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Fishmeal and oil from Baltic Sea herring: current uses and challenges for full transparency

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Abstract

Fishmeal and oil from Baltic Sea herring: current uses and challenges for full transparency

Baltic Sea herring fisheries have in recent years attracted considerable media interest in Sweden. The main concerns are deteriorating stock status and lack of herring catches suitable for human consumption. One recurring theme is that the demand of feed raw materials by the Norwegian salmon aquaculture industry is driving the development of increasing volumes destined for fishmeal and oil production. However, it is unclear to which extent Baltic Sea herring is used by the Norwegian salmon industry. This report has the specific objectives to map where Baltic Sea herring ends up, including identification of potential obstacles for full traceability – with the overall aim to identify how different actors may contribute to safeguarding long-term sustainable use of marine resources. Based on data provided by the Danish fishmeal and oil processing industry, it is found that Baltic Sea herring is primarily used for the aquaculture sector, especially the fish oil. However, although some feed and salmonid producers were helpful in providing the requested information, responses varied and only piecemeal information could be obtained on the next step in the value chain, i.e. to which specific species and countries. Although annual sustainability reports are published, efficient, fit-for-purpose extracts on the destination of raw material from a certain stock may be effort-demanding to extract and official data detailing this is at large lacking. The same situation also applies for certified aquaculture. Further, the definitions of 'sustainable fisheries' applied in current certification systems are inadequate to fully safeguard use of sustainable marine raw material for certified, farmed seafood. Several actors are however working with improvements, such as a new feed standard for Aquaculture Stewardship Council and updates on internal reporting systems by feed producers. In conclusion, to improve transparency and build consumer trust – and ultimately foster sustainable use – it calls for i) more efficient data management strategies and detailed reporting by feed producers to be able to meet questions raised; and ii) sharper rules for feed ingredients allowed by current aquaculture certification standards and a more distinct difference to non-certified seafood related to sustainability and transparency of marine resource use.

Key words: Baltic Sea, herring, fishmeal and oil, feed, aquaculture, salmon

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Content

1 Background

Baltic Sea herring fisheries are struggling with poor stock status and landings are increasingly being destined for feed instead of food. There is a common perception in Sweden that the Norwegian salmon farming industry is an important recipient for fishmeal and oil from Baltic Sea herring fisheries, driving current practices, yet it remains unclear to which extent Baltic Sea herring landings are ending up in Norwegian salmon feeds (Hornborg et al. 2023). World Wildlife Fund (WWF) in Sweden considers improved traceability and transparency in this question as important, as well as identifying improvement potentials. To provide further clarity, WWF in Sweden has therefore commissioned RISE Research Institutes of Sweden, to investigate the matter.

1.1 Aim

The overall aim with this report is to identify how different actors may contribute to safeguarding long-term sustainable use of Baltic Sea herring resources. The specific objectives are to, as far as possible, map where fishmeal and oil from Baltic Sea herring ends up, with focus on Swedish salmonid consumption and production, and identify potential challenges both related to full traceability and differences between actors in the value chain.

The mapping is performed through direct contact with value chain stakeholders and examination of available data, combined investigating the following questions to fulfil the objectives:

1. Which companies deliver feed for farmed salmonid production of relevance to the Swedish market (consumption and production) – and how much herring from the Baltic Sea is used in these feeds?
2. Are there other destinations than the aquaculture sector for industrial landings of Baltic Sea herring?
3. What are the dynamics of end destination of Baltic Sea herring between years?
4. Is there a difference in opportunities for full traceability of certified and non-certified feed?

If answers cannot be provided, the reason why is provided and will form the base for recommendations to achieve improved transparency in a topic of societal concern.

2 Material and methods

To identify relevant companies that deliver feed to producers of salmonids of relevance to the Swedish market (defined as 90% of production or consumption respectively), recent reports (Sundblad et al. 2020; As et al. 2022; Johansen et al. 2022), European Market Observatory for fisheries and aquaculture products (EUMOFA) statistics on seafood production and trade (EUMOFA 2024) and expertise on the aquafeed market formed the basis for compilation of information on relevant species, countries and companies. The year investigated was 2023.

Based on this information, different actors in Baltic Sea herring (ICES subdivisions 22-32) and salmonid value chains were contacted via email and telephone between May and December 2024:

–*Fishmeal and oil production facilities*: focus on Denmark through Marine Ingredients Denmark (MID), due to their importance to Swedish industrial landings of Baltic herring (Hornborg et al. 2023), but also other countries around the Baltic Sea processing herring and sprat for fishmeal and oil.

–*Aquaculture feed producers*: main feed producers who supply most of the feed to Norwegian salmon producers were asked on the use of Baltic Sea herring and the dynamics between years. Questions asked are found in Appendix 1.

–*Salmonid producers:* Salmon and rainbow trout producers in Norway and Sweden were contacted to investigate feed use, and specifically use of Baltic Sea herring.

–*Certification:* Aquaculture Stewardship Council (ASC) (https://asc-aqua.org/) , the Swedish organic label KRAV (https://www.krav.se/en/), Debio (https://debio.no/english/) and the Swedish Board of Agriculture (who is responsible for rules for organic certification in Sweden) were contacted to investigate potential differences in opportunities for full traceability of certified and non-certified feed.

In the finalisation of this report, ASC and KRAV were allowed to provide feedback on the first draft on the chapter on their respective organisations concerning the feed approval process and transparency. Input that improved clarity was incorporated in the final version.

To quantify the herring volume in feed, i.e. live-weight fish biomass required behind one tonne fishmeal and oil, is not straightforward. Firstly, the conversion factors differ between species, different fishing areas for the same species and if whole fish or trimmings has been used (Cashion et al. 2016). Further, one tonne of live weight fish is turned into both fishmeal and oil, making it imperative to not double count the volumes needed. Here, a considerably lower volume of fish oil is derived from one tonne of fish compared to fishmeal. As an example, based on industry data, processing live-weight herring from the Baltic Sea into fish oil and meal production (whole fish or trimmings) has a yield of around 15-18% for fishmeal and 6-8 % for fish oil respectively (Quirijns et al. 2023). Standard practice uses the factor with the lowest yield, i.e. oil production, to estimate the total requirement of live weight fish. With this method, which is applied in this report, the extra fish meal generated from the live weight volume (that may or may not be used for the same farmed species) is not subtracted, i.e. representing ‘worst case’ scenario for use of live-weight fish.

3 Results

3.1 The Swedish salmonid market

Based on EUMOFA data for 2023, Swedish import of salmonids comprised of over 98% Atlantic salmon (*Salmo salar)* of which 99% was imported from Norway (Table 1). Farmed salmonid production of relevance to the Swedish market from a consumption perspective is thus Atlantic salmon from Norway. Note that the actual consumption in Sweden (balance between import and export) is considerably less; in the year 2019, Atlantic salmon consumption in Sweden was estimated to be 29 870 tons edible (Hornborg et al. 2021). There is also a discrepancy between different official statistics in total volumes, where e.g. the Norwegian Akvafakta (Akvafakta 2024a) reported exports of 38 397 tonnes of round-weight salmon to Sweden in 2023. The reason for this large variation may be related to complex re-export of volumes from processing in different countries but is not further investigated here.

Table 1 Swedish imports of salmonids in 2023 according to EUMOFA.

Species	Tonnes*	Main import countries
Atlantic salmon	569 615	Norway (99%); Poland (1%)
Trout+	8 249	Norway (94%); Finland (3%), Denmark (1%); the Netherlands (1%)
Other salmonids	943	Denmark (43%); Norway (39%), the Netherlands (13%), Germany (2%), Estonia (1%) and Poland (1%).

*Different presentation formats, sum of both LW and prepared.
+Mainly Rainbow trout (*Oncorhynchus mykiss)* but might also include Brown trout (*Salmo trutta).*

Form a production perspective, Rainbow trout (*Oncorhynchus mykiss)* and Arctic char (*Salvelinus alpinus)* dominate Swedish aquaculture for human consumption (Table 2), but Atlantic salmon and Brown trout (*Salmo trutta)* are also produced for restocking purposes. In 2023, Rainbow trout was farmed for consumption in 41 localities and Arctic char in five. The production of Rainbow trout is largely exported (Sundblad et al. 2020).

Table 2 Swedish aquaculture production of salmonids in 2023 according to the Swedish Board of Agriculture (SBA 2024). Note that these numbers are based on voluntary reporting.

Species	Tonnes (live weight)
Rainbow trout	8 467
Arctic char	Not reported due to confidentiality (1 270 tonnes in 2021)
Other salmonids	Not reported due to confidentiality

In summary, the Swedish salmonid market is on the one hand complex. Considerable volumes of salmonids produced in Norway enters Sweden to be re-exported to other markets, and Swedish aquaculture production of salmonids is mainly exported and thus not consumed in Sweden. On the other hand, Swedish consumption is very homogenic, almost exclusively comprising of Atlantic salmon produced in Norway.

3.2 Destinations of industrial landings of Baltic herring

3.2.1 By sectors

According to ICES Advice in 2024, the total landings of Baltic herring (ICES subdivisions 22-32) by all countries in 2023 was 167 678 tonnes live weight (excluding landings from Gulf of Riga which is mainly destined for human consumption). These landings comprise of different stocks and are fished by different countries, in 2023:

- Out of a total 66 827 tonnes of Gulf of Bothnia landings (ICES subdivisions 30-31), Finland catches the largest share (83%). The Finnish landings are primarily processed in Finland, both to fishmeal and oil and direct human consumption. The remaining volume was caught by Swedish fisheries and primarily processed into fishmeal and oil in Denmark.
- The total 98 696 tonnes of central Baltic Sea herring landings (ICES subdivisions 25-29 and 32 excluding the Gulf of Riga) are fished by many countries: Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. Russia stands for the largest volumes (estimated at 25%, but data are not officially reported to ICES). Poland stands for the second largest fishery (20%), followed by Sweden (17%), Finland (14%), Estonia (11%) and Denmark (5%).
- Fisheries for the most southern stock (ICES subdivision 22-24) contributed to only around 1% of total Baltic Sea herring landings (or around 2 155 tonnes). These landings are primarily destined for direct human consumption and are fished by Denmark, Germany, Poland and Sweden.

Danish fish meal and oil processing factories received 38 027 tonnes of Baltic herring in 2023, representing 23% of total landings described above, which were turned into 6 501 tonnes fishmeal and 2 653 tonnes fish oil. The processing industry in Denmark is a large actor when it comes to processing EU landings from the Baltic Sea, in particular Swedish landings (from all fishing areas) and those from the southern and central Baltic Sea. Based on their data from the year 2023, Baltic herring oil was almost exclusively destined for the aquaculture sector (Figure 1). Baltic herring meal was by 69.3% also destined for the aquaculture sector, the rest being used in agriculture (13.1%) and for pet food (17.5%). A similar pattern is observed for Baltic sprat. Of note, herring and sprat landings are often mixed from the Baltic Sea, and physically separating a mix of the two species into pure herring or sprat products when processing for fish meal and oil is currently not possible (Hornborg et al. 2023). Therefore, the fishmeal and oil processing factories record percentages of the different species in the product and provide this as documentation for each delivery, i.e., a ‘mass balance approach’.

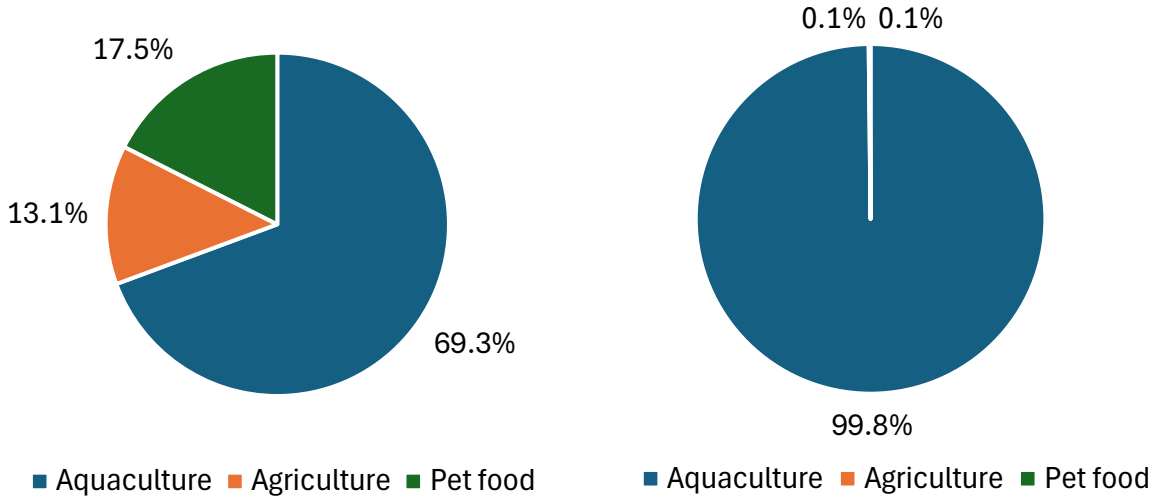

Figure 1 Destination of Baltic herring meal (left) and oil (right) by sector after processing in Denmark in 2023.

The Danish fishmeal and oil processing industry may provide qualitative estimates concerning destinations of the products, informed by export statistics. This indicates that the fishmeal and oil delivered for the aquaculture sector is mainly destined to Norway and the UK. In a next step, feed producers will deliver feed for different species, sectors and countries. It is thus in their internal record keeping systems information is found where the fishmeal and oil is used, following traceability regulations for feed ingredients.

Other factories around the Baltic Sea also process pelagic fish to fishmeal and oil, e.g., facilities in Finland, Poland and Estonia. One of these factories reports that they turned 39 584 tonnes of herring (54%) and sprat (46%) into 8 306 tonnes of fish meal and 3 830 tonnes of oil in the year 2023 (99% of this was based on whole fish). Another of these factories did not process any herring at all in 2023. The production from these factories, are often sold to intermediators that further sell to feed producers, therefore no information on destination could be provided. Some information is found online, e.g. one Estonian factory[1], annually processing around 40 000 tonnes of Baltic herring and sprat, reports that main markets have so far been the European Union, but also countries such as Ukraine, the United Kingdom, the United States, Turkey, Canada and South Korea.

Based on overall data on fishmeal and fish oil usage (all species) from European Fishmeal and fish oil producers (EFFOP 2023), most of the fishmeal destined for aquaculture is used in Asia – in 2021, China used 41% and other Asian countries used 28% – while Europe used 10%. However, the fish oil destined for aquaculture was mainly used in Europe (39%), while only 25% in Asia. Other sources may indicate utilization of fishmeal in livestock production (i.e. pigs and poultry), but not if – and how much – of this that is based on herring from the Baltic Sea. As an example, Swedish pig production utilizes fishmeal, estimated at roughly >0.01 kg/kg per slaughtered pig (Landquist et al. 2020). Chicken production under the label 'Svensk fågel' in Sweden (99% of production) is not allowed to include fishmeal in the diets (Svensk fågel 2024). However, fishmeal is utilized in organic production of eggs in Sweden (Svenska ägg 2024), since the dietary

[1] https://www.fishoil.ee/

inclusion of synthetic amino acids is banned for organic production following EU legislation. In terms of utilization of Baltic Sea landings, data in Hornborg et al. (2023) indicated that pig production used a larger share of fishmeal from Baltic Sea fisheries (all species) than poultry production.

3.2.2 Salmonids

In 2023, Norway produced over 1,5 million tonnes of salmon and almost 90 000 tonnes of Rainbow trout (Akvafakta 2024b), a production mainly (>99% of market) supported by a few feed companies (Johansen et al. 2022). The four major feed producers in Norway are Skretting, Cargill, BioMar and Mowi Feed (Aas et al. 2022).

Swedish salmonid farming for human consumption mainly consists of production of Rainbow trout. To our knowledge, mainly two feed producers currently supply the Swedish salmonid production, with one being almost exclusively used for Rainbow trout.

Public reports are available on marine raw material use by different feed companies, but these do currently not report on e.g. how much fish meal and oil is used from a specific species and fishing area (i.e., on a fish stock basis). Upon repeated contact with aquaculture feed producers, it becomes evident that the information sought for is not easily extracted from available reporting systems (see Appendix 1 for questions posed). Few delivered the requested information, and it appeared to be a time-consuming effort. Thus, available systems do not seem to currently allow for simple extracts of the level of detail of data sought for. A general notion was that the use of Baltic herring is a minor share of the total marine raw material used.

Following legal requirements on traceability of food and feed ingredients, records on fish volumes purchased and sold are kept all actors in the value chain but at different level of detail depending on requirements. For example, monthly information can be received by a company on e.g., marine ingredients used, degree of certification and use of side-streams, but species and fishing area may only be collected on yearly basis to be aggregated in sustainability reports – where the level of detail currently reported on in these reports may not be used to identify fish stocks. Fishmeal and oil producers can provide this information, if the customer asks for it, but it is unclear how this information is currently stored and used by feed producers. One of the feed producers stated that they are in the process of improving their internal documentation system, indicating that there are potential areas for improvement.

Another complicating factor in determining live weight herring used for a farmed species is that companies use both trimmings and whole fish, of which trimmings may have other conversion factors and originate from mixed stocks. When trying to determine the total annual catch volume of whole herring from the Baltic Sea used for a certain year to feed a certain volume of salmonid, combined, this complicates the calculation, following input from one salmonid producer.

3.2.3 Examples of herring utilization in feed for salmonids

Although a full account of Baltic herring inclusion in relevant salmonid feeds could not be obtained, some data was provided that could be analysed:

- Based on data provided by one Norwegian producer of Atlantic salmon and Rainbow trout, 0.015 kg live-weight Baltic herring per kg live-weight salmon/trout was used in 2023.
- Data received for the Swedish salmonid production estimates a use of about 650 tonnes live weight Baltic herring in 2023. Based on that the total Swedish salmonid production (for food purpose) was around 8 467 tonnes in 2023 (Table 2), and assuming that this is all Baltic herring that is used for this production (it is estimated that the data covers most of the feed used in Sweden, indicatively 90%), this would equal to roughly 0.08 kg live-weight Baltic herring per kg live-weight Rainbow trout produced in Sweden. Note that while the analysis provides some insights, it is not comprehensive due to lack of data and therefore not robust.
- Another feed producer of importance to global aquaculture of salmonids reported that, based on an earlier investigation, around 1-2% of the landed Baltic Sea herring is utilized for fishmeal and oil in their feed. It is however unclear for which year and species farmed this is relevant for, and which total volumes of farmed seafood this supports.

3.3 Dynamics over time

Since the requested information for one year (2023) was not possible to obtain, it was impossible to receive data on dynamics over time for destination of herring from the Baltic Sea. In general terms, it is reported that the annual purchase volume of Baltic Sea herring by feed producers varies based on availability, price, degree of certification, dioxins, PFAS and demands from customers.

3.4 On the role of certification

3.4.1 Organic labelling for aquaculture

3.4.1.1 Volume covered

Organic aquaculture production of salmonids in the EU was 12 900 tonnes salmon and 4 500 tonnes trout in 2020, i.e. production that adhere to the objectives and principles set out in Regulation (EU) 2018/848 and may use the “green leaf” label (CINEA 2023). A large variability between countries is seen, where e.g., Ireland has a 100% organic aquaculture production while Sweden has 0%. In 2021, Norway ranked second globally in terms of total organic production volume; still, only 27 000 tonnes of Norwegian aquaculture was certified organic.

The Swedish organic label KRAV follows Regulation (EU) 2018/848 with additional national rules and specifications, certifying a minor share of salmon on the Swedish market; the actual volume could not be obtained.

3.4.1.2 Fisheries approved for feed raw material

As defined by Regulation (EU) 2018/848 on organic production, marine feed ingredients from fisheries used in organic aquaculture should come from *sustainable fisheries*. The criteria for being a sustainable fishery is decided on a country basis. In Sweden, following

the rules set out by the Swedish Board of Agriculture (SJVFS 2021:47), feed raw material originating from fisheries must be certified by either Marine Stewardship Council (MSC), Naturland, KRAV or Marin Trust. In Norway, only MSC and Marin Trust are listed as approved certification bodies according to Debio. Because availability of fish meal and oil certified by Naturland and KRAV is marginal, the rules between Sweden and Norway are basically the same. To this end, certification for organic aquaculture thus rely on other certifications when it comes to defining sustainable fisheries.

Over email, KRAV reports that they performed an internal check on use of herring in KRAV-certified salmon farms earlier in 2024. It was found that no raw material sourced from whole herring from the Baltic stocks was used; however, no documentation has been provided to the report authors to be able to verify this.

3.4.1.3 Traceability and transparency

Based on input from KRAV, the traceability concept in certification is not to be seen as standard owners and certification bodies collect data on origin of ingredients. Thus, KRAV (standard owners) does not keep records of which fish species are used in KRAV-certified aquaculture and are able to share this with third parties. Further, the control organisation Debio do not keep their own records of raw material used in certified farms but are only responsible for verifying that rules are followed during their controls of producers. KRAV may however request specific information to improve understanding, support development of the rules, provide answers to consumers and initiate dialogues for improvement. In these cases, they have been provided with information requested. For an external investigation such as is performed here, Debio report over email that they can get hold of the information but cannot share this with third party following current practice related to sharing of information, where trust between producers and certification is essential.

3.4.2 Aquaculture Stewardship Council (ASC)

3.4.2.1 Volume covered

In 2023, 30% of the global production of Atlantic salmon (712 farms) were certified by ASC and 109 farms producing freshwater trout (ASC 2023).

3.4.2.2 Fisheries approved for feed raw material

ASC has a set of basic sustainability requirements for feed ingredients based on fisheries, including assessment of risks for illegal, unregulated and unreported (IUU) fisheries and forced/child labour. For whole marine ingredients, the ASC Feed Programme has the intention to incentivise fisheries to improve their practices by requiring marine ingredients to be increasingly sourced by responsibly managed fisheries. At least 50% of whole fish ingredient purchases must follow an improvement model with four levels. These are:

1. Marin Trust Fishery Improvement Program (FIP) or Fishery Progress listed basic FIP,
2. Marin Trust approved fishery,
3. Fishery Progress listed comprehensive FIP,
4. MSC certified fishery.

The idea is that the feed mill increases the majority sustainability level (MSL) of its whole-fish-based marine ingredients over time, moving up one level from the entry level every three years towards the maximum level (4).

The remaining <50% of whole fish ingredients are not subject to the MSL improvement process, i.e. allowing sourcing of a large part of the whole fish from non-certified fisheries. However, risk for legal, social and environmental impacts are still assessed for this volume as the ASC Feed Standard requires any aquafeed ingredient above 1% of the total annual purchased volume to go through a process of due diligence. All such marine ingredients need to be low risk for forced/child labour, IUU fishing and use of endangered species before sourcing.

3.4.2.3 Traceability and transparency

The ASC standard for feed ingredients from fisheries sourced for salmon requires farms to 'ensure full traceability back to a responsibly managed source, preferably certified' (ASC 2024).

Currently, following questions posed to ASC on use of Baltic herring, it is found that ASC does not have compiled information on fish stocks used in feed for ASC-certified aquaculture. However, with the new ASC Feed Standard, companies will be required to annually publish which fishery sources they use. Further, the ASC is currently working toward making data on fish stocks used in feed for ASC-certified aquaculture to be more accessible and trackable by reviewing existing tools and data submission templates. It is however unclear to which level of detail, i.e. if information on use of certain stocks will be provided, particularly if feed is sourced from trimmings and byproduct ingredients.

3.4.3 May Baltic Sea herring be used for certified aquaculture?

Based on the current rules on approved feed for organic aquaculture and ASC, no formal restrictions exist on using Baltic herring stocks in certified aquaculture. For Baltic Sea herring stocks, the "Denmark, Estonia, Germany, Sweden Baltic herring and sprat"-fishery for the stock in the northern Baltic (Gulf of Bothnia, ICES area 30-31) is certified by Marine Stewardship Council (MSC) until Dec 31, 2025, and Finnish fisheries for the same stock is certified until June 30, 2029 (MSC 2024). Furthermore, the rest of the herring stocks in the Baltic Sea is certified by Marine Trust since 2022, i.e. fisheries in Denmark, Estonia, Latvia (Marine Trust 2024).

Although Baltic Sea herring fisheries are certified as sustainable by e.g., MSC, when looking at the latest stock assessment advice (ICES 2024a), the herring stock in central Baltic Sea (ICES subdivision 25–29 and 32, excluding the Gulf of Riga) has had a spawning stock size (SSB) around B_{lim} since the mid-1990s, and the stock occurring in the western Baltic (ICES subdivision 20-24) has a SSB below B_{lim} under since the early 2000s and now a zero catch advise. The stock in the Gulf of Bothnia in the northern part of the Baltic Sea ICES subdivision 31-32) has shown a decreasing SSB in recent decades, although the recent advice indicates a sustainable fishing mortality relative to Maximum Sustainable Yield. However, the EU has requested ICES to identify actions needed to improve understanding of potential drivers of the observed changes in age and size structure and condition of both central Baltic and Gulf of Bothnia herring (ICES 2024b).

In summary, given these trends, it may be argued if the Baltic Sea herring fisheries may be categorised as sustainable.

4 Discussion

4.1 Transparency and traceability

Although a full account could not be provided, this report has further detailed the destination of Baltic Sea herring fish meal and oil after processing in Denmark compared to Hornborg et al. (2023). Compared to the data for 2021 for all Baltic Sea landings, it has been found that Baltic Sea herring is mostly destined to aquaculture, particularly the fish oil (99.8%). Different accounts exist on main export markets, i.e. where and to which species the fishmeal and oil is destined. Based on the responses received, Baltic Sea herring is used to feed salmonids produced or consumed in Sweden, although in marginal volumes compared to other ingredients used.

From direct contact with feed producers, it appears that development of suitable internal systems to answer questions such as 'where does Baltic herring end up' are needed – reiterating a finding in Hornborg et al. (2023). This is perhaps not a common question to have to respond to, but with increasing consumer awareness these questions may become more frequent where improved traceability and transparency arguable improved trust. It also became apparent that the response rate differed between companies, ranging from making an effort to compile the requested information, not being able to provide the exact information sought for but indications (due to confidentiality, or inadequate internal reporting systems) to no response at all. Overall, companies were however supportive, agreeing that improved transparency is important and needed.

Several factors complicate exact estimates of destination of Baltic herring fishmeal and oil. Baltic herring is often landed together with Baltic sprat, and it is impossible to physically separate them by species when producing fish meal and oil – why a 'mass balance' approach is applied (Hornborg et al. 2023). The share destined to different sectors after processing into fishmeal and oil is thus only based on percentages, not actual flows. Another complicating factor for determining live weight volume of whole fish used for a certain fish stock based on fishmeal and oil use is the different conversion factors for live weight to fishmeal and oil. When a fish is processed, both fish meal and oils is produced, with different conversion factors between species and also between whole fish and trimmings (Cashion et al. 2016).

4.2 Sustainability

Although internal reporting systems may be seen as inadequate to efficiently address questions raised in this report, feed producers are working with sustainability in different ways. Annual reports are provided on their businesses, however, currently not provide enough details on origin of marine raw materials used. Further, they are informed by different sustainability assessments in their purchases, driven by e.g., consumer demands. Besides MSC and Marine Trust mentioned above, one feed producer also mentioned Fish Source Score (Fish Source Score 2024), a rating system that may inform more feed producers. This producer reported that Baltic herring is not fulfilling the

thresholds set for sustainability following this rating system, indicating that different outcomes are obtained for different market initiatives. This is a general challenge observed for market-based initiatives for sustainability assessments of seafood (e.g., Hornborg and Axelsson 2023).

Current certification standards for farmed seafood (ASC, KRAV) have no restrictions in use of Baltic herring stocks that show signals of overfishing. The reliance on other certification schemes (e.g., Marine Trust and MSC) for defining sustainable fisheries may thus need scrutinization if to provide added value to non-certified, farmed seafood. Further, certification standards contacted (ASC, KRAV) do not keep their own records on stocks used in certified aquaculture. Thus, overall, certified farmed seafood does not offer improved transparency to the extent that was sought for in this investigation. The new feed standard for ASC may offer improved opportunities but is unclear to which level of detail origin of marine raw material will be publicly available.

Lastly, fishmeal is less crucial than fish oil for the demand by the aquaculture industry, seen here in the form of Baltic herring fishmeal to a larger extent being destined for other sectors than aquaculture. The aquaculture industry in general, and salmonid sector in particular, has a high need for oils and lipids to fulfil the nutrient requirements of omega-3 long-chain polyunsaturated fatty acids (LC-PUFAs). New sources of LC-PUFAs, like microbial oils, are emerging on the horizon but a widely accessible and cost-effective supply have not available (Zhang et al. 2024). However, the global algae oil market is growing steadily, with one of the largest producers increasing their production volume by 50% in 2023 compared to 2022 and achieving a reduction in product carbon footprint. Hopefully, this can facilitate less demand of fish oil by the salmonid industry in the near future.

5 Conclusions and recommendations

- **To meet societal concerns and allow for fact-based discussions, it would be beneficial if the feed producer industry improved the transparency of the origin of fish feed raw material utilized.** Based on information from Danish fishmeal and oil producers, Baltic herring is primarily used for the aquaculture sector, particularly the oil. Aquaculture in Norway and the UK appears to be important based on qualitative information from Denmark, but other Baltic Sea herring processing facilities report other main destinations. The exact destination needs information from the purchasers of fishmeal and oil, i.e. the feed and aquaculture industries, which could be disclosed in e.g., annual sustainability reports to improve transparency.
- **Based on the varied response rate by feed producers, internal record keeping formats would benefit from being structured in a way that may efficiently allow for answers to questions on use of specific fish stocks.** Few companies supply feed for salmonids that are produced or consumed in Sweden, which in theory enables an efficient mapping of use of Baltic herring. However, the information sought for was not provided by all within the project time frame (six months). Although some companies provided the information and the information exists, it appears to be a time-consuming process to extract the data, calling for innovations in internal documentation systems.
- **For certified farmed seafood, added societal value would be provided from public, annual reports stating quantity and origin of fish meal and oil used – i.e. volumes used on a stock-basis.** There is in general little difference in transparency of certified and non-certified feed and farming systems related to ease of obtaining data on marine raw material used down to fish stock.
- **Current certifications systems for farmed seafood would benefit from scrutinization of how 'sustainable fisheries' are defined and applied to fully avoid use of marine ingredients with sustainability challenges.** Both ASC and KRAV relies on other certification systems in their rules on marine raw materials allowed, i.e. criteria used for the definition of 'sustainable fisheries'. Different ratings exist between systems, and fisheries such as Baltic Sea herring may be in trouble despite being categorized as sustainable. Further, ASC has more lenient rules, not requiring 100% of marine raw material to be sourced from certified fisheries.

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Appendix 1

Questions asked to key feed manufacturers.

1. How much Baltic herring do you handle (ICES 22–32)? Provide tonnes for the year 2023:

Raw material	**Ton**
Purchased volume of fish meal based on whole Baltic herring	
Purchased volume of fish oil based on whole Baltic herring	
Purchased volume of fish meal based on trimmings of Baltic herring	
Purchased volume of fish oil based on trimmings of Baltic herring	

2. Where is the main volume of Baltic herring used? Add sectors if needed.

Sector	**Country**	**Ton meal**	**Ton oil**	**Comment**
Atlantic salmon				
Rainbow trout				
Brown trout				

3. How much does the use of Baltic herring vary over time – purchase volume, final destination, etc? What is the main driver for potential variation?

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