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Increased Emergency Preparedness in Coastal Aquaculture

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ABSTRACT: Aquaculture is an industry that has developed rapidly over the past decades. Despite several hazards in the operations, emergency preparedness is not at the same level as in the rest of the maritime industry. This paper highlights some possibilities to increase the aquaculture industry's coastal emergency preparedness. This paper is the result of the innovation project "Coastal Emergency Preparedness" funded by the Norwegian Research Council and industry partners. The aquaculture industry must establish its own emergency preparedness. In this paper, the innovation of a fleet of emergency preparedness vessels along the coastline, which could fill the gaps in emergency preparedness, is presented. The vessels would be of varied sizes, with different equipment and response times, and could assist the aquaculture industry during local incidents or large-scale ones, such as algae blooms or winter storms, that affect many sites at the same time. Each production zone would need its own dedicated fleet due to biosecurity regulations. The emergency preparedness vessel fleet would be led by an on-scene commander. The fleet would deal with oil spills and tasks such as emergency towing, firefighting, rescue of people, recapturing of fish, silage making, algae detection, and diving missions. With such a vessel fleet, small and large aquaculture companies could increase their emergency preparedness with a common strategy and shared resources.

1 INTRODUCTION

Aquaculture is an important industry that needs emergency preparedness to protect employees, fish welfare and health, the environment, and material assets and ensure food safety [1]. Most fish farms are situated in coastal areas. In a fish farm, one cage is allowed to hold up to 200 000 fish [2]. A fish farm often has six to ten cages that require daily inspection on the ring; equipment needs maintenance, and the fish must be fed and cared for. Fish farmers have many tasks in a demanding environment at sea.

Figure 1. An aquaculture site with open net pens, a feeding, a barge, and work boat. Photo: Magnus Oshaug Pedersen, SINTEF Ocean AS.

A continued sustainable growth in the seafood industries is a stated goal for the Norwegian government, and safe operations require robust emergency preparedness. Figure 2 shows how the number of licenses increased in 2006–2021. At the same time, the number of aquaculture sites decreased with an increase in the average size of the sites, requiring more emergency preparedness.

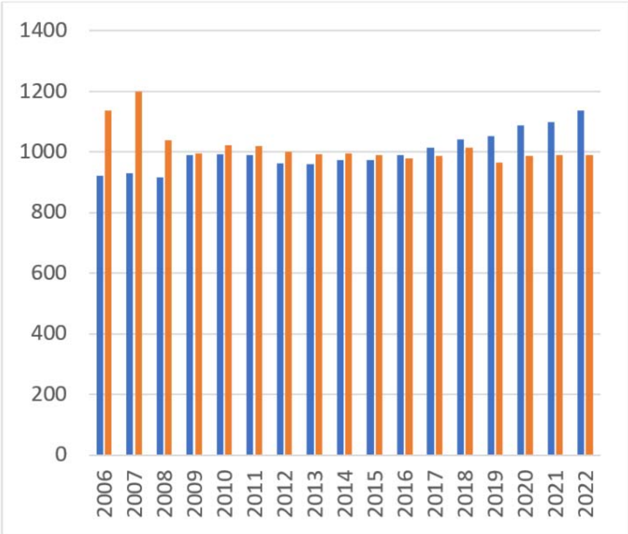

Figure 2. The blue columns show the number of licenses for the production of salmon, rainbow trout, and trout at sea, and the red columns show the number of aquaculture sites in 2006–2021 [3].

The aquaculture industry is regulated by the Ministry of Trade, Industry and Fisheries, but the authorities do not dispose of or manage their own emergency resources. The industry depends on other stakeholders to ensure that it has the resources to ensure emergency preparedness. Aquaculture-related hazard and accidents include personal accidents, ship accidents, fish escapes, algae blooms, acute environmental emissions, and vessel collisions with facilities (cargo ships, passenger ships, leisure vessels, etc.). The consequences of such situations can be loss of lives, damage to people or the environment, economic losses, reduced fish welfare, or large losses of fish.

Data from the website Kystdatahuset (in Norwegian), by the Norwegian Coastal Administration (NCA) [4], show the number of accidents in the Norwegian Economic Zone from 2012 to 2021. These data are presented in Fig. 3. The accidents are fire, drifting object, vessel in drift, vessel with engine problems or black-out, shipwreck, grounding, and collision.

A harmful algae bloom in Northern Norway in May 2019, which caused a mass mortality event involving eight million farmed fish, is an example of an incident that created challenges in the aquaculture industry's capacity for emergency preparedness [5]. In addition, several accidents with work vessels have been recorded. Many serious personal accidents in aquaculture occur outside facilities and vessels [6].

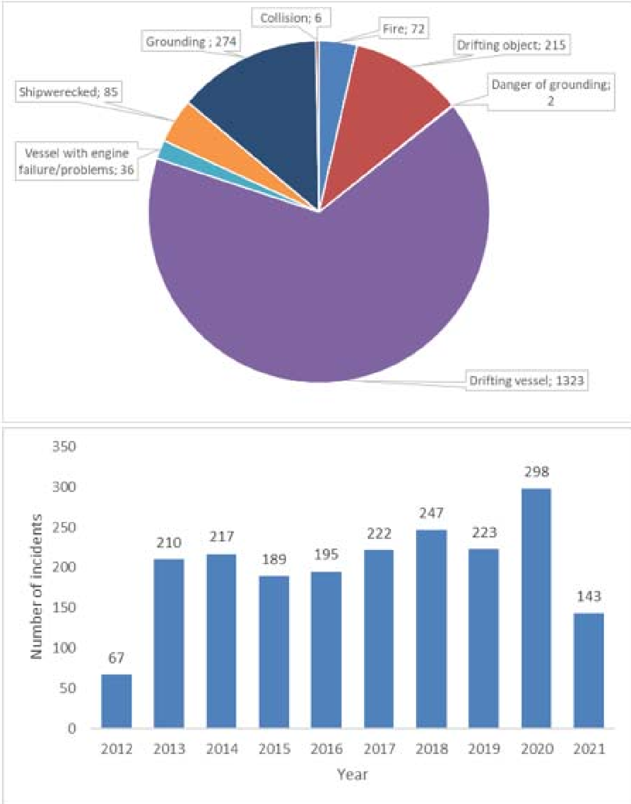

Figure 3. Number of accidents in the Norwegian Economic Zone [4].

2 METHODS AND MATERIALS

Interviews and workshops were the key methods used in this work. Several interviews with fish farmers, public bodies, and the Norwegian Coastal Guard (NCG) were conducted. Several workshops were arranged, and stakeholders representing fish farmers, well-boat owners, vessel designers, vessel builders, companies offering courses and drills, the Norwegian Society for Sea Rescue, the NCA, and local public bodies contributed with their experience and knowledge of coastal emergency preparedness. Vessel design was conducted by Marin Design—a partner in the project this paper is based on—in collaboration with the authors.

3 RESULTS

3.1 *Commercial Emergency Preparedness*

In the interviews, the fish farmers described how they establish their own emergency preparedness. To some extent, they have in-house resources and contracts with well-boat owners, silage companies, divers, tow boats, and fishermen (that can help recapture escaped fish).

Aquaculture companies have both formal and informal cooperation. "If there is an incident, we stand up for the neighbor. No written agreement," one fish farmer said. Assistance from a neighbor fish farm and other local resources are usually used to cope with incidents/accidents. A formal cooperation can be based on joint strategies of good operations in a production zone, including agreements to borrow well-boats or slaughterhouse/slaughter vessels, a joint preparedness agreement for mass mortality, agreements on de-lice vessels, shared equipment for recapturing fish, and a joint fish health forum for a production zone. Vessels from other industries can also be of assistance, such as towing vessels. The availability of such vessels when an incident occurs is unknown, so they are unreliable.

The interview respondents expressed that the capacity of the emergency preparedness services was good enough for local incidents, but for larger ones, such as algae bloom or winter storms, which occurred on several fish farms at the same time, capacity was a challenge. For example, diving services, towing, pumping, silage capacity, and slaughtering could be insufficient if several fish farms were in need at the same time. This is an example of the level of regional emergency preparedness in the aquaculture industry. Today, the industry's regional emergency preparedness includes lice control and response to selected diseases for each production zone. The oil and gas industry has a dedicated fleet of emergency preparedness vessels standing by in case of an incident. The aquaculture industry could learn from other industries, how they solve logistic and resource challenges regarding emergency preparedness by cooperating and sharing common resources in a larger area.

The trend of placing new aquaculture sites in more demanding areas and further from the shore would increase the need for dedicated emergency preparedness. Far from other fish farms, it would be difficult to depend on the resources of a neighbor farm. The risk of an incident increases with an increase in the size of the aquaculture site, the number of fish it contains, the distance to the shore, demanding logistics, automatization, and remote operations [7].

3.2 *Public Emergency Preparedness*

Interviews with the county government show that the public emergency preparedness has three main aspects, prioritized in the following order:

1. Life and health
2. Nonreplaceable natural resources
3. Industry values

This prioritizing means that public emergency preparedness will only contribute to the aquaculture industry if they have time and resources available. Therefore, the aquaculture industry must have their own emergency preparedness resources.

The NCA, with seven vessels, is responsible for coordinating state, municipal, and private preparedness in the national preparedness system [8]. The NCA's pollution control authority includes the responsibility and authority to make decisions, supervise, and implement measures.

The NCG, which solves tasks for the police, among others, and the NCA assist the Joint Rescue Coordination Centre (JRCC) and have an important role in environmental preparedness along the coast and at sea. NCG resources include 12 vessels, six of which are allocated to the Norwegian Emergency Towing Service (NETS) [9]. The NCG is often appointed as on-scene coordinator by JRCC during search and rescue operations as well as oil spill collection. They are also well-equipped for towing other vessels. The Coast Guard's vessels belong to the outer or inner coast guard, and some have the capacity for helicopters. All vessels have their home base, and operations are managed from Sortland, Northern Norway. Most relevant for emergency preparedness in coastal waters is the Nornen class that operates in coastal waters in different zones and consists of five vessels [10].

The Norwegian Society for Sea Rescue is a voluntary, humanitarian member organization, whose task is to make it safe to travel by sea. The main tasks are search and rescue missions, as well as diving missions for the fishing fleet. There are 26 vessels with permanent crews, and 60 divers share two shifts [11].

As a part of the risk mitigation actions to prevent vessels from drifting ashore, the NCA established the NETS, as described by Berg and Selvik [12]. As of today, the NCG operates all vessels in the NETS. The vessel traffic center in Vardø, NOR VTS, monitors all traffic along the coast (and in the Norwegian EEZ). It identifies cases with unusual motion patterns to pinpoint possible uncontrolled drifting vessels. Suspicious cases are reported to the operational branch of the NETS and the NCA's emergency response team. Commercial tugs or NCG vessels will respond to prevent a possible grounding or collision with ocean structures.

3.3 *Examples Where the NETS Is Used*

There have been incidents along the Norwegian coast where the NETS has been crucial and prevented a major disaster.

One recent example was the 190 m bulk carrier MV Melinda, which lost control of the rudder and started to drift toward the coastline in Vesterålen (see Fig. 4). It was approximately 10 nm off Andenes in rough sea (wave height of 5 m) with a wind speed of 17 m/s and a deteriorating weather. The carrier drifted with a speed of 4 knots toward the shore. The master of MV Melinda refused support from the ETS vessel KV Harstad several times, stating they had control and would fix the failure themselves soon. NOR VTS surveyed the situation using their tool for ship drift prediction, which estimated that the bulk carrier would ground within four to five hours. The master on the Coast Guard vessel then told the master on MV Melinda that they prepared for an emergency towing operation. The master accepted the situation, and on the second attempt, a towing connection was set up (the first time the line broke due to the high waves). The emergency towing operation prevented grounding, the spill of fuel from the bulk carrier (having 800 tons of heavy oil and 250 tons of diesel), and a possible crew rescue operation.

In October 2022, a general cargo vessel had an engine breakdown and started to drift toward the shore in the second largest aquaculture production zone in Norway (see Fig. 5). The ETS vessel KV Bison was only 45 minutes away and set course at the best speed toward the disabled vessel. The transit time was used to prepare for the task ahead with a toolbox talk and by rigging the emergency tow line. Overall, the weather was good, but a southerly wind caused Rane Express to drift to the north toward the shore at approximately 1.5 knots. Due to the drifting speed and wind condition, three attempts were needed to successfully secure a tow line. At this point, the disabled vessel had around 0.3 nm to the shore or 10–12 minutes before the vessel had been grounded. During this, another emergency resource was available—a rescue vessel from the Norwegian Society for Sea Rescue, which has an estimated time of arrival of 10–15 minutes later than KV Bison. This rescue vessel was called off. The ETS vessel KV Bison was close enough to assist. Normally, this would not be the case.

Figure 4. Towing of MV Melinda (in sheltered waters). Photo: Bjørn Amundsen, Norwegian Coast Guard.

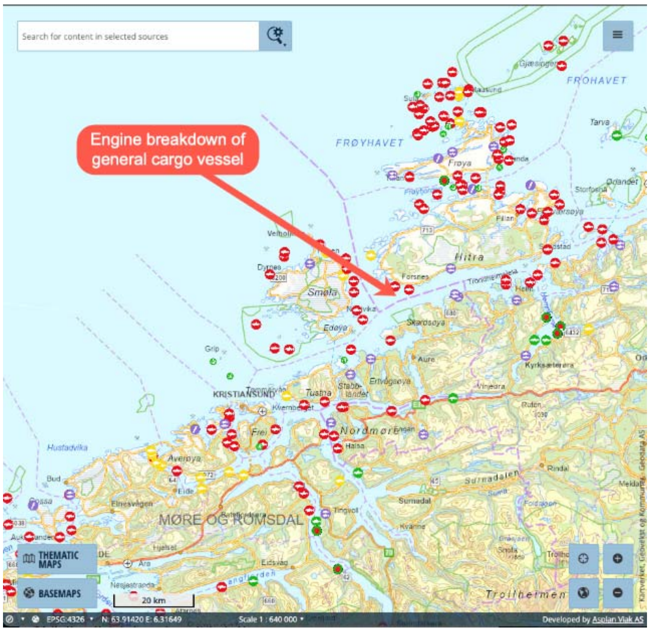

Figure 5. A map indicating where the general cargo vessel got an engine breakdown. The red circles show aquaculture surfaces. The map (without the red callout and arrow) is found using the Norwegian Coastal Administration's service Kystinfo.no.

3.4 *Emergency Preparedness Vessel for the Aquaculture Industry*

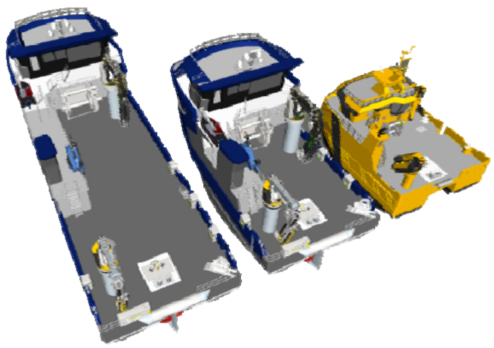

Figure 6. Three emergency preparedness vessel concepts for coastal emergency preparedness of 15, 26, and 40 meters, respectively. The vessel design was made by Marin Design.

The aquaculture industry therefore relies on its own resources: service vessels, well-boats, towboats, silage boats, feed boats, veterinarians, and fishermen on contract to assist during a fish escape. These emergency preparedness stakeholders have their tasks to fulfill, but when an incident happens, some gaps in the emergency preparedness show:

- An on-scene commander to take the lead in an emergency
- Towing capacity
- Oil protection (equipment and expertise)
- Firefighting (equipment and expertise)
- Recapture of escaped fish (equipment and expertise)
- Silage equipment (grinder and storage capacity)
- Diving equipment and capacity
- Algae sensors
- Equipment to rescue people from the sea

An emergency preparedness vessel can address these gaps if it has the right equipment and competent staff.

Three aquaculture emergency vessel designs have been proposed, as shown in Fig. 6. The two smallest designs are 15 and 26 meters, respectively, and are modified service vessels. With additional on-board equipment, they can be used for emergency preparedness situations. They will be used as normal service vessels under normal working conditions. They are also suitable as emergency vessels to assist in an emergency situation within a given timespan. The vessel concept of 40 meters is a purpose-built emergency vessel. This vessel will have more emergency equipment on board, will be equipped with a larger work boat/MOB boat (man overboard), and can withstand bad weather. This vessel will also be suitable for service assignments in the aquaculture industry, such as anchor handling and towing.

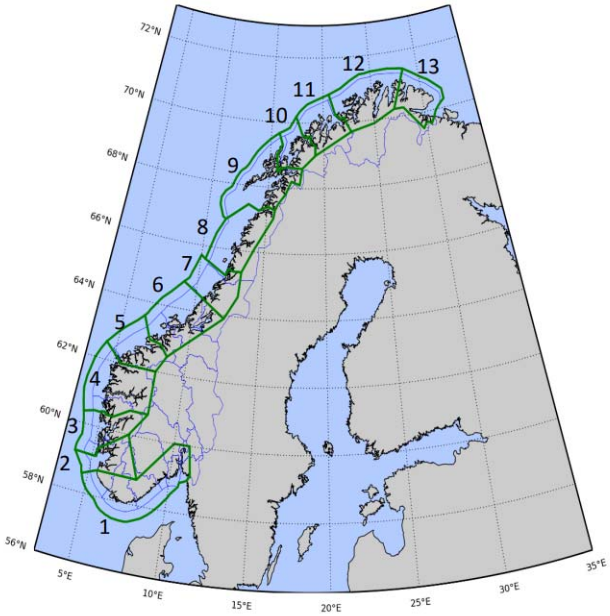

Figure 7. A map of the 13 aquaculture production zones in Norway [13].

One possible organization of the emergency vessel response is for the combi vessels to enter normal service operations, but with a presence contract and a given response time. This means that the vessel must be able to stop the work it is doing and be ready to respond within the timespan. In this way, emergency preparedness could be improved without excessive costs.

A vessel purely for emergencies can maintain emergency readiness in a defined area, such as a production zone. Because of biosecurity restrictions, crossing a production zone border (see Fig. 7) might be time-consuming and economically costly. Also, depending on the incident, an emergency preparedness vessel situated in a different production zone than the one the incident occurs in might not make it in time to assist during the emergency response [14]. Aquaculture companies must have large emergency preparedness vessels as a common resource in a production zone at the same time as having smaller combination service and emergency preparedness vessels that can quickly assist.

1. Emergency Preparedness Vessel Equipment:
   - Cranes: The size of the cranes will be adapted to the size of the emergency preparedness vessel. Large vessels will have two cranes with different capabilities.
   - Oil spill equipment: The equipment allows oil collection with an oil trawl and encircling of the casualty or contaminated object with a traditional bilge. For small emergency preparedness vessels, tanks for collection on board take up a lot of space, and it may make sense to use a temporary storage in oil barges. For large emergency preparedness vessels, oil can be stored in tanks onboard as well.
   - Towing equipment: The equipment will have a ready-rigged light towline configuration available. The towing arrangement will consist of a strong and easily handled fiber rope, craw foot, and equipment to transfer the towline from the preparedness vessel to the disabled vessel.
   - Equipment for recapturing fish: Emergency vessels will have nets and other equipment suited for recapturing escaped fish.
   - Operations center: For large emergency preparedness vessels, the bridge can be split in two, where a separation between navigators and the operations center can be created. This is very effective for leading actions at sea where there is a short distance between the bridge and the operations center. For small emergency preparedness vessels, the operation center will be in a corner of the bridge.
   - Infrared camera: A forward-looking infrared (FLIR) camera is very useful. The camera has the option to follow objects automatically, either via AIS (Automatic Identification System) or by selecting an area to be followed. An IR camera is very useful in oil detection.
   - Light boat: Having an MOB boat is important in emergency preparedness. The placing and size of the MOB boat will vary with the size of the emergency preparedness vessel.
   - Silage capacity: For small emergency preparedness vessels, the silage will be handled by modular units, for example, placed in containers. This gives good flexibility. Only large emergency preparedness vessels could separate tanks on board for storing silage.
   - Firefighting equipment: Water and foam canon will be used in firefighting scenarios.
2. Competence Requirements: An important part of an emergency preparedness vessel for use in the aquaculture industry is the competence of the crew on board. Experience, practical skills, and equipment-specific competence will be important to solve emergency response tasks in the best possible way. It is likely that the vessel will also be used in the day-to-day operation of aquaculture facilities, and the crew's basic competence is essential in an emergency setting.

Typically, crew members on service vessels in the aquaculture industry have taken the STCW-95 course. Other courses are on crane, hot works, fish health, chemistry, and ROV (Remotely Operated Vehicle). In addition, the crew would need knowledge, practice, and experience on top of their competence as a crew on a service boat. This competence can be gained in different ways, for example, through certified training, documented training, and experience gained from conducting operations, training, exercises, etc.

The first key competence is emergency preparedness management. This is a very crucial skill because the crew will face many different scenarios, both known and unknown, and will take the lead in solving the task ahead of them. Qualified and trained personnel on an emergency preparedness vessel should act as an on-scene commander and lead the handling of the incident. This course could be held by a training facility.

Another important competence is handling an MOB boat. To lower an MOB boat in most weather conditions, use it safely, and haul it will require courses and drills.

Fish escape is an incident in the aquaculture industry that varies from one year to another. In 2010–2018, an average of 219 000 fish escaped each year. The incident peaked in 2011, when 327 000 fish escaped; the opposite was in 2017, when only 20 000 fish escaped. The fish farmers are required by law to attempt to recapture escaped fish [15]. Recapturing escaped fish is important, and the crew on board must know how to handle nets and quickly place them in the right position in the sea in collaboration with the fish farmers.

In case of a mass mortality of fish , it is important to remove the fish from the cages so the cages will not collapse under the weight of the fish. Here, it is important to learn how to use lift-up systems and pumps without damaging the nets. Damage to the net increases the risk of fish escape. After pumping up dead fish, one must know how to handle and store silage. Another key competence is how to stabilize the cage and keep it floating until enough dead fish have been removed and the risk of collapse has been eliminated.

Oil spill is a threat to the fish. The crew on board must have knowledge of how to use oil lenses and oil barges so they can use this equipment around an aqua culture site. It is also important to have knowledge about different types of oil and how they can affect the fish in the cages.

Emergency towing of other vessels, cages, or barges will be an important task for the crew on emergency preparedness vessels. This task requires equipment and competence to do safely.

Firefighting will mainly be conducted from a distance using water or foam canons. The crew must be drilled in how to use the equipment. They also have to gain knowledge about different types of fires, such as battery fire and fire on a conventional boat.

Algae knowledge is important, especially during algae blooms. If the crew can take water samples and indicate which algae it is, this would ease the handling of an algae bloom. Qualified personnel would still be needed to examine the water samples and give exact answers, but this process takes time. For the aquaculture industry, a quick, temporary result is important.

3.5 *The Contribution of an Emergency Preparedness Vessel*

There have been incidents along the Norwegian coast where an emergency preparedness vessel could have prevented a major disaster.

1. A Freight Vessel Was Drifting: A freight vessel was drifting on the second largest aquaculture area in Norway, as described in Section III-C. This vessel was a threat in several ways. In this situation, a smaller emergency preparedness vessel could use a towing line to hold the freight vessel in place, and a larger emergency preparedness vessel could tow the ship to harbor. If the ship already damaged a fish farm site, then the destruction of the structures with a mass escape of fish would be a likely scenario. The emergency preparedness vessel could have three possible tasks:

– Assist with cranes to lift the structures to prevent (more) escaped fish.
– Assist with the recapture of escaped fish.
– Tow the freight vessel away from the site and prevent other sites from being hit or the freight vessel from hitting the shore.

An oil spill is another threat from the vessel. If this occurs, the emergency preparedness vessel will assist the fish farm sites with oil lenses to protect their fish. The last threat to mention here is fire in a barge or a boat hit by a freight vessel. In this case, the emergency preparedness vessel can assist with firefighting or personnel rescue. The flow diagram of this process is shown in Fig. 8.

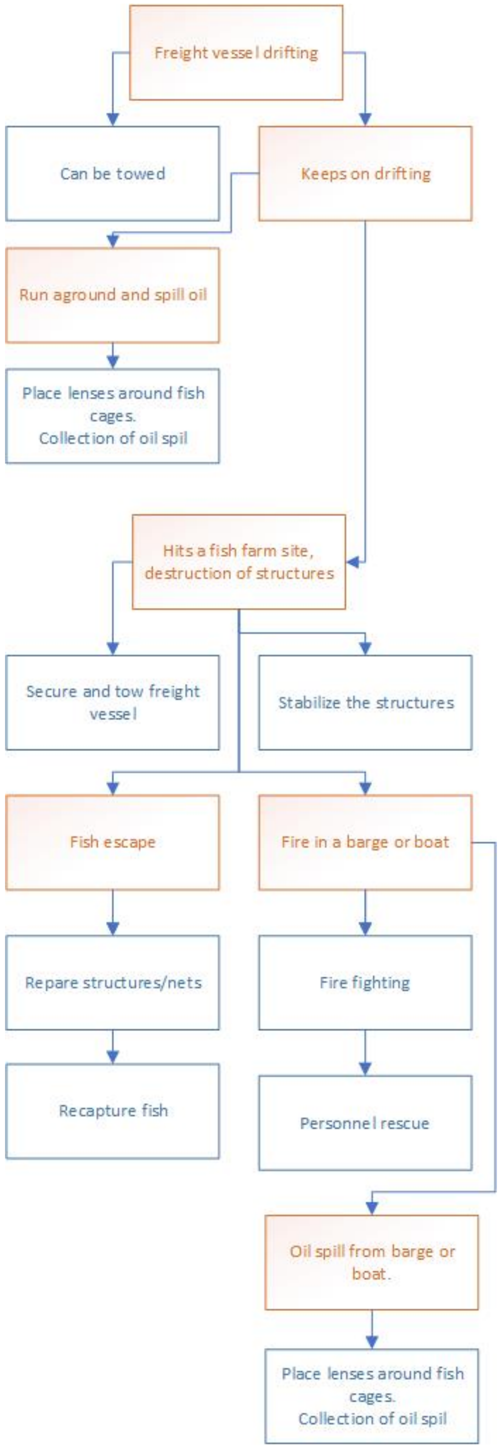

Figure 8. A freight vessel is drifting, and this scenario shows where an emergency preparedness vessel can assist. Red boxes indicate dangerous situations, and blue boxes show a solution to the previous danger.

2. Algae Bloom: A toxic algae bloom hit a large area in Northern Norway in 2019 (see Fig. 9). Several companies were affected, and 13 500 tons of fish died [5]. At first, the toxic algae bloom was detected near fish farming facilities, and the company considered actions to move fish from several cages/locations. When they realized the potential in this situation, other companies were warned so they had time to act and save their fish. Not all companies could move fish, and the moving also entails a great strain on the fish. A mass fish mortality occurred after some time, mainly because of toxic algae but also due to fish handling. The capacity to pump up and move a lot of fish as well as the large quantities of fish that should be moved were challenging. Given the circumstances, there were exemptions on moving cages with fish inside, which is normally forbidden. In this incident, the fish farming companies relied on the same emergency preparedness resources, but their pumping, silage, and towing capabilities were inadequate. A fleet of emergency preparedness vessels could be useful in these tasks (see Fig. 10) and could help address the consequences of fish handling, such as causing holes in nets, requiring repair and the recapture of escaped fish.

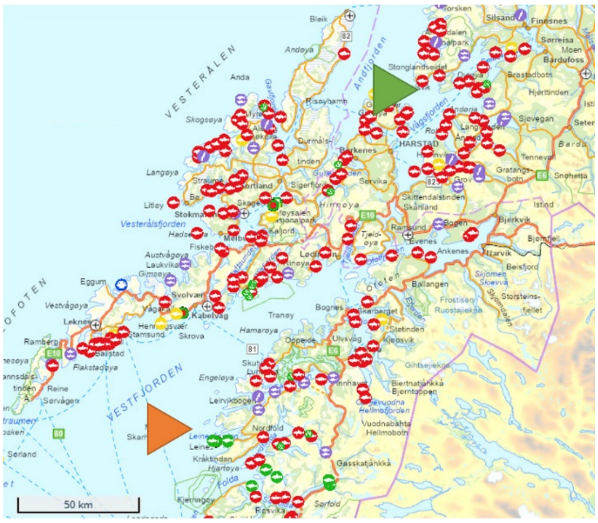

Figure 9. The area hit by a toxic algae bloom in 2019 was in Northern Norway. The red circles show aquaculture sites. The orange arrow shows where the algae bloom started, and the green arrow shows where it ended. The area and aquaculture sites affected were determined by the sea current.

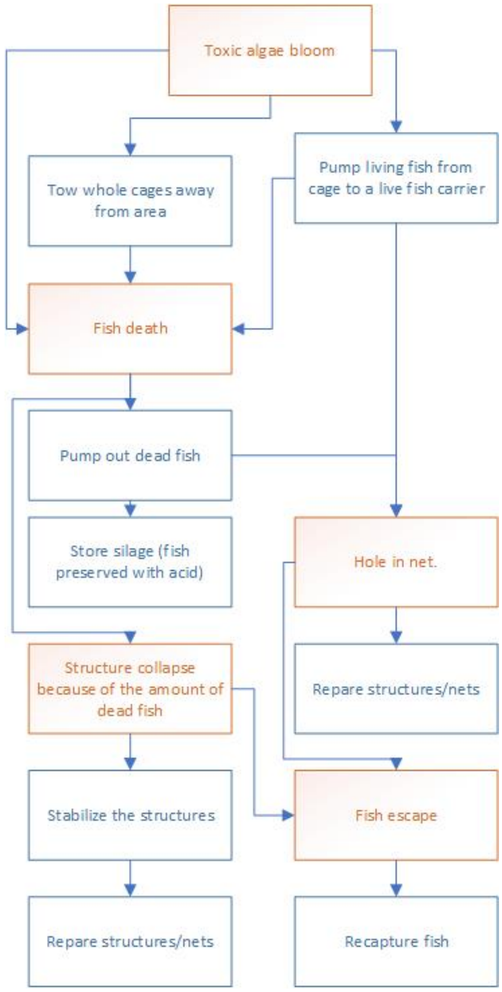

Figure 10. Toxic algae bloom; this scenario shows where a fleet of emergency preparedness vessels can assist. Red boxes show dangerous situations, and blue boxes shows a solution to the previous danger.

3. Mass Death of Fish: Another scenario is mass death in cages during and after a mechanical de-lice operation (see Fig. 11). The de-licing was carried out on one of the company's de-licing barges. A total of 100 000 fish died because of the de-licing process. A tear was discovered in the netting of the cage, and a repair net must be deployed. 10 000 fish are believed to have escaped. In this case, the emergency preparedness vessel could assist the fish farmers (Fig. 11) by pumping to remove dead fish, placing nets in the sea for fish recapture, and repairing the damaged net. The on-scene commander (on board the emergency preparedness vessel) must prioritize these tasks while in dialog with the fish farmers and other relevant stakeholders.

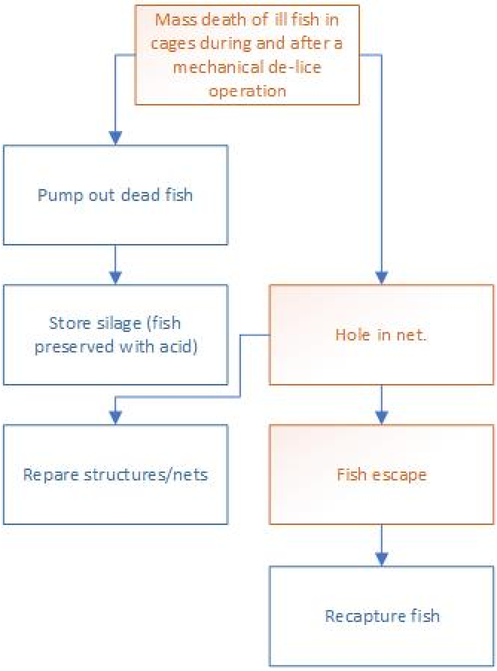

Figure 11. Mass death in a cage and fish escape; this scenario shows where an emergency preparedness vessel can assist. Red boxes show dangerous situations, and blue boxes show a solution to the previous danger.

4. A Well-Boat on the Ground: The fourth case discusses how a dedicated emergency vessel for the aquaculture industry could have been used when a well-boat run aground with ill fish on board. Also, in this case, the location of the incident was the second largest fish farming area in Norway. Steps to minimize the consequences of the incident are shown in Fig. 12. In the actual case, the well-boat owner searched for vessels that could help within their own shipping company and external vessels as well. The vessels they had that could provide assistance were occupied with another task, and it would take too much time to release them. Luckily, a towing vessel was close enough to be of assistance, and the Norwegian Society for Sea Rescue had a vessel that could hold a towing line but not the engine power to tow away. The well-boat needed a towing line from the stern and bow for the boat to come off the ground safely. They started to empty ballast water, but the tide reduced the time span available. Then, the vessel from the Norwegian Society for Sea Rescue received an emergency call. Their primary task is to save life at sea, not hold vessels in place. An emergency preparedness vessel could, in this incident, have replaced the vessel from the Norwegian Society for Sea Rescue and taken the lead. An on-scene commander could lead the operation from the emergency preparedness vessel and be in charge. The towing boat would assist, and not be the main towing capacity. If emptying the ballast water was not enough, the emergency preparedness vessel could pump water from the fish tanks into its own tanks and secure no further spread of the disease from the ill fish. If the well-boat started to leak oil, the emergency preparedness vessel could place lenses around the well-boat and start the collection of oil spill.

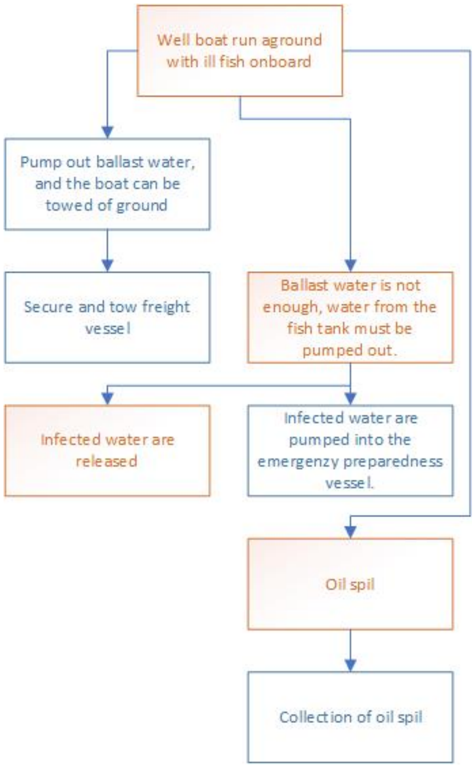

Figure 12. A well-boat with ill fish run aground; this scenario shows where an emergency preparedness vessel can assist. Red boxes show dangerous situations, and blue boxes show a solution to the previous danger.

4 CONCLUSION

The fish farms in the Norwegian aquaculture industry are mainly situated along the coastline, but utilizing more exposed and offshore areas are also a part of the industry's development. It is crucial that the emergency preparedness follows the growth and development of the aquaculture industry. To be better prepared, a fleet of emergency preparedness vessels in each production zone, as a common resource for every aquaculture site, could increase the emergency readiness level and give every company, small or large, the opportunity to secure their employees, their industry values, and the environment they are situated in.

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REFERENCES

[1] X. Yang, I. B. Utne, and I. M. Holmen, "Methodology for hazard identification in aquaculture operations (MHIAO)," Saf. Sci., vol. 121, pp. 430–450, 2020, doi: https://doi.org/10.1016/j.ssci.2019.09.021.

[2] "Forskrift om drift av akvakulturanlegg (akvakulturdriftsforskriften) - Kapittel 3. Særskilte krav ved produksjon av fisk." Lovdata. https://lovdata.no/dokument/SF/forskrift/2008-06-17-822/KAPITTEL_3#%C2%A747 (accessed Jan. 4, 2023).

[3] Ministry of Trade, Industry and Fisheries. "Akvakulturstatistikk: matfiskproduksjon av laks, regnbueørret og ørret." Ministry of Trade, Industry and Fisheries. https://www.fiskeridir.no/Akvakultur/Tall-og-analyse/Akvakulturstatistikk-tidsserier/Laks-regnbueoerret-og-oerret/Matfiskproduksjon (accessed Jan. 2, 2023).

[4] "Kystdatahuset." Kystdatahuset. https://kystdatahuset.no/artikkel/om-kystdatahuset

[5] K. M. Karlsen, R. Robertsen, and B. Hersoug. Kartlegging av hendelsesforløp og beredskap under giftalgeangrepet våren 2019 - Astafjorden, Ofotfjorden, Vestfjorden og Tysfjorden. Nofima, 2019. Accessed: Nov. 25, 2022. [Online]. Available: https://munin.uit.no/handle/10037/16616

[6] S. M. Holen, I. B. Utne, I. M. Holmen, and A. Halvard, "Occupational safety in aquaculture – Part 1: Injuries in Norway," Mar. Policy, vol. 96, pp. 184–192, 2018, doi: https://doi.org/10.1016/j.marpol.2017.08.009.

[7] Ministry of Trade, Industry and Fisheries. "Havbruk til havs." Regjeringen. https://www.regjeringen.no/contentassets/e29cc668cbf54448a599c6da58cb1b9f/rapport-havbruk-til-havs.pdf (accessed Jan. 31, 2023).

[8] "Kystverkets reiarlag og fartøy," Kystverket - tar ansvar for sjøveien. https://www.kystverket.no/om-kystverket/kystverkets-fartoyer/ (accessed Feb. 13, 2023).

[9] "Statlig slepeberedskap." Kystverket. https://www.kystverket.no/oljevern-og-miljoberedskap/ansvar-og-roller/statlig-slepeberedskap/ (accessed Feb. 13, 2023).

[10] "Forsvaret." https://www.forsvaret.no/om-forsvaret/utstyr-og-materiell (accessed Oct. 13, 2022).

[11] "Redningsselskapet." https://rs.no/ (accessed Oct. 13, 2022).

[12] T. E. Berg and Ø. Selvik, "Changes in and recent experiences from Norwegian Emergency Towing Service (NETS)," TransNav Int. J. Mar. Navig. Saf. Sea Transp., vol. 15, no. 1, 2021, doi: 10.12716/1001.15.01.21.

[13] "Forskrift om produksjonsområder for akvakultur av matfisk i sjø av laks, ørret og regnbueørret (produksjonsområdeforskriften)." Lovdata. https://lovdata.no/dokument/SF/forskrift/2017-01-16-61?q=Forskrift%20om%20endring%20av%20produksjonsomr%C3%A5deforskrift#KAPITTEL_5 (accessed Feb. 13, 2023).

[14] H. T. Slette, B. E. Asbjørnslett, S. S. Pettersen, and S. O. Erikstad, "Simulating emergency response for large-scale fish welfare emergencies in sea-based salmon farming," Aquac. Eng., vol. 97, p. 102243, May 2022, doi: 10.1016/j.aquaeng.2022.102243.

[15] H. M. Føre and T. Thorvaldsen, "Causal analysis of escape of Atlantic salmon and rainbow trout from Norwegian fish farms during 2010–2018," Aquaculture, vol. 532, p. 736002, Feb. 2021, doi: 10.1016/j.aquaculture.2020.736002.