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Intelligent Fish feeding through Integration of ENabling technologies and Circular principle

Grant Agreement (GA) No: 818036

D14 Demonstration Performance (KPIs) for S-CCS

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1 Introduction

Sustainable growth in the aquaculture sector has numerous challenges such as environmental limitations, increasing feeding efficiency and sustainable ingredients, disease and parasite infecting not only cultured fish but also the spread to wild populations, and climate change is impacting production with warmer temperatures and increased harmful algae blooms causing massive mortalities. The salmon and trout biomass production in 2017 was 1.3 million tons with a corresponding sludge (10% Total Solids) volume of 2.145 mill tons. By 2050 the fish biomass production market will reach 6.5 mill tons and the sludge volume will reach 11 mill tons. This amount of generated sludge can be considered a showstopper to reach the 2050 activity targets and there is a need to find sustainable solution for waste-free aquaculture as well as to collect and remove actual waste. In Norway, the industry has over the last decade been developing a range of new production systems, giving solutions to mediate these challenges.

Semi-closed containment systems (S-CCS) floating at sea is one important solution that is making headway with a variety of prototypes being tested including, e.g., Egget©, Fish Globe, Neptune, that not only protect the fish in production but also protect the surrounding environment with the potential to collect up to 95% of the particulate waste. What is common with these systems is they have a walled barrier to the surrounding sea, protecting the production from exposure to sea lice in the upper water column, prevents escapes that is seen in damaged open cage systems, and reduced transfer of disease to wild populations. They also have an increased control of the water quality and production environment optimizing production and welfare, as they can pump incoming water from different depths up to 50m deep, in Norway providing a more stable environment in summer and winter. In addition, they can add oxygen directly to the system when oxygen levels drop below a certain level, for instance at higher densities and during feeding. In some of these systems, as Egget© in this demonstration, the outlet water can be filtered and the sludge collected and reused in new feed ingredient production (e.g., algae, yeast), biogas production, fertilizer, and other circular pathways. While these systems have many benefits, the production success is dependent on robust digital control to optimize feeding, water quality, energy use, and fish welfare. Developing digital systems that can integrate data from different sources from the production systems and provide real-time understanding of the production and components as well as early warnings, and in the case of this demonstration guidance for optimal feeding efficiency will be essential for S-CCS. The iBOSS and Fish-Talk-To-Me applications developed for recirculating aquaculture systems (RAS) and open-cage systems (see public Deliverables 2.5 and 3.4) are relevant for S-CCS.

The following technologies have been demonstrated in the S-CCS, Egget©.

1. iBOSS (iFishIENCi Biology Online Steering System) is a flexible system for monitoring multiple aspects of fish biology and environment. This includes water quality parameters (e.g., temperature, dissolved oxygen, pH), characteristics of the microbiota within cultivation systems, fish behaviour, and relevant production metrics such as feed consumption and growth rate measurements. It consists of two main components. iBOSS Cloud: a platform in which data will be stored and processed by analytical algorithms. iBOSS Edge: A local interface that sends and receives data to and from the cloud, and which allows monitoring and control of the farming system. Both iBOSS components can be connected to other farm management cloud systems and data aggregators collecting data from various sensors.

2. Fish-Talk-to-Me is an integration of technologies and biology to better understand the state of the fish and to anticipate feeding requirements (e.g., smart feeding). This information could be used for optimizing production site knowledge with early warning information as well as for optimizing AI and machine learning from other group-based sensors or cameras. The know-how of the product includes:
    - Camera technology for monitoring fish behaviour;
    - Environmental sensors as oxygen, temperature, carbon dioxide.

2 Key Performance Indicators

iBOSS is designed to adapt to the available data inputs from sensors a site has available, gathering into one cloud-based system that can then optimise management and control features to maximise feeding efficiency. In addition, the Fish-Talk-To-Me feeding behaviour algorithms developed for seabass (see public deliverables D2.5 and D3.2) has been tested in salmon to allow the behaviour of the fish to regulate how and when to feed. In this demonstration, a standard feeding camera is being testing using this algorithm.

The key performance indicators (KPIs) for this demonstration were as follow:

- Integration of water quality data from Egget© sensors into iBOSS.
- Adapt Fish-Talk-To-Me feeding behaviour algorithms for salmon standard feeding camera.

3 Demonstration Methodology

The Egget© is a semi-closed flowthrough salmon production system that floats at sea. The present system is a pilot with a volume of 1800m^3 and the construction of 20 000m^3 system is planned to be in operation by 2024.

Figure 1. Ovum´semi-closed containment system Egget©.

Egget© is moored in at Ovum´s grow-out sea cages sites at 62,6275° N, 7,192817° Ø, sea locality in Vestnes, Møre and Romsdal, Romsdalsfjorden, Norway (Figure 2).

Figure 2. View outside Egget©.

For this demonstration, Egget© was stocked with 40 000 Atlantic salmon at an average weight of 1 kg. The fish are fed continuously and are exposed to continuous light (Figure 3).

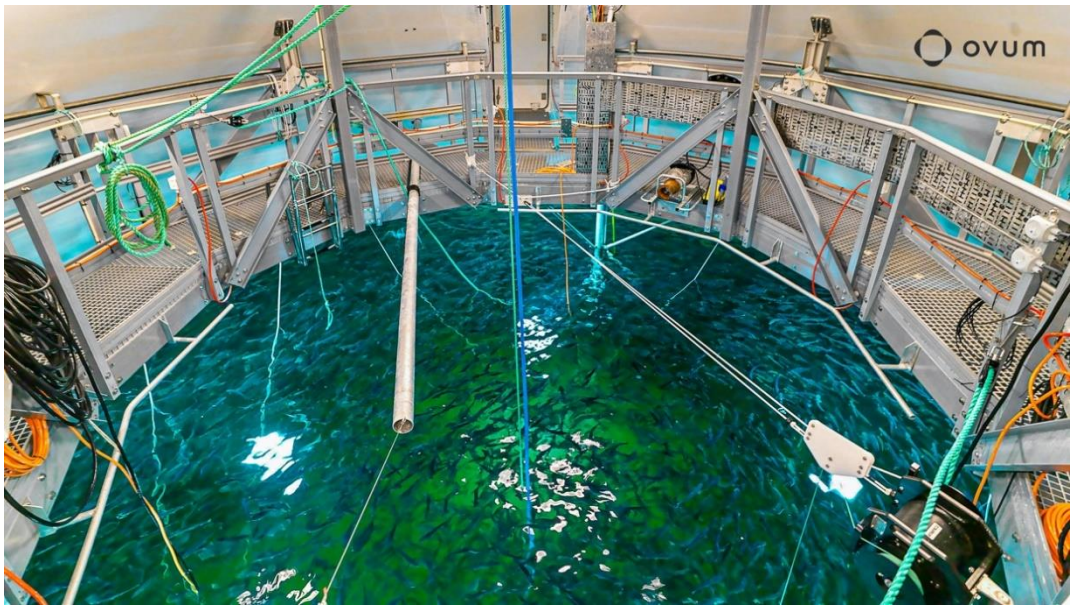

Figure 3. View inside Egget© with Atlantic salmon with pneumatic feeding system and camera on pulley system.

3.1.1 Connection to iBOSS

As most salmon production systems, the demonstration site is remote and communication to the cloud can be variable and relies on stable G4 or G5 network. In this demonstration, the Guard control system together with iTeam setup a VPN so that OxyGuard, through Cobália, could relay sensor data to iBOSS for realtime monitoring.

3.1.2 Camera and installation in Egget©

In this demonstration, the Imenco Gemini feeding and inspection camera was used. The camera is fitted with double IP colour cameras, 360 degree viewing angle. The camera installed in Egget© is connected to a pulley system that allows for flexibility of placement and inspection. The camera was placed at 5m depth under the feeder for this demonstration

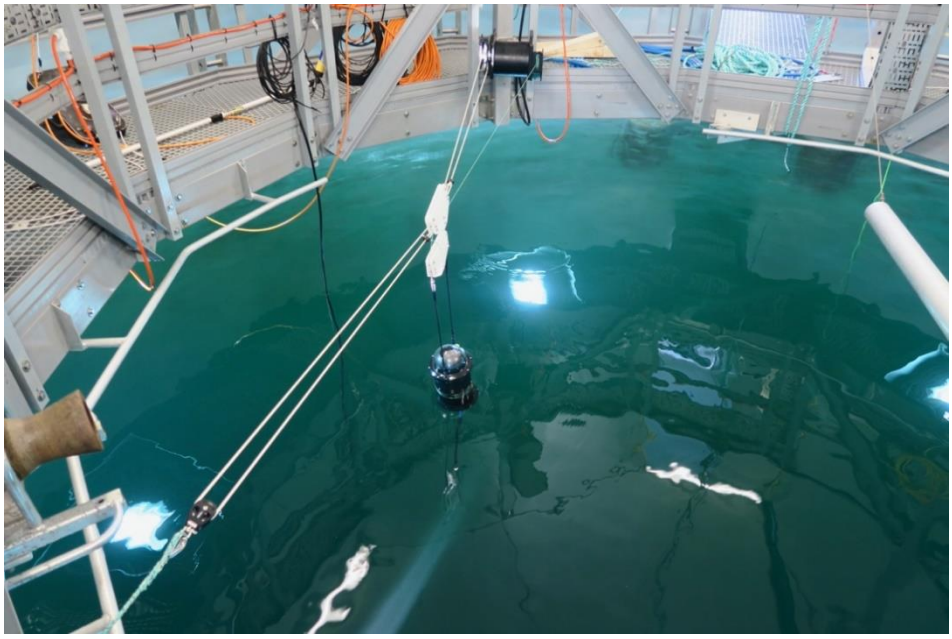

Figure 4. Imenco Gemini feeding and inspection camera on Pulley system.

The camera was installed July 15 and remain until Oct 15 2023. The camera was placed 5m under the feeder with one camera facing upwards and the bottom camera facing horizontally. Videos before, during and after feeding were tested to demonstrate the application of the feeding behaviour algorithm in salmon in S-CCS.

4 Demonstration Results

4.1.1 Integration of water quality data sensors into iBOSS

It has been demonstrated that a wide range of sensor data can be streamed from Egget to data iBOSS dashboard, through Guard, to Cobália and then to iBOSS cloud.

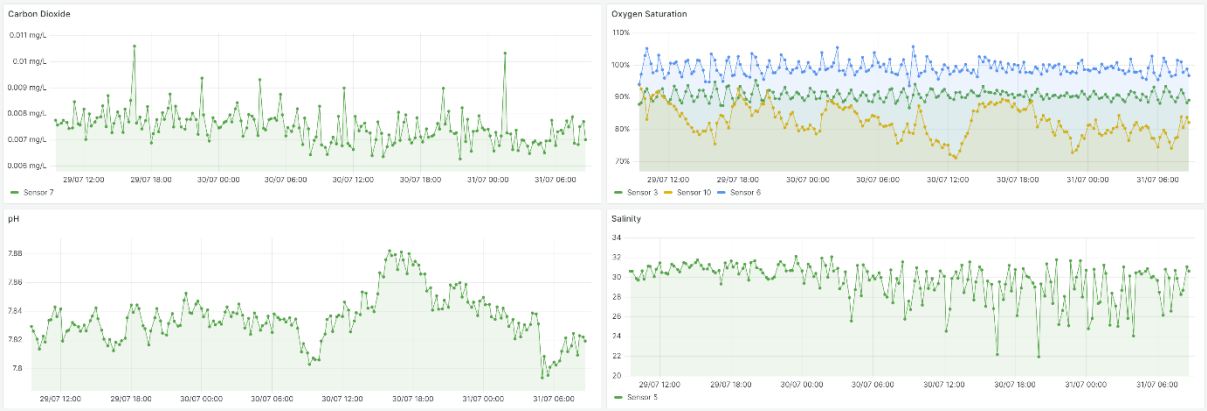

Figure 5. Screenshot of real-time streaming of sensor data (CO2, O2 (from inlet (blue), inside (green) and outlet (yellow)), pH and salinity) from Egget©.

Figure 6. Screenshot of real-time streaming of sensor data (temperature, total gas saturation and turbitity) from Egget©.

4.1.2 Video collection and testing Fish-Talk-To-Me feeding algorithm

Here it was demonstrated that the video data from Egget could be streamed and stored for future analysis. Videos were captured before, during and after feeding following a cleaning event (see Figure 7) to test the Fish-Talk-To-Me feeding algorithm developed in European seabass.

Figure 7. Screenshots of video streaming of salmon from Egget© following cleaning maintenance, top camera.

Employing the Fish-Talk-To-Me feeding algorithm, salmon show significantly higher speeds before feeding, and the speed value per se, and could be used as an indicator for hunger after disturbance and possible threshold values could be potentially defined to determine when to start feeding (Fig 8).

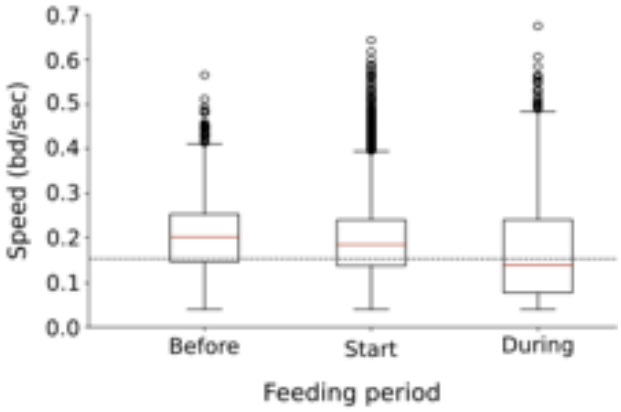

Figure 8. Fish speeds before, at start and during feeding analysed by Fish-Talk-To-Me algorithm in Egget..

5 Conclusions, recommendation for application of the results in the industry

It was shown that iBOSS can incorporate sensor data from different technical suppliers, demonstrating the flexibility of iBOSS to adapt to the existing systems of the fish farmer. The diversity of sensors is as comprehensive as seen in RAS systems, and with equal importance. As this is a commercial site, this demonstration was not allowed to connect to Egget©'s control system that regulates feeding, water pumps, oxygen pumps, and lighting. However, the potential is high to apply the iFishIENCi products and applications from iBOSS, Fish-Talk-To-Me, and SmartRAS to S-CCS systems for improved feeding efficiency with improved production and reduced feed spill. iBOSS represents an important tool for farmers that presently get data from a set of suppliers individually but not a system where this can be integrated and used together to make more robust decisions on for example how to optimally regulate feeding.

Fish-Talk-To-Me uses behavioural and physiological information to non-invasively understand the fish´s state. Behavioural algorithms will be applicable for periods when the feeding is interrupted for example during routine maintenance, as cleaning, but may be less effective during normal feeding as it is continuous and will not invoke dramatic behavioural changes. Algorithms that monitor oxygen in and out of Egget© would be able to monitor physiological changes over time that can be important indicators of feeding physiology and disturbances in the system.

6 Dissemination of the demonstration

- Hungarian (MATE) event: The adaptation of iBOSS and Fish-Talk-To-Me in relation to salmon S-CCS in Norway were presented at the Fisheries and Angler Specialists Meeting in Gödöllő, Hungary on 26th. Of January 2023. Over 200 participants from aquaculture companies attended the event. The lecture covered the potential uses of these products in salmon production, but also how they could be adapted to different types of fish production systems.
- 23rd Annual Embedded Vision Workshop in Vancouver, Canada June 19, 2023. The iBOSS and Fish-Talk-To-Me was presented and in particular the machine vision challenges and needs associated with behavioural analysis in different salmon production systems to enable robust edge control systems.
- The adaptation and importance of iBOSS and Fish-Talk-To-Me in relation to Egget© were discussed together with Ovum as part of the iFishIENCi final event under the iBOSS Technical Workshop on the 21st of June 2023.