Report of the Industry workshop of the MEESO project held on 29 March 2021

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Ecologically and Economically Sustainable Mesopelagic Fisheries

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1 Introduction

On Monday 29 March 2021, researchers from Wageningen University and Research, on behalf of the MEESO project, held a workshop about mesopelagic fishing for industry stakeholders. The workshop was hosted online on Microsoft Teams and had a duration of 3.5 hours. The objectives of the workshop were as follows:

- To bring stakeholders from the fishing industry, processing companies, gear manufacturing companies, and research together to share insights and develop contacts;
- To understand country-specific factors and interests regarding fishing in the mesopelagic zone;
- To gather questions that stakeholders have about the mesopelagic zone and offer preliminary answers;
- To understand which questions are of greatest priority for the various stakeholders.

Approximately 45 people participated in the workshop, from six different European countries: Norway, Iceland, Ireland, Denmark, the Netherlands and Spain.

The agenda of the meeting was as follows:

Welcome, introduction round, present SUMMER and MEESO projects
Presentation LIE: Experiences so far with mesopelagic fisheries
Presentation EFFOP: State of affairs in processing and using mesopelagic catch
Plenary inventory - Introduction and demonstration of workshop software (Miro) - What questions do the various actors in each country or region have for fishing companies, gear manufacturers, processing companies, researchers, and policy makers?
Breakout Session 1: What are the specific factors in the commercial and technical viability of mesopelagic fishing in this country or region? Country divisions: Iceland, Ireland, Norway & Denmark, Spain During this session participants are free to add questions to the Miro plane used in the plenary session.
Breakout Session 2: Please select one of the questions posed to your group during the last two sessions, starting with the 'high priority' ones. How certain are you that this question can be answered with our current knowledge? What do you think or expect should be the answer? Group divisions: Fishing companies, processing companies, gear manufacturers, others
Plenary discussion: main results from breakout groups and next steps

This report summarises the information shared in the workshop and the outcomes of the sessions.

The next section will summarise the presentations given (section 2) followed by summaries of the break-out sessions (sections 3 and 4), the final plenary (section 5), conclusions (section 6) and discussion (section 7). The questions that were gathered during the plenary inventory were further discussed in the second break out session. The highest priority and most answerable questions from this collection are presented in the conclusion (section 6).

2 Presentations

Rolf Groeneveld gave a short introduction to the MEESO project (www.MEESO.org) and the goals and agenda of the workshop.

2.1 LIE Gruppen

A representative of LIE unfortunately could not make it to take part in the workshop. Instead, Rolf Groeneveld gave a short run-through of the presentation slides LIE Gruppen had provided. These slides were shared with the participants of the workshop.

See Appendix for slides.

2.2 EFFOP

Haarslev started processing mesopelagic fish some 10-15 years ago. The raw material contains a lot of water and fat and needs to be processed into a stable product. The typical stages in processing are coagulation, usually by cooking; and separating the liquid from the solid phase, which is typically done by presses. The water that comes from the first separation phase is also further processed to obtain the protein, which is very valuable. Resulting dry powder has 8-9% moisture and 10-12% fat; the rest is ash, which is comprised of, among others, bony material.

So far, Haarslev has done little on mesopelagic fisheries but it has experience with krill, and the process is likely to be similar. Krill is typically pumped directly into the processing line, where it is drained to take out the salt, as salt is a problem in processing. The substance then goes into a cooker for coagulation, it is separated, and then dried. A new coagulation method for krill had to be developed, instead of the standard method used for fish. An important difference from fish is also that krill contains a lot of polyphosphate, which makes it an interesting nutritional source but it also creates problems because it cannot be processed the same way as triglycerol, which is usually found in fish. Another important ingredient is astaxanthin, which is also very valuable but also very volatile. Therefore the krill is dried at low temperature. The krill is then stored in bags purged with nitrogen to protect the krill meal, and frozen so that it can be further processed on shore. All this takes place on board so a lot of equipment needs to be stored in a small volume in the vessel's hold. The fat content of krill also depends on the season and the location. The end-products are quite valuable. The meal is sold a lot as pet food, and it tastes and smells good. We have seen the equipment on a range of boats, from boats that do 10 tons/hr to boats that do 40 to 50 tons/hr.

Question: Is ensiling an option? Ensiling is a process where you hydrolyse the protein. That is good, but if the oil is of high value it may not be the best option.

Question: Do Maurolicus and Benthosema have the same prospects? We will look into this. We need to know what quantities to expect. One option may be to do the processing halfway on the vessel and then the rest on land. It depends on the trip length.

A video recording of this presentation is available on request to rolf.groeneveld@wur.nl.

3 Breakout Session 1: What makes fishing the mesopelagic different for the fisheries in varying countries?

During this breakout session, participants were grouped by country and asked, 'What are the challenges, opportunities and requirements of fishing the mesopelagic zone in your country? What are the specific characteristics in your place? (e.g. seasonality, main fishing grounds, currently available technology, market, etc.)'. Each group had a facilitator and a note-taker, and participants used the online whiteboard tool (Miro) to record their thoughts.

3.1 Iceland

The participants from Iceland were unsure whether pursuing mesopelagic fish would be realistic for Icelandic fishers because of two main issues: the low value of the product and the capacity of existing vessels.

The first comment was that there has been a lot of discussion about mesopelagic fishing in Iceland since 2010, but that there has been little real development of the fishery. For instance, in 2009-2011 there was a brief interest in mesopelagic fish, especially while capelin fishing was under moratorium in 2009, but if there is quota available for capelin then they are more profitable to target. The group noted that a key barrier is the low price of mesopelagic fish, but that processing catches would make it more valuable and would then make it more appealing as a target for fishers. The participants mentioned that, while they believe they are likely to be abundant, mesopelagic fish are also difficult and expensive to locate (in depth and location). There is a lack of experience in identifying these fish with echosounders.

Furthermore, during processing, the small mesopelagic fish can clog the pumping systems onboard, but one fisher said that slowing the pumping system resolved this issue. Another issue with onboard processing is the high levels of salt. One participant stated that combining equal parts mesopelagic fish (Mueller's pearlside) and fresh water was an effective storage solution for up to three days onboard, and did not lead to the unacceptably high levels of salt present in other methods.

While there are potentially large stocks in the nearby Irminger Sea, an issue for the viability of mesopelagic fishing is that the distance from the fishing grounds to the processing facility is too great. The fish need to be landed within 2-3 days of being caught. Onboard freezing and/or processing is a potential solution for this, but would require significant changes to the hold of the vessel to be feasible at a large scale. Some participants stated that converting existing vessels would not be possible, so if they were to pursue mesopelagic fish they would need to acquire new vessels altogether (freezer trawlers). There are not many such vessels in the Icelandic fleet, so the country would need to build technical capacity to support this development.

The group also mentioned that vertical integration (i.e. fishing companies investing in processing facilities so that they can increase the value of mesopelagic fish) is a potential opportunity, but they experience a lack of support from the Icelandic government in the form of prohibitively high taxes on fisheries profits. A comparison was made to the situation in Norway, where the national government is co-investing in the exploration of mesopelagic fishing.

3.2 Ireland

The Irish fishers, processors, net manufacturers, and engineers all expressed interest in the mesopelagic resource. The discussion focused mainly on questions that the Irish participants had about the fishery. These questions regarded mainly the logistics of the fishery, the science, and the governance. Although the two Irish net manufacturers in attendance had previous experience with designing and supplying nets for mesopelagic exploratory trials internationally, fishers' knowledge was acknowledged to be limited. The main driver of interest is the potential to access new resources during the Refrigerated Sea Water (RSW) fleets' six month down-time and the relative proximate access to resources off the Shelf.

Fishers posed questions regarding how much initial modifications are required in terms of vessel layout, catching and handling processes and whether existing vessels could readily be adapted as the fishery was being developed. In particular, discussions focused on what gear modifications are required and both the net manufacturers and Marine Institute (MI) scientists provided input. If resources were made available a small fit-for-purpose net could be developed and attending net manufacturers were open to pursuing this further.

Regarding the science, the breakout discussion and the whiteboard yielded many questions on stock abundance: which species can we expect, what are the core areas of abundance, what

is the seasonality of the relevant species, to what extent do they form shoals or aggregations? For comparison: blue whiting forms clear distinct aggregations at 150m. By contrast, in the deep scattering layer the species is usually unclear. Learning about these issues first is key to the development of this fishery. Participants also asked about the current state of the science in Ireland, i.e. whether the MI had already conducted studies and whether the existing science can already help inform industry decision-making. It was suggested to make an inventory of available data and then reconvene. MI scientists explained that a significant volume of historical acoustic survey data spanning fifteen years has been collected and if current surveys including sampling with nets could help interpret the historical data, there is potential to extrapolate temporally. MI scientists also suggested that in addition to 'piggybacking' on the blue whiting surveys, additional survey time would be invaluable to improve our understanding of the resources. Fishers also asked how they could assist in collecting data and samples during commercial trips, with some suggesting that a small net that could be deployed during traditional pelagic commercial trips when interesting marks are identified on the echosounder. It was agreed that this warranted further discussion. Fishers were also keen to participate in exploratory fishing trips, however resourcing would have to be considered.

Regarding governance, three issues were raised: available government support, regulations including quota regulations, and public perception. Participants wondered whether support was available for the development of this fishery through existing subsidies or specific support from the Department of Agriculture, Food, and the Marine (DAFM) for exploratory fishing. Questions on regulations mostly regarded how and when quota will be distributed. Participants raised some frustration regarding the fact that historically previous fisheries (e.g. boarfish) were developed and by a small number of fishers who bore the costs. Later, other fishers benefited despite not bearing the development costs. A more equitable system should be considered that reflects the resource inputs of the initial fishers to develop the fishery. Participants wondered to what extent the DAFM has a focus on the opportunities in a mesopelagic fishery. There were also serious concerns regarding public perception: How do we communicate about the fishery in a precautionary and coherent manner? How do we relay concerns? How do we provide robust information? How do we deal with inevitable opposition from NGOs? It was agreed that Irish stakeholders including industry, scientists, and other relevant development agencies meet to discuss the best development options at a national level that could also dovetail with the activities of the MEESO project.

3.3 Norway and Denmark

The Norwegian industry was not present at this meeting. The Danish fleet segment most likely to become active in a mesopelagic fishery is characterised by relatively large vessels (2000 tonnes or more) that are already involved in pelagic activities. These vessels use refrigerated sea water (RSW) to preserve the catch and are currently mainly fishing for blue whiting and sandeel. The time it takes to reach fishing grounds would be a serious issue for these vessels because refrigerated sea water systems can only store mesopelagic catch for a maximum of three to five days before compromising the quality of the catch. Detailed knowledge on fishing ground locations and expected catch rates were raised as an important factor to determine fishing trip length and thereby viability.

Questions from the Danish participants focused on the development of a viable business model, i.e. the costs of exploitation and the expected revenues. Regarding costs it was remarked that the Icelandic trial fishery reached break-even right before its closure, but that more information is needed on the costs of trawling, fuel, and processing (either onboard or on land).

Regarding revenues, the group expected that the price of the catch will depend largely on its quality, i.e. its nutritional composition, digestibility (which also depends on the drying method), and how different components will be valued and marketed, and how easily they can be extracted. So far it seems that the quality is comparable to herring meal, although there were limited issues with wax esters. Other quality issues are salt content, freshness, and the variance in quality. The question was raised whether consumers may be willing to pay more for high-quality and more sustainable fish; this most likely depends on certification and content.

3.4 Spain

Participants from Spain discussed several key questions. The group proposed that the challenges to the fishery are not technical but financial, and considered whether revenues would be high

enough. It is still unknown whether these species can be sold whole as fish for human consumption. The value of the product is still unknown, and if fishing grounds are far from port then it would require a new vessel with different equipment. This was seen as a different situation to countries such as Iceland and Norway where the mesopelagic waters are often relatively close to port. Participants agreed that Spanish vessels are currently not suitable for this fishery.

The participants were concerned about the impact on the fishing areas and about the stability of the market, too. For example, they wondered how long the fish oil market would last. The group discussed that the international market for these products, which is a market where there is a lot of competition, would require policies at the European level to promote the fish oil market for European companies. For fishers, a certain stability is needed to decide whether or not to refurbish the vessel. The importance of knowing the daily catches as a basic parameter to determine the profitability of this fishery was also highlighted.

In the Bay of Biscay, the months between March and June are potentially suitable to fish for mesopelagic species because the proportion of lipids in the catch can be higher. However, one participant pointed out that this is spawning season and it may not be advisable from a sustainability point of view to fish in these months, depending on the volumes caught.

Another question raised concerned the interactions between mesopelagic species and other commercial species, especially related to impact of fishing for mesopelagic fish on the economic performance of other species.

One participant added that, during scientific trawls, the catches of mesopelagic species are usually limited in bycatch (i.e. they only catch one species), which indicates limited bycatch. This links to questions that remain open for this group about minimum mesh sizes, the need for excluder grids, dual cod ends, and other technical adaptations. In addition to gear-related regulations, there are also questions about the legal framework surrounding this fishery, in terms of access and quota.

In closing, members of the group pointed out that in order to make a business plan for the future it would be necessary: (1) to consider in more detail the transformation process of the mesopelagic fish harvest; (2) to be able to estimate the costs of an exploitation like this (perhaps there are already answers to this); and (3) to know the market prices of the derived products (which the group suspects is also already somewhat available). These data could be used to explore the options for configuring a value chain that is optimal for each fishery.

4 Breakout Session 2: What questions do the various sectors have and which should be prioritised?

During this breakout session, participants were grouped by sector (fishers, processors, gear manufacturers and others) and asked, 'Can we sort the questions by priority and answerability? If you know the answer, please put an indication on a green sticky note. If a question is unanswerable, leave it out'. Each group had a facilitator and a note-taker, and participants used the online whiteboard tool (Miro) to record their thoughts.

4.1 Overall set-up

The Miro board showed a two-dimensional plane with two intersecting arrows: on the horizontal axis were an arrow pointing left showing 'less answerable' and an arrow pointing right showing 'more answerable'. On the vertical axis were an arrow pointing up showing 'high priority' and an arrow pointing down showing 'low priority'. All the questions gathered during the Plenary Inventory, were copied into the space to the left of this plane. Participants were instructed to sort these questions in the two dimensional space to represent their assessment of 'answerability' and 'priority'. An example is provided below.

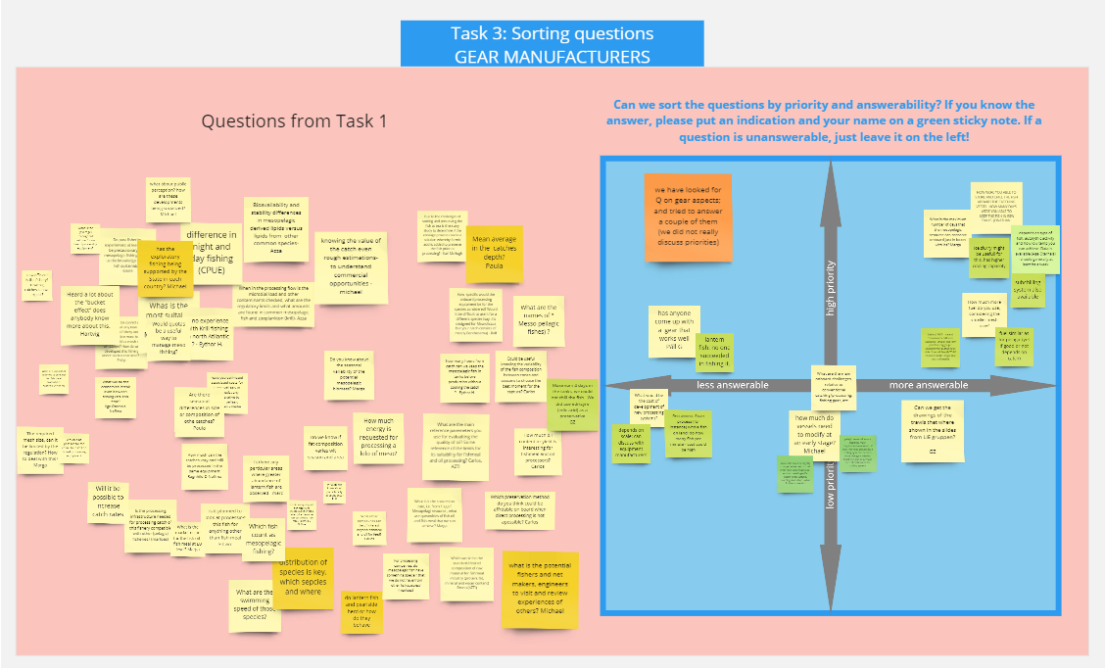


Figure 1. Example of the Miro board, in this case of the 'Gear manufacturers group', showing in the left all the questions gathered in the plenary inventory. At the right side the selection of questions, ordered as explained above.

4.2 Notes from breakout groups sorting and discussing questions

Each group took a slightly different approach to the exercise. The fishers sorted 39 questions, discussing and answering questions where possible. The processers sorted 73 questions, working quickly and with little discussion. The researchers had a similar result, sorting 66 questions. The gear manufacturers took a slightly different approach, selecting the questions that were directly related to fishing gear and sorting and answering them where possible.

4.2.1 Fishing companies

<u>Discussion during this breakout</u>

The fishers discussed strategies for preserving catches, with one fisher suggesting that a 50/50-80/20 ratio of fresh water and mesopelagic fish was effective at preserving the fish, and that the addition of ascetic acid could extend the preservation to up to 4 days. Some responded that the effectiveness of the preservation depends on the species of fish, autolytic activity, and how low a

temperature can be maintained. Apparently some data is available on this, which indicates that a combination of techniques can be effective in preserving catch for at least a week.

Fishers from Iceland and Ireland highlighted the success of industry-science cooperation, pointing to mutual benefits. Fishers do not have extensive access to or experience with echosounders, so would benefit from fisheries scientists sharing echosounder data. In return, fishers could help mitigate some of the large expenses associated with dedicated research trips by sharing catch data or collecting samples on behalf of science. Lowering the barrier for science-industry cooperation for other countries would bring advances in understanding. Participants from Denmark agreed with the importance and opportunities, but pointed to challenges in terms of misaligned goals and values between science and industry, and the importance of building a history of collaboration.

The Icelandic fishers were asked whether they have issues with bycatch. They responded that their experience with mesopelagic fishing is that it is a very 'clean' (i.e. mostly one species) catch. They occasionally catch small quantities of redfish and saithe alongside small mesopelagic species. The fishers stated that due to the low towing speed (one fisher stated that 3 knots was the average for mesopelagic trawls), they see that other larger species are able to escape the trawl. Another participant responded that avoiding bycatch will be a key issue for the future of a mesopelagic fishery given the incoming landing obligation.

<u>High priority answerable questions</u>

The fishers identified the following questions as being both high in priority and likely to be answerable in coming years:

Biology:

- What is the annual cycle for these species?
    - Where are they in winter?
    - Where do they spawn?
    - What is their life cycle?
    - Are there seasonal differences in the size composition and potential biomass of the catch?
- What size catches can be expected?

Technology:

- How efficient is a fishery for mesopelagic fish?
- What are the main onboard challenges relative to conventional (e.g. capelin, blue whiting) catching/processing/fishing gear?
- What is the most effective gear? (with request for LIE Gruppen to share technical drawings of their gear)
- What is the optimal towing speed? [answer from Iceland: 3 knots]
- What would vessels need to modify to begin testing this fishery?
- Is formic acid an effective preservative to store the fish onboard before processing?
- How much energy is required to process a kilogram of mesopelagic fish?
- How much fuel is used, given the smaller mesh size?

Social and governance questions:

- What are the public perceptions? How are developments in this fishery going to be perceived?
- Will it be possible for fishers to get a license to use such a small mesh size?
- What is the market niche for fish oil and fish meal from mesopelagic species at the EU level?
- How has exploratory fishing been supported by the government in each country?

4.2.2 Processing companies

<u>High priority answerable questions</u>

The group of processors identified the following questions as being both high in priority and likely to be answerable in coming years:

Biology:

- Which would be the standard/desired composition of raw material for fishmeal industry (protein, fat, mineral and water content)?
- How much oil content or yield is interesting for fishmeal and oil processors?

- Do we know if fat composition varies with season and area?
- What is the variability of the fish composition between zones and seasons? Can that help to choose the best moment for capture?
- What are the main reference parameters that processors use for evaluating the quality of oil?
- What is the seasonal variability of the potential mesopelagic biomass?
- Is there any particular area where greater abundance of lantern fish is observed?
- How different would fishing and processing Benthosema be from Maurolicus?
- Is there a difference in night and day catches in terms of catch per unit of effort (CPUE)?
- What are the bioavailability and stability differences in mesopelagic derived lipids versus lipids from other common species?

Technology:

- How efficient is a fishery for mesopelagic fish?
- Will it be possible to increase catch rates?
- Is the processing infrastructure needed for processing catch of this fishery compatible with other (pelagic) fisheries?
- What about the 'bucket effect'?
- What is the (average) throughput volume for onboard processing equipment?
- Would it be possible for the vessel to install onboard processing equipment?
- Which preservation method could be affordable onboard when direct processing is not possible?
- How many hours from catch can we keep mesopelagic fish in tanks before production without cooling the catch?
- What could be the cost of development of new processing systems?
- How much energy is required for processing a kilo of meso?
- Does the EFFOP experience (presented earlier in session) with krill also hold for lantern fish and pearlside? What are the similarities and differences?

Market:

- What are important volumes to consider for fish meal production?
- What is the market niche for the fish oil or fish meal at EU level?
- For processing companies, do mesopelagic fish have something special that we do not get from other fish species?

Social and governance questions:

- Do past fisheries experiences teach us to be precautionary with mesopelagic fishing? Do these past experiences also give us the knowledge now to fish sustainably?
- Is there some reference of the limits for its sustainability for fishmeal and oil processing?

4.2.3 Gear manufacturing companies

<u>High priority answerable questions:</u>

The group of representatives from gear manufacturing companies identified the following questions as being both high in priority and likely to be answerable in coming years. The participants also shared some preliminary answers to these questions:

- How much more fuel is used, considering the smaller mesh size?
    - Answer: Fuel use is similar to pelagic fishing, yet whether this is acceptable depends on the catch
    - Answer: Iceland 16.4 mm – Ireland 16mm (cod end lower sections). If you go smaller you get flow problems, and if you go bigger you get problems with pumping on the side of the vessel. Trawl length is 70m-90m – necessary due to small mesh.
- Is it possible to store and chill the fish onboard? How many days does it keep in RSW tanks?
    - Answer: It depends on the fish species, autolytic activity, and how low a temperature you can achieve. There is some data (NOFIMA) that indicates this should generally be at least a week. Subchilling systems are also available.

<u>Other answerable questions:</u>

- Has anyone devised a gear that works well for lanternfish?
    - Answer: No one has succeeded in fishing for this species.
- What would be the cost of developing new processing systems?
    - Answer: It depends on the scale. We need to discuss with manufacturers.

    - Answer: We should first assess whether it's possible to process whole fish on land. How many fish per minute? The cost might be too high.
- How much do vessels need to modify at this early stage?
    - Answer: Some nets could be slightly modified at the lead end to cod end. They would need tailor-made cod ends and need a pacific leader to the cod end. Learning what would be needed beyond that would only really start with testing at that stage.

4.2.4 Researchers/Others

<u>High priority answerable questions:</u>

The group of researchers and other invited attendees identified the following questions as being both high in priority and likely to be answerable in coming years:

Biology:

- Which would be the standard/desired composition of raw material for fishmeal industry (protein, fat, mineral and water content)?
- How much oil content or yield is interesting for fishmeal and oil processors?
- Are there seasonal differences in size composition of other catches?
- Do you know about the seasonal variability of the potential mesopelagic biomass?
- Do we know if fat composition varies with season and area?
- Is there a difference in night and day catches in terms of catch per unit of effort (CPUE)?
- What are the bioavailability and stability differences in mesopelagic derived lipids versus lipids from other common species?

Technology:

- Has anyone come up with a gear that works well?
- Would it be possible for the vessel to install on board processing equipment?
- What do we know about predictability of abundance?
- Which preservation method could be affordable on board when direct processing is not possible?
- How specific would the onboard processing equipment be for the species considered? Would it be difficult to use it for a different species (say it's designed for Mauroliccus but your catch consists of mostly Benthosema)
- Due to challenges of storing and preserving the fish at sea is there any study to determine if the ensilage process can be a solution whereby formic acid is added to preserve the fish prior to processing?
- What is the most suitable mesh size for Mauroliccus and Benthosema?
- What could be the cost of development of new processing systems?
- How much do vessels need to modify at an early stage?
- How much more fuel is used, considering the smaller mesh size?

Market:

- What are important volumes to consider for fish meal production?
- What will be the economical break even between fishing rate and time?
- Is the processing infrastructure needed for processing catch of this fishery compatible with other (pelagic) fisheries?
- What is the market niche for the fish oil or fish meal at EU level?
- Is it planned to look at processing this fish for anything other than fish meal?
- For processing companies, do mesopelagic fish have something special that we do not get from other fish species?
- What are the main reference parameters you use for evaluating the quality of oil?
- Is it possible to determine the value of the catch (even in rough estimations) to understand commercial opportunities?
- If sufficient quality, will fish meal from mesopelagic fish get a better price than other "less sustainable" fish meal?
- Has anyone estimated associated costs for mesopelagic fishing or is there an existing comparison to other pelagic fisheries?

Social and governance:

- What are some reference of the limits for the sustainability of fishmeal and oil processing?
- The required mesh size, can it be limited by the regulation? How to deal with this?

- Do past fisheries experiences teach us to be precautionary with mesopelagic fishing? Do these past experiences also give us the knowledge now to fish sustainably?
- Will it be possible for fishers to get a license to use such a small mesh size?
- What is the potential for fishers and net makers, engineers, etc. to visit and review experiences of others in other countries?
- How is exploratory fishing being supported by the state in each country (if at all)?

5 Plenary discussion: Main results and next steps

During the closing plenary the participants briefly summarised the discussions that were had during each of the breakout groups, detailed in Section 3 and 4 above. One participant noted that the high omega 3 content of these fish means that they are likely to have some market value, and that they are investigating other bio-activity. The question of whether the fish can be consumed whole will also be investigated. One participant emphasised the importance of the commercial factors (such as the potential value of the catch and market stability) for the fishers involved. There was also a call for gaining a more long-term perspective by involving actors from past experimental mesopelagic fisheries, such as in South Africa.

The organisers request that participants share length and distribution data for mesopelagic fisheries with the MEESO project, if it is available. The organisers outlined the next steps for this stakeholder group's collaboration and thanked the participants for their time and input.

6 Conclusion

This workshop brought together stakeholders from Iceland, Denmark, Norway, Ireland, The Netherlands (not present in the break out groups), and Spain. There were representatives from the fishing industry, processing companies, gear manufacturing companies and research present. The factors that affect the development of a mesopelagic fishery in these countries were discussed. Technical and commercial questions relevant to all parties were raised and collected. The priority and accessibility of answering these questions was then considered by the various stakeholder groups. This process resulted in the following list of priority questions about mesopelagic fishing from stakeholders. Some preliminary answers and suggestions are made where possible.

1. *How efficient is the fishery in terms of the expected catch size (or catch per unit effort)?*
2. *Will it be possible to increase catch rates in future?*
3. *What is the market niche for the fish oil and fish meal at EU level?*
4. *What oil content or yield would make mesopelagic species interesting as input for fishmeal and oil processors?*
5. *Are there seasonal differences in the size composition of mesopelagic catches?*
6. *How can mesopelagic fish be stored and chilled aboard fishing vessels, and how long is this effective?*
    a. *The fish can be stored for a maximum of 4 days in RSW tanks without chilling but with the addition of acetic acid as a preservative*
    b. *Experience in trial fisheries suggests that adding fresh water to storage can extend the time before spoilage*
    c. *There is an indication that it can be stored for roughly a week. It depends on the type of fish, autolytic activity, and how low a temperature you can achieve. There is some data available (NOFIMA)*
    d. *A sub-chilling system is also available*
7. *Due to challenges of storing and preserving the fish at sea, is there any study to determine if the ensilage process can be a solution whereby formic acid is added to preserve the fish prior to processing?*
8. *What are the main onboard challenges relative to conventional catching, processing and fishing gear?*
9. *What is the seasonal variability of the potential mesopelagic biomass?*
10. *Has anyone come up with a gear that works well?*
    a. *For lantern fish, it appears that no one succeeded in fishing it at commercial scales.*
11. *Can we get the drawings of the trawls that were shown in the slides from LIE Gruppen?*
    a. *See Appendix*
12. *What could be the cost of development of new processing systems?*
    a. *It depends on scale, but this is something that can be discussed with equipment manufacturers*

    b. *It is first necessary to assess if can process whole fish on land; if so, how many fish per minute? It could be that the costs become too high*
13. *How much do vessels need to modify at an early stage to engage in this fish?*
    a. *Some nets could be slightly modified at the lead end to cod end. They would need tailor-made cod ends and need a pacific leader to the cod end. Learning what would be needed beyond that would only really start with testing at that stage.*
    b. *For a pelagic vessel (e.g., one that fishes for mackerel) there does not need to be too much modification if they will land the fish to be processed. However, if a chilling system is needed, more changes to the vessel will be needed. This is because the fish are very small, which may necessitate alterations to the chilling system and pumps*
14. *What is the maximum number of days that the mesopelagic resource can be conserved onboard just in boxes with ice?*
    a. *Not sure precisely, but ice slurry might be useful for this because it has a higher cooling capacity*
15. *How much energy is required for processing a kilo of mesopelagic fish?*
16. *If it is of sufficient quality, will fish meal from mesopelagic fish get a better price than other "less sustainable" fish meal?*
17. *How much more fuel would be used fishing for mesopelagic fish, considering the smaller mesh size?*
    a. *The fuel use is expected to be similar to pelagic fishing. Whether or not this is profitable depends on the catches.*
    b. *Iceland 16.4mm – Ireland 16mm (cod end lower sections). If you go smaller you get flow problems, and if you go bigger you get problems with pumping on the side of the vessel. Trawl length is 70m-90m – necessary due to small mesh.*
18. *What is the public perception? How are these developments being socialised?*

7 Discussion

This workshop identified priority questions for various stakeholders in mesopelagic fishing. Most questions were of a technical and economic nature, relating to processing capabilities and costs of mesopelagic fishing.

During the country-specific breakout groups (Breakout Session 1), stakeholders from different countries engaged in conversations with different themes. The Irish and Icelandic groups mostly discussed developments in their own contexts, sharing insights from their experiences so far. Attendees from Spain tended to be more interested in ecology and governance. For the Norwegian and Danish group, the focus tended to be on market questions, especially in relation to the Norwegian fishery. This exercise with the stakeholders shows that i) there are many context-dependent factors that will influence the potential development of a mesopelagic fishery, and that ii) participants from different countries have different focuses as they consider the future development of this fishery.

During the sorting and prioritising exercise (Breakout Session 2), the groups took varied approaches. The biggest themes across all stakeholders were to do with technicalities of fishing and processing catches, with other questions relating to market, ecology, and social acceptance. Every stakeholder group placed the majority of questions in the 'high priority' section and most were seen as 'more answerable'. This means that most stakeholders have some urgent questions about the mesopelagic zone and the potential for a fishery there, and they see these questions as being feasibly answerable, either by fishing companies, gear manufacturers, processors, or researchers. Answers (at least preliminary indications) were given to roughly one third of the high priority questions, which means that there is knowledge amongst stakeholders that can be shared and communicated.

8 Appendix: Presentation from LIE Gruppen

Grimsmo, L., Grimaldo, E. and Toldnes, B. (SINTEF Ocean), Birkeland, A. (Br. Birkeland Fiskebåtrederi) Lie, Ø. (Liegruppen) and Sandnes, K. (Biomega)

The Industry's Mesopelagic Initiative

Strategy for sustainable harvesting and processing of mesopelagic fish

The Industry's Mesopelagic Initiative

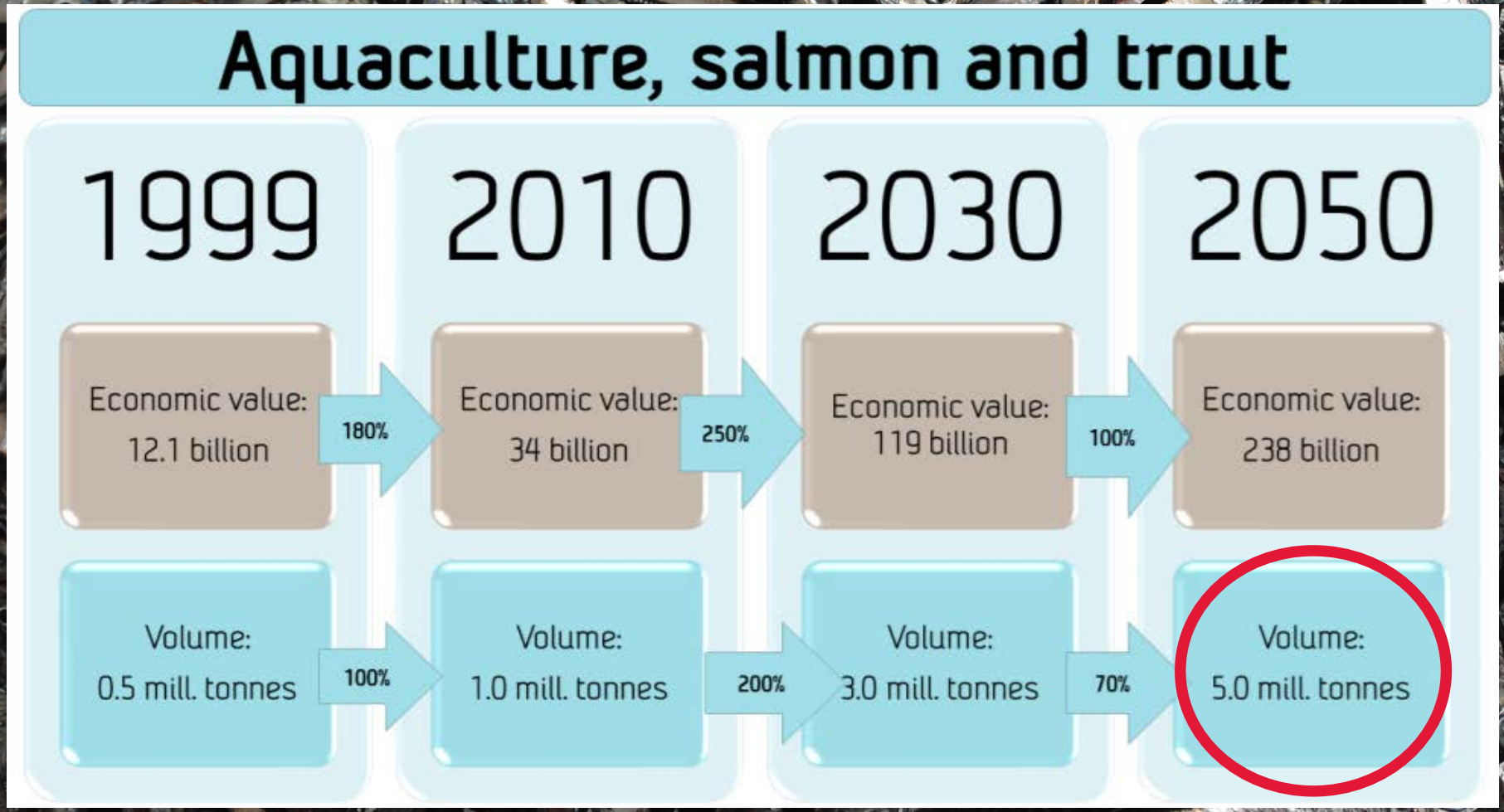
To develop the commercial potential in the mesopelagic fisheries is not a one-company task, but a national or Nordic/international responsibility

The Industry's Mesopelagic Initiative

Outline

- Why mesopelagic fish (salmon feed example)?
- Liegruppen
- Surveys with "Birkeland" 2016 – 2018
- Catch
- Chemical analyses
- Processing
- Gear
- Further strategy

Why mesopelagic fish? Salmon feed & soy protein



Why mesopelagic fish? Salmon feed & soy protein

5 mill. tonnes Atlantic Salmon (2050), same recipe, correspond to 912 000 ha. soybean farmland covering the protein content

Or:
93 % agricult. land in Norway
1,3 mill. soccer fields*

Photo: ALBERTO CESAR-GREENPEACE / AP

Production of 5 mill tonnes:
= 6 mill. t. mesopelagic fish
= 0,6 ‰ of biomass 10 bill.t
+ essential marine oils

*) Grimsmo, L., Almås K. A. og Hognes, E. (2017). "Industriell utvikling av et mesopelagisk fiske – miljøeffekter" SINTEF rapport OC2017 A-196

Pioneering mesopelagic fishing in the Oman Gulf by Liegruppen 1992

Challenges for business development:

- ❑ Resource biology knowledge
- ❑ Fishery technology
- ❑ Product refinements
- ❑ Market developments
- ❑ Geopolitics challenges

The pioneers

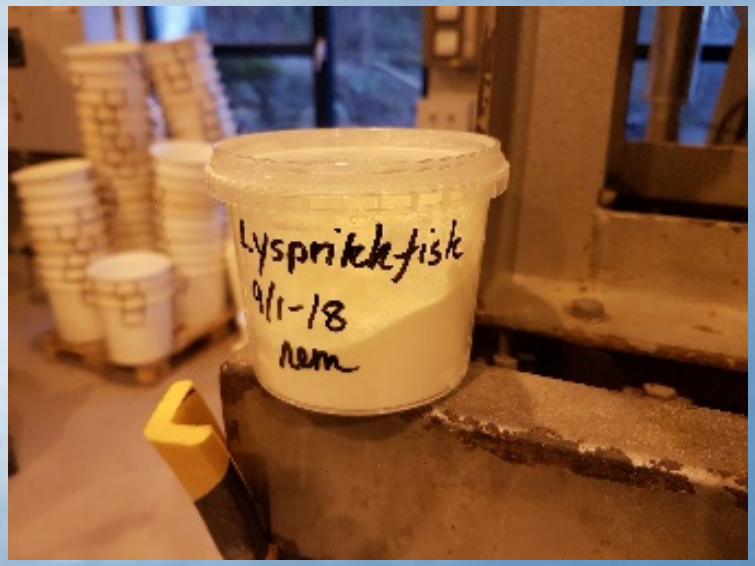
LIE GRUPPEN

First commercial catch of Mesopelagic fish in Norway sold by "Liafjord" 17 tonnes pearlside, July 2018

LIE GRUPPEN

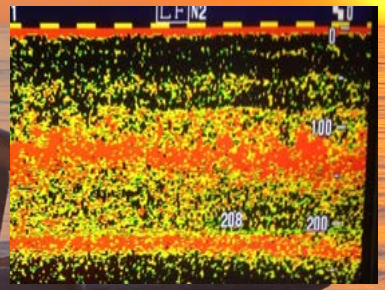
Pearlside protein refined by Biomega Group in waffles!

(Courtesy Kjartan Sandnes, Biomega)



Surveys with "Birkeland" 2016 - 2018

Surveys with "Birkeland" 2016 - 2018



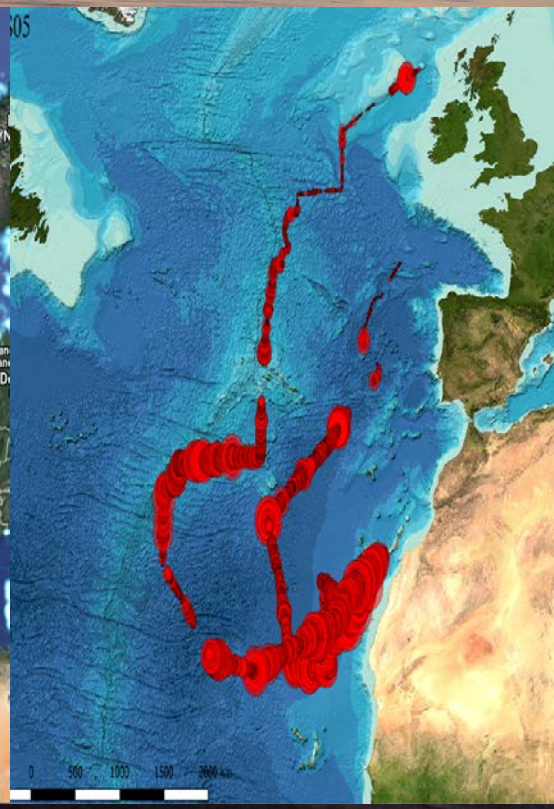
Surveys with "Birkeland" 2016 - 2018

June - July 2016

April – May 2017

July 2017

April – June 2018

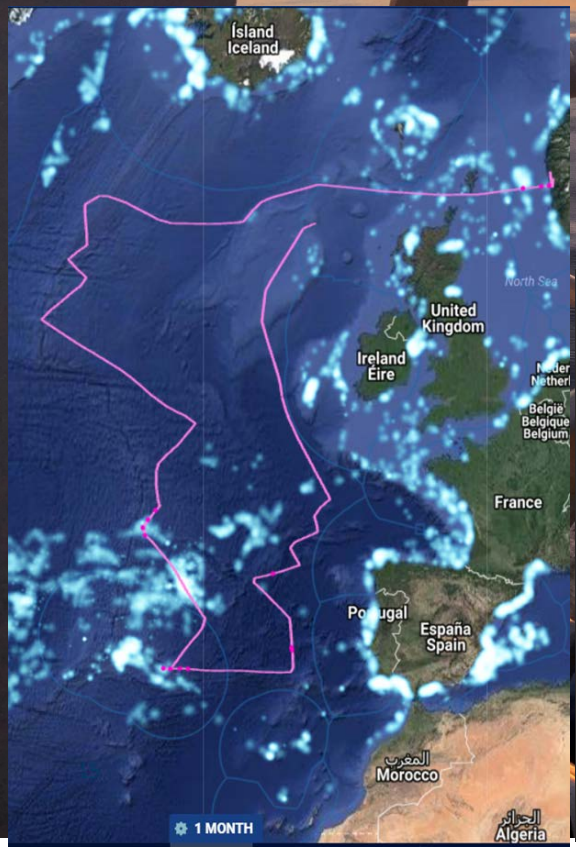


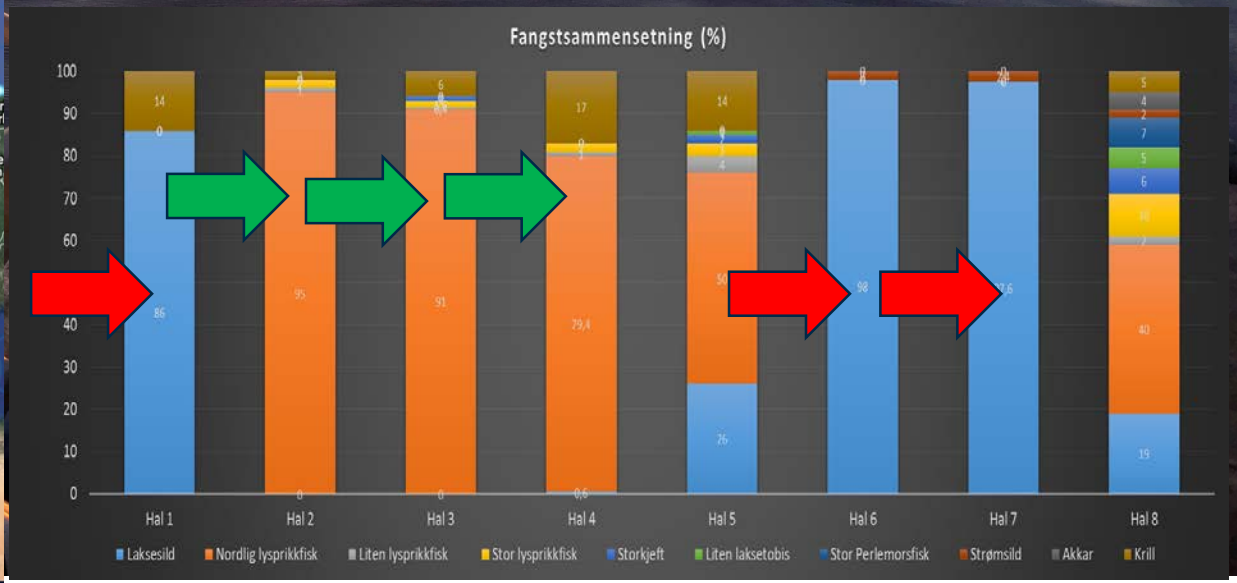
Catch

Maurolicus muelleri

Benthosema glaciale

Catch composition (June-July 2016)





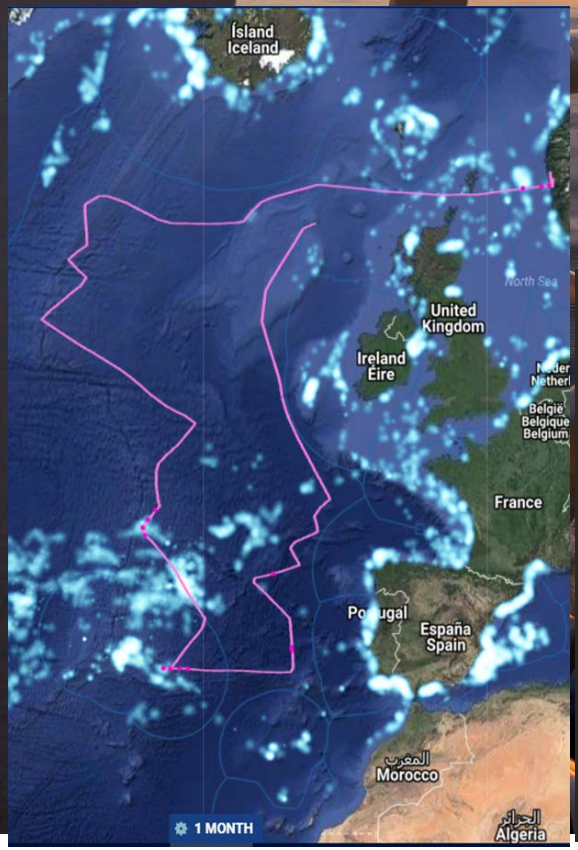
SINTEF

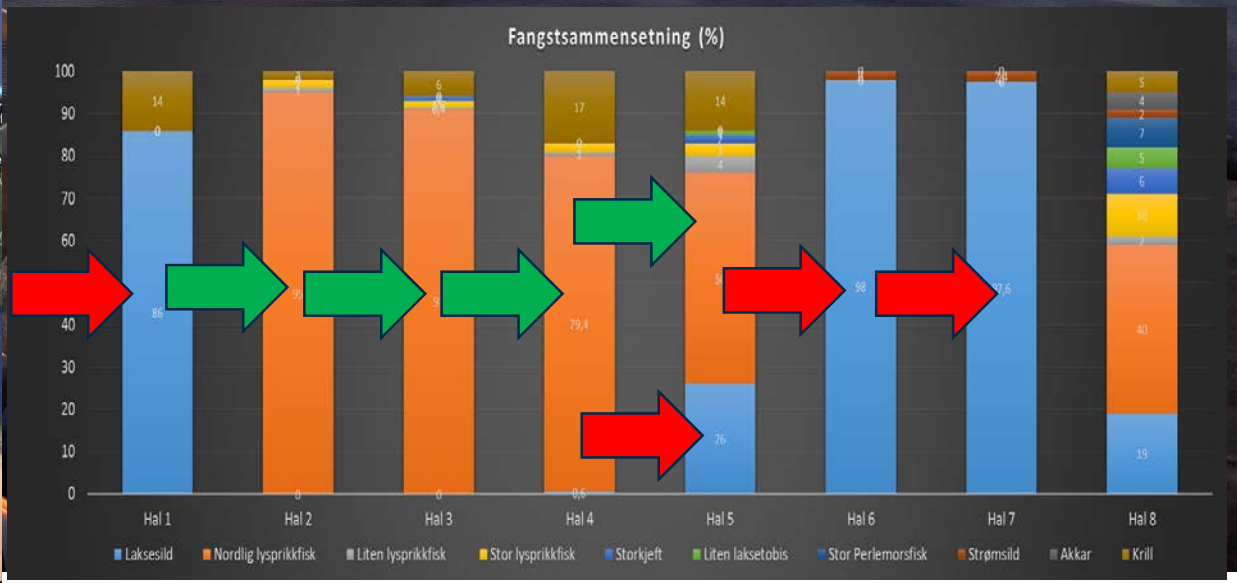
Catch

Maurolicus muelleri

Benthosema glaciale

Catch composition (June-July 2016)

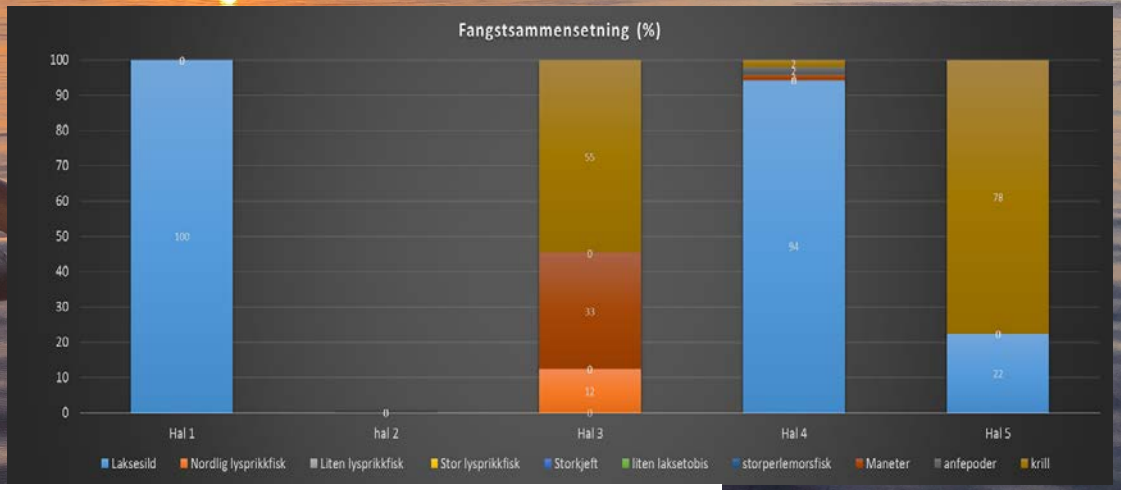




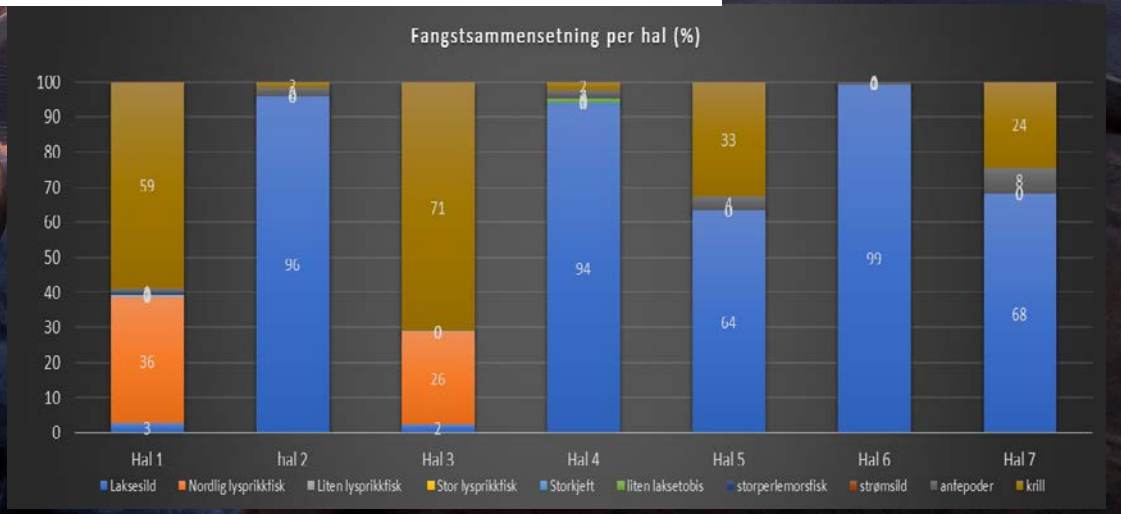
SINTEF

Catch

Catch composition (April-May 2017)

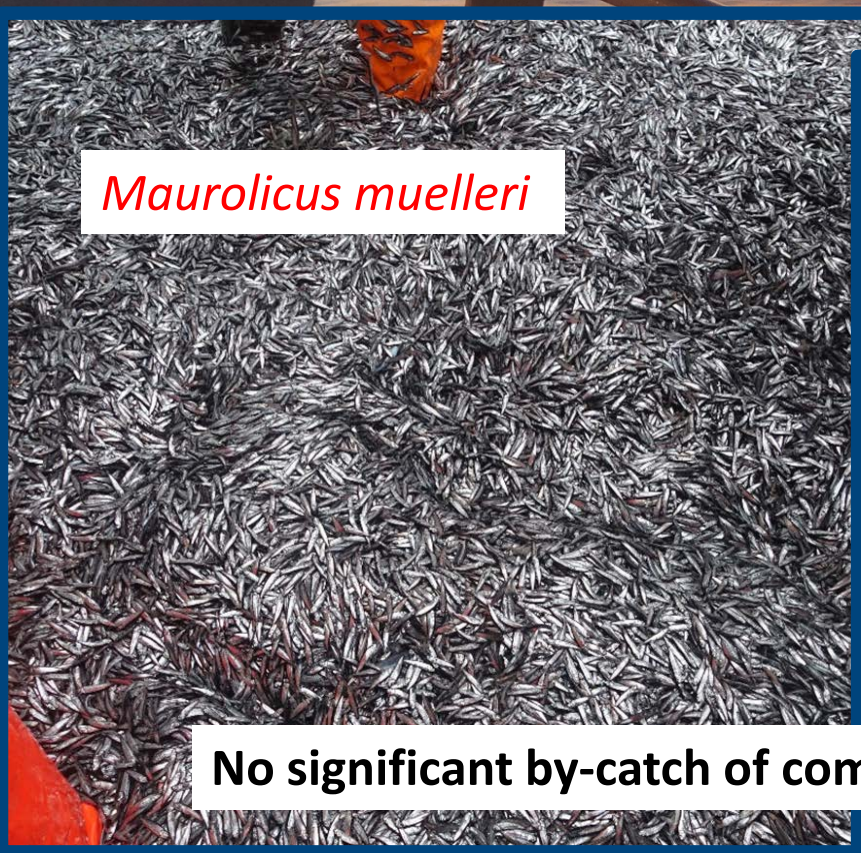


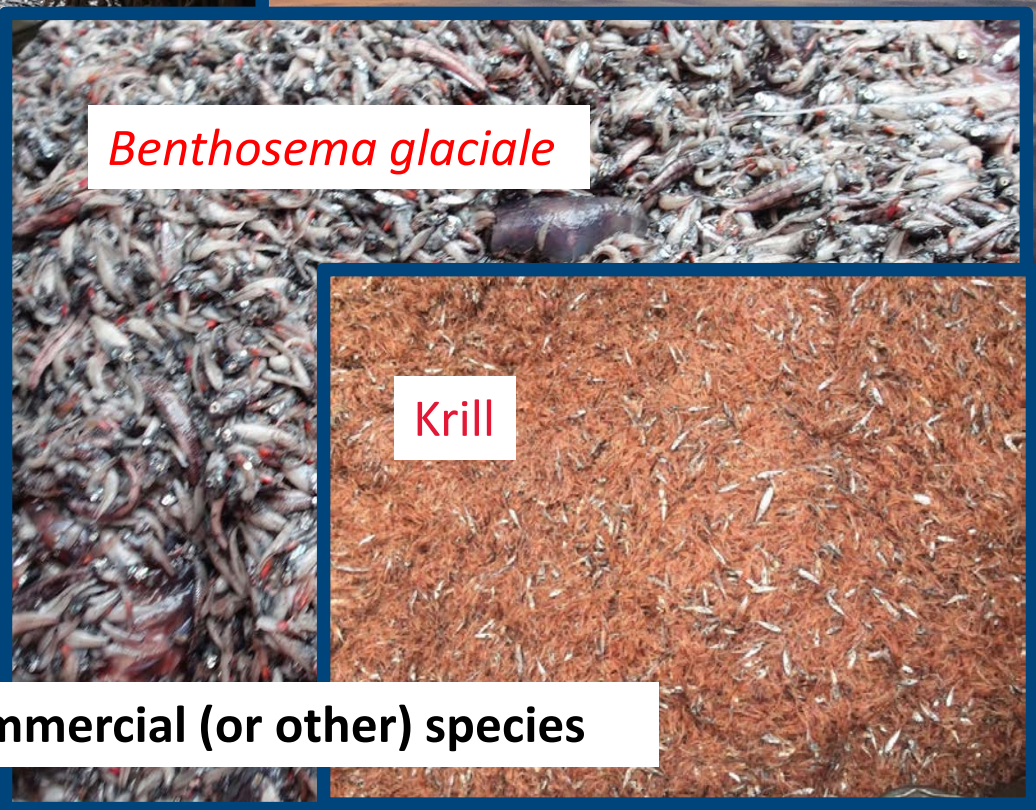
Catch composition (July 2017)



Catch

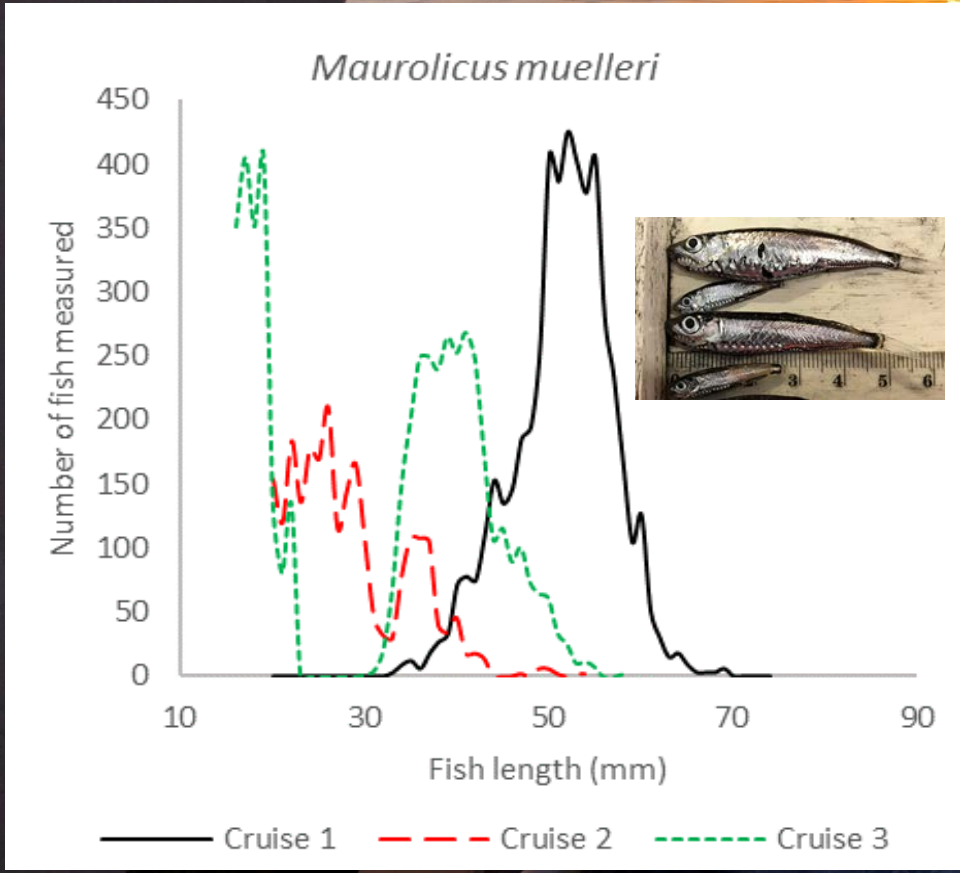
30 mesopelagic species, but 98%: pearlside, *Benthosema* & krill

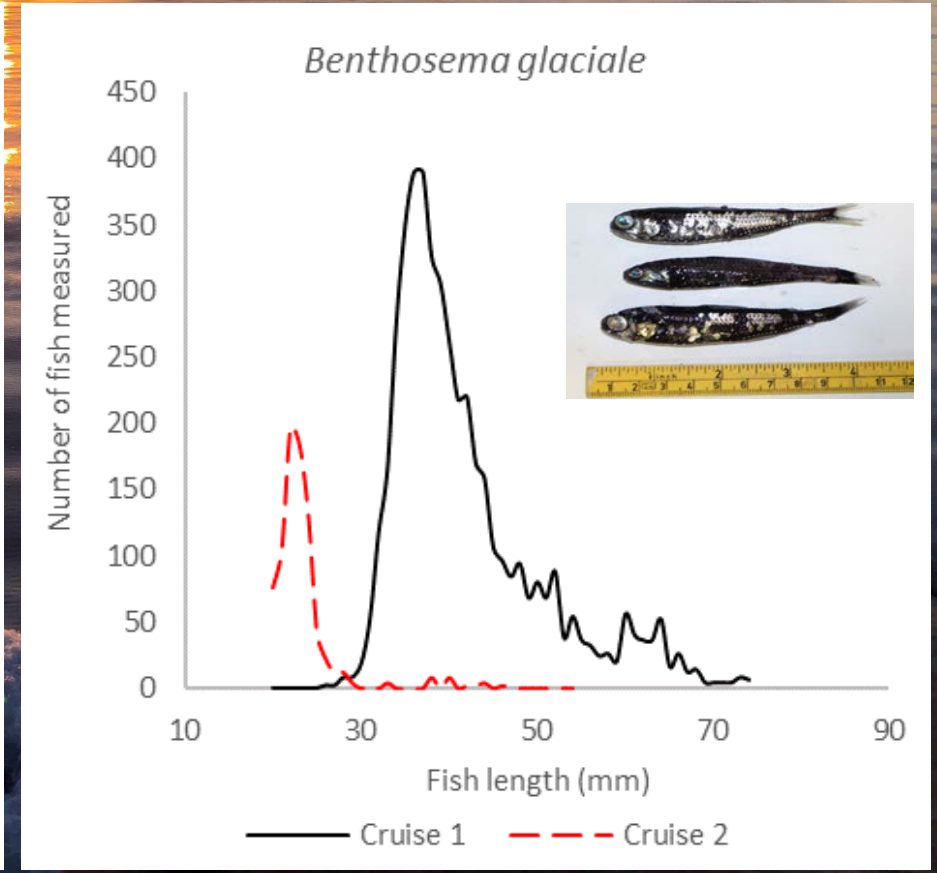




No significant by-catch of commercial (or other) species

Catch

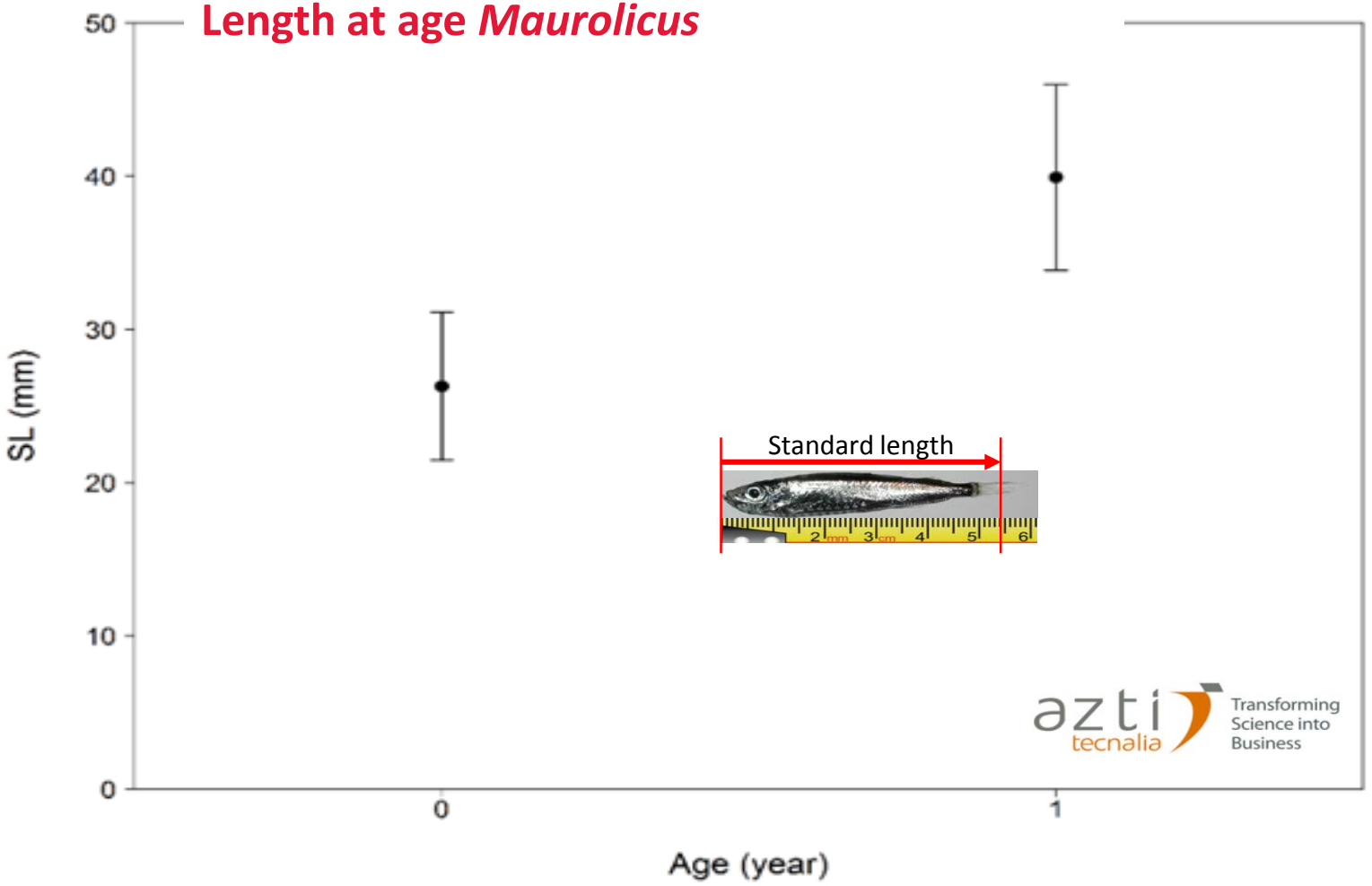




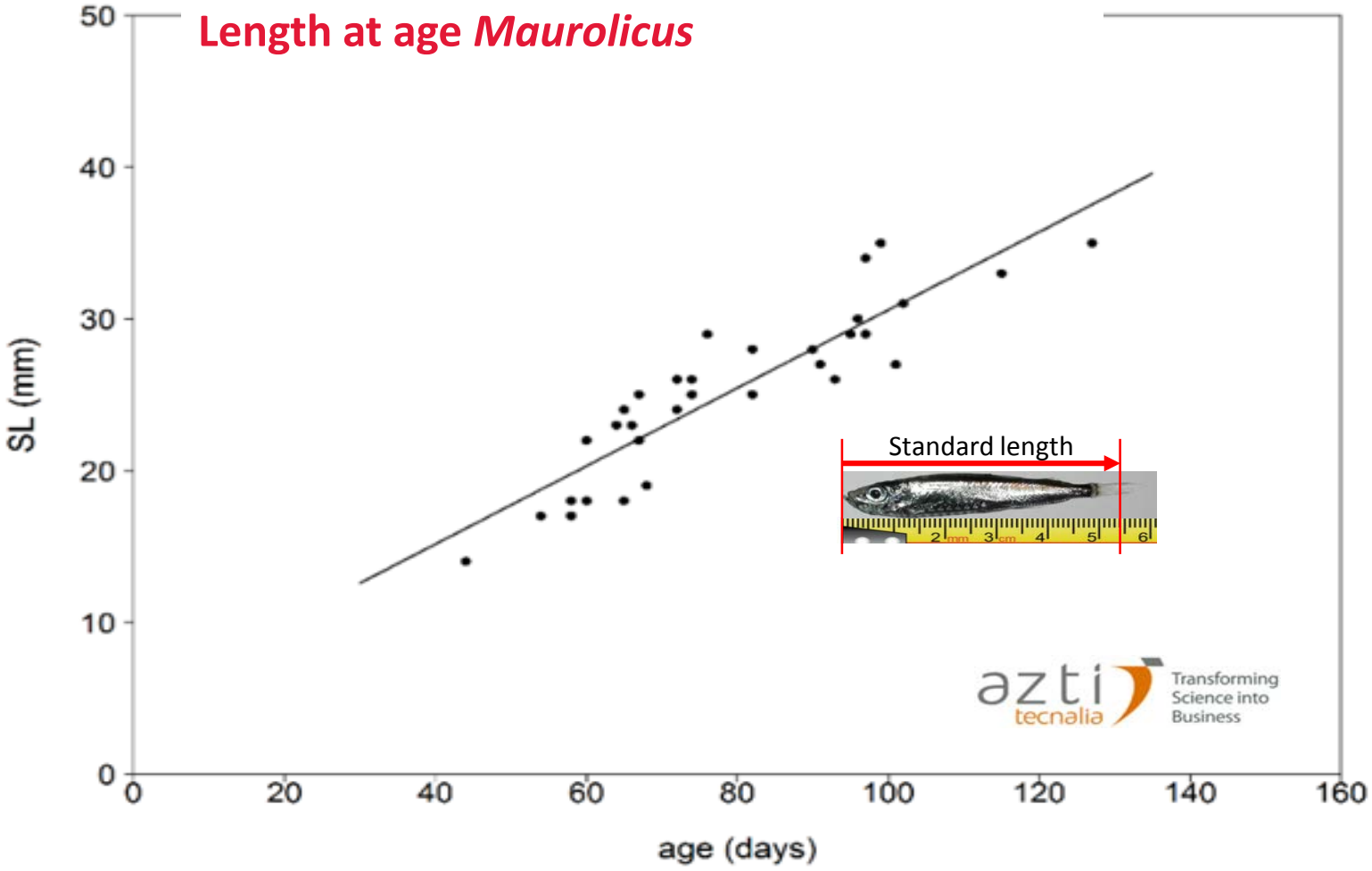
Crruise 1 2016, cruise 2 & 3 2017

Catch

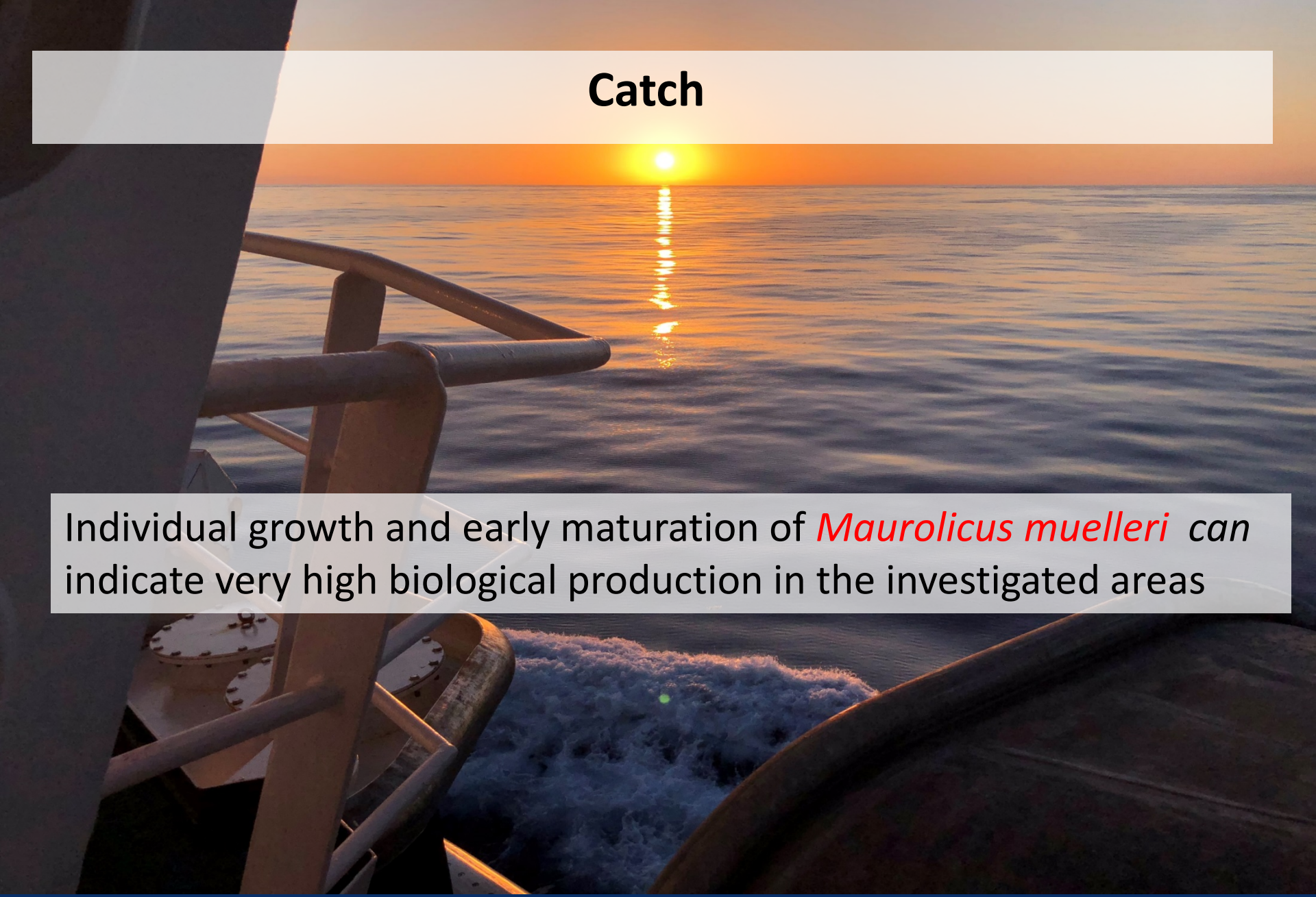
Length at age *Maurolicus*



Catch


Length at age *Maurolicus*
SL (mm)
age (days)
0
10
20
30
40
50
0
20
40
60
80
100
120
140
160
Standard length
azti
tecnalia
Transforming
Science into
Business

Catch



Individual growth and early maturation of *Maurolicus muelleri* can indicate very high biological production in the investigated areas

Chemical analyses

Lipids (extracted):	**4,3% -15,8% (wet)**
	17,9% - 49,7% (dry)
Omega 3 (average):	**24,5% of tot. lipids**
EPA+DHA (average):	**22% of tot. Lipids**
Protein:	**13,5%-16,5% (wet weight)**
Water:	**68,2%-76%**

Chemical characterization indicates high commercial values

Chemical analyses

Benthosema glaciale

70-80% waxesters

Maurolicus muelleri

70-80% triglycerides

Processing

Processing

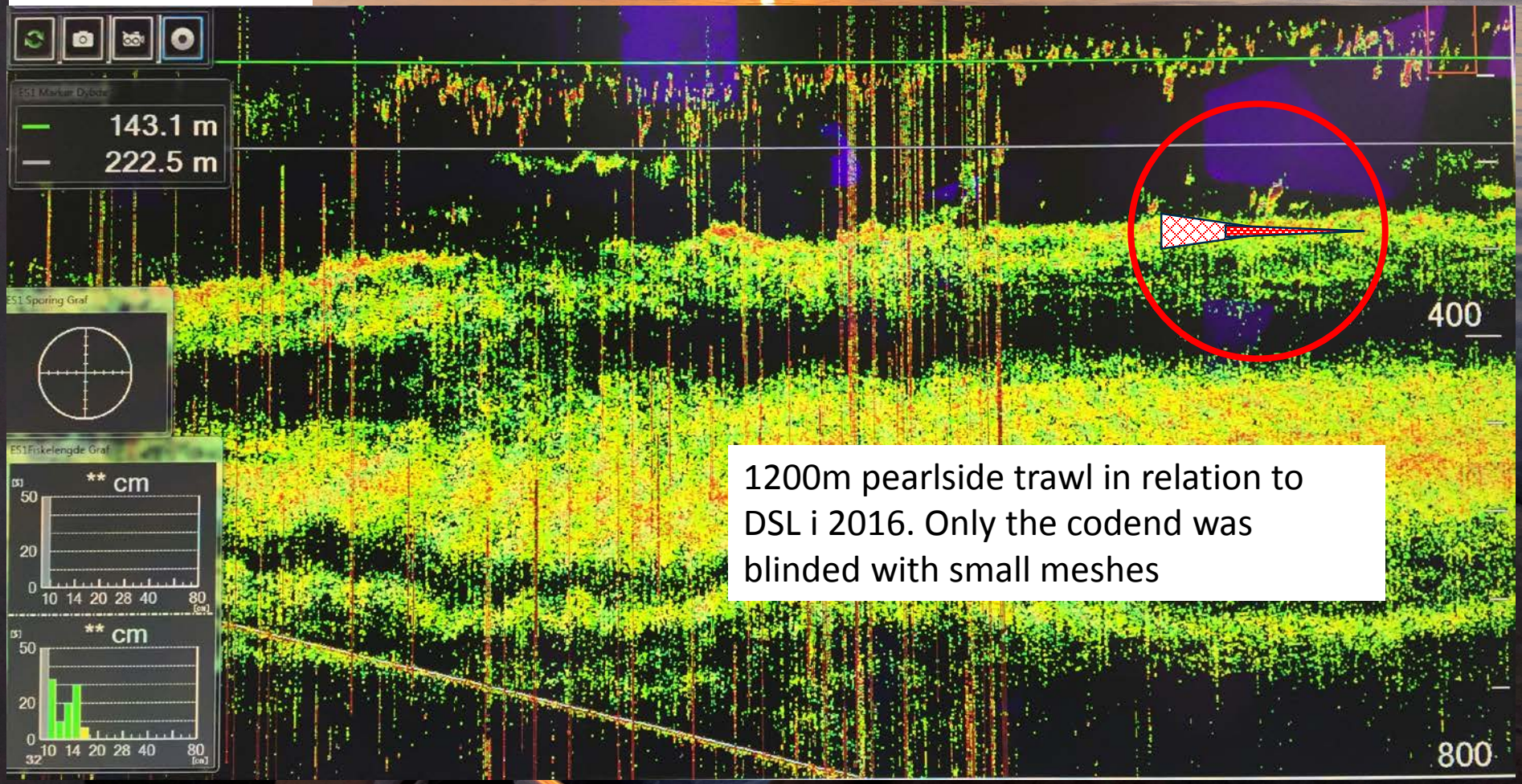
Processing

Oil yields lab scale from wet weight

	Raw material	Termic	Endogenous	Enzyme a	Enzyme b	Enzyme c
Fat haul 1	15,8 %	12,4 %	12,8 %	14,1 %		
Fat haul 2	11,1 %	10,1 %	12,5 %	13,7 %	13,7 %	14,4 %
Fat haul 3	13,7 %	12,7 %	16,8 %	15,5 %	15,3 %	14,6 %
Fat haul 4	12,0 %	11,3 %	15,3 %	14,4 %	15,8 %	16,5 %
Fat haul 5	12,2 %	9,5 %	11,3 %	12,5 %	13,1 %	14,2 %
Fat haul 6	6,2 %	5,3 %				6,2 %
Fat haul 7	4,3 %	2,8 %	2,4 %	2,4 %	2,4 %	2,5 %
Fat haul 8	7,0 %	5,9 %	10,3 %	9,2 %	6,8 %	9,8 %
Fat haul 9	5,4 %					
Fat haul 10	11,1 %					
Average	9,9 %	8,8 %	11,6 %	11,7 %	11,2 %	11,2 %

Gear

38kHZ ecogram



1200m pearlside trawl in relation to DSL i 2016. Only the codend was blinded with small meshes

SINTEF

Gear

Trawl development: Small scale testing

TRAWL 1:
1200m mesopelagic fish trawl, Danmark 21.sep.2016

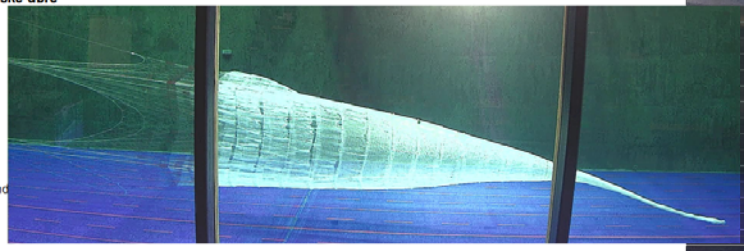
Company	**EGERSUND TRAWL**		**Model No:**	**1166**	
Trawl	**1200 m Mezopelagisk**		**Scale:**	**1 :**	**50**
Trawl doors	**25 m² ET Speed**				
Sweepline		m			
Bridles		120 m			
Set Back		8 m			
Clump Weights		1500 kg			
Other	1000 kg	sonde			
	300 kg	opdrift			

Test			1	2	3	4	5	6	7	8	9	10
Towing speed		knots	2,5	2,5	2,5	2,5	2,5	2,5	2,0	2,5	2,5	2,0
Distance between doors		m	150,0	150,0	150,0	155,0	155,0	100,0		100,0	95,0	92,5
Spread	Headline	m										
	Footrope	m										
	Side lines	m			84,9	74,6	76,6	60,4	57,6	57,7	55,8	54,1
Height	Wingend	m										
	Centre	m			54,5	41,7	49,1	54,6	61,3	59,9	50,6	53,6
Tension per side		tons	56,6	49,5	43,2	36,5	35,3	32,9	24,0	32,2	28,3	21,0

Test	Notes
1	Original rig
	Indgang til Bleen 100x 68 m = 5400 m²
2	Halvdelen af bleen fjernet de 3 første sektioner
3	INDGANG Ble: 85 m x 55 m = 3600 m²
4	totalt 4.5 sektioner fjernet,
	Indgang ble, 74.5 x 42 m = 2450 m²
5	Trawlen skåret ned med 4 masker per plade
	Indgang ble : 2953 m²
6	Mindre avstand mellem døre
	Indgang Ble 2590 m²
7	Som test 6, indgang ble 2850 m²
8	Rigget med 90 m stjerter
	Indgang ble 2710 m²
9	1.5 sektion ble fjernet , 2200 m²
10	Som test 9, Areal indgang ble: 2276 m²

TRAWL 2:
800 m pearlside trawl, Danmark 14.okt. 2016

Company	**EGERSUND TRAWL**		**Model No:**	**1168**	
Trawl	**800 m Laksesild trawl**		**Scale:**	**1 : 40**	
Trawl doors	**Pelagiske døre**				
Sweepline		m			
Bridles		90 m			
Set Back		10 m			
Clump Weights		2000 kg			
Other		500 kg i sond			

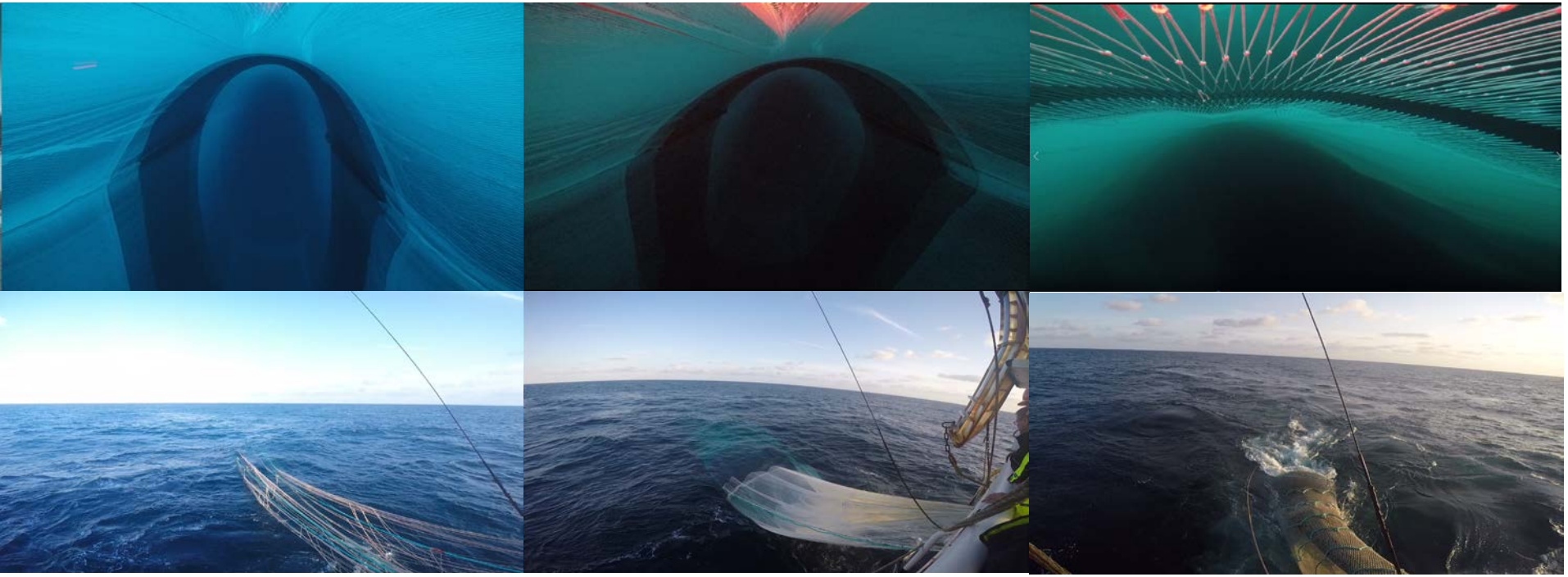


Test			1	2	3	4	5	6	7
Towing speed		knots	2,5	2,0	2,5	2,0	2,5	2,0	2,0
Distance between doors		m						56,0	41,1
Spread	Headline	m							
	Footrope	m							
	Side lines	m	71,5	47,2	41,9	42,7	45,4	47,0	42,5
Height	Wingend	m							
	Centre	m	37,7	45,0	30,0	34,1	44,9	45,0	45,9
Tension per side		tons	41,2	22,3	27,8	20,4	31,6	22,0	

Test	Notes
1	1000 kg kjlumper areal 2100 m²
2	2000 kg klumper areal 1920 m²
3	to bleer fjernet Indgang næsten rektangulært ca 1200 m²,
4	Mindre slæbehastighed areal ca. 1250 m²
5	Trawls forstykke reduceret, areal indgang 1600 m²
6	Mindre slæbehastighed areal ca. 1680 m²
7	Afstand ved galger 30 m, Areal indgang ble 1530 m²

Gear

Trawl development: Geometry measurements



Undesirable substances

- Very low values of unwanted substances such as dioxins, PCBs, PAH, chlorinated pesticides, and heavy metals (Pb., Cd., Hg. og As.). *)

- Far below recommended limits in the the directive on undesirable substances in animal feed*

*) DIRECTIVE 2002/32/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 7 May 2002 on undesirable substances in animal feed.

Further strategy

- The Norwegian government recommend a strategy for establishing more knowledge on mesopelagic resources and their potential as future food and feed resources
- The fleet owners in this Industrial Mesopelagic initiative have considerable excess capacity in their fleet of pelagic trawlers
- There are challenges to fit in with the available sources for funding of expensive but necessary surveys

Further strategy

- The mesopelagic potential can only be investigated and realized in a joint and committed long time effort between:
  - Governmental bodies including the Norwegian Institute of Marine Research (IMR)
  - Leading private companies and
  - Leading R&D institutions


CAN WE FIX IT?
YES WE CAN
LIE GRUPPEN
BIOMEGA
HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH
SINTEF