Norway

WorldFish 50 YEARS 1975-2025

CGIAR

Final technical report

Increased Sustainability in the Aquaculture Sector in SSA through Improved Aquatic Animal Health Management project

December 1, 2020–March 31, 2025

Veterinærinstituttet
Norwegian Veterinary Institute

UNIVERSITY OF GHANA

UNIVERSITY OF NAIROBI

Increased Sustainability in the Aquaculture Sector in SSA through Improved Aquatic Animal Health Management project

Citation

This publication should be cited as: WorldFish. 2025. Increased Sustainability in the Aquaculture Sector in SSA through Improved Aquatic Animal Health Management project. Penang, Malaysia: WorldFish. Technical report: 2025-16.

Acknowledgments

The Increased Sustainability in the Aquaculture Sector in Sub-Saharan Africa through Improved Aquatic Animal Health Management (Norad grant number: RAF-19/0051) was jointly led by WorldFish and the Norwegian Veterinary Institute (NVI), with financial support from the Government of Norway.

We extend our deepest gratitude to Dr. Mohan Chadag Vishnumurthy for his outstanding leadership, from the project's inception in December 2020 until his retirement from WorldFish in early 2024. Following Dr. Mohan's retirement, Dr. David Verner-Jeffreys assumed leadership of the aquatic animal health team at WorldFish. We thank him for the guidance and expertise he brought to the project.

We warmly thank our project partners at the College of Basic and Applied Sciences (CBAS), University of Ghana (UoG), led by Dr. Sam Addo and his team—Dr. Sam Duodo, Dr. Eunice Konadu Asamoah, Dr. Winnie Sowah, Dr. Collins Duodu Prah and Dr. Angela Ayiku. We also acknowledge with appreciation our partners at the College of Agriculture and Veterinary Sciences (CAVS), University of Nairobi (UoN), led by Dr. Philip Nyaga and his team—Prof. Joyce Gichiku Maina, Dr. Paul Mbuthia, Dr. Karanja D. Njuguna, Dr. Isaac Mulei, Dr. Robert M. Waruiru, Prof. Samuel M. Githigia, Dr. Lucy Njagi, Prof. Mbuthia Paul Gichohi and Dr. Christine Minoo Mbindyo. We thank both partner institutions for their unwavering support and collaboration throughout the project.

We are sincerely grateful to our NVI colleagues, led by Dr. Edgar Brun and his team—Dr. Kofitsyo S. Cudjoe, Dr. Saraya Tavornpanich, Dr. Shimaa Elsayed M. Ali, Dr. Mona Jansen Dverdal, Dr. Jacob Zornu and Dr. Haakon Hansen—for their leadership, guidance and contributions. We also extend our sincere thanks to Laura Khor (WorldFish) for her leadership and close collaboration with NVI colleagues in supporting the training of the UoG and UoN teams to carry out the national epidemiological studies in Ghana and Kenya. Her dedication and passion were equally instrumental in the development of the online courses on the Learn.ink platform.

Special thanks go to the six master's students from the UoG—Abigail Amankwah, Kofi Ferni Anyan, Kwame Issifu, Mabel Ackah, Philip Kwasi Banini and David Narteh Batsa—and the seven master's students from the UoN—Ndegwa Joseph Macharia, Mercy Hamisi Matuma, Merceline Ndinda Ndambuki, Ageng'o Finnan Okoth, Jacob Munene Wainaina, Cidee Night Khaseke and Victor Omondi Ogweny. We thank them and their supervisors for their dedication and research, which has made a significant contribution to advancing aquatic animal health in Ghana and Kenya.

Finally, this project is the result of a dynamic collaboration among diverse partners, students and stakeholders—ranging from farmers, hatchery operators and policymakers to academics and international development agencies. We gratefully acknowledge their active participation, insights and contributions, all of which were instrumental to the project's success.

The contents of this publication are the sole responsibility of WorldFish and can in no way be taken to reflect the views of the Government of Norway. This final technical report was prepared by Dr. Jérôme Delamare-Debouteville, with valuable inputs from colleagues and by drawing on a range of materials and previous reports developed by project partners at the NVI, UoG and UoN.

Contact

WorldFish Communications and Marketing Department, Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas, Penang, Malaysia. Email: worldfishcenter@cgiar.org

Photo credits

WorldFish.

Table of contents

List of abbreviations

AAH	Aquatic animal health
AAHM	Aquatic animal health management
AARTC	Aquaculture Research and Training Center
AFRAQ	Africa Aquaculture
AGRF	Africa Food Systems Forum
AHA	Aquatic Health Africa
AMR	Antimicrobial resistance
AST	Antimicrobial susceptibility testing
CMS	content management systems
Cefas	Centre for Environment, Fisheries and Aquaculture Science's
FAIH	Fish for Africa Innovation Hub
FEHE	Fish epidemiology and health economics
ILRI	International Livestock Research Institute
MEL	Monitoring, evaluation and learning
MSc	Master of Sciences
NMBU	Norwegian University of Life Sciences
Norad	Norwegian Agency for Development Cooperation
NVI	Norwegian Veterinary Institute
OI	World Organisation for Animal Health
PCR	polymerase chain reaction
SSA	Sub-Saharan Africa
UoG	University of Ghana
UoN	University of Nairobi
WGS	Whole genome sequencing
WOAH	World Organisation for Animal Health

General information

Name of grant recipient	International Center for Living Aquatic Resources Management (ICLARM)
Norad agreement number	Norad project (RAF-19/0051)
Agreement period	December 1, 2020–March 31, 2025
Reporting period	December 1, 2020–March 31, 2025
In a short paragraph, please indicate how the Project is related to the UN Sustainable Development Goals (SDGs).	The research and education outputs under this project contributed directly to SDGs 1 (No poverty) and 2 (Zero hunger). Research related to antimicrobial resistance (AMR) contributed to SDG 3 (Good health and well-being). Women's involvement in all training courses conducted throughout the year and in MSc work under the project was relevant to SDG 5 (Gender equality). SDG 14 (Life underwater) was also relevant. Networking to improve access to technology and knowledge was an important way to share ideas and foster innovation. SDG 17 was also relevant to the project through research, educational and networking outputs 
Partners	• The Norwegian Veterinary Institute (NVI) • The College of Agriculture & Veterinary Sciences of the University of Nairobi (UoN) in Kenya • The College of Basic & Applied Sciences of the University of Ghana (UoG)

Executive summary

Executive Summary

The Norad-funded Aquatic Health Africa (AHA) project Increased Sustainability in the Aquaculture Sector in Sub-Saharan Africa through Improved Aquatic Animal Health Management was successfully carried out from December 1, 2020, to March 31, 2025, across Ghana, Kenya and other countries in Sub-Saharan Africa (SSA). The project was funded by the Norwegian Agency for Development Cooperation's (Norad) Aquatic Health Africa (AHA) project and led by WorldFish, in partnership with the Norwegian Veterinary Institute (NVI), the University of Ghana (UoG) and the University of Nairobi (UoN). The project aimed to improve the sustainability and resilience of aquaculture systems by strengthening the research capacity of aquatic animal health (AAH), expanding education and training programs, and building active regional networks. In line with its overarching goal, the AHA project achieved notable outcomes across three main areas: research, education and networking. In doing so, it directly benefitted government institutions, researchers, students and industry stakeholders in more than eight SSA countries.

Outcomes against project objectives:

- Improved research capacity was demonstrated by the quality and volume of student-led and institutional publications, the successful execution of disease surveillance studies, and widespread adoption of diagnostic tools and training resources.
- Education and extension capacity were expanded through new digital and physical training programs, enhancing AAH service delivery across multiple SSA countries.
- Regional knowledge sharing and collaboration were significantly strengthened through formal training cycles, student networks and strategic participation in global scientific and policy platforms.

Key achievements

Research and scientific innovation:

- A total of 13 MSc students (6 in Ghana, 7 in Kenya) were successfully supported, with 9 having graduated and the rest on track to finish by 2025.
- A total of 22 peer-reviewed scientific articles (10 by students and 12 by partner institutions) were published, exceeding the initial output goals and increasing the global visibility of African AAH research.
- Comprehensive epidemiological surveys were completed across 292 farms in Kenya and Ghana, providing solid data on farming practices, biosecurity and disease risk factors.
- An opinion paper was published promoting inland aquaculture to lessen environmental pressures on Lake Volta, contributing to regional policy discussions.

Education and capacity building:

- Seventeen interactive online courses were developed on the Learn.ink platform, reaching 757 learners, including 303 women, far exceeding the goal of 10 courses.
- More than 100 participants from 8 countries were trained through 7 intensive hands-on training cycles at the WorldFish Abbassa facility in Egypt.
- Additional in-country training covered basic epidemiology, outbreak investigation, molecular diagnostics and sequencing, with a total of 15 in- person training sessions delivered.
- Institutions in Ghana and Kenya received upgraded laboratory infrastructure, including a new wet lab at the UoN.

Networking and regional collaboration:

- Participation in 14 conferences and events across Africa, Asia and Europe, such as the Africa Aquaculture (AFRAQ) conferences from 2021 to 2024, the Africa Food Systems Forum (AGRF) in 2023 and the World Organisation for Animal Health (WOAH) expert workshops, resulted in active regional and international engagement.
- Two national closure workshops and one midterm review meeting improved stakeholder engagement and planning for sustainability.

- An expanding network of trained professionals, supported by shared tools, publications and a centralized digital repository, established a strong foundation for ongoing knowledge exchange in AAH.

Deviations and adaptive management

The project experienced moderate deviations from the original implementation plan, mainly due to COVID-19 restrictions during the initial stages, which caused delays in in-person meetings, training, fieldwork, and equipment procurement. In response, adaptive management measures were put in place to keep progress and quality intact. These included shifting to remote training and virtual coordination, as well as creating online learning modules through the Learn.ink platform. Budget allocations were adjusted to support research activities and strengthen local capacity, while a no-cost extension ensured the completion of planned outputs within the available resources. These changes maintained the project's overall direction and enhanced institutional resilience and digital readiness among participating partners.

Lessons Learned

The project offered valuable insights into how AAH initiatives can be more effectively implemented across different institutional settings. Early challenges related to administrative procedures, fund disbursement, and resource access highlighted the need for streamlined management systems and flexible financial planning, lessons already influencing future collaborations. Strengthening supervision structures and mentorship proved essential for maintaining postgraduate progress and research quality. The experience also showed that networking must go beyond isolated events, with clear follow-up and shared outcomes to ensure lasting collaboration and impact. Efforts to improve gender balance would benefit from proactive inclusion strategies integrated into training and recruitment from the start. The combination of digital and in-person training proved especially effective for ongoing capacity development. While online learning targets were exceeded, future initiatives will aim to include digital courses within institutional curricula to foster long-term ownership. Lastly, expanding communication and outreach to farmers and practitioners through accessible channels will help transform scientific achievements into practical on-farm improvements.

Sustainability of project interventions

Sustainability has been intentionally incorporated into the project through long-term institutional partnerships, capacity building, and the integration of tools and knowledge products into national research systems. Trained personnel have been integrated into universities, research institutes, private sector companies, and government agencies, ensuring that aquatic animal health management skills remain active beyond the project's duration. Laboratory infrastructures are now integrated into university research, and standardized protocols developed during the project have been published and incorporated into routine operations, while the Learn.ink digital platform and training materials continue to support ongoing education and extension efforts. The project's strong collaboration among WorldFish, NVI, UoG, and UoN has established a regional foundation for continuous knowledge exchange and innovation, creating a solid platform for scaling efforts through future investments. Together, these measures have laid the groundwork for sustained impact, enabling national partners to maintain educational and research efforts to address emerging disease threats and expand aquatic animal health management practices across Sub-Saharan Africa.

Cost efficiency and impact

The project showed high cost-effectiveness by using digital tools, shared platforms and cross-institutional partnerships. With a final expenditure of NOK 26.5 million out of a budget of NOK 27 million, and more than 90% of deliverables achieved, the AHA project serves as a model of an impactful, resource-efficient development program.

Conclusion

The AHA project significantly advanced AAH in SSA by empowering institutions, training future leaders and producing actionable research. Its integrated approach not only filled immediate capacity gaps but also positioned partner institutions to lead future efforts in sustainable aquaculture development. The lessons and innovations developed will continue to inform national policies, regional collaboration and international partnerships long after the project's life cycle.

1. Project overview

Project goals

Africa is rich in a wide variety of aquatic animal resources that significantly contribute to food security, job creation and the economies of many countries on the continent. However, several factors, including infectious pathogens, strongly threaten the sustainability of such resources, putting the aquatic food production systems at serious risk.

The status of aquatic animal diseases in several countries within SSA has yet to be fully investigated, and the recent outbreaks of certain diseases in Africa have highlighted the continent's limited capacity to prevent and control emerging diseases. Therefore, the goal of this regional project was to increase sustainability and resilience in the aquaculture sector in SSA by improving AAHM and biosecurity governance. WorldFish and the NVI used their combined expertise and networks to implement the project, primarily in Ghana and Kenya. In addition, many other countries in SSA benefitted through intensive training programs aimed at building the capacity of the targeted groups and networking participants representing several countries within SSA.

Expected project outcomes

Higher-level outcomes:

- Research capacity on AAHM in SSA countries improved.
- Institutional capacity and learners' knowledge and practical skills in AAH were enhanced to improve aquaculture-related education services and extension capacity in SSA countries.
- New knowledge on AAH in aquatic food systems, within the framework of One Health and the One Food system, was widely shared in SAA through sustainable networking.

Research outcomes:

- Gaps in research and knowledge of AAHM in the selected countries (Ghana and Kenya) were identified and either addressed or filled.
- Relevant stakeholders in Ghana, Kenya and other SSA countries (Department of Fisheries, policymakers, academic institutions, extension agents from the public and private sectors, etc.) availed themselves of research findings and new knowledge on AAH.

Education outcomes:

- State-of-the-art educational modules on aquaculture and AAH for implementing regular face-to-face and online virtual training programs for SSA from WorldFish's Aquaculture Research and Training Center (AARTC), based in Abbassa, were developed and available.
- The availability and accessibility of SSA countries to training programs on aquaculture and AAHM increased.

Networking outcomes:

- A dynamic and operational networking mechanism was developed for sharing AAH knowledge among SSA countries.
- Effective coordination and monitoring, evaluation and learning (MEL) were established to capture the main highlights and achievements, facilitating knowledge sharing.

Target groups

The target groups were extension service providers, fish farmers, hatchery operators, university students, academic and research institutions, representatives from national competent authorities, donor agencies and project implementing agencies in SSA, regional and international agencies involved in promoting AAHM, biosecurity governance and One Health.

2. Results: Project status

2.1. Based on the structure of the approved results framework, please describe progress towards achieving the objectives of the Project and analyze the change in indicator values for the reporting period.

At the end of this report is the approved results framework, which was slightly updated based on recommendations from Prof. Stephen Mutoloki during the midterm review in November 2023. The framework is up to date and includes revised indicators covering the entire project period. We acknowledge that the framework could have been simplified from the outset.

Implementation progress during the period under review

Overall implementation progress

January 1, 2024–March 31, 2025

Regular online partner meetings

During the review period, partners from WorldFish, the NVI, UoG and UoN held regular virtual meetings to monitor progress and review activities outlined in the implementation plan. Separate sessions were conducted for students and supervisors to discuss research progress and thesis development in detail. Numerous follow-up and activity-specific planning meetings also took place throughout 2024–2025.

Completion of master's research studies, graduation

All 13 master's students received continuous support from their local supervisors, as well as co-supervisors from WorldFish and the NVI. At the UoG, all six MSc students completed their theses. Five were submitted in December 2023, with four receiving final acceptance in May 2024 and one in April 2024. Three students graduated in August 2024, two in February 2025 and the final student is expected to graduate by November or December 2025. At the UoN, seven MSc students were at different stages of thesis completion. Four graduated in December 2024. Of the remaining three, one was given the intention to submit for examination, another submitted in April 2025 with ongoing delays from reviewers, and the third was expected to submit by July 2025. Based on thesis review timelines, graduation was anticipated in either September or December 2025. Delays for two students were due to medical-related challenges. Full student details are available in Research Output 1.2.2 and Tables 3 and 4.

Aquatic animal health–related publications

Between 2024 and 2025, the AHA project supported the publication of 13 peer-reviewed scientific articles—nine authored by master's students and four by partner institutions. Of these, eight were published in 2024 and four in 2025, with one currently in press. These publications demonstrate the project's success in strengthening research capacity and fostering international collaboration in AAH. The studies span a wide range of topics, including biosecurity and disease management in catfish aquaculture in Nigeria, sustainable aquaculture practices in Ghana and Kenya, probiotic alternatives to antibiotics, microbiome dynamics in tilapia systems, and the application of nanopore sequencing for detecting pathogens in finfish (Research Output 1.2.3).

Advanced molecular diagnostics and sequencing workshop

The Advanced Molecular Diagnostics and Sequencing Workshop, held in May 2024 at WorldFish headquarters in Penang, Malaysia, brought together 10 participants from Ghana, Kenya and Bangladesh. The training combined lectures and hands-on sessions that covered DNA extraction, polymerase chain reaction (PCR), nanopore sequencing and bioinformatics analysis. Participants worked in groups to process fish and water samples, amplify and sequence 16S rRNA genes and analyze microbial communities. Emphasis was placed on practical skills, data interpretation and collaborative scientific writing (Education Output 2.3.8).

New resources developed for research and education

Building on materials developed between 2021 and 2023, additional resources were created to enhance

research and education on AAH in SSA. In 2024, two new online courses were launched on the Learn.ink platform: (1) Tilapia Lake Virus (TiLV) and (2) Basic Insight into Molecular Diagnostics in Aquaculture (Education Output 2.2.1). These courses are publicly accessible and designed to support self-paced learning. Additionally, new training materials were developed for in-person sessions focused on advanced molecular diagnostics and nanopore sequencing (Education Output 2.3.8).

Policy/opinion paper

Building on insights gathered during brainstorming sessions with students at the midterm review and the AFRAQ23 conference in Zambia, the NVI and UoG teams published a policy and opinion paper advocating for inland aquaculture transition strategies to protect Lake Volta and promote sustainable fish production (Research Output 1.3.2).

Epidemiological studies in the main targeted countries

Following initial data cleaning and preliminary analysis by the NVI of fish epidemiology and health economics (FEHE) datasets from Ghana and Kenya, a more comprehensive analysis was conducted to identify risk factors associated with unusual fish mortalities. The NVI carried out this analysis, based on data from 193 farms in Kenya and 99 farms in Ghana, and submitted it to WorldFish. It examined variables related to farm characteristics, management practices and biosecurity measures. Combined findings from both countries are currently being prepared for publication (Research Output 1.1).

Major conferences and knowledge-sharing events

In 2024 and early 2025, the AHA project engaged in a series of strategic national and international events to advance AAH and foster collaboration. In Ghana, the Aquaculture Ghana Stakeholder Collaboration Event (May 30–31, 2024) in Accra brought together government, academia and industry to address key issues in sustainable aquaculture. Centre for Environment, Fisheries and Aquaculture Science's (Cefas) events (February 27–30, 2024) in Accra addressed AMR using a One Health Aquaculture approach. Internationally, the project participated in the Aquaculture Sustainability Conference (July 24–26, 2024) in Bangkok and contributed to knowledge sharing and regional policy dialogue at AFRAQ24 (November 19–22, 2024) in Hammamet, Tunisia. The team also participated in the WOAH Meeting (July 8–10, 2025) in Tunis, aligning project outcomes with international partners. Most recently, at the WOAH Paris Workshop (February 20–21, 2025), the project contributed to identifying the highest-priority research areas for finfish health, thereby supporting global efforts to strengthen aquatic health research agendas. Further information on key events and conferences can be found in Networking Output 3.2.1.

Project closure and stakeholder engagement workshops

Two national closure workshops for the AHA project were successfully held in Ghana and Kenya in late 2024, bringing together key stakeholders, students, supervisors and government representatives. These events served as platforms to reflect on project achievements, share lessons and explore future collaboration. A detailed overview is provided in Networking Output 3.2.2.

End-term evaluation of the project

Prof. Stephen Mutoloki conducted the end-term evaluation of the AHA project and also carried out the midterm review. The purpose of the assessment was to assess the project's achievements in terms of relevance, coherence, efficiency, effectiveness and visibility. It involved reviewing key documents such as technical and financial reports, evaluating progress since the midterm review, and conducting interviews with WorldFish and partner institutions in Kenya and Ghana. The review yielded practical recommendations to inform future project design and ensure sustainability. Further information can be found at the end of the report in Results Monitoring and Evaluations, sections 5.

In the rest of this final technical report, we refer to specific sections of the 2021 (Appendix 1), 2022 (Appendix 2) and 2023 (Appendix 3) annual progress reports. Additionally, we provide a more detailed account of the activities undertaken during the current reporting period (January 1, 2024, to March 31, 2025). Together, these elements offer a comprehensive overview of the results achieved throughout the whole project implementation period (December 1, 2020, to March 31, 2025). Key indicators and outcomes are presented with the targets defined at the onset of the project (Results Framework).

3. Key project activities and outputs

The project had three key components/activities: research, education and networking.

3.1. Component/activity 1: Research

Research outputs

1.1 Assessment of fish health status and economic impact of aquaculture diseases in Ghana and Kenya using WorldFish and the NVI epidemiology and health economics online survey tool completed.

1.2 Field and laboratory studies to elucidate and characterize endemic and emerging pathogens of economic significance using molecular diagnostic tools, rapid genomic sequencing approach, AMR genes, and autogenous vaccine development to tackle diseases and reduce antimicrobial use (AMU) completed.

1.3 AAHM and biosecurity governance gaps identified and policy analyses in SSA under the One Health framework completed.

Fish diseases continue to pose a significant threat to global aquaculture, resulting in substantial economic losses. In Africa, efforts to understand disease epidemiology and implement effective control measures for key species such as tilapia and catfish have historically received limited attention and investment. However, as fish production expands across the continent, disease outbreaks have become more frequent, underscoring the urgent need for stronger biosecurity governance and improved capacity in AAH. To respond to this need, the project supported 13 master's students from the UoG and the UoN by equipping them with in-depth training and sustained mentorship through collaboration with WorldFish and the NVI. This component of the project aimed to strengthen regional expertise and research capacity in AAH to better address current and emerging challenges in the sector.

Research Output 1.1: Epidemiological studies in Kenya and Ghana using EPI-Tool

As part of the AHA project, a comprehensive epidemiological study was conducted in both Kenya and Ghana through a collaborative partnership involving the UoN, the UoG, WorldFish and the NVI. Data collection in both countries used the FEHE digital survey tool, co-developed by WorldFish and the NVI. The tool was adapted to capture the specific local fish species and aquaculture production systems in each country.

Before data collection began, extensive virtual and in-person training sessions were delivered to data collectors and management teams. These sessions familiarized participants with the survey instrument, incorporated their feedback to refine the tool, and provided hands-on guidance for data entry, uploading and retrieval processes to ensure data quality and consistency.

In Kenya, the survey covered 193 farms across five counties: Embu, Meru, Nyeri, Taita-Taveta and Tharaka-Nithi. In Ghana, 99 farms were surveyed across six regions: Western North, Bono, Central, Greater Accra, Western and Volta.

Progress 1.1: Epi-Study data processing and analysis

The NVI led the initial data cleaning, processing and preliminary analysis of FEHE datasets from Ghana and Kenya, which were subsequently submitted to WorldFish. Building on this foundation, a comprehensive analysis was conducted to identify risk factors associated with unusual fish mortalities, drawing on epidemiological survey data from both countries. The Kenyan dataset comprised 193 farms and 30 biologically relevant variables, encompassing farm characteristics, management practices and biosecurity measures. The Ghanaian dataset, in contrast, included 99 farms and 38 comparable variables. The integrated findings from both countries were synthesized and being finalized for submission as peer-reviewed journal articles later in 2025.

Further details on the training activities and capacity building efforts associated with these studies can be found in the Education Outputs of the 2023 Progress Report (Appendix 3).

Research and Education Output 1.2.1: Overview of MSc coursework completion

The coursework undertaken in Kenya and Ghana reflects comprehensive academic preparation in aquaculture and AAH. In Kenya, the focus was on key topics such as fish bacteriology, virology, immunology, diagnostics, epidemiology and vaccinology, providing a strong foundation in aquatic animal disease and health management (Table 1).

Course units covered
• Fish Bacteriology and Mycology • Fish Biology • Principles of Scientific Communications • Biostatistics and Computer Use • Fish Virology and Immunology • Fish Inspection, Certification, Quality Control: Hazard Analysis Critical Control Points Systems (HACCPS) • Fish Farming: Management, Breeding and Feeding • Fish Parasitology and Non-infectious Conditions • Diagnostic Pathology of Fish Diseases
Elective course units
• Epidemiology • Aquatic Pharmacology and Toxicology • Advanced Histopathology • Vaccinology

Table 1. MPhil coursework in Kenya.

In Ghana, the MPhil Aquaculture program combines foundational and advanced topics across aquaculture practices, genetics, physiology, biotechnology and fish pathology. Together, these programs emphasize both theoretical knowledge and practical skills essential for sustainable aquaculture development. The list of courses is presented in Table 2.

Course units covered	
First year – First semester	**First year – Second semester**
• AQUA603: Aquaculture Practice • AQUA07: Reproductive Endocrinology of Fish • AQUA609: Aquaculture Holding Facilities • AQUA613: Genetics in Aquaculture • FISH609: Environmental Fish Physiology • FISH623: Fish Processing and Utilization • FISH339: Fish Microbiology (BSc course, a sit-in for MSc Aquaculture students) • BCMB403: Molecular Biotechnology Techniques and Applications (a sit-in arranged by Prof. Samuel Duodu)	• AQUA614: Aquaculture Economics • AQUA616: Technologies for Sustainable Aquaculture Development • FISH616: Fish Pathology • MAFS602: Research Methods • AQUA624: Fish Breeding and Hatchery Management • MASC612: Aquatic Health and Impact Studies • FISH622: Fish Nutrition and Energetics • Total credits for coursework are a minimum of 24 and a maximum of 36.
Second year	
AQUA600	Thesis Research (30 credits)
AQUA601	Seminar I (3 credits)
AQUA602	Seminar II (3 credits)
The minimum number of total credits required for graduation in the MPhil Aquaculture program is 62.	

Table 2. MPhil coursework in Ghana.

Progress 1.2.1: MSc coursework

All master's students completed their coursework in 2022. Based on their strong academic performance, all were approved to advance to the research phase in 2023, receiving ongoing technical support from their respective universities, the NVI and WorldFish.

Research Output 1.2.2: Overview of MSc research activities, thesis submission and graduation

Under the AHA project, the 13 MSc research projects encompassed a broad spectrum of topics, including (i) biosecurity, AMU and AMR, (ii) bacterial, mycotic and viral infections and their control, (iii) parasitic infestations, (iv) dietary probiotics/postbiotics and (v) the effects of different protein sources on the growth and immunity of tilapia, the primary focus species. In addition, one of the projects involved wild-caught shrimp in Ghana.

Progress 1.2.2: Thesis submission and graduation

All six MSc students from the UoG completed their theses. Five submitted their theses in December 2023, with four receiving final acceptance in May 2024 and one in April 2024. Four students graduated in August 2024 and two in February 2025. One student, whose thesis was recently been accepted by the university, was expected to graduate in November or December 2025. Full details for the Ghanaian MSc students are provided in Table 3.

All final theses submitted by the MSc students from Ghana are available in full in Appendix 4.

Name	Title	Completion date	Graduation date
Abigail Amankwah	Parasitic infestations of cage-cultured Nile tilapia (*Oreochromis niloticus*) in Ghana	May 4, 2024	August 2024
Kofi Ferni Anyan	Effects of commercial dietary probiotics on growth performance and disease resistance of Nile tilapia fingerlings in Ghana	May 4, 2024	August 2024
Kwame Issifu	Fish diseases, farm practices, and biosecurity measures adopted by fish farmers in the Eastern Region of Ghana	May 24, 2024	February 11, 2025
Mabel Ackah	Comparative study of the efficacy of traditional and chemical methods in the control of *Saprolegniasis* in Nile tilapia	May 4, 2024	August 2024
Philip Kwasi Banini	Molecular investigation of major viral pathogens of the giant tiger shrimp *Penaeus monodon* (Fabricius, 1798) along the coast of Ghana	April 4, 2024	February 11, 2025
David Narteh Batsa	Effect of hyperthermia treatment of infectious spleen and kidney necrosis virus (ISKNV) infection in fingerlings of cultured tilapia in Ghana	May 2025	November/ December 2025

Table 3. Thesis completion date and graduation timelines for the UoG MSc students.

The seven MSc students from the UoN were at different stages of thesis completion. Four graduated in December 2024. Of the remaining three, one was given the intention to submit for examination, another submitted in April 2025 with ongoing delays from reviewers, and the third was expected to submit by July 2025. Based on thesis review timelines, graduation was anticipated in either September or December 2025. Delays for two students were due to medical-related challenges. Full details for the Kenyan MSc students are provided in Table 4.

All final theses submitted by MSc students from Kenya are available in full in Appendix 5.

Name	Title	Completion date	Graduation date
Ndegwa Joseph Macharia	Pathogenicity of *Aeromonas veronii* var *sobriae* recovered from fish in Kenya	June 2024	December 13, 2024
Mercy Hamisi Matuma	Potential pathogenic and zoonotic bacteria affecting farmed and wild *Oreochromis jipe* in Taita-Taveta county, Kenya	May 2024	December 13, 2024
Merceline Ndinda Ndambuki	Effects of postbiotics supplementation on growth performance, haematological parameters, and susceptibility of Nile tilapia (*Oreochromis niloticus* to *Aeromonas hydrophila* infection	April 2024	December 13, 2024
Ageng'o Finnan Okoth	Prevalence, intensity and influence of water quality on farmed fish parasites in Kericho and Narok counties, Kenya	May 2024	December 13, 2024
Jacob Munene Wainaina	Prevalence, intensity, and influence of parasites in the production of Nile tilapia (*Oreochromis niloticus*) fingerlings in Homa Bay County, Kenya	June 2025	September 2025
Cidee Night Khaseke	The prevalence of antimicrobial-resistant bacteria and antimicrobial use in farmed and wild fish in Narok and Nakuru counties of Kenya	July 2025	December 2025
Victor Omondi Ogweny	Influence of fish feeds formulated with different protein sources on water quality, growth performance and survival of juvenile Nile tilapia (*Oreochromis niloticus*)	April 2025	September or December 2025

Table 4. Thesis completion date and graduation timelines for the UoN MSc students.

Research Output 1.2.3: Aquatic animal health–related publications funded, and acknowledging the AHA project

Progress 1.2.3: Aquatic animal health–related publications

Under the AHA project, both the MSc students and project partners made significant achievements in the publication of peer-reviewed scientific articles. The master's students from Ghana and Kenya published 10 peer-reviewed journal articles, showcasing research outputs related to aquaculture health, disease surveillance, diagnostics and treatment strategies. These publications reflect collaborative efforts across institutions and underscore the quality and relevance of the students' work in advancing knowledge in the field. Details of all 10 publications are provided in Table 5.

Year	Authors	Title	Journal
2023	Ogweny et al.	Effects of different dietary protein sources on water quality parameters and growth performance of Nile tilapia (*Oreochromis niloticus*) fingerlings	Journal of Aquaculture, Marine Biology & Ecology
2024	Ageng'o et al.	Relationship between water quality parameters and parasite infestation in farmed *Oreochromis niloticus* in selected Rift Valley counties, Kenya	Aquaculture Research
2024	Ageng'o et al.	Management practices and risk factors associated with parasitic infestations in farmed Nile tilapia in Bomet and Kericho counties, Kenya	International Journal of Fisheries and Aquatic Studies
2024	Hamisi et al.	Prevalence of potential pathogenic and zoonotic aerobic bacteria in wild and farmed *Oreochromis jipe*, *Oreochromis niloticus*, and source water in Taita-Taveta County, Kenya	International Journal of Fisheries and Aquatic Studies
2024	Wainaina et al.	Prevalence and intensity of ectoparasites in Nile tilapia hatcheries in Homa Bay County, Kenya	International Journal of Fisheries and Aquatic Studies
2024	Banini et al.	Rethinking freshwater cage aquaculture: A case in Ghana	Water
2024	Ackah et al.	In vitro and in vivo activity of herbal and chemical treatments against *Saprolegnia ferax*—A causative agent for saprolegniasis	Aquaculture International
2025	Ageng'o et al.	Parasites of farmed and wild tilapine fishes from selected farms and Lake Jipe in Taita Taveta County, Kenya	Aquaculture, Fish and Fisheries
2025	Ndegwa et al.	Conventional and molecular characterization of an *Aeromonas* isolate recovered from an aquaculture farm with high fish mortality in Kenya	International Journal of Fisheries and Aquatic Studies
2025	Ndegwa et al.	Lethal dose, clinical signs, gross and microscopic lesions induced by *Aeromonas veronii* Biovar *sobria* A4 strain in experimentally challenged Nile tilapia (*Oreochromis niloticus*)	Veterinary Medicine International

Note: Hyperlinks to the peer-reviewed articles are embedded in the names of the journals.

Table 5. Peer-reviewed journal articles published by AHA-supported MSc students in Kenya and Ghana.

In addition to the student-led publications, 12 additional peer-reviewed articles were published by partner institutions, acknowledging the AHA project. The articles cover a wide range of topics, including microbial characterization, the development of new diagnostic methods, disease management, biosecurity and microbiome analysis. These contributions strengthened the project's scientific foundation and enhanced its visibility within the broader research community. Refer to Table 6 for details on all 12 publications.

Year	Authors	Title	Journal
2021	Abbas et al.	Fish diet supplemented with Yemeni Zeolite improves growth performance and reduces lead toxicity in Nile tilapia (*Oreochromis niloticus*)	Aquaculture Research
2022	Elgendy et al.	Molecular characterization, virulence profiling, antibiotic susceptibility, and scanning electron microscopy of *Flavobacterium columnare* isolates retrieved from Nile tilapia (*Oreochromis niloticus*)	Aquaculture International
2022	Ali et al.	Genetic characterization and antimicrobial profiling of bacterial isolates collected from Nile tilapia (*Oreochromis niloticus*) affected by summer mortality syndrome	Journal of Fish Diseases
2022	Elgendy et al.	Vibriosis outbreaks in farmed Nile tilapia (*Oreochromis niloticus*) caused by *Vibrio mimicus* and *V. Cholerae*	Aquaculture International
2023	Zornu et al.	Bridging knowledge gaps in fish health management through education, research, and biosecurity	Frontiers in Sustainable Food Systems
2023	Elgendy et al.	Onion (*Allium cepa*) improves Nile tilapia (*Oreochromis niloticus*) resistance to saprolegniasis (*Saprolegnia parasitica*) and reduces immunosuppressive effects of cadmium	Aquaculture International
2023	Dong et al.	From the basics to emerging diagnostic technologies: What is on the horizon for tilapia disease diagnostics?	Reviews in Aquaculture
2023	Delamare-Deboutteville et al.	A multiplexed RT-PCR assay for nanopore whole genome sequencing (WGS) of tilapia lake virus (TiLV)	Scientific Reports
2024	Khor et al.	Understanding aquaculture biosecurity to improve catfish disease management in Ogun and Delta states, Nigeria	Aquaculture
2024	Lubis et al.	Review of quorum-quenching probiotics: A promising non-antibiotic-based strategy for sustainable aquaculture	Journal of Fish Diseases
2025	Delamare-Deboutteville et al.	Multiplex polymerase chain reaction (PCR) with nanopore sequencing for sequence-based detection of four tilapia pathogens	PeerJ
2025	Delamare-Deboutteville et al.	Microbiome dynamics in tank- and pond-reared Genetically Improved Farmed Tilapia (GIFT)	Frontiers in Microbiomes

Note: Hyperlinks to the peer-reviewed articles are embedded in the names of the journals.

Table 6. Peer-reviewed journal articles published by partner institutions supported by the AHA project.

Several manuscripts are still in preparation, under review or in press. In Ghana, five students are currently finalizing or revising manuscripts based on their thesis work to submit them to reputable journals (Table 7).

Authors	Title	Journal & status	Notes
Amankwah et al.	Prevalence, mean intensity, and abundance of ectoparasites in cage-cultured Nile tilapia in Ghana	KNUST Journal of Science and Technology	This has been submitted to the journal, with responses sent to reviewers and the editor.
Anyan et al.	Effects of commercial dietary probiotics on growth performance and control of *Streptococcus agalactiae* infection in Nile tilapia fingerlings in Ghana	Aquaculture International (resubmission in prep)	This was previously rejected by the Journal of Comparative Immunological Reports.
Issifu et al.	Fish health management, farming practices, and biosecurity measures adopted by fish farmers in the eastern region of Ghana	Journal of Veterinary Medicine International (resubmission in prep)	This was rejected by two previous journals. It is currently under revisions for resubmission.
Banini et al.	First detection of infectious myonecrosis virus (IMNV) in *Penaeus monodon* shrimps in the coastal waters of Ghana	Transboundary and Emerging Diseases (planned)	PCR confirmed the virus, and sequencing has been repeated using Oxford Nanopore Technologies. The first draft of the write-up is ready, but the processed sequences still need to be submitted to the National Center for Biotechnology Information (NCBI) for an accession number.
Batsa et al.	Hyperthermia treatment improves the survival of cultured Nile tilapia (*Oreochromis niloticus*) naturally infected with ISKNV	Transboundary and Emerging Diseases (planned)	The manuscript was ready for submission in early July.

Table 7. Manuscripts by master's students in Ghana that are in prep, submitted or under review.

In Kenya, ongoing efforts by four students included multiple manuscripts at various stages of development for submission. These pending publications are expected to enhance the project's legacy and impact further. Details of those publications can be found in Table 8.

Authors	Title
Khaseke et al.	Aquaculture practices and antimicrobial resistance risks in tilapia farming systems in Nakuru and Narok counties, Kenya
Khaseke et al.	Bacterial diversity and phylogenetic characterization of pathogens in tilapia ponds in Nakuru and Narok counties, Kenya
Ndambuki et al.	Effects of *Saccharomyces Cerevisiae* postbiotics on growth performance, haematological parameters, and disease resistance in Nile tilapia (*Oreochromis Niloticus*) fingerlings (submitted to the East African Journal of Science and Technology)
Macharia et al.	Antimicrobial susceptibility of *Aeromonas veronii* biovar *sobria* (A4 strain), a clinical isolate recovered from an aquaculture farm with high fish mortality in Narok County, Kenya
Matuma et al.	Occurrence of bacterial infections in *Oreochromis jipe* fish under different climatic and physico-chemical environments in Taita-Taveta County, Kenya
Matuma et al.	Assessment of bacteriological composition and antibiotic susceptibility of bacteria isolated from *Oreochromis* fish species from farms in Taita-Taveta County, Kenya

Table 8. Manuscripts by master's students in Kenya that are in preparation for submission.

Research Output 1.3.1: Published gap analysis on research or education capacity in aquatic animal health in SSA

Under the AHA project, a baseline survey was designed and implemented to evaluate the current capacity for research and education in AAH across Ghana, Kenya and other African countries. The primary aim was to identify strengths, gaps and opportunities for strengthening institutional and national capabilities in this domain.

Initial data collection involved feedback from over 50 participants in Ghana. In total, responses were received from a range of countries. Participants originated from Ghana (53%), Kenya (23%) and other African countries (24%), specifically representatives from Madagascar, Mozambique, Malawi and Zambia who were engaged in in-person training at the Fish for Africa Innovation Hub (FAIH), WorldFish's Abbassa facility in Egypt, under the AHA project. The aggregated data was thoroughly analyzed and key findings published in the following peer-reviewed article, which highlights critical gaps and provides recommendations for advancing fish health management through targeted investments in education, research and biosecurity:

Publication: Bridging knowledge gaps in fish health management through education, research, and biosecurity

Journal: Frontiers in Sustainable Food Systems

Authors: Zornu J, Tavornpanich S, Shimaa AE, Addo S, Nyaga P, Dverdal MJ, Norheim K, Brun E and Cudjoe KS.

DOI: 10.3389/fsufs.2023.1256860

Research Output 1.3.2: Policy opinion perspective on sustainable aquaculture

Progress 1.3.2: Opinion paper

Together, the NVI and UoG published a policy paper that built upon insights gathered during brainstorming sessions with the students at the midterm review and the AFRAQ23 conference in Zambia, and through continued engagement with Ghanaian students. The publication emphasizes the crucial need for inland aquaculture transition strategies to protect Lake Volta, prevent the spread of diseases, and foster the production of safe and sustainable fish.

Publication: Rethinking freshwater cage

Aquaculture: A case in Ghana

Journal: MDPI Water

Authors: Banini PK, Anyan KF, Zornu J, Ackah M, Batsa DN, Issifu K, Amankwah A, Ali SE, Addo S and Cudjoe KS.

DOI: 10.3390/w16213054

Abstract

Lakes around the world, including Ghana's Lake Volta, are facing insidious threats from pollutants due to high dependency on aquatic ecosystems. Cage aquaculture is expanding across Africa because of its potential to address food insecurity, provide livelihoods and boost local economies. However, the uncontrolled expansion of cage aquaculture can have significant negative impacts on water resources, including environmental footprints that threaten biodiversity. Given the intensification of cage aquaculture for tilapia farming on Lake Volta, we advocate for a transition to inland-integrated aquaculture systems that promote circularity. Strengthening stakeholder collaboration is essential for enhancing competence in mapping inland aquaculture areas, identifying eco-friendly alternatives and reinforcing aquaculture regulations, with particular emphasis on cage culture on Lake Volta. These strategies can reduce the pressures imposed by tilapia cage farms on the lake while promoting best management practices. Additionally, capacity building must be an ongoing process to address knowledge gaps, including the development of effective preparedness plans executed during emergencies. The ongoing pollution from illegal mining in the Black Volta River, a tributary of Lake Volta, along with endemic diseases in the lake, further compounds fish health and welfare issues. This underscores the urgent need to implement inland transition strategies to protect the lake, mitigate disease spread and ensure safe fish food production.

3.2. Component/activity 2: Education

Education outputs

2.1 All existing training materials developed by WorldFish, the NVI, the Food and Agriculture Organization (FAO), World Organisation for Animal Health (OIE), Cefas and others were reviewed, and new online open course modules were developed.

2.2 Pilot testing of modules conducted, and modules finalized and ready for uptake.

2.3 Face-to-face and online virtual training programs for SSA implemented and promoted.

Strengthening education and capacity building in AAH is essential for expanding support services to small-scale farmers, extension staff, students, researchers, policymakers and regulatory authorities. FAIH continues to serve as a hub for hands-on training and experimental research for students and early-career researchers from across Africa and beyond. As part of the education component of the AHA project, we developed new AAH resources for both research and education. MSc students received enhanced support through online fortnightly seminars and in-person sessions designed to improve their research writing and presentation skills for manuscript development and scientific conferences. Training activities covered key topics, including basic epidemiology, outbreak investigation and risk assessment in AAH. Field-level capacity was strengthened through training on epidemiological survey tools for data collection in Kenya and Ghana, as well as practical instruction on bacterial DNA extraction for diagnostic purposes. Advanced molecular diagnostics and sequencing training sessions were also conducted at WorldFish headquarters in Penang, Malaysia. Additionally, Learn.ink e-learning courses were developed, and a critical review and gap analysis of existing online resources for AAH education were completed.

Education Output 2.1: Critical review and gap analysis of online aquatic animal health educational materials

Progress 2.1: Critical review and gap analysis

As part of Education Output 2.1, an international consultant conducted a thorough review and gap analysis of online open-access educational materials in AAH. A preliminary search across various databases using relevant keywords produced over 130,000 hits, which were narrowed down to 287 relevant resources. Of these, 107 were reviewed in detail, and 51 were chosen for general analysis based on specific criteria. Analyzing 15 representative materials showed that, while some were of high quality in both content and delivery, none fully met the training needs and regional context of stakeholders in SSA. This highlighted the need for more accessible, locally relevant educational resources in AAH.

Three platforms were identified as most suitable for adaptation within this project and similar future efforts: CourseFish, the MSD Veterinary Manual and WorldFish's Learn.ink. The accompanying gap analysis recommended using the Development of a Curriculum methodology to guide the development of new training content and highlighted key gaps in content and delivery. Given the continuous evolution of internet-based learning technologies, the report recommends adopting state-of-the-art content management systems (CMS) with integrated AI features. Such platforms would enable the scalable and sustainable delivery of training materials to target users over time, supporting long-term capacity building among regional stakeholders. In the context of the AHA project, the consultant identified the Learn.ink platform as the most accessible CMS for adding features like AI functionalities and integration with repositories.

The findings from this critical review and gap analysis are being prepared for publication as a separate output, with completion expected by the end of 2025. The publication will include full acknowledgment of the AHA project for its financial support.

Additional details are available in Annex 8 of the 2023 Progress Report (Appendix 3).

Education Output 2.2.1: Learn.ink digital e-learning courses

We developed a series of online training courses on the Learn.ink platform—an easy-to-use digital learning tool optimized for low-end devices. This platform enables WorldFish and partners to create and share training materials on AAH under the AHA program with participants in Ghana, Kenya and other countries across Africa and Asia. Learners can access the courses remotely using their own mobile devices at their convenience.

Learn.ink is used by over 100 organizations in 35 countries, including CGIAR centers such as the International Livestock Research Institute (ILRI) and the International Rice Research Institute, to reach users in Kenya, Tanzania, Nigeria and the Philippines. Every WorldFish Learn.ink training course is structured into modules, each comprising lessons and quizzes to support and assess learning. Courses are accessed via unique URLs generated by the platform.

Progress 2.2.1: WorldFish's Learn.ink courses

A total of 17 online courses were developed and published on the Learn.ink platform during the project period (Table 9). These courses were accessed by 757 individuals (with more than 600 people across SSA alone) comprising 303 females and 454 males. The platform continues to serve as a valuable learning resource, and efforts will be sustained to promote and expand its reach throughout 2025 and beyond.

We also developed a series of introductory, case study and end-user guidelines for using the courses on the Learn.ink platform:

1. Introduction and summary
   - Aquatic animal health: Remote training courses on Learn.ink https://hdl.handle.net/20.500.12348/4899
2. Case study
   - Building a microlearning curriculum at WorldFish https://hdl.handle.net/20.500.12348/5015
3. End-user guidelines
   - How to sign up and access the course on the aquaculture survey with Open Data Kit (ODK) on Learn.ink https://hdl.handle.net/20.500.12348/4894

- How to sign up and access the fish sampling microlearning curriculum on Learn.ink https://hdl.handle.net/20.500.12348/4897

In 2024, two new online courses were launched on the Learn.ink platform: (1) Tilapia Lake Virus (TiLV) and (2) Basic Insight into Molecular Diagnostics in Aquaculture (Table 9). These courses are publicly accessible and designed to support self-paced learning.

As Prof. Mutoloki highlighted in his end-of-term evaluation of the AHA project, either the UoN, UoG or both, need to host the online courses, with ongoing support from WorldFish. Doing so would increase course visibility, improve accessibility and strengthen the capacity of academic institutions in SSA. Additionally, the courses should be actively promoted through the various networks developed under the project, and targeted social media campaigns should be considered to maximize visibility and participation among the intended audiences.

No.	Learn.ink course	Total users	Females	Males
1	Aquaculture Survey with Open Data Kit (ODK)	48	19	29
2	Intro to Fish Sampling for Disease Diagnostics	136	55	81
3	Foundations in Fish Disease Sampling	101	35	66
4	Wet Mount Sampling	75	31	44
5	Microbiome Sampling	61	34	27
6	Blood Sampling	66	26	40
7	Bacteriology Sampling	53	19	34
8	Molecular and Virology Sampling	38	16	22
9	Histology Sampling	45	21	24
10	Fish Syndromic Surveillance	36	13	23
11	Fish Farm Biosecurity	51	16	35
12	Data Collection with SurveyCTO Collect	19	7	12
13	Antimicrobial Usage (AMU) Survey for Aquatic Systems	23	7	16
14	Principles of Conducting Social Surveys			
15	Epizootic Ulcerative Syndrome (EUS)	3	2	1
16	Tilapia Lake Virus (TiLV)	1	1	0
17	Basic Insight on Molecular Diagnostics in Aquaculture	1	1	0
		757	303	454

Note: Hyperlinks to the courses are embedded in the course titles.

Table 9. List of online courses developed on the Learn.ink platform from 2021 to 2024, and the total number of users for the period disaggregated by gender.

Education Output 2.2.2: Aquatic animal health resources developed for research and education

Progress 2.2.2: Aquatic animal health resources

In addition to the online Learn.ink courses, WorldFish and partners created several resources, including course guidelines and a "package of practices" on AAH. They also developed a series of quick fish sampling protocols for disease diagnostics in tilapia, carp and catfish production systems. These training materials provide guidance to project team members, students, researchers, veterinarians, extension officers and farmers involved in conducting FEHE surveys, syndromic surveillance, disease outbreak investigations, water quality monitoring, fish farm biosecurity, and collecting quality biological samples for laboratory diagnosis during routine checks or disease outbreaks on farms or hatcheries. Supported by the AHA project and other initiatives, these resources have been published and are available online to assist the project's target groups. A list of AAH resources developed for research and education, along with their corresponding links, is provided in Table 10.

Category	Resources
FEHE	• Aquatic animal health package of practices: Fish epidemiology and health economics
Syndromic surveillance and disease outbreak characterization	• Aquatic animal health package of practices: Syndromic surveillance and disease outbreak characterization
Online tool for fish health and water quality monitoring	• Aquatic animal health: Online fish health and water quality monitoring tool
End users' and content creators' guidelines to access digital surveys	• How to access digital surveys for aquaculture using the ODK Collect mobile app and KoboToolbox • How to manage digital surveys for aquaculture using KoboToolbox and the ODK Collect mobile app
End users' guidelines to access online courses on Learn.ink * Please read the corresponding guidelines before accessing courses	• How to sign up and access the course on the aquaculture survey with ODK on Learn.ink • How to sign up and access the fish syndromic surveillance course on Learn.ink • How to sign up and access the fish farm biosecurity course on Learn.ink • How to sign up and access the fish sampling microlearning curriculum on Learn.ink
Quick fish sampling guides for disease diagnostics	• Aquatic animal health package of practices: Fish sampling for disease diagnostics • Sampling materials for fish disease diagnostics • Wet mount sampling guide (for ectoparasites & fungi) • Microbiome sampling guide • Blood sampling guide • Bacteriology sampling guide • Molecular and virology diagnostics sampling guide • Histology sampling guide • Antimicrobial susceptibility testing (AST) in aquatic animal species from aquaculture and fisheries

Note: Hyperlinks to the resources are embedded in the resource titles.

Table 10. AAH resources developed for research and education.

Education Output 2.3.1: E-Learning initiative through the NMBU–NVI Fish for Development diploma course

As part of Norad's Fish for Development program, the NVI, in collaboration with the Norwegian University of Life Sciences (NMBU), organized an additional e-learning opportunity in December 2022. This included access to Fish for Development, an online diploma course developed by the NMBU and structured into six comprehensive modules:

1. Introduction to fish farming
2. Production systems in fish farming
3. Fish feeding in fish farming
4. Fish health in fish farming
5. Disease control in fish farming
6. National and international regulations in fish farming.

All students completed the modules and received training certificates (refer to Appendix 6 of the 2022 Progress Report, referenced in this report as Appendix 2). The course provided essential foundational knowledge in aquaculture and was highly valued by participants, who described it as "very detailed and containing useful information needed for aquaculture." Students also noted that it enhanced their ability to contribute meaningfully to the blue economy sector in the region. They suggested adding more content on marine fish species, expanding species coverage (e.g. catfish), translating some interface elements into English and making the course more interactive through engagement with lecturers.

Education Output 2.3.2: Preparation for excellence by strengthening the research, writing and presentation skills of the MSc students through online seminars and in-person mentorship

To support the academic development of the 13 MSc students, a series of online biweekly seminars was held from June 23 to September 15, 2023. These sessions offered a platform for students to share updates on their thesis research, discuss challenges and receive technical feedback, while also encouraging peer-to-peer learning and engagement. In preparation for the AFRAQ23 conference, all of the students had the chance to present their research during partner and midterm review meetings. These preparatory sessions provided valuable practice opportunities, during which students received personalized feedback from both national and international supervisors. The guidance focused on enhancing content clarity, visual design and the communication of key messages in slide and poster presentations. As a result, the students significantly improved the quality of their work and gained confidence to present effectively at AFRAQ23 and other scientific conferences.

Education Output 2.3.3: Physical training at the WorldFish Abbassa facility

Strengthening education and capacity development in AAH is essential for expanding services accessible to small-scale farmers, extension agents, students, researchers, policymakers and regulatory authorities across the region. FAIH has emerged as a key regional center for hands-on training and applied research in aquaculture. It serves as a platform for knowledge exchange among students, graduates and professionals from across Africa and beyond. In support of this regional role in building capacity across SSA, the AHA, in collaboration with the NVI and local specialists, organized seven intensive in-person training cycles at FAIH. These programs engaged participants from multiple SSA countries, focusing on priority themes in aquaculture and the management of AAH.

Progress 2.3.3: Physical training at FAIH

Throughout the AHA project, the following seven training cycles were successfully conducted at FAIH, with details of the topics covered under each cycle:

Cycle 1: July 3–8, 2021

1. Introduction to epidemiology and fish health management
2. Practical epidemiological concepts in aquatic animal health
3. Interactive session: Review of aquaculture practices in participating countries
4. Sampling strategies and interpretation of diagnostic test results
5. Disease prevention and general biosecurity principles, with emphasis on farm-level implementation

Summary: 13 participants, 3 countries, 8 institutions

- Participants by gender: 7 males, 7 females
- Participants by country: Kenya (6), Ghana (5), Mozambique (3)
- Participants by institution: County Government in Kenya (6), Fisheries Commission in Ghana (5), Aquaculture Research Center, CEPAQ (2), Aquaculture Research and Development Centre of the Water Research Institute (1).

Cycles 2 and 3: July 17–29, 2022

a. Biosecurity
    1. Applying risk analysis to develop practical farm-level biosecurity plans
    2. Managing interactions between wild and farmed aquatic animal populations
    3. Risk-based characterization and zoning of aquaculture farms
    4. Promoting staff engagement and ownership in biosecurity practices
    5. Developing biosecurity plans and standard operating procedures
    6. Assessing the economic benefits of biosecurity implementation
    7. Planning and phasing of biosecurity measures implementation at farm level

b. Vaccines: Theoretical and practical training
    1. Understanding the fish immune system and its application to the immune protection of fish in aquaculture
    2. Overview of vaccination methods used in aquaculture
    3. Hands-on training in injection vaccination techniques

c. Aquaculture principles and AAHM

d. Aquatic epidemiology

Summary: 22 participants, 5 countries, 8 institutions

- Participants by gender: 13 males, 9 females
- Participants by country: Ghana (6), Madagascar (5), Zambia (5), Kenya (3), Mozambique (3)
- Participants by institution: Fisheries Commission in Ghana (6), Ministry of Fisheries and Livestock in Zambia (5), Ministry of Fisheries and Blue Economy of Madagascar (5), Kenya Fisheries Service (2), UoN (1), National Institute for Aquaculture Development in Mozambique (1), National Fisheries Research Institute in Mozambique (1), Polytechnic Institute Mártir Cipriano de Nacala-Moduril (1).

A detailed report is attached to Appendix 2 of the 2022 Progress Report (Appendix 2).

Cycle 4: October 16–20, 2022

Like the July course (cycles 2 and 3), topics included the following:

1. Overview of aquaculture production systems
2. Principles of genetic improvement programs
3. Hatchery management and seed production
4. Fish nutrition and feeding management
5. Water quality monitoring and management
6. Basic fish anatomy
7. Diagnosis of common aquatic animal diseases in Africa
8. Biosecurity practices and PCR principles
9. Fish processing, product handling and value addition
10. Virtual session: AAHM in Malaysian aquaculture

Summary: 20 participants, 4 countries, 12 institutions

- Participants by gender: 12 males, 8 females
- Participants by country: Kenya (9), Mozambique (4), Zambia (4), Malawi (3)
- Participants by institution: Kenya Fisheries Service (4), UoN (4), WorldFish (2), Ministry of Fisheries and Livestock in Zambia (2), Aquaculture Research Center Mozambique (1), National Institute of Fisheries Research in Mozambique (1), Higher Polytechnic Institute of Gaza in Mozambique (1), National Institute for Development of Fisheries in Mozambique (1), Department of Fisheries in Malawi (1), Ministry of Agriculture in Malawi (1), Central Veterinary Research Institute in Zambia (1), private farm (1).

A detailed report is attached to Appendix 3 of the 2022 Progress Report (Appendix 2).

Cycle 5: Intensive, long-term physical training for AHA MSc students

Initially, we planned to bring together the Ghanaian and Kenyan MSc students for practical, hands-on training at FAIH so that they could acquire the necessary skills before beginning their research work. However, the Ghanaian students were not granted visas to Egypt. Meanwhile, three of the Kenyan students joined the second and third merged training cycles, and the remaining four joined the fourth cycle with other participants from different countries. The Kenyan students then continued with longer-term intensive training. Initially, student research proposals were reviewed, and the students also joined some of the daily farm activities at FAIH. The students also undertook various field visits to tilapia farms and hatcheries located in the top tilapia-producing governorates in Egypt. A study trip to Skretting in Egypt was also arranged. At FAIH, various topics were covered, including fish feed (ingredient alternatives, immunostimulants), water quality, fish bacteriology, fish parasitology, fish hematology, PCR theory and practical applications, and biostatistics. Two online sessions on parasitology were presented virtually by the NVI. The students also participated in intensive training on fish histopathology at the Faculty of Veterinary Medicine, Cairo University. A detailed report is attached to Appendix 9 of the 2022 Progress Report (Appendix 2).

Two sessions of online training for the AHA MSc students were held at FAIH on November 9 and 11, 2022:

1. From mapping to eradication: The Atlantic salmon ectoparasite *G. salaris* case study
2. Fish parasitology

Summary: 7 AHA MSc students from Kenya, representing the UoN

Cycle 6: March 4–10, 2023

Interactive section on the prevailing practices in participant's countries:

- Best management practices and farm-level biosecurity
- National aquatic animal health strategies
- Genetics and taxonomic characterization
- Necropsy and fish anatomy
- Parasitology examination and blood sampling

Summary: 21 participants, 4 countries, 9 institutions

- Participants by gender: 10 males, 11 females
- Participants by country: Ghana (8), Kenya (5), Zambia (5), Malawi (3)
- Participants by institution: UoG (7), Ministry of Fisheries and Livestock in Zambia (3), County Government in Kenya (3), WorldFish (2), Kenya Fisheries Service (2), Zambia Institute of Animal Health (1), Department of Fisheries in Malawi (1), Lilongwe University of Agriculture and Natural Resources in Malawi (1), Veterinary Services in Ghana (1).

A detailed report is attached to Annex 9 of the 2023 Progress Report (Appendix 3).

Cycle 7: September 2–8, 2023

- Interactive session: Review of aquaculture prevailing practices in participating countries
- Aquaculture production systems
- Water quality management
- Fish genetics and taxonomy
- Fish preparation for diagnostics
- Parasitology examination and blood sampling
- Molecular techniques (DNA and PCR)

Summary: 24 participants, 6 countries, 17 institutions

- Participants by gender: 15 males, 9 females
- Participants by country: Ghana (7), Kenya (5), Zambia (4), Nigeria (4), Malawi (3), Mali (1)
- Participants by institution: Government Republic of Zambia / Ministry of Fisheries and Livestock in Zambia (4), University of Ibadan in Nigeria (2), County Government in Kenya (2), Ensapuh Veterinary Services Limited (1), Nigeria Agricultural Quarantine Service (1), Ministry of Agriculture, Department of Animal Health and Livestock Development in Malawi (1), Department of Animal Health Central Veterinary Laboratory in Malawi (1), WorldFish (1), Kwame Nkrumah University of Science and Technology in Ghana (1), University of Energy and Natural Resources in Ghana (1), Fisheries Commission in Ghana (2), CSIR–Water Research Institute in Ghana (1), University for Development Studies in Ghana (1), University of Environment and Sustainable Development in Ghana (1), Kenya Fisheries Service (2), Makindi Fish Farm in Kenya (1), University of Segou in Mali (1).

A detailed report is attached to Annex 10 of the 2023 Progress Report (Appendix 3).

Education Output 2.3.4: Basic epidemiology, outbreak investigation and risk assessment in aquatic animals

Progress 2.3.4:
The NVI developed two training courses on AAH, which were delivered by experts from the NVI, WorldFish and the University of Pretoria. The courses were held in Nairobi on March 15–17, 2023, and at the UoG on April 19–21, 2023.

The training course in Ghana brought together 22 participants (13 males, 9 females), including academic staff and assistants from the UoG, AHA MSc students, a PhD student, members of the field study team, and representatives from the Fisheries Commission. In Kenya, 23 participants (13 males, 10 females) attended the training. They represented Kenya Fisheries Services and county offices, the Directorate of Veterinary Services (Diagnostic and Laboratory Services), the Aquaculture Association of Kenya, the AHA MSc program and academic staff from the UoN.

The training covered core principles of epidemic investigation and risk assessment, alongside key challenges in epidemiology, AAHM and related health concerns. The program combined lectures, group discussions and hands-on exercises to reinforce learning. Practical activities were designed to help participants apply theoretical knowledge in real-world scenarios, particularly in the context of epidemic investigation and risk assessment.

The following topics were addressed:

- Epidemiology in AAH: Management and challenges
- Disease frequency and measures of association
- Diagnostic tests with imperfect diagnostic sensitivity and specificity
- Practical exercises on diagnostic tests (scenario-based and farm-level data, use of pivot tables, WinEpi)
- Designing a sampling strategy
- Outbreak investigation and disease control
- Review of outbreak investigation procedures.

These training courses correspond to the 8th and 9th in-person training sessions outlined under Output 2.3 of the results framework. Further details can be found in the 2023 Progress Report and the associated training reports in Annexes 5 and 6 of the same report (Appendix 3).

Education Output 2.3.5: Training on the epidemiology survey tool for data collection in Kenya and Ghana

Progress 2.3.5: Training on the fish epidemiology and health economics survey tool

WorldFish conducted a series of hybrid and in-person training sessions in Kenya and Ghana to teach enumerators, data managers and students the skills needed to carry out FEHE surveys. The training focused on using tools such as KoboToolbox and ODK Collect, with an emphasis on applying the FEHE questionnaire, managing data and conducting surveys.

Initial hybrid training took place in Nairobi (March 14–15) and Accra (April 16–17), followed by in-person sessions in Ghana (July 25–26) and Kenya (August 1–2). In Ghana, 9 participants (6 males and 3 females) were from the UoG. In Kenya, 15 participants (11 males and 4 females) represented the county government (12 participants) and the UoN (3 participants). The program featured practical modules on questionnaire design, mobile data collection, data visualization and field planning. Custom versions of the FEHE tool were created for each country, and dedicated KoboToolbox accounts were set up for field use.

These training courses correspond to the 10th and 11th in-person training sessions outlined under Output 2.3 of the results framework. Detailed information, including training reports and contextualized survey tools, can be found in Annexes 1–3 of the 2023 Progress Report (Appendix 3).

Education Output 2.3.6: Training on bacterial DNA extraction for disease diagnostics

Progress 2.3.6: Training in the new bacterial DNA extraction method

To strengthen laboratory skills in molecular diagnostics, WorldFish conducted hands-on training in DNA extraction at the UoG on July 24, 2023, and at the UoN on August 4, 2023. In Ghana, seven participants (four males and three females) from the UoG took part in the training. In Kenya, 11

participants (five males and six females) from the UoN attended the session.

The sessions included a lecture and practical exercises on DNA extraction methods suitable for research and disease diagnostics. Participants learned about a magnetic-based DNA extraction technique, focusing on low-cost, efficient and environmentally friendly methods ideal for resource-limited settings. Hands-on activities used in-house lysis buffers and pure bacterial cultures to demonstrate the entire extraction process—cell lysis, purification, binding, washing, elution, quantification and electrophoresis. These training courses correspond to the 12th and 13th in-person training sessions outlined under Output 2.3 of the results framework. Additional details are available in Annex 7 of the 2023 Progress Report (Appendix 3).

Education Output 2.3.7: WorldFish and International Livestock Research Institute training, laboratory and bioinformatics support for MSc students in Kenya

Three Kenyan master's students (one male, two females) received training and support in processing their biological samples using essential laboratory techniques. WorldFish covered all associated costs, with ILRI laboratory staff providing technical support. The students successfully prepared their bacteriological samples for submission to the ILRI, conducted MALDI-TOF MS bacterial identification in December 2023, and carried out AST and WGS of selected bacterial isolates in 2024. Specialists from the UoG and WorldFish later analyzed the sequencing data, and the results were provided to the students.

Education Output 2.3.8: Advanced molecular diagnostics and sequencing

A significant milestone under the AHA project was the successful implementation of a hands-on laboratory training in advanced molecular diagnostics and sequencing, held at WorldFish headquarters in Penang, Malaysia. This initiative aimed to enhance the capacity of early-career researchers and postgraduate students from SSA to detect and manage aquatic diseases. With aquaculture playing a critical role in food security and income generation across the region, the training directly supported the project's goal of improving sustainability through better AAHM.

Progress 2.3.8: Advanced molecular diagnostics and sequencing training

Participants received practical instruction in molecular diagnostic techniques, including DNA extraction, primer design, PCR amplification, sequencing and data analysis. These advanced tools enable early and accurate detection of pathogens, which is essential for containing disease outbreaks that can otherwise lead to devastating economic losses for fish farmers. The training also emphasized real-world application, with participants engaging in lab-based simulations that mirrored field conditions.

Plate 1. Trainees and facilitators from the Advanced Molecular Diagnostics and Sequencing Training Program.

The workshop fostered a strong sense of knowledge sharing and regional collaboration. Participants from Kenya and Ghana expressed their intent to transfer the skills they gained back to their institutions and communities, supporting disease surveillance, student training and ongoing research. Testimonials highlighted how this experience would enhance diagnostic capabilities and even support the development of pathogen databases for future outbreak responses.

Plate 2. Trainees taking part in the molecular diagnostics course at WorldFish headquarters in Penang, Malaysia.

By investing in local capacity building, the AHA project ensures that aquaculture professionals across Africa are better equipped to manage health challenges proactively. The training serves as a foundation for long-term improvement in disease diagnostics and surveillance, enabling a more resilient and productive aquaculture sector. This initiative is a clear example of how targeted education and technology transfer can drive meaningful progress toward regional food security and economic development goals.

A summary report and full slide decks from the 2024 Advanced Workshop on Molecular Diagnostics and Nanopore Sequencing—including training materials on molecular techniques, NGS and bioinformatics—can be found in Appendix 6.

3.3. Component activity 3: Networking outputs

3.1 Activities and strategies/approaches for harnessing and sharing knowledge and lessons identified/developed.

3.2 Synthesis of knowledge and lessons from research, education and networking for supporting competent authorities in SSA.

Inclusive partnerships and strategic networking are vital for the success and sustainability of development efforts, especially those focused on strengthening AAH systems in SSA. Recognizing this, the AHA project emphasized structured networking at the global, regional and national levels—not only to foster collaboration but also to share knowledge, exchange experiences and promote institutional learning. From 2021 to 2025, the project actively built and engaged a broad network of stakeholders across research, education and industry, as summarized in Figure 1.

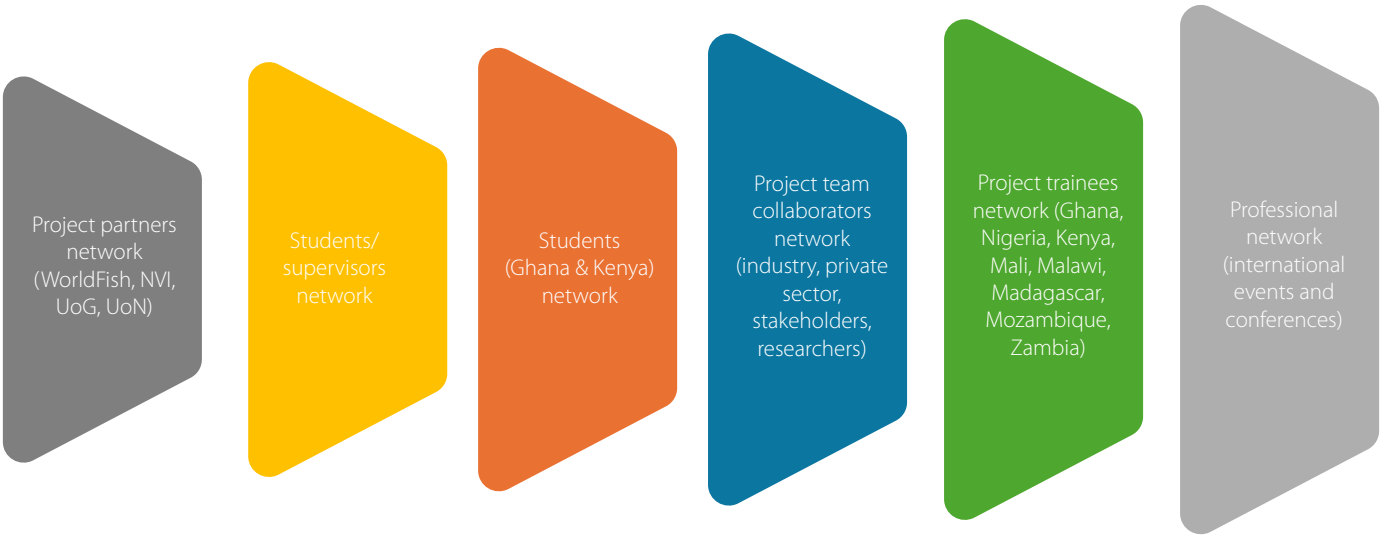

Figure 1. Project networks developed throughout 2021–2025.

Throughout the project, partners—WorldFish, the NVI, the UoG and the UoN—enhanced their outreach and engagement through regular online coordination meetings, joint training sessions, conferences and seminars. These platforms provided important opportunities to synthesize lessons learned, share best practices and disseminate research findings and educational innovations. Importantly, these activities involved not just students but also academic staff, field practitioners, and representatives of competent authorities, thereby strengthening institutional capacity and regional cooperation in AAH.

The project also actively promoted international exposure and participation by supporting students and institutional representatives in attending several high-level conferences and events. These included AFRAQ21/23/24, AquaEpi II, the Aquaculture in the Digital Age forum, and the AGRF summit, along with WOAH events, among others. Attending these events provided students with valuable opportunities to present their research, connect with global experts and build international professional networks—further reinforcing the project's commitment to being inclusive and globally focused.

Although the project did not establish fully operational and dynamic networks in the formal sense, it successfully built a broad and inclusive contact base from many stakeholders—including trainees, public and private sector actors, farming communities and subject-matter experts. These networks, although informal, laid a valuable foundation for future collaboration and projects. Additionally, the project developed numerous training resources and knowledge products that could be used more effectively. Going forward, we will use our centralized repository where these resources are stored. By leveraging our existing contact base, improving our communication, we will increase access to these training materials and share information about upcoming events and opportunities—turning these informal connections into lasting, strategic networks for greater impact.

Networking Output 3.1.1: Inception-phase networking and stakeholder collaboration

Following the official launch of the AHA project in December 2020, WorldFish and the NVI focused on building a strong collaborative network among partners and stakeholders to strategically plan the implementation of the project. Despite COVID-19 travel restrictions, the early months featured a series of virtual meetings, including a project kickoff on December 8, 2020, that successfully brought together representatives from all partner institutions. These engagements helped clarify project goals, roles and deliverables while also fostering early connections among multidisciplinary teams. Subgrant agreements were finalized in the first half of 2021, setting clear expectations for each partner institution in Norway, Ghana and Kenya.

With the gradual easing of travel restrictions, hybrid inception workshops were held in Ghana (October 2021) and Kenya (November 2021). These events brought together over 100 participants, including researchers, academics and private

sector actors, as well as representatives from regulatory authorities, farmer associations and media. The workshops not only introduced the AHA project and its research agenda but also created valuable opportunities for networking, feedback exchange and alignment with national aquaculture priorities. Supervisory committees for MSc students were also established during this period, pairing local and international experts to provide consistent academic and technical mentorship, further strengthening cross-institutional collaboration.

The full inception workshop reports for Ghana and Kenya can be found in Annexes 1 and 2 of the 2021 Progress report (Appendix 1).

Networking Output 3.1.2: Strengthening regional connectivity and capacity in aquatic animal health through student and trainee networks

The AHA project significantly expanded its student and trainee network across Africa, laying a strong foundation for long-term collaboration and capacity building in AAH. At the core of this effort were seven training cycles conducted at FAIH (Education Output 2.3.3), which collectively trained over 100 participants from 8 countries and 38 institutions. These participants—primarily government officers, researchers and university staff—took part in intensive, hands-on modules covering sustainable aquaculture production, aquatic epidemiology, diagnostics, fish health management and biosecurity. The seven cycle training sessions fostered peer learning and established lasting professional connections across SSA.

The network was further strengthened at the AFRAQ23 conference in Lusaka, which provided a key opportunity for MSc students to convene as a group for the first time and to engage with international researchers. Additional efforts included two regional training courses led by the NVI in Ghana and Kenya, focusing on basic epidemiology, outbreak investigation and risk assessment (Education Output 2.3.4). The project also facilitated targeted training on the use of the WorldFish–NVI epidemiological survey tool for data collection (Education Output 2.3.5), as well as hands-on experience on the use of new innovative bacterial DNA extraction techniques for disease diagnostics (Education Output 2.3.6). These initiatives were complemented by an advanced molecular diagnostics and sequencing course held in 2024 in Penang, Malaysia (Education Output 2.3.8), which brought together trainees and experts from multiple countries to explore cutting-edge tools and technologies.

Collectively, these multitiered training activities cultivated a dynamic regional network of early-career professionals and midlevel technical officers. To support continued collaboration and knowledge exchange, all training materials were shared with participants and are available through the MEL Platform of the AHA project. This growing network now represents a vital resource for advancing sustainable AAHM and collaborative research across the region.

Networking Output 3.1.3: Midterm review meeting

As part of the project's midterm review, all partners, MSc students and an external observer convened for the first time in person in Lusaka, Zambia, on November 8–12, 2023. The workshop-format meeting reviewed project performance across key evaluation areas: relevance, coherence, efficiency, effectiveness and visibility. It also generated recommendations for optimizing resources and developing a sustainability strategy. Presentations from WorldFish, the NVI, UoG and UoN provided country-level updates. Special talks were delivered by Dr. Mwansa Songe on Zambia's AAH landscape and by Prof. Mutoloki (NMBU), the external reviewer, on the importance of AAH in Africa. All proceedings were compiled in a report, alongside the formal midterm assessment and recommendations from Prof. Mutoloki (refer to Annexes 11 and 12 in Appendix 3 of this report).

3.2 Synthesis of knowledge and lessons from research, education and networking for supporting competent authorities in SSA.

Networking Output 3.2.1: International conferences and stakeholder engagements

Between 2022 and 2025, the AHA project participated in 14 key conferences and stakeholder events across Africa, Asia and Europe (Table 11). The project demonstrated increasing engagement over time, with one event in 2022, six in 2023, six in 2024 and one high-level meeting in early

2025. These gatherings served as critical platforms for showcasing research outputs, strengthening regional networks and reinforcing the project's commitment to sustainable aquaculture and AAH. Across all events, several thematic priorities emerged consistently. One Health was the most prominent, discussed in four separate events, highlighting the project's focus on integrating human, animal and environmental health considerations in aquaculture systems. Other recurring themes included AMR, diagnostics and AAH, each addressed in three events, reflecting the project's technical depth in disease prevention, surveillance and health system resilience. Capacity building, digital tools and collaboration also featured strongly, underlining the emphasis on empowering young researchers, deploying innovative technologies and fostering multistakeholder partnerships.

Through these events, the AHA project not only disseminated research findings and shared success stories from Ghana, Kenya and beyond, but also positioned itself as a leader in developing sustainable, resilient aquaculture systems in SSA. The events also created meaningful opportunities for student engagement, institutional visibility and policy influence on both regional and international stages.

Detailed summaries of the conferences and the events can be found in Appendix 13.

Event	Date	Location	AHA involvement	Outputs/Links
First World Aquaculture Africa (AFRAQ21)	Mar. 25–28, 2022	Alexandria, Egypt	The WorldFish–NVI team presented project goals and activities during the WorldFish hybrid session.	In Appendix 2, see Appendix 10; event webpage; book of abstracts.
Malaysia Fisheries Society: Aquaculture in the Digital Age 2023 Seminar	June 10, 2023	Kuala Lumpur, Malaysia	WorldFish staff presented digital surveillance tools and diagnostic innovations	In Appendix 3, see Annex 16; event webpage.
The Africa Food Systems Forum's (AGRF) 2023 Summit	Sep. 3–6, 2023	Dar es Salaam, Tanzania	Two MSc students (one each from Ghana and Kenya) participated in the youth-focused aquatic food side event.	In Appendix 3, see Annex 13.
Second World Aquaculture Africa (AFRAQ23) 2023 Conference	Nov. 13–16, 2023	Lusaka, Zambia	All 13 MSc students presented their research (oral and poster presentations).	In Appendix 3, see Annex 14; event webpage; book of abstracts.
The fourth cycle of the WOAH Focal Points Aquatic Animals (Africa) 2023 training	Oct. 1–4, 2023	Kigali, Rwanda	WorldFish staff engaged with focal points from over 10 African countries to share progress on the AHA project.	In Appendix 3, see Annex 15.
1st Annual FVM Scientific Conference & Outreach	Oct. 25–27, 2023	UoN, Kenya	Three MSc students presented on fish parasites, hatchery management and bacterial infections.	Event webpage
Aquatic Animal Epidemiology (AquaEpi III) 2023 Conference	Nov. 29–Dec. 1, 2023	Lucknow, India	The WorldFish team presented digital survey tools for aquatic epidemiology in Africa and Asia.	In Appendix 3, see Annex 16.
Cefas Sustainable One Health Aquaculture and AMR Events	Feb. 25–28, 2024	Accra, Ghana	WorldFish, NVI and UoG partners participated in the meetings, reviewed AHA progress and planned activities	Event news article.
58th Kenya Veterinary Association (KVA) Annual Scientific Conference	Apr. 24–27, 2024	Isiolo County, Kenya	UoN partner presented on fish parasites of economic and zoonotic potential in cultured and wild freshwater systems in Kenya.	Book of abstracts; news article; YouTube video.
WOAH Meeting Training of National Focal Points for Aquatic Animal Health (Cycle IV)	July 8–10, 2024	Tunis, Tunisia	WorldFish presented aquatic health partnerships and support for AAH in Africa, including the AHA initiative.	Appendix 7.
Aquaculture Ghana Stakeholder Collaboration Event	May 30–31, 2024	Accra, Ghana	Four MSc students presented their research; the event also featured high-level panels on feed, health and finance.	Appendix 8.
AquaSustain Scientific Conference	July 24–26, 2024	Bangkok, Thailand	WorldFish participated in panels on health, rising feed costs, recirculating aquaculture systems, aquaculture financing, fish health, marketing, and risk assessment.	Appendix 9.
Third World Aquaculture Africa (AFRAQ24) 2024 Conference	Nov. 19–22, 2024	Hammamet, Tunisia	Three abstracts from the AHA project: (1) AAHM and capacity building carried out under the AHA project, (2) heatshock treatment for ISKNV in tilapia, and (3) One Health approach to combat AMR in aquaculture across Asia and Africa.	Appendix 10; book of abstracts.
WOAH Paris Headquarters Workshop to Identify the Highest Priority Research Areas for Finfish Health	Feb. 20–21, 2025	Paris, France	WorldFish shared its AAH research program and the AHA initiative.	Appendices 11 and 12; event webpage; pre-workshop report; policy brief; workshop report.

Table 11. International conferences and stakeholder engagements (2022–2025) attended by AHA students and partners across three continents.

Networking Output 3.2.2: Project closure and stakeholder engagement workshops

Progress 3.2.2: In partnership with WorldFish and the NVI, the UoG and UoN successfully held closure workshops for the AHA project in both Ghana and Kenya. The Ghana workshop took place at the Volta Hotel in Akosombo on September 26–27, 2024, while the Kenya workshop was held at the Wambugu Agricultural Training Centre, Wambugu Farm, under the County Government of Nyeri, on September 30–October 2, 2024.

Both events brought together key stakeholders, including all master's students supported by the project, their national and international supervisors, other trainees, representatives from relevant government agencies such as the Fisheries Commission (Ghana) and Veterinary Services (Kenya), aquaculture associations, farmers and academics. These workshops provided an opportunity to reflect on the project's key achievements, share lessons learned and chart a path forward for continued collaboration and sustainable aquaculture development.

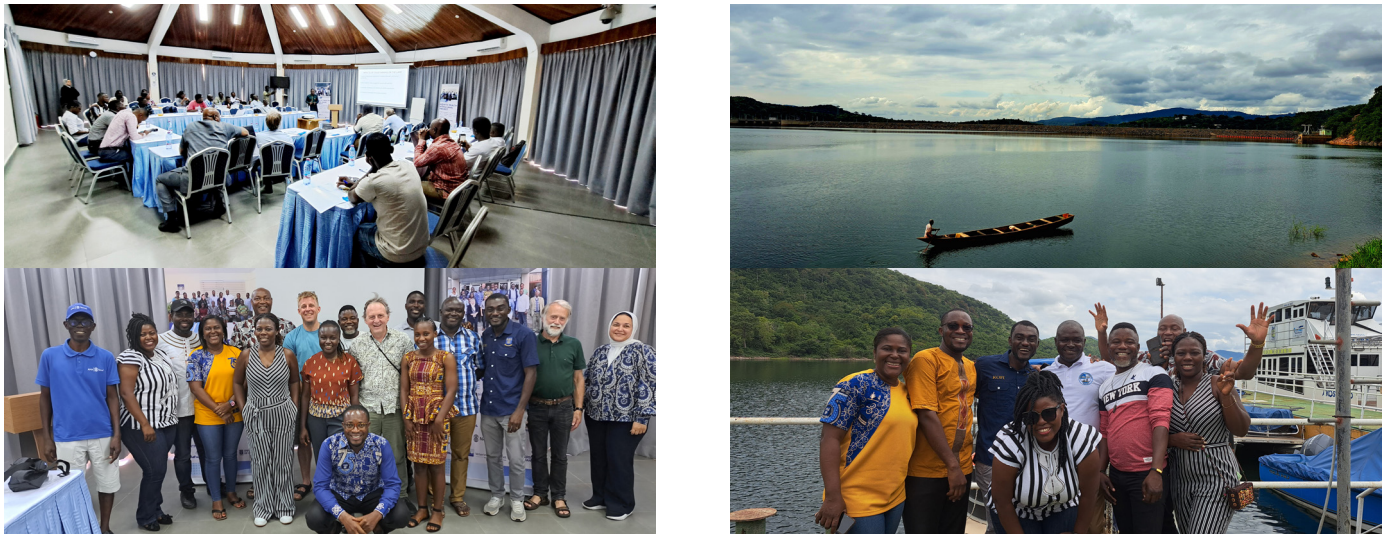

Plate 3. Project teams members, MSc students and stakeholders at the Ghanaian project closure workshop.

Comprehensive reports were compiled for both the Ghana closure workshop (Appendix 14) and Kenya (Appendix 15). Additionally, the workshops featured presentations from both the NVI and WorldFish, including institutional overviews, a project update presentation, and two summary presentations highlighting the key activities and findings from the FEHE surveys conducted in Ghana and Kenya (Appendix 16). Two short video recordings capturing key moments from the workshops were also included (Appendix 16).

Plate 4. Project teams members, an MSc student and stakeholders at the Kenyan project closure workshop.

4. Communication outputs from the AHA project

1. Project webpages

To ensure visibility and knowledge dissemination, the AHA project maintained two dedicated online portals:

- Main AHA project page – WorldFish website: This webpage was regularly updated with the latest news, photos and highlights from activities in Ghana, Kenya and the in-person training cycles at FAIH in Egypt. It also features links to peer-reviewed publications, events and educational resources, such as Learn.ink.
- MEL Platform – AHA Project: This knowledge-sharing platform archived project outputs, reports and lessons learned.

2. Stories and blogs

- **Impact story**
  WorldFish at the AGRF 2023 – Aquatic Foods for Africa's Food Systems Transformation: This contains coverage of the participation of MSc students at AGRF 2023 in Dar es Salaam, Tanzania.
- **Field visit highlight**
  Cavarino Fish Farm visit – University of Nairobi: This features a story on an academic trip to a fish farm in Narok County in Kenya's Rift Valley.
- **Institutional feature**
  NVI News: Contributing to sustainable aquaculture in Africa: This highlights the NVI's contributions and collaboration in Africa.
- **Youths in aquatic food systems Spotlight Series**
  - Spotlight: Mercy Matuma Hamisi (Kenya)
  - Spotlight: Philip Kwasi Banini (Ghana)
- **Technical blog**
  Success in advanced molecular diagnostics and sequencing: This documents capacity-building and molecular diagnostic training for AHA stakeholders.

3. Learning and case studies

- **Case study**
  Building a microlearning curriculum at WorldFish: This contains an overview of the Learn.ink microlearning modules developed for aquaculture training.
- **Factsheet**
  AHA Project Factsheet (2021): This factsheet was widely disseminated at events and stakeholder meetings to promote project goals and activities.

4. Key events page

- AFRAQ21: WorldFish Research and Development in Africa: This features success stories and lessons learned by AHA project stakeholders at the Aquaculture Africa Conference.

The project published regular updates on its social media platforms throughout its implementation and is currently producing a video showcasing its overall achievements.

4.1. Choose one or more representative example(s) of results at the outcome level

Describe the chain of events leading to the result in line with the format and short guide. If it is too early to describe outcomes, please explain the reasons for this.

The AHA project achieved several key outcome-level results, demonstrating measurable progress toward its objectives in strengthening AAH capacity in SSA. The following are five representative examples:

1. **Peer-reviewed publications by MSc students**
   Through targeted training, mentorship and field research support, AHA-supported MSc students produced 10 peer-reviewed journal articles addressing fish health challenges in Kenya and Ghana. These publications represent a significant contribution to scientific knowledge and highlight enhanced national capacity in research design, diagnostics and publication.

2. **Development of Learn.ink mobile courses based on gap analysis**
   A critical review and gap analysis of existing online AAH materials revealed a lack of accessible, context-specific training for African stakeholders. This directly informed the development of new interactive Learn.ink mobile courses focused on disease recognition, farm biosecurity, molecular diagnostics and best practices—improving knowledge dissemination to students, researchers and extension agents.

3. **Large-scale epidemiological surveys in Ghana and Kenya**
   Following training on the EPI-Tool, national teams successfully conducted large-scale surveys covering over 290 farms in Ghana and Kenya. The resulting datasets were analyzed and are currently being prepared for publication. These will inform national disease surveillance strategies. This work builds sustainable capacity for evidence-based health interventions in aquaculture.

4. **Policy perspective on sustainable aquaculture in Ghana**
   Drawing from student input during the midterm review meeting and AFRAQ23 brainstorming sessions in Lusaka, Zambia, WorldFish, the NVI and the UoG co-authored an opinion paper titled Rethinking Freshwater Cage Aquaculture: A Case in Ghana. The paper advocates for inland aquaculture transition strategies and emphasizes the need to reduce pressure on Lake Volta, control the spread of diseases and ensure safe, sustainable fish production, supporting policy-level change.

5. **Published gap analysis on AAH education and research capacity**
   Bridging Knowledge Gaps in Fish Health Management through Education, Research, and Biosecurity is a publication that identified key weaknesses in AAH education, research and biosecurity across SSA. Although it is too early to assess its long-term impact fully, the paper provides a valuable reference for guiding early discussions on curriculum training programs, research infrastructure, regional collaboration and investments in fish health management.

4.2. To what extent has the Project been implemented as planned?

Give a brief account of deviations that could affect the achievement of the objectives, and describe what has been done to deal with the deviations. Which risk factors (internal or external, identified previously or new) have affected the implementation of the Project in particular? Have any of these had unintended negative consequences for any of the cross-cutting issues? If the risk situation has changed, an updated risk management plan for the Project must be submitted by November 1 together with the updated implementation plan and budget for the following year.

Based on the end-term evaluation report, the AHA project was largely implemented as planned, with the majority of its targets met or exceeded. The evaluation found that over 90% of the project deliverables were achieved, demonstrating a high level of effectiveness despite some challenges. In the area of research, the project successfully supported 13 MSc students, nine of whom had graduated by the end of the project period; the remaining students were expected to complete their theses and graduate by 2025. The project also exceeded its target of 12 scientific publications, with 10 peer-reviewed articles published by the master's students and 12 additional publications by project partner institutions. Infrastructure development was another major accomplishment, marked by the establishment of a new wet lab at the UoN and the upgrading of an existing laboratory at the UoG, which significantly enhanced institutional research capacity. In education and training, the project developed and published 17 online Learn.ink courses, far surpassing the initial target of 10, which reached over 640 participants across SSA. Additionally, over 100 extension agents, farmers, students, researchers and government officials from 8 countries participated in at least 15 physical training sessions.

These achievements underscore the project's significant contribution to strengthening AAHM and biosecurity capacity in the region.

4.3. Please make an assessment of the Project's cost efficiency on output level (products and/or services)

The AHA project demonstrated strong cost-efficiency at the output level, particularly in terms of research productivity and training delivery. This assessment is based on the volume, diversity, quality and dissemination reach of outputs relative to the investments made.

1. **Research and academic outputs**
    - A total of 22 peer-reviewed scientific articles were published under the project:
        - AHA-supported MSc students (2023–2025) directly authored 10 of these publications, as documented in the student publication table.
        - Partner institutions published the other 12, acknowledging support from the AHA project.
    - Most of these were published in international open-access journals, increasing their accessibility and impact.
    - This publication output reflects exceptional value for money in terms of scientific contribution, visibility and capacity strengthening, reflecting both strong supervision and student engagement.

2. **Training and capacity building**
    - Over 100 professionals from more than eight countries were trained through seven intensive hands-on training cycles at FAIH, in addition to multiple regional, international and online courses.
    - The delivery of structured e-learning courses and the awarding of training certificates further improved accessibility and reduced travel-related costs.

3. **Cost-efficient partnerships**
    - The project capitalized on existing institutional platforms such as shared training responsibilities with the NVI/NMBU and strategic use of Learn.ink for online courses.
    - High partner engagement and cost-sharing, such as through joint workshops, supervision and shared lab access, reduced duplication and optimized resource use.

Considering some of the challenges faced by education and research under the AHA project, the number, quality and relevance of outputs produced were exceptionally high, indicating excellent cost-effectiveness in delivering both services (training and capacity building) and products (scientific knowledge and tools). This was achieved through effective partnerships, low-cost digital solutions and strategic deployment of technical expertise.

5. Results monitoring and evaluations

5.1. Please provide an overview of any reviews/evaluations conducted during the year

Prof. Mutoloki conducted the end-term evaluation of the AHA project and also carried out the midterm review. The purpose of the assessment was to assess the project's achievements in terms of relevance, coherence, efficiency, effectiveness and visibility. It involved reviewing key documents such as technical and financial reports, evaluating progress since the midterm review, and conducting interviews with WorldFish and partner institutions in Kenya and Ghana. The review yielded practical recommendations to inform future project design and ensure sustainability. The evaluation was conducted over five working days in March and April 2025.

The end-of-term evaluation report of the AHA project can be found in Appendix 17.

5.2. How did these contribute to learning and improvement of the Project?

Table 12 summarizes the key lessons learned and corresponding recommendations derived from the end-term evaluation of the AHA project. These insights are intended to guide future project design, implementation and sustainability planning, particularly in the context of capacity building, coordination and institutional engagement.

These lessons and recommendations not only reflect the real-world challenges faced by multi-partner development projects in SSA but also provide valuable insights for improving the design, execution and sustainability of similar initiatives in the future.

5.3. Have external reviews/evaluations been sent to Norad's evaluation database?

Yes. Please refer to the independent midterm and end-term review assessment reports (Annex 12 in Appendix 3 and Appendix 17).

5.4. Please state the type of review/ evaluation – external/independent, internal or a mixture of external/internal

External/independent review.

5.5. Assess research innovations and impactful contributions from students and local partners

The AHA project supported 13 MSc research projects in Ghana and Kenya that tackled critical challenges in aquaculture health, production and biosecurity. These student-led studies introduced practical innovations—from the use of postbiotics and hyperthermia treatment in fish disease management, to the first molecular confirmation of viral pathogens in Ghanaian shrimp populations, and the application of risk assessment tools in tilapia farming. Many projects directly engaged local farmers and institutions, generating actionable insights for disease prevention, feed optimization, AMR monitoring and environmental sustainability. The collaborative nature of these efforts strengthened ties with national research institutions, regulatory agencies and private sector actors. Several of the studies have already been published in peer-reviewed journals, contributing to the regional and global body of knowledge on AAH. Full details of the student research contributions and local partnerships are presented in Appendix 18.

5.6. Building capacity for the future: How the project advanced the careers of the MSc students in the aquaculture Industry

One of the key successes of the AHA project was the strong post-graduation outcomes of the MSc students it supported in Ghana and Kenya. These graduates have transitioned into impactful roles across various sectors, including government agencies, universities, the private aquaculture sector and international fellowships. Their current employment reflects the project's long-term contribution to building human capacity in AAH and sustainable aquaculture across SSA. Appendix 19 provides an overview of each graduate's career trajectory, including their institutional affiliations, job roles and areas of professional engagement.

Category	Lessons learned	Recommendations
Institutional challenges	Delays from strikes, procurement issues and limited admin capacity affected implementation timelines.	Strengthen operational support: Allocate dedicated project resources for admin and logistical support at partner institutions.
Supervision and student progress	Inconsistent supervision, feedback and limited access to resources led to delayed MSc completions and publications.	Agree on a shared online supervision platform at project onset, and hold regular joint meetings to ensure timely feedback and consistent student progress across institutions.
Fund disbursement to partners	The 75% threshold for fund release caused cash-flow issues, delaying activities.	Use time-based disbursements: Replace the 75% expenditure rule with a time-based funding model, and permit Norad to disburse funds directly to Norwegian institutions to avoid delays and currency exchange losses.
Underdeveloped networking	Events and meetings were held, but without structured follow-up or clear indicators, they did not yield sustainable networks or measurable long-term impact.	Formalize networking structures by establishing sustained, outcome-oriented networks with clear objectives, roles and measurable indicators for tracking progress and impact.
Gender	Female participation was limited, highlighting missed opportunities to apply proactive affirmative action measures to promote gender equity.	Implement proactive affirmative action strategies during recruitment and training selection to improve female participation.
Overall project efficiency	Variations in understanding and applying the results framework among partners hindered effective monitoring and coordination. Establishing early alignment on processes for results tracking is essential for coherent and streamlined project implementation.	Conduct results management workshops: Train partners early on the results tracking framework and logic to improve monitoring and consistency across partners.
Visibility to end-users	Academic/technical dissemination was strong, but there was minimal outreach to farmers via popular channels.	Develop communication strategies that effectively target fish farmers via accessible platforms, including radio, TV, social media and local extension services.
E-learning courses	Although the project exceeded targets for online course development, a lack of institutional ownership limited their integration into formal education systems, affecting long-term sustainability.	Institutionalize online courses: Host courses at the UoN/UoG with WorldFish support for sustainability.

Table 12. AHA project lessons learned and recommendations.

5.7. Risks and sustainability

5.7.1. Materialized risks and mitigation measures

During implementation, the AHA project faced several contextual and operational risks that required adaptive management to ensure the achievement of intended results.

1. **COVID-19 disruptions**:
   The pandemic caused significant delays in the first two years, impacting international travel, procurement of laboratory equipment, and in-person training.

   Actions taken: The project quickly shifted to online learning (e.g., Learn.ink platform) and virtual coordination via Microsoft Teams. In-country training activities were decentralized to empower local partners.

   Effects: Although initial delays slowed progress, the move to hybrid delivery ultimately expanded reach and accessibility, increasing digital readiness across institutions.

2. **Partners' administrative and financial bottlenecks**:
   Fund disbursement thresholds, procurement procedures, and complex administrative approvals occasionally delayed activities and payments to partners.

   Actions taken: WorldFish provided flexibility, closely following up with country teams and maintaining ongoing communication with Norad about any necessary adjustments.

   Effects: Despite temporary slowdowns, financial execution remained strong, with 98% budget utilization and all major output completed within the no-cost extension period.

3. **MSc student progress**:
   Several MSc students needed additional time to complete their theses, mainly due to technical delays or medical issues.

   Actions taken: WF, NVI, and partner universities offered flexibility by providing additional technical support to students facing challenges and extending deadlines when needed to ensure successful research completion.

   Effects: These adaptive measures improved MSc students' research coordination and continuity, helping them stay on track to complete their work with ongoing supervision beyond the project period.

4. **Visibility to end-users**:
   Academic and technical dissemination was strong, but outreach to farmers through popular communication channels was limited.

   Actions taken: Some efforts were made to improve communication strategies to better reach fish farmers via accessible platforms, including radio and social media.

   Effects: Ongoing dissemination efforts aim to increase awareness and promote biosecurity and management practices among farmers, enhancing disease prevention and productivity. Greater visibility of results will connect research with practical application, encouraging private sector and extension engagement. Long-term, these activities will foster informed communities, wider dissemination of innovations, and increased adoption of aquatic animal health guidelines across Sub-Saharan Africa.

5. **Gender participation imbalance**:
   Women's participation in MSc programs and certain technical training remained below targets.

   Actions taken: Implement proactive affirmative action strategies during recruitment and training selection to increase female participation.

   Effects: Female participation steadily grew (40% of total learners), serving as a model for inclusive capacity-building efforts.

5.7.2. Lessons learned on risk management

The project demonstrated that proactive risk monitoring combined with transparent communication among partners is essential for maintaining momentum amid uncertainty. Decentralized management and local ownership were crucial for reducing delays and ensuring interventions are relevant to the local context. Utilizing digital learning platforms early in the project design improved resilience, enabling rapid adaptation to external shocks like COVID-19. Future AAH funded initiatives should establish flexible planning systems, increase financial independence at the partner level, and make risk communication a regular part of management.

5.7.3. Sustainability of project interventions beyond the project period

Sustainability has been intentionally integrated through capacity building, institutional collaboration, and developing lasting partnerships. Trained personnel remain employed at universities, research institutes, private companies, and government agencies, ensuring that technical expertise continues to support national programs. Laboratories upgraded under the project are now part of university research, utilizing standardized protocols and molecular tools introduced by the AHA project. The Learn.ink platform continues to serve as a regional training resource.

The strengthened partnership among WorldFish, NVI, UoG, and UoN has evolved into regional networks dedicated to ongoing research and technical exchange, establishing a foundation for future aquatic animal health initiatives. These networks support ongoing mentoring of students, collaborative research efforts, and coordinated responses to emerging transboundary diseases.

Additionally, national authorities in Ghana and Kenya can incorporate elements of the project into their ongoing programs, directly connecting research outputs to policy and practice. Through these combined efforts, AHA's legacy extends beyond its active phase, supporting resilient aquaculture systems, better disease preparedness, and stronger regional cooperation across Sub-Saharan Africa.

6. Financial reporting

6.1. The financial report and the audited financial statement shall be in accordance with the requirements outlined in the grant agreement, including part 3 of the General Conditions "Financial Report." This implies that the financial report shall follow the same budget structure as the last approved budget, including a comparison of actuals against the budget, and make it possible to identify deviations between the two

As of March 31, 2025, the AHA project reported a total expenditure of NOK 26,507,624 against an approved budget of NOK 27,000,000, resulting in an overall positive balance of NOK 492,375 (Table 13). Most budget lines were well managed, with underspending observed in areas such as training and workshops (NOK 145,208), partners and collaboration (NOK 250,041) and publications (NOK 107,946). These balances were primarily due to delays or the inability of partners and WorldFish to spend and report within the revised implementation period, which ended on March 31, 2025.

Detailed budget information for the partners (NVI, UoG and UoN) is provided in the financial report for the period January 1, 2024 to March 31, 2025, prepared by WorldFish and available in Appendix 20.

Budget line items	Total revised budget	Total cumulative expenditures: December 1, 2020–March 31, 2025	Budget balance
	NOK	NOK	NOK
A. Personnel costs	4,898,762	4,887,460	11,302
B. Travel	1,048,692	1,062,508	13,816
C. Consultancy	500,593	579,797	79,204
D. Publication	259,827	151,881	107,946
E. Training/workshop	2,841,385	2,696,177	145,208
F. Supplies and operations	1,474,798	1,443,089	31,709
G. Partners and collaboration	13,714,810	13,464,769	250,041
H. Institutional overhead	1,731,721	1,701,707	30,014
I. Consortium costs	529,412	520,236	9176
Total budget / expenditure	**27,000,000**	**26,507,624**	**492,375**

Table 13. Budget and expenditure summary as of March 31, 2025.

6.2. The financial report shall identify the organization's own contribution and Norad's share of indirect cost contribution, any unused Norad funds at the end of the reporting period, as well as interest earned on Norad funds

The detailed financial report (Table 13 and Appendix 20) presents all required financial information. There were no contributions from the implementing organization, nor was any interest earned on Norad funds. The project concluded with a positive budget balance of NOK 492,375, representing approximately 1.82% of the total budget of NOK 27,000,000.

6.3. Any significant deviations between actuals and the last approved budget shall be justified

Minor overspending was recorded under consultancy (NOK 79,204) and travel (NOK 13,816); however, these were covered through formal requests for budget reallocation and a no-cost extension, both of which were submitted and approved in writing by Norad. Overall, the project's financial performance remained strong, with all variances documented and managed following established governance procedures.

6.4. If the Project also receives contributions from other donors, consolidated accounts for the Project as a whole must be submitted

No contributions from other donors were received.

6.5. Report preparation statement

Jérôme Delamare-Deboutteville prepared this final technical report, drawing on a range of inputs from colleagues, materials and previous reports developed by project partners.

6.6. Date and attestation

I am authorized to enter into legally binding agreements on behalf of the grant recipient and attest that to the best of my knowledge and belief, the information given in this report is correct.

Date: July 4, 2025

Project leader of the AHA project
Dr. Jérôme Delamare-Deboutteville
Scientist
WorldFish

Appendices

Appendix 1. AHA project progress report 2021

https://hdl.handle.net/20.500.12348/5273

Appendix 2. AHA project progress report 2022

https://mel.cgiar.org/reporting/download/report_file_id/46605

Appendix 3. AHA project progress report 2023

https://mel.cgiar.org/reporting/download/report_file_id/46323

Appendix 4. MSc student theses: University of Ghana

https://mel.cgiar.org/reporting/download/report_file_id/49781

Appendix 5. MSc student theses: University of Nairobi

https://mel.cgiar.org/reporting/download/report_file_id/49781

Appendix 6. Workshop: Advanced Molecular Diagnostics and Sequencing

https://mel.cgiar.org/reporting/download/report_file_id/47226

Appendix 7. WOAH24: Workshop program and presentation

https://mel.cgiar.org/reporting/download/report_file_id/47730

Appendix 8. AquaGhana24: Program, abstracts and presentations

https://mel.cgiar.org/reporting/download/report_file_id/49788

Appendix 9. AquaSustain24: Program and speaker list

https://mel.cgiar.org/reporting/download/report_file_id/49792

Appendix 10. AFRAQ24: Program, abstracts and presentations

https://mel.cgiar.org/reporting/download/report_file_id/49794

Appendix 11. WOAH25: Paris program, abstract and presentation

https://mel.cgiar.org/reporting/download/report_file_id/49797

Appendix 12. WOAH25: STAR-IDAZ workshop report, survey results and policy brief

https://mel.cgiar.org/reporting/download/report_file_id/49799

Appendix 13. AHA project conference and event summaries

Detailed summaries of the conferences and the events (2022–2025)

First World Aquaculture Africa (AFRAQ21)

Date: March 25–28, 2022
Location: Alexandria, Egypt

WorldFish and NVI project team members participated in the AFRAQ21 international conference. AHA project goals and activities were highlighted during the WorldFish hybrid session titled Aquaculture Africa (AFRAQ21) – WorldFish Research and Development in Africa: Success Stories and Lessons Learned. All leaders from WorldFish, the NVI, Kenya and Ghana presented their project activities and explained how capacity building programs can support the sector across Africa and within their respective countries (Ghana and Kenya).

Malaysia Fisheries Society: Aquaculture in the Digital Age 2023 Seminar

Date: June 10, 2023
Location: Kuala Lumpur, Malaysia

Alongside its 36th Annual General Meeting, the Malaysian Fisheries Society and the Centre of Research for Advanced Aquaculture brought together experts from academia, industry and government to share the latest innovations and technologies in monitoring, management, disease surveillance, diagnosis and Internet of Things systems to advance sustainable aquaculture production systems. Among the presentations were two by WorldFish staff, who joined the talks to highlight digital tools for surveillance of aquaculture production systems, reporting disease outbreaks and disease diagnosis in a fish farmer's backpack.

The Africa Food Systems Forum's AGRF 2023 Summit

Date: September 3–6, 2023
Location: Dar es Salaam, Tanzania

Two master's students, one from Ghana and one from Kenya, were chosen to attend. Alongside the WorldFish delegation, the students took part in a side event titled Thriving Africa with Aquatic Food, which offered a chance to promote key agendas on youth involvement in aquatic food discussions and share their challenges and opportunities. They also emphasized the importance of capacity building for youths, particularly in AAH programs, to support the sector's sustainability. This event served as an excellent networking opportunity for students from Ghana, Kenya and other African countries.

Second World Aquaculture Africa 2023 (AFRAQ23) Conference

Date: November 13–16, 2023
Location: Lusaka, Zambia

The AFRAQ23 conference, hosted by the World Aquaculture Society, was held at the Mulungushi International Convention Centre in Lusaka, Zambia. The event brought together aquaculture researchers, practitioners, industry leaders, policymakers and students from across Africa to explore the theme "resilient value chains in the blue economy." Featuring plenary and parallel sessions, satellite workshops, student activities, an international trade exhibition and farm tours, the conference emphasized the latest research, capacity building and market development in areas such as AAH, genetics, nutrition, sustainability and finance. All 13 AHA master's students participated and presented their research findings in the form of oral or poster presentations.

The fourth cycle of WOAH Focal Points Aquatic Animals (Africa) 2023 training
Date: October 1–4, 2023
Location: Kigali, Rwanda

Two WorldFish staff members attended, engaging with WOAH Focal Points from multiple African countries, including Egypt, Kenya, Malawi, Nigeria, Rwanda, South Africa, Tanzania, Uganda, Zambia and Zimbabwe. The event provided an excellent platform to hear from various global experts and organizations involved in AAHM. This meeting shared and highlighted activities and results from ongoing projects, such as the AHA project, across different African nations. It fostered strong partnerships and explored how stakeholder collaboration can improve the delivery of AAH activities in Africa.

1st Annual Faculty of Veterinary Medicine (FVM) Scientific Conference and Community Outreach
Date: October 25–27, 2023
Location: Faculty of Veterinary Medicine grounds, UoN, Kabete Campus

Held under the theme "harnessing research in veterinary science for resilience and sustainability of communities," the event brought together researchers, students, practitioners and government representatives to share knowledge on topics such as One Health, AMR, livestock production and aquaculture. Notably, students and academic staff from AHA project partners at the UoN delivered three presentations: (1) Fish farm management practices and their impact on fish parasitism in Kericho and Bomet counties, Kenya, (2) Comparative hatchery management practices and ectoparasitic infections of Nile tilapia in Homa Bay County, Kenya, and (3) Occurrence of bacterial infections in different sizes of Oreochromis jipe under varying climate and physio-chemical conditions in Taita-Taveta County, Kenya. A community outreach activity was also held on October 28 at the Ndubuini Centre.

Aquatic Animal Epidemiology (AquaEpi III) 2023 Conference
Date: November 2–December 1, 2023
Location: Lucknow, India

Organized by the Indian Council of Agricultural Research, this event welcomed officials from various government departments, epidemiology researchers, students and industry advisors from both national and international levels. A WorldFish team member delivered one of the presentations, titled Insights into Aquatic Epidemiology in Asia and Africa Using Digital Surveys. This presentation highlighted both past and current uses of the FEHE survey tool developed by WorldFish and the NVI, explaining the survey development process and sharing insights from epidemiological studies in South Asia and Africa.

Cefas Sustainable One Health Aquaculture and AMR events
Date: February 25–28, 2024
Location: Accra, Ghana

The Ocean Country Partnership Programme, funded by the UK's Blue Planet Fund, supports marine science and sustainable aquaculture in ODA-eligible countries. The Ghana workshop focused on promoting sustainable aquaculture through the One Health Aquaculture approach, aiming to enhance aquatic food safety by addressing environmental, animal and human health risks. Ghanaian, UK and international experts gathered to identify supply chain hazards, showcase innovative diagnostic tools and encourage collaboration. The event also offered a valuable opportunity for the WorldFish team to connect with NVI and UoG partners and MSc students, review progress on AHA project activities and strengthen partnership networks.

58th Kenya Veterinary Association (KVA) Annual Scientific Conference
Date: April 24–27, 2024
Location: El-Boran Resort, Isiolo County, Kenya

This event brought together veterinary professionals, researchers and policymakers from various institutions, including the UoN, the Kenya Veterinary Association, the Ministry of Agriculture and Livestock Development, the ILRI, the Kenya Veterinary Vaccines Production Institute and private sector organizations. Key activities included scientific paper presentations, workshops on One Health, AMR and animal welfare, as well as community outreach initiatives like livestock vaccination and deworming. The AHA project partner from the UoN delivered a presentation titled Fish Parasites of Economic and Zoonotic Potential in Cultured and Wild Freshwater Systems in Kenya.

WOAH Meeting Training of National Focal Points for Aquatic Animal Health (Cycle IV)
Date: July 8–10, 2024
Location: Tunis, Tunisia

The workshop focused on improving disease reporting, implementing international standards and enhancing regional cooperation in AAH. Sessions covered topics such as certification, biosecurity, surveillance and strategic planning, with insights from WOAH, FAO and representatives from various countries. The workshop also emphasized the importance of public–private partnerships, regional networking and capacity building through initiatives like Aquae Strength and the PVS pathway. It concluded with a discussion on revising focal point roles and a field visit. WorldFish presented about its partnership and support for AAH health in Africa, including the AHA initiative.

Aquaculture Ghana Stakeholder Collaboration Event
Date: May 30–31, 2024
Location: Accra, Ghana

This event brought together key stakeholders to strengthen collaboration and resilience in Ghana's aquaculture sector. It featured high-level participation from government officials, researchers, private sector leaders and youth innovators. The program included expert panels and technical sessions on critical topics such as climate change, rising feed costs, RAS, aquaculture financing, fish health, marketing, and risk management. A diverse range of oral and poster presentations showcased advances in fish nutrition, health, genetics and sustainability. The event wrapped up with an awards night honoring outstanding contributions to the aquaculture industry across multiple categories. Notably, four of the AHA-supported MSc students attended and presented their research findings during the event.

AquaSustain Scientific Conference
Date: July 24–26, 2024
Location: Bangkok, Thailand

This conference brought together leading experts and practitioners to discuss innovations in sustainable aquaculture. The program included keynote addresses, panel discussions and technical sessions on AAH, feed innovations, climate change resilience, digital technologies and biosecurity. Speakers featured representatives from FAO, academia, development organizations and industry, highlighting interdisciplinary approaches and collaborative strategies to improve productivity and sustainability in aquaculture systems across Asia and Africa.

Third World Aquaculture Africa 2024 (AFRAQ24) Conference
Date: November 19–22, 2024
Location: Hammamet, Tunisia

AFRAQ24 was a significant international event that brought together stakeholders to promote sustainable aquaculture development in Africa through science, innovation, policy discussions and capacity building. Three abstracts included in the appendix highlight key scientific contributions presented at AFRAQ24 under the AHA project. They cover improved AAHM and capacity building carried out under the AHA project in SSA, advancements in the molecular understanding of heat-shock treatment for ISKNV in tilapia, and a One Health approach presentation focused on combatting AMR in aquaculture across Asia and Africa. These studies emphasize the project's influence on research, disease management and sustainable aquaculture practices.

WOAH Paris Headquarters Workshop to Identify the Highest Priority Research Areas for Finfish Health
Date: February 20–21, 2025
Location: Paris, France

The 2-day WOAH workshop brought together global experts to identify the top research priorities for finfish health. Day 1 covered significant challenges, including AMR, emerging diseases and biosecurity, followed by group discussions on epidemiology and control strategies. Day 2 focused on diagnostics, vaccines and therapeutics, concluding with a panel discussion on transforming priorities into funded research plans and actionable steps, promoting collaboration among funders, researchers and industry to develop resilient and sustainable AAH systems worldwide. WorldFish shared its AAH research program and the AHA initiative. The event also provided valuable networking opportunities with NVI colleagues and international partners.

Appendix 14. AHA Ghana closure workshop: Report and presentations

https://mel.cgiar.org/reporting/download/report_file_id/46543

Appendix 15. AHA Kenya closure workshop: Report and presentations

https://mel.cgiar.org/reporting/download/report_file_id/46545

Appendix 16. AHA closure workshops: NVI and WorldFish presentations and videos

https://mel.cgiar.org/reporting/download/report_file_id/49810

Appendix 17. AHA project end-of-term evaluation report

0

End of term Evaluation Report for the Increased Sustainability in the Aquaculture Sector in Sub-Sahara Africa (SSA), through improved Aquatic Animal Health Management (AHA) project.

Grant recipient: International Center for Living Aquatic Resources Management (ICLARM)

Norad Agreement number: RAF-19/0051.

By Stephen Mutoloki

Professor of Aquatic Animal Health

Norwegian University of Life Sciences

Faculty of Veterinary Medicine

Desk-top evaluation of the Project

Date: 25th April 2025

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report presents the findings of an end of term evaluation of the Increased Sustainability in the Aquaculture Sector in Sub-Saharan Africa (AHA) project coordinated by WorldFish (WF). The purpose of the evaluation was to assess the relevance, coherence, efficiency, effectiveness and visibility of the project based on results achieved, and to provide recommendations for improvement for future projects.

The methodology used was a desktop approach to compare achieved results against targets as contained in relevant project documents, and also by interviews with project partners and beneficiaries.

Key findings of the evaluation:

1. Project Achievements

Significant achievements have been made in capacity-building since the start-up of the projects, including enhancing research competence, academic opportunities, and infrastructure. Below are the highlights of outputs:

- Research
  - 9 of the 13 recruited Msc students have graduated
  - 14 articles against the 12 targeted have been published
  - 1 wet lab established at UoN
  - 1 lab upgraded and retooled at UG
- Education
  - 14 physical training meetings held against a target of 10. More than 100 extension workers and government officials from 8 countries in SSA trained.
  - 17 online courses developed and published against a target of 10. These courses were accessed by more than 641 people from SSA during project lifetime

2. Challenges identified

- Bottlenecks such as industrial action affecting entire university, lengthy procurement processes, poor access to labs and equipment for students and limited admin capacity within the project led to delayed technical and financial reporting requirements.

- The 75% threshold for fund disbursement was challenging for partners especially procurement processes take long.

3. Intermediate outcomes

- Human capacity developed through better qualified graduates- 3 of the graduates have been offered jobs, one a scholarship/fellowship for further training.
- Institutional capacity developed at UG through equipping a lab at the Department of Marine science and a wet lab at UoN College of Veterinary Medicine.

Recommendations:

- Provision of additional admin and logistical support to partner institutions would ease some of the administrative and technical challenges they face
- Time-based disbursement of funds to partners institution instead of the 75% threshold rule would work better for institutions that depend on cash transactions.
- Regular planning and coordination meetings (with key PIs) targeting outputs and timelines would harmonise and optimize performance while reducing variations between UoN and UG. In addition to the regular meetings for student progress updates.
- A results management workshop (at the start of the project) to provide a clear understanding of the flow of the results chain for all project partners would enhance the management of results and better tracking of project achievements
- The developed online courses should be hosted by either UoN, UG or both but supported by WF. This will augment visibility, enhance access and also add to the capacity of the SSA partners.

Conclusion

The AHA project has made significant achievements towards enhancing capacity of research and education in aquatic animal health management especially in Kenya and Ghana. It has also contributed with initial steps in 6 other countries in the rest of SSA. While challenges in Institutional capacity and the aquaculture industry remain, proactivity in the network

sustenance and spread of knowledge products will be key in maximising the project´s long-term impact.

1. INTRODUCTION

1.1 BACKGROUND AND CONTEXT

The “Increased Sustainability in the Aquaculture Sector in Sub-Saharan Africa” was a regional project created to enhance capacity, education and networks in aquatic animal health research in the region. The background to this was that aquaculture in Africa, especially sub-Sahara Africa, was on the increase with tilapia and catfish among the leading farmed species. The status of aquatic animal diseases in several sub-Saharan African (SSA) countries is yet to be fully investigated. The recent outbreaks of diseases like EUS, TiLV and ISKNV in Africa highlighted the continent's lack of capacity to prevent and control such emerging diseases. The goal of this regional project was to increase the sustainability and resilience in the aquaculture sector in SSA, through improving aquatic animal health management and biosecurity governance. This 4-year project had four partners – WorldFish, the Norwegian Veterinary Institute (NVI), the University of Nairobi, and the University of Ghana. WorldFish and the NVI were using their expertise and networks to implement the project mainly in Ghana and Kenya. In addition, many other countries within SSA benefited from this project through intensive training programs aimed at building the capacity of the targeted groups and also networking of participants within SSA.

The project worked to achieve the following higher-level outcomes, including specific research, educational and networking outcomes:

A. Improving Research capacity in aquatic animal health management in SSA countries
B. Improving Institutional capacity and learners’ knowledge and practical skills in aquatic animal health as well as to enhance aquaculture related education services and extension capacity in SSA countries.
C. Generating new knowledge in aquatic animal health, in aquatic food systems from the framework of one health and one food systems widely shared in SAA through sustainable networking.

A. Research outcomes

- Research/Knowledge gaps in the aquatic animal health management in the selected countries (Ghana and Kenya) identified and addressed/filled.
- Research findings and new knowledge on aquatic animal health are availed by relevant stakeholders in Ghana/Kenya and other SSA countries (DOF, policy makers, academic institutions, extension agents from the public and private sectors, etc.)

B. Education outcomes

- State of the art educational modules on aquaculture and aquatic animal health for implementing regular face-to-face and online virtual training programs for SSA from WorldFish Aquaculture Research and Training Center (AARTC), based in Abbassa developed and available.
- Availability and accessibility of SSA countries to training programs and online self-learning course modules on aquaculture and aquatic animal health management increased.

C. Networking outcomes

- Dynamic and operational networking mechanism developed for sharing of aquatic animal health knowledge amongst SSA countries to support national and regional aquatic animal health strategy operationalization.

1.2 OBJECTIVES

The purpose of the evaluation was to conduct an end of term review focusing on results achieved by the Norad project AHA.

The End of term external evaluation was to particularly assess:

- **Relevance**: to what extent is the work done relevant to the project beneficiaries
- **Coherence**: to what extent were project activities and outputs consistent with the project objectives?

- **Efficiency**: determine the rational use of resources within project implementation budget; were the resources used in the best possible way?
- **Effectiveness**: Were the project outputs delivered as planed?
- **Visibility**: in relation to communication and dissemination of project outputs.
- **Recommendations**: make recommendations on efficient use of project resources, and sustainability strategy for future project design.

1.3 TERMS OF REFERENCE

The consultant was to compare achieved results with targets, based on the findings presented in relevant project documents including the program proposal, result framework, annual Technical Progress Report (TPR), and annual Financial Report (FR). In addition, virtual interviews were to be conducted with all four partners:

1) WorldFish (WF)
2) Norwegian Veterinary Institute (NVI)
3) University of Ghana (UG)
4) University of Nairobi (UoN)

2.0 METHODOLOGY

The evaluation involved comparing achieved results against the initial targets from project reports, specifically the TPR for 2023 from WF to Norad, the audit report for 2023, and the results framework; the final Technical and Financial Reports from UG, UoN and NVI. In addition, the mid-term evaluation report was also consulted.

Interviews were held with all partners. In addition, one Msc student from UoN, Cidee Night Khaseke, and another from UG, David Batsa were also interviewed. The selection of these two students for interviews was based on projections that they would finish their studies last in their groups.

The purpose of these interviews was 1) to verify facts 2) seek clarification on different issues and 3) to find out opinions about different aspects of the project including their own self-evaluation.

3.0 GENERAL FINDINGS

The evaluation revealed that very good progress had been achieved by the project with more than 90% of the deliverables being met, or at least with a good likelihood that they will be met.

3.1 RELEVANCE

One of the higher-level outcomes of the project is the improvement of research capacity on aquatic animal health management in SSA countries. The impact would be better disease prevention and control leading to higher productivity. The ultimate beneficiaries of the project therefore were fish farmers while the Msc students and extension workers and other government officials were target groups.

Enhanced capacity of the target groups would contribute to achieving the higher-level outcome. Most of the Msc candidates at UG were already employees of the Fisheries Commission of Ghana. None of them had undergone training in fish health although they may have been required to offer this service as part of their job. An example is David Batsa who had a veterinary background but with no prior knowledge of fish health, yet he was assigned to oversee a fish hatchery about the time that he was enrolled as an Msc student in the program offered by the project. Training in the program equipped him with knowledge to discharge his duties from a position of strength, and so it was for all the other students.

Another measure of relevance of a training program is the employability of the graduates. In line with this, one of the students, Finnan Okoth Ageng'o, from UoN got employed as an assistant lecturer at Egerton University, Kenya upon graduation. Abigail Amankwah from UG got employed by a commercial fish farm in Ghana upon completion. Similarly, Cidee Night Khaseke, a student from UoN was offered a position as an aquaculture contact person for the Fleming fund even before completion because of the training she acquired in the project. Mercy Hamisi (UoN) was offered a fellowship to attend a leadership course at University of California- Davis, USA as an off-shoot of this program. All these examples attest to the relevance of the project.

3.2 COHERENCE

At the beginning of the project, a baseline study was conducted to establish the needs of the aquaculture industry in terms of fish health in the region. Although this information should have been known even before the start of the project, the findings formed a good foundation for subsequent activities. The recruitment of 6 Msc students at UG and 7 students at UoN, offering them course work and support in aquatic animal health as well as supervision of their research work were consistent with the project objectives of building capacity for research and education in Ghana and Kenya. Furthermore, training of Msc students to conduct research in the two countries also contributed to bring out the fish health status and economic impact of diseases affecting aquaculture in the two countries. Similarly, government and fisheries/aquaculture extension workers from countries in Sub-Sahara Africa including Ghana, Nigeria, Kenya, Mali, Malawi, Madagascar, Mozambique, and Zambia that underwent training at FAIH, Egypt also benefited from increased capacity. These trainings also provided the participants the opportunity to get acquainted with each other and form a network through which they could support each other. This is an activity that contributed to regional transformation, in line with the project objective. Cooperation between countries, especially those that share common water bodies is a necessity given that fish know no borders.

3.3 EFFICIENCY

The allocation of funds for different activities was in general well done. Most, if not all of the targets for research, education and networking were met if not exceeded. This demonstrates efficient use of funds to generate results. This, however, was not without any challenges. One of the challenges was the requirement that 75% of funds disbursed should have been used before a new disbursement can be requested from WF (75% threshold). An illustration of a problem this can create is as follow: Suppose that a partner institution receives a disbursement of $10.000 for activities from Jan to September. They only manage to spend $7.300 because of delays in procurement of some goods and so are not eligible for a new disbursement in October. In November, the partner´s team needs to attend a conference and the total cost is $2.900. The partner has a $200 deficit and has to decide: either to borrow the $200 shortfall or not attend the conference altogether.

The basis for the 75% threshold is justified, but as illustrated above, has a caveat. Partners in the South do not have credit facilities that they can use to bridge lapses in availability of cash. It is therefore important that the funding system is adjusted to take this into account. In the example given above, an alternative approach would be to disburse the funds as scheduled in October but then less the balance at hand ($2700 in the example above) is released. This will ensure that partners have funds available to conduct activities at all times. This said, and also to be fair with WF, this issue can be due to planning, and with some flexibility from the grant recipient, it can easily be averted. UoN admitted that they, as an example, had no issues with the 75% threshold rule during the final year of the project, with the understanding and flexibility of WF.

Another issue was the design of the transfer of funds to the Norwegian partner. In their model, Norad transferred all funds to WF which in turn transferred some funds back to the Norwegian partner. This process required currency exchanges both ways (NOK to USD and vice-versa) that may have resulted in gains or losses in funds. Although this can even out in the long run, the threat is than funds can be lost and this can be avoided.

Delayed feedback to students by supervisors is one of the challenges that was faced in this project. Uneven access to the students´ work, whether theses or manuscripts by external supervisors, led to poor progression. This was apparent even before the mid-term and continued in the final project year. To resolve this, the use of shared platforms of data storage that all partners are obliged to use is necessary.

Finally, it is noteworthy that most, if not all activities that were delayed, were at UoN and UG (see also below). These delays include industrial actions by workers that led to prolonged closures of campuses for example of UG, procedural bottlenecks, technical and administrative challenges. Collectively, they issues impacted the efficiency of the project and need to be addressed proactively in the future by redefining new management clauses in the respective contracts.

3.4 EFFECTIVENESS

In general, most of the outputs of the project were met albeit not always on in the planned timeframe. A summary of some of the outputs delivered are as follows:

3.4.1 Research

- Msc students recruited: 13 against the targeted 12
- Msc students graduated: 9 against an adjusted total of 13 (5/6 for UG; the last one expected to graduate this year; 4/7 for UoN; the remaining 3 expected to graduate this year)
- Publications: 15 against a target of 12 (9/6 from students at UoN; two more under preparation; 1/6 at UG, 5 still under preparation; 12. Additional articles by partners)
- Dissemination meetings: 2 closure workshops held with stakeholders (Ghana 1; Kenya 1)
- Conference presentations: AFRAQ23- 11 oral and 1 poster; AquaEpiII -oral; Aquaculture in the Digital Age forum- oral, AGRF23- 2 etc
- Equipment: 1 lab upgraded at UG; 1 Wet lab established at UoN

The outputs listed above demonstrate the positive progress made by the project. The overall graduation rate of Msc students stands at 69% with a good likelihood of increasing. Individually, the graduation rates of the two universities are currently at 83% (UG) versus 57% (UoN). The publication rates on the other hand, stand at 17% (UG) versus 150% (UoN) with those by the project partners coming in addition at 12. The overall publication record is impressive, with an excellent performance by students at UoN. This can be a reflection of different priorities and routines by the different universities, or a lack of coordination at partner and project level. Whichever is the case, there are lessons that the two universities can learn from each other about boosting performance, be it on graduation rate or publications. It must also be mentioned that those students that have not yet graduated are in the process of preparing their theses and may graduate at the next opportunity. Similarly, the students that have not yet published articles, 5 (UG) and 2 (UoN) have manuscripts under preparation or already submitted to journals for peer-review. The anticipation is that the publication record will rise even higher.

As already state above, there were challenges associated with training of students which affected the timeline to their graduation. Delays started before the mid-term evaluation for both groups and continued through to the end of the project and as already mentioned above, include 1) Administration - registration etc, 2) Procurement of reagents/access to equipment, 3) slowness by some of the students themselves, 4) delayed input from supervisors, 5) illnesses.

3.4.2 Education

- 6 physical training courses conducted against 7 targeted at FIAH with 100 physical participants from 8 countries in SSA
- 8 additional physical training courses focussed on Kenya and Ghana were also conducted in addition.
- 17 online courses on the *Learn.ink* platform against a target of 10, with at least half of the participants coming from SSA.

In general, the project delivered very well on training, both in physical meetings but also online courses, exceeding the planned targets for either category. Although the target group of training, especially physical, were extension workers and other government employees as well as the Msc students, the ultimate beneficiaries as already stated are the fish farmers. It is at the level that farmers receive better services in terms of fish health management that one expects to see the outcome of the training. Follow-up with the participants therefore needs to be proactive. The project has contact information for participants, especially those that attended physical training, and should use this as a follow-up tool to find out what benefits the training had provided to participants upon returning to their home countries. The post-return follow-up is not so apparent in the project document.

On the developed online courses, the project should be commended for developing so many online courses that exceeded the target by far. However, it is noteworthy that WF is not an education institution although they may conduct training as part of its various projects. Transferring the online courses to educational institutions, such as UG or UoN and attaching them to existing programs would enhance their utilization, access as well as empower the universities to support capacity development of aquatic animal health management in SSA.

WF can then support the programs through the universities that can even give credits for courses taken. NVI and NMBU have a similar model.

3.4.3 Networking

Networking outputs as described in progress years (2021-2024) especially in the results framework, are difficult to relate with how they contribute to the higher-level outcomes (specifically "Dynamic and operational networking mechanism developed for sharing of aquatic animal health knowledge amongst SSA countries to support national and regional aquatic animal health strategy operationalization"). In the reports, meetings seem to be reported as networks, rather than events that facilitate networking. A physical or virtual meeting affords participants an opportunity to network but does not guarantee formation of a network. A functional network needs to be actively maintained and is not a one-off event. *Indicators* given in the results framework, i.e. *number of partnerships or cooperatives* established are meaningful indicators of networks but are not reported. Were none achieved? Furthermore, internal project meetings for example, comprising project partners/students/supervisors can hardly be classified as measures of networks formed (rather, they are part of the original AHA project network). In other words, from the results presented, it is difficult to establish what networks have been formed and whether these networks exist.

In general, the results framework contains several mix-ups of activities and outputs making it not always easy to measure the progress made. A workshop on results management would benefit the project members especially at the start of the project.

3.4.4 Gender

The participation of females in aquaculture at many levels is well-known to be poor, especially in SSA. Deliberate efforts to encourage their participation is therefore required. The overall female: male ratio of Msc students in this project was 1:2; the female to male ratio of participants that underwent physical training at FIAH was 2:3. Gender is one area where the project could have done better.

Affirmative action demands that deliberate action be taken in favour the disadvantaged. For the Msc students, the skewing towards male was mainly at UG where the female: male ratio

was 1:3. The reason given for this was project´s desire to recruit employees of the Fisheries Commission where the female pool is low. This is precisely why affirmative action should have been taken, to increase the number of females in the Fisheries Commission of Ghana! The more well-qualified females, the more the Fisheries Commission or any other industry will take them.

For the training participants at FIAH, it was probably not up to the project to nominate participant from different countries but a condition on the gender balancing from the project to appointing authorities could have gone a long way to balance gender.

3.5 VISIBILITY

Effective communication of generated results requires the use of specific media to reach specific target groups, beneficiaries or stakeholders. In this project communication of results to the scientific community including extension workers and other government officials was done by way of publications, conference presentations and closure meetings. The scientific and academic communities are the main beneficiaries of conferences and publications. To this effect, several conferences and meetings including AFRAQ23, AquaEpiII, Aquaculture in the Digital Age forum, and were attended by the project team where presentations were made. Similarly, a good record of publications in peer reviewed journals has been achieved.

Dissemination events that are conspicuous for the ultimate beneficiaries, the fish farmers, are the two last closure meetings held in Ghana and Kenya. A lot more could have been done to engage the farmers. It is quite unlikely that they would attend conferences or read scientific publications, but they do use popular channels like television, radio or even farming magazines, if any.

The networking activity in the project should be a driving force behind visibility of the project but has not been used effectively so far. This need to be followed up proactively. Online courses have the potential to increase the project impact, but for them to be accessed, they need to be visible enough. If attached to a learning institution, the anticipation is that they will be easily accessible.

4.0 RECOMMENDATIONS

Based on the findings discussed above, the following recommendations are aimed at enhancing the different parameters used in this evaluation including efficiency, effectiveness, coherence, visibility of this and future projects.

1) Regular planning and coordination meetings (mainly with PIs) targeting outputs and timelines would harmonise and optimize performance while reducing variations between UoN and UG
2) Higher institutions of learning in SSA have inherent administration and technical challenges that contribute to project inefficiency. Provision of additional administrative and logistical support to partner institution budgets will ease some of these challenges.
3) Time-based disbursement of funds to partners institution instead of the 75% threshold rule will ensure availability of funds for project activities at all times.
4) Norwegian partners should receive disbursements directly from NORAD. This will ensure that there is no risk of losing money in currency exchange and will also cut down on delays in money transfers.
5) Gender mainstreaming should be given more priority, affirmative action in favour of disadvantaged gender should be done more proactively.
6) The developed online courses should be hosted by either UoN, UG or both but supported by WF. This will augment visibility, enhance access, empower institutions of learning in SSA.
7) A results management workshop to provide a clear understanding of the flow of the results chain for all project partners would enhance the management of results and better tracking of project achievements

Appendix 18. MSc research innovations and local partnerships advancing aquatic animal health

Ghana

MSc student name	Thesis title	Research Innovation	Key local partners who supported the students
Abigail Amankwah	Parasitic infestations of cage-cultured Nile tilapia in Ghana	• Studied parasitic infestations in cage-cultured tilapia on Lake Volta, addressing a gap in existing research focused on ponds. • Engaged farmers through a participatory survey to identify peak infestation periods. • Intended molecular characterization of parasites.	Aquaculture Research and Development Centre (ARDEC); Phil-Brooks Aquaticus Ltd; Fisheries Commission (FC); Ghana National Aquaculture Association (GNAA).
David Narteh	Effect of hyperthermia treatment of infectious spleen and kidney necrosis virus (ISKNV) infection in fingerlings of cultured tilapia in Ghana	• Developed and tested experimental heating devices for hyperthermia treatment of ISKNV in tilapia fingerlings. • Demonstrated a more consistent and effective disease management strategy compared to traditional outdoor heating methods.	FC; Lee Farms.
Kofi Ferni Anyan	Effects of commercial dietary probiotics on growth performance and disease resistance of the Nile tilapia fingerlings in Ghana	• Investigated the effects of dietary probiotics on growth and disease resistance in Nile tilapia. • Provided histological evidence of probiotic-induced structural changes in fish organs. • Conducted novel gene expression analysis before and after disease challenge to elucidate immune mechanisms.	FC; Oceanography & Fisheries; BACL Probiotics Ltd.
Kwame Issifu	Risk factors and biosecurity measures on tilapia farms in the Eastern Region of Ghana	• Applied the EPI-Tool for the first time in Ghana to assess biosecurity and risk factors on tilapia farms. • Generated critical baseline data for disease prevention and management planning. • Focused on smallholder systems in the country's leading aquaculture region.	FC; GNAA; small-scale fish farmers in the Eastern Region.
Mabel Ackah	Comparative study of the efficacy of traditional and chemical methods in the treatment of Saprolegniasis in Nile tilapia	• Molecularly characterized the fungal pathogen causing Saprolegniasis in Nile tilapia, providing critical insights into pathogen identification and disease management. • Assessed the efficacy of traditional and chemical treatments, including herbal leaf extracts. • Explored water quality effects of these treatments, promoting environmentally friendly options.	FC; ARDEC.
Philip Kwasi Banini	Molecular investigation of major viral pathogens of the giant tiger shrimp *Penaeus monodon* (Fabricius, 1798) along the coast of Ghana	• Delivered the first molecular confirmation of infectious myonecrosis virus in wild black tiger shrimp (*Penaeus monodon*) along Ghana's coast. • Raised awareness of disease risks in wild shrimp populations and the need for enhanced coastal surveillance. • Highlighted implications for shrimp biosecurity and regional aquaculture resilience.	FC; fishers at Ada-Foah, Anloga, Moree and Winneba.

Kenya

MSc student name	Thesis title	Innovation(s) from the research	Key local partners who supported the students
Ndegwa Joseph Macharia	Pathogenicity of *Aeromonas veronii* var *sobriae* recovered from fish in Kenya	• Identified *Aeromonas veronii* var. *sobriae* from farmed fish as pathogenic to Nile tilapia fingerlings. • Highlighted its potential as a zoonotic agent, raising public health concerns. • Recommended enhanced diagnostic capacity and surveillance.	Fish farm; ILRI; Directorate of Veterinary Services (DVS); Central Veterinary Labs (CVL); VPMP-UoN microbiology/ pathology labs.
Mercy Hamisi Matuma	Potential pathogenic and zoonotic bacteria affecting farmed and wild *Oreochromis jipe* in Taita-Taveta county, Kenya	• Detected *Aeromonas veronii* and *A. hydrophila* in farmed and wild Oreochromis jipe. • Linked fish health decline to pathogen presence and poor water quality (e.g. high ammonia and nitrate levels, elevated pH). • Underlined importance of environmental monitoring in fish health management.	ILRI; DVS-CVL; VPMP-UoN microbiology lab; Lake Jipe fishing management unit; Kenya Wildlife Services; Taita-Taveta; farmers in each of the four subcounties; county director for agriculture, livestock and fisheries.
Merceline Ndinda Ndambuki	Effects of postbiotics supplementation on growth performance, haematological parameters and susceptibility of Nile tilapia (*Oreochromis niloticus*) to *Aeromonas hydrophila* infection	• Evaluated Saccharomyces spp. postbiotics in tilapia diets. • Found improved growth, hematological parameters and disease resistance to *Aeromonas hydrophila*. • Demonstrated potential for postbiotics as functional feed additives.	Fish farmers in Nairobi City, Eastlands and Thika; Unga Limited – standard fish feed source; VPMP microbiology/ pathology labs; government chemist; DVS-Nakuru Regional Veterinary Laboratory.
Ageng'o Finnan Okoth	Prevalence, intensity and influence of water quality on farmed fish parasites in Kericho and Narok counties, Kenya	• Assessed parasite diversity and prevalence in farmed fish in Kericho and Narok counties. • Identified biosecurity gaps and limited farmer knowledge as major risk factors. • Highlighted the zoonotic potential of some parasites affecting productivity.	County directors of fisheries in Jericho, Bomet and Taita-Taveta, as well as the fish farmers in these counties; UoN helminthology section.
Jacob Munene Wainaina	Prevalence, intensity and influence of parasites in production of Nile tilapia (*Oreochromis niloticus*) fingerlings in Homa Bay county, Kenya	• Tracked parasite intensity across the production stages of Nile tilapia in Homa Bay County. • Discovered stage-specific burdens from eggs to broodstock. • Recommended targeted interventions at each life stage to improve hatchery health.	UoN Department of VPMP Parasitology Section; fish farmers and private fish hatcheries in Homa Bay County; Victory Farms Company.
Cidee Night Khaseke	The prevalence of antimicrobial resistant bacteria and antimicrobial use in farmed and wild fish in Narok and Nakuru counties of Kenya	• Investigated AMR in bacteria from farmed and wild fish. • Found AMR genes in fish pathogens across Kericho, Nakuru and Bomet. • Raised alarms over biosecurity and zoonotic AMR transmission risks.	County directors of fisheries in Kericho, Bomet and Nakuru; ILRI; DVS-CVL; DVS-RVL in Nakuru; VPMP-UoN microbiology lab; private data analysts.
Victor Omondi Ogweny	Influence of fish feeds formulated with different protein sources on water quality, growth performance and survival of juvenile Nile tilapia *(Oreochromis niloticus)*	• Compared fish feeds using black soldier fly (BSF) larvae to conventional protein sources. • Observed higher growth and survival rates in tilapia fed BSF diets. • Noted elevated phosphorus in cage water, suggesting need to balance productivity with environmental sustainability.	Fish farmers in Nairobi City Eastlands and Thika; Unga Limited – standard fish feed source; VPMP microbiology/ pathology labs; government chemist; DVS-Nakuru Regional Veterinary Laboratory.

Appendix 19. Post-graduation employment of AHA-supported MSc students

Kenya

MSc student name	Employer | Position | Location | Start Date | Contract Duration
Ndegwa Joseph Macharia	Joseph is currently undertaking export fish quality certification duties on behalf of the Directorate of Veterinary Services (DVS) as part of his official responsibilities. He has recently been seconded to the Lunga Lunga border point, a key location for importing and exporting aquaculture products. This assignment began after he completed his MSc studies. Previously, he was stationed in Mombasa, where he was involved in inspecting captured fish exports. The duration of his current posting is subject to internal duty allocations, as he is a permanent employee of the Government of Kenya under the DVS, Ministry of Agriculture and Livestock Development.
Mercy Hamisi Matuma	Mercy has been awarded a prestigious fellowship in the Leadership in Public Management track at the University of California, Davis (UC Davis) as part of the 2025 Mandela Washington Fellowship. The selection criteria emphasized demonstrated capacity to engage in community livelihood initiatives—an area in which Mercy has excelled through her field visits to fish farmers and her responsibilities at the county office. The fellowship also required relevant publications in areas linked to community livelihoods, which Mercy fulfilled through her contributions to project activities and research publications. The 6-month training at UC Davis will cover a range of topics, including leadership development, community resilience, sustainable livelihood strategies, and best practices in food security. Mercy is a permanent employee of the County Government of Taita-Taveta.
Merceline Ndinda Ndambuki	Merceline is currently pursuing her studies at Ghent University in Belgium, having begun in March 2024. Although not formally employed, Merceline is bonded by the UoN, which allows her to seek external employment should there be no available position at the university upon completion of her studies. Given the current circumstances, it is likely that she will pursue opportunities outside the university.
Ageng'o Finnan Okoth	Finnan began serving as a part-time lecturer at Egerton University in Kenya in early 2025, leveraging his MSc qualification and research publications. The duration of his lecturing role will depend on departmental needs and his continued availability, with the potential to continue if he can continue to teach. He remains in full-time employment with the Government of Kenya under the Directorate of Fisheries Services.
Jacob Munene Wainaina	Jacob is employed by Victory Farms, a leading tilapia hatchery recognized for having the highest fingerling production capacity in Kenya. He remains actively engaged in the company's operations through various deployments aligned with its ongoing activities.
Cidee Night Khaseke	Cidee is employed by the Government of Kenya under the DVS. She serves as the deputy to the officer-in-charge at the Regional Veterinary Investigation Laboratory in Nakuru.
Victor Omondi Ogweny	Victor is currently deployed by the Kenya Fisheries Services as the fisheries officer in charge of the Nairobi metropolitan subregion, which includes the counties of Kiambu and Machakos as well as the Eastlands area of Nairobi City. Before joining the MSc program, he worked with a private aquaculture enterprise, Dolphine Farms.

Ghana

MSc student name	Employer | Position | Location | Start Date | Contract Duration
Abigail Amankwah	Abigail is currently employed as the farm manager at Lartman Farms Ltd, a commercial aquaculture enterprise based in Accra, Ghana. She assumed this role in May 2024 on a 2-year contract. In this position, she is responsible for overseeing day-to-day farm operations, coordinating production activities, and ensuring the implementation of best practices in fish health and farm management.
David Narteh Batsa	David is currently serving as the hatchery manager at the Fisheries Commission facility in Vea, located in the Upper East Region of Ghana. This is a permanent position under the Government of Ghana. In this role, he is responsible for managing hatchery operations, including broodstock management, fry and fingerling production, and implementing quality control measures to support aquaculture development in the region.
Kofi Ferni Anyan	Kofi is currently employed as a senior technologist in the Department of Marine and Fisheries Science at the UoG. This is a permanent position within the university. His responsibilities include supporting teaching and research activities, maintaining laboratory equipment and facilities, and assisting in fieldwork and data collection related to marine and fisheries science. He also helps train students in practical and technical aspects of aquatic science.
Kwame Issifu	Kwame is currently serving as the principal fisheries officer and acting regional fisheries officer with the Fisheries Commission in Dormaa Ahenkro, located in the Bono Region of Ghana. In this leadership role, he oversees regional fisheries management activities, including the coordination of aquaculture development programs, regulatory enforcement, stakeholder engagement, and supervision of field officers. His position reflects a high level of responsibility in advancing sustainable fisheries and aquaculture practices within the region.
Mabel Ackah	Mabel is currently employed as an assistant fisheries officer with the Fisheries Commission in Takoradi, located in the Western Region of Ghana. In this role, she supports the implementation of fisheries and aquaculture programs, assists in data collection and monitoring activities, and engages with local stakeholders to promote sustainable aquaculture practices. Her responsibilities also include contributing to extension services and regulatory compliance efforts within the region.
Philip Kwasi Banini	Philip is the team lead of iWatch Africa, a policy-focused nongovernmental organization that promotes transparency, accountability and civic engagement across the continent through data-driven journalism and AI-powered civic tech solutions. Under his leadership, iWatch Africa has advanced human rights, digital freedoms and anticorruption efforts by leveraging technologies such as AI, blockchain and open data to enhance government accountability. With a recent academic background in aquaculture and sustainable development, Philip is now seeking to transition into research or policy roles within the aquaculture sector. His goal is to apply his MPhil expertise in innovative and sustainable aquaculture systems, policy and governance, and climate adaptation strategies for food security.

Appendix 20. Financial report in NOK for the period January 1, 2024–March 31, 2025

Docusign Envelope ID: F6CDAD8F-9314-4093-AF9F-D2451AF2B362

WorldFish

FINANCIAL REPORT
FOR THE PERIOD 01/01/2024 to 31/03/2025 IN NOK

Contract/Project Processing No.	RAF-19/0051
Project Code	AG10519
Project Title	Increased Sustainability in the Aquaculture Sector in SSA, through improved Aquatic Animal Health Management
Project Duration	01/12/2020 - 31/03/2025
Project Leader	Delamare-Deboutteville, Jerome
Donor	Norwegian Agency for Development Cooperation (NORAD)
Total Grant	NOK 27,000,000

BUDGET LINE ITEMS	TOTAL REVISED BUDGET	PREVIOUS PERIOD Expenditures 1st Dec 2020 - 31st Dec 2023	Current period			TOTAL CUMULATIVE EXPENDITURES 1st Dec 2020 - 31st Mar 2025	TOTAL BUDGET BALANCE
			Budget period 1st Jan 2024 - 31st Mar 2025	Actual Expenditures 1st Jan 2024 - 31st Mar 2025	Budget Balance 1st Jan 2024 - 31st Mar 2025		
	1	2	3	4	5=3-4	6=2+4	7=1-6
A. Personnel Costs	NOK	NOK	Nok	NOK	NOK	NOK	NOK
B. Travel	4,898,762	3,187,193	1,711,569	1,700,267	11,302	4,887,460	11,302
C. Consultancy	1,048,692	693,931	354,761	368,576	(13,816)	1,062,508	(13,816)
D. Publication	500,593	275,815	224,778	303,982	(79,204)	579,797	(79,204)
E. Training/Workshop	259,827	12,603	247,224	139,278	107,946	151,881	107,946
F. Supplies & Operations	2,841,385	2,646,404	194,981	49,773	145,208	2,696,177	145,208
G. Partners & Collaboration	1,474,798	1,156,206	318,592	286,882	31,709	1,443,089	31,709
G1. Norwegian Veterinary Institute							
• Personal	5,713,656	]3,109,987	2,603,669	2,603,669	-	5,713,656	-
• Travel	760,000	352,154	407,846	361,609	46,238	713,762	46,238
• Operating	317,941	–	317,941	317,941	-	317,941	-
• OH	323,683	172,773	150,910	150,910	-	323,683	-
G2. University Of Nairobi							
• Personal	784,019	218,587	565,432	565,432	-	784,019	-
• Travel	288,081	258,196	29,885	17,904	11,981	276,100	11,981
• Publications	54,699	54,699	-	-	-	54,699	-
• Training	154,981	154,981	-	-	-	154,981	-
• Operating	2,091,325	1,246,370	844,955	717,925	127,030	1,964,295	127,030
G3. College of Basic and Applied Sciences							
• Personal	784,019	536,343	247,676	232,177	15,499	768,520	15,499
• Travel	288,081	205,252	82,829	75,335	7,494	280,587	7,494
• Publications	54,699	54,699	-	-	-	54,699	-
• Training	154,981	154,981	-	-	-	154,981	-
• Operating	1,944,645	1,584,244	360,401	318,602	41,799	1,902,846	41,799
H. Institutional Overhead	1,731,721	1,136,654	595,067	565,053	30,014	1,701,707	30,014
I. Consortium Costs	529,412	347,491	181,921	172,745	9,176	520,236	9,176
Total Budget/Expenditure	27,000,000	17,559,562	9,440,437	8,948,062	492,375	26,507,624	492,375

Certified by:

DocuSigned by:
Cherry Kek
C305AF88F6B54B7...

Kek, Cherry
Global Finance Lead
Date : 25 May 2025

Approved by:

DocuSigned by:
Jerome Delamare-Deboutteville
3CBF8AEBDA88449...

Delamare-Deboutteville, Jerome
Project Leader
Date : 25 May 2025

Results framework

Norad project (RAF-19-0051)

Impact: Increased sustainability and resilience in the aquaculture sector in Sub-Saharan Africa (SSA), through improved aquatic animal health management and biosecurity governance.

Project objective: To develop the aquatic animal health research capacity, knowledge and practical skills in SSA for advancing the aquatic animal health management for a more sustainable aquaculture development in the region.

LEVEL	EXPECTED RESULT	INDICATORS	BASELINE 2020	FINAL TARGET 2024	Progress 2021	Progress 2022	Progress 2023	Progress 2024
HIGH LEVEL OUTCOME 1	Research capacity on aquatic animal health management in SSA countries improved through new (1) training, (2) knowledge resources, (3) networks/events, (4) educational modules, (5) research projects, and (6) publications	Number of institutions from targeted countries being trained in new research methodologies and tools for use and adoption in their own countries	2	10	-	See output 2.3.	See output 2.3.	See output 2.3.
		Research tools and findings shared with the national competent authorities	0	2	-	See output 2.1, 2.3	See output 2.1, 2.3	See output 2.1, 2.3
		Number of new research findings, knowledge, lessons learned, generated and shared with other African countries using the network created through outcome 3.	0	10	See outputs 1.2, 1.3	See outputs 1.2, 1.3	See outputs 1.2, 1.3	See outputs 1.2, 1.3
		Number of education modules developed under outcome 2, integrating/ including new research knowledge generated	0	15	See output 2.3	See outputs 2.1, 2.2, 2.3	See outputs 2.1, 2.2, 2.3	See outputs 2.1, 2.2., 2.3
		New research projects developed by national counterparts based on the new research knowledge generated under this project	0	15		See outputs 1.2, 1.3	See outputs 1.2, 1.3	See outputs 1.2, 1.3
		Number of articles published by national counterparts based on the new knowledge generated under this project	0	15	See outputs 1.2, 1.3	See outputs 1.2, 1.3	See outputs 1.2, 1.3	See outputs 1.2, 1.3
INTERMEDIATE OUTCOME 1.1	Research/Knowledge gaps on aquatic animal health management in the selected countries (Ghana and Kenya) are identified and addressed.	Number and type of publications/studies/ datasets generated and available	0	12	See outputs 1.1, 1.2, 1.3	See outputs 1.1, 1.2, 1.3	See outputs 1.1, 1.2, 1.3	See outputs 1.1, 1.2, 1.3
		Number of research methodologies and tools introduced.	0	5	-	See output 1.2	See outputs 1.1, 1.2, 1.3	See output 2.1
INTERMEDIATE OUTCOME 1.2	Research findings and new knowledge on aquatic animal health are made available to relevant stakeholders in Ghana/Kenya and other SSA countries (DOF, policymakers, academic institutions, extension agents from public and private sectors, etc.)	Number of research finding papers that can influence decisions/ actions (e.g. policies, strategies, adoption of best practices, etc.)	0	2	-	See output 1.3	See output 1.3	See output 1.3
OUTPUT 1.1	Assessment of health status and economic impact of aquaculture diseases in Ghana and Kenya using WorldFish-NVI epidemiology and health economics online survey tool completed.	Number of country-wide EPI studies with related activities completed in Ghana and Kenya	0	2 datasets: 1 report for each country; 2 peerreviewed papers		The EPI-tool study was introduced to two countries and adopted by two institutions. 2 Epi-tools contextualized 2 EPI studies planning	Two digital courses on the EPI tool have been developed. 2 WF EPI-tool training courses completed 2 NVI epidemiology courses delivered 2 EPI survey datasets completed in Ghana (from 99 farms) and Kenya (from 179 farms). 1 EPI conference in India. 1 EPI presentation in Malaysia.	Two Epi datasets for Ghana and Kenya have been analyzed and are being finalized for publication.
OUTPUT 1.2	Field and laboratory studies elucidate and characterize endemic and emerging pathogens of economic significance, using molecular diagnostic tools, rapid genomic sequencing approach, AMR genes, innovative treatments and functional feeds to tackle diseases and reduce AMU completed.	Number and type of research studies/ publications	0	13	1 partner paper published	13 MSc research methodologies developed: Ghana: parasite (1), Fungal (1), Viral (2), functional feed/bacteria (1), biosecurity (1) Kenya: parasite (2), functional feeds/bacteria (2), bacteria (3) 3 partner papers published.	Published papers from master's student from partners 13 Conference Papers published, WAS Conference-Zambia, 2023	Graduation of master students: Kenya (3) in 2024, (1) graduate in 2025; Ghana (3) in 2024, (2) in 2025, (3) from both countries to graduate in 2025. Published papers 2024 6 from master's student 3 from partners 2025 3 from master's students Papers in preparation 9 from students 2 from partners 13 MSc research studies have been completed. Overall, 10 papers were published by MSc students, as well as 12 by partner institutions. Over 10 in preparation for submission
OUTPUT 1.3	Aquatic animal health management and biosecurity governance gaps identified in subSaharan Africa under the one health framework completed	Number and type of knowledge products used to inform decision making/relevant stakeholders produced	0	2 research papers		1 Gap analysis baseline survey developed, implemented, and report completed	1 Gap analysis paper published «Bridging knowledge gaps in fish health management through education, research, and biosecurity" 1 Critical review and gap analysis of online AAH educational materials report submitted. 1 ongoing study of the challenges in Lake Volta due to the expansion of cage aquaculture;	Paper published "Rethinking Freshwater Cage Aquaculture: A Case in Ghana" In total, two research papers on gap analysis and policy were published.

LEVEL	EXPECTED RESULT	INDICATORS	BASELINE 2020	FINAL TARGET 2024	Progress 2021	Progress 2022	Progress 2023	Progress 2024
HIGHER LEVEL OUTCOME 2	Institutional capacity and learners' knowledge and practical skills on aquatic animal health to improve the aquaculture related educational services and extension capacity in SSA countries enhanced.	Number of academic and public institutions attending the training courses	0	10	See output 2.3	See output 2.3	See output 2.3	See output 2.3
		Number of learners engaged in aquaculture activities as a result of the intervention (training)	0	50	See output 2.3	See output 2.3	See output 2.3	See output 2.3
		Extension agents/ aquaculture service providers taught better aquatic animal health management practices for adoption in their respective countries.	0	50	See output 2.3	See output 2.3	See output 2.3	See output 2.3
INTERMEDIATE OUTCOME 2.1	State-of-the-art educational modules on aquaculture and aquatic animal health for implementing regular face-to-face and online virtual training programs for SSA from WorldFish Aquaculture Research and Training Center (AARTC), based in Abbassa developed and available.	Overall number of modules developed and ready for uptake	0	At least 6 training modules developed on Learn.ink platform ready for uptake	See outputs 2.1, 2.2, 2.3	See outputs 2.1, 2.2, 2.3	See outputs 2.1, 2.2, 2.3	See outputs 2.1, 2.2, 2.3
INTERMEDIATE OUTCOME 2.2	Availability and accessibility of SSA countries to training programs on aquaculture and aquatic animal health increased.	Number of online and face-to-face training programs available Number of participants/ countries/ institutions involved in the trainings	0	At least 10 programs, 1000 participants, 10 SSA countries, 10 academic/public institutions	See output 2.3	See output 2.3	See output 2.3	See output 2.3
OUTPUT 2.1	All existing training materials on aquatic animal health management developed by WF, the NVI, FAO, OIE, Cefas and others reviewed, and new online massive open courses (MOC) modules developed.	Number of representative training/educational materials reviewed	0	15 educational modules, including online versions, reviewed		International consultant appointed to review all existing open-access training modules developed by national and international organizations in aquatic animal health management	1 critical review and gap analysis of all the online AAH educational materials report submitted	A total of 287 resources of interest were selected for indepth review. Reading the full text or material accessible through the link resulted in 107 resources to be included in the detailed analysis. One draft manuscript is under preparation.
		Number of new online courses and materials developed	0	10	Nine quick fish sampling guides for disease diagnostics have been developed. 4 guidelines to access online courses on Learn.ink platform developed. 11 online training courses developed on Learn.ink platform: • Intro to fish sampling for disease • diagnostics • Foundations in • fish disease • sampling • Wet mount • sampling • Blood sampling • Microbiome • sampling • Bacteriology sampling • Histology sampling • Fish farm • biosecurity • Aquaculture • survey with Open Data Kit (ODK) • Molecular • diagnostics & virology sampling • Fish syndromic • surveillance 2 guidelines to access digital surveys 1 online fish health and water quality monitoring tool 1 syndromic surveillance and disease outbreak characterization tool	Two new online courses have been developed on Learn.ink: • Antimicrobial usage (AMU) Survey for aquatic systems • Data collection with SurveyCTO Collect	Two new online courses have been developed on Learn.ink: • Epizootic Ulcerative Syndrome (EUS) • Principles of conducting social surveys 1 protocol for magnetic-based DNA extraction tested in Ghana and Kenya	Two new online courses have been developed on Learn.ink: • Tilapia Lake Virus (TiLV) • Basic insight into Molecular Diagnostics in aquaculture Number of lectures and laboratory protocols developed and used during the "Advanced workshop on Molecular Diagnostics and Nanopore Sequencing"
OUTPUT 2.2	Pilot testing of modules conducted and modules finalized and ready for uptake.	Number of modules finalized and deployed	0	6 face-to-face training programs in WorldFish Abbassa, and the same five online training modules finalized and deployed	One cycle, see output 2.3	Four cycles, see output 2.3	Nine cycles, see output 2.3	One cycle, see output 2.3 By 2024, a total of 15 faceto-face training programs had been completed. In total, 17 online Learn.ink training modules have been developed and finalized
OUTPUT 2.3	Face-to-face and online virtual training programs for SSA implemented and promoted	Number of participants attending physical training programs (disaggregation by stakeholder types can be found in the network file) Number of participants attending online training programs	0	A minimum of 100 people attending physical training at FAIH, etc. From 10 SSA countries. A minimum of 900 people are attending online training from 10 SSA countries.	1st physical training at FAIH (3-8 July 2021) #Participants: 14→7 males; 7 females; #Countries (Ps): Ghana (5), Kenya (6), Mozambique (2); #Institutions: 4 (more details in higher level outcome 3); Summary: 14 participants from 4 institutions from 3 SSA countries 14 participants have participated in the Learn.ink courses	2nd and 3rd physical training at FAIH (17-29 July 2022). #Participants: 22→13 males; 9 females; #Countries (Ps): from Ghana (6), Kenya (3), Madagascar (5), Mozambique (3), Zambia (5); #Institutions: 8 (more details in higher level outcome 3); Summary: 22 participants from 8 institutions from 5 SSA countries. 4th physical training at FAIH (16-20 Oct 2022) #Participants: 20→12 males, 8 females); #Countries (Ps): Kenya (9), Malawi (3), Mozambique (4), Zambia (4); #Institutions: 12 (more details in higher level outcome 3); Summary: 20 participants from 12 institutions from 4 SSA countries. 5th One intensive, long-term physical training at FAIH for AHA-MSc students (7) from Kenya, representing UoN. 5 Online training sessions for 15 MSc, three countries involved (Ghana, Kenya, Nigeria). 257 participants have attended the Learn.ink courses, 175 from SSA	6th physical training at FAIH (5-10 Mar 2023); #Participants: 21→10 males, 11 females; #Countries (Ps): Kenya (5), Malawi (3), Ghana (8), Zambia (5); #Institutions: 9 (more details in higher level outcome 3); Summary: 21 participants from 9 institutions from 4 SSA countries 7th physical training at FAIH (2-8 Sep 2023); #Participants: 24→15 males, nine females; #Countries (Ps): Kenya (5), Ghana (7), Zambia (4), Nigeria (4), Malawi (3), Mali (1); #Institutions: 17 (more details in higher level outcome 3); Summary: 24 participants from 17 Institutions from 6 SSA countries 6 MSc students attended the 5th and 6th physical training at FAIH 8th and 9th physical training: 1 NVI Course on Basic epidemiology & Outbreak investigation in Aquatic Animals developed and delivered in Ghana (19-21 April 2023); #participants: 22→13males, nine females; #Countries: Ghana (22); #Institutions: University of Ghana (17), Fisheries Commission Ghana (4), Veterinary Services (1); in Kenya (15 March 2023); # Participants: 23→13 males, 10 females; #Countries: Kenya (23); #Institutions: Kenya Fisheries Services (4), Directorate of Veterinary Services: Diagnostic and laboratory services (4), Aquaculture Association of Kenya (1), University of Nairobi (14).	15th physical trainings: Advanced workshop on Molecular Diagnostics and Nanopore Sequencing (27-31 May 2024); #Participants: 10→5 males, five females; #Countries (Ps): Ghana (6), Kenya (3), Bangladesh (2); #Institutions: University of Ghana (4), Fisheries Commission Ghana (1), WorldFish (2), University of Nairobi (3); Summary: 10 participants from 4 institutions from 3 countries. 2021: 14; 2022: 257; 2023: 370; Total end 2023: 641 Total until the end of 2024: 757 (303 females). Overall, since 2021, 17 online Learn.ink courses were developed and made public

LEVEL	EXPECTED RESULT	INDICATORS	BASELINE 2020	FINAL TARGET 2024	Progress 2021	Progress 2022	Progress 2023	Progress 2024
OUTPUT 2.3							10th and 11th physical trainings (+virtual pre-trainings): 1 WF EPItool training course developed and implemented in Ghana: (25-26 July 2023); #Participants: 9→6 males, three females; #Countries: Ghana (9); #Institutions: University of Ghana; and in Kenya (1-2 Aug 2023); #Participants: 15→11 males, four females; #Countries: Kenya (15); #Institutions: County Government Kenya (13), University of Nairobi (2); Summary: 24 participants from 3 institutions from 2 countries 12th and 13th physical trainings: 1 WF Training in bacterial/Tissue DNA extraction for disease diagnostics developed and implemented in Ghana (24 July 2023); #Participants: 7→5 males, 5 females); #Institution: University of Ghana (7); in Kenya (4 Aug 2023); #Participants: 11→5 males, 6 females); #Institution: University of Nairobi (11); Summary: 18 participants from 2 institutions from 2 SSA countries. 14th physical training: Training on bacterial culture, AST, DNA extraction, and sequencing (Jan-April 2024); #Participants: 3→1 male, 2 females; #Institution: University of Nairobi (3) master students; Summary: 3 participants from 1 institution from 1 SAA country. 370 participants have participated in the Learn.ink courses from 18 countries, 171 females and 199 males	
HIGHER LEVEL OUTCOME 3	New knowledge on aquatic animal health in aquatic food systems in the framework of one health and one food systems widely shared in SSA through sustainable networking	Number of partnerships/ cooperation/networks established	0		Kick off meetings in Ghana and Kenya 1st physical training at FAIH (3-8 July 2021) #Institutions: Fisheries Commission Ghana (5), Aquaculture Research and Development centre of Water Research Institute (1), County Government, Kenya (6), Aquaculture Research Center, CEPAQ (2);	2nd and 3rd physical training at FAIH (17-29 July 2022). #Institutions: Ministry of Fisheries and Livestock Zambia (5), Fisheries Commission Ghana (6), Ministry of Fisheries and Blue Economy of Madagascar (5), Kenya Fisheries Service (2), University of Nairobi (1), National Institute for Aquaculture Development Mozambique (1), National Fisheries Research Institute Mozambique (1), Polytechnic Institute Mártir Cipriano de Nacala - Moduril (1) 4th physical training at FAIH (16-20 Oct 2022): #Institutions: Department of Fisheries Malawi (1), Ministry of Agriculture Malawi (1), WorldFish (2), Ministry of Fisheries and Livestock Zambia (2), Central Veterinary Research Institute in Zambia (1), Kenya Fisheries Service (4), Private Farm (1), University of Nairobi (4), Aquaculture Research Center Mozambique (1), National Institute of Fisheries Research Mozambique (1), Higher Polytechnic Institute of Gaza, Mozambique (1), National Institute for Development of Fisheries Mozambique (1);	6th physical training at FAIH (5-10 Mar 2023); #Institutions: University of Ghana (7), Veterinary Services Ghana (1), Kenya Fisheries Service (2), County Government Kenya (3), WorldFish (2), Zambia Institute of Animal Health (ZIAH) (1), Ministry of Fisheries and Livestock Zambia (3), Department of Fisheries Malawi Government (1), Lilongwe University of Agriculture and Natural Resources (LUANAR) Malawi (1); 7th physical training at FAIH (2-8 Sep 2023); #Institutions: Government Republic of Zambia/Ministry of Fisheries and Livestock Zambia (4), University of Ibadan Nigeria (2), Ensapuh Veterinary Services limited (1), Nigeria Agricultural Quarantine Service Nigeria (1), Ministry of Agriculture, Department of Animal Health and Livestock Development (Malawi) Malawi (1), Department of animal health Central Veterinary Laboratory Malawi (1), WorldFish (1), Kwame Nkrumah University of Science and Technology, KNUST, Ghana (1), University of Energy and Natural Resources, Ghana (1), Fisheries Commission Ghana (2), CSIR-Water Research Institute, Ghana (1), University for Development Studies, Ghana (1), University of Environment and Sustainable Development, Ghana (1), Kenya Fisheries Service (2), County Government Kenya (2), Makindi Fish Farm, Kenya (1), University of Segou, Mali (1); 13 MSc students presented at major conferences and events • AGRF, Tanzania • AFRAQ23, Zambia Other networks made at: • AQUAEPIII, India • MAF Malaysia • WOAH OIE CVO Focal point, Rwanda Details of institutions from other physical training (see output 2.3)	Networks made at events and conferences: • Patriot Biotech (private sector) involved in advanced molecular training • Aquaculture Ghana stakeholder collaboration event, World Trade Center, Accra (30-31 May 2024) • Cefas One Health Aquaculture and AMR events in Accra, Ghana (27-30 Feb 2024) • Aquaculture Sustainability conference, Bangkok, Thailand (24-26 July 2024) • AFRAQ24, Hammamet, Tunisia (19-22 Nov 2024) • OIE WHOA Tunis, Tunisia (8-10 July 2024) • WOAH Paris Headquarters Workshop to Identify the Highest Priority Research Areas for Finfish Health (20-21 Feb 2025) Details of institutions from other physical training (see output 2.3)
					• Project partners network (WF, NVI, UoG, UoN) • Students/supervisors network • Students (Ghana/Kenya) network • Project team collaborators network (industry, private sector, stakeholders, researchers) • Project trainees' network from physical training (Ghana, Kenya, Mali, Malawi Madagascar, Mozambique, Zambia			
		Number of policies/ strategies/investments generated from the intervention	0					One Paper published "Rethinking Freshwater Cage Aquaculture: A Case in Ghana" The publication is calling for policy change and encouraging the shift from the lake to inland aquaculture.
INTERMEDIATE OUTCOME 3.1	Dynamic and operational networking mechanism developed for sharing of aquatic animal health knowledge amongst SSA countries	Number/type of dynamic and operational networking mechanism developed for sharing of aquatic animal health knowledge amongst SSA countries	0		Group emails One Drive/Google Drive for Students to share their theses and manuscripts for inputs from supervisors Network between project team partners, students, supervisors, researchers, industry, private sector, stakeholders, people trained at FAIH and other physical educational events, international conferences			
		Evidence of cross learning and knowledge sharing activities	0		Using existing learning platforms (Learn.ink, Teams, OneDrive, project webpage, WhatsApp groups).			
INTERMEDIATE OUTCOME 3.2	Effective coordination and MEL established to capture main highlights/ achievements and create knowledge sharing	Number of lessons learning shared	0		Annual Work Plan, Deliverables, Annual reports uploaded to WF- MEL system as part of project management systems;			
		Number of outcome/ impact cases	0		Success stories published online			
OUTPUT 3.1	Activities and strategies/ approaches for harnessing and sharing knowledge and lessons identified/ developed	Number and types of activities in place	0	Peer-reviewed paper activities developed (1 research, 1 education) past projects anddirect stakeholders involved Tools and material from 2 past projects used in our project	See intermediate outcome 3.1, 3.2 output 1.1, 1.3, 2.3	See intermediate outcome 3.1, 3.2 output 1.1, 1.3, 2.3	See intermediate outcome 3.1, 3.2 output 1.1, 1.3, 2.3	See intermediate outcome 3.1, 3.2 output 1.1, 1.3, 2.3
		Stakeholders/knowledge exchange platforms/ meetings	0	4	Using existing learning platforms (Learn.ink, Teams, OneDrive, project webpage, WhatsApp groups).			
OUTPUT 3.2	Synthesis of knowledge and lessons from research, education and networking for supporting competent authorities in SSA	Number of SSA focused reviews, syntheses, policy briefs	0	1 SSA focused review paper 3 SSA focused policy briefs			See output 2.1: 1 critical review and gap analysis of all the online AAH educational materials report submitted (not published yet) See output 1.3: Bridging knowledge gaps in fish health management through education, research, and biosecurity (Gap analysis published)	See output 1.3: Rethinking Freshwater Cage Aquaculture: A Case in Ghana: paper published

Indicator data/data source of verification:
- Workshop reports
- Donor reports
- WorldFish, NVI, partner internal reports
- MEL platform
- Knowledge sharing platforms
- Success stories
- Official documents
- Journal and policy articles

About WorldFish

WorldFish is a leading international research organization working to transform aquatic food systems to reduce hunger, malnutrition and poverty. It collaborates with international, regional and national partners to co-develop and deliver scientific innovations, evidence for policy, and knowledge to enable equitable and inclusive impact for millions who depend on fish for their livelihoods. As a member of CGIAR, WorldFish contributes to building a food- and nutrition-secure future and restoring natural resources. Headquartered in Penang, Malaysia, with country offices across Africa, Asia and the Pacific, WorldFish strives to create resilient and inclusive food systems for shared prosperity.

For more information, please visit www.worldfishcenter.org