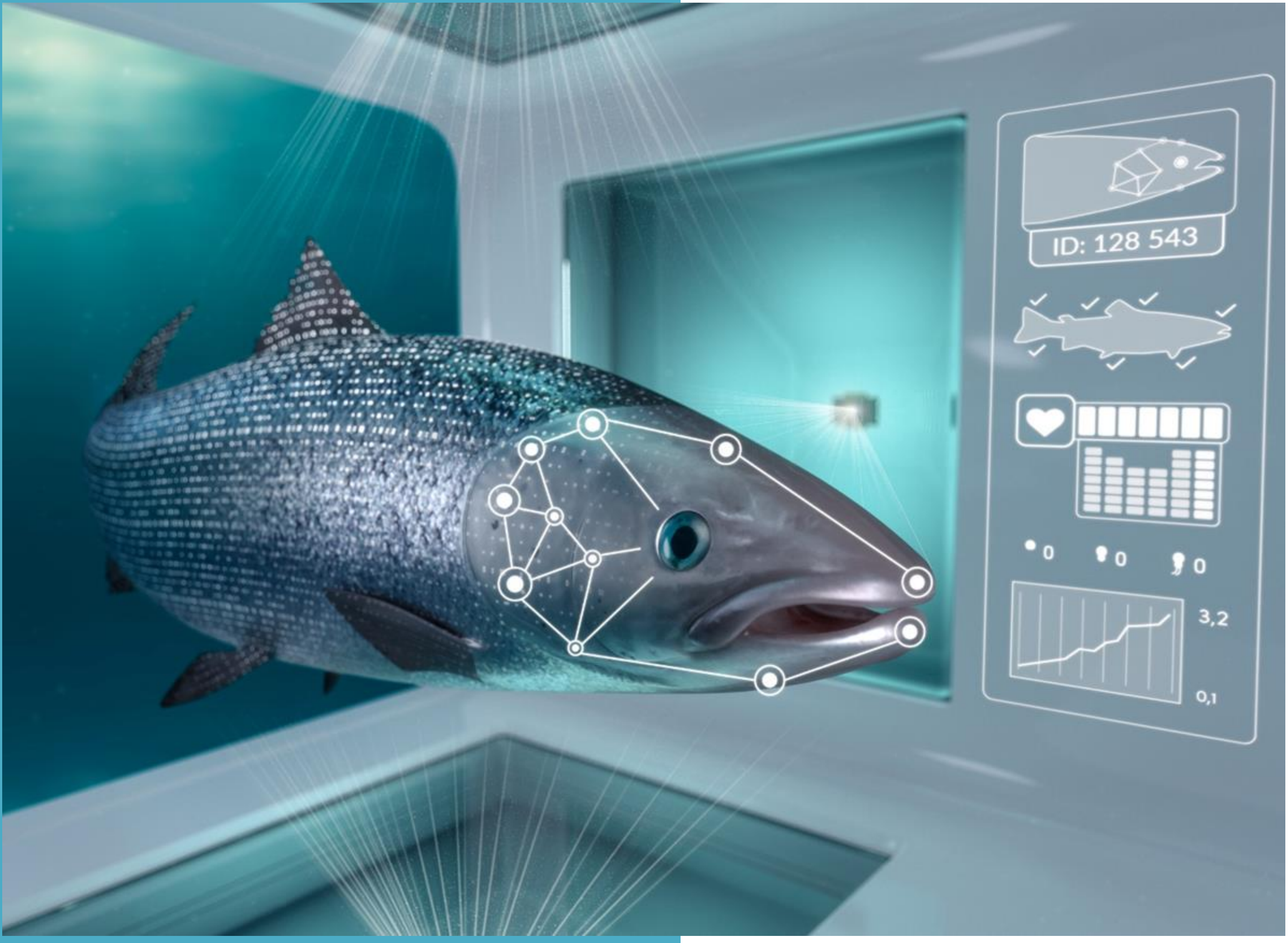
iFarm: Midway report documenting the biological and technological results from Phase 1 (Concept-test) - Cermaq Norway avd Martnesvika



Cermaq Norway

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Innhold

Introduction

The iFarm aquaculture concept, being developed by BioSort AS in partnership with Cermaq Norway AS was granted four development licences by the Norwegian Directorate of Fisheries in 2019. The iFarm concept is a novel production system that aims to introduce individual-based Precision Fish Farming (Føre et al., 2018) to Atlantic salmon aquaculture. It aims to use advanced illumination/camera technologies and computer vision algorithms to identify individual fish, as well as counting lice on the fish and other parameters related to health, welfare and growth on individual salmon held within adapted aquaculture sea cages from smolt transfer to slaughter. The development licence project also aims to grade and sort fish based on their size. The iFarm production system in Phase 1 consists of adapted snorkel cages that hold fish 10-15m below the ocean surface to limit their interactions with potential lice rich surface waters. Cages are also fitted with lice skirts around the main cage collar (not adapted snorkel) down to a depth of 5 meters. The fish can access the ocean surface to refill their swim bladder with air through the snorkel. Each time the fish swims to the surface it must pass through the iFarm sensor which will then identify it and measure various performance, welfare and health parameters. Three phases of the iFarm project are planned from 2020-2024. This midway report addresses the first half of Phase 1 from September 2020 until June 2021 and summarises the technological developments that occurred during the report period in addition to results from the monitoring of biological (fish health and welfare) and production performance during the reporting period.

Technical design and Developments

Geographical location

This proof of concept commercialisation study was carried out at Cermaq Norway AS's Martnesvika production site 67.76705° N, 15.580867° E (see Figure 1).

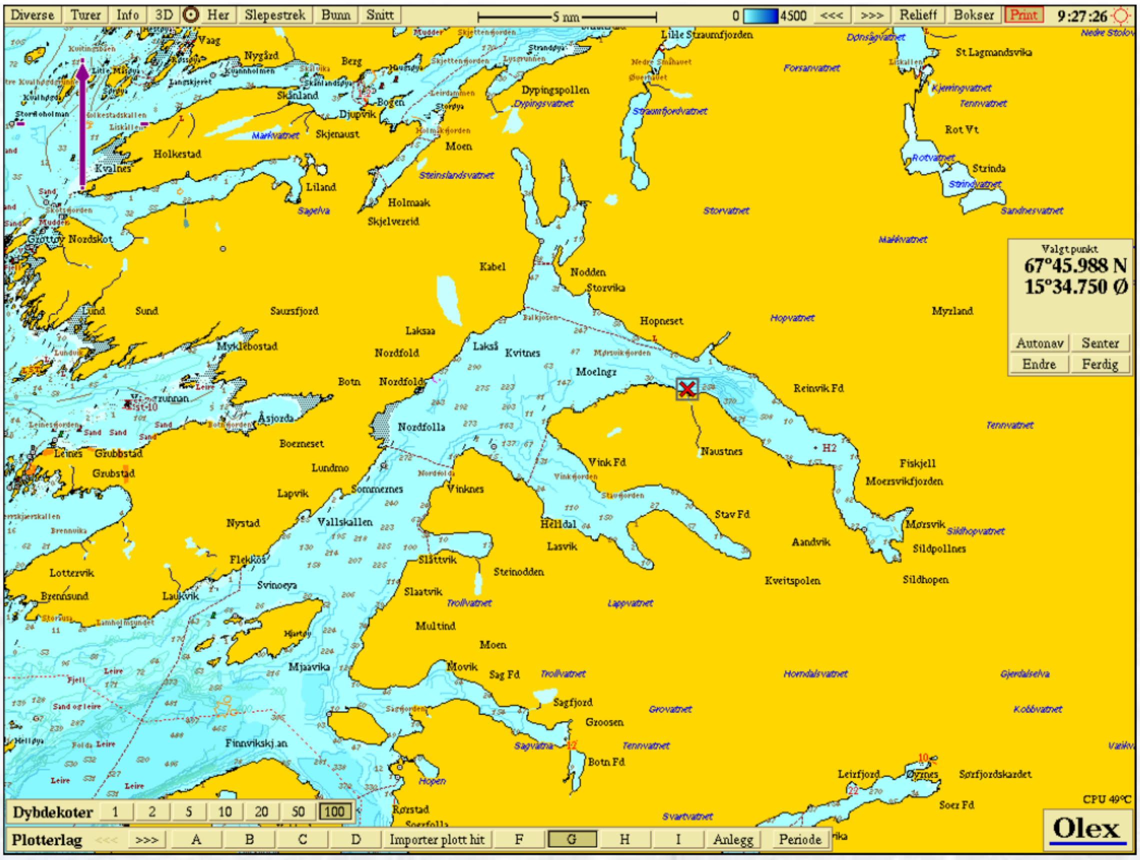


Figure 1 Map showing the Cermaq Norway AS facility Martnesvika, where the iFarm cages are located (map location highlighted with a red boxed x). Map courtesy of Olex AS and reproduced from the Martnesvika site report by Akvaplan-niva.

Phase 1 timeline and set up

Phase 1 of the project is currently underway and began when the fish were transferred to seawater on the 14th and 16th September 2020. Phase 1 uses autumn 0+ smolts stocked in three production cages at Martnesvika, including 1 associate adapted snorkel cage (cage M9) and two iFarm cages, (cages M10 and M11), hereafter termed the associate cage/M9, iFarm 1/M10 and iFarm 2/M11, respectively. Placement of the cages within the cage group at the Martnesvika site is shown in Figure 2 below.

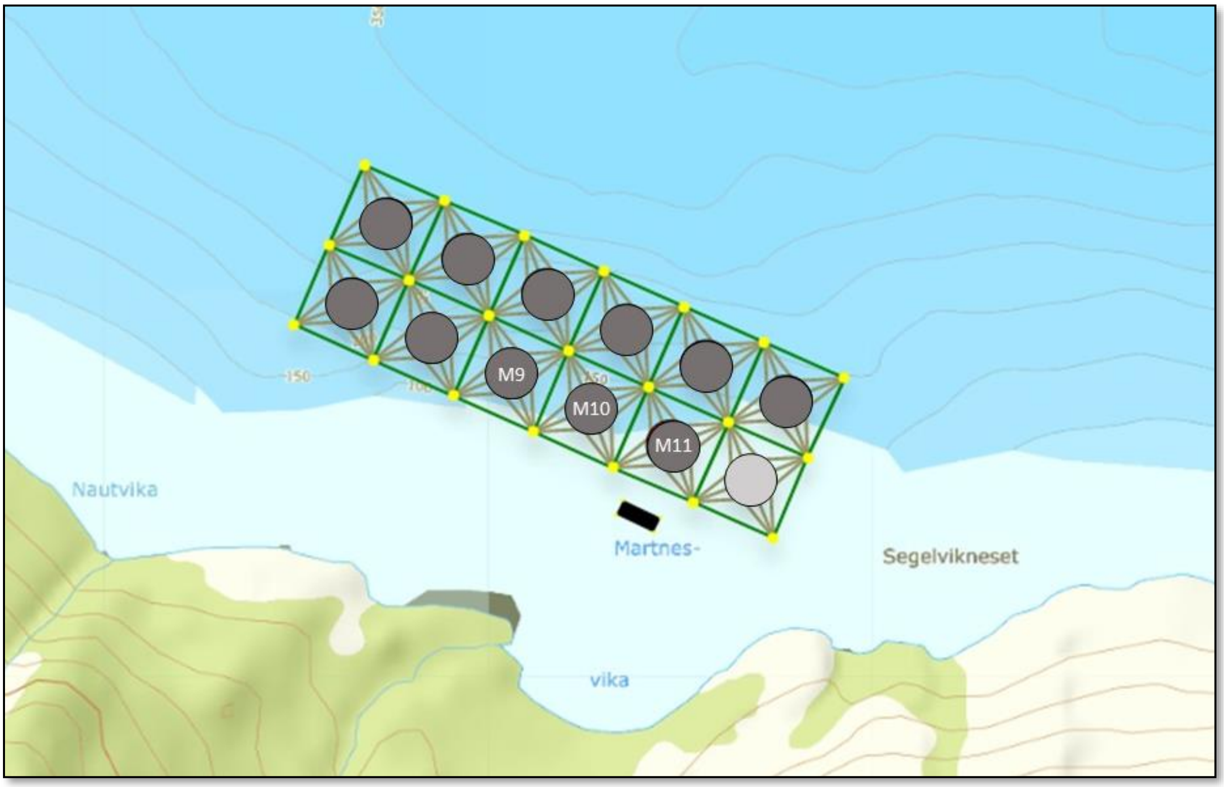


Figure 2 Figure showing the placement of the Phase 1 cages within the Cermaq Norway AS facility Martnesvika. Specifically, the associate cage (M9) and the two iFarm cages, (cages M10 and M11, respectively)

Fish were from a pooled hatchery AquaGen QTL-Innova SHIELD stock from Lødingen fisk AS hatchery. One group of fish were transferred from the hatchery via the Langsund wellboat on the 13th September 2020 and deployed into the associate cage M9 on the 14th Sept. Further fish transfers were undertaken using the Viknatrans wellboat from the same hatchery on the 15th September 2020, and fish were transferred into iFarm 1, M10 and iFarm 2, M11 on the 16th September 2020. Average seawater temperatures at the time of transfer on the 14th and 16th September 2020 at 3m depth were 11.9 °C and 12.3 °C, respectively. Lice skirts were not initially deployed on these cages until mid-November (Permaskjørt, Botngaard, 5m depth). Numbers of fish in each cage at the time of transfer were: 157 430 (mean weight ca. 80 g) for the associate cage (M9); 144 927 (mean weight ca. 98 g) for iFarm 1 (M10), and 165 405 (mean weight ca. 109 g) for iFarm 2 (M11).

Technical development

Adapted snorkel cage

The iFarm production systems in Phase 1 are adapted snorkel cages with a net roof that starts at either 10 m (iFarm 1, M10) or 15 m (iFarm 2, M11) below the water surface (Figure 3). The associated cage has a snorkel and net roof that starts at 11 m deep (Figure 3). From fish stocking in mid-September 2020, until the iFarm sensor houses were mounted on the docking stations in February 2021, iFarm 1 (M10) and iFarm 2 (M11) were identical, except for the geometries of the net roofs. Based on daily observations for 5 months, the project concluded that there was not a large difference between the two cages in terms of fish behaviour and that both geometries would serve the purpose. Given that the 15 meter net roof reduces cage volume below the net roof substantially, cage geometries based upon the 10 meter net roof were chosen for Phase 2 of the project. However, to improve the potential lice protecting effect of the snorkel (see Oppedal et al., 2017), it was decided to use a 12 meter net roof depth for phase 2 but keeping the net roof shape the same as for M10

With regard to the horizontal placement of the snorkel collar ring, the two iFarm cages at Martnesvika both have the snorkel placed 5 meters off centre in each of the cages and a separate work platform is used to allow people to move from the outer cage collar to the inner snorkel collar. Both in terms of boat-crane access and staff access to the iFarm collar, this has not been ideal. Based on this, the project decided that the snorkel will be placed 10 meters off centre within the outer collar of the 160 m circumference net in Phase 2. This will improve crane access and also allow the separate working platform to be replaced with a working platform that is integrated with the iFarm collar.

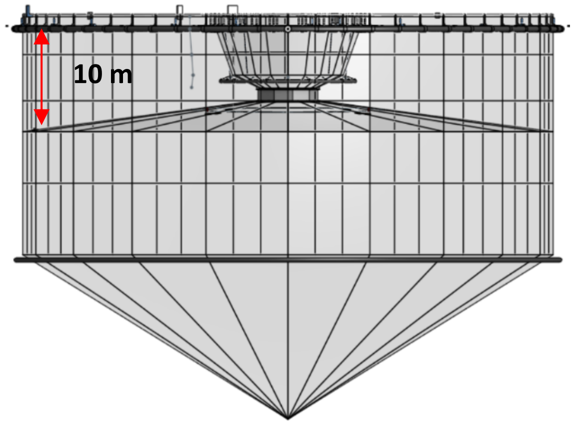
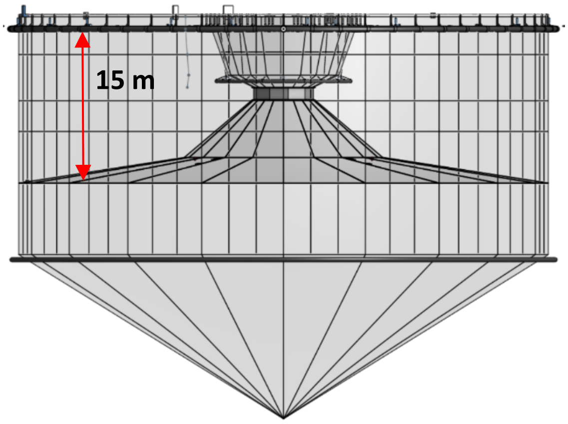
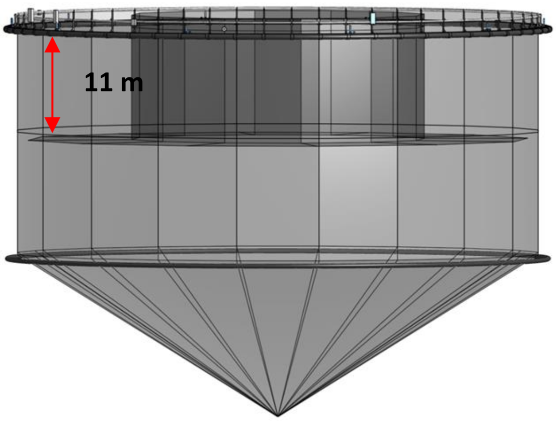
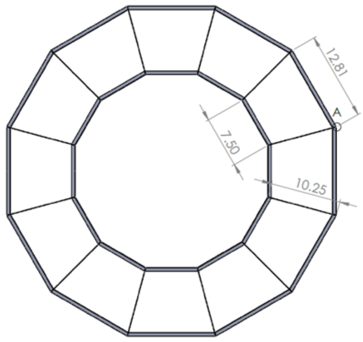
	
iFarm 1 with the roof net starting at 10 m deep	*iFarm 2 with the roof net starting at 15 m deep*
	
Associate cage with roof net starting at 11 m deep	*Overview of the snorkel dimensions for the associate cage*

Figure 3 Technical specifications and information for each of the iFarm and associate cages utilised in Phase 1 of the iFarm project at the Cermaq Norway AS facility, Martnesvika.

iFarm sensor

With regard to testing the geometry of the iFarm sensor, two different iFarm sensor units were tested at Martnesvika, the Dome (iFarm 1) and the Saddle housing configurations (iFarm 2). These two houses differ both in their shape and number of openings. It is too early to reach a final conclusion on the effects of these differing designs upon fish traffic and surface activity from the data we have so far in the midway report, so we will continue to explore different geometrical designs and the number of sensor house openings for the remainder of Phase 1 and also in Phase 2. The net roof and snorkel are both sewn into the docking station, which is very labour-intensive both at initial installation and also during net change operations. Due to this, Phase 2 will utilize a less labour-intensive method than sewing to connect the net to the docking stations.

The full sensor arrangement that is included in the Dome housing (iFarm 1), utilises 11 high resolution cameras as well as 10 illumination units. The valuable experiences gained during Phase 1 with regard to camera settings, illumination type, the depth of sensor as well as the camera arrangement and tests of the next iteration sensor will be done in Phase 2.

Regular operational routines, such as manual lice counting, manual fish health monitoring and net cleaning operations are currently working well in each of the iFarm cages. However, bringing the iFarm docking and sensor housing to the surface for cleaning has proven difficult and potential solutions will be explored further in the remainder of Phase 1 and also Phase 2.

CERMAQ

Fish health and Welfare

Fish health monitoring

The purpose of Cermaq Norway's fish health monitoring plan is to ensure good fish health in our aquaculture facilities. This plan has been applied throughout Phase 1 for the associate cage and the corresponding iFarm systems. With close monitoring, one wants to detect possible situations that may reduce fish health and/or welfare at an early stage. Compared to regular farming cages, the fish in the iFarm system have reduced/smaller openings to the surface. The purpose of fish health monitoring is therefore to assess the extent to which this affects the fish in the iFarm system.

The health of the fish is monitored in two ways:

1) As a part of daily operations all relevant production parameters are registered daily. This includes environmental parameters, feed consumption, mortality, growth (and sea lice weekly). There is also daily camera surveillance and recording of fish behaviour at multiple depths within the systems (iFarm 1, M10 and iFarm 2, M11)
2) The fish health situation at the facility are followed up with monthly fish health visits by authorized fish health personnel.

Health and Mortality

Fish health has in general been good in both the associate and iFarm cages. Cumulative mortality during Phase 1 was generally low for both the associate (0.7 %) and iFarm cages (1.4 % and 1.1 % for iFarm 1 and 2, respectively). Even though mortalities were generally higher during late winter/early spring in the iFarm cages compared to the associate cage, mortalities are still low when benchmarked against historical data from all farms in Martnesvika's corresponding farming region (P09) (Grefsrud et al., 2021). For example, during the April-May 2021 period where mortality was greatest in all cages, mortality figures were 75 %, 50 % and 35 % lower than the monthly 2020 average for region P09 in the associate, iFarm 1 and iFarm 2 cages, respectively. When examining the cause specific mortalities in each cage, a high portion of late winter/spring mortalities were driven by ulcers, especially in both iFarm cages. Mortalities attributed to HSMI/CMS also increased during the last month of the Phase 1 reporting period and Piscine orthoreovirus 1 (PRV-1), the causative agent behind HSMI was detected in 6/20 samples on April 22nd 2021. Macroscopic scoring of gill status reported no fish with moderate/severe gill problems in the iFarm cages for the majority of the sampling OWI scoring events.

Gill and heart histopathology

Gills and hearts were histopathologically examined to investigate if the elevated mortalities observed during the late winter/early spring period in the iFarm cages could be related to deviating fish health. Fish in iFarm 1 had a higher gill score than fish from the other two cages, and significantly more so compared the associate cage. The average gill score of iFarm 1 was borderline mild/moderate, and the changes observed can be expected to have mild to moderate effect upon gill function. From the qualitative evaluation, it seems like various particles in the water and zooplankton and non-planktonic stages of sea lice could have contributed to the higher score in iFarm 1. For the histological heart score, the same distribution of score was seen with highest level in the hearts of fish from iFarm 1, followed by iFarm 2 and the associate cage. Observed histological changes in the heart in terms of general heart inflammation/pancarditis appeared typical for HSMI. Overall, as evaluated from the histological evaluation, fish from iFarm 1 appeared to have more histopathological changes than fish from the other two cages. Gill and heart health will be examined further for the rest of the Phase 1 reporting period.

Fish welfare monitoring

The purpose of fish welfare monitoring is to document the welfare of the fish in the iFarm systems (M10 and M11) and the corresponding associate cage (M9). Following on from the health monitoring program outlined above, with the use of detailed and on-hand monitoring of fish welfare, one hopes to detect possible situations that may reduce welfare at an early stage. The welfare monitoring program utilises a suite of OWIs (Operational Welfare Indicators) and LABWIs (Laboratory-based Welfare Indicators) based upon the environment the fish are subjected to (input-based OWIs) or the fish themselves (individual or group level outcome based OWIs and LABWIs).

Environmental Operational Welfare Indicators

Input based environmental Operational Welfare Indicators, OWIs (Dissolved oxygen, DO and water temperature) were also monitored at three depths in both iFarm cages and the associate cage. DO saturations were generally over 80 % for the entire reporting period and did not drop to levels that are sub-optimal in relation to water temperatures the fish were exposed to during the reporting period (Remen et al., 2016). Water temperatures at all depths in all cages dropped from a peak in mid-September 2020 to a low in mid-March 2021. Water temperatures began naturally increasing in late April and early May 2021 at both 3 m and 10 m, but temperature remained somewhat stable at 25 m and a weak rate of increase started around late May at 25 m.

Morphological Operational Welfare Indicators

Morphological OWIs were followed closely throughout Phase 1 using the Cermaq Welfare Scoring scheme for scoring 11 external injuries according to a 0-3 scale. Particular attention was paid to OWIs that are especially applicable to snorkel cages (snout damage, skin damage and fin damage, after Stien et al., 2016a and Oppedal et al., 2019). In general, no major differences were found between the range of OWIs measured in each cage for the duration of the reporting period. In Phase 1, fish in the associate cage generally had more moderate snout damage than the iFarm cages and it was generally the case that no fish had severe snout damage in either of the iFarm or associate cages. Levels of scale loss and fin damage were generally similar between the iFarm and the associate cages. The prevalence of moderate skin haemorrhaging increased in all cages as Phase 1 progressed and 0 – 2 % of fish exhibited severe skin haemorrhaging at the end of the reporting period in both the associate and iFarm cages. We therefore suggest its use as a relevant OWI for adapted snorkel/iFarm cages, especially if it can be indicative of mechanical trauma/abrasion injuries or contact with the rearing unit.

Fish Behaviour

Fish behaviour is a valuable indicator for assessing fish welfare and was closely followed in Phase 1 using a suite of behavioural OWIs and LABWIs (Laboratory-based Welfare Indicators). There was a marked decrease in fish surface activity and fish traffic through the docking station/sensor house unit when the sensors were mounted in the iFarm cages, revealing a reluctance for the fish to utilise the snorkel after the sensor housing was mounted. During the period the sensor houses were mounted in both the iFarm 1 and iFarm 2 cages, jumping activity averaged ca. 0.04 jumps/fish/hour and did not appear to vary markedly for the majority of the reporting period between the iFarm cages or different iterations of iFarm development within each cage. However, some modifications of the dome sensor house in iFarm 1 when it was first mounted increased surface activity to levels similar to that seen in iFarm 2. When the saddle house sensor unit was removed after 12 weeks in iFarm 2, there was an increase in surfacing activity in the 10 days after its removal, up to ca. 0.1 jumps/fish/hour. When comparing surface activity in the iFarm cages to other studies on standard and snorkel cages, surface activity frequencies the iFarm cages are somewhat similar (see Dempster et al., 2008; Dempster et al., 2009; Wright et al., 2018; Oppedal et al., 2019). The number of fish in the snorkel increased from ca. 2 % prior to sensor mounting to 3 – 4 % after sensor mounting in each of the iFarm cages. The drivers for this increase are unclear (especially as fish were fed using underwater feeding systems) and this will be examined further if it persists in later stages on Phase 1. Increased aggregations of fish in the snorkel have also been noted elsewhere (see Kolarevic, Stien et al., 2018). DO saturations in the snorkel did not drop to suboptimal levels. No tilt angle swimming behaviour was observed that could be indicative of buoyancy problems in the fish. Swimming speeds at night and outwith feeding times were generally higher than during feeding in iFarm 2 in the month prior to the mounting of the sensor house. This trend was not apparent in iFarm 1 and may have related to net geometry. The net roof start at 10 m depth in iFarm 1 and 15 m depth in iFarm 2. Fish swimming below the snorkel depth in iFarm 2 had both a steeper net roof and a reduced cage volume at the observation depth than fish iFarm 1 and this may have affected how their swimming dynamics. Swimming speeds were also greater at night for part of the study, and this may have been due to the fish in each of the associate and iFarm cages being subjected to continuous submerged artificial lighting for the entire Phase 1 period (Sievers et al., 2018). Group cohesion below the snorkel were generally lower in the iFarm 1 cage (M10) compared to iFarm 2 (M11) before and after the sensor was mounted, especially at night and during non-feeding periods. Cohesion during feeding was similar for both iFarm cages irrespective of whether the sensor was mounted or not. This trend may again have been related to net geometry - fish swimming below the snorkel in iFarm 2 were swimming in a cage with a steeper net roof and a reduced cage volume at the observation depth than fish iFarm 1 and this may have meant fish schooled more tightly than the other iFarm cage.

Sea lice and Production performance

Sea lice monitoring

Sea lice monitoring in the iFarm systems (M10 and M11), and the associate cage (M9) is an important part for this project. To have good control over the sea lice situation in the cages, lice are counted on at least 20 fish each week by Cermaq personnel with an approved lice counting course. In addition, lice are counted as part of the Cermaq Welfare Scoring Protocol.

After smolt transfer in 2020 there have generally been low sea lice levels in the fjord system. Sea lice infestation levels were generally low throughout Phase 1 for the associate and iFarm cages and required a single Slice intervention for two weeks from 8th November 2020. Lice were observed in the iFarm systems earlier than anticipated in October2020, which is most likely because the lice skirts weren’t installed from the start.

Production performance

Reported production performance is similar between the associate cage and both iFarm cages during the first reporting period. TGC and eFCR values are closely matched at the end of the reporting period for all cages and the condition factor of fish was greater than 1.3 in all cages at the end of the study.

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Collaborators

BioSort

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