COMPLETED PROJECT CASE STUDY

DEVELOPING AN EARLY WARNING SYSTEM FOR INFECTIOUS SEA LICE WITH HOLOGRAPHIC IMAGING

PARTNERS

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BACKGROUND

Sea lice pose one of the most persistent challenges in modern aquaculture, particularly in Atlantic salmon farming. These parasitic crustaceans, primarily *Lepeophtheirus salmonis* and *Caligus spp*., attach to the skin of farmed and wild fish, feeding on mucus, blood, and tissue. Infected fish may suffer from skin damage, stress, and increased susceptibility to secondary infections, impacting growth rates and overall survival. For aquaculture businesses, infestations result in higher production costs due to the need for treatments, lost livestock, and regulatory restrictions.

Detecting and quantifying sea lice larvae (SLL) in the wild and at farm sites presents a significant challenge, and traditional methods struggle to provide real-time data on their distribution. Non-invasive early detection of infective larvae would enable proactive management, improving fish welfare and environmental sustainability while reducing the risk of infections.

This case study explores the development of a novel method for identifying sea lice larvae using holographic imaging and artificial intelligence (AI), with the ultimate goal of ground-truthing lice dispersal models. The University of Aberdeen's Optics Research Group, a world leader in underwater holography, led this project, building and deploying holographic cameras, analysing data, and developing AI models.

The Scottish Association for Marine Sciences (SAMS) established a sea lice hatchery, carried out holographic SLL imaging and tested field methods, while the Scottish Government's Marine Directorate supported the collection of general plankton images. Industry project partners include Mowi Scotland, which provided valuable expertise on sea lice dispersal and feedback on modelling outputs, while Hi-Z 3D supported the development of the holographic system.

All partners worked in close support from the Sustainable Aquaculture Innovation Centre (SAIC).

AIMS

The project aimed to develop a rapid and reliable sea lice larvae detection system based on digital holographic imaging integrated with automated image analysis, with the specific objectives to:

1. Develop a digital holographic imaging system for detecting SLL;
2. Establish a dedicated sea lice hatchery to supply specimens for imaging;
3. Generate a dataset of holographic images of larvae in various environments;
4. Develop AI-based classification models to identify sea lice larvae accurately;
5. Conduct field demonstrations assessing the practical application of the imaging system;
6. Engage stakeholders and disseminate findings.

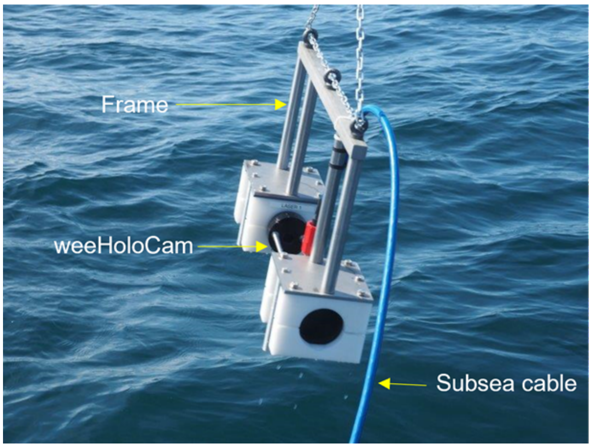
DEVELOPMENT OF HOLOGRAPHIC IMAGING SYSTEM AND AI CLASSIFICATION

Researchers at the University of Aberdeen adapted compact camera designs for SLL detection, creating a high-resolution imaging system (9 µm) mounted on a portable triangular optical bench. Once validated, a field-deployable version was designed with protective enclosures for moisture resistance while maintaining compatibility with various flume designs.

A dedicated sea lice hatchery was established at SAMS, providing a steady supply of L. salmonis larvae at both nauplii and copepodite stages.

Researchers at both Aberdeen and SAMS developed and refined multiple imaging chambers and flumes, evolving from a static imaging microcosm to a flowing imaging flume that enabled diverse larval orientations and accurate quantification.

Precise flow control was achieved using peristaltic pumps, ensuring continuous imaging across a 10mm x 100mm arena. A final field-deployable flume was designed to integrate the best features of earlier versions while ensuring compactness, weather resistance, and compatibility with the "weeHoloCam" – the name given to the existing field-deployable holographic camera. (For clarity: the field-deployable flume has not yet been tested in the field or imaged with



sea lice: this work ended at the design stage.) Holographic imaging captured SLL at various developmental stages, both in controlled lab conditions and in natural zooplankton samples. Initial imaging focused on live pure SLL cultures, later expanding to preserved pure SLL and preserved mixed plankton samples.

The AI classification system, built using Convolutional Neural Networks (CNN), was trained to differentiate SLL from other planktonic organisms. The process began with creating a dataset of larvae images in a static lab tank, which provided the initial "positive" dataset, while "negative" examples came from existing ocean plankton datasets.

To improve accuracy, size-based filters were implemented that discarded irrelevant images, significantly refining the data.

The field sampling in Loch Linnhe in June 2024, near active salmon farms, assessed larvae distribution in correlation to environmental conditions. Zooplankton samples were collected with a refined sampling method that allowed high volume (~10m3) sampling at two defined depths (0.5m and 12m), after which the samples were then concentrated and preserved. Traditional microscopy of preserved samples provided a baseline for AI-based quantification comparison.

RESULTS

Early training of the model showed that the use of a flume was necessary to better replicate real-world conditions and for abundance quantification. Transfer learning and data augmentation then enhanced model performance dramatically. The model initially achieved accuracies in detecting SLL of 84.73% and 85.77% on the first and second version flume test sets. Additional refinements through false positive reduction and hard negative mining resulted in final accuracy rates in detection of 99.23% and 93.47% for live and preserved sea lice larvae, respectively.

The imaging system performed well detecting live SLL, which retained their natural shapes and features, but faced challenges in the identification of preserved specimens due to morphological variability and loss of distinguishing features. The field methods of combined large-volume depth-defined water sampling, sample concentration, and microscopic identification proved effective in providing a dataset on sea lice larvae abundance in the natural environment. Further refinement of AI training and modelling, and flume imaging for preserved samples are now needed to adapt AI techniques for detecting plankton in the water column.

Results from the Loch Linnhe field trial validated the sampling method and indicated that most SLL preferred deep (i.e., 12m) water when compared with shallow (i.e., 0.5m) water, suggesting salinity aversion influenced their distribution.

IMPACT

A SAIC-supported stakeholder workshop at the MASTS Annual Science Meeting in November 2024 gathered input from aquaculture professionals, regulators, and researchers on improving sea lice monitoring methods. Feedback contributed to a draft manuscript (Murray et al.) on surveillance for the planktonic phases of larval sea lice, planned for submission in 2025.

This project successfully demonstrated the potential of holographic imaging and AI for sea lice monitoring, providing a scalable solution for improved aquaculture management. The system enables fast, automated detection with high precision, supporting proactive management strategies. Future work will focus on refining models for real-time quantification and exploring advanced imaging techniques to enhance accuracy, including real-time quantification and capturing colour and 3D shapes, paving the way for widespread application in sustainable aquaculture.

Ultimately, this project has established a ground-breaking framework for automated SLL detection, with the potential for real-world application to support sustainable aquaculture practices.

Also, research has unexpectedly revealed that sea lice are more abundant in deeper waters, highlighting the need for a better understanding of their ecology and spatial distribution throughout the water column.

ADDITIONAL INFORMATION

- Holographic cameras bring sea lice early warning system into focus
- More information on diel (diurnal) vertical migration in the water column

REFERENCES

Murray et al. Reviewing surveillance for the planktonic stages of larval salmon lice in the marine environment, a key parasite of wild and farmed salmon. In preparation.