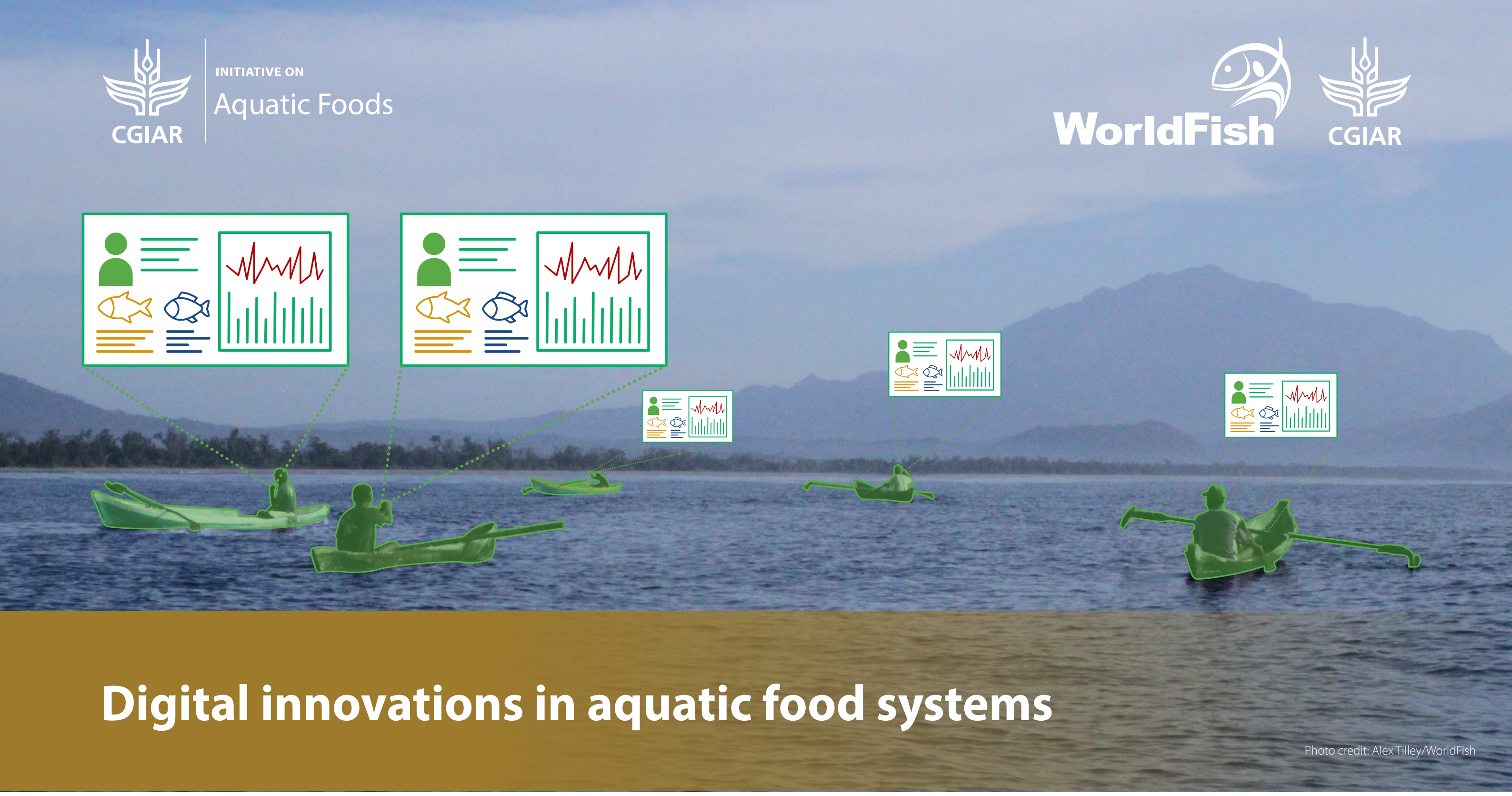


Digital innovations in aquatic food systems

Photo credit: Alex Tilley/WorldFish

Executive statement

The world faces an enormous challenge in feeding 9.8 billion people by 2050. The scale of the demand for safe, nutritious and affordable food is compounded by a more variable and unpredictable climate affecting natural production systems (FAO 2020). The COVID-19 pandemic has highlighted fundamental weaknesses in existing global food systems, but at the same time has illustrated how digital innovation can revolutionize the way people interact and benefit in agriculture value chains (Ferrer et al. 2021). Digital innovations are transforming the way information can be collected, analyzed, communicated and used to improve human well-being and environmental sustainability. There are few baselines against which to compare fisher and farmer well-being and access before-and-after exposure to digital tools, and this gap represents an important research strategy for WorldFish and CGIAR. This brief summarizes key innovations at various stages of development and scaling, which are transforming our understanding of aquatic food systems, and how we can accelerate their positive and inclusive transformation. CGIAR is uniquely positioned to develop and test digital innovations with local partners and stakeholders to expand knowledge of how they can positively influence fishers and farmers at scale. This brief presents case studies of digital innovations that are providing novel information to stakeholders to improve capacity and enable rapid decision-making in aquatic food systems affected by climatic, social and global health shocks.

Context

Digital innovations can increase the efficiency of food systems by enabling faster and more dynamic interactions and transactions between value chain actors, and enhance resilience to climate and market shocks by improving adaptive capacity of fishers and farmers (FAO and WorldFish 2020). The opportunities to drive inclusive growth and optimize the efficiency of food systems are substantial, but this transformation comes with substantial risks of increasing exclusion of marginalized groups (Blythe et al. 2018), thereby widening what is termed the "digital divide." This is the separation between banked, literate, affluent smartphone owners and poor and marginalized groups in terms of access to the opportunities and benefits from digital tools and services.

To maximize the transformational impact of digital innovations, we must address systemic barriers to equal access by poor and marginalized groups. Digital development must be mindful of the enabling conditions for uptake of innovations, and focus on how to add value for small-scale actors in ways that are ethical and transparent (USAID 2017). Small-scale fishers, fish farmers and fish workers often live and work in isolated and informal markets where infrastructure is weak. As such, there is widespread concern that the digital divide is exacerbating social divisions and local power hierarchies, especially for women and marginalized groups.

So far, the success of digital interventions has only been assessed qualitatively and relatively, in terms of uptake, sustainability and local legitimacy. There is much less evidence of proactive confrontation of inequality through data access and ownership. Furthermore, there are few examples of developing mechanisms for fishers and fish farmers and workers to hold, access or own their data, and few legal mechanisms to recognize their ownership or protect them against misuse or manipulation of their own data. Co-generated and co-owned data fosters transparency and accountability, and it enables small-scale actors to have an active role in decisions in resource governance (FAO and WorldFish 2020). WorldFish and partners are developing the Aquadata Data to Action Portal, aimed to provide a platform to integrate available aquatic foods data, to identify gaps, derive new data, and enable informed action through new knowledge. This brief details some developing innovations that form part of this effort. For more information, follow: www.worldfishcenter.org/Aquadata

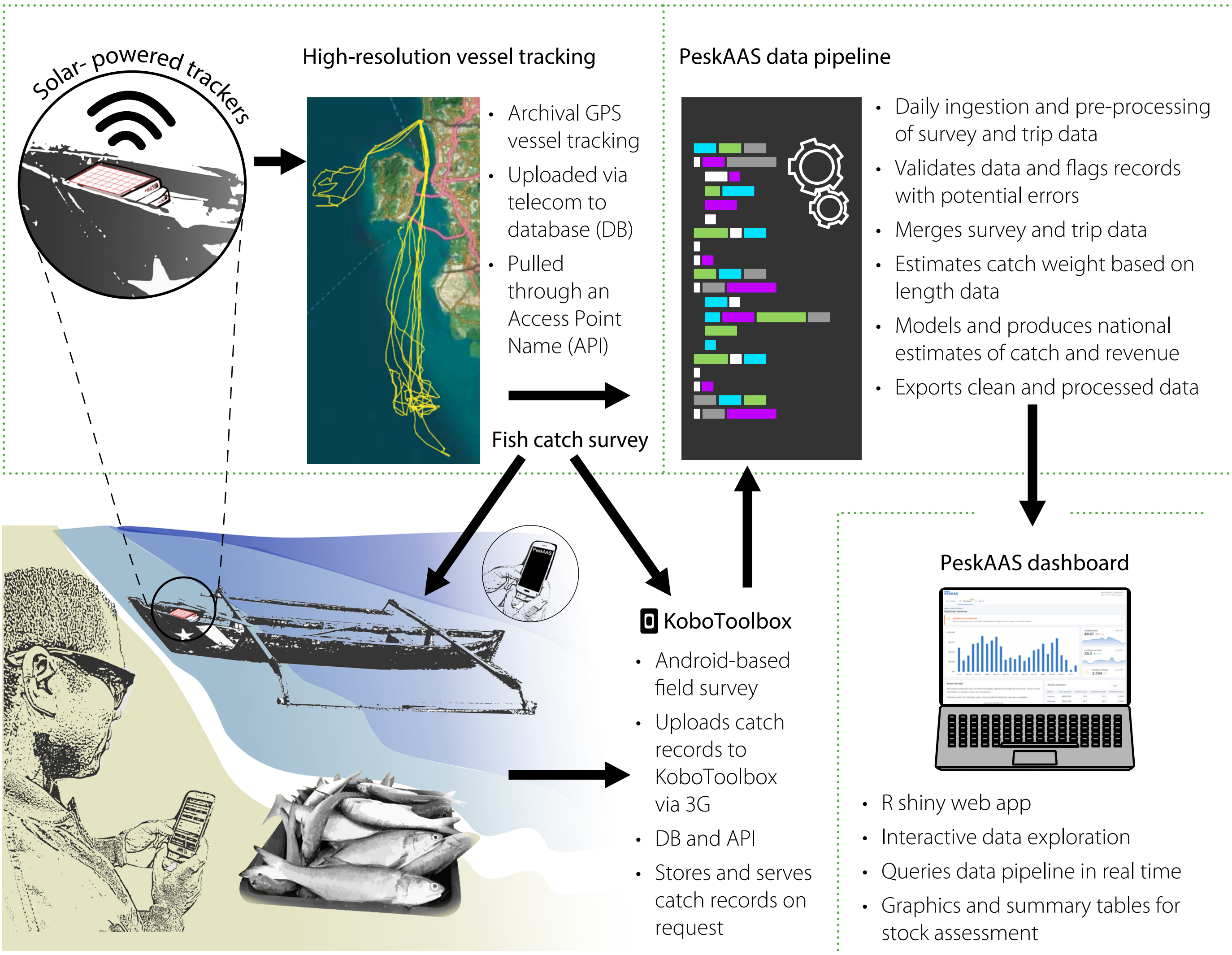
PeskAAS: Near real-time fisheries monitoring

The problem:
Small-scale fisheries worldwide are informal and marginalized, yet their contribution to food production and food security is substantial. The global COVID-19 pandemic has highlighted the need to monitor and predict food deficits and plan spending on food reserves in response to climate change. Managers (be they fishers or government officials) need near real-time tools to measure the production, trade, price and stocks of food, yet the characteristics of small-scale fisheries have historically made them difficult to access and data-poor.

The innovation:
PeskAAS is a monitoring system that processes and analyzes fisheries catch and effort data to provide high resolution, near real-time production data from small-scale fisheries for the first time. Developed by WorldFish in Timor-Leste in 2016, PeskAAS has now been adopted as the national fisheries information system and is included in the annual budget of the Ministry of Agriculture and Fisheries. It is used by the government for national and international statistical reporting (e.g. FAO) and to develop fishery management plans and interventions for growth of the sector. To date, the direct beneficiary of PeskAAS is the Government of Timor-Leste, because the system enables effective monitoring of small-scale fisheries production in time and space.

The PeskAAS data pipeline is open-source and connects to free or very cheap software, so it is inherently scalable and adaptable to other countries and food systems to enable collection, analysis and visualization of data in near real time (Tilley et al. 2020). A key factor in the sustainability and scaling of PeskAAS has been the co-design and validation process with end-users, which has provided local legitimacy and ownership of the system. The next two key phases in the development of PeskAAS are getting this data into the hands of fishers to make informed decisions about their lives and businesses, and to collect and display market information to drive new enterprise development in small-scale fisheries.

More information:
Big Data transforming small-scale fisheries: A new reporting system in Timor-Leste. Minderoo Foundation, Global Fishing Index.



Digital tracking of fish farm performance and health

The problem:
Achieving climate resilience and environmental sustainability within aquatic food systems requires more efficient use of land, water and inputs (feed and fingerlings). Adoption of improved fish breeds and best management practices has been shown to increase well-being, enhance resilience and minimize socioecological trade-offs. However, there is a lack of tools for accurate and effective monitoring of fishpond performance and baseline data from different geographies, economics, and social and agroclimactic conditions. This limits our understanding of the broader potential and scaling readiness of aquaculture systems, technologies and practices.

The innovation:
Co-designed user-friendly digital survey tools for tracking on-farm aquaculture systems performance and risk factors were developed for a smartphone. A step-by-step manual was developed to guide users in how to implement digital surveys for indicators, including productivity, profitability, input use and farm management practices, fish epidemiology and environmental changes. These tracking tools have been adapted and piloted by public and private sector partners in Bangladesh, Myanmar, Egypt and Nigeria, where they have helped to identify risk factors and to target context-specific interventions to improve performance and reduce the incidence of infectious diseases. In Bangladesh, the growth performance of Genetically Improved Farmed Tilapia (GIFT) was shown to be 27%–36% faster than non-GIFT strains, and more profitable.

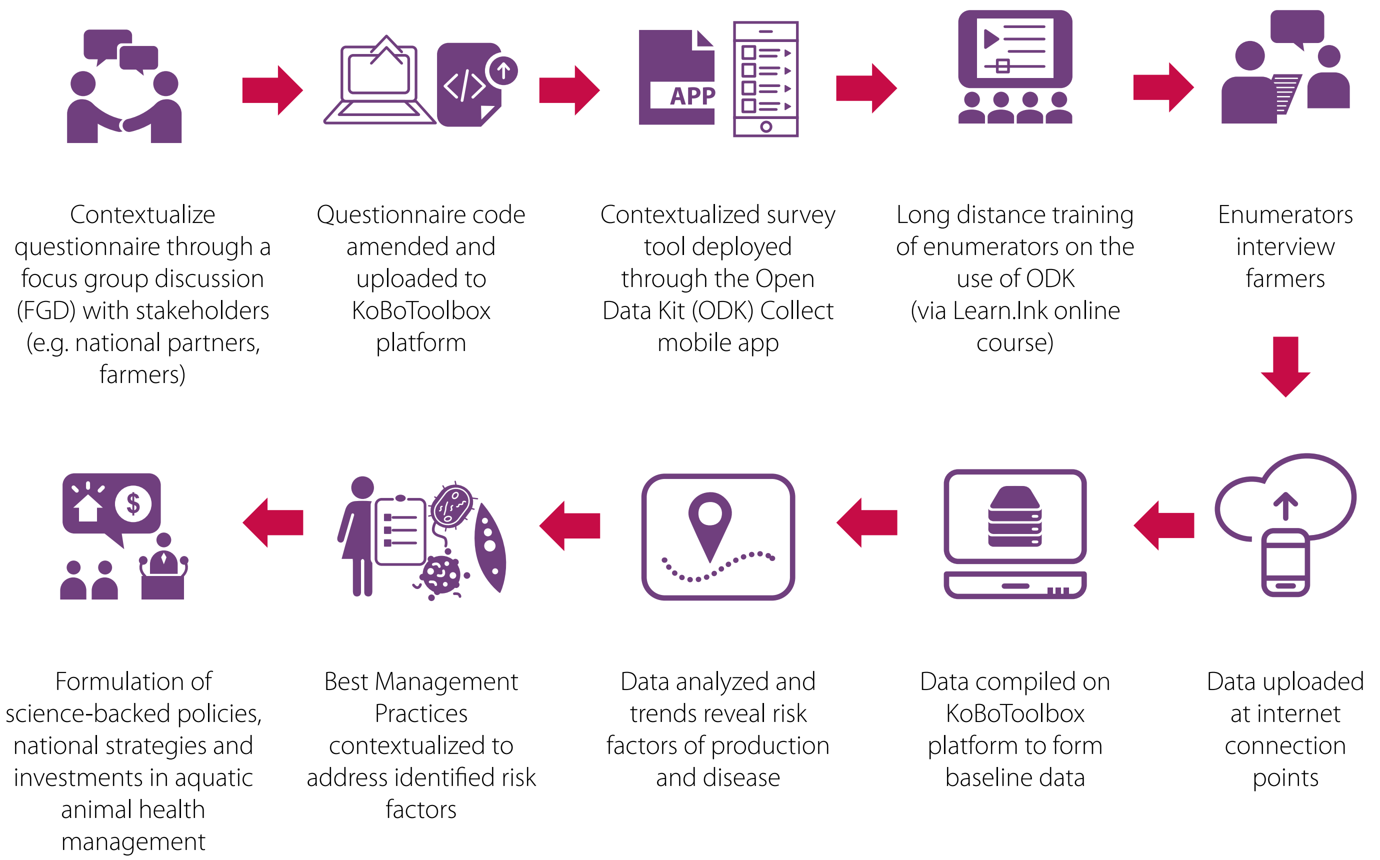
More information:
Toward a core approach for cross-sectional farm household survey data collection: A tiered setup for quantifying key farm and livelihood indicators:
https://cgspace.cgiar.org/handle/10568/105714

Aquatic Animal Health Package of Practices: Fish epidemiology and health economics:
https://hdl.handle.net/20.500.12348/4900

Aquatic Animal Health Package of Practices: Syndromic surveillance and disease outbreak characterization:
https://hdl.handle.net/20.500.12348/4895

Key risk factors, farming practices and economic losses associated with tilapia mortality in Egypt:
https://hdl.handle.net/20.500.12348/4189

Two-year surveillance of tilapia lake virus (TiLV) reveals its wide circulation in tilapia farms and hatcheries from multiple districts of Bangladesh:
https://hdl.handle.net/20.500.12348/4352



Lab-in-a-Backpack: Fish disease detection, control and prevention to reduce farmer dependency on antibiotics

The problem:

Fish diseases can have devastating impacts on small-scale farmer livelihoods. Aquaculture production is limited by a lack of knowledge and tools to rapidly identify pathogens and their origin, and manage their spread. In most developing countries, ponds are overstocked to compensate for losses to disease, and readily available antibiotics are used liberally. Indeed 67 different antimicrobials are used in the 11 major producing countries, contributing to the global increase in antimicrobial resistance (AMR). Accurate identification of the causes and sources of infectious disease is essential for implementation of evidence-based treatment, biosecurity and prevention. Pathogen genomics can provide sufficiently detailed information but has, to date, been too expensive and time consuming.

The innovation:

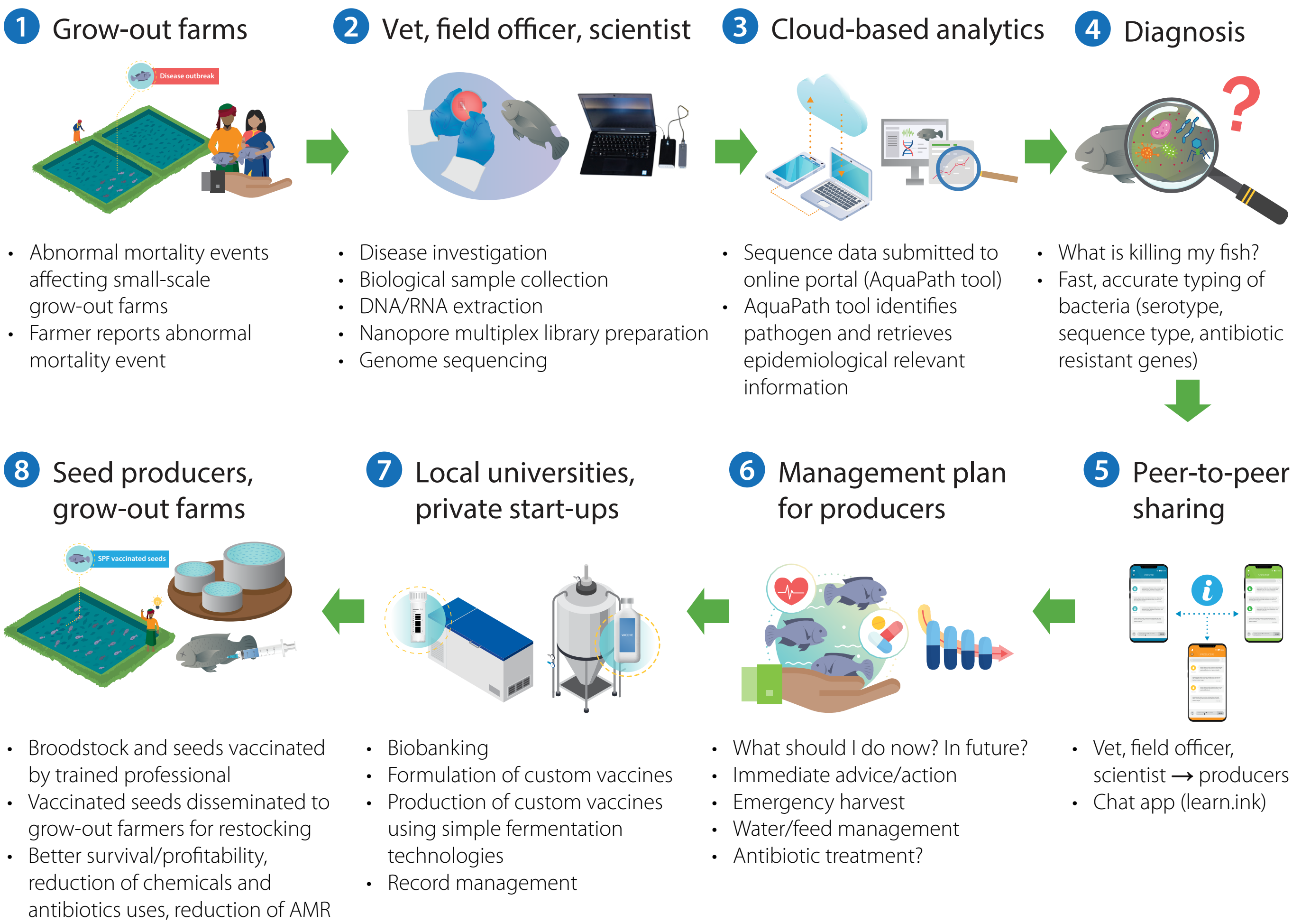
This innovation improves disease management practices by providing accurate and rapid diagnosis of aquaculture pathogens. The Lab-in-a-Backpack uses nanopore sequencing technology and low-cost, low-waste sample preparation to generate whole pathogen genome sequence data from diagnostic samples on the farm without laboratory support. It offers a simplified and safe workflow, including a cloud-based identification tool that returns near real-time information about the pathogen using any laptop or smartphone. Reduced reliance on antibiotics has positive global health implications by minimizing AMR in the fastest growing food production sector. These big-data-informed but locally implemented solutions align well with the Food and Agriculture Organization's recently proposed Progressive Management Pathway for Improving Aquaculture Biosecurity and can deliver real advances in local economy, nutritional security, antimicrobial stewardship and animal welfare.

More information:

Crawford Fund: A new concept for rapid genomic detection of fish disease:
https://www.youtube.com/watch?v=pUqmgQ-AuXM

Rapid genotyping of tilapia lake virus (TiLV) using nanopore sequencing: https://hdl.handle.net/20.500.12348/4706

Autogenous vaccination in aquaculture: A locally enabled solution towards reduction of the global antimicrobial resistance problem:
https://hdl.handle.net/20.500.12348/4942



Interactive digital training of remote farming communities

The problem:
Digital resources and tools on fish farm management practices are now widespread, but "last mile" rural farmers, are often excluded by systemic barriers such as literacy, or the cost of technology, data or power. These farmers rely on extension workers and local service providers who are themselves dependent on government or external investment. COVID-19 further decreased the potential for face-to-face contact time between farmers and advisors, and farmers' lack of familiarity and access to technology means they struggle to adopt new alternatives. At a time when many value chains and transactions are becoming increasingly digitized, many rural stakeholders risk becoming increasingly excluded and marginalized from crucial information. It is therefore vital to build the capacity of remote extension workers so that they can provide farmers with quality advice, up-to-date resources and digital tools for improvement of existing farm management practices.

The innovation:
WorldFish partnered with the Learn.ink platform to co-design and deliver an online learning curriculum for remote extension workers. A hybrid "train-the-trainer" approach was used to enable local project staff to deliver training to rural farmers on relevant digital resources and tools to identify disease outbreaks, collect biological samples and mitigate the spread of disease. The digital training courses complement virtual meetings and are deployed in advance to allow more time to absorb and understand concepts and encourage better engagement from participants. Courses are web-hosted to eliminate the need to download or install a mobile app, and trainees can interact with advisors outside of training sessions via chat and discussion threads. Invitations to sign in and access the training can be sent through social media platforms (such as Facebook, Whatsapp, Outlook, Twitter and Telegram) to reach out to a wider community. This innovation has been piloted with enumerators in Nigeria to train them to conduct a fish epidemiological and health economics survey among tilapia and catfish farmers.

More information:
Aquatic Animal Health: Remote training courses developed by WorldFish on Learn.ink platform:
https://hdl.handle.net/20.500.12348/4899

Farmer Mojammel Hawlader talking with a staff member from the Aquaculture for Income and Nutrition project in Madhob Pasha, Babugong, Barisal, Bangladesh.

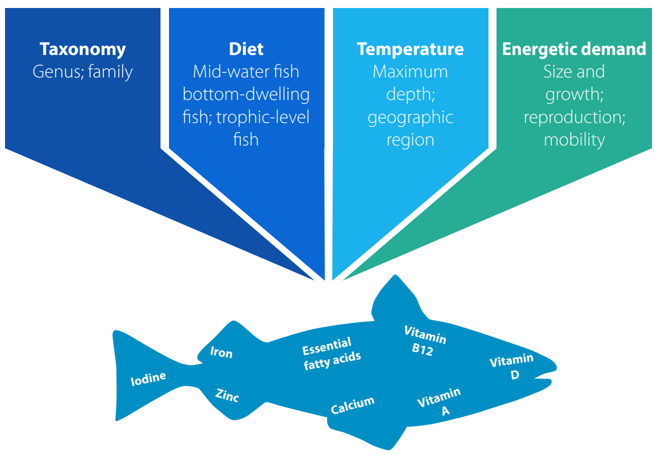
Fish nutrient analysis tool

The problem:
Not all fish are made nutritionally equal—the composition of fresh fish in terms of nutrients important for human health depends on species, diet and season. Empirically measuring nutrients in fresh fish samples is prohibitively expensive, and for that reason nutrient composition has only been determined for a small proportion of species known to be consumed by people. Starting in 2015, the Fish Nutrients initiative complemented the established nutrient composition database (FAO InFoods) to complete the collation of nutrient data for over 500 fish species. Using this data, the initiative developed a statistical model (Hicks et al. 2019) that predicts the nutritional makeup of a species based on diet, geographic region, size, growth and phylogeny. Launched as a function on FishBase (the world's largest online encyclopedia of fish) in 2021, Fish Nutrients now predicts the nutrition composition of 5000 different species. The model was first applied to understand the nutritional potential of catches from all marine capture fisheries to address nutrient deficiencies of people living in adjacent coastal populations (Hicks et al. 2019). The completion of the Fish Nutrients database, model and integration with FishBase was run in parallel with the Illuminating Hidden Harvests initiative, which used the model to understand the nutrient potential of small-scale fisheries catches from both inland and marine waters.

The innovation:
This innovation allows fisheries managers and researchers to understand the nutritional value of current fishstocks and fisheries landings. This was achieved by developing and refining a predictive model of nutrient composition values of marine fish species (Hicks et al. 2019) to freshwater species and making this resource available to the public through the creation of a species-specific analysis tool on FishBase.org.

The model outputs (i.e. predictions of the nutrient content of more than 5000 species) are now available through the Species Nutrient Search Tool on FishBase. The tool was tested by a suite of fisheries, biology and nutrition researchers to determine utility, accuracy, clarity of methods and clarity of measures. This work lays the groundwork for a new generation of data tools and public goods.

More information:
This short video describes the global collaboration, as well as its utility for understanding the potential of fisheries for meeting the nutritional needs of coastal populations.



FishScores

The problem:
The identification of sustainable aquatic food products and production practices requires environmental benchmarks. These are commonly derived from Life Cycle Assessments (LCAs) that are costly and time-consuming and influenced by modeling choices, making them inadequate for accurate comparisons. As a result, most LCAs of aquatic foods have so far focused on production in the Global North. This limits our understanding of aquatic foods potential in future sustainable diets at the global level.

The innovation:
As part of the Blue Food Assessment, a Bayesian environmental benchmarking framework was designed for aquatic foods, using a streamlined LCA approach and data available in scientific literature. For example, the framework categorizes feed ingredients based on their environmental profiles such as fish-derived, livestock byproduct meals, crops, and/or soybeans. The Bayesian framework also informs other parameters necessary for the environmental footprint, such as electricity use, fuel use, and eutrophic emissions. Using this approach, the most prominent aquatic food systems were benchmarked at the global level. The FishScores website fishscores.com utilizes this calculation pipeline to allow individual users to upload and benchmark their aquaculture systems online. This enables farmers and scientists to easily evaluate their production systems and identify environmental hotspots in their value chains.

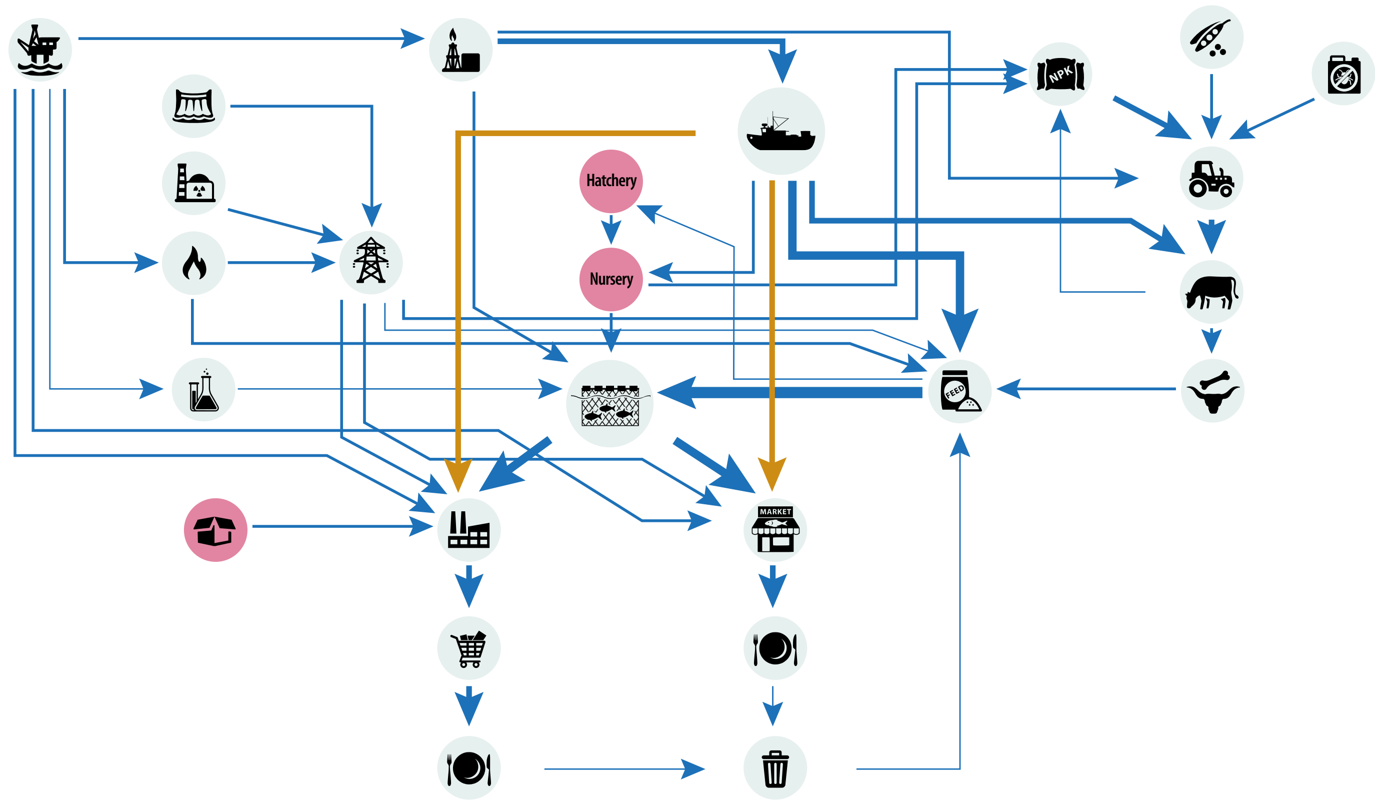
More information be:
Aquatic foods' environmental impacts. https://fishscores.com/
The Blue Food Assessment. https://bluefood.earth/

Figure below. Study system boundaries. System boundaries for fisheries (orange arrow) and aquaculture (blue arrow) with inputs in red indicating components excluded from the study.

Digital climate information services for aquatic food systems

The problem:
Climate variability affects aquatic food systems in multiple ways. For example, rapid fluctuations or sustained changes in water temperature or salinity can lead to fish mortality, while erratic or intense rainfall events can cause extensive harvest losses. Increasing access to climate information and quality forecasts, tailored to aquatic food systems, can empower producers and other value chain actors to mitigate climate risks. However, contextualized services for aquatic food systems, using timely and reliable climate information, are scarce.

The innovation:
WorldFish and CGIAR have explored the application of Climate Information Services (CIS) in aquatic food systems in Bangladesh and India. To do this, a new web-based interface for verified, localized, timely, actionable and simple climate information services was developed for fish farmers in Bangladesh and is now available at www.agvisely.com. The platform integrates local data from the Bangladesh Meteorological Department and water temperature from reference ponds into a decision-making tool for fish farmers. The decision framework uses temperature and rainfall thresholds for the grow-out phase of four widely cultivated and economically important fish species in Bangladesh. With this information, the automated processing of the input data generates advisories for farmers in response to the forecasted climatic situation, with a five-day lead time. By providing relevant climate information and tools to respond, this novel system helps farmers manage risks and minimise losses related to temperature and rainfall variability in day-to-day aquaculture operations. The new CIS's have been progressively extended to 86,961 fish-farmers in Bangladesh. The resulting knowledge and experience have also been applied to interventions in the State of Odisha, India, where climate advisories have been integrated into a mobile phone platform.



Meanwhile, a seasonal CIS with one month lead time is also being explored to provide information for decision making in aspects such as timing for pond preparation and fingerling stocking, changes of production volumes, maintenance adjustments and harvesting schedules. The approach is also being applied in Zambia and the Southern African Development Community, where it is expected to contribute to the capacity of fish farmers in predicting and managing local climate risks.

More information:

A training dialogue report: Introduction to climate services for aquaculture

Managing climate variability with smart and innovative climate information services

Building resilience through climate information services for aquaculture in Bangladesh

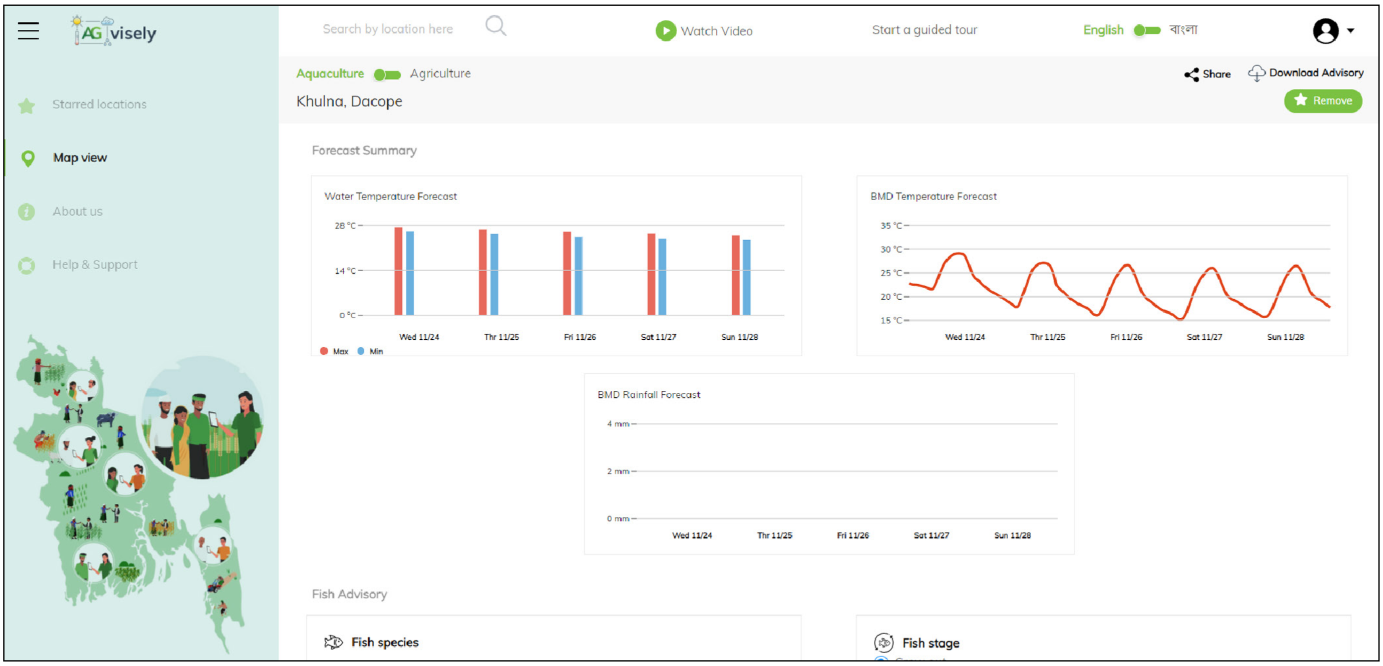
Accelerating climate resilience of aquatic food system

Climate-smart and gender-inclusive innovations for aquatic food systems transformation

Climate-smart innovations can boost aquatic food systems productivity in Bangladesh

Climate-smart innovations provide a window of opportunity to transform aquatic food systems

Screenshots from the Agvisely platform for aquaculture CIS



References

Blythe J, Silver J, Evans L, Armitage D, Bennett NJ, Moore M-L, Morrison TH and Brown K. 2018. The dark side of transformation: Latent risks in contemporary sustainability discourse. *Antipode* 50:1206–23.

[FAO] Food and Agriculture Organization. 2020. The State of Food Security and Nutrition in the World 2020: Transforming food systems for affordable healthy diets. Rome: FAO, IFAD, UNICEF, WFP and WHO.

[FAO] Food and Agriculture Organization and WorldFish. 2020. Information and communication technologies for small-scale fisheries (ICT4SSF): A handbook for fisheries stakeholders. In support of the implementation of the Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication. Tilley A and Roscher MB, eds. Bangkok: FAO and WorldFish.

Ferrer A, Pomeroy R and Akester MJ. 2021. COVID-19 and small-scale fisheries in Southeast Asia: Impacts and reponses. *Asian Fisheries Science*.

Gephart JA, Henriksson PJG, Parker RWR et al. 2021. Environmental performance of blue foods. Nature 597:360–365. doi: 10.1038/s41586-021-03889-2.

Hicks CC, Cohen PJ, Graham NAJ, Nash KL, Allison EH, D'Lima C, Mills DJ, Roscher M, Thilsted SH, Thorne-Lyman AL and MacNeil MA. 2019. Harnessing global fisheries to tackle micronutrient deficiencies. *Nature* 574:95–98.

Tilley A, Dos Reis Lopes J and Wilkinson SP. 2020. PeskAAS: A near-real-time, open-source monitoring and analytics system for small-scale fisheries. *PLoS One* 15:e0234760.

[USAID] United States Agency for International Development. 2017. Principles for digital development. Accessed March 12, 2021. https://digitalprinciples.org/principles/

Citation: Tilley A, Shikuku KM, Cohen P, Khor L, Henriksson PJ, Hossain PR and Delamare-Deboutteville J. 2022. Digital innovations for resilient aquatic food systems. Penang, Malaysia: CGIAR Initiative on Aquatic Foods. Policy Brief.

Acknowledgement
The innovations presented here were developed by WorldFish and partners under various CGIAR initiatives supported by contributors to CGIAR Trust Fund. We would like to thank all funders who supported this research through their contributions to the CGIAR Trust Fund: https://www.cgiar.org/funders/