Forage Fish in the Marine Environment and Their Management

Hans Lassen
Nordic Marine Think Tank

Email: hans.lassen.nmtt@gmail.com

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Key Messages

- Raw material for the fish meal and fish oil industry consists of trimmings, other residues from the filleting industry (~35% in weight) and catches that are taken with the purpose of landing for the fish mill (~65 % in weight).
- Globally, the fish meal and fish oil industry processes 16–20% of total world capture fisheries production.
- The species that dominate landings for reduction purposes are small pelagics but other species are also processed.
- The species that are taken in the directed catches in the Northeast Atlantic and the Baltic Sea include capelin, sandeel, herring, sprat, Norway pout, blue whiting and boarfish.
- The public debate on which species are suitable for processing as fish meal and fish oil mixes the forage fish concept with the criteria which make fish interesting for fisheries for the mill. The industry is looking for raw material which can be delivered at low cost and in high quantities, only some of the species that meet such criteria are forage fish.
- Management of the resources is subject to high transaction costs as for all fisheries in the Northeast Atlantic. Fisheries for the mill present special challenges to management such as bulk landings, by-catches and the structure of the catching industry.
- Small pelagic fish can experience rapid population expansion and collapses. The population size is usually strongly environmentally driven. The management strategy is typically to preserve as far as possible sufficient spawning capacity in the population to ensure that recruitment can be successful when the environmental conditions are good. These species are susceptible to changes in abundance and distribution due to climate changes.
- Management is based on the same tools as for other fisheries and similar the objectives for management are Maximum Sustainable Yield (MSY) and sustainable production of the stocks.
- There is increased use of management plans that defines the allowed fishing pressure or TAC based on scientific input thereby changing management decisions from a political process to a more rational and transparent process based on data and with well-defined rules. This opens possibilities for more industry self-management. The fisheries for meal and oil are prime candidates because of the structure of the industry – large capital heavy enterprises – to lead the development.

Introduction

The demand for fish meal and fish oil is high and growing for the production of protein and fat for aquaculture feeds (e.g., salmon), agriculture feed (pigs, poultry) and human consumption (omega-3 fish oil). In Europe there is a gap between protein demand and internal production. In 2011 the European Parliament adopted a resolution to address the EU's protein deficit stating that urgent action is needed to replace imported protein crops with alternative and new European sources. Currently Europe is reliant on importing 70% of its protein for animal feed, mainly soya and maize for agriculture. Fish meal and fish oil fill a small part of this demand but as presented by other speakers at this Symposium, this is a particular valuable commodity because of the high content of long chained omega-3 fatty acids and amino acids required for fish production. Aquaculture presently allocates significant funds in developing aquaculture products using protein and fat from other sources than fish including plants and, perhaps more farfetched insects. Alternative materials such as krill (zooplankton), phyto- and mesozooplankton, and algae are also considered valuable future alternatives as raw material for the processing industry.

The raw material for production of fish meal and oil is catches of fish (65%) as well as trimmings and other residues from production of filets etc. (35%)[1]. On a global scale the fish meal and fish oil industry processes 16–20% of total world capture fisheries production (for 2012, 91.3 mill t of which 79.7 mill t came from marine areas). The species dominating landings for reduction purposes are at the global level small pelagics such as anchovy, small mackerels (e.g., Rastrelliger spp.), Menhaden, sardines and sardinellas, jack mackerels, herring and sprat. But also other species such as blue whiting and krill are processed. Not all landings of these species are for meal and oil production, e.g., small amounts of anchovy and sprat for human consumption and sardines for canning or direct human consumption. Herring is used for human consumption on a large scale.

Landings that can be directly used for human consumption fetch higher prices per kg than do landings for the fish mill and from a superficial view landing for direct human consumption would be the preferred option for the fisher. However, landings for direct human consumption are more labour intensive than landings for the fish mill. For many species there is no market or only certain categories and limited amounts of these landings are in demand for human consumption.

Having experienced a long series of stock collapses many of which were brought about by heavy fishing, e.g. Atlanto-Scandian herring, North Sea herring, North Sea mackerel, a general accepted conclusion is that government management is required to regulate the fishing mortality. This also applies to fishing for raw material for the fish meal fish oil industry.

Managing a fishery requires good understanding of the population dynamics of the resource combined with a snapshot of its current status but also an understanding of the dynamics of the fisheries involved. In the North Atlantic Ocean, management is based on a 'rational fisheries management model' that sometimes is claimed to be Nordic, it is, however, rather global. This management model aims at sustainable and economic viable fisheries and bases regulation on scientific advice, followed by consultations between stakeholders and management and finally government decision and implementation. The model includes a monitoring, control and surveillance component that often is downplayed in presentations of the system as it is assumed that the consultation process has assured compliance with the regulations; control and deterrence measures are therefore of less importance. The rational fisheries management model is embedded in the conventions of international fisheries commissions and in most national fisheries legislations.

Fisheries management is based on specialised institutions producing formalised knowledge, which by a centralised bureaucracy is used as a basis for management decisions and implementation. A key factor in this process is the communication through this chain. Science, management and fisheries are different cultures that clash and it is not easy to get these to understand each other. This lack of understanding has led to general mistrust between the system components; a mistrust for which society pays dearly in the form of costly institutions to regulate the data flow and to observe each player's move, i.e., the system has high transaction costs.

These reflections are general and apply to the fisheries for the fish mill as well. There are, however, several aspects where these fisheries present special challenges to management such as bulk landings, by-catches and the structure of the catching industry as discussed in the subsequent sections.

Fishing for the Fish Mill

The fisheries providing the raw material for the fish meal and oil industry fall into two categories:

1) Directed fisheries, typically highly industrialised vessels; and
2) Low value catches, e.g., by-catch in shrimp fisheries (trash fish).

The first group by far provides the larger amounts.

[1] FAO 2014. The State of World Fisheries and Aquaculture 2014 (SOFIA). (Based on data for 2012).

Globally, the fish meal and fish oil industry is based on the availability of cheap raw material (low price per landed weight unit) and it is a common misunderstanding that the industrial fisheries are specifically directed at forage fish or small pelagics. Rather, the fishing strategy reflects the economy of the fishery and the landings are sold to the highest bidder. Current fishing technology can only deliver low cost fish if the fish is easy to find and occur in large quantities and in high concentrations, typical shoaling species, so they can be fished with high catch rates. Furthermore, the catch and its handling must require little use of manpower e.g. no manual sorting, bleeding or gutting. Fish behaviour changes through the life phase but also by season and many species are only seasonally available in concentrations which make them interesting to the industrial fleets. Much of these resources are small fish which because of their size are fished with non-selective gears (e.g., 16 mm mesh trawl or sandeel trawl with even smaller meshes).

Some amounts of fish caught under these conditions are used for direct human consumption and the price for such fish prohibits their use as raw material for the fish meal and oil industry, examples include anchovy, sprat and herring. But for many of the species the fish mill is the only buyer. However, in some cases the fish can be used fresh for fur production (e.g., fox and mink).

In the Northeast Atlantic there are direct fisheries for raw material for the fish meal and fish oil industry targeting sandeel (North Sea), sprat (North Sea, Baltic Sea), Norway pout, (North Sea), boarfish, (The Channel), capelin (Iceland, Barents Sea), blue whiting (Northeast Atlantic), and herring (Baltic Sea). Several of these species (e.g., sandeel, sprat, Norway pout, capelin) are forage fish, see below, and it is this share of the raw material that we consider in this section of the Symposium.

Where management in many other fisheries has to deal with numerous small fishing units – which in themselves present particular problems – the fisheries for the mill are capital-heavy large vessels, able to handle large quantities. The fleets are also highly mobile to match the seasonal availability of the resources.

Forage Fish and Their Role in the Marine Ecosystems

"Forage fish" is a biological classification that considers their role in the marine ecosystem

> *Forage fish are prey for upper trophic-level predators and as such providing a route for energy transfer from plankton to higher trophic levels in marine ecosystems: predatory fish, birds, and mammals. They transfer a large proportion of energy in the ecosystem and support or regulate a variety of ecosystem services. Few species are in this trophic role in marine food webs, but they are the largest vertebrate component of each system by number and weight. Forage fish retain their unique role in the food web from egg to adult (modified from Lenfest report 2102)[2].*

Much the same fish are also classified as Low Trophic Level (LTL) species in the context of Marine Stewardship Council (MSC) certification. The MSC[3] certification definition for Key LTL species[4] include three criteria:

- A large proportion of the trophic connections in the ecosystem involve this stock, leading to significant predator dependency;
- A large volume of energy passing between lower and higher trophic levels passes through this stock; and

[2] Pikitch, E.; Boersma, P.D.; Boyd, I.L.; Conover, D.O.; Cury, P.; Essington, T.; Heppell, S.S.; Houde, E.D.; Mangel, M.; Pauly, D.; Plagányi, É.; Sainsbury, K. and Steneck, R.S. 2012. Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs. Lenfest Ocean Program. Washington, DC. 108 pp.
[3] Marine Stewardship Council. Certification of Sustainable Fisheries.
[4] MSC Fisheries Certification –Requirements Section SA 2.2.9. 1st October 2014 © Marine Stewardship Council 2014.

- There are few other species at this trophic level through which energy can be transmitted from lower to higher trophic levels, such that a high proportion of the total energy passing between lower and higher trophic levels passes through this stock (i.e., the ecosystem is 'wasp-waisted').

The Marine Ingredients Organisation (formerly IFFO)[5] has introduced its own certification scheme that does not operate with a special definition or treatment of 'forage fish' or 'low trophic level' species but rely on "Management actions must be scientifically based on long-term fishery and ecosystem conservation objectives". This is further described in additional criteria in the checklist of the certification scheme, in the end, however, leaves it to the scientific advisory system on how to take the resource's ecosystem role into account.

Fisheries for these species are in competition with the predators seeking food such as larger fish e.g., cod, seals and/or sea birds. This competition has occasionally been resolved through banning of trawling e.g., in the vicinity of bird colonies.

Many of these species are short lived and only spawn once (e.g., capelin and Norway pout) and this suggests that there should be focus on the survival of the juveniles to ensure that the spawning stock is maintained. International Council for the Exploitation of the Sea (ICES) advisory scheme[6] considers these short-lived species as a special category and has defined a harvest control rule applicable for these species. The MSC certification scheme defines its own limits on the allowed fishing pressure based on Yield per Recruitment considerations i.e. that the spawning stock should be at 75% of the virgin biomass. This criterion can be reduced to 40% if documentation is available that such higher fishing pressure is within sustainable limits.

Management needs to balance the allowed catch with the needs of the ecosystem. This increases the demand on data and understanding of the functioning of the ecosystem. These needs also increase the costs for a relevant assessment based on an 'ecosystem approach' compared to management that considers the target stock only (single species assessment).

Maximum Sustainable Yield and the Ecosystem Approach

Commercial fishing influences the population dynamics of a fish stock, may threaten the reproduction of the fish and cause fish stocks to collapse through recruitment failure if the spawning stock is brought to a low level. This applies to all fish species. Fisheries management therefore has two fundamental objectives i.e. to restrict the fishing pressure within sustainable limits and to achieve as much yield that is possible within such limits.

The overall objective of present fisheries management in the Northeast Atlantic is MSY[7]. The UN WSSD Johannesburg Conference in 2002 brought the MSY concept back in good standing[8] after MSY had been buried for more than two decades[9]. MSY can be interpreted – and has been – in many different contexts many of which are defined through the scope of the model underlying setting the regulation.

Figuring out what the appropriate MSY is and hence the Total Allowable Catch (TAC) or corresponding effort level requires consideration of the reproduction of the target species, and typically management plans are based on assuring sufficient spawning to avoid recruitment collapse. Thereby one focuses on the target stock and the ICES advice for fish stocks in the Northeast Atlantic is mostly based on such considerations.

[5] IFFO The Fishmeal and Fish Oil Organisation. In 2012, IFFO changed its name to IFFO The Marine Ingredients Organisation.
[6] ICES Advice 2016 Book 1 section 1.2.5.3
http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2016/2016/Introduction_to_advice_2016.pdf.
[7] MSY is the largest yield (or catch) that can be taken from a species' stock over an indefinite period. The MSY is usually higher than the maximum economic yield.
[8] Plan of Implementation of the World Summit on Sustainable Development 2002 Chapter IV §31 (a).UN Johannesburg.
[9] Larkin, P. A. 1977. An epitaph for the concept of maximum sustained yield. Transactions of the American Fisheries Society 106:1–11.

However, there are strong voices that call for consideration of the yield from the ecosystem perspective, thereby bringing the species interaction into the equation. The interactions considered are largely confined to those in the fish and shellfish compartment. At ICES, this is termed 'an ecosystem approach' and used in this context it is about the biological model behind the scientific advice on sustainable fishing. While the 'single species' approach assumes that interaction with other species are constant over time an 'ecosystem approach' accounts for the temporal (and spatial) variation in these interactions.

The key energy transport in the ecosystem between trophic levels is through prey-predation. It is normally assumed that there is a balance between prey and predators because should there be food surplus (large prey biomass) the predator population will grow until prey and predator biomasses balance[10]. The biological classification as 'forage fish' emphasise this mechanism. In many cases these small pelagic fish take the ecological role as forage fish. A specific problem arises when the by-catch is of juvenile stages of species that are caught in human consumption fisheries which creates competition for the resources between different groups of fishers. These problems are fishery specific, irrespective of whether targeting small pelagic fish or not and irrespective of whether these fish are forage fish or not.

The small pelagics, however, present additional challenges. Small pelagic fish can experience rapid population expansion because of their relatively small body size, fast growth, early maturity, and relatively high fecundity. The population size is usually strongly environmentally driven and often exhibit large annual, inter-annual, or decadal-scale fluctuations. Classical examples include the Peruvian anchovy which links the recruitment to the strength of upwelling[11]. An example where the species interaction is important is the Barents Sea capelin where the abundance is linked to the occurrence of young herring[12] combined with cod predation[13]. However, their short life span can also lead to sudden population collapse when adult mortality rates are high and spawning biomass therefore low. The management strategy is therefore typically based on preserving as far as possible sufficient spawning capacity in the population that assure that recruitment can be successful when the environmental conditions are good. In the light of climate changes these species are susceptible to changes in abundance and distribution[14].

However, the term 'ecosystem approach' is also used in a wider context as the basis for fisheries regulation. FAO (2003)[15] defines an Ecosystem Approach Management as:

> *An ecosystem approach to fisheries strives to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecological meaningful boundaries.*

Against this background, ecosystem management approach is a multi-objective problem. The ecosystem approach does not in itself define the multi-objective function and the objective function will vary between ecosystems in response to the human activities and the biological processes in the ecosystem.

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[10] Smith A.D.M.; Brown C.J.; Bulman C.M.; Fulton E.A.; Johnson, P.; Kaplan I.C.; Lozano-Montes, H.; Mackinson S.; Marzloff M.; Shannon L.J.; Shin Y-J.; Tam J. 2011. Impacts of Fishing Low–Trophic Level Species on Marine Ecosystems *Science* 26 Aug 2011:Vol. 333, Issue 6046, pp. 1147-1150 DOI: 10.1126/science.1209395.

[11] FAO: http://www.fao.org/docrep/005/y2787e/y2787e0b.htm
See also Singh Ashneel A;, Sakuramoto Kazumi; Suzuki Naoki. 2014. Model for stock-recruitment dynamics of the Peruvian anchoveta (Eugraulis ringens) off Peru. Agricultural Sciences Vol.5, No.2, 140-151 (2014) http://dx.doi.org/10.4236/as.2014.52017.

[12] Gjøsæter, H. and Bogstad, B., 1998. Effects of the presence of herring (Clupea harengus) on the stock-recruitment relationship of Barents Sea capelin (Mallotus villosus). Fisheries Research Volume 38, Issue 1, 1 September 1998, Pages 57–71.

[13] Gjøsæter, H.; Bogstad, B. and Tjelmeland, S. 2002. Assessment methodology for Barents Sea capelin, *Mallotus villosus* (Müller). ICES Journal of Marine Science, 59: 1086–1095.

[14] Checkley, D.; Alheit J.; Oozeki Y. and Roy C. (eds.), 2009. Climate Change and Small Pelagic Fish. Cambridge University Press.

[15] FAO (2003) The Ecosystem Approach to Fisheries. Technical Guidelines for responsible fisheries Nos 4 and 2 Rome Italy.

Managing Fisheries for the Mill

Management of fisheries for the mill is based on the same principles as other fisheries[16]. The two main concerns are that exploitation of the target species should be within sustainable limits and aim at MSY. The management measures used to achieve these aims are similar to those applied to other fisheries, e.g., TACs, effort and capacity regulation, technical measures, by-catch regulations and close areas and seasons. There are two specific issues however, because:

1) Fishing is often with non-selective gears (typically purse seines or small mesh trawls); and
2) The landings are in bulk, the species composition of the landings can only be established by sampling the landings and the risk for exploiting undersized and other unwanted fish is higher than if more selective gears are used.

Therefore, by-catch regulations are more elaborate than for other fisheries. While mixed species catches are an issue in several fisheries there are large fisheries providing raw material for the meal and oil industry where the catches are clean i.e. that they largely consist of a single species only. Purse seine catches will very often take a single shoal and where (often the case) this shoal holds a single species only there is little by-catch. Trawl catches for North Sea sandeel are also with little by-catch. Furthermore, small pelagic species usually form dense schools, making them highly accessible to fishing even when the total abundance is low. Effort regulation schemes are doomed at the outset simply because it is possible to find the last school and fish this at a profit.

As discussed above, the raw material for the fish meal and oil industry is from a variety of sources and the management of these resources cannot be treated Procrustean[17]. Hence, there is no 'one size fits all' and management must be done on a case by case basis.

Challenges

The fish meal and fish oil industry is facing a number of challenges in the coming years:

- There is a public lack of understanding of how the fish meal and fish oil industry operates. Partially this include the scientific community as well. Misunderstandings relate to mixing the forage fish concept with the criteria which make fish interesting for the fisheries for the mill.
- Raw material for the fish meal and oil industry is becoming scarce. The fisheries that supply raw material for the fish meal and oil industry shows decreasing yields. This has been offset by increased use of residues and offal from the filleting industry.
- Aquaculture is actively searching for substitutes for fish meal and fish oil for fish feeding and the demand for fish meal and oil may change dramatically in the next decade.
- There are calls for reducing the acceptable exploitation level for forage fish, e.g., through MSC certification of key LTL species.
- Costs for an assessment using the ecosystem approach are higher than for traditional 'single stock' assessments. However, public willingness to pay for management and scientific advice is decreasing while there are calls for even more detailed and hence costly assessments.
- A major share of the directed fisheries relies on small pelagics. Small pelagic fish can experience rapid population expansion and collapses. The population size is usually strongly environmentally driven. The management strategy is typically to preserve as far as possible sufficient spawning capacity in the population ensuring that recruitment can be successful whenever the environmental

[16] FAO (2005) Code of Conduct for Responsible Fisheries. Rome, FAO. 1995. 41 p.
[17] Marked by arbitrary often ruthless disregard of individual differences or special circumstances.

conditions for reproduction are good. These species are susceptible to changes in abundance and distribution due to climate change.

Opportunities

- Demand for fish oil for the pharmaceutical industry is increasing.
- Demand for fish meal and oil for aquaculture is increasing. This is likely to lead to increasing prices. However, the main costumer – the aquaculture industry – is actively looking for substitutes for fish meal and oil.
- The discussions of the 2014 EU Common Fisheries Policy reform included many topics that were subsequently dropped e.g. the role of the fishing industry in the management process sometimes under the name of 'reversing the burden of proof' which involves a discussion of the role of the industry in management and if under certain conditions a certain degree of industry self-management is possible.
- As part of this self-management the industry may consider contributing actively to fish stock assessments. These are based on two inputs:
  - Documentation of the fisheries; and
  - Fishery independent data from research vessels.

  Hence the industry can in principle be responsible for the fish stock assessments or part of the assessments.
- Another general tendency is the increased use of management plans that defines the allowed fishing pressure or TAC-based on scientific input, e.g., trends in abundance survey results. This changes the decision from a political process to a more rational and transparent process based on data, with well-defined rules and thereby opens for more industry self-management. These two last points suggest that the development will be increased self-control of the fisheries. The fisheries for meal and oil are prime candidates to lead the development because of the structure of the industry, i.e. large capital heavy enterprises.
- Certification of fisheries. There is a proliferation of fisheries, notably the MSC scheme and specifically for the fish meal and fish oil industry the IFFO scheme. This is also a step towards more self-control of industry performance.
- The discard ban being introduced in the EU may provide additional raw material but the Norwegian experiences rather suggest that the fishing pattern will change[18] and that the catch of fish that hitherto has been discarded will be avoided in the future.

[18] Gullestad P.; G.Blom G.; Bakke G.; Bogstad B. 2015. The "Discard Ban Package": Experiences in efforts to improve the exploitation patterns in Norwegian fisheries. Marine Policy 54(2015)1–9.