2. Flagship projects

2.1 Flagship 1: Sustainable aquaculture

2.1.1 Flagship project narrative

2.1.1.1 Rationale, scope

Background analysis. Aquaculture currently supplies around half of the fish consumed globally (FAO 2014) and is projected to grow from 66.6 million metric tons in 2012 to 93.2 by 2030 (World Bank 2013). However, significant improvements in aquaculture technologies, farming systems and value chains are needed to achieve this increase in production—and in ways that are socially and environmentally responsible. This will require intensification and expansion into new sites together with research on improving aquaculture breeds, seedstock, feeds, health, nutritional quality, production systems, environmental management and value chains. Flagship 1 (FP1) responds to these needs through an integrated program of research that aims to grow aquaculture sustainably while enabling poor men and women fish farmers and value chain actors to achieve their full potential to create wealth, alleviate poverty and improve nutrition and food security.

Problem statements. Aquaculture enterprises, particularly those in developing countries, typically have low production efficiency, experience episodic mass mortalities of stocks (World Bank 2013), and have contributed to the loss of mangroves and the pollution of waterways (Phillips et al. 1993; Naylor et al. 1998; Hamilton 2013; Ahmed and Glaser 2016). Many aquaculture sectors depend on wild or unselected stocks, precluding the possibility of production gains by selective breeding and increasing the risk of introducing disease. Every year 20–30 million metric tons of fish, one-third of the global fish catch, are used to produce fishmeal for aquafeeds (Waite et al. 2014), highlighting the need to develop cost-effective alternatives. The need for socially and environmentally sustainable pathways for growth is widely acknowledged (FAO 2016).

In response to these challenges, FP1 will develop new knowledge and technologies to help aquaculture industries in the developing world use domesticated, high-health genotypes reared on sustainable aquafeeds in production systems that have low carbon footprints with limited adverse environmental impacts. We focus on (1) developing and applying genetic technologies, (2) developing cost-effective alternatives to wild-harvest fishmeal in aquafeeds, (3) improving disease detection and control, and (4) optimizing production system efficiency without impairing the health and genetic performance of aquaculture species or the health of adjacent or proximate ecosystems. We also address the need for equity in sustainable intensification to ensure that poor farmers, their families and communities receive direct nutritional and economic benefits from increased aquaculture production. The focus is on tilapia and carp, the world's top two farmed fish species groups, which are in high demand in the developing world and will continue to play dominant roles in future aquaculture production (World Bank 2013; OECD/FAO 2016).

Scope and approach. Our research will build on previous international public goods developed by WorldFish and partners, including improved breeds of tilapia in Asia (GIFT strains), Egypt (Abbassa strain), Ghana (Akosombo strain) and Malawi (*Oreochromis shiranus* strain), and of Rohu carp in Bangladesh and India. We will continue to develop and disseminate faster growing strains and develop understanding of barriers to adoption of genetically improved seed, but the scope of our collaborative research will be broadened via multidisciplinary integration of selective breeding, fish health, aquafeeds and environmental management. Research on genomics and resilience characteristics is intended to prepare fish farmers for the future. The impending pressure from climate change and increasing evidence of disease risks, such as the Tilapia Lake Virus (TILV) that threatens tilapia stocks globally (Bacharach et al, 2016), make it imperative that research is conducted on integrating disease and other resilient traits into farmer strains, in addition to characteristics such as fast growth. We will focus on countries with low and medium Human Development Indicators and high dependence on fish for food, where (1) aquaculture is in early stages of development but needs accelerated growth to fill projected 2030 fish shortfalls, or (2) aquaculture is already established but opportunities exist to sustainably intensify to the supply levels required. As the fastest-growing food production sector in the world, aquaculture is creating new engagement, employment and enterprise opportunities for youth and women. Developing these opportunities is a core component of our research strategy. In parallel with technical research innovations, the flagship will provide inputs to the enabling policies and institutional environments to ensure farmers have secure access to production sites, knowledge and inputs necessary to create impacts at scale.

Grand challenges and Sustainable Development Goals. FP1 aims to contribute to several Sustainable Development Goals (SDGs), but primarily to goals 1 (no poverty), 2 (end hunger) and 14 (sustainably use oceans). Through research to develop aquaculture in an environmentally and socially responsible way, aquaculture has the potential to produce the fish needed to meet the demand for safe and highly nutritious food by a growing population (FAO 2016). The flagship addresses several grand challenges, including *unsustainable harvests of fish and other aquatic products* and *climate change*. We will develop and deliver domesticated, high-health aquaculture genotypes reared on sustainable aquafeeds to help reduce pressure on wild capture fisheries. The flagship will reduce the already low carbon footprint of fish by enhancing water-use and nutrient efficiency and developing fish genotypes suited to production environments impacted by climate change. Enhancing the efficiency of land use for fish production will address *competition for land,* and we will focus on *new entrepreneurial and job opportunities* for youth and women by supporting growth of the aquaculture sector. Finally, increasing the productivity of aquaculture will contribute to building *nutritious and diverse agri-food systems and diets.*

2.1.1.2 Objectives and targets

The objective of FP1 is to secure environmentally sustainable increases in farmed fish supply and enhance the contribution of aquaculture to poverty reduction and food security in priority geographies.

The flagship delivers research outputs and outcomes that support system-level outcome (SLO) 1 (*reduced poverty)* and SLO 2 (*improved food and nutrition security for health)*. Our research on environmentally sustainable production systems will also contribute to SLO 3 (*improved natural resource management)* through mitigating greenhouse gas emissions and enhancing the capacity of vulnerable men and women fish farmers to adapt to climate change risks and extreme weather.

Multiple sub-IDOs are addressed through the flagship, with the most important being *enhanced genetic gain* (sub-IDO 1.4.3/2.1.3); *closed yield gaps through improved agronomic and animal husbandry practices* (sub-IDO 1.4.2/2.1.1); *reduced livestock and fish disease risk associated with intensification and climate change* (sub-IDO 2.4.2); *more efficient use of inputs* (sub-IDO 1.3.4); *diversified enterprise opportunities* (sub-IDO 1.3.1); and *improved livelihood opportunities* (sub-IDO 1.3.2).

FP1 also contributes to cross-cutting sub-IDOs related to climate change (*reduced net greenhouse gas emissions* and *enhanced capacity to deal with climate risks and extremes*); gender and youth (*gender-equitable control of assets and resources*); policies and institutions (*enhanced individual capacity in partner research organizations through training and exchange*) and capacity development (*increased capacity of beneficiaries to adopt research outputs*).

There are four primary flagship-specific targets related to (1) *fish farm households using genetically improved fish seed*; (2) *increasing adoption of improved fish health, feed and aquaculture management practices*; (3) *enhancing the supply of sustainably farmed fish*; and (4) *improving livelihood opportunities for poor men, women and youth from increased farmed fish supply and value chain development*. The contribution of these outcome targets to SLO targets and sub-IDOs is summarized in Table 5.

Our assessment of target numbers across these four domains draws on analysis and WorldFish experience of the aquaculture sector within focal and scaling countries. This includes L&F research in Bangladesh on aquaculture productivity and employment (Belton et al. 2011); recent impact assessments of L&F interventions in aquaculture value chains in Egypt (Dickson et al. 2016); recent and ongoing national-level supply-demand modeling in Bangladesh, Zambia and Cambodia, (WorldFish 2011) as well as Indonesia; and global studies (FAO 2014; OECD/FAO 2016) and national datasets of aquaculture employment compiled by FAO. The target estimates have been further informed by WorldFish, AAS and L&F experiences in aquaculture technology delivery and dissemination of improved fish seed in Egypt (Dickson et al. 2016), Bangladesh (Karim et al. 2016), as well as two decades of research with GIFT, which has achieved widespread uptake in Asia as confirmed by independent impact studies (ADB 2005; Spielman 2009). Potential environmental gains are assessed based on L&F research in Egypt (Henrikson et al, 2016). Further details of the assumptions made and previous sector experiences are provided in a Addendum 1.

Flagship-specific outcome targets by 2022 PRIMARY (annual milestones included in PIM Table D)	Target geographies
1.5 million farm households have access to and are using our selectively improved, faster growing and more resilient strains of tilapia and carp seed Addresses SLO target 1.1 and sub-IDO: *Enhanced genetic gain*	**All clusters** Focal countries: Bangladesh, Cambodia, Egypt, Myanmar, Nigeria, Tanzania and Zambia Scaling countries: Africa: Ghana, Kenya, Malawi Asia: India Indonesia, Philippines, Vietnam
2.5 million farm households have adopted disease detection and control strategies, cost-effective and sustainable aquafeeds, and/or improved aquaculture management practices Addresses SLO target 1.1 and sub-IDOs: *Reduced livestock and fish disease risk associated with intensification and climate change* *Closed yield gaps through improved agronomic and animal husbandry practices* *More efficient use of inputs* *Enhanced capacity to deal with climate change risks and extremes*	
4.8 million metric tons of annual farmed fish production[2] with reduced environmental impact and increased resource-use efficiency (measured by 20% reduction in greenhouse gas emissions and 10% increase in water and nutrient-use efficiency) Addresses SLO targets 3.1 and 3.2 and sub-IDOs: *Reduced net greenhouse gas emissions from agriculture, forests and other forms of land use* *Enhanced capacity to deal with climate change risks and extremes*	
2.3 million poor men, women and youth access improved livelihood opportunities resulting from increased aquaculture production and associated value chains and enterprise development Addresses SLO target 1.2 and sub-IDOs: *Closed yield gaps through improved agronomic and animal husbandry* *More efficient use of inputs* *Diversified enterprise opportunities* *Increased livelihood opportunities*	
Flagship-specific outcome targets by 2022 SECONDARY (progress measured through CRP-level M&E)	
0.7 million people, of which 50% are women, without micronutrient deficiencies as a result of increased consumption of farmed fish Addresses SLO target 2.3 and sub-IDOs: *Increased availability of diverse nutrient-rich food* *Increased access to diversified nutrient-rich food*	
1.8 million more women of reproductive age consuming an adequate number of food groups as a result of increased aquaculture production Addresses SLO target 2.4 and sub-IDOs: *Increased availability of diverse nutrient-rich food* *Increased access to diversified nutrient-rich food*	
1.25 million ha of ecosystems restored through more productive and equitable management of aquaculture ponds Addresses SLO target 3.3 and sub-IDOs: *Enhanced adaptive capacity to climate change risks* *Increased resilience of agro-ecosystems and communities, especially those including smallholders*	

Table 5. FP1 outcome targets by 2022.

[2] Represents an improvement in annual fish production (i.e., tons/year); all other targets are cumulative over the period of the CRP, from 2017-2022.

FP1 will pursue an integrated program of aquaculture research for development under three research clusters in Egypt, Nigeria, Tanzania, Zambia (in Africa) and Bangladesh, Cambodia and Myanmar (in Asia). In Egypt and Bangladesh, we will build on a foundation of L&F research on dissemination of improved tilapia strains; in Cambodia and Myanmar we will establish new programs following requests for GIFT introduction; in Kenya and Zambia, we will build on existing WorldFish collaboration with nascent tilapia improvement programs; and in Nigeria and Tanzania we will assist with decision making and/or establishment of selective breeding programs for tilapia.

These focal countries were selected on the basis of potential for an integrated aquaculture research program to contribute to CGIAR SLO targets, support from public and private partners, donor interest and in some countries a history of country engagement, including under AAS and L&F. The potential for impact through an aquaculture research program in each country is guided by our analysis of anticipated future shortfalls in fish supply versus demand, strong reliance on fish as a key animal-source food, and opportunities for sustainable intensification and/or expansion of aquaculture to deliver impacts on income, employment and nutrition for poor men, women and youth. We also anticipate research scaling to countries where public and private sector partners have expressed strong interest in engagement with FISH, and where the market, policy and regulatory context is favorable to scaling FP1 innovations.

Key assumptions relating to scaling and impact underpin the outcome targets provided in Table 5. These include the following: (1) prior engagement of our fish genetics research programs in FISH focal and scaling countries in Africa and Asia represents an opportunity to reach large numbers of farmers with improved fish strains; (2) public-private sector partnerships and networks established within some focal countries provide an opportunity for improved management practices; (3) experiences from L&F fish value chain assessments can be used to assess entry points for early development in Nigeria and Tanzania; (4) profitable or near-profitable value chains can be identified that can be nurtured to achieve their growth potential and stimulate private sector investment; and (5) investment trends indicate that further public and private sector resources can be mobilized for scaling.

FP1 will adopt a staged approach to scaling, with an initial focus on research experiments in Egypt and Bangladesh, extending research findings from these core research platforms to integrated research for development programs in the other focal countries. Priority countries in which to establish integrated aquaculture research programs within the first three years are Nigeria and Zambia in Africa and Cambodia and Myanmar in Asia. Extension of the integrated aquaculture research program in Tanzania will be subject to more detailed assessments, partnership development and bilateral resource mobilization. The staged approach to FP1 growth is reflected in outcome milestones provided in the Performance Indicator Matrix, and the program approach to outcome monitoring, evaluation and impact assessment is addressed in Annex 3.6.

FP1 investments for each sub-IDO are summarized in Table 6.

Sub-IDO name	Total amount	W1+W2 (%)	W3/Bilateral (%)
SLO related			
1.4.3 Enhanced genetic gains	$18.00M	$5.22M (29%)	$12.78M (71%)
1.4.2 Closed yield gaps through improved agronomic and animal husbandry practices	$14.00M	$4.06M (29%)	$9.94M (71%)
1.3.4 More efficient use of inputs	$6.00M	$1.74M (29%)	$4.26M (71%)
2.4.3 Reduced livestock and fish diseases	$6.00M	$1.74M (29%)	$4.26M (71%)
1.3.1 Diversified enterprise opportunities	$3.55M	$1.03M (29%)	$2.52M (71%)
1.3.2 Increased livelihood opportunities	$6.55M	$1.90M (29%)	$4.65M (71%)
Cross cutting (XC)			
XC 1.1.4 Enhanced capacity to deal with climate risks and extremes	$2.60M	$0.75M (29%)	$1.85M (71%)
XC 1.1.1 Reduced net greenhouse gas emissions from agriculture, forests and other forms of land use	$2.50M	$0.73M (29%)	$1.77M (71%)
XC 2.1.1 Gender-equitable control of productive assets and resources	$9.60M	$2.78M (29%)	$6.82M (71%)
XC 3.1.1 Increased capacity of beneficiaries to adopt research outputs	$4.40M	$1.28M (29%)	$3.12M (71%)
XC 4.1.2 Enhanced individual capacity in partner research organizations through training and exchange	$4.40M	$1.28M (29%)	$3.12M (71%)
Total (USD)	**$77.60M**	**$22.50M (29%)**	**$55.10M (71%)**

Table 6. Investments by sub-IDO for FP1 for 2017–2022. Note that only the most relevant sub-IDOs are listed—a wider set of sub-IDOs is addressed in collaboration with other flagships.

2.1.1.3 Impact pathway and theory of change

FP1 aims to overcome barriers to achieving environmentally sustainable increases in fish supply through aquaculture. Research focuses on three barriers: (1) the very limited occurrence of improved fish breeds suitable for use in the aquaculture systems of significance in Africa and Asia; (2) the health risks and nutritional constraints that limit the ability of fish to realize their full genetic potential in diverse fish farming environments; and (3) variations in farm management practices and technology delivery systems that constrain the ability of fish farmers to benefit from healthy, improved seed and sustainable feeds. Addressing these barriers requires research in the development of fish genetics and improved feeds; in fish health, nutrition and feeds; and in aquaculture systems, combined with efforts to improve the enabling environment through shifts in policies, implementation capacities in governments and investment by private and public sector development actors. Research outcomes and development outcomes are achieved both directly from research products developed within each cluster (i.e. dissemination of improved fish breeds) and through products developed through integration of research across key disciplines and clusters (i.e. integrated breed, feeds, health packages).

FP1 focuses on two fish species groups that are of critical importance for food security: tilapias in Africa and Asia and carps in Asia. These two species groups (along with catfishes) are projected to account for most of the increase and 60% of global aquaculture production in 2025 (FAO, 2016). No sustainable carp genetic improvement program has been established in south Asia and the continued heavy reliance on wild stock for this species group represents a major vulnerability to sustainable development of aquaculture within Bangladesh and the South Asian region.

Cluster 1 will continue dissemination of improved tilapia strains and research to deliver cumulative, permanent genetic gains in tilapias and carps. By conducting research in our focal countries in Africa and Asia, we seek to develop and disseminate improved breeds of fish that can be used in these countries and benefit large numbers of people there, while transferring technologies and breeds, where possible, to partners regionally. Impacts throughout the duration of the CRP will largely derive from an accelerated dissemination of improved tilapia breeds already developed by WorldFish, combined with newer generations and strains during the latter part of the CRP. In all locations we posit that providing improved breeds will establish a foundation of genetic gain in fish upon which other improvements in fish feeds, health and management improvements can build and lead to significant increases in productivity and economic return for farmers. We hypothesize that strong private-public partnerships provide an essential enabling environment for delivery of these technology improvements. We will therefore support and test the efficacy of national breeding programs, assess models for private and public sector investments in sustainable breeding programs and enable local entrepreneurs to develop multiplication hatcheries for improved seed. We will also enable capacity for broader community engagement, including of women and youth, in assessing on-farm performance of improved fish stocks, and ensure the preferences of poor women and men farmers inform fish breeding and dissemination investments.

Cluster 2 will conduct research to reduce the risk that disease will diminish the performance of improved breeds of tilapia and carp and in the worst cases lead to catastrophic failure of fish farming enterprises and loss of broodstock. We will combine this work with research to overcome the key nutritional hurdles limiting fish performance and efforts to expand aquaculture. This will include research to improve understanding of fish nutritional requirements and develop sustainable aquafeed ingredients that provide cost-effective and socially acceptable alternatives to wild-harvest fishmeal and agricultural products used for human consumption. We hypothesize that the production of sustainable, cost-effective and nutritious aquafeeds, using locally available resources, is an emerging opportunity for profitable small-scale enterprises, especially for youth and women or cooperatives. We will encourage and facilitate the development of such enterprises by providing knowledge, technology and training in partnership with the private sector, government agencies and nongovernmental organizations (NGOs).

Cluster 3 will assess on-farm performance under a diversity of farming practices for genetically improved fish seed, and different technology combinations and environments that can deliver improved performance from healthy, improved seed and sustainable feeds. A major emphasis will be on assessing performance from wide dissemination of existing improved tilapia strains (e.g. in Egypt and Bangladesh and through new introductions in Cambodia and Myanmar), enabling understanding of the multiple barriers to impact at scale of genetically improved fish. We will take a gendered approach to this analysis and seek opportunities for poor women and youth. Obstacles to the dissemination and adoption of improved fish farming technologies at scale will be assessed and options for improvements in institutional, policy and regulatory frameworks identified. We hypothesize that careful identification of best farming practices combined with appropriate investments in capacity development can stimulate rapid and sustainable integration of aquaculture enterprises in locations where market environments and other enabling conditions are supportive. This will provide opportunities for

poor women, men and youth to increase livelihood opportunities and income through sustainable intensification and expansion of aquaculture.

Delivery of sustained gains at scale through improved fish breeds, health and feeds, together with improved management systems, requires navigating a range of risks. To meet this challenge, we will (1) co-develop the technologies in partnership with farmers and other value chain actors, including using influential farmers to pilot new technologies; (2) analyze potential negative tradeoffs for youth and women, including by designing specific woman- and youth-friendly pond management and harvesting technologies; (3) work with private sector actors who have proved their commitment to engaging with research and testing outputs; (4) enable national-level innovation platforms and networking to encourage use of research findings; and (5) support extensive capacity building of key actors for technology dissemination.

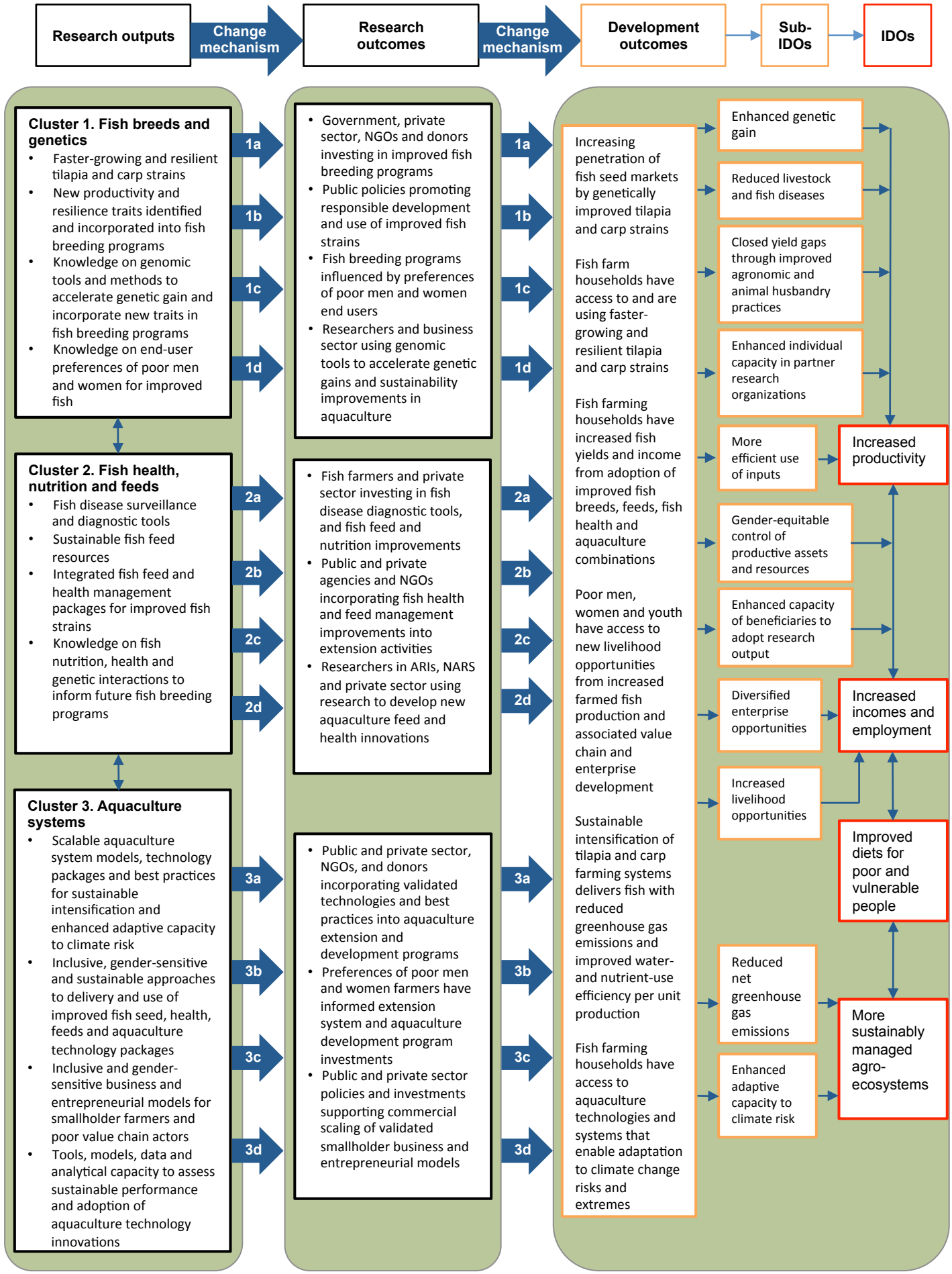

Figure 4. FP1 impact pathways.

Change mechanism	Key assumptions and risks associated with change mechanisms	Corresponding strategies and risk management actions
a Local adoption and dissemination of technologies and management practices	**Research outputs to research outcomes** **1a – 3a** National extension agencies, private sector and NGO development partners incorporate improved fish strains, fish health and feed best practices and farming system designs into extension activities and development investments. (Risk: poor integration) **1a – 3a** Industry associations and research institutions motivated to share aquaculture knowledge and gender-sensitive approaches to extension. (Risk: limited sharing) **Research outcomes to development outcomes** **1a** National government, donors and private investors provide sustained funding for fish breeding, genetic improvement and dissemination programs. (Risk: inadequate investment) **1a – 3a** National government and donors have sufficient capacity to extend research results to small-scale farmers. (Risk: inadequate capacity)	**Research outputs to research outcomes** **1a – 3a** Use participatory approaches adapted to local conditions, such as farmer field schools and cluster management, in partnerships and communications between researchers and development partners; provide science-based evidence of on-farm performance of improved fish strains and aquaculture technologies in user-friendly formats. **1a – 3a** Ensure platforms and networks provide ownership among enablers of change; provide training programs for national extension agencies, private sector and NGO development partners in (i) facilitating change; and (ii) maintenance, dissemination and use of genetically improved fish strains for farmers, extension agencies and researchers, fish feeds and disease control measures, and sustainable aquaculture systems. **Research outcomes to development outcomes** **1a – 3a** Use effective development communication on performance of improved strains among farming communities; encourage relationship building, feedback and co-ownership of research in national and local research and innovation platforms;.
b Private sector investment and replication of innovative business models in fish production, processing and trade	**Research outputs to research outcomes** **1b – 3b** Business case and investment environment is suitable for private sector investment in genetic improvement, breeding and dissemination programs, improved feeding, disease control and farming systems. (Risk: inadequate investment) **Research outcomes to development outcomes** **1b – 3b** Smallholders have ready access to technologies developed by private sector. (Risk: barriers to access) **1a – 3a** National regulations and market requirements create demand for private sector investment and adoption. (Risk: inadequate investment) **1b – 3b** Business models adopted by private sector are inclusive (Risk: limited livelihood opportunities for poor; increased inequities)	**Research outputs to research outcomes** **1b – 3b** Collaborate with private sector partners in designing and testing technologies; enable national-level innovation platforms and networking that encourage participation of private sector in research activities **1b** Develop business models for genetic improvement, breeding and dissemination that are sustainable and appropriate to country contexts and investments available. **1b – 3b** Use communication activities, advocacy and other interactions with private sector to raise awareness of investment opportunities and engage in scaling of research. **Research outcomes to development outcomes** **1b – 3b** Identify and advocate models that can be scaled through private sector and conduct business incubation type activities and networking with development partners.
c Public sector policy improvement and institutional strengthening	**Research outputs to research outcomes** **1c – 3c** National policy and regulations conducive to dissemination of improved fish strains and adoption of new technologies, such as vaccines and novel feed ingredients. (Risk: policy barriers) **Research outcomes to development outcomes** **1c – 3c** National policies conducive to public-private partnerships for scaling and dissemination of improved fish seed and improved aquaculture technologies and practices. (Risk: policy barriers) **1c – 3c** Institutional capacity sufficient to support scaling of aquaculture technologies among small-scale farmers, with sufficient gender equity. (Risk: inadequate capacity)	**Research outputs to research outcomes** **1c – 3c** Undertake training needs assessments and training of national extension agencies to support key areas of intervention; identify specific and generic barriers to adoption from institutional and regulatory framework dimension; support policy reform. **Research outcomes to development outcomes** **1c – 3c** Implement communication activities to raise awareness of public benefits from investments in aquaculture, with special emphasis on those "hard to reach," such as smallholder farmers. **1c – 3c** Ensure ownership of outcomes rests with national agencies, building commitment to adapt policies and invest in institutional capacities in a timely manner to accomplish development outcomes.
d Influence on policies and priorities of civil society and development agencies	**Research outputs to research outcomes** **1d – 3d** Civil society and development agencies raise awareness and co-ownership of research outputs. (Risk: poor integration) **1d – 3d** Development partners willing to invest in technologies with key countries. (Risk: inadequate investment) **Research outcomes to development outcomes** **1d – 3d** Civil society organizations and development agencies direct sufficient investment into aquaculture to support national adoption of research results; investments in "fish" are cost-effective compared to competing interventions (Risk: limited scaling)	**Research outputs to research outcomes** **1d – 3d** Invest in dialogue and communications between researchers and civil society organizations and development agencies; provide rigorous evidence and "package" evidence in user-friendly ways **1d – 3d** Use communications and awareness-raising events to provide evidence on the benefits of aquaculture for development agency investment at national, regional and international levels **Research outcomes to development outcomes** **1d – 3d** Increase networking and communication activities with civil society to provide evidence of the benefits of aquaculture and ways of investing in aquaculture for achieving development goals; use training tools and guidelines that support key areas of intervention.

Table 7. FP1 change mechanisms.

2.1.1.4 Science quality

FP1 convenes recognized leaders in fish genetics, health, nutrition, aquaculture systems and sustainable intensification, with strong commitment to science delivery and quality. The flagship will assure science quality through (1) well-defined research questions and experiments; (2) the latest tools, theory and technologies; and (3) engagement with expert partners who can provide access to new intellectual developments in genetics, nutrition and health within and beyond the fish domain. The flagship will engage with communities of practice at the forefront of particular research topics, within and outside CGIAR, to ensure efficiencies and access to relevant knowledge and experiences. This engagement includes the CGIAR Excellence in Breeding platform and gender and capacity development groups, as well as external peer networks and platforms such as the International Institute of Fisheries Economics and Trade (IIFET).

The flagship's novelty lies in the integration of research across key disciplines. Each cluster includes specific elements of science and research innovation.

Cluster 1: Fish breeds and genetics will embark on research that is new for fish, particularly the species of focus for WorldFish—tilapia and carp. These species are key commodities in developing country aquaculture production, and innovative research has a high likelihood of new scientific discovery and impact. Existing collaborations with Wageningen University (WUR) and the Scottish cluster of Roslin, the University of Stirling (UoS) and Scotland's Rural College (SRUC) and James Cook University on quantitative genetics and molecular tool development will be expanded to include the Genome Analysis Centre (TGAC) at the University of Norwich and University of Bangor in Wales with experience of tilapia genomics and biodiversity, and Norwegian researchers at Nofima and the Norwegian University of Life Sciences (NMBU) with experience in developing salmon genomic tools. This team will bring together key groups working on tilapia, together with those central to developing genomic selection theory and its application to fish. They, together with collaborators at University College Cork (UCC) in Ireland, also have skills in fish and human microbiome analysis that will permit development of biomarkers that reflect the integrated effects of environment, feed and disease. Under WorldFish leadership, this group will develop a consortium, including the private sector, initially to develop a single nucleotide polymorphism (SNP) chip as an approach to the rapid genotyping required in the flagship, drawing on recent experiences with Atlantic salmon (Houston et al. 2014). Close collaboration with these experts in genomics and microbiome analysis (Roslin, TAGC, SRUC, UCC) and those developing tools to increase genetic resilience in fish breeding (SRUC, NMBU, WUR, UoS) will enable interaction on the latest developments and their practical application to fish. Collaborative research on natural biodiversity and tools to investigate the interaction of native and cultured stocks (TGAC, Bangor, UoS) will enable effective risk assessment and impact of fish transfers. Working with skilled groups will permit the identification and incorporation of resilience traits into breeding programs and provide a platform for biotechnology discovery to enable more rapid additional technology developments in fish feeds and health and provide for greater quality control. These processes will be further strengthened through interaction with the CGIAR Excellence in Breeding platform and the broader community of practice, specifically in assisting the development of genomic breeding strategies, accessing the latest molecular and bioinformatics tools to apply to fish and contributing to a consolidated approach to reporting of genetic gain by CGIAR.

Cluster 2: Fish health, nutrition and feeds will use robust epidemiological and molecular tools to contribute new knowledge to emerging yield-limiting diseases in genetically improved tilapia strains and develop early warning systems and farmer-friendly health management packages. Health profiling (disease susceptibility and resistance) of improved tilapia and comparisons with other improved and commercial strains through epidemiological and molecular tools are novel. Research partnerships with the University of Exeter; Center for Environment, Fisheries and Aquaculture Science (CEFAS); and University of Liverpool bring leading epidemiological skills to the flagship. We will use metagenomics and environmental DNA (eDNA) methods to identify biomarkers for fish health status and disease and contribute to mitigating the impact of yield-limiting diseases on genetically improved tilapia strains. Research findings will explore the genetic basis for fish disease control and health management in genetically improved tilapia strains. Ongoing collaboration with leading researchers at WUR, Royal Veterinary College London (RVCL), MSD Animal Health and the International Livestock Research Institute (ILRI) will continue to be strengthened, ensuring science quality and delivery of IPGs.

Research on fish nutrition and feeds will build on an existing collaboration with WUR and be expanded with researchers at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) experienced in developing novel feed ingredients for replacement of fishmeal in shrimp and fish diets and in developing feeding concepts whereby the role of

natural food is enhanced. Collaboration with the RICE and RTB CRPs will involve research on the utilization of agricultural crop wastes and residues, such as cassava peels (ILRI 2015), to develop novel ingredients for fish feeds. Research on the "nutritious pond" concept is very new and builds on the idea that feeding systems should be based on the entire system's requirements. Research on applying genomic selection and the incorporation of microbiome analyses to improve feed efficiencies of fish being raised in different environments and production conditions also represents a new frontier for tilapia and carp genetics research, with high potential for scientific discovery and significant impact.

Cluster 3: Aquaculture systems will assess dissemination systems and outcomes from dissemination of improved tilapia breeds, contributing to new knowledge on yield gaps and factors constraining access, adoption and on-farm performance of improved fish breeds. This knowledge will contribute to the development of innovative sustainable aquaculture system models, systems and approaches to technological application within the context of sustainable intensification as well as creating opportunities for women, young people and marginalized groups in growing national aquaculture sectors. Gender-responsive research that helps determine and calibrate how to deliver sustainable intensification of aquaculture systems and enhance resilience to climate change at household and landscape levels will fill a significant gap in literature and implementation understanding on the practical application of such concepts to aquatic systems (Attwood et al. 2016a). This research will draw on a systematic review of applying sustainable intensification management actions from other production domains (e.g. terrestrial cropping, livestock) to priority sustainability issues in aquaculture (Waite et al. 2014; Attwood et al. 2016b). Bio-economic modeling, gendered livelihoods analysis, resilience frameworks and lifecycle analysis (LCA) tools will allow us to characterize aquaculture systems and identify new system designs, management practices, investments and policy interventions for sustainable aquaculture intensification and expansion. New interdisciplinary approaches will enable identifying and managing synergies and tradeoffs among economic, environmental, production and social objectives in sustainable intensification. Applying gender-transformative research within those intervention strategies is novel, as is the specific orientation towards the design of gender-equitable and inclusive growth strategies in the aquaculture sector for poor women and youth. Cross-disciplinary partnerships with researchers in aquaculture systems at the UoS and Auburn University, resilience and LCA at the Stockholm Resilience Center (SRC), and gender at the Institute of Development Studies (IDS) will strengthen research quality, as will links with sustainable intensification researchers at Bioversity International.

2.1.1.5 Lessons learnt and unintended consequences

FP1 builds on substantial research on technological innovation and delivery done under L&F and AAS, as well as earlier WorldFish investment. Cluster 1 leverages research on improved tilapia strains—notably GIFT in Southeast Asia and Bangladesh and Abbassa in Egypt—conducted over the past two decades by WorldFish and partners, with significant impact documented by the International Food Policy Research Institute (IFPRI) (Spielman 2009). As part of L&F and AAS, WorldFish developed a model for the dissemination of genetically improved tilapia in Bangladesh and its upscaling throughout the country. The 2015 L&F Independent External Evaluation visit to Bangladesh concluded that there is proof of concept for the approach to tilapia genetic improvement and dissemination, and found that aquaculture value chain research is having a positive impact on gender inequity and is increasing the income of poor families.

The flagship addresses gaps and new challenges identified by prior research. Cluster 2 ramps up investment in novel feeds, learning from global research with ILRI and partners under L&F, which focused on identifying and improving the quality and use of existing feed resources. This cluster will continue recent L&F research on emerging tilapia disease challenges in Bangladesh and Egypt. We will research options to address previously identified gender inequities, assessing barriers to poor women's employment and entrepreneurship in feed supply chains (cluster 2) and opportunities for youth employment in aquaculture systems (cluster 3). The latter will build on WorldFish's business incubator experiences in Southeast Asia, as well as efforts in Bangladesh and Egypt, where scaling has begun.

Cluster 3 is also designed to probe and respond to unintended consequences identified in recent research. As part of L&F, a 2015 impact assessment (Dickson et al. 2016) led to the reexamination of the relationship between aquaculture productivity improvement and employment generation. The study found that fish farmers trained in better management practices and supplied with the Abbassa strain focused on improving their efficiency—resulting in significantly increased profits—rather than increased production or employment. Fish farmers who stocked the Abbassa strain used the faster growth to achieve the targeted harvest weight slightly earlier, but as they only stock once per season this did not result in higher production. Cluster 3 will build upon this assessment to better understand fish farmer decisions and identify factors to more quickly translate productivity gains into increased production, employment and fish consumption among the poor.

With aquaculture technology development initiatives typically focused on productivity gains, there is a risk that human nutrition, gender, and social and environmental concerns are poorly integrated (Waite et al. 2014). FP1 addresses these concerns through interdisciplinary research design and implementation, e.g. by integrating gender analysis into basic technology design and prioritization and implementing new research on the implications of fish feeding practices for human nutrition. The risks, challenges and opportunities for poor men, women and youth to benefit from commercial aquaculture enterprise growth will also receive special attention in cluster 3. Analysis of potential impacts on women's workloads and time burdens will identify gender equity risks and aid in development of gender-transformative strategies to proactively mitigate these. Environmental impacts of aquaculture will be researched and mitigated through LCA (Henrikson et al. 2015). We will also address environmental concerns on the dissemination of genetically improved fish strains with research on environmental and pathogen risk analysis (Lind et al. 2015), including the genetics of domesticated-wild tilapia interactions, generating science-based policy guidance for national and regional government agencies.

2.1.1.6 Clusters of activity

Leading-edge science will be applied across the flagship through three interconnected research clusters. Cluster 1 aims to accelerate genetic gains in fish to respond to user demand for new and improved fish breeds that are adapted to diverse fish farming systems across Africa and Asia. Cluster 2 aims to provide new disease control measures and affordable and environmentally sustainable fish feeds by which fish farmers can improve farming efficiencies and capture the productive potentials of improved fish breeds. Cluster 3 will assess technologies emerging from clusters 1 and 2 and design profitable and environmentally sustainable fish production systems and value chain interventions that increase employment and income opportunities for poor women, men and youth. Integration between the clusters will be achieved through co-development of experiments over the life of the program, testing the performance of fish breeds in relation to key disease, feed and environmental variables. This approach will achieve efficient use of research resources and maximize synergies across research teams and the effective development of integrated technologies relevant to end users.

Cluster 1: Fish breeds and genetics

Cluster 1 builds on and extends WorldFish's track record in fish breeding and genetics to deliver cumulative, permanent genetic gains in fish farmed widely in Africa and Asia. Two major research activities will be conducted: first, active dissemination of recent generations of improved breeds from our long-established tilapia pedigreed breeding programs; and, secondly, an expansion of our genetics research to incorporate resilience traits through the use of genomic tools started in L&F. Strong genetic gains of 7%–10% growth per generation have been maintained for over two decades in WorldFish tilapia programs (Gjedrem et al. 2012; Khaw 2015), and these improved strains are now being used in at least 11 countries in Asia, though only three in Africa. We will pursue similar productivity increases through further improvements in tilapia strains and similar selective breeding in carps. We will pursue this research through our integrated flagship approach in our four focal countries in Africa (Egypt, Nigeria, Tanzania and Zambia) and three in Asia (Bangladesh, Cambodia and Myanmar). Outputs from this research will include (1) faster-growing and more resilient tilapia and carp strains; (2) new productivity and resilience traits identified and incorporated into fish breeding programs, based on gender-responsive analysis of user needs; and (3) knowledge of genomic tools and methods to accelerate genetic gain and incorporate new traits in fish breeding programs; and (4) knowledge on end-user preferences of poor men and women for improved fish.

Research on dissemination in cluster 1, in collaboration with cluster 2, will enable us to understand the multiple barriers to impact at scale of genetically improved fish. Research will be informed by rigorous on-station and gender-integrated on-farm field assessments of genetic gain. We will use feedback from surveys of the on-farm performance of the Abbassa (Egypt) and GIFT (Bangladesh) strains released in L&F, combined with new introductions in Cambodia and Myanmar, to investigate yield gaps and conduct expanded assessments of performance, including environmental stressors, disease and management practice. The surveys will include the use of molecular markers to assess adoption and provide molecular characterization for input to the genomic selection program. We will combine this with strategic experiments in our field stations in Egypt, Bangladesh and at WorldFish headquarters in Malaysia, in collaboration with the other FP1 clusters, to test combinations of technologies, such as fish feeds that optimize new breed performance using more cost-effective feed ingredients aimed at reducing yield gaps. We will use SNP markers, under development in L&F, to create fine-scale maps, develop and test genomic selection strategies to increase efficiency of selection, and assess and utilize additional traits to increase genetic gain. The results from this genomic analysis will be combined with data from on-farm performance and from market and gender-based assessments under cluster 3 to determine new traits to be included in breeding programs.

Our genomic selection will focus first on the tilapia programs, given their relatively advanced development in release and on-farm performance assessment. The need for feed efficiencies and resilience is clearer for tilapia and likely to yield results within the next six years. Our carp research will collect tissue samples to enable genomics research in the next stage of the program, utilizing lessons learned from tilapia genomics research. In pursuing our genomics research, we will work with the CGIAR Excellence in Breeding initiative and select a broader range of traits, including disease tolerance, feed efficiencies and other resilience traits. New strategic gender research will inform the breeding program in terms of women's and men's distinct needs and preferences. Molecular genomic tools will be used as a practical means to select for such characteristics and develop a gene discovery platform to identify other nutritional or disease management solutions to production or sustainability issues.

Assessments of on-farm performance will include strategic gender research with smallholder women and men farmers, providing feedback into selection programs. The use of information communication technology (tablet and cellphone-based applications) for collecting information about on-farm performance and dissemination, developed and tested in Egypt and Bangladesh in L&F, will be expanded during FISH to allow geographical expansion and efficient performance assessments across more countries, creating increased knowledge on genetic gains from FISH investments.

Cluster 2: Fish health, nutrition and feeds

Improved fish breeds need to be healthy and have the right feeds and environmental conditions to achieve their full productive potential. Cluster 2 aims to capture this opportunity by developing fish disease and health management measures, sustainable fish feed ingredients and feeding systems that will enable women and men farmers to harness the productive potential of improved fish breeds. By targeting our health and nutrition research at enhancing the performance of genetically improved strains, our research in cluster 2 will enable new efficiency and health traits to be incorporated into the fish genetic improvement programs of cluster 1. This will contribute to further improvements in the productivity, efficiency and resilience of tilapia and carp production systems. Outputs from the cluster include (1) fish disease surveillance and diagnostic tools, (2) sustainable fish feed resources, (3) integrated fish feed and health

management packages for improved fish strains, based on gender-responsive needs analysis, and (4) knowledge on fish nutrition, environment, health and genetic interactions to inform future fish breeding programs.

Our fish disease research will involve population-based studies to assess farm performance and disease susceptibility (including risk factors) of improved tilapia strains in different agro-climatic conditions. We will pursue this discovery research at facilities in two focal countries (Bangladesh and Egypt) and also at WorldFish and Department of Fisheries facilities in Malaysia. This will involve the development of eDNA technology to characterize fish and pond microbiomes, and assess their role in growth and development and in disease susceptibility and resistance. Gender-responsive on-farm research, including farmer needs assessment, will enable practical tools to be developed to tackle production losses due to fish disease, including early warning systems, rapid pondside diagnostics and prophylactic and therapeutic strategies.

Our fish feeds research will focus on the priorities of improving feed ingredients, feed intake and efficiency in use of ingredients, plus horizon-scanning research on interactions between fish feeding and human nutrition. Although tilapia needs comparatively less fishmeal than many other farmed species, further reductions are required to reduce dependence on expensive and unsustainably caught wild fish supply (Phillips et al. 2015). Cluster 2 therefore aims to develop cost-effective and nutritious aquafeeds in which fishmeal and other ingredients are replaced with alternative protein and lipid sources. We will seize opportunities to incorporate local raw materials and agricultural byproducts into fish feeds, where there is little conflict with human food uses. This will include technological, enzymatic and microbial enhancement of crop wastes, the use of algal and microbial protein and lipids, insect-based feeds, and alternative processing practices for conventional plant raw materials (Glencross et al. 2014). Research collaboration with RICE, RTB and Grains, Legumes and Dryland Cereals (GLDC) will be pursued to explore the bioconversion of different forms of rice, cassava and sorghum waste. WLE and PIM collaboration will also be pursued to explore land use interactions associated with enhanced demand for agricultural crops and their byproducts for aquaculture (Annex 3.7).

Research will build on the potential fish feed ingredients identified in Bangladesh and Egypt through L&F, where a broad range of crop residues and wastes were sourced, analyzed and evaluated, taking into account variability of ingredient quality, possible contaminants and anti-nutritional factors. The nutritional value of the various ingredients and the nutrient requirements of fish in specific production systems will be evaluated, both on-station and through gender-integrated on-farm analysis, along with the use of a range of ingredient and feed processing technologies. Our research on feed efficiency builds on evidence from L&F showing that major efficiency gains can be achieved by optimizing feeding and aquaculture system management practices. Research will focus on gender-integrated testing of improved feeding systems, documenting and understanding the scaling process during their adoption by women and men farmers, and assessing impacts in terms of farm economics and on the environment.

The nutritional content and value of farmed fish can be influenced by the rearing system used and/or the nutrient content of the feeds. WorldFish and WUR are currently working with partners to test the impacts of green-pond systems on the levels of omega-3 fatty acids and other micronutrients in farmed fish. We will build on this research to test the use of supplemented feeds to supply these essential nutrients.

Cluster 3: Aquaculture systems

Cluster 3 will conduct systematic, comparative assessments of different models for integrating improvements in fish breeds, health and feed technologies into farming system design and delivery systems that achieve sustainable intensification and resilience in ways that benefit poor women, men and youth. Research will also assess barriers to private and public investments in sustainable selective breeding and adoption of genetically improve seed. Outputs from cluster 3 research will be (1) scalable aquaculture system models, technology packages and best-practice interventions for sustainable intensification and enhanced adaptive capacity to climate risk; (2) inclusive, gender-sensitive and sustainable approaches to delivery and use of improved fish seed, health, feeds and aquaculture technology packages; (3) inclusive and gender-sensitive and women-targeted business and entrepreneurial models for scaling aquaculture technologies in ways that generate wealth and benefits for smallholder farmers and poor value chain actors; and (4) tools, models, data and analytical capacity to assess sustainable performance and adoption of aquaculture technology innovations.

We will use tools for gender-integrated systems analysis to understand, communicate and manage tradeoffs and synergies of aquaculture systems (e.g. household labor), identify efficiencies and constraints, and compare existing practices and strategies. Bio-economic modeling, livelihoods analysis and LCA will allow characterization of aquaculture systems, explain how they function, evaluate their environmental impacts and identify and propose effective

management strategies to prevent or mitigate any unintended consequences. We will build upon a systematic review of sustainable intensification of management actions (Attwood et al. 2016b) to conduct on-station assessments in Bangladesh and Egypt and on-farm assessments there and in other focal countries. This will include collaboration with flagship 3 to identify which aquaculture systems and technology approaches are best suited to deliver nutritional gains for poor households, including behavior change communication in scaling investments to ensure fish gets to the people who need it most.

LCA and inventories developed in L&F (Phillips et al. 2015) will be used to assess resource use and environmental impacts with the aim of improving management and technology combinations, thus reducing greenhouse gas emissions, freshwater consumption, energy use and land requirements. We will compare monoculture and polyculture systems, water and nutrient recycling, and novel solar power technologies to identify options that reduce greenhouse gas emissions by >20% from current levels. Bangladesh and Egypt, where the intensification of aquaculture is challenged by water, land and energy constraints, will be initial sites of focus for this research.

Research on delivery and use systems will involve country-level assessments and field activities in all focal countries in Asia and Africa to better demonstrate how aquaculture technology research from clusters 1 and 2 can be relevant, gender-responsive, applicable and accessible to smallholder farmers, operating within a variety of agro-ecological, economic and social contexts. This includes engaging in participatory research with national partners to address local challenges, such as market access, seed and input availability, integration with rice and other key agricultural farming systems and cross-cutting issues such as gender and climate change, to understand barriers to accessing improved technologies for women and youth and opportunities to overcome those barriers. Research and development partners with experience in inclusive business will assist in the development of inclusive, gender-sensitive and women-targeted business, finance and entrepreneurial models and institutional and policy interventions to support sustainability and scaling of promising technologies and smallholder enterprise models that create income and employment for smallholder women, men and youth. Gender-inclusive awareness raising and training on the delivery and use of improved strains and technology packages, accompanying guidelines and manuals, and potential for wider use of mobile applications, building on L&F learning with mobile technologies in Bangladesh, will be tested and developed for scaling. These will be adapted to additional languages and training on their use in additional countries.

The cluster will also conduct foresight research to place technology and systems research within the context of scenarios for future market drivers and growth, including assessments of climate change vulnerabilities and adaptation strategies. This will enable the design of aquaculture systems and approaches to technology dissemination that respond efficiently to climate change and other future trends and drivers at micro (farm and community) and macro (national and international) levels, differentiated by women and men in anticipation of need.

2.1.1.7 Partnerships

The multi-stakeholder partnership brought together through FP1 provides a globally unique capability to harness cutting-edge aquaculture science targeted at the development and delivery of IPG research designed to increase the sector's contribution to achieving SDG targets. We will build upon the extensive national, regional and global partnerships developed by WorldFish over the past 25 years. Key elements of these partnerships are summarized below, and Table 8 details the role of partners across flagship clusters and along the impact pathway.

Advanced research institutes. FP1 will work with advanced research institutes to draw effectively on recent advances in key areas of science. For example, we will partner with the network of the Roslin Institute at the University of Edinburgh, UoS, SRUC, TGAC and Bangor University, together with JCU, Nofima, the Norwegian University of Life Sciences and the French Agricultural Research Centre for International Development (CIRAD) to apply recent advances in molecular genetics to further enhance the rate of genetic gain and respond to growing demand for high-quality fish seedstock.

Cluster 2 on fish health, nutrition and feeds will be led by the Aquaculture and Fisheries Group at WUR. They bring to this role leading-edge science capacity in fish nutrition, health and aquaculture feeds development, as well as access to a wider range of animal science skills within the university, specifically the Animal Breeding and Genetics Group for genetic and environment interactions. We will also partner with CSIRO in the development of bioactive compounds as fishmeal replacements, and the University of Exeter, UoS and CEFAS to develop fish disease diagnostic tools. Our aquaculture systems research will be pursued in collaboration with Auburn University, SRC and UoS with enterprise

development in partnership with the BoP Innovation Center and gender researchers at the Institute of Development Studies.

NARES. In all focal countries, FP1 will work through national research partners. Breeding programs are already being conducted with national aquaculture research institutions in Bangladesh (Bangladesh Fisheries Research Institute [BFRI]), Egypt (Agricultural Research Center [ARC]) and Ghana (Water Research Institute [WRI]), and this work will be extended to other focal countries through FISH. Similarly, FP1 will work with university research teams to bring together relevant skills and build research capacity, such as with the Bangladesh Agricultural University (BAU) and Egypt's Kafr El Sheikh University for fish health research.

Private sector. FP1 will seek to strengthen collaboration with private sector partners for successful scaling of the technologies and business models being developed through FP1. At the global level we are partnering with Skretting through a new research facility at the WorldFish Abbassa facility for raw material evaluations and fish feed developments, Aquaspark on development and testing of models for financing of emergent aquaculture enterprises, and Merck/MSD on the development of new treatments for emerging tilapia diseases.

Discovery	Proof of concept	Scaling
FP1 Cluster 1: Fish breeds and genetics		
Roslin Institute – University of Edinburgh; UoS; SRUC; JCU; Nofima Norwegian University of Life Sciences (consortium developing genomic tools for identification and incorporation of resilience traits/efficiencies in fish improvement programs). The Genomic Analysis Centre, University of Norwich; Bangor University (methods for genomic analysis of tilapia genetic diversity and domesticated-wild tilapia interactions). Wageningen University; CIRAD (research on fish genetic- environment, yield gaps and feed efficiencies).	**Egypt**: Ain Shams University in Egypt (field research on gene-environment interactions of Abbassa tilapia strain)	**Egypt**: Private sector associations, hatcheries and farms (hatchery investments, broodstock management and dissemination of improved tilapia breeds)
	Nigeria: University of Ibadan (management of tilapia breeding program)	**Nigeria**: Federal Ministry of Agriculture and Rural Development (policy and capacity development initiatives); private sector associations, hatcheries and farms (hatchery investments and dissemination of improved tilapia breeds)
	Zambia: Department of Fisheries (management of facilities for tilapia breeding program and strain comparisons)	**Zambia**: Department of Fisheries (policy and capacity development initiatives for aquaculture); private sector (hatchery investments and dissemination of improved tilapia breeds)
	Bangladesh: BAU and Department of Fisheries (management of carp genetics and breeding programs)	**Bangladesh**: Department of Fisheries and BRAC (investments in tilapia and carp breeding programs and dissemination of improved tilapia and carp); private sector (investments for tilapia breeding satellites and dissemination of improved seed)
	Myanmar: Department of Fisheries (management of rohu carp and tilapia breeding programs)	**Myanmar:** Department of Fisheries (fish seed policy) and Myanmar Fisheries Federation (dissemination of private sector models); private sector (hatchery investments and dissemination of improved tilapia breeds)

FP1 Cluster 2: Fish health, nutrition and feeds		
Health: CEFAS; University of Exeter; UoS; Wageningen University (characterization of pond microbiomes, development of pondside diagnostics and early warning tools, novel alternative prophylactic products) **Feed**: Wageningen University and CSIRO (novel technologies, including the use of microbial processes to bio-convert plant wastes into bioactive aquafeed ingredients)	**Egypt**: ARC-Central Laboratory for Aquaculture Research (CLAR), Kafr El Sheikh University, Suez Canal University (field testing of diagnostic tools, health management packages, novel prophylactics for tilapia) ARC-CLAR, Kafr El Sheikh University, Alexandria University, Skretting (field testing of novel tilapia feeds)	**Egypt**: Fish farmers and hatchery associations, General Authority for Fisheries Resources Development (GAFRD) (investments in scaling application of better health management practices); private sector (investments for processing of raw materials for new feeds and feeding systems)
	Nigeria: University of Ibadan, Federal University of Technology in Akure and Skretting (field testing of novel tilapia feeds)	**Nigeria**: Federal Ministry of Agriculture and Rural Development (policy and capacity development initiatives); private sector associations, hatcheries and farms (investments in use and dissemination of improved feeds)
	Tanzania: Institute of Marine Sciences, University of Dar es Salaam (testing applicability of bioactive aquafeeds)	**Tanzania**: Ministry of Livestock and Fisheries Development (policy and capacity development initiatives)
	Myanmar: Department of Fisheries, universities and NGOs through the Fisheries Research and Development Network (FRDN) (research on improved feeds and health management)	**Myanmar:** Department of Fisheries (policy and capacity development initiatives in support of feed fed aquaculture systems); Myanmar Fisheries Federation and fish farmers cooperatives (dissemination of better health and feed management practices for improved tilapia and carp)
	Cambodia: Fisheries Administration, Department of Aquaculture and private sector (co-development of profitable feed fed aquaculture systems adapted for Cambodia)	**Cambodia:** Fisheries Administration (policy and capacity development initiatives in support of feed fed aquaculture systems); private sector (investments in feed formulation and dissemination of improved fish feeds)

FP1 Cluster 3: Aquaculture systems		
Stockholm Resilience Center (design of research using resilience frameworks and LCA) Wageningen University and Auburn University (design of social aquaculture system research and development of tools and models) Institute of Development Studies and BoP Innovation Center (support to gender analysis and gender-sensitive and inclusive business models) UoS (methodological guidance on integrated farm assessments) Australian National University (supply and demand modeling for aquaculture)	**Egypt**: Kafr El Sheikh University and CLAR (farm trials and verification of aquaculture systems research)	**Egypt**: Skretting, GAFRD, governorate-level fish farmers associations (dissemination of improved technologies and private fish farms for adoption of newly developed farming systems [e.g. in-pond raceways] and implementation of BMPs); CARE and World Food Program (testing scaling of small-scale homestead aquaculture system packages in Upper Egypt)
	Tanzania: Institute of Marine Sciences, University of Dar es Salaam (verification and adaptation of coastal integrated aquaculture system research)	**Tanzania**: NGOs and private sector (incorporating validated aquaculture systems in investment priorities and disseminating validated and improved technologies and gender-sensitive business models)
	Zambia: Department of Fisheries and Indaba Agricultural Policy Research Institute (verification and adaptation of integrated aquaculture systems research)	**Zambia**: Department of Fisheries (policy and capacity development initiatives); private sector (scaling validated technologies and business models); Copperbelt University, Natural Resources Development College (NRDC) and Kasaka Fisheries Training Institute (KFTI) (research and development [R&D] capacity building)
	Bangladesh: BAU, Bangladesh Institute of Development Studies (verification and adaptation of aquaculture systems research; gender-sensitive value chain	**Bangladesh**: Department of Fisheries, BRAC and private sector (dissemination of integrated packages of improved tilapia and carp technologies)
	Cambodia: Fisheries Administration (testing and monitoring new production systems); Helen Keller International (verification and adaptation of small-scale aquaculture system research)	**Cambodia:** Fisheries Administration (policy and capacity development initiatives in support of improved production systems); private sector (adoption of improved production systems); NGOs (deployment of aquaculture systems within livelihood programs)

Table 8. Selected non-CGIAR partners at discovery, proof of concept and scaling stages of the impact pathway.

Development organizations. FP1 research priorities have been identified in collaboration with development partners at regional and national levels, and research will be undertaken in collaboration with local partners. For example, in Africa, FP1 responds to the AU's newly developed Africa Aquaculture Action Plan and national priorities such as improved seed, feed and fish health. In Egypt we will pursue these priorities by working with the Ministry of Agriculture, NGOs such as CARE, and private sector partners. In Bangladesh, FP1 addresses priorities of the Country Investment Plan and National Aquaculture Development Strategy and Action Plan for Bangladesh (2013–2020), and we will work with the Department of Fisheries, BFRI, national and international NGOs, and the private sector to pursue these.

2.1.1.8 Climate change

FP1 research contributes aquaculture technologies and husbandry systems that respond to climate change, in close collaboration with CCAFS flagships and the associated cross-CRP Learning Platforms.

Firstly, our research will develop, test and scale up climate-smart aquaculture technologies and production systems to build adaptive capacity and resilience to climate change for farmers and stakeholders in aquaculture value chains, contributing to CCAFS Flagship 2, Climate Smart Technologies and Practices. By introducing new traits for climate resilience in tilapia, such as temperature or salinity tolerance, or reducing production time via faster growing fish, we will empower fish farmers affected by salinization and changing rainfall patterns. Further, brackish- and high temperature-tolerant tilapia with

excellent growth efficiency will enable farmers to maintain food production in times of climatic instability. This research builds on work by WorldFish and CCAFS in Bangladesh and Vietnam on climate-smart agriculture.

Secondly, our research contributes to climate change mitigation by reducing greenhouse gas emissions from fish farming, contributing to CCAFS Flagship 3, Low Emissions Development. Recent L&F research on Egyptian tilapia production systems using LCA tools (Henrikson et al. 2016) indicates that greenhouse gas emissions can be reduced by ~20% per unit of production by improving pond management and reducing fish feed wastage. Building on this research, we will identify deeper reductions in greenhouse gas emissions from aquaculture through better pond management, reducing reliance on fossil fuels, identifying cost-effective alternatives to wild-harvest fishmeal in aquafeeds and siting aquaculture facilities away from areas with sequestered carbon.

Collaboration with CCAFS Flagship 1, Priorities and Policies for Climate Smart Agriculture, will enable us to draw on analyses of future climate scenario projections, early warning systems of monsoon shifts, and saline incursions, feeding into the design of climate-smart aquaculture systems for wider scaling. A collaboration between FAO and WorldFish to analyze aquaculture vulnerability and adaptation to climate change in Africa will be completed in mid 2016, providing a foundation for future research on development of climate-smart approaches to aquaculture in Africa, which are urgently needed.

2.1.1.9 Gender

An estimated 76 million new jobs will be created globally by the growth of aquaculture between 2010 and 2050, with most in developing countries (Waite et al. 2014). FP1 gender research will focus on how opportunities arising from the growth of aquaculture can be gender- and socially inclusive and equitable. This will inform FP1 innovations to leverage equal opportunities for women to generate wealth through aquaculture production and value chain employment and entrepreneurship.

Cluster 1 generates new knowledge about the gendered needs and preferences of women and men in relation to improved tilapia and carp strains in different countries and contexts. It analyzes gendered experiences of the benefits and drawbacks from the production and release of improved fish seed, including labor demands, to better integrate gender into fish breeding R&D.

Cluster 2 identifies previously unassessed differences and commonalities in women's and men's priorities, needs and knowledge on fish feeds and health, to generate new gendered insights to inform technology R&D. The cluster will identify and test gender-responsive feed and husbandry innovations that can enhance women's engagement in aquaculture production while maintaining a manageable workload. Working with FP3, the cluster will investigate how feed quality affects the nutritional content of fish, in particular for consumption by pregnant and lactating women, and young children.

Cluster 3 investigates which factors limit or enable women's access to and control over aquaculture assets such as fish fry, extension, finance and storage. The cluster will draw on this research to identify and test opportunities and strategies for more gender-equitable engagement in and wealth generation from aquaculture value chains, through safe, dignified and higher-return employment and entrepreneurship. This includes building on cluster 2 to identify and assess opportunities for women-led fish feed formulation enterprises.

2.1.1.10 Capacity development

Capacity development is an enabler of all change mechanisms of the CRP-level theory of change. A tailored capacity development program will be implemented through an iterative process starting with *capacity needs assessments and intervention strategies* (CGIAR Capacity Development Framework element 1) to provide the foundation for operationalizing the impact pathways. It will focus on capacity of smallholders to demand and adopt aquaculture technologies and use improved management practices, as well as needs of service providers to supply inputs, knowledge and skills targeted at men and women fish farmers. Resulting interventions will use innovative *learning materials and approaches* (element 2) such as partnering with IT providers to pilot the use of mobile financial services in Bangladesh and training in aquaculture technology and policy development and entrepreneurship for Africa. All materials and approaches will be *gender and youth sensitive* (element 5) in line with our gender and youth strategies (see Annexes 3.4 and 3.5).

Aligning with the program's partnerships strategy, our needs assessment will identify gaps and interventions to increase the *capacity of scientists to partner* (element 3). We will *develop future research leaders* (element 4) through internships and

postgraduate programs, such as through partnerships with the Lilongwe University of Agriculture and Natural Resources (LUANAR, an Africa Center of Excellence in Aquaculture and Fisheries for postgraduate training of aquaculture researchers), and at the WorldFish aquaculture research and training center in Abbassa, Egypt. *Monitoring and evaluation of capacity development* (element 7) will be integrated into program-level M&E (see Annex 3.3).

Institutional strengthening (element 6) will focus on strengthening public and private sector capacity in fish breeding and dissemination of new technologies in extension and outreach programs. This will include multi-stakeholder dialogues to inform improved policy and legal frameworks in the countries where we work.

2.1.1.11 Intellectual asset and open access management

FP1 will manage intellectual assets consistent with CGIAR, center and partner policies and procedures, as well as those of our bilateral donors. The flagship will contribute to and take advantage of program-level mechanisms to ensure widespread usage and analysis.

FP1 research outputs will be available through the CRP website, as well as those of our partners where appropriate. Prompt and broad dissemination in appropriate formats will maximize the accessibility and impact of research outputs. Tools for genomic analysis, feed ingredient assessments, aquaculture business planning, social and environmental impact assessment, and other scientific and development applications will be placed online or in other open access media and formats as appropriate. Genetically improved fish seed and preserved samples archived in our biorepository will be made accessible to partners according to WorldFish policies, such as that related to the transfer of improved strains. WorldFish will advise partners on responsible transfers and introductions and how to set up and maintain improved stock, as well as how to multiply and disseminate it to farmers. Exceptions to open access may include information that is sensitive due to privacy concerns, political sensitivity and adverse effects on farmers' rights and confidential information associated with permitted restrictions or subject to limited delays to seek intellectual property rights.

Datasets will be anonymized and made available as open access. They will be generated through each research cluster and include genetic datasets, feed ingredients and nutritional quality data, and technology performance assessments. FP1 will also contribute aquaculture species data to FishBase, the world's leading open access database on fish biology. Science outputs will, when appropriate, be published in open access journals, or the program will purchase open access privileges for publication in non-open access journals.

2.1.1.12 FP management

The flagship will be led by WorldFish. The flagship leader, Dr. Michael Phillips, will (1) provide overall strategic leadership for flagship research, (2) work with cluster leaders, scientists and other flagship leaders to develop and oversee execution of the research agenda for the flagship, and (3) lead identification and negotiation of significant strategic science partnerships that will strengthen links between the flagship science team and leaders in the appropriate body of science. A country coordinator for FP1 will act as a focal point for the flagship's engagement in each focal country.

Cluster 1: Fish breeds and genetics will be led by WorldFish in collaboration with key science partners at the Roslin Institute, SRUC, TGAC, Bangor University, and Nofima and Norwegian Agricultural University for genetics research.

Cluster 2: Fish health, nutrition and feeds will be led by WUR in collaboration with key science partners at CSIRO on novel fish feed ingredients and CEFAS, UoS and University of Exeter for fish health research.

Cluster 3: Aquaculture systems will be led by WorldFish in collaboration with key science partners at IDS, BoP Innovation Center, Auburn University, UoS, and the Stockholm Resilience Center for systems research.

Each cluster will be planned and executed in close collaboration with key science partners. Cluster leaders will (1) provide overall strategic leadership for cluster research, (2) work with contributing scientists to develop and oversee execution of the research agenda for the cluster, and (3) lead identification and negotiation of significant strategic science partnerships for the cluster.

CVs of flagship leads, cluster leads and other key scientists leading implementation of the flagship research are provided in Annex 3.8.

2.1.2 Flagship budget narrative

2.1.2.1 General information

CRP Name	FISH
CRP Lead Center	WORLDFISH
Flagship Name	FLAGSHIP 1: Sustainable Aquaculture
Center location of Flagship Leader	Malaysia

2.1.2.2 Summary

Total Flagship budget summary by sources of funding (USD)

Funding Needed	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2	3,343,862	3,471,252	3,643,642	3,831,351	4,039,804	4,245,203	22,575,114
W3	0	0	0	0	0	0	0
Bilateral	7,663,828	8,170,710	8,769,865	9,423,301	10,131,109	10,894,045	55,052,858
Other Sources	0	0	0	0	0	0	0
	11,007,690	11,641,962	12,413,507	13,254,652	14,170,913	15,139,248	77,627,972

Funding Secured	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Assumed Secured)	3,343,862	3,471,252	3,643,642	3,831,351	4,039,804	4,245,203	22,575,114
W3	0	0	0	0	0	0	0
Bilateral	1,541,399	1,087,370	49,703	0	0	0	2,678,473
Other Sources	0	0	0	0	0	0	0
	4,885,261	4,558,622	3,693,345	3,831,351	4,039,804	4,245,203	25,253,586

Funding Gap	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC Members)	0	0	0	0	0	0	0
Bilateral (Fundraising)	-6,122,428	-7,083,339	-8,720,161	-9,423,301	-10,131,109	-10,894,045	-52,374,385
Other Sources (Fundraising)	0	0	0	0	0	0	0
	-6,122,429	-7,083,340	-8,720,161	-9,423,301	-10,131,109	-10,894,045	-52,374,385

Total Flagship budget by Natural Classifications (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
Personnel	4,293,517	4,659,241	5,087,719	5,558,206	6,077,228	6,649,099	32,325,011
Travel	618,979	630,367	661,928	691,514	719,551	748,245	4,070,588
Capital Equipment	78,200	67,600	70,980	74,529	78,255	82,168	451,732
Other Supplies and Services	3,842,632	4,004,780	4,188,371	4,393,393	4,611,767	4,825,103	25,866,049
CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	1,013,060	1,048,260	1,089,840	1,131,882	1,180,426	1,226,777	6,690,245
Indirect Cost	1,161,301	1,231,712	1,314,666	1,405,125	1,503,683	1,607,853	8,224,344
	11,007,689	11,641,960	12,413,504	13,254,649	14,170,910	15,139,245	77,627,957

Total Flagship budget by participating partners (signed PPAs) (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
WorldFish Center	10,758,832	11,411,158	12,179,682	13,017,732	13,930,820	14,895,903	76,194,129
UoW - Wageningen University	248,857	230,803	233,824	236,919	240,093	243,344	1,433,842
	11,007,689	11,641,961	12,413,506	13,254,651	14,170,912	15,139,247	77,627,966

Explanations of these costs in relation to the planned 2022 outcomes:

Major cost drivers and how these relate to planned activities and target outcomes

Major cost drivers are scientific personnel, travel, consumables and capital equipment. Scientific personnel costs include those of flagship and cluster leaders, principal investigators and cluster research teams, including those at WorldFish HQ (Malaysia) and our key research hubs in the focal countries Bangladesh and Egypt. During the implementation of the flagship we plan to increase allocation of funds to focal country programs in Africa (Nigeria, Tanzania, Zambia) and Asia (Cambodia, Myanmar), while maintaining the core cluster investments in scientific personnel. Investments are also made in personnel for leading/coordinating key cross-cutting dimensions of flagship activities, including gender, youth and capacity development. We anticipate funding a coordinator for flagship 1 activities in each focal country where we operate. Scaling to countries beyond the core program countries will be through bilateral funding. Travel includes investments in field visits and assessments, planning and review meetings/workshops, partner consultations and scientific supervision. Capital equipment includes items for the tilapia breeding program necessary to upgrade their efficiency and to support experiments in Egypt (Abbassa), automated fish measuring systems for genetics research, genomics analysis software and associated large data hardware (with M&E component of the CRP), and fish health and feeds equipment for cluster 2 research in the Abbassa aquaculture research and training center in Egypt. Consumables include the costs for molecular characterization of fish stocks and diseases, which are a fundamental part of the research.

Risks and plans to mitigate risks

Major risks are associated with funding uncertainties across each cluster. Cluster 3 is sufficiently well funded by current/pipeline bilaterals to proceed as planned until 2018, but cluster 1 and 2 need further investments to implement the research agenda and achieve the development outcomes indicated. Funding risks increase beyond 2018 when the funding pipeline becomes more uncertain. Risk mitigation measures will include implementation of systems of financial planning in accordance with WorldFish procedures and more flagship-level initiatives for business development, including communication/dialogue with donors from public and private sectors, scanning of investment opportunities and development of proposals to increase the pipeline of bilateral funds available.

2.1.2.3 Additional explanations for certain accounting categories

Benefits: Personnel costs are based upon best estimates of the level of effort required by specific staff positions to deliver upon the objectives of the Flagship.

This level of effort has been expressed as a number of days per period. The personnel costs have been determined via the application of daily standard rates per position/staff member. In addition to the daily standard rates, the cost of benefits have been calculated on an individual basis and expressed as a function of salary. The benefits included are those that are applicable per the employing Center's established policies and procedures.

The estimated cost of the allowances and benefits vary depending on the classification of the individual staff member as well as the location in which they are working. WorldFish has three staff designations: Global (GRS), Home Country International (HCI), and National (NRS). The following benefits are have been included in the budgeted salary costs:

Retirement contributions: WorldFish contributes the equivalent of 15% of base salary to a retirement fund for staff. This is applicable to all designations of staff (GRS, HCI, NRS).
Insurance premiums: this includes medical (GRS, HCI & NRS), accidental death and dismemberment (AD&D) (GRS & HCI), long-term disability (LTD) (GRS & HCI), and life insurance (GRS, HCI, & NRS).

Annual medical examination costs: applicable to all staff designations (GRS, HCI, NRS), WorldFish encourages annual medical examination for all staff and agrees to subsidize the costs thereof for all staff over the age of 40, up to $250USD per annum.

Housing allowance: generally applicable for GRS staff only, WorldFish provides an allowance of up to 75% of the cost of housing, subject to monthly maximums established by location.

Dependant Education Allowance: applicable for GRS staff only, WorldFish provides the cost of education (up to end of secondary education) for dependant co-located children.

Home Leave: applicable for GRS staff only, WorldFish funds the cost of an annual trip to the staff members' home country for the staff member and dependants.

Relocation and Repatriation costs: applicable for GRS staff only, WorldFish covers the cost of relocating GRS staff from their home location to their duty post. Once the staff member has completed at least 3 years of continuous service, WorldFish will also cover the cost of repatriating the staff member to their home location upon termination of employment.

Location specific benefits (i.e. hardship allowances), where applicable, have also been included in the cost as have the cost of statutory employment related taxes applicable in certain operating locations.

As there is great range in the cost of benefits by location and by staff designation, we assigned a specific percentage (of salaries) to each location/staff designation combination. The following provides the range of percentages that were used by staff designation:

Range of Benefit %		
	High	**Low**
HCI	Zambia (63.56%)	Philippines (21.6%)
GRS	Zambia (129.03%)	Egypt (36.59%)
NRS	Solomon (62.15%)	Zambia (21.64%)

Other supplies and services: Other supplies and services include: (i) specialist consulting services for support to integrated farm assessments, country scaling plans, capacity assessments, data collection and other field studies; (ii) support to operations and genetics, feed and health experiments at the three fish genetic improvement programs in Bangladesh, Egypt (Abbassa) and Malaysia (WorldFish HQ), including aquarium equipment, fish-tagging, molecular characterization, feeding, casual help, and facility maintenance; (iii) non-CGIAR partner costs, including contracts for supporting national fish breeding programs, field assessments of improved strains, epidemiological studies, and feed ingredient/value chain studies, as well as costs associated with participation in planning and design meetings at global/national levels; and (iv) workshops for annual flagship and cluster planning, stakeholder consultations and training, scaling activities and national research platforms.

2.1.2.4 Other sources of funding for this project

Should full funding not become available, we will reduce the scope of the activities across the flagship, which will have knock on effects on the research and development outcomes that can be achieved. Research focus under a restricted funding environment will be directed more towards tilapia, and potential investments in carp genomics and genetic improvement will be postponed until later in the program or as funds become available. Hiring of key new appointments, including bioinformatics, geneticists, fish disease and feeds will also be postponed until sufficient funds are available. We will continue to seek bilateral donor funds to implement the research priorities identified in the proposal, and have several bilateral projects in the pipeline or under development. Longer-term fish genomics and genetic improvement programs, which require continued attention to the maintenance and management of live animals, will be placed at risk through decline or uncertainty in W1/W2 funds, and will shift towards potentially uncertain and/or shorter-term bilateral funding windows.

2.1.2.5 Budgeted costs for certain key activities

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Gender	1,544,442	Gender investment of US$9.3M over the 6 years represents 11.9% of the budget allocated to the flagship and supports integration of gender into all flagship activities, as well as gender-focused research to increase the impact of the research on development outcomes for women. These include global and national scientists, specialist consultancy, partners, workshops and training of research teams and development partners and operating expenses for field research in focal countries and cross-country synthesis. Investments are made across all research clusters, including research on gender-integrated fish breeding programs (cluster 1), women-led enterprises in fish feed value chains (cluster 2) and most viable models and entry points for women entrepreneurs in aquaculture (cluster 3). Early program investments during 2017-18 are oriented towards participatory assessments, and from 2018-2022 increasingly towards action research and implementation of best bets arising from the assessments, followed by scaling of research with national and international development partners. Funds are also invested in contributions of key international partners and national partners for research and scaling activities.
Youth (only for those who have relevant set of activities in this area)	375,661	Youth investment of US$2.3M over the 6 years represents 2.9% of the budget allocated to flagship 1 and supports integration of youth into all flagship activities. Global and national scientists are funded, including a part-time young scientist as coordinator of flagship 1 youth research, together with a specialist consultancy for national studies, partnerships, workshops and training of research teams and development partners and operating expenses for field research in focal countries and cross-country synthesis. Funds are also allocated for youth internships and mentoring across the flagship, enabling us to capitalize on activities for engaging youth in program activities and supporting youth-oriented capacity building. All research clusters receive investments, though youth employment receives particular attention in cluster 3. Early program investments during 2017-18 are oriented towards assessments of youth, and from 2018-2022 increasingly towards engaging youth in action research and catalytic support to scaling of promising youth interventions in aquaculture production and value chains in focal countries.

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Capacity development	1,481,329	Capacity development investment of US$8.9M over the 6 years represents 11.4% of the budget allocated to flagship 1 and supports integration of capacity development into all flagship activities, including assessments during early stages of the program, followed by targeted capacity building investments. Funds are allocated to global and national scientists for conduct of training activities for researchers and development partners, specialist training consultancy, internships for young scientists within the program research activities, and implementation of regular Africa regional aquaculture training courses in the Abbassa research and training center in Egypt. A dedicated coordinator for aquaculture capacity building in Africa is proposed for funding, also to be based at the Abbassa center, to facilitate transfer of our core aquaculture research learning in Egypt more widely in support of scaling across the region. Investments are also made in staff to support capacity building across our Asian focal and scaling countries.
Impact assessment	516,047	Impact assessment investment of US$3.1M over the 6 years represents 4% of Flagship 1 budget and supports staff time and tools for data collection associated with documentation of research and development outcomes including estimating and validating dissemination of improved fish strains, on-farm assessments of productivity, income, fish disease control/feed technology adoption, fish price monitoring, and annual review/learning events with partners to capture lessons learned and document research and development outcomes.
Intellectual asset management	38,378	Intellectual asset management investment of US$230K over the 6 years is allocated for assessment, protection and suitable arrangements with partners in ownership of intellectual property, lawyers fees, meeting requirements of the Nagoya protocol and appropriate access to data. The budget is largely comprised of external expert resources (legal, training, contracting) and allocation of personnel time towards ensuring capacity development of intellectual asset management best practices throughout the Flagship operations.
Open access and data management	205,005	Open access and data management investment of US$1.2M over the 6 years is allocated for maintenance of databases, mainly for genetic data collected through the cluster 1 research and supports publication of research data and papers (including OA publication costs) and management of OA databases, including collection and management of the large amount of genomics and associated data being collected through cluster 1. The budget also consists of external expert resources (legal, training, contracting) and allocation of personnel time towards ensuring capacity development of open access data management best practices throughout the Flagship operations.

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Communication	452,826	Communication investment of US$2.7M over the 6 years supports publication of research papers, and communication activities (policy briefs, manuals, technical reports, outcome stories) that will support the communication of research to end users with and through partners, including farming communities in focal countries (costs of pamphlets, manuals), policy makers (policy briefs) and NGO or government partners (extension manuals). Investment in mobile technology approaches to communication to end-users will be assessed through an study planned for 2017.

2.1.2.6 Other

The level of ambition of the Sustainable Aquaculture flagship requires mobilization of approximately $55 million in bilateral and Window 3 funds over the life of the program. This calls for flexibility to address the priorities of funders in terms of country focus and thematic interest. **Window 1 and 2 funds are used primarily to support core elements of the program** that can be widely applied when matched with bilateral funds. Given the breadth of the flagship and the funding model, with dependence on all sources of funding, funds from different sources are often integrated in support of tasks that have been determined to fit within the scope and priorities of the Program.

Annual funding certainty of W1 and W2 funds will be critical to ensure the flagship achieves it's objectives on time and on target. As a means of risk mitigation, WorldFish will dedicate organizational resources to securing the bilateral funding targets identified in the proposal, however W1 and W2 funds will need to secured and received in order to leverage the bilateral opportunities. Delays in receiving W1 and W2 funds will have a knock-on effect on implementation and execution of the flagship as WorldFish will not be in a position to pre-finance Program activities that are designated to be funded from W1 and W2 sources.

Due to the limitations of the online submission form, the funding figures presented herein have combined all bilateral and Window 3 funds into the bilateral fields. It is our full expectation that there will be a mix of both bilateral and Window 3 funds contributing to the flagship.

Indirect costs included in the budget have been set at 12%, which is consistent with existing audited indirect costs for WorldFish, adjusting for information technology and facility costs which have been specifically included as direct costs in the flagship budget.

2.1.3 Flagship Uplift Budget

This Uplift budget has been prepared based on the scenario whereby the aggregate portfolio of funding increases by 50% from the $900M indicative budget. The following additional activities would be prioritized within this Flagship. Please refer to descriptions of these activities in the CRP Uplift Budget narrative, section (1.1.7):

- **Aquaculture in Africa**
- **Rice-fish production systems in Asia**
- **Global agenda setting to better profile fish in development**
- **Climate change in fisheries and aquaculture**
- **Integrated assessment of sustainable/resilient pathways for fisheries and aquaculture development in Tanzania**
- **Enhancing fish supply and consumption for human nutrition in Timor Leste**
- **Aquaculture, capture fisheries and fish trade interdependencies in the Mekong Delta**

Outcome Description	Amount Needed	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other (%)
1.1 - 4.9 million producer households adopted improved breeds, aquafeeds, fish health and aquaculture and fisheries management practices	8,875,500	32%	0	68%	0
1.2 - 3.5 million people, of which at least 50% are women, assisted to exit poverty through livelihood improvements related to fisheries and aquaculture value chains	8,052,000	32%	0	68%	0
2.3 - 2.4 million people, of which 50% are women, without deficiencies of one or more of the following essential micronutrients: iron, zinc, iodine, vitamin A, folate & B12	6,374,500	32%	0	68%	0
2.4 - 4.7 million more women of reproductive age consuming adequate number of food groups	6,374,500	32%	0	68%	0
3.3 - 3.3 million ha of ecosystems restored through more productive and equitable management of small-scale fishery resources and degraded aquaculture ponds restored	884,500	32%	0	68%	0