Report on Dialogue Session # 2 February 19, 2024

Joint OFI-SINTEF Canada-Norway Dialogues on Marine Aquaculture Hazards and Risk Assessment

Charlie Mather from Geography at Memorial University moderated Dialogue Session #2. He opened by welcoming everyone, reading Memorial's land acknowledgement and introducing the presenters, Trine Thorvaldsen, Senior Research Scientist from SINTEF and Gerald Singh, formerly with OFI at Memorial but now at the University of Victoria. Charlie also introduced the discussant, Heather Burke from Memorial's Marine Institute, and stakeholder Michael Szemerda, Global Chief Sustainability Officer, Cooke Canada and thanked them for their engagement with the Dialogue. The presentations and discussant comments were recorded and the recording is available here: https://youtu.be/XK7w6-oJnf0

Notes were taken during the stakeholder comments and Q and A. The remainder of this report summarizes key points raised throughout Dialogue #2.

Trine Thorvaldsen has been working on risk in aquaculture for several years. Her presentation examined emergency preparedness in Norwegian salmon farming. She opened with a high-level overview of the Norwegian salmon farming indicating the industry employees about 7,000 workers on the farm operations plus 2,000 in hatcheries and many others employed on vessels that support the farms. The industry is export-oriented, market demand is very high and, she noted, there is a political ambition to increase production. Expansion requires the industry to confront some key challenges including salmon lice and fish escapes. Historically, prevention of escapes has been a major driver of technological development in the Norwegian industry. Norway's 2004 Technical Standard helped to improve fish farm technology and Norway has developed a traffic light system related to salmon lice reporting and management.

A recently completed SINTEF project examined the development licenses introduced by government in 2015 to boost innovation in the industry. There were 104 applications. Large offshore structures such as semi-submersible platforms and other strong, rigid structures with permeable enclosures (nets) have been particularly successful in this application process, receiving relatively many development licenses. In sheltered fjord areas, many concepts involving closed enclosures (bags and tanks) have been suggested and awarded licenses. In a recent paper, they compare the technological innovations noting that in addition to preventing escapes, the new technologies are designed to support using new areas in fjords that are more exposed to wind, waves and currents, as well as offshore.

Her presentation today looks at two topics: emergency preparedness and offshore aquaculture. The current regulations they found are designed for current areas and, they argue, offshore production will require a more proactive approach to emergency preparedness given increased distance to shore, more fish per pen and staffing changes at more remote operations, automation and logistics will be more demanding. Their research looked at the state of emergency preparedness today and the risk picture for coastal versus offshore production sites to identify the improvements needed for offshore areas. She worked with several colleagues who looked at emergency preparedness in other sectors and also conducted interviews, hosted workshops, held webinars and dialogue meetings with the authorities between 2020 and 2022. Their approach used the same risk dimensions outlined by Ingunn Holmen in Dialogue #1 including (the same approach as outlined by Ingunn Holmen in Dialogue #1) workers' OHS, the external environment, material assets, food safety and fish welfare dimensions.

What is emergency preparedness?

Risk assessments are needed to identify risks and actions designed to reduce those risks but it is not possible to eliminate all of the risks. It is the residue risk that emergency preparedness is designed to handle. In Norway, as outlined by Ingunn, the safety and risk management framework covers seven regulatory areas. In the case of grow out areas, all companies have to perform risk assessments, these are mandatory and discussed in one of their publications. The regulatory requirements for emergency preparedness relate to personnel, infectious fish diseases, mass die-offs, Harmful Algae Blooms (HABS), harmful habitat conditions, acute pollution as in the case of jellyfish which have been an important problem for Norwegian fish farmers. A second publication summarizes findings from a second parallel project where they looked at the many actors involved in emergency preparedness including on vessels, training providers, etc. Some of their key findings on the status of emergency preparedness are based on interviews with fish farmers who see the preventative work they do as an important part of emergency preparedness, i.e. the procedures, risk assessments, safety management, and safety checks they do daily, weekly, monthly. The recommendations in user handbooks for equipment and equipment maintenance are all, they think, very important for emergency preparedness. Industry representatives took part in workshops where they discussed the need for dedicated plans at the company level to allow for local adaptations for fish farms. Overall, they all seemed to be satisfied with their emergency response plans and positive about management developing those plans. Another positive aspect of emergency preparedness they identified was cooperation between the fish farms in each company; they valued standardized procedures and equipment but not all agreed that cooperation was optimal. One informant, for example, said cooperation in emergency preparedness in the industry is key and could be an area for future development.

The industry conducts emergency preparedness drills. There are different kinds of drills for fish escapes. These are all documented and management monitors to ensure they are performed according to the plans but not all scenarios are practical for drills. The regulations require emergency response plans for events but industry does not have unified performance requirements for, for example, response times as found in oil and gas.

In the case of emergency preparedness in offshore versus coastal development, they studied company emergency preparedness plans and looked at an open document from the Smart fish farm, one of the concepts that emerged from the development licenses. The hazards listed in the application were similar to what they found in response plans for the coastal locations but in the case of extreme weather, for example, which was explicitly mentioned and a topic in their workshops, coupled with increased distance from shore, one of the representatives from the authorities said establishing emergency preparedness for coastal versus open fish farming involves dealing with two different worlds. One noted that if they are going to use helicopter operations, the situation will be different from coastal areas. There are also different cyber security concerns around the risk of sabotage on offshore farms if they are dealing with more remote operations. Cybersecurity is very important and may affect fish welfare. Their publication suggests some recommendations that would be very valid for coastal and offshore farms. For instance, they noted that it is not common practice for the industry to perform systematic emergency preparedness analyses to provide input into the emergency response plans. There is also the issue of performance standards for, for example response times for worker overboard, mass mortality events, etc. as in the offshore oil and gas industry. The latter has established some preparedness requirements and this creates some commonalities across the industry.

They also heard in the interviews that things are always getting added to emergency preparedness but nothing is ever removed so the content for the requirements keeps growing. How do you prevent this but remain responsive to emerging evidence and keep improving? In relation to improvement, management teams have different levels and it is important to ensure ownership of the plans and to strengthen emergency preparedness competence in the industry. There need to be drills related to the plans to ensure competence training across the organization and to allow opportunities to learn from each other. So, the industry could benefit from more collaboration across companies and with authorities. Fish farmers said they envision more collaboration in the future but while fish farmers share information, there is no obligation to investigate accidents and no system that allows companies to share information in a regular manner.

They have generated a Guide for emergency preparedness analysis that includes step by step instruction for how this should be done. It is openly available and easy to translate using online programs. We have posted both the Guide and a rapid translation of the first 11 pages of the Guide using the program DeepL with the Guide at the following links:

The Guide: https://www.sintef.no/publikasjoner/publikasjon/2138792/

Translation of the Executive Summary of the Guide into English:

https://coastalfutures.ca/wp-content/uploads/2024/03/GUIDE-FOR-CONTINGENCY-ANALYSIS-FOR-AQUACULTURE-Deepl-translation-Executive-summary.pdf

References for the relevant papers for Trine's presentation:

Prepared for the worst? Emergency preparedness in Norwegian fish farming – Status and further improvements - ScienceDirect

TransNav Journal - Increased Emergency Preparedness in Coastal Aquaculture

Technological innovations promoting sustainable salmon (Salmo salar) aquaculture in Norway - ScienceDirect

Gerald Singh gave a presentation on work he and many others have been doing on mass mortality events (MME) in salmon aquaculture. The main focus of the presentation was two manuscripts, one of which is on the development and analysis of an international database on on salmon aquaculture MMEs and a second manuscript which is under review based on findings from a multi-disciplinary risk assessment for MMEs. He also referenced a couple of recent, related publications using risk assessment results for MMEs and occupational health and safety (one international and one focused on Chile) that are already published. (see references and links below). The MME database and risk assessment analysis involved Zaman Sajid, a process engineer with a background in risk engineering, who has since taken up a permanent position at Texas A and M, and Charlie Mather who is a faculty member in the Geography Department at Memorial University. Gerald noted this research started, in part, because they noticed that discussions of risk in salmon aquaculture focused largely on risk from salmon aquaculture to the surrounding environment (i.e. equipment, siting, location, effects on wild fish) rather than risk to aquaculture from the environment and the larger system aquaculture is part of. They were concerned about some reports and rising issues related to MMEs, events where in a short amount of time, a large number of fish, ranging from 10,000s to millions of fish can die. MMEs entail production and

reputational risks for companies. There have been cases in Canada where regulators have suspended the licenses for companies where MMEs have occurred. There are also potential risks to OHS associated with cleanup and disposal of dead fish when large volumes have to be handled in short periods of time. So they designed a risk assessment exercise for MMEs that encompassed, similar to Trine's work, multiple risk dimensions including environmental stressors, issues of fish vulnerability, salmon nutrition, pathogens and toxins as well as OHS, worker livelihoods and community sustainability dimensions and looked at how the different variables come together to either produce or mitigate risk. They also developed a global database of MMEs to try to assess trends in this area – the focus of a separate manuscript and the main focus of this presentation.

Zaman is a risk engineer and he introduced a method used in engineering called interpretive structured modelling, i.e. a structured way to characterize complex systems. This approach was used to take input from experts related to each of the risk dimensions and to develop preliminary dependency network diagrams. These preliminary diagrams were reviewed and revised in multidisciplinary workshops with these experts to get to the final model. In terms of causes of these complex events, the dependency matrix model points to the possibility that trying to mitigate risk associated with one variable, such as environmental stressors, could enhance overall risk. A lot of times, MMEs are the result of a combination of external environmental factors and decision-making that might involve mis-calibrated or mis-timed decisions which, when combined with, for example, poor monitoring and emergency preparedness can result in larger and more severe events. For example, high water temperature can cause stress to fish and, if the feeding regime is not optimal, these things can, in combination, increase the risk of MMEs that, due to other factors like monitoring and staffing resources can amplify potential risks. The resulting manuscript from this exercise (referenced below) is currently under review.

The second manuscript, and the focus of today's talk, involved a much smaller team. These researchers assembled a large dataset from government accounts and company records of MMEs that captured thousands of these events all over the world, focusing on the world's largest salmon producers including Norway, the UK, Canada, Chile, Australia and New Zealand. This manuscript was published on March 7th, shortly after the second Dialogue (see below). The objective of this research was to generate insight into the scope of MMEs and their patterns in terms of where they are occurring, when, size and frequency. Based on the large dataset of findings, they were able to map documented MMEs between 2012 and 2022 and, using animation, to explore patterns and trends. The animation showed some odd yearly spikes that are partly due to differences in the time intervals of reporting in different parts of the world. For example, countries in the Southern hemisphere only report losses on a yearly scale and this limits what they can say about these events. In the Northern hemisphere, losses are reported on a monthly basis or even more frequently. One of their first questions was how often are MMEs occurring? Given the variability in reporting by countries, they decided to gather all the data for each country and then to look at the top 10% of MMEs in terms of size and when these occurred. For the northern countries they were able to track number of these large events by month and year. In every case they found an increase over time in the number of events. In the south, in Chile, Australia and New Zealand, where they had less data to work with they were too restricted when they limited sampling to the top 10% so they looked at the top 50%. There they found the picture was much less clear than in the North and they could not see a particular trend.

They also tracked the magnitude of loss from MMEs over time for MMEs in northern countries – i.e. how many fish were dying over time? They did this for Canada, Norway and the UK and, looking at the

largest magnitude events, what emerges is also rising trends, i.e. larger scope for loss. In some countries, like Canada, results were more variable with outliers and extremes but we see that partly because we have more fine-grained data. In the South, the picture is fuzzier.

They also asked the question: theoretically, how bad could the worst case get? The focus on worst case situations comes from extreme value theory where in order to characterize and predict what is happening, you calculate how bad things could get if the last ten years are a somewhat accurate portrayal of the distribution of loss. They tried to estimate the size of the worst 1 in 1,000 events and one in 10,000 events. In basically every case, there were basically millions of fish lost.

Implications of this research? There is the issue of data standardization and varying geographic resolution with different countries reporting events at different temporal and spatial scales. Everywhere except Norway is reporting at the site level but Norway reports at the country level and temporally mortalities are available monthly or even more frequently in some places and only on a yearly basis elsewhere.

The data are signaling MMEs are becoming more frequent, widespread, and larger in scale overtime and may well be an under-appreciated risk to aquaculture and to the 'blue foods' idea. They are both a food production risk and a reputational risk. What would be causing MMEs to increase in scope and frequency at global scales? This could easily be increased environmental variability, i.e. changing ocean conditions, climates, increased likelihood of extreme weather events are likely affecting patterns. But going back to Charlie's opening discussion of risk, there is also the possibility of manufactured risk, i.e. risk that is the result of decisions humans make that can create or enhance risk. One thing that can contribute to this kind of risk is the use of technologies and tools that provide a sense of security and justify growing fish in more risky situations. If we rely on more technology such as early warning systems to reduce vulnerability, these systems can help us justify growing fish in increasingly risky environments, such as offshore. Trying to have a very controlled growing system in an increasingly variable environment could be a recipe for worse conditions at this scale. And economic systems that shape production systems at this scale including, for example, financialization, lack of regulatory oversight in some contexts, and a rush to develop while reducing emphasis on risk assessment, can lead to a rush to grow fish. We think these are two important areas for future research on aquaculture and MMEs.

Here is a link to the MME paper: https://www.nature.com/articles/s41598-024-54033-9

Discussant Heather Burke's comments

Heather thanked the organizers for the opportunity to participate and Trine and Gerald for the work they are doing on emergency preparedness and on mass mortality events (MMEs). These are very relevant and interesting topics. As the presentations outline, there are some increased risks and hazards to people, industry and to the environment within marine aquaculture, and how we respond to these will affect fish welfare, occupational health and safety, and other aspects of the industry. In terms of her background, she pointed out that she was involved in a Newfoundland and Labrador provincial government evaluation of the September, 2019 MME that happened that year on the South coast of Newfoundland. At that point in time, she had a rapid and intense introduction to the topic. She was on vacation and had no idea the MME had occurred until she returned. When she was asked to join the investigation, she had to rapidly come up to speed but she wanted to let Dialogue participants know she

is not an expert in this field. But from her experience dealing with the largest MME in the history of Newfoundland and Labrador, she learned some important lessons. The event was the result of a prolonged increase in water temperatures and spiral of deaths and unfortunately, as both presenters have indicated, extreme conditions such as those in NL in 2019 are likely to be more common going forward. They will require emergency response strategies. The NL event and their evaluation of the cause of it led to changes in industry reporting requirements and industry practices as well with some similarities to an MME in Norway in 2019 that impacted 14 companies and about 8 million fish. They experienced similar challenges to those encountered in NL including a lack of available vessels for fish removal, insufficient capacity for fish disposal, a shortage of workers (in our case the shortage of divers led to delays in the cleanup and led to longer workdays and potentially worker fatigue). We need to factor occupational health and safety into our risk assessments of these events. There are also issues around complex reporting requirements and a lack of formalized emergency preparedness in the industry that cross cut NL and Norway. Trine outlined five risk dimensions and these are also relevant to Canada. Together we can learn from each other how to develop and implement appropriate emergency preparedness plans and practices with all of the actors involved in emergency response activities. The Norwegian work illustrates the complexities, logistics, coordination and communication efforts required; these can be enormous. The emphasis here is on both plans and other requirements such as practice drills and the need to take discussions beyond coastal events as aquaculture expands offshore. This expansion will bring new technologies, possibly more risk of vessel collisions, and in some cases the risk of helicopter crashes. So, we need specific emergency preparedness plans based on systematic analysis or assessment and these need to be customized for each company. We also need performance standards as with the Norwegian oil and gas response times for different events. Coordination could also be improved and this applies in Canada as well as Norway. Response plans need to be detailed but not so detailed that they are hard to implement.

Michael Szemerda from Cooke Aquaculture Canada thanked the organizers for asking him to be the industry respondent for this Dialogue session. In his remarks on the presentations he opted to ask some questions and present some challenges based on how he, as an industry player, perceives some of the issues addressed. Starting with Trine, he noted the industry has matured since it started. It developed, especially on the east coast of Canada, from a fishing background and informed by fishing experience where a lot of the safety practices that existed were marine safety practices based on fishing boats. Since then, they have become more and more familiar with the industry as farmers as they recognized the need for a mixture of farming and offshore worker training. Training changed over time, as did safety standards to meet those needs. In terms of risk profiles, whether formal or not, they always did risk assessments. They would assess what was the best way to complete a task that would be safer for workers. They have standard operating procedures (SOPs) and sets of work instructions they developed as they went through each of the tasks. The industry is only 40-45 years old and as it has developed and innovated, they have had to continually update their SOPs. Over the last 10-15 years they have undertaken more on the drills side and have SOPs on man overboard, fire at sea, those types of drills. In terms of commuting to the workplace on vessels, most of the jurisdictions have rules from the Coast Guard marine authority, but they also have these internally within the companies. SOPs are important and it is important to ensure drills are done and that they have competency in all areas. As technologies and practices continue to develop, they are always looking at what is coming up next from the point of view of worker safety. Heather mentioned the review of the MME incident in Newfoundland and the issue with limited amount of divers in NL, and the short amount of bottom time for each diver per day

because of the depth of the nets, making these a higher risk operation. One of the recommendations from the review that was presented to the provincial government was to use deeper nets to try to avoid warmer water temperatures. The NL government created a regulation without talking to industry requiring them to use deeper nets. This increases the risk for dive operations both during regular operations and especially during mass mortality events. The government took one piece of information and made regulations, but we need to look at the whole picture, not just one piece at a time. The presenters talked about moving offshore but he prefers to talk about moving into higher energy environments and the risk that there could be critical mistakes in that context. Any time there is an incident they document it, find the causes, and make changes to the SOPS as they move forward. He thinks that is something that is being done as they move to higher energy farms globally including in Norway, Scotland and in Australia and Chile. Chile is running out of concessions and farms are more and more exposed. In Canada, there are higher energy environments but these are not necessarily further offshore. This can be very site specific. Trine mentioned the Norwegian standards for offshore. There is also a Scottish standard and Canada is using a mixture of some Norwegian standards, some Scottish and others when developing its site standards. But farm designs generally need to be site specific.

Looking at Gerald's presentation on MMEs, he would question changes in regulations and reporting. But he would agree that if they have an incident, as time progresses, these have the potential to be larger; with more fish in the water there could be higher risk with offshore farms. One of the important things for them, as a company, is developing maintenance programs and understanding their risk. Their engineered farms have a good inventory of programs and protocols and most companies are doing that now.

In terms of the numbers of MMEs, we need to keep in mind that we are working in a marine environment where we are seeing thousands of tons of fish washing onshore naturally just based on changes in oceanographic conditions and some of these die-offs might never be recorded. There are natural MMEs in the Gulf of Mexico, Canada, Asia; how well-recorded these are and how well understood is up for debate. Also, looking at MMEs and how they are recorded, these are more highlighted in aquaculture than in other industries like poultry where, because these facilities are located on private land, there is less information. In 2022, over 52 million chickens died just in the US and just from avian flu. That doesn't include the MMEs from power outages etc. This is not to say that they haven't learned from incidents. As a protein-producing industry, they are not immune to incidents and being prepared for them, learning how to mitigate them is important. If we are going to do studies or models, it is important to involve industry associations just so they have an understanding. If it is being developed, people will want industry to look at it, take it into account and to be more involved. Models are models. DFO models sea lice in oceanographic conditions, but it is hard to ground truth those models. They can do some back-casting to try to verify some of it but moving forward, it is always important to keep in mind that it is a model and is usually focused more on worst case scenarios versus average situations.

He noted that the insurance industry that ensures aquaculture facilities around the globe have their own matrix. He is not sure how that would stack up against the new model but there are some there already. As industry, they are trying to improve every aspect. It is not that they don't understand where risk comes from; they are working with a biological stock – fish in an ocean environment and two things are very complex. When you add the human to that, you have a very complex situation. They need to try to simplify as much as they can and the number one thing is to reduce the stress on the fish. So they are

not handling them at high water or low water, etc and these are things industry is learning as they move forward. Also, for emergency preparedness, they need to have the right format for us as a company. But there is also a need for more industry response. How might they set up an incident command centre? Have seen that with flooding, forest fires, MMEs, storms. They generally set up an incident command centre that has control over resources and communication with outside agencies to allow for effective response. Might need to push more for this on the industry side versus the company side.

Q and A and discussion

Gerald was asked if the numbers of MMEs presented were events relative to overall production, i.e. while the rate of events may have increased, given production has increased, the number of MMEs per unit of production may have actually decreased.

Gerald commented this could be a good point and is one of the reasons why they don't try to make any specific conclusions in terms of food output. He also noted, however, that on this issue of the scale of loss versus the scale of production and the assumption that they should expect more loss with increased production that this was not necessarily the case. It depends, he thinks, on why the MMEs are happening. If they have the same number of production sites but are doubling production, they would not expect per site loss events to necessarily increase. But this is why they decided not to filter the data more than they did.

A question was raised about reporting standards. Gerald said they thought about this. Some places are more likely to report later so that is why they focused on just tracking the extremes, the worst cases, in most if not all the countries. There are supposed to be reporting standards related to licenses. If they are tracking the worst events, these are more likely to be reported over time. But there are real limits in terms of their ability to talk about cases and that is why they wanted this study to be an introduction to encourage more thorough research going forward. They did look at the reports done on MMEs going back to the 1980s to try to understand causes. One finding was that very few reports said there was only one cause for a particular MME. Most events were caused by multiple interacting causes.

Someone asked about the emergency preparedness document from Norway mentioned by Trine: who was the intended audience – managers, workers or both? Trine responded that it was made for the industry and it is supposed to be a very practical guide on how to do emergency preparedness analysis.

Someone from Norway commented that fish farming is a very risky occupation, both in Norway and Canada.

Michael indicated that at Cooke, his company, they have seen their injury rates going down over the last 5 to 10 years and a lot of that goes back to training and to their SOPs. They work in some harsh conditions, cold weather, some hot weather. In Eastern Canada, they have SOPS and part of the training for all of the employees relates to working in warm weather, cold weather and the safety gear they provide for them is there for safety and comfort. They do man overboard drills; in the wintertime especially, that can be hazardous quickly. They have been fortunate in the industry in Canada in that they have seen very few serious injuries and they take every one seriously. Heather mentioned diverse. They can get bent over the years, especially at the depths they go to and with going back and forth. They went over their SOPs and looked at these incidents. In one incident the diver went diving recreationally on the weekend and didn't tell their supervisor so they could not safely dive as much at work. In general,

accidents are going down. In the Atlantic provinces, they are no longer listed as one of the higher risk industries. When they are lumped in with the fishing industry the rates are high.

A question for Gerald: he was asked if it was possible to dissect regional data on physical causes to address the issue of aggregation and scale in the datasets? Gerald noted that in some of the data, there has been attribution of causes, mainly in the data from Canada. In the case of Norway, this is not possible because they aggregate data across counties. In Southern countries, they only have total mortality for the year. Multiple things are happening there too and sometimes, especially when they are grabbing data from specific incidents … so, there would be a lot of juggling with that – not to say it would be impossible but they would need to do a lot more fine-grained work.

Trine noted that they know, in Norway, that the risk of MMEs increases with delousing operations and delousing also increases the risk of tears to the nets and escapes, as well as for personal injuries. Someone commented that they are looking at the Norwegian traffic light system in Canada now. Lice is such a major challenge for the sustainability of production; delousing increases risk and the best thing for the fish is to be left alone.

Michael agreed with Trine. As a farmer, they are trying to add the least amount of stress to the salmon's life as possible. They give them the most nutritious diet, try to ensure they are safe from predators, it is all about stress. They are trying to achieve a balance. Sometimes regulations run counter to that and sometimes they help you do that. As a farmer, you have to live with the government bodies where you operate and do the best you can in that context. In Norway, if they go over the sea lice threshold, it is mandatory to treat and they know in the summer when there is warm water, there is also less oxygen and they are going to treat the fish, it won't be in their best interests to handle them. They have to keep the whole thing in balance.