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Icing Challenges In Northern Norway's Aquaculture: Insights From Field Data Collection And Analysis

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The aquaculture industry in Norway plays a vital role in the global seafood supply (Johansen et al., 2019). Especially in the northern part of the country, the industry has seen a steady expansion due to the favorable fish growing conditions and increasing seafood demand (Espinasse et al., 2023). These aquaculture facilities, featuring floating cages moored to the seafloor, offer a controlled environment nurturing fish growth. However, despite the advantageous ecological conditions for fish cultivation, the region faces challenges from harsh climates, including strong winds, waves, and freezing temperatures, all of which contribute to the risk of ice accumulation on fish cages due to sea spray ice accretion (Jensen et al., 2014); see Figure 1.

Sea spray icing occurs when sea spray, produced by waves or wind, comes into contact with the exposed surfaces of fish cages, particularly when the air temperature is below freezing (Dhar et al., 2022). As the spray freezes upon contact, it gradually accumulates into layers of ice on these surfaces. Over time, as this freezing process persists, the additional weight of the ice layer can impose considerable stress on the structure, potentially causing it to rupture and collapse under the increased load, resulting in huge environmental and economic consequences.

Fig. 1. Damage to fish farm cages caused by ice accretion in Northern Norway (Picture: Alexander Boiko).

Therefore, an accurate icing forecast for the fish farms can be highly beneficial for operators as they can proactively plan their operations and implement risk-reducing measures. The existing marine icing forecast models, such as MINCOG (Samuelsen, 2017) used by the Norwegian Meteorological Institute (MET), are primarily tailored for ships developed from empirical data from specific ship types and may not accurately predict ice accretion on fish farms (Dhar et al., 2023a). Considering the distinct spray generation and icing mechanisms affecting fish cages, along with the unique environmental conditions and intricate wind flow patterns in Northern Norway, there arises a need to develop or adapt existing marine icing models to incorporate these factors.

In order to address this issue, under the SPRICE project, sea spray measurements and met-ocean data are being gathered from fish farm cages in Skjærvika (68.73° N, 17.23° E) in Astafjorden, Northern Norway (Figure 2), situated above the Arctic Circle. While a weather station on a stable feed barge records wind and meteorological parameters, in particular, wind speed (Figure 2a), special instruments are designed and deployed to collect spray flux data, consisting of a SPRICE Sea spray collector (Figure 2b) and a SPRICE Sea spray sensor (Figure 2c). Additionally, a wave buoy positioned adjacent to the fish farm location collects significant wave height and wave period (Figure 2d).

Accurately determining the quantity of liquid water available for freezing on a structure is crucial for developing an effective icing estimation model, as it directly influences the amount of ice formation. Hence, the SPRICE Sea spray collector (Dhar et al., 2023b), inspired by the cyclone separator design, is specifically engineered to measure the real-time spray amount arriving at the fish-cage structure. Additionally, the SPRICE Sea spray sensor, equipped with capacitive sensors, measures the change in dielectric constant, which is proportional to the amount of sea spray coming into contact. The device operates autonomously, collecting data at a frequency of 5 Hz in three different heights and directions, which can be further analyzed to model two critical parameters of spray flux, namely, spray duration and frequency, with respect to wind speed, significant wave height, and wave period. Compared to past methods for collecting spray data, which could provide a limited dataset, these instruments' fast data capture rate ensures an accurate representation of the spray dynamics. Also, they offer the advantage of collecting comprehensive data that can be analyzed by employing advanced statistical methods and AI tools to further develop a spray flux model explicitly for fish farm cage structures. The model can be incorporated into marine icing estimation models to generate predictions that can support the informed operation and maintenance of fish farms and ensure their safety.

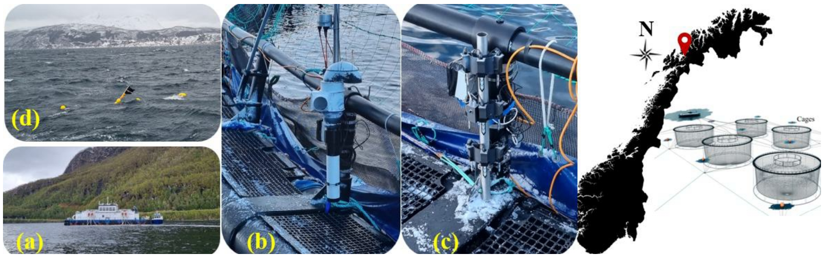

Fig. 2. Instruments deployed: (a) Wind and meteorological parameters measuring instruments deployed on top of the feed barge; (b) SPRICE spray collector; (c) SPRICE spray sensor; (d) OBS-Buoy400 Wave Buoy.

The aim of the present work is to share and discuss insights from field data collection and present a preliminary analysis of the collected data while highlighting several relevant methodological challenges when analyzing the field data, including the inherent stochasticity of the involved meteorological phenomenon, disparate temporal resolution of the collected data (from milli-second to 30-minute intervals), imbalanced datasets containing less number of rare events (i.e., high spray frequencies and long spray durations) that are of interest from a risk analysis perspective. The field data, collected since March 7, 2023, are stored in the MET Norway repository and will be made publicly available. This project ultimately aims to improve the safety and efficiency of Northern Norway's aquaculture industry by enhancing the prediction of the icing phenomenon. The design can be adapted, in general, for vessels and stationary offshore structures such as platforms.

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