Runoff from Road Freight of Fresh Salmon in Norway: A State-of-the Art

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SUMMARY

Norwegian news media frequently feature roadside heavy vehicle inspections where trucks are being stopped for meltwater runoff from fresh seafood shipments. This has been ongoing for many years, and the Norwegian Public Roads Administration, and other organizations, cite this as a potential traffic safety problem. This article presents a state-of-the art on the problem of meltwater runoff and suggests venues for future research which may strengthen the argument that it actually causes traffic safety issues. The objective behind such research is to expedite technical and organizational changes to stop meltwater runoff from occurring.

OVERVIEW

The Norwegian Salmon Farming Industry

The salmon farming industry is an important driving force of the Norwegian economy. In 2023, Norwegian seafood exports totaled 2.8 million metric tons, valued at 172 billion NOK. Farmed salmon comprised 1.2 million metric tons, and 71% of the value created from the export of Norwegian seafood products.

Farmed salmon is the second largest export commodity of Norway, rivalled only by oil and gas (Norwegian Seafood Council, 2024). For comparison, net cash flows from the oil and gas industry in 2023 amounted to 986 billion NOK (Norwegian Offshore Directorate, 2024).

Norway is the largest producer of Atlantic salmon in the world, and the small nation accounted for more than half of global salmon production in 2020 (Pandey et al., 2023, p. 3). The industry has grown spectacularly from its inception in the early 1970s, and there are now well over 1 000 fish farming locations along the Norwegian coastline (The Norwegian Seafood Federation, 2014). Between 1992 and 2012, production of farmed fish in Norway grew by 10% annually.

Based on conservative growth estimates of roughly 4% annually, researchers and industry experts believe that production is likely to surpass 5 million tons per year in 2050 (Olafsen et al., 2012, p. 42), with an inflation-adjusted 2023-value of about 331 billion NOK. Hence, the Norwegian salmon farming industry is large, and its importance for the Norwegian economy is likely to increase with the passing of time.

Production

Salmon is farmed mostly in open net-pens (Nofima, 2019) on the surface of Norwegian fjords, and at any given time, 400 million individual fish are being farmed (Grefsrud et al., 2022). Having reached their harvesting weight of 3 to 6 kg within 12 to 18 months (Hansen, 2019), the salmon are shipped using well-boats (IntraFish, 2018) to one of approximately 45 slaughterhouses (Norsk Fiskerinæring, 2022). Figure 1 illustrates that Norwegian seafood slaughterhouses are evenly distributed throughout the coastline.

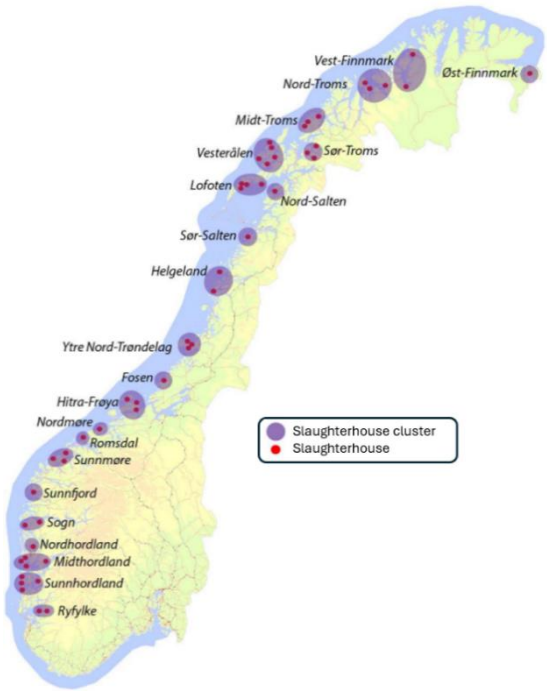


Figure 1: Location of Norwegian slaughterhouses for farmed fish (Sandberg Hanssen et al., 2014, p. 8).

Transportation

Ten percent of fresh seafood exports from Norway are flown to distant overseas markets, e.g., Asia, Oceania and the Americas. The bulk of the volume is headed for the European continent, where a small percentage travels by rail or boat (Norwegian Seafood Council, 2021). Nevertheless, the large majority of Norwegian fresh seafood, 81% of the total volume, travels by truck (Sandberg Hanssen et al., 2014, p. v), bound for the European continent. Assuming this modal share, a per-truck seafood haulage capacity of 19 metric tons, and considering current volumes of farmed salmon, this constitutes 173 daily outbound truck shipments[1]. The number of trucks is somewhat unclear, however, and different sources state that it amounts to even 350 (Brostrøm, 2022) and 1 000 trucks per day during the peak season (Brostrøm, 2021). The shipments occur continuously, both day and night (Kristensen, 2021). Each truckload of farmed salmon has an estimated market value of approximately 1.5 - 2 million NOK (Berge, 2023; Nodland, 2024).

In 2002, total fresh seafood exports were 25% below what they currently are, and the value of the transportation services for fresh seafood trucking comprised approximately 1 billion NOK (Larsen, 2003, pp. vii, 38). Adjusted for inflation, and increased by 25% to reflect current volumes, fresh seafood transport adds an estimated 2 billion NOK in annual revenues to the trucking companies involved.

In 2019, more than 75% of fresh salmon was sold whole or head-on-gutted (Rotabakk & Lerfall, 2021, p. 1), meaning the head stays on but the viscera are removed (IntraFish, 2018). During slaughtering, the salmon usually has a temperature of around 4 - 6 °C (Boge, 2022). Afterwards, salmon are packed into expanded polystyrene crates containing 20 - 22 kilograms of salmon each, along with 3 - 5 kilograms of ice. Each pallet holds twenty-seven crates, and each semitrailer fits thirty-three such pallets, totalling 891 crates (Berg-Olsen, 2021, p. 12; H. Karlsen, 2020; Rotabakk & Lerfall, 2021, p. 5).

[1] This is based on the same calculation methods as described by Berge, (2014), resulting in 130 trucks based on 2014-volumes.

Adding together the weight of the ice in each individual crate, each truck carries somewhere between 2 700 and 4 500 kilograms of ice. The trailers used are insulated and refrigerated, with diesel-powered cooling units (Berg-Olsen, 2021, p. 13) which typically use 2 - 4 liters of diesel per hour of operation (Sundolitt, 2021).

The polystyrene crates have drainage holes in the corners at the bottom, to allow meltwater to drain away, washing away bacteria with it, serving to keep the fish fresh during transport. Upon arrival at the destination, 2 - 4 kilograms of ice per crate has usually melted away (H. Karlsen, 2020), leaving a few kilograms of ice as a safety assurance to the buyer that the fish has remained refrigerated during its journey (Rotabakk & Lerfall, 2021, p. 5).

THE MELTWATER TANGLE

Introduction

The aforementioned practice of packaging and transporting fish results in between 1 800 and 3 600 liters of meltwater runoff from each truck over the duration of typical shipments (Nodland, 2024). This water drips to the floor of the trailer, and leaks out of the rear or side doors, eventually making its way onto the roadway.

Ideally, the salmon should have a temperature of 0 °C when it is packed (Boge, 2022), but it should not be frozen, as this reduces its market value (Brostrøm, 2022). Industry experts state that most slaughterhouses strive to keep the fish at a packaging temperature of 4 °C, while others are closer to 8 °C. Even what may seem like small temperature increases lead to large amounts of ice melting (Olsen, 2020).

Recent research suggests that the meltwater runoff problem is mainly caused by leaving insufficient time for cooling and letting the fish bleed out before shipment (A.-M. Johansen, 2023; Sae-Khow et al., 2022; Vatlestad, 2021). A common Norwegian saying states that "*no one is in as much of a hurry as a dead salmon*" (e.g., Furuset, 2013; Solli & Sandmo, 2017), as customers "*want the fish as fresh as possible*" (Medby, 2023). Consequently, producers are incentivized to dispatch shipments as soon as possible, often before the fish has cooled sufficiently (Jenssen, 2023; Vatlestad, 2021).

The recently created *Thermodynamic Model of Meltwater Drainage during Fresh Fish Transport* (Rotabakk et al., 2023, p. 11; SINTEF, n.d.) shows that the majority of meltwater production occurs in the first few hours after packaging, i.e., at the beginning of the journey. This is illustrated in Figure 2. Assuming that each shipment of fresh seafood destined for the European continent traverses Norwegian roads for a duration of 8 hours, 650 liters of meltwater runoff are deposited on Norwegian roadways, truck stops and ferries, per truck, totaling more than 110 metric tons on a daily basis.

While this at first may not seem consequential, it is made more significant by the fact that meltwater runoff does not *only* contain water from melted ice. It also contains water, blood and fat which naturally resides within the slaughtered fish and which dissipates during shipment (Rotabakk & Petrich, 2022, p. 1). Together, these ingredients produce a lightly slimy fluid with a distinct pink or reddish color (Wolden, 2020).

Runoff from salmon trucks is often covered by local news media, and the frequency of reporting indicates that the problem persists throughout the year (Bye, 2020). Based on its prevalence, many believe that the issue is damaging the reputation of the Norwegian salmon farming industry (Rotabakk, 2022; Wolden, 2020).

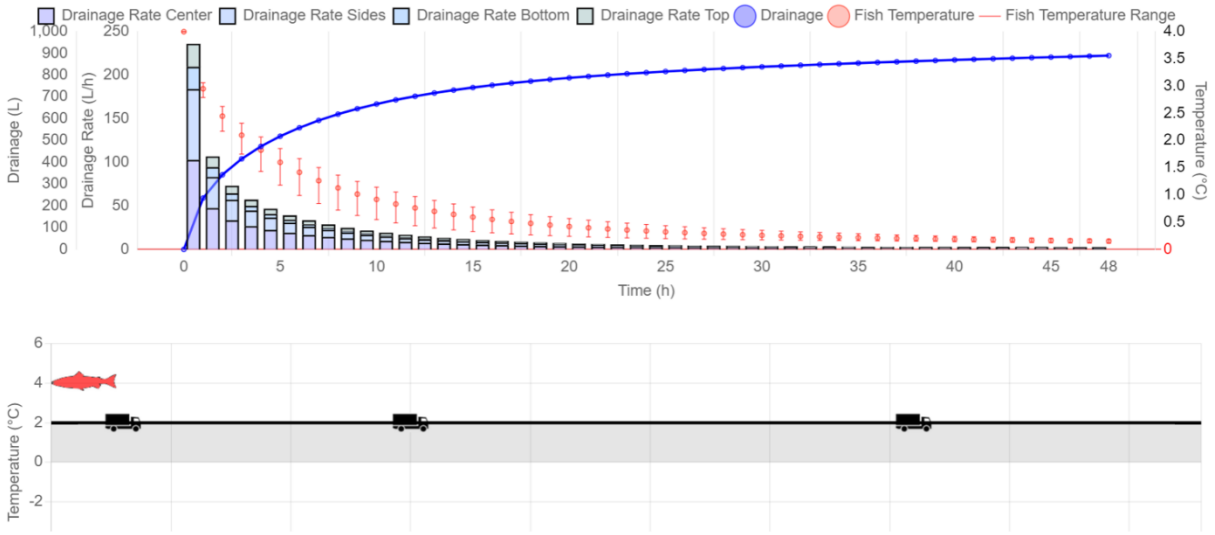


Figure 2: Results from the Thermodynamic Model of Meltwater Drainage during Fresh Fish Transport using with standard parameter settings (SINTEF, n.d.)

Postulated Traffic Safety Effects

The Norwegian Public Roads Administration (NPRA) and the Norwegian truck-owners association consider meltwater runoff as a major risk to traffic safety (Hunnestad & Toftaker, 2022). Local inhabitants which depend on roadways which are heavily trafficked by salmon trucks also worry about the traffic safety effects (Jenssen, 2023; Tellevik, 2018). There are multiple reasons for this, which are discussed in following sections.

First of all, once the runoff drips out of the trailer, turbulence may propel it upwards, causing it to end up on the windshields of trailing vehicles, to the annoyance of drivers, and potentially leading to dangerous overtaking maneuvers (Solberg, 2023).

During winter, when outdoor temperatures are at or below freezing, the meltwater runoff may drip or flow off of the rear or side doors of the trucks, creating icicles, or even larger lumps and blocks of ice. This is illustrated in Figure 3 by photographs taken by vehicle inspectors. Such lumps may break and fall off in motion, causing potentially dangerous situations for road users which are trailing behind the trucks (Norwegian Public Roads Administration, 2021). Moreover, if the runoff does not freeze into icicles immediately upon exiting the truck, it may do so once it has reached the road surface, causing slippery road conditions.

In spring and summer, meltwater runoff is postulated to be an even larger problem, especially for two-wheeled road users (A. D. Johansen, 2023), whose balance may be challenged if they are caught off-guard by the unexpected presence of local patches with oily consistency (Lorentsen, 2021; Toftaker, 2022).

The NPRA also believes that meltwater runoff may increase the risk of dangerous situations in tunnels (Sandholm, 2024b). While the reasons for this are not explicitly stated, it presumably has to do with the fact that the oily consistency from the runoff may accumulate in tunnels, since it is not washed away by rainfall.

While low-friction roads are known to increase accident risk, particularly in combination with narrow and winding road alignment (Myrhaug, 2018), the relationship between meltwater runoff from salmon trucks and traffic safety has not actually been scientifically studied.

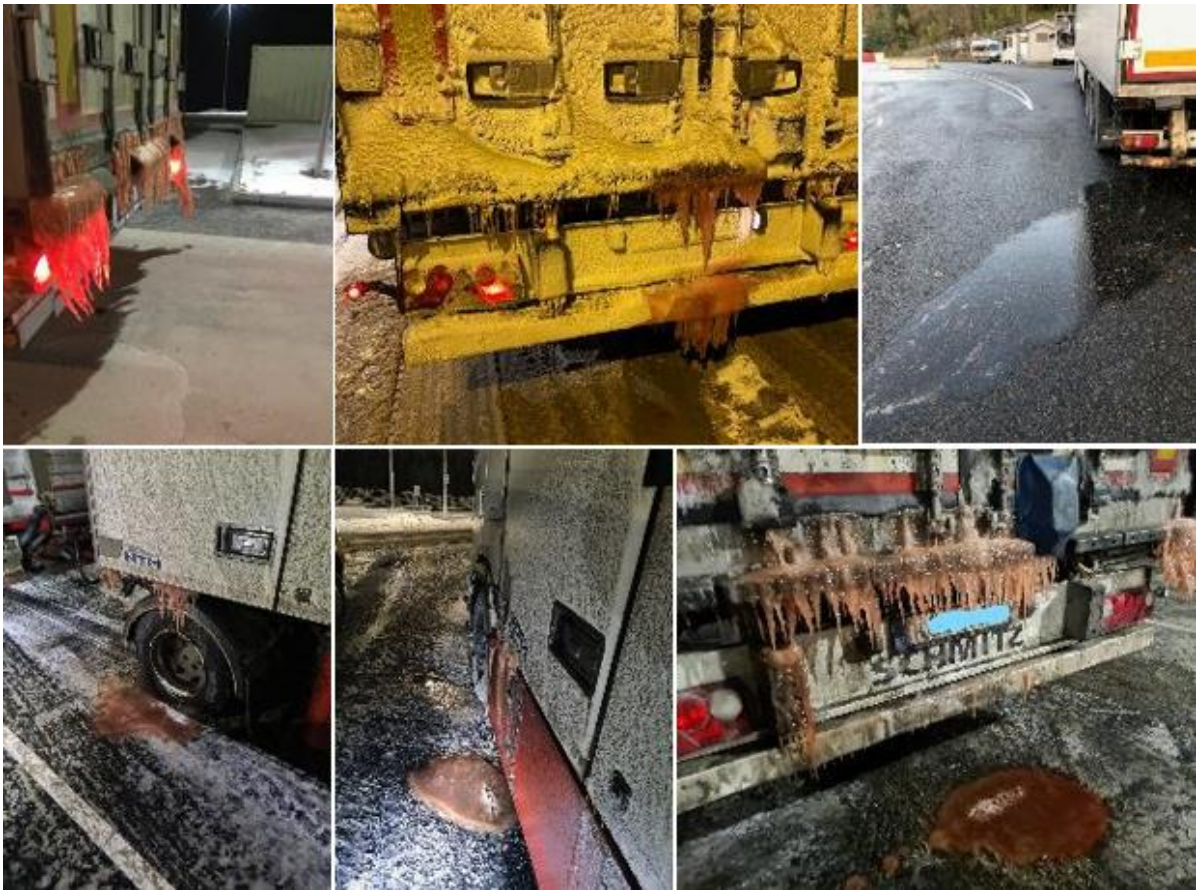


Figure 3: Examples of meltwater runoff (Norwegian Public Roads Administration, 2021).

On a daily basis, trucks are stopped in roadside vehicle inspections on Norwegian roads due to meltwater runoff (Vatlestad, 2024), at large scale. In the fall of 2022, 8 roadside inspections conducted simultaneously in three Norwegian counties resulted in 109 usage bans due to runoff. Seven trucks received two separate bans on the same southbound trip, while one truck received bans *three times* (Norwegian Public Roads Administration, 2022).

These situations are by no means unique (Holberg, 2021a). Over the past few years, quick searches reveal that news reports were written for more than 30 individual roadside inspections[2]. Trøndelag and Nordland counties seem to top the list among counties which face the bulk of the problem, followed by Innlandet county. These results are as expected, based on the export routes which are frequented.

Roadside inspection personnel state that usually, 20-25% of trucks which are stopped are given usage bans for meltwater runoff (Jensen, 2023; Medby, 2023). When the runoff is at its peak, inspectors state that 10-liter

[2] (Andersen, 2024; Aune, 2023; Barbøl, 2019; Bekken, 2023; Bergheim, 2024; Brostrøm, 2021; Bye, 2020, 2021; Eikebrokk, 2021; Ersfjord & Kringstad, 2020; Førde, 2021; Hammervik, 2024c, 2024a, 2024b; Hofstad, 2023; Holberg, 2021b; A. D. Johansen, 2023; Johnsen, 2023; Kalseth-Iversen, 2023; Lorentsen, 2021; Martinussen, 2021; Njåstad, 2020; Norwegian Broadcasting Corporation, 2024; Nøstberg, 2024, 2024; Olsen, 2020; Riesto, 2023; Sandholm, 2024a, 2024b; Søberg, 2024; Solberg, 2023; Wilcox, 2023).

buckets easily fill to the brim within the course of a few minutes (Ersfjord & Kringstad, 2020). This is shown in Figure 4. One inspector states that when opening the cargo doors of trucks during some inspections, the trailer floors may be covered with up to 10 centimeters of bloody runoff, which gushes out onto the pavement (Bye, 2020). A rough estimate using interior measurements of standard semitrailers, this amounts to more than 3.2 metric tons of meltwater runoff.

Over the course of approximately 20 weeks of normal inspection frequency, from Easter to September in 2021, driving bans were handed out to over approximately 450 trucks due to meltwater runoff (Hernes, 2021; Hunnestad & Toftaker, 2022; Kristensen, 2021; Lorentsen, 2021). Nearly all of these incidents are heavily featured in local news media. Often, tips from the traveling public make the NPRA initiate inspections (Jensen, 2023; Medby, 2023).

Other Effects

In addition to the postulated traffic safety effects, meltwater runoff demonstrably causes adjacent issues. For instance, meltwater runoff makes truck stops and vehicle decks of ferries wet and slippery, while causing bad smell for users and passengers. Moreover, it creates added work for ferry personnel, which have to clean their vessels more regularly (A. D. Johansen, 2023; Sandholm, 2024b; Vatlestad, 2021; Wilcox, 2023).

Furthermore, it may pose an environmental issue (Sae-Khow et al., 2022). According to the Norwegian Food Safety Authority, meltwater runoff may spread fish-borne bacteria and diseases to roadside ecosystems (Norwegian Public Roads Administration, 2021; Sae-Khow et al., 2022; Skog-stad, 2021) and waterways (Brostrøm, 2022; Kristensen, 2021).

Quarreling, Sanctions and Legal Basis

There is much discussion as to whether it is the drivers, the trucking company or the slaughterhouse who are responsible for the meltwater runoff issue. As of today, it is the driver who is responsible for such cargo (Solberg, 2023). When traveling on Norwegian roads, truck drivers ultimately carry the responsibility for securing the cargo in accordance with the Road Traffic Act. Several transport ministers, from both sides of the political aisle, have clarified that meltwater runoff is in violation with this act (Myrhaug, 2018), and there is precedence on reporting drivers to the police whose trucks are repeatedly stopped due to meltwater runoff (Ersfjord & Kringstad, 2020). In 2018, the regulations for vehicle use were amended, so that requirements for load securing now also account for environmental aspects, providing the authorities with additional basis for stopping trucks with meltwater runoff (Tellevik, 2018). Currently, paragraph 3-2 of the regulations for vehicle use maintains that goods must be secured so that they do not pose a threat to health, property or the environment. Specifically, goods should not fall off the vehicle, disrupt road users, or otherwise be a nuisance to the surroundings (Bye, 2020).

Trailers are to be kept refrigerated to assist in avoiding the issue, but meltwater runoff still occurs in large scale. Some blame the drivers for keeping their cooling systems off to save fuel (A. D. Johansen, 2023; Vatlestad, 2021). However, the problem cannot be pinned solely on the trucking industry. In fact, the police and the Norwegian Public Roads Administration (NPRA) have considered reporting producers for complicity (A.-M. Johansen, 2023), citing that the industry should be held accountable to a larger extent to prevent meltwater runoff (Hernes, 2021).

Figure 4: Meltwater runoff collected in a bucket (Norwegian Public Roads Administration, 2022).

For over a decade, seafood corporations and the trucking companies contracted by them to deliver the fish, have blamed one another for the problem. Trucking companies blame the slaughterhouses for insufficiently cooling the fish before packing, as corroborated by stories from former truck drivers (Hitra-Frøya, 2018). Likewise, the fish farming industry is criticized for contracting foreign trucking companies with underpaid drivers (Hernes, 2021), though meltwater runoff also occurs from trucks operated by Norwegian trucking companies (Medby, 2023).

Roadside heavy vehicle inspections, performed by the NPRA, are the main venue for catching the perpetrators. If meltwater runoff is observed during such inspections, the trucks are given out-of-service orders, meaning they are prohibited from continuing their journey until the runoff fully subsides (Hofstad, 2023; Skogstad, 2021), and any solid chunks of ice in the winter season are removed (Skogstad, 2024). Drivers often comply by running their refrigeration units at sub-20 °C temperatures, still often having to wait for several hours before they are allowed to continue driving (Ersfjord & Kringstad, 2020). Naturally, this comes at a cost for the transport companies and producers, and it puts drivers in tough situations to meet delivery timelines.

Roadside vehicle inspection personnel are also disheartened, some displaying remorsefulness when sanctioning truck drivers, as "*that is not where the problem starts*" (Hofstad, 2023).

Solutions to the Problem

In the fall of 2020, the seafood industry established a working group in partnership with the Norwegian Truck Owners Association, in order to compose a national industry standard to tackle the meltwater runoff problem. Most importantly, it mandates that the consignment note, i.e., document which follows the shipment, should state the core temperature of the fish before loading.

Further, the temperature within the trailer is to be logged throughout the shipment. Lastly, there is to be direct communication from the NPRA with the slaughterhouse from which the shipment originated, if any particular truck is found to cause salmon runoff during a roadside vehicle inspection (Kyst.no, 2020). However, the agreement does not seem to open up for the possibility of warranting sanctions against producers, drivers or trucking companies who fail to comply with the terms.

In addition to industry agreements, there are other solutions proposed to end the problem of meltwater runoff (A.-M. Johansen, 2023):

1. Fish may be refrigerated for longer periods of time at the slaughterhouse before being placed in the crates. Slaughterhouses are also looking into installing enhanced cooling systems, but these have costs which may amount to 12-14 million NOK (Nodland, 2024). Systems which facilitate so-called *supercooling* nearly eliminate the need for ice in the crates. Supercooled fish is chilled quickly using subcooled liquids or dry ice, such that less ice is needed during shipment to maintain the appropriate temperature (Brostrøm, 2022). This makes room for more fish in each crate, with prospects for removing 15 000 trucks annually. Alternative refrigerants could also be used, which do not produce runoff, such as dry ice. This, however, is more expensive than ice production, while introducing health and safety concerns and removing the possibility for visual quality inspection by the customer upon arrival at the destination.

2. Trailers can be retrofitted with collection tanks, as are used for all salmon shipments in the Faroe Islands (Barbøl, 2020). These, however, have a limited capacity of approximately 250 liters, and require expensive modifications. Furthermore, there are very few places to dispose of this liquid, which would have to take place up to two or three times in Norway during conventional shipments. These factors make the scalability of collection tanks limited in the short-term. Yet, there are a few Norwegian trucking companies who have put such equipment to use (Førde, 2021).

3. Watertight crates may be used instead of the current ones. Such crates are already used for transporting salmon by air (Rotabakk et al., 2022, p. 1,), and they differ from the conventional ones in that they do not have holes which allow the meltwater to escape. Such crates, however, must be designed with absorbent pads or closed compartments to collect the meltwater, preventing it from splashing back up and contaminating the fish. Hence, they come at a price premium to current crates, at an added cost of about 3 NOK per crate, or 0.14 NOK per kilogram of fish (Sundolitt, 2021), amounting to 1 000 NOK per truckload (Nodland, 2024). In the case of absorbent pads, these are cited to be expensive while constituting a previously non-existent waste product which the customers must get rid of. For the case of closed compartments which collect the runoff, customers are skeptical of the prospects of receiving “process water” at the bottom of the crates (Olsen, 2020). In spring 2024, the largest Norwegian salmon farming company announced that it plans to ship 70% of its volumes in watertight crates, but the rest of the industry has thus far not followed suit (Lorentsen, 2024).

More than three years after the industry standard was created, the problem persists, and the extent of the problem does not seem to diminish (Adresseavisen, 2023; Hestad, 2020; Vatlestad, 2024). In fact, in some areas, it even seems to have worsened (Jenssen, 2023). As stated by the NPRA, "*runoff from fish transport is far from being a closed chapter*". According to the seafood industry, "*the solution will not come tomorrow, because this is work that will take time"* (Bye, 2021). In the meantime, some suggest that more frequent inspections and tougher penalties could stop the problem. Some even suggest penalizing the buyers of the fish to force the upstream supply chain to comply (Adresseavisen, 2023).

To this effect, the NPRA has submitted a proposal to the Ministry of Transport to change the regulations such that stricter fees can be imposed at roadside inspections. The amended regulations would be better suited for this particular challenge (Vatlestad, 2024), as opposed to the more vague formulations in the aforementioned regulations for vehicle use. The magnitude of the fee has not yet been determined, but the proposal seems to open up for fining the slaughterhouse, the trucking company and the driver (Jenssen, 2023). This regulation is postulated to be in place by the end of 2024. The NPRA believes that the ability to enforce economic sanctions may persuade more companies to use watertight crates, as the cost of such crates may be lower than the fee for non-compliance (Lorentsen, 2024).

THE MISSING PIECE

While the aforementioned solutions do exist, the Norwegian salmon farming ecosystem has thus far largely failed to solve the problem. Alongside stricter sanctions, it is pertinent to believe that conclusive, data-backed research on the traffic safety effects of meltwater runoff would expedite the necessary changes.

An introductory literature review using various combinations of key phrases used to describe the runoff problem was undertaken on Google Scholar[3] in May 2024. In summary, a state-of-the art on the traffic safety effects of runoff from salmon road freight is conspicuously absent from the scientific literature, until now. Only a handful of newspaper articles in English were found which brings up the issue (The Fish Site Limited, 2023; Wilcox, 2023). Apart from the work carried out by Nofima, literature on *any part* of the problem is in short supply. In fact, all other academic publications which materialized from the literature review look solely at how runoff *from* roadways, e.g., road dust and tire particles, affects fish in nearby waterways, which is nearly the polar opposite of the Norwegian case, where the runoff originates on trucks and *ends up* on the road.

The seafood industry acknowledges that the meltwater runoff may adversely impact traffic safety (Grøntvedt, 2023), but it still calls for documentation on the actual traffic safety effects. County officials have also requested such reports (Myrhaug, 2018; Rønningen, 2018), but nevertheless, such research has not yet been undertaken. As stated by the Norwegian Seafood Federation: "*We have to look at whether [runoff] is a serious problem. If we have clear and unambiguous documentation that [runoff] causes cars to end up off the road, we have to sit down with the transport industry and see how we can solve the problem* (H. Karlsen, 2020)".

Since Norwegian seafood exports are poised to grow in the future, such research may provide a suitable and productive venue for ending the meltwater runoff problem. Ideally, such research should be published in open-access

[3] Keywords and phrases: Salmon, farmed fish, runoff, transport, road freight.

journals, making Norwegian findings available to an increasingly international audience of researchers, practitioners and policymakers as the fish farming industry grows.

The following paragraphs suggest research opportunities to study the safety effects of meltwater runoff from salmon shipments.

Qualitative Stakeholder study

The news media portray the runoff issue nearly exclusively from the perspective of roadside vehicle inspection personnel at the NPRA. Hence, it would be useful to undertake a qualitative study by means of semi-structured interviews with more actors involved in the salmon transport ecosystem. Examples could be ferry operators, representatives from the Norwegian Accident Investigation Board, the police, the Norwegian Truck Owners' Association, traffic safety organizations, trucking companies, the fish farming industry, vehicle recovery firms, road owners, and maintenance contractors with operational responsibility for heavily trafficked salmon roads. The study should have at least 15 - 20 informants to be suitable for publication in highly ranked international journals. Interviews may elicit examples and anecdotes to contextualize the problem beyond what is available in short-form online newspaper articles.

GIS-Analysis on the Norwegian Road Network

Until the runoff problem is solved, local roads authorities have stated that it is difficult to predict where runoff will lead to low friction, and hence difficult to decide where to intensify winter maintenance to avoid slippery areas (M. Karlsen et al., 2017).

The *Thermodynamic Model of Meltwater Drainage during Fresh Fish Transport* (Rotabakk et al., 2023, p. 11; SINTEF, n.d.) may be put to use by combining it with geographical data on the Norwegian road network. Using truck volumes from each slaughterhouse cluster, alongside data about the typical routes chosen by the drivers, the meltwater model could be used to create a geographic map that allocates the runoff along the road network. This would show which areas and road sections are most prone to the issue, providing basis for e.g., increased inspection frequency or preemptive winter maintenance. Such data could also suggest areas for future localization of disposal facilitates for meltwater collection tanks.

Sharp curves and steep uphill gradients would conceivably lead to more concentrated disposal of meltwater runoff than would flat areas with forgiving alignment. Therefore, horizontal and vertical geometry data from the Norwegian Road Database (Norwegian Public Roads Administration, 2023) could also be used to refine the model by explicitly including problematic areas along the road network.

Quantitative Study of Roadside Inspection Data, Cost of Delays and Traffic Accidents

Access could be obtrained to data from the NPRA regarding roadside vehicle inspections to get a better understanding of the issue, e.g., the frequency of usage bans, and potentially estimate the value loss associated with such bans. The NPRA recorded statistics on the runoff issue until 2021, and this data could also be accessed and used to refine the analysis (Vatlestad, 2024).

Industry estimates suggest that the value of seafood falls by 3 - 8% per day of delay from the start of shipment, and clients may wish to renegotiate purchasing contracts if shipments arrive late (Handberg et al., 2023, pp. 31, 5). While delays from being stopped in roadside inspections may not amount to days, the total hours of delay do add up, and it would be useful to quantify these effects. Such data may also facilitate a better understanding of where in Norway metlwater runoff takes place. The new vehicle recovery database (Norwegian Public Roads Administration, 2024) could also

be accessed and inspected regarding whether it could provide valuable data for such analysis.

Field Study of Friction at Runoff-Prone Road Sections

A field study could be undertaken, for instance within the Hitra or Frøya subsea road tunnels in Trøndelag county. These tunnels connect an archipelago comprising one of the largest salmon farming industry clusters in Norway, such that these tunnels are parts of a heavily trafficked salmon route (Rønningen, 2018). One of the NPRA Roar5 (Road analyzer and recorder) friction measurement vehicles, illustrated in Figure 5 (left), could be used to measure roadway friction, and the tests could be done according to established standards (Norwegian Public Roads Administration, n.d.).

Both tunnels are steep, such that meltwater runoff occurs on uphill sections, of which there is one in each tunnel, and exclusively when leaving the islands, as the trucks mostly return empty. The NPRA may contribute with closing the tunnel for a short while in a low-traffic period of the day, and baseline measurements could be established while driving uphill towards the island, in the oncoming traffic lane. There, the road will be equally worn, but the friction would be unaffected by runoff.

It would also be interesting to explore how the runoff is distributed along the cross-section of the lane. Such a field study would likely gain wideapread attention in news media, county administrations and the local salmon industry, and would showcase a proactive approach to researching and understanding the problem.

Laboratory experiments

Controlled experiments could be performed, e.g., in the snow and asphalt laboratories at NTNU in Trondheim, the former of which is illustrated in Figure 5 (right). There, friction can be measured as a function of varying parameters, such as runoff rate, dry or wet pavement, different levels of pavement wear, road temperature and ambient temperature.

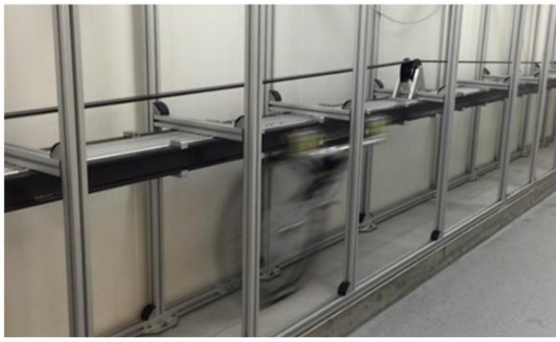
Different temperatures of the runoff itself could also be tested. The goal should be to establish how the friction measures compared to a baseline of a dry, normal road. Can the friction associated with meltwater runoff be compared with e.g. a downpour of rain, an icy road, or something in between?

CONCLUSION

Meltwater runoff from road freight of fresh salmon is a cross-disciplinary issue which has been facing the Norwegian road freight and salmon farming industries for years, and it does not seem as if the problem will subside anytime soon.

While technical solutions exist to avoid it, this paper suggests that more conclusive data on the traffic safety effects of runoff would be useful to expedite the necessary changes. This paper has provided an updated status on the issue, and it has suggested five constructive venues for future research work.

Figure 5: Friction measurement vehicle (Norwegian Public Roads Administration, n.d.) and NTNU snow lab (Klein-Paste, n.d.)



REFERENCES

Adresseavisen. (2023, September 24). *Griseri på trønderske veier: Blodet burde vært stoppet for lengst*. adressa.no. https://www.adressa.no/midtnorskdebatt/i/vej7Jw/griseri-paa-troenderske-veier-blodet-burde-vaert-stoppet-for-lengst

Andersen, N. (2024, April 26). *Måtte parkere etter dette*. adressa.no. https://www.adressa.no/nyheter/trondelag/i/jQPl7b/blodig-avrenning-foerte-til-bruksforbud

Aune, K. V. (2023, October 3). *(+) Da fisketransporten kjørte forbi kontrollplassen, kastet Vegvesenet seg på hjul: – Alvorlig*. Namdalsavisa. https://www.namdalsavisa.no/5-121-1234648

Barbøl, H. K. (2019, October 15). *Stoppet tolv vogntog med fisk*. https://www.mtlogistikk.no/avrenning-fisk-fisketransport/stoppet-tolv-vogntog-med-fisk/164474

Barbøl, H. K. (2020, October 22). *- Her har alle oppsamlings-tank til fiskevann*. https://www.at.no/transport/498245

Bekken, P. R. (2023, September 19). *(+) Stoppet seks vogntog*. opp.no. https://www.opp.no/nyheter/i/gEeyAa/stoppet-seks-vogntog

Berge, A. (2014, November 20). Fyller 130 vogntog—Hver dag. *iLaks*. https://ilaks.no/fyller-130-vogntog-hver-dag/

Berge, A. (2023, December 6). Tyver stjal laks for halvannen million kroner fra parkert lastebil. *iLaks*. https://ilaks.no/tyver-stjal-laks-for-halvannen-million-kroner-fra-parkert-lastebil/

Bergheim, C. (2024, February 11). *(+) Grufullt syn: Hengeren minnet mest om en skrekkfilm*. Hamar Arbeiderblad. https://www.h-a.no/5-139-1417497

Berg-Olsen, V. E. (2021). *Bærekraftig transport av fersk laks* [Bachelor thesis, NTNU]. https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2981104

Boge, L. M. (2022, March 24). *Verdt å vite om superkjøling*. Nofima. https://nofima.no/fakta/verdt-a-vite-om-superkjoling/

Brostrøm, Ø. (2021, June 22). *(+) 19 kjøretøy «tatt» for avrenning: - Dette er triste, men normale tall.* avisa-st.no. https://www.avisa-st.no/nyheter/i/G3BBBl/19-kjoretoy-tatt-for-avrenning-dette-er-triste-men-normale-tall

Brostrøm, Ø. (2022, December 6). *(+) Superkjøling kan få slutt på farlig avrenning: – En ny teknologi som er under utprøving*. avisa-st.no. https://www.avisa-st.no/nyheter/i/8JG2RW/superkjoeling-kan-faa-slutt-paa-farlig-avrenning-en-ny-teknologi-som-er-under-utproeving

Bye, A. E. (2020, August 20). *Avrenning gjør veiene farlige*. Tungt. https://www.tungt.no/article/view/764949/avrenning_gjor_veiene_farlige

Bye, A. E. (2021, February 18). *Ti vogntog fikk bruksforbud i natt! Vil avrenningen noen gang bli borte?* Tungt. https://www.tungt.no/article/view/777837/ti_vogntog_fikk_bruksforbud_i_natt_vil_avrenningen_noen_gang_bli_borte

Eikebrokk, E. (2021, April 10). *(+) Ti vogntog med laks fikk ikke kjøre videre etter storkontroll*. avisa-st.no. https://www.avisa-st.no/nyheter/i/nw1apB/ti-vogntog-med-laks-fikk-ikke-kjore-videre-etter-storkontroll

Ersfjord, E., & Kringstad, K. (2020, September 23). *Trafikkfarlig lakseslam: Her fyller de en tilitersbøtte med rosa gørr på to minutter*. NRK. https://www.nrk.no/trondelag/avrenning-fra-vogntog-skaper-sapeglatt-fore-_-frykter-dodsfall-i-trafikken-1.15172208

Førde, A. H. A. (2021, November 24). *Fiskevann i utekontroll: En transportør hadde oppsamlingstank og alt på stell*. Tungt. https://www.tungt.no/article/view/821706/fiskevann_i_utekontroll_en_transportor_hadde_oppsamlingstank_og_alt_pa_stell

Furuset, A. (2013, October 11). - *Ingen er så travel som en død laks*. IntraFish.No | De Siste Nyhetene Om Oppdrettsnæringen. https://www.intrafish.no/nyheter/-ingen-er-sa-travel-som-en-dod-laks/1-1-733151

Grefsrud, E. S., Andersen, L. B., Bjørn, P. A., Grøsvik, B. E., Hansen, P. K., Husa, V., Karlsen, Ø., Kvamme, B. O., Samuelsen, O., Sandlund, N., Solberg, M. F., & Stien, L. H. (2022, May 4). *Risikorapport norsk fiskeoppdrett 2022—Risikovurdering*. Institute of Marine Research. https://www.hi.no/hi/nettrapporter/rapport-fra-havforskningen-2022-12

Grøntvedt, R. (2023, September 27). *Det er ikke fiskeslo, fiskeavfall og fiskeblod som renner ut på veiene*. adressa.no. https://www.adressa.no/midtnorskdebatt/i/BWX5AG/det-er-ikke-fiskeslo-fiskeavfall-og-fiskeblod-som-renner-ut-paa-veiene

Hammervik, T. (2024a, January 28). *(+) Avrenning fra laksetrailere—Fire fikk bruksforbud*. avisafroya.no. https://www.avisafroya.no/nyheter/i/3EynOv/avrenning-fra-laksetrailere-fire-fikk-bruksforbud

Hammervik, T. (2024b, January 28). *(+) Fire laksetrailere med bruksforbud på grunn av avrenning*. hitra-froya.no. https://www.hitra-froya.no/nyheter/i/q10qMo/fire-laksetrailere-med-bruksforbud-paa-grunn-av-avrenning

Hammervik, T. (2024c, January 28). *Fire laksetrailere med bruksforbud på grunn av avrenning i kontroll på Hitra (+)*. europower.no. https://www.intrafish.no/samfunn/fire-laksetrailere-med-bruksforbud-pa-grunn-av-avrenning-i-kontroll-pa-hitra/2-1-1589725

Handberg, Ø. N., Rognsås, L. L., Ulstein, H., Lund, E. R., Aalen, P., Vennerød, Ø., Gulbrandsen, M. U., & Midttømme, K. (2023). *Menon har vurdert verdien av det offentlige veinettet* (110/2022; p. 60). Menon Economics. https://www.menon.no/menon-har-vurdert-verdien-av-det-offentlige-veinettet/

Hansen. (2019, March 28). *Laks i oppdrett*. Havforskningsinstituttet. https://www.hi.no/hi/temasider/arter/laks/laks-i-oppdrett

Hernes, S. (2021, October 19). Bruksforbud for avrenning. Sjåførene fortviler, mens Statens Vegvesen er oppgitt over næringa. *iLaks*. https://ilaks.no/stadig-flere-

laksetrailere-far-bruksforbud-pa-grunn-av-avrenning-sjaforene-fortviler-mens-statens-vegvesen-er-oppgitt-over-naeringa/

Hestad, K. (2020, August 24). Avrenning fra vogntog med sjømat må stoppe. *Sjømatbedriftene*. https://sjomatbedriftene.no/2020/08/24/avrenning-fra-vogntog-med-sjomat-ma-stoppe/

Hitra-Frøya. (2018, March 17). - *Noen egenerfaringer og spørsmål rundt laksefabrikkenes ansvar når det gjelder avrenning fra laksetrailere*. hitra-froya.no. https://www.hitra-froya.no/meninger/i/7KELXV/noen-egenerfaringer-og-sporsmal-rundt-laksefabrikkenes-ansvar-nar-det-gjelder-avrenning-fra-laksetrailere

Hofstad, M. (2023, August 11). *(+) Avrenning fra 12 av 16 trailere i kontroll*. banett.no. https://www.banett.no/nyheter/i/eJBpO4/avrenning-fra-12-av-16-trailere-i-kontroll

Holberg, J. A. (2021a, August 25). *(+) Fikk bruksforbud – så ble sjåføren stoppet for det samme noen mil lenger sør*. Trønder-Avisa. https://www.t-a.no/5-116-1395905

Holberg, J. A. (2021b, October 19). *(+) Seks fikk bruksforbud i natt: – Ett kjøretøy måtte vente i over én time før avrenningen stoppet*. Trønder-Avisa. https://www.t-a.no/5-116-1422827

Hunnestad, M., & Toftaker, J. (2022, February 3). *Lakseslam skaper trafikkfarlige situasjoner*. NRK. https://www.nrk.no/trondelag/lakseavrenning-fra-vogntog-er-et-vedvarende-problem-for-trafikksikkerheten-1.15839991

IntraFish. (2018, September 21). *Ordforklaringer*. IntraFish.No | De Siste Nyhetene Om Oppdrettsnæringen. https://www.intrafish.no/nyheter/ordforklaringer/2-1-429925

Jensen, B.-A. (2023, July 6). *Avrenning: Seks av sju vogntog ble stoppet (+)*. europower.no. https://www.intrafish.no/hendelser/avrenning-seks-av-sju-vogntog-ble-stoppet/2-1-1482475

Jenssen, T. T. (2023, November 10). Plages av laksesøl i nord: - Kan ikke huske å ha fått så mange klager før. *iLaks*. https://ilaks.no/plages-av-laksesol-i-nord-kan-ikke-huske-a-ha-fatt-sa-mange-klager-for/

Johansen, A. D. (2023, November 11). *Blodvann renner ut av vogntog: 13 av 16 kjøretøy fikk bruksforbud i Steigen*. NRK. https://www.nrk.no/nordland/blodvann-renner-ut-av-vogntog_-13-av-16-kjoretoy-fikk-bruksforbud-i-steigen-1.16632216

Johansen, A.-M. (2023, March 30). *Fullt mulig å bli kvitt avrenning fra lastebiler som transporterer fersk fisk*. Nofima. https://nofima.no/resultater/fullt-mulig-a-bli-kvitt-avrenning-fra-lastebiler-som-transporterer-fersk-fisk/

Johnsen, S. (2023, August 11). *12 av 16 biler fikk bruksforbud fordi det rant fiskeslo av transporten: – Tydelig at dette må følges opp videre*. iSandnessjøen. https://www.isandnessjoen.no/5-108-124477

Kalseth-Iversen, R. G. (2023, September 26). *(+) Rant fiskeblod ut: Nektet flere vogntog å kjøre videre*. opp.no. https://www.opp.no/nyheter/i/4oAM

yR/rant-fiskeblod-ut-nektet-flere-vogntog-aa-kjoere-videre

Karlsen, H. (2020, December 17). *Ny bransjestandard for frakt av fisk*. https://lastebil.no/Aktuelt/Nyhetsarkiv/2021-og-eldre/2020/Ny-bransjestandard-for-frakt-av-fisk

Karlsen, M., Sandmo, E., Bye, A., & Toftaker, J. (2017, December 14). *Laksetransporten iser ned vintervegene*. NRK. https://www.nrk.no/trondelag/laksetransporten-iser-ned-vintervegene-1.13824697

Klein-Paste, A. (n.d.). *IBM - Snowlab—NTNU*. Retrieved May 26, 2024, from https://www.ntnu.edu/ibm/snowlab

Kristensen, K. (2021, October 19). - *Det er ikke vann, det er blod og fett*. adressa.no. https://www.adressa.no/nyheter/i/9Kaan5/det-er-ikke-vann-det-er-blod-og-fett

Kyst.no. (2020, December 17). *Vil stoppe avrenning fra laksetrailere*. https://www.kyst.no/avrenning-sjomatbedriftene/vil-stoppe-avrenning-fra-laksetrailere/638409

Larsen, I. K. (2003). *Verdiskaping ved fisketransporter* (p. 57). Institute of Transport Economics. https://www.toi.no/publikasjoner/verdiskaping-ved-fisketransporter

Lorentsen, O. (2021, October 18). *(+) – Det var så ille når jeg passerte at det luktet fisk*. Trønder-Avisa. https://www.t-a.no/5-116-1417398

Lorentsen, O. (2024, March 13). *(+) Varsler bøter: Nytt produkt kan hindre blodsøl*. Trønder-Avisa. https://www.t-a.no/5-116-1913110

Martinussen, T. M. (2021, May 5). *Ti vogntog i Trøndelag fikk kjørenekt—Fiskeslam rant fra lasten*. europower.no. https://www.intrafish.no/nyheter/ti-vogntog-i-trondelag-fikk-kjorenekt-fiskeslam-rant-fra-lasten/2-1-1005937

Medby, M. (2023, July 12). *Seks av syv vogntog fikk ikke kjøre videre: – Livsfarlig svineri*. VG. https://www.vg.no/i/8JLkBE

Myrhaug, J. M. (2018, February 23). *Utelukker ikke at avrenning kan føre til ulykker*. avisa-st.no. https://www.avisa-st.no/nyheter/i/36pmz0/utelukker-ikke-at-avrenning-kan-fore-til-ulykker

Njåstad, M. (2020, September 24). *13 vogntog med kjøreforbud etter avrenning fra laks*. europower.no. https://www.intrafish.no/nyheter/13-vogntog-med-kjoreforbud-etter-avrenning-fra-laks/2-1-880771

Nodland, E. (2024, April 8). *Roser Mowi: – Forventer at de andre følger etter* [Norwegian Truck Owners Association]. https://lastebil.no/Aktuelt/Nyhetsarkiv/2024/Roser-Mowi-Forventer-at-de-andre-foelger-etter

Nofima. (2019, March 19). *A brief overview of fish farming systems*. Nofima. https://nofima.com/worth-knowing/a-brief-overview-of-fish-farming-systems/

Norsk Fiskerinæring. (2022). *Vekst og investeringsvilje i lakseslakterier*. https://norskfisk.no/2022/10/05/formidabel-vekst-og-investeringsvilje/?

Norwegian Broadcasting Corporation. (2024, April 20). *Åtte vogntog stoppa for avrenning*. NRK. https://www.nrk.no/trondelag/atte-vogntog-stoppa-for-avrenning-1.16851986

Norwegian Offshore Directorate. (2024, May 13). *Statens inntekter fra petroleumsvirksomhet*.

Norskpetroleum.no. https://www.norskpetroleum.no/okonomi/statens-inntekter/

Norwegian Public Roads Administration. (n.d.). *Tilstandsregistrering på veg*. Statens vegvesen. Retrieved May 26, 2024, from https://www.vegvesen.no/fag/teknologi/vegteknologi/tilstandsregistrering-pa-veg/

Norwegian Public Roads Administration. (2021, April 28). *Livsfarlig svineri*. Statens vegvesen. https://www.vegvesen.no/om-oss/presse/aktuelt/nasjonalt/livsfarlig-svineri/

Norwegian Public Roads Administration. (2022, November 4). *109 vogntog måtte stå etter storkontroll mot fisketransporter*. Statens vegvesen. https://www.vegvesen.no/om-oss/presse/aktuelt/2022/11/109-vogntog-matte-sta-etter-storkontroll-mot-fisketransporter/

Norwegian Public Roads Administration. (2023). *Vegkart*. Vegkart. https://vegkart.atlas.vegvesen.no/

Norwegian Public Roads Administration. (2024, February 15). *Nytt samarbeid med bilbergingsselskapene skal gi færre ulykker og bedre framkommelighet*. Statens vegvesen. https://www.vegvesen.no/om-oss/presse/aktuelt/2024/02/ny-nytt-samarbeid-med-bilbergingsselskapene-skal-gi-farre-ulykker-og-bedre-framkommelighet/

Norwegian Seafood Council. (2021, October 4). *Transport av laks*. https://laksefakta.no/lakseoppdrett-i-norge/transport-av-laks/

Norwegian Seafood Council. (2024, January 4). *Prisvekst og svak krone ga eksportrekord for norsk sjømat i 2023*. Mynewsdesk. https://www.mynewsdesk.com/no/seafood/pressreleases/prisvekst-og-svak-krone-ga-eksportrekord-for-norsk-sjoemat-i-2023-3295360

Nøstberg, T. (2024, May 14). *(+) Flere fikk bruksforbud og gebyr etter kontroll på E6*. s-n.no. https://www.s-n.no/nyheter/i/mPRyOq/flere-fikk-bruksforbud-og-gebyr-etter-kontroll-paa-e6

Olafsen, T., Winther, U., Olsen, Y., & Skjermo, J. (2012). *Verdiskaping basert på produktive hav i 2050* (p. 77). Det Kongelige Norske Videnskabers Selskab (DKNVS) og Norges Tekniske Vitenskapsakademi (NTVA). https://www.sintef.no/siste-nytt/2012/verdiskaping-basert-pa-produktive-hav-i-2050/

Olsen, S. (2020, August 6). Avrenning fra laksevogntog: - Vi må fjerne kilden til problemet. *iLaks*. https://ilaks.no/avrenning-fra-laksevogntog-vi-ma-fjerne-kilden-til-problemet/

Pandey, R., Asche, F., Misund, B., Nygaard, R., Adewumi, O. M., Straume, H.-M., & Zhang, D. (2023). Production growth, company size, and concentration: The case of salmon. *Aquaculture*, *577*, 739972. https://doi.org/10.1016/j.aquaculture.2023.739972

Riesto, M. (2023, November 10). *(+) Avrenning: 14 vogntog fikk bruksforbud*. banett.no. https://www.banett.no/nyheter/i/69GQne/14-vogntog-fikk-bruksforbud-etter-kontroll

Rønningen, ilaks/Bjørn. (2018, March 6). *Avrenning fra vogntogene kan ha*

bidratt til ulykker på lakseveiene. hitra-froya.no. https://www.hitra-froya.no/nyheter/i/6zmKOL/avrenning-fra-vogntogene-kan-ha-bidratt-til-ulykker-pa-lakseveiene

Rotabakk, B. T. (2022, October 15). *På tide å få slutt på avrenning fra lastebiler?* fiskeribladet.no. https://www.fiskeribladet.no/debatt/pa-tide-a-fa-slutt-pa-avrenning-fra-lastebiler-/2-1-1334055

Rotabakk, B. T., & Lerfall, J. (2021). *Konserveringsmetoder for sjømat – Muligheter for forlenget holdbarhet til laks* (14/2021; p. 21). Nofima. https://nofima.no/publikasjon/1965610/

Rotabakk, B. T., & Petrich, C. (2022). *Tilgjengelig utstyr for å hindre avrenning—Transport av fersk fisk i Norge* (ISBN: 978-82-8296-736-5 1/2023; p. 16). Nofima. https://nofima.brage.unit.no/nofima-xmlui/bitstream/handle/11250/3041747/Rapport+1-2023+-+Tilgjengelig+utstyr+for+%C3%A5+hindre+avrenning.pdf?sequence=1

Rotabakk, B. T., Petrich, C., & Lerfall, J. (2022). *Hvordan håndteres avrenning fra ferskfisktransport i andre fiskenasjoner, en komparativ studie av Irland, Island og Færøyene*. Nofima AS. https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/3050171

Rotabakk, B. T., Petrich, C., & Lerfall, J. (2023). *Reduksjon av smeltevann fra fisketransport*. Nofima AS. https://sintef.brage.unit.no/sintef-xmlui/handle/11250/3085904

Sae-Khow, N., Svendsen, M., & Toftaker, J. (2022, February 5). *Alle er enige om at dette «gørret» er trafikkfarlig – men ingen gjør noe med det*. NRK. https://www.nrk.no/trondelag/sjomatnaeringen-har-vaert-klar-over-at-lakseavrenning-er-trafikkfarlig-_-men-pa-ti-ar-har-lite-skjedd-1.15841511

Sandberg Hanssen, T.-E., Solvoll, G., Nerdal, S., & Mathisen, T. A. (2014). *Transportstrømmer av fersk laks og ørret fra Norge* (5–2014; p. 67). Universitetet i Nordland, Handelshøgskolen i Bodø, Senter for Innovasjon og Bedriftsøkonomi (SIB AS). https://core.ac.uk/download/pdf/225902952.pdf

Sandholm, J. G. (2024a, January 31). *(+) Tatt i kontroll: Flere bruksforbud og avskilting*. andalsnes-avis.no. https://www.andalsnes-avis.no/nyheter/i/mQABQO/tatt-i-kontroll-flere-bruksforbud-og-avskilting

Sandholm, J. G. (2024b, March 22). *(+) Slitt med store problem: – Men nå er det inngått en avtale*. andalsnes-avis.no. https://www.andalsnes-avis.no/nyheter/i/q1zrR1/slitt-med-store-problem-men-naa-er-det-inngaatt-en-avtale

SINTEF. (n.d.). *Avrenning Fra Ferskfisktransport—SINTEF Narvik*. Retrieved May 14, 2024, from https://ndat.no/avrenning/

Skogstad, K. (2021, July 1). *Svært mange tatt for illeluktende og farlig problem i år*. TV 2. https://www.tv2.no/broom/svaert-mange-tatt-for-illeluktende-og-farlig-problem-i-ar/14095064/

Skogstad, K. (2024, February 12). *Har blitt et stort problem på norske veier*. TV 2. https://www.tv2.no/broom/har-blitt-et-stort-problem-pa-norske-veier/16454051/

Søberg, C. (2024, March 14). *(+) Her renner det så mye at sjåføren fikk bruksforbud*. Arbeidets Rett. https://www.retten.no/5-44-870693

Solberg, P. E. (2023, September 21). *Her står de på rekke og rad etter å ha fått bruksforbud: – Dette er sleipt*. adressa.no. https://www.adressa.no/nyheter/trondelag/i/O8720k/her-staar-de-paa-rekke-og-rad-etter-aa-ha-faatt-bruksforbud-dette-er-sleipt

Solli, B., & Sandmo, E. (2017, March 2). *– Ingen har det så travelt som en død laks*. NRK. https://www.nrk.no/trondelag/_-ingen-har-det-sa-travelt-som-en-dod-laks-1.13405783

Sundolitt. (2021, August 26). *Sunpack 20—Isoporkasse uten avrenning*. https://www.sundolitt.com/globalassets/sundolitt/02.-norwegian-market/01.-blocks/dokumentasjon/2021-08-26-aqua-nor-sjomatbedriftene--avrenning-fra-transport-av-sjomat-final.pdf

Tellevik, A. F. (2018, February 16). *Fikk bruksforbud for avrenning fra fiskelasten*. Tungt. https://www.tungt.no/article/view/763970/fikk_bruksforbud_for_avrenning_fra_fiskelasten

The Fish Site Limited. (2023, April 18). *Study suggests how to eliminate water runoff from fish transport vehicles*. The Fish Site. https://thefishsite.com/articles/study-suggests-how-to-eliminate-water-runoff-from-fish-transport-vehicles

The Norwegian Seafood Federation. (2014). *Laks er viktig | Fagfolk om framtiden*. https://laks.no/lakseeventyret/

Toftaker, J. (Director). (2022, November 3). *8. Kontroll av lakseavrenning på Berkåk*. NRK. https://tv.nrk.no/serie/distriktsnyheter-midtnytt/202211/DKTL98110322

Vatlestad, J. (2021, August 30). *Mattilsynet om avrenning under transport: – Kjempepinlig at Norge som sjømatnasjon sitter og diskuterer dette (+)*. europower.no. https://www.intrafish.no/samfunn/mattilsynet-om-avrenning-under-transport-kjempepinlig-at-norge-som-sjomatnasjon-sitter-og-diskuterer-dette/2-1-1058170

Vatlestad, J. (2024, January 28). *Vegvesenet sier de ikke ser noen bedring. Nå sender de et forslag til departementet (+)*. europower.no. https://www.intrafish.no/samfunn/vegvesenet-sier-de-ikke-ser-noen-bedring-na-sender-de-et-forslag-til-departementet/2-1-1586785

Wilcox, M. (2023, September 20). Runoff from salmon a road hazard warns transport authority: Spot check finds 38% of vehicles unfit for use. *SalmonBusiness*. https://www.salmonbusiness.com/runoff-from-salmon-a-road-hazard-warns-transport-authority/

Wolden, P. D. (2020, September 28). *Vann Stopp stopper vogntog-avrenning*. https://www.mtlogistikk.no/avrenning-vogntog/vann-stopp-stopper-vogntog-avrenning/494224