AQUAHUBS-PROJECT: SUPPORTING AQUACULTURE INNOVATION EXPERIMENTS

Case automatic estimation of fish stock

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XAMK DEVELOPMENT 197

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ABSTRACT

Aquaculture and fishery are sub-sectors of agri-food that are among the least digitized, automated or in other ways influenced by recent developments in high-tech. Yet, they are sub-sectors that are becoming increasingly important in the context of economic efficiency, environmental sustainability, rural development and food supply chain resilience. To enable the digital transformation of aquaculture and fishing, favourable policy conditions, relatively low market competition, and the pre-existing technological know-how within other agri-food sub-sectors need to be exploited. Above all else, those working with aqua-tech innovations require targeted support in end-user outreach, demonstration, validation, commercialization and market uptake of their novel products or services – such support is a core mission of Digital Innovation Hubs (DIH).

The purpose of AquaHubs project was to strengthen cross-border collaboration between three DIHs and promote the use of digital technologies in aquaculture sector. The primary mechanism in AquaHubs project to achieve such objectives were to develop DIH services and use them on a practical level when conducting Innovation Experiments (IE). Through the implementation of three separate IEs, one by each AquaHubs partner, we aimed at producing novel knowledge regarding the aquaculture and fishery industry and, in parallel, at establishing the necessary channels, tools and methods for this knowledge and experience to be shared amongst the interested stakeholders throughout Europe.

This publication illustrates how the DIH services, developed in the AquaHubs project, guided the innovation experiment conducted in Finland. To this end, we describe activities and outcomes of developing a digital solution for the automatic estimation of fish stocks, using data gathered by sonar and underwater imaging.

Keywords: Aquaculture, Sonar, Underwater imaging, Image recognition, Automatic fish stock estimation, Digital Innovation Hub, Innovation Experiment

FOREWORD

A common European goal is to create awareness among consumers about the importance of local, seasonal and sustainable consumption. Fish and seafood can have an important place in a sustainable diet, with an environmental and carbon footprint much lower than most land-based animal protein. Obtaining a lower carbon footprint requires that fish is produced or harvested correctly. South-Eastern Finland University of Applied Sciences, Xamk focuses on researching and developing the use of under-fished species for human food, developing commercial fishing methods, digital systems and use of technology.

Increasing the use of local fish can be achieved when the whole fish value-chain is profitable and fish stocks are well managed. Managing fish stocks requires data of the current state of each fish population. Currently, the primary ways to estimate fish stocks are exploratory fishing and catch reports provided by commercial fisherman. In current methods, there are gaps relating to, for example reliable generalization or use of past data. The project strengthening cross-regional DIH collaboration in aquaculture innovation support services, funded by SmartAgriHubs EXPAND programme, offered an international platform for technology-based innovation experiments. The leading partner, AgriFood Lithuania, focused on digitization of aquaculture and fisheries, and AgriFood Croatia carried out a spectrometric oyster quality assessment. Xamk DIH concentrated on the automation of fish stock estimation, utilizing sonar data and video images obtained from aquatic drone, and automatic recognition of type of fish.

The methods for designing the Finnish Innovation Experiment, selection criteria for devices, and the concept for automatic fish stock estimation and its commercial opportunities are explored in this publication. Additionally, the Aqua Hubs project and the role of innovation demonstrations are described. This publication offers new methods and tools for fish stock estimation as well as sharing information and knowledge in research, fisheries administration, and fisheries sector. The role of collaborative planning in workshops is described, and the publication also brings forward observed obstacles, challenges and further development needs.

Extensive collaboration is needed to carry out new methods and their commercialization in the fishing sector. For that reason, I hope this publication gives you food for thought.

Teija Rautiainen
Head of Research Group
Mikkeli 27th June 2022

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Aquaculture and fishery are sub-sectors of agri-food that are among the least digitized, automated or influenced by recent developments in high-tech. Yet, they are sub-sectors that are becoming increasingly important in the context of economic efficiency, environmental sustainability, rural development and food supply chain resilience. To enable the digital transformation of aquaculture and fishing, favourable policy conditions, relatively low market competition and the pre-existing technological know-how within other agri-food sub-sectors need to be exploited. Above all else, those working with aqua-tech innovations require targeted support in end-user outreach, demonstration, validation, commercialization and market uptake of their novel products or services – such support is a core mission of Digital Innovation Hubs (DIH).

In this article, we explain how cross-border collaboration between three DIHs were strengthened with an AquaHubs project to promote the use of digital technologies in the aquaculture sector. To this end, we first describe the purpose of DIH and then proceed to outlining the objectives and outcomes of the AquaHubs project.

WHAT IS A DIGITAL INNOVATION HUB (DIH)?

Digital Innovation Hubs are one-stop-shops that help companies become more competitive with regard to their business/production processes and products or services using digital technologies (Kalpaka et al. 2020). One of the main goals of a DIH is to be a critical actor of the regional/national innovation ecosystem. To achieve this goal, the DIH needs to establish and maintain partnerships with actors with complementary competencies and specializations at a regional, national and European level. It should be able to act as a doorway providing access to knowledge and expertise not available locally but via the network of DIHs across Europe. At the heart of the DIHs' functions is the goal of creating awareness about business or production opportunities with digital technologies, while acting as trusted and neutral party providing relevant advice.

DIHs are both a means to reduce search costs for appropriate solutions, by serving as knowledgeable brokers that can analyze the need for digitalisation, and to provide appropriate services either through in-house expertise or with a partner. At the same time, the services of a DIH should be complementary and as such not replace existing commercial services. A DIH could also choose to dedicate resources to a potential niche and serve a need, by providing something additional that did not exist before. In many regional innovation ecosystems, a large variety of actors and initiatives already exist. Therefore, the introduction of a DIH should not create further fragmentation and complexity, or confusion among existing actors and potential beneficiaries regarding the provision of digitalisation services already existing in the region. An important task is rather to map, structure and align different services to make it more coherent to the beneficiary-SMEs, i.e., to better coordinate the offer with a view to satisfy the latent demand previously identified.

DIH SERVICES

The four main categories of services that DIHs can provide to the local SMEs/public sector beneficiaries are (Kalpaka et al. 2020):

- **Test before invest:** DIHs should be able to provide services and facilities to raise awareness and provide access to digital transformation expertise, testing and experimentation facilities so that potential beneficiaries can make better decisions for investments that will help them develop improved new products and services. The testing services include the provision of facilities for experimentation of hardware and software, where companies and public actors can come and try out new digital technologies that they may want to start utilizing in their processes or incorporate in their services and products. They can also serve as environments where suppliers can showcase technologies for future users, as well as facilities where pilot solutions can be tested for development purposes.

- **Skills and training** to make the most of digital innovations. An essential part of DIH services is training and skills development. DIHs can coordinate with education providers to provide short-term training for workers and internships for students. Activities in relation to training and skills can cover the whole employment spectrum but should be based on an analysis of regional needs. The rationale for the DIH to secure these types of training is to overcome incentives issues around who will pay for the training and who will receive the benefit (company, employee, or future employers), and the lack of universities or other public or private training institutions to provide educational services tailored to the specific needs of SMEs.

- **Support to find investments:** DIHs should support companies, especially SMEs and start-ups to access regional, national and/or European funding (i.e., ERDF and ESF) to make use of new technologies. This can also include access to public and private financial institutions and investors, including InvestEU and the Enterprise Europe Network (EEN). The support can be directed towards the public and wider public sector. This category of activities also covers finding funding to finance the DIHs' own support activities or to develop a tech start-up company. Financing services consist of different ways to provide funding assistance for digitalisation activities, ranging from the provision of subsidized services or innovation vouchers that can help companies procure digitalisation support from external actors, to assist companies in applying for grants and other forms of R&D support, and connect companies with investors.

- **Innovation ecosystem and networking:** DIHs can be seen as platforms that facilitate transactions between users and producers and reduce transaction costs, by making it easier to find what one is looking for by gathering a wide range of services and goods in one place. Many platforms also have mechanisms to create a secure and trusted environment. The DIH can provide opportunities for actors to meet and initiate collaboration, either spontaneously or in a more directed way. DIH can be a tool for coordination. DIHs can function as platforms and one-stop shops, being able to provide market and technology intelligence and advice to agencies when they develop new programmes.

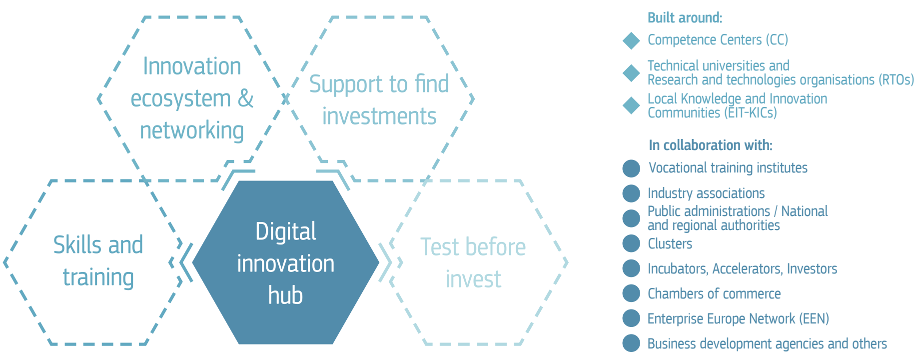

Figure 1. Overview typical DIH services and stakeholders (Kalpaka et al. 2020)

AQUAHUBS PROJECT

The overall goal of the AquaHubs project was to strengthen collaboration and joint activities of three Digital Innovation Hubs: AgriFood Lithuania DIH (AFL), the South-Eastern Finland University of Applied Sciences (Xamk) and AgriFood Croatia (AFC). The primary focus was on improving the innovation support services for the aquaculture and fishery sub-sectors of agrifood. The project received total of €270,000.00 funding from SmartAgriHubs EXPAND call, and was carried out between July 1st 2021 and June 30th 2022. Specifically, the project revolved around supporting digital technology-based innovation projects for open sea, coastal and inland aquaculture and fishing, organized into three Innovation Experiments (IEs):

- Digitization of Aquaculture and Fisheries (AgriFood Lithuania)
- Automatic Fish Stock Estimation (Xamk, Finland)
- Spectrometric Oyster Quality Assessment (AgriFood Croatia)

The objectives of the AquaHubs project were:

1. Development and preparation of the capacities, capabilities and resources of cooperating AquaHubs partners to provide services to supported IEs and other relevant stakeholders working in the aquaculture tech innovation support domain.
2. Provision of common DIH services to IEs that are supported under the AquaHubs project with the aim of advancing their innovation management and exploitation capacities and capabilities.
3. Ensuring the replicability and dissemination of the AquaHubs project results among various European stakeholders involved in aquaculture technology and innovation process.

To this end, the project planned to provide following services to support IEs:

- **Capacity building workshops.** A series of online workshops delivered by each of the partners of AquaHubs to all supported IEs. The aim of these workshops was to enable cross-regional knowledge transfer from DIHs to IEs and develop IEs capacities and capabilities in innovation management and exploitation.
- **IE needs assessment and validation.** A framework for assessing the innovation support service needs of IEs, which will be prepared and later instrumentalized to help identify what kind of DIH-provided services would be most needed and relevant for aquaculture tech stakeholders.
- **Commercial exploitation strategy development support.** IEs and prospective investors were to be supported with the cross-border expertise of DIHs in developing commercial exploitation strategies, business models, value propositions, commercial benefit analysis, investment readiness services and market entry plans of their technologies, products or services.
- **Innovation demonstration support.** IEs were to be supported in co-organizing test-before-invest type demonstration events, during which their novel solutions

will be presented to prospective end-users and stakeholders in the national/regional innovation ecosystems.
- **Access to relevant information, resources and tools.** A compendium of available DIH and CC services, digital tools and resources relevant for aquaculture tech IEs (both for those within and beyond this project), as well as other stakeholders active in the domain. This will serve as a vital resource in accessing and utilizing niche support services and tools for IEs across Europe.

As a result, the project sought to develop following replicable results:
- **Compendium of resources.** A reserve tank of resources and tools relevant to the aquaculture and the fishery industries, available to be deployed by any interested party.
- **Needs assessment framework.** A framework for assessing the innovation support service needs of IEs with the aim of helping identify what kind of DIH provided services would be most needed and relevant for aquaculture tech stakeholders.
- **Policy recommendations.** A set of policy guidelines, based on the insights regarding the needs, capacities and opportunities of aquaculture and fishery industries, available to be disseminated among national and/or regional policy makers and innovation ecosystems.
- **Workshop and Demonstration Materials.** Recorded visual material, presentations and reports from the workshops and the test-before-invest demonstrations.
- **Commercial Benefit Analysis Tools.** A set of tools, focused mainly on the end-users needs, used for commercial benefit analysis regarding their potential investment on innovative digital technologies in the aquaculture and fishery industries.

In the remainder of this publication, we will focus on AquaHubs activities carried out in Finland. To this end, we shall describe in more detail the Finnish Innovation Experiment, automatic fish stock estimation, and report the support activities provided by the AquaHubs-project.

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THE INNOVATION EXPERIMENT IN FINLAND: AUTOMATIC FISH STOCK ESTIMATION

Sami Jantunen, D.Sc., Research Manager, Xamk

In the previous article, we explained the role of a Digital Innovation Hub (DIH) to act as a one-stop-shop, helping companies to become more competitive by means of digital technology. We also described the AquaHubs project, with the purpose of strengthening the services and cross-border collaboration of three DIHs. The primary mechanism in the AquaHubs project to achieve such objectives were to develop DIH services and use them on a practical level when conducting Innovation Experiments (IE). Through the implementation of three separate IEs, one by each AquaHubs partner, we aimed at producing novel knowledge regarding the aquaculture and fishery industry and, establishing the necessary channels, tools and methods for this knowledge and experience to be shared amongst the interested stakeholders throughout Europe.

Innovation experiments are practical innovation projects implemented by a DIH and consortium of relevant stakeholders. The AquaHubs project provided an important link between innovation developers and prospective end-users through common services in respect to test-before-invest demonstrations, innovation transfer to end-users, commercial exploitation readiness and access to international competence networks. To ensure that the innovations developed during this project will reach the end-users of the aquaculture and fishery industries, and that they will be benefited from the tools and services provided by us, we organized and conducted test-before-invest sessions, demonstrations on operational environments and assessment of the proposed innovations, in accordance with the IEs implementation plans. A total of five distinct services were offered to IEs, encompassing service needs assessment and validation, support in innovation commercial exploitation strategy development, a series of online capacity building workshops, support in holding innovation demonstrations to potential end-users, and a compendium of other available services, tools and resources that would aid the IEs in their future developments. In the remainder of this article, we will introduce the IE implemented in Finland.

BACKGROUND FOR THE FINNISH INNOVATION EXPERIMENT

One of the goals in the government programme (Finnish Government 2019) by Sanna Marin (Prime Minister of Finland) is to double the use of local fish by 2027 in a sustainable way. Achieving such a goal demands significant changes in fish primary production industry, as well as in development of new fish products to address the demands of consumers. Strong fish stocks, good water conditions, and quality of fish products are all prerequisites for a viable fish economy and for increased use of local fish. Sustainable fishing is also good for the body of water, because it helps to remove nutrients, and thus reduces eutrophication. The increased use of local fish is also hoped to improve the business opportunities for fish primary production. A competitive and predictable operative environment would enable sustainable growth of fish primary production and attract new firms and capital to the field.

Being able to maintain strong fish stocks and to predict the amount and type of fish to catch requires new technological solutions. Up to date estimations of fish stocks have been created in two ways:

1. *Exploratory fishery* is currently considered the most reliable method for estimation. However, the reliability of this method has been questioned, with the main argument that different fish species may behave in different ways and the results are not generalizable in a reliable way.
2. *Commercial fishery.* In this method, estimations of existing fish stocks are created on commercial fishermen's reports of caught fish. The main challenges of this method are that the estimations are created on past data and that many of the lakes do not have commercial fishermen.

These methods have room for improvement in terms of cost-efficiency, accuracy and use of digital technologies. Using new technologies, however, is not a straightforward task. Some of the known challenges related to fish stock estimation are:

- Sonar mainly provides data about the quantity of fish, not type of fish
- Fishing business is currently too unpredictable. Consumers are unsure what fish and what quantities will be available.
- Fishermen do not know what type of fish and how much can be caught in a sustainable way, without harming the viability of fish stock.
- There are not enough data currently to maintain viable fish stocks in a sustainable way, and vice versa not enough real-time data for fish stock management, e.g., to estimate the need to remove low value fish species
- Granting permits for commercial fishing could be made easier if there were reliable data showing the viability of fish stock in the body of water.
- There are not enough reliable ways to estimate existing fish stocks in the body of water.

THE FINNISH IE: AUTOMATIC ESTIMATION OF FISH STOCK

The purpose of our IE was to increase understanding of how the estimation of existing fish stock (type and quantity of fish) can be automated and made more accurate. To this end, we sought to complement sonar data with underwater video, in order to automatically identify the type of fish, and eventually estimate the size of fish stock in the body of water. On a more concrete level, our objectives related to our IE were to:

1. explore technological opportunities to gather data of fish stocks (particularly sonar, underwater drones, and underwater cameras)
2. explore real-life challenges of gathering data
3. determine workable methods for data gathering
4. evaluate the quality and usability of gathered data for automatic recognition of type of fish.
5. develop Proof-of-Concept for the automated estimation of fish stock.

Achieving these objectives would help us to create a new method for estimating existing fish stocks, or at least provide new data that can be used to improve existing estimation models. As a result, the predictability of fish to catch would improve and opportunities to maintain healthy and viable fish stocks would increase. These are desirable outcomes, as a diverse water environment and sustainable fish stocks are prerequisites for the sustainable use of water resources. In addition, being able to produce real-time data related to fish to catch is likely to affect consumer behavior.

We planned to engage relevant stakeholders (fisherman, researchers, and technology advisors) and facilitate the exploration of data gathering methods and technologies, necessary to improve existing ways to estimate fish stocks. To this end, we organized two workshops in autumn 2021 for exploring the problem domain and determining plans for the IE. We also planned to organize a demonstration event once the IE was implemented, in order to discuss the feasibility of the IE from a wide range of viewpoints (i.e., practical, technological and commercial). The results of these activities are reported later in this publication.

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SUPPORTING COLLABORATIVE PLANNING OF THE INNOVATION EXPERIMENT

Sami Jantunen, D.Sc., Research Manager, Xamk

Teija Rautiainen, Master of Hospitality Management, Research Manager, Xamk

As part of the services supporting Innovation Experiments (IE), AquaHubs organized capacity building workshops. The aim of these workshops was to develop capacities and capabilities in innovation management and exploitation, and enable cross-regional knowledge transfer from DIHs to IEs. In this article, we will explain how we organized two workshops for determining the objectives for our IE.

WORKSHOP 1: EXPLORING THE TOPIC OF AUTOMATIC FISH STOCK ESTIMATION

The first workshop was organized on October 18, 2021. The event was held in a virtual form by using Microsoft Teams for voice and video connection, and XLeap (**www.xleap.net**) for collaborative working, such as brainstorming and voting. XLeap allowed all participants to contribute simultaneously in a written and structured way, making the collaborative work efficient, and allowing the creation of a workshop report right after the workshop with just the push of a button.

The purpose of the initial workshop was to collaboratively explore the problem for understanding better different viewpoints on the topic of automatic fish stock estimation. To this end, we invited participants representing wide range of viewpoints. In total, ten experts participated in the workshop representing universities (four persons), companies (three persons), research institutions (one person), and public officials (two persons).

The workshop began with a round of introductions. We then started the collaborative work in XLeap by brainstorming stakeholders that are related to, or affected by, fish stock estimation. This phase resulted with 16 identified stakeholders. To understand better the relative significance of each of the stakeholders, we then asked the participants to vote on a scale from 0 to 10 according to two criteria:

1. How important is the topic of fish stock estimation for each stakeholder?
2. How interested would each of the stakeholders be to participate in the innovation experiment (IE)?

Based on the voting results, we then collectively selected the ten most important stakeholders for further exploration (Figure 1).

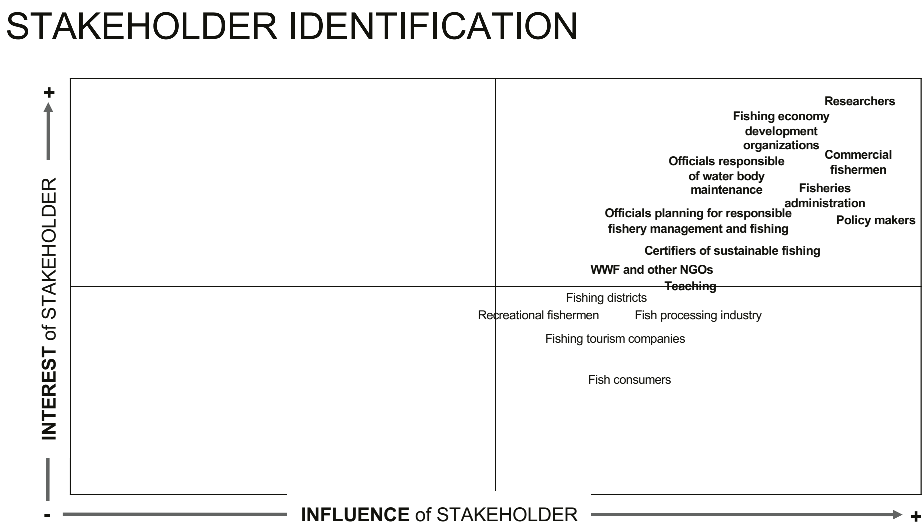

Figure 1. Identified stakeholders and estimation of their interest to the topic and interest to participate in the IE. The stakeholders emphasized with bold font were selected for further exploration

After our focus was narrowed down to ten stakeholders, we asked the participants to write for each of the stakeholders:

- What does the stakeholder want to accomplish in their work?
- What opportunities would the automatic fish stock estimation create for the stakeholder?
- What challenges does the stakeholder have related to fish stock estimation?
- How could the stakeholder contribute to the innovation experiment?

As a result of these steps, we were able to develop a deeper understanding of the relevant stakeholders, along with their needs, challenges and opportunities related to automatic fish stock estimation, as well as how the stakeholder could contribute to the innovation experiment (Figure 2).

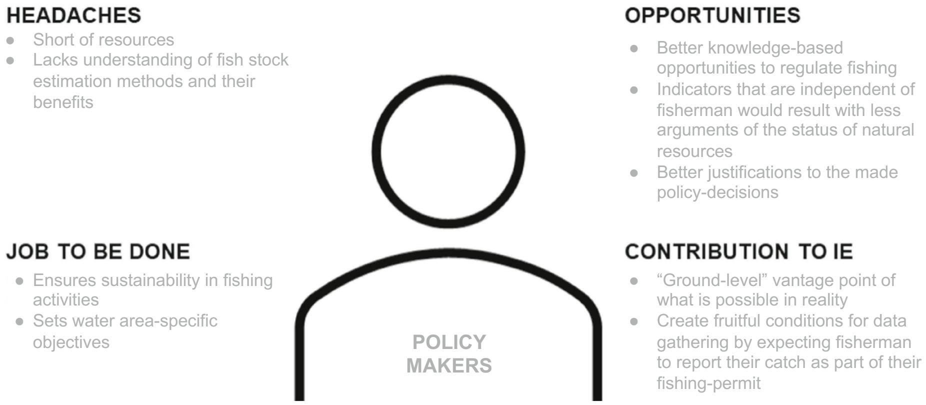

Figure 2. Example of the detailed description of a relevant stakeholder.

In the next phase, participants brainstormed potential technologies that could be utilized for automatic fish stock estimation and provided more information for each proposed technology by answering following sub questions:

- What are the strengths/weaknesses of the proposed technology?
- What kind of data would the proposed technology provide?
- What kinds of challenges are there in utilizing the chosen technology?
- How could we mitigate the identified challenges?

This phase resulted with an overview of technological possibilities, as partially shown in Table 1.

Table 1. Examples of proposed technologies and their benefits, outputs, challenges, and ways to mitigate the challenges.

Technology	Benefits	Outputs	Challenges	Ways to mitigate challenges
Computer vision	Automation, process huge amounts of data, accuracy	Once properly processed, it can generate presence-absence data, relative density data, other ecological data, that can be further processed and modelled into estimates of fish identity and potentially some sort of fish stock estimates.	High quality training data; Reach General models; Expert dependent, costs, etc.; Muddy waters may cause difficulties; Fish may be scared of underwater drones	Stationary underwater cameras that gather data during longer periods of time
Sonar	Cost-efficient; timely; long used and reliable	Fish density; Size of fish Spatial distribution of fish; Fish movements	Expensive devices; Requires hydroacoustics skills; Does not identify species	Training; Taking samples also with traps and video
Video	Ability to identify species Information of behavioral differences of species. One can generate lots of data with the method. Can be inexpensive to accumulate data. Easy to expand protocols even to citizen participation when collecting data	Visual information once properly processed can generate presence-absence data, relative density data, other ecological data, that can be further processed and modelled into estimates of fish identity and potentially some sort of fish stock estimates.	Data quality and standardization Collect data that actually has the fish included; Collect data in standard quality throughout the seasons and different light conditions. Quality depends on conditions (light, visibility)	Stationary underwater cameras that gather data during longer periods of time

In the final stage of the workshop, we brainstormed what we should accomplish with the innovation experiment and collaboratively determined:

- How we can measure success and what is the target level?
- How realistic are the objectives?

The participants then voted to select most relevant objectives for the IE (Table 2).

Table 2. Participants' determination of the most relevant objectives for the IE

Objective (votes)	Metrics (targeted value)	Doability
Reliability and accuracy (7 votes)	Reliability = accuracy and precision. As small margin for bias and error as possible; Identification of sources of bias/error and mitigation with sampling methods; Retrospective evaluation of results; Comparison with current methods	Relatively possible to accomplish with lower expectations
New knowledge of utilizing technology in fish stock estimation (6 votes)		
New knowledge of data gathering methods (5 votes)	Documentation of experiences and comparison against expectations	Possible to accomplish
Improved cost-efficiency (4 votes)	Number of fish stocks, whose harvesting is based on estimated yield of fish stock; Expenses should be on reasonable level compared to the profit from the fish stock. Analytical estimation is reasonable to do only for the largest fish stocks; It would be good to be eventually able to estimate all commercial fish stocks	Realistic to do better when compared to existing methods

WORKSHOP 2: DETERMINATION OF THE INNOVATION EXPERIMENT

The collaborative work continued with a second workshop, organized on November 8th 2021. The composition of the group was similar to the previous workshop. This time, we had twelve participants, seven of them had a scientific background, two from companies, and three representing policy makers. The workshop was organized in a similar virtual format; Microsoft Teams was used for voice and video connection, and XLeap for collaborative working.

The second workshop started with a round of introductions, followed by the presentation of results from the first workshop. Then, the collaborative work begun by brainstorming ways to increase the reliability of fish stock estimation, and commenting on the following:

- why participants believed that the proposal would work
- what we don't know yet.
- how can we find answers to the things we don't know yet

The participants were then asked to select the five most important inputs written by any participant in the workshop. The most selected items included concerns of:

- is it possible to gather sufficiently useful and good quality image data about fish (6 votes)
- is it possible to identify accurately type of fish from sonar and image data (6 votes)
- how do fish behave when image data is gathered (4 votes).

Some experts also raised the concern that certain species of fish are scared of light. For that reason, infrared photography should be considered.

In the next phase a similar kind of brainstorming was conducted with the purpose of identifying ways to increase cost efficiency. To this end, participants proposed to automate work by humans, and hoped for a real-time information system for gathering and maintaining data about fish stocks.

In the final stage of the workshop, we brainstormed tasks that need to be conducted in the IE. Some of the suggestions included:

- gathering video data of fish first in laboratory environment.
- training Artificial Intelligence to identify fish species.
- developing a proof-of-concept that identifies fish species, regardless of the camera angle.
- developing a tool for volunteers to identify fish from images for AI training purposes.
- gathering existing data about fish stocks into a unified database.
- limiting the IE for only particular species of fish in a specific body of water.
- exploring suitable technologies for the IE.
- gathering data with chosen technologies.
- continuously evaluating the results with an expert steering group.
- comparing results of the IE with existing methods of evaluating fish stocks.

FEEDBACK FROM THE PARTICIPANTS

At the end of the workshops, we asked participants to give feedback about the way workshops were organized. According to the participants, they appreciated the opportunity to strengthen network of relevant stakeholders. They also felt that the used methods succeeded in having all the participants actively involved, and served their purpose in building an overview of the problem. In particular, the participants considered brainstorming as a useful activity, although they also felt that there was too little time to answer the questions properly.

SELECTING DEVICES FOR THE INNOVATION EXPERIMENT

Matti Ryhänen, BBA, RDI - Specialist

Before finalizing the technological selections for our innovation experiment, we briefly explored what kind of work others have already done related to fish stock estimation. We identified three interesting solutions that are shortly described below.

FISHHEART: IDENTIFYING FISH WHILE HELPING MIGRATORY FISH TO BYPASS DAMS

Fishheart (Fishheart Ltd. 2022) is a hydraulic fishway system designed to revive migratory fish stocks in altered bodies of water, by providing fish an access to bypass dams (Figure 1).

Figure 1. Fishheart – Hydraulic Fishway system.

Implemented by Lapland University of Applied Sciences, a fish recognition system was added to the fishheart process (Lapland University of Applied Sciences 2022). The goal for the prototype was to help the system to be more automatized and therefore save energy as the process would only start when there is a fish waiting to be lifted. While the fish swims into the Fishheart system, data is collected by photographing the fish. Data is then sent for analysis as the process to lift the fish safely over the dam starts. Fish recognition system recognizes the fishes that swim into the process, sends the information onwards, and creates statistics about the fishes.

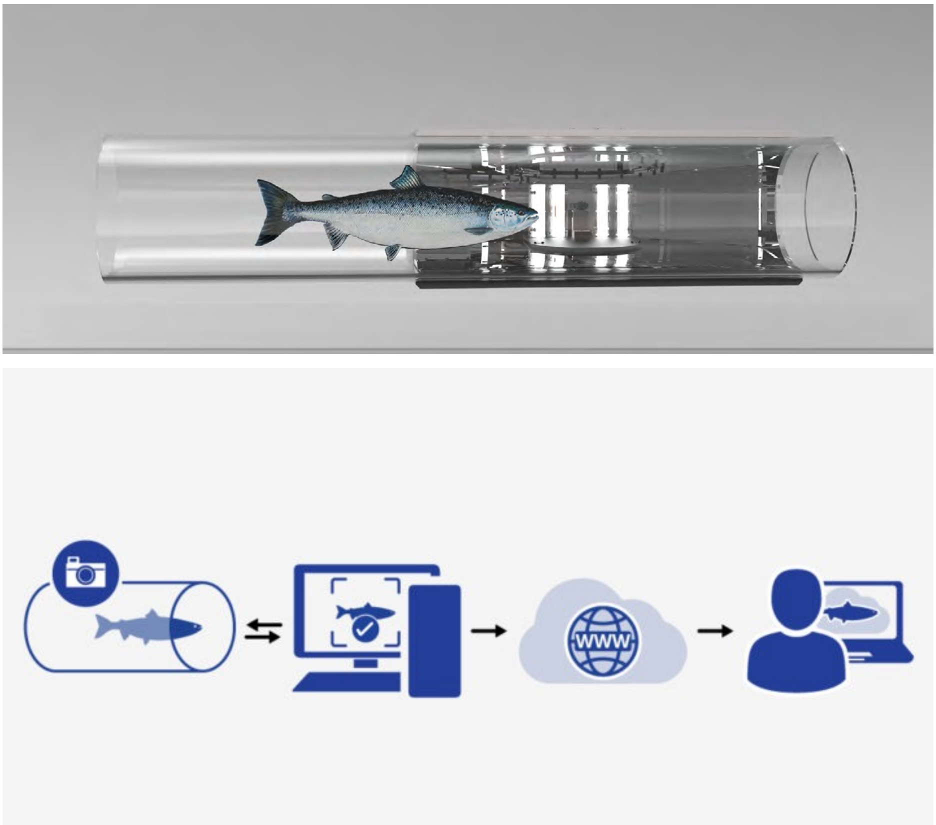

Figure 2. Fish recognition system, implemented for Fishheart process.

KONNEVESI RESEARCH STATION: TAKING PHOTOGRAPHS OF FISH IN A LABORATORY ENVIRONMENT

Another opportunity we considered was the use of Biological Konnevesi Research Station (University of Jyväskylä 2022), belonging to Jyväskylä University's Department of Biological and Environmental Science. The station has a fish tank with a volume of approximately one cubic meter. As the Finnish lakes were frozen at the time the IE implementation was scheduled, we considered the option to take pictures of fish in a laboratory environment. To this end, we planned to have vendace and smelt populations in the fish tank and then train an artificial intelligence system to recognize the species from each other. This option was disregarded due to the challenges of gathering the fish population for the tank.

SONAR IMAGING WITH DIDSON SONAR

The Natural Resources Institute Finland (Luke) is a research organisation operating under the Ministry of Agriculture and Forestry of Finland (Luke 2022). Luke's task is to promote competitive business based on the sustainable use of renewable natural resources, as well as the wellbeing and the vitality of the countryside. Luke does different kinds of research in Finland in the field of fishing. They have purchased a high quality Dual-Frequency Identification (DIDSON) sonar, that is a type of imaging sonar that transmits sound pulses and converts the returning echoes into digital images (Soundmetrics 2022). We considered using this sonar in cooperation with Luke to detect the vendace and smelt populations for trawlers. These small fish look very similar in normal sonars and are difficult to separate, increasing the chances of trawlers to fish the wrong fish species. We had to disregard this option, due to the winter conditions in Finland. The DIDSON sonar can mainly be used in open water conditions, and the device is challenging to use in cold temperatures. Furthermore, the cost of the Didson sonar is so high that it will not become common in the use of every day Fisherman in Finland.

TOWARDS SELECTING DEVICES FOR THE IE

Despite the harsh winter conditions, we decided to proceed with our original plan of experimenting different technologies for automatic fish stock estimation. To this end, we identified the following criteria from the workshops to be considered when choosing the devices for the IE:

- As some fish are scared of drones, the device should be as unobtrusive as possible.
- As some fish are scared of light, the device should have the possibility to take pictures with infrared.
- Since the objective is to make good estimates of fish stocks in the body of water, it would be beneficial to use Global Positioning System (GPS).

CHASING F1 FISH FINDER DRONE

We purchased Chasing F1 Fish Finder drone, which swims on the surface of the water. At any given point the user can lower a camera from the drone down to a depth of 28 meters. Our hypothesis was that the fish might not be so scared about a small camera compared to a whole diving drone. CHASING F1 is a hi-tech digital full HD wireless fish finder drone with a remote control providing intelligent information about the underwater terrain, surroundings, other objects, the location of fish masses, and the position of fish in water (Chasing Innovation 2022). The drone has 4 thrusters, 2 antennas and for example, a hanging buckle for extra functions. It has a swappable battery with a runtime of approximately 6 hours. The camera of the drone has an Infrared light with nighttime filming capacity. The operating temperature for the drone is between -10C and 45C. The F1 fish finder has GPS function, which supports maintaining position, tracking, multiple fishing spots recording, automatic cruise between fishing locations and one key return. If the remote control distance is exceeded it will automatically return to the set point of return. (Chasing Innovation 2022)

The camera detector with built-in depth and temperature sensors can deliver images, real-time readings of depth and temperature back to the app interface through WiFi. The camera detector can be controlled by APP using built-in automatic reel, and the maximum depth range is 28 meters. The detector will shoot vertically but when it hits the bottom, it adjusts to a horizontal direction. The camera angles can be observed in real-time as to quickly monitor the location of fishes. The drone is operated by the Chasing GO2 app which can be installed from Google Play. It gives real-time data for the user and all the functions of the drone can be operated wirelessly through the app. (Chasing Innovation 2022)

Figure 3. CHASING F1 fish finder drone

CHASING F1 fishing camera has built-in Sony stellar sensor, which supports 1080P videos/2M pixel photos. With an Infrared Light, even in dark environment, the visual range can reach up to 1 meter, and the fishing process can be monitored and video-recorded clearly. (Chasing Innovation 2022)

CHASING F1 can be mounted such spherical sonars as Deeper and Lucky, and attached bait boat that can drop off the nest bait with one click on the APP. In addition, the fish finder drone has built-in tele-communication and power supply interfaces, which can support more accessories. (Chasing Innovation 2022)

DEEPER SMART SONAR CHIRP +2

Since the F1 Fishing drone has a mounting bracket for supplementary equipment, we decided also to purchase Deeper Smart Sonar Chirp +2 (Figure 4). It is a sonar that can be installed to the drone's mounting bracket and can be used at same time with the camera. In that way, we were able to combine the use of sonar data and camera recording. Deeper Sonars use a Wi-Fi connection to pair with your smartphone or tablet, eliminating the need of an internet or mobile network connection. The deeper has a 15 hours runtime for a single charge and the scanning depth is 100 meters. (Deeper 2022)

Figure 4. Deeper Smart Sonar Chirp +2

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THE CONCEPT FOR AUTOMATIC FISH STOCK ESTIMATION AND ITS COMMERCIAL OPPORTUNITIES

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One of the objectives of the AquaHubs-project was to offer common DIH services to Innovation Experiments with the aim of advancing their innovation management and exploitation capacities and capabilities. This article describes the concept for automatic fish stock estimation, developed in our IE. The article also outlines commercial opportunities of the concept that were determined by using AquaHub's *commercial exploitation strategy development support* services.

CONCEPT FOR AUTOMATICALLY ESTIMATING FISH STOCKS

We designed a Software-as-a-service (SaaS) concept for automatically estimating fish stocks. The SaaS had the capabilities of documenting and estimating fish stock, based on sonar data and video images obtained from aquatic-drone surveys, and uploaded to a cloud service. The software would provide an interface where users can upload survey- and video data, which will then be automatically processed and analyzed for the detection of fish species.

The proposed software serves as a database for survey data (sonar and video data) and their associated metadata (geo- and time-referenced tracks of the surveys, environmental accessory data, etc.), as well as the automatically obtained summaries of fish species and their relative abundance. All the information would be hosted under user accounts and could provide valuable insight on the assessment of fish stock. The data collected by multiple teams could be used to improve the models and estimation of similar systems and regions. The software is powered by cutting-edge Machine Learning and statistical methods used in ecology and aimed to provide reliable counts of detected fish species.

The proposed solution would contain following services:

- **Service to track boat and drone surveys** that is used as a library to keep boat and drone geo- and time-referenced survey data. Users can sign-in to the system and upload their boat and drone data to the cloud. The tool will make visualizations about the tracked surveys over a map, and users can manage their collections of surveys directly from the UI.
- **Service to detect, identify, and count fish from the video recordings** that is used to process and classify fish data. From the surveys, users get the time of detection, the species identification, and individual counts over a given area. Users can sign-in to the service and upload and analyze video data obtained from the drone surveys. The service will automatically process the video, detect and identify the fish species present and generate lists of counts of fish.
- **Service to share and integrate data from multiple users.** In this component, users can search and access the public library of surveys and data analysis made by other users. Users can sign-in to the service and visualize not only their own data, but all data that was made public by other users as well. With access to more data, users get improved and more reliable estimates, and can also see data from regions they did not survey directly.

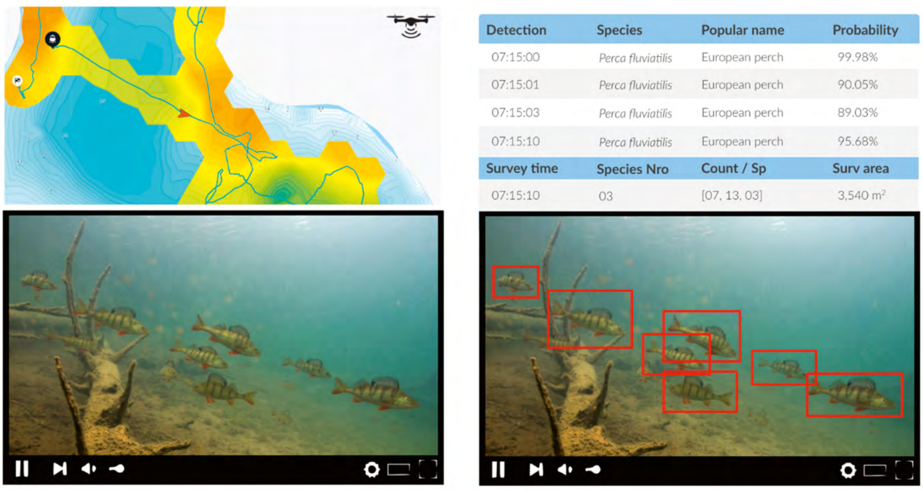

Figure 1. Tentative user interfaces of the proposed concept. Drone tracks are marked over the map, and regions of video with fish have lists of detections with the relevant data such as time of detection, species, area surveyed and probability of correct identification.

MARKETS

In the beginning, the primary target market for the automatic fish stock estimation system is Finnish aquaculture officials and commercial fishermen of inland waters. There are currently approximately 300 full-time and 1900 part-time inland fishermen in Finland. It is estimated that the number of Finnish officials working in inland water bodies is counted in the hundreds. In the long term, the market could be expanded to stakeholders of inland fisheries of other countries as well.

VALUE PROPOSITION

The service will provide an easy-to-use interface to upload sonar and video data of a particular water body, based on which would automatically create estimates of fish stock in the body of water. Gathered data and estimated fish stock is visualized for aquaculture-related stakeholders. There is no need for experts throughout the entire process.

CUSTOMER OR END-USER PROFILE

Example of users that can benefit from the services and tools provided by our concept product are presented in Table 1 and Figure 2.

Table 1. Description of potential customers and their needs

Customer (end-user) group	Customer profile description	Customer needs and requirements
Aquaculture policy/ decision makers	Responsible for regulating fishing activities to ensure the sustainability of fish stock.	Needs accurate data about fish stocks for setting lake-specific objectives to ensure sustainability.
State/regional fisheries administration	Takes care of maintaining and promoting the operating conditions for all aspects of fisheries. The closest to the fisheries administration is the regional fisheries administration, which is now part of the regional economic, transport and environmental centers.	Needs accurate data about fish stocks for monitoring the impact of regulations.
Commercial fishers	Parties conducting fishing activities on a professional basis.	Needs to have opportunities for long-term profitable fishing. This can only be achieved by ensuring the sustainability of fish stock.

	Academic and Researchers	Certifiers of sustainable fishing	Water body management	Fishery management and fishing
What do they need?	Ecological data collected at low costs, and with quality and quantity	Information on sustainability of populations / effects of fishing activities on fish stock	To ensure viable populations, to identify and protect the locally endangered species	Assess fish stock statuses and the new methods that can add value to fishery activities
Interested in?	The datasets and the trained AI models; also in collaboration and R&D	Getting access to snapshot and long-term data across specific locations	Knowledge about common / rare species, and the drivers of ecosystem dynamics	Knowledge about the quantities and dynamics of commercial species
Main risks	Abundance data is difficult to obtain, and the estimates might not be reliable	Long-term spatio-temporal data they need to rely might not be easily available	Fish abundance is just one of the multiple ecological factors needing consideration	The data acquired does not have the necessary quantity and resolution to be useful
Main Opportunities	Scientific community can help to develop faster and more accurate methods	Information utilized for the certification is based on collected field data	Citizen science portal and services to engage with the local communities.	Explore new models of certification and added value

Figure 2. Description of the primary stakeholders of the proposed concept.

CUSTOMER WILLINGNESS TO PAY

The proposed concept creates improved opportunities for fact-based decision making. The improved accuracy of estimations enables better decision-making with more impact, and the transparency of data would also reduce potential arguments. Furthermore, the concept would improve the ability to inform stakeholders about the status of fish stock and help to conduct fishing activities in a sustainable and profitable way. These are all compelling reasons for customers to pay for the offered services. The ease of use, independence from experts to identify the fish, and access to crowd-sourced data are additional features that bring value for the users.

BUSINESS STRATEGY

Being able to maintain strong fish stocks and predict the amount and type of fish to catch requires new technological solutions. Automated estimation of fish stock in a body of water can be used to increase opportunities to maintain healthy and viable fish stocks, and improve the predictability of fish to catch. In addition, being able to produce real-time data related to fish to catch is likely to affect consumer behavior.

The distinctive features of the proposed system include:

- Ability to upload gathered data (boat track, sonar data, video, metadata).
- Ability to visualize and browse the uploaded data.
- Automatic identification and counting of fish species from video.
- Automatic estimation of fish stock of a particular body of water.
- Dashboard functionality for communicating created knowledge related to a particular body of water.
- Interface for accessing gathered data for further R&D purposes.
- Access to crowd-sourced data from other users, lakes, and fish counts.

The offered features are believed to increase the use of local fish, which in turn is hoped to improve the business opportunities for fish primary production. Competitive and predictable operative environment would enable sustainable growth of fish primary production and would attract new firms and capital to the field.

PRICING STRATEGY

There is a clear need for increased cost-efficiency and accuracy when estimating fish stocks. In particular, state/regional fisheries administrations have not been sufficiently successful in monitoring the impact of regulations on a practical level, due to the labor intensity of current methods. Utilization of automation and mechanisms for crowdsourcing would provide more data with increased accuracy and cost-effectiveness. There are clear incentives for aquaculture officials to subscribe to these services and there are also opportunities in future for expanding customer groups and revenue streams.

REVENUE MODEL

Example of possible revenue streams could include monetization for:

- the right to use the services (i.e., a subscription system).
- buying extra storage to host their own videos.
- gaining access to the general knowledge database and abundance maps.
- buying annotated training data for AI, as well as trained AI models to identify fish species.

As the proposed devices to gather data are relatively inexpensive and already targeted to leisure fishermen, the software solutions could also be offered to a larger audience. This would notably increase possibilities for gathering data, which in turn would improve the estimation of fish stock.

In the future, the concept could benefit from non-academic / research versions, aimed for hobbyists, enthusiasts and sport fishers. The option to track and collect fish sessions, access to beautiful visualizations of maps, upload videos and photos, etc., can all be turned into services that might attract the interest of such groups.

COMMERCIALIZATION PLAN

As the concept is in its early stages, there are still many steps to be taken before commercialization. By far, the biggest challenge is how the fish abundance can be accurately extrapolated from the gathered data. In order to work with this challenge, we first need to gather data. Therefore, the next steps on the commercialization path are:

- Development of interfaces to upload gathered data and browse uploaded data in a user-friendly way. The ability to browse historical data is considered vital for being able to motivate users to gather and upload data.
- Building capabilities to automatically identify fish species and count them (i.e., training computer vision and statistical ecology models).
- Building ways to estimate the size of fish stock based on gathered data.
- Developing a dashboard of created knowledge to satisfy the stakeholders' needs.
- Expanding the product features to larger audiences, such as leisure fishermen.

These first steps need to be taken in close collaboration with research partners as well as aquaculture officials. After the methods are reliably built, the product would benefit from e.g., service design work to transform the core-concept into a usable digital product. Validation and user testing of the proposed user interfaces and user experiences, as well as interaction design are necessary to create an intuitive, easy to use service.

PARTIES, PARTNERS AND STAKEHOLDERS

The primary parties exploiting the services are those aquaculture officials, who are:

- regulating fishing activities.
- maintaining viability of water bodies and sustainability of fish stock.
- enforcing regulations and monitoring their impact.

Key exploitation partners are:

- Research institutions and expert researchers from the fields of biology, ecology, computer science, and Artificial Intelligence.
- Governmental agencies responsible for incubating applied research into profitable business.
- Private individuals and companies interested in investing and commercializing the innovation.

Stakeholders and relevant parties include parties having indirect interest in the offered services, such as:

- Research institutes involved in fish stock assessment and fisheries management in inland fishery (including authorities)
- Locally and nationally operating associations and agents that have an important role in promoting fisheries and communication.
- Companies for fish processing and wholesale.

COSTS AND RESOURCES

Estimated costs are presented in Table 2.

Table 2. Cost estimation of proposed concept

Cost category	Cost description	Estimate annual costs
R&D of AI and Statistical Ecology methods	Necessary further re-search, data collection and analysis work necessary for the robust estimation of fish abundance.	50,000 €* *1 time cost for the basic implementation
Software implementa-tion	MLops, UI/UX, and all the implementation work for the software wrapping the AI-engine.	100,000 €* *1 time cost for the basic implementation
Service hosting and maintenance (AI and cloud services)	Costs related to main-taining the system online, training and updating AI models, and processing and storing user data.	10,000 €*, **, *** *Can vary depending on the number of active users. **Can vary depending on the volume of data uploaded to the system. *** cost per year
Other	Market analysis research, Service design, UI/UX design, and release plan activities.	20,000 €* *1 time cost for the basic implementation

INTERNAL RESOURCES:

Xamk Memory Lab could offer computational infrastructure for training and running the machine learning structure necessary for the services, as well as video-hosting databases. Furthermore, an active and diverse expert network is needed to collaboratively develop the services

BUSINESS RISKS AND RISK MITIGATION

We identified risks and their mitigation strategies, described in Table 3.

Table 3. Identified risks and ways to mitigate them

Risk	Risk description	Risk mitigation strategy
Not acquiring the minimum necessary user base, especially the necessary number of paying customers.	Releasing a software or service is not only about the need for the product, but also quality, user friendliness, timing and marketing strategy.	Release the first versions of the software as a free alpha-version, and a paying beta-release later. Make sure that paying users get value out of the tool; this is the only measure that will make the product viable over time.
Who came to the first problem, the users or the data?	In order to have users, the tool needs data; In order to have data, the tool needs users.	Releasing free versions, especially in partnership with institutions that can generate quality data in quantity and quality. This should provide the initial input to guarantee solid services that would attract new users.
Reliable abundance estimates are critical for the service to work, and therefore attract paying users.	Estimate animal abundance is no easy task. Acquiring, automatically processing, and classifying species on video, are all simpler compared to estimating abundance.	R&D work related to statistical ecology methods. Partnering up with academia and research institutions is key.
Spatiotemporal coverage of the data might not be sufficient to estimate some parameters of interest.	The value the product and services provide, at least for some users, might not be felt before there's enough data available in the system.	Stimulate collaboration between teams, and reinforce the need for teams to share their data. This can enhance data coverage both in space and time.
Software can be expensive to develop and host when ready.	Expert software is never cheap to develop. The idea presented here brings together cutting-edge Machine Learning methods, as well as modern software development (SaaS models). The costs to implement and maintain such services might be higher than expected.	The research and public-service aspects of the product might be helpful to mitigate costs, and raise money to cover R&D and hosting costs.

CHANGE MANAGEMENT

This type of project and product creation is better executed by a multidisciplinary team of experts, following an Agile development framework. The goal is to implement such services in close collaboration with academia and researchers (for the theory and methods), as well as with service designers and the potential users (for usability and feature-based implementation). The practical implementation of core-methods happens during a proof-of-concept project, and most of the service-design and implementation of the methods as a SaaS software happens during the execution of a minimum viable product. This format allows to quickly ideate, validate and implement ideas defined jointly with the experts and real users, as well as quickly correct directions and new developments discovered along the way. The agile format makes it possible to account for unforeseen circumstances, both positive or negative, and to release the software and services in installments, that can be used and validated by the real users. Continuous development and integration strategies, together with real-user validation and feature-based development are key to create a product that will have features and value to attract the interest of paying users.

BUSINESS MODEL CANVAS

Our business plan is summarized in Business Model Canvas (Table 4).

Table 4. Business Model Canvas of the proposed concept

Key Partners	Key Activities	Value proposition	Customer relationship	Customer segments
Research institutions and expert researchers from the fields of biology, ecology, computer science, and Artificial Intelligence. Governmental agencies responsible for incubating applied research into profitable business. Private individuals and companies interested in investing and commercializing the innovation.	The key activities relate to identifying potential users and their needs, together with developing the MVP version of the system. Market research and Service design, to construct the product UI/UX and services from the perspective or acquiring and converting paying users. R&D and implementation of ML methods and Statistical Ecology models necessary to obtain reliable estimates of fish abundance.	Expert methods made easily available to non-expert users. Inference based on collectively acquired field data. Portal to collect information and bring together relevant actors.		1. Academic users and research teams. 2. Governmental actors (e.g., Certifiers of sustainable fishing). 3. Agents responsible for water body management. 4. Actors responsible for the management of fisheries. Potentially, also private users such as hobbyists, sports fishery, tourism and other actors.
	Key resources		**Channels**	
	Xamk Memory Lab for training and running the ML structure necessary for the services, as well as video-hosting databases. AI experts as partner collaborators for consultancy and hands-on work on development of the services.		The software is distributed as a cloud-based Progressive Web Application (PWA), available online directly from the users' browsers. The users gain access to team spaces, where they can store data about different surveys and run multiple analyses.	

Cost structure	Revenue streams
Costs relate to the following activities: – R&D related to building reliable methods to estimate fish abundance. – Implementation of machine learning models to identify and count fish. – Work to develop and implement the software around the ML methods. – Hosting costs: computing power to train and run ML models in production. – Hosting costs: cloud services to serve the software for its users. – Hosting costs: cloud data storage costs for uploaded videos.	Example of possible revenue streams. Monetization for: 1) the right to use the services (i.e., a subscription system). 2) buying extra storage to host your own videos. 3) gaining access to the general knowledge database and abundance maps. 4) buying annotated training data for AI, as well as trained AI models to identify fish species.

INNOVATION DEMONSTRATION AS A WAY FOR EVALUATING CONCEPT FEASIBILITY AND FUTURE OPPORTUNITIES

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One of the tasks of AquaHubs was "supporting IEs in innovation demonstrations to end-users". To this end, the project offered guidance on how to organize innovation demonstration events. This article describes the innovation demonstration event held in Finland, and the feedback gathered from the participants during the event.

ORGANIZING THE INNOVATION DEMONSTRATION EVENT

We demonstrated our concept for automatically estimating fish stocks in a virtual meeting on April 29th 2022, using Microsoft Teams. Since the purpose of the event was not only to demonstrate the proposed concept, but also to initiate discussion evaluating its opportunities, we aimed for participant diversity. A total of eleven participants attended the event, four of which worked in universities, two in companies, two in research institutions and three in the public sector.

The guidance, offered by AquaHubs on organizing innovation demonstration events included a set of questions for gathering feedback from the participants. We gathered answers for these questions throughout the innovation demonstration event, by using the polls-feature of Microsoft Teams. In the remainder of this article, we describe the presentations given in the event, with the feedback gathered from the participants.

PRESENTATION OF THE HARDWARE AND DEVICES

The event started with an opening talk explaining the purpose of AquaHubs and the innovation demonstration event. Then, the selected devices used for gathering data were presented, including CHASING F1 Fish finder drone, and DEEPER SMART SONAR CHIRP+ 2.

After the presentation, we asked how useful the participants found the presented devices for gathering data about fish stock? Eight participants answered, out of which 38% found the devices extremely useful, 38% somewhat useful, 13% neutral, and 13% somewhat not useful.

We then asked what the participants considered promising in the technology? The following answers were given:

- Easy to use by non-expert
- Combination of drone and sonar
- Affordable
- Easy to use, low-price equipment
- Getting closer to the fishes, but how different the results are if compared to ones taken from the surface
- Drone and sonar
- Fish stock assessments without catching fish
- Future

For the question of what the participants consider problematic in the technology, we received following answers:

- Murky waters, winter
- snap-shot in time
- Ice and requirement for a boat :)
- May miss specific species
- Winter conditions
- Biased for common species
- Our lakes are too large for this kind of technology
- Conditions
- areal coverage
- Conditions
- Needs good weather and visibility, how to cover large areas, is sonar accurate enough

When asked: "What kind of improvements you would wish to see in the used technologies?", the participants answered:

- Ability to cover more area
- Long term measuring
- automated data transport from equipment to database

- could thermal imaging help...?
- Thorough inspection of reliability and comparisons for established methods
- Capacity
- laser counting (size and amount)

Finally, when presenting the statement of: "Users are likely to be interested to use these devices", 25% of the participants strongly agreed, 50% agreed, and 25% were neutral.

All of these responses suggested that the choice of technologies seemed promising.

PRESENTATION OF THE SOFTWARE SOLUTION

After the devices were presented, the conceptualized software solution for gathering, analysing and visualizing data was presented.

When we asked how useful the participants find the proposed software service estimating fish stock, 50% of the participants believed the solution to be extremely useful, 38% somewhat useful, and 13% were neutral.

When asking what type of service/feature presented interested the participants the most, we received following answers:

- Counting fish individuals
- specimen recognition with AI (I assume)
- Identification
- AI based fish recognition and counting
- Detecting different fish species
- automatic detection/recognition
- fish
- fish identification

When stating that the proposed solution is likely to increase accuracy of fish stock estimation, 13% strongly agreed, 38% agreed, 38% were neutral, and 13% disagreed.

For the question of "To what extent you would trust extrapolated estimates of the fish stock?", 14% had strong trust and 86% trusted a little.

When stating that the proposed solution is likely to increase the cost effectiveness of fish stock estimation, 63% of the participants agreed, 25% were neutral, and 13% disagreed.

For the statement that the proposed solution is easy to use, 13% of the participants strongly agreed, 38% agreed, and 50% were neutral.

When stating that the proposed solution leads to better and more transparent decision making, 14% of the participants strongly agreed, 71% agreed, and 14% were neutral.

When asking the participants to pick three stakeholders who would benefit from the proposed solution, the most selected stakeholders were:

- researchers (27%)
- fisheries administration (18%)
- policy makers (14%)
- Officials planning for responsible fishery management and fishing (14%)
- Commercial fisherman (9%)
- Individual users, fish enthusiasts, sport fishers (9%)

When asking which feature(s) (presented or not) would increase stakeholders' willingness to pay for the proposed solution, we received following answers:

- Access to general data
- Access to data collected by other users
- Off the shelf stuff. Just go to the store, purchase and start using
- data
- Accuracy
- automatically generated fish stock estimates
- statistically reliable
- data products like thermal maps

For the question of: "Which of the features you would be interested at?", we received following responses:

- Utilizing data from other people (35%)
- Estimating fish stock in a particular body of water (29%)
- Identifying and counting fish from the data in a particular body of water (18%)
- Uploading and browsing sonar/video data from a particular body of water (12%)
- Utilizing labelled fish-video for R&D purposes (6%)

To the question of: "Which of the data you would be willing to make public?", the participants responded:

- survey (boat/drone) tracks (28%)
- video recordings (33%)
- counts of fish and abundance estimates (39%)

For the statement of "The proposed solution is realistic to implement", 75% of the respondents agreed, and 25% were neutral.

When asking the strengths of the concept, we received following answers:

- User friendly expert tool
- Actual fish sightings
- if succeeding, provides benefits to many user groups
- AI
- information increases
- New data

When asking about the weaknesses of the concept, we received following answers:

- Reliability is hard
- Time consuming
- Not a commercial product yet, in prototype stage
- Still a lot of development work to do
- Our waters are cloudy and dark. Visibility is too low.

When asking for advice for further development actions, we received following answers:

- Collaboration is key
- test with a group of users and get genuine feedback
- Collaboration and funding

Finally, for the question of "How fish stock estimation could be made to be more accurate?", the participants answered:

- Collective data knowledge
- combine results with other data, e.g. catch and effort

Overall, the responses gathered from the participants suggests that there is potential for future development of the proposed solution for automatically estimating fish stocks.

DISCUSSION

With the innovation demonstration event, we wanted to assess the general interest and discuss the viability of the proposed solution and potential for future development. The tools and services, offered by AquaHubs helped us to accomplish this objective by giving advice on the practicalities of organizing the events with stakeholders and proposing questions to be asked from them.

As a final question from the participants, we asked feedback about the innovation demonstration event itself, and received following answers:

- Good brainstorming session
- interesting presentation
- Well organized, very interesting!
- Interesting demo
- good job
- Happy 1. May

The gathered feedback suggests that the AquaHub project's guidance helped to build interaction with relevant stakeholders that was positively experienced by the participants.

Overall, the activities conducted in AquaHub served their purposes in building capabilities for supporting digital technology-based innovation projects. The outcomes of the project proved their usefulness when supporting innovation experiments, and hence strengthen the services of three Digital Innovation Hubs participating in the project.

XAMK DEVELOPMENT