications, at 18. Regardless of impact factor, *Aquaculture* is considered the premier journal in the field of aquaculture. Additionally, several articles were published in premier journals such as *Nature*, the *Nature* series, and *Proceedings of the National Academy of Sciences of the United States of America* (PNAS). Several papers have very high citation rates, including one in *Nature Climate Change* that has been cited 92 times in three years or less. This paper had an Altmetric score of 656 and was widely shared across 28 news networks with 1,098 tweets.

The top 50% of journals in agricultural and biological sciences have an impact factor of ≥ 1.44 ; in genetics and molecular biology, ≥ 2.79 ; in environmental sciences, > 2.05 ; and in social sciences, > 1.27 (SCI Journal, 2018). To make the list of the top 75 journals for fisheries and aquaculture research, the impact factor has to be at least 1.03, with some considered the best in North America for fisheries being 1.44 (Branch, 2020).

Table 3: Percentage of papers published in journals by impact factor

Impact factor of journal	≥ 20	≥ 10	≥ 5	≥ 3	≥ 2	≥ 1.5
Papers at each impact level (%)	2.0	4.7	21.6	61.5	77.0	89.90

Source: CRP dashboard data pre-analyzed by CAS, 2020.

Based on the criteria above, 90% of FISH papers would be subjectively considered above average. Approximately 62–77% would be good to very good, 22–62% would be excellent, and 5% would be exceptional. These papers were frequently cited, with 5% of papers cited at least 10 times per year, 11.3% at least five times per year, and 44% at least two times per year. In addition, FISH has produced numerous award-winning outputs, including, for example, the paper “Harnessing Global Fisheries to Tackle Micronutrient Deficiencies.” (Hicks et al. 2019) This paper was published in *Nature* with an impact factor of 42.8 and was cited 92 times over a three-year-period. This output comes from what was intended to be part of FP3 (enhancing the contribution of fish for the nutrition and health of the poor). When funding was not awarded for FP3, priority areas such as nutrition and micronutrients were integrated into FP1 and FP2. Both the bibliometrics and Altmetrics of this paper are extremely high. In this sense, this work can be considered a landmark output that may have long-lasting dramatic impact if used properly, suggesting that funding of and emphasis on FP3 should be reconsidered in the future.

Likewise, a FP2 output “Supporting coastal fishing communities and improving food security in Bangladesh”⁶ was highlighted as one of the best outputs in the 2019 CGIAR performance report. Also, research on small-scale fisheries made significant progress in setting critical high-level policy and investment agendas at global and national levels. High-impact research products also included a 2019 report *The Future of Food from the Sea*. This report included related recommendations for decision-makers as an output of the expert group to the High-Level Panel (HLP) for a Sustainable Ocean Economy (Costello et al., 2019).

Aquaculture pathogen sequencing was combined with rapid diagnostics to build and scale a “Lab in the Backpack” concept to improve fish disease detection and management. This output won this year’s biggest prize at the 2019 Inspire Challenge, CGIAR’s digital signature process run by the CGIAR Platform for Big Data in Agriculture. As this technology matures and is scaled, it should have worldwide impact in both low-income and high-income countries, according to respondents. In addition, the nutritious pond concept was recognized by the Rockefeller Foundation and private sector partners as a key innovation for increasing productivity and improving the environmental benefits of pond-based tilapia aquaculture, and several high-quality papers were published on the nutritious ponds efforts.

Also, in FP2, *Hidden Harvest* (program brief) and documentation of the importance of small-scale fisheries was cited as well known and impactful in KIIs and the 2019 annual report. However, although large-scale fisheries and commercial fisheries are not totally missing from the CRP’s analyses, the interaction of large-scale fisheries and small-scale fisheries needs more emphasis because of the multiple ways that large-scale fisheries affect small-scale fisheries. Additionally, integrating aquaculture and small-scale fisheries with other food production systems into an agri-food systems approach within the CRP, such as cooperating with Rice CRP and RTB, could be an impactful approach (one KII).

In addition, KII comments from all stakeholder groups noted that FISH produces many useful training manuals such as *Guidelines for Community Fish Refuge: Rice Field Fisheries System Management in Cambodia* (Khmer version). Some of these outputs are in the native tongue of the target countries, and clientele in KIIs described finding these extremely valuable and want many more in their own languages.

FISH’s science is leveraged by its effective communications and marketing strategy. During 2017–19, the CRP produced 527 grey outputs, including books, book chapters, reports, blogs, briefs, videos, posters, and conference papers. The number of outputs is accelerating as the CRP matures; 329 were produced during the first eight months of 2020 prior to the initiation of this review. Results and outputs target different audiences, often using innovative digital technologies. Evaluation of samples of these outputs suggests they are of high quality. For example, a blog on small-scale fisheries research impact won the 2018 RAID blog award (<https://raidnetwork.crawfordfund.org/blog/connecting-with-timorese-youth-through-fisheries-research/>), and three of these grey reports received recognition. Overall, 29 outputs or programs received awards, recognition, or scholarships. Some were in multiple FPs and cross-cutting themes: 8 were in FP1, 17 in FP2, 2 in Climate Change, 3 in Gender, 4 in Big Data, and 1 in Management.

2.2 Effectiveness

2.2.1 Degree of Achievement of Planned Outcomes

The review team implemented this analysis in three parts: First was a quantitative assessment of CRP (and FP) performance against planned milestones, annually and for the three years under review. Further quantitative analysis examined performance disaggregated by milestone risk levels; cross-cutting issues; and achievement of policies, innovations, and outcomes (recorded in OICRs). Second was a qualitative appraisal of CRP and FP performance based on interviews with respondents from the CRP, partners, and others. Third was an assessment of documented performance against the CRP ToC (and FP impact pathways) to ascertain how the annual planning and conduct of research was derived from and linked to the ToC.

For most FISH FPs and clusters, outputs and outcomes are on schedule, although some delays occurred because of late arrival of funding for FP2 from W1/W2. Throughout the KIIs, respondents stressed the urgent need to streamline the funding process, stating that “the combination of delayed funding and early termination of CRPs is not conducive to meeting milestones in a timely fashion.” Nonetheless, a

⁶ As part of a five-year project (2014–2019), “Enhanced Coastal Fisheries in Bangladesh” (ECOFISH-BD)

high percentage of milestones have been completed or partially completed and extended. Some genetics milestones are behind schedule because of an outbreak of a new disease, tilapia lake virus disease, which forced FISH to quarantine brood stocks and delay experiments for biosecurity. Thus, the percentages of milestones completed, extended, and canceled are 76.7%, 23.3%, and 0.0% respectively. FP1 and FP2 had 83.3% and 68.4% of milestones completed from 2017 to 2019. KII respondents stated that this apparent difference was due to the delayed funding of FP2. However, as of September 2020, when this review was initiated, only one of the milestones extended in the respective reporting years remains extended, while six have been successively completed and three are due to be completed and reported in 2020. This would bring the current values respectively to 90.7% and 6.3% (97.7% and 0.3% by end of 2020).

Table 4: Share and number of milestones completed or extended, by FP and year

FP and year	Completed	Milestones completed	Extended	Milestones extended	Total	Milestones total
2017	87.50%	14	12.50%	2	100%	16
FP1	100.00%	10	0.00%		100%	10
FP2	66.67%	4	33.33%	2	100%	6
2018	68.75%	11	31.25%	5	100%	16
FP1	71.43%	5	28.57%	2	100%	7
FP2	66.67%	6	33.33%	3	100%	9
2019	72.73%	8	27.27%	3	100%	11
FP1	71.43%	5	28.57%	2	100%	7
FP2	75.00%	3	25.00%	1	100%	4
CRP level	76.74%	33	23.26%	10	100%	43

Source: CRP dashboard data pre-analyzed by CAS, 2020.

Output and outcomes are gaining momentum each year. FISH has produced 87 innovations to date, and as expected this number is increasing as the CRP matures. According to FISH annual reports, there were 22, 20, and 45 innovations in 2017, 2018, and 2019, respectively. Innovations originated from nine Asian countries, nine African countries, and two Pacific countries. Fifty-eight percent of the innovations were generated in Asia, 18.6% in Africa, and 11.6% in the Pacific; 3.5% were regional, and 34.9% were global. The status and number of CRP innovations are illustrated in Table 5 (see Annex 7: Classifications).

Table 5: Share and number of innovations at innovation stages 1–4, by FP

Innovation stage	Innovations from gender cross-cutting issue		Innovations from FP1		Innovations from FP2		Innovations at CRP level	
	%	Number	%	Number	%	Number	%	Number
Stage 1	50.0	1	46.0	23	34.3	12	41.4	36
Stage 2	50.0	1	22.0	11	37.1	13	28.4	25
Stage 3	0.00	0	20.0	10	22.96	8	20.7	18
Stage 4	0.00	0	12.0	6	5.7	2	9.2	8
Total	100.0	2	100.0	50	100.00	35	100.00	87

Source: CRP dashboard data pre-analyzed by CAS, 2020.

Respondents in KIIs described numerous highlights, including a small-scale feeds project, a legacy from the L&F CRP, which is progressing well and is impactful (see CGIAR-IEA, 2016). The FISH annual report shows that the nutritious pond concept and novel ingredients project are being scaled through a partnership with the Skretting fish feed company in Egypt, several national feed companies in Bangladesh, and DeHeus. Pilot projects in Vietnam around small farmer shrimp production had promising results (Tran et al., 2017).

The CRP measures progress of OICRs by level of maturity according to three levels (see Annex 7: Classifications). A total of 29 OICRs were produced, almost equally split between FP1 and FP2. Within these, 20.7% related to climate change, 48.3% included capacity development, 17.2% included youth, and 65.5% contained gender. The status and number of FISH CRP OICRs are illustrated in Table 6.

Table 6: Proportion of OICRs by maturity stage, by FP

Stage of maturity	OICRs from FP1		OICRs from FP2		OICRs from CRP level	
	%	Number	%	Number	%	Number
Level 1	40.0	6	35.7	5	37.9	11
Level 2	40.0	6	28.6	4	34.5	10
Level 3	0.00	0	7.1	1	3.5	1
Unknown	20.0	3	28.6	4	24.1	7
Total	100.0	15	100.0	14	100.0	29

Source: CRP dashboard data pre-analyzed by CAS, 2020.

2.2.2 Extent to Which Outcomes Contributed to Broader Goals, Cross-Cutting Issues

To derive findings, the team conducted a deep dive on two selected OICRs to assess: (1) sub-IDOs and other unanticipated outcomes reported by the CRP, whether positive or negative in context, to link to the CRP ToC and the CGIAR Strategy and Results Framework (SRF); (2) the program's engagement with cross-cutting issues, namely gender, youth, capacity development, and climate change, as well as partnerships; (3) the program's age and maturity (with research in some cases preceding the current CRP cycle); and (4) the relationship of the reported outcomes to the CRP ToC and FP impact pathways (see Annex 9: OICR Analysis Templates).

Box 1: OICR 1 - Hilsa Production and Fishers' Income Increased

Hilsa Production and Fishers' Income Increased due to co-management strategies aimed to enhance the socioeconomic resilience of fishing communities in Bangladesh is related to a level 3 outcome. The main findings are as follows:

Co-management interventions helped in producing a 6% annual incremental increase in production, resulting in production of over 130,000 tons of hilsa over the past three years, valued at over US\$1.04 billion. As a result of increased hilsa production and improved hilsa size, total household income of fishers and income from fishing activities increased by 65% and 67%, respectively. A total 4,257 hilsa fishing households were fully engaged in sound and sustainable alternative income generation as a strategy to improve co-management.

This activity met sustainable development goals targeted by FISH for successfully completing a pathway to the FISH ToC and the CGIAR SRF. The outcome resulted in progress toward goals to conserve and sustainably use the oceans, seas, and marine resources for sustainable development; end poverty in all its forms everywhere; end hunger; and achieve food security and improved nutrition. An additional benefit was attained as the livelihoods of fishers and traders in the hilsa value chain and the nutrition of the consumers throughout the country was improved. Effectiveness will be multiplied, as the success of hilsa management in Bangladesh attracted attention in two neighboring countries, India and Myanmar, which will apply similar incentive-based management. Myanmar has already initiated this approach for fish stocks in the Ayeyarwady Delta to safeguard biodiversity and improve the livelihoods of local fishing communities.

In terms of improvements in nutrition, 30% of participants impacted by this initiative were women and youth. The process was highly legitimate as the villages formed a number of organizations and committees and took ownership by supplying their own governance and enforcement. The research effort resulted in a sound, high-quality journal article and several grey outputs. The project required significant impact assessment research, and to study impact, the CRP collected baseline data in 2016, just prior to the initiation of FISH, and completed this research in 2019.

Box 2: OICR 2 - How Rice Field Fisheries Are Netting Nutrition Gains

How rice field fisheries are netting nutrition gains for over 124,876 people in Cambodia is related to a level 2 outcome. The main findings follow:

Well-managed community fish refuges (CFRs) significantly improved fish productivity in the rice field environment as soon as one year after the intervention. In one year, the quantity of fish caught increased by 30%, and the proportion of young children under five eating small fish increased by 50%. Over 124,876 people in Cambodia consumed more fish at home following behavior change interventions associated with enhanced rice field fish productivity. This activity met the FISH goal for completing a pathway to the ToC and for using a sphere of influence to increase the availability of diverse nutrient-rich foods for people, of whom 50% are women, with deficiencies in one or more essential micronutrients, making it a highly relevant activity.

To accomplish this objective, the pathway included establishing local and Cambodian government policy. Cambodia's 10-year Strategic Plan for Fisheries Conservation and Management was altered to include CFRs. Acute malnutrition of children and the associated stunting and micronutrient deficiencies cost Cambodia up to US\$266 million annually, or about 1.7% of the country's gross domestic product (GDP). This project promoted wild fish conservation and improved management of 140 community fish refuges, making more nutritious fish—one of the best sources of nutrients such as iron, zinc, calcium, and vitamin A—available for catch in the surrounding areas. Rice fish environments are particularly beneficial for lactating mothers and other caregivers who experience poverty and vulnerability. Local communities managed CFRs, adding a high level of legitimacy to the project (also adhering to the ICLARM (WorldFish) philosophy of “give a fish to a man and he will eat for a day; teach a man to fish and he will eat for a lifetime”). Local communities provided their own night patrols to prevent illegal fishing.

Future orientation and expectations are that by 2021 more than 296,000 people will benefit from the project's integrated approach to improving food and nutrition security. Fish consumption by young children in households participating in the project was very high, including 67.7% of children aged 6–11 months and 95.5% of children aged 12–17 months. Between 2017 and 2019, the proportion of households maximizing the nutritional value of small fish species increased steadily and significantly from 7.9% in March 2017 to 34.5% in September 2019.

The effort was highly credible, resulting in several high-quality grey outputs, primarily reports and briefs, and one journal article. The contents of the reports are highly credible, and at least two high-quality journal articles have been published related to the background and pilot aspects of this project. The baseline data and a pilot study were conducted jointly by USAID and L&F prior to the start of FISH. The project was implemented by FISH, and all impact assessment data were collected from 2017 to 2019.

2.2.2.1 Capacity Development

In KIIs, respondents described capacity development activities as extremely active and effective. Involvement of graduate students and postdocs has greatly increased since the end of the L&F CRP and mentoring and opportunity have expanded. Likewise, students from low-, middle-, and high-income countries have gone on to be employed in good positions, and some of these have become FISH scientists (2+). There are good advancement and development opportunities for young scientists. In contrast, a minority opinion of CRP respondents described the mentoring as “poor.” These opinions are partially based on the fact that FISH does not normally consider any projects under US\$100,000 unless they are of strategic importance. Given that FISH is already handling a large number of projects and grants and cannot handle more administratively, it preferentially targets higher-value (monetarily) projects. The paucity of smaller projects decreases opportunities for postdoctoral fellows to be heavily involved in grant writing and project management.

In KIIs with CRP staff, respondents describe the relationship with the managing partners as highly synergistic and beneficial for capacity building as the ongoing research and vast network of the FISH CRP has provided opportunities for development-related research for large numbers of MS students, PhD students, and postdocs from low-, middle-, and high-income countries that can lead to careers in development research. This, coupled with the education, course work, and mentorship of top aquaculture, fisheries, and social scientists from the managing partners at universities completes this symbiotic capacity building of top young scientists for the future.

For example, the CRP provides young Africans with the opportunity to engage with the UN and other high-level organizations, according to PMU staff. FISH annual reports show that it has provided training for 8 bachelor of science students, 30 master of science students, 14 doctoral students, and 15 postdoctoral fellows. These students came from a minimum of 10 African countries (Cameroon, Côte d'Ivoire, Ghana, Malawi, Nigeria, South Africa, Tanzania, Uganda, Zambia, and Zimbabwe), and approximately 50% were women. FISH also assists the African Centre of Excellence in Aquaculture and Fisheries in Malawi to train MS and PhD students

(<http://pubdocs.worldbank.org/en/539331567579036327/090219-7-Lilongwe-University-of-Agriculture-Natural-Resources.pdf>).

Capacity building via training individuals involved or wanting to be involved in the fisheries and aquaculture value chain has been extensive, according to FISH annual reports. From 2017 to 2019, 552,998 people received training in low-income countries, with 7 in 10 being women (Table 7). Short-

term vocational, practical training in aquaculture was offered by FISH through the Africa Aquaculture Research and Training Center in Egypt, with 323 people (70 of them women) from 32 countries participating. In 2019 FISH capacity development activities targeted researchers, national partners, farmers, and communities, and a total of 339 capacity development initiatives were initiated. Finally, practical short-term training in aquaculture technologies was conducted with the Technologies for African Agricultural Transformation (TAAT) Aquaculture Compact, expanding training in aquaculture practices and policies to 12 countries.

Table 7: Number of people receiving training (2017–19)

Short-term	Female (%)	Long-term	Female (%)
552,998	69.8	59	37.3

Source: 2019 FISH CRP annual report.

2.2.2.2 Climate Change

The Climate Change program of the CRP works across both FPs. The CRP has demonstrated that genetically improved tilapia has a positive impact on greenhouse gas emissions. However, climate change data are still under analysis by the CRP. Climate change science is complex; it is difficult to obtain proper training in this area, and it can be problematic to convince donors to focus on the complexity of this problem.

Climate Change program has produced only three journal articles, but their impact factors were high or exceptional: 4.5, 13.1, and 20.9. The paper “Building Adaptive Capacity to Climate Change in Tropical Coastal Communities,” produced by FP2 and published in *Nature Climate Change*, had a very high Altmetric score (284) and provided a new approach to building and analyzing the adaptive capacity of coastal communities across five domains. This article was widely shared across 11 news networks and generated 479 tweets. In addition, an associated FISH program brief was prepared in cooperation with the Climate Change, Agriculture and Food Security (CCAFS) CRP to apply these principles in diverse inland and coastal fisheries systems and to provide policy guidance to national governments and investors. Another influential paper mapped global human dependence on marine ecosystems at national and global levels and produced an associated framework to guide ocean management and policy improvements. Finally, the Climate Change program of FISH has received prestigious awards, including the Climate Change Award from the Prince Albert II of Monaco Foundation and the CGIAR fourth most impactful paper of 2019.

2.2.2.3 Gender

In KIIs, a number of respondents stated that the director of aquaculture and fisheries for FISH has fostered an environment conducive to progress in gender studies. In terms of staffing, while the Gender team (12 people spread across three regions) has a predominance of women (as with other CRPs), there are researchers from both genders on the team. In terms of gender integration in FISH research, Gender has pursued an enthusiastic and systematic approach to enabling integration in all clusters of FISH. This has been accomplished despite unpredictable and inadequate funding, making gender research more challenging as a result of low personnel numbers. Training efforts emphasize gender inclusion, as 75% of training has been geared toward women.

The Gender program has discovered important nuances regarding effectiveness evaluation and developed interventions and invested in innovations to increase impact, including gender-transformative approaches. Enumerating women in training activities was found to be a poor indicator of effectiveness. Upon returning home, women were prevented from contributing to fish activities and prevented application of the training, as husbands were threatened by changes in gender roles. However, by integrating gender-transformative sessions into future trainings—including engaging husbands and mothers-in-law of trainees—this obstacle was overcome, and women were able to contribute what they had learned to the benefit and appreciation of the entire household. Respect and happiness for the trained women was increased. KIIs respondents described follow-up research as “essential.”

Another key innovative training approach involved transfer of knowledge to poor communities in remote areas where face-to-face training may not be possible. In this case, the approach was to focus not solely on individual training, but on researcher and government staff training. This includes instruction of trainers and staff at other partners or institutions. The domino or pyramid effect of spreading knowledge scales the number of individuals trained and the subsequent impact.

Gender was active across all clusters and themes despite a minimal gender science legacy from AAS and L&F. The FISH CRP has already generated 30 science-based outputs on gender, with more in progress. These include policy contributions to the High-Level Panel on Sustainable Ocean Economies (Blue Paper on Equity), articles for high impact factor journals, and leading a chapter for the collaborative CGIAR Gender Platform book. According to the CRP's dashboard data, it generated 30 relevant journal articles in a three-year period examining gender in aquaculture, small-scale fisheries, gender preferences, and the value chain. Innovative approaches also contribute to gender research related to genetics, feeds, and biodiversity. Insightful findings indicate that even choice of feed impacts gender, as common fish feeds have ingredients that compete for nutrients used in women's other livelihoods. Men and women prioritize the same traits for genetic enhancement but rank them differently. With regard to biodiversity, women can have a different view on how to best utilize a resource. Large-scale fisheries are dominated by men, but small-scale fisheries are more important to women.

FISH expertise and outputs are well recognized for their attention to gender. A 2019 [Gender Special Issue of the journal *Maritime Studies*](#) was led by a member of the FISH gender team. A young emerging scientist on the Gender team brought together multicountry insights as editor of the first *Gender in Aquaculture and Fisheries Newsletter*. According to the 2019 annual report, additional awards and recognitions include "Gender in Aquaculture and Fisheries," which was awarded best student paper at the Global Conference on Gender in Aquaculture and Fisheries in Bangkok; a student fellowship for the Crawford International Engagement Award from the Crawford Fund for small-scale fisheries and gender training; and a merit award from the Asian Fisheries Society for organizing the Gender Aquaculture and Fisheries Society meeting in 2019.

2.2.2.4 Youth

This review found youth-related outputs to be "limited," although some interviewees expressed that the output is excellent considering the low level of funding. Despite low funding, youth was addressed in five OICRs, and FISH was selected by the Steering Committee of the High-Level Panel of Experts on Food Security and Nutrition (HLPE) to be part of the project team that will draft the 16th HLPE report "Promoting youth engagement and employment in agriculture and food systems," according to the 2019 annual report and dashboard data. Obstacles to youth engagement cited in KIIs included lack of interest by youth in aquaculture and fisheries in some countries and older farmers' practice of not employing youth because of their generally poorer work ethic compared with older, more experienced workers. Some reviewers stated that for youth research to be effective, funding must increase.

2.2.3 Management and Governance

The review team considered issues such as (1) changes and adaptations in the program's planned activities, objectives, and strategy based on lessons learned; (2) capacity to meet the unaddressed changes in context or other challenges; and (3) risk management planning (identification, prevention, and mitigation) by the CRP. The team also assessed the value of the CRP research management committee, the Program Management Team, the MEL unit, and its independent steering/advisory committee. The review identified practices that have supported (or not) the quality of research for development and considered the country coordination structure as well.

In KIIs, respondents say the director of aquaculture and fisheries for FISH has created a pleasant, agile, flexible working environment with free discussion that the vast majority of the scientists interpret as conducive to high productivity, high morale, and transparency. They described the policies and processes of FISH as reasonable and effective, conducted in ways that prevent bias. The ethics policy is administered internally. Animal welfare and human subject approval and protocols are conducted by institutional review boards (IRBs) outside of WorldFish, depending on national legislation where the research is conducted. On the other hand, several respondents, particularly researchers, added that administration is "top heavy."

MEL has helped promote accountability in meeting milestones and reporting deadlines by producing a quarterly review to keep scientists informed and keep milestone schedules on track. A system was also developed for researchers to upload deliverables, planned outputs, and status of deliverables in real time. CGIAR's end-of-year reporting requirements have made this time of year extremely challenging and stressful, but the new MEL real-time reporting system has organized and streamlined the process, making it much more effective and "livable" by accumulating reporting materials year-round. MEL also assists with an adaptive management style and lessons learned.

On the other hand, CGIAR indicators and reporting requirements were portrayed as difficult and frustrating for scientists, leading to a lack of cooperation. In addition, reporting requirements are different for different donors to CGIAR and the CRP, resulting in a double reporting burden that wastes time and effort. MEL is trying to work with all parties involved to unify reporting.

The MEL team of the FISH CRP has developed a “strong” data management capacity, taken advantage of the Big Data platform, worked on data quality, made archiving improvements, and improved how data are collected. Collaborative partners have helped vision and harmonization across all the countries. The data management is described as “a great improvement” (from 2016 evaluation of L&F) in which large volumes of data were accumulated without analysis at the CRP level.

There are varying opinions within FISH regarding certain management and governance aspects. Some respondents believe there are too many meetings and excessive bureaucracy, while some within the administration feel that scientists respond too slowly and resist necessary bureaucracy. A challenge for the MEL team, described in KIIs, is to change researchers’ mentality regarding reporting on workshops and training. The central question is “how do you measure quality of training?” Many scientists resist surveys and training follow-up. However, MEL expresses a need to run surveys about workshop at 6 months and 12 months after training to measure the impact and retention of the material. If the donor requires surveys, scientists cooperate, but they sometimes resist MEL efforts regarding surveys for impact assessment. Nonetheless, some programs such as Gender have used this methodology, suggested by MEL, with apparent success.

Some scientists interviewed said that human resources (HR) at WorldFish is one negative aspect of the FISH working environment and reported feeling that HR is not supportive of workers. At least some scientists feel that HR projects an atmosphere of “supremacy” and a “lack of appreciation of the scientist’s efforts.”

The MEL team within FISH works to fill gaps and together with research leads is implementing a strategy for increasing quality, according to KIIs. This strategy includes (1) creating a research quality group to set up research, (2) hiring high-quality scientists and placing them in the right places or positions, (3) reinforcing data management and the quality check process (though not enough resources are available to completely execute this properly), and (4) implementing a research pipeline. To ensure quality and transparency, clearly written protocols are reviewed internally and by partners. Experiments are examined for rigor, robustness, and ethics. The relevance of research is guided by consultations with multiple stakeholders, partners within countries, and country teams.

Communications and marketing have impacted the QoS. The CRP has developed a communications strategy that includes a branding identity, development of the website, production of short video abstracts of high-impact papers and an innovative online annual report, quarterly program newsletters, the monthly *Hot off the Press* publications newsletter, and aggressive social media marketing. The review team found the WorldFish website to be not user-friendly, lacking links to specific topics, cluster areas, and lists of outputs, for example. Advanced planning is used to increase impact and Altmetrics. The communications and marketing team works with scientists to help translate key science outputs into more digestible formats for different target different audiences.

Outputs are displayed at meetings of the Food and Agriculture Organization of the United Nations (FAO), and the team reaches out to various countries, picking the most important projects to highlight. They target high-tier journalistic outlets. The CRP has implemented a fish learning hour and a “Fish for Thoughts” to share information across the CRP and partners online. In 2019 there were 38 learning hours and 38 “Fish for Thought” events, with estimated attendance of approximately 100 per event.

2.2.4 Progress along the Theory of Change

To derive findings regarding progress along the ToC, the review team assessed issues such as (1) the quality of the ToCs (explicit or implicit), (2) how the program has used its ToC to inform the plan of work and budget (POWB), (3) progress along the ToC-defined impact pathways, and (4) the degree of adaptation based on evidence and experience (see Annex 8: FISH Theory of Change and Table 8).

With regard to SLO 1.1—impacting 5 million households through improved breeds, feeds, aquaculture systems, aquaculture management practices, and fisheries management practices—the CRP disseminated genetically improved tilapia in 16 countries, according to the 2017 annual report. To date, 53% of the hatcheries in Bangladesh and 40% of the hatcheries in the Philippines are using GIFT or GIFT-derived tilapia. This is highly effective and likely to position FP1 significantly closer to achieving SLO 1.1. COVID and lack of research funding have prevented actual measurement of the number of households impacted. However, the data throughout this review as well as the constant rise of tilapia production, let alone

other species targeted by FISH, would lead to a conclusion that 5 million households or more have likely been impacted (Mapfumo, n.d.).

Table 8: Evidence of progress toward SRF targets (sphere of interest)

SLO target for 2022	Progress as of 2019
5 million more farm households adopted improved varieties, breeds, and/or management practices	104,215 households
3.5 million people, of which 50% are women, assisted to exit poverty	350,477 people
2.4 million more people, of whom 50% are women, without deficiencies in one or more essential micronutrients	309,365 people
Increase in efficient fish production by 4.8 million metric tons (MT) to reduce water consumption by 5%	400,000 MT of fish produced; water use down 37%
Increase in efficient fish production by 4.8 million MT to reduce greenhouse gas emissions by 5%	400,000 MT of fish produced; greenhouse gas emissions down 22%
3.3 million hectares (ha) of land and water ecosystems restored	981,771 ha of water

Source: FISH CRP annual reports, 2017–19.

However, according to KIIs, not all farmers are obtaining increased production from the genetically enhanced tilapia. The very best genotypes cannot exhibit enhanced performance without being placed in a good environment and properly managed. The problem may lie in the dissemination system, as the farmer may not put forth the proper effort if his own investment is not required. Impact research revealed this yield gap, and more scaling impact research needs to be conducted for the germplasm releases. However, funding is a limitation.

Establishing the impact of research is especially difficult considering the extent of impact research needed along the entire value chain. For example, and in the case of the GIFT tilapia, elite breeders sell to multiplier hatcheries, then the multiplier hatcheries sell to small farmers, who both consume and distribute in the community. To obtain true numbers on the impact, additional research is needed to determine the on-farm performance and benefit of the genetically improved fish.

Traditional dissemination can be problematic, and FP1 is addressing this in two ways with their partners and clientele. Involvement of the private sector may improve the effectiveness of dissemination. Farmers are being trained in Best Management Practices (BMPs) to derive the improved benefit from the genetically enhanced brood stock and fingerlings. According to KII respondents, this is being done in several countries (such as Egypt and Timor-Leste) but needs to be expanded. However, lack of personnel and funding would be an impediment in this case. There may be a shift to more partnering with private industry to more effectively achieve the dissemination and effectiveness goals of improved germplasm. Government policy and protectionism as well as societal norms can impede dissemination and effectiveness. Private industry had a significant role in overcoming this block in India, leading to high effectiveness of legacy outputs of improved tilapia germplasm.

One impediment to the ToC goals cited in KIIs is that poor farmers need genetically enhanced fish to have greater access to protein. This trait, however, also enhances value and thus raises the price of fingerlings, putting them out of reach of some of the targeted poor farmers. Timor-Leste scientists believe increased fingerling production will bring down costs and rectify this problem. This is an important topic, and research is needed to show causality of poverty reduction and dietary diversification and whether those are achieved through income or production pathways, since selling higher-priced fish does have the benefit of increasing income.

Although great increases in hatchery skills of small-scale farmers have been reported, hatchery research on reproduction could improve both FP1 and FP2, according to the 2019 annual report. In the case of genetically enhanced tilapia, demand is outstripping supply, and improved reproduction can help alleviate this obstacle as well as decreasing costs and increasing profits. Supplemental stocking, necessitating hatchery expertise, may be a future tool in small-scale fisheries management. Spawning of highly nutritious fish such as mola in hatchery environments could lead to new opportunities for small-scale fish farmers and impact community nutrition. A reproductive specialist would add another dimension to understanding the dynamics of small-scale fisheries. Reproduction is a major component of fitness, and

fitness is key to small-scale fisheries. Reproduction and reproductive cycles are key to recruitment, sustainability, and policy on harvest and management. Additionally, from the perspective of small-scale fisheries, gamete cryopreservation, preservation of stem cells, and technologies such as xenogenesis would be beneficial. This allows preservation and protection of biodiversity and genetic biodiversity of the South's natural resources. If this preservation were parlayed into technologies such as xenogenesis, endangered species of importance to small-scale fishers could be more readily expanded, and difficult-to-propagate species could be propagated for aquaculture, supplemental stocking, or stock rescue, which could be of great value to the poor or hungry directly or indirectly.

Under SLO 1.1, 104,215 households benefited from improved aquaculture and fisheries practices. Some examples of this impact include women involved in carp-based polyculture improvements, improvements in hilsa management, and management of rice-fish refuges. In addition, increased adoption of fisheries co-management was accomplished in Bangladesh, including government policy as well as the most marginalized fisher communities, benefiting 4,350 households. Fisheries co-management and community-based fisheries management (CBFM) measures were implemented in Bangladesh, Cambodia, Myanmar, and Solomon Islands. In Cambodia, 244 management plans for fish refuges integrated within community investment plans benefited 12,300 households. A total of 64,459 households across five countries benefited from aquaculture and fisheries improvements; 30,115 of these were women fish producers and 2,563 were youth.

Progress was also made toward SLO 1.2, the goal of having 3.5 million people exit poverty. Another 320,717 people in four countries exited poverty through aquaculture and fisheries interventions. Additionally, in Bangladesh, 25,473 household members (15,180 men and 10,293 women) showed increased economic benefits through provision of livelihood support measures during the period when hilsa fishing was banned by government legislation. Furthermore, the co-management interventions helped raise extra annual incremental production by 6%, which comprised about 130,000 tons of hilsa over past three years, worth about US\$1,040 million.

As a result of increased hilsa production and improved hilsa size, the total household fishers' income and income from fishing activities have been increased by 65% and 67%, respectively. A total of 4,257 hilsa fishing households have been fully engaged in sound and sustainable alternative income-generating activities (AIGAs) as a strategy to improve co-management. Gender-transformative approaches in small-scale fisheries and small-scale aquaculture have contributed to gender equality and women's empowerment—for example, catalyzing increases in women's engagement in fishing (from 5 to 75% of women) and enhancing women's contributions to intrahousehold decisions about the income generated from processing fish (from 45 to 94% in Zambia).

Significant gains were made toward meeting SLO 2.3: 2.4 million more people, of which 50% are women, without deficiencies in one or more essential micronutrients. The CRP documented increased fish consumption and/or dietary diversification among 309,365 vulnerable women, children, and men associated with aquaculture and small-scale fisheries interventions. Examples include Cambodia, where 104,478 people consumed more fish at home following behavior change interventions associated with enhanced rice field fish productivity, and India, where 2,300 children received more fish through school feeding programs.

Progress was also made toward SLO 3.1 (5% increase in water and nutrient efficiency in agroecosystems) and 3.2 (reduction in agriculturally related greenhouse gas emissions by 5%). To reduce water consumption and greenhouse gas emissions, the FISH CRP increased efficient fish production by 4.8 million metric tons, according to the 2019 annual report. Overall, 400,000 metric tons (MT) of fish were produced under efficient management practices and technologies, reducing the water consumption by 37% and cutting greenhouse gas emissions by 22%. The FISH CRP target for SLO 3.3 is 3.3 million hectares (ha) of restored land and water ecosystems. A total of 981,771 ha of water area was added under improved management through co-management in four countries.

The CRP is high quality and effective with regard to impact on policies in the target countries for both aquaculture and fisheries. A few examples from the 2019 annual report include the fish health commission in Bangladesh, feed policy in Zambia, FAO fisheries management, Myanmar government policy enabling rice fish culture, and national fish health policies developed in several African countries. FP1 and FP2 produced or influenced 19 and 27 policies, respectively. Setting appropriate policies is critical for providing the environment needed for impact. Policy change has led to the establishment of rice fish gateways, refuges, and ecosystems, providing impact toward multiple SLOs.

FP1 is working with both small-scale and large-scale feed companies and having a large influence by increasing feed availability to small-scale farmers. This work has led large feed companies to engage with

small-scale farmers, resulting in great impact. The nutritious pond concept and the use of novel ingredients in feed are being scaled through partnerships with Skretting, several national feed companies in Bangladesh, and DeHeus. Pilot projects in Vietnam on small farmer shrimp production also had promising results.

Impacts sometimes are not evident until long after a CRP has ended. By employing and interacting with people in low-income countries, hard-to-measure qualitative impact can occur with changing culture and attitudes. A legacy example is found in the Solomon Islands, where WorldFish former in-country employees independently rescued and perpetuated giant clam brood stock during a period of civil unrest, according to the 2019 annual report. Recently, many years after the event, these individuals received an award from the Solomon Islands government for this heroic act.

Finally, innovations' level of maturity—that is, their stage of development and adoption—is indicative of progress toward the ToC. Bibliometric data show that a total of 26 innovations reached stage 3 or 4, available/ready for uptake or uptake by next user.

2.3 Future Orientation

To derive findings related to this review question, the review team took a holistic view of research under the CRP and how the program has added value to that research, to assess (1) the potential future contribution of the program's deliverables at the CGIAR sub-IDO level; and (2) aspects of the program's management and governance (i.e., enabling environment, capacities, partnerships, etc.) that are considered to be useful for a future research modality.

The past is an indicator of the future. FISH occupies a unique niche and is widely respected across the world. Historically and currently, FISH and its legacy CRPs and research programs been productive, of high quality, and effective. They have high-quality, dedicated scientists. Scientists at top-ranking institutions, low-income governments, private industry, international organizations, other NGOs, CGIAR Centers, other NGOs, and NARSs are working with FISH because of the complementary assets all parties bring to the table, and they have expressed a desire to continue working with FISH. Within each cluster skilled expertise exists. The research plan is innovative and impactful. Good progress has been made on the ToC. Innovations, scientific outputs, and outcomes are increasing each year as the CRP matures. These are indicators of future success and effectiveness.

Additional indicators of future success in FISH include high-quality collaborative scientists and related facilities, long-term relationships with target governments accompanied with trust, involvement of graduate students, innovative and successful leveraging of funding, high-quality journal articles, high-quality training sheets, videos and social media outputs, awards won, collaboration with private industry, and logical thinking and innovation for increasing true effectiveness.

However, COVID-19 is a possible impediment to future effectiveness. Some projects such as certain survey research and nutritious pond work in Zambia have been delayed or are in danger of being canceled because of COVID-19. There are also delays in genetics and genomics research. However, MEL and communications and marketing staff are implementing measures to overcome the detrimental effects of COVID-19 by moving toward more virtual activities. The other cited obstacles to future progress are the history of uncertainty of W1/W2 funding and the unexpected changes in length of projects and early termination of projects.

3 Conclusions

This section presents the conclusions of the review team by review questions and review sub-question based on analysis of data collected over the review period.

3.1 Quality of Science

3.1.1 Quality of CRP Scientific Inputs

The quality of the inputs is quite variable. However, mechanisms have been implemented to turn the main disadvantages to advantages, leading to overall inputs leading to effectiveness.

- W1/W2 funding was inadequate.

- Funding is insufficient to conduct dissemination and impact research in genetics, as well as in other aspects of the FISH CRP, to fully accomplish the theory of change.
- Scientific expertise was of high quality, but output appears quite variable among the team.
- FISH is highly effective in leveraging available funding (4:1) and resources for increased funding, scientific expertise, and facilities access.
- Managing partners are highly supportive of FISH and its comparative advantages, which connects them to resources, research opportunities, outputs and impacts that they would not otherwise have. They desire a long-term relationship.
- There are shortcomings in number of WorldFish and managing partner scientists that are at least partially funded with W1/W2 resources, facilities, and budget. However, this is overcome by a vast network of high-quality collaborators, a legacy of effectiveness, the building of a very high-quality team, resulting in a high-quality CRP that is highly effective.
- In summary, low levels of investments such as small budgets, low number of core scientists, and insufficient facilities under FISH direct ownership, represent low-quality inputs, creating significant challenges for the lead center of FISH, WorldFish, and its managing partners and in-country stakeholders

3.1.2 Quality of CRP Scientific Processes

The CRP scientific processes are of high quality, facilitating high quality and effective outputs.

- Scientific processes ensure high quality outputs and effectiveness.
- The director of aquaculture and fisheries has helped support a workplace that scientists perceive as transparent, communicative and lifts morale.
- MEL has implemented processes that are conducive to high quality outputs and effectiveness.

3.1.3 Quality of CRP Scientific Outputs

The quality of scientific outputs, journal articles, grey outputs, germplasm, and tools are outstanding.

- Germplasm outputs are outstanding with GIFT tilapia growing 18-200% faster than commonly used Nile tilapia and controls.
- Tools and technology developed is of high quality and have been recognized with awards.
- Many outputs are award winning.
- Journal articles are of very high quality, including one with 92 citations in 3 years or less.
- Grey outputs such as reports, manuals, blogs, videos, as well as scholarships, are numerous and of high quality and award winning (29 awards).

3.2 Effectiveness

3.2.1 Degree of Achievement of Planned Outcome

The vast majority of planned outcomes have been achieved and are on track for likely total completion.

- The majority of milestones (76.7%) expected during 2017-2019 have been achieved.
- Both innovations and OICRs are numerous, 87 and 29, respectively.

3.2.2 Extent to Which Outcomes Contributed to Broader goals, Cross-Cutting Issues

Outcomes greatly contributed to the cross-cutting issues, capacity development, climate change, gender and youth, particularly in a strong way for gender and least so for youth.

The CRP achieved high-quality outcomes for Capacity Development, Climate Change, Gender, Youth and Partnerships despite the lack of predictability of funding and legacy timeframe for the CRP.

Capacity Development

- A total of 552,998 people received training in low-income countries with 69.8% being women. Scientists, farmers, fishers, various members of the value chain and students have received training.

Climate Change

- Climate Change has produced extremely high-quality outputs and has made progress in the ToC with an increase of fish production resulting in a 37% and 22% reduction in water usage and greenhouse gases, respectively.

Gender

- Gender has significantly increased the participation of women in fisheries and aquaculture, (women's engagement in fishing (from 5 to 75% of women), and for example, enhanced contributions to intra-household decisions about the income generated from processing fish from 45 to 94% in Zambia. Also, female empowerment in family contributions, their income and their access to nutritious foods increased.
- Gender has produced high quality and innovative outputs (four awards and recognitions).

Youth

- Youth has been effective considering the low level of funding and was part of 5 OICRs.

3.2.3 Management and Governance

Management and government were effective in facilitating science and impact.

- Management and governance have had a positive influence on the on the translation of research results into meaningful impacts.
- Impacts and budgets have both been tremendously leveraged due to the management style and reputation of FISH. FISH leadership has organized itself, other NGOs, research institutes, governments, and country partners into coordinated productive teams in various countries to enhance research and policy development.

3.2.4 Progress Along the Theory of Change

Excellent progress was made along the Theory of Change. Goals were high so much still needs to be accomplished. More has been accomplished than appears because of delayed impact assessment from lack of funding.

- Significant progress has been along the Theory of Change, and the impact appears to grow each year. Hundreds of thousands of individuals in low-income countries have had income, empowerment and nutrition enhanced (the initial 2022 goal was 3.5 million people to exit poverty and nutrition of 2.4 million to be improved).
- SLO 1.1 target was 5.0 million more farm households have adopted more improved varieties, breeds, and/or management practices and 104,215 have been reached, but assessment is incomplete.
- SLO 1.2 Target was 3.5 million people assisted to exit poverty, of which 50% are women, and 350,477 have been assisted to date.
- SLO 2.3 target was 2.4 million more people without deficiencies in one or more essential micronutrients, of which 50% are women, with 309,365 without deficiencies thus far.
- SLO 3.1 target was to increase of efficient fish production by 4.8 million metric tons to reduce water consumption 5% and thus far 400,000 MT more fish were produced, decreasing water usage 37%.
- SLO 3.2 target was to increase of efficient fish production by 4.8 million metric tons to reduce greenhouse gas emissions 5%, and thus far 400,000 MT more fish were produced, decreasing greenhouse gas by 22%.
- SLO 3.3 target was to restore 3.3 million hectares (HA) of land and water ecosystems, and 981,771 HA of water was restored.
- Market actors and practitioners perceive that FISH has accomplished much that has benefited them greatly, look forward to more interaction and desire even more outputs and innovations in the future.
- Policy development and intervention has created an environment and landscape to improve the lives of the poor in respect to both benefits of aquaculture and small-scale fisheries.

3.3 Future Orientation

- Past and current accomplishments, resources, inputs, networks, and collaborations predict that high quality of science and effectiveness will continue.
- Uncertainty of funding and COVID-19 are potential obstacles that could prevent high quality of science and effectiveness.
- In relation to One CGIAR, with its emphasis on food (land and water) systems, FISH can provide a sound foundation and starting point to the future One CGIAR. Most of the flagships, clusters and

cross-cutting themes are highly impactful and should be continued to derive full benefit from the strong foundation that has been laid. Genetics, feed stuffs, diseases (the most important problem in aquaculture), nutritious ponds, micronutrients, small scale fisheries in general, rice refuges, policy enhancement, the small community self-management as a continuum and gender stand-out, in particular. Youth and climate change are difficult topics, and perhaps increased collaboration with other centers in One CGIAR would be beneficial. Obviously, increased efforts on impact assessment research should be part of the way forward.

3.4 Lessons Learned

1. Effectiveness is not just total numbers of people reached. Retention of knowledge and performance of outputs and tools must be measured.
2. Involving small communities as a continuum of coordinated management units and teaching them conservation and fish management principles while giving them ownership through self-governance and enforcement can be highly effective in sustaining and increasing a natural resource that ultimately greatly increases the income and nutrition of low-income communities.
3. Partnering with medium and large enterprises in transferring technology to the poor can increase the likelihood of successful dissemination, with benefits for the entire value chain.
4. Facilitating communication between men and women can break down barriers, resulting in greater empowerment and participation of women while increasing their income and self-satisfaction.

4 Recommendations

This section presents the recommendations of the review team by review question based on analysis of data collected over the review period. It also presents CGIAR system-level recommendations.

4.1.1 Quality of Science

1. Efforts to unify and reduce reporting effort should continue.
2. The interaction of small- and large-scale fisheries should be given slightly more consideration in the future.
3. Slightly more emphasis on reproduction has the potential to enhance quality of science and effectiveness in both aquaculture and small-scale fisheries as outlined in this review.

4.1.2 Effectiveness

1. More funding needs to be devoted to research on impact assessment.
2. The value of various traits differs among countries. To increase impact, different lines will likely need to be developed for different countries.
3. The development of genetically enhanced tilapia is at a critical juncture. To make a quantum leap forward, either multiple trait selection or the simultaneous use of multiple genetic enhancement programs is needed.
4. The poor are not always in a position to adopt some of the most effective new technologies. Increased involvement of medium and large private businesses may help with technology transfer to the poor and may open employment for the poor, shifting the paradigm toward more exporting of foods and fish and less importing, improving the nutrition and quality of life of the poor.
5. An increased number of manuals and grey outputs should be produced in the native tongue of the target countries.

4.1.3 Future Orientation

1. Shortcomings in resources and inputs were overcome by partnering and leveraging with high-quality scientists from universities, research institutions, NGOs, and other CRPs, creating a large web or network. The legacy, reputation, and vast network of WorldFish have allowed them to leverage the investment in FISH into a high-quality and effective CRP, and this strategy should continue.

2. Partners stated that WorldFish's reputation and network have allowed them to obtain significant bilateral funding and partnerships with universities, research institutions, the private sector, and governments that bring resources and funds into the CRP; thus "the spider has spun an enormous, highly effective, and high-quality web." Respondents describe the strategy as "to work with the best," an approach and result recognized and highly admired by all partners interviewed, including all managing partners, several private companies, end users, and country partners, and this should continue.
3. Harnessing Global Fisheries to Tackle Micronutrient Deficiencies was extremely impactful research. Perhaps small-scale fisheries, aquaculture systems, and genetics should diversify even more in the future and gravitate more toward increasing micronutrients and protein, not just protein. This paper focuses upon marine fish, and it would be impactful to repeat this analysis with freshwater fish.
4. Although this CRP is high quality and effective, small improvements in communication would be beneficial for improving the remaining life of FISH. Perhaps a small number of team-building exercises could be considered to improve communication, trust, empathy, and respect between administration and research, which would likely impact quality and effectiveness.
5. Most of the flagships, clusters, and cross-cutting themes are highly impactful and should be continued in One CGIAR to derive full benefit from the strong foundation that has been laid. Genetics, feed stuffs, diseases (the most important problem in aquaculture), nutritious ponds, micronutrients, small-scale fisheries in general, rice refuges, policy enhancement, small community self-management as a continuum, and gender stand out in particular. More impact assessment research should be instituted. Youth and climate change are difficult topics, and increased collaboration with other Centers in One CGIAR may be beneficial.

4.2 CGIAR System-Level Recommendations

1. Quality of science and effectiveness would benefit in the future if delays in funding and early termination of CRPs could be avoided.
2. The main objectives of the unfunded FP3 (enhancing the contribution of fish for the nutrition and health of the poor) were integrated into FP1 and FP2. This has been one of the most successful and impactful areas of research and should receive increased support in the future.
3. The FISH CRP, which had a relatively small budget, has done an excellent job of leveraging resources (US\$4 per every dollar invested), and increased support would likely result in a good return on investment.
4. More funding needs to be devoted to research on impact assessment.
5. More funding needs to be devoted to the highly impactful work on small-scale fisheries.

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