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Institutional nuts and bolts for a mesopelagic fishery in Norway

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ABSTRACT

While most commercial fish stocks in the north Atlantic are regulated with TAC's (total allowable catch), access regulations and IVQ's (individual vessel quotas), harvesting mesopelagic fish resources, such as pearlsides (*Maurolicus muelleri*) and glacier lanthern fish (Benthosema glaciale), represents a clear exception. Neither TAC's nor rules for bycatch are implemented. As mesopelagic fish resources are classified as one of the largest fish resources globally and abundant in the north-Atlantic, the species represent a significant potential for the development a new fishery and source for the biomarine industry. However, with reference to the historical development of other fisheries, lack of TAC-regimes represents a major driver for capacity expansion. As a new mesopelagic fishery may be conducted either as a new- and additional season for today's deep-sea pelagic fleet or by specialized vessels for a year-round mesopelagic fishery, the alternatives represents different capacity adaptations and institutional implications for the management regime. This article outlines the mesopelagic potential, which management principles may be implemented to a mesopelagic fishery and the interplay to other TAC-regulated pelagic fisheries.

1. Introduction

From 1950 to 1990, world fishery catches increased from 20 to 90 million tonnes, a growth rate of 8–9% per year. However, since the early 1990s, the global wild fish catch has not increased [1]. As early as the 1970s, Gulland [2] expressed the view that stagnation could be expected. Still, over-fishing remains a major problem in word fisheries. During the last 50 years, the fraction of marine fish stocks exploited within biologically sustainable levels showed a decreasing trend, from 90.0% in 1974 to 66.9% in 2015. Within the same time span, the percentage of stocks fished at biologically unsustainable levels (over-exploited) increased from 10% to 33.1%. In 2015, fully fished stocks accounted for 59.9% and underfished stocks for 7.0% of the total assessed stocks [1]. To bring all fish resources within safe biological limits, the United Nations Sustainable Development Goals include targets to end over-fishing and bring over-exploited stocks to levels that can produce maximum sustainable yield (MSY) in the shortest time feasible [1].

This development also applies for commercial fisheries in Norway. Since the end of the 1970s, most commercial pelagic and demersal fish resources have been fully exploited, and Total Allowable Quota (TAC) regimes and access regulations have gradually been implemented in most commercial fisheries [3]. For actors within the deep-sea fleet, further commercial expansion may be obtained by either purchase of extra quotas within the framework of the individual transferable quota (ITQ) regime or by fishing down the marine food web for unexploited and less valuable fish resources, such as mesopelagic species [4]. As the availability of ITQs in the quota markets for key pelagic species, such as herring (*Clupea harengus*), mackerel (*Scomber scombrus*), and blue whiting (*Micromesistius poutassou*), are scarce and the time of ownership of purchased ITQs is limited (20–25 years), mesopelagic fish species with no TAC regime represent a potential key growth strategy for the deep-sea pelagic fleet. However, within Norway's economic exclusive zone (EEZ) and the most relevant areas for mesopelagic fish species (The Norwegian Sea), commercial fish stocks, such as herring, mackerel and blue whiting, are well managed and within safe biological limits. In this setting, the search to develop a mesopelagic fishery does not correspond to Pauly et al.'s [5] perspective that fishing for unexploited mesopelagic fish resources is driven by over-harvested or depleted fish stocks higher up in the marine ecosystem. Instead, the new approach refers to a fishery in addition to already existing pelagic fisheries, as addressed by Essington et al. [6].

Mesopelagic fish species are abundant in the world oceans and represent a size in biomass that is not comparable to any other commercial fish resource. Estimates of the global biomass of mesopelagic fishes show huge variations ranging between 1000 and 10,000 million tonnes [7–10]. Vast amounts of mesopelagic fish resources are also expected to be present in the northeast Atlantic Ocean, including the Norwegian EEZ, and in other nations' EEZs and in international waters [7,11–13].

Despite the anticipated vast biomass of mesopelagic fish resources, they remain one of the least investigated components of the biomarine ecosystem, with major knowledge gaps in their biology and ecology [4]. To increase knowledge about mesopelagic fish resources and lay the

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foundation for sustainable management and a new biomarine industry, the Norwegian Institute of Maritime Research (IMR) launched a new mesopelagic initiative titled *"Unleashing new marine resources for a growing human population"* [14]. In this setting, the Norwegian Fisheries Directorate [15] has granted preliminary licenses for experimental trial fisheries of mesopelagic fish resources to commercial vessels within the deep-sea pelagic fleet. During the last three years, trial fisheries have been carried out in international waters (the North East Atlantic – North East Atlantic Fisheries Committee (NEAFC) RA 1 Reykjanes ridge area) and within the Norwegian EEZ [16].

However, history shows that the devolvement of commercial fisheries and management regimes are subject to substantial changes [17]. Open access and free fishing has been replaced by the introduction of TACs, access restrictions, individual vessel quotas (IVQs), via resource allocation keys among groups and regions [18,19]. As fish resources represent a potential resource rent that are defined as free to harvest, lack of a TAC regime and open access represent major drivers for capacity expansion, over-capitalization, declining fish stocks, and rent dissipation [20–22]. According to Ekerhovd [23], the race for harvesting unregulated fish species is also explained as a "positioning fishery" to obtain future fishing rights prior to the closing of an unregulated fishery.

In a historical context, development from open access and free fishing to closing the commons and introduction of strict resource regimes also applies to commercial fisheries throughout the North Atlantic [23,24]. Since the introduction of TACs and fixed resource allocation schemes to provide for biological and social sustainability, capacity reducing measurements to obtain economic sustainability became the main management tool for the last three decades [25,26].

A new mesopelagic fishery may correspond to different capacity adaptations, either as an additional season for existing vessels already conducting combined TAC-regulated fisheries (herring, mackerel, and blue whiting, etc.) or as specialized vessels for year-round mesopelagic harvesting with no quota rights for other TAC-regulated fisheries. The latter adaptation could include large-scale vessels with on-board processing facilities, which is an approach that would resemble the factory trawlers harvesting krill in the Antarctic Ocean. Crucial questions are how potential actors adapt fishing capacity for harvesting mesopelagic fish resources without a TAC regime and which management principles should be implemented for a sustainable fishery.

This article focuses on the development of a potential new fishery based on unexploited mesopelagic fish resources in the Northeast Atlantic and within the Norwegian EEZ. Overall drivers for capacity adaptations are outlined. Different models for harvesting mesopelagic fish resources are described, and relevant management principles for a new mesopelagic fishery are identified. The article is organized as follows: Section two outlines commercial aspects for mesopelagic fish resources, and different harvesting adaptations are described. Section three presents relevant management principles. Aspects of the capacity concept are described, and two relevant fisheries case-studies are presented. Section four outlines implementation of central management principles, potential management implications for different capacity adaptations, and some key points for further development.

2. Mesopelagic opportunities

Mesopelagic fish species have been a potentially harvestable resource since the 1970s [7]. Some species are considered suitable for human consumption, but mostly they are used as a raw material in the global fish meal market [27]. Due to an increasing demand for feed for the growing aquaculture industry, the supply of marine oils containing the marine omega-3 fatty acids icosapentanoic acid and docosahexaenoic acid does not meet the demand. Marine lipids are partially replaced in fish feed by other lipids from land-based sources such as soya bean. In the salmon industry, the replacement levels have reached their maximum based on evaluation of fish performance and health [28]. If exploited at sustainable levels, without impacting biodiversity and compromising the oceans' role in climate regulation, the biomass of mesopelagic species may be a vital source of proteins with high nutritional value and polyunsaturated fatty acids to meet aquaculture demands and human nutrition needs [14].

Globally, only a few commercial attempts have been made to develop commercial mesopelagic fisheries in the Gulf of Oman and in the southern parts of Iceland. In 2009 and 2010, Icelandic vessels landed 46 and 18 thousand tonnes of the mesopelagic fish species pearlsides (*Maurolicus muellery)*, respectively. The Icelandic catch rates reached up to 560 tonnes per day and were associated with bycatch of other TAC-regulated fish species, such as cod (*Gadus morhua*), saithe (*Pollachius virens*), blue whiting, and Norway pout (*Trisopterus esmarkii*). However, Icelandic landing of mesopelagic fish has been recorded since 2013. During June–July of 2019, three vessels conducted an experimental fishery targeting mesopelagic fish species off the west coast of Norway. The total catch was 1192 tons of pearlsides, and it was associated with the bycatch of TAC-regulated species, such as mackerel, blue whiting, and saithe. In total, 150 tons of blue whiting, 30 tons of saithe, and minor quantities of mackerel (less the 1 ton) were caught as bycatch [29].

Due to the expected harvest potential and resources for the biomarine industry, mesopelagic fish resources have attracted more than the traditional deep-sea pelagic fleet. Large-scale industrial actors outside the traditional fisheries domain are paying attention to the potential new fishery. In this context, representatives from the stock-broking company Pareto Securities [30] expect the future fleet structure and industrial operations of a mesopelagic fishery to be comparable to that of the krill fishery in Antarctic waters. Big companies such as Aker BioMarine [31] have the knowledge and needed resources (human capital and financial strength) to operate and further develop huge factory trawlers with full-fledged on-board processing plants for fish meal, oil, etc. According to Pareto Securities [30], this mesopelagic approach refers to investments of 1 billion NOK per vessel, daily catch rates of 500 tonnes, 200 operating days per year, and a total catch of 100,000 tonnes per year per vessel. Such catch rates would produce approximately 30,000 tonnes meal and oil per vessel per year. Provided a market price of 1200 US $ per ton, the gross catch-value per vessel is estimated to be 36 million US $ or 302 million NOK per year. Catch and processing costs and depreciation are estimated to be 125 million NOK and 50 million NOK, respectively, which indicate an annual operating profit of 100 million NOK before tax. However, a reduction in daily catch rate to 300 tonnes would result in a steep reduction in revenue. Likewise, catch rates higher than 500 tonnes per day would represent an even higher operating profit than 100 million NOK per year. Hence, the high investment in specialized vessels targeting large volumes of low-value mesopelagic fish on a year-round basis represents both great economic potential and high risk under extreme uncertainty [30].

An alternative approach to large factory trawlers [30] is the addition of a fishing season for the existing deep-sea pelagic fleet, whose members hold combined IVQs within TAC-regulated fisheries. According to the Fisheries Directorate's annual profitability survey of the Norwegian fishing fleet for 2009–2017, the largest pelagic vessels fished for an average of 159 operating days per year [32]. Hence, substantial numbers of fishing days are available for a seasonal mesopelagic fishery. For today's deep-sea pelagic fleet, investments in a new seasonal fishery mainly correspond to new trawl systems, storage facilities, and fish finding electronics that are specially designed for detecting and harvesting mesopelagic fish resources. Such investments represent far lower costs than the year-round factory trawler approach.

3. Framing the capacity concept

As mesopelagic fish resources lack a TAC regime and biological reference points for a precautionary approach, such as management criteria for stock size and limits for fishing mortality to secure MSY, basic fisheries economic principles may serve as guidelines for managing mesopelagic fish resources and fisheries. The Gordon-Schaefer model for fish resources [33] links together the biological and economic [34,35] effects of different fishing efforts on a limited fish resource. According to Holm [36], the model is constructed to understand and examine how fish resources and commercial fishermen adapt to each other. When fisheries are open and not regulated, rational actors increase their fishing capacity (effort) until income from the fishery equals costs. In basic theory this means that unregulated fisheries may lead to unprofitable over-capacity and over-harvested fish stocks and no profit. According to Gordon and Schaefer [34,35], unregulated fisheries represent an inefficient and unsustainable adaptation. Hence, to achieve maximum economic yield (MEY) or MSY from a single fish stock, effort or catch in fisheries must be restricted. This approach requires that the government impose restrictions to the fishing fleet's access to harvest limited fish resources. Alternative to the top-down approach to target MEY or MSY, sustainability goals may also be achieved by more decentralized governance models, such as incentive-based regulations, co-management and regional management bodies for self-organization through collective action [17,37,38].

Even though the bio-economic model represents a radical simplification of reality [34], the principles have been implemented as profound guidelines for sustainable fisheries management at different managerial levels (UN/FAO, NEAFC, and national management bodies). According to a number of studies [4,7–9], mesopelagic fish resources are dispersed over the EEZs of several countries and in international waters. As the relevant nations in the Northeast Atlantic are signatories to UN/FAO-fisheries protocols, relevant nations share the responsibility to manage common fish resources as joint management regimes and within national 200 mile EEZs in a manner that complies with the UN Nation Convention Law of the Sea [39] and the Code of Conduct for Responsible Fisheries [40].[1] The Environmental Agenda for the 21st Century (Agenda 21) [41] from the Green Summit in Rio de Janeiro identified global fishing capacity levels as an international management problem and included a call for governments to cooperate in addressing over capacity in global fisheries. Relevant for the potential conduct of mesopelagic fisheries in both national and international waters, three international agreements address guidelines to restrict harvesting capacity in world fisheries [42]: 1) the FAO CCRF; 2) The Agreements to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas; and 3) The Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks. According to the FAO [42], these agreements impose that coastal states implement sustainable management principles and restrict fishing capacity. In Norway, ecosystem resource management principles are outline in the Ocean Resources Act [43], while sustainable capacity adaptations are expressed in the Participation Act [44] and explicitly in §1a; *adapt fishing capacity to available fish resources.*

In the international fisheries management discourse, the needs for resource management regimes and methods to define capacity and institutional approaches to avoid unprofitable over capacity have been high on the agenda for years [42]. According to Bell et al. [45], capacity and fishing effort at vessel and group levels can be measured in different manners, such as the numbers of vessels, the quantity of gear used [46], duration of fishing (e.g., time spent trawling) [47], the physical size of fishing vessels [48], or the amount of horse power (HP) and fishing gears [49]. Standal [50] describes an integrated approach to how technical parameters (length, breadth, HP, gross registered tonnes (GRT), and amounts of fishing gears) affect fishing capacity.

As mesopelagic resources may represent a new seasonal fishery, sustainable capacity adaptations may be further complicated for vessels conducting combined fisheries with the same vessels for different fish stocks with a different managerial status (e.g., TAC-regulated and non-TAC-regulated fisheries). Different fish stocks also vary in biomass, population dynamics (e.g., seasonality and migrating patterns), and cost-income harvesting profiles. In this setting, multispecies management and capacity adaptations for combined fisheries may be more complex to measure and difficult to manage than single species MSY management [51,52]. In a Norwegian context, the development of a mesopelagic fishery should, thus, follow the principles for an ecosystem management approach [53] as outlined in the Ocean Resources Act [43].

Relevant for the inclusion of a new mesopelagic season in the present deep-sea pelagic fleet in Norway, Ekerhovd [23] found that most vessels' holds combined quota rights for different species, such as herring, mackerel, and blue whiting. Although MSY targets are commonly used as a management goal for fish resources, different fish stocks are managed separately, and they may be subject to different managerial practices. In modern fisheries management, the most valuable fish stocks traditionally connect to TAC regimes and the allocation of IVQs. Other fisheries may constitute free fishing within a TAC, which allows the fishermen to catch as much as possible within a TAC, or there are no quotas at all.

Combinations of TAC-regulated fisheries and fisheries with no TAC regime may thus contribute to complex capacity adaptations for the commercial fleet. When some fisheries are managed by TACs and IVQs and some are not, Ekerhovd [23] stated that unregulated fisheries will attract a greater fishing effort than if none of the fisheries were quota regulated. As the fishermen's incentive is to obtain as high a share as possible before the non-IVQ fishery is closed, the opportunity to increase their income may go beyond what they may earn when catching their TAC-regulated IVQs.

However, the magnitude of the extra profit depends the characteristics of the unregulated fishery and the opportunity costs of foregoing a unit of quota fish for one unit of unregulated fish. This means that if the vessel has a limited fishing capacity, the unregulated fishery will be indirectly restricted by the quotas deducted from TAC-regulated species. Hence, when fishermen can conduct a combination of TAC-regulated and non-TAC-regulated fishing, increased capacity adaptations beyond the needed capacity to fish their IVQs or harvest as much as possible of unregulated species may be a rational choice. As such, capacity adaptations to the fisheries without TAC regulations may serve as the dominating guideline for the vessel's total capacity adaptation.

Relevant to the capacity discourse for vessels conducting combinations of TAC-regulated and non-TAC-regulated fisheries, the inclusion of the blue whiting fishery as an additional season to the combined herring and mackerel fisheries represents a clear example of how actors expanded from closed and TAC-regulated fisheries (herring and mackerel) into a new seasonal fishery with no TAC regulations (blue whiting) [54]. To add pelagic trawling for blue whiting to their existing purse seine fisheries for herring and mackerel, the original 50 m purse seiners were replaced by a new 70 m class and built as combined purse seiners and pelagic trawlers at the end of the 1990s. Most of the 47 vessels in the deep-sea pelagic group were renewed. While 19 vessels holding licences for blue whiting trawling were more than 60 m in length in 1988, the numbers of vessels longer than 60 m increased to 45 in 2003 [55]. As the vessel's technical parameters, such as length, GRT, cargo hold, HP, and size of fishing gears, increased in a radical manner, the vessel's total group capacity increased by 153% [47,51,56].[2] This development represented an important condition that allowed low-value fish species, such as blue whiting, to become a large-scale and economically viable fishery [52].

[1] The Code of Conduct and international environmental agreement only applies to those States that have signed and ratified the agreement [4].

[2] According to FAO [51], fishing capacity is the "ability of a vessel or fleet of vessels to catch fish. Fishing capacity (capacity output) can be expressed more specifically as the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet if fully utilized, given the biomass and age structure of the fish stock and the present state of the technology".

The increased catch capacity can easily be traced in the catch statistics for blue whiting [57]. Beginning in 1995, the Norwegian blue whiting fishery rapidly increased and peaked at more than 950,000 tonnes in 2004. In 2004, the total catch rates from all participating nations (EU, Iceland, Faeroes, and Russia) reached almost 2.5 million tons [57]. As participating nations were not able to reach a mutual agreement about sharing of the straddling blue whiting stock, total catches far exceeded the annual TAC recommendations of the International Council for the Exploration of the Sea (ICES)/Advisory Committee on Fishery Management [54]. Due to long-term severe over-fishing of the blue whiting stock, a radical decline in stock biomass and catch rates occurred, falling from 2.38 million tons in 2004 to 0.1 million tons in 2011. Hence, severe unprofitable over-capacity became visible, and it carried considerably higher capital costs. This also affected the capacity adaptations to the vessels' original arena (i.e., mackerel and herring fisheries).

A similar development occurred for the cod trawler fleet in Norway. Since the end of the 1990s, shrimp trawling was conducted by vessels holding combined licenses for cod and shrimp trawling. Due to high market prices for cold water shrimp (*Pandalus borealis*) and low fuel prices at the time, trawling for shrimp in the high north was characterised by considerable optimism. Parallel to the blue whiting fishery, shrimp trawling was only managed by access restrictions, and no TAC was in place. At the same time, the Northeast Atlantic cod stock in the Barents Sea was relatively low and the transferability of cod quotas to reduce unprofitable over capacity were limited. This also correspond to a limited time of ownership of purchased quotas via the ITQ markets.

In this setting, perpetual ownership of shrimp licences and a fishery without any TAC regulations as an additional season were considered as a viable expansion strategy for the cod trawlers. Hence, to strengthen the operating basis for the vessels, most cod trawlers engaged into a combination of cod and shrimp trawling as a year-round strategy [58]. Existing trawlers were reconstructed from fishing cod (and other white fish species) with a single trawl to double trawl systems for shrimp trawling. In addition, lines for on-board processing of shrimp were built into the vessel's factory deck. The new seasonal adaptations also required stronger main engines, electronic fish-finding equipment for shrimp, and more powerful winch systems. In total, the new combined adaptations led to investments of roughly 40 million NOK per vessel at the end of the 1990s [58].

However, just a few years later shrimp prices were halved and fuel costs more than doubled. In addition, strict by-catch rules for juvenile cod, red fish (*Sebastes norvegicus*), and Greenland halibut (*Reinhardtius hippoglossoides*) in the shrimp catches led at times to the closure of important areas for shrimp trawling, making shrimp trawling less attractive. From 2000 to 2015, Norwegian catch rates have shown a long-term steady decline, from 66,501 tonnes to 13,717 tonnes [59]. Thus, the cod trawlers' investment in shrimp trawling was a fiasco. After a few years of extensive economic losses, shrimp trawling as a seasonal addition to cod trawling ended. The cod trawlers were left with their original arena and with considerably higher capital costs and increased catch capacity.

As both the blue whiting fishery and shrimp trawling were characterised by a combination of restricted access fisheries and no TAC regime, this managerial status resulted in a strong increase in technical capacity and capital costs. However, as both new seasonal arenas declined, increased capacity and capital costs also affected the vessels' original fisheries (e.g., mackerel and herring for the pelagic fleet and cod for the trawlers). To reduce surplus catch capacity for the pelagic and cod trawler fleet, the pressure towards the quota regime increased. In 2005, a significant market orientation of the quota regime occurred. During the ensuing years, the entire deep-sea fleet was subject to several quota and vessel transactions, which reduced the numbers of vessels and improved the quota base and economy for the remaining vessels, especially within the cod trawler fleet [26].

4. Discussion

Although a mesopelagic fishery is in its infancy or at an experimental level, the nature of the resource, histories of the development of well-established fisheries, and modern management principles provide useful information with relevant management implications for a future mesopelagic fishery.

For Norway, an important feature is that none of the commercial fish resources (except for saithe north of 62 Nº) are sole Norwegian resources. Instead, Norway shares and manages common stocks together with other nations, such as Northeast Atlantic cod with Russia in the Barents Sea and herring, mackerel, and blue whiting together with the EU, Iceland, the Faroes, and Russia in a joint management regime [60]. Consequently, to achieve sustainable management, all commercial fish stocks are TAC-regulated, and fragile resource allocation keys are elaborated among nations and different vessels groups for the national TACs. For the commercialization of a mesopelagic fishery, precautionary and ecosystem-based management principles will thus serve as profound guidelines.

However, the managerial status of mesopelagic fish resources is subject to divergent views. With reference to potential large-scale harvesting of mesopelagic fish resources and the poorly known roles of climate regulations, ecosystem, and biodiversity, The Pacific Council supported a Comprehensive Ecosystem-based Amendment (CEBA 1). The regulation claims a precautionary approach and states that it [4]:

> "..prohibits the development of new directed fisheries on forage fish species that are not currently managed by the Council or States, until the Council has had an adequate opportunity to assess the science relating to any proposed fishery and any potential impact to our existing fisheries and communities".

Contrary to the strict precautionary approach from the Pacific Council, the EU's positioning paper "Blue Growth Strategy" is currently more open to the exploration and exploitation of new ocean horizons such as mesopelagic fish resources [61]. While commercial harvesting mesopelagic fish resources is currently not on the NEAFC agenda, the EU's policy also corresponds to Norway's national blue-growth strategy to explore and exploit mesopelagic fish resources [62]. In 2019, only three preliminary licenses for trial fisheries were issued by the Fisheries Directorate [63].

Due to the expected abundance of mesopelagic fish resources, implementation of a TAC regime will depend on the future interest and magnitude of the fishery. To secure biological sustainability and avoid a surplus capacity expansion, a sound stock assessment and biological reference points, such as limits for minimum stock size and fishing mortality for the MSY target, are needed to provide scientific knowledge to develop a future TAC regime. Such knowledge may also serve as input for an overall management plan and lay the foundation for joint management among relevant nations. Due to the complexity of harvesting further down the marine ecosystem, traditional management must move away from single species management towards an ecosystems-based management approach, which also includes assessment of ecosystem services. In a Norwegian context and among relevant nations, the IMR and trial fisheries should provide scientific input at the national level. At the supranational management level, the ICES and NEAFC should contribute to a joint management regime among member states.

Regardless of a potential mesopelagic quota regime, a strong focus should be on the rate of bycatch from other TAC-regulated species, which are subject to sharing among nations and groups in Norway. Significant amounts of quota-regulated species as by-catch in a mesopelagic fishery may contribute to higher fishing mortality for quota-regulated species, such as herring, mackerel, and blue whiting. Hence, to avoid over-fishing of TAC-regulated species, the potential by-catch must be included in the TAC regime and the total allocation keys for relevant species. High rates of bycatch of herring, mackerel, and blue whiting may thus be subject to a reallocation from existing quota holders to actors conducting a mesopelagic fishery. Such reallocation also represents a possible alternative economic loss for the quota holders of herring, mackerel, and blue whiting.

Hence, strict rules for bycatch of other TAC-regulated species and the use of sorting grids in trawl systems specially adapted for relevant bycatch species must be expected. Vessels holding quota rights for the most possible bycatch species may thus be in the best position to gain access to a mesopelagic fishery. Likewise, vessels without quota rights for potential bycatch species may encounter stricter access to a mesopelagic fishery. A specific bycatch quota deducted from the TAC and earmarked for a mesopelagic fishery may represent a complex and conflicting allocation theme. However, except for potential bycatch, vessels designed for a year-round mesopelagic fishery with no quota rights in other TAC-regulated fisheries will have no institutional bindings to capacity adaptations and the management regime for other TAC-regulated fisheries. Consequently, vessels holding only mesopelagic fishing rights represents an autonomous adaptation that is decoupled from the fisheries management regime for herring, mackerel, and blue whiting.

Most mesopelagic fish species are low-value species. Therefore, an economically viable fishery demands large-scale catch volumes per fishing trip (economics of scale). Although a surplus catch capacity is available for the present fleet (e.g., numbers of operating days per year), an important question is whether today's deep-sea pelagic vessels are suitable- or large enough to develop a sufficient large-scale mesopelagic fishery. Moreover, it is unknown whether the future fleet adaptation may follow the same trajectory as the replacement of 50 m purse seiners with 70 m combined vessels for the inclusion of seasonal blue whiting trawling. Consequently, as no TAC regulations exist for mesopelagic fish resources (only access regulations), today's 70 m class of pelagic vessels may be replaced by bigger and more costly vessels for large-scale harvesting operations of mesopelagic fish resources.

The rationale for increased harvesting capacity corresponds directly to increased catch rates and profit. At the same time, larger and more costly vessels also contribute to higher fixed and operating capital costs. Hence, if the new mesopelagic season(s) does not remains successful in the long term, increased harvesting capacity and costs will also affect the economic performance within today's TAC-regulated IVQ fisheries in a negative manner and put pressure on the quota regime to further reduce the numbers of vessels [26].

It is also unclear what kind of economic actors will provide needed capital, competence, and the willingness to spend strategic resources to develop a new fishery. The development of a mesopelagic fishery may resemble the commercialization of the krill fisheries in the Antarctic [30]. This approach opens the search for potential actors outside the traditional domain of being a fisherman in Norway. However, as the Participation Act [44] states that only professional/active fishermen have the right to own fishing vessels and fishing rights, the law excludes potential economic actors (e.g., large biomarine entities) that otherwise might provide the needed strategic resources to commercialize mesopelagic fish resources. This factor might have been considered when the Fisheries Directorate announced guidelines for allocating 10 licences for harvesting copepods/zooplankton (*Calanus finmarchicus*). The licenses are divided into two distinct groups: five licences to actors who *do not fulfil* the legal criteria for the Participation Act and five licences for actors who *fulfil* the Participation Act [64].

It remains to be seen whether the institutional framework to attract new and more industrial-like actors to the *Calanus* fishery is applicable to the challenges of developing a new mesopelagic fishery. The allocation of five licences to actors who do not fulfil the Participation Act represents a clear liberalization and a strong incentive to stimulate more industrial-like partners to contribute to developing the *Calanus* fishery into a new biomarine industry. The new practice also represents a clear break from a long-standing practice in Norwegian fisheries to protect traditional fishers and coastal communities from outsiders, with no "natural binding" to fisheries.

In the long-term perspective, a new mesopelagic fishery may challenge existing practices within the present management regime to maintain biological, social, and economic sustainability. However, in the short-term perspective, policy instruments should stimulate the deep-sea fleet to participate in a more intensive trial fishery that may be transformed into a commercial fishery. If the authorities and most innovative front-runners within the deep-sea pelagic community manage to steer the experimental fishery towards commercialization, this path would possibly attract other vessels to participate as well. Knowledge about a new potential resource would then increase and attract more vessels for a "positioning fishery" to gain a fishing right, if closed and regulated in the future. Based on the knowledge currently available, development of a mesopelagic fishery most likely will proceed with incremental steps as a new seasonal fishery within the present deep-sea pelagic fleet. However, if sufficient knowledge is acquired for commercialization, larger and more specialized vessels may be added to the fleet in the future.

Author statement

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Appendix A. Supplementary data

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