Innovation and Technology Report

Update 2021

BC SALMON FARMERS

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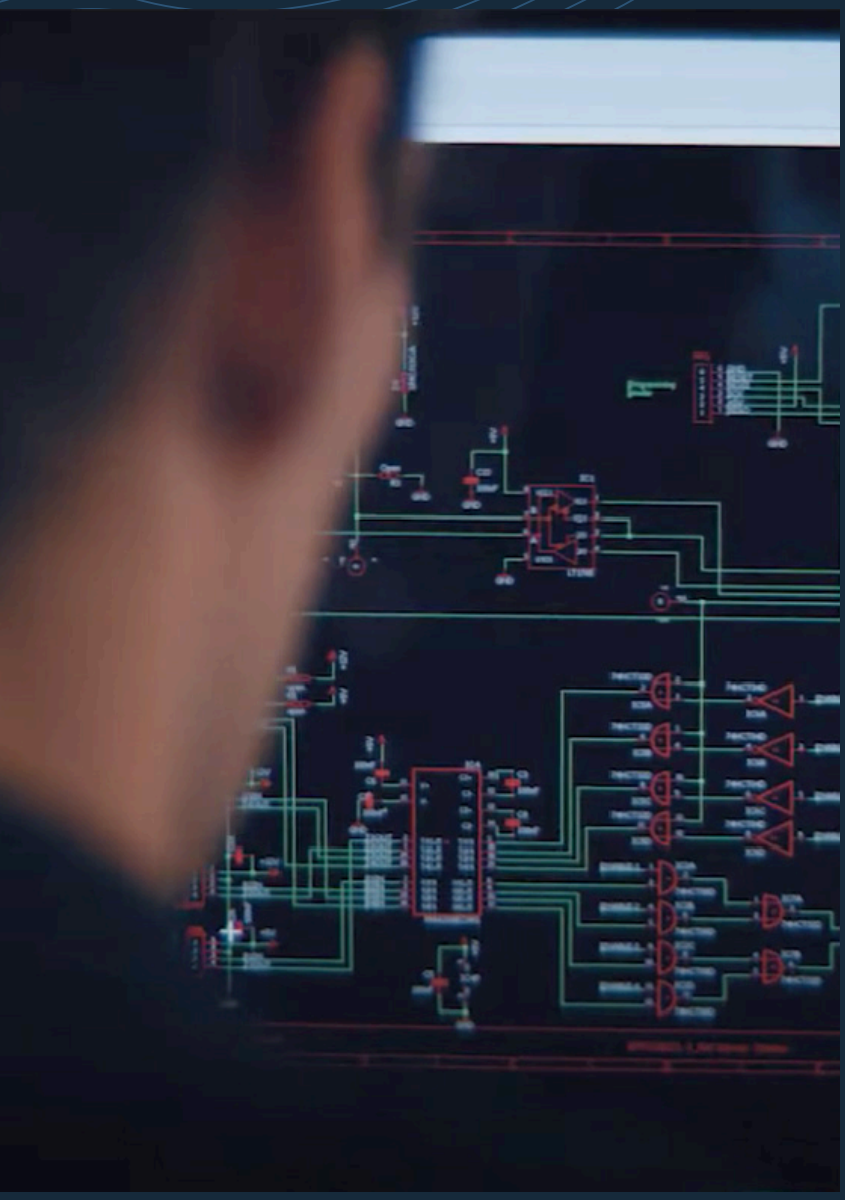


Global Leaders in Innovative Technology

Since its inception in the late 1960s, BC's salmon farming industry has followed an ongoing, orderly transition toward greater environmental stewardship by implementing cutting-edge technologies and innovations.

The BC salmon farming industry's high standard of environmental responsibility has been recognized by multiple independent, global environmental certification systems. Since the first BC Salmon Aquaculture Innovation and Technology Report in 2019, the industry has continued its transition toward technologies and innovations that will reduce environmental impacts even further. These new technologies and innovations are being implemented at the hatchery, grow-out and processing phases of the farm-raised salmon production cycle.

02

Ocean-Based Containment Systems

AS DESCRIBED in the 2019 Technology Report, modern ocean-based farm-raised salmon containment systems are much more than simply floating 'pens' used to restrain the geographic movement of salmon during their later growth and development. Rather, today's containment options are integrated, technologically sophisticated production systems strategically designed, operated and maintained to ensure economic, environmental, and social sustainability.

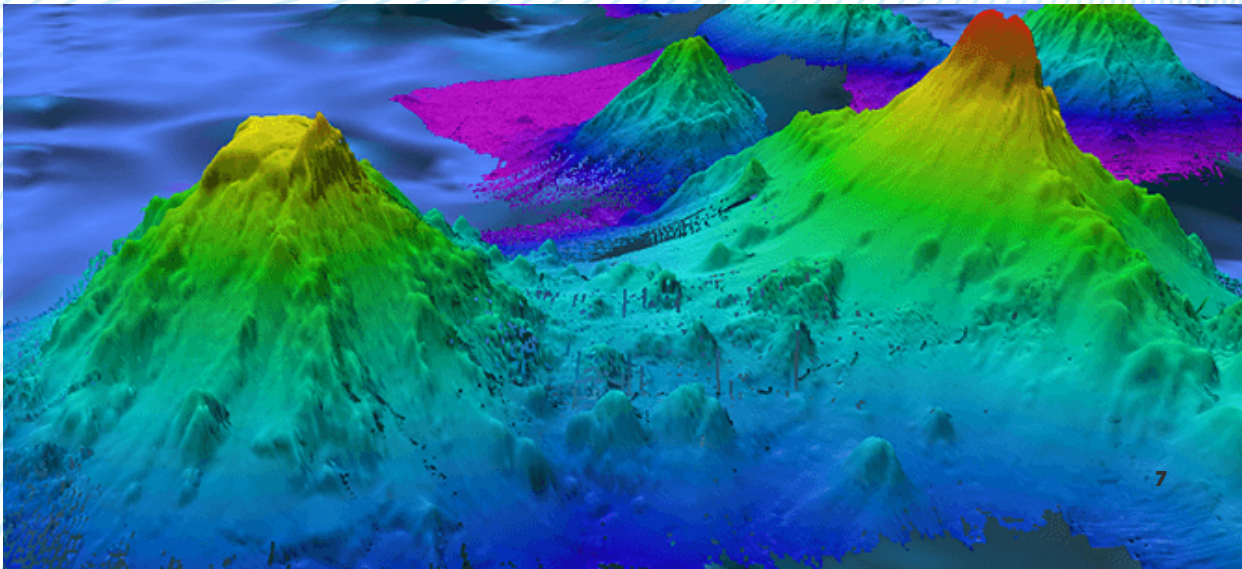
1 Ocean Net Pen Systems

Net pen systems in BC are now being engineered to meet Norwegian Standard 9415 (e.g. Trident Hybrid™ Sea Cage System; Midgard® Cage System). This standard encodes the type of technology (e.g. pens, mooring systems) that can be used at farming sites; the technology used at a specific site must be capable of withstanding the maximum forces the site would experience in a once-in-50-year storm or severe weather event. Since the introduction of NS 9415 in Norway, escapes of farm-raised salmon due to complete farm failures have been eliminated.

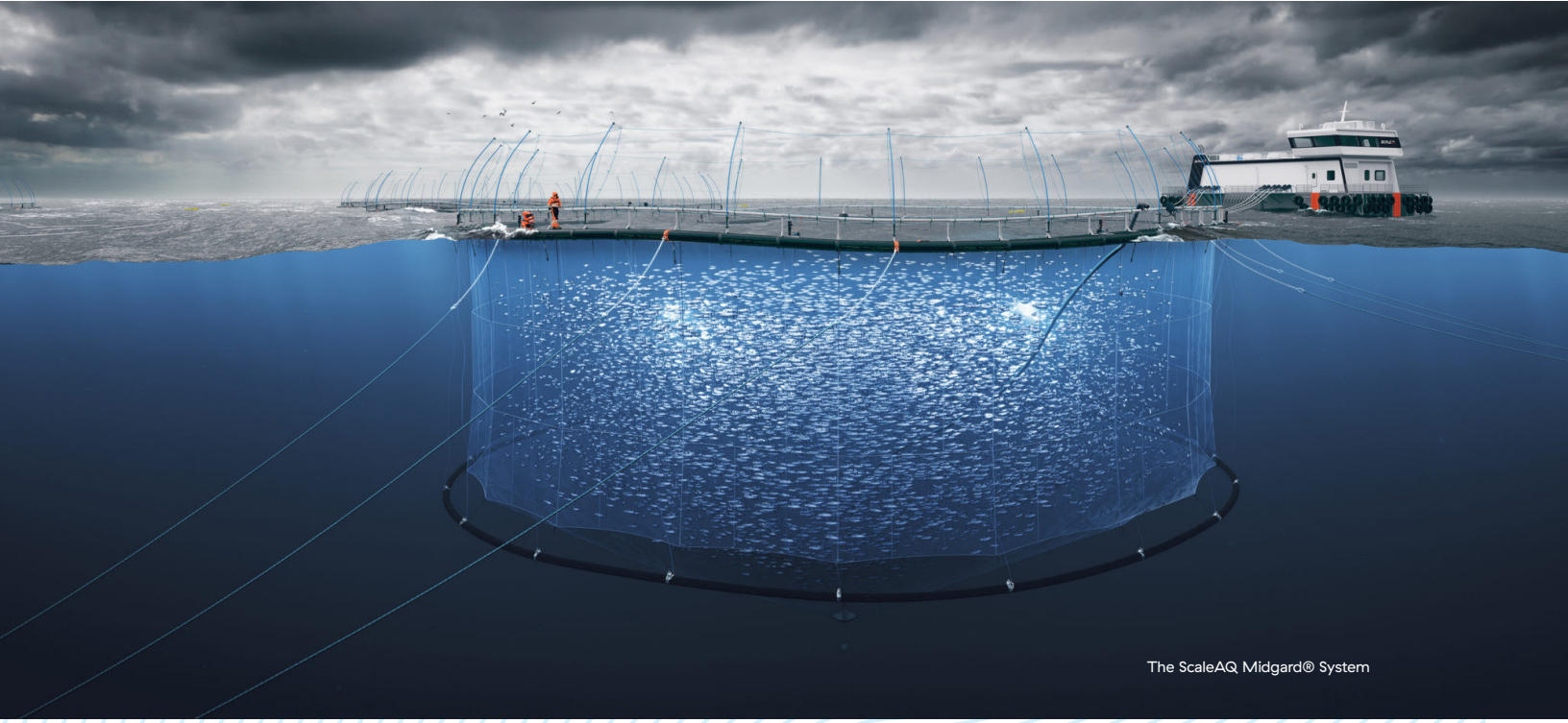
Modern net pens are anchored to the seabed via sophisticated mooring systems designed and modeled by engineering firms to ensure fitment for the conditions of the infrastructure and the site e.g. engineered to dampen the forces generated by site-specific wave motion. The anchors of net pens can now be deployed with pinpoint accuracy through the use of multi-beam sonar technology to create accurate 3-dimensional maps of the sea floor.

2 Innovative Ocean-Based Containment Systems

While the ocean net pen remains the best farm-raised salmon production system, its traditionally low production costs are being challenged by losses due to water-borne insults such as changing water chemistry (dissolved oxygen and temperature), increased risk of loss due to harmful algal blooms, increased costs for sea lice mitigation measures, and other costs related to managing the rearing environment. The industry is therefore designing and trialing innovative new ocean-based systems to reduce the impact of these challenges.



Sea floor mapping. Multibeam bathymetry of the Pao Pao Seamount (right) and an unnamed guyot (left), near American Samoa in the Pacific Ocean, shows one example of nearby seamounts with very different geomorphology. Image credit: NOAA Office of Ocean Exploration and Research, Discovering the Deep: Exploring Remote Pacific MPAs.



The ScaleAQ Midgard® System

The ScaleAQ Midgard® System

Trident Hybrid Sea Cage System

3 Floating Semi-Closed Containment Technologies

The industry is currently trialing floating, semi-closed containment systems. Semi-closed systems provide increased biosecurity and welfare for both farm-raised and wild salmon — and are a first step towards the development of in-water closed containment farming technology.

Semi-closed containment technology separates farm-raised fish from the ocean environment by surrounding the traditional salmon farm netting system with an impermeable barrier that prevents sea lice and harmful plankton from entering the pen. To ensure optimal fish health and welfare, water drawn from significant depth is pumped into the farming enclosure; this deep water is free from juvenile sea lice and harmful plankton. Oxygen can also be added to the water as required via aeration systems (e.g. Poseidon Flowpressor; CPI Aeration Systems) and oxygenation systems using oxygen compressors (e.g. Poseidon Oxygenation Systems) and/or nanobubble generators (e.g. Moleaer Nanobubble Technology).

The benefits of semi-closed systems include:

- Algae and sea lice are generally found in the top layers of the water column. By drawing sea water from depth, these layers of the water column can be avoided — thereby, minimizing the introduction of algae and sea lice into the system.
- Interaction between farm-raised and wild salmon is reduced — which also reduces the potential transfer of pathogens and sea lice between wild and farm-raised populations.
- High tensile strength of the system can easily withstand storm activity and predator attacks.

Several design variations of semi-closed systems are currently being trialed in BC:

- Cermaq Canada is currently trialing a semi-closed system at its Millar Channel site. The Cermaq semi-closed system design has only a single exit for organic waste at the bottom of the bag; this single exit creates the opportunity for the collection of solid fish waste in the future as technology becomes available. Cermaq has been trialing this semi-closed system in Norway since 2017; all groups of fish reared in the system have shown overall better growth, improved animal welfare, and lower mortality than ocean net pen systems — and required no treatments for sea lice.
- In 2020, Grieg Seafood Canada successfully trialed pen-skirting systems at multiple ocean sites to decrease the impact of harmful environmental factors like sea lice and plankton blooms.

Millar Channel Site

Cermaq Semi-Closed Containment (SCCS) technology

03

Feeding Systems

EVEN THOUGH salmon farming produces the least waste of any animal protein producing industry, BC salmon farmers work collaboratively with Fisheries and Oceans Canada (DFO) to minimize the impact that farm-raised salmon waste has on the marine environment (For more, see 2019 Innovation and Technology Report).

Since the 2019 Report, BC salmon farms have continued to implement technologies and innovations to protect the sea floor below salmon pens. For example, farms continue to implement automated feed delivery systems that evenly distribute a set amount of feed throughout the pen at designated times. To avoid feed accumulation on the sea floor due to overfeeding, unconsumed feed pellets are closely monitored via underwater video cameras. Pellet detection software then analyses the video stream to conduct live detection, counting, and marking of pellets — and alerts the feed system operator if too many pellets have fallen past the camera.

In addition to pellet detection, it is becoming increasingly common to use video streams as the basis for monitoring fish feeding behavior (appetite analyses), lice counting, biomass measurement and other analyses based on algorithms and machine learning. As an extension of basic machine-learning models, artificial intelligence (AI) and Deep Learning can be used to integrate feeding information with data provided by sensors that monitor parameters such as dissolved oxygen, water temperature and salinity levels. AI software can then work out an optimal course of action (e.g. how to optimize the feeding process given farm conditions and fish behaviour) with minimal human interference — learning from its past experiences every time.

To gain even greater precision and consistency in feeding, Mowi Canada West has recently completed construction of the Seagate Feed Control Centre in Port Hardy. The Feed Centre allows remote feeding at four farms that are located on exposed ocean sites. Remote feeding will help to keep staff safe while enabling continued feeding during periods of rough weather.

Fish at the four farms will be fed through a wireless point-to-point network with small antennas (30ft) constructed at each farm. The antennas connect to a mountain top antenna near Port Hardy — which then beams signals back down to the Feed Centre. Staff at the Centre can remotely control all the feeding equipment and underwater cameras exactly as though they were at the site.

This centralised Feed Centre will allow Mowi to deliver more precise and consistent feeding practices by utilising dedicated feeding staff who are 100% focused on feed — without the distraction of daily farm tasks or the risks of travelling to sites in dangerous weather.

Previous: The ScaleAQ Vision Software

04

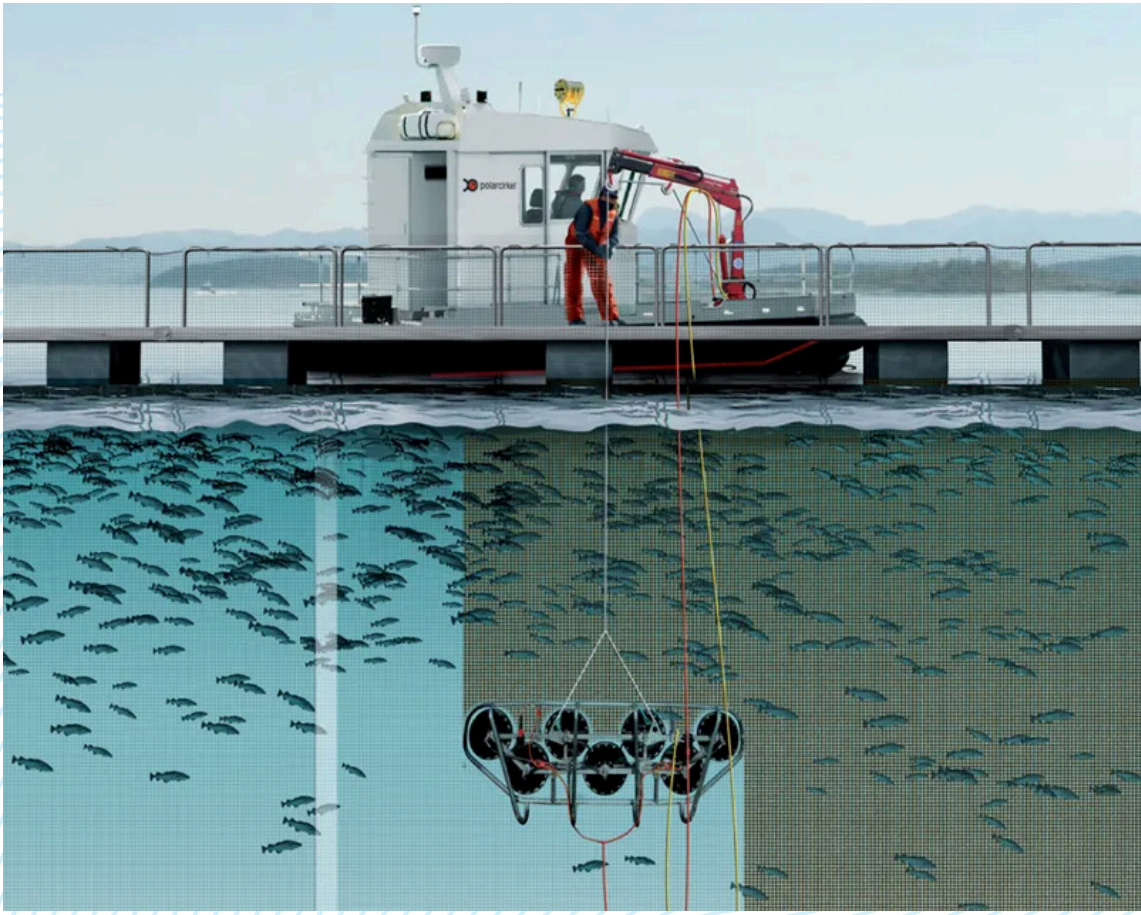
Net Cleaning Solutions

DIVERSE MACRO-ALGAE, bivalves (e.g. mussels and oysters), sea urchins, sponges, and others sessile organisms settle onto nets and farm structures. This 'biofouling" can limit water exchange in the pen, thereby reducing water quality and depleting dissolved oxygen. These conditions can cause a reduction in feed consumption and increase fish stress due to poor water quality.

Technological advances now allow nets to be cleaned on a regular basis, thereby ensuring optimal fish health and welfare. Net cleaning solutions often consist of a net cleaning vessel equipped with remotely operated net cleaners that utilize high pressure seawater to remove fouling organisms. These cleaners can be operated with a mobile pilot console or a pilot chair with integrated control system — and include advanced camera solutions and sensors that offer a graphic visual presentation showing the cleaner's position in 3D and providing full control of its movement within the pen (e.g. AKVA Net Cleaner).

Some BC salmon farms are also deploying fully programmable, automated net cleaning machines (e.g. Trimara Autoboss) in which everything required to run the cleaning head is contained in a floating pontoon — rather than aboard a boat. Once deployed in a pen, these systems are completely autonomous — and are capable of cleaning large areas of net quickly.

AKVA Net Cleaner



05

Sea Lice Prevention Innovations

1 Integrated Pest Management

BC salmon farmers have developed an industry-wide Integrated Pest Management Memorandum of Understanding (MOU). Integrated Pest Management (IPM) is a globally recognized decision-making process to manage pests in an effective, economical, and environmentally sound way. IPM involves the coordinated application and rotation of all available management practices — with monitoring, communication and cooperation between operators within an appropriately defined area. The goal is to effectively manage sea lice numbers in a way that prevents the development of resistant lice populations.

The MOU outlines how all BC salmon farming companies will cooperatively operationalize pest management, particularly during the sensitive juvenile wild salmon out-migration period. It details the degree of monitoring, use of bioassays, rotation of treatments, equipment sharing, and response times. The MOU also addresses steps to expand the range of sea lice tools currently available, including accessing global research and techniques applicable to the BC coast.

2 Post-Smolt Strategies

Traditionally, newly hatched farm-raised salmon have been reared in land-based hatcheries until they reached a weight of 100 - 150g — and then transferred to ocean net pens for the grow-out phase. However, recent research has shown that when juvenile salmon are grown to larger sizes (250g — 1kg) in hatcheries, their growth and survival rates in ocean net pens surpass those of smaller juveniles. BC salmon farmers are therefore developing new land-based recirculating systems that allow them to raise juveniles to larger, more robust sizes before transferring them to ocean-based grow-out systems.

Rearing juveniles on land to larger sizes before transfer to the ocean can reduce the time that farm-raised salmon spend in the marine environment from the current 2 years down to a single year. By using this “hybrid” production strategy, BC salmon farmers are able to reap the clear benefits of ocean-based grow-out, yet significantly lower the length of time that the salmon spend in the ocean, effectively reducing production and environmental challenges related to sea lice infestation and potential interactions with wild salmon stocks.

3 Wild and Farm-Raised Salmon Sea Lice Data Base

In parallel with its commitment to effective sea lice management, BC salmon farmers are committed to understanding the dynamics of sea lice loads in both wild and farm-raised salmon. To this end, they have monitored sea lice on juvenile wild salmon through a variety of partnerships with First Nations, DFO, academic researchers, and ENGOs in their areas of operation. Many of the monitoring datasets are long term, stretching from 2005 to present day.

BC salmon farmers have now created a repository for this extensive BC sea lice data set, which will include data from both industry operations and wild salmon sampling. Ongoing analysis of this data will expand the knowledge of the impact of sea lice on wild and farm-raised salmon, thereby informing future management and mitigation strategies. Data in the repository will:

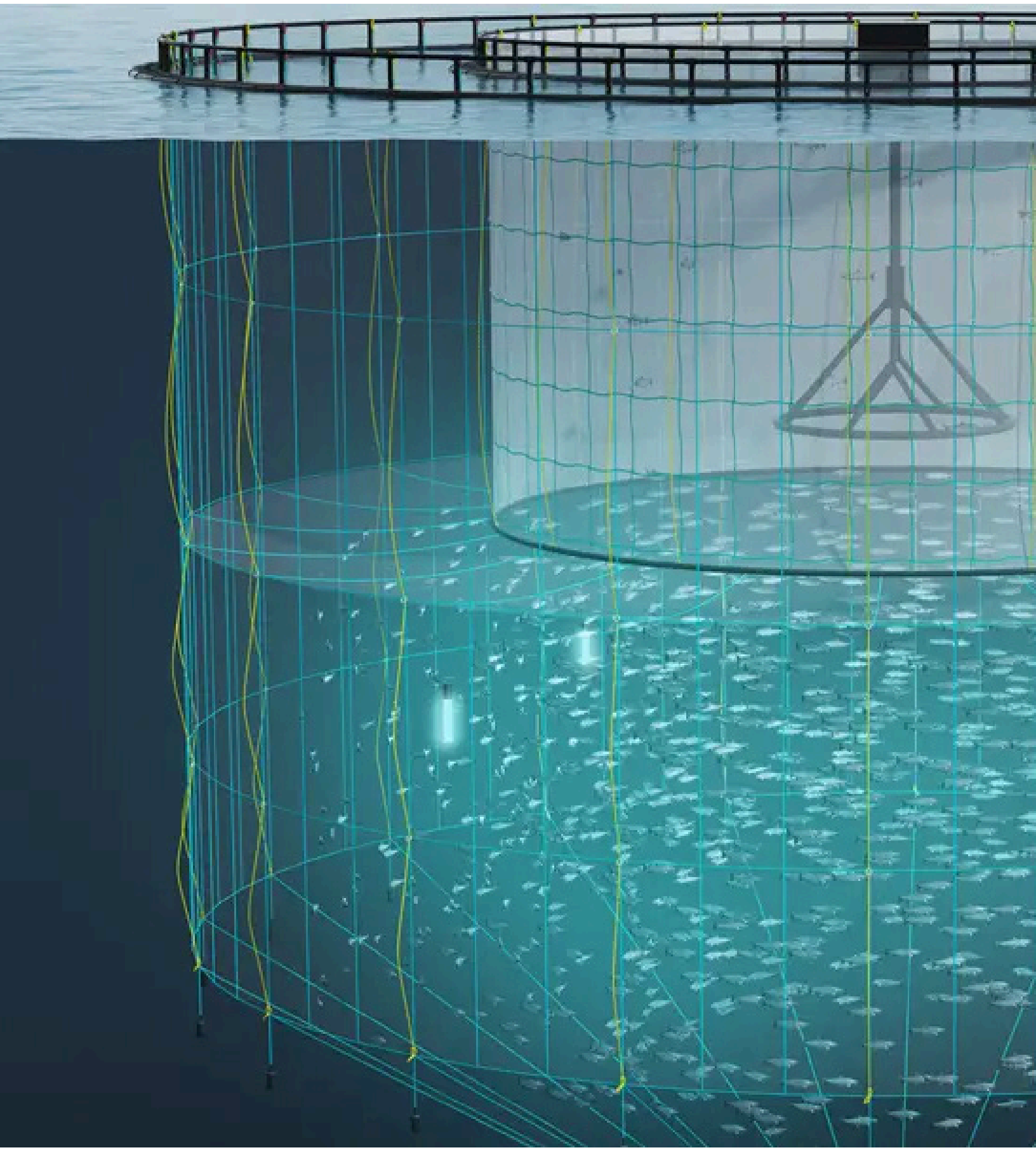
- Be available to all collaborating researchers seeking sea lice data for their studies
- Inform area-based management planning
- Inform government/Indigenous partners on long-term trends
- Inform Integrated Pest Management scenarios by region (e.g. provide trend information to industry to help guide treatment strategies)
- Inform communications to the general public on sea lice management

4 Sub Sea Net Systems

Sub sea systems (e.g. Akva Tubenet™) reduce sea lice infestation on farm-raised salmon by submerging the fish to depths where lice presence is minimal. A tube positioned in the centre of the net creates a sea lice-free zone through which the salmon can access the surface of the water.

5 Sub Sea Feeding Systems

Sub sea feeding systems (e.g. AKVA Subsea Feeder) feed the fish at depths where lice presence is minimal, thereby decreasing fish exposure to sea lice.



AKVA Tubenet™

06

Sea Lice Treatment Innovations

BC SALMON FARMERS recognize that overuse of chemotherapeutant treatments may increase sea lice resistance to the treatment. They are therefore developing a full suite of alternative, non-chemotherapeutic treatment options. The use of alternative options is reducing the frequency of chemotherapeutant treatments. Alternative treatments implemented since 2019 include:

1 Wellboat Technology

Since the release of the 2019 Aquaculture and Innovation Report, Mowi Canada West launched the $35 million Aqua Tromoy — a vessel equipped with a state-of-the art non-chemotherapeutant sea lice treatment system. For treatment, fish are lifted from farm pens and immersed in freshwater baths in the vessel's holds. While Atlantic salmon are not harmed by freshwater immersion, freshwater causes sea lice and other saltwater parasites to fall off the fish; the lice are subsequently captured by the vessel's filtration system.

2 Hydrolicers

In 2019, Cermaq Canada deployed its first Hydrolicer — a custom built barge capable of effectively treating an entire farm for sea lice in two or three days using only pressurized ocean water (i.e. no use of chemicals or medications). The barge works by bringing fish onboard through four gentle intake tubes where the fish are then moved through two chambers of opposing water pressure — the first loosens and the second removes the lice and eggs. The ocean water is then triple filtered to capture lice, eggs or other biological materials removed during the treatment. The filtered water is then released back into the ocean — while the collected lice, eggs and other materials are stored for disposal on land.

Previous: 'The Salar,' Cermaq Canada Hydrolicer

3 Sea Farm Innovations Systems

Similar to the Hydrolicer, Cermaq Canada's new Sea Farm Innovations (SFI) System uses only a directional spray of pressurized, ambient-temperature ocean water to remove sea lice and eggs — with no need for chemicals or medications. Fish are brought into the SFI System through the intake pump, where they then travel to the gravity controlled flushing chamber. Once in the chamber, a patented flushing technology loosens, then removes, sea lice from the fish. The fish are then returned to a new pen — and the water used during the process is filtered, allowing the removed lice, eggs and other materials to be collected for disposal on land. The SFI system is small enough to be mounted on a vessel for easy transport between farms.

4 Skamik 1.5 Delouser

Grieg Seafood BC's new Skamik 1.5 treatment unit is set to arrive in late 2021. The Skamik 1.5 treatment unit uses low-pressure water nozzles to remove sea lice from the fish. The Skamik 1.5 is engineered to meet stringent fish welfare standards. The treatment process lasts only 1.5 seconds — with each fish returned to its net pen within 15 seconds. All the water used as part of the treatment-process is separated and goes through a double-filtering system to ensure 100% of the lice removed from the treated fish is captured before the water is returned into the ocean.

Cermaq Canada's Sea Farm Innovations (SFI)

SkaMik 1.5 Delouser

07

Fish Health

1 Advanced Environmental Monitoring

BC salmon farmers are launching innovative ocean analytics and data management platforms (e.g. SeaState Dashboard) that will provide real-time data on ocean environmental conditions. The platforms combine a complex system of marine data visualization tools layered with numerical ocean models and statistical analysis of local waterways to provide historical, current, and future-focused models of performance; the models allow farm managers to monitor current conditions, revisit past weather or mortality events, and plan for weather-related or environmental events that may take place in the future.

The platforms unify existing sensor networks on farms to collect information and provide a clear window into how salmon farms react to changing ocean conditions using both in-pen data and publicly available data. The platforms will allow improved prediction of ocean trends, thereby providing BC salmon farms with the opportunity to reduce their exposure to marine risks, such as harmful plankton blooms and sea lice outbreaks, as well as improve fish welfare and efficiency.

Some of the data collected will also be accessible to Indigenous groups, universities, scientists and eNGOs to support the study of ocean trends and understand the interaction between ecological systems (like wild salmon) and the changing ocean environment.

2 Individual-Based Salmon Farming

Until very recently, BC salmon farmers have lacked the technology to monitor the health status of individual fish within a pen. As a result, health treatments (e.g. sea lice treatments) have been administered to all the fish in a pen — rather than only those fish requiring treatment. However, Cermaq is currently developing the iFarm system that will use artificial intelligence and machine learning to identify each fish in a net pen, thereby allowing individualized health records to be kept for each fish — and for targeted health interventions, if required.

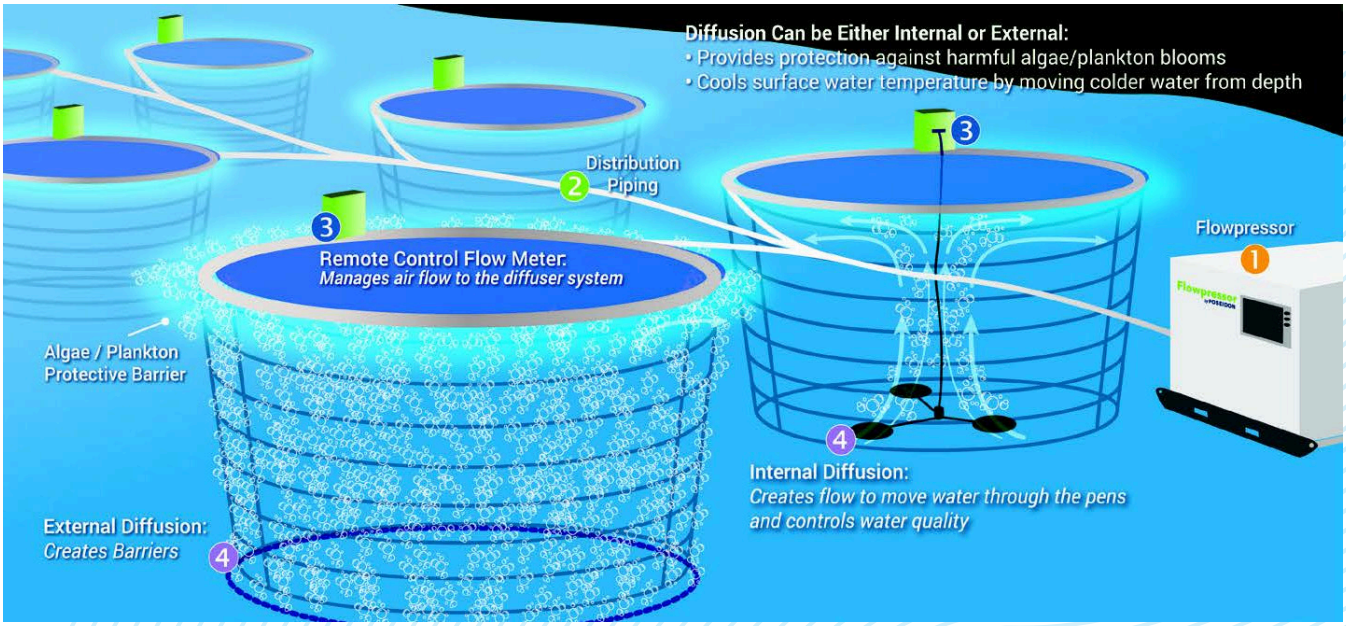
iFarm utilizes sensor chambers with computer vision that recognize each individual fish based on the pattern of dots on the fish's body. In the sensor chamber, fish size, number of sea lice, and possible signs of the disease can be registered. Individual fish requiring treatment can then be diverted to a treatment facility — without stressing the remaining fish.

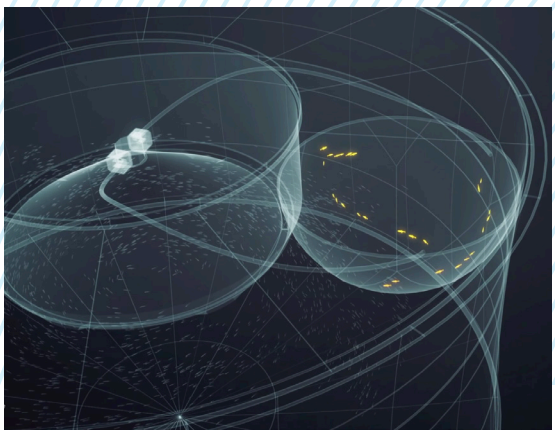
3 Algal Bloom Remediation

Algal blooms are caused by the proliferation of free-floating microscopic algae known as phytoplankton. A densely concentrated algal bloom can deplete dissolved oxygen (DO) in the water due to the high respiration rate of the algae — or by bacterial respiration when the algae begin to decay. Some algae also cause damage to the gills of fish, interfering with their ability to take in oxygen. If DO levels drop too low — or if gill damage is excessive — fish die-offs can occur.

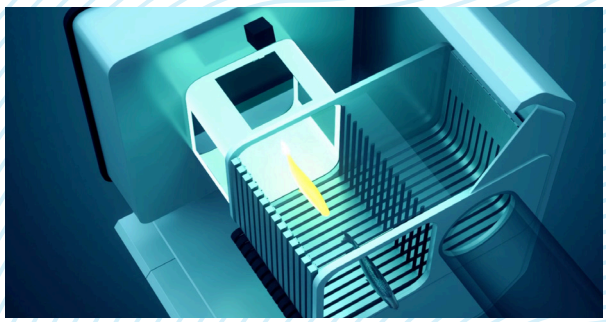
During an algal bloom, BC salmon farms now position aeration and oxygenation systems within pens to ensure that DO is maintained at optimal levels. Additionally, aeration diffusers can be positioned around the perimeter of the pen to create a 'bubble curtain' that prevents algae from entering the pen. The bubbles also create an outward flow at the surface—which helps to push plankton away from the containment system.

Poseidon Flowpressor Aeration & Life Support System





Cermaq iFarm



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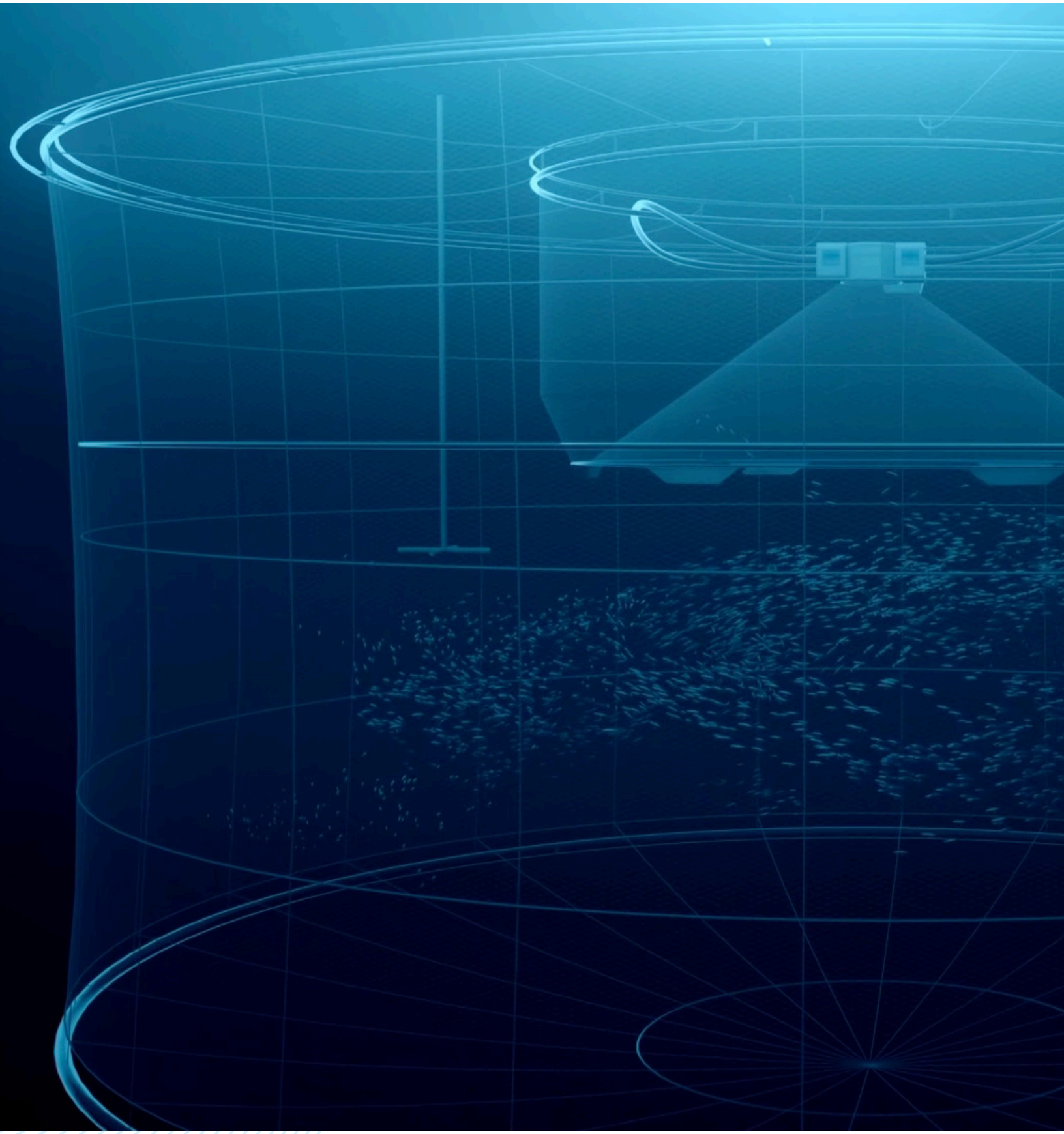

Cermaq iFarm

08

Processing Wastewater

BC farm-raised salmon processing facilities are now equipped with innovative wastewater treatment technologies—including UV and chlorine treatment—that support the health of the marine environment and minimize the potential of disease transfer to wild fish stocks. To further ensure that its discharged wastewater will have no negative impacts on the marine environment, Brown's Bay Packing Company has installed a fluidized bed reactor that allows removal of 80-90% of the organics from processing wastewater.

09

Clean Energy Adoption

1 Solar Power

In 2019, Mowi Canada West installed an emissions-free solar power system at its Dalrymple Salmon Hatchery. The system is helping Mowi to reach its sustainability target to reduce emissions by 35% by 2030: in its first year, the system generated over 205,000 kWh of solar energy, thereby offsetting GHG emissions equivalent to 4.1mT of CO2.

2 Green Boats

Aquaculture boat suppliers now offer hybrid and electric boats suitable for use on BC salmon farms. These boats will support the commitment of BC salmon farmers to significantly reduce climate emissions. In addition, the boats will provide better working conditions for crews by greatly reducing noise and vibrations.

3 Wave Energy Conversion

Grieg Seafood BC is partnering with Accumulated Ocean Energy Inc. (AOE) to investigate whether the energy of ocean waves can be used to provide power to its semi-closed containment systems. AOE has developed a pneumatic Wave Energy Converter (pWEC) that functions similar to a bicycle pump being driven by the movement of ocean waves, capturing the energy of the waves and converting it to potential energy in the form of highly compressed air. A series of pWECs can be linked via an array of buoys to add greater compression down the line. The compressed air can then be transported by pipeline or hoses to onshore reservoirs for storage and later used to produce electricity or provide aeration within containment systems. Compressed air poses no danger either in or out of the ocean environment, is easily transportable, and can be stored indefinitely.

Moen MarinNabCat 1512 Electric

Elida', E-boat equipped with Evoy technology

Previous: Moen Marin NabWork 1250 Electric

Read the 2019 Technology and Innovation Report here.

Have a question or want to connect about our report? Contact john@bcsalmonfarmers.ca

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