

Algal Bloom Management Plan

Water quality is essential for healthy fish and the environment. With climate change and a new horizon of challenges in our oceans, it is essential that exposure to marine risks, such as harmful plankton blooms, is reduced to improve fish welfare and efficiency.

To face these challenges, Grieg Seafood BC Ltd. (Grieg) has developed a detailed algal bloom management strategy. This strategy includes real-time monitoring and forecasting to ensure the implementation of prevention and mitigation strategies.

Note: Relocating sites to locations outside of blooming areas is not an option in BC.

MONITORING & FORECASTING

Data Collection

During low plankton season (November 1 to April 1) site staff complete twice daily plankton tows from a depth of 25m to the surface from a location representative of the site's water quality. During high plankton season (April 1 to November 1), the site staff collect and examine discrete water samples from 1m, 5m, 10m, 15m, 20m, and 25m for the presence of harmful plankton. Also, during the high plankton season, at least three times per week staff must examine water samples from 1m, 5m, 10m and 15m depths for the presence of harmful plankton in designated seed areas. Seed areas are locations outside the site where blooms have historically been known to originate.

Staff also collect data measuring dissolved oxygen (% saturation and mg/L), temperature, and salinity at 1m, 5m, 10m, 15m, 20m, and 25m depths using handheld probes multiple times a day. There are also wireless environmental probes inside and outside the pens that continuously collect environmental data that upload directly into SeaState.

All water and plankton samples are recorded or examined, and the results entered manually to SeaState immediately after sampling. Samples are analyzed using a microscope by staff trained in plankton identification with detailed standard operating procedures and harmful plankton identification guides available. The microscopes are also connected remotely to the Environmental Monitoring Department for real time support, as required.

SeaState Dashboard

Grieg BC has worked with Scoot Science¹ to develop a "SeaState" Dashboard; an all-in-one digital interface that collects and displays information about the past and present environmental conditions at each of our farms². Every day over one million data points are collected at Grieg farms, creating one of the largest oceanic datasets in British Columbia. Our farms use this page to monitor the oxygen, temperature, salinity, and plankton levels at their site.

¹ <https://www.scootscience.com/>

² <https://griegseafood.com/news/grieg-seafood-partners-with-california-start-up-to-analyze-ocean-data.-reduce-environmental-impact>

The “SeaState” platform includes one of the worlds first ocean forecasting systems, which uses predictive modelling to forecast the environmental conditions up to three days in advance with extreme accuracy. All site staff diligently monitor the environmental sensor data displayed in SeaState for their site every day. They utilize the forecast tool to initiate preventative mitigation strategies to help manage events such as harmful algal blooms or low oxygen events.

Our SeaState dashboard has specifically tailored with company-specific thresholds for algal species and oxygen levels. If any thresholds are crossed, both the farm staff and supporting departments will receive an email, a notification banner (Figure 1), an audible alarm from their computer, and text alerts. This instantaneous alerts function allows for us to respond to potential environmental risks as soon as possible.

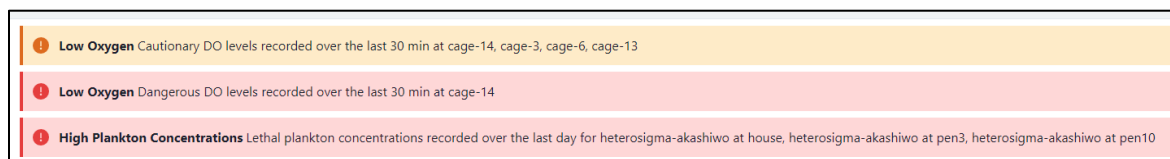


Figure 1 – Example of alert banners sent by the SeaState dashboard to site staff.

RESPONSE & MITIGATION

When plankton classified as harmful, toxic to farmed fish, are identified by the staff they follow detailed procedures associated with the mitigation response. Dependent on the count of the harmful plankton species in cells/ml, the water is classified as being at a safe, cautionary or harmful level. An example of the categorization of one of the 19 categories of species that we monitor is shown in Figure 2.

Harmful plankton	Safe (cells/mL):	Cautionary (cells/mL):	Danger (cells/mL)
<i>Alexandrium</i> species ***	< 300	300 – 1,000	> 1,000

Figure 2 - Example of the guidance table for site staff to evaluate the risk and mitigation strategy for *Alexandrium* species counts.

Dependent on the classification of the level of the results from the farm or seed site sampling, staff will notify the Environmental Monitoring Department and take one or more of the following steps:

- Initiate the Plankton Mitigation System, according to Grieg’s aeration system guidelines
- Monitor fish behavior
- Pause or stop feeding
- Increase Environmental Monitoring and Plankton Monitoring to 3 times a day

Plankton Mitigation System

Grieg utilizes deep-water upwelling via pressurized aeration systems to displace plankton away from all the farms (Figure 3). Plankton is generally found in the top layers of the water column. By pumping deeper water into the pens, it reduces plankton counts within the pens. This method also helps to stabilize oxygen and temperatures for fish.



Figure 3 - Deepwater upwelling in action. Plumes of bubbles within the pen draw water from depth to the surface.

Barriers

To reduce the risk of algae bloom's impact on farmed salmon, Grieg is currently trialing floating, semi-closed containment systems, at which are the first of their kind in BC. Semi-closed technology uses impermeable barriers between the farm-raised fish and the surrounding ocean to prevent harmful plankton from entering sea pens. Deep water is pumped into the farmed enclosure, bringing cooler, higher oxygenated water to the farmed fish. If needed, additional oxygen can be added via aeration systems during low oxygen events. (Figure 4).

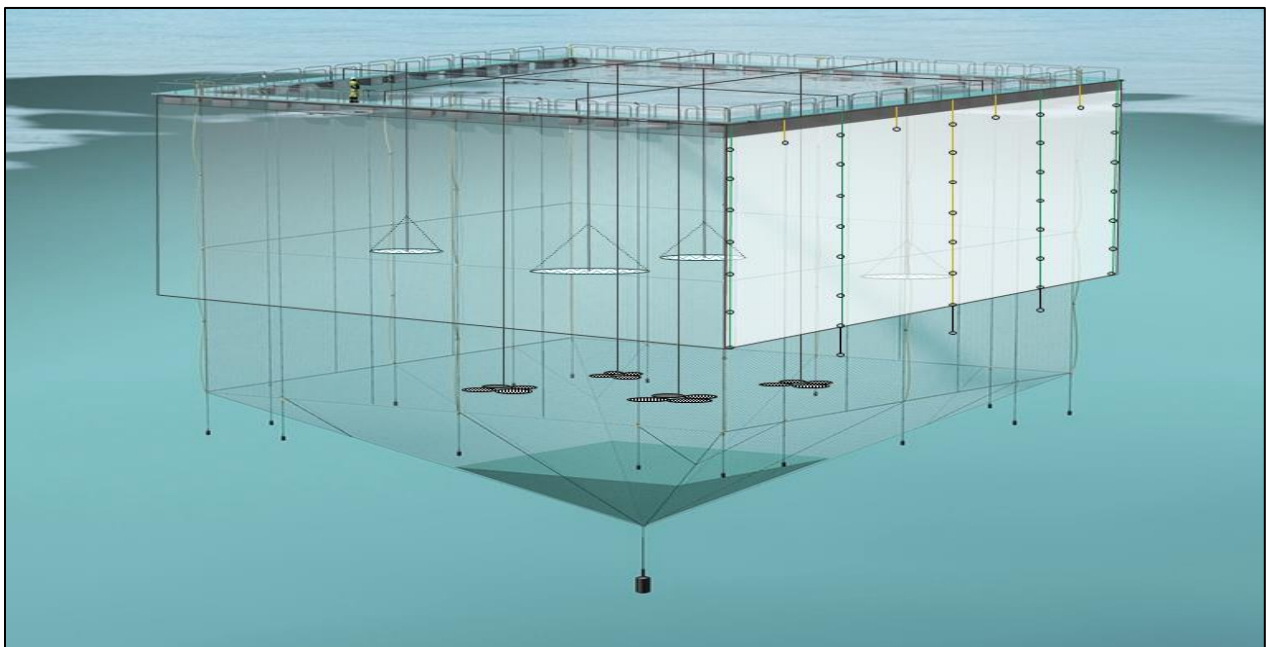


Figure 4 - Schematic of semi-closed containment system.