



Technical Report

Improving the technological foundations for sustainable aquaculture

Reporting period

September 2016 – December 2017

Project information and resources

Project title:	Improving the technological foundations for sustainable aquaculture
Implementing Partner(s) and local Partner(s)	Implementing partner: WorldFish <u>Local Partner(s)</u> : The Bangladesh Fisheries Research Institute (BFRI), Department of Fisheries (DOF) Bangladesh and selected private sector and public sector hatcheries and farms in Bangladesh. The Centre Laboratory for Aquaculture Research (CLAR) and selected private sector and public sector hatcheries and farms in Egypt. The Ministry of Fisheries in Mozambique. Ministry of Agriculture, Livestock and Fisheries. Kenya Agricultural Research and Livestock Organization. The Department of Fisheries (DOF) Malaysia and Universiti Sains Malaysia.
Responsible Persons	Principal Scientist, Sustainable Aquaculture, WorldFish
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Project Starting date	Project completion date
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Approved Total Budget	USD 1,500,000
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1. Background and objectives

Robust fisheries and aquaculture are vital to reducing hunger and poverty and improving nutrition for millions in the developing world. Currently, overfishing, industrial development and agricultural pollution have reduced wild fish stocks and aquaculture is growing to meet expanding global fish demand. Fish supply-demand research suggests that aquaculture production may need to double by 2030 to meet the world's growing demand, and need, for a supply of affordable, safe and nutritious fish. Projected fish supply deficits are large globally, but Africa and Asia will face particularly significant shortfalls unless investments are made in sustainable aquaculture growth. Aquaculture, in particular, has tremendous potential to promote food and nutrition security, increase incomes, be an environmentally sustainable supply of animal source food, and meet the global demand for fish. Sustainable intensification, yield improvements and growth in aquaculture are reliant on a combination of factors including improved fish seed, better fish feeds, fish health management and improved farming technologies. The current project builds on the knowledge and experiences on genetic improvement, and dissemination activities across Asia and Africa, including earlier projects funded by IFAD/EC, providing a combination of support to accelerating fish breeding and improvement programs and increasing the impact dissemination of improved fish breeds to national breeding programs and farmers. Africa receives special attention in this grant. More focus is also given to scaling up of existing breeding programs and ensuring effective dissemination to farmers, particularly small-scale fish farmers. The project is an important investment in aquaculture growth, and ultimately the lives of millions who rely on fish for food, income and nutrition

2. Project goal and objectives

The goal of the project is to ensure that improved fish strains in target systems are widely available, and used sustainably and equitably, providing nutritious, affordable food and income for the poor. The project objectives are to:

- a) Maintain and have available more productive and adaptable strains of fish that fit the needs of target production systems using conventional breeding and genomic technologies; and
- b) Improve systems of delivery and assess use and performance of these improved fish strains.

3. Outputs and activities

This report presents the activities performed during Sep 2016 – Dec 2017 and progress of the Improving the technological foundations for sustainable aquaculture project. The extended period of deliberation from the initial proposal to funding has meant that the particular generations identified in the activities and logframe for development in the project were achieved in earlier years and additional, later generations will be developed in the project. The focus of this first year was on maintaining the breeding programs and on preparatory activities, building the contacts and developing the institutional foundations for later work on breeding and dissemination in country.

1) Output 1

More productive and adaptable strains of fish for aquaculture in Asia and Africa that fit the needs of target production systems using conventional breeding and genomic technologies.

Objectively verifiable indicators:

- Generation 15 of the improved strain of Nile tilapia (Abbassa strain) in Egypt will have been developed and previous generations released to aquaculture producers.
- A program of genetic improvement for African catfish is active
- Breeding programs for genetically improved fish in Asia will have been successfully continued with development of generation 16 of the GIFT Tilapia at WorldFish, Malaysia
- Genetic improvement program for three carp species in Bangladesh will have been designed and initiated.
- Support, training and advice will have been provided to national partners designing and implementing fish genetic improvement programs in Bangladesh, Kenya and Mozambique.

a. Activity 1.1

Development of improved fish strains of tilapia, carp, and African catfish. This cluster of activities involves continued maintenance and further development of improved fish strains of tilapia, carp, and African catfish in selected core countries (Bangladesh, Egypt and WorldFish HQ Malaysia). In each country, activities will include selection of fish for breeding, mating and grow-out in controlled conditions, leading to assessment of on-station performance, prior to selecting the new generation of fish for breeding. This cycle of production has to be maintained unbroken for the success of the programs. Particular timing of each of the operations depends on the species and their geographical location since breeding can occur at different times of the year depending on environment.

Key achievements related to Activity 1.1 have been 1) the successful maintenance and production of the next generations of each of the core breeding programs of GIFT and red tilapia in Malaysia and the Abbassa tilapia strain in Egypt in 2016, in particular the production of generation 15 of Abbassa strain and generation 16 of the GIFT Malaysia strain, 2) the continued rearing of the first selected generation of Rohu carp in Bangladesh after its successful production in June-July 2016 and 3) the development of base breeding populations of Catla and Silver Carps in May-July 2017. All the carp programs have established approximately 150-200 family breeding programs which make them among the largest pedigreed fish genetic improvement programs worldwide.

Difficulties in achieving further continued improved performance of the fish in two programs (catfish in Egypt and red tilapia in Malaysia) have been identified and appropriate assessments are underway. In particular the growth and reproductive

performance of the African Catfish program is very poor and new strategies are being developed to re-invigorate the strains.

Several further technical advances designed to improve the efficiency and accuracy of the breeding programs. The development of molecular markers for carps and tilapia has allowed their application to assist avoid inbreeding in the development of the base populations for Rohu, Catla and Silver carp in Bangladesh and the management of inbreeding in the Abbassa strain in Egypt. Molecular markers that allow the discrimination of different tilapia strains to assist measurement of adoption and on-farm performance in farming systems have also been developed. Methods to rear Rohu carp in hapas have been successfully developed and tested demonstrating that, while growth is slower initially, this is compensated by faster growth later in the rearing cycle. Use of this technique will improve the efficiency of breeding programs for this species and was used successfully in the Bangladesh program for all three species Rohu, Catla and silver carps.

A significant development has been the recruitment of two postdocs in association with CGIAR initiative of gender sensitive breeding programs, one based in Egypt and one based in Malaysia, working on end-user requirements through a gender perspective and sex-disaggregated impacts of improved breeds.

Twelve papers have been published from this work and several others accepted or under review for publication. These are listed in Annex 1.

b. Activity 1.2

Technical assistance to NARS in Bangladesh, Mozambique and Kenya for fish genetic improvement programs. This cluster of activities involves technical assistance to NARS in Bangladesh, Mozambique and Kenya for the development and establishment of fish genetic improvement programs, through training, advisory services and development of supporting training manuals and tools. Special attention will be given to assisting NARs in selection and preparation of mating lists. In Mozambique, there are no fish genetic improvement programs; the project will provide a baseline assessment of the requirements for establishing such a program. A workshop for NARs partners in Asia and Africa will be held in Q4 of year 2 to share knowledge and experience.

Technical assistance has been provided in the reporting period to DoF Bangladesh on hatchery genetic management. Negotiations have begun for re-location of the carp genetic improvement programs on Department of Fisheries Bangladesh controlled sites. This is to provide greater security of tenure for the program but also begin integrating activity with DoF Bangladesh for future release and dissemination of improved strains with the first release planned being that of Rohu in 2022. General technical advice was provided to tilapia breeding nuclei established in the last four years in Bangladesh and through training in collaboration with University of Stirling of a Bangladeshi PhD student working on sex-determining genes in tilapia who submitted her thesis in Q4 of 2016. Three DoF staff from Mozambique were provided training on breeding at Abbassa 2016. Visits to Kenya including the Government breeding program at Sagana and private sector sites near Kisumu were made in 2016 to assess the genetic resources in Kenya. Genetic advice was provided to Jewlet hatcheries in Kenya including sampling broodstock for later molecular genetic analysis.

Genetic services were provided by the Fish Breeding and Genetics group in WorldFish Penang to WRI in Ghana and RGCA and ICAR in India to develop mating lists and to DoF Myanmar, DoF Timor Leste. In addition specific training was provided to 3 PhD students from Tanzania during the AgriFoSe workshops. In the case of Malawi the extant shiranus breeding program was visited to assess its current status as reports had been received that the program had ceased. Having established that the population still survived further financial support was provided for that program and in addition to the tilapia and freshwater prawn programs in Vietnam in August 2017. Strong partnerships with DoF Malaysia, and CLAR in Egypt and with DoF in Bangladesh which are a key factor in the successful implementation of the core breeding programs in each country have been maintained. A major international conference was held in Egypt organized by WorldFish and CLAR in November 2017 allowing exchange of technical information on aquaculture in the region. Additional relationships interacting on breeding programs or in scaling have been established including, DoF Kenya, DoF Tanzania, DoF Zambia, DoF Ghana, Lilongwe University (Bunda College) Malawi, Farm Africa (NGO) in Kenya and in Asia with DoF Timor Leste and DoF Myanmar.

2) Output 2

Delivery systems for genetically improved fish and assessments of the use and performance of these improved fish strains.

Objectively verifiable indicators:

- Analysis of at least two country delivery systems completed (Bangladesh, Egypt)
- In–depth surveys of on-farm performance of improved fish strains in Egypt and Bangladesh will have been conducted.
- Nucleus breeding sites strengthened with enumerated output of fry to farmers and preliminary on-farm performance data obtained for at least one sub-Saharan country.
- Data sets available for these.

c. Activity 2.1

Country level assessments and field studies of delivery systems and on-farm performance in Asia and Africa. This cluster of activities involves country level assessments and field studies of delivery systems and on-farm performance, production efficiency and yield gap in different farming systems, covering all selected countries in Asia and Africa. Activities will include development and dissemination of ICT applications for assessing impacts of improved strains and dissemination activities of improved strains. Tablet and cell phone based applications have been developed and tested in Egypt and Bangladesh for the collection of information of on farm performance and dissemination. These will be adapted to additional languages in the first half of the project and training provided in their use in additional countries.

Tablet and cell phone based applications ICT applications have been developed and tested in Egypt and Bangladesh for the collection of information of on farm performance

and dissemination. These surveys have been translated into Arabic and Bangla to date and surveys of on-farm performance, production efficiency and yield gap of improved tilapia strains in Bangladesh and Egypt were completed.

Data collection for an analysis of delivery systems began. As part of this work one peer reviewed publication on historical Bangladesh tilapia hatchery characterization was published (see Annex 1).

Data analysis of the Bangladesh material began in August 2017 but revealed issues of quality control preventing their use in full analyses of on-farm performance. This survey will be repeated in 2018. However, the data did show that genetically improved GIFT comprised 73% of the pond area stocked in the three regions of Bangladesh surveyed (Dhaka, Khulna and Rangpur) so demonstrating good adoption since its release in 2013.

The Egyptian data were sound and showed that the Abbassa strain had shown strong adoption in the areas surveyed with 40% of the ponds surveyed being stocked with Abbassa strain (see Annex II). The survey included farms from all of the four main aquaculture producing regions in Egypt. Furthermore a comparison on the growth rate, food conversion ratio (FCR) and profitability showed greater growth (12%), FCR (13%) and profitability (48%) of the Abbassa strain compared with existing farmed strains.

d. Activity 2.2

Awareness raising and capacity building on delivery and use of improved fish strains.

This cluster of activities involves raising awareness and capacity building on delivery and use of improved strains, through provision of training and development of guidelines and manuals. Project workshops will be held to support planning and capacity building, with a larger workshop planned for Africa during year 2 (Q4) to share knowledge and experience on fish breeding among participants in Africa, as well as partners in Asia. AU/IBAR, ASARECA and FARA are expected to partner in the workshop to ensure wider dissemination of project experiences. This work will include assessment of strategies for broader dissemination of information on improved strains and their use to farmers and other value chains actors (e.g. radio, community activities).

A key meeting in October 2016 was the AgriFoSe workshop in Tanzania which led to the “Zanzibar Declaration” – a strategy for joint activity between Tanzanian Institutions engaged in Aquaculture and Fisheries and external agencies including WorldFish. This work was followed up by a meeting with senior representatives from the Tanzanian Fisheries Research Institute and Sekoine University 30 Aug – 1 Sept 2017 in Penang to plan Aquaculture activities there, including genetic resource management, over the next six years.

A successful workshop held in collaboration with SADC and including representation from African Union and EAC as part of the World Aquaculture Society Conference in Cape Town in June 2017 led to the formation of a SADC Technical Working Group on Genetic Resources. This platform was successfully established with the first SADC Technical Working Group on Genetic Resources meeting in Zambia in October 2017 supported in part by the present grant. The meeting was held jointly with FAO and used to road test the FAO guidelines for AqGR management for input to the COFI Advisory

Group meeting later that month in Rome attended also by representatives from EAC and the Lake Victoria Fisheries Organization. The meeting in September 2017 in Lusaka extended the membership to the EAC and FAO to become the SADC-WorldFish-FAO-EAC Platform for genetics and Biodiversity management in Aquaculture.

In July 2017 and September/October 2017, visits were made to Zambia and Malawi to assess respective Departments of Fisheries and University sites for future breeding programs and to discuss the activities needed to undertake appropriate planning for future genetic improvement programs. In Bangladesh, broader training of farmers and hatchery owners in relation to use of high quality seeds and fingerlings was undertaken through the AIN program and reached several thousand farmers. A list of Conferences and Workshops attended where awareness of genetic improvement was raised are given in Annex 2.

An emerging issue of considerable importance for the development of genetic resources is that associated with Access and Benefit sharing and the implementation of the Nagoya Protocol. The potential impact of these developments on aquaculture is little understood and WorldFish commissioned an expert legal review of available literature on this topic, which was completed in December 2017, and an associated scoping document to identify additional work needed to better understand legislative processes in key aquaculture countries in which WorldFish operates. The larger report is currently under revision to make it suitable for publication to a general audience as this will be a valuable resource to assist understanding by industry and government of “Global ABS Regimes and Their Relevance to Aquaculture”, so that their activities are compliant with new and emerging legislation. A workshop on Access and Benefit sharing was also attended in December 2017 (see Annex 2):

4. Challenges

A number of staff changes led to difficulties in meeting workloads and led to some delays in activities. The disease, tilapia lake virus (TiLV) is emerging worldwide and will have a considerable effect on the need to maintain biosecurity in all our sites and may impact on dissemination activities until its effects are clearer.

In Egypt: TiLV is emerging in Egypt making the biosecurity improvements planned over last year more critical to achieve. Disease testing on site has been made and will continue. Improved procedures and infrastructural improvements such as greenhouse covering to juvenile rearing areas have been made. These delayed family production this year. Managing these necessary changes with the continuing production of families and experiments will remain challenging for some time.

Bangladesh: As a result of poor feeding by the contracted farmer only 25 families could be produced for Catla because of the poor condition of the parent fish. Management of the fish was regained by WorldFish and the remaining base population was produced in May – June 2017.

Kenya: No major issues. Visits were made to KEMFRI breeding programs and to those in the private sector to start planning the best strategy for improvement in Kenya.

Malaysia: Experimental capability at WorldFish HQ has been improved with the addition of small scale aquarium facilities that will better allow estimation of key traits such as feed efficiency and enable fish nutrition work. The DoF Station at Jitra is being upgraded to improve, water quality, operations and biosecurity. As a result there are scheduling conflicts for remedial works, the key operations of the breeding program and experiments. These are being addressed through the joint Technical Committee on Research Collaboration between DoF Malaysia and WorldFish to minimize impact while these positive changes are being made. The threat of disease in Malaysia is also a clear and growing threat to the genetic improvement programs there.

5. Work plan

Output/Activity	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
<i>Output 1: More productive and adaptable strains of fish for aquaculture in Asia and Africa that fit the needs of target production systems using conventional breeding and genomic technologies</i>												
1.1 Improved fish strain development												
<u>Tilapia (WF HQ)</u>												
Selection												
Mating												
Growout												
<u>Tilapia (Egypt)</u>												
Selection												
Mating												
Growout												
<u>Catfish (Egypt)</u>												
Selection												
Mating												
Growout												
<u>Carp (Bangladesh)</u>												
Selection												
Mating												
Growout												
1.2 Technical assistance												
Selection and mating lists for NARs												
Supervision												
Workshops on fish breeding programs												
<i>Output 2: Delivery systems for genetically improved fish and assessments of the use and performance of these improved fish strains.</i>												
2.1 Dissemination and on-farm performance of improve strains												
<u>ICT apps for assessment</u>												
Developing ICT apps												
ICT apps distributed to Bangladesh and Egypt												
ICT apps distributed to Kenya												
<u>Dissemination of improved tilapia in:</u>												
Egypt and Africa												
Bangladesh												

On-farm performance assessed												
Training for data collection staff												
Ongoing general advice												
2.2 Awareness training for famers and VC participants on delivery systems												

6. Conclusion

The principal activities have been achieved or are on-track for completion as outlined. The core improved fish breeding programs have all been maintained with continued selection for greater growth and are well managed with respect to inbreeding. Difficulties in achieving further continued improved performance of the fish in two programs (catfish in Egypt and red tilapia in Malaysia) have been identified and appropriate assessments are underway. Research on additional traits for inclusion in the successful programs is progressing with experiments assessing the effects of fish social behavior, reproduction and an important new approach relating to selection for feed efficiency has been introduced. Molecular tools have been successfully developed and used to assist inbreeding management, and identification of tilapia strains in farming systems in Bangladesh and the Philippines will be useful in the future in assessing new traits and the introduction of genomic selection. Additional support has been provided to Vietnam and Malawi for the breeding programs of tilapia and in the case of Vietnam freshwater shrimp. Analysis of the on-farm performance of the improved strains in Bangladesh was commenced. The base populations for genetic improvement programs for Catla and for Silver carp were successfully completed.

Technical advice was provided to NARS and private sector actors in several countries including Zambia, Malawi and the key targets of Bangladesh, Kenya and Mozambique, including supervision and training of postgraduate students.

A major step in developing greater awareness of the importance of genetic resources and the utility of genetic improvement programs was achieved through the development of a Platform for the discussion of these topics with key NARS partners associated with SADC through the SADC Aquaculture Working Group at the June 2017 WAS Conference in Cape Town. This was extended at the inaugural meeting in September 2017 in Lusaka to include the EAC and FAO to become the SADC-WorldFish-FAO-EAC Platform for genetics and Biodiversity management in Aquaculture.

7. Annex 1

Publications

Peer-reviewed

1. Lind, C.E., Dana, G.V., Perera, R.P. and Phillips, M.J. 2015. Risk analysis in aquaculture: A step-by-step introduction with worked examples. WorldFish Manual 2015-08. Penang, Malaysia: WorldFish.
2. De Verdal, H., Mekki, W., Lind, C.E., Vandeputte, M., Chatain, B., Benzie, J.A.H., 2016. Measuring individual feed efficiency and its correlations with performance traits in Nile tilapia, *Oreochromis niloticus*. *Aquaculture*. 468, 489-495.
3. Khaw, H.L., Ponzoni, R.W., Yee, H.Y., Aziz, M.A., Mulder, H.A., Marjanovic, J. and Bijma, P. 2016. Genetic variance for uniformity of harvest weight in Nile tilapia (*Oreochromis niloticus*). *Aquaculture* 451:113–120.
4. Khaw, H.L., Ponzoni, R.W., Yee, H.Y., Aziz, M.A., Bijma, P. 2016. Genetic and non-genetic indirect effects for harvest weight in the GIFT strain of Nile tilapia (*Oreochromis niloticus*). *Aquaculture* 450: 154-161.
5. Marjanovic, J., Mulder, H.A., Khaw, H.L., Bijma, P., 2016. Genetic parameters for uniformity of harvest weight and body size traits in the GIFT strain of Nile tilapia. *Genetics Selection Evolution* 48: 41.
6. Said, M. M. and Mekki, W. 2016. Genetic Evaluation of Growth and Survival at 6 Weeks old Fry of Egyptian Nile Tilapia (*Oreochromis niloticus*) between improved Abbassa and Commercial Manzala strains in a diallel crossing. *Egyptian J. Anim. Prod.* (2016) 53(2)141-146.
7. Bentsen, H.B., Gjerde, B., Eknath, A.E., de Vera, M.S.P., Velasco, R.R., Danting, J.C., Dionisio, E.E., Longalong, F.M., Reyes, R.A., Abella, T.A., Tayamen, M.M., Ponzoni, R.W. 2017. Genetic improvement of farmed tilapias: Response to five generations of selection for increased body weight at harvest in *Oreochromis niloticus* and the further impact of the project. *Aquaculture*, 468: 206-217.
8. De Verdal, H., Komen, H., Quillet, E., Chatain, B., Allal, F., Benzie, J.A.H., Vandeputte, M. 2017. Improving feed efficiency in fish by selective breeding: a review. *Reviews in Aquaculture* doi:10.1111/raq.12202
9. Lind, C. E., Kilian, A. and Benzie, J. A. H. 2017. Development of Diversity Arrays Technology markers as a tool for rapid genomic assessment in Nile tilapia, *Oreochromis niloticus*. *Animal Genetics* 48: 362–364. doi:10.1111/age.12536
10. Hickey, J.M., Chiurugwi, T., Mackay, I., Powell, W. and Implementing Genomic Selection in CGIAR Breeding Programs Workshop Participants [incl. Benzie, J.A.H.] 2017. Genomic prediction unifies animal and plant breeding programs to form platforms for biological discovery. *Nature Genetics* 49:1297-1303. doi: 10.1038/ng.3920.
11. Mekki, W., Barman, B.K., Kohinoor, A.H.M. and Benzie, J.A.H. (2017) Characterization of mono-sex Nile tilapia (*Oreochromis niloticus*) hatcheries in Bangladesh. *Journal of Aquaculture Research & Development* 8: 498. doi: 10.4172/2155-9546.1000498

12. Pillai, B.R., Lalrinsanga, P.L., Ponzoni, R.W., Khaw, H.L., Mahapatra, K.D., Mohanty, S., Patra, G., Naik, N., Pradhan H., and Jayasankar, P. 2017. Phenotypic and genetic parameters for body traits in the giant freshwater prawn (*Macrobrachium rosenbergii*) in India. *Aquaculture Research*. 48(12): 5741-5750. [doi/10.1111/are.13397](https://doi.org/10.1111/are.13397)

Non-peer reviewed papers

Agha, S., Mekkawy, W., Ibanez-Escriche, N., Kumar, J., Mandal, A., Lind, C.E., Benzie, J., Doeschl-Wilson, A.B. 2016. Genotype by environment interaction and genetic heterogeneity of environmental variance of body weight at harvest in genetically improved farmed tilapia (*Oreochromis niloticus*) reared in 3 different countries. *Journal of Animal Science*, 94 (Suppl. 4): 19-20.

Publications in preparation

Accepted

Agha, S., Mekkawy, W., Ibanez-Escriche, N., Kumar, J., Mandal, A., Lind, C.E., Benzie, J.A.H., Doeschl-Wilson, A.B. 2017. Breeding for robustness: Investigating the macro- and micro-environmental sensitivity for Genetically Improved Farmed Tilapia (GIFT) (*Oreochromis niloticus*). *Animal Genetics*.

Submitted

Murphy, S., Cole, S., McDougall, C., Dickson, M. A systematic literature review of fish and fish trait preferences of retailers and consumers using a pro-poor, gender lens: Implications for fish breeding in Egypt and Zambia. *Aquaculture*.

Ravakarivelo, M., Benzie, J.A.H., Mikolasek, O., Pepey, E., de Verdal, H. Genetic variation in farmed and feral populations of Nile tilapia, *Oreochromis niloticus*, in Madagascar.

Mekkawy et al. A complete diallel cross analysis for growth, at stocking and harvest, and survival from stocking to harvest using two nursery systems for the fry of Rohu carp (*Labeo rohita*).

Mekkawy et al. Estimation of the genetic correlations of growth and survival of Rohu carp (*Labeo rohita*) in mono and polyculture systems.

De Verdal et al. Quantifying the genetic parameters of feed efficiency in Nile tilapia.

In preparation

Mehar et al. Gender preferences of, and impacts on, women and men fish farmers regarding genetically improved fish: a systematic literature review.

Taslina, K., Taggart, J.B., Wehner, S., de Verdal, H., Benzie, J.A.H., Bekaert, M., McAndrew, B.J., Penman, D.J. Analysis of sex determination in genetically improved farmed tilapia.

8. Annex 2

Workshops / conferences attended and papers presented

Workshops / conferences attended

2016. SPIA Impact of widely-adopted CGIAR research-related innovations: Mid-term workshop. 30 July, Boston, USA.

2016. Agriculture for Food Security (AgriFoSe) Workshop on tilapia genetic improvement. 1-5 August, Penang, Malaysia.

2016. 67th Annual Meeting of European Association of Animal Production (EAAP), 28 August – 4 September, Belfast, UK.

2016. Stakeholder workshop on tilapia aquaculture in Tanzania and the way forward. 5-7 October, Zanzibar, Tanzania.

2016. Gender, Breeding and Genomics Workshop. 18-21 October, Nairobi, Kenya.

2017. EURASTIP, Horizon 2020. Kick-off meeting 5-10 January, Ghent and Brussels, Belgium.

2017. Plant Animal Genome Conference Aquaculture Workshop 14 January, San Diego, USA.

2017. CGIAR Excellence in Breeding Platform Workshop. 16, 18 January, San Diego, USA.

2017. CGIAR Excellence in Breeding Platform Expert Advisory Group Meeting. 12-15 March, Soesterberg, The Netherlands.

2017. Joint SADC-WorldFish Working Group on Aquaculture, Cape Town, South Africa, 26 June 2017

2017. World Aquaculture Society Meeting. June 26-30, Cape Town, South Africa.

2017. Genetic Improvement Meeting. July 4, Lilongwe University of Agriculture and Natural Resources (LUANAR), Bunda Campus, Lilongwe, Malawi.

2017. Conference on Impacts of International Agricultural Research: Rigorous Evidence for Policy. Standing Panel on Impact Assessment (SPIA) of the CGIAR's Independent Science and Partnership Council (ISPC) and the CGIAR Research Program on Policies, Institutions and Markets (PIM). July 6-8, World Agroforestry Centre in Nairobi, Kenya.

2017. Meeting on National Fish Breeding Programme. October 13, Malawi College of Fisheries, Mpwepwe, Mangochi, Malawi.

Papers presented at workshops/conferences

Agha S., Doeschl-Wilson, A., Mekkawy, W., Lind, C., Benzie, J.A.H., Ibanez-Escriche, N. (2016). Genetic variation in microenvironmental plasticity of body weight in Tilapia (*Oreochromis niloticus*). In: the 67th Annual Meeting of European Association of Animal Production (EAAP), Belfast, The UK, 28th August-4th September.

Benzie J.A.H., Lind, C.E. (2016) Adoption of Genetically Improved Farmed Tilapia (GIFT) twenty years after release to industry: A GIFT that keeps on giving? SPIA Impact of widely-adopted CGIAR research-related innovations: Mid-term workshop. 30 July, Boston, USA.

Benzie J.A.H., Thilsted, S., McDougall, C. (2016) Mola: Gendered preferences, breeding and genetics of a nutritious small fish. Gender, Breeding and Genomics Workshop. 18-21 October, Nairobi, Kenya.

Benzie, J.A.H. (2017) The importance of genetically improved tilapia for aquaculture. Aqua Aquaria Nehru Maiden, Mangalore India. 14-16 May 2017.

Benzie, J.A.H. (2017) Options for Genetic Improvement in Aquaculture for Africa. Joint SADC-WorldFish Working Group on Aquaculture, Cape Town, South Africa, 26 June 2017.

Benzie, J.A.H. (2017) Lessons on breeding programs from WorldFish experience. SADC Technical Working Group on Genetic Resources Meeting, Lusaka, Zambia, 25-30 September 2017.

Benzie, J.A.H. (2017) Approaches to genetic improvement, management, production and effective dissemination of quality fish seed. SADC Technical Working Group on Genetic Resources Meeting, Lusaka, Zambia, 25-30 September 2017.

Benzie, J.A.H. (2017) Genetics and aquaculture development. First International Conference and Exhibition on Sustainable Development, Cairo, Egypt. 20-22 November 2017.

Benzie, J.A.H. (2017) Aquaculture and access and benefit sharing in the CGIAR. Genetic Resources and Information Workshop, Canberra, Australia. 6 December 2017.