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Supply Chain Network analysis and recommendations for improved logistics within the SUPREME project

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Skýrsla/Report Matís nr. 18-23

September 2023
ISSN 1670-7192

DOI no. 10.5281/zenodo.8354846

Skýrsluágrip Matís ohf.
Matvælarannsóknir

matís

Report Summary
Icelandic Food and Biotech R&D

ISSN 1670-7192

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Report no.	18-23	Publication date	September 2023
Project no.	62566		
Funding:	The research council of Norway (project nr. 970141669)		
Summary:	This report provides an overview of the main findings of work package 1 in the SUPREME project, which is funded by the Norwegian Research Council (Forskningsrådet). The primary objective of the project is to increase the resource utilization and value creation from whitefish rest-raw materials from the Norwegian sea-going fleet into valuable ingredients and WP1 focuses on mapping and logistics management. WP1 has previously published a report on supply chain process mapping, and this report follows up on that work by presenting a Supply Chain Network analysis and providing recommendations for improved logistics to increase utilisation of rest-raw materials (RRM) from the Norwegian sea going fleet. The total utilisation of whitefish is fairly good compared to most other countries, but it is still possible to improve. The report provides and overview of where, when and in what format whitefish is landed in Norway, and the extent of current RRM utilisation. The whitefish landings are mostly concentrated over just a three-month period (February – April) and overwhelming majority of the catches are landed in just a handful of municipalities. It is therefore evident that in order to increase utilisation the focus should be on improvements where most of the raw material is available. Major part of the catches of the sea-going fleet is landed frozen, headed and gutted; and then exported in the same format. Much of the heads and viscera are not landed in these cases, and other raw materials do not become available in Norway. It is difficult for the sea-going fleet to make changes on their supply chain, as for example onboard technology, human resources and storage space limits the possibilities to preserve and land heads and viscera. In addition, the logistics are also very challenging in Norway. Among the solutions suggested in this report is for the authorities to provide additional incentives for landing RRMs, particularly in the municipalities with significant whitefish landings. This could for example be in the form of adding to the infrastructure in the harbours, or by facilitating that a collector vessel would tranship RRMs to land. Probably the most practical and applicable solution identified in the report is however a rather “low-hanging fruit” that concerns improving information sharing between the different links in the supply chain. Sharing information between the fishing vessels and the processing companies would have mutual benefits in increasing revenue and increasing utilization.		
English keywords:	*Whitefish, Rest-Raw Materials, by-products*		

[1] *Matís ohf.* [2] *SINTEF ocean AS*

SUPREME

Forskningsrådet

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1. Introduction

This report provides an overview of the main findings of work package 1 in the SUPREME project, which is funded by the Norwegian Research Council (Forskningsrådet). The primary objective of the project is to ***increase the resource utilization and value creation from whitefish[*] rest-raw materials from the Norwegian sea-going fleet into valuable ingredients*** and WP1 focuses on ***mapping and logistics management***. WP1 has previously published a report on supply chain process mapping, and this report follows up on that work by presenting a Supply Chain Network analysis and providing recommendations for improved logistics to increase utilisation of rest-raw materials (RRM) from the Norwegian sea going fleet.

2. Background

2.1 Available rest-raw materials and their utilization

The total catches of the Norwegian fishing fleet amounted to 2.140 thousand tonnes (round weight) in 2021, of which 1.365 thousand tonnes (64%) were pelagic species, 718 thousand tonnes (34%) whitefish species, and 57 thousand tonnes (3%) crustaceans (Myhre, Richardsen, Nystøyl, & Strandheim, 2022). The aquaculture industry produced additional 1.616 thousand tonnes of fish. The 718 thousand tonnes of whitefish were used to produce 403 thousand tonnes (56%) of main products, and the remaining 315 thousand tonnes (44%) were therefore the "so-called" RRM, of which 175 thousand tonnes were utilised into various applications, including human consumption, feed and biogas production. This means that 80% of the total whitefish catches were utilised in one form or another, while 20% were not utilised at all. From the 315 thousand tonnes of RRM that were available in 2021, a total of 175 thousand tonnes were utilised, which amounts to 56% of the available materials. For the past three years there has been a decrease in utilization of RRM, from 61% being utilized in 2019.

Compared to most other seafood nations an 80% utilisation factor is extremely good, especially when considering that majority of the RRM that are not currently utilised are viscera and heads that are discarded at sea. One of the primary explanations for why the utilisation factor is not even higher is that there is still a shortage of technological solutions and economic incentives to bring the RRM to shore.

There were three counties that accounted for more than 94% of the total available whitefish RRM in 2021. The counties are Troms og Finnmark, Møre and Romsdal, and Nordland. Within these counties there are relatively few municipalities that account for the mainstay of the landings, such as Ålesund and Giske in Møre og Romsdal, Tromsø and Båtsfjord in Troms og Finnmark, and Sortland, Vestvågøt

[*] *Overwhelming majority of Norwegian whitefish catches are of the species Atlantic cod (Gadus morhua), haddock (Melanogrammus aeglefinus), and saithe (Pollachius virens); but to much less degree species such as common ling (Molva molva), tusk (Brosme brosme), Atlantic wolffish (Anarhichas lupus), and more.*

and Øksnes in Nordland. Figure 1 shows the availability of whitefish RRM by county in 2021, and what type of RRM they were i.e. heads, viscera, liver, roes, milt, cut-offs, bones/frames and other (Myhre, Richardsen, Nystøyl, & Strandheim, 2022).

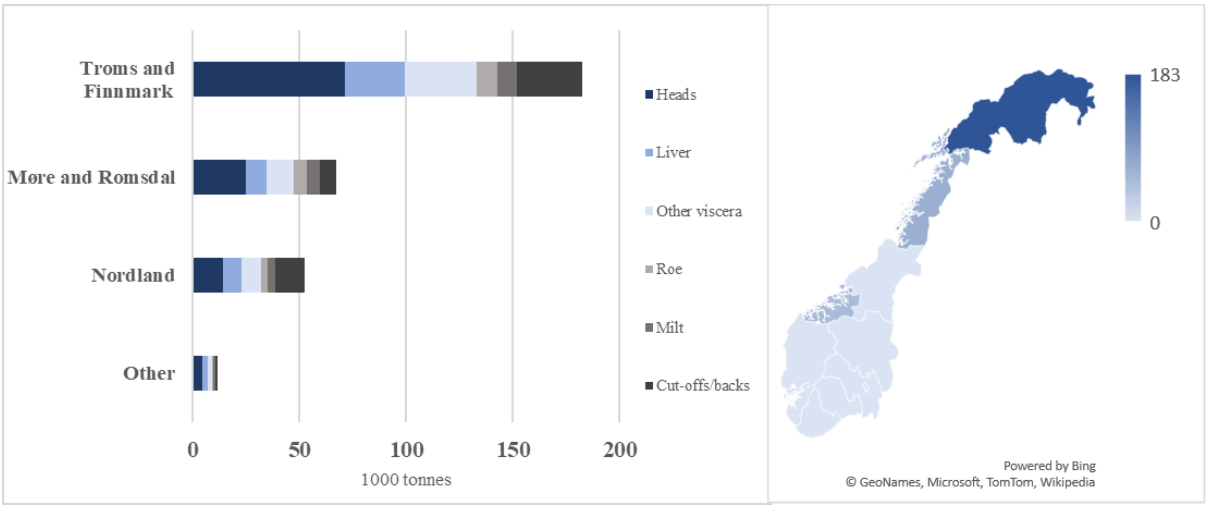

Figure 1 – Available RRM from the whitefish sector by regions in 2021.

Most of the whitefish is landed as frozen, headed and gutted (H/G) whole fish, especially in Tromsø where 89% of the whitefish landings in 2021 were whole frozen fish. There are few municipalities that land significant proportions of the catches as fresh fish, but those that do are Øksnes in Nordland, Nordkapp in Troms & Finnmark. The proportion of catches being landed as frozen-at-sea fillets or portions is extremely small. The coastal fleet lands its catches fresh and the seagoing fleet lands most of its catches frozen. There is very little utilisation of RRM onboard the fishing vessels, but there are though some vessels that process the RRM into silage or fish meal onboard.

For the most parts, there is clear separation between the catching and processing in Norway, where the fishing vessels and the processing companies are owned by separate entities. It is therefore a push supply chain system where the processors must process the fish they receive. The incentives to land the RRM are therefore limited, as the vessels want to get the most profit out of each fishing trip (days-at-sea) and save their storage space for the highest value products. The Icelandic whitefish industry provides an example of the opposite, where a vertically integrate supply chain, or pull supply chain system where the processors place an order to their fishing vessels based on the customer orders and quota status. By this way the processors, who own the vessels, try to get the most value from their quota, which creates an incentive to make as much value out of the entire catch as possible, including RRM.

There are 524 actors in Norway that process the fish by conventional methods (klipp fish, salted fish and stock fish) and 1.003 other actors. Troms & Finnmark, and Nordland have 84% of all conventional actors but only 53% of other actors. Nordland stands out, having the majority of other actors compared to conventional actors (270 vs. 169, respectively). Nordland also has the highest number of

actors processing fresh fishwhich has the highest value seen from a hierarchy of valorisation and probably the most significant options increased utilisation of RRM.

Among the challenges for improved utilisation of whitefish RRM in Norway is the extreme fluctuations in supply, as around 50% of the catches are landed in the period from February to April (Fiskeridirektoratet, 2023). This uneven supply makes it complicated to invest in infrastructure that is able to cope during high supply and is also economically viable when supply is low.

2.2 Landing sites and processing facilities

The total landings of whitefish by the Norwegian fleet in 2021 amounted to 706 thousand tonnes* (round weight) of which 95% were landed in just three counties, as shown in Figure 2 (Fiskeridirektoratet, 2023)

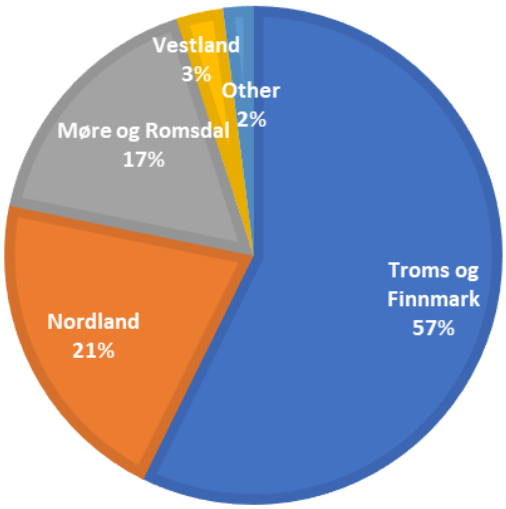

Figure 2: Proportion of total whitefish landings of the Norwegian fleet by county in 2021

When including the landings of foreign vessels in Norwegian harbours, the total whitefish landings amounted to 818 thousand tonnes, and if the flatfish landings are also included the total volume reached 917 thousand tonnes, as shown in Table 1 (Fiskeridirektoratet, 2023)

* *There is a small discrepancy in total whitefish landing numbers presented in chapter 2.1 and 2.2, which is most likely explained by the fact that Fiskeridirektoratet is constantly updating its databank, whilst the Sintef report was based on the available data at the time the report was published.*

Table 1: Landings of whitefish and flatfish by county in 2021

County	Norwegian fleet whitefish landings	Norwegian fleet whitefish and flatfish landings	Total whitefish landings	Total whitefish and flatfish landings
Troms og Finnmark	404.807	445.536	510.551	560.297
Nordland	147.643	163.336	153.374	169.225
Møre og Romsdal	118.642	147.460	118.645	147.648
Vestland	21.193	23.459	21.200	23.473
Other	13.951	15.844	14.000	15.899
Total	**706.236**	**795.635**	**817.770**	**916.542**

These counties are however quite big and have a large number of municipalities and landing harbours. There are for example 35 municipalities with one or more harbours in Troms og Finnmark alone. This geographical distribution of landing sites, coupled with often long and difficult transportation routes, make it particularly challenging to increase utilisation of RRM that requires some sort of infrastructure for added value processing. There are though relatively few municipalities that account for the mainstay of the whitefish landings, which can provide the necessary economy of scale to justify investment in infrastructure. There were for example two municipalities that accounted for 53% of the whitefish landings in Troms og Finnmark in 2021, and the top seven accounted for 88% (Figure 3). Similarly, there were three municipalities that accounted for 58% of the whitefish landings in Nordland (Figure 4), and 80% of all whitefish landings in Møre og Romsdal were landed in Ålesund, as shown in Figure 5 (Fiskeridirektoratet, 2023).

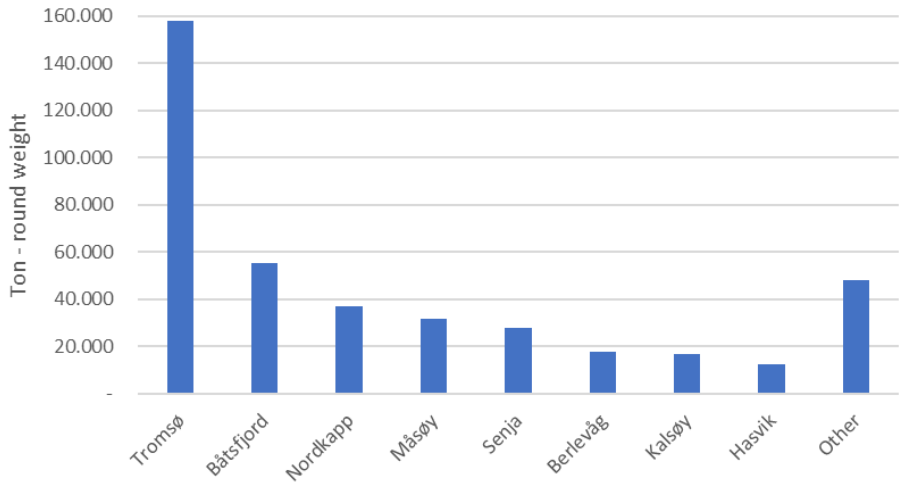

Figure 3: Whitefish landings in Troms og Finnmark in 2021 by municipalities

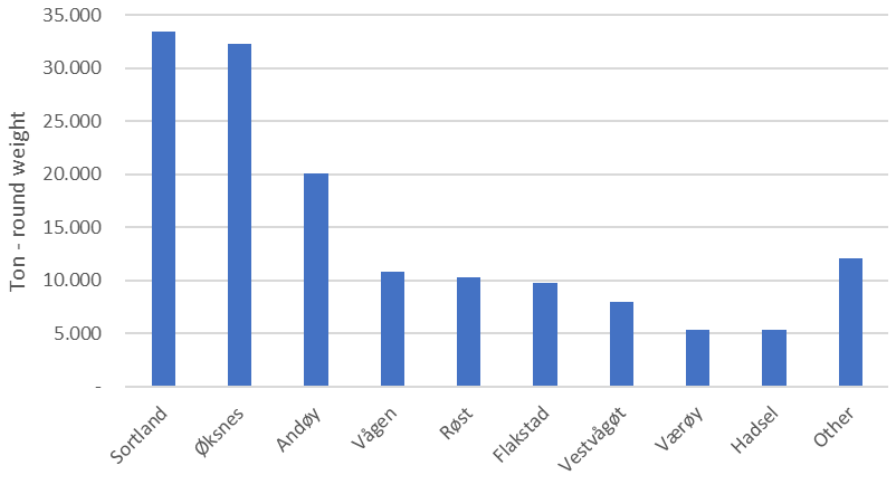

Figure 4: Whitefish landings in Nordland in 2021 by municipalities

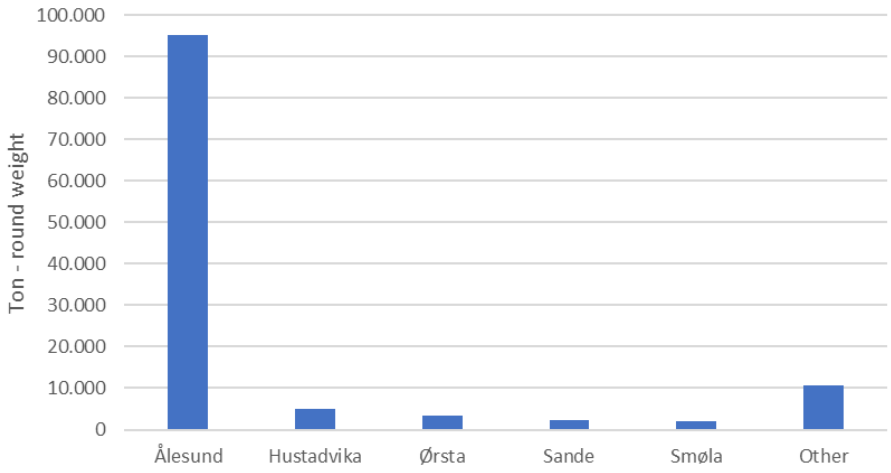

Figure 5: Whitefish landings in Møre og Romsdal in 2021 by municipalities

Tromsø is by far the most important municipality in Norway when it comes to landing whitefish species, representing 22% of the total landings in 2021. Ålesund followed with 13% of the total landings and Båtsfjord with 8%. There were in fact only nine municipalities where an excess of 20 thousand tonnes of whitefish were landed in 2021, and these accounted for 69% of the total landings, as shown in Figure 6 (Fiskeridirektoratet, 2023).

1	Tromsø	158.144	22%
2	Ålesund	95.035	13%
3	Båtsfjord	55.239	8%
4	Nordkapp	36.965	5%
5	Sortland	33.469	5%
6	Øksnes	32.329	5%
7	Måsøy	31.568	4%
8	Senja	27.914	4%
9	Andøy	20.087	3%
10	Other	215.486	31%
		706.236	100%

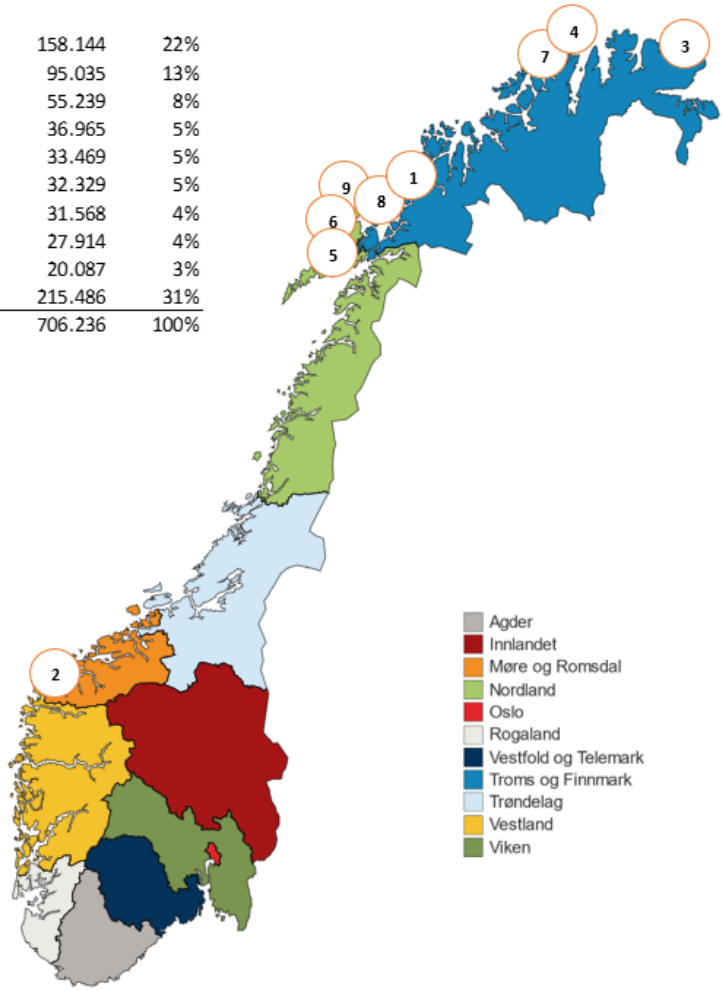

Figure 6: Location of nine municipalities that accounted for 69% of the total whitefish landings in 2021

The geographical distribution of the main landing sites of whitefish suggests that there might be three main hubs for processing of RRM that depend on larger-scale investment. The type of products landed does however make a big difference regarding potential utilisation of RRM, where as almost the entire volume of whitefish landed in Tromsø, Ålesund and Sortland is frozen-at-sea (mostly H&G) that is exported without any furter domestic processing. The opportunity to utilise RRM from such landings are therefore extremely limited. Fish that is landed fresh and then processed into e.g., fillets, portions, salted, dried or other such added value products provide more opportunities for utilising RRMs. The proportion of frozen and fresh landings in the main whitefish municipalities are shown in Table 2 (FangsData, 2023).

Table 2: Whitefish landings in the most important municipalities in 2021, showing volumes landed by Norwegian and foreign vessels as well as the distribution between frozen and fresh products.

		Norwegian vessels	Foreign vessels	Total	Frozen	Fresh	Frozen	Fresh
1	Tromsø	158.144	58.571	216.715	207.391	9.324	96%	4%
2	Ålesund	95.035	0	95.035	87.390	7.645	92%	8%
3	Båtsfjord	55.239	29.479	84.718	56.613	28.105	67%	33%
4	Nordkapp	36.965	0	36.965	221	36.744	1%	99%
5	Sortland	33.469	5.726	39.195	39.195	0	100%	0%
6	Øksnes	32.329	0	32.329	0	32.329	0%	100%
7	Måsøy	31.568	0	31.568	0	31.568	0%	100%
8	Senja	27.914	140	28.054	4.061	23.993	14%	86%
9	Andøy	20.087	0	20.087	0	20.087	0%	100%
10	Other	215.486	17.618	233.104				
	Total	**706.236**	**111.534**	**817.770**				

In 2021 approximately 358 thousand tons of cod, haddock and saithe products were exported from Norway (Norwegian seafood council, 2022). In Figure 7, the number of actors within each region is presented (Sintef, 2023). The actors are divided into those who have conventional processing plants such as Klippfisk, salted fish and stock fish, and then other types of processing actors. Data on exports of products from each municipality mentioned previously is not accessible, as such detailed information is considered private.

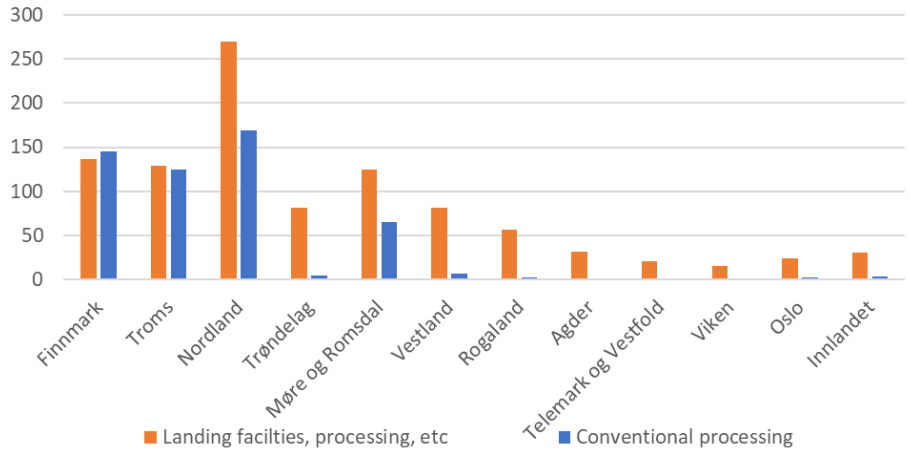

Figure 7 - Number of actors per county (Troms and Finnmark separated) (SINTEF Ocean, 2023).

Table 3 shows the number of whitefish processing facilities by method of processing in the counties where most of the whitefish is landed (Sintef, 2023). When looking more closely at the data, and by comparing it to the landing statistics presented in Table 1, it becomes apparent that processing methods vary between counties.

Table 3 - Number of actors per county for each processing type in 2021

	Finnmark	Troms	Nordland	Trøndelag	Møre og Romsdal	Vestland
Fresh fishery products plant	57	47	111	33	43	21
Mechanically separated meat est.	1	-	4	1	1	-
Prepared fishery products	45	44	74	27	37	37
Processing plant klipp fish	4	8	5	1	33	1
Processing plant salted fish	22	20	60	3	27	4
Processing plant stock fish	119	97	104	1	5	2
Processing plant-general	11	11	38	5	15	9
Processing plant-wild fish	22	22	33	9	20	9
Re-wrapping establishment	1	4	5	4	5	1
Slaughtering of marine fish	-	1	5	2	4	4
Total	**282**	**254**	**439**	**86**	**190**	**88**

In Troms and Finnmark there are 536 actors who process fish, of which 216 (40%) produce stock fish, whilst the proportion of stock fish processors is much lower in the other counties. Trøndelag also stands out with high proportion (38%) of fresh fish processing, and Vestland with high proportion (42%) of companies producing prepared fishery products. Another interesting observation is that most of the whitefish landed in Møre og Romsdal is landed frozen, but still they generate relatively high quantities of RRM as shown in Figure 1 and have 43 actors producing fresh fishery products and 37 actors producing prepared fishery products. Finnmark, Troms and Nordland have a combined total of 439 conventional actors or 84% of all conventional actors and 536 other actors or 53% of all other actors. This means that these regions which share highest quantity of whitefish landed have lower degree of processing than other regions such as Trøndelag, Møre og Romsdal and Vestland who have higher proportion of unconventional actors.

2.3 Transportation of fish and seafood products in Norway

Norway spans approximately 1,750 km from its northernmost point to its southern most point, which is a further distance than from London to Rome. The roads in Norway are also challenging due to harsh weather conditions, high mountains, deep fjords, and thick forests. Still, there is a saying that "*nothing is in as much hurry as Norwegian salmon*". Logistics and transportation of fish and seafood products is therefore a key issue for the industry, and a major factor when considering utilisation of RRM. As presented in the previous chapter, whitefish is landed in harbours all across the country, but the majority of the landings are in relatively remote municipalities in northern Norway, where logistics are particularly challenging.

Transportation by sea is the most common transport method for fish and seafood products, representing 60% of the total transported volume. Relatively large part of Norwegian seafood is frozen, salted or dried, which makes sea transportation ideal as the logistics are not so dependent on quick delivery. Land-based transportation is however dominating for logistics of fresh seafood and

RRM. Figure 8 shows the main land-based transportation routes in northern Norway in 2021 and the location of the main actors / seafood suppliers (Transportutvikling, 2023). There are about 200 processors and 20 salmon slaughterhouses in the area, which transported 1,695 thousand tonnes of seafood and byproducts in 2021. The transport of wild capture fish amounted to 960 thousand tonnes (57%) and aquaculture products 765 thousand tonnes (43%). About 46% of the volume was trucked over the border to Sweden, Finland, and Russia, of which overwhelming majority went to Sweden where the road system is better for large trucks (onward to Europe and beyond), 35% was transported domestically by train, and 19% was trucked domestically. There are 12 border posts in northern Norway connecting to Sweden, Finland, and Russia, 11 of them are being used for transportation of fish, and two of them are open 24 hours/day.

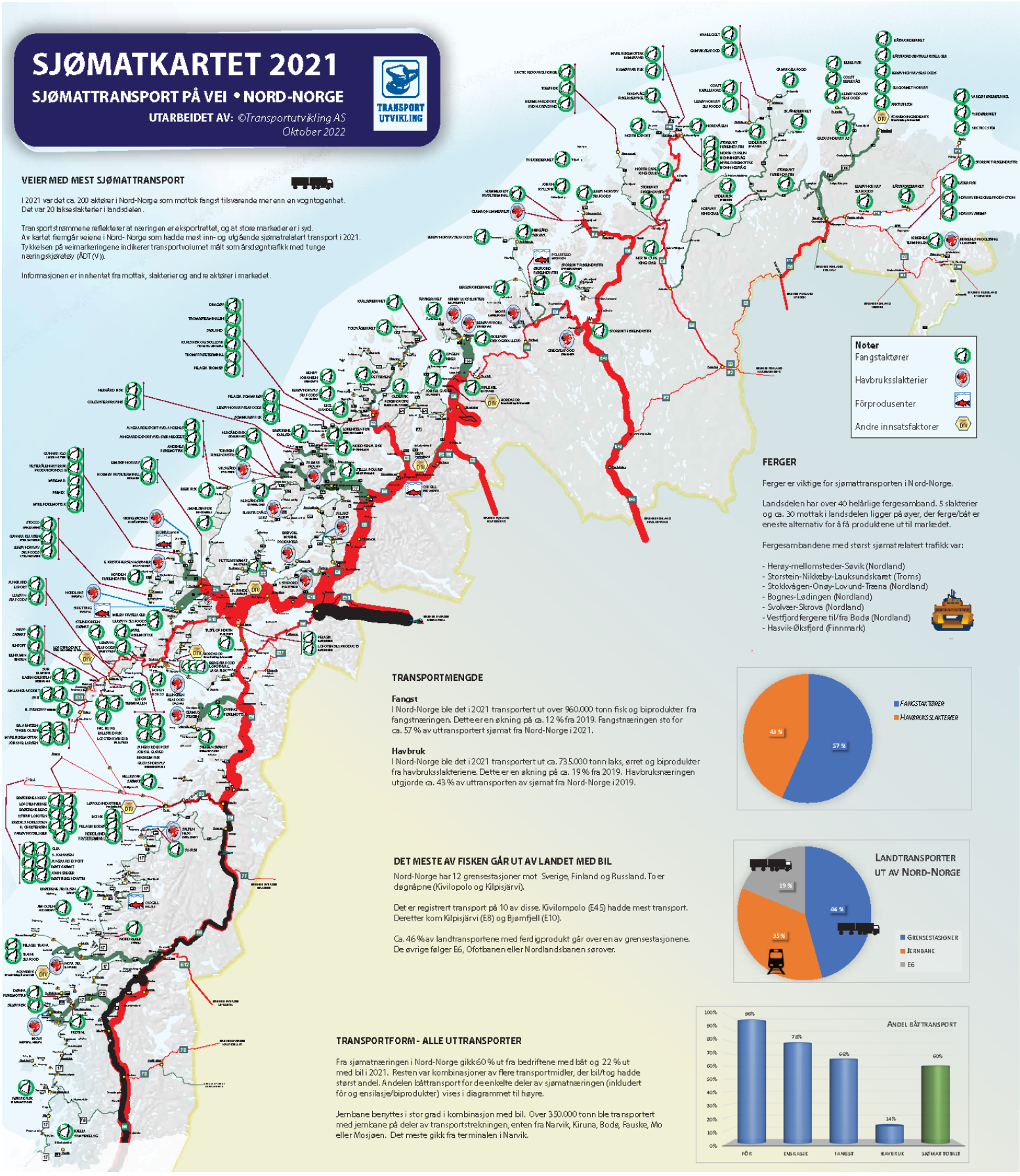

Figure 8: Transportation routes of fish in north of Norway 2021

The figure shows the logistics routs of Norwegian seafood from the north of the country and builds on the information already presented on where the whitefish is landed. The information provides some indications on where RRMs are generated and therefore where there might be the biggest opportunities to increase utilisation.

2.4 Supply chain network

The Norwegian whitefish supply chain is relatively complex in nature due to seasonal variations, high supply uncertainty, complicated logistics and rapid quality deterioration. The cod fishery takes largely place when it's easiest to catch the Barents Sea cod, which results in high volumes of cod being landed between February and April. About 50% of the annual whitefish catches are landed in February, March and April, as shown in Figure 9 (Fiskeridirektoratet, 2023).

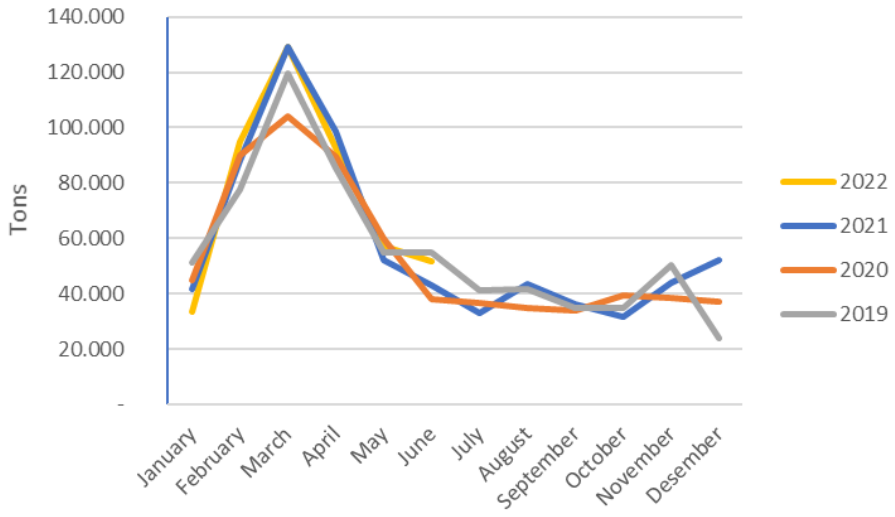

Figure 9 - Whitefish landed by Norwegian vessels by month.

In 2021 the Norwegian fleet landed a total of 706 thousand tonnes of whitefish with a catch value (first-hand price) of 10.6 billion NOK (Ølmheim, 2022) . Cod represented 54% of the volume and 65% of the value, saithe accounted for 27% of the volume and 17% of the value, and haddock for 14% of the volume and 14% of the value (Norwegian seafood council, 2022). Exported cod products amounted to 199 thousand tonnes of products, valued at 9.8 billion NOK, where klippfisk represented 46% of the value, frozen cod products 34%, and salted products 12%. Exported volume of saithe was 98 thousand tonnes valued at 2.5 billion NOK, and exports of haddock products amounted to 61 thousand tonnes valued at 1.6 billion NOK.

In comparison, the Icelandic whitefish fishery takes place all year round with relatively stable supply of fish that is dominantly landed fresh. As shown in Figure 10, there is good availability of whitefish throughout the year and never a particular overflow (Statistics Iceland, 2023).

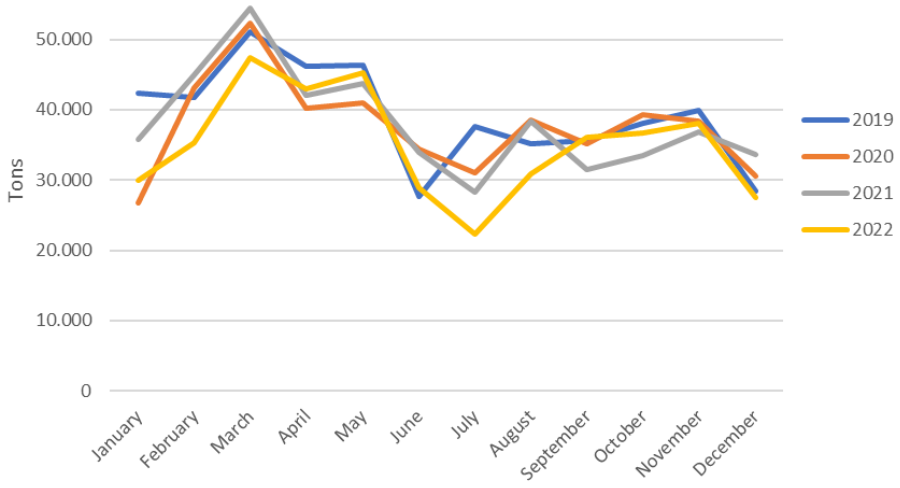

Figure 10 - Whitefish landed by Icelandic vessels by month.

A total of 457 thousand tonnes of whitefish was landed in Iceland 2021 with a catch value of approximately 7.8 billion NOK. Cod represented 59% of the volume and 66% of the value, saithe accounted for 13% of the volume and 9% of the value, and haddock 12% of the volume and 14% of the value (Statistics Iceland, 2023). The total volume of whitefish products exported was 281 thousand tons, valued at 13.5 billion NOK. Cod products accounted for 50% of the volume and 66% of the value, saithe for 12% of the volume and 7% of the value, and haddock for 9% of the volume and 11% of the value. Approximately 38% of the cod products were frozen accounting for 35% of the value, 33% were fresh accounting for 43% of the value, and 17% were salted representing 16% of the value.

The Norwegian and Icelandic whitefish industries have similarities in main products produced and export markets. Their approach is however different, as Iceland focuses more on domestic processing and exporting high price, fresh whitefish fillets and value-added products. whilst Norway focuses more on exporting main products with minimum processing, such as whole frozen (h/g), fresh whole fish and klippfisk. Approximately 45% of the Norwegian whitefish exports in 2021 were frozen fish, of which 90% was whole frozen. At the same time only 20% of the exports were fresh products, of which 95% was whole, unprocessed, fish (Ølmheim, 2022). The main export country for frozen fish from Norway in 2021 was China[*] with approximately 40% of frozen exports, followed by the UK with 14% of the volume. The exports of fresh whitefish went predominantly to Denmark, which accounted for 58% of the volume.

The different approaches partly explain why there is less availability of RRM in Norway than in Iceland. Large parts of the available fish heads are discarded at sea in Norway, and cut-offs, frames/bones, skin, viscera and other potential side streams are exported as part of the final product, whilst these are generally processed into by-products in Iceland. Figure 11 shows a flow chart for RRM from whitefish, identifying where the side streams are generated (Myhre, Richardsen, Nystøyl, & Strandheim, 2022).

[*] *Norwegian whitefish is exported to China for processing and is then largely re-exported back to the EU*

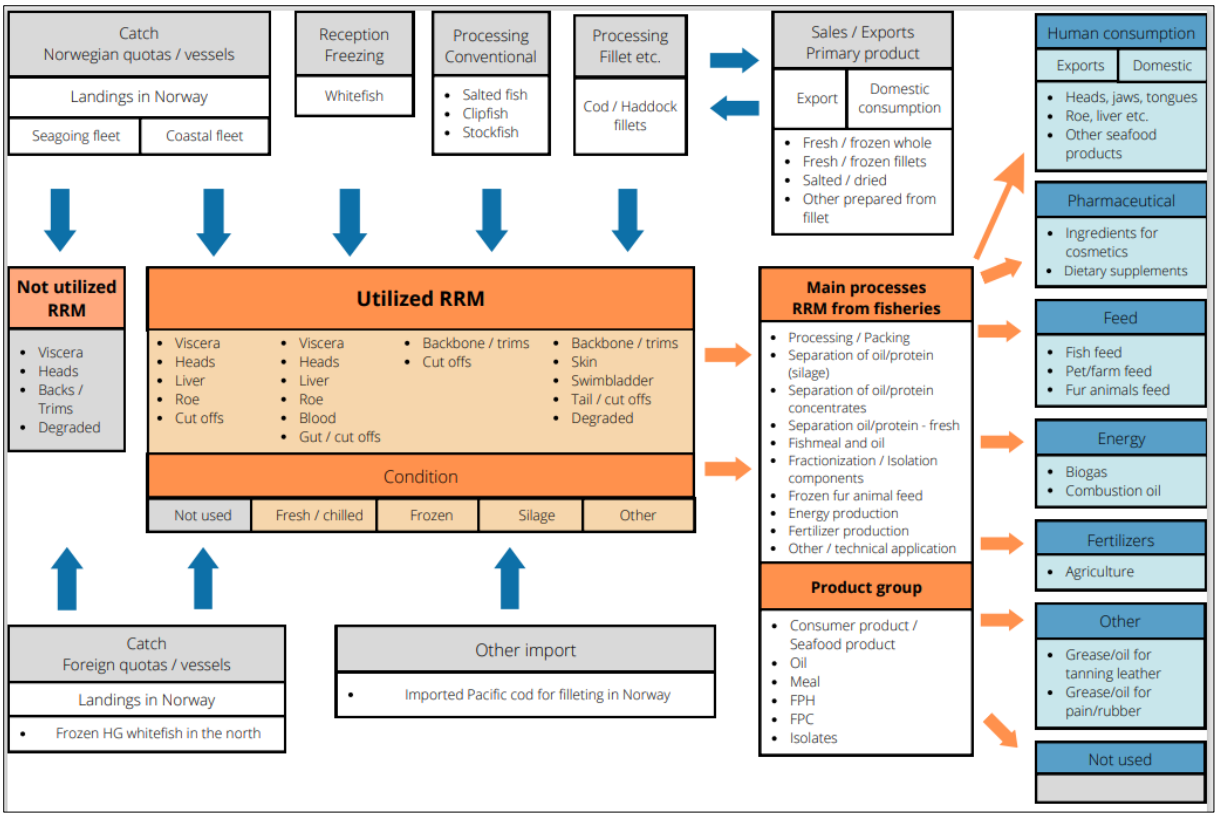

Figure 11 - Flow chart for rest raw material from whitefish

In 2021 approximately 63 thousand tons (13%) of products produced from RRM was made for human consumption, whilst 327 thousand tons (67%) was animal feed and 99 thousand tons (20%) biogas (Myhre, Richardsen, Nystøyl, & Strandheim, 2022). This distribution suggests that there should be opportunities to increase focus higher up in the value pyramid.

2.5 Traceability and information flow within the whitefish industry

The organization of transactions, the flow of goods and information flow in the supply chain is of great significance for value creation and depends on many factors. Information sharing is one of the main supply chain strategies for reducing uncertainty. Between the processors and the vessels, it plays a central role in supply chain collaboration and is vital for supply chain efficiency, in terms of reducing costs and creating coordinated decision-making (Sahin & Robinson, 2005). In food production the information systems in marketing are often well connected to the processing information systems, or at least to the product inventory. However, when it comes to displaying marketing information from the other parts of the value chain, no such system is generally available in the seafood industry in Norway (Thakur & Gunnlaugsson, Information sharing strategies in whitefish supply chains in Norway vs. Iceland: Impact on supply chain decision making, 2018). Information on products exported from individual processors in Norway is considered proprietary information and was therefore not available for this report, but some assumptions were made from the available data in previous chapter.

Norway and Iceland produce similar products from whitefish and export to similar markets, but studies have shown that Iceland has had more market success over the same periods of time, where Icelandic whitefish is generally fetching higher prices than the Norwegian whitefish. Norway and Iceland have different strategies in the whitefish industry, as has been mentioned in previous chapters. Norwegians catch whitefish in bulks over a short period and therefore their marketing is more unified while Icelanders catch whitefish all year round with market strategies that are more fragmented and on company level. Figure 12 shows the flow of information and material at the seagoing fishing vessel in Norway. The company has direct contacts with buyers or can sell through auctions. Daily production reports are used to manage the on-board operations (Thakur & Gunnlaugsson, Information sharing strategies in whitefish supply chains in Norway vs. Iceland: Impact on supply chain decision making, 2018).

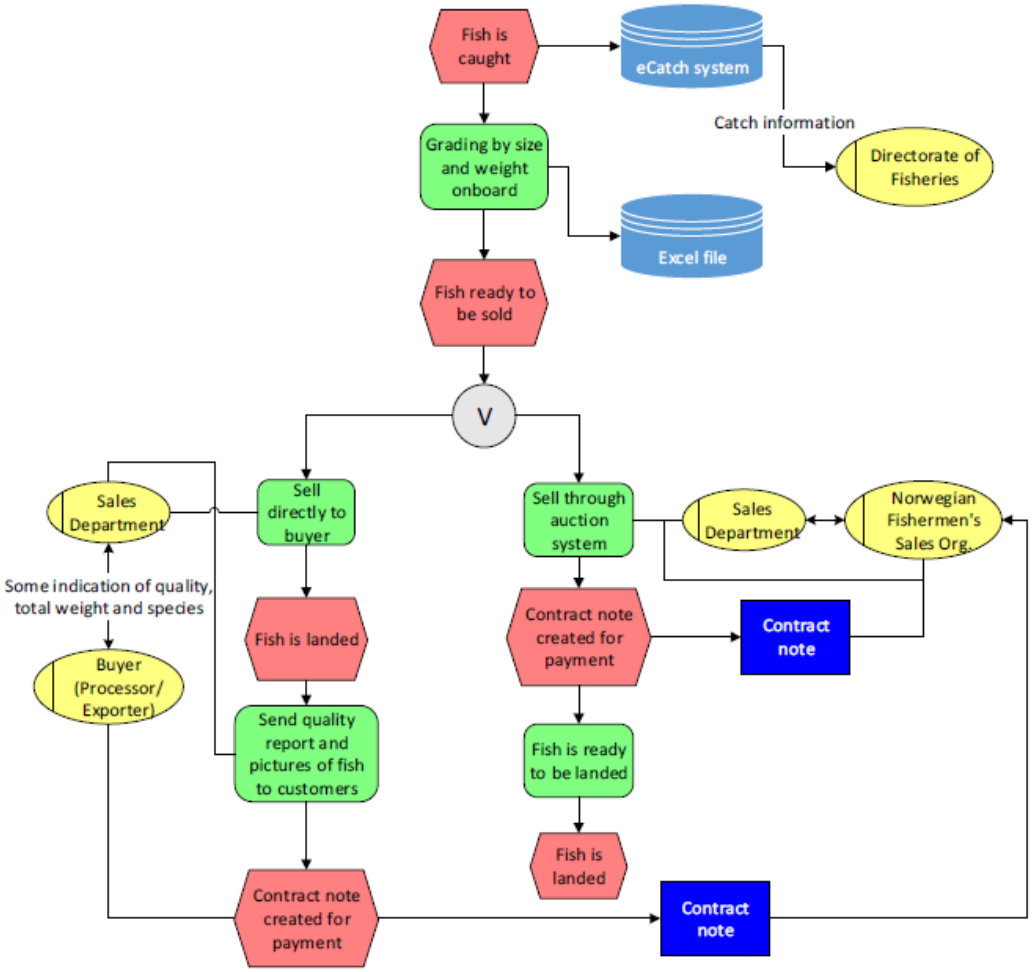

Figure 12: Information and material flow at the seagoing fleet in Norway

Figure 13 shows the flow of information and material at the processor in Norway. The first step in the supply chain is the catching process which is described in Figure 12. In-season, the fish is mostly delivered by coastal vessels (fresh) while in off-season, the fish is delivered mostly frozen either by seagoing vessels or transported from another processing plant of the same company. Fish is graded on board by size and a contract note is created using the information from grading. This information

is communicated to the respective Norwegian fishermen's Sales Organization that communicates the catch information to Catch Certificate SA for issuing the catch certificate (Thakur & Gunnlaugsson, Information sharing strategies in whitefish supply chains in Norway vs. Iceland: Impact on supply chain decision making, 2018).

Figure 13: Information and material flow at the processor in Norway

Figure 14 shows the flow of information and material between the fishing vessel and the processor in Iceland. The Icelandic whitefish industry uses a vertically integrated supply chain, where the

processors own their own fishing vessels. That means the processors place an order to their fishing vessels based on the customer orders and quota status. This can be called pull supply chain system instead of push supply chain system used in Norway, where the processors must process the fish they receive (Thakur & Gunnlaugsson, 2018).

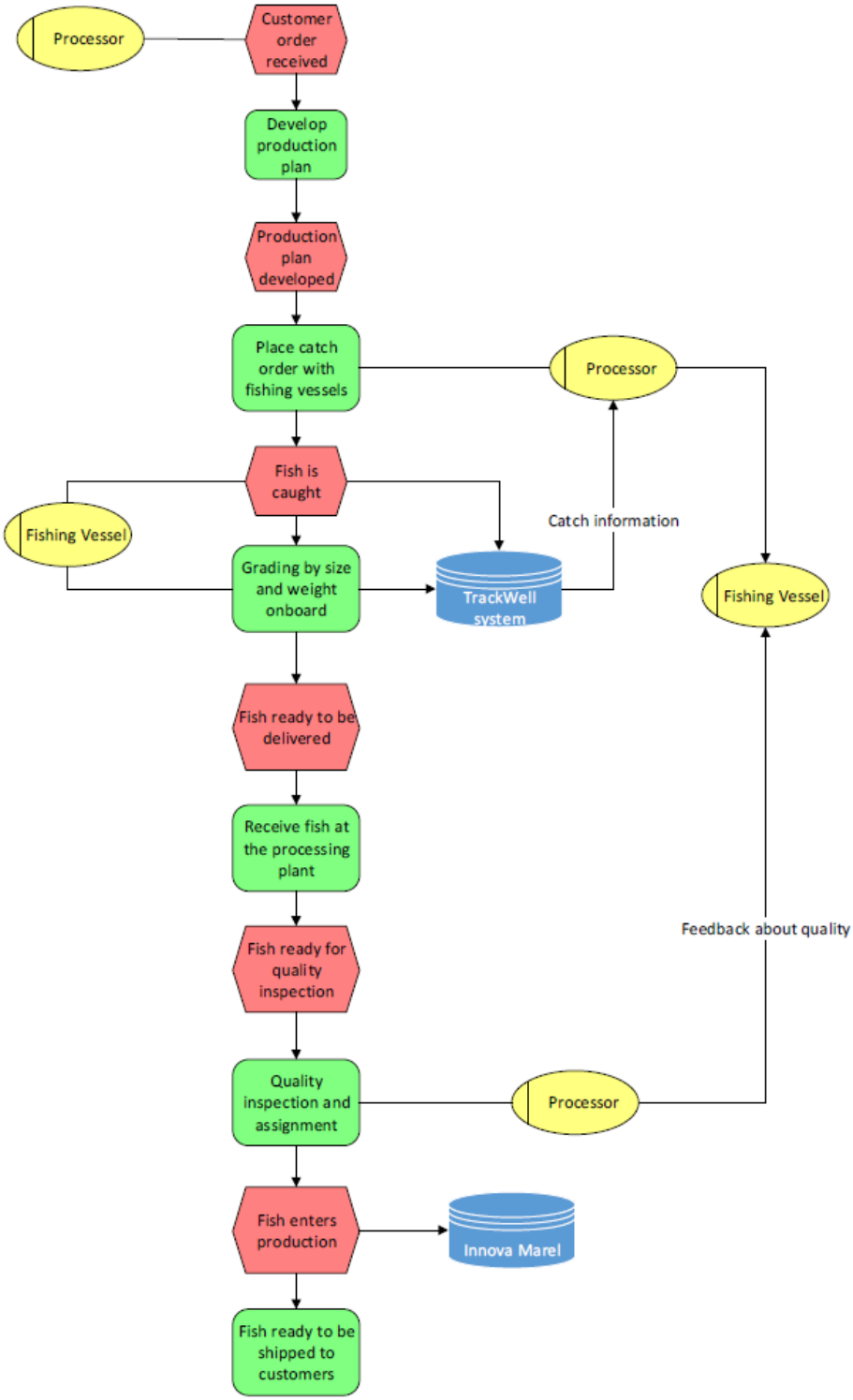

Figure 14: Information and material flow between the fishing vessel and the processor in Iceland

The Icelandic processors send orders to the vessels concerning demand of volume of each species, area of catch and when to land, to deliver the desired size and quality of raw material needed for fulfilling customer orders. By this approach, the complete catch information as well as the additional information, such as the trip, haul, fishing gear, etc. is available to the processors. Most of the information however is not used for improving the supply chain planning but can be used to plan fishing trips in the future. The quality check is done after landing and not on the fishing vessel. The haul time, haul size, sea temperature or time from catch till bleeding, could be used as a quality indicator. The processor however buys 20-25% of their raw material on the market as the Norwegians do and face similar problems with information sharing. The desire of all Icelandic processors is to cover their market demand solely through catches from their own vessels to be able to have a better control of the catch quality.

3. Recommendations for supply chain improvements

3.1 Improved supply chain network

Based on the information presented in this report, and in the previously published report on supply chain process mapping, it is evident that utilisation within Norwegian whitefish supply chains can be improved, especially RRMs resulting from the sea-going fleet. Potential (theoretical) available RRMs from the whitefish industry was approximately 315 thousand tons in 2021, of which about 175.000 tons (56%) was utilised (Myhre, Richardsen, Nystøyl, & Strandheim, 2022). This means that approximately 80% of the round weight of the whitefish caught in 2021 was utilised in one form or another. Compared to most countries an 80% total utilisation from round weight is extremely good, as most countries only utilise 45-55% of their whitefish catches (Icelandic Ocean Cluster, 2021). But there is still room for improvement.

The main challenge for the sea-going fleet is that the fishing trips typically last for long time and the vessels have limited processing capacities and storage space. The human resources onboard the vessels are as well occupied in handling the main products, and the time available for attending to RRM is therefore extremely limited. Efficient technological solutions onboard the vessels are therefore needed, along with the proper economic incentives. But these are largely lacking in the Norwegian sea-going fleet. There are some vessels that have an onboard fishmeal plant, which provides the opportunity to utilise 100% of the catches, but the value adding is limited. There is also an option to produce/preserve the RRM in silage, which is though even less valuable than the fishmeal but requires less expensive and complicated technology. Producing fish protein hydrolysate (FPH) or fish protein concentrate (FPC) onboard a vessel has also been attempted, with variable results (Egelyng, o.fl., 2018) (Gamlem & Farstad, 2016). Simply freezing the RRMs is one way of landing the side-streams with good quality, but the freezing is challenging due to limited freezing capacities and storage space in the freezing hold. The size and shape of whitefish heads is an extra challenge when freezing in block freezers and the capacity of the systems is often maxed out with just freezing the main products.

Suggesting solutions for use of whitefish RRM depends on the objective of the utilisation. If the aim is solely to increase utilization within the whitefish industry, regardless of value creation, then finding the easiest way to land the RRM resulting from sea-going vessels and processing it into low value products such as fishmeal or silage could be the solution, since all of the RRM is then going to be processed. The high price of fishmeal and fish oil at the moment might make this a viable option for some vessel owners. If the goal however is to maximise value, the solution could be to process higher amounts of RRM into high-quality added-value products such as pet food, protein hydrolysates, collagen, or bioactive compounds. This can be done onboard fishing vessels, but at high cost. It would therefore likely be more practical and cost-efficient for municipalities with high quantities of whitefish landed every year, such as Øksnes, Nordkapp, Båtsfjord, Tromsø and Ålesund, to invest in infrastructure to facilitate added value processing of RRMs.

It could also be a good idea to operate a transport vessel that sails between the larger sea-going vessels and picks up the RRMs and brings it ashore when storage is full. That way the large sea-going

vessels would have more space for main products during their fishing trips and wouldn't be limited to landing heads or viscera which take up considerable storage space. This solution, however, needs a cost-benefit analysis as well as an environmental consideration for being feasible.

Utilisation of viscera can be particularly complicated, due to the fact that it contains digestive trace content that falls into Category 2 of the EC animal by-products regulation and is therefore not allowed for human consumption (EC, 2009). It is therefore necessary to separate the intestines that are intended for human consumption before further processing or storage. If the liver is then separated from the viscera, then it will create new challenges, as handling it will contaminate the machinery with oil/lipids and storage is complicated due to lipid oxidation. If liver is frozen in block freezes the storage is tricky, as only part of the water content will actually be frozen.

Comparing the whitefish utilisation in Norway to Iceland suggests that it is possible to improve. A recent study by the Icelandic Ocean Cluster shows that whitefish utilisation in Iceland is approximately 90% (Icelandic Ocean Cluster, 2021). The 10% difference in utilisation between the two countries has several explanations, but the main reason is that higher proportion of the round weight is not landed in Norway. The integration between catching and processing in Iceland is also a big factor, and the logistics are as well more challenging in Norway. An example of the differences between Norway and Iceland when it comes to practical obstacles to grab opportunities for added value processing is the utilisation of fish skin into collagen. The investment in processing equipment is substantial and requires reliable high-volume supply of fish skin to be economically viable. Many of the larger Icelandic seafood companies have therefore invested together in a collagen factory where their fish skins are processed (Marine Collagen ltd.). The owners can secure the factory approximately 50% of all fish skins that are available in Iceland, and the logistics are relatively easy. Similar approach would be much more complicated in Norway, and the logistics would also be more challenging. A joint venture by the industry, similar as Marine Collagen ehf. in Iceland, or infrastructure investment by key municipalities such as Øksnes, Nordkapp, Båtsfjord and Tromsø that have large quantities of whitefish raw material flowing through, could have great opportunities for higher value-added production, such as collagen. For this option to be feasible the whitefish suppliers within these municipalities would need to cooperate, as the investment cost is substantial.

3.2 Value added Rest-Raw Materials

Whitefish RRMs, such as skin, scales, bones, heads, cut-offs, roe, milt and visceral components can be categorized depending on handling. To be suitable for human consumption and animal feed, the RRM must be handled according to the hygiene regulatory framework, and national/international classifications (EC, 2009). Some RRMs handled according to the by-product regulatory framework cannot be used for human consumption but can still be used for animal feed if the quality is good. Low quality and high-risk materials on the other hand can be used exclusively in production of feed for animals that are not intended for human consumption, biofuels, as fertilizers or be destroyed (Hellnes, Rustad, & Falch, 2020).

In 2021, approximately 67% of the utilized RRMs in Norway were processed into feed for fish and animals, while 12.9% were processed for direct or indirect human consumption (Myhre, Richardsen, Nystøyl, & Strandheim, 2022). It has been estimated that increasing RRM processing into products for human consumption can potentially yield a five-fold value-addition, while also contributing to reduction of malnutrition and hunger globally (Hellnes, Rustad, & Falch, 2020). Products intended for human consumption have generally the highest value-addition, but it is however worth mentioning that pet food has increased in value in the past years due to humanization of pets and increased focus on sustainable production from the pet owners. Figure 15 shows the development of the world price of pet food from 2017 and projected prices until the year 2027 (Bedford, 2023).

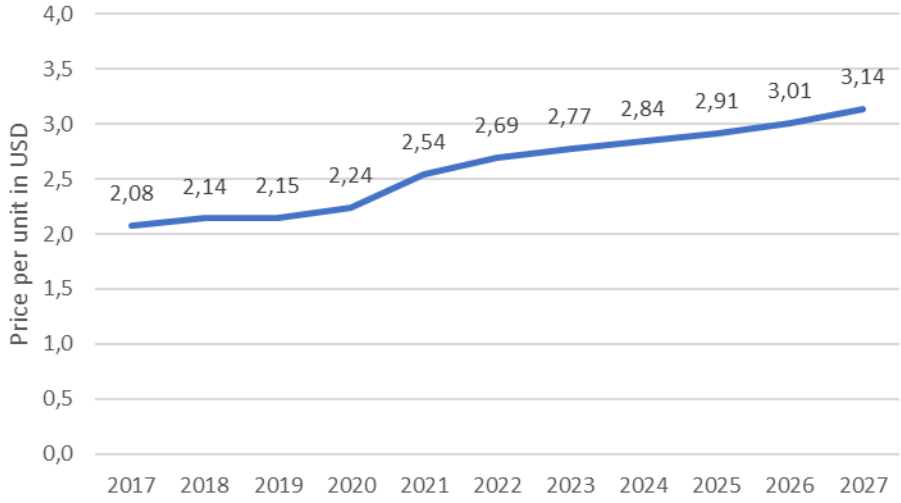

Figure 15 – Average price per unit of pet food from 2017 and projected price increase until 2027

If the projections come true, the average prices of pet-food will increase by 63% in the ten-year period, making pet-food a competitive alternative to human food for suppliers.

There are also niche markets for high-value products made from RRM within food supplement-, cosmetics- and pharmaceutical sectors; all of which depend on high-quality RRMs. The development of these products is generally time consuming and expensive, and subjected to Intellectual Property Rights (patents). There are many success stories of such products being marketed, but more often they are focused on low volume and high value. Examples of these are Unbroken that contains hydrolysed salmon proteins marketed to athletes for faster recovery, Kerecis that produces tissue regeneration plasters from fish skin (and was recently bought by the healthcare company Coloplast for 1.3 billion USD), and ColdZyme that is a mouth spray that protects against common cold viruses and is made from enzymes extracted from cod RRMs.

3.3 Increasing quality of the catch

Increasing quality of fish catches may lead to increased value added and greater profits for all actors along the value chain. However, fresh fish is highly perishable and spoils rapidly, thus appropriate handling during harvest and post-harvest as well as preservation methods are crucial to maintain the

quality and nutritional attributes of fish, as well as reducing waste. It's important to note that a decline in quality during harvest can never be regained in later stages of the value chain. Fishing methods influence the quality of the catch and subsequently the value. Studies have for example shown that market prices for frozen whitefish (cod and haddock) from Norway caught with longlines gained 15% and 13.3% higher prices than fish caught with bottom trawling (Sogn-Grundvåg, Zhang, & Dreyer, 2020). Since fishing methods influence fish quality, it can be assumed that fishing methods represent useful quality signals to buyers. However, there may be quality differences between vessels within the groups of vessels fishing with the same gear due to variations in fishing tactics such as soaking time for gillnets and longlines, and the size of hauls when fishing with Danish seines and trawl. It should be noted that quality grades are usually self-reported, and they may be used to deliberately influence prices (Sogn-Grundvåg, et al., 2021).

The quality of the harvested fish influences the share of high-value products that can be made from the catch. When the catch contains fish of lower quality, the share of high-value products is reduced, diminishing the value of the product mix as a whole. Depending on prices gained, this may then have negative influence on processors costs, revenues, and profits. Thus, when considerable quantities of fish landed are of low quality, there may be negative economic and social consequences for local communities, many of which are strongly dependent on fisheries. There are technical regulations in place, such as draining of the fish's blood or fish that were dead when being taken onboard that should be stored separately. However, compliance with these regulations during peak season might be lacking (Sogn-Grundvåg, et al., 2021).

Many vessels now hold relatively large quota portfolios, often combining different whitefish species such as Atlantic cod, haddock, and saithe with pelagic fish such as herring and mackerel. In order to catch all the different species with sometimes overlapping seasons, incentives for intense and swift fishing tactics are created, where fish quality may be compromised by the quantity of fish landed.

Within the study done by Sogn-Grundvåg et al. (2021), they observed that a high share (30%) of the Atlantic cod in the assessed catches was downgraded, representing a substantial waste of quality compromising the value of the final product in onshore processing. However, the economic results showed that the quality had a rather modest effect on the prices where fishing method was more important for price formation.

As shown in Figure 16 there has been an increase in the proportion of bottom trawl catches in recent years, at the expense of line fishing. Long line fishing is considered the highest quality fishing method and should therefore be the highest value fishing method (Sogn-Grundvåg, et al., 2021).

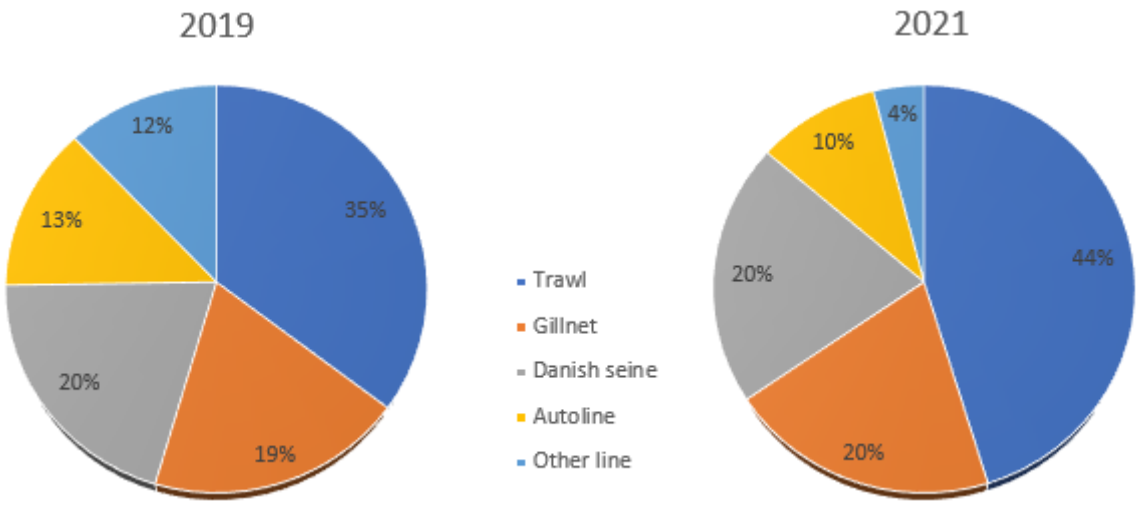

Figure 16: Fishing methods for whitefish for the year 2019 and 2021

Studies have however shown that there is not necessarily a link between quality and prices. Sogn-Grundvåg et al., (2021) reported for example that fish caught using Danish seines gained almost the same price as fish caught by longline, despite substantially better-quality of the longline caught fish. They concluded that buyers lack the information of the quality of fish in individual catches. Typically, the quality of cod is not assessed by the buyers, and the buyers are in addition totally dependent on their suppliers for raw material in a seller's market economy. Buyers are therefore reluctant to reduce prices for poor-quality fish, as the suppliers will then simply just sell to someone else.

3.4 Reverse logistics

Supply chain flows within the whitefish industry in Norway are mostly focusing one-way to this day where the fishers control the supplies to companies processing the fish before it reaches the consumer, or from material and resources to customers. There is a need for a new approach regarding supply chains and collaboration because of growing concerns for environmental issues and the impact of logistics and Supply Chain Management on sustainability. Reverse logistics have grown in interest in the past years in order to increase the sustainability of logistics and supply chain management.

The term reverse logistics was defined by De Brito and Dekker (2003) as the "process of planning, implementing, and controlling flows of materials, in process inventory, and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal". This is for example highlighted by Kibii (2013) in Figure 17, as the main focus in the waste management hierarchy should be placed on prevention and reduction of waste, followed by recycling and recovery.

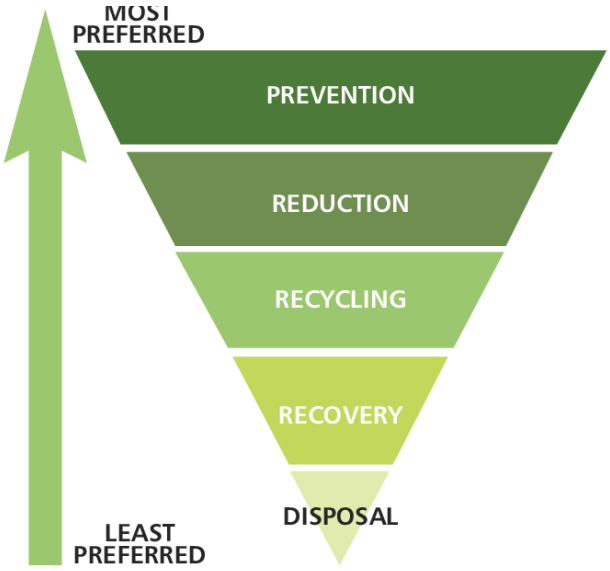

Figure 17 - Waste management hierarchy

In Norway the fishers and processors are typically two individual companies and therefore what is considered waste with the fishers could be valuable raw material for the processors. Information sharing between these industries is very important in order to land more of the RRM from the vessels, especially those that are targeting large quantities of fish each trip, such as the large trawlers that process the main products onboard. Both the fishers and the processors stand to benefit from either collecting the RRM and landing it or processing it into intermediate or final products for consumption.

In the fishing industry, reverse logistics can be quite challenging. Every step of the supply chain needs to be assessed in terms of quantity available and methods to transform products lost at each step into value-added products, not only to reduce the amount lost, but also to create economic value out of those products (Jouvenot, 2015).

3.5 Upgrading

Research in food technology is now tied to environmental considerations and responsible management of scarce resources. This approach tries to connect different goals such as highest product quality and safety, highest production efficiency and integration of environmental aspects into product development and food production (Laufenberg, Kunz, & Nystroem, 2003). The upgrading concept tries to add value to the RRMs and residues generated throughout the supply chain. A transition has already been made from the 'waste logic' to the 'raw materials logic' underlying that waste from fishers can be considered raw materials for the processors (Arason, et al., 2009).

It has already been pointed out that utilization in the Norwegian whitefish sector is very good compared to most countries, but there is room for improvement, especially in the seagoing fleet in the whitefish industry. The seagoing fleet which has onboard processing produces RRM that are discarded into the sea. Hence, an opportunity to apply the upgrading concept and add value to the RRM discards. The quantity and possible strategies for utilizing the discarded volumes have been

presented within this report, and also the logistics for implementing these strategies. The key step in upgrading the RRM strategies is developing markets of products obtained from these RRM to create driving force for collecting and landing the RRM resulting from the onboard processing vessels or process them into intermediate or final products for consumption.

3.6 Landing RRM from seagoing fleet

There are many business opportunities for processing of RRMs onboard vessels, but the lack of human and technical resources, along with limited storage space are the main challenges. The fishermen aren't incentivized properly to collect the RRM since they would lose space for their main products and therefore lose revenue. Some vessels are equipped with an onboard fishmeal and oil plant to process the RRM generated by the main processing line. This is an important step for the willingness of utilizing RRM, although it hampers the possibility of upgrading the RRM to a higher-value end product (Jouvenot, 2015). Without going too deep into regulations and bans on discarding RRM at sea, a solution for landing the RRM could be a collector ship mentioned before. This would lead to better quality RRM being landed for upgrading and would allow fisherman to gain space for their main products. A regulation (or incentive) to empty the storage of RRM once or more to a collector ship before allowing the fishing vessel to land would both allow the fishermen to use their full capacity on main products and the collector ship to make income. The collector ship could bring supplies to the fishing vessels in addition to transporting the RRM, such as fuel, provisions, fishing gears, mail or other items. The vessels, or their owners, would be trading with the processing companies, and they would negotiate prices and onboard procedures guidelines based on their market assessment. Taking this solution further, a collaboration and information sharing between more than one processor would give a stronger incentive to fishermen to land their RRM and give a broader product portfolio.

The main challenges the industry as a whole needs to overcome is information sharing. The collector vessel needs to know where the fishing vessels are, what they have in storage, the route and location for unloading. Other issues that need to be addressed if this solution is to succeed is assessing the needs of the raw materials that the collector vessels are picking up, such as separating, sorting, preserving, and storing the RRM onboard and training of the fishermen if an intermediate processing step is required. The need for additional workers should also be addressed. The recommendation would be to do a feasibility study prior to implementing this solution where all factors would be considered both seen from the processors and the fishermen's interests and analysing every step of the value chain.

3.7 Information sharing

In Norway, improving the information exchange between the vessels and processing companies presents several benefits. These benefits include improved production planning and improved fishing operations e.g., selecting the best fishing areas. The temperature and product condition are available onboard the fishing vessels but aren't shared with the processors. If available in advance, the

processors could improve their production planning decisions and in return they could share their information on the quality of the product to the fishing vessels which they can then use to optimize their fishing operations, such as selecting the best fishing areas (Thakur & Gunnlaugsson, 2018).

Improved information sharing between vessels and processors can increase value within the whitefish industry by meeting market demands for better transparency within the value chain. Suggested improvement in information exchange from Thakur and Gunnlaugsson (2018) is shown in Figure 18.

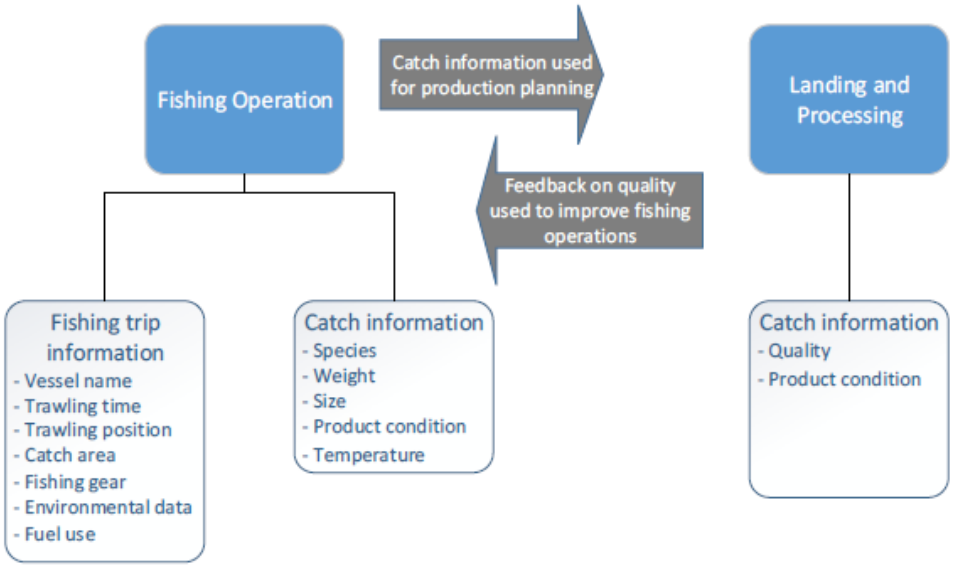

Figure 18 - Suggested information exchange between fishing and processing

The information linked to each operation is already available in the existing systems that are used such as the eCatch and TrackWell systems, and the quality information is recorded by the processors in their internal databases but is not being shared between the two links in the value chain.

In addition to the improved production planning and fishing operations through improved information exchange, it can potentially lead to more benefits such as product differentiation, marketing strategies and supply chain coordination.

In recent years consumer awareness has increased, leading to a stronger demand for product information, especially regarding the origin, sustainability, quality and product history. They want the information to be verified or come from a trustworthy source. A lot of this data is already available, such as where it was landed, processed, packet etc. and can be communicated to the consumer. Such data can provide a differentiation opportunity for the processors that are looking to capture a higher market share by telling a story about their product by means of for example a simple QR code (Viðarsson, et al., 2015).

4. Discussion and conclusion

This report provides an overview of the supply chain network of the Norwegian fisheries industry, its key logistic nodes and information links between the fishing vessels and the processors. Utilization of whitefish RRMs has decreased for the past years from 61% in 2019 to 56% in 2021 (proportion of the theoretically available RRMs). During which time there were restrictions due to covid which may have impacted the RRM utilization and put a hold to investment in new technology for collecting and processing RRMs.

There are three regions in Norway (*Troms & Finnmark, Norland, and Møre &Romsdal)* that share approximately 95% of the total landed catch of whitefish and has therefore the most availability of RRMs that have the greatest potential for being value added. Within these regions there are municipalities that are of particular interest within the whitefish industry with considerable amounts of raw material landings in their ports. These municipalities are Tromsø, Ålesund, Båtsfjord, Nordkapp, Sortland and Øksnes. Providing incentives for the respective vessels landing whitefish in these municipalities, could increase the landings of additional RRM and increase the revenue for the processing companies. In Troms & Finnmark and Nordland most of the whitefish catches landed is processed by conventional processing (klippfisk, salted fish and stock fish) with those two regions having 84% of all conventional actors and only 53% of other processing actors. In Møre & Romsdal however there are almost two times more other processing actors than conventional actors, processing whitefish into high value products.

In recent years there have been considerable investments in technological solutions to handle and preserve the RRM, such as producing fishmeal or oil onboard, or producing fish silage. These solutions are great for increasing utilization but require high investment costs and not all fishing vessels can invest in this machinery. Fish meal, oil and silage are also limited in product portfolio, value adding or upgrading. Case studies from previously published SUPREME report on supply chain process mapping has shown the return of investment for these onboard solutions for Icelandic vessels. The plan of this report's authors had been to replicate and compare such rate of return in selected Norwegian case studies. Unfortunately, the results after contacting several companies were insufficient to complete such exercise. The report focuses therefor more on identifying solutions for improved supply chain network and information sharing within the whitefish industry in Norway.

The solutions presented follow both on how to land the RRM resulting from the seagoing fleet as well as how to increase value of the RRMs already landed. Strong technological solutions for storing the RRMs resulting from seagoing vessels are lacking because the vessels cannot easily afford to lose storage space for their main products. One of the solutions presented is having a transport vessel that picks up RRM from the seagoing vessels and transports it to land where it can be processed into high value products. This vessel can be independent from the companies that own the fishing vessels, or it could be owned by the processors. Another solution presented is increasing the quality of the catch and the RRM. The main products whether they are whole fish, headed and gutted or filleted is frozen or kept cold until landing, same storage conditions are needed for the RRM if they are to be processed into high value products.

Since Norway follows a push supply chain system where the processors must process the fish that they can get, there are limitations to what they can do with the RRM. In order to increase value from alternative processing of RRM, markets must be built and analysed, and production must be planned to know how much quantity can be gathered for the production to return profit. Probably the most important solution presented in this report is information sharing. Sharing information between the fishing vessels and the processing companies can have mutual benefit in increasing revenue and increasing utilization.

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