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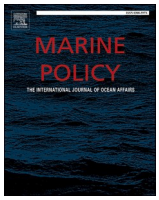

Walking sideways? Management of the Norwegian snow crab fishery

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ABSTRACT

The snow crab (*Chionoecetes opilio*) in the Barents Sea is an invasive species, first discovered in 1997. Since 2012, a commercial fishery has developed, and various management measures have been implemented. Despite fishing gear restrictions, limits for the catch season and the implementation of a TAC-regime in 2017 onwards, the fishery struggles with substantial sustainability challenges. Vessels allocated a licence demonstrate radical differences in catches, and the fleet suffers from an unprofitable overcapacity and lack of environmentally friendly harvesting operations. The management authorities and the fishermen's organizations seem to agree that the regulated open access and the Olympic fisheries model are the main sources of the present problems. The Directorate of Fisheries (DoF) [1] has introduced a discussion paper outlining various options for closing the fishery. The article outlines these- and other options, and discusses the alternatives in terms of improved sustainability, i.e., environmental, economic as well as social. A key point is that closing the fishery (like many other management measures), are not only technical interventions. They are also political, and they contribute to modify both the regulating system and the system to be regulated.

1. Introduction

Most commercial fish species in the North-east Atlantic are fully exploited and strict TAC-regimes (total allowable catch) are implemented to secure sustainable fish resources [2,3]. Fishing on unexploited marine species thus represents new commercial opportunities, and the snow crab in the Barents Sea is a prime example. Furthermore, as commercial fisheries for snow crab are conducted in Alaska, Canada, and Russia since the 1930 s, the international markets are well established. Hence, paired with the perspectives of a new resource and future stock expansion, high expectations for a new fishery in the Barents Sea gained ground since 2012 onwards. While Bertheussen et al. [4] and Bertheussen and Nøstvold [5] have been mainly concerned with the entrepreneurial aspects of this new fishery, Kvalvik [6] and Voldnes [7] have examined how this new resource became *manageable*. This article is a continuation of the latter, investigating how the new fishery can be *more sustainable*, covering all dimensions of the concept; environmental, economic, social as well as administratively.

To secure a sustainable fishery, the Norwegian Directorate of Fisheries (DoF) has gradually implemented both input and output restrictions as management rules since 2012. A TAC-regime and a restricted harvest season were implemented in 2017 to provide for biological sustainability, while gear restrictions were introduced to secure quality and avoid unprofitable overcapacity [1].

However, compared to the management of other commercial fisheries, the management of the Norwegian snow crab fishery represents significant differences. Access to the fishery is liberal, resource allocation keys among vessel groups are absent and individual vessel quotas are not implemented [8,9]. Instead, the management system is organized for free fishing or "Olympic fishery" until the total annual TAC is reached. This management status has thus attracted several vessels, which contribute to an unprofitable overcapacity, rough competition, and conflicts between vessels in the crab fishing fleet as well as conflicts with other fleet groups, such as the shrimp trawlers [1]. The fishery also struggles with lack of an environmentally friendly profile, as the negative impact from significant losses of crab pots and ghost fishing are well documented [10–12]. For the shrimp trawlers fishing in the same area, the lost crab pots represent a nuisance, taking time and effort away from their main task.

To increase the overall sustainability, there is thus a mutual understanding among the management authorities and the Norwegian Fishermen's Association, that the harvesting capacity must be restricted. However, with reference to the participating vessels' significant variation in terms of days at sea and catch rates, the closing process and design of the future management system, may be complex and not straightforward. Shall e.g., the management authorities plan a fleet

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structure which supports specialization and maximum economic profit, or shall they use the potential resource rent to support more vessels to increase employment in fisheries dependent areas? A third option could be to increase state income by auctioning the annual rights for these crab fisheries. Auctioning catch rights has no precedence in Norwegian fisheries, while the principle is frequently used in the aquaculture industry. In the public debate surrounding what is defined as sustainable fleet structures and capacity adaptation, the notion encompasses different meanings, values, and norms, depending on the participants' position in the fisheries sector. As the two (extreme) options implies radically different fleet structures, resource allocation and number of vessels, the discourse may be confronted with conflicting policy goals, such as securing economic efficiency versus increasing employment, both within the framework of a TAC-regime.

As the Barents Sea snow crab fishery represents a new fishery in the making, we study how the Norwegian snow crab fishery has developed from 2012 onwards. The article contributes to the management and sustainability discourses, and addresses the following research questions:

1. How has the Norwegian Barents Sea snow crab fishery developed since 2012 onwards, and what is the present status regarding the fleet's harvesting capacity, participation in the fishery and distribution of catch?
2. What are the management options for a more sustainable and environmentally friendly snow crab fishery in the future? Shall the management authorities continue the Olympic fishing model under a TAC-regime with a liberal entry policy, or should they support the closing of the fishery, based on individual vessel quotas (IVQs), which later on may be developed to a system of transferable quotas?
3. What are the consequences of the different management options, in terms of sustainability (environmental, economic, and social), legitimacy and management costs?

In section two we present a relevant theoretical framework as input to the ongoing management discourse. Section three outlines how the snow crab fishery has developed in terms of management, fleet structure and catch. In section four, we present a current discussion paper, presented by the DoF, discussing different models for a future closing process, as well as further technical regulations. Finally, in section five we discuss different management options and their possible consequences in terms of sustainability and management costs. We consider the Norwegian crab fishery a particularly interesting case, as most Norwegian fisheries have been closed *after* overfishing and overcapacity have been established [13]. In this case, the management authorities had the possibility of closing the fishery *before* many of the traditional problems occur.

2. Theoretical framework

Fish resources are defined as common property that is free to utilize. In principle, this free production factor allows the fleet to realise an economic rent above normal compensation for capital investment, labour and other relevant inputs [14]. The Beverton and Holt [15] population-dynamics model for fish resources and the Gordon-Schaefer model [16,17] outline the principles for modern fisheries management and the same paramount consequences as Hardin's [18] description of the tragedy of the commons. Contrary to Hardin's famous article, however, the Gordon-Schaefer model deals specifically with the relationship between the fish and the fishermen. The model links together the biological and economic effects of a given fishing effort on a limited fish resource. According to Holm [19], the Gordon-Schaefer model is constructed to examine how fish and fishermen adapt to each other. The Gordon-Schaefer model tells us how we should manage fish resources; when fisheries are open and not regulated. Rational economic actors will then increase their fishing efforts until income equals costs. This means that unregulated fisheries may lead to unprofitable over-capacity, depleted stocks, and no profit. To achieve maximum sustainable yield (MSY) or maximum economic yield (MEY), fisheries must be closed, and the collective effort limited.

Once the fishery is closed and access to fish is limited, income from fishing increases at a greater rate than costs, which again generates a profit. Consequently, the profit from fishing creates a demand and a willingness to pay for fish quotas reflected in the anticipated profit. By closing the commons, fishing has moved away from the point at which income is equal to costs. This means that economic rent can be extracted. Hence, a market is created for transactions of quotas [19]. Profitability from a given fishery will be greatest when the allocated quota is harvested with the lowest possible cost [20].

However, the common property theory and the Gordon-Schaefer model has met criticism from various corners. Holm (2005) refers to the Gordon-Schaefer model as *a radical simplification* of the relationship between fish and fishermen. Eide [21] and Eide et al. [22] point out that the nature of fishing is so dynamic that it is impossible to fix an optimal fleet structure over a longer time. Hence, flexibility is a more viable strategy to meet changing natural conditions and stock variations. Despite such objections, the Gordon-Schaefer model represent the fundamental underpinning of today's fisheries management system. In the Norwegian context, the goal of MEY is always moderated by various social concerns, while MSY seems to be a paramount goal.

This approach is also supported by common-property theory [23]. To avoid the negative consequences of open access fisheries, the common property theory puts forth two fundamental strategies; the establishment of private property rights or the introduction of a public sphere of authority (institutions) to restrict harvesting of common resources.

To achieve public policy goals and implement the management principles fisheries are managed by and through *institutions* [24,25]. In a regulative institutional perspective, harvest rules such as MSY and TACs, resource allocation keys, technical and legislative access restrictions, and the design of quota regimes, are key management tools to achieve sustainable fisheries.

According to Peters [25], institutions can be characterised by the following basic qualities: Institutions are a structural part of society, formal or informal, they exist over time, they affect individual behaviour, and demonstrate some sense of shared values and meaning among the members of an institution. However, fisheries management regulations cannot be perceived as sole static units. As technology develops, increased catch capacity and natural shifts in stock size and distribution occur, the field of operation for regulative institutions are required to change over time. Institutional learning thus rests on historical events, the ability to solve present sustainability challenges and implement new policy goals [26]. To what extent the current snow crab management functions well or poorly, may therefore be a question of institutional design and its ability to respond to new management challenges.

What is special in the case of the Norwegian snow crab fishery, is that by the time the fishery started (in 2012), the knowledge of the new, invasive species was nearly non-existent. As pointed out by Kvalsvik [6], the new species had to be made *manageable*, it had to be turned into a management object. In the following years a combination of research and practical fishing determined the area distribution and the actual catching area. However, the most important step was the crucial decision that the snow crab was a *sedentary species* and hence had to be managed according to the Convention on the Continental Shelf, [27]. This meant that Norway had the exclusive right to manage the resource on its continental shelf, including the shelf around Spitzbergen [28], while Russia had a similar right within its continental shelf, thus eliminating the previous "free fishery" in international waters. By introducing total quotas, limiting access, and specifying catching gear (pots), minimum size and catching seasons, the snow crab fishery became manageable, within the existing institutional structure, consisting of the Ministry of Fisheries, the Directorate of Fisheries, and the Institute of Marine Research (IMR), being the main provider of scientific

knowledge. As described by Kvalsvik [6], the major challenge was to define the snow crab so that it became manageable according to *Norwegian interests*.

This can in turn be connected to a much larger debate regarding how to deal with resource management in general and fisheries management in particular [29,30]. The starting point was the clearcut division into *the governing system* and *the system to be governed*. Later contributors, like Song et al. [31], have stressed that the actual management is constituted by the interaction between the two systems. Johnsen [32] is even more explicit by calling to attention that regulatory instruments are more than technical devices, they are also political in the sense that they influence the allocation of important resources (like fish and money). The access to such resources may in the next round influence the power situation between various groups within the fishery. Summing up, management measures contribute to change both the governing system and the system to be governed, and quite often they also turn out to have unexpected outcomes. In this respect, Vatn [33] makes an important distinction: "The difference between the costs of ex post and ex ante regulations - that is reactive as opposed to proactive policies – may be substantial as investments made under the assumption of no harm have to be changed/reversed."

Turning back to the snow crab fishery, the successful establishment of a management regime as per 2020 was not the end point of snow crab management. New challenges occurred, and here we are going to describe some of these challenges and how they can be dealt with in the future.

3. Mapping the Norwegian snow crab fishery

3.1. Management, catch and fleet structure

In 1996, the snow crab (*Chionoecetes opilio*) was first observed in the Barents Sea [34]). Contrary to the red king crab (*Paralithodes camtschaticus)*, genetic studies indicate that the species has migrated from the Tsjuktsjer Ocean [35]. Since 1996, the size of the snow crab stock has increased and spread northwards throughout the Norwegian and Russian Exclusive Economic Zones (EEZs) of the Barents Sea, including the Svalbard waters [36]. This means that the species is considered an *invasive species*, but unlike the king crab, it is not an introduced and hence, an *alien species* [34]. The snow crab fishery is therefore considered an ordinary fishery, managed according to international obligations. However, in 2017, Norwegian vessels were excluded from the Russian shelf zone and are only allowed to harvest snow crab within the limits of the Norwegian continental shelf [37].

Since the nationalization of the snow crab fishery the Norwegian Directorate of Fisheries has gradually implemented a comprehensive management regime to achieve a long-term sustainable fishery. Biological output regulations in the form of annual TACs, as well as time restrictions have been implemented. The harvest is limited to two seasons (1/1–31/6 and 1/11–31/12 each year).[1] Moreover, each snow crab vessel is restricted to operate a maximum of 9000 pots while actively fishing, and the soaking time is restricted to three weeks.[2] During the fishing season, the most active vessels conduct several trips with a duration of 4 – 6 weeks per fishing trip, depending on the harvest and weather conditions. The vessels mainly operate according to a two-shift system for continuous harvest and on-board processing. For the harvesting operation, approximately 200 or 400 pots are linked together in chains, with an average distance of about 25 m per pot. A chain of 200 crab pots thus corresponds to an average distance of 5 km, while a 400-crab-pot chain corresponds to 10 km. No formal rules regulate the parallel distance between each chain. However, there exists a mutual understanding that there shall be two cable-length (370 m) between each chain of crab pots [38,39].

Implementation of the annual TAC has become the main management tool to secure a sustainable snow crab fishery [36]. A single species MSY (maximum sustainable yield) management serves as guideline to produce an annual TAC for the snow crab stock. Also, precautionary approach (PA) criteria, such as limits for the fishing mortality (F) and rules for minimum stock size (B_{lim}), are vital elements of the total stock management. The recommendations are based on the annual Norwegian Russian ecosystem cruise in the Barents Sea, the snow-crab cruise by IMR, catch logbooks and landing receipts from the fishery [36].

The annual TAC also serves as the main reference for surveillance and control of the fishery and for law enforcement to avoid overfishing [40].[3] Since the implementation of the TAC-regime in 2017, the annual quota has increased from 4000 tons in 2017–7117 tons in 2023 tons. The annual catches increased from 2 to 7659 tons during the period 2012 – 2023. In 2012, with a total catch value of 2000 NOK. In the following year the value increased to 3.2 million NOK, reaching 618 million NOK in 2022 and a steep decline to 131 million NOK in 2023. However, over the years 2015–2020 the operating margin as well as the total return on capital was negative, making a positive upturn in 2021. This trend has continued in 2022 and 2023. According to the IMR, a further stock growth is expected in the years to come [36] and in 2024 the TAC is further increased to 10,300 tons. The increased annual TAC also reflects the development of the total catch value, which peaked at 641 mill NOK in 2021. For 2023, a strong decline in the catch value occurred, due to increased competition (from Russia and Canada) and lower prices in the export markets. Table 1.

For 2023, a total of 69 licenses were allocated, but only 21 vessels actively participated in the fishery, while the majority (48 vessels) remained passive. However, the number of passive vessels allocated a license still represent a large *potential* harvesting capacity, which may contribute to unprofitable overcapacity and reduced catch rates for the most active vessels.

Regarding the fleet structure, we have data for 12 of the most active vessels. In average they are 53 m long, 10 m wide, with motor effect of 716 KW, and 43 years old. Most of them are former trawlers or purse seiners, rebuilt for the snow crab fishery. Only a very few of them have ice class and snow crab fleet is the oldest vessel group among all vessel groups in Norway [41]. This means that the most active operators have bought old, fairly large vessels, where there is space for installing specific hauling systems for crab pots, production facilities, including freezing equipment for on-board storage.

3.2. Environmental and social challenges

The open access status and stiff competition under rough harvesting conditions challenge the sustainability of the snow crab fishery. In terms of biological sustainability, lost crab pots and ghost fishing, negatively impact the crab stock and contributes to economic losses for the fleet [10–12,42]. In this setting, ghost fishing represents a hidden fishing mortality (F), which threatens a sound stock management. As the TAC-production is vulnerable to data input errors, this may negatively impact the scientific quality of the stock and quota assessment. Sources of such errors may be poor data collection or wrong or unreliable datasets as input to the TAC-setting. Hence, if the actual (unregistered) catch rates significantly exceed the recommended fishing mortality (F) for the MSY-management, this may lead to miscalculated quota advice (TAC) and poor stock management in the long run [43]. According to the fishers involved, the loss of crab pots is significant, and reduction of ghost fishing is therefore crucial to achieve long-term biological

[1] Technically it can also be described as one catching season, stretched over two years.

[2] For the 2024 season, the last catching period has been reduced by one month and the number of pots reduced to 8000.

[3] For the 2024 seasons, the overfishing of TAC for 2023, has been deducted from the fixed 2024 TAC.

Table 1
Annual TAC, annual catch and value, total no. of allocated licenses, vessels with and without catch (mill. NOK), 2023.

År	2012	2014	2016	2018	2020	2021	2022	2023
TAC	-	-	-	4000	4500	6500	6725	7117
Catch (tons)	2	1881	5406	2812	4387	6861	7960	7643
Catch value	2	56.3	191.1	166.2	329.1	641.0	618.0	451.4
Catch value per kg		29.93	35.35	59.10	75.02	93.43	77.64	59
Allocated licenses					44	73	77	69
Vessels with catch	1	9	15	11	11	13	32	21
Vessels without catch					33	60	45	48

Source: Directorate of Fisheries, [1]

sustainability.

The stiff competition between vessels for the best harvesting grounds, contributes to a high density of pot chains within limited areas. The current situation leads to internal conflicts between vessels and is further strengthened by drift ice which move the pot chains towards other vessels' pot chains, and out of the GPS-position for retrieving and hauling the pots [44].

Lost crab pots also create significant problems for the shrimp trawler fleet. The shrimp trawlers start fishing in the same areas after the snow crab fleet have finished its season. During summer 2022 and September 2023, the skippers on board the shrimp trawlers F/Tr. "Remoy" and F/Tr. "Gadus Poseidon" reported the capture of large amounts of unmarked snow crab pots during trawling in the relevant areas [45,46]. According to the skippers, many other shrimp trawlers experienced the same problems. As large amounts of lost crab pots are unmarked and not registered in the mandatory log-book reporting systems for lost/derelict fishing gears, the owners of the pots are unknown, and nobody are responsible for the losses. Due to the shrimp trawlers total "bycatch" of lost crab pots, the skipper on board the F.Tr. "Remoy" [45] estimates that thousands of crab pots may be lost during the 2022 season. In this setting, lost crab pots impose damage to their trawl system, extra costs and time for repairing the trawl, and consequently loss of time and catch for active shrimp trawling.

Right from the start, this fishery was characterized as a "Wild West fishery" [47]. During the first six years, at least six fishers died while operating in the north. When the international fleet was excluded from 2016 onwards, working conditions, at least in the Norwegian fleet, seem to have improved somewhat, but as late as 2023, a Norwegian snow crab vessel had another fatal accident, leading to stronger control and in this case, the vessel eventually also lost its license [48]. While it is up to the vessel owner and the skipper to operate safely, there are some structural factors which contribute to make this fishery extremely dangerous. First, the weather conditions are harsh and the net pots heavy and difficult to handle in rough sea. More important is that the Olympic fishery implies fierce competition between the vessels participating. The most active will try to get the largest share of the TAC before the fishery is being closed. This implies in turn that time is short and the vessels will try to handle as many pots as possible within the shortest possible time, making the fishery rather stressful. Finally, the traditional high prices of snow crab also imply good salaries for the crew members, i.e., if the vessel owners operate within the standard contracts used in the Norwegian fishing fleet. Scattered evidence from some of the vessels indicate many foreign workers onboard, many of whom do not understand Norwegian nor English. They have been paid far less that the usual salary, but due to the situation in the labour markets in their home countries, the interest of working under these harsh conditions is still great [49]. According to a senior researcher in the field of fisher safety, the competition increases the chances for serious accidents [50]. This view is also supported by the Vessel Owners Association [51].

Shortly summarized, an important element of *social sustainability* seems to be lacking in this fishery.

4. Towards a new management system

By 2023, it had become evident (for the DoF) that too many licenses had been granted and most of the allocated licenses had not been used. In addition, most vessels within the active fleet only produced symbolic catches.

However, all vessels allocated a license still represent a *potential* harvesting capacity.

The unprofitable overcapacity has developed over years without any significant state intervention. The present management thus resembles a sort of institutional inertia, as the regulative institutions have not acted in concert with the real-time sustainability challenges. This is also why the DoF launched the hearing document in 2023, with the overall purpose to outline a new management regime to reduce unprofitable overcapacity, increase economic efficiency and implement a more environmentally friendly fishery [1].

According to DoF, the existing technical regulations function as intended. This applies to:

- snow crabs can only be caught by pots and the pot lines shall be marked by vessel registration mark,
- each vessel can operate 9000 pots and the soaking time is fixed to maximum 3 weeks,
- there is a minimum size of 9.5 cm, and each vessel is only allowed to catch 20% soft shell crab,
- between 1. July and 31. October the fishery is closed,
- in addition, there is a fixed TAC, in 2023; 7117 tons.

However, DoF admits that unprofitable overcapacity, gear conflicts and "ghost fishing", are major sustainability problems. One suggestion is therefore to reduce the numbers of vessels and the number of pots to maximum 6000 per vessel. Another proposal is to reduce the fishing season to six months. It is also indicated that a part of the TAC could be reserved for the land-based processing industry. The main issue in the discussion paper is, nevertheless, the actual management regime, based on *open access* and an *Olympic fishery*. The discussion paper presented by the DoF offers several options for a future closing of the snow crab fishery:

The first alternative describes a closing procedure based on previous participation in one of the three last years. Without any demands as to minimum catch, this would qualify 27 vessels. If minimum registered catch is set at 1, 5 or 10 tons, the participation would be 22, 18 or 17 respectively. If the entry requirement is increased to two of the last three years (2021, 2022 and 2023) only 10 vessels would be included. This is the alternative recommended by DoF.

The second alternative implies a partial closing, whereby the TAC is divided between a closed and an open group, with qualification demands for the closed group. DoF suggests that this alternative could imply either fixed quotas for the closed group, or maximum quotas. If allocated maximum vessel quotas (IVQs), they could be differentiated, with higher quotas for the most active vessels.

The third alternative would be to maintain the crab fishery as open, but subject to registering all potential participants, and then make the allocation by lottery. This would imply more new entrants and less

security for the established crab fishers, a situation which DoF ([1]) describes as “demanding”.

According to DoF:

> “a closure could result in a higher number of participants than expedient and there will still be a basis for conflicts between gear groups and between vessels within the group. If snow crab fishing is no longer regulated as Olympic fishing, but with an increased quota security for the individual actor, this will also contribute to an increased focus on own recovery of lost pots because of gear conflicts and other conditions that could lead to the temporary loss of fishing gear. Closing the snow crab catch will result in increased predictability in the development between fishing effort and new knowledge about the distribution of the stock and its size” [1] (authors’ transl).

The same conclusion has been reached by the most active vessel operators and by the Norwegian Fishermen’s Association (NFA). According to NFA [51] the fishery should be closed as soon as possible. NFA seems to favour both previous participation and a minimum quantity as entry qualifications. In addition, they recommend entry for those who have positioned themselves for active participation, by way of investment in gear or vessel before the official cut-off date. Recognizing large differences in terms of catches, NFA suggests that the most active vessels receive a quota factor of 1, while the others obtain a quota factor of 0.75. NFA argues against a reduction of pots, shorter fishing season and quotas allocated to the processing industry. As always, NFA’s consultation statement represents a compromise, representing both the original entrepreneurs as well as hopeful new entrants, i.e., closing the fishery, but based on generous criteria.

5. Explaining catch history

Relevant for the closing process it is vital to understand why vessels allocated a snow crab license have not participated in the fishery. It is thus relevant to investigate to what extent their technical capacity is radically different from the active vessels. According to the Norwegian Auditor General (Riksrevisjonen) [52] and FAO [2], analysis of the fleets’ technical catch capacity, is vital to adapt a sound fishing capacity to available fish resources and avoid unprofitable overcapacity. The analytical approach is defined as the term VCU (vessel capacity unit), where vital technical parameters, such as overall length (m), breadth (m), engine power (kW) and GRT (gross registered tons) are included in the equation. We have estimated the total VCU for each specific vessel allocated a license for 2023 and summarized the total VCU for the active and passive groups [53].

The total amount of VCUs for all vessels allocated a license is estimated to 548 VCUs. The total VCUs for the active- and passive vessels, are estimated to 191 VCUs and 358 VCUs respectively. Moreover, the average VCU per vessel for the active- and passive fleet is estimated to 9.0 and 8.0 respectively. Hence, given the vessels’ relative similarities of VCUs among active- and passive vessels, the passive vessels’ lack of participation can hardly be explained by lack of capacity, measured as VCUs per vessel. This may change when new specialized snow crab vessels are brought into the fishery, from 2024 onwards. [4]

However, we also find radical internal differences in the catch rates and days at sea between vessels which have actively taken part in the fishery. In 2022, a total of 33 vessels participated in the fishery. Only 13 vessels are registered with catches above 200 tons, while 20 vessels are registered with negligible catch records. The two best vessels stand out with exceptional total catches, compared to the rest of the active fleet. The vessels numbered 3 – 12 in Fig. 1, also show a high number of days at sea, but exhibit significantly lower catch rates than the two most effective vessels. For the vessels representing the lowest catches (vessels 13–33), only 150–400 kg are registered per vessel. Despite the radical increase in the numbers of participating vessels, the top ten vessels thus represent more than 90% of the total catch for 2022.

The vessels’ strategic position is important to understand their participation in the snow crab fishery. A crucial dimension is the total portfolio of quotas allocated to a vessel. Fishing vessels often participate in several fisheries, which provides an important financial basis for being able to participate in the snow crab fishery. However, an important prerequisite for participating in fishing for snow crab, is that the new fishery does not displace fishing for more lucrative species, such as NEA cod. A possible explanation of the radical differences in catch rates and operating days at sea within the active snow crab fleet (c.f. Fig. 1), could be that these vessels are holding combined fishing rights in other seasonal fisheries. This could restrict or displace their participation in the snow crab season, e.g., as alternative costs due to overlapping season (s) in time [56,57]. Table 2.

While the majority of the 10 most active vessels, representing approximately 90% of total catches (TAC) (c.f. Fig. 1), have no other fishing rights than the snow crab license, 11 vessels of the active fleet hold licenses within other seasonal fisheries, e.g., NEA cod or e.g., a combination of pelagic fisheries and shrimp trawling. The vessels holding most combined fishing rights represent the lowest catch rates and days at sea within the active fleet. The seasonal fishery for the most important NEA cod fishery during intense winter months (January-April), clearly overlap with the snow crab season. However, only three vessels hold a license for the NEA cod. Also, the NVG herring fishery during the months of January-February and fishing for saithe with conventional gears may partly overlap with the snow crab season. Other combined fishing rights, such as shrimp trawling and purse seining for saithe in the high north and other seasonal pelagic fisheries, do not significantly overlap with the snow crab season. Hence, the low catch rates and operating days at sea for the vessels with combined fishing rights within other seasonal fisheries, represent a weak explanation regarding these vessels’ low participation in the snow crab fishery.

Instead, the most significant differences between the 8–10 vessels recorded with the largest catch shares and the remaining active fleet, may be found in the specific investments tailor-made for the snow crab fishery. The most efficient vessels, holding only a snow crab license, are especially adapted to efficient setting and hauling the crab pots, and they contain efficient processing plants and sufficient freezer storage volumes for 4–5 weeks duration of each trip. In comparison, vessels holding a variety of fishing rights are equipped to operate different fishing gears, processes, and store different fish species, e.g., a combination of purse seining and conventional gears. These vessels thus have limited space for an efficient snow crab fishery. Moreover, the vessels holding only a snow crab license are also the most experienced part of the fleet. The active vessels’ different technological status and the crew members’ skills and know-how are thus vital for the outcome of harvesting snow crab. A preliminary conclusion is therefore that a number of vessels, both the passive- and active vessels with symbolic catch rates, have registered in order to position themselves for a possible closure, and later on, a system based on merging quotas, from the less efficient to the most efficient vessels. This will in turn imply a windfall gain for the registered entrants. Such a "positioning fishery", has previously been described by Ekerhovd [60], with reference to the blue whiting fishery.

The implementation of a new management regime by DoF thus imply a classical dilemma: If the main priority is maximum profit, allocating the TAC to the vessels with the highest catch rates and most days at sea within a closed regime, this may be achieved by both the Olympic model, and by closing the fishery through allocation of individual vessel quotas (IVQs). However, as the most efficient vessels hold no other quota rights than the snow crab license, the fleet will be laid up for the rest of the year, after the (rather short) snow crab season is finished.

[4] The most recent newcomer is MS “Frøyanes”, a 70 m combined snow crab and shrimp trawler, with the possibility of hauling the pots through a separate well in the middle of the boat, thus increasing catch efficiency and improving health- and security concerns [54].

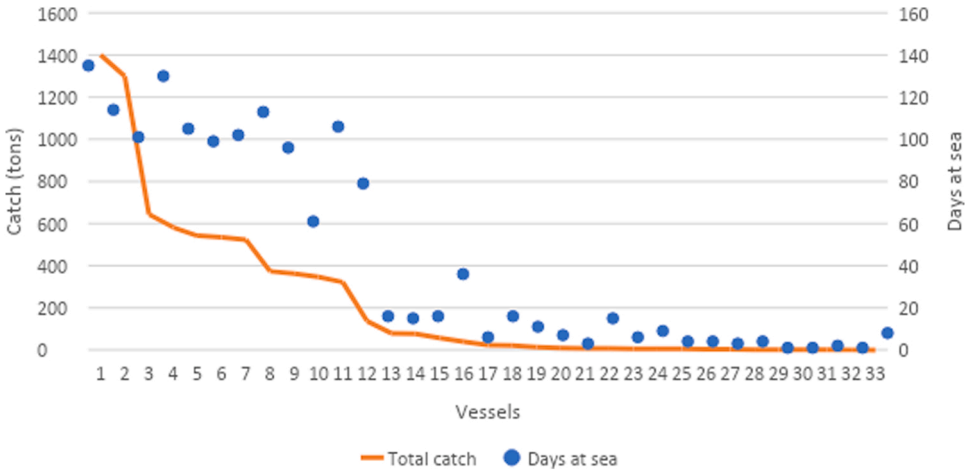

Fig. 1. Snow crab catch (tons) (red line) and days at sea (blue dots). Population: 33 vessels, 2022. Source: Directorate of Fisheries [55].

Table 2
Fishing rights per vessel registered with snow crab catch, 2022. (The vessel numbers correspond with the numbering of vessels in Fig. 1).

Vessel	license	other licenses pr. vessel
1	snowcrab	
2	snowcrab	
3	snowcrab	
4	snowcrab	limited pelagic trawl (saithe), shrimp trawl
5	snowcrab	
6	snowcrab	cod/white fish, north of 62 N
7	snowcrab	
8	snowcrab	
9	snowcrab	limited pelagic trawl (saithe), shrimp trawl
10	snowcrab,	
11	snowcrab	limited pelagic trawl (saithe), mackerel
12	snowcrab	limited pelagic trawl (saithe), shrimp trawl
13	snowcrab	capelin trawl, Barents Sea
14	snowcrab	
15	snowcrab	shrimp trawl
16	snowcrab	limited pelagic trawl (saithe), shrimp trawl.
17	snowcrab	cod/white fish., north of 62 N
18	snowcrab	cod/white fish north of 62 N
19	snowcrab	limited pelagic trawl, cod south of 62 N
20	snowcrab	purse seine (saithe), north of 62 N
21	snowcrab	saithe north of 62 N

Source: Directorate of Fisheries [58,59].

Contrary to this model, the authorities may support the snow crab fishery as a new supplementary fishery for vessels already engaged in other fisheries. This is an approach which may qualify for more participating vessels and increased employment. This is precisely what was done with the new *king crab* fishery, where quotas were reserved for small-scale vessels, comprising more than 500 vessels between 6 and 15 m [61].

In the end, this is a political choice as to which goal is considered most important. The tradition for closing Norwegian fisheries has been to strike a compromise. Securing MSY has always been the first priority, while the issue of MEY has most often been compromised by a two-part regime: one closed group with guaranteed quotas and another group with open access [62]. The first closed group gets allocated the lion's share of the TAC, while the second group receives a minor share, where the open access contributes to secure recruitment of new entrants. This model was developed when closing the Norwegian cod fisheries in the 1990 s and has since been practised when closing other fisheries [13].

A further complicating element is that the potential size of the stock is unknown, as it is invasive and may expand further [63]. Hence, an early closure and a radical reduction in the numbers of participating vessels, may create a completely new situation, requiring the need to increase the access to the fishery at a later stage. On the other hand, the fact that the fishery is relatively new, also implies that technological and knowhow development can be expected, resulting in increased efficiency and fewer vessels required to take the TAC in the future. These uncertainties point to the need for a flexible management approach. Hence, there will have to be compromise solutions and trade-offs between the various goals. In principle there is a variety of possible solutions, where none fulfil all the demands for sustainability.

6. Discussion

To simplify the discussion, we will deal with six alternative models. For all of them we take certain management measures as given. They refer to the use of a binding TAC each year, a fixed fishing season, specific gear restrictions (use of pots), a specified maximum soaking time and a maximum number of pots per vessel. Furthermore, there will be certain minimum requirements as to the technical standard of the vessels (i.e., they must be suitable for fishing in these inhospitable waters). The six alternatives can then be described, all of them in terms of sustainability (economic, environmental, and social) as well as administrative costs involved.

6.1. *Olympic fishery with open access*

This alternative will be most like the current management set-up. This will probably result in further specialization of the active fleet and relatively good income for vessel owners as well as crew, while a steady stream of new entrants would most probably position themselves for a possible closure, sometimes in the future. This would most likely result in the building up of a large *potential* overcapacity. On the positive side, this could represent a much-needed security valve for the conventional fleet, if other fisheries fail. It could also, as previously mentioned, contribute to increased employment in the coastal fleet. In environmental terms this model would imply further ghost fishing (due to collisions and lost lines) and to increased conflicts, both within the snow crab fleet and with other fleet segments, such as the shrimp trawlers. This will in turn imply increased control costs and a relatively large management burden, especially when seen in the context of the relatively low number of fishing boats involved.

6.2. *Olympic fishery with closed access*

In this case the fishery will be closed, most probably through a requirement referring to previous participation in one or two years during the last three years, possibly combined with a minimum requirement regarding catch. Olympic fishery will benefit the most

efficient vessels, while leaving a small portion of the TAC for the remaining vessels. With strong competition, in order to take the largest share of the TAC, the gear conflicts will persist (as today). There will be no further increase in terms of employment, but on the positive side, the administrative burden will be reduced, due to the limited number of vessels involved.

6.3. Closed fishery with IVQs

In this case quotas could be allocated based on previous catch history or according to vessel size (as in the cod fisheries). In the first case, the most efficient vessels will maintain their position, while the less efficient will be fixed with small quotas and hence, low profits. In the second case, the most efficient will lose their present strong position, while offering better prospects for the remaining vessels. With fixed quotas, the gear conflicts will be reduced and probably also the problems of ghost fishing (due to lost lines and pots). Keeping track of quotas and catch can probably be done by the Norwegian Raw Fish Association (*Råfisklaget*), as for all other commercial fish species, with little extra in terms of added administrative costs.

6.4. Closed fisheries with transferable IVQs

In the previous case, increased efficiency will probably encourage quota merging, especially if the most efficient fishing vessels do not have alternative fisheries. An IVQ-system (where transferability depends on approval by the fisheries authorities)[5] will lead to a reduced fleet, probably better profitability for the remaining vessels and reduced employment [64]. Control problems would most likely be reduced, as the number of participants will be further reduced over time.

6.5. Combined closed and open access

This alternative equals the closing of the cod sector, where the most efficient vessels with a long catch history will receive fixed quotas (IVQs) while a smaller share of the TAC will be accessible for new entrants. Their quotas will hardly be sufficient for specialization but could serve as an extra income for vessels primarily occupied with other fisheries. Profitability will be reduced and just like the present situation, there could be a build-up of latent overcapacity. This option will also increase control costs, and probably also increase environmental problems with an increased number of participants.

6.6. Public auction of available quotas

This alternative would be more like the system we find in Norwegian aquaculture, where production capacity is sold on public auction every second year but limited to prequalified bidders [65]. This alternative would secure a larger share of the resource rent for the state, while profits will be reduced for the operators. Lack of security, as a result of not knowing whether the vessel can participate next year, will lead to increased risk and reduced technical development. Depending on who gets the available quotas, such a model could result in a larger turnover of participants, thus not reducing the environmental problems. Organizing the auction (and securing prequalified operators) would also increase the administrative burden.

As can be seen, none of the possible solutions can fulfil all the challenges of the existing management regime. That is probably also the reason why the hearing paper issued by the DoF in July this year is rather open-ended, asking for recommendations from the operators involved. However, closing the fishery, combined with historic activity demands, seems to be the recommended solution, while it is completely open as to *how* this may be done and hence, how many operators that will be allowed to participate in this new, promising fishery.

Right from the beginning the Ministry of Fisheries allocating licenses for the snow crab fishery has stated:

> "Furthermore, we draw attention to the fact that the granting of a permit to catch snow crab does not preclude that the Ministry can at a later date close the fishery and determine the criteria for participation which is then necessary. Granted a permit for catching snow crab also does not form any basis or expectation of participation in a closed group in the event of a possible future closure of this fishery." [8].

While this is a standard procedure, to avoid legal challenges at a later stage, it is evident that the operators still have expectations. In the end, all license holders have an expectation of a possible future benefit, while the first movers (the entrepreneurs, starting these fisheries) [4,5] have even stronger expectations, most often based on experiences with previous closing of other fisheries. This applies not only to established fisheries, but to new emerging fisheries as well, as with the case of cleaner fish for the aquaculture industry [66]. While it is largely accepted that the real entrepreneurs should benefit, having taken the risk and, and incurred serious losses, it is harder to understand why the fishers just positioning themselves should be handsomely remunerated. However, as long as Norwegian fishers pay no resource rent, it is hard for the state to recover the costs of control and management. Also, in this case it is reason to believe that "the winner takes it all", only subject to the reservation that the number of winners still must be decided.

7. Conclusion

The case of the Norwegian crab fishery offers an interesting illustration of how a new and emerging fishery becomes *manageable*. But this is not the end of (management) history. A taller task is to make the fishery *sustainable*, not only in strict biological terms (by setting and enforcing TACs) but encompassing larger environmental concerns (such as ghost fishing), economic concerns (obtaining a resource rent from the fishery) and handling the social obligations regarding conflicts between vessels and obtaining good working conditions for crew members. On top of that, administrative costs connected to control and surveillance must also be kept within reasonable limits. As discussed in this paper, these challenges must be met urgently. If not, this promising new fishery could end up with all the classical problems: overfishing (largely due to ghost fishing), overcapacity (no resource rent and weak profitability for all operators involved), conflicts among the crab fishing vessels (due to strong competition forced by Olympic fishing), and high control and management costs. This is not least due to the fact described by Vatn [33] that ex post regulations normally are much more expensive to carry out than ex ante regulations.

In this case most actors seem to agree that setting a TAC and imposing various technical regulations have not been sufficient to secure a sustainable fishery. The introduction of open access and an Olympic fishery made sense in the initial phase of the fishery, while as per 2024 this management regime has produced numbers of unexpected results. So far, it looks like the management institutions are characterized by *inertia,* i.e., slow efforts to act on new developments and challenges. In this case it is reasonably clear what constitute "the governing system" as well as "the system to be governed" (the resource and the fishers) [28]. It is the mismatch in terms of *governability,* which is now the greatest challenge [31]. The crucial question is: will closing the fishery and allocation of individual vessel quotas solve the current sustainability challenges, and lead to a greater degree of governability? Again, it should be reiterated that closing is a *technical solution*, that also have important political implications, i.e. in terms of allocating resources

[5] In strict technical terms the Norwegian IVQ-system is not a full scale ITQ-system, as all merging of quotas has to be officially sanctioned by the fisheries authorities. The seller returns the quota to the Ministry, which in turn allocates the catching right to the new owner. Payment for the transaction is a matter between buyer and seller [64].

("who is getting what"). The same applies to the other tools involved (maximum number of pots, limited fishing season, specific vessel requirements, etc.). They all contribute to define what the Norwegian snow crab fisheries should look like, and in the process, they also modify both the regulating system and the system to be regulated. Making the snow crab resource *governable* was an important first step, but definitely not the end of the (regulatory) history.

So, what are the lessons for regulating other, new fisheries? Setting and enforcing a TAC is, as always, a first step. As part of securing biological sustainability, other management measures will be required. Allocating the TAC will be necessary to secure economic sustainability and escape the building up of unprofitable overcapacity. But the allocation must be considered legitimate and fair, both in relation to the public, other fishers as well as between owners and crew, contributing to social sustainability. Finally, effective, and legitimate management institutions must have the capacity to handle the various conflicts, including the ability to handle new information and act with flexibility.

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Author agreement statement

We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We understand that the Corresponding Author is the sole contact for the Editorial process. He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

CRediT authorship contribution statement

Dag Standal: Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization, Validation, Visualization, Writing – original draft, Writing – review & editing. **Bjørn Hersoug:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Conceptualization, Investigation, Methodology.

Data Availability

Data will be made available on request.

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