FISH: CGIAR Research Program on Fish Agri-Food Systems
Tilapia health research 2017–2022: Priorities and partnerships

WorldFish

FISH: CGIAR Research Program on Fish Agri-Food Systems
Tilapia health research 2017−2022: Priorities and partnerships

Authors

Chadag Vishnumurthy Mohan and Rohana Subasinghe

Contents

List of collaborating partners

The CGIAR Research Program (CRP) on Fish Agri-Food Systems (FISH) is designed to be implemented through partnerships with relevant and interested stakeholders: national and international research agencies, the private sector, academia and state agencies. A tilapia health research prioritization workshop held in November 2017 to discuss and elaborate a research and partnership agenda for key health research activities within FISH was attended by a number of identified research partners. The following are the collaborative partners represented at the workshop held at WorldFish Headquarters in Penang, Malaysia.

Benchmark	Benchmark Holdings PLC
Cefas	Centre for Environment Fisheries and Aquaculture Science
CSIRO	Commonwealth Scientific and Industrial Research Organization
DoF	Department of Fisheries
FAO	Food and Agriculture Organization of the United Nations
FVG	FishVet Group
MSD	Merck, Sharp and Dohme; Merck & Company Inc
MU	Centex/Mahidol/Biotech, Mahidol University
NAs	national authorities
NUs	national universities
NVI	Norwegian Veterinary Institute
RI	The Roslin Institute, University of Edinburgh
UMT	University Malaysia Terengganu
UPM	University Putra Malaysia
UoE	University of Exeter
UoS	University of Stirling, Institute of Aquaculture
USM	University of Science Malaysia
WB	World Bank
WU	Wageningen University

Executive summary

The CGIAR Research Program on Fish Agri-Food Systems (FISH) focuses on the interlinked challenges of sustainable aquaculture and small-scale fisheries (SSFs), and enhancing the contribution of fish to poverty reduction, improved human nutrition and environmental management, with a geographical focus on Africa, Asia and the Pacific. Sustainable aquaculture research within FISH includes a cluster of research on "fish health, nutrition and feeds."

This report is the outcome of a workshop held at WorldFish HQ on 28–29 November 2017 intended to elaborate a research and partnership agenda for key health research activities within the FISH, with an emphasis on tilapia from 2017 to 2022. The workshop identified key partnerships and responsibilities for implementing the research, and impact pathways for delivering outcomes at scale in key focal and scaling countries. Workshop participants agreed that the envisaged target of "2.5 million households having adopted disease detection and control strategies and improved aquaculture management practices" could only be achieved through (a) widespread dissemination of improved tilapia seed, (b) widespread adoption of management practices that integrate practical tilapia health management practices, combined with effective surveillance and diagnostic tools, and (c) development and commercialization of disease prevention tools and technologies more widely—all in ways which are useful and affordable to the small-scale farming sector. The workshop acknowledged the importance and timeliness of research into the genetic improvement of tilapia toward disease tolerance. Considering the current spread of tilapia lake virus (TiLV), the workshop recommended the following: (a) improve understanding of the molecular genetic aspects of TiLV, (b) better understand the virus and its pathogenicity, and (c) make TiLV-related research material virtually available to the public as community resources. The workshop participants also agreed that the impact of the research program would be enhanced by a set of community resources that would (a) be widely disseminated, (b) build human capacity development, (c) contain strong private sector participation in the prevention and control of diseases in tilapia aquaculture, and (d) create policy change at national and global levels. Participants agreed that a policy dialogue with national authorities and international networks for creating a conducive and enabling policy environment toward reducing the risks of diseases in tilapia aquaculture was a key avenue for change.

Genetically Improved Farmed Tilapia (GIFT) in Jitra, Malaysia.

Background

FISH pursues an integrated body of research in six focal countries: three in Asia (Bangladesh, Cambodia and Myanmar) and three in Africa (Nigeria, Tanzania and Zambia), plus research platforms in Egypt and Solomon Islands, and a number of scaling countries where the program cooperates with partners to scale research innovations and learning from focal countries. The overarching research question for the program is: *How can we optimize the joint contributions of sustainable aquaculture and SSFs in select geographies to reduce poverty and improve food and nutrition security, while enhancing environmental sustainability*?

FISH is divided into two flagships, the first being sustainable aquaculture. This flagship focuses on enabling enterprises to progressively enhance production efficiency and sustainability using domesticated, selectively bred, high-health fish (with the focus on tilapia) reared on sustainable feeds in gender-inclusive production systems that have low carbon footprints with no adverse environmental impacts. Focusing on these areas will have the highest probability of achieving productivity gains while avoiding adverse economic, social or environmental impacts. In this regard, the flagship focuses on the key research question: *How can productivity-improving technologies and management practices enable aquaculture to achieve its fullest contribution to equitable livelihoods and food and nutrition security while delivering environmental benefits*? The flagship builds on WorldFish's history of genetic improvements in tilapia, particularly Genetically Improved Farmed Tilapia (GIFT). Within the flagship, there are three research clusters:

Cluster 1–Fish breeds and genetics: This research cluster develops and applies advanced molecular genetics and genetic tools, building on prior selective breeding of GIFT, as well as facilitating the dissemination of existing improved tilapia strains to a wider group of partner countries. Research outputs are delivered through existing and new tilapia breeding programs and partner networks in South Asia and Africa. The research focuses on a number of traits, including the genetic basis of increased resilience to pathogens and production environments, reproduction, metabolic efficiency and nutrient composition.

Cluster 2–Feeds, fish nutrition and health: This research cluster initiates new fish health research and

partnerships with international research institutions, government agencies and companies specializing in disease diagnosis and prevention. The research is intended to build capacity to detect disease at breeding nuclei, multiplication centers, hatcheries and farms, and then develop disease prevention and control strategies, including breeding for disease tolerance (with cluster 1). A key research focus is improving understanding of the nutritional requirements for fish and developing sustainable aquafeeds with ingredients that provide cost-effective and socially acceptable alternatives to wild-harvest fishmeal, while also increasing nutritional benefits to consumers.

Cluster 3–Aquaculture systems: This research cluster seeks to enhance fish farmers' ability to benefit from improved seedstock (cluster 1) and enhanced fish health and sustainable feeds (cluster 2). Research assesses different models for integrating improved breeds, health and feeds for gender-responsive sustainable intensification. Lifecycle analysis and foresight modeling provide insights into the social and environmental implications of aquaculture growth. For farm-scale enterprises, the research prioritizes innovations that create new engagement, employment and enterprise opportunities for youth and women.

Achieving 2022 targets

FISH seeks to deliver significant impacts for small-scale farmers throughout the three regions where it works, contributing to the CGIAR System Level Outcome (SLO) targets and the UN's Sustainable Development Goals (SDGs).

The research within the aquatic animal health component of FISH is intended to deliver the following: **"2.5 million households have adopted disease detection and control strategies and improved aquaculture management practices."** Conducting research and disseminating technologies and tools for achieving this target will only be possible with a well-planned and articulated research program, which will be executed by a group of research and development partners, in close collaboration. The partners should consist of (a) credible research agencies with specific expertise, experience and skills, (b) experienced private sector companies interested in investing in developing and commercializing aquatic animal health management tools, (c) academic institutions with good track records and relevant research interests, and (d) relevant national authorities (NAs) and appropriate civil society organizations.

AIN project in Bangladesh.

Aquatic animal health research partner workshop

To bring together a robust research partnership for the aquatic animal health component of FISH, a workshop was held at WorldFish HQ in Penang 28-29 November 2017. The workshop was attended by 22 participants from 16 public and private institutions (see list of participants in Annex 1). The main objectives of the workshop were to
- improve familiarity among partners on FISH, its research priorities and expected outcomes;
- identify key tilapia health research activities for 2017–2022;
- elaborate key partnerships and responsibilities for implementation of the research;
- draft impact pathways for achieving research and development outcomes at scale.

The participants presented their research interests and programs and discussed how they could contribute to FISH. The workshop attempted to develop a coherent research program on tilapia health, identifying key research activities and key research partners for delivering high quality, solution oriented research, as well as to explore funding avenues. Key discussion points after the presentations included the following:

- The participants agreed that research should also focus on developing further knowledge on economically important traits, including tolerance to disease and the concept of "resilient" tilapia, using genomic tools. Participants believed that, in an era in which TiLV has become a risk to global tilapia culture, FISH should deepen partnerships and collaboration to assist the aquaculture industry and policymakers with better understanding of and solutions for the emerging tilapia health challenges globally.

- There is a clear need for a better understanding of the biology, molecular epidemiology and socioeconomic impacts of TiLV. Understanding of the molecular genetic aspects of TiLV is limited, and conducting research into genomic analysis, typing and mapping of the TiLV genome is timely. Once there is greater understanding of the TiLV gene and characteristics, development of rapid and affordable diagnostic tools and protocols will become less complicated.

- Experience indicates that TiLV is generally associated with multiple pathogenicity and infections. Knowledge on the interactions between pathogens and their implications on how the infection is manifested in the host is minimal, so more research into the multiple pathogenicity of TiLV is an important area of future research. There is a timely need for making TiLV diagnostic and surveillance tools and relevant reference material, such as histopathology images, virtually available to the public as community resources.

- Since there is greater knowledge on the spread of TiLV and its significant socioeconomic impacts, research into better understanding of the genetic and health interactions of tilapia, considering resilience and resistance to TiLV, is timely. Preventative strategies, such as resistant traits and varieties and vaccines, have been identified as highly relevant future researchable areas.

- The participants also agreed that (a) research findings and community resources must be commercialized and disseminated among the relevant aquaculture stakeholders, (b) human capacity must be built through training, and (c) strong private sector participation must be encouraged in the prevention and control of diseases in tilapia aquaculture. Initiating a policy dialogue with NAs and international networks for creating a conducive and enabling policy environment toward reducing the risks of diseases in tilapia aquaculture received high importance and priority.

Key research outputs

Health research with FISH specifies three key types of outputs (Annex 2). The workshop participants considered these all relevant, while providing some specific suggestions on priorities and research activities.

1. Fish disease surveillance and diagnostic tools: Improvements in surveillance and diagnostic tools will assist researchers, breeding programs and farmers to improve capabilities in surveillance and diagnosis of key tilapia health challenges. FISH should therefore engage partners to design, field test, commercialize and disseminate surveillance and diagnostic tools that are accurate, practical and affordable to small-scale farmers. The workshop considered that key products from this research should be

- a common assessment framework for tilapia health economics (epidemiological and surveillance tools);
- molecular diagnostic tools that are applicable to small-scale farming systems;
- web-based, public access databases and information packages (community resources) that will enable better and accurate diagnosis of important diseases of tilapia.

The scaling of such research productions would be through widespread adoption and promotion of the tools, training, human capacity development and commercialization of the tools through the private sector, followed by more global promotion and adoption for inclusion into national surveillance and disease diagnosis. Key partners include NVI, Cefas, MU, CSIRO and UoS.

2. Integrated fish health management packages for improved fish strains: These outputs would be developed by integrating research findings from epidemiology, surveillance and diagnostics into simple and practical management practices with a focus on farm-level biosecurity and better production packages for farming improved tilapia strains. The envisaged products of this output include

- on-farm biosecurity tools and manuals;
- strategies for reducing the risks of disease in tilapia aquaculture (with an emphasis on small-scale producers);
- integrated better production practices packaged as better management practices (BMPs).

The scaling of management practices will be disseminated among small-scale tilapia sectors, initially within the focal countries. Wider application and scaling will be promoted through engagement of state authorities and private sector service providers, including training programs at the Abbassa research and training center in Egypt. Relevant information packages and manuals will be produced and made available as community resources. Key partners include NAs, private sector service providers, relevant civil society organizations and farmer societies.

3. Knowledge on fish health and genetic interactions to inform future fish breeding programs: Knowledge on fish health-genetic interactions coming from field performance assessments, experimental infection studies and genomics would be used to incorporate health research findings into future fish breeding programs to produce resilient strains. The main output would be the knowledge gained through genomic research aimed at developing improved traits and varieties of tilapia that are more resilient to health problems and resistant to specific pathogens. The research might extend beyond FISH to developing the envisaged products, which are the genetically improved varieties/traits of tilapia with better performance. The key partners include RI, CSIRO and NAs. The scaling of such knowledge is unlikely to occur during the period of the FISH, but knowledge would provide a sound foundation for dissemination beyond 2022.

Theory of change

The scaling and impact of the research is expected to take place via several pathways and change mechanisms (Annex 3). The workshop participants identified the following key mechanisms for change associated with tilapia health research:

Develop human capacity through targeted training of relevant technical staff in WorldFish focal and scaling countries, as well as trainer training toward knowledge development among the small-scale farming sector on the application of new diagnostic tools, surveillance programs and better management practices. The key partners would be MU, Cefas, and the Department of Fisheries (DoF) in each of Bangladesh, Egypt and Malaysia, as well as national universities (NUs) from across the world.

Produce community resources for the benefit of researchers, policymakers and the industry. Examples of community resources include a digital library of histopathology slides, online surveillance tools, online health economics assessment tools, BMPs, biosecurity and health management manuals and brochures. Community resources will be made available and accessible to relevant personnel in the tilapia production sector, particularly through efficient dissemination in the small-scale sector. The key partners would include NVI, Cefas, CSIRO, NAs, DoFs and NUs.

Engage the private sector for development, commercialization and dissemination of diagnostic tools, disease prevention technologies (e.g. vaccines) and capacity development on the use of such tools and technologies. WorldFish and private sector players will collaboratively create awareness on the usefulness of technologies like vaccination in tilapia farming and collaboratively undertake field trails for commercial vaccines in countries like Bangladesh and Egypt. The key private sector partners would include Merck, Sharp and Dohme; Merck & Company Inc. Singapore (MSD), FishVet Group, Bangkok (FVG) and Benchmark.

Influence policies toward creating an enabling and conducive environment for reducing the risk and impact of disease in tilapia at national, regional and global levels. This global tilapia health research partnership facilitated under FISH will flag and incorporate research findings of global relevance into policy work of global agencies, such as Food and Agriculture Organization of the United Nations (FAO), World Animal Health Organization (OIE), European Union (EU), World Bank and relevant and responsible NAs.

These change mechanisms provide opportunities to reach 2.5 million households with better health management systems, thus contributing to the broader SLOs and SDGs.

GIFT shipment to Myanmar, Jitra, Malaysia.

Conclusion

The November 2017 workshop, which brought together 22 participants representing 16 public and private collaborating research partner institutions, increased familiarity with the FISH and its expected outputs, outcomes and overarching goals and targets. Research partners saw immense value in pursuing a collaborative research agenda to find solutions to emerging tilapia health problems, with a special focus on TiLV. There was an overwhelming consensus to work closely under the FISH framework of WorldFish, communicate regularly and share experiences in the coming years.

Annex 1. List of participants

Name	Organization
Edgar Burn	NVI (Norway)
Agus Sunarto	CSIRO (Australia)
Senapin Saengchan	Centex/Mahidol/Biotech, Mahidol University (Thailand)
Dong Ha	Centex/Mahidol/Biotech, Mahidol University (Thailand)
David Verner	Cefas (UK)
Manfred Weidmann	UoS (UK)
Jorje del Pozo	RI, University of Edinburgh (UK)
Melba Reantaso	FAO (Italy)
Franck Berthe	World Bank (USA)
Andy Shinn,	FVG (Thailand)
Matthijs Metselaar	FVG (UK)
Srinivasulu Kilari	MSD (Singapore)
Kua Bengchu	NaFish, DoF (Malaysia)
Rimatulhana Ramly	NaFish, DoF (Malaysia)
Azilla Adullah	NaFish, DoF (Malaysia)
Ms Ainul Yasmin Binti Md. Yusoff	Biosecurity, DoF (Malaysia)
Mohammad Syafiq	NaFish, DoF (Malaysia)
Muhammad Fadhil	UPM (Malaysia)
Zary Yahaya	USM (Malaysia)
Kamarul Zarkasi	USM (Malaysia)
Sandra Catherine	UMT (Malaysia)
Mwansa Songe	Central Veterinary Research Institute (Zambia)
Debnath Partho	WorldFish (Bangladesh)
Rahman Meezanur	WorldFish (Bangladesh)
Shimma Ali	WorldFish (Egypt)
John Benzie	WorldFish (Malaysia)
Michael Phillips	WorldFish (Malaysia)
Dave Shearer	WorldFish (Malaysia)
Rohana Subasinghe	WorldFish (Malaysia)
Chadag Mohan	WorldFish (Malaysia)

Annex 2. Key research outputs, activities, geographies and partners

Key Activities	Key Scaling Milestones	Period	Geography	Partners
Output 1: Fish disease surveillance and diagnostic tools				
Vision: Wide use of a set of common assessment frameworks for tilapia health economics (e.g. epidemiological and surveillance tools) and field level diagnostic and early warning tools across focal and scaling countries by 2022.				
Surveillance tools				
1.1.1 Design a common assessment framework (epidemiological and surveillance tool) for tilapia health economics for major tilapia diseases and for supporting a multi-country data platform for data analysis.	A common assessment framework is designed and deployed in Egypt and Bangladesh. Refinements made during testing are incorporated into an improved tool by year-end.	2018	Bangladesh, Egypt, Zambia, Ghana	NVI, FAO, UoS
1.1.2 Field test, provide training for research staff in focal countries and refine the tool for wider deployment.	National research staff are trained.	2018–2019	Bangladesh, Egypt	NVI, UoS, DoFs, NAs, NUs
1.1.3 Produce research outputs using data from the tool.	Peer reviewed research papers are published.	2018–2019	Bangladesh, Egypt	NVI, WorldFish national teams, other partners
1.1.4. Make training tools available and support the capacity building of national teams in focal countries.	The tool is widely deployed across FISH focal countries.	2019	Ghana, Myanmar, Nigeria, Zambia	NVI, DoFs, FAO, NAs
	The epidemiological tool and global database on tilapia health are widely available and used within focal and scaling countries.	2022	FISH focal countries and scaling countries	NVI, DoFs, NAs
Diagnostic tools				
1.2.1 Develop early warning tools through pathomicrobiome research.	Early warning tools are field tested.	2018–2019	Bangladesh	Cefas, UoE
1.2.2 Research the development of point of care (PoC) tools and procedures for tilapia pathogens.	PoC tools are available for the farmers to use.	2018–2019	Bangladesh, Egypt	UoS, Cefas,
1.2.3 Develop novel and rapid diagnostic tools for tilapia diseases.	More farmers are using rapid diagnostic tools.	2018–2019	Bangladesh, Egypt, Malaysia	Cefas, UoS, CSIRO, MU
1.2.4 Study genetic diversity of TiLV and establish a new polymerase chain reaction (PCR) method for detection.	Research communications are published.	2018–2019	Thailand	MU

Key Activities	Key Scaling Milestones	Period	Geography	Partners
1.2.5 Develop non-lethal TiLV detection techniques, tools and protocols.	More accurate TiLV detection technique is available.	2018–2020	Malaysia	Cefas, MU, CSIRO
1.2.6 Build capacity of national partners in focal and scaling countries for wider adoption and use of early warning and rapid diagnostic tools.	National capacity on health management is improved.	2019–2021	Bangladesh, Egypt, Myanmar, Ghana, Zambia	UoS, Cefas, MU, CSIRO, NAs, NUs
	Other focal and scaling countries have adopted and conducted national tilapia health assessment surveys, using novel diagnostic techniques, web-based information and experience from pilot countries.	2021–2022	Ghana, Myanmar, Nigeria, Zambia	Cefas, NVI, MU, DoFs, NAs
Output 2: Integrated fish health management packages for improved fish strains				
Vision: Widely integrate management and production practices in the form of BMPs and farm-level biosecurity programs for implementation in focal and scaling countries by 2022.				
2.1 Design and conduct epidemiological and farming practice studies to identify risk factors for tilapia farming systems in focal countries.	Mortalities are reduced and production is increased in farming systems.	2018	Bangladesh, Malaysia, Egypt	WU, NVI, DoFs
2.2 Design BMPs for reducing the risks of diseases in tilapia at hatchery, nursery and farm levels.	Income and yield are increased.	2018–2019	Bangladesh, Egypt, Malaysia	WU, NVI, DoFs
2.3 Field test BMPs and farm level biosecurity programs.	More farmers are using BMPs in their production systems.	2019	Bangladesh, Egypt, Malaysia	WU, NVI, DoFs
2.4 Hold capacity and awareness building activities in focal and scaling countries to increase adoption and use of BMPs.	Farmer capacity and knowledge on aquatic health management is increased.	2021–2022	Ghana, Myanmar, Nigeria, Zambia	FAO, DoFs, NAs

Key Activities	Key Scaling Milestones	Period	Geography	Partners
Output 3: Knowledge on fish health and genetic interactions to inform future fish breeding programs				
Vision: Generate sufficient research knowledge for inclusion of special traits in WorldFish tilapia breeding programs by 2022.				
3.1 Discuss, design, develop and mobilize resources for conducting research toward the development of genetically improved varieties of tilapia resilient and resistant to diseases.	Peer reviewed research papers are published.	2018–2019	Malaysia, UK, Australia	RI, CSIRO
3.2 Conduct laboratory and field research to understand the differences in susceptibility of different strains of tilapia to TiLV.	Scientific knowledge is improved on disease resistance and genetics in tilapia.	2019–2022	Malaysia, UK, Australia	RI, CSIRO
3.3 Discuss, design, develop and mobilize resources for mapping the TiLV genome.	Scientific knowledge is improved on disease resistance and genetics in tilapia.	2018–2019	Malaysia, UK, Australia	CSIRO, RI
3.4 Hold research workshops to identify traits and knowledge to include in WorldFish GIFT breeding programs.	New traits of GIFT tilapia are included in WorldFish research program.	2021–2022	Malaysia, UK, Australia	CSIRO, RI

Annex 3. Crosscutting components of FISH

Activities	Key Scaling Milestones	Period	Geographies	Partners
Output 4: Developing human capacity				
Vision: Build human capacity in focal and scaling countries for tilapia health management by 2022.				
4.1 Train field staff on the diagnosis and use of novel diagnostic tools for detecting TiLV and other important diseases of tilapia.	Health management is improved and mortality reduced in farming systems.	2018–2019	Bangladesh, Zambia	MU
4.2 Train tilapia hatchery staff on biosecurity maintenance and improvement.	Tilapia hatchery mortality is reduced.	2018–2020	Bangladesh, Ghana, Myanmar, Nigeria, Zambia	NAs
4.3 Train trainers on molecular diagnostics.	More trained diagnosticians are providing health services to small-scale farmers.	2018–2020	Bangladesh, Ghana, Myanmar, Nigeria, Zambia, Egypt	CSIRO
4.4 Build awareness programs on the benefits of fish vaccination in tilapia farming.	Small-scale farmers are using vaccines in aquaculture.	2018–2020	Bangladesh, Egypt, Malaysia	MSD, FVG
4.5 Create PhD research programs, internships and post-doctoral fellowships on tilapia health management and biosecurity.	More qualified national researchers are conducting tilapia health research.	2018–2020	Global	Cefas, CSIRO, MU
Output 5: Producing community resources				
Vision: Produce and make sufficient community resources available for stakeholders to benefit from improved tilapia farming by 2022.				
5.1 Prepare and disseminate a tilapia hatchery biosecurity manual.	More farmers are using biosecurity protocols with reduced farm mortality.	2018–2019	Bangladesh, Egypt, Myanmar	DoFs
5.2 Develop local language translation and publication of tilapia BMPs through FISH research.	More guidance material is available for small-scale farmers on aquatic health.	2018–2019	Bangladesh, Egypt, Myanmar	DoFs
5.3 Develop a manual and standard operating procedures for biosecure production of the GIFT and Abbassa strains.	GIFT and Abbasa stains of tilapia are farmed using more biosecure procedures.	2018–2019	Malaysia, Egypt	DoFs
5.4 Develop codes of practice and protocols for biosecure dissemination of GIFT and Abbassa strains.	Survival in production systems is improved.	2019	Global	All partners
5.5 Create a field diagnostic guide for major diseases of tilapia.	More farmers are using field diagnostic guides to reduce disease impacts.	2018–2019	Global	MU, NUs
5.6 Develop global health assessment and surveillance tools.	Focal country experiences are scaled to other geographies.	2018–2019	Global	NVI, FAO, World Bank

Activities	Key Scaling Milestones	Period	Geographies	Partners
5.7 Create digital resources for supporting diagnosis.	A database is developed.	2018–2019	Global	Cefas
5.8 Develop bio-banks and a digital repository of material to support surveillance, impact assessments and disease diagnosis.	Virtual surveillance and diagnostic tool is available for small-scale farmers worldwide.	2020–2022	Global	All partners
Output 6: Engaging private sector				
Vision: Collect evidence of private sector engagement in scaling disease prevention strategies and tools in WorldFish focal and scaling countries by 2022.				
6.1 Conduct research into further improvement of TiLV and *Steptococcus* vaccines.	Peer reviewed research communications are published.	2018–2019	Bangladesh, Egypt	MSD
6.2 Field test TiLV and *Streptococcus* vaccines.	Small-scale farmers have better awareness on vaccination.	2019–2020	Bangladesh, Ghana, Myanmar, Nigeria	MSD
6.3 Design and implement commercialization strategies for health management tools such as TiLV and *Streptococcus* vaccines, rapid diagnostic kits, etc.	Small-scale farmers are using vaccines in aquauclture.	2019–2022	Bangladesh, Ghana, Myanmar, Nigeria, Zambia	MU, CSIRO, MSD, Skretting
6.4 Design and implement integrated tilapia health management strategies.	Small-scale farmers are using health management strategies including vaccination.	2019–2022	Bangladesh, Ghana, Myanmar, Nigeria, Zambia	FVG, Benchmark
6.5 Investigate fish-born trematode infections and their human health implications.	Research is published.	2019–2020	Myanmar	FVG, Benchmark
Output 7: Influencing policies				
Vision: Operationalize national aquatic animal health management strategies in WorldFish focal and scaling countries by 2022.				
7.1 Hold national workshops, meetings and discussions on creating enabling and conducive policy environments for better biosecurity and health management.	Some changes into relevant national policies are evident.	2018–2022	Bangladesh, Egypt, Ghana, Myanmar, Nigeria, Zambia	DoFs, NAs, FAO, World Bank
7.2 Allow advanced research findings arising out of global tilapia health research partnerships to feed into global policy discussions, such as FAO's Progressive Management Pathway (PMP), OIE's One Health, Antimicrobial Resistance (AMR) issues, etc.	More peer review research papers are published and direct engagement of WorldFish on health management discussions with global partners is increased.	2018–2022	Bangladesh, Egypt, Ghana, Myanmar, Nigeria, Zambia	FAO, World Bank, all partners

Photo credit: Backcover, Kate Bevitt/WorldFish

www.fish.cgiar.org

100% RECYCLED

WorldFish

RESEARCH PROGRAM ON Fish

CGIAR