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The "Discard Ban Package": Experiences in efforts to improve the exploitation patterns in Norwegian fisheries

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ABSTRACT

A source to long-term increased catches and profitability for the fishing fleet is the reduction of discards and improvements in exploitation patterns. This article details the development of Norwegian regulatory measures to this end, in particular the introduction of a discard ban and the Barents Sea programme of real-time closures of fishing areas. Actual benefits of this policy are outlined.

1. Introduction

In order to improve exploitation patterns and reduce the problem of discards in the fisheries, Norway has over the years established a suite of regulations and management measures [1,2]. The main objective has been to promote an exploitation pattern where fish below minimum legal size are spared, and where unwanted bycatch can be minimised. This has been achieved through several interconnected measures, which can be referred to as the "Discard Ban Package".

There are several causes or incentives for discarding [2–4], including:

- juvenile fish; discarding of fish below minimum landing/commercial size
- highgrading; filling scarce quotas with fish of size and quality obtaining a higher price per kg
- lack of quota; discarding of species for which the vessel has exhausted its quotas or exceeded bycatch limits
- too large catches; discarding the part of catch exceeding the vessel's processing or carrying capacity
- species of low value; discarding of bycatches of species of little or no commercial value
- damaged fish; discarding of fish that is damaged or otherwise unfit for human consumption.

The incentives for discarding may vary according to a range of parameters such as e.g. ecosystem, size and age structure of target stocks, season, gear type, available quotas and the regulatory framework. Discarding is often regarded as a waste of living resources [5,6]. Minimising unwanted bycatch that might otherwise be discarded is relevant both to conservation and to economical and distributional aspects of fishing activities. The term "unwanted" may in this context encompass bycatches of threatened species and species without economic interest to the fisher, as well as species for which a particular fisher or fleet does not hold a quota or fishing right.

Norway introduced a discard ban on cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) in 1987 for both economic and ethical reasons [7]. The very existence of the ban has been beneficial in changing the fishers' attitudes and discouraging the practice of discarding. The ban was gradually expanded to new species, and from 2009 an obligation to land all catches was introduced, albeit with certain exemptions [8,9]. It should be noted that the ban applies to dead or dying fish. Viable fish can be released back to the sea.

The discard ban was preceded by a programme of real-time closures of fishing areas (RTCs) which evolved from 1984 and onwards.

Area closures are well developed measures in fisheries as well as environmental management. An overview of the usage of area restrictions, including Marine Protected Areas, in Norwegian fisheries management is available online [10]. In fisheries management,

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closed areas can basically be grouped into two main categories: permanently closed areas and RTCs.

1.1. Permanently closed areas

Areas can be permanently closed year-round or seasonally, for all gear or specific gear, and for a variety of reasons—nursery areas, coral reefs, trawler-free zones to prevent conflicts between gear, lobster habitats, etc. An example is the nursery area that is permanently closed for bottom trawling year-round is the 20 nautical mile zone around Bear Island, established in 1978 [11] (Fig. 1).

1.2. Real-time closures

RTCs are imposed temporarily on areas where the number of fish below the minimum legal size or the level of bycatches exceeds permitted limits. RTCs have turned out to be an effective tool in situations where unwanted intermixture of fish varies from year to year and/or with respect to time and place. As seen from the fishers' perspective and that of economic efficiency, it is a flexible measure; unlike permanent closures, it allows fishing to take place in a controlled and sustainable manner when not in conflict with economic and conservation objectives.

The programme for closing and opening of areas on a real time basis in the Barents Sea was developed from 1984 and onwards to prevent catching of fish below the minimum legal size or bycatches of protected species. Similar but less comprehensive programmes are now emerging for the North Sea and Skagerrak, in dialogue between EU and Norway.

2. The Barents Sea programme for RTCs

The background for establishing this programme was that after seven consecutive years with weak year-classes combined with overly high fishing pressure, the stock of Northeast Arctic (NEA) cod was in very poor condition. However, in 1983 a strong year-class of NEA cod was documented [12,13]. Experiences from the 1960s and 1970s showed that strong year-classes would be grossly reduced during their first years of life owing to excessive discarding in the trawl fishery for Northern shrimp (*Pandalus borealis*), and during subsequent years also in the trawl fishery for cod and haddock. The pressing question at that time was what would happen if there were seven more lean years with poor recruitment of NEA cod after 1983. Steps had to be taken immediately to ensure that this precious year-class would survive and contribute to the spawning stock and to the economically important cod fisheries in the years to come. The solution was the establishment of a programme for temporary RTCs of fishing grounds, a programme which between 1984 and 1986 successfully contributed to protecting the strong 1983 year-class through its most vulnerable juvenile phase.

2.1. Financing and operation of the Barents Sea programme

In subsequent years the programme has been further developed, and it now covers the most commercially important fisheries in the region. Commercial fishing vessels are chartered to investigate the fishing grounds with specially assigned and trained inspectors on board (most of them having their professional background from fisheries). The financing of the programme is twofold. Until 2014 the chartering of fishing vessels was financed by the industry, as a total of 4600 t of cod, haddock and saithe (*Pollachius virens*) were set aside from the total allowable catches, and given as quota bonus/payment

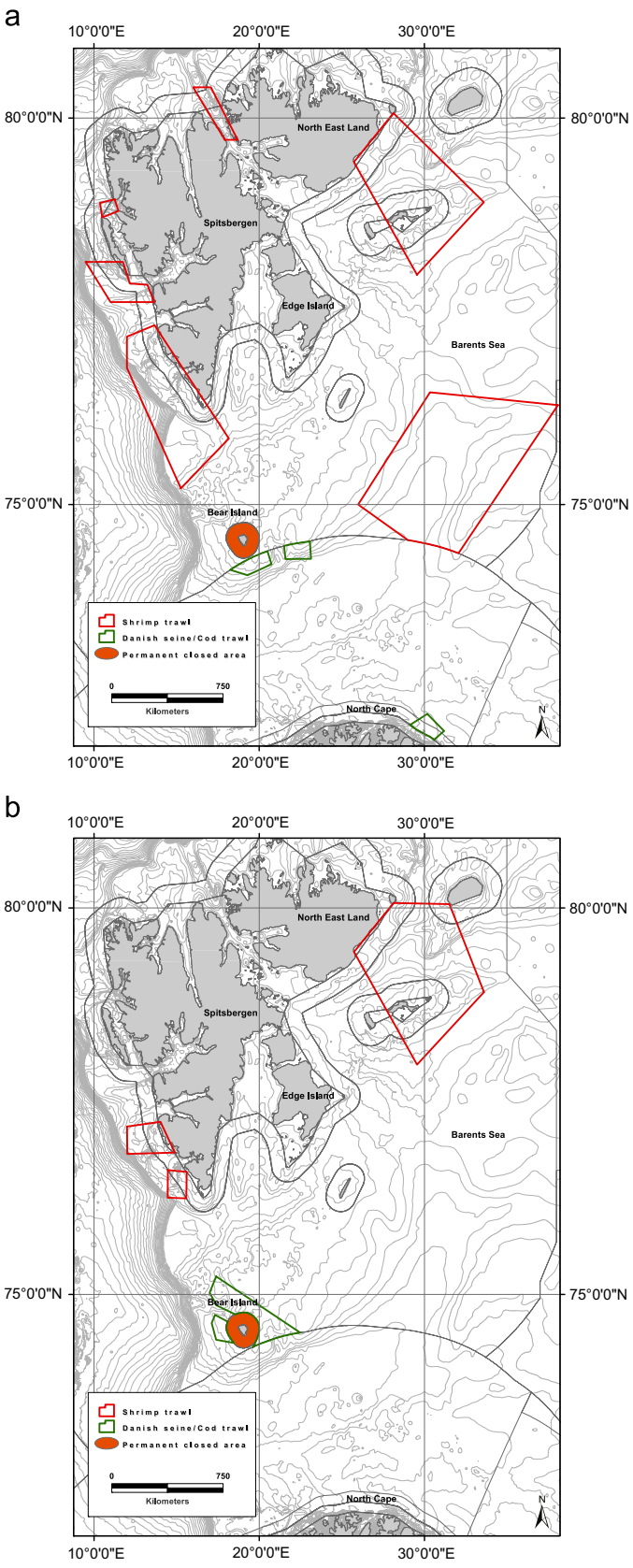

Fig. 1. (A) Closed areas in March/April 2005. (B) Closed areas in October 2005. Solid orange area: the permanent closed area around the Bear Island. Open red and green areas: Real-time closures. *Source*: Norwegian Directorate of Fisheries.

to fishing vessels participating in the programme. As of 2014 the chartering of vessels is still financed by the industry, but now through the income from a general fee on firsthand sales of fish. The costs for 18 inspectors and the running of the programme, which amount to approximately 20 million NOK or 2.7 million EUR per year, are covered by the government (all data refer to 2012). The programme is operated by the Surveillance Service, a branch of the Norwegian Directorate of Fisheries' (DoF) regional office in Tromsø.

The annual work plan of the Surveillance Service is based on risk assessments that take into account not only expected fleet activity, but also research data on expected changes in stocks and year-class strength. On this basis decisions are made concerning how many days should be chartered on vessels of different categories over the following year. Purchase of vessel days follows public tender procedures, and one important element in the selection is that the vessels are representative of the relevant segment of the fishing fleet with regard to gear technology, engine power etc.

2.2. Criteria for closures

Specific criteria relating to intermixture of juveniles and level of bycatches are laid down in the relevant fisheries regulations as basis for closure [9]. In the Northern shrimp fishery the criteria are a maximum permitted number of specimens for each of the species cod, haddock, redfish (*Sebastes* spp.) and Greenland halibut (*Reinhardtius hippoglossoides*) per 10 kg of shrimp. The present limit is 8 for cod, 20 for haddock, and 3 each for redfish and Greenland halibut. The criteria for cod and haddock are based on the results from a bio-economic model where the value of present shrimp catches is balanced against future losses in economic yield of cod and haddock [14]. The stocks of redfish and Greenland halibut have been in a precarious state for a long time, and for these species the criteria are more restrictive, based on the precautionary approach and biodiversity considerations. However, the situation for these stocks has gradually improved during recent years, and the criteria are presently being revised. Also the bio-economic criteria need to be revised from time to time, due to changes in relative prices and other relevant model parameters.

In the trawl fishery targeting cod, haddock and saithe, a combined maximum per haul of 15% juveniles (fish below their respective minimum sizes) of the said species are allowed. The criterion is measured in numbers of fish. For inspectors and for fishers (Section 4.3 and the move-on provision), it is operationally easier to count the fish than to weigh them. (Furthermore, a limit measured in weight instead of numbers of fish would have to be considerably higher than 15% to provide the same level of protection of juveniles). The 15% limit, based on biological considerations, was introduced together with the RTC programme in 1984.

In addition to the criteria already mentioned, which are the most important with respect to triggering RTCs, there are several other bycatch criteria related to specific fisheries or stocks, for example to minimise the intermixture of cod in Barents Sea capelin (*Mallotus villosus*) fisheries, or the intermixture of protected redfish in cod fisheries.

2.3. Procedures for closing areas—Notification and communication to the fleet

Procedures have been established with regard to sampling and delimiting the area to be closed. Accordingly, when investigations by the Surveillance Service reveal that one or more criteria have been exceeded, the area will be closed. Delimitation is based on the actual geographical occurrence of juveniles or bycatches, not, for example, on a predetermined grid size. As a consequence, a closure may be quite extensive and non-rectangular in shape. The formal decision on closure is made by the head office of DoF in Bergen in the form of a legally binding regulation, based on advice from the regional office in Tromsø. Normally, the regulations will be adopted and enter into force within hours, not days, after sampling took place.

The regulations are communicated in Norwegian to the fleet through the Norwegian Broadcasting Corporation, which has a daily radio service that distributes short, important messages to the fleet. In addition regulations are communicated to the fleet from relevant coastal radio stations through channel 16. The regulations are also published (in Norwegian, English and Russian) on the DoF website, accompanied by a map of the closed area, the data on a haul by haul basis from the trial fishery that motivated the closure, and the Surveillance Service's summary/evaluation from the trial fishery.

When an area is closed, it affects all fishing vessels from the moment they have received the relevant information. In the case of foreign vessels, notification must follow a formal procedure and go through diplomatic channels. This may in practice take a week or more. In order to speed up the process, by bilateral agreement, a copy of the decision is sent simultaneously but informally from the DoF to fisheries authorities in Russia, EU, Faroe Islands, Iceland and Greenland. However, normally the Coast Guard or the Surveillance Service will inform vessels fishing in the relevant area directly by radio communication about the closure. If a foreign vessel continues fishing until it is notified by its own authorities, it is warned that it may be inspected. Given that it is probably impossible to continue fishing without violating the rules, this warning usually results in immediate compliance with RTCs, irrespectively of flag and formal notification procedures. In situations with many fishing vessels present and high fishing intensity, rapid closure and compliance are essential for the protection of juvenile fish.

The decisions on relevant areas to investigate are based on accumulated experience of the Surveillance Service, and on updated information from scientists, the Coast Guard and the fishing fleet. Closed areas are re-examined after some time to check whether it is still motivated to have these closed. The time lag between closure and re-examination is determined case by case based on experience from similar situations. If the intermixture of juveniles in the catches no longer exceeds the permitted levels, the closed areas are re-opened for fisheries. In many cases the re-examination may justify an amendment to the extent of the closed area. The number of closures, amendments and re-openings depends primarily on the relative strength of year-classes of relevant stocks, and ranges between 30 and up to 70, annually.

In advance of a closure, the Coast Guard has the possibility – if present at the fishing ground – of establishing a "Precautionary area". When set out in the map and communicated to the fleet present, this serves as a warning that fishing in the specified area will most likely imply violating regulations. The area is not formally closed, but fishing within the area might nevertheless have legal consequences.

Fig. 1A and B show the large variation in the size and shape of closed areas, and also the major changes over time, here illustrated by changes from March/April to October in 2005.

2.4. Stakeholder acceptance of RTCs

The concept of closure and opening of areas is generally regarded – also within the industry – as an important instrument for achieving rational exploitation patterns in these areas. Seen from a conservation perspective, no negative side effects have been observed with regard to the method of closing areas with undersized fish or excessive bycatch. As a regulatory measure RTC is, based on discussions with stakeholders and the authors long personal experiences, generally recognised and respected by fishers, among whom it has gained a fairly high degree of legitimacy. The reason for this is that closing of areas with small fish or overly high bycatch levels creates a level playing field, and prevents behaviour that is contrary to fishers'

professional code of conduct, as fishers in general accept that catching (and discarding) fish below accepted minimum size is unprofessional and morally wrong.

It has been argued that instead of formal closures, one could rely on some sort of self-policing whereby fishers would voluntarily leave areas with large numbers of juveniles. Although a move-on provision does exist, see Section 4.3, experience shows that this is not enough in practice. The law-abiding fisher will perceive that colleagues with a more relaxed attitude towards rules and regulations continue fishing and become the economic winners. When high moral standards compete with economic return, the moral standards tend to lose out. In such a context a formal closure policed by the government creates a level playing field.

From time to time fishers complain that the Surveillance Service is too slow in re-examining a closed area. This is mainly a question of finding the right balance between fishers' understandable impatience, and the concerns of government related to the cost/efficiency of the Surveillance Service. Automatic re-opening of closed areas is not considered feasible in the Barents Sea, as experience shows that when intermixture of juveniles occurs, it may often prevail for a long, indefinite period (often months rather than weeks). Accordingly, the occurrence of juveniles or bycatches must be assessed and re-assessed in each individual case.

The rules of RTC programmes differ, due to differences both in natural conditions in the objectives and ambitions set for the programme. In the emerging RTC programme for the North Sea and Skagerrak, EU and Norway have so far not managed to harmonise the relevant rules and criteria. Both parties do apply automatic re-opening after 14 days, but no agreement has yet been reached concerning the size (predetermined or not) of closed areas and whether limits should be measured in weight or numbers.

2.5. Co-operation with Russia

Several stocks in the Barents Sea are shared and managed jointly between Norway and Russia as coastal states. In 1975 the two parties established the Joint Norwegian–Soviet (Russian now) Fisheries Commission, and in 1976 a framework agreement on mutual fisheries relations was signed [15–17]. The Joint Norwegian–Russian Fisheries Commission and its subcommittees meet regularly to discuss and decide on management issues, including technical measures. There is a common understanding that protection of juveniles is an essential part of responsible management, and the criteria and procedures for RTCs are jointly agreed. Both parties have restrictions on discarding in their legislation.

3. The introduction of a discard ban in Norway

Returning to the strong 1983 year-class of cod: in late 1986 and early 1987 this year-class reached what was then the minimum landing size, and the basis for area closures was no longer present. However, alarming messages from both inspectors and the fishing fleet indicated that a practice involving extensive high-grading was now emerging. Fishers would fill their quotas with the largest, best-paid fish and discard the smaller but still legally sized fish. This behaviour was perfectly legal under the existing laws and regulations.

As described above, considerable effort had already been put into saving this particular year-class; furthermore, subsequent year-classes were reported to be poor. The Minister of Fisheries at that time, Mr. Bjarne Mørk-Eidem, was naturally very upset: "This is terrible," he said, and his experts answered: "Yes, Minister, it is really terrible." And he went on, saying: "We must do something; we have to ban this practice." But the experts said: "Ah, well—no, Minister, that is not possible. There are all sorts of legal problems, not least internationally. But first and foremost, a discard ban is more or less impossible to enforce." However, the Minister refused to give in: "This practice is both economic madness and morally wrong—I know it, you know it, and so do the fishers. Even if it is hard to enforce, at least it should not be legal to do what they are doing. Therefore, no more discussions; make me a discard ban!" (Bjarne Mørk Eidem, pers. comm.). Subsequently, the ban on discard of dead or dying cod and haddock came into force in April 1987 [7].

This story is an example of political leadership. When his experts were stuck in conventional thinking, the Minister pointed out the direction for a new and sustainable policy in this field.

Over the next 20 years, the ban on discarding of dead or dying fish was gradually extended to include new species, and by 2008 a total of 18 species were covered by the no-discard policy. On 1 January 2009 the old Act relating to Seawater Fisheries was replaced by a new Marine Resources Act [8], and at the same time an obligation to land all catch of fish (discard ban) was made the general norm. The earlier Act related only to fisheries and focused mainly on the exploitation of commercial stocks, whereas the new Act applies to all living marine resources. After initial adjustments the following years, the discard ban comprises approximately 55 species by 2014 [9]. Some further adjustments for species of low economic value could be expected in order to adapt the discard policy to some of the practical problems encountered by the fishing fleet.

3.1. Enforcement and sanctions of the discard ban

Discarding is an offence that may be difficult to detect. Nonetheless, enforcement of regulations concerning the obligation to land catches has high priority, and the Coast Guard and the Directorate of Fisheries do detect some cases each year.

Presence and surveillance at sea by the Norwegian Coast Guard is extensive compared to most coastal states, with 15 inspection vessels conducting in the order of 2000 inspections annually. Presence and inspection at sea are the main tools for preventing and uncovering discarding. Some of the inspection vessels are equipped with a helicopter, and "surprise" filming for evidence followed by boarding has proved effective in uncovering discarding. Norway does neither operate an observer programme collecting scientific data at sea, nor a closed-circuit television (CCTV) programme to monitor potential discarding. However, scientific data, including some data on discards, are collected by the Institute of Marine Research through their Reference fleet [18].

When discarding is revealed, both the captain of the vessel and the owner may be fined. In extreme cases, for example if it is revealed that discarding is an integral part of the vessel's 'ordinary' production process, the fishing licence may be withdrawn for a period, and considerably higher fines are expected than for minor infractions. In blatant cases, depending on the evidence, the entire catch onboard may be considered illegal, and a corresponding value confiscated by the prosecuting authority or by the court, in a separate decision. Over the years, the Coast Guard, in co-operation with the Public Prosecutor, has succeeded in learning how to collect evidence in discard cases in a way that will satisfy the Norwegian judicial system, so that it is possible to get convictions in a Court of Law. As a result, approximately half a dozen captains/companies are fined annually. The fines are around 15 000 to 25 000 NOK for the captain, and in addition up to 150 000 NOK for the company that owns the vessel.

3.2. What about damaged fish—Are there any exceptions to the discard ban?

The regulations relating to seawater fisheries [9], list the species for which the discard ban applies. Neither the act nor the regulations include any formal exemptions from this ban. However, in practice it

is not possible to avoid all situations where fish are damaged to an extent where they are no longer fit for human consumption. Examples include fish stuck in meshes and fish that have been partly consumed by other marine organisms. Retaining such fish on board may result in practical problems. However, the amount of fish damaged in this way during a fishery conducted in accordance with all applicable regulations is very low. The authorities have thus acknowledged that these practical problems have to be dealt with. Recognising that it is not possible to list all situations and set limits in a regulation that will give the desired result, the authorities have found a pragmatic solution. Under the Norwegian legal system, the enforcement agencies have the authority to decide whether an infringement should be followed up. Based on this authority, it has become a practice for the enforcement agencies not to prosecute discarding of fish that are provable damaged in fishing operations, and thus unfit for human consumption. This also applies to the amount of waste resulting from fish production on board vessels according to the official conversion factors, and to the smallest juvenile fish not being sorted out by the sorting grid in a shrimp trawl, as long as the number of juveniles per kg of shrimp caught is within the legal limit.

4. Accompanying measures to facilitate the discard ban

A commonly asked question with regard to the Norwegian discard policy is how to handle all the 'illegal' catches that are now supposedly landed. Questions like this tend to overlook the combined set of measures that lie at the core of the policy. The discard ban, the obligation to change fishing ground, RTCs, the tailoring of quota regulations, gear restrictions and minimum fish and mesh sizes, and the development of more selective gear—all these measures aim at reducing the amount of unwanted catches in the first place. The accompanying measures are discussed below.

4.1. Compensation to fishers for landing of 'illegal' catches

Although there is no doubt that the extent of unwanted catches in Norwegian fisheries has been greatly reduced, it is a fact, supported by detected cases, that discarding still occurs. Sometimes it occurs deliberately and as a result of an intended and unlawful harvest strategy, but sometimes to dispose of an unintentional bycatch. As an incentive to land the unintended catch instead of discarding it, fishers may apply for compensation for the extra work of handling and landing the fish. The 'illegal' catches may be sold together with the rest of the catch and through ordinary market outlets. However, as all firsthand sales and all payments for fish are by law [19] channelled through one of the six Norwegian fishermen's sales organisations, the value of the 'illegal' part of the catch is retained by the sales organisation. Nevertheless, 20% of the value of the 'illegal' catch may be paid to the fisher as compensation for any extra work. In purse seine fisheries for mackerel, herring and capelin, this 20% rule was abandoned as it turned out to be too strong an incentive for vessels to exceed their quota by "filling up" on the last trip.

The sales organisations are allowed to keep the confiscated 80% of the value, and use the money on their lawful duties related to fisheries control, which include the collection and revision of all data related to firsthand sales of fish in Norway.

Generally, the landings of 'illegal' fish do not represent a large amount of fish or a significant logistical problem. However, some challenges have been encountered by fishers who comply with the discard ban and land certain species with little or no market value. The occasional and unintended bycatch of polar cod (*Boreogadus saida*) in the Northern shrimp fishery is an example. Such catches may be ensiled and reduced to meal and oil, or used for animal feed. As such catches represent small and occasional volumes, there has been no direct effort triggered by discards to develop new markets. Over the years there have, however, been several initiatives to develop new fisheries and markets for hitherto underutilized species. Some of these species has historically been discarded as low value bycatch.

4.2. From minimum landing sizes of fish to minimum fishing sizes of fish

Historically, an important element when deciding on minimum mesh sizes in bottom trawl has been the objective of utilising the growth potential of the individual fish, and letting each fish spawn at least once before it is caught [20]. The minimum landing sizes of fish have often been set at levels where on average 75% of the fish below that size are expected to swim through the meshes, whereas 25% are captured (and discarded if the minimum landing size is enforced). The introduction of a discard ban led to a conceptual change with regard to the interpretation and function of permissible minimum sizes of fish. The minimum sizes of the fish that are actually fished have replaced the minimum landing sizes in technical regulations; for example, fishing sizes are crucial elements in the decision rules for RTCs. The focus on reduction of potential discards has also been an invitation to revisit – and if possible harmonise or improve – the connection between mesh sizes, allowed minimum fish sizes and the actual commercial minimum market sizes. For targeted fisheries, for example, there is no obvious reason why it should be legally permissible to take fish that are smaller than what is commercially accepted in the market. Hence, the option of increasing the minimum mesh size in trawls accordingly should be considered. For mixed fisheries the situation is, admittedly, more complex.

4.3. Obligation to change fishing ground—The move-on provision when limits on juveniles or bycatches are exceeded

According to Norwegian legislation, it is prohibited to fish 'illegal' fish, as distinct from a prohibition that merely limits the landing of such fish. This prohibition constitutes an obligation for fishers to change fishing ground when the fishing operations contravene the regulations. For instance, whenever bycatch limits or the permitted intermixture of undersized fish have been exceeded, the fishing operation on the fishing ground in question must cease and operations must move to an area where, to the best of the fisher's knowledge, it is probable that the catch composition is within the limits of the relevant regulations. It is not expedient within the Norwegian legal system to stipulate a fixed shift in terms of depth or distance in nautical miles. If the logbook, satellite tracking or other sources of information reveal that more than one haul has been conducted in the same area without moving, the fisher will be subject to arrest/reporting to the police and may be fined for the offence. The catch in the relevant hauls is considered illegally caught, and its value confiscated by the prosecuting authority or the court in a decision separate from the fine. If illegal catch is mixed with legal catches on board the vessel, the entire catch may be considered illegal and its value confiscated.

If the fisher has acted in compliance with the move-on provision, there is no offence. The value of the part of the catch that is in excess of permitted limits will, however, be subject to confiscation through an administrative decision by the DoF.

It should be noted that it is a crucial element of the anti-discard policy that fishing operations are recorded in logbooks on a haul by haul basis.

4.4. Tailoring of national quota regulations

Different ways of regulating fisheries by means of quotas may provide different incentives with regard to discarding. As a

consequence of the introduction of a discard ban, the government was forced to re-think its practices, not only in terms of technical regulations, but also with regard to national quota regulations. It was important to ensure that the regulations were formulated to minimise possible incentives to discarding, such as quotas per trip or week. Weekly quotas face the fisher with a weekly temptation to discard excess catches in the last haul, whereas annual quotas limit that temptation to once a year.

Another important measure was to allocate quotas to cover expected unavoidable bycatches in non-direct fisheries, before allocating remaining national quotas to vessels licensed to target the species in question. In addition the bycatch allocation must be reconciled with the permissible bycatch limits, and the government must refrain from "solving" distributional issues by implicitly accepting that fishers discard excess catches. Bycatch allocations are now common in many Norwegian fisheries; examples include allocation of North Sea cod to cover unavoidable bycatches in saithe and in Northern shrimp fisheries, saithe in Norway pout (*Trisopterus esmarkii*) trawling, and blue whiting (*Micromesistius poutassou*) in herring (*Clupea harengus*) fisheries.

Small coastal vessels fishing with passive gear have limitations in terms of mobility and ability to change fishing ground. In some of the fisheries carried out by these vessels, actual bycatches may vary considerably from setting to setting or from day to day. In such cases, bycatch limits may be set for a longer period, for example a week, to reduce incentives to discard.

4.5. Development of selective gear technology

The focus on the discard problem and in particular the regulations introduced to minimise the problem, have had a beneficial influence

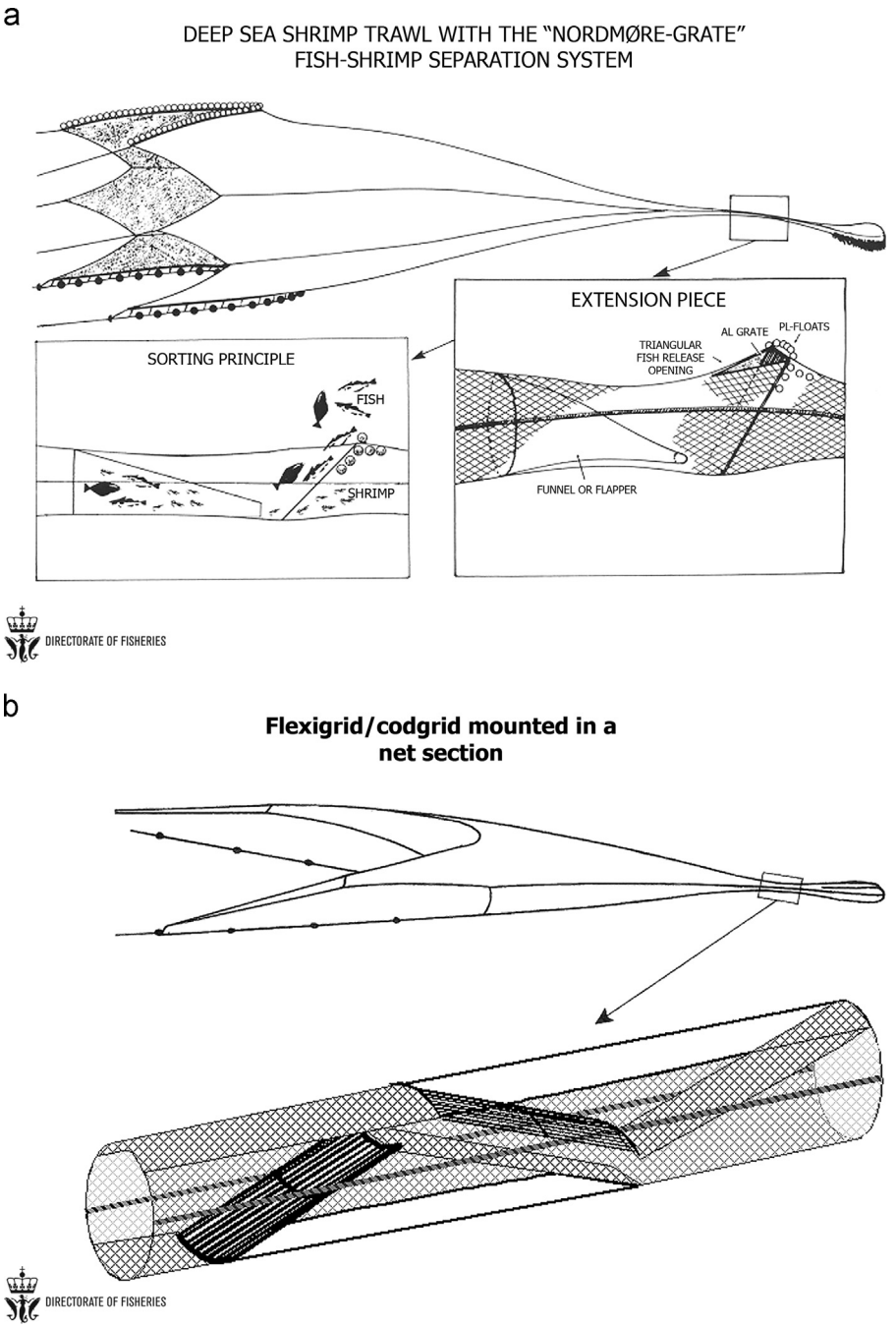

Fig. 2. (A) Sorting grid installed in a Northern shrimp (*Pandalus borealis*) trawl to separate and release fish from shrimp catches. (B) Sorting grid installed in a bottom trawl to separate and release juvenile fish. *Source*: Norwegian Directorate of Fisheries.

on the research and development of more selective fishing gear. The introduction of grid technology both in shrimp and cod trawls (compulsory north of 62°N from 1991 and 1997, respectively) are examples of this spin-off effect created first of all by the RTCs (see the illustrations in Fig. 2A and B). The industry took an active part in this development when large areas were closed due to too large inter-mixtures of juveniles. With sorting grids still at a test stage, fishers could get an exemption to fish in closed areas, provided they used a sorting grid. To this end closures turned out to be far more effective and instrumental to innovation and implementation than years of traditional, publicly financed research on selectivity. The successful use of grids in the test phase paved the way for the agreement between Norway and Russia to make the use of grids compulsory throughout the Barents Sea.

The introduction of the discard ban and RTCs has led to creative pressure on research, management and industry to cooperate and contribute to technical and regulatory innovations in order to improve selectivity and reduce unwanted bycatches, and also to reduce various sources of unintended fishing mortality. One recent example is the development of the Excess Fish Exclusion Device which release fish to avoid too large catches in trawl and Danish seine. With the sharp increase in stock and availability of cod, burst nets and extensive non-registered fishing mortality caused by very large hauls in a short time, have become a problem. This challenge is now about to be successfully solved in a constructive co-operation between the industry, science and management [21].

5. Gains from improvements in the exploitation patterns

Below, Northeast Arctic cod is used to illustrate the potential gains from improvements in exploitation patterns. Fig. 3 shows the yield of NEA cod as a function of age-at-catch. With an initial stock of 1000 three-year-old cod where all are caught immediately, the total yield amounts to 724 kg live weight. If the catch is postponed until the fish are nine years old, many of the initial 1000 fishes have died from natural mortality, but due to the individual growth of the remaining fish, the total yield has nearly doubled to 1337 kg. The figure illustrates a central and general point with regard to potential gains from improvements in exploitation patterns.

Fig. 4 shows the dynamics in mean age- and weight-at-landing from 1946 to 2013. In the 1970s the mean age-at-landing fell to around 4 years when a strong year-class entered the NEA cod fishery, whereas from 1990 and onwards the mean age-at-landing has not been below 5 years in spite of the entrance of several strong year-classes in the fishery. From 1946 to 1950 the mean age-at-landing was higher than 7 years; in 2013 the mean age-at-landing was above 7 years for the first time since 1950. Mean weight-at-landing was lowest in the 1960s and 1970s, and in these decades it fell below 2 kg (see Table 1). From 2010 to 2013 the mean weight-at-landing increased by more than 1 kg from 2.84 kg to 3.87 kg, and in 2013 the highest mean weight-at-landing after the Second World War was reported. Table 1 illustrates how the selectivity in the NEA cod fishery in the Barents Sea deteriorated from the 1950s to the 1970s, but later improved due to the continuous and combined efforts to improve exploitation patterns since the 1980s. Important milestones in this regard are illustrated in Table 2.

According to data in a recent report [23], the mean age-at-landing of NEA cod decreased from 5.9 years in the 1950s to around 5.3 years in the 1960s and 1970s, and then increased again to 5.6–5.7 years during 1990s and 2000s and to 6.8 years in the period 2010–2013. The increase in the period 2010–2013 is due to both very low fishing mortalities (2010–2013: an average of 0.28 per year) and the dominance of the strong 2004 and 2005 year-classes in the catches. Based on data on growth, selection and cannibalism mortality from the same report [23], the mean age-at-landing in 2014 when fishing

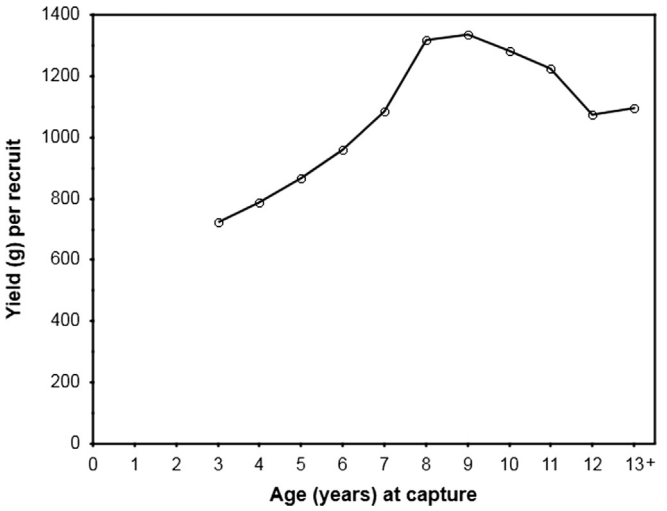

Fig. 3. Yield-per-recruit of Northeast Arctic cod (*Gadus morhua*) as a function of age-at-catch. The data in the figure have been calculated from catch weights-at-age in 2010 given in Table 3.7 and natural mortality-at-age in 2010 used in the final separable virtual population analysis run given in Table 3.17 in [22].

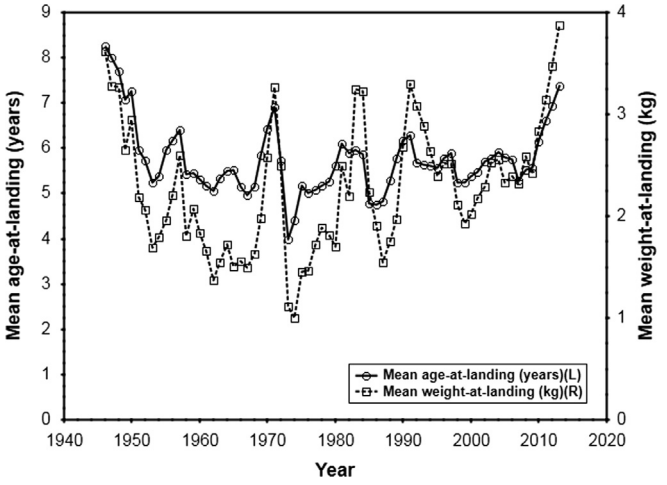

Fig. 4. Mean annual age- (left *y*-axis) and weight-at-landing (right *y*-axis) of Northeast Arctic cod (*G. morhua*) during the period 1946–2013. The calculations are based on data from 1946 to 2013 in Tables 3.5 and 3.7 in [23].

at the target fishing mortality of 0.40 per year, will be 6.5 years in an equilibrium situation, compared to 6.9 years with the recent fishing mortality of 0.28 per year (Table 3.25 in [23], data for 2014).

The increase of 1.5 years in mean age-at-landing since the 1970s represents – all other things being equal – an 18% increase in annual yield. Applied to the total allowable catch of 1000 000 t for cod in 2013, this amounts to about 180 000 t and to a firsthand value of approximately 1517 million NOK or 194 million EUR, based on the average Norwegian firsthand prices in 2013. Although this calculation is based on simplified assumptions, it illustrates the substantial gains that might accrue from improvements in exploitation patterns. Also note that since this calculation is based on change in the average age-at-landing, it does not include the gains reaped from reduced levels of discards. In the absence of reliable data on historical discard levels, these gains are not possible to calculate separately. However, with knowledge of the history of the Barents Sea fisheries, and with reference to similar fisheries where discard data do exist [5,6], it is likely that these gains have been considerable. An earlier paper [24] showed that at a low fishing pressure, the gain in yield-per-recruit of NEA cod may be around 25% if exploitation is postponed for two years.

Table 1
Mean age- and weight-at-landing of Northeast Arctic cod (*Gadus morhua*) in different decades from 1946 to 2013 (*source*: [23]).

	Mean age- and weight-at-landing of NEA cod in different decades							
Decades	**1946–1949**	**1950–1959**	**1960–1969**	**1970–1979**	**1980–1989**	**1990–1999**	**2000–2009**	**2010–2013**
Mean age-at-landing (years)	7.76	5.90	5.30	5.32	5.49	5.71	5.62	6.78
Mean weight-at-landing (kg)	3.20	2.13	1.63	1.88	2.23	2.60	2.36	3.33

Table 2
Important steps in improving exploitation patterns for Northeast Arctic cod (*G. morhua*) and haddock (*Melanogrammus aeglefinus*) during 1980–2013.

Year	Milestones in improving the exploitation patterns in the Barents Sea
1980	Norwegian–Russian agreement to ban mid-water trawling for cod and haddock
1981	Norwegian–Russian agreement to increase minimum legal mesh size to 125 mm in bottom trawl
1982	Norwegian–Russian agreement on minimum legal sizes of 42 cm for cod and 39 cm for haddock
1983	Unilateral Norwegian increase of minimum legal mesh to 135 mm in bottom trawl
1984	Introduction of RTCs and the move-on provision in Norwegian waters
1987	Introduction of a discard ban for cod and haddock in Norwegian waters
1990	Unilateral Norwegian increase of the minimum legal sizes to 47 cm for cod and 44 cm for haddock
1991	Norwegian–Russian agreement on mandatory sorting grid (19 mm bar spacing) in Northern shrimp trawl
1997	Norwegian–Russian agreement on mandatory sorting grid (55 mm bar spacing) in bottom trawl
2010	Norwegian–Russian compromise on a joint minimum legal size of 130 mm in bottom trawl
2010	Norwegian–Russian compromise on joint minimum sizes of 44 cm for cod and 40 cm for haddock

For fishers and the fishing industry, mean weight-at-landing is in itself an important economic parameter and is also easier to relate to than mean age-at-landing. Both these measures show similar trends, as seen in Table 1. From an average weight-at-landing between 1.6 and 2.6 kg in most of the decades between 1950 and 2009, the mean weight-at-landing increased to 3.3 kg in the period 2010–2013. Based on data on growth, selection and cannibalism mortality [23], the mean weight-at-landing in 2014 when fishing at the present target fishing mortality of 0.40 per year will be 3.1 kg in an equilibrium situation, compared to 3.6 kg with the recent fishing mortality of 0.28 per year (Table 3.25 in [23], data for 2014).

6. Development of the spawning stock and total landings of Northeast Arctic cod and haddock during 1980–2013

The development of the spawning stock biomass (SSB) and in total landings may be used as indicators of the overall successfulness of fisheries management: SSB represents the stock fortune and total landings the annual yield or income from that fortune. The development of these two indicators is basically influenced by a combination of three factors: variability in environmental conditions, exploitation pattern, and exploitation level. Fisheries management may control the last two, but it is more than difficult to adequately separate the effect from each of the three factors. Besides resulting in a substantial increase in annual yield, as illustrated above, the discard management measures and improved exploitation patterns have also, beyond reasonable doubt, made a valuable contribution to the rebuilding of the two stocks.

With regard to the exploitation levels of the Barents Sea stocks there has been a positive development during the last 5–10 years, owing both to bringing an excessive illegal, unregulated and unreported (IUU) fishing under control, and to the introduction of precautionary Harvest Control Rules, reducing the fishing mortality levels from 2007 and onwards.

The average annual spawning stock, landings and fishing mortalities for Northeast Arctic cod and haddock in the two periods 1980–1989 and 2007–2013 are given in Table 3. The precautionary approach reference points *B*pa and *F*pa, for SSBs and fishing mortalities, respectively, are included as references. All data refer to the ICES Advice in 2014 [25,26].

Table 3
Development of spawning stock biomass (SSB), landings and annual fishing mortality (*F*) of Northeast Arctic cod (*G. morhua*) and haddock (*M. aeglefinus*) during two periods from 1980 to 2013 (*sources*: [25,26]).

Species/SSB/landings/fishing mortality (*F*)	Time period		Reference values
	1980–1989	**2007–2013**	
NEA cod			
Mean annual SSB (× 1000 t)	210	1376	460
Mean annual landings (× 1000 t)	374	643	
Mean F—ages 5–10	0.82	0.29	0.40
NEA haddock			
Mean annual SSB (× 1000 t)	69	296	80
Mean annual landings (× 1000 t)	71	227	
Mean F—ages 4–7	0.42	0.35	0.47

For both stocks and particularly for cod, a significant reduction in fishing mortality has been achieved since the 1980s. SSBs have increased four to fivefold for both stocks, giving room for large, but nonetheless sustainable increases in total allowable catches.

7. Conclusions

The positive development in the Barents Sea fisheries since the 1980s cannot be attributed to one or a few causes or measures. It has been brought about by a suite of measures in combination with favourable natural conditions [27,28]. The lesson learnt is that a prudent management regime should give attention to and investigate possible improvements both in exploitation patterns to provide incentives for more selective fishing, as well as in the levels of exploitation [6,24,27,29]. Stakeholders' acceptance of the change in policy has grown over time, and it could optimistically be argued that the success of these policy changes has led to changes in the perception on how the fisheries should be best exercised.

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References

[1] Gullestad P, Aglen A, Bjordal Å, Blom G, Johansen S, Krog J, et al. Changing attitudes 1970–2012: evolution of the Norwegian management framework to prevent overfishing and to secure long-term sustainability. ICES J Mar Sci 2014;71:173–82.
[2] Johnsen JP, Eliassen S. Solving complex fisheries management problems: what the EU can learn from the Nordic experiences of reduction of discards. Mar Policy 2011;35:130–9.
[3] Catchpole TL, Frid CLJ, Gray TS. Discards in North Sea fisheries: causes, consequences and solutions. Mar Policy 2005;29:421–30.
[4] Condie HM, Grant A, Catchpole TL. Incentivising selective fishing under a policy to ban discards; lessons from European and global fisheries. Mar Policy 2014;45:287–92.
[5] Diamond B, Beukers-Stewart BD. Fisheries discards in the North Sea: waste of resources or a necessary evil? Rev Fish Sci 2011;19:231–45.
[6] Heath MR, Cook RM, Cameron AI, Morris DJ, Speirs DC. Cascading ecological effects of eliminating fishery discards. Nat Commun 2014:1–8 (DOI: 10.1038/ncomms 4893).
[7] Forskrift om forbud mot utkast av torsk og hyse i Norges økonomiske sone utenfor det norske fastland. Fiskeridirektoratet; 1987. J-45-87 (cited in Fiskets Gang 1987; 10: 314).
[8] Nærings- og fiskeridepartementet. Lov om forvaltning av viltlevande marine ressursar (havressurslova). Norsk Lovtidend avd I, 6: LOV-2008-06-06-37. In English, ⟨http://www.fiskeridir.no/english/fisheries/regulations/acts/the-marine-resources-act⟩; 2008.
[9] Nærings- og Fiskeridepartementet. Forskrift om endring i forskrift om utøvelse av fisket i sjøen. Norsk Lovtidend avd I, 4: FOR-2014-03-21-308. In English, ⟨http://www.fiskeridir.no/english/fisheries/regulations⟩; 2014.
[10] Marine protected areas. Norwegian Directorate of Fisheries, ⟨http://www.fiskeridir.no/english/fisheries/marine-protected-areas⟩; 2011.
[11] Nærings- og fiskeridepartementet. Forskrift om regulering ved fiske og fangst mv. i Svalbards territorialfarvann og indre farvann. Norsk Lovtidend avd I; 1978. 258: FOR-1978-04-28-20.
[12] Sundby S, Bjørke H, Soldal AV, Olsen S. Mortality rates during the early life stages and year-class strength of northeast Arctic cod (*Gadus morhua* L.) Rapports et Procès-verbaux des Réunions Conseil international pour l'Exploration del la Mer, vol. 191; 1989. p. 351-358.
[13] Nakken O. Causes of trends and fluctuations in the Arcto-Norwegian cod stock. ICES Mar Sci Symp 1994;198:212–28.
[14] Veim AK, Sunnanå K, Sandberg P, Gullestad P. Bycatch of juvenile fish in the shrimp fishery—management based on bioeconomic criteria. ICES CM; 1994/T:14.
[15] Jakobsen TJ, Ozhigin VK. The Barents Sea. Ecosystem, resources, management. Trondheim: Tapir Academic Press; 2011.
[16] Hønneland G. Making fishery agreements work. Post-agreement bargaining in the Barents Sea. Cheltenham, UK: Edward Elgar; 2012.
[17] Hammer M, Hoel AH. The development of scientific cooperation under the Norway—Russia fisheries regime in the Barents Sea. Arctic Rev Law Polit 2012;3:244–74.
[18] Institute of Marine Research. The Norwegian Reference Fleet—a trustful cooperation between fishermen and scientists. Focus on Marine Research; 3. Available at ⟨http://www.imr.no/temasider/referanseflaten/en⟩; 2013.
[19] Nærings- og fiskeridepartementet. Lov om førstehandsomsetning av viltlevande marine ressursar (fiskesalslagslova). Norsk Lovtidend avd I; 2013. 9: LOV-2013-06-21-75.
[20] Hylen A, Nakken O, Nedreaas K. Northeast Arctic cod: fisheries, life history and stock fluctuations. In: Nakken O, editor. Norwegian spring-spawning herring & Northeast Arctic cod: 100 years of research and management. Tapir Academic Press; 2008.
[21] CRISP. 5.3 Active selectivity and release in fishing gears. Annual report, ⟨http://www.imr.no/crisp/products_and_outputs/annual_reports/crisp_annual_report_2013/crisp_2013_til_web.pdf/en⟩; 2013.
[22] ICES. Report of the Arctic fisheries working group. Lisbon/Bergen; 22–28 April 2010. ICES C.M. 2010/ACOM:05, p. 664.
[23] ICES. Report of the Arctic fisheries working group. Lisbon; 23–29 April 2014. ICES C.M. 2014/ACOM:05, p. 656.
[24] Kvamme C, Bogstad B. The effect of including length structure in yield-per-recruit estimates for northeast Arctic cod. ICES J Mar Sci 2007;64:357–68.
[25] ICES. Barents Sea and Norwegian Sea. Cod in Subareas I and II (Northeast Arctic cod). ICES Advice; 2014. Book 3 (Chapter 3.3.2).
[26] ICES. Barents Sea and Norwegian Sea. Haddock in Subareas I and II (Northeast Arctic haddock). ICES Advice; 2014. Book 3 (Chapter 3.3.4).
[27] Kjesbu OS, Bogstad B, Devine JA, Gjøsæter H, Howell D, Ingvaldsen RB, et al. Synergies between climate and management for Atlantic cod fisheries at high latitudes. PNAS 2014;111:3478–83.
[28] Stenevik EK, Sundby S. Impacts of climate change on commercial fish stocks in Norwegian waters. Mar Policy 2007;31:19–31.
[29] Eikeset AM, Richter AP, Dankel DJ, Dunlop ES, Heino M, Dieckmann U, et al. A bio-economic analysis of harvest control rules for the Northeast Arctic cod. Mar Policy 2013;39:171–81.