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TECHNICAL REGULATIONS AND BY-CATCH CRITERIA IN THE BARENTS SEA FISHERIES

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Murmansk, 14-15 August 2001

Edited by
Mikhail Shevelev and Stanislav Lisovsky

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PREFACE

The sea fishery has presently turned into a powerful factor of impact on the biological resources and without a proper management may entail destructive consequences. This thesis is proved by numerous examples of such management of fish stocks when due to improper fisheries regulation the stocks come to a depression and their fisheries is much restricted or halted.

Fisheries management measures are manifold and may include various requirements and conditions restricting or restraining the fishing activity within certain scientifically substantiated limits. The principal regulation measure in the fishery is total allowable catch while technical regulations limiting the use of certain gear and ways of harvesting, by-catch of young fish and organisms of one species in the fishery for the other are of ancillary nature.

One of the conditions necessary for rational exploitation of commercial stocks is selective fishery based on specific requirements to a trawl bag construction that allows to limit a catch of immature fish and to avoid too much escapement of large fish. Groundless increase in selectivity may cause a loss of practical importance of fishery due to a low fishing efficiency while its decrease may result in over-catch of young fish and severe impact on the spawning stock.

To reach the efficient fishery management for countries, which jointly exploit the stocks like Russia and Norway do in the Barents Sea, it is important to employ comparable technical regulation measures and Rules of Fisheries, which would make allowance for specific conditions of national fishery including distribution pattern of the stocks and their availability with the account for species area structure.

Successful management of the stocks requires a comprehensive analysis of the practical experience gained from implementation of technical regulation measures. In this field of activity problems arise persistently which invites further development and approbation of new technical regulations or some other solutions. Thus, it is important to study the efficiency of not only technical but also other regulation measures and to improve them.

Great importance and obvious topicality of this side of fisheries for its flourishing in both countries and conservation of the Barents Sea stocks encouraged the Joint Russian-Norwegian Fisheries Commission to held the 9th Joint Russian-Norwegian Symposium on Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries with a hope that participants of the Symposium, scientists, fishermen and managers would present their views on the top issues of the technical regulations and find the agreed ways to solve problems of stock management in favour of sustainable fishery of both countries.

The editors

Murmansk, October 2001

9th Joint Russian-Norwegian Symposium
Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

OPENING STATEMENT

by

A.N. Makoedov

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12 Rozhdestvensky Blvd., Moscow, 103031 Russia

Dear colleagues, scientists, fishermen and manager of fish resources,

Cooperation between Russia and Norway in the field of fishery management has a long history and there is natural and historical background for that. Both countries exploit common biological resources in the Barents Sea and adjacent waters of the Norwegian and Greenland Seas. The ultimate goal of the cooperation is having joined efforts of both countries for rational exploitation of these resources to ensure sustainable fishery.

At present cooperation between Russia and Norway in the field of fisheries is performed in accordance with the Agreement between Governments of the USSR and Norway of 11 April 1975, as well as with the signed pursuant to it Intergovernmental Agreement of 15 October 1976. Within the frames of the Agreement on cooperation in Fisheries, in January 1976, bilateral, now Joint Russian-Norwegian Fisheries Commission was established.

The Commission focussed its major attention on the study of stock status of joint fishing species and on the development of the agreed measures of the stocks' management and exploitation including technical regulation rules in fisheries which are primarily based on the scientific advice. This was a reason behind the title of the present Symposium: "Technical regulations and by-catch criteria in the Barents Sea fisheries".

The use of technical regulations of fishery in the Nordic Seas has a wealth of history. In 1937 in London "International Convention for the Regulation of Meshes of Fishing Nets and the Size Limits of Fish" was signed. This Convention was primarily aimed at fishing regulation in the North Sea and adjacent waters. Similar International Conventions for fishery management in our region were signed in 1946, 1959, 1967 and 1980.

To reach the efficient management of the fishery for both countries it is important to employ comparable technical regulation measures and Rules of fisheries which make allowance for specific conditions of national fishery including distribution patterns of stock and their availability in relation to structure of species area.

Successful management of the resources requires further analysis in detail and discussion of the experience got through application of technical regulation measures. Stock management raises new and new problems which requires a through study and the use of new technical regulation measures or some other solutions. Therefore, it is important to study the efficiency of the other regulations compared to technical ones and to improve them.

We hope that the participants of the present Symposium will present their views on the top issues of the technical regulations, which in its turn will allow to find the agreed ways to solve these problems in favour of sustainable fishery of both countries.

Russian-Norwegian experience in the management of the Barents Sea resources is known to have got a high international appreciation. We hope that the outcome of this Symposium will enrich it and appear helpful for the other countries in the other regions.

I wish all the participants success in this important work.

OPENING STATEMENT

by

Jørn Krog[1]

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I would like to start this introduction by thanking the Chairmen, Mr. Shibanov and Mr. Bjordal, for the invitation.

In Bergen 17 - 18 June 1999 I attended the 8th Joint Norwegian-Russian Symposium on "Management Strategies for the Fish Stocks in the Barents Sea". This was the first attempt to gather scientists, managers and representatives of the fishing industry in one symposium. I think that this was a very good idea and the symposium in Bergen became a success. I am sure that the presentations and the discussions here in Murmansk will be just as interesting.

However, in my introduction, I would like to take the opportunity to emphasise some of the main principles and goals of the Norwegian fishery policy for the Barents Sea. I hope that this could be helpful after noticing a series of statements, in both Norwegian and Russian newspapers and periodicals, where severe misconceptions about the Norwegian fishery policy have been presented. In the following, I will therefore try to bring across the actual "Norwegian thinking". Hopefully, this could also serve as a useful background for this symposium.

1. The main goal is to ensure long term sustainable management

At the fisheries conference " Sea and Sea Food 2001" in Murmansk in March, some participants claimed that the demersal stocks of the Barents Sea are in good and stable conditions. Furthermore, it was claimed that the reasons that Norway argues for reductions of the cod quota, is that it is in the interest of Norway to maintain high prises for cod and that we want to protect the market for the Norwegian production of farmed cod.

Such statements are truly misleading.

The latest report from the Advisory Committee on Fisheries Management of ICES (ACFM) indicates that the reduction in fishing mortality is not as expected. This means that the target reference points decided by the Norwegian-Russian Fisheries Commission will not reach as planned. Responsible managers cannot ignore such a fact. I can assure you that the Norwegian

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[1] Mr J.Krog's statement was presented by Mrs L.Plassa

people and politicians are not ignoring this information. But it would be wrong to say that it is in the interest of Norway "to keep quotas down", as some Russians seem to believe.
I would like to inform you that it may in fact take several years, approximately 5-10 years, until the industry of cod farming is able to produce significant volumes for the market. If it was true that Norway made considerations about farmed cod when managing the wild cod, it would then be in our interest, not to have low quotas, but to have the highest possible cod quotas in the short term to ensure that the cod quotas were low in 10 years from now on, preparing the market for farmed cod !

The true main goal of the Norwegian fisheries policy is to ensure stable and economically viable condition for the fishing industry. The basis for this, is long term sustainable management of resources - not short-term economic benefit. We must be prepared to make some sacrifices in the short term to ensure long-term gains. The collapse in the cod stock at the end of the 1980s taught us a lesson we must not forget.

The most appropriate way to ensure long term sustainable economic yield of the cod stock is to reduce the fishing mortality. Norway and Russia have for several years agreed in the Commission that fishing mortality for North-East Arctic Cod should be reduced to 0.42.

However, when discussing sustainable management, we have to take into consideration both ecology, business economy and socio-economics. But of these three pillars, the ecology - the state of the stocks - is an absolute condition for the two other pillars.

2. Scientific advice must be the basis for setting quotas

In the Russian newspaper "Rybatskie Novosty" (No 3-4 2001) it has been stated that the elaboration of ICES/ACFM advice is strongly influenced by the political interests of Norway and EU countries. The statement consequently implies that ICES/ACFM does not have scientific integrity and that the organisation works against Russian interests.

This is a serious accusation and it is false.

ICES was founded in 1902 and it is the oldest intergovernmental marine science organisation in the world. Its mandate that applies to scientists from all 19 members is to give the best possible scientific stock assessments and advice for fisheries management. It is not to make policy. The basic idea behind the ICES system is that the work of national scientific organisations, like for instance the work of the Institute of Marine Research and PINRO, can be presented and discussed openly in a wide international forum to ensure the quality of data and analyses.

However, we do not always have to be satisfied with the results of the analyses, and we do not always have to accept the results, but we have a common commitment to contribute to achieve the best and most reliable results.

The Norwegian point of view is that the total quotas set by the Norwegian-Russian Fisheries Commission must be based on management advice given by ACFM - to ensure transparency, quality, and international legitimacy for marine science in the North.

Scientific advice should be the basis, but we also have to take business economy and socio-economics into consideration when setting the quotas.

3. Norway and Russia have mutual interest in a strong management regime for the Barents Sea

If the Joint Norwegian-Russian Fisheries Commission sets quotas too high over a number of years, the legitimacy of the regime will be damaged. This is truly not in our common interests.

Norway and Russia must find a way to agree on medium and long term strategies, and as part of this, yearly quotas for the most economically important species in the Barents Sea. We have started by establishing a 3-year quota and stating some goals for the managing of the cod stock.

Both parties have a responsibility to come to agreement on management of the Barents Sea fishing resources. If we should fail in doing so, it would be a disaster for the resources and consequently the lack of management would lead to enormous problems for both the Norwegian and the Russian fishing industry.

I would like to underline that from the Norwegian point of view, this scenario should never have to be the case. We must work to find a common platform of understanding. Furthermore, we must agree on management strategies for the main stocks of the Barents Sea to strengthen the basis and the reputation of the Commission. I believe that such an approach would be of great benefit to both countries.

4. Principles for control: Necessary enforcement, but non-discriminatory practice in all Norwegian jurisdictions

I know that statements has been made by important people from the Russian side that an unregulated fishery is going on within the 12 mile zone of Norwegian waters.

During the last year, focus has been set on illegal fisheries and illegal fish trade in Norway. Some illegal activity has been discovered and reacted against, but some of the alleged crimes are still under investigation.

I have to stress that fishing activity within the Norwegian 12 mile zone is regulated and it is in this respect, no different from than the fisheries outside 12 miles. A special unit of the coastguard has the responsibility to enforce regulations within 12 miles, and Norwegian authorities have no information that indicates any particular illegal activity in the zone.

However, as you may be aware, it has been estimated that unreported catches could be up to 20 % of the quotas in the Barents Sea. Norwegian authorities work hard to reveal unreported catches, and both Norway and Russia must work together through the Commission to improve the system of catch reporting. But I can assure you that all the catch statistics available for Norwegian authorities are made available to the Joint Norwegian-Russian Fisheries Commission and the Permanent Committee.

Fighting illegal activity is a major challenge: Management of resources has no value if the fishing industry does not respect the rules. Thus, control activity is necessary in order to enforce regulations – both in Norwegian and in Russian waters.

The Norwegian Coastguard controls the activity of both Norwegian and foreign fishing vessels in areas under Norwegian fishery jurisdiction. Their primary task is to be present in areas where fishing activity is taking place, and to perform inspections frequently to survey the quantities taken from the sea. However, there have been some complaints from the Russian side that

Norwegian inspections are too time consuming and that they hamper the fishing activity. Some also claim that Russian vessels are inspected more frequently than vessels from other countries.

The Coastguard has not changed the duration of inspection, and it is a principle that the fishing activity should not be interfered with more than absolutely necessary. On the average an inspection lasts for approximately 4 hours. After the fishing gear has been checked, the vessel can resume fishing with the inspectors on board. While the vessel is fishing, the inspectors examine the catch and the relevant documents on board.

From 1998 to 2000 the intermixture of undersized fish in the catches has been too high. Against this background, more frequent inspections were carried out. But the focus of this additional control activity has been measuring of catches and not full scale inspections. So the fact is that there have been more, but shorter inspections in this period.

In general, the high number of Russian vessels inspected only reflects the high fishing activity of Russian fishing vessels, especially in the Svalbard area. I can assure you that inspections are carried out in a non-discriminatory manner.

On one point I really feel an apology is required: In regards to confiscation of catches and fines following illegal fishing activity in Norwegian waters, foreigners, and especially Russians, have got stronger reactions than Norwegians. This is the dramatic conclusion of both a Tromsø lawyer and also the District Attorney in Troms and Finnmark county. This practice has now been criticised and the persons involved in enforcement have now got guidelines to prevent discrimination of foreigners in the future. As a consequence of this process, the level of the penalties for Norwegians would be increased to the same level as foreigners have experienced - not the other way around.

5. Technical measures: an important part of fisheries management

In order to ensure the best possible pattern of exploitation and protect the fish stocks efficiently, the Commission has adopted a number of technical regulations such as criteria for closing areas with to high concentrations of undersized fish, by-catch criteria and mandatory use of grid sorting systems. Seen from a conservation perspective, this type of regulations is proven to be efficient. However, I believe that it is important that we have a constant evaluation of which measures should be implemented and that we put more effort into assessing the effect of the different measures already in place. The work of the Permanent Committee is vital in this respect, and this symposium will most likely contribute to target the technical regulations in a better manner.

I wish you all good luck with the Symposium.

Thank you for your attention.

OPENING STATEMENT

by

G.V.Stepakhno

Director of the Association of Fishing Enterprises of the North,
43, Schmidt Street, Office 94, Murmansk, 183788 Russia

Dear colleagues,

Let me cordially welcome the participants of the 9th Joint Russian-Norwegian Symposium on behalf of representatives of the fishing industry of the North basin.

We hope that during this Symposium scientists and representatives of the fishing industry of both countries would make a careful and critical analysis of efficiency of existing fisheries management measures and by-catch criteria based on results of an actual fisheries dynamics in the recent years and on data from joint sea surveys.

As Director of the Association of Fishing Enterprises of the North I represent the interests of Russian fishermen who share with scientists the joint responsibility for fishing activities and for stable condition and conservation of main stocks in the Barents Sea.

The Barents Sea ecosystem is said to belong to 50 so-called "great sea ecosystems" supplying 95% of the world seafood.

Taking this into account, we believe that both the marine science and the fishing industry must try to combine their efforts and to work out unified measures for fisheries management in order to contribute to conservation and sustainability of the fisheries resource potential in the unique Barents Sea which is managed by both countries.

In our opinion, the regulation measures have to meet the following requirements:

- to be easy for implementation and control;
- they do not have to lead to misrepresentation of catch statistics;
- they do not enable to accept in the future too high or too low levels of assessments for commercial fish stocks and TACs for the main Barents Sea resources.

Regretfully, since two years the ICES advice seems to urge us to accept such levels of assessment (by tacit agreement of Norwegian experts and scientists).
Taking into account the above requirements, I would like to express some concrete wishes of representatives of the Russian fishing industry to the participants of the present Symposium

with a view to discussing and making appropriate recommendations. The question is that the difference between minimum landing sizes for cod and haddock in the NEZ and in the Spitsbergen area, on the one hand, and in the REZ, on the other, as well as a low level of the allowable by-catch of young fish seem to lead to unwarrantable discards of small fish, and consequently, to underreporting of catches and uncertainty in regard to stock forecasting.

In this context we suggest that following measures should be considered:

- to set a common mesh size at 130 mm;
- to set a common minimum catching size for cod at 45 cm;
- to increase the allowable by-catch of undersized gadoids from 15% to 25%;
- to work out a common procedure (agreed by both parties) for opening and closing of fishing areas;
- to extend the above conditions to the whole area of the Barents Sea.

Sorting systems. Russian fishermen over a number of years have been feeling doubts about efficiency of the use of sorting systems and grids. One may remember that these systems have been introduced to settle a problem of fishing areas closing due to high densities of small fish. And what came of it in practice ? Both the sorting grids have been introduced and fishing areas continued to be closed. Hence, this measure was not effective, not safely, so there is a need to raise a question about its cancellation.

Greenland halibut. In the course of ban on the directed trawl fishery for Greenland halibut from 1992 the halibut commercial and spawning stocks have not only stabilized but also considerably increased. In opinion of ship's masters and experts this development enables us to raise a question on re-opening of commercial fishery for Greenland halibut by both countries.

Saithe. In our view, the time is came when we must remove the 25% restriction on saithe by-catch for Russia during the cod and haddock fishery. Taking into account the fact that young saithe at age of 3-4 years occur, feed and form commercial concentrations in the REZ the status of this species should be defined for the future as a common stock. I would like to mention that we have conducted a special fishery for saithe 30 years ago over the total area of their distribution and harvested ca. 10 000 tonnes. Thus, it is essential that from the next year the TAC level for saithe should be set for both countries in the same manner as the TAC values for cod and haddock, and a quota for the Russian party should be allotted in tonnes but not as by-catch percentage.

Precautionary principle. The precautionary approach. applied by scientists to estimate the exploitation rate for gadoids under present fishery conditions as well as the ICES requirements to reduce the fishing mortality rate of cod below $F_{pa} = 0,42$ and to set the cod spawning stock at 500 000 tonnes as a optimal criterion for the stock state may bring up the question of limitation on the Norwegian catch of prespawning cod in their own waters, i.e. reduction in the fishing pressure of Norway on the spawning stock of cod.

In conclusion let me wish all the participants of the Russian-Norwegian Symposium fruitful work, successful search for truth and reasonable compromises in relation to actual problems of optimal exploitation and conservation of biological resources in the Barents Sea.

9th Joint Russian-Norwegian Symposium
Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

OPENING STATEMENT

by

Oddmund Bye

Chairman
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TRAWL SELECTION WHEN FISHING GADOIDS NORTH OF 62° N: EXPERIENCES OF NORWEGIAN FISHERMEN

Honorable Russian friends and conference participants.

First, I would like to stress the importance of organising this kind of conference, where representatives of the scientific community, public administration and the industry participate to highlight and discuss important questions related to the management of our common marine resources in the Barents Sea. The last time we met, as you know, was in Bergen two years ago.

My task here today is to present some points of view that Norwegian fishermen have on trawl sorting gear, and to touch on other important technical regulatory measures used for regulating Barents Sea fisheries.

With only a few exceptions, all Barents Sea fish stocks are found in the northern waters, including the Russian and Norwegian zones. In order to achieve a successful management of these stocks, it is essential that we introduce uniform and equal administrative routines for fishing, regardless of zone.

Looking back, Norwegian trawling was introduced in fisheries in the 50s, and thus became a fast-growing part of a huge international fleet. From that time and until 1977, sorting capacity was not an important part of trawling equipment design. Thus, relatively small fish were caught, but fish meeting the current minimum size criteria were landed and included in landings statistics. At the time, small fish were caught only one time in the trawl, unlike the current situation, where small fish probably pass through sorting grids several times before reaching commercial size.

After the establishment of 200-mile economic zones in 1977, trawl mesh size in Norwegian zones has been increased two times, from 120mm to 125mm, and then to 135mm. Minimum sizes for cod and haddock have been increased twice for Norwegian waters, and are currently 47cm for cod and 44cm for haddock.

Up to the mid-80s, under-sized fish had to be discarded. Later, however, this routine was replaced by regulations prohibiting discards of most commercial species. From around this time, regulations were also introduced to ensure the closing of areas having an unacceptable proportion of undersized fish in relation to the minimum sizes of cod, haddock and saithe.

As you know, a mandatory use of sorting grids was introduced in the 90s, first for prawn trawling, later for cod. At the time, Norwegian fishermen were very favourable to the sorting grid technology, and they were convinced that it would have a beneficial effect.

After having used the sorting grid for some years, the same fishermen were sorry to see that they in all probability were wrong in their assumption. The effect of the sorting grid did not meet their expectations in terms of favourable stock development or stability, and we ask ourselves, »Why do we not see a more favourable stock development?» This is particularly relevant regarding the stocks of Norwegian arctic cod.

The reasons may well be complex ones.

If the same fish are caught and sorted several times, does this in any way have a detrimental effect on the fish?

Is the food demand of growing stocks of marine mammals a reason why fish stocks fail to reach levels that marine biologists find satisfactory?

Have the different phases of oil production off the Norwegian coast had a negative effect on the reproduction and development of stocks? (seismic studies, prospecting)

I am afraid we have more questions than answers.

Reports on alleged discards of fish may well be correct. My comment is as follows:
Barents Sea cod stocks were harvested harder before, and there was poor or no selection, lower minimum sizes of fish, discards of fish below minimum sizes, and there were no closing routines of waters to protect undersized fish.

I do not accept discards of fish, of course, but illegal discards cannot alone be the reason why fish stocks in the northern waters do not satisfy the researchers' estimates on volume and stability.

In my opinion, we would be barking up the wrong tree, if we were to conclude that discards of fish constitute the sole explanation of this poor development. I believe there are other disadvantageous aspects as well, that have a considerably more negative effect on fish stocks than alleged discards of fish.

Norwegian fishermen, of course, support an effective young fish protection programme, thus ensuring that we do not harvest the youngest year classes. This may be achieved by having a sensible minimum size combined with corresponding mesh sizes. As I already mentioned, we have become a bit more reserved when it comes to the effects by using grids. I am aware of the fact that research is being done on the various aspects of the usage of sorting grids, including mortality and damage rates of fish passing through the grids. Furthermore, we are very optimistic about a recently developed grid (flexigrid), which will be easier to handle and which is said to have favourable sorting qualities. I am sure we will hear more about this and other results during the conference. Thus, we can acquire new knowledge for evaluating selection equipment.

Norwegian fishermen accept that we continue temporary closing routines of waters as an important measure to protect young fish. The criteria for closing should be the same in the Russian and Norwegian sectors. To avoid that this be counterproductive, it is imperative that we undertake continuous monitoring/control of closed waters to prevent that they stay closed longer than necessary, and to ensure that a necessary closing is undertaken quickly. In Norway we have seen that waters have remained closed for a long period of time simply because of insufficient resources for control. Consequently, Norwegian fishermen would like to see improved procedures regarding the closing and opening of waters. As far as I know, Norwegian authorities are now willing to prioritize a more continuous control of closed waters. Therefore, both countries should make efforts to draw up joint administrative routines which should be effective for the entire Barents Sea.

Some of our members would like to close a fairly large area between Bear Island and the island of Hopen to protect young fish, but no decision on this is reached in the Association, yet.

In conclusion, I would like to mention that Norway and the EU have been conducting negotiations on technical regulation measures for the North Sea. We have arrived at some joint regulations, but some areas, unfortunately, still remain to be agreed upon. Norway, however, will on a unilateral basis advocate a bigger trawl mesh size in the Norwegian zone than the EU accepts in EU waters. The new regulations will probably be effective from 1 January 2002. Norwegian fishermen support the new regulations, because they are seen as essential in the work to improve demersal fish stocks in the North Sea.

I believe we still have to focus on the protection of young fish in the Barents Sea. Even though we have sorting equipment in trawls, I am of the opinion that Norway and Russia need to agree on a common minimum size for the various Barents Sea stocks, and a common mesh size for fish in both the Russian and the Norwegian zones. If our intention is to achieve a rational harvesting of our common fish stocks, both Norway and Russia will need to demonstrate adequate flexibility in terms of access to fish quotas in the two zones.

Thank you for your attention, and I hope you will have a productive conference.

Session 1: Fishing gear and sorting grid systems

9th Joint Russian-Norwegian Symposium
Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

EVOLUTION OF TECHNICAL MEASURES REGULATING FISHERY ON COD AND HADDOCK IN THE BARENTS AND NORWEGIAN SEAS

by
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The concept of fisheries regulation has a wide scope of meanings. It includes regulation by quotas, requirements for fishing gears, minimum commercial size, bycatch of undersized fish and non-target species, closure of fishing areas, catch quality requirements etc.

As known, rational fishery should be based on maintaining the spawning stock on a certain level ensuring sustained reproduction and protection of juveniles.

One of the most important measures is technical regulation of fisheries, which involves, first of all, age (length) requirements to caught fish and limitations on bycatches of undersized fish.

The key role of these measures in the development of rational fishery rules is proved by the fact that already in 1937 (23 March 1937), an International Convention for the Regulation of Meshes of Fishing Nets and the Size Limits of Fish was signed in London. The Convention was intended primarily for the regulation of fishery in the North Sea and adjacent waters.

The next convention for the regulation of meshes of fishing nets and the size limits of fish was signed on 5 April 1946 in London and entered into force on 5 April 1953 (USSR acceded to the Convention on 15 March 1958). As before, the convention area was mainly the North Sea, but it also covered the areas north of 48°N between 42° and 38°E, except the Baltic Sea.

At the Conference it was proposed to increase the mesh size in nets and the size limits of fish recommended by the International Convention of 1937. It was noted that this measure, although necessary, would not help avoid overfishing. This resulted in the introduction of additional limitations on total catches in the regulatory area and on the number of fishing days in a year, closure of some fishing areas for a long time, more stringent requirements to periods of fishing on some species, and reduction of the fishing fleet.

After discussion the Conference recommended to increase the minimum mesh size from 70 and 105 mm (for Manila hemp), as recommended by the 1937 Convention, to 80 (south of 66°N) and 110 (north of 66°N) mm according to fishing area. Commercial size of cod which should not be kept onboard, landed or sold, should be 30 cm, that of haddock – 27 cm.

Concerning mesh size recommendations, it was directed that a flat probe of 2 mm thickness and of the width corresponding to minimum mesh size should pass freely through a diagonally extended mesh.

In herring, mackerel and shrimp fishery it was allowed to have a bycatch of up to 10% by catch weight, which could be used as food.

The issue of protecting fish and other marine animals was further developed in the Resolution of the UN General Assembly No.900 of 14 December 1954 which declared that the main goal of conservation of live marine resources was to obtain maximum catch in order to ensure the greatest possible amount of food or other marine resources.

The Resolution also listed measures for conservation of fish resources. They included regulation of catches aimed at maintaining or increase of mean sustainable yield; protection of fish of a certain size aimed at the increase of mean catches and improvement of their quality by introducing fishing gear regulations; limitations on landings of undersized fish; regulation measures aimed at ensuring sustained reproduction by prohibiting fishery in the reproduction or spawning areas etc.

At the Conference 24 January 1959 the nations fishing in the Northeast Atlantic signed the North-East Atlantic Fisheries Convention. The regulatory area lay between 41°W and 51°E. The Convention entered into force on 27 June 1963.

The Conference founded the North-East Atlantic Fisheries Commission which was to consider and make recommendations, *inter alia*, on the following:
- any measures regulating mesh size;
- any measures regulating size limits of fish that may be retained on board vessels or landed;
- any measures regulating fishing gears and appliances.

At the 2nd session of the Regulation Committee the recommended mesh size was since 4 April 1964 set up at 100 mm for nets, 110 mm for cotton, hemp and polyamide trawls and 120 mm for trawls made from other materials. Adopted were also the recommendations on size limits of cod (30 cm) and haddock (27 cm). Bycatch of undersized fish should be returned to the sea, except fish caught for farming. Small fish should not be sold.

These recommendations of the Committee have been since 07.08.1964 included in the USSR Fishing Regulations.

At the 3rd session of NEAFC it was recommended to introduce for a 3 years' trial period, since 1 January 1967, the minimum mesh of 110 mm for nets, 120 mm for cotton, polyamide and polyester trawls and 130 mm for trawls from Manila hemp and other materials. At the same session the recommendations on the use of protective appliances for nets were made.

On 1 June 1967 the Convention for the Procedure of Fishing Operations in the North Atlantic was signed, which regulated fishing in that area.

The change in the legal status of waters of the coastal states and the introduction of 200-mile economic zones resulted in the signing of the new North-East Atlantic Fisheries Convention (18 November 1980). Under this Convention the North-East Atlantic Fisheries Commission

(NEAFC) was also established. The Commission has been providing fisheries recommendations up to the present time.

After the introduction of economic zones the fishery on Arcto-Norwegian cod and haddock has been since 1967 jointly regulated within the frames of Joint Russian-Norwegian Fisheries Commission.

Concerning mesh size in cod-ends, the Commission at the first stage used the recommendations of the Regulation Committee of 4 April 1964. Commercial size of cod caught north of 64°N was increased to 34 cm, that of haddock – to 31 cm.

At the VII session of the Commission in October-November 1978, the Parties agreed to use round straps and chafers in cod-ends.

At the VIII session of the Commission in November 1979, the Parties agreed within 1980 to turn to 125 mm mesh size in cotton, polyamide and polyester trawls and 135 mm in trawls made from other materials. Simultaneously, the commercial size of cod was since 01.01.1980 set at 39 cm, of haddock – at 35 cm. Bycatch of undersized fish should not be over 15% by weight of catch. Fishing for cod by midwater trawl was prohibited.

IX session of the Commission (October-November 1980) confirmed the decision made at the previous session about the introduction of a new mesh size for fisheries on demersal species in the zones under Russian and Norwegian jurisdiction since 01.01.1981.

01.01.1982 an agreed commercial size of 42 cm for cod and 39 cm for haddock was adopted. Bycatch of undersized fish should not exceed 15% by the amount of fish in catch. Simultaneously, Norway unilaterally increased minimum mesh size in trawls for fishery on demersal species in its economic zone up to 135 mm regardless of trawl material.

1.01.1990 Norway increased the commercial size of cod to 47 cm and of haddock to 44 cm.

In 1989, Norway and Russia carried out joint research on testing selectivity of trawl cod-ends made from Russian materials with 125 mm mesh size and those made from Norwegian materials with 135 mm mesh size. The results indicated similar selectivity of both cod-ends in cod and haddock fisheries.

In 1992-1996, experiments with sorting grids aimed at reducing catch of young fish were conducted. Joint trials of 1995 proved similar selectivity of Russian single-grid system "Sort-V" used in Russian trawls and double-grid system "Sort-X" – in Russian and Norwegian trawls. By the results of these tests, grids with 55 mm inter-bar space were since 01.01.1997 brought into use in fishery for cod and haddock in some limited areas of the Barents and Norwegian seas.

Our aim at this symposium is to assess the efficiency of such sorting systems in fisheries.

In view of the difficulties associated with using "hard" trawl grids, Russian researchers have studied selectivity of "flexible" sorting systems and plastic grids.

I believe that the mentioned issues will be enlarged on in the contributions of both Russian and Norwegian authors.

9th Joint Russian-Norwegian Symposium
Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

SIZE- AND SPECIES SELECTION IN DANISH SEINE

by
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Abstract

The Norwegian seine fishery has traditionally been performed in relative shallow water close to the coast, and this as inevitable led to a high proportion of small fish in the catches. A work on size selectivity was therefore started in the early 90'ies. Based on earlier experience with grid in trawls, similar experiment was conducted with seine nets. Grids in seine nets gave selectivity results similar to those obtained for trawl, but grids turned out to be difficult to handle onboard seine net vessels. Further experiments were performed with square mesh codends, which gave similar good selectivity results. The square mesh codends were much easier to handle, and from 1997 square mesh codends with a minimum mesh size of 125 mm has been used by the seine net fleet on a temporarily basis.

In the last few years the seine net fleet has got problem with bycatch of strict regulated species. A project on species selectivity was initiated some years back in order to sort out unwanted species. With a big meshed horizontal square mesh panel in the extension piece, it is possible to shift the species composition in the codend compared to the normal composition on the fishing ground.

Introduction

Danish seine was introduced as a fishing gear for the Norwegian coastal fleet in the early 1930s, and was primarily used during the three first decades for flatfish like plaice (*Pleuronectes platessa*) and sole (*Microstomus kitt*) in relatively shallow waters. In the late 1960s, the gear was gradually introduced in the fishery for cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*), mainly in the Lofoten area. The gear is now primarily used for cod, haddock, saithe (*Pollachius virens*), and to a lesser extent flatfish. Other species that are occasionally caught by seine net are redfish (*Sebastes marinus*), herring (*Clupea harengus*), capelin (*Mallotus villosus*), and catfish (*Anarhichas minor*).

During the last two decades the seine net method has become a very popular in the costal fleet (vessels shorter than 90 feet). The gear is now larger and the ground gear has been modified to fish on rougher bottom than before, and most of the boats are using 8-10 coils of rope (of 220 m) on each side. The fishing method used by the Norwegian seine boats is now more like fly dragging. When fishing without anchor, as in Scottish seining, the vessels are stationary or slowly mowing forward by means of the propeller.

The seine net fishery has traditionally been performed close to the coast in shallow waters. This has inevitably led to a high proportion of small fish in the catches. With the introduction of the discard ban, many of the traditional fishing grounds have been temporarily closed due to a to high proportion of fish below minimum landing size. In order to prevent that juvenile fish from being discarded, and also to give the fishermen access to closed but otherwise good fishing grounds, a work on size-selective devices for seine net was initiated in the early 1990s, first with grids (Isaksen 1993) and later with square-meshed codends.

The strict quota regulations the last few years have caused problems for the seine net fleet when the accessibility for the different species has not been proportional with the size of the quotas. The seine net fishery is a mixed fishery for cod, haddock and saithe, and consequently the quota for one species may be taken before the whole quota for another species are caught, and thereby creating a bycatch problem when fishing for the other species. In order to make the seine net more species selective, the Fish Capture Division started a work on the development of a species-selective device for seine net in late 1990s (Engås and Isaksen 1998; Isaksen and Jørgensen 1999).

Size selectivity in the Norwegian seine net fishery

Experiments with grids 1991-1995

Materials and methods

Inspired by the promising results with grid sorting devices in shrimp trawls (Isaksen et al. 1992) and bottom trawls for ground fish (Larsen and Isaksen 1993), grid experiments were initiated in 1991 (Isaksen 1993). The first grid device tested was a series of three steel grids of 70x70 cm, hinged together by hammerlocks (Figure 1). The grids were mounted in the upper panel and replaced an equal length of this panel. To give the grids some angle of attack, most of the floats used to make the grid system a bit buoyant was mounted in front part of the system (Figure 2). Later (1992-1994) the grids were mounted in a square mesh extension piece at a theoretical angle of 30 degrees (Figure 3). Most of the selectivity experiments in 1994 and 1995 were performed with this configuration (Table 1a-c).

During the main test period in 1994 and 1995, bar spacing of 50 and 55 mm were used. To establish selectivity parameters for the grids alone the main codend was blinded and a collecting bag of the «top cover» design was mounted above the grid (Anon 1996). The program CC-Selectivity was used to calculate the different important parameters (Holst 1994).

Results – selectivity parameters

The results from the main test periods in 1995 with two boats involved are given in Table 1a-c. An example of the analysis reports from the selectivity program is given in Appendix I. The selectivity parameters for cod, haddock and saithe are quite in accordance, or actually slightly better than those obtained for grids in bottom trawls for the same bar spacing and species. This can partly be explained by the relatively slow towing speed of the seine net. Underwater observations indicate that nearly 100% of the fish escape actively; i.e. head first through the grids.

Results – handling aspects

The pilot experiments in 1991 revealed that it was relatively easy to shoot the grids from middle and large seine net boats. However, the grid was difficult to haul through the power block when retrieving the gear. The extension piece with the grid device had to be lifted out of the power block, the grids had to be carried in front of the block before the extension piece could be put back in the power block (Figure 4). Experiments with hinging the grids both across- and lengthwise using six grids did not improve the performance of the hauling procedure; the grids still had to be taken out of the power block when hauling the gear.

In 1995 the grid device for seine net was tested onboard a vessel who used a Triplex instead of a power block. As for the power block, the hauling of the grid through the triplex was difficult.

Many of the Norwegian seine net vessels are relatively small fishing boats (40-90 feet). For the smaller ones, and especially the older ones with the wheelhouse aft, it became evident that using grids on a regular basis would cause problems. In bad weather and with good catches of haddock and subsequent «sinking codend», a procedure including removal of the extension piece from the power block (or triplex) was out of the question, mostly of safety reasons.

Experiments with square-meshed codends 1993-1996

Materials and methods

Due to the handling problems with grids in the seine net fishery, pilot experiments with square-meshed codends started in 1993 and continued in 1994. Due to the relatively poor results from square-mesh experiments in the late 1980s with normal knotted and relatively thin twinned netting (Robertson and Stewart 1988; Isaksen and Larsen 1988), the square mesh codend was now made of 7 mm Ultra Cross netting. This braided, knotless netting made from polyethylene is relatively expensive, but nevertheless one of the best nettings to be used in a square mesh configuration.

In 1995, it was believed that the square-meshed codend had got its final design, and it was tested against seine net grids (Table 1 a-c). To obtain selectivity parameters for this codend, the trouser trawl method was used (Figure 5) (Isaksen et al. 1990).

Results – comparison of square-meshed codends and grids

The comparison of grids and square-meshed codends for seine net in 1995 were performed onboard two typical seine nets boats, one with a power block (M/S «Heidi Anita») and one with a Triplex (M/S «Skulbaren»).

As can be seen from Table 1a-c, a square-meshed codend of 122 mm gave selectivity parameters both for cod and haddock similar to those for grids with a bar spacing of 50 and 55 mm. For most of the experiments, the square-meshed cod end gave a more narrow selection range than the grid device.

Results - handling aspects

It soon became evident that the square-meshed codend had far better handling properties than the grids. Although the net panels are cut on bars and joined, thus making the codend more bulky, it can still be handled as a normal codend.

Recommendations and introduction

In late 1995, representatives from the Directorate of Fisheries, Institute of Marine Research and the seine net fleet met and agreed upon a temporary introduction of a 125 mm square-meshed codend in the seine net fishery inside the Norwegian 12 nautical mile zone (Isaksen 1997). The main objective of this decision was first to give the fishermen a possibility to get acquainted to the codends, secondly to introduce a device that would help the fishermen to get access to otherwise closed grounds.

Fishermen have used the 125 mm square-meshed codend from the summer of 1997 and till this date, and there have been few complaints on the device (Figure 6). One of the few complaints is on the price. Other comments are on the design of the codend. Due to a given length and width on a square-meshed codend, there is relatively poor elasticity in this type of codend compared to diamond mesh codend.

Today quite a few fishermen are even claiming that the mesh size used for square codends should be increased, and actually a few fishermen are using square mesh codends up to 160 mm Ultra-Cross.

Further work

The square-meshed codend for the seine net has so far been temporarily used in the NEZ inside the 12-nautical mile zone. During a seine net cruise in the autumn 2001, the final mesh size will be set for the square-meshed codends as well as other details of design for this type of codend (lifting bag, strengthening ropes and wedge-shaped sidepanels).

Species selectivity in seine net

The Norwegian seine net fishery is often a multispecies fishery, with cod, haddock and saithe as the most common fish species. Up to the late 1980s, the conventional fleet, i.e. the coastal fleet, had quite good quotas of all these species, and it was seldom a question to try to avoid any of these species. Except for delivery problems in summer for haddock, the coastal fleet caught and sold what they got.

With the introduction of individual boat quotas for cod and haddock for the larger coastal vessels the situation changed, and the species composition became a problem for this fleet. With very low cod quotas in the early 1990s, quite a few seine net boats tried to catch plaice, and with the use of 170 mm square-meshed codends all haddock escaped and only very large cod (overall length > 70 cm) were retained in the cod end. In addition, some experiments with a horizontal separating panel in trawl in the early/middle 90s showed promising results with regard to separating cod from haddock (Engås et al. 1998). However, the separating device did not work very well in combination with the grid devices (Sort-X, Sort-V) that were made compulsory in demersal trawl from 1997.

Pilot experiments

In 1996/1997 a pilot experiment with a horizontal separating net was performed. The net was about 15 m long and split the extension piece in two equal halves, an upper and a lower part (Figure 7). The split net had a mesh size of 60 mm and the fish that entered the net on one side would eventually end up in the respective codend. The experiments indicated that there was a relatively even distribution of fish in the extension piece. Video observations showed that all fish had to be forced down under a separating net and then hopefully one of the species would escape up through the separating net.

Full scale experiments

From 1999 and up to now four cruises have been performed on species selectivity in seine net. Prior to the design of the nets, Scanmar equipment was used to measure the dimension of the extension piece where the separating panel was to be installed.

The extension piece used in the last cruises (2000-2001) has dimensions as given in Figure 8. In front of the separating net, a small-meshed half-moon shaped leading panel will force all fish down under the main separating panel of either 200 or 300 mm square-meshed knotless netting with a twine thickness of 5 mm. Knotted netting with a thinner twine has been tried but ended up with a lot of fish getting meshed in the separating panel.

The fishing experiments indicated that about 70-80% of the haddock escaped up through the separating panel and ended in the upper codend, while only 30% of the cod would escape up through the panel. With regard to saithe, the results are not consistent.

Video observations from the extension piece with the panel showed that haddock started to swim up through the panel as soon as they passed the small-meshed leading panel. A tendency of panic was observed among the haddock while cod swam relatively slowly beneath the separating netting. Both cod and haddock swam in the towing direction, but both species fell back towards the codend relatively quick. Saithe escaped up through the separating net stayed just behind the small-meshed netting. When hauling the seine net, most of the saithe swam back down through the net, thus making the results difficult to interpret.

The separation of cod and haddock through a horizontal panel has so far been regarded as a behavioural function. Closer analyses of the data revealed that the species separation is a combined function of behaviour and size. This is clearly demonstrated in Figure 9, where the larger individuals of both cod and haddock tended to stay behind in the lower part of the extension piece.

Further work

The work on species separation will continue for at least another year. The main objectives will be to get better observations of fish behaviour towards the separating net, and hopefully creating new ideas of how to improve the system. Planned experiments in 2002 with big meshed square mesh codend (160 mm) to get rid of saith and haddock during the Lofoten cod fishery , has already been accomplished by 10-15 seine net fishermen that have seen the true benefits of applying selective devices.

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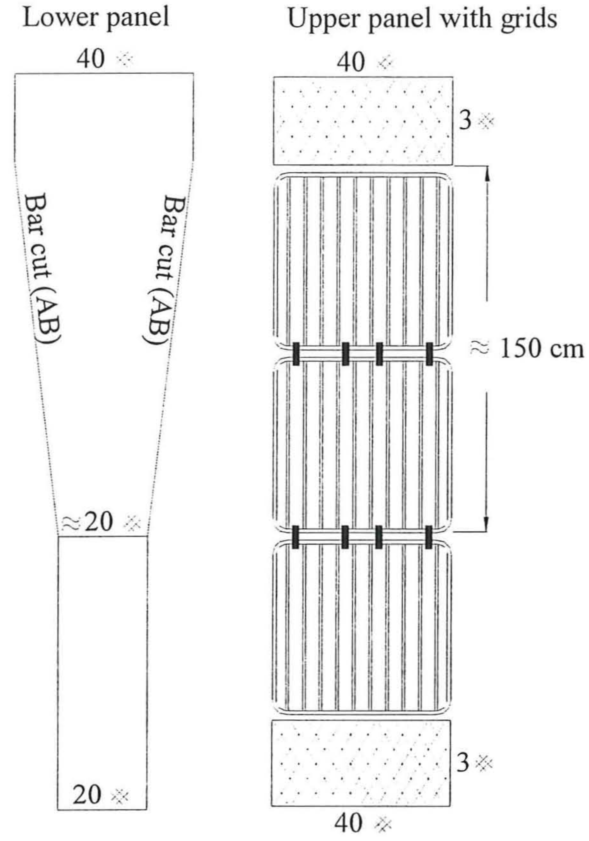


Figure 1. Illustration of extension pice with three hinged grids mounted in the upper panel (netting: 2x7 m/m PE, mesh size 137 mm).

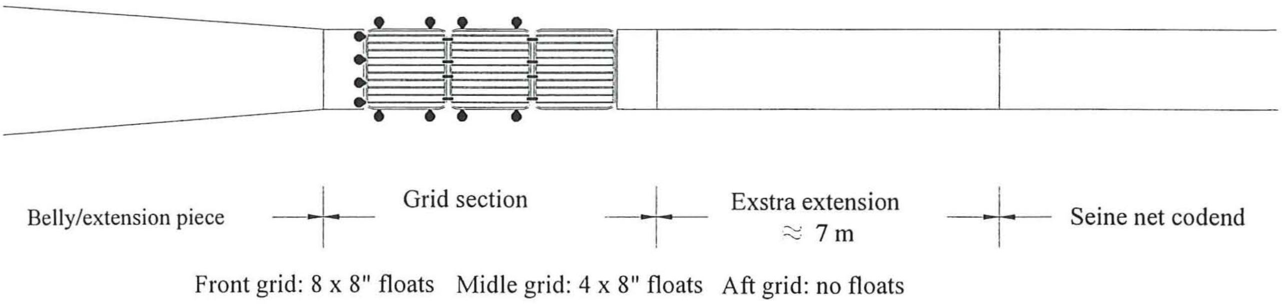


Figure 2. Illustration of rigging of the grid system for seine net boats.
Front grid: 8 pcs. 8" floats; middle grid: 4 pcs. 8" floats; aft grid: no floats.

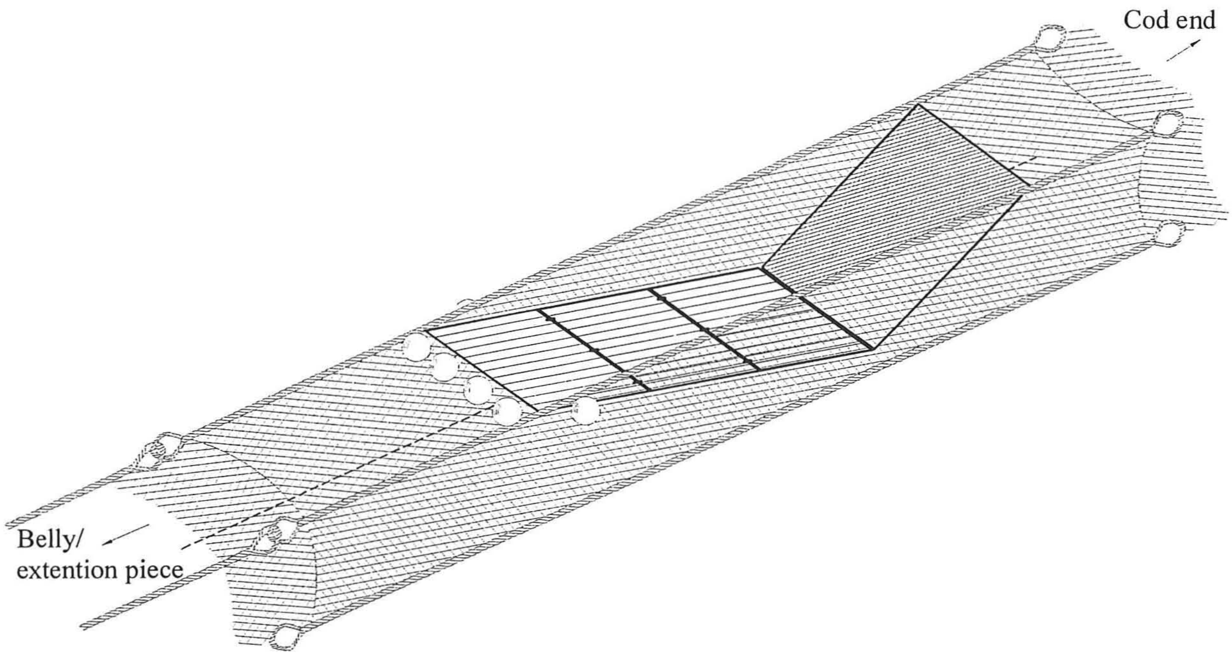


Figure 3. Seine net grid mounted in a square-meshed extension piece (final version).

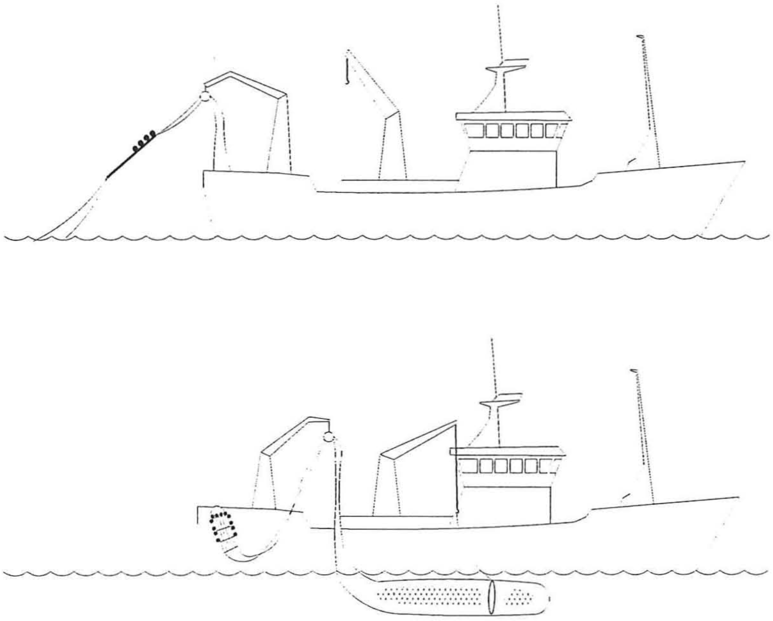


Figure 4. Hauling procedure for seine net and lifting the catch on board.

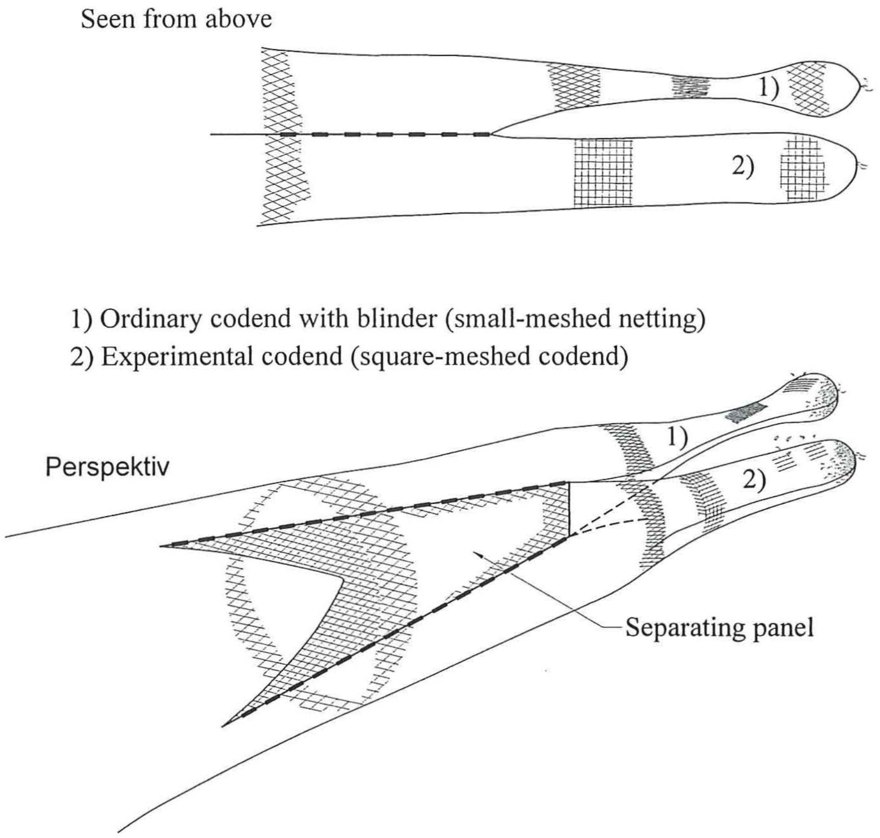
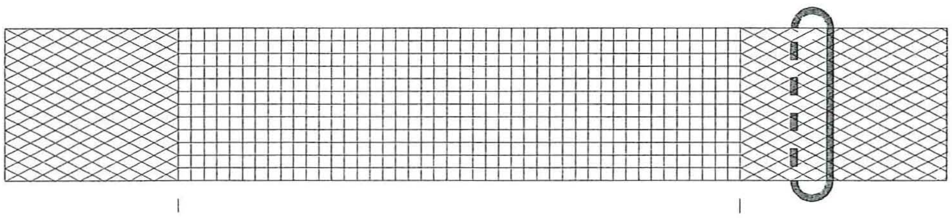


Figure 5. Experimental set-up "trouser trawl"-method.
1) Standard codend with blinder (small-meshed netting)
2) Experimental codend (square-meshed codend)



	Front part	Square mesh cylinder	Codend lift
Material:	PE - Knotted netting	PE - Knotless netting, twisted or braided	PE - Knotted netting
Twire:	Max 2x4 mm	Max 7.5 mm	Max 2x5 mm
Mesh size:	Min 135 mm	Min 125 mm	Min 150 mm
Length:	5-8 *	Min 12.5 meter	Max 4* between lifting strop and square mesh cylinder
Width:	Max 100 *	Max 100 bars	Max 80 *

Figure 6. Specifications for the square mesh codend used by the seine net fleet since 1997.

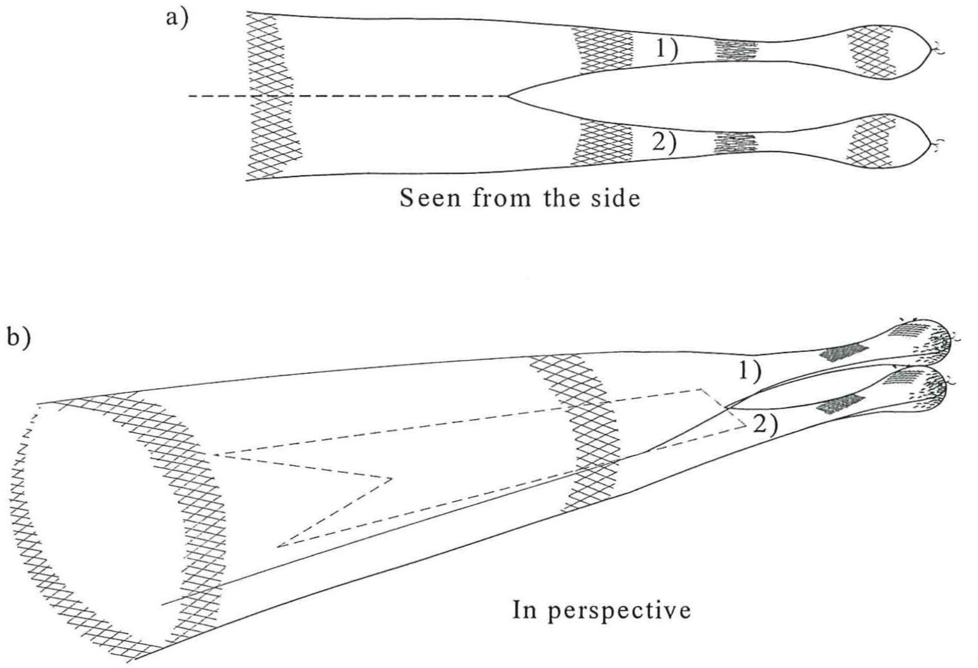


Figure 7. Extension piece with a horizontal small-meshed panel to examine natural fish distribution. a) Seen from the side; b) in perspective.

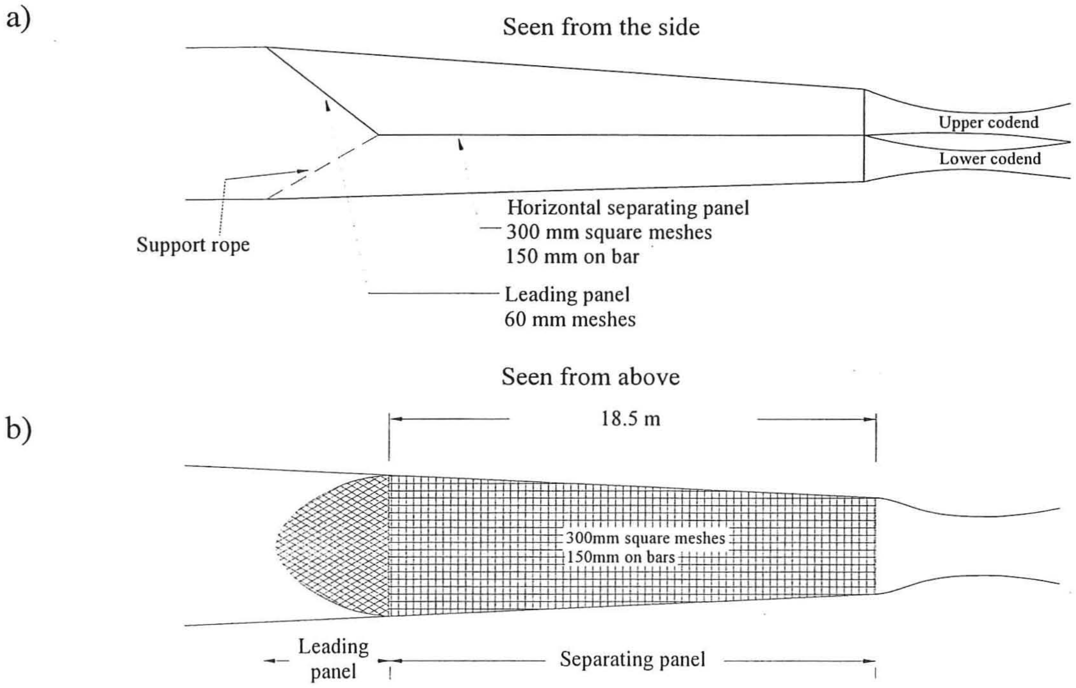


Figure 8. Seine net extension piece with species separator. a) Seen from the side; b) in perspective.

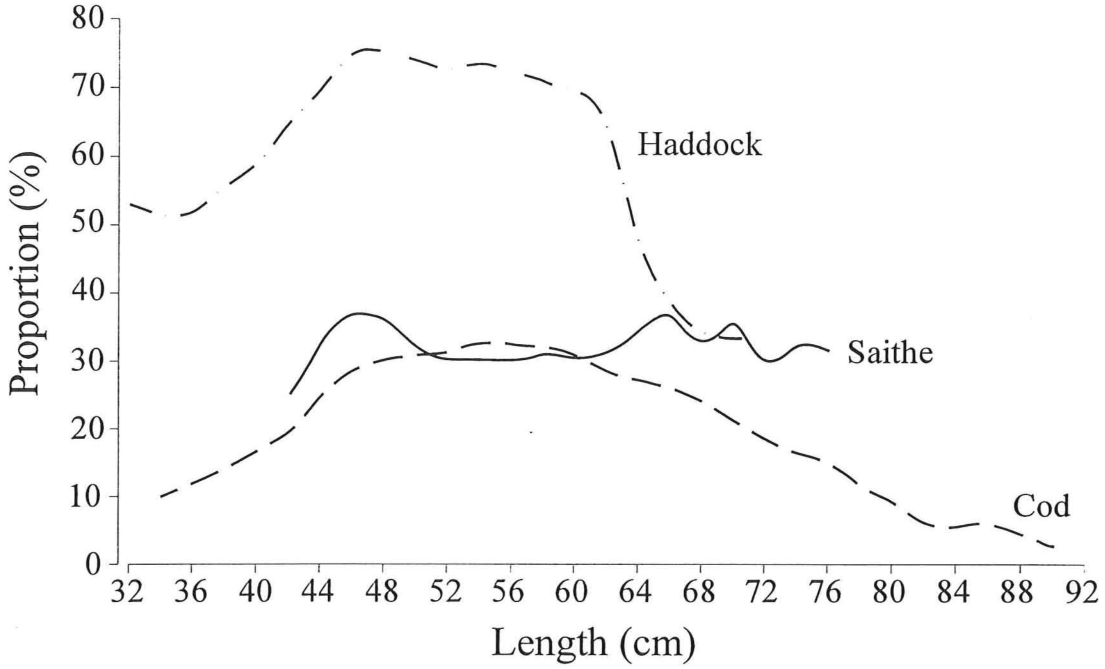


Figure 9. Proportion (%) of cod, haddock and saithe escaping upwards through a separating panel in seine net.

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H A U L   I N F O R M A T I O N

Date    :    05/21/95          Reg. No          :    Torsk 30-37
Vessel  :    "Skulbaren"       Fishery Ground   :    ¥st-Finnmark
Gear    :    55mm stålrist

Name      :    BI/KG
Institute :    HI-Fangstseksjonen

Experimental Type :    Covered Codend


FILES :    NAME              RESULT

           TORSK30.SEL       __√_
           TORSK31.SEL       __√_
           TORSK32.SEL       __√_
           TORSK34.SEL       __√_
           TORSK35.SEL       __√_
           TORSK36.SEL       __√_
           TORSK37.SEL       __√_


A N A L Y S I S   R E P O R T
      V A R I A N C E
     C O M P O N E N T
         M O D E L


ANALYSIS METHOD :  MLE


LINK FUNCTION :  C-LOG-LOG

Parameters

     Intercept       -7.64784
     Slope            0.13663


Variance of Parameters

   [   0.50642     -0.00820  ]
   [  -0.00820      0.00013  ]
```

```
Variance Component

     ┌                           ┐
     │   3.13692      -0.05016   │
     │  -0.05016       0.00081   │
     └                           ┘

Calibration-points with  95.000 % confidence limits

     L-25%      46.855         36.826     -     56.075
     L-50%      53.291         49.847     -     56.291
     L-75%      58.364         55.584     -     60.988
     SR         11.509          9.597     -     13.421
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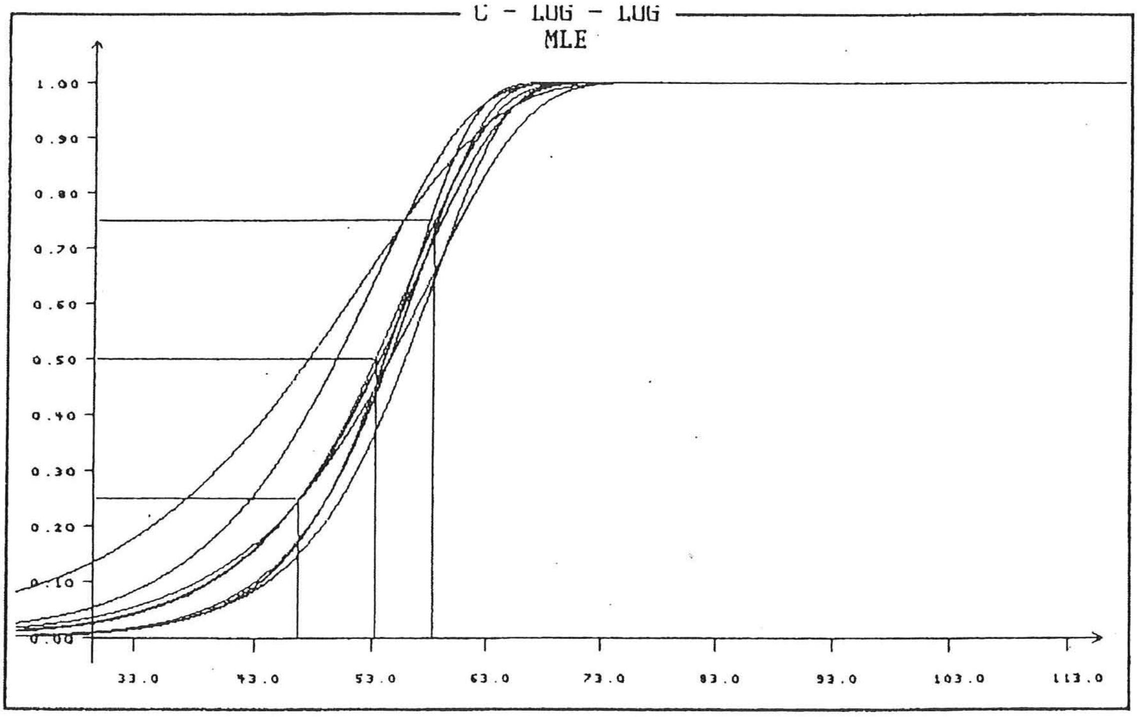

9^{th} Joint Russian-Norwegian Symposium
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(PINRO, Murmansk, 14-15 August 2001)

STUDYING OF SELECTIVITY OF THE SORT-V SORTING SYSTEM USING A 55 MM PLASTIC GRID DURING THE FISHERY FOR COD IN THE BARENTS SEA

by
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Abstract

Selective and commercial fishing characteristics of a plastic sorting grid are compared with those of a metallic one. As a result of technical and fishing experiments a bottom siamese trawl was established to be applied for studying selectivity. The comparative experiments on the plastic grid, when applying the bottom pair trawl, have shown its higher selective properties in regard to cod compared to the metallic one. More mean-size fish are caught by a trawl rigged with the experimental grid than with the metallic one. It is suggested that the plastic grid should be applied during the fishery for cod and haddock.

Introduction

The sorting grid systems - the Norwegian SORT-X (two-grids) and Russian SORT-V (single-grid) - have been applied during the fishery for cod and haddock in the limited areas of the Barents and Norwegian Seas since 1997. Both sorting grid systems have similar selectivity and contribute to a reduction in catches of young fish by means of their release through the metallic grids. However, in recent years the fishery for cod in the Barents Sea was complicated even by the bottom trawls rigged with the systems mentioned. Such situation is conditioned by a large proportion of young gadoid species in aggregations that does not allow to efficiently release it through the metallic grids even at a distance of 80 mm between the lengthwise bars. Besides, a practice of applying the "rigid" sorting grid systems has shown that they are not safe under storm conditions, especially the SORT-X sorting system, not durable and their cost is high.

When studying a trawl selectivity, some instrumental methods are used to collect data. The "cover" method was accepted as the basic one, which suggests an installation of a small-mesh fishcatcher, in which the escaping from a trawl fish congregate over a tested section of a trawl. However, along with the advantages of the method mentioned, its disadvantage, i.e. availability of "masking effect of the cover", was noted by some researchers. The fishcatcher and small-mesh insertion in a trawl codend, which are used in this method, affect the hydrodynamics of water flow in a trawl, and escaping of fish from it somewhat differs from that occurring during the operation of a trawl without applying them. The method of "siamese trawling" is therefore used most frequently in recent years, which allows to perform the alternating (or parallel) hauls using a single trawl, two-codend trawl, and to provide fishing by two trawls onboard a vessel, etc.

Materials and methods

The experiments were undertaken onboard the trawler "OLAINE" along the Southern and Western slopes of the Bear Island Bank (ICES Div. IIb) and in the Murman Shallows (ICES Subarea I) in April-May 2001.

Particulars of "OLAINE":

- overall length - 66.2 m;
- breadth - 13.8 m;
- maximum draught - 6.4 m;
- displacement (light) - 2467 (1767) t;
- gross tonnage (net tonnage) - 1898 (492) reg.t;
- main engine - 2x880 kW (2x1200 h.p.). The fishing deck of the trawler was rigged with the equipment for "double" trawling.

A bottom siamese trawl (48.3/53.9 m) was used during the investigations. The trawl was rigged with:

- Cable:	100 m
- Headline floats AMG:	200
- Groundrope:	Sectional Groundrope "rockhopper" (Central section - 8.3 m, 2 wing sections - 6.3 m, 2 wing groundropes - chain -9.85 m and 2 steel ropes - 18.7 m). The weight of groundrope in the water is 10.5 kgN; a total length is 77.8 m.

- Trawl boards are V-shaped "Morgere polivalente R"(PS-13), the area is 7.2 m^2 and weight is 1900 kg;
- Four-panel trawl bags (conical and cylindrical parts are made of polyethylene double-twisted netting B=135mm);
- "SORT-V" sorting system with a 55 mm grids (metallic and plastic).

When estimating a discrepancy between the catches taken by two trawls it was found that the catches in two trawl codends were nearly similar and made up from 1 to 1.5 t/trawling hour. Correlation between the length composition of cod catches for the left (N_{left}) and right (N_{right}) codends was verified using correlation analysis.

The equation of the summarized linear regression is the following:

$N_{right} = 1.0090 * N_{left} - 0.02$ coefficient of correlation R=0.9872

Thus, the deviation of the length composition in two codends is minimum and constitutes not more than 2%. Therefore, one can draw a conclusion that the total catch by length-weight composition is similarly distributed in two codends of the pair trawl.

Two methods were used to test the plastic grid selectivity, i.e. using a small-mesh "cover" (fishcatcher) and a bottom siamese trawl with a 70-mm "blinder" in codends. A plastic (flexible) grid is produced of polyester resin PH-1 (1.56 x 1.27, about 15 kg in weight). A scheme for mounting the plastic grid into the SORT-V system did not differ from that used for installing a metallic one. The only difference was that 6 floats (200 mm in diameter) were installed along the front edge of the plastic grid and 16 - along the metallic one.

When testing the plastic grid selectivity the method of a small-mesh "cover" was initially used. The experiments were performed off the Bear Island Bank Southern slope at 270-310 m depths, where aggregations of immature small- and mean-size cod with a modal group 46-55 cm long were fished off. The catch (in a trawl codend) consisted mainly of cod with the mean length being 49.5-52.0 cm; by-catch of the small-size fish varied from 12 to 17%. The experiments with the bottom siamese trawl in use were done off the Bear Island Bank Western slope at 300-310 m depths, where aggregations of immature mean-size cod with the modal group 51-60 cm were fished off. The main catch (in a trawl codend) consisted of cod with the mean length being 56 cm; the small-size fish bycatch varied from 7 to 12%. Selectivity of the grids, obtained by two methods, is given in Fig.1.

Commercial fishing characteristics of the experimental plastic grid were compared with those of the metallic one. A "pair trawling" method was used in the experiments. To that end, the bottom pair trawl, rigged with two SORT-V systems, was applied. One of the sorting grid systems was rigged with the experimental grid, and the second one - with the metallic grid. The cylindrical parts (codends) of both bags were made of polyethylene double-twisted netting with a rope (5 mm in diameter) and consisted of 4 panels, each of which had the following dimensions: width - 17 meshes (excluding the meshes taken for joint) and length - 70 meshes. Mesh size in both codends was approximately similar, i.e. 139.2 mm - in the right and 139.1 mm in the left codend. The experiments were done along the Western slope of the Bear Island Bank (ICES Div.IIb) and in the Murman Shallows (ICES Subarea I). Length composition of catches is given in Figs. 2 and 3.

Discussion

Analysis of the data derived on the plastic grid selectivity has shown that the selectivity parameters obtained by two methods much differ from each other. For example, when applying the bottom pair trawl the major parameters of selectivity made up: $L_{50\%} = 46.5$ cm and $D_s = 7$ cm; and $L_{50\%} = 42.3$ cm and $D_s = 10$ cm - when applying a small-mesh "cover". This was probably both due to a different length composition of the fish caught at each stage of the experiments and also to a method applied during the experiments. In our opinion, more reliable data on selectivity can be obtained using the bottom pair trawl.

Results from the experiments carried out off the Bear Island Bank Western slope have shown that the amount of small-size cod at 42-50 cm length reduced by 0,5-2% in the length composition of catch taken by the SORT-V system with a plastic grid, compared to a metallic one; and vice versa, the amount of cod 52-58 cm long increased by 0.4-0.8%. The amount of cod above 60 cm long in the catches taken by both bags, irrespective of a type of grid, was approximately similar. The cod catch in a bag with a plastic grid reduced on the average by 16% compared to that taken with a metallic grid in use.

Analysis of the data from the Murman Shallows area has shown that on the whole a proportion of length compositions of catches in both bags (plastic or metallic grids) did not change. The amount of cod 30-45 cm long in catches from bag using a plastic grid reduced by 0.5-2% compared to that from the bag with a metallic grid; and, vice versa, the amount of cod 50-62 cm long increased by 0.8-1.8%; the amount of cod above 62 cm was approximately similar.

Thus, the plastic grid selectivity was established to be higher for the small-size cod compared to the metallic grid. At the same time, the amount of mean-size fish fished off by the experimental trawl with the plastic grid is higher compared to that with the metallic one in use.

Comparable commercial fishing characteristics of both grids were estimated during a whole period of the experiments. Above 150 hauls were done with the experimental grid and 120 - with the metallic grid in use. The catches taken with both grids made up from 0.5 to 10 t. The observations showed no variations in the operational parameters and in the plastic grid shape (malfunction took place only in a netting of the sorting system). At the same time, a deformation of lengthwise bars in metallic grid was observed under a load and its performance changed.

Conclusion

The experiments on the plastic grid in cod trawls have indicated higher selective properties in regard to small-size cod compared to those of the metallic grid. At the same time, more fish are fished off by a trawl with the plastic grid than with the metallic one. Therefore, it suggested that the plastic grid should be applied in the cod trawls rigged with the SORT-V sorting system.

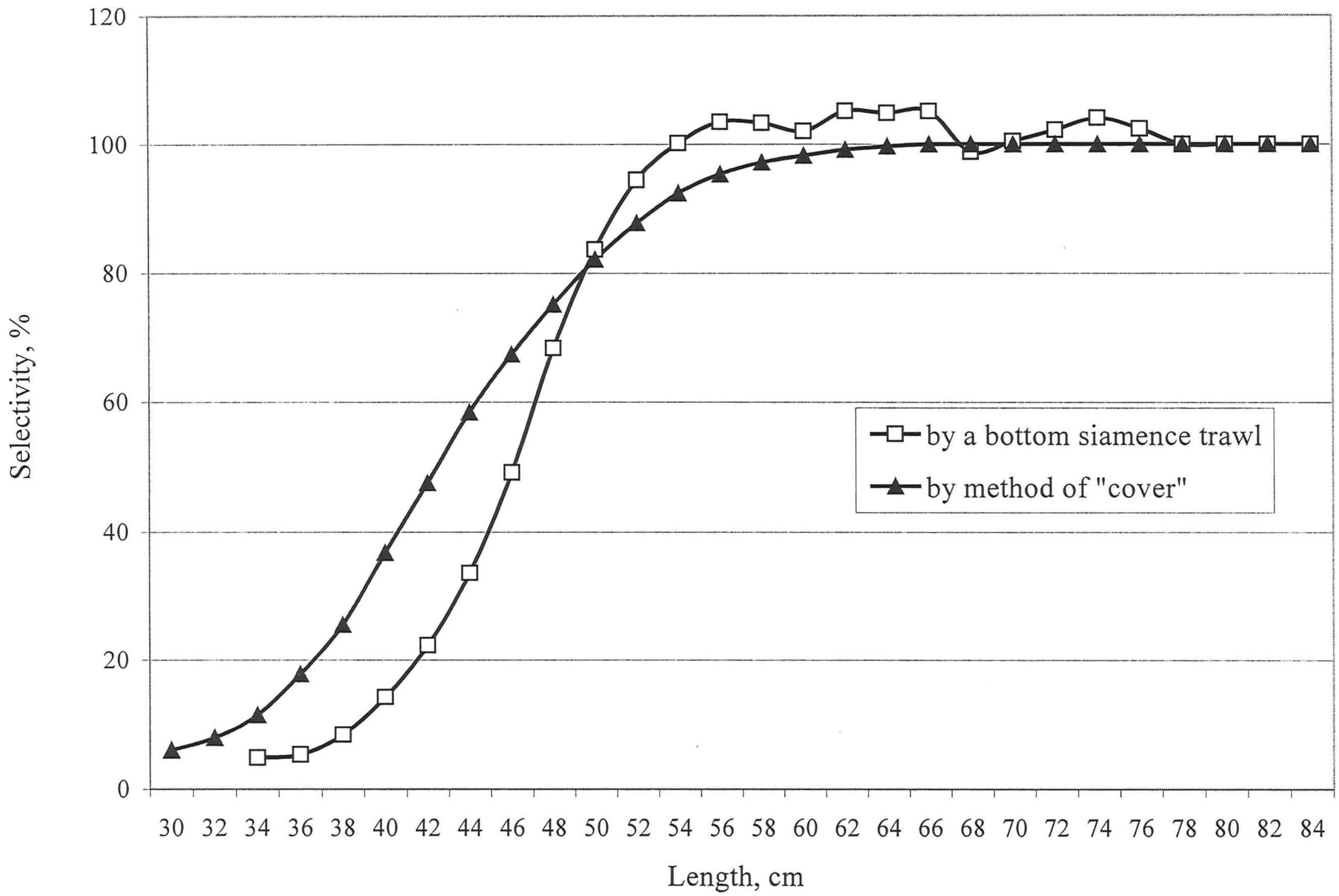

Fig.1. Selectivity of a plastic grid during cod fishery, obtained by different metods

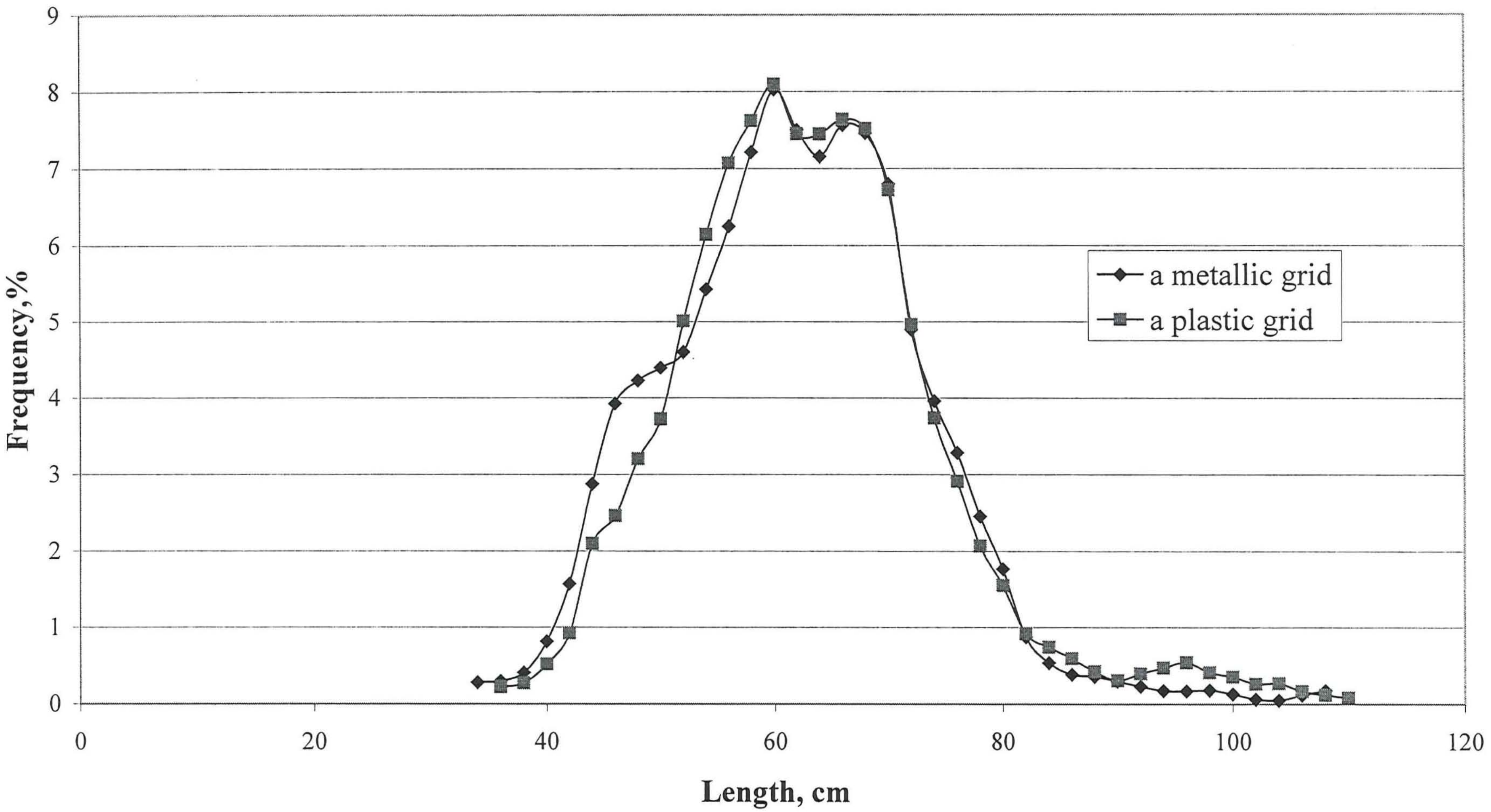

Fig.2. Length composion in cod catches taken by a siamece trawl, using different sorting grids, on the Bear Island Bank Western slope

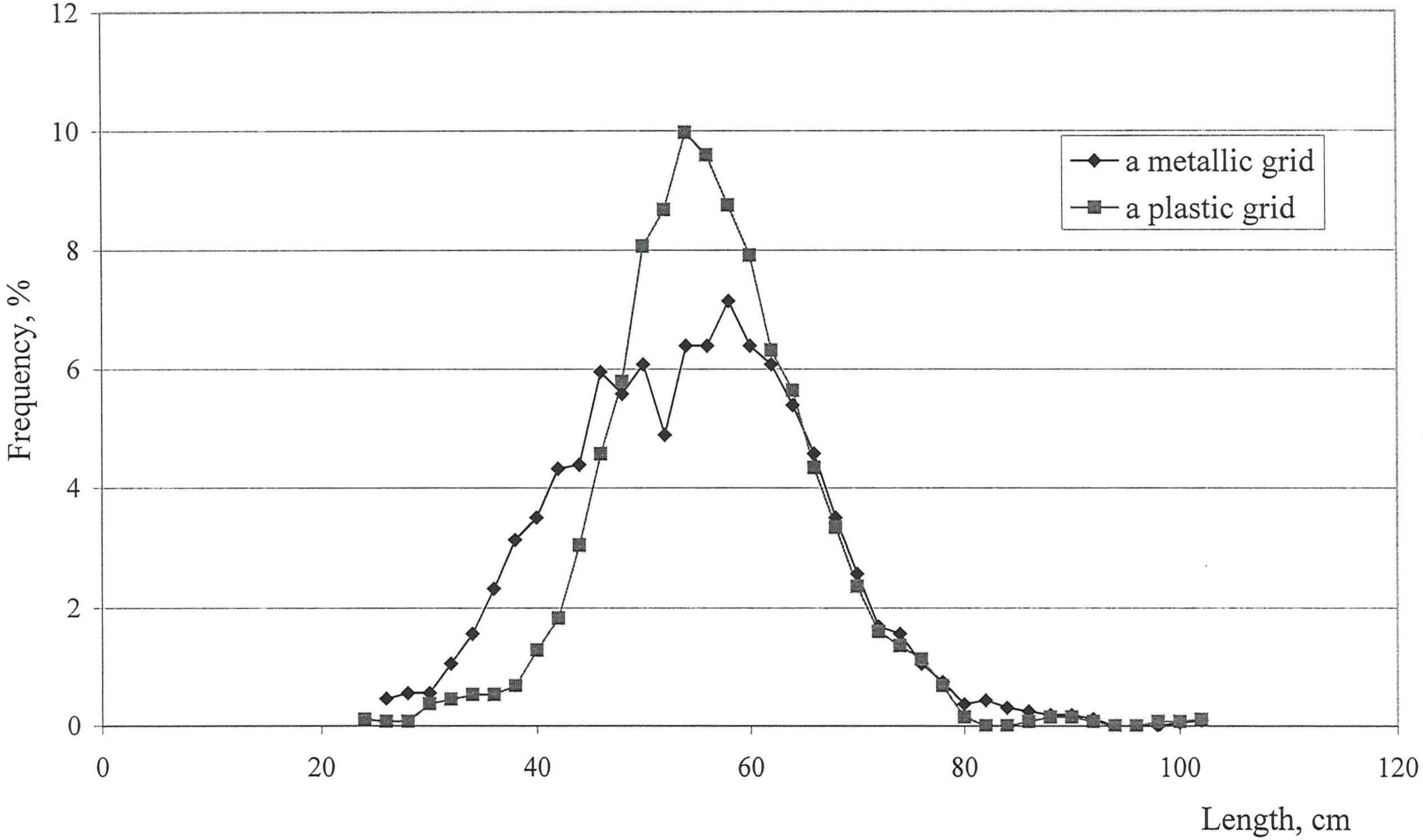

Fig.3. Length composition of cod catches taken by a botton siamence, using different sorting grids, un the Murman shallows

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INCLINED WATER FLOW AND ITS APPLICATIONS FOR REDUCED BYCATCH IN SHRIMP TRAWLS

by

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Abstract

The use of the Nordmøre grid in the Pandalus fishery has significantly reduced the bycatch of finfish. Grids operate on physical separation based on size to achieve bycatch reduction. However, problems arise when the size range of fish overlaps the shrimp.

In this paper results from an initial trial in northern Norway with a new selection device creating a vortex circulating out of the escape opening to force/stimulate fish are presented. The water flow (vortex) seemed to be fairly low and varied during the six observations hauls. Observations of fish behaviour showed that 0-group cod and haddock reacted to the water flow created by the device. The escape rate of fish varied between the six hauls possibly due to the variation in flow pattern.

Introduction

In the course of the past few decades the development of various devices for installation in trawls has considerably reduced bycatches of unwanted species. Such devices include grids in shrimp trawls, which have reduced the bycatches of both fish and turtles (Isaksen et al., 1992; Watson et al., 1986; Mitchell et al., 1995). However, situations arise in which grids based on physical separation do not function satisfactorily because the species and/or size groups to be sorted out are the same size, or smaller than, the target species. Examples from our own fishing ground include 0-group cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and redfish (*Sebastes* spp.) in the shrimp fishery.

Where it has proved impossible to use grids, selection devices that exploited differences in the swimming characteristics of fish and shrimp have been designed (Valdemarsen and Isaksen, 1986; Watson et al., 1986). To a great extend it has been possible to separate the fish from the shrimp inside the trawl itself. The problem has often been that the fish will not actively leave the trawl via the escape window during trawling (Engås et al., 1999) This is because the fish sense that the water velocity is greater outside than inside the trawl (Engås et al., op. cit.). In the course of testing a new type of selection device in the Gulf of Mexico it was discovered that this devices created a vortex whereby the water current circulated out of the escape opening at an angle relative to the horizontal plane (vertical water current). Observations revealed that fish that were attached to the escape window were immediately stimulated to leave the trawl (Engås et al., 1999).

This paper describes the results from an initial trial in northern Norway with a prototype selection device as described above. The experiment had the following objectives; study the behaviour of 0-group cod and haddock near the escape window and to determine whether there is a potential loss of shrimp when the new device is employed.

Material and methods

The experiment was carried out in Lyngenfjorden, Northern Norway in February 2001 onboard "Jan Steinar". Towing speed during the experiment was 1.2 knots. The selection device was mounted in the extension 135 cm behind the lower part of the Nordmøre grid (Figure 1). In addition to the device a tunnel was mounted above the device in order to lead the shrimp past the area with the escape window and the vertical water current and to guide the fish to the release window. A camera using artificial light was mounted in the lower part of the extension looking forward towards the escape window. White thin twine was mounted at several positions in the area of the selection device in order to identify the water flow direction.

A total of six successful observations hauls were carried out.

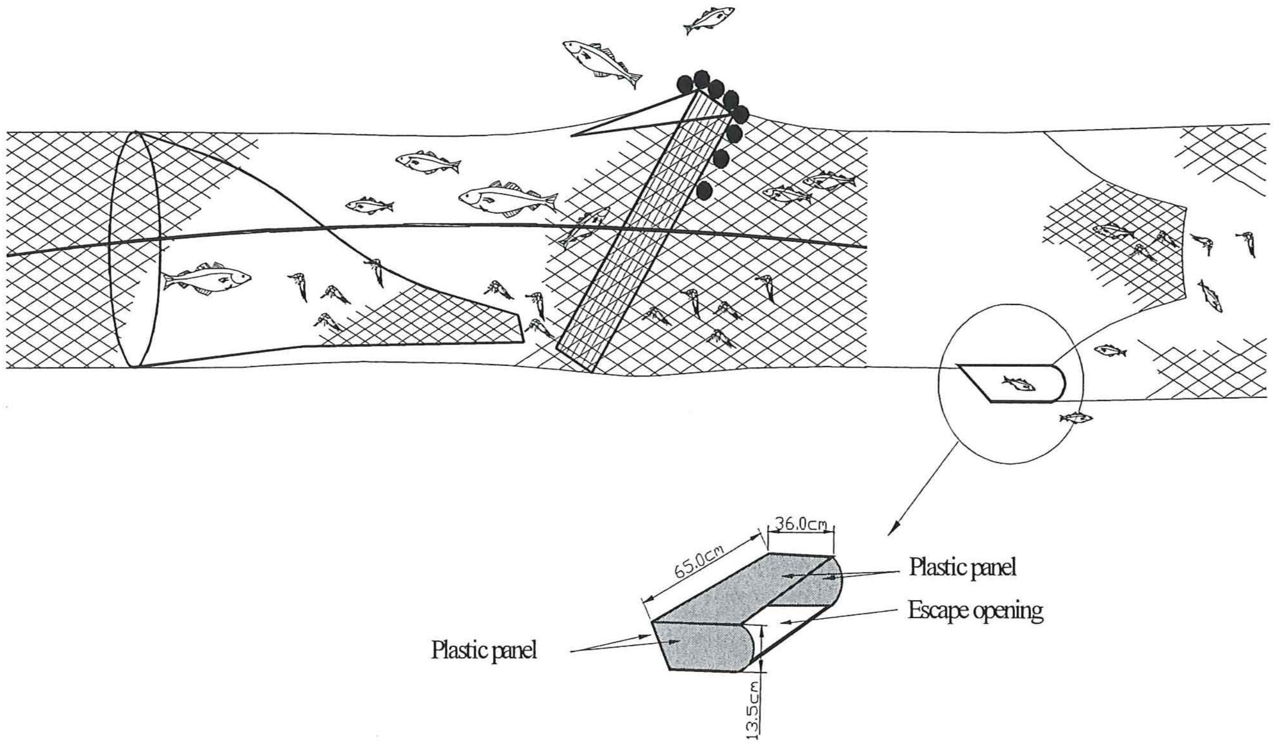

Figure 1. Schematic diagram of the gear configuration.

Results and discussion

The twine showed that the water circulated through the escape opening, back into the trawl, and forward toward the escape opening (Figure 2). The water flow (vortex) seemed to be fairly low and varied during the tow depending on factors such as the position of the selection device and the position of the lower funnel in relation to the device. During some hauls, especially when a high number of shrimp entered through the tunnel, it was observed that shrimp was "caught" in the lower part of the funnel. As shrimp accumulated in this area, a "bag" was created which was forced down below the top plate of the selection device by the water flow. This created a barrier to water flow forward towards the escape opening; i.e. reducing the vortex.

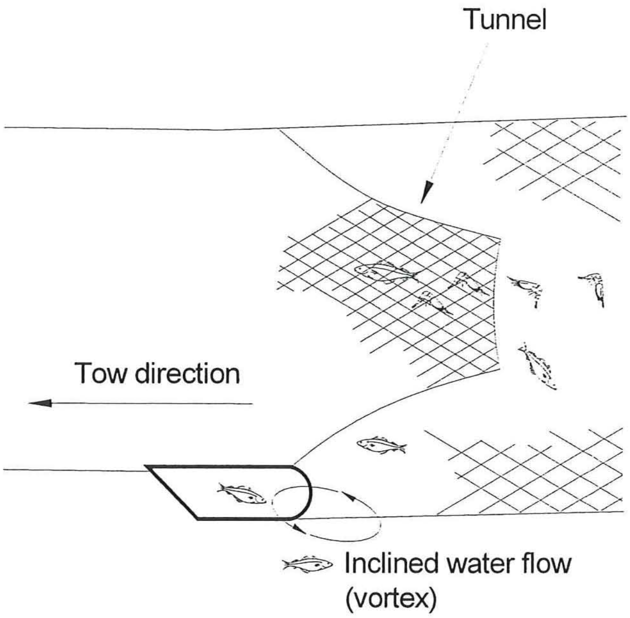

Figure 2. Schematic presentation of the water flow pattern.

Fish that passed through the tunnel where observed swimming forward towards the escape window. When entering the back part of the vortex they were observed turning towards the codend (i.e. towards the water flow). Some fish escaped immediately as they entered the escape opening, but the majority was observed swimming with very low tail beat frequency inside the selection device for an extended period, before they escaped or when back towards the codend. If these fish came forward again during the tow is impossible to know from the observations. One possible reason that fish took up a position in the area of the escape opening for an extended period without being forced or stimulated to leave may be due to the low water flow as indicated above. Despite that, the number of fish observed escaping compared to the catch, showed that the escape rate for cod varied between 11 and 100 %, while it varied between 0 and 66% for haddock (Table 1). It is reason to believe that this is an underestimate since the observations lasted for only one hour, while towing time varied between two and three hours. No shrimp loss through the escape opening was observed during the six hauls.

Table 1.Results obtained from catch and observation data.

Haul no.	Duration (hrs)	Catch of cod (no.)	Observed cod escaped (no.)	Catch of haddock (no.	Observed haddock escaped (no.)
1	1.5	3	5	10	0
2	2.5	11	13	1	2
3	3.0	4	3	4	1
4	2.0	0	7	1	0
5	2.0	16	5	7	1
6	2.5	9	3	8	2

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ON EVALUATION OF THE EFFECTS OF APPLYING THE SORTING GRID SYSTEMS IN THE FISHERY FOR ARCTO-NORWEGIAN COD

by
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Abstract

Based on the results of 12 300 trawling hours by fishing and research-fishing vessels of PST and SRTM-type in the Barents and Norwegian Seas in June-December 2000, the influence of sorting grids on mean efficiency of cod fishery is studied. A long-term effect of increase in the spawning stock abundance due to sorting grids is shown. The use of grids in trawls with 125 and 135 mm meshes reduces by-catch of undersized cod and enhances the efficiency of fishery by both type vessels. The increase in the abundance of the cod stock in general and of its mature part in particular is calculated as 3%.

Introduction

At the 25th Session of the Joint Russian-Norwegian Fisheries Commission the decision was taken about mandatory application of sorting grids in the limited areas of the Barents and Norwegian Seas since 1 January 1997, as an additional conservation measure to protect young Arcto-Norwegian cod and haddock Results from studies of selectivity of cod trawls both with and without grids, as well as from the experiments conducted by fishing vessels, served as the basis for this decision. The studies were focused on the reduction in young fish by-catches and, to a less extent, on a possibility to improve efficiency of the fishery.

Therefore, based on the analysis of results from fishery, the paper attempts to evaluate actual efficiency of sorting grids used in cod trawls.

The effect of sorting grids upon the mean fishing efficiency of PST- and SRTM- type vessels, which fished cod in the Barents and Norwegian Seas from June to December 2000, is considered in the paper. Besides, an existence of a long-term effect consisting in the increase of the abundance of the spawning cod stock due to the sorting grids in trawls used by the PST-type vessels, is shown.

Materials and methods

The results obtained during 12 313 hours of trawling performed by the fishing vessels, as well as by research and fishing vessels (PST- and SRTM-type), equipped with the trawls (125 and

135 mm mesh size) with and without sorting grids, served as the basis of the paper. The hauls were performed in the Barents and Norwegian Seas from June to December 2000.

Data on length composition of catches were collected by scientific observers. Catches of cod from each haul were classified by length groups with a 5-cm interval, beginning from 6 cm. The total of 855 439 individuals were measured. By comparison, the total fishing effort of PST-type vessels in fishery for cod with the other demersal fish by-catch in the Barents and Norwegian Seas made up 28 700 trawling hours for June-December 2000, and the total number of cod measured in the Barents Sea for the whole year 2000 was 1 336 191 individuals. Length frequencies and the number of trawling hours were aggregated by vessel type, mesh size and rigging of trawl (with a grid or without it), month and area of operation. Data on the fishery and on the samples collected from catches are given in Table 1.

The effect of sorting grids upon the fishing efficiency of vessels was analysed on the basis of variations in length composition and of growth in cumulative proportion of cod retention with fish length increasing from 6, 41 and 46 cm in a mean catch per trawling hour. Existence of the long-term effect of increase in the spawning population abundance due to sorting grids, was calculated by comparing losses and a potential growth of the mature fish abundance during operations of PST-type vessels.

The losses and potential growth of the mature fish abundance due to sorting grids were calculated by the following algorithm. The assumption was made that new trawls were with grids, and old ones - without them, and had the trawl bags with 125 and 135 mm mesh size; the weight of catch taken by new trawls was assumed to be equal to the weight of catch that was actually taken by the old trawls in June-December 2000.

The fishing effort of PST-type vessels equipped by new trawls will then be equal to:

$$f_1 = f_0 \cdot \frac{\overline{B}_{f_0}}{\overline{B}_{f_1}}, \qquad (1)$$

where

f_0 is actual fishing effort of PST-type vessels rigged with old trawls in the Barents and Norwegian Seas for June-December 2000, [trawl.hr.];

$\overline{B}_{f_0}$ is mean efficiency of PST-type vessels rigged with old trawls in the Barents and Norwegian Seas for the period investigated, [kg/trawl.hr.];

$\overline{B}_{f_1}$ is mean efficiency of PST-type vessels rigged with new trawls in the Barents and Norwegian Seas for the study period, [kg/trawl.hr.].

Mean fishing efficiency of PST-type vessels equipped by new and old trawls (Table 1) was defined by the following equalities:

$$\overline{B}_{f_0} = \sum_k \overline{C}_{f_0,k} \cdot \overline{\omega}_k \qquad (2)$$

and

$$\overline{B}_{f_1} = \sum_k \overline{C}_{f_1,k} \cdot \overline{\omega}_k \qquad (3)$$

where $\overline{C}_{f_0,k}$ and $\overline{C}_{f_1,k}$ are mean catch of cod of the size group K pr. 1 hour of trawling by PST-type vessels equipped by respectively old and new trawls [individuals]; k=1, 2, 3, …, 27;

$\overline{\omega}_k$ is mean weight of one cod the length of which corresponds to the middle point of the size interval k, [kg]. Mean weight was calculated by age samples from Russian catches taken by conventional trawl in the Barents and Norwegian seas in 2000.

Knowing the fishing efforts f_0 and f_1, we calculated the total amount of cod for each 5-cm interval k, caught by old and new trawls

$$C_{0,k} = \overline{C}_{f_0,k} \cdot f_0 \ , \qquad (4)$$

$$C_{1,k} = \overline{C}_{f_1,k} \cdot f_1 \ , \qquad (5)$$

and their deviations:

$$\Delta C_k = C_{0,k} - C_{1,k} \ . \qquad (6)$$

Positive deviations ΔC_k denote a lower fishing efficiency and show the current losses of the fleet equipped by new trawls. On the other hand, they indicate the number of fish which successfully passed through the codend with grid and did not die in fishery. These are chiefly small immature fish. It is assumed that additional natural mortality of these fish caused by damages from grids is equal to zero. A certain portion of them will survive and join the spawning stock, thus being the source of potential abundance increase. Conversely, negative deviations of ΔC_k denote a higher fishing efficiency and show the current gains of the fleet. They account for larger and mostly mature fish the amount of which indicates the current decline of the stock abundance in general and future loss of the spawning stock. To estimate the potential increase of the spawning stock, as well as the potential damage to its abundance, the age composition of all deviations ΔC_k was defined. Then the total amount of fish in each age group with a positive or negative sign was calculated. The abundance of these fish was computed as of the beginning of the 4th quarter of 2000. The age composition of the deviations ΔC_k was defined using the length-age key converted to weight-age key. The loss and the potential increase in the abundance of the spawning stock in 2001 and in the subsequent years were defined on the basis of natural and fisheries mortality coefficients, as well as the portion of mature fish, accepted by the ICES Arctic Fisheries WG for 2000 (Anon., 2001).

Results and discussion

Length composition of cod catches per 1 hour of trawling by the PST and SRTM- type vessels equipped by trawls with 125 and 135 mm mesh size with and without sorting grids infers that the bulk of catches was made up by fish within a narrow length range – from 50 to 70 cm (Figs. 1a, 2a, 3a, 4a). In all cases the length frequencies had two local maxima and one or two local minima. The former corresponded to cod length of ca. 40 and 60 cm, or to the yearclasses of respectively 1997 and 1995. The local minima corresponded to the length of ca. 20 and 45 cm, or to the yearclasses of 1999 and 1996. The presence of the local minima suggests that the strength of the yearclasses of 1999 and 1996 is lower than that of the adjoining ones. In catches obtained with grids the length frequency mode of large cod was generally higher and that of small cod – lower than in catches taken without grids.

The lowest length of retained cod – 6 cm - was recorded for the PST vessels rigged by trawls without grids with the 125 mm mesh size. The amount of cod from the first length group – from 6 to 10 cm - made up 3.05% of the total amount of fish in catch per one hour of trawling, which is quite a high value. Sorting grids increased the minimum length of retained juveniles by 10 cm. Total number of fish (16 cm and larger) in mean catch pr. one trawling hour did not decrease much (Table 1), but the amount of cod in the length group from 16 to 20 cm was nearly halved, being only 0.15%. The portion of cod from 6 to 20 cm length declined by more than one order of magnitude – by 37 times. The amount of young cod of up to 41 and 46 cm length decreased by respectively 7 and 5 times. In trawls with grids, a slight reduction in the portion of larger fish – 41 cm and longer and 46 cm and longer – was also observed, while in trawls without grids this reduction constituted 30 and 34%, respectively. As a consequence, the number of large cod of more than 41 cm and more than 46 cm length in trawls rigged with grids in relation to trawls without grids rises steeply by 32 and 38%, respectively. Hence, in spite of the fact that the number of individuals from 6 cm on in the mean catch per tow diminishes, total biomass of fish in the catch increases by 28%. Even more increases the mean weight of catch of cod from 41 cm on and from 46 cm on – by 36 and 38 %, respectively.

Variation of the cumulative portion of cod retention in relation to the increase of cod length (length of retention ℓ_k) depends on the initial size of fish retained (ℓ_0) in both trawls rigged with grids and not. Cumulative portion of cod of any size retained in trawls without grids is higher than that in trawls with grids if the initial length of fish retained is 6 cm (Figure 1b). In this case the discrepancy between the portions reduces with the increase of length of retained fish. The discrepancy between the portions becomes much lower as the initial size of fish retained increases. At $\ell_0 = 41$ cm it is small even for fish of $\ell_k = 41$ cm, and is close to zero for fish with the length of retention of 56 cm and more (Figure 1c). At $\ell_0 = 46$ cm there is no discrepancy even for fish with retention length equal to ℓ_0 (Figure 1d). The coincidence of retention curves in Figure 1d shows that at $\ell_0 = 46$ cm the ratio between the number of cod of fixed length ℓ_k in trawls with grid and corresponding number of cod in trawls without grid is proportional to the ratio of both numbers of cod with length from ℓ_0 and larger in these trawls. Having assumed that the number of cod from ℓ_0 on with the retention length of ℓ_k is equally available to these trawls and taking into account that the total number of such cod in trawls with grids is larger (Table 1), it may be inferred that efficiency of these trawls with respect to cod of $\ell_k \geq \ell_0$ length is also higher, and their ratio to the respective efficiency of trawls without grids is equal to the following ratio:

$$\frac{\sum_k \overline{C}_{f_1,k}}{\sum_k \overline{C}_{f_0,k}} \qquad (7)$$

So, the application of sorting grids in trawls with 125 mm mesh size used by vessels of PST-type precludes by-catch of undersized cod below 16 cm, reduces by-catch of juveniles up to 41 and 47 cm approximately by respectively 7 and 5 times and increases efficiency of trawls with respect to large cod. Hence, the efficiency of PST vessels for cod of more than 41 and 46 cm increases by 36 and 38 %, respectively, which should lead to a considerable reduction of fishing effort and expenses of PST vessels.

The application of sorting grids in trawls with 135-mm mesh size used by PST-type vessels produced somewhat different results. First, the minimum length of cod retained in trawls with and without grids is the same and equal to 16 cm, and the number of fish from the first size group - from 16 to 20 cm - retained by each trawl accounts for less than 0.01%. Portion of juveniles below 41 and 46 cm in both trawls is low and close to that in trawls with 125-mm mesh size rigged with sorting grids. The reduction in the number of fish retained with the increase of the initial size ℓ_0 up to 41 and 46 cm is insignificant in both trawls (Table 1). Secondly, cumulative portion of the retained cod of $\ell_k \geq 46$ cm at the initial size of retained fish of 16, 41 or 46 cm in trawls without grids is larger compared to trawls with grids (Figure 2b, c, d). This is due to the fact that the portion of cod of 41-65 cm length in trawls without grids is larger than in trawls with grids (Figure 2a). However, the number of large fish of 65 cm length and more in trawls rigged with grids is larger, thus fishing efficiency of these trawls is higher by 16 %. Number of large fish in both trawls is far higher than that in trawls with 125-mm mesh size equipped with grids.

The use of sorting grids in trawls with 125-mm mesh size by SRTM-type vessels also proved efficient. Minimum length of cod retained in trawls with grids and without them is equal to 16 cm, and the number of fish of the first size group, from 16 to 20 cm, retained by each trawl make up 0.0007 and 0.0004 %, respectively. In trawls rigged with grids the portion of juveniles of up to 41 and 46 cm length is far less, and the portion of cod of ≥ 50 cm length is larger (Figure 3a). The change in retention curves (Figure 3b, c, d) is similar to that for trawls with the same mesh size used by vessels of PST-type. These peculiarities increase the efficiency of SRTM-type vessels rigged by trawls with grids compared to trawls without grids (Table 1). This increase is estimated at 42%. It is worth noting that the efficiency of SRTM-type vessels fishing with such trawls compared to trawls with the same mesh size used by PST-type vessels is 10-17% higher.

Particularly advantageous is the use by SRTM-type vessels of grids in trawls with 135-mm mesh size. Minimum retention length of cod in trawls with and without grids is equal to 26 cm (Table 1) and the number of fish in the first size group, from 26 to 30 cm, retained by each trawl constitutes 0.01 and 0.06%, respectively. Juveniles of up to 41 and 46 cm occur in these trawls also in insignificant amounts (Figure 4a). In trawls with grids they account for 1.8 and 2.5%, in trawls without grids 3.5 and 5.3%, respectively.

However, in trawls with grids the portion of fish from 41 cm on and from 46 cm on was much higher - by respectively 41 and 43% - than in trawls without grids. The absolute amount of these fish in trawls with grids was more than in any trawls applied by PST vessels and in any trawls with 125 mm mesh applied by SRTM-vessels. The alteration of the retention curves (Figs. 4 b, c, d) is similar to that of the retention curves presented in Figs. 3 b, c, d. Due to this, the fishing efficiency of SRTM-type vessels equipped by trawls with grids was by 41% higher than that of trawls without grids (Table 1).

Variations in the abundance of the cod stock resulting from the application of sorting grids in trawls with 125 mm mesh size by PST vessels in June-December 2000, are shown in Table 2. It follows from the table that age composition of retained and lost fish differ markedly. The portion of retained fish exceeds that of lost fish by almost 7 times. Abundance increases owing to cod aged 1-4 years. The increase is incommensurably low as compared to the stock abundance. In comparison with the effect of cannibalism the abundance growth in cod aged 1-3 years is also extremely low. The last ratio will not be changed if we roughly suppose that the annual Russian catch in 2000 was taken by PST-type vessels and with the mentioned fishing gears. However, by this assumption, this catch will make up about 3% of the stock abundance.

The increase in the abundance of mature fish due to the “saved” juveniles will occur in two years (Table 3). It will continue to grow into 2008, but its rate will increase only to 2003. Annual losses will be the greatest in 2001 and will continue into 2005. The annual damage to the spawning stock will be compensated in 2 years, i.e. in 2003. The abundance growth will exceed the losses by 3 000 individuals. The summarised abundance increase will also become visible in 2 years, amounting to 11 000 individuals. In 8 years it will increase by 7.7 times and reach 85 000 individuals. Mean annual increase in the abundance of mature fish relative to the abundance of the spawning stock will also be low – less than 3%.

CONCLUSIONS

Applying of sorting grids in trawls with a 125 mm mesh size by PST-type vessels, excludes by-catch of undersized cod of below 16 cm length, that corresponds to the age 1, reduces by-catch of young fish below 41 and 46 cm length by respectively ca. 7 and 5 times and increases the trawl fishing efficiency in regard to large cod. Therefore, efficiency of PST-type vessels fishing for cod of 41 cm and larger and 46 cm and larger increases by 36 and 38%, respectively. It increases by 28% when fishing cod of 6 cm long and above.

Applying of sorting grids in trawls with a 135 mm mesh size by the same vessels does not result in an increase of the minimum size of retained cod. The minimum size is 16 cm. The proportion of young fish below 41 and below 46 cm in both trawls is insignificant, being close to the proportion of juveniles of the corresponding length in trawls with a 125 mm mesh size, equipped by sorting grids. The proportion of fish ≥65 cm in trawls with sorting grids is higher, therefore the fishing efficiency of these trawls is higher by 16%.

Applying of sorting grids in trawls with 125 mm mesh size by SRTM-type vessels, is also efficient. The minimum size of cod retained in trawls with and without grids is 16 cm, and the amount of fish in the first length group, from 16 to 20 cm, retained by each trawl is nearly by 2 orders of magnitude lower than the corresponding number of fish in the same-type trawls applied by PST-type vessels. The proportion of young fish of below 41 cm and below 46 cm length is much lower in trawls with grids and the proportion of cod ≥ 50 cm is higher. The fishing efficiency of SRTM-type vessels equipped by trawls with grids, compared to those operating without grids, is higher by 42%. For PST-type vessels the increase in fishing efficiency, compared to those using a trawl with a 125 mm mesh size, is 10-17%.

The use of sorting grids in trawls with 135-mm mesh size by SRTM-type vessels is very efficient. Minimum retention length of cod in these trawls with and without grids is equal to 26 cm which corresponds to age 2, and the number of fish in the first size group, from 26 to 30 cm, retained by each trawl makes up 0.01 and 0.06%, respectively. Young cod up to 41 and 46 cm length are present in these trawls also in insignificant amounts. In trawls with grids they account for 1.8 and 2.5%, in trawls without grids for 3.5 and 5.3%, respectively. When using trawls with grids the efficiency is 41% higher than when trawls without grids are applied.

The increase in fishing efficiency as a consequence of the use of sorting grids leaves no doubt as to the advisability of the application of sorting systems in trawls by PST- and SRTM-type vessels. These actions should adequately reduce fishing effort and expenses.

The effect of increase in the mature fish abundance due to sorting grids in trawls with 125-mm mesh size on PST-type vessels exists but it is very little. It can be concluded with confidence that the use of grids does not have an adverse impact on the stock abundance of cod in general and on its spawning stock, in particular.

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ANON. 2001. Report of the Arctic Fisheries Working Group (Draft). ICES C.M. 2001/ACFM:19, 377 pp.

Table 1

Amount of trawling hours and fish measured; minimum length; mean portion and weight of cod in different length intervals per 1 hour of trawling by the PST and SRTM-type vessels equipped by trawls with 125 and 135 mm meshes, with and without sorting grids, in catches taken from June to December 2000 in the Barents and Norwegian seas

Vessel type	Mesh size, mm	Presence of grid	No. of trawling hours	No. of fish measured	Min.length of cod in mean catch pr. 1 hr. of trawling, cm	No. of fish in mean catch pr. 1 hr. of trawling			Mean weight of catch pr. 1 hr. of trawling, kg		
						6 cm and longer	41 cm and longer	46 cm and longer	6 cm and longer	41 cm and longer	46 cm and longer
PST	125	no	1 228	79 820	6	65.0	45,8	43,0	103,6	96,9	94,8
PST	125	yes	1 985	125 539	16	63.2	60.5	59.5	133.0	131.6	130.9
SRTM	125	no	1 773	97 390	16	54.9	49.0	47.3	109.7	106.9	105.5
SRTM	125	yes	4 313	306 186	16	71.0	67.3	66.2	155.6	153.8	153.0
PST	135	no	141	11 379	16	80.7	77.7	76.8	167.8	166.4	165.7
PST	135	yes	1 731	145 587	16	84.1	80.0	79.0	194.1	192.2	191.4
SRTM	135	no	270	16 308	26	60.4	58.3	57.2	147.1	146.1	145.2
SRTM	135	yes	872	73 230	26	84.0	82.5	81.9	207.4	206.6	204.9

Table 2

Age composition of cod survived and dead in fishery by PST-type vessels using trawls with sorting grids and 125 mm mesh size in June-December 2000 in the Barents and Norwegian seas, thou.indiv.

Age, years	Effect from application of sorting grids	
	Abundance increase	Abundance decline
1	152	0
2	83	0
3	279	0
4	163	0
5	0	63
6	0	25
7	0	1
8	0	4
9	0	4
10	0	2

Table 3

Long-term effect on the abundance of the spawning stock of cod due to applying sorting grids in trawls with 125 mm mesh by PST-type vessels in June-December 2000 in the Barents and Norwegian seas (in thousand individuals)

Effect	Calendar year							
	2001	2002	2003	2004	2005	2006	2007	2008
Annual increase	9	18	44	40	22	11	3	1
Annual decline	32	21	7	2	1	0	0	0
Long-term annual effect	-23	-3	37	38	21	11	3	1
Summarised long-term effect		-26	11	49	70	81	84	85

Table 4

Long-term effect on the abundance of the spawning stock of cod due to the increase of mesh size from 125 mm to 135 mm in trawls with sorting grids used by PST-type vessels in June-December 2000 in the Barents and Norwegian seas (in thousand individuals)

Effect	Calendar year				
	2001	2002	2003	2004	2005
Annual increase	33	42	21	7	2
Annual decline	34	11	3	1	0
Long-term annual effect	-1	31	18	6	2
Summarised long-term effect		30	48	54	56

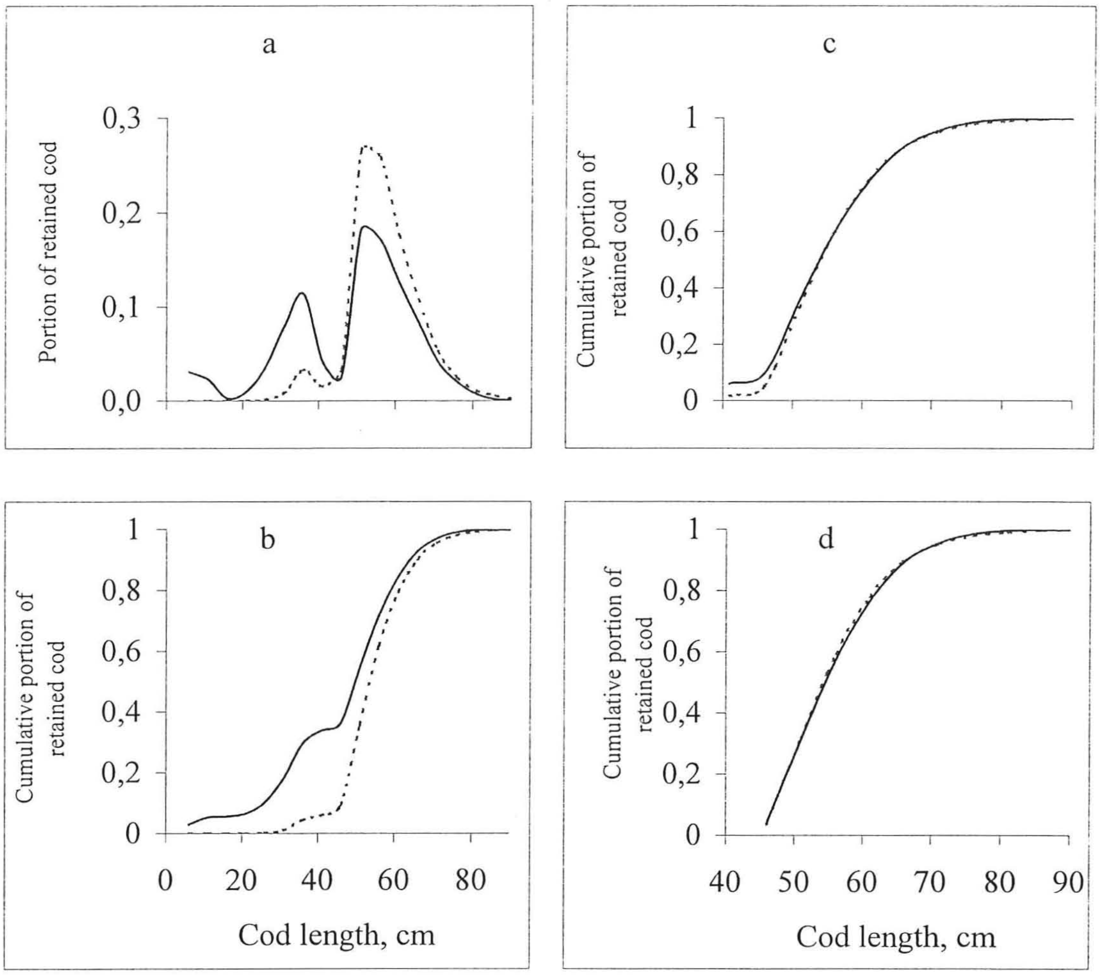

Fig.1. Length series of mean cod catches pr. 1 hour of trawling by PST trawls with 125 mm mesh size, equipped (-----) and unequipped (—) by sorting grids (a), and the cumulative portion of retained fish of different length from 6 (b), 41 (c) and 46 (d) cm

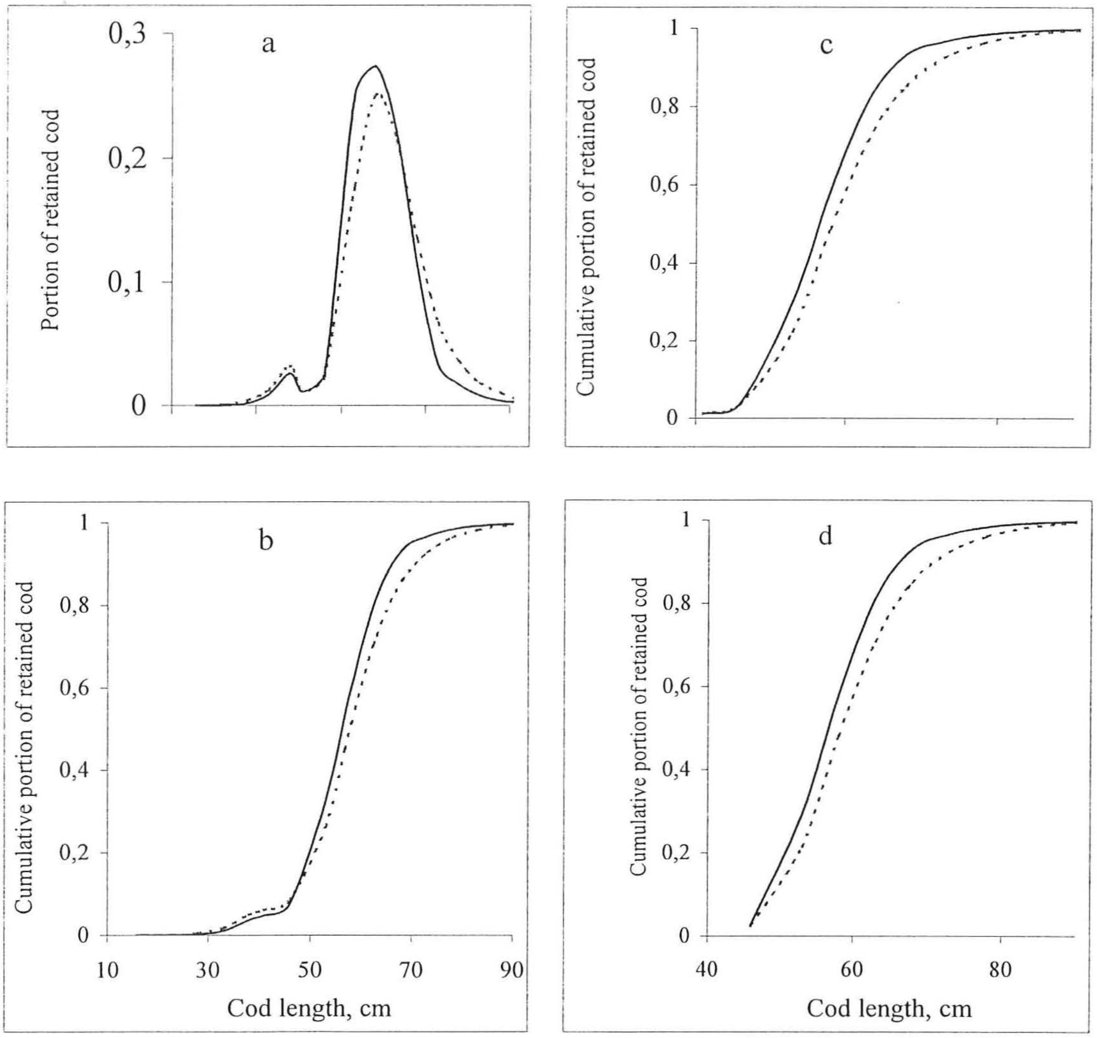

Fig.2. Length series of mean cod catches pr. 1 hour of trawling by PST trawls with 135 mm mesh size, equipped (-----) and unequipped (—) by sorting grids (a) , and the cumulative portion of retained fish of different length from 16 (b), 41 (c) and 46 (d) cm

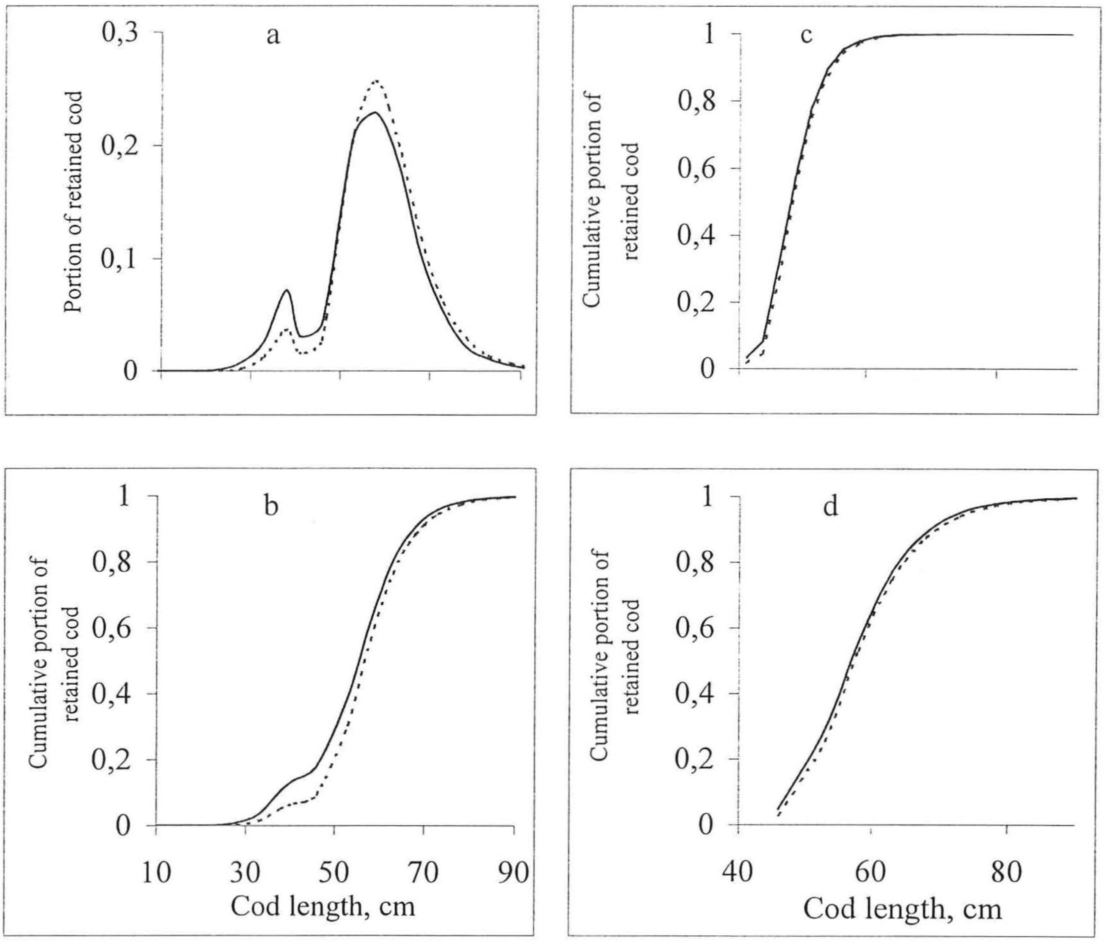

Fig.3. Length series of mean cod catches pr. 1 hour of trawling by SRTM trawls with 125 mm mesh size, equipped (-----) and unequipped (——) by sorting grids (a) , and the cumulative portion of retained fish of different length from 16 (b), 41 (c) and 46 (d) cm

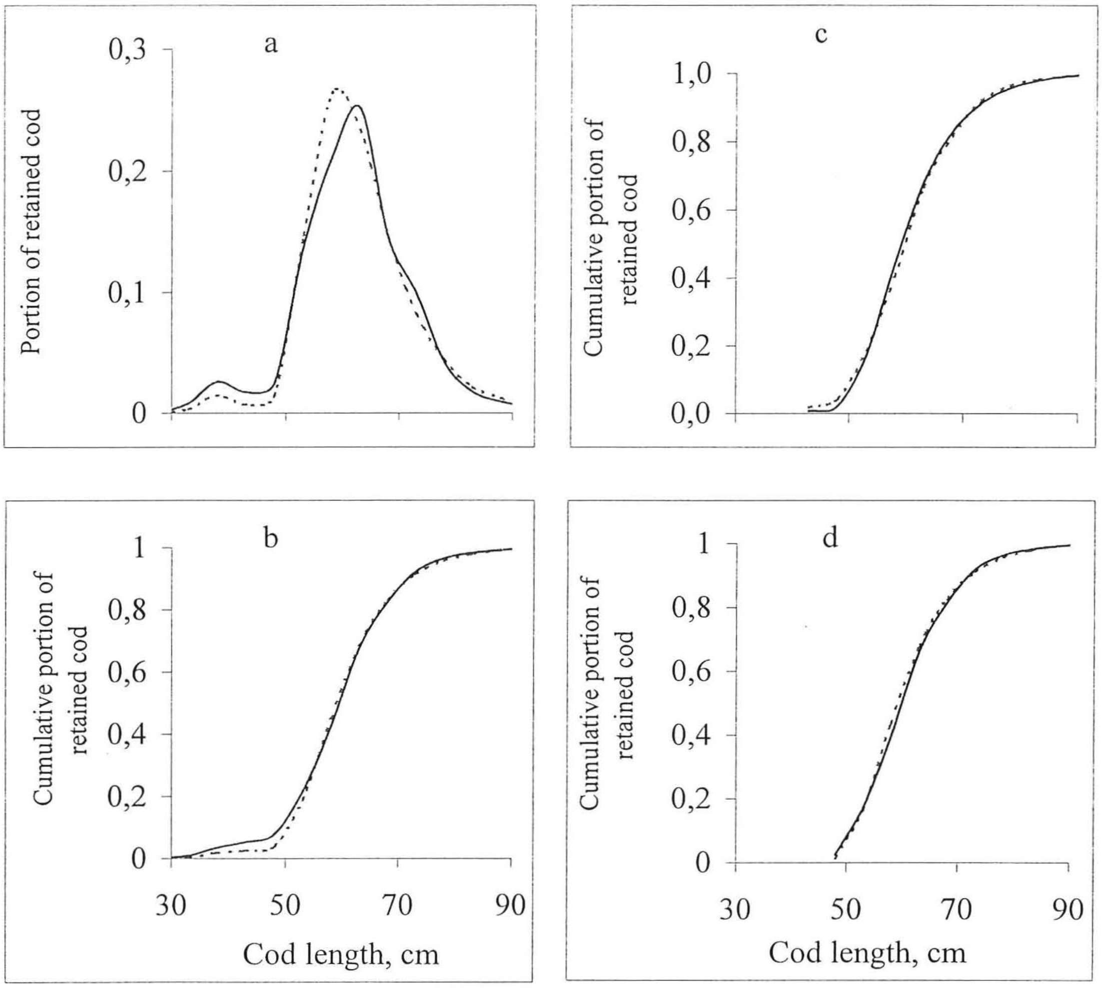

Fig.4. Length series of mean cod catches pr. 1 hour of trawling by SRTM trawls with 135 mm mesh size, equipped (-----) and unequipped (—) by sorting grids (a), and the cumulative portion of retained fish of different length from 26 (b), 41 (c) and 46 (d) cm

9th Joint Russian-Norwegian Symposium

Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

DEVICES TO AVOID BY-CATCH OF BIRDS IN LONGLINE FISHERY[1]

by

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Abstract

Seabirds scavenge baits from the hooks of commercial longlines, resulting in incidental seabird mortality and bait loss. As interactions between seabirds and longline fishing may cause decline in seabird populations and reduced gear efficiency, the potential for solving this problem by means of various mitigation measures has been tested. Four fishing experiments were conducted in commercial longlining in the north Atlantic to investigate the effectiveness of a bird-scaring line, underwater setting and a lineshooter in reducing seabird bycatch during longline setting. These results are reviewed and the performance of the mitigation measures is evaluated. Accidental catches of birds were reduced by all three methods, most clearly by the bird-scaring line that had an efficiency of 98-100%. The experiments also produced a reduction in bait loss and raised the catch rates of target species, which are important incentives for fishermen to employ mitigation measures.

Introduction

Seabirds are accidentally killed in longline fishing (Brothers, 1991; Cherel et al., 1996; Kalmer et al., 1996; Weimerskirch et al., 1997; Løkkeborg, 1998). During setting, they take baits from hooks floating on or near the surface and birds are occasionally caught. The solution of this problem would make longlining a wholly environmentally friendly fishing method as the operation of longline gear has no destructive effect on bottom habitats, vessel fuel consumption is low and ghost fishing or marine mammal bycatch are not regarded as problems. Incidental bycatch of seabirds in longlining is a twofold problem as it also reduces gear efficiency due to the associated bait loss, and a solution to the problem is thus likely to raise fish catches.

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[1] *This paper was originally presented at the 2000 ICES Annual Science Conference, Brügge, Belgium (cp.* S.Løkkeborg.Review and evaluation of three mitigation measures - bird-scaring line, underwater setting and line shooter - to reduce seabird bycatch in the Norwegian longline fishery.

Several mitigation measures capable of reducing the likelihood of seabird bycatches have been described (Brothers et al., 1999). In addition to being efficient, a mitigation measure should be practical and easy to implement in commercial fishing. The greatest potential for solving this problem in the north Atlantic fisheries thus lies in modifications that either make the baited hooks less available to seabirds or devices that deter birds from taking baits (Løkkeborg, 2000).

In the north Atlantic, interactions between seabirds and longline fisheries are regarded merely as a problem for longline efficiency as the species mainly caught, the northern fulmar (*Fulmarus glacialis*), shows no sign of population decline (Lloyd et al., 1991; Løkkeborg, 1998). Four fishing experiments have been conducted in commercial longlining in this region to investigate the effectiveness of mitigation measures that fulfil the requirement of practical applicability (Løkkeborg and Bjordal, 1992; Løkkeborg, 1998; 2000; Løkkeborg and Robertson, in prep.). These were a bird-scaring line to deter birds from the area where the baited hooks emerge in the water, an underwater setting funnel to guide the lines down to a certain depth and a line shooter to set lines with slack (no tension) to increase the sink rate. Here, I review these results and evaluate the performance of the mitigation measures on the basis of their effectiveness in reducing seabird bycatch and bait loss and increasing target fish catches.

Methods

The four experiments were conducted on commercial longliners operating on fishing grounds off the coast of Norway (Table 1). The vessels were equipped with the Mustad autoline system, and used 7 or 9 mm longlines rigged with EZ-baiter hooks and baited with a combination of mackerel and squid baits.

The bird-scaring line was deployed astern during line setting and had floats (gillnet float rings or a punctured buoy) attached to its after end. Twelve 8 cm-wide streamers of yellow tarpaulin were attached at intervals of 5.0 – 5.5 m and increasing in length from 0.5 m at the free end to 3.0 m at the end secured to the stern of the vessel (Fig. 1). The setting funnel tested was designed to set lines underwater so that the baited hooks first emerge in the water out of sight of seabirds (see Fig. 1 in Løkkeborg, 1998). It guided the lines down to about 1 m beneath the surface, the exact depth being dependent on the pitch angle of the vessel. A line shooter is designed to set lines at a speed slightly faster than the vessel's speed during setting. It is placed behind the baiting machine, and ensures that the line is set slack (no tension) into the water.

Each day during the experiments, one fleet of longlines was set using each of the mitigation measures tested. Another fleet of longlines was set as a control without using any mitigation measure. The fleets were set in the morning and retrieved during the day and night, as is typical of this commercial fishery. Most of the lines were set in daylight. During hauling, the numbers of marketable species and seabirds caught were counted for each fleet of longlines.

Bait loss due to seabirds was determined by setting lines without anchors and retrieving them immediately in order to prevent fish and scavengers at the seabed from taking baits. Lines baited with both mackerel and squid were set, and lost baits were counted during retrieval. This test was also carried out on control lines set without any mitigation measure and for lines using the measures tested. Details of the experimental procedure and statistical testing of results have been described in the following publications: Løkkeborg and Bjordal, 1992; Løkkeborg, 1998; 2000; Løkkeborg and Robertson, in prep.

Results

There were significant differences in the numbers of seabirds caught using the various setting methods in all experiments (Table 2). The bycatch of seabirds was reduced by all the mitigation measures tested, most definitely with the bird-scaring line. Seabird catch rates (number of birds per 1000 hooks) ranged from 0.55 to 1.75 for the control lines and from 0 to 0.49 for the lines set when one of the measures was employed. The great majority of the birds caught were northern fulmars.

All the experiments also produced significant differences in bait loss using the various setting methods (Table 3). Fewer baits were lost when lines were set using the bird-scaring line than with the control and the other two mitigation measures. Bait losses for lines set through the setting funnel increased in Cruise no. 2, but decreased in Cruise no. 3.

The catch rates of target species were higher with lines that were set using one of the mitigation measures than with those set without any measure (Table 4). However, the difference in catch rates were significant only in Cruise no. 3 where lines set with the bird-scaring line gave a 32% catch increase compared with the control. The catches consisted mainly of torsk (*Brosme brosme*), but ling (*Molva molva*) and haddock (*Melanogrammus aeglefinus*) were also taken.

Discussion

The problem of incidental bycatch of seabirds in longline fishing should be solved by mitigation measures that are effective in preventing birds from taking baits and that can be implemented in commercial fishing without causing restrictions in or practical problems to fishing operations. In addition, there should be incentives for fishermen to employ such mitigation measures, otherwise compulsory measures will have to be enforced. Various mitigation measures are capable of reducing interactions between seabirds and longline fishing (see Brothers et al., 1999), but they do not all fulfil the above requirements.

Fishing area or seasonal closures and limiting line setting to night time, which have been proposed in other regions, are less acceptable to fishermen operating in the north Atlantic as such restrictions affect profitability. Area and seasonal closures may exclude vessels from operating at attractive fishing grounds. Although studies on feeding activity rhythms have shown that longlines set at or before dawn increase catch rates (see Løkkeborg et al., 1989; Løkkeborg and Pina, 1997; Løkkeborg and Fernö, 1999), line setting at night (in darkness) is impossible during the polar summer. Discarding fish offal during line setting in order to lure birds away from the baited hooks has been shown to reduce greatly the incidental capture of seabirds in the longline fishery in Kerguelen waters (Cherel et al., 1996), but this method is not possible in the north Atlantic where lines may be set continuously for several hours. Weighting the lines to increase the sink rate is a suitable method in manual longlining, but involves practical complications in mechanized longlining. Furthermore, when fishing in deep waters and rough weather, lines are more easily broken if they are weighted. Dyeing the bait to make it less visible has reduced bird interaction (i.e. number of contacts) by about 90% (Boggs, 2000). However, in mechanized longlining the baits are cut during setting, and this approach is therefore feasible only for artificial baits that can be dyed during manufacture. Mitigation measures such as acoustic deterrents, water cannon and magnetic deterrents have not been effective due to habituation or short range (Brothers et al., 1999).

The results reviewed in this paper demonstrate that bird-scaring lines, underwater setting and line shooters are all capable of reducing incidental catches of seabirds in the north Atlantic longline fishery. Seabird catch rates ranged from 0 to 0.49 birds per 1000 hooks for the mitigation measures tested, compared with 0.55 to 1.75 when no measures were employed. The bird-scaring line almost eliminated seabird catches that were reduced by 98 – 100% for lines set using this device. A bird-scaring line with narrowly spaced streamers works as both a visual and physical deterrent that hits birds as they approach the baited line, and a decrease in efficiency due to habituation is therefore unlikely (Løkkeborg, 2000). The results reviewed showed that the bird-scaring line was still efficient at the end of a 12-day period. This mitigation measure is acceptable to fishermen, and it is likely that it can be successfully implemented in the north Atlantic fishery as fishermen in this region frequently use bird-scaring lines without streamers. Furthermore, large increases in catch rates were observed even under conditions of relatively low bait loss due to seabirds compared to the 70% bait loss documented by Løkkeborg and Bjordal (1992). This potential for increased catches and profit is an incentive for fishermen to employ seabird mitigation measures, which is of particular importance for a region where the seabird mainly caught has undergone massive increases of range and number rather than declining (Lloyd et al., 1991; Løkkeborg, 2000).

The underwater setting funnel reduced seabird bycatch by 72% and 92% in Cruises nos. 2 and 3, respectively. Different pitch angles due to the loading of the vessel are the most likely explanation for this difference (Løkkeborg, 2000). Cruise no. 3 was conducted when the vessel was unloaded (i.e. during the early part of a trip) and the funnel was at its maximum depth, whereas Cruise no. 2 was conducted during the last part of a trip when the freezing room (midships/forward) was filled with catch and lines set through the funnel emerged closer to the surface. In this condition, the vessel's wake and the turbulence created by the propeller may bring the baited hooks to the surface. It is thus likely that this measure could be improved by using a funnel whose length can be adjusted with changes in the pitch angle. The performance of the setting funnel can be further improved as my results indicated that some baits are thrown off the hooks as they pass through the funnel (Løkkeborg, 1998; 2000; Table 3). This mitigation measure is practical in use, and of all known measures, underwater setting is the only with the potential to avoid incidental catch of seabirds (Brothers et al., 1999).

Seabird bycatch was reduced by 59% for lines set with the lineshooter. This device does not seem to be as efficient as the bird-scaring line or the setting funnel in reducing seabird bycatch. The lineshooter is believed to increase the longline sink rate and thereby make the baits less accessible to seabirds. However, the results indicate that birds were still able to take baits. The simultaneous use of weighted lines is one possible way of improving the efficiency of the lineshooter, and it is likely that less weight would be needed when the lines are set slack with no tension.

The development of responsible fishing methods through the reduction or elimination of the effects on the ecosystem of current fishing operations has become an important topic. Although the species mainly caught in the north Atlantic longline fisheries has undergone massive increases of range and number, and these fisheries do not seem to be the cause of declines in seabird populations, efforts should be made to solve the seabird bycatch problem for this region too. The solution of the problem would make longlining a wholly environmentally friendly fishing method. On the basis of our current knowledge, this review has documented that of all known mitigation measures, the bird-scaring line is the most feasible and effective one.

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Table 1. Periods and areas of longline fishing experiments conducted to test various mitigation measures to reduced incidental catch of seabirds.

Cruise no.	Period	Area	Mitigation measures tested	No. hooks set
1	17 May, 1992	Barents Sea	Bird-scaring line	812*
2	9 – 22 May, 1996	Mid-Norway	Bird-scaring line, setting funnel	56 700
3	13 – 24 Aug., 1998	Mid-Norway	Bird-scaring line, setting funnel	70 200
4	10 – 20 Aug., 1999	Mid-Norway	Bird-scaring line, line shooter	58 420

*Only bait loss due to seabirds was recorded in this experiment.

Table 2. Numbers and catch rates (number per 1000 hooks in parentheses) of seabirds caught by longlines set with no mitigation measure, bird-scaring line, setting funnel and line shooter. For details of individual cruises see table 1.

Mitigation measure	Cruise no. 2	Cruise no. 3	Cruise no. 4
No measure	99 (1.75)	74 (1.06)	32 (0.55)
Bird-scaring line	2 (0.04)	0 (0.00)	0 (0.00)
Setting funnel	28 (0.49)	6 (0.08)	*
Line shooter	*	*	13 (0.22)

*Not tested.

Table 3. Bait losses (percentage of hooks without bait) of mackerel and squid bait for longlines set with no mitigation measure, bird-scaring line, setting funnel and lineshooter.

Mitigation	Cruise no.1		Cruise no.2		Cruise no. 3		Cruise no.4	
measure	Mackerel	Squid	Mackerel	Squid	Mackerel	Squid	Mackerel	Squid
No measure	69.9	18.2	19.5	21.1	30.9	22.5	14.5	1.6
Bird-scaring line	26.3	13.0	13.1	17.2	15.2	15.6	2.1	0.9
Setting funnel	*	*	22.7	26.0	26.6	16.7	*	*
Line shooter	*	*	*	*	*	*	12.7	3.7

*Not tested.

Table 4. Total catches of target fish species for longlines set with no mitigation measure, bird-scaring line, setting funnel and lineshooter. The catches are given in number in Cruise nos. 3 and 4, and in kg in Cruise no. 2.

Mitigation measure	Cruise no. 2	Cruise no. 3	Cruise no. 4
No measure	4895	5434	2461
Bird-scaring line	5549	7173	2805
Setting funnel	5218	6360	*
Line shooter	*	*	2712

*Not tested.

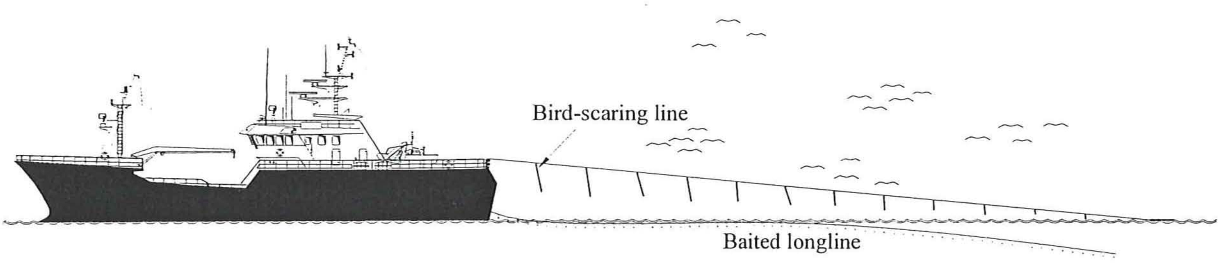

Figure 1. The bird-scaring line. (Redrawn after Løkkeborg, 1998.)

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Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

PROPOSAL FOR A CHANGE OF A MINIMAL LANDING SIZE FOR CAPELIN

by

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Abstract

Capelin is one of the most abundant commercial species in the Barents Sea. Its importance as a prey for other species and as a commercially harvested species is enormous. Drastic variations of its abundance take place under both the impact of nature-related factors (predation, environmental conditions, availability of food) and the fishery.

Precautionary approach currently applied to the management of fisheries is implemented to ensure sustainable harvesting of resources with an aim of securing their biological safety in view of natural stock dynamics. In this context it is topical to continue actions aimed at improving the regulatory measures for capelin fisheries so as to most efficiently provide a sustainable recruitment to this stock.

Capelin fishery is primarily regulated by TACs, as well as by measures concerning mesh size, size limits of fish, bycatches and area closure. Analysis of the size-age structure of capelin stock in various years has shown that the minimal landing size for capelin (11 cm) currently applied in the fishery is not consistent with a need for biologically safe harvesting of the resource.

This paper contains proposals to advance the methods for minimizing the impact of the fishery on recruitment. To this end is proposed to change the minimal landing size for capelin from 11 cm to 13 cm (total length). A proposed change would in the future allow to remove a number of restrictions incorporated in the fisheries regulations regarding seasons and areas of the fishery.

Introduction

Capelin is one of the most abundant species in the Barents Sea. It is an important link in the ecosystem, and simultaneously a valuable commercial species. An improvement of the measures for rebuilding and stabilization of the Barents Sea capelin stock is required to ensure stability of resources available to the fisheries.

Populations of fish migrating over vast areas for feeding and having large capacity for rebuilding show well pronounced yearly fluctuations. The abundance of strong year classes may 60 and even 100 times be more than the abundance of poor year classes (Zemskaya, 1964). This is in full measure relevant to capelin, a large amplitude of variations of its abundance resulting in a considerable increase or decline of the total stock is a specific feature. As species with a short life cycle capelin has a large potential for rebuilding. However, sharp variations of recruitment produce a significant impact on the entire capelin stock.

This necessitates a revision of a number of established approaches to the management of capelin fishery. (Ushakov, 2000; Tereshchenko, 2000).

Materials and methods

For computations biological data on capelin for 1968 to 2000 collected by PINRO have been used. Data for 45443 fish from samples collected over January to June and 33894 fish – from July to December provided by both scientific research vessels and commercial vessels were analyzed.

For computations only samples collected in winter/spring season when the maturity stage of fish could be precisely determined were used.

Identification of maturity stage was done on the basis of a 6-point scale. Regarded as mature were fish which had clear signs of maturation in a pre-spawning period (from maturity stage 2-3 and further).

It should be noted, that the maturity scale for capelin is lacking stage 2-6 (fish which omit spawning). In field analysis it is often identified as stage 2. This stage is typical of large mature capelin with the length of 15 cm and more. To identify the maturity stage in such fish a histological analysis is required which is rather difficult to do at sea. Therefore, in computations these fish have been included into the category "immature", stage 2.

History of the fishery and establishment of the minimal landing size

In 70s-80s, the yearly catches of capelin were as large as several million tons. A record-high yearly catch was obtained in 1977-1978 – 2.6-3.0 mill. t (Table1).

For the first time (in late 70s – early 80s) high natural mortality of capelin coupled with heavy fishery became a reason behind distortions in the age structure of the spawning stock, decreased recruitment and, as a consequence, decline of the stock and catch (Ushakov, 1989). Eventually this led to a complete closure of the fishery from the autumn of 1986 to 1990. For the second time (late 80s – early 90s) a very strong year class of 1989 contributed to a short-term increase of the stock. However, a natural decline of this year class led to a further sharp decrease of the stock and closure of the fishery (Table 1).

Capelin fishery was reopened in 1999 after a 5-year period of closure and notable increase of the stock. Computations of the total allowable catch are based on the minimum safe level of the spawning stock (B_{lim}) of 200 000 t. Such a level of the spawning stock is in essence a limit beyond which no exploitation can be permitted and does not assure the production of strong year classes (Ushakov, 2000).

Except the periods of a complete closure, capelin fishery was based on feeding, wintering and pre-spawning aggregations and there was no fishing allowed during 4 month in summer (from May to August). However predation, primarily by cod, takes place the whole year round and is particularly heavy in winter and spring ("Cod of the Barents Sea ...", 1996). Therefore, capelin is a highly vulnerable species, an easy prey for predators and target for the fishery, a continuous monitoring of the status and dynamics of the stock is required as well as restrictive measures as appropriate.

In late 70s the issue of establishing a minimal landing size was explored by both Russian and Norwegian researchers who considered two basically close options.

1. It was established that capelin began to mature at age 2, being ca.11 cm long (Fig. 1).

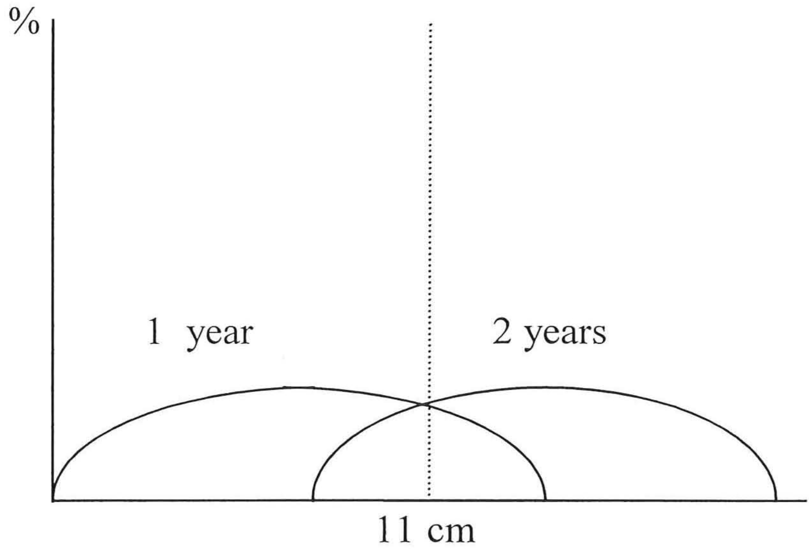

Fig. 1. The 1978 model for identification of the initial point of maturation in capelin (simplified version)

2. A mean length at which sex could be identified and fish could be regarded mature was determined. However, the problem consists in that signs of sexual dimorphism in capelin can be identified as early as in its first year when the fish is 9-10 cm.

Finally, at a meeting of the Soviet-Norwegian Working Group in Bergen (1978) it was proposed to set the minimal landing size for capelin at 11 cm. Since 1979 this measure has been included in the Fisheries Regulations.

Analysis of management measures

To ensure high productivity of the stock and optimal demographics of the spawning stock and stabilization of its abundance a proper management of the fisheries and protection of recruitment are required. To attain these objectives a complex of measures should be applied: TAC, closure of fisheries by season and area, minimal landing size, allowable by-catch of undersized fish and minimal mesh size in a fishing gear. These regulatory measures were put in place by the Joint Soviet-Norwegian Fisheries Commission in 1978.

Let us review each of the above measures individually in context of conservation of recruitment (immature part of the stock).

To establish a TAC a possible catch in number by age is computed and only after that a total allowable catch is derived, which is undeniably correct. Regulation of catch by weight without numbers of fish subject to harvesting taken into account could lead to overfishing (Nikolsky, 1958).

However, estimates of allowable catch can not in practice coincide with the actual catch taken in the fishery. A decrease of the mean weight of fish in catch by a few grams (compared to estimated) would lead to an increase of the numbers of fish captured by hundreds of thousands fish. In practice it is not possible to avoid overfishing in terms of numbers of fish under intensive fishery. A considerable part of fish, small in particular, escapes through the trawl mesh and die. The reliability of fisheries statistics is also questionable. In addition, such factors as discards, sorting of fish at sea, by-catch of capelin in other fisheries or enmeshment are not taken into account.

Seasonal and areal closure of fishery is an additional measure which enables to restrain the impact of the fishery on juveniles in winter and spring (no fishing is permitted north of 74° 00'N, and in summer, when the growth of biomass reaches its peak. However, it is difficult to separate mature and immature capelin when they are fished in the foraging areas in autumn and in wintering areas in winter/spring. And it is spring only when the capelin split into spawners and those remaining in wintering areas, it is possible to avoid considerable by-catches of immature fish in coastal areas.

At the same time, any territorial division of the sea has its weak points. For example, according to the Fisheries Regulations in the winter/spring period it is allowed to fish capelin south of 74°00' N. A relevant question arises why it is 74°00'N rather than 74°10' or 73°40'? This regulation is based on the long-term mean data on the distribution of juveniles. However, there could be a high probability of that depending on the hydrographic conditions (warm or cold year) or varying times of massive spawning the area of distribution of fish may change and not fit one or another "territorial scheme". Fig. 2 shows changes in the distribution of juveniles at age 1+ between years. In one and the same season they were distributed over different areas, both to the north and to the south of 74°00' N.

For example, in January 2001 at 73° 00'N individual fishing vessels had from 20% to 80% juveniles (less than 11 cm) in their catches.

On the other side, in the beginning of January the existing prohibition of the fishery north of 74° 00'N hampers a search for commercially important aggregations of wintering fish, though over that area individual sites with aggregations of large mature capelin suitable for directed fishery could well be found.

Mesh size in a fishing gear could not serve as an absolute tool enabling capture of fish of specified size because there are significant differences in selectivity of trawl and purse-seine.

Practical experience has shown that capelin by virtue of its morphological structure is highly subject to "enmeshing". Netting of the trawl and bag get heavily clogged with fish, which results in a reduced selection by trawl. Capelin catches are normally measured in tens of tons, and observations have shown that the size distribution of fish is not the same throughout the entire length of a trawl bag. With the catch of 30-40 t by-catch of undersized capelin (less than 11 cm) in codend of a trawl bag was 2-3% while in was as big as 30-40% in the outlet.

Anyway, immature capelin are either contained in catch or pressed out through the mesh and become non-viable.

It is not possible to select such a mesh size in trawl so that to completely eliminate by-catch of undersized fish and at the same time assure a catch of desired level.

Minimal landing size is probably the most effective juvenile fish conservation measure. On the basis of by-catch of undersized fish a variety of conservation actions could be taken such as closure of fishery in certain areas, change of a fishing gear etc. Minimum landing size is applied throughout the entire permitted period of fishery irrespective of its geography. This removes the need for constant "territorial" restrictions of the fishery, as the by-catch of undersized fish in areas of massive concentration of juveniles would exceed the allowable limit and for this reason the fishery there would have to be closed.

Currently, it is not allowed to fish for capelin in the autumn season, however, this fishery is likely to be re-opened in the nearest future. A considerable portion of catch will in this case be made up by recruits.

Let us imagine the situation when in January, during fishery on wintering aggregations, up to 20% by weight of catch are made up by one-year-olds (10-12 cm length)which are of no commercial value and are, at best, sorted out for fish meal. At the same time, the portion of undersized (below 11 cm) fish will not exceed 10% by the amount of fish in catch, thus being normal.

In case of resumption of autumn fishery the suggested new landing size would be an efficient tool which would allow to avoid mass catching of young fish.

Main approaches to defining minimum landing size

Minimum landing size for commercial fish species was introduced in Russia as far back as 1897. Since that time it had been changed several times depending on the current situation. The objective of these changes was to select the best biological parameters of fisheries objects. *Thus, changes of minimum landing size must be viewed as a natural process rather than an extraordinary measure.*

There have been different approaches to the definition of the minimum landing size. Some researchers based the age starting from which a yearclass should be harvested on the age-dependent changes in natural mortality (Lukashev, 1964).

For long-living species, the relationships between age structure, mean weight, fecundity and food consumption are considered (Bervald, 1961).

A number of authors believed that the productive capacity of a spawning part in a fish stock, which assures its well-being, is an ability which has developed in philogenesis, and mature fish play a decisive role in production of abundance. In accordance with natural biological features in fish developed historically harvesting of stocks should be such as, in the first place, not to undermine their productive capacity and to provide the possibility for juveniles to attain maturity (Bryuzgin, 1972).

G.V.Nikolsky (1958) for salmonids, sturgeons, minnows and a number of other species formulated conditions for a catch contingent as follows: "A harvest of fish of such a size is admissible whereby a maximum high quality production is assured; required recruitment and, hence, sufficient number of spawners is secured; a harvest of fish is possible when they have acquired a high value as food and when they have already used the available food supply".

L.I. Berdichevsky (1960) believed, that a minimal landing size which establishes a lower limit for the quality of fish (age, weight, size) allowed for harvest should be the basis of Fisheries Regulations. Mesh size in fishing gears is established according to this minimal size. Specific biologically justified landing size could generate great economic benefits due to increased mean weight and enhanced condition of fish, better quality of raw material.

In any event, most researchers agreed that when establishing a minimum landing size one needs to proceed from the concept generally recognized in marine biology that fish should not be harvested before they have attained maturity and spawned, at least, once in their life time. Fish show the largest weight growth and best condition after first spawning rather than when immature. A harvest of fish at an older age would let them most fully use their productive potential and natural food supply available in water bodies.

A majority of methods used to establish the minimal landing size and referred to in the literature were applied to species with a long life cycle.

It is obvious that only a multi-age structure of the stock can ensure the succession of generations and stability of production. The capelin stock should also be harvested with due regard for rebuilding and maintaining a multi-age structure of the stock (Luka, Ushakov, Ozhigin *et al.,* 1991).

However, from analysis of these approaches a difficulty which arises is that which of the methods should be selected specifically for capelin.

Firstly, age and length in capelin are not always strictly related. Size distribution by age is very extended with a large overlapping interval: for example, at age 1 year the length of fish varies from 6 to 14.5 cm, at age 2 years from 9 to 18.5 cm (Gjøsaeter, Dommasnes, Røttingen, 1998). Besides, sexual dimorphism also plays an important role (at the same age males are, as a rule, larger than females). Secondly, maturation is rather related to length than to age (Anon.,1985).

Thirdly, high post-spawning mortality of capelin makes it more difficult to apply the approach stipulating that fish must spawn at least once in its life time.

Variations of abundance of year classes and natural mortality, complexities associated with assessment of numbers of youngest and oldest age groups lead to the difficulty of applying an "age" approach to capelin. It is more appropriate to operate with fish size only.

Comparative analysis of existing and proposed minimal landing size

Now a key question arises, how an optimal minimal landing size for capelin should be defined, and what fish should be regarded as juveniles – with size of 11cm, 12 cm or 16 cm?

An approach to define the minimal landing size which was suggested in 1978 had its flaws. At age 2 years only single individuals of capelin are mature. Besides, immature capelin at age 1 year can be as large as 11 cm and more; the lack of possibilities technically to separate spawners from immature fish in acoustic surveys was also a source of error in assessment of the spawning stock and mortality.

In 1979 it was suggested to separate the spawning stock from immature part based on the fish size. Length-at-maturity, at which more than a half of all fish become mature, was assumed at 13.5 cm (Anon., 1985).

This is in agreement with the opinion expressed by a number of researchers (Prokhorov, 1965; Luka, Ozhigin, Panasenko, 1986), who at various times noted, that the majority of capelin became mature at age 2-3 years at length 13-14 cm. Norwegian researchers take the length at 50% maturity to be 13.8 cm for females and 14.5 for males (Gjøsaeter, 1998).

In trawl-acoustic surveys capelin of more than 14 cm are referred to the spawning stock (Gjøsaeter, Dommasnes, Røttingen, 1998). So, a limit for the length at 50% maturity has long been established and used. However, a minimal landing size (11 cm), established in 1978 and included in the Russian and Norwegian Fisheries Regulations remains to be effective. An issue of minimal landing size was not so acute in the years when the stock was at a high level, and the focus was on establishing a TAC, as well as at times of severe decline of the stock, when the fishery was closed.

To establish the relationship between maturity and length of capelin an additional review of all materials available was undertaken separately for spring and autumn season. A comparison of diagrams has shown that both in the periods of severe decline and in the periods of stock recovery size-at-maturity was practically the same. Therefore, this paper presents data pooled by year but split between spring and autumn. Fig. 3 shows the results obtained with a ratio between immature (A), stage II, and mature (B) fish, stage III to VI.

To illustrate the number of fish in each size group in Fig. 3 a ratio between mature and immature fish in a sample is given; in Fig. 4 - proportion of mature and immature fish in each size group. Farthest to the right part of the diagram in Fig. 4 should be neglected because capelin of more than 21 cm occur only as single individuals.

So, for each size group a ratio between fish participating and not participating in the spawning is given. From Fig. 4 it is clear that at length 11 cm the proportion of mature fish is less than 10% while at length 13 cm more than a half of all fish are mature.

A difference in admissible by-catch of juveniles for 11 cm minimal landing size and 13 cm minimal landing size, shown in Fig. 3, suggests that in the latter case (13 cm) admissible by-catch of juveniles would be 2 times less. The proportion of mature fish below 13 cm (Fig.3) is about 10% of the total number, which would allow to leave a possible by-catch of undersized capelin equal to this percentage.

Results obtained are consistent with the findings from research done before.

In Figs. 5-6 a ratio between mature and immature capelin in the autumn season is shown. These data are more of an informative nature since it is difficult to identify reliably a maturity stage in fish in autumn. As seen in Fig. 5 a proposed minimal landing size would not have any significant effect on the proportion of mature (i.e. fishable) capelin and would enable to considerably reduce by-catch of juveniles. Proceeding from the said above, it is proposed to set the minimal landing size for capelin at 13 cm leaving the allowable by-catch of undersized fish (less than 13 cm) unchanged, equal to 10% in number.

Conclusions

The existing minimal landing size for capelin (11 cm) is not sufficiently justified from a biological point of view and not in line with a need for biologically safe harvesting of the stock.

Most lucrative for the fishery are capelin of 14-15 cm and more. By-catch of smaller fish (11-12 cm), although allowed now, only deteriorates marketable state.

Implementation of the proposed minimal landing size for capelin (13 cm) would contribute to conservation of the recruitment, enhancement of total and spawning stock and, hence, to sustainability of the fishery.

In the future this measure would allow to remove some of the territorial or temporal restrictions in the fishery for capelin in the Barents Sea which would secure more freedom for the fishing fleet in searching for fish and fishing.

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Table 1. Details of the stock and catch of capelin in 1972-2001 ('000 tonnes)

Year	Stock		Yearly TAC	Total catch				
	Total	Spawning		Spring		Autumn		Total
				Russia	Norway	Russia	Norway	
1972	6600	2727		24	1208	13	347	1592
1973	5144	1350		34	1078	12	213	1336
1974	5733	907		63	749	99	237	1149
1975	7806	2916		301	559	131	407	1440*
1976	6417	3200		228	1252	368	739	2587
1977	4796	2676		317	1441	504	722	2987*
1978	4247	1402		429	784	318	360	1915*
1979	4162	1227	1800	342	539	326	570	1783*
1980	6715	3913	1600	253	539	388	459	1648*
1981	3895	1551	1900	429	784	292	454	1986*
1982	3779	1591	1700	260	568	336	591	1760*
1983	4230	1329	2300	373	751	439	758	2358*
1984	2964	1208	1400	257	330	368	481	1478*
1985	860	285	1100	234	340	164	113	868*
1986	120	65	120**	51	72	0	0	123
1987	101	17	0	0	0	0	0	0
1988	428	200	0	0	0	0	0	0
1989	864	175	0	0	0	0	0	0
1990	5831	2617	0	0	0	0	0	0
1991	7287	2248	1100	159	528	195	31	933*
1992	5150	2228	1099	247	620	159	73	1123*
1993	796	330	600**	170	402	0	0	586*
1994	200	94	0	0	0	0	0	0
1995	193	118	0	0	0	0	0	0
1996	503	248	0	0	0	0	0	0
1997	909	312	0	0	0	(0.5)	0	(0.5)
1998	2056	932	0	(2)	0	(1)	0	(3)
1999	2775	1718	80**	32	48	(22)	0	102
2000	4273	2098	435**	95	278	(27.6)	0	401*
2001***	4788	2879	630**	180	380	0	0	560

In brackets – in the period of monitoring by Russia

* Catch in the autumn season by other nations included

** Spring season only

*** 2001 – projection of the stock status and provisional catch

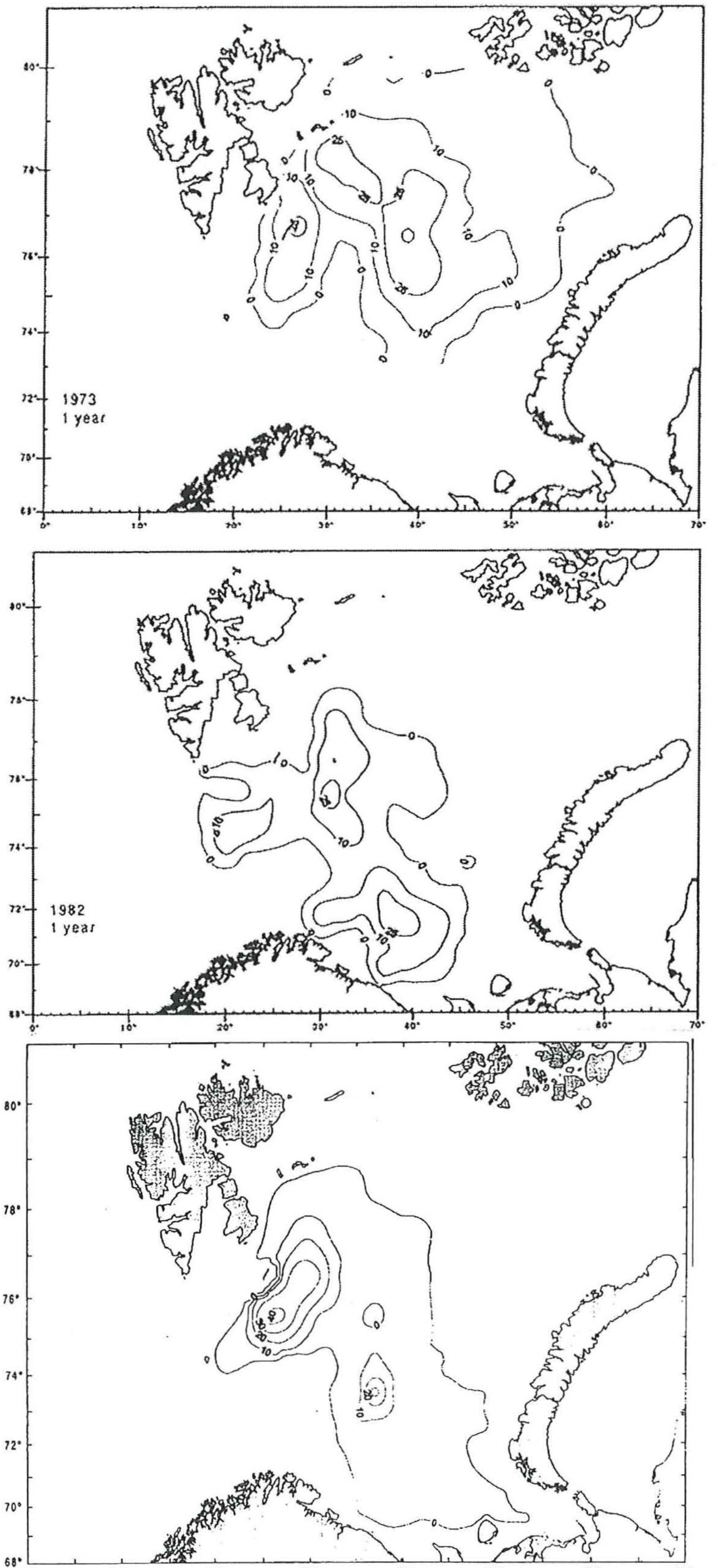

Fig. 2. Distribution of capelin at age 1+ in autumn of 1973, 1982 and 1998 (t/mile^2)

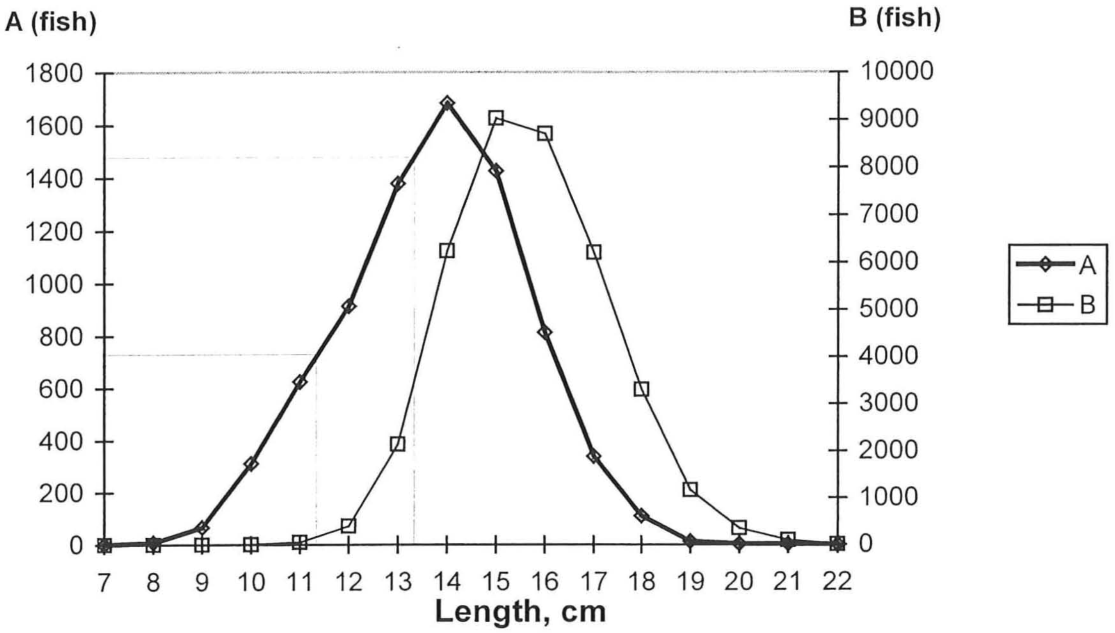

Fig. 3. The number of immature (A) and mature (B) capelin in the total number of fish examined in winter/spring.

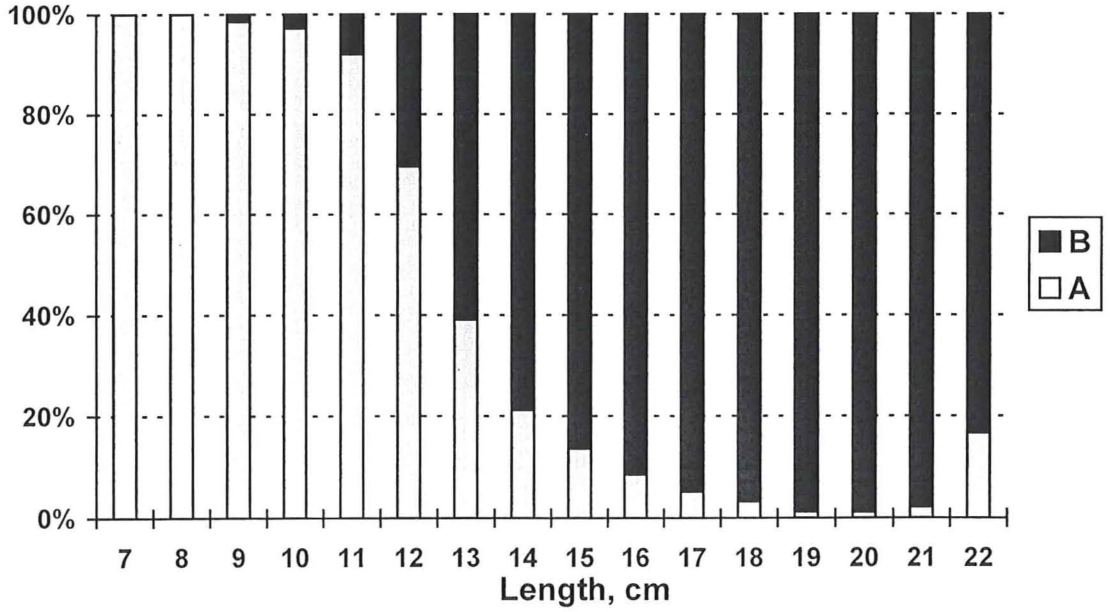

Fig. 4. Proportion (%) of immature (A) and mature (B) capelin in each size group in winter/spring.

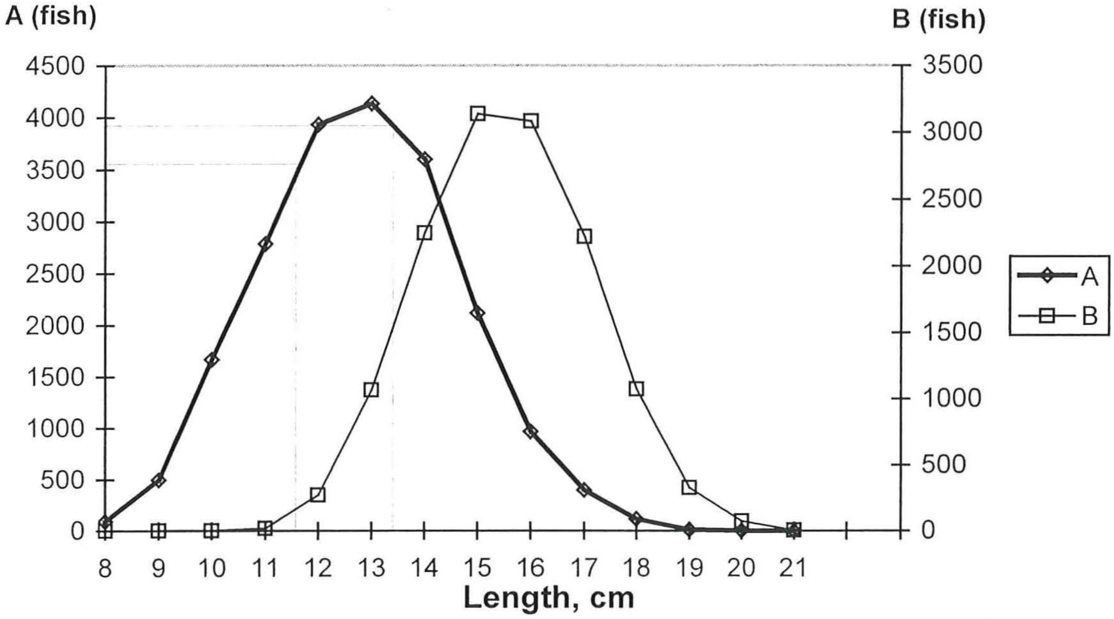

Fig. 5. The number of immature (A) and mature (B) capelin in the total number of fish examined in autumn.

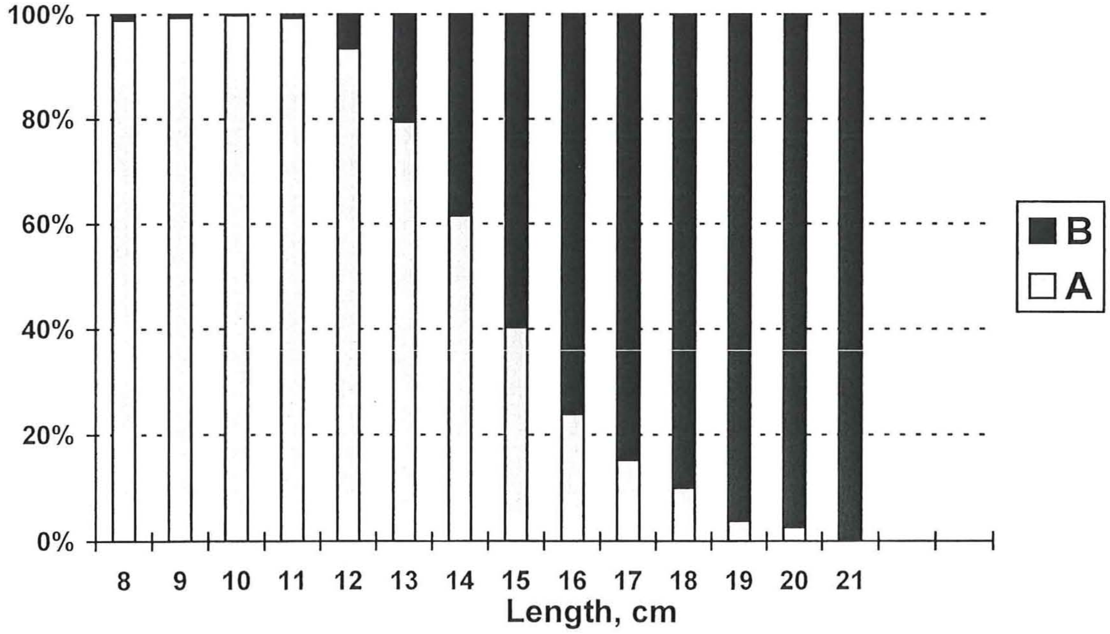

Fig. 6. Proportion (%) of immature (A) and mature (B) fish in each size group in autumn.

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SURVIVAL EXPERIMENTS WITH COD TRAWLS: SUMMER 2000

by

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Abstract

Survival trials with gadoid fish sorted out from a demersal trawl by sorting grids and mesh selection, were carried out in August 2000 off the coast of East Finnmark. The experiments offered no evidence that the sorting grid in cod trawls results in higher mortality rates in sorted undersized gadoid species than trawls that lack a sorting grid. Indeed, the results suggest that haddock mortality rates are lower when a grid is utilised. No mortality was observed in cod or saithe in the course of these experiments. These species appear to be able to tolerate selection via both meshes and grids. A certain degree of uncertainty with regard to the experimental methods employed, however, means that the trials will be repeated in order to obtain more certain results for haddock.

Introduction

In August 2000 the Marine Research Institute (IMR) carried out a series of survival trials on fish (cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus* and saithe (*Pollachius virens*)) that had escaped from a cod trawl either with or without a sort grid. The trials were financed by the Research Council of Norway, by the IMR itself and with significant support from the Norwegian Directorate of Fisheries through its "Fishing Trials and Guidance Scheme".

In the early nineties a number of survival trials were performed on cod, haddock and saithe escaping from a trawl via a grid or through the meshes of a cod-end. All these trials showed that the mortality in cod and saithe was virtually zero, and was low (about 5%) in haddock (Jacobsen, 1994; Main and Sangster, 1991; Suuronen et al., 1995). A further series of Norwegian survival trials led by the IMR was also carried out off the coast of Finnmark, using chartered cod trawlers and commercial trawling gear. Tests were made of both sorting grids and ordinary trawls with 135 mm meshes in the codend. The Norwegian results were in complete agreement with what had been found by other countries (Soldal and Isaksen,1993; Soldal et al., 1993; Soldal and Engås, 1997).

Following the announcement of compulsory use of sorting grids in demersal trawl in the cod fisheries north of 62°, voices were raised within the trawling industry to the effect that selection by means of grids resulted in fatal injuries to fish. This claim was repeated during a one-day seminar on the use of sorting grids in cod trawls, organised in Bergen by the Directorate of Fisheries on November 23, 1999. It was claimed that the survival trials organised by the Marine Research Institute in 1991 had not been carried out under realistic conditions. It was claimed that during practical commercial fishing operations, the effects of grid selection on fish would be significantly greater, and would have fatal consequences.

Following this meeting it was decided that the IMR ought to carry out new survival trials. These were to be performed under as realistic conditions as possible. The Norwegian Fishing Boat Owners' Association was drawn into the planning process, in order to ensure that scientists and fishermen would be in agreement regarding the meaning of "realistic conditions" before the trials started.

Trials: set-up and methods

The trials were carried out off the Varanger Peninsula from August 3 to 25, 2000 (Figure 1). Five days before the survival trials themselves commenced, three chartered stern trawlers began to fish within the designated test area. The boats used their own bottom trawls with sorting grids (Sort-X). The vessels' skippers themselves decided where to trawl within the trial area, towing length, etc. The only requirement on the part of the IMR was that hauls should be made within the designated area and that fishing was to be carried out under normal commercial conditions. The underlying intention was to simulate a normal fishing situation on

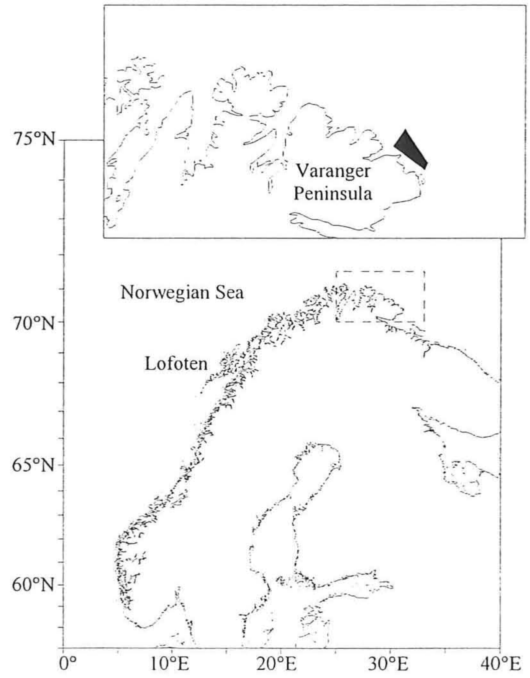

Figure 1. The trial area off the Varanger Peninsula

a fishing ground with several boats fishing at the same time. This was done in order to ensure that the fish in the area would experience the same level of "stress" as on a normal fishing ground where several boats are fishing, and in order to ensure that a certain proportion of the fish would pass through the sorting grids several times before the start of the survival trials.

The trials as such started on August 8 on board "Myrefisk II". The rigging of the trawl with its cover net and collection cages is shown in Figures 2, 3 and 4. Fish that passed through the sorting grid or the meshes of the cod-end were collected by a fine-meshed cover net stretched over the grid or around the cod-end. At the end of the cover net was fastened a cage of fine-meshed netting stretched over metal rings. Fish for a control group were also collected by a collection cage mounted directly on an extension of the trawl. These fish had passed through neither meshes nor grid. Hauls were made at depths of 60 - 90 m.

At the beginning of each trawl haul, the collection cage was left open at each end so that the fish that escaped from the trawl could pass out freely. After towing for about one hour the cages was closed at one end by means of an acoustic release unit, and escaped fish began to be collected. The trawl hauls were thus as long as they would have been during normal commercial fishing operations. During the whole process, the underwater vehicle FOCUS (Figure 9) was used to study the configuration of the trawl, the quantity of the catch and how the cover net and the cage behaved in the sea. After the cage had been closed, the quantity of fish entering the cage was checked. When the number of fish was regarded as sufficient (usually after five to ten minutes), the cage was released from the trawl and its front end was closed. An acoustic release was also employed here to release and close the cages (Figures 2 and 7). The cages were raised to depths of 40 - 50 m and anchored on the fishing grounds (Figure 5). An active radar sonde was mounted on the marking buoy in order to track the cages during the next few days.

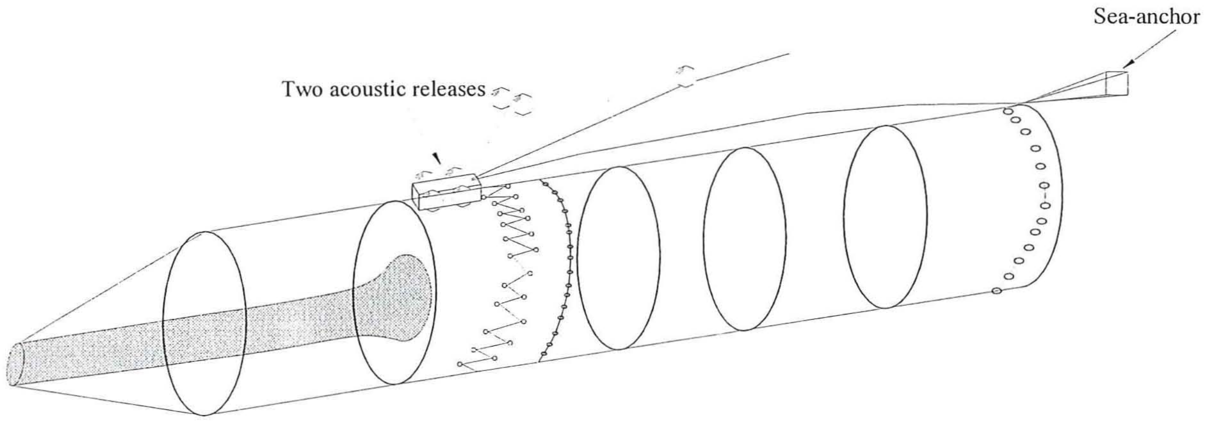

Figure 2. Arrangement of the cover net and collection cage for collecting fish that had escaped through the meshes of the cod-end.

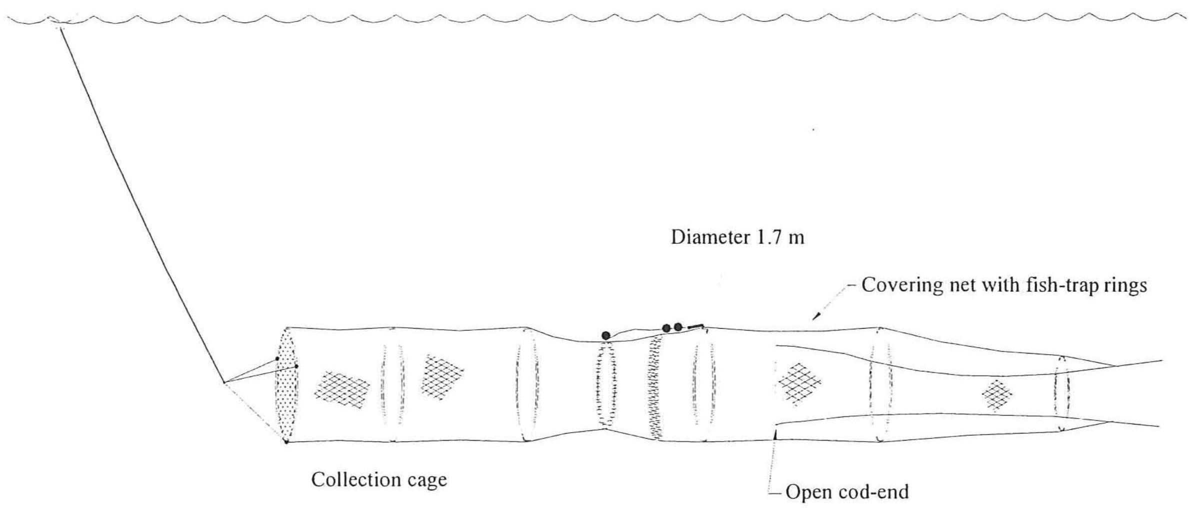

Figure 3. Arrangement of the cage for collecting the control group. The cage is secured to the extension, and is towed with the cod-end open.

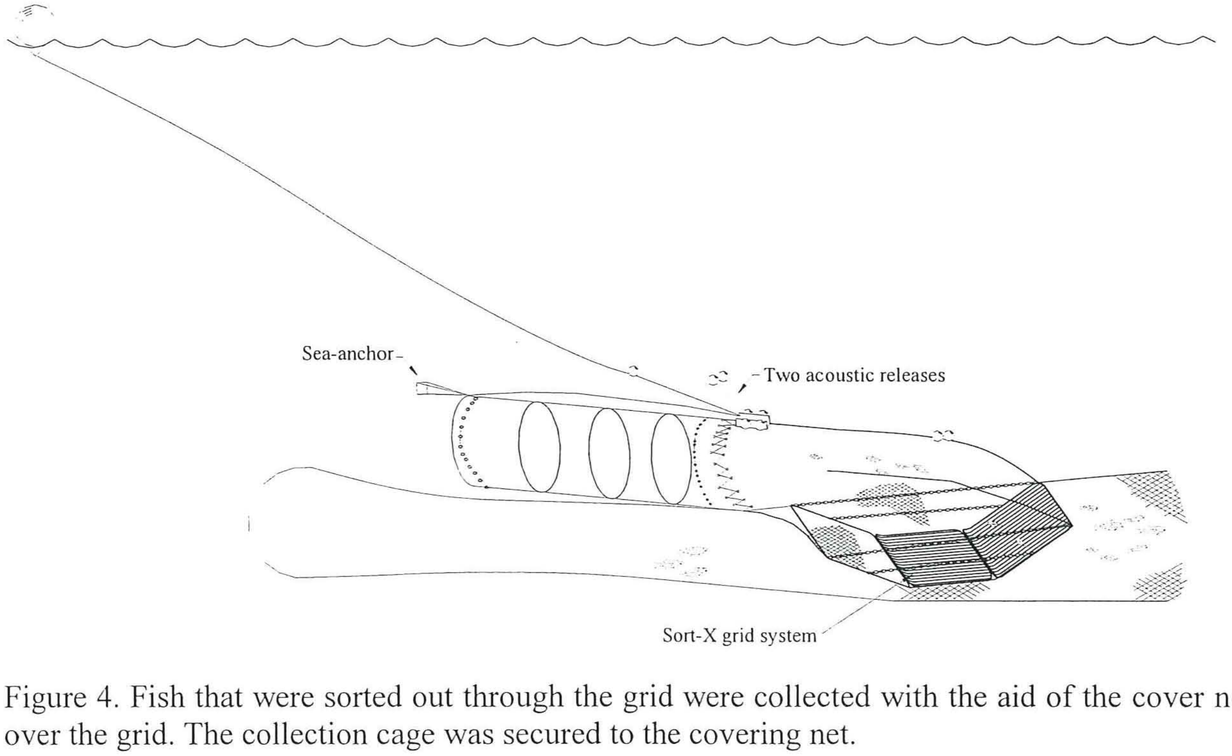

Figure 4. Fish that were sorted out through the grid were collected with the aid of the cover net over the grid. The collection cage was secured to the covering net.

Immediately after the cages had been anchored they were inspected by underwater camera in order to check that they contained sufficient fish, and that they were closed at both ends. The cages were subsequently inspected every second day until they were recovered after seven days in the sea, when the number of live and dead fish of each species, the size of the fish and the degree of injuries suffered were registered.

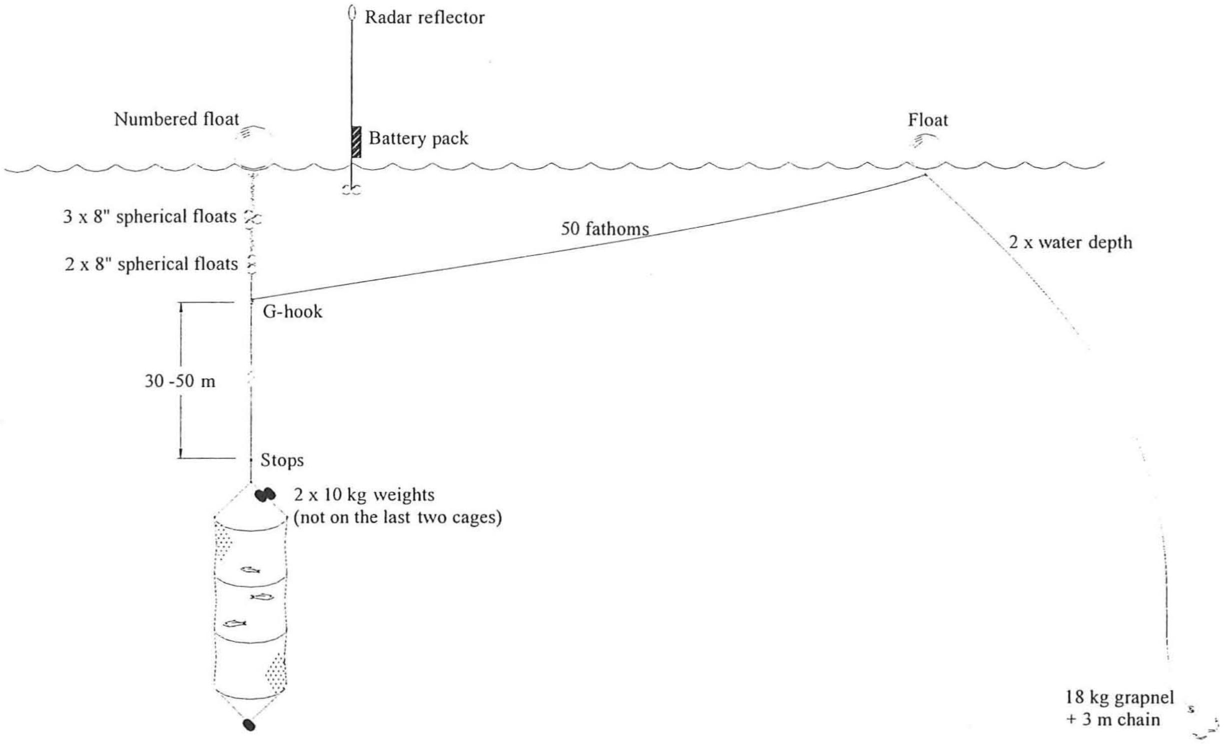

Figure 5. The cages were anchored on the fishing ground at depths of 40 - 50 m. The fish were observed by means of an underwater video camera every second day for a week.

Results

There was no mortality in cod or saithe during the trials. Haddock mortality was higher, and varied widely from cage to cage within the same category of trials (Table 1). Rates of morta-lity in the control and grid-selected group were virtually identical, with means rates of 8 and 10% respectively, while mortality in the mesh-selected group was considerably higher (28%).

Visual observations of the fish in the cages at the end of the trials showed major injuries on the skin of haddock (Figure 11). The scale layer was partly worn off in large areas, particularly along the lateral line organs and at the tail. There were also major wear injuries on

Table 1. Mortality rates in haddock (*Melanogrammus aeglefinus*), cod (*Gadus morhua*) and saithe (*Pollachius virens*) in the observation cages.

	Control			**Grid selection**			**Mesh selection**		
Cage no.	Total no. of fish in cage	No. of dead fish	Mortality (%)	Total no. of fish in cage	No. of dead fish	Mortality (%)	Total no. of fish in cage	No. of dead fish	Mortality (%)
Haddock									
1	194	23	**11,9**	64	1	**1,6**	45	4	**8,9**
2	74	3	**4,1**	85	17	**20,0**	139	70	**50,4**
3	133		**0,0**	40	4	**10,0**	33	8	**24,2**
Mean	133,7	13,0	**5,3**	63,0	7,3	**10,5**	72,3	27,3	**27,8**
Cod									
1	20	0	**0**	4	0	**0**	15	0	**0**
2	3	0	**0**	16	0	**0**	15	0	**0**
3	3	0	**0**	16	0	**0**	2	0	**0**
Mean	8,7	0	**0**	12,0	0	**0**	10,7	0	**0**
Saithe									
1	2	0	**0**	8	0	**0**	10	0	**0**
2	0	0	**0**	36	0	**0**	4	0	**0**
3	3	0	**0**	0	0	**0**	19	0	**0**
Mean	1,7	0	**0**	14,7	0	**0**	11,0	0	**0**

the fins. Some of these injuries may have been acquired in the trawl during towing and the passage through the grid or meshes, but since the majority of the injuries were found on the tail and fins, is seems likely that the haddock had problems in avoiding the walls of the net during the observation period. It appears likely that the swimming capacity of the haddock was insufficient to enable them to avoid the walls during periods when current speeds were high.

Neither cod nor saithe displayed equivalent skin injuries.

Discussion

The fact that no mortality was found in cod and saithe confirms the results of earlier experiments (Soldal et al, 1993; Jacobsen 1994; Suuronen et al, 1995). The higher mortality in haddock than in cod or saithe also confirms earlier findings (Main and Sangster, 1991; Soldal et al, 1993). However, the haddock mortality observed in these trials was higher than expected. In the trials carried out on the coast of Finnmark in the early 90s, the mean mortality rates of the grid-selected and mesh-selected groups were 7.9% and 3.7% respectively. The mortality of the control group was as high as 20% in these trials, a result due to cannibalism following the entry of a number of large cod into the cages.

In theory, mortality in the control group should have been virtually zero if the cause of death was injuries suffered in the course of passing through the grid or mesh. In our experiments, we observed a mean mortality of 8% in this group. This must be due to injuries that the fish suffered in the trawling process before the fish were sorted out through the grid or meshes, or which we caused them as a result of the experimental methods we utilised.

The experimental methods used in survival trials are extremely complex and critical. Handling and storage of the sorted fish after capture can easily cause them further injury and stress, thus raising mortality above that caused by the trawl itself. Last year's trials were planned in collaboration with the Fishing Boat Owners' Association, in order to ensure that the experimental methods would be acceptable to the fleet. Important industry requirements were that the trials should be carried out under normal commercial fishing conditions, i.e. by commercial vessels using standard trawling gear and on fishing grounds where active fishing takes place. This meant that the trials were carried out in the open sea off the coast of East Finnmark. The cages in which the undersize fish were collected were anchored floating at a depth of 40 - 50 m on the fishing grounds. Previous trials have shown that towing the cages into sheltered waters causes more injuries to the fish and raises mortality rates significantly (Breen et al., 1998).

Examination of external injuries demonstrated that haddock suffered wear damage to their skin and fins after a week in the cages (Figure 11). This was probably due to the fish finding it difficult to avoid the walls of the net cages in the strong currents that they experienced in this area. Saithe and cod seemed to be better able to deal with this situation, and did not suffer from such injuries. Nor was there any mortality in these species.

However, Table 1 indicates that there was a tendency towards higher mortality in the mesh-selected group than in the grid-selected or control groups. If the experimental method had functioned satisfactorily we would have expected mortality in the control group to be virtually zero. Variations between individual cages within the same group should also have been small.

The high mortality in the control group, in combination with the wide variation in rates between cages, means that we cannot have complete confidence in the results of these trials. However, the trend does show that mortality is greater in haddock escaping through the meshes of a cod-end than haddock escaping via a sorting grid. These trials offer no suggestion that the sorting grid itself is the cause of high mortality rates in cod, haddock or saithe, as has been claimed by the trawling fleet.

However, the trials will be repeated in the summer of 2001, using improved techniques based on the experience gained in summer 2000, in order to remove all sources of uncertainty regarding the results.

Conclusions

These survival trials, which were carried out in August 2000 off the coast of East Finnmark, offered no evidence that the sorting grid in cod trawls results in higher mortality rates in sorted undersized gadoid species than trawls that lack a sorting grid. Indeed, the results suggest that haddock mortality rates are lower when a grid is utilised. No mortality was observed in cod or saithe in the course of these experiments. These species appear to be able to tolerate selection via both meshes and grids. A certain degree of uncertainty with regard to the experimental methods employed, however, means that the trials will be repeated in order to obtain more certain results for haddock.

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Figure 6. The survival experiments were carried out on board the stern trawler "Myrefisk II"

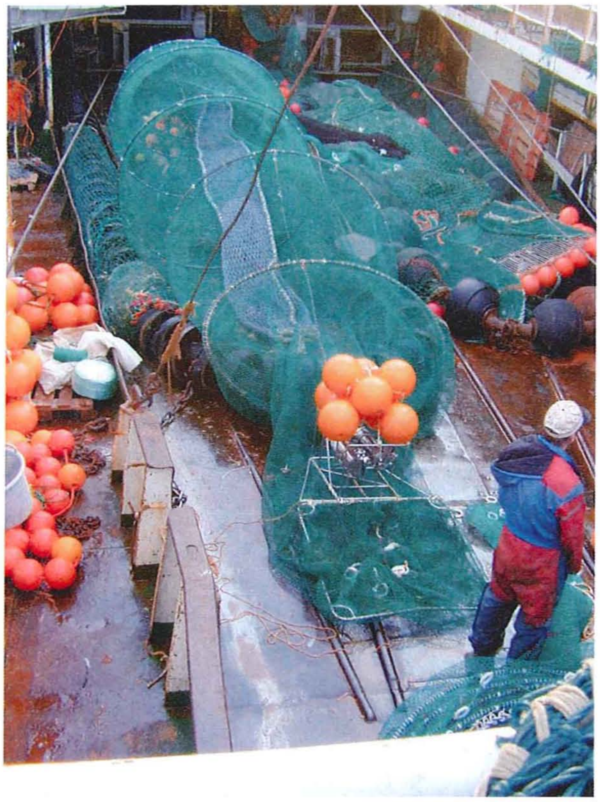

Figure 7. Cod-end with cover cage and acoustic releases on the deck of Myrefisk II

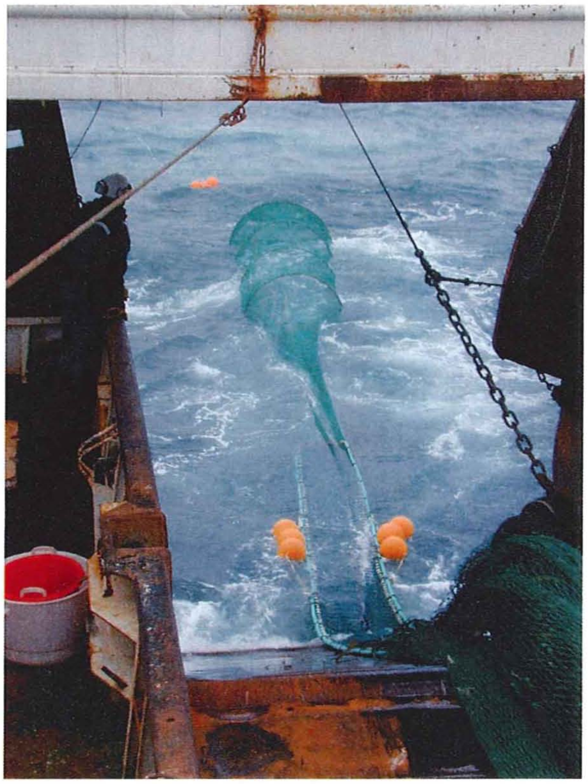

Figure 8. The collection cage floating at the surface as the trawl is set

Figure 9. The underwater vehicle FOCUS being steered during trawling

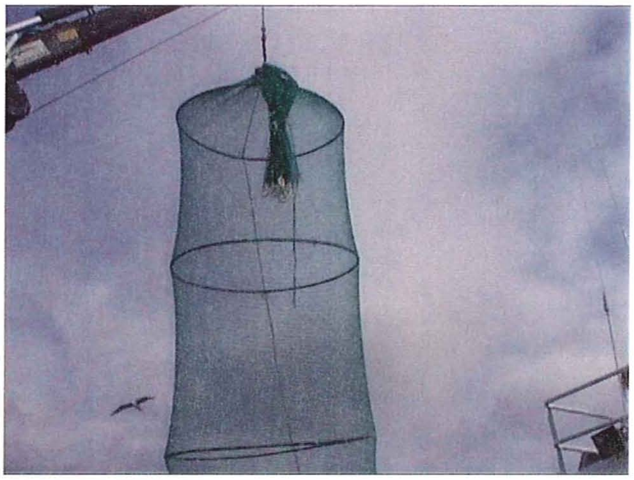

Figure 10. The observation cages, in which the fish sorted out from the trawl remained for a week after being caught, were 8 m long, with a diameter of 2 m

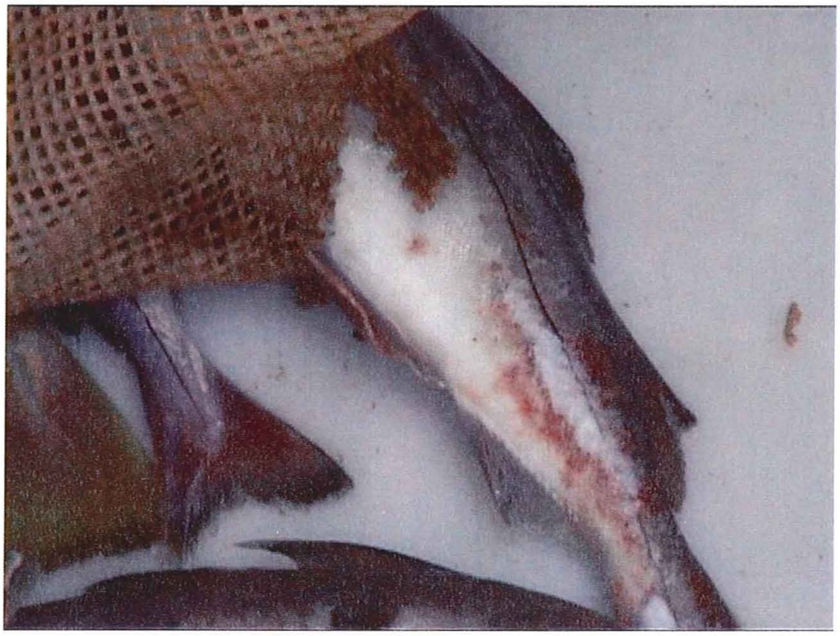

Figure 11. Typical fin and tail injuries in haddock that had been in the observation cages for a week

9th Joint Russian-Norwegian Symposium
Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

ON THE HYDROACOUSTIC WAY OF DETERMINING TRAWL CATCH EFFICIENCY AND SELECTIVE CHARACTERISTICS

by

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Abstract

Length composition of fish from the trawl catches does not correspond to the real one because of trawl selectivity that brings in a significant error when testing trawl catch efficiency and selective characteristics to substantiate and work out the technical measures of carrying out rational fishing.

In PINRO a new methodological foundation of conducting these investigations - the hydroacoustic method and LTSD100 (Length and Target Strength Distributions) Computer Program to determine length composition of fish in real aggregation in the zone of fishing by trawl - has been developed. A personal computer (PC) with LTSD100 Program is connected to the echo sounder measuring the area backscattering coefficient of fish aggregation s_A and fish target strength TS (echo sounders SIMRAD EK500 or EY500). According to the results of processing target strengths, LTSD100 Program simultaneously determines length compositions of two any fish species predominating in aggregation in 100 linear length groups including fish lengths from 1 to 500 cm at the same time. Comparing the catch size and length composition of fish in trawl with value s_A and that one in the real aggregation in the fishing zone determined by the hydroacoustic method allows us to determine the integral (in relation to fish of every size) and differential (in relation to fish of every length group) trawl catch efficiency and its selective characteristics.

In 2000 in the Barents Sea at RSV «Olaine» using developed hydroacoustic way the estimations of fish length compositions in the fishing zone and the catch efficiency of bottom trawls applied for cod and haddock aggregations were obtained. The works were performed when testing the selectivity of bottom trawls including those ones with two codends, sorting grids and fish catchers. This paper presents the results from the analysis and processing of the data obtained showing the outlook of applying the new methods of testing catch efficiency and selectivity of different design trawls based on using developed hydroacoustic method to determine length composition of fish in real aggregation in the fishing zone. The works in this direction have been continuing for the aggregations of cod, haddock, redfish and blue whiting.

Introduction

Trawl so far remains to be the only instrument to determine length composition of fish in the aggregation. However, the coefficients of trawl efficiency are significantly different relative to the fish of different size even applying small-meshed insertions (Korotkov, 1998; Ermolchev, 2000). For this reason, the length composition of fish in catches does not correspond to the real one in the aggregation in the fishing zone. This may lead to significant errors when testing trawl catch efficiency and selective characteristics.

Existing Norwegian hydroacoustic method of determining size composition of fish in aggregation realised in fishing echo sounders ES380, ES400, ES500 and ES60 was useful when fishing, but not effective to test trawl catch efficiency and selective characteristics because of applying the logarithmic scale instead of the linear one in determining fish length (Foote et al., 1984; 1986).

In PINRO the hydroacoustic method to determine length composition of fish in aggregation, in which the linear scale to determine fish length is applied, has been developed (Ermolchev, 2000). The present paper gives the results of applying developed hydroacoustic method when testing trawl catch efficiency and selective characteristics.

Legends

N - number of fish in the fishing zone at trawling interval;
L_{tc} - trawling interval in miles;
N_e - number of echo signals from single fish in the fishing zone;
N_t - number of fish in trawl catch;
N_j - number of fish from the length group j in the fishing zone at trawling interval;
N_{tj} - number of fish from the length group j in trawl catch;
P_j - portion of fish from the length group j in the fishing zone at trawling interval;
$P_j = N_j/N$;
P_{tj} - portion of fish from the length group j in trawl catch; $P_{tcj} = N_{tcj}/N_{tc}$;
j - index of length group;
TE - integral trawl efficiency;
DTE_j - differential trawl efficiency relative to fish from the length group j;
$RDTE_j$ - relative differential trawl efficiency;
RF_{LC} - recovery factor of length composition of fish in aggregation by fish length composition in trawl catch;
TL - total length of fish, cm;
s_A – the area backscaterring coefficient of fish aggregation; $m^2/mile^2$;
$\langle\sigma\rangle$ - the mean backscattering cross- section of individual fish; m^2;
<TS> - mean target strength of individual fish, dB;
$\langle\rho\rangle$ - acoustic estimation of mean density of fish aggregation in fishing zone; ind./m^3;
H_f - vertical extent of fish aggregations producing s_A, m;
L_V - vertical trawl opening, m;
L_h - horizontal trawl opening, m;
A_O - passport section of trawl mouth, m^2;
A_e - effective section of trawl mouth, m^2;
C_F - curvature factor of trawl mouth shape

Methods

In the hydroacoustic method to determine length composition of fish in aggregations *in situ* developed in PINRO 100 length groups in the linear scale including the sizes of marine organisms from 1 to 500 cm were chosen. Numbers and values of length groups were input into the specially developed program LTSD100 (Length and Target Strength Distributions) for the personal computer PC of IBM type. The program LTSD100 was written by M.V. Ermolchev. PC is connected to the echo sounder measuring the area backscaterring coefficient of fish aggregation sA, the target strength TS and the angles of fish position in the acoustic beam in fore-and-aft (faa) and athward (athw) directions relative to the vertical axis (SIMRAD EK500 or SIMRAD EY500). For the intervals ΔTL of every length group the program calculates the intervals of the target strength ΔTS simultaneously using two equations of the target strength (TS) dependence on the fish length (TL): $<TS_1>=B_1*\log(TL)+A_1$ and $<TS_2>=B_2*\log(TL)+A_2$.

At the first stage a user inputs probable coefficients A_1, B_1, A_2 and B_2 for two predominating fish species and angles «faa1», «athw1», «faa 2» and «athw2» to process the target strength of fish from the central part of acoustic beam into the program. As marine experimental tests showed, by comparison with processing from the whole acoustic beam, that one from the central part bounded by angles «faa1», «athw1», «faa2» and «athw2» not exceeding 2-3° increases the accuracy of determining fish target strength and length by 20-30%. Then Program LTSD100 is loaded and operates in the regime of the real time and when conducting hauls it makes:

- collection, analysis and sorting of fish target strength measured by echo sounder simultaneously by 100 length groups into two data files at the same time: the first one - when using the first equation of target strength and angles «faa1» and «athw1»; the second one - when using the second equation and angles «faa2», «athw2»;
- determining length composition of fish belonging to the first species using the results of processing the first data file in compliance with the first equation of target strength;
- determining length composition of fish belonging to another species from the results of processing the second data file in accordance with the second equation of target strength;
- constructing the tables and histograms of fish length composition including on the screen of the monitor.

At the first stage the trawlings of one species concentrations are carried out and the trawls to catch fish of every size comparatively equally are used. Then obtained acoustic and biological data are processed and final values of coefficients A_i and B_i in the equations of the target strength for fish species investigated i (where i - index of species) are determined.

At the second stage the final values of coefficients A_1, B_1, A_2, B_2 for any two fish species are input into the program and LTSD100 Program is ready for determining length composition of these species fish in the zone of fishing by trawls.

To characterise trawl efficiency and selectivity the following equations of the estimations of trawl efficiency integral TE and differential DTE_j and factor of the recovery of fish length composition in concentration RF_{LC} by length composition of fish in trawl catch are considered (according to the legends mentioned above):

$$TE = N_t/N = N_t/<\rho>A_o L_t\,1852 = 2075.07\,Nt<\sigma>H_f/s_A L_v L_h L_t; \qquad (1)$$

where $\langle\rho\rangle = s_A 10^{-6}/\langle\sigma\rangle\ 3.43\ H_f$; $A_o = (4+\pi)\ L_v L_h / 8$;

$$DTE_j = N_{tj}/N_j = P_{tj} N_t / P_j N = (P_{tj}/P_j)\ TE = (RDTE_j)TE; \tag{2}$$

$$RF_{LC} = P_j/P_{tj} = 1/(RDTE_j) \tag{3}$$

As is clear from the equations (1) and (2), to determine the integral and differential trawl catch efficiency in absolute units it is necessary to know fish concentration density in the fishing zone and the trawl mouth section. Determining the density of fish concentration in the fishing zone by hydroacoustic method using s_A is a complicated task and, especially, in the zone of fishing by the bottom trawl due to the effect of the «shadow» acoustic zone and masking echo signals from fish by echo signals from the ground roughness. Determining the section of the trawl mouth is a very complex task too, as it depends on many factors including the speed of trawling, species and size of fish and their behaviour in the fishing zone and in the trawl. When fishing small fish the situation becomes more complicated also by the fact that due to fish being caught in the trawl mouth its shape is distorted and the section is diminished. And instead of the passport trawl mouth A_o the necessity to determine the effective mouth of the trawl has appeared: $A_e = (4+\pi)$ $\langle L_v\rangle$ and $\langle L_h\rangle$ - mean values of vertical and horizontal trawl opening and C_f - factor considering the distortion of trawl mouth shape because of fish caught in the mouth part of the trawl. In these cases the value A_e may be equal to $(0.2 - 0.5)A_o$.

The situation becomes more simplified essentially, if when testing trawl efficiency and selectivity characteristics the relative differential trawl efficiency $RDTEj = P_{tj} / P_j$ (it may be considered as correct, since the value of the integral coefficient of efficiency TE for the trawl given and fish species may be taken as a constant) or the reverse value - the recovery factor of fish length composition in aggregation RF_{LC} in accordance with the equation (3) are used. In the both cases the necessity to determine density of fish aggregation in the fishing zone and the trawl mouth section is excluded, it is enough to estimate fish length compositions in the trawl catch and in the aggregation of the fishing zone. The developed hydroacoustic method allows estimating fish length compositions in the aggregation in the fishing zone using the number of echo signals from single fish of every length group N_{ej}.

Results

Marine measurements of cod, haddock, redfish, blue whiting and capelin target strength were made by PINRO aboard RVs «F.Nansen» and «AtlantNIRO», RSVs «Persey-3» and «Persey-4» by means of the hydroacoustic method in the Barents and Norwegian Seas in 1999-2000. PC of IBM-type with LTSD100 Program was connected to the series port of echo sounder EK-500, the frequency of 38 kHz was applied. At the same time, the aggregations were fished by bottom trawls with 135-mm mesh size with both small-meshed insertions with 16, 32 and 60 mm mesh size and without them. As a result of processing the data, the equations of the target strength (equations of linear regression between the average target strength <TS> of fish and their mean lengths <TL>) for cod and haddock were obtained.

Later, in 2000 in the Barents Sea aboard RSV «Olaine» fish length compositions in cod and haddock aggregations were estimated in the fishing zone by bottom trawls of different constructions when testing their efficiency and selectivity applying obtained equations of the target strength, by means of echo sounder EK500 and hydroacoustic method. In the trawls small-meshed insertions, sorting grids and fish catchers were used; two-codend trawl was also tested.

Tables 1-8 present several examples of cod and haddock length composition estimations obtained in the fishing zone by hydroacoustic method (the left side in tables), by trawls with small-meshed insertions and fish catchers, two codend trawl and estimations of the efficiency of these trawls.

Discussion

Tables 1-3 show that the bottom trawl with small-meshed insertion and fish catcher fishes the middle-aged haddock more effectively and the younger and elder length groups - with less effectiveness. For this, there were no haddock less than 17 cm and over 32 cm found in the codend with the small-meshed insertion (the efficiency of codend with small-meshed insertion for those haddock length groups was equal to zero). Only fish catcher fished those length groups. As is clear from Tables 2 and 3, the summary relative differential efficiency of the trawl with small-meshed insertion and fish catcher increases in proportion to haddock size increasing, reaches the maximum value for haddock 27-28 cm in length, though according to the hydroacoustic estimation, the portion of these length groups is significantly less than that one of the closest length groups, then decreases and reaches the minimum value for haddock as long as 36-38 cm and afterwards has a tendency to increase again. The ratio of maximum differential efficiency (or maximum factor of fish length composition recovery in aggregation) to the minimum value was 44. But the estimations of haddock middle length in the fishing zone obtained by hydroacoustic method and in trawl were close to each other: the biased error BE of the estimation of middle length fish in the codend was 1.5%; in the catcher - (-1.5%); in the codend and catcher - (-0.4%).

The similar situation was noticed for cod aggregations (Tables 4-8). Bottom trawl with small-meshed insertion and fish catcher fishes the middle-aged cod more effectively, than fish from the younger and elder length groups. There were no several younger length groups less than 24 cm in the codend with small-meshed insertion (the efficiency of codend with small-meshed insertion was zero for those cod length groups). The catcher fished those length groups, but did not do this for fish with length over 60 cm. As Tables 5 and 6 show, the summary relative differential efficiency of the trawl with small-meshed insertion and catcher increases from 0.1 to 1.7 as the cod length increases to 21 cm, then becomes the intermediate value between 1.7 and 0.4 for fish 21-70 cm in length and afterwards has the trend to decrease. The ratio of maximum differential efficiency (or maximum factor of fish length composition recovery in aggregation) to the minimum value was 27. The estimations of middle length cod in the fishing zone by the hydroacoustic method and in trawl were significantly different: the biased error BE of the estimation of middle length cod in the codend was 19.2%; in the cover - (-16.1)%; in the codend and cover - (-1.4)%.

In Tables 7 and 8 the results of testing two codend trawl efficiency (one codend with small-meshed insertion, another - without it) are given. The tables show that all cod length groups were fished by only the codend with small-meshed insertion. The relative differential efficiency of the codend with small-meshed insertion increases from 0.08 to 2.1 as far as cod length grows to 40 cm, then becomes the intermediate value between 2.0 and 3.1 for fish of 42-55 cm size, afterwards diminishes to 0.1 for cod as long as 85 cm and later has the tendency to increase for cod 90-95 cm in length. The ratio of maximum differential efficiency (or maximum factor of fish length composition recovery in aggregation) to minimum value was equal to 38. The biased error BE of middle length estimation for cod in the codend with small-meshed insertion was equal to 11.2%; in the codend without small-meshed insertion - (+23.2)%.

Thus, the developed hydroacoustic method of determining fish length composition in the fishing zone allows the tests of trawl efficiency and selectivity to be conducted more effectively.

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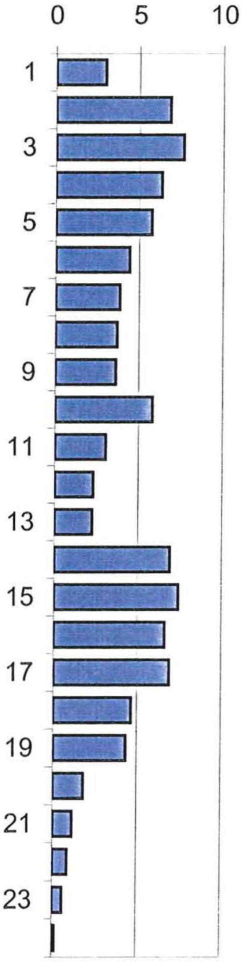
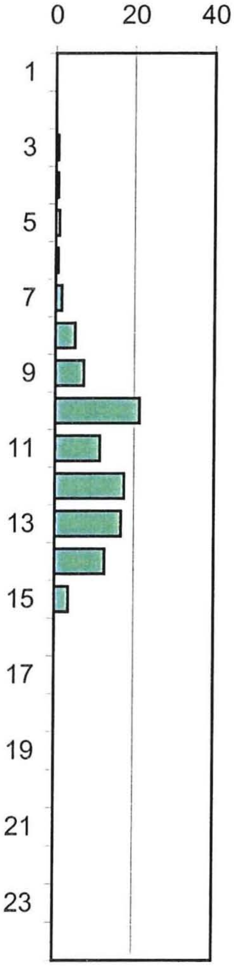
Table 1. Estimations of haddock length composition in aggregation by HA - method and trawl

(R/V "OLAYNE"- 11.2000)

A1 = - 89,1; B1 = 34,4
faa < 2.0°; athw < 2.0°

			HA - method PINRO LTSD100+EK500	Bottom trawl 41 (2517/135/60) Codend with 60mm small-meshed insertion	Bottom trawl 41 (2517/135/60) GRID SORT-V-55 60mm sorting cover
j	TL-class		P,%	P,%	P,%
1	15	16	3,0	0,0	0,7
2	16	17	6,8	0,0	2,3
3	17	18	7,6	0,6	7,7
4	18	19	6,3	0,6	7,1
5	19	20	5,7	0,9	7,3
6	20	21	4,4	0,6	4,5
7	21	22	3,9	1,6	4,5
8	22	23	3,7	5,0	3,2
9	23	24	3,6	7,3	3,4
10	24	25	5,8	21,3	7,6
11	25	26	3,1	11,5	5,1
12	26	27	2,3	17,5	6,2
13	27	28	2,3	16,8	7,9
14	28	30	6,9	12,7	15,3
15	30	32	7,4	3,5	7,7
16	32	34	6,6	0,0	4,2
17	34	36	6,9	0,0	1,2
18	36	38	4,7	0,0	0,9
19	38	40	4,4	0,0	1,3
20	40	42	1,8	0,0	0,9
21	42	44	1,2	0,0	0,4
22	44	46	0,9	0,0	0,3
23	46	48	0,6	0,0	0,2
24	48	50	0,1	0,0	0,2
Ne			1377		
Nt				3197	5684
<TL>			26,0	26,4	25,6
BE,%				1,5	-1,5





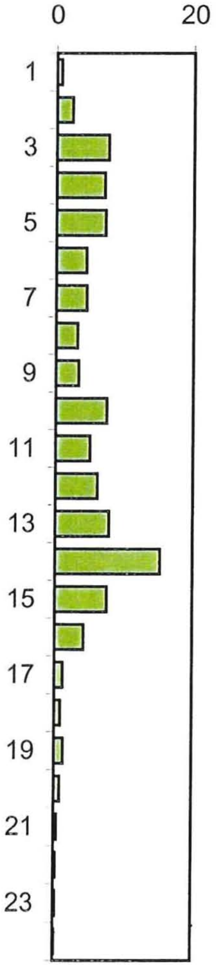


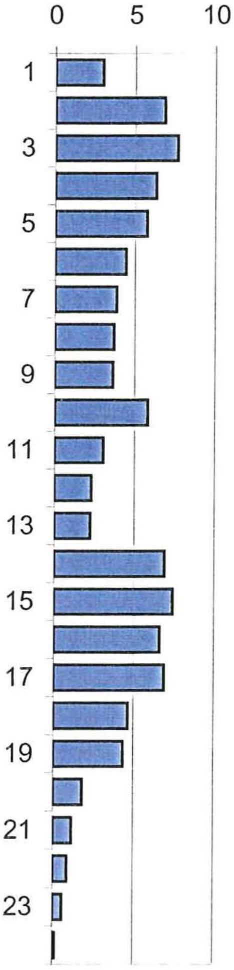
Table 2. Estimations of haddock length composition in the Fishing zone and relative differential catch efficiency of trawl codend and fish-catcher by HA - method

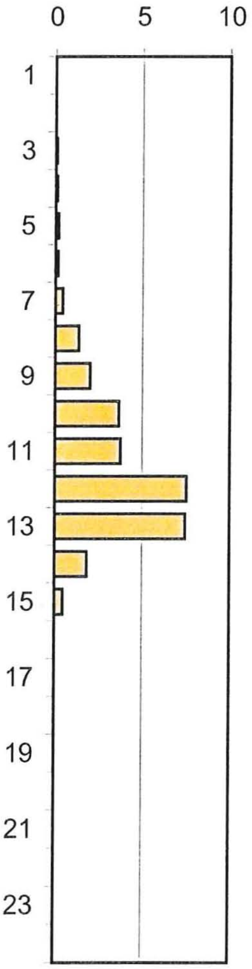
(R/V "OLAYNE"- 11.2000)

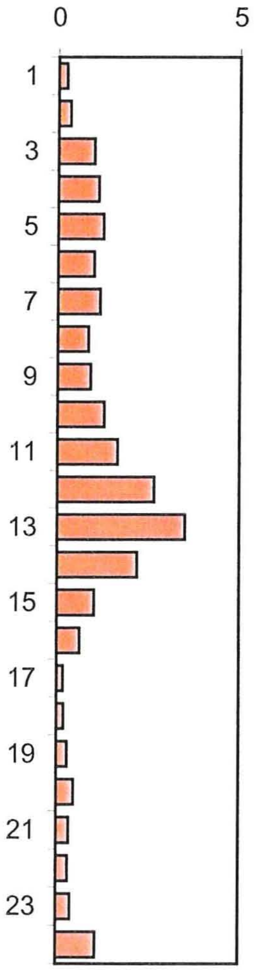
HA - method PINRO LTSD100+EK500 Length composition				Bottom trawl 41 (2517/135/60) Codend and Fish-Catcher Relative differential catch efficiency	
				Codend	Fish-catcher

A1 = - 89,1; B1 = 34,4
faa < 2.0°; athw < 2.0°

j	TL-class		P,%	Codend	Fish-catcher
1	15	16	3,0	0,0	0,2
2	16	17	6,8	0,0	0,3
3	17	18	7,6	0,1	1,0
4	18	19	6,3	0,1	1,1
5	19	20	5,7	0,2	1,3
6	20	21	4,4	0,1	1,0
7	21	22	3,9	0,4	1,2
8	22	23	3,7	1,4	0,9
9	23	24	3,6	2,0	0,9
10	24	25	5,8	3,7	1,3
11	25	26	3,1	3,8	1,7
12	26	27	2,3	7,5	2,7
13	27	28	2,3	7,5	3,5
14	28	30	6,9	1,8	2,2
15	30	32	7,4	0,5	1,0
16	32	34	6,6	0,0	0,6
17	34	36	6,9	0,0	0,2
18	36	38	4,7	0,0	0,2
19	38	40	4,4	0,0	0,3
20	40	42	1,8	0,0	0,5
21	42	44	1,2	0,0	0,3
22	44	46	0,9	0,0	0,3
23	46	48	0,6	0,0	0,4
24	48	50	0,1	0,0	1,1







	HA - method	Codend	Fish-catcher
Ne	1377		
Nt		3197	5684
<TL>	26,0	26,4	25,6
BE,%		1,5	-1,5

Table 3. Estimations of haddock length composition in aggregation by HA - method and trawl and relative differential catch efficiency of trawl with Fish-catcher

(R/V "OLAYNE"- 11.2000)

HA - method PINRO
LTSD100+EK500

Bottom trawl 41 (2517/135/60)
Codend +Fish-Catcher

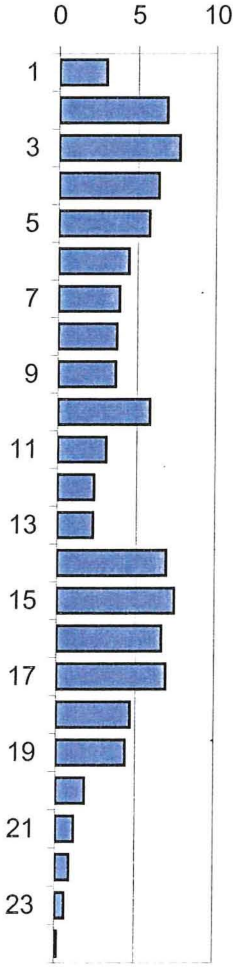
Length composition

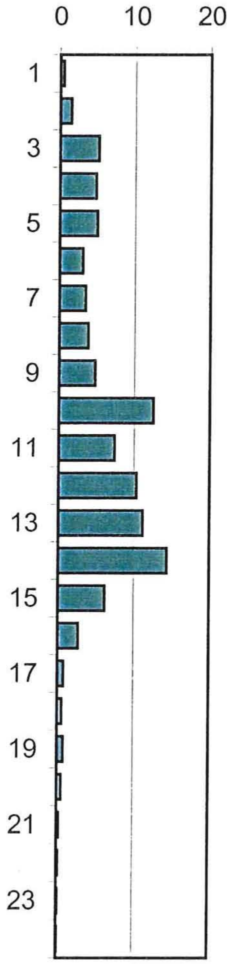
Relative differential trawl catch efficiency

A1 = - 89,1; B1 = 34,4
faa < 2.0°; athw < 2.0°

j	TL-class		P,%	P,%	RDTE
1	15	16	3,0	0,5	0,2
2	16	17	6,8	1,5	0,2
3	17	18	7,6	5,1	0,7
4	18	19	6,3	4,8	0,8
5	19	20	5,7	5,0	0,9
6	20	21	4,4	3,1	0,7
7	21	22	3,9	3,5	0,9
8	22	23	3,7	3,8	1,0
9	23	24	3,6	4,8	1,3
10	24	25	5,8	12,5	2,1
11	25	26	3,1	7,4	2,4
12	26	27	2,3	10,3	4,4
13	27	28	2,3	11,1	4,9
14	28	30	6,9	14,4	2,1
15	30	32	7,4	6,2	0,8
16	32	34	6,6	2,7	0,4
17	34	36	6,9	0,8	0,1
18	36	38	4,7	0,6	0,1
19	38	40	4,4	0,8	0,2
20	40	42	1,8	0,6	0,3
21	42	44	1,2	0,3	0,2
22	44	46	0,9	0,2	0,2
23	46	48	0,6	0,15	0,3
24	48	50	0,1	0,1	0,7

Ne	1377	
Nt		8881
<TL>	26,0	25,9
BE,%		-0,4





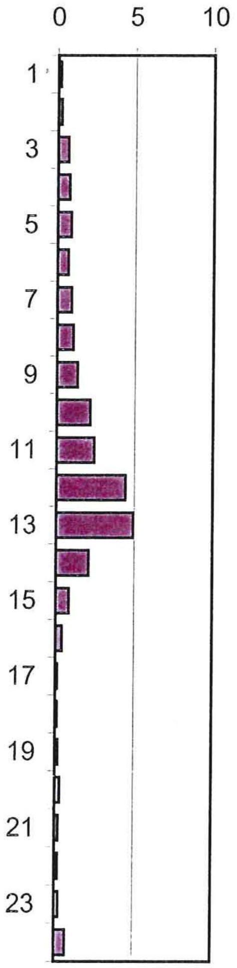


Table 4. Estimations of haddock length composition in the Fishing zone, Relative differential trawl catch efficiency and Factor of fish length composition recovery in aggregation by HA-method

(R/V "OLAYNE"- 11.2000)

HA - method PINRO
LTSD100+EK500

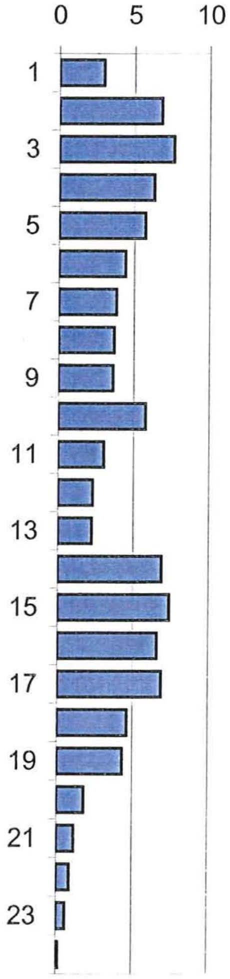
Bottom trawl 41 (2517/135/60)
Codend +Fish-Catcher

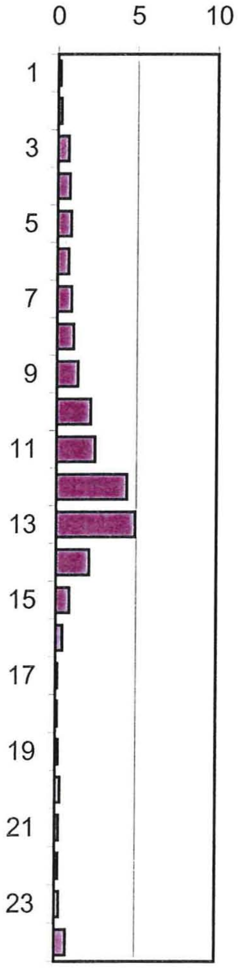
Relative differential trawl catch efficiency

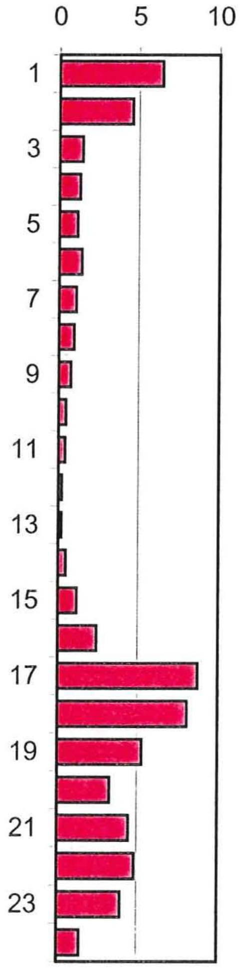
Factor of fish length composition recovery

A1 = - 89,1; B1 = 34,4
faa < 2.0°; athw < 2.0°

j	TL-класс		P,%	RDTE	RFLC
1	15	16	3,0	0,2	6,5
2	16	17	6,8	0,2	4,6
3	17	18	7,6	0,7	1,5
4	18	19	6,3	0,8	1,3
5	19	20	5,7	0,9	1,2
6	20	21	4,4	0,7	1,4
7	21	22	3,9	0,9	1,1
8	22	23	3,7	1,0	1,0
9	23	24	3,6	1,3	0,8
10	24	25	5,8	2,1	0,5
11	25	26	3,1	2,4	0,4
12	26	27	2,3	4,4	0,2
13	27	28	2,3	4,9	0,2
14	28	30	6,9	2,1	0,5
15	30	32	7,4	0,8	1,2
16	32	34	6,6	0,4	2,4
17	34	36	6,9	0,1	8,8
18	36	38	4,7	0,1	8,1
19	38	40	4,4	0,2	5,3
20	40	42	1,8	0,3	3,3
21	42	44	1,2	0,2	4,5
22	44	46	0,9	0,2	4,8
23	46	48	0,6	0,3	4,0
24	48	50	0,1	0,7	1,4







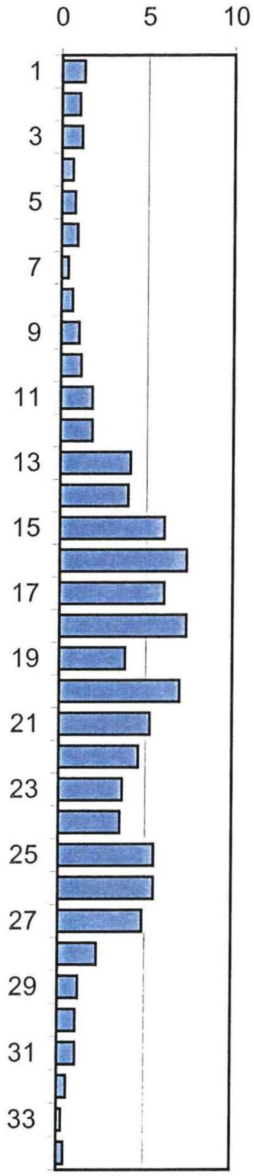
Ne	1377	
Nt		8881
<TL>	26,0	25,9
BE,%		-0,4

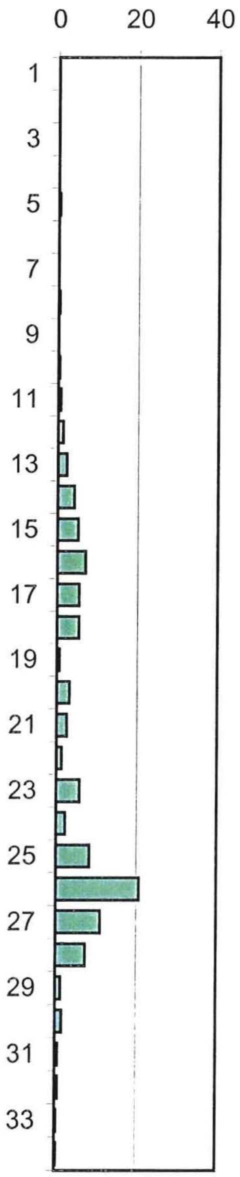
Table 5. Estimations of Cod length composition in aggregation by HA - method and trawl

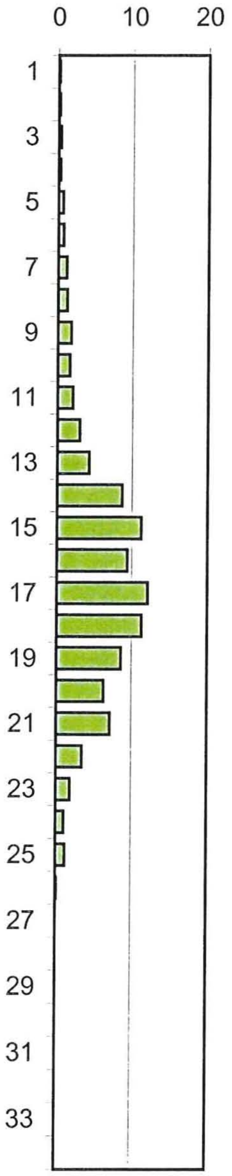
(R/V "OLAYNE"- 11.2000)

A2 = - 91; B2 = 35,6
faa<2.0°; athw<2.0°

			HA - method PINRO LTSD100+EK500	Bottom trawl 279 (2517/135/60)	
				Codend with 60mm small-meshed insertion	Fish-catcher GRID SORT-V-55 60mm sorting cover
j	TL-class		P,%	P,%	P,%
1	15	16	1,3	0,0	0,14
2	16	17	1,0	0,0	0,2
3	17	18	1,2	0,0	0,3
4	18	19	0,7	0,0	0,3
5	19	20	0,8	0,3	0,6
6	20	21	0,9	0,0	0,7
7	21	22	0,4	0,0	1,1
8	22	23	0,7	0,3	1,2
9	23	24	1,0	0,0	1,8
10	24	25	1,2	0,3	1,6
11	25	26	1,8	0,6	2,1
12	26	27	1,8	1,3	3,0
13	27	28	4,1	2,2	4,2
14	28	30	3,9	4,1	8,7
15	30	32	6,0	5,1	11,2
16	32	34	7,3	7,0	9,4
17	34	36	6,0	5,4	12,1
18	36	38	7,3	5,4	11,3
19	38	40	3,8	0,6	8,6
20	40	42	6,9	3,2	6,3
21	42	44	5,2	2,5	7,1
22	44	46	4,6	1,3	3,5
23	46	48	3,7	5,7	1,9
24	48	50	3,5	2,2	1,0
25	50	55	5,5	8,3	1,2
26	55	60	5,5	20,7	0,1
27	60	65	4,8	11,1	0,0
28	65	70	2,2	7,3	0,0
29	70	75	1,2	1,3	0,0
30	75	80	1,0	1,6	0,0
31	80	85	1,0	0,6	0,0
32	85	90	0,5	0,6	0,0
33	90	95	0,3	0,3	0,0
34	95	100	0,4	0,3	0,0







	HA - method	Codend	Fish-catcher
Ne	765		
Nt		1570	2191
<TL>	41,7	49,7	35,0
BE,%		19,2	-16,1

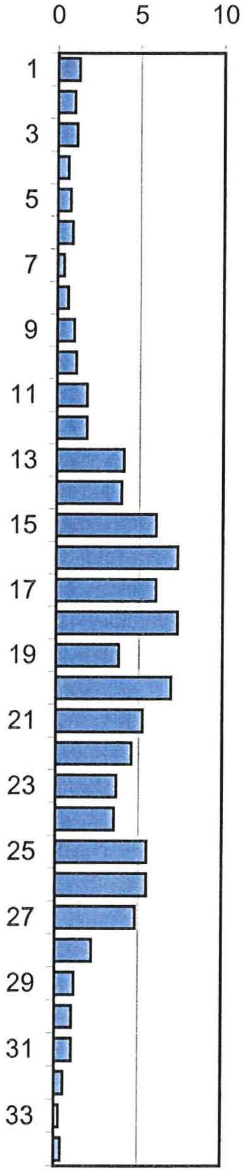
Table 6. Estimations of Cod length composition in the Fishing zone and relative differential catch efficiency of trawl codend and fish-catcher by HA - method

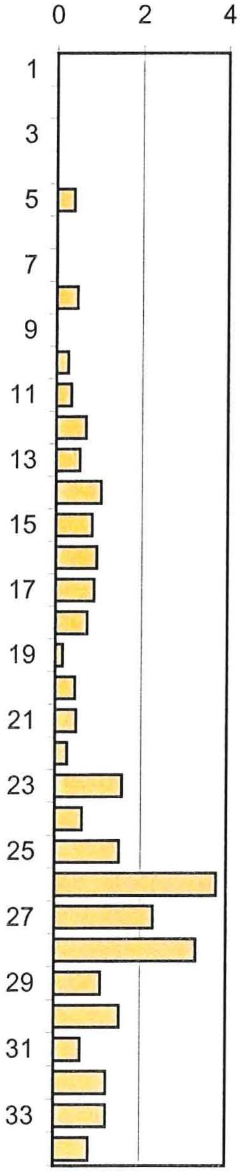
(R/V "OLAYNE"- 11.2000)

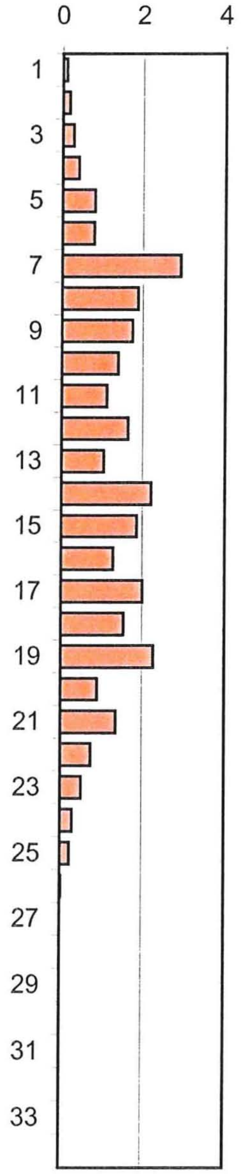
HA - method PINRO
LTSD100+EK500
Length composition
A2 = - 91; B2 = 35,6
faa<2.0°; athw<2.0°

Bottom trawl 279 (2517/135/60)
Codend and Fish-Catcher
Relative differential catch efficiency

j	TL-class		P,%	Codend	Fish-catcher
1	15	16	1,3	0,0	0,1
2	16	17	1,0	0,0	0,2
3	17	18	1,2	0,0	0,3
4	18	19	0,7	0,0	0,4
5	19	20	0,8	0,4	0,8
6	20	21	0,9	0,0	0,8
7	21	22	0,4	0,0	2,9
8	22	23	0,7	0,5	1,9
9	23	24	1,0	0,0	1,7
10	24	25	1,2	0,3	1,4
11	25	26	1,8	0,3	1,1
12	26	27	1,8	0,7	1,6
13	27	28	4,1	0,6	1,0
14	28	30	3,9	1,1	2,2
15	30	32	6,0	0,8	1,9
16	32	34	7,3	1,0	1,3
17	34	36	6,0	0,9	2,0
18	36	38	7,3	0,7	1,5
19	38	40	3,8	0,2	2,3
20	40	42	6,9	0,5	0,9
21	42	44	5,2	0,5	1,4
22	44	46	4,6	0,3	0,8
23	46	48	3,7	1,6	0,5
24	48	50	3,5	0,6	0,3
25	50	55	5,5	1,5	0,2
26	55	60	5,5	3,8	0,0
27	60	65	4,8	2,3	0,0
28	65	70	2,2	3,3	0,0
29	70	75	1,2	1,1	0,0
30	75	80	1,0	1,5	0,0
31	80	85	1,0	0,6	0,0
32	85	90	0,5	1,2	0,0
33	90	95	0,3	1,2	0,0
34	95	100	0,4	0,8	0,0







	HA - method	Codend	Fish-catcher
Ne	765		
Nt		1570	2191
<TL>	41,7	49,7	35,0
BE,%		19,2	-16,1

Table 7. Estimations of Cod length composition in aggregation by HA - method and trawl and relative differential catch efficiency of trawl with Fish-catcher

(R/V "OLAYNE"- 11.2000)

HA - method PINRO
LTSD100+EK500

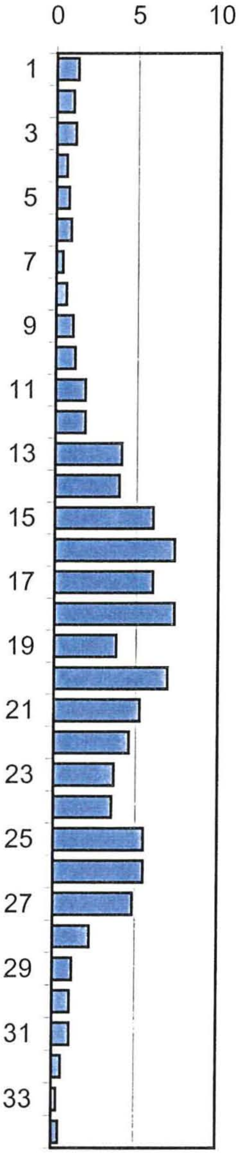
Bottom trawl 279 (2517/135/60)
Codend +Fish-catcher

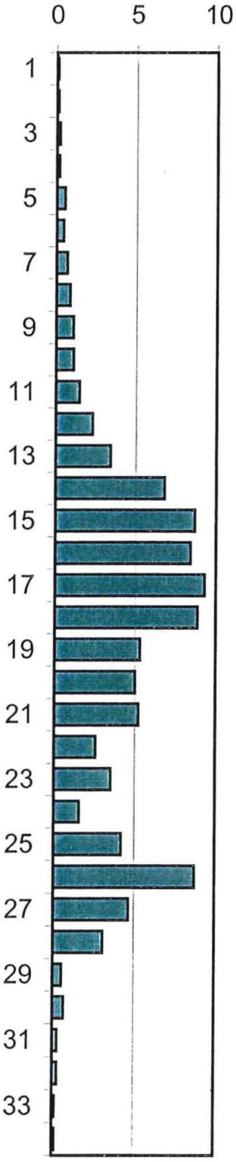
Length Composition

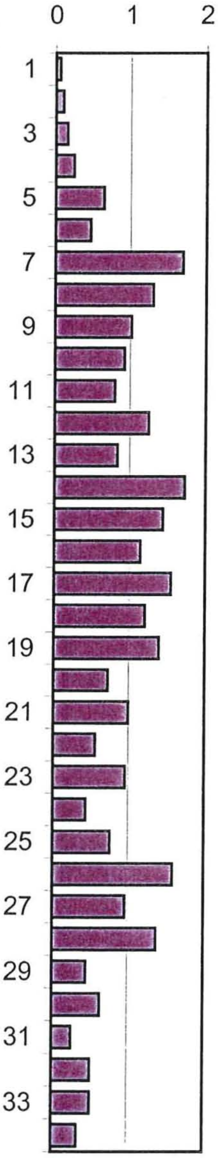
Relative differential catch efficiency

A2 = - 91; B2 = 35,6
faa<2.0°; athw<2.0°

j	TL-class		P,%	P,%	RDTE
1	15	16	1,3	0,08	0,1
2	16	17	1,0	0,1	0,1
3	17	18	1,2	0,2	0,2
4	18	19	0,7	0,2	0,2
5	19	20	0,8	0,5	0,6
6	20	21	0,9	0,4	0,5
7	21	22	0,4	0,7	1,7
8	22	23	0,7	0,9	1,3
9	23	24	1,0	1,1	1,0
10	24	25	1,2	1,1	0,9
11	25	26	1,8	1,5	0,8
12	26	27	1,8	2,3	1,2
13	27	28	4,1	3,4	0,8
14	28	30	3,9	6,8	1,7
15	30	32	6,0	8,7	1,4
16	32	34	7,3	8,4	1,1
17	34	36	6,0	9,3	1,5
18	36	38	7,3	8,9	1,2
19	38	40	3,8	5,3	1,4
20	40	42	6,9	5,0	0,7
21	42	44	5,2	5,2	1,0
22	44	46	4,6	2,6	0,6
23	46	48	3,7	3,5	1,0
24	48	50	3,5	1,5	0,4
25	50	55	5,5	4,2	0,8
26	55	60	5,5	8,7	1,6
27	60	65	4,8	4,7	1,0
28	65	70	2,2	3,1	1,4
29	70	75	1,2	0,5	0,5
30	75	80	1,0	0,7	0,6
31	80	85	1,0	0,3	0,3
32	85	90	0,5	0,3	0,5
33	90	95	0,3	0,1	0,5
34	95	100	0,4	0,1	0,3







Ne	765	
Nt		3761
<TL>	41,7	41,1
BE,%		-1,4

Table 8. Estimations of Cod length composition in the Fishing zone, Relative differential trawl catch efficiency and Factor of fish length composition recovery in aggregation by HA - method

(R/V "OLAYNE"- 11.2000)

HA - method PINRO
LTSD100+EK500

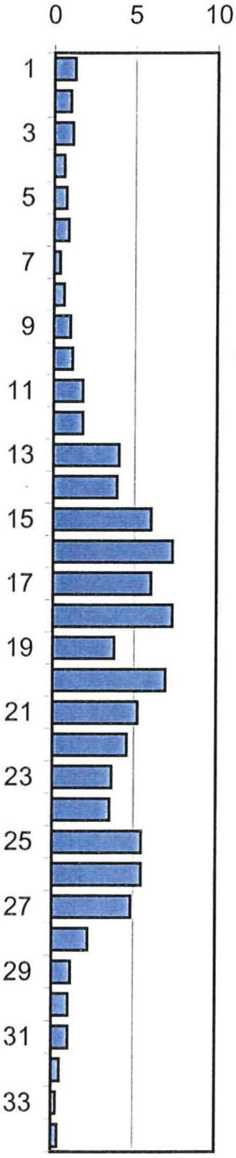
Bottom trawl 279 (2517/135/60)
Codend +Fish-catcher

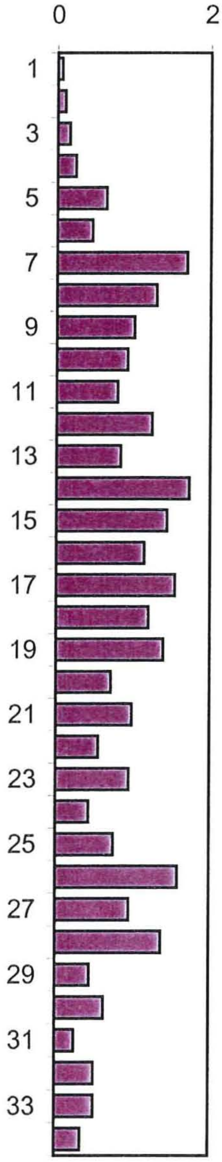
Relative differential catch efficiency

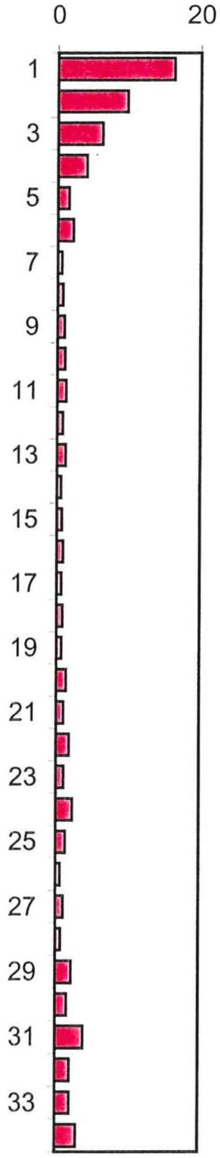
Factor of fish length composition recovery

A2 = - 91; B2 = 35,6
faa<2.0°; athw<2.0°

j	TL-class		P,%	RDTE	RFLC
1	15	16	1,3	0,06	16,4
2	16	17	1,0	0,1	9,8
3	17	18	1,2	0,2	6,3
4	18	19	0,7	0,2	4,1
5	19	20	0,8	0,6	1,6
6	20	21	0,9	0,5	2,2
7	21	22	0,4	1,7	0,6
8	22	23	0,7	1,3	0,8
9	23	24	1,0	1,0	1,0
10	24	25	1,2	0,9	1,1
11	25	26	1,8	0,8	1,3
12	26	27	1,8	1,2	0,8
13	27	28	4,1	0,8	1,2
14	28	30	3,9	1,7	0,6
15	30	32	6,0	1,4	0,7
16	32	34	7,3	1,1	0,9
17	34	36	6,0	1,5	0,6
18	36	38	7,3	1,2	0,8
19	38	40	3,8	1,4	0,7
20	40	42	6,9	0,7	1,4
21	42	44	5,2	1,0	1,0
22	44	46	4,6	0,6	1,8
23	46	48	3,7	1,0	1,0
24	48	50	3,5	0,4	2,3
25	50	55	5,5	0,8	1,3
26	55	60	5,5	1,6	0,6
27	60	65	4,8	1,0	1,0
28	65	70	2,2	1,4	0,7
29	70	75	1,2	0,5	2,2
30	75	80	1,0	0,6	1,6
31	80	85	1,0	0,3	3,9
32	85	90	0,5	0,5	2,0
33	90	95	0,3	0,5	2,0
34	95	100	0,4	0,3	2,9





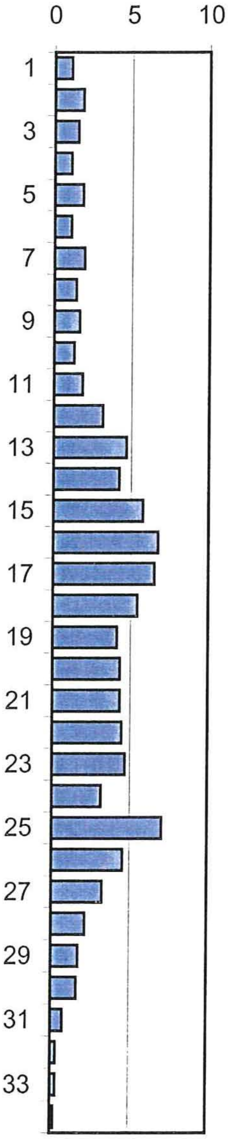


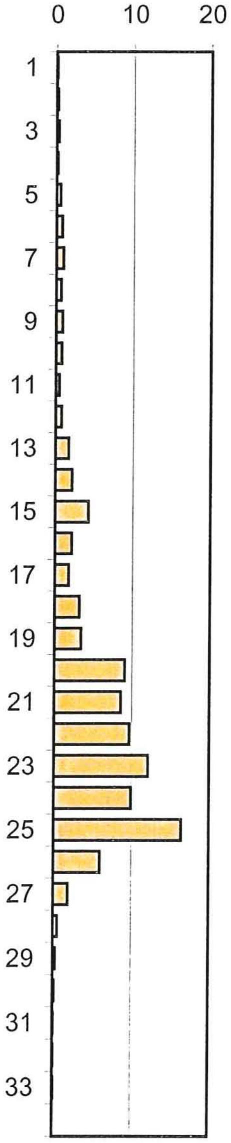
Ne	765	
Nt		3761
<TL>	41,7	41,1
BE,%		-1,4

Table 9. Estimations of Cod length composition in aggregation by HA - method and trawl

(R/V "OLAYNE"- 11.2000)

			HA - method PINRO LTSD100+EK500	Bottom trouser trawl No 95 1.With small mesh-sized insertion (2517/135/60)	Bottom trouser trawl No 95 2.Without small mesh-sized insertion (2517/135)
			A2 = - 91; B2 = 35,6 faa<2.0°; athw<2.0°		
j	TL-class		P,%	P,%	P,%
1	15	16	1,1	0,1	0,0
2	16	17	1,8	0,2	0,0
3	17	18	1,5	0,3	0,0
4	18	19	1,1	0,2	0,0
5	19	20	1,8	0,5	0,0
6	20	21	1,1	0,8	0,0
7	21	22	2,0	0,9	0,0
8	22	23	1,4	0,7	0,0
9	23	24	1,6	0,9	0,0
10	24	25	1,3	0,8	0,7
11	25	26	1,8	0,4	0,8
12	26	27	3,2	0,8	1,0
13	27	28	4,7	1,7	2,8
14	28	30	4,2	2,2	5,9
15	30	32	5,8	4,3	3,6
16	32	34	6,7	2,2	3,8
17	34	36	6,5	1,8	4,2
18	36	38	5,4	3,2	5,2
19	38	40	4,1	3,5	3,2
20	40	42	4,3	9,1	2,0
21	42	44	4,3	8,5	3,4
22	44	46	4,5	9,7	2,4
23	46	48	4,7	12,1	4,8
24	48	50	3,2	9,9	3,8
25	50	55	7,1	16,4	19,9
26	55	60	4,6	6,0	12,8
27	60	65	3,3	1,9	11,2
28	65	70	2,2	0,5	4,9
29	70	75	1,7	0,3	2,5
30	75	80	1,6	0,2	0,4
31	80	85	0,8	0,1	0,4
32	85	90	0,3	0,1	0,1
33	90	95	0,3	0,1	0,1
34	95	100	0,2	0,0	0,0
Ne			923		
Nt				1159	713
<TL>			40,1	44,6	49,4
BE,%				11,2	23,2





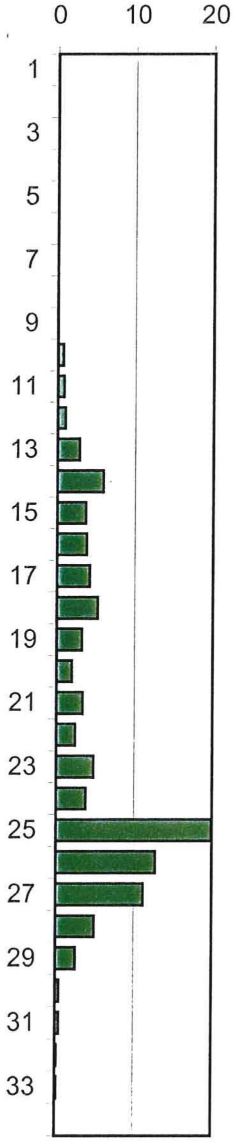


Table 10. Estimations of Cod length composition in the Fishing zone and relative differential trawl efficiency of Bottom trouser trawl

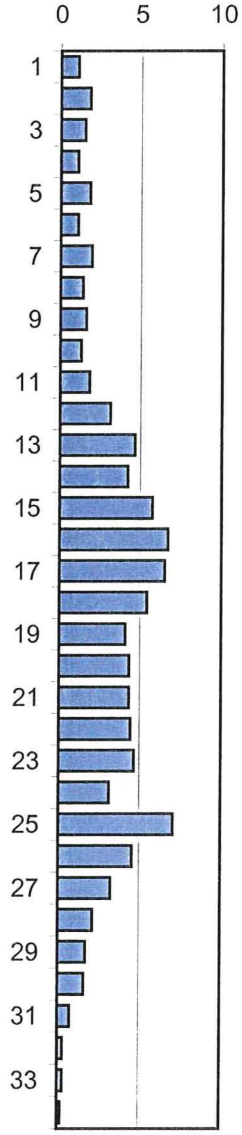
(R/V "OLAYNE"- 11.2000)

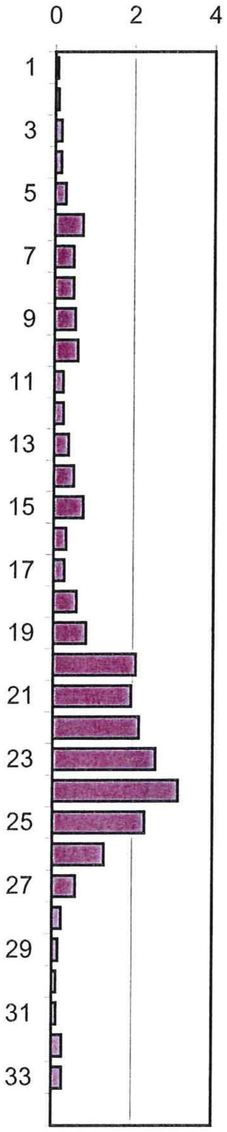
HA - method PINRO
LTSD100+EK500

Bot. trouser trawl No 95 (2517/135/60)
Relative differential catch efficiency

A2 = - 91; B2 = 35,6
faa<2.0°; athw<2.0°

j	TL-class		P,%	1.With small mesh-sized insertion (2517/135/60)	2.Without small mesh-sized insertion (2517/135)
1	15	16	1,1	0,1	0,0
2	16	17	1,8	0,1	0,0
3	17	18	1,5	0,2	0,0
4	18	19	1,1	0,2	0,0
5	19	20	1,8	0,3	0,0
6	20	21	1,1	0,7	0,0
7	21	22	2,0	0,5	0,0
8	22	23	1,4	0,5	0,0
9	23	24	1,6	0,5	0,0
10	24	25	1,3	0,6	0,5
11	25	26	1,8	0,2	0,5
12	26	27	3,2	0,2	0,3
13	27	28	4,7	0,4	0,6
14	28	30	4,2	0,5	1,4
15	30	32	5,8	0,7	0,6
16	32	34	6,7	0,3	0,6
17	34	36	6,5	0,3	0,6
18	36	38	5,4	0,6	1,0
19	38	40	4,1	0,8	0,8
20	40	42	4,3	2,1	0,5
21	42	44	4,3	2,0	0,8
22	44	46	4,5	2,2	0,5
23	46	48	4,7	2,6	1,0
24	48	50	3,2	3,1	1,2
25	50	55	7,1	2,3	2,8
26	55	60	4,6	1,3	2,8
27	60	65	3,3	0,6	3,4
28	65	70	2,2	0,2	2,3
29	70	75	1,7	0,1	1,5
30	75	80	1,6	0,1	0,3
31	80	85	0,8	0,1	0,6
32	85	90	0,3	0,3	0,4
33	90	95	0,3	0,3	0,4
34	95	100	0,2	0,0	0,0
Ne			923		
Nt				1159	713
<TL>			40,1	44,6	49,4
BE,%				11,2	23,2





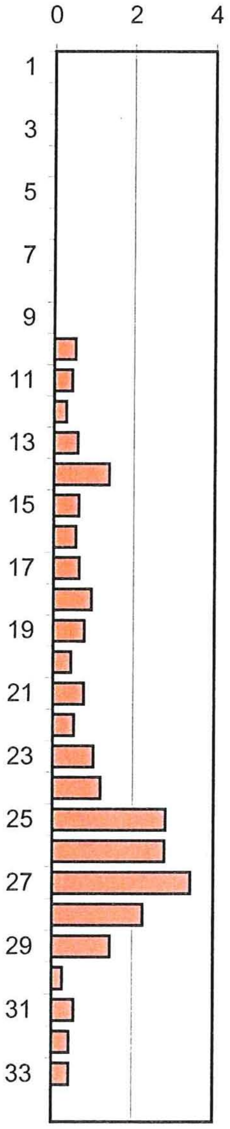


Table 11. Estimations of Cod length composition in the Fishing zone, relative differential trawl catch efficiency and Factor of fish length composition recovery in aggregation by HA - method

(R/V "OLAYNE"- 11.2000)

HA - method PINRO
LTSD100+EK500

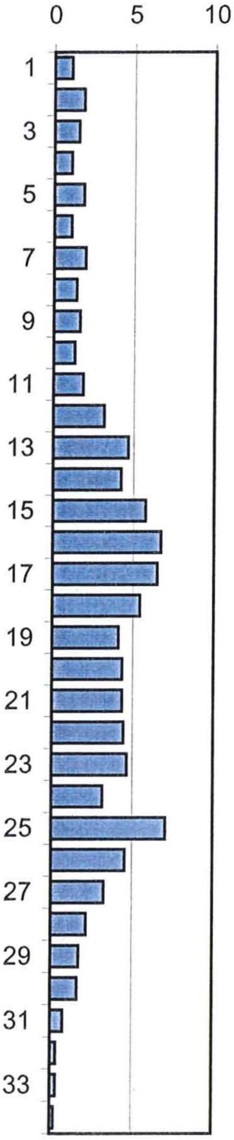
Bot. trouser trawl No 95 (2517/135/60)

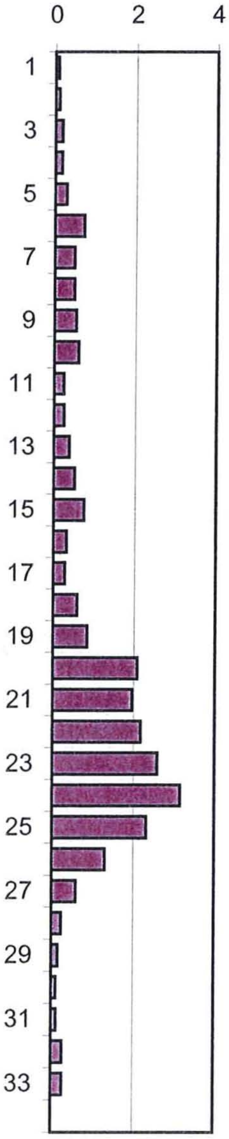
Relative differential catch efficiency

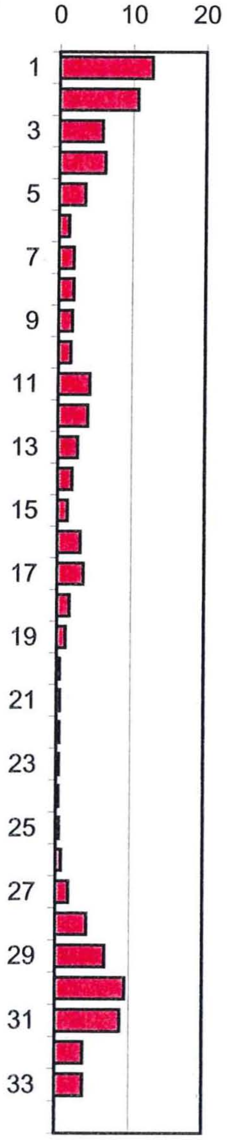
Factor of fish length composition recovery

A2 = - 91; B2 = 35,6
faa<2.0°; athw<2.0°

j	TL-class		P,%	RDTE	RFLC
1	15	16	1,1	0,08	12,6
2	16	17	1,8	0,09	10,7
3	17	18	1,5	0,2	5,9
4	18	19	1,1	0,2	6,3
5	19	20	1,8	0,3	3,6
6	20	21	1,1	0,7	1,4
7	21	22	2,0	0,5	2,1
8	22	23	1,4	0,5	2,0
9	23	24	1,6	0,5	1,9
10	24	25	1,3	0,6	1,7
11	25	26	1,8	0,2	4,3
12	26	27	3,2	0,2	4,1
13	27	28	4,7	0,4	2,7
14	28	30	4,2	0,5	2,0
15	30	32	5,8	0,7	1,3
16	32	34	6,7	0,3	3,1
17	34	36	6,5	0,3	3,6
18	36	38	5,4	0,6	1,7
19	38	40	4,1	0,8	1,2
20	40	42	4,3	2,1	0,5
21	42	44	4,3	2,0	0,5
22	44	46	4,5	2,2	0,5
23	46	48	4,7	2,6	0,4
24	48	50	3,2	3,1	0,3
25	50	55	7,1	2,3	0,4
26	55	60	4,6	1,3	0,8
27	60	65	3,3	0,6	1,7
28	65	70	2,2	0,2	4,2
29	70	75	1,7	0,1	6,7
30	75	80	1,6	0,1	9,4
31	80	85	0,8	0,1	8,8
32	85	90	0,3	0,3	3,8
33	90	95	0,3	0,3	3,8
34	95	100	0,2	0,0	?
Ne			923		
Nt				1159	
<TL>			40,1	44,6	
BE,%				11,2	







9^{th} Joint Russian-Norwegian Symposium
Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

DEVELOPMENT OF SORTING GRIDS IN THE NORWEGIAN FISHERY – A REVIEW

by

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Shrimp trawls (the Nordmøre grid)

The northern shrimp fishery is developed entirely by otter trawls in the North East Atlantic, with large trawls. The cod-end mesh size is, however, as small as down to 35 mm. The deep-sea fishery for small northern shrimp developed rapidly during the 1970`s in Norway. Soon after major criticism of this fishery came due to rather large quantities of non-marketable by-catches of juvenile fish from important species. For the fishermen, most of these by- catches represented a lot of wasted energy and time consuming effort to sort the catches.

Throughout the 70`s and the 80`s different techniques with mesh panels were tested. By the mid 80`s a sorting panel in the aft end of the trawl became mandatory for certain coastal shrimp fisheries in Northern Norway. Most of the techniques, however, gave fishermen more practical problems compared to the advantages they gained in removing by-catches.

The real breakthrough came in 1989, as a fisherman (Mr. P.Brattøy) gave scientists the idea of a rigid metal grid to remove unwanted by-catch. The grid was originally developed as a "blubbershute", with the one and only purpose of removing jellyfish from shrimp-catches.

From the very beginning, the experiments with the Nordmøre grid became successful in reducing by-catches in shrimp trawls. Less than one year later the Nordmøre grid was introduced as mandatory for the coastal shrimp fleets in Norway. By 1 January 1993 the legislation covered the hole North East Atlantic (i.e. Barents Sea, including the waters around the Spitzbergen islands).

Cod bottom trawls (size selective sorting grids)

The development of a sorting grid system in cod bottom trawls started in October 1989. Since March 1990 various tests have been carried out on hired trawlers under the direction of the Directorate of Fisheries. These experiments have taken place in close cooperation between the authorities, the scientists and the fishing industry. Our research institutes, The Norwegian College of Fishery Science, University of Tromsø and Institute of Marine Research, Bergen have been responsible for the scientific quality of the experiments.

In the period 1990 – 2000, considerable resources has been spent on hiring vessels, buying adequate equipment, and on the engagement of personnel. Both Russian and Norwegian trawlers of various types have been hired, and they have spent several hundred days at sea in connection with the experiments and tests. As a result of this work, obligatory use of sorting grids was introduced in the cod fishery from January 1, 1997, in a specified area north and east in the Barents Sea. This decree was extended from January 1, 2000, to comprise the whole area north of 62° N.

During the development of sorting grids in cod bottom trawls, various concepts as regards the construction of grids have been tested. Today three types of grids are approved for use – the Norwegian system Sort-X, the Russian system Sort-V and an adjusted version of this called single sorting grid.

In addition to this, it has also been carried out experiments with grids produced of other materials such as plastics, nylon and rubber. These grid systems are called Euro- grid and Flexi-grid. The intention behind developing these systems, is to be able to offer the industry grids that can be more easily handled, are more user-friendly and cheaper to purchase.

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NEW TYPE OF SIZE SELECTIVE SYSTEM MADE OF PLASTIC AND RUBBER: THE "FLEXIGRID"

by
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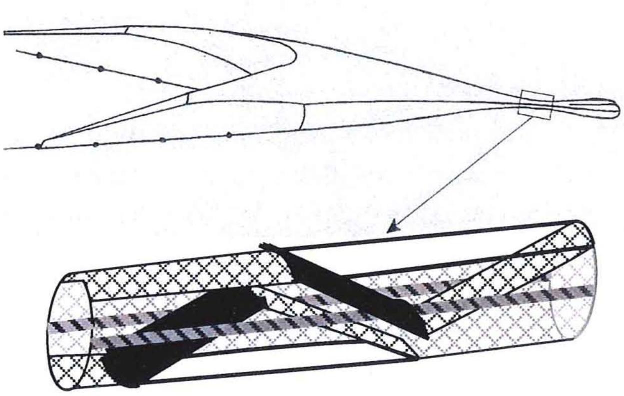
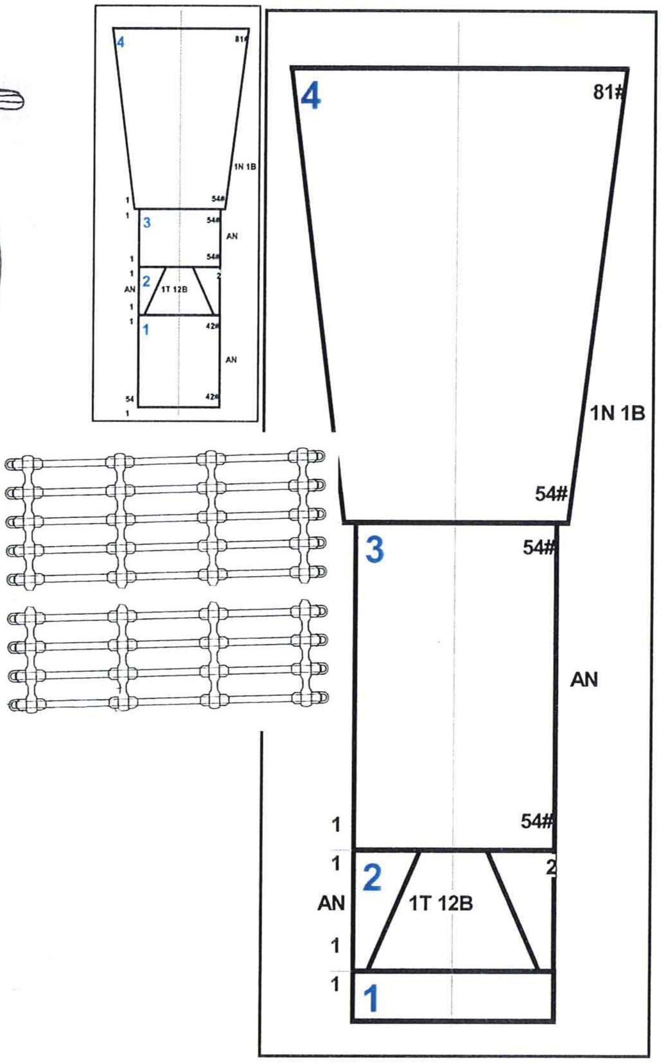
In connection with his post-graduate thesis at the Norwegian College of Fishery Science, Tromsø, Snorre Angell (now working at SINTEF Fisheries and Aquaculture, Trondheim), developed a new grid for sorting out undersized fish from bottom trawl. The new with this concept is the placing of the grids, and that the grids are made of plastic and rubber, which makes them flexible. In 1998 the first cruise was conducted on board the research vessel "Jan Mayen". From 1999 has the Flexigrid been tested onboard commercially operated vessels to establish selectivity parameters and to compare Flexigrid with Sort-X. The Norwegian Directorate of fisheries in cooperation with SINTEF arranged these cruises. The system seems to give at least as good selectivity as Sort-X for saithe, and the results for cod are also good (see enclosed figures). Before finishing the documentation of the systems selectivity properties there will be conducted a cruise to compare directly Flexigrid and Sort-X when fishing for cod.

Short description of the system

The selection system consists of a tubular two panel net section (like a belly), and two flexible grids mounted in the net section with fixed angels and positions. The net section is placed between the trawl belly and the codend (or extension of the codend if present). The grids are mounted in the aft part of the net section, one in the lower panel and one in the upper panel, with theoretical angle of attack of 25°. The intention with this construction is that fish entering the codend, first will meet the grid in the lover panel and fish small enough will then have the possibility to escape. Small fish that have not escaped and bigger fish will then be guided to the grid in the upper panel and get a new chance.

The net section is approx. 14m long and made of 4mm double polyethylene with 160mm-mesh length. The grids are about 95cm wide and 160cm long. The longitudinal bars in the grids are made of polyamide (PA) bolt and they are held together and given a constant distance by transverse rubber bands. This makes the grid more flexible in the transverse direction than in the longitudinal direction. At both ends of every bar there is a shackle witch makes the connection to the net panels easy. The long sides of the grids can be attached to the net panels by using strips.





Conducted tests

During the developing process, different materials and dimensions of bars and transverse bands have been tried, and the materials breaking loads and durability have been tested. Full-scale testes of the selection system with the first prototype of the grids have been carried out in a towing tank at Marintek, Trondheim, at to research cruises with the research vessel F/F Jan Mayen, Tromsø. Grids with different bar diameter and different distance between transverse bands were tested with regard to selectivity efficient. The grids placing and angle of attack were also varied (Angell, 1999).

Based on these first tests a new prototype of the grids was made. The selection system with the new grids has been tested at the flume tank in Boulogne in full scale (Repecaud et. al., 2000), and at four research cruises at the commercial fishing vessel "Bliki" (Angell, 2000). The tests gave us many answers regarding to optimal placing of grids, and what kind of material we should use in the transverse bands.

All the tests with regard to establish the systems selective characteristic have been carried out by the recommendations in ICES report no.215, (1996). Methods like "Covered codend", "Top cover" and "Alternate haul" have been used and statistical software from ConStat, Denmark (CC-Selectivity, CC2000 and EC-Model) has been used to process data.

Results and Discussion

The results from the developing process and the tests show that the flexible grids have good strength and keeping qualities. No permanent deformations of the grid components were observed and there was no disruption on lower panels. The grids roughly weight in air and water is respectively 15 and 5 kilos. The weight in air and water for stainless steel grids with the same length and width as the flexible grids is 45 and 37 kilos. This means that the weight reduction is 70% in air, and 90% in water. The handling of the grids on deck is easy and there are no safety risks by using the system in bad weather. It is also possible to take the grids onto a net drum, without damaging them. The system is in other words very user-friendly and the reason is both the flexibility and low weight of the grids. Other positive experiences are that there is no need for extra floats, support chains or guiding panels so maintenance and control is easy. The selection system can also be produced at a considerable lower price than existing systems.

Regarding to selectivity properties we have relatively good measurements on cod (*Gadus morhua*) and saithe (*Pollachius virens*) and some but to few measurements on haddock (*Melanogrammus aeglefinus*) to give any certain figures. Table I shows the selection range (SR) and the 50% retention length (L50%) from the latest trails

Table I Selectivity properties

Species	**Bar distance**	**Model**	**SR**	**L50%**
Cod	55 mm	(EC-Model)	8,4 cm	50,3 cm
Cod	60 mm	(EC-Model)	10,0 cm	52,3 cm
Saithe	50 mm	(EC-Model)	7,7 cm	48,5 cm
Saithe	55 mm	(EC-Model)	6,7 cm	52,6 cm
Haddock	50 mm	(EC-Model)	6,9 cm	44,2 cm*

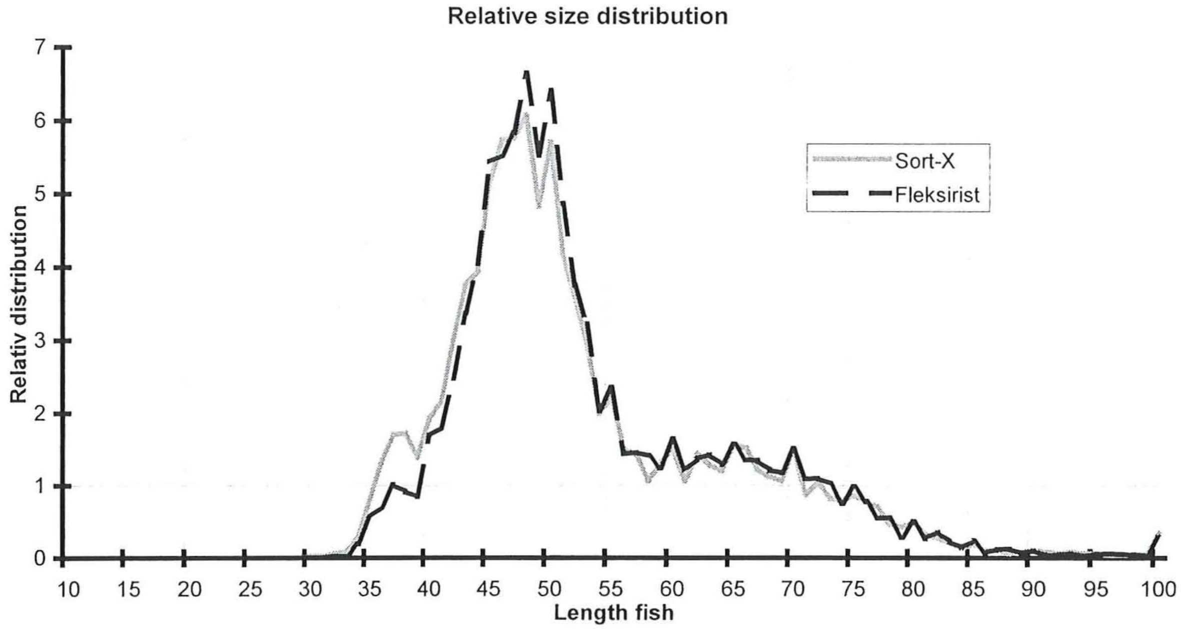
(**Old figures from first prototype of the Flexigrid)*

Compared with e.g. Sort-X we can presume that the SR and L50% is approximately the same.

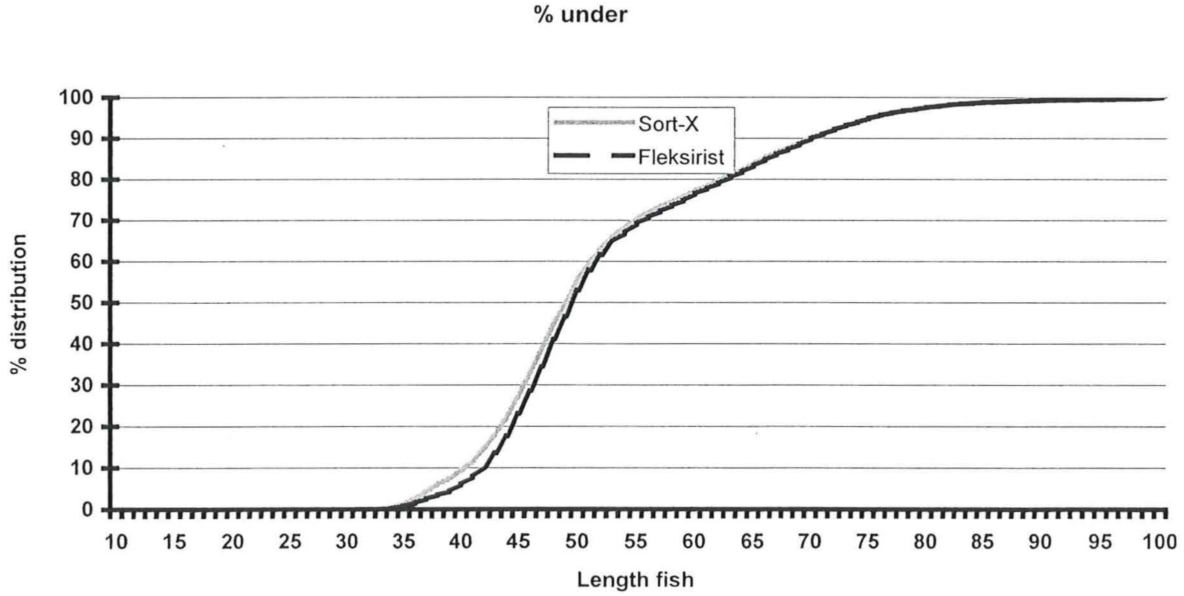
Of other results worth mention is that the distance between the transversal bars is of importance of how effective the selection is. Short distance gives poorer selectivity. By separating the fish sorted out from the grid in the lower panel from fish sorted out through the upper grid we found that as much as 45 to 50 percent of the total amount of sorted out cod is passing through the lower grid. For saithe and haddock a larger percent is passing through the upper grid, approx. 60 to 70 percent. A very interesting observation is that there is relatively smaller fish sorted out through the lower grid than through the upper grid.

An overall conclusion is that the concept with flexible grids made of plastic and rubber materials and mounted as described earlier seems very favourable.

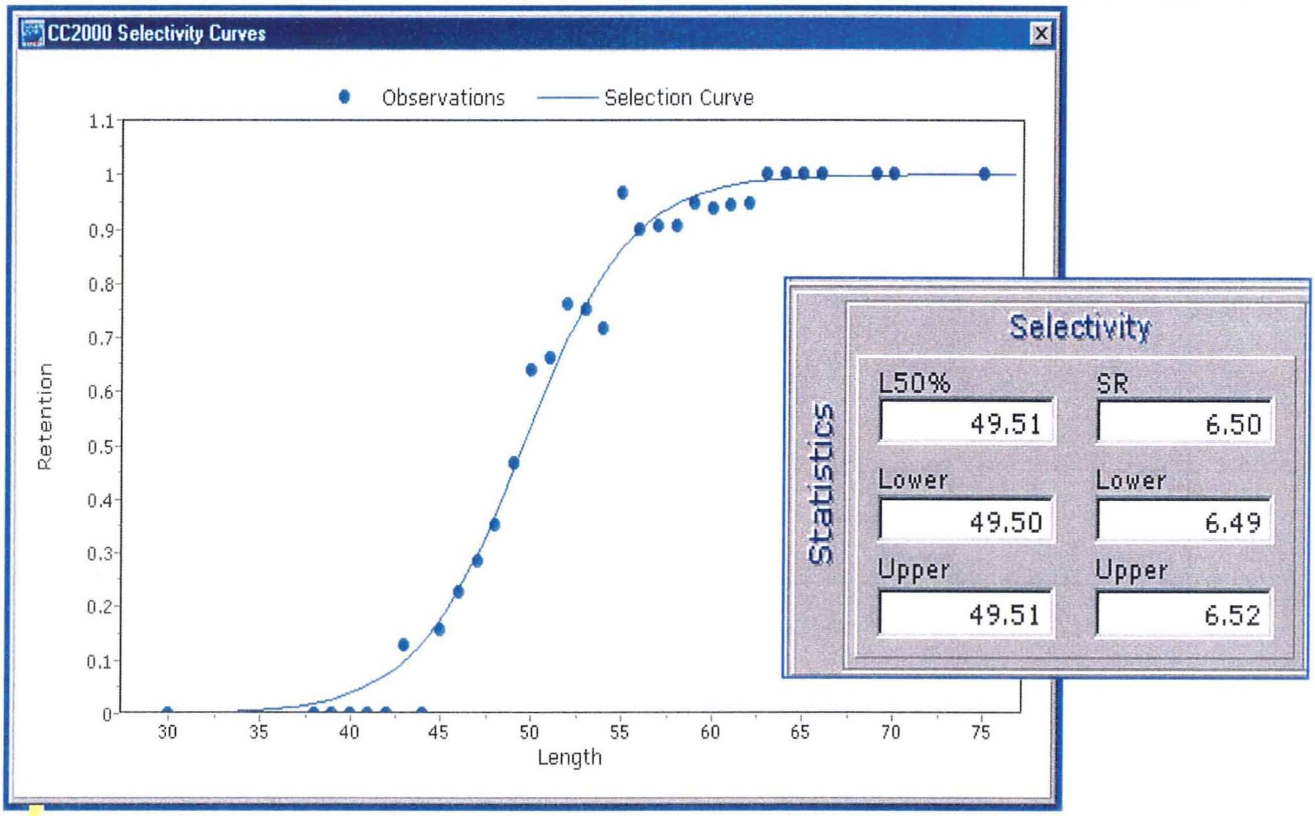
The testing of the system is expected to be finished by the end of 2001.



COMPARISON OF FLEXIGRID AND SORT-X. FISHING FOR SAITHE IN MARCH 2001. THE FIGURE SHOWS THE SIZE DISTRIBUTION OF THE FISH IN THE CATCH WHEN USING FLEXIGRID AND SORT-X.



THE FIGURE SHOWS THE PROPORTION OF FISH BELOW A CERTAIN LENGTH. COMPARISON BETWEEN FLEXIGRID AND SORT-X.



L50% 49.51

SR 6.50

Lower 49.50

Lower 6.49

Upper 49.51

Upper 6.52

EXAMPLE OF SELECTION CURVE FROM THE CRUISE IN JUNE 2001.

Session 2: Fishing regulation measures and by-catch criteria

9th Joint Russian-Norwegian Symposium
Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

A PRELIMINARY ASSESSMENT OF THE EFFECTS OF INTRODUCING A GRID IN THE TRAWL FISHERY FOR NORTH-EAST ARCTIC COD *

by

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Abstract

A number of studies have dealt with the testing of alterations of existing gears meant to reduce by-catch of non-target species or sizes. Such alterations can for example be changes in mesh size, mesh shape or introduction of sorting devices (grids, outlets etc.). Some of these gear alterations have also been implemented in the fishery. In the fishery for North East Arctic cod, e.g., the use of an approved sorting grid became mandatory in 1997. However, an assessment of what one should expect to gain concerning stock size, stock composition and thus yield by introducing a new gear has usually not been done, probably because it is difficult to do such assessments with age-structured stock models. Lately, however, there has been an increasing demand for studies dealing with these aspects. The aim of the present work is to simulate the effects on fishing mortality, stock size and yield by introducing a sorting grid in the trawl fishery for North East Arctic cod. Results from selectivity studies with ordinary commercial trawls with mesh size 135 mm in the codend, both with and without a sorting grid (Sort-X, single grid) mounted in the extension, are used in an age-length structured stock model, Fleksibest, to simulate these effects.

Introduction

By-catch of non-target species and sizes is a serious problem in fisheries (Alverson & al. 1994, Hall 1996), and an estimate of the yearly discard in commercial fisheries is between 17.9 and 39.5 million tons (Alverson & al. 1994). A number of studies to improve selectivity in existing gears by changing for example meshes (size, shape), introducing sorting devices (grids, outlets) etc. have been completed. Many of these gear alterations have also been implemented in the fishery. For example, the use of an approved sorting grid became mandatory in the fishery for North Arctic cod in 1997. Before such introductions characteristics of the gear, like catch (selectivity, loss of target species etc.), survival of individuals escaping and user-friendliness of

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* *This paper is a modified version of a working document presented at the FTFB (Fisheries Technology and Fish Behaviour) Working Group Meeting in Seattle, 23-27 April 2001*

the new gear are usually studied (Broadhurst 2000). However, the perhaps most important issue of them all, what one could expect to gain in stock size, composition and thus yield by introducing this new gear, has usually not been studied.

Stock effects of gear changes should always be assessed before introduction. In stocks with large year-to-year changes in recruitment, growth or mortality, like North East Arctic cod (Mehl 1991, Mehl & Sunnanå 1991, Nakken 1994), the effect of introducing a new gear cannot be assessed by comparing stock characteristics before and after the implementation. One problem of introducing a new gear without simulating stock effects in advance, is that if the stock size and thus quotas decline after the introduction, as observed in North East Arctic cod after 1997, the fishermen will naturally become more and more unwilling to use the new gear. Lately, the increasing criticism of the grid in Norway has consequently enhanced the demand for results showing how the use of a sorting grid influences the state of the cod stock.

An age-length structured stock model, Fleksibest (Frøysa & al. in press), have been developed to handle for example the large variations in size at age observed e.g. for NA cod (Mehl 1991, Mehl & Sunnanå 1991). Fleksibest models biological processes like growth, maturation and mortality as a function of length instead of age. In addition, Fleksibest contains an optimisation tool, changing model parameters to give the best possible fit between observed data (catch, surveys) and the model. The model part of Fleksibest can also be used alone as a pure simulation tool. In our study Fleksibest is used as a pure simulation tool, but the input for the simulations are real data from the best available optimisation run. Fleksibest is well suited for simulating stock effects of using different fishing gears, since selectivity is linked to size (and length is a good proxy for size) whereas most stock models are structured by age. Our study compare simulated stock size (total stock, spawning stock), catches and fishing mortality for a fishery with an ordinary cod trawl against a fishery with a sorting grid mounted in the extension ahead of the codend. In our simulations, all parameters but the selectivity are kept constant.

Material and methods

SELECTION EXPERIMENTS

The selection curves used in our simulations come from data from selectivity studies on mesh selection and grid selection (Table 1). For the mesh selection, a logistic selection curve gave the lowest deviance. For each of the 16 hauls, a logistic selection curve was fitted to the data by CC2000 (ConStat) and then a mean curve (Table 2) for all hauls was calculated by EC (ConStat). The grid selection curve is calculated by Isaksen & al. (in press), and is a mean curve for the selection studies comparing single grid (Sort-V) and Sort-X (Table 1). The selection curves for the two grids were not significantly different, and all the hauls were thus combined. The common mean selection curve (Table 2) was calculated by the same method as described for mesh selection.

Table 1 The selection experiments. Vessel: Anny Kræmer, selection curve: logistic.

Date	Area	Survey	Experiment	# hauls	
25. August - 5. September 1989	East of Rybackya Bank, Barents Sea	Mesh selection	Covered codend	16	Isaksen & al. (1990)
15. - 28. August 1997	Around Bear Island	Grid selection	Cover bag over grid and blinded codend	19	Isaksen & al. (1998), (in press)
3. -16. August 1998	Around Bear Island	Grid selection	Cover bag over grid and blinded codend	29	Isaksen & al. (1998), (in press)

Table 2 Selection parameters for mesh and grid selection (see also figure 1)

Selection curve	Experiments	l_{50}	SR	α	β
mesh	1989	47.09	13.36	-7.74	0.1645
grid*	1997, 1998	51.95	12.08	-9.45	0.1819

* from Isaksen & al. (in prep.)

The formula for the logistic selection curve is

$$r(l) = \frac{1}{1 + e^{-\alpha - \beta l}}$$

where r(l) is the retention probability, and α and β are parameters.

l_{50}, the length where the probability of retention is 50 %, is calculated as

$$l_{50} = -\frac{\alpha}{\beta}$$

and the selection range, SR, as

$$SR = l_{75} - l_{25} = \frac{2 \ln(3)}{\beta}$$

In our simulations we are interested in fleet selectivity, but we only have information about the gear selectivity and use this instead since the aim of the study is to compare trawl fisheries with and without grid. The difference between fleet and gear selectivity is probably the same whatever gear used, and these simulations should thus be valid for comparisons.

We are interested in the total selection of the gear (within the net), but in the selectivity experiments with grid only grid selectivity has been examined. We thus do not know anything about the potential selectivity in the codend when a grid is mounted. To get a realistic estimate of the total selection we have included two possible scenarios of selection in a trawl with grid:

1) Exclusively grid selection, no selection in codend

2) Grid and codend selection independent (i.e. the grid does not influence the selection in the codend). The total selection thus becomes the product of the retention in the grid (1997, 1998) and the retention in the codend (1989) resulting in a logistic times a logistic selection curve (see figure 1).

The truth is probably somewhere in-between, and in June this year both grid and codend selection was be examined simultaneously.

This gives 3 different simulations:
1) Mesh selection
2) Grid selection
3) Mesh and grid selection

In the simulations only the selection curves (figure 1) are varied.

For the simulations we need a stock model, and chose Fleksibest.

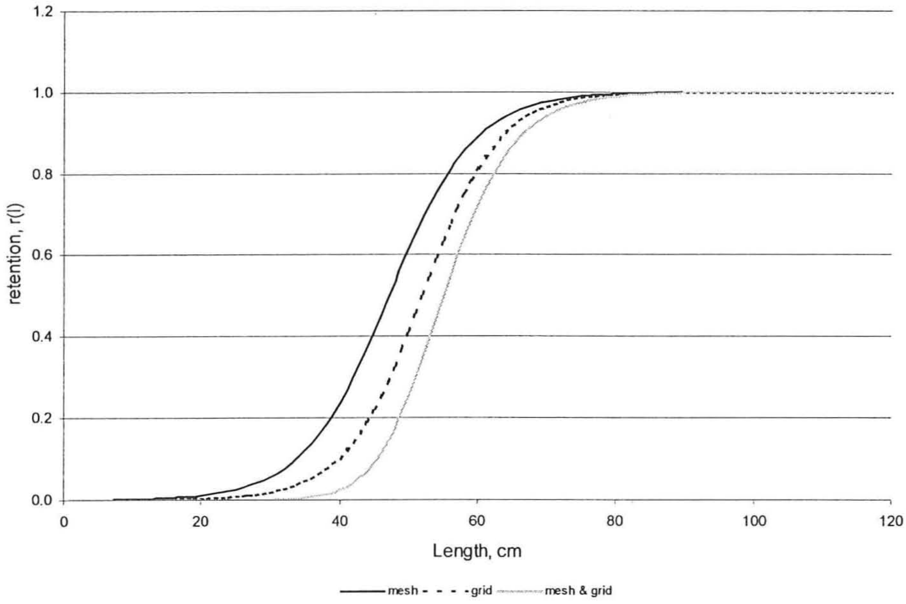

Figure 1 The selection curves used in the 3 simulations

FLEKSIBEST

Fleksibest is an age-length structured stock model, where a self-contained population model is fitted to observed data as reported landings, survey indices and stomach data (Frøysa & al. in press). The different age-length classes are kept track of by the model's matrix structure. Stock models are usually age structured, but in boreal systems variations in inter-annual growth and consequently size at age are large (Mehl 1991, Mehl & Sunnanå 1991). Since most biological processes, like growth, mortality and reproduction are closer related to length than age, stock models in such areas should be length structured (Frøysa & al. in press). This is also favourable when simulating changes in the selectivity of a fishery, since selection is connected to size which length is a good proxy for.

The current version of Fleksibest divides the cod stock into an immature and a mature cod stock, uses one area and four equal time steps a year. Each length class is 2.5 cm and true age is used for all age classes except for the 12+ class, which is a plus group. The length span is 5-135 cm and the age span 3-12+. The immature stock includes age classes 3-10 years, and the mature stock 5-12+ years. Length classes are 5-120 cm for the immature stock, and 45-135 for the mature stock. These settings are, however, flexible. Fleksibest contains models for growth, predation due to cannibalism, fishing mortality and maturation (Frøysa & al. in press). During a stock assessment with Fleksibest observed and modelled stock and fisheries characteristics are compared, and the model parameters are optimised to minimize the deviance between modelled and observed data giving the best possible fit of all chosen parameters at the same time.

Growth

The quarterly mean growth is modelled as (figure 2)

$$\Delta l(s,y,t) = k(s) \times k(y) \times \Delta t$$

where s is stock (immature, mature), y year, t time step, Δl growth in cm, k(s) a stock factor (immature: 1, mature: 0.8), k(y) yearly growth (cm year^{-1}) and $\Delta t = 0.25$ year. Based on the mean growth, the cod in a length group is transferred to new length groups in the next time step. For more details see Frøysa & al. in press.

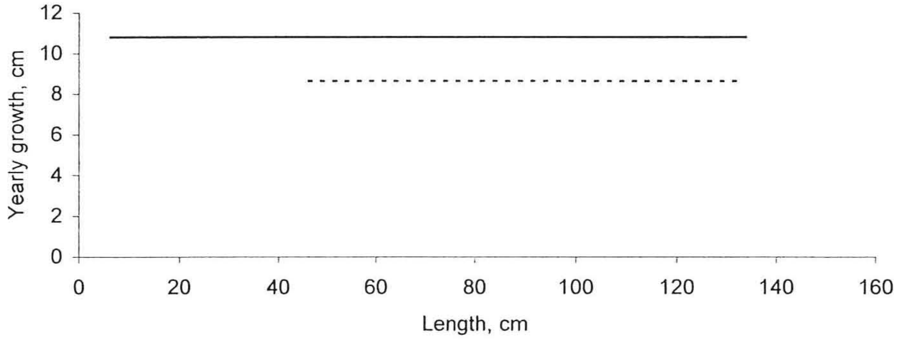

Figure 2 The growth is not length-dependent, and the figure show the yearly growth of the immature (solid line) and mature (broken line) stock for 1999. k (1999) = 10.8 cm year^{-1}.

The growth in weight is not modelled explicitly. Mean weight for each length group at each time step is given by observations.

Maturation

The maturation is modelled by a logistic function (figure 3)

$$P(l) = \frac{1}{1 + e^{-4\alpha(l - l_{50})}}$$

where l is length, P(l) the probability of maturation (i.e. being moved from the immature to the mature stock) for a given length, l_{50} the length with a 50 % probability of maturation (78.44 cm) and α a parameter deciding the slope of the maturation curve (0.03). In addition there is a minimum age of maturation (5 years), working by returning "maturing" fish (fish moved from the immature to the mature stock) younger than five years back to the immature stock.

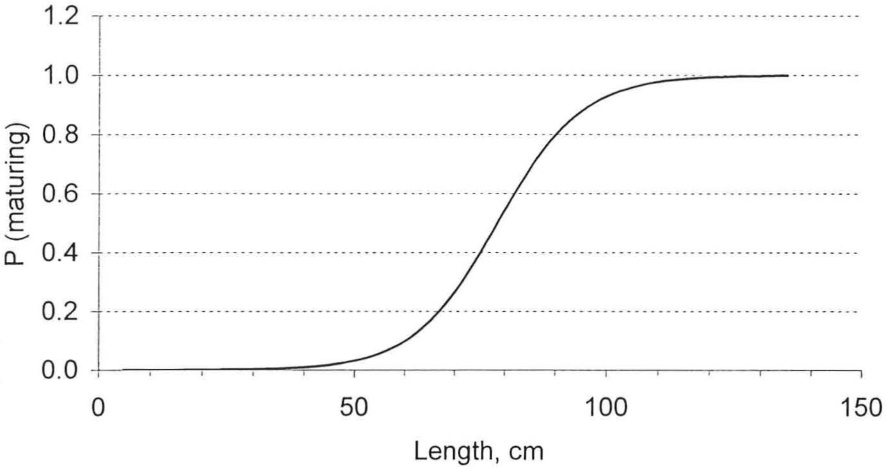

Figure 3 The maturation model used in the simulations. Note that P (maturing) is the probability of being moved from the immature to the mature stock for a given length, and thus not the proportion of mature individuals in the entire stock.

Mortality

The quarterly mortality is modelled as

$$Z(l,t) = F(l,t) + M(l,t)$$

where l is length, t time step, Z(l,t) total mortality (quarter^{-1}), F(l,t) fishing mortality (quarter^{-1}) and M(l,t) natural mortality (quarter^{-1}).

Further, fishing mortality is modelled as

$$F(l,t) = \sum_{f=1}^{N_f} d(f,t) \times S(f,l)$$

where l is length, t time step, f fleet (1 fleet = trawl in these simulations), d(f,t) the fishing pressure of a specific fleet during time step t and S(f,l) the fleet selection curve. The three simulation runs are equal in every aspect (models, input) but the selection curves. d(f,t) is defined as

$$d(f,t) = \theta(f,t) \times \phi(f,y)$$

where y is year, ϕ(f,y) yearly level of fishing mortality for fish lengths fully recruited to the fisheries of a specific fleet and θ(f,t) a factor distributing ϕ(f,y) on time steps by observed weight of catch (see Frøysa & al. in press).

The natural mortality is modelled as

$$M_s(l,t) = M1(l) + M2_s(l,t)$$

where s is stock (immature / mature), l length, t time step, M total natural mortality, M2 natural mortality due to cannibalism (only for immature stock) and M1 residual mortality (0.05 time step^{-1} = 0.2 year^{-1}).

The cannibalism mortality fish of length l is exposed to is modelled as

$$M2(t,l) = \frac{\alpha e^{-\beta \times l^{\gamma}} \times B(t,21_{+})}{V(t)^{\delta}}$$

where t is time step, l length, $B(t,21_{+})$ biomass (ton) of cod with length 21 and larger, V(t) capelin biomass (ton, food for cod). The cannibalism mortality increase with decreasing capelin biomass and increasing biomass of large cod, $B(t,21_{+})$. In our simulations cannibalism mortality range from 0.0169 to 0.3000 year^{-1} for 3 year old cod and from 0.0047 to 0.0934 year^{-1} for 4 year-olds.

INPUT FOR THE SIMULATIONS

The aim of this work was to study the effects of introducing the sorting grid in the cod fishery by modelling the stock development from 1985-2000 for a trawl fishery both with and without grid. All input parameters and models but the selection (see equation for fishing mortality) was kept constant between the three simulations. The Fleksibest model used as a pure simulation tool needs information about:

- Initial year: number and length distribution (defined by a normal distribution) for all ages, distributed among the immature and mature stock
- Recruits (3 year-olds): number and length distribution (normal) every year
- Yearly fishing mortality for each fleet
- Mean growth each year
- Residual natural mortality
- Maturation: maturation model (estimate of l_{50}), and
- Total biomass of capelin each time step for calculation of cannibalism mortality

Our simulations cover the period 1985-2000, and the input needed (see table 3-4 and the text describing the model) comes from the best available assessment run with Fleksibest.

Table 3 Input for Fleksibest in our simulations. Initial numbers and length distribution (defined by a normal distribution) for the immature and mature stock in the first time step in the first year (1985).

	Immature			Mature		
Age	Number, 10^7	Mean length, cm	SD(mean length), cm	Number, 10^7	Mean length	SD(mean length), cm
3	52.390	40.6	5.1			
4	31.610	48.7	4.1	0.000	51.0	14.9
5	8.780	61.3	4.9	0.868	59.6	1.1
6	2.980	71.1	5.3	1.680	71.1	6.7
7	0.920	81.2	5.4	1.130	79.0	3.2
8	0.100	85.7	8.7	0.540	88.2	5.1
9	0.010	90.0	8.7	0.300	97.3	3.1
10	0.000	90.0	8.7	0.190	105.2	5.4
11				0.040	114.0	10.6
12+				0.030	114.0	3.3

To do these simulations we had to do some assumptions:

- Fleet selection assumed equal to gear selection
- All the catch was taken by one fleet, the trawler fleet (with or witout grid, depending on simulation)
- No escapee mortality after gear contact
- Recruitment and growth not influenced by gear type (with or without grid) and potential consequences of using this gear
- Yearly fishing mortality experienced by fish lengths fully recruited to the fishery identical between simulations

Table 4 Input for Fleksibest in our simulations. The growth factor, k(y), numbers and mean length of recruits (3 year-olds), total fishing mortality for lengths fully recruited to the fishery, $\phi(y)$, and capelin biomass (the value for the first time step each year is shown, but the input is for each time step).

Year	k(y), cm year^{-1}	# recruits, 10^7	Mean length recruits, cm	$\phi(y)$, year^{-1}	Capelin biomass, tons
1985	9.4	*	*	0.70	1884000
1986	7.0	103.94	34.3	0.87	510000
1987	4.7	28.67	32.0	0.95	156000
1988	9.2	20.47	30.0	0.98	115000
1989	13.3	17.27	33.5	0.67	718000
1990	12.6	24.27	38.8	0.28	2011000
1991	8.4	41.15	42.6	0.32	6307000
1992	9.1	71.39	40.0	0.45	7406000
1993	6.1	89.66	35.5	0.55	3777000
1994	10.1	81.48	30.4	0.87	737000
1995	8.5	64.82	29.9	0.79	156000
1996	9.7	43.43	28.3	0.70	313000
1997	9.7	73.1	28.6	1.04	779000
1998	10.7	89.44	29.3	0.93	1240000
1999	10.8	58.51	29.0	0.96	2376000
2000	10.8	71.15	28.7	0.96	2264000

* see table 3

Results

These simulations show that with our assumptions, the use of a grid in the trawl fishery reduces the fishing mortality (figure 4) for 3-6 year old fish with between 0.05 (only grid selection) and 0.1 (both grid and mesh selection). The fishing mortality for fish aged 7-12+ stays the same.

Concerning total stock biomass (figure 5), the modelled gain by using a grid is between 150 000 (only grid selection) and 300 000 tons (both grid and mesh selection) at the end of the simulation period. For the spawning stock (figure 5), the modelled increase is between 50 000 (only grid selection) and 100 000 tons (both grid and mesh selection).

When looking at the weight of total catches (figure 6), the first 2 years of the period (1985-1986) the catches would be lower (maximum 50 000 tons) when using a grid in the trawl compared to no grid. However, already in 1988 the modelled catches are higher in the simulated fishery with grid. This can be explained by the observed increase in stock biomass when fishing with a grid. When splitting the catches by age, we can see that with a grid there is much lower modelled catch of 3- and 4-year-olds, whereas the catches of 5-year-olds are about the same in all the three simulations. For fish of age 6+, the catches after 1986 are higher in the simulated fishery with grid, which can be explained by higher stock biomass. The observed catches are also included in the figures (figure 6), and coincide quite well with the modelled total catches and catches of age 5+. However, for 3- and 4-year-olds there is a large mismatch between observed and modelled catches.

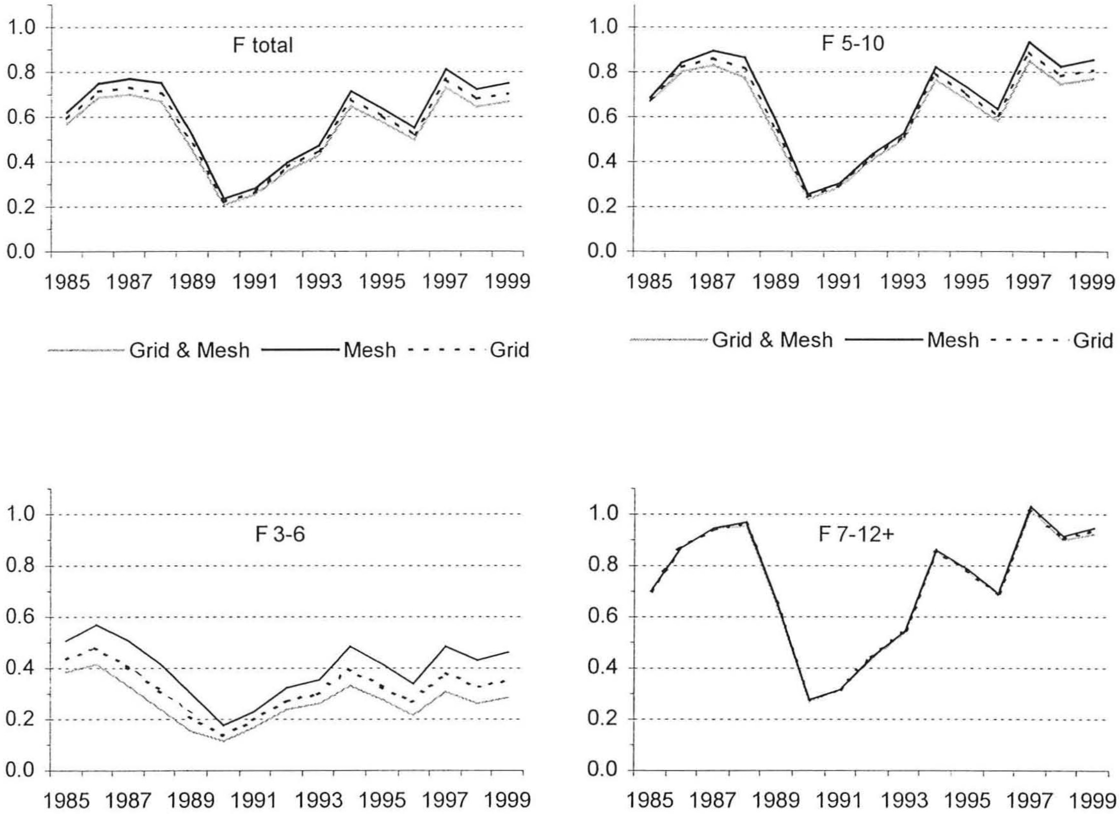

Figure 4 The fishing mortality in each of the 3 simulations (mesh, grid, mesh & grid – see selection experiments, material and methods) for each year in the period 1985-1999. F total is the arithmetic mean fishing mortality for all age classes (3-12+ years), F 5-10 for age 5-10, F 3-6 for age 3-6 and F 7-12+ for age 7-12+.

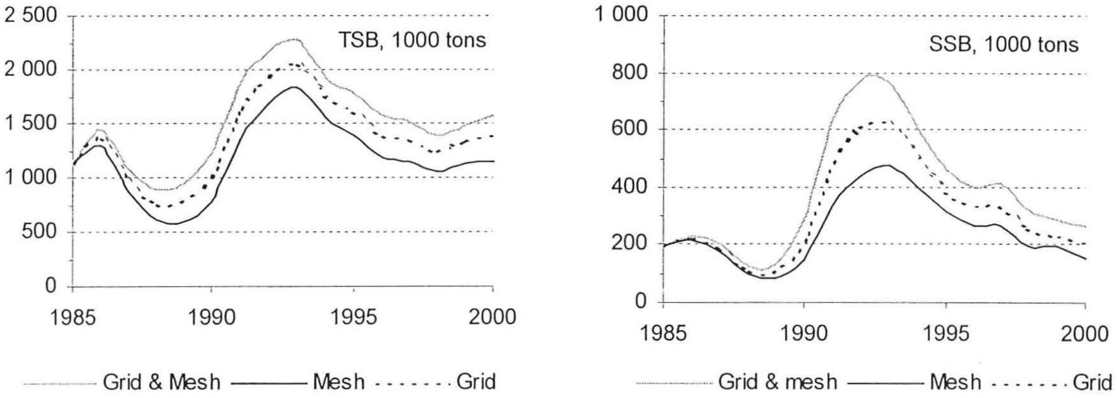

Figure 5 Total stock biomass (TSB) and spawning stock biomass (SSB) in thousand tons for each of the three simulations (mesh, grid, mesh & grid – see selection experiments, material and methods) each year in the period 1985-2000.

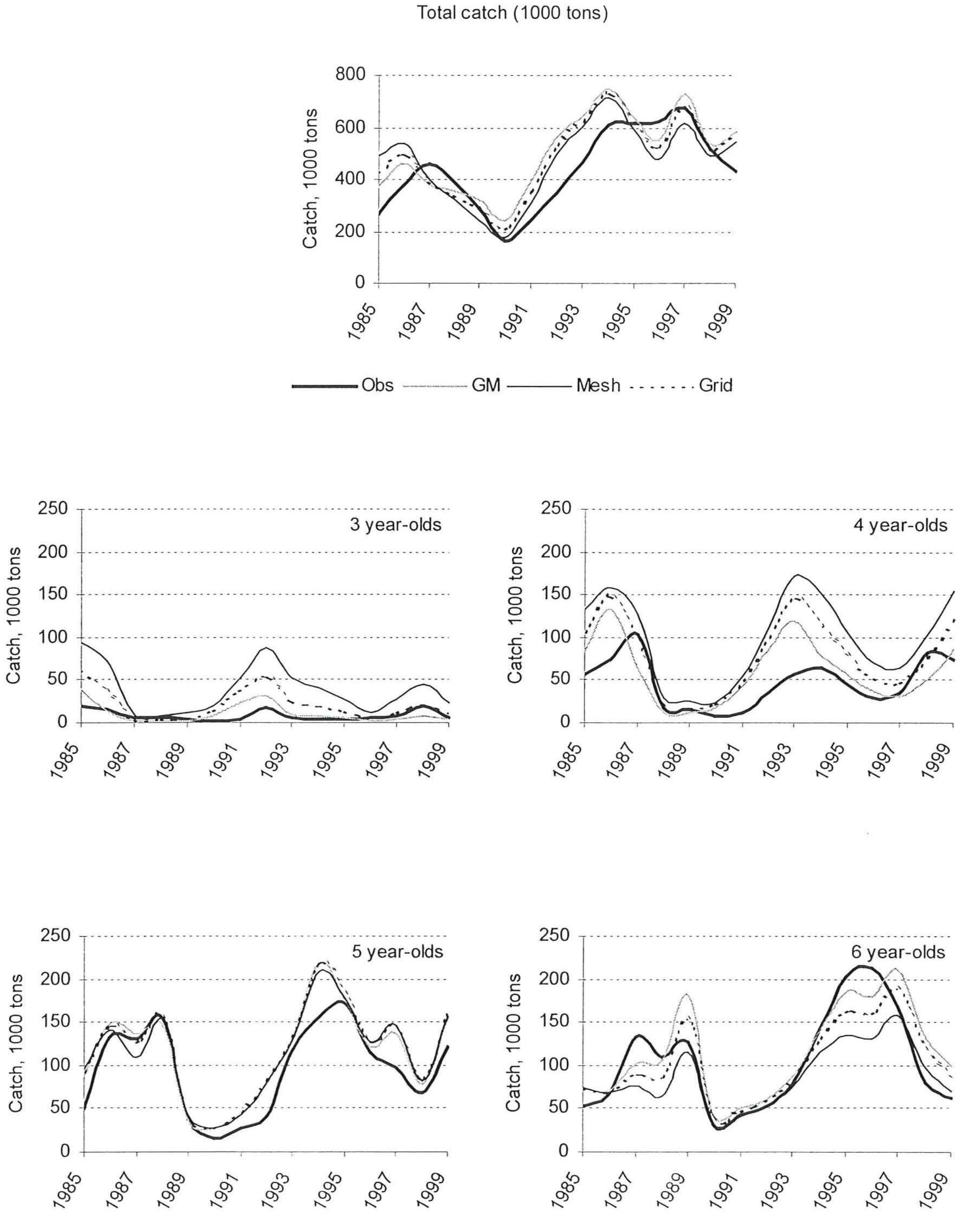

Figure 6 Observed catches (Obs) and modelled catches (for each of the three simulations: mesh, grid, grid & mesh (GM) – see selection experiments, material and methods) in thousand tons for each year in the period 1985-1999. The total catches and the catches of 3-, 4-, 5-, and 6-year-olds are shown.

Discussion and further work

This preliminary assessment of the effects of introducing a grid in the trawl fishery for North-East Arctic cod, indicate that the effects are positive. In our simulations, the fishing mortality of 3-6 year-olds was reduced, leading to an increase in stock biomass after about 3 years (1988). The total catch decreased the first 2 years, but subsequently increased as the general increase in stock biomass compensated for the loss of 3- and 4-year-olds in the catches. It thus seems that by saving 3- and 4-year-old fish and reducing the fishing pressure on 5- and 6-year-old fish, a reward in stock biomass is achieved within a few years. We might thus speculate that the state of the North East Arctic cod stock might have been even worse than today without the introduction of the grid in the trawl fishery.

There is a large mismatch between modelled and observed (reported) catches, especially for 3- and 4-year-old fish. The most obvious reasons for this mismatch may be the use of gear selection instead of fleet selection in the simulations, the use of only one fleet in the simulations and discard / misreporting. The most likely explanation is a combination of all these factors. If the fishermen deliberately avoid areas with much small fish, the fleet selection will mirror this by being located further to the right, with a higher l_{50}, than the gear selection. The use of only one fleet, the trawler fleet, in these simulations can also explain the difference. The gillnet fishery for example, also contribute much to the catches of cod (Toresen & al. 2000). This fishery is mainly located in the cod's spawning area, and by omitting this fleet the catches of small cod were overestimated. Discards and misreporting of catches can also explain the differences between modelled and observed catches.

The selection experiments, which the selection curves in the simulations are based upon, are all done at about the same time of the year and with the same vessel, but in different years (1989, 1997, 1998) and partly in different areas (mesh: east of Rybachya Bank - Barents Sea, grid: around Bear Island). However, in all the experiments the catches were quite high and the size distribution of cod good (both small and large fish). The difference in year and area may, however, have affected the comparability of the selection experiments (Wileman & al. 1996), and in June this year a selection experiment looking at both mesh and grid selectivity at the same time was carried out in the area around Bear Island. The data are now being analysed.

In the simulations, certain assumptions are made. The gear selectivity from each selection experiment is used as fleet selectivity in the simulations. Thus, the results must be considered as indices of differences between fisheries with and without grid instead of absolute differences. If the fishermen's behaviour do not differ too much when using grid compared to when not using grid, the error of using gear selectivity as fleet selectivity should be similar in all these simulations, thus providing comparability. The use of only one fleet in the simulations overestimates the effect of introducing a grid, and future simulations will be run with several fleets (handline, gillnet, Danish seine, trawl). The assumption of no escapee mortality should be reasonable, as nearly 100 % survival has been observed for cod after escaping from a trawl (Soldal & al. 1993). The input for the simulation period, 1985-2000, (numbers, mean and SD of length for 1985 [initial year] and recruits, yearly growth, cannibalism and maturation model) come from an assessment run of Fleksibest, where the models of Fleksibest are fitted in the best possible way to the observed data (survey indices, reported catches and stomach data for cod) (see Frøysa & al. in press), and the input should thus be reasonable. The residual natural mortality was set to 0.2 year^{-1}, which is the value used by the AFWG. The yearly recruitment and growth were input to the model (model estimates from observed data), and there were large year-to-year variations (table 4). The input was kept constant for all simulations, as no model for a stock - recruitment or a stock size – growth relationship is included in the model. The existence of such relationships would influence the stock in opposite directions, and some of the bias added to the simulations by keeping recruitment and growth constant between simulations would thus cancel out. A large spawning stock should, in the long run, give a higher recruitment than a small spawning stock (Pitcher & Hart 1982), and the growth may decrease if the stock size increases. The uncertainties about the model foundation for stock – recruitment and stock size – growth relationships may cause a choice of a certain model linking the parameters to stock size to create more uncertainty than keeping these parameters constant between simulations.

In the near future, further simulations on the subject of estimating the effects of introducing a grid will be run. More fleets (gillnet, handline, Danish seine, trawl) will be included in the following runs. We will also run a simulation with a theoretical mesh selection curve with the same l_{50} as for grid, to evaluate if similar results as for grid could be achieved by increasing mesh size. By now, the fishermen are allowed to take out the grid when the weather is bad, and this can be modelled by splitting the trawler fleet into two fleets. It is also possible to include escapee mortality in the simulations to see how this might affect the benefits of using a grid.

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ON BIOLOGICAL SUBSTANTIATION OF THE MINIMAL LANDING SIZE FOR COD AS A FISHERY REGULATION MEASURE

by

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Abstract

The paper presents a brief overview of a variety of methods used to determine the minimal landing size of fish which have been proposed by Soviet and Russian authors, and their analysis. A feasibility of application of each particular method to determine the minimal landing size for the North-East Arctic cod has been evaluated.

Analysis of the methods has confirmed that a problem of establishing a minimal landing size of fish is a problem of choosing a compromise option which could meet the requirements of maximising the catch and maintaining the spawning potential of a population which can assure an adequate recruitment to the stock. It is noted in the paper that major factors deciding which of the compromise options is chosen, are size structure of a fishable population, growth and maturation rate of fish in this population, specific features of the distribution of fish from different size groups and selectivity of fishing gear.

An appropriateness of application of the minimal landing size of 42 cm for the North-East Arctic cod as satisfying most of these factors has been reinforced.

Introduction

High and stable yearly catch is possible only with efficient management of the fishery achieved through establishing various restrictions on the harvesting of resources such as closure of areas for fishery at specific times, regulation of fishing gear and fishing techniques, minimal landing size, minimal mesh size and allowable by-catch of undersized fish.

All above measures are closely interrelated and could be effective only when they are implemented together supplementing each other.

According to many researchers (Tyurin, 1967; Nizovtsev et al., 1990) a biologically substantiated catch limit (total allowable catch, TAC) is the most important management measure. Other measures including minimal landing size are of ancillary nature. This is supported by the fact that in the 60-70's before the Joint Soviet/Norwegian Fisheries Commission was established and a TAC was implemented such regulatory measures as the minimal mesh size in trawls, minimal landing size of fish and allowable by-catch of small fish could not preclude abrupt fluctuations and reduction of fishing efficiency, decline of the total cod catch and did not contribute much to sustainability of the cod stock.

At the same time, the effect of a TAC established to maintain the spawningtock at a level which could safeguard the population from appearance of weak year classes due to insufficient number of parent fish could be reduced to zero because of inadequate protection of juveniles of commercial species from the fishery.

In Russia back in history the first legislative act limiting the minimal landing size of fish was a special decree of 1665 issued by the tsar Aleksei Mikhailovich (1645-1676), which prohibited fishing for sterlet of less than 8 vershoks[1].

In the world commercial saltwater fishery practices a minimal landing size of fish was first used as a measure to regulate the fishery in the beginning of the XX century in the plaice fishery in Kattegat (Baranov, 1918). Minimal size of fish landed as catch was limited by 26 cm.

In the Barents Sea and adjacent waters historically the first regulatory measure applied was a minimal mesh size (110 mm) in a codend of industrial trawls in cod and haddock fishery. Such a regulation of the mesh size in bottom trawls was implemented from 1959 after ratification of the Convention on Fisheries in the North-East Atlantic established in 1946.

A limitation for the minimal landing size of cod and haddock in the Barents Sea and adjacent waters was first implemented in the fishery practices in 1967, simultaneously a minimal mesh size of netting in trawls was increased to 120 mm. Subsequently, concurrently with an increase of the minimal mesh size the minimal landing size for cod and haddock was revised, however, it was not biologically substantiated (Kovtsova, Shevelev, Yaragina, 1991) (Table 1).

Presently, according to national Fisheries Regulations the following limitations are in force in the Barents Sea and adjacent waters in the areas under fisheries jurisdiction of Russia and Norway:

In the Exclusive Economic Zone of the Russian Federation in the fishery for bottom fish it is allowed to use bottom trawls with the mesh size of no less than 125 mm, minimal landing size for cod is 42 cm.

In the Economic Zone of the Kingdom of Norway it is allowed to use bottom trawls with the mesh size of no less than 135 mm, minimal landing size for cod is 47 cm.

In the area of joint fisheries and 200-mile fish protection zone around Spitsberegen in the trawl fishery for cod fishermen of Russia and Norway follow, as a rule, their national Fisheries Regulations.

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[1] About 36 cm.

Table 1. Minimal landing size for cod and minimal inner size of mesh in bottom trawls in the Barents Sea and adjacent waters.

Year of implementation	Minimal landing size, cm	Minimal mesh size, mm
1967	34	130 for Manila or 120 for capron
1981	39	125 for capron
1982	42	125 for capron
1983*	42	135 for capron
1990*	47	135 for capron

* in the Economic Zone of Norway

From 1997 on, in all areas of the cod fishery sorting grids with the distance between bars of 55 mm are mandatory for use, which are mounted in a conical part of the trawl and serve for screening the young fish from the catch.

A difference in the cod minimal landing size currently applied in the fishery creates additional difficulties for the joint management of the stock and is one of the reasons for conflicts between fishers and control authorities during inspections of fishing vessels.

For this reason and bearing in mind the need for protection of juveniles, establishing a biologically substantiated minimal landing size for cod is of great interest from the practical point of view.

The Russian (Soviet) scientific literature dedicated to this problem suggests a number of points of view regarding the methods of determining a minimal landing size of fish. This papers concentrates on their analysis, and evaluates the possibility of the use of one or another method for determining the minimal landing size for the North-East Arctic cod.

Discussion

There is no single viewpoint among researchers on how the problem of determining a biologically substantiated minimal landing size of fish should be resolved. There is one and only theoretical basis for this – a general concept by K. M. Ber (1860) and N. Ya. Danilevsky (1875) about maintaining the productive capacity of a population at a high level and, hence, a need for protection from capture of fish which have not reached maturity so that each individual could at least once in its life time participate in spawning.

On the basis of this general concept researchers have suggested a number of approaches to substantiate a minimal landing size of fish.

1. *A minimal landing size of fish should correspond to the length and age at which with allowance made for natural mortality a maximum biomass of a year class is achieved.*

Such a substantiation of a minimal landing size of fish was given by P. V. Tyurin (1962) and was one of the first attempts to resolve this problem. It was him who first came up with an idea of a necessity of establishing a minimal landing size for all valuable species. Subsequently, using this approach a number of methods were suggested for estimating the minimal landing size of fish (Lukashev, 1964; Rozenstein, Tolmachev, 1971).

According to this method a coefficient of natural mortality is first estimated. Then, knowing the growth of individual fish in weight by age a growth of biomass by age is computed. After that, based on the maximum biomass gained by a year class it is decided at which age the fish should begin to be harvested by the fishery and what the mean length corresponding to this age is.

This methodology did not receive much support and was later a subject of criticism from many points of view (Boiko, 1962; Bryuzgin, 1972). The reason for this was a complexity of computation of the natural mortality coefficients, which in addition were often mismatching real processes in fish populations.

There is a number of papers dedicated to estimation of the natural mortality coefficient by age for the North-East Arctic cod (Borisov, Shatunovsky, 1973; Blinov, 1979; Tretyak, 1984, etc.). Also known are coefficients of natural mortality for this species used by the ICES Arctic Fisheries Working Group. Based on these estimates and length and weight data provided by trawl-acoustic surveys minimal landing size for cod can be computed with the help of. V. Tyurin's method.

Despite a considerable decline of the abundance of each individual year class due to natural mortality, its biomass in the absence of fishery could have been growing until age 9-11 years, after that it began to decrease. A maximum of biomass corresponds to age of about 10 years, and according to P. V. Tyurin it is exactly these age classes which should be harvested by the fishery. At this age cod has a length of about 100 cm. In a year class of cod hypothetically not harvested the proportion of individuals of less than 100 cm could account for about 50% of the total biomass of this year class. It means that with this minimal landing size a considerable part of the stock composed of large traditionally harvested fish would have been under-utilised.

It is obvious, that a prohibition of fishing for cod of less than 100 cm would not be efficient and would lead to considerable losses in catch. For example, the application of this minimal landing size in the period from 1981 to 2000 would have caused a loss in catch in the range of 106 000 to 386 000 tonnes annually.

2. A minimal landing size of fish should correspond to the length at which in ontogenesis individuals have passed the stage of maximum growth in weight.

Such a viewpoint has been suggested by E. A. Bervald (1964). The author proposed to take the mean length, which the fish have in the period of maximum weight growth as a minimal landing size and define it from a plot of the relationship between length and weight. Later on this approach was also criticised, because it was based on the assumption which was not quite correct that the curve of ontogenetic growth of weight of one individual fish repeats the curve of biomass growth of the whole year class.

Since the growth in weight of the North-East Arctic cod is nearly isometric and absolute weight growth in cod increases with age, it is not possible to use this parameter for defining the minimal landing size.

3. A minimal landing size of fish should correspond to the length at which a large yearly growth of biomass of a year class is favourably combined with high fecundity.

The author of this approach (Balagurova, 1963) proposed that the mean length of fish of the age group where a large yearly growth of biomass per unit of fish weight is favourably combined with a high individual fecundity should be assumed to be a minimal landing size. In practice this author used only individual fecundity to establish a minimal landing size. Since the highest fecundity is noted for large repeat spawners, application of this parameter to cod would result in a too large minimal landing size.

An attempt is known of the application of this approach (with a number of additions) to establish a minimal landing size for the Pacific cod (Kin Sen Tok, 1990). On the basis of factual data concerning the age at which a maximum of the biomass is achieved and the majority of fish become mature – 5 years, the author has substantiated the possibility of harvesting the fish from age 4 years. A minimal landing size for the pacific cod in this case would be 55 cm.

Application of this approach to the North-East Arctic cod suggests that it should be harvested beginning from the age of massive maturation - 7 years, i.e. a minimal landing size would be about 75 cm. Should this length be used as a minimal landing size in the last two decades, more than a half of the catch would have been lost (Figure 1).

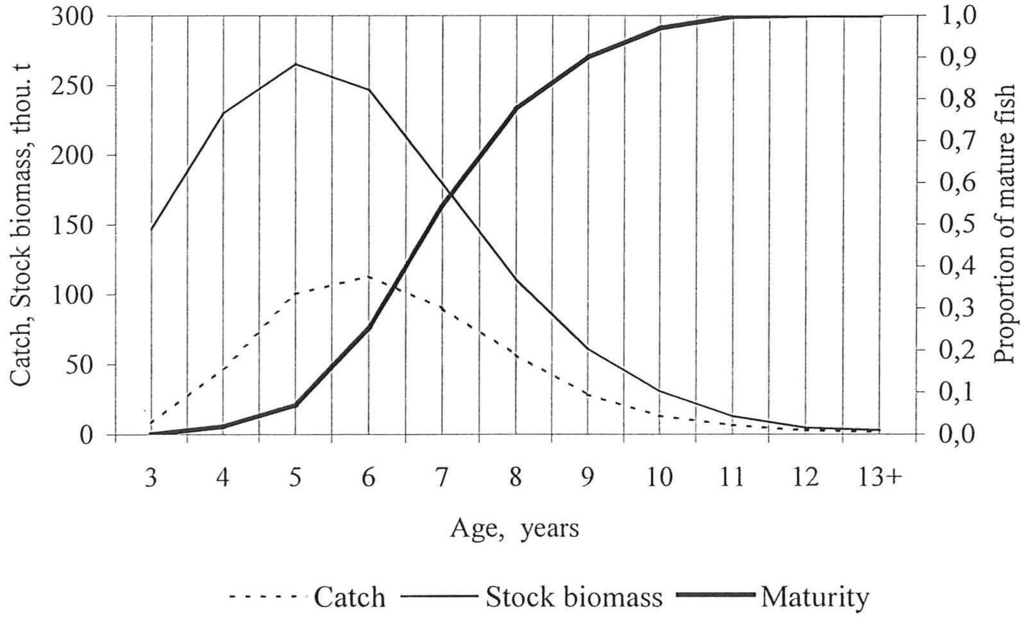

Figure 1. Long-term mean catch, stock biomass and proportion of mature North-East Arctic cod by age in 1981-2000 (Anon., 2001)

4. A minimal landing size of fish should correspond to the length of females at the maximal possible age at maturity

This method based on a generative capacity of age groups of fish has been worked out by V. N. Zhukinsky (1964). Experimentally it was established that egg fertilisation success and larvae survival rates were the best for repeat spawners of certain species. On these grounds the author proposed to use the mean length of mature females from the oldest age group as a minimal landing size. Application of this measure, in his opinion, would enhance the spawning success, and correspondingly, abundance and fishable biomass of the population.

As known, the North-East Arctic cod belongs to species with a long life cycle and extended period of maturation. There are groups of early, medium- and late maturing individuals in the stock, the ratio between them can vary considerably under the impact of various factors (Borisov, 1978). Impacted by the fishery the spawning stock rejuvenates. For example, in the 60's of the last century the majority of fish became mature at age 11-12 years (Glebov, 1963; Ponomarenko, 1984), while in the 80's the age-at-maturity decreased to 8-10 years (Lebed, Ponomarenko, 1985; Lebed, Ponomarenko, 1986). The length of cod at this age is 80-90 cm. Sometimes the spawning stock is dominated by 7- and even 6-year-old cod (Jacobsen, 1978). Also noted is maturation of males at a younger age compared to females (Ponomarenko, Yaragina, 1981; etc.). Nowadays, practically all females become mature not before than the age of 11-12 years (Figure 1). Taking into account this fact, a minimal landing size for cod in accordance with this approach should be, at least, 100 cm.

With this approach modified and the mean length of females at the age, when 50% of females reach maturity, suggested as a minimal landing size, a harvest of cod should begin when they have attained the age of, at least, 7 years, while the minimal landing size should be in the range of 70-80 cm.

In our opinion, such a minimal landing size for cod is also an overestimate and would result in a considerable under-utilisation of the fishable stock. In 1981-2000 the use of such a measure would have led to a loss of about 2/3 of the actual catch.

5. A minimal landing size of fish should be defined on the basis of allowable mesh size in fishing gear

This approach has been used to determine the minimal landing size for cod and haddock currently applied in the Barents Sea and adjacent waters. Established by the "Fisheries Regulations in the Exclusive Economic Zone of Russia" the minimal landing size of 42 cm for cod and 39 cm for haddock is close to the point of 50% escapement on the selectivity curve for the inner mesh size in trawl codends of 125 mm. Before 1990, these sizes were effective in all areas under jurisdiction of Russia and Norway.

A major flaw in this approach is that the minimal landing size defined this way has not been adequately substantiated from the point of view of fish biology. Besides, selectivity of trawls is impacted by a large number of factors such as haul direction, number of fish in a trawl bag, density of aggregations and others (Sakhno, Sadokhin, 1983; Isaksen et al., 1990), which can lead to either an increased or decreased 50% selectivity length.

6. A minimal landing size should correspond to the length at which maturation of individuals in the stock begins with selectivity of fishing gears used taken into account

The authorship of this approach, based on the maturation rate of cod, belongs to G. P. Nizovtsev, M. V. Kovtsova and V. L. Tretyak (Nizovtsev et al., 1990). According to these authors, individuals, which have not reached the length at which maturation begins, should be referred to juveniles. Mature individuals can be found already among 3-year-olds with the length of 36-40 cm. Therefore, it is appropriate to refer all cod of 40 cm and less to juveniles and consider the length of 41 cm as minimal landing size. Moreover, this minimal landing size is close to the length at which 50% of fish escape from a trawl codend with the inner mesh size of 125 mm.

According to this approach, allowable by-catch of fish below the minimal landing size should be of a varying magnitude and would depend on the numbers of recruitment to the fishable stock and catch quota which would enable a considerable part of fast growing individuals to spawn more than one time. A harvest of immature cod within certain limits estimated with due regard to the need to maintain the spawning stock at a safe level is, according to the authors of this approach, quite possible and biologically justified.

So, under this approach the minimal landing size for cod has been substantiated with due consideration of the two most important factors - retention capacity of fishing gear (trawls with the mesh size in a bag of 125 mm) and maturation rate of cod, which meets the requirement of maximising the catch and maintaining the production capacity of this species.

However, this approach is not flawless either. The major difficulty is that the period of maturation is very extended. At age 3-4 years at the length of 50 cm only insignificant number of fish are mature (less than 1%). Therefore, this measure would not allow to take as full benefit of the production capacity of the stock as possible.

Conclusions

Analysis of available Russian (Soviet) papers dedicated to determination of the minimal landing size of fish has shown that the majority of proposed methods are by no means applicable to every commercial species. In particular, for the North-East Arctic cod which is a species with a long life cycle and rapid growth rate, whose individuals reach considerable length and weight well before the age when the majority of fish become mature and become excellent “marketable” fish, the application of these methods could result in establishing a too large minimal landing size and a considerable under-utilisation of this resource.

From an overview of approaches and methods it is clear that a task of establishing a minimal landing size of fish is a task of choosing a compromise option which could meet the requirement of maximising the catch of "marketable" fish and maintaining the production capacity of the stock assuring its replenishment.

Referred to key factors deciding the choice of a compromise option can be the age structure of the fishable stock, growth and maturation rate of fish in this stock, specific features of distribution of fish from different size groups and selectivity of fishing gear.

In addition, influencing the choice of a minimal landing size of fish factors are market and historical fishing practices.

In our opinion, for the North-East Arctic cod such a compromise option taking into account the majority of the above factors is the minimal landing size of 42 cm. This size is biologically substantiated and allows to harvest this resource efficiently from the economic point of view.

It should be noted that at the 17th meeting of the Joint Soviet/Norwegian Fisheries Commission (1988) the Soviet and Norwegian sides confirmed the minimal landing size of 42 cm for cod and 39 cm for haddock be biologically substantiated and used in their respective economic zones. In 1989 a joint Soviet/Norwegian paper was produced where a Russian trawl with the mesh of 125 mm and a Norwegian trawl with the mesh of 135 mm were noted to be close in selectivity (Isaksen et al., 1990). However, in the same year of 1989 at the 18th meeting of the Joint Soviet/Norwegian Fisheries Commission Norway informed USSR of implementing unilaterally a new minimal landing size of 47 cm for cod and 44 cm for haddock in the Norwegian economic zone from 1 January 1990. A difference in the minimal landing size for Gadidae between the areas of fisheries jurisdiction of Norway and Russia is one of the factors provoking fishermen oriented to the European market to discard cod smaller than 47 cm which leads to the use of catch in an insufficiently efficient manner and makes the management of common resources more difficult.

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9th Joint Russian-Norwegian Symposium
Technical Regulations and By-Catch Criteria in the Barents Sea Fisheries
(PINRO, Murmansk, 14-15 August 2001)

METHODS TO REDUCE BYCATCH OF RED KING CRAB (*PARALITHODES CAMTSCHATICA*) IN PASSIVE FISHING GEARS

by

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King crab

The king crab (*Paralithodes camtschatica*) is a new species in the Norwegian fauna. In order to establish a commercially exploitable king crab population in the Barents Sea the Russians transplanted juvenile and adult crabs off Murmansk in the 1960's). The stock of red king crab has increased radically over the past few years, and the crabs are now present by the million. The government's intention is to build up a sustainable resource for future exploitation. The king crabs are therefore protected and only allowed fished through a limited pot fishery with a total quota of 75 000 crabs (2000) shared by Russia and Norway. The quota for 2001 has been increased to 200 000 crabs.

The bycatch of king crab in gillnets, cod pots and on longlines is an increasing problem along the coast of northern Norway (Finnmark). The problems are largest in the eastern part of Finnmark, but the bycatches are spreading westwards in the county. The fishermen are not allowed to land the bycatch and thus the crabs must be put back to sea. The Fish Capture Division at the Institute of Marine Research in Bergen has been working on a project aiming to reduce the bycatch of red king crab in passive fishing gears since 1999. The project's main goal has been to modify stationary fishing gears (gillnets, longlines, cod pots) in order to reduce bycatch of king crab and the damages caused by this species on gear and catch.

Gillnets

The bycatch of king crab is especially high in cod gillnets. Catches of thousands of king crabs on a single gillnet fleet (approximately 400 m length) have been reported several times, and catches of several hundreds are not unusual. Since the king crab is only allowed caught through at limited pot fishery, the crabs caught in the gillnets have to be discarded. The crabs often get crushed in the net hauling system, and are also often crushed by the fishermen to make them easier to disentangle from the net. In the wintertime crabs may freeze to death on deck as large bycatches require long time to be disentangled. This means that discarded crabs are often dead or have considerable damages, and the bycatch may therefore be an important contribution to the mortality in the crab population.

Furthermore, disentangling large bycatches of crabs causes extra work for the fishermen and causes damages on their gear. In addition entangled crabs reduce the net area for the target species. Crabs feeding on fish caught in the net reduce the value of the catch. Thus bycatches of king crab may seriously reduce gear efficiency and profitability. Proper management of the king crab stock and a profitable commercial gillnet fishery for cod require development of gear solutions which will reduce the bycatch. One method to reduce the bycatch is to use norsel-mounted nets floated of the bottom, where the idea is that the crab can pass under the net without entangling.

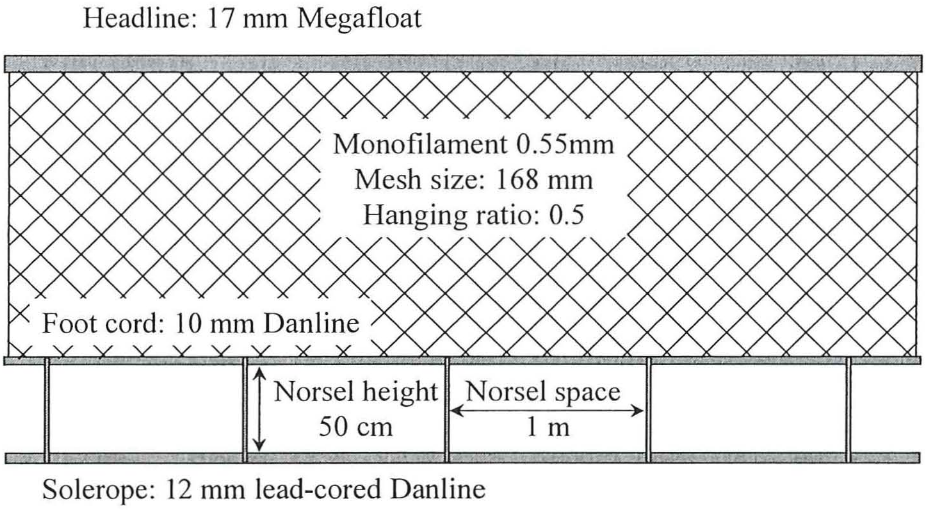

Figure 1 Sketch of a norsel mounted cod gillnet. In addition to the megafloat it was needed to attach extra floats (3 rings per net with a buoyancy of 240 g each) to get the norsels properly stretched.

The use of norsel mounted nets has given somewhat varying results. To avoid bycatch of king crab, it is important that the norsel nets have a sufficient amount of floats in order to get the norsel propely "stretched" so that the nets avoid bottom contact. The bycatch of king crab has been reduced down to an average of 0.8 crab/net. The problem is that the catch of cod in some periods has been considerably reduced as well (up to 65% in numbers and 60% in weight). During IMR's trials in 2001 the norsel nets caught 40% less cod and 60% less crab. The norsel nets caught larger fish so the reduction of cod in weight was only 30%. Several fishermen have tested norsel nets along the coast of Finnmark during the 2001 season, and the results show small differences in the catch efficiency.

Cod pots

Cod pots have been introduced as an alternative to gillnets and longlines and have in some periods shown good catches. The bycach of king crab is also high in the cod pots, but most of the crabs can be put back to sea relatively unharmed. However, large bycatches make the pots difficult to handle and create much extra work for the fishermen. The crab also causes abrasion on the pots, destroys other catch and reduces the catch efficiency. The solution tried here is to mount the pots on norsels lifting the entrances of the pot 0.5 m above seabed (see figure 2).

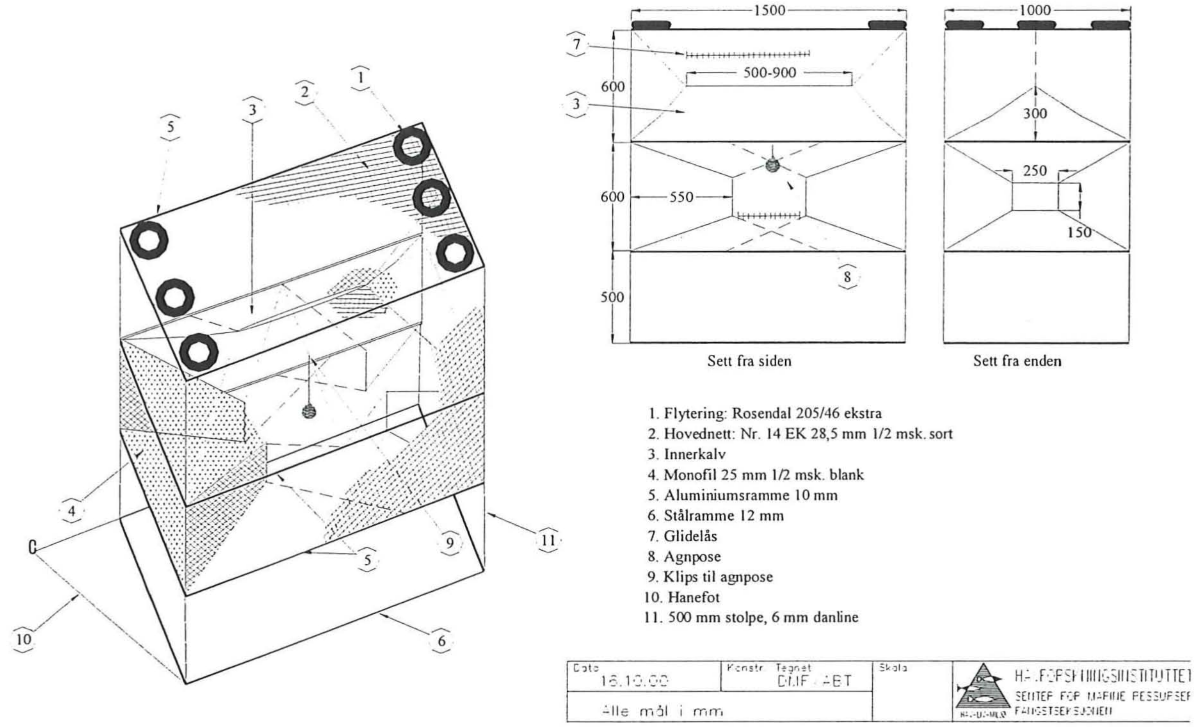

Figure 2 Cod pot mounted on norsels. The pot it self is lifted 0.5 m above seabed by use of norsels.

By mounting the cod pot on norsels the bycatch of king crab were reduced with 83% compared wit the standard bottom set cod pot. The bycatch of crab in norsel-mounted pots were mainly due to a large number of crabs in a few pots. The norsel-mounted pots caught 8% less cod than the regular pot.

Longline

The bycatch of king crab is not particularly high in the traditional bottom longline fishery, and only a few crabs are hooked and damaged. The problem experienced here is that the crabs eat up the baits on the longline and thereby reduces the gears catch efficiency considerably. Additionally the crab feeds on the fish already hooked on the longline. The solution here is use of pole set longlines, where the longline is lifted off the seabed by using floats, sinkers and poles, in such a way that the crabs cannot reach the longline (see figure 3).

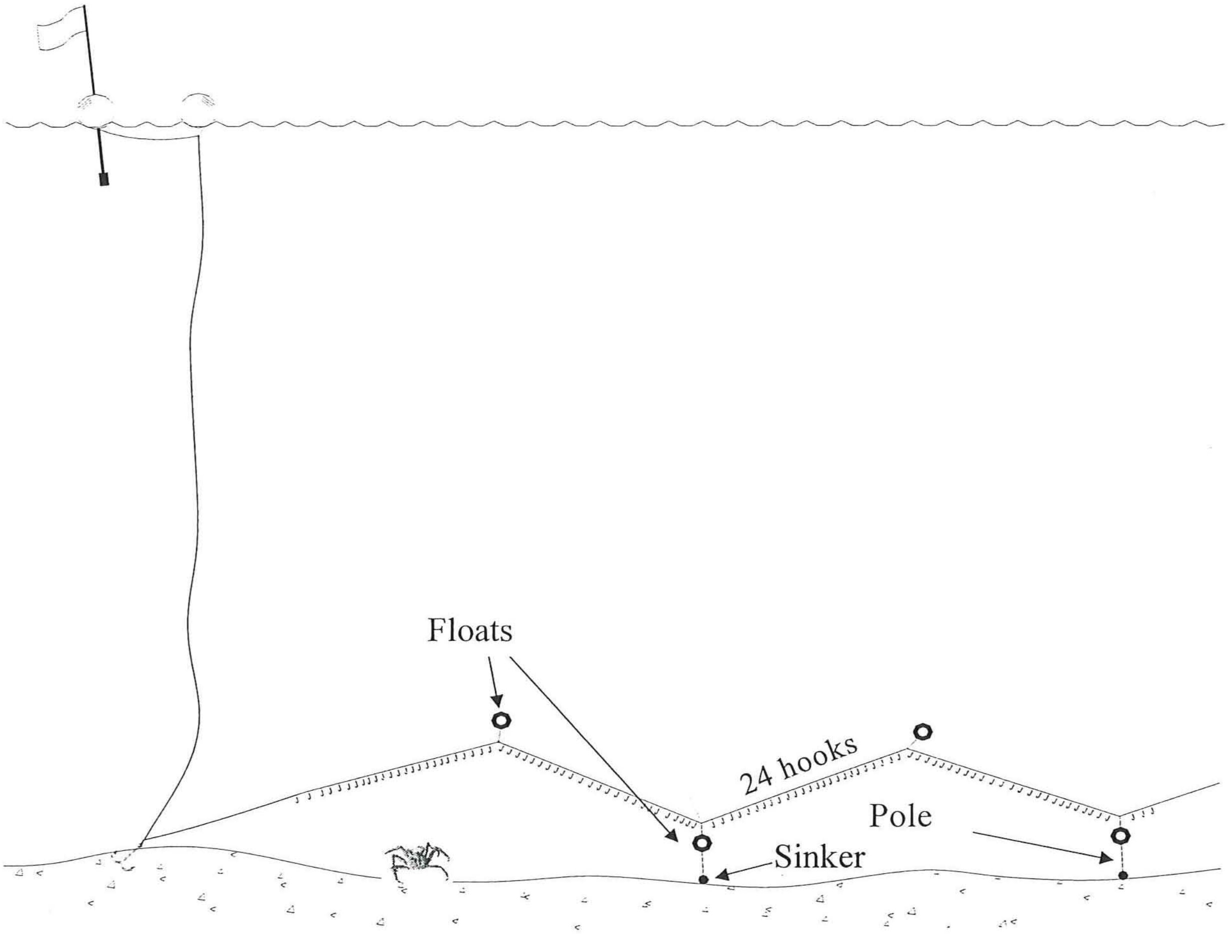

Figure 3 Pole set longline. The longline is lifted off the seabed by using floats, sinkers and poles.

Trials in the Varangefjord during the autumn 2000 showed a bycatch of king crab on bottom set longlines of only 1.6 crabs per 100 hooks, while pole set longline caught only 0.1 crab per 100 hooks. The pole set longline also caught more fish than the traditional bottom set longline. During the trails there was mainly haddock in the area, and the pole set longlines caught about twice as many haddock as the bottom set longline. All the baits were eaten by the crab on fields with high crab density, whilst they were intact on the pole set longline. Pole set longlines caught up to 5.8 as many fish as the bottom set on fields with high crab density. Of the total catch were 14 % of the fish caught on bottom set longlines destroyed by the crab while 4% were destroyed on the pole set longlines.

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ON FEASIBILITY OF ASSESSMENT OF DISCARDS OF SMALL COD IN TRAWL FISHERY FOR *GADIDAE* IN THE BARENTS SEA AND ADJACENT WATERS IN 1996-2000

by

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Abstract

The paper proves feasibility of assessment of discards of small North-East Arctic cod in the Barents Sea and adjacent waters, a method to assess the discards in the trawl fishery for cod is suggested. Using the suggested method presumed discards of small cod in the Russian bottom trawl fishery for this species in 1996-2000 are estimated, their dynamics over the period under consideration is studied and major factors which impact on them are identified.

According to computations done the presumed discards of small cod in 1996-2000 were most plentiful in the trawl fishery in the Exclusive Economic Zone of the Russian Federation and in the area of joint fisheries between Russia and Norway. To the greatest extent cod at age 3 and 4 years were discarded. On the basis of computations and analysis it is inferred that it would be expedient to re-allocate the fishing effort of the Russian fleet fishing for cod from the Exclusive Economic Zone of Russia to the Economic Zone of Norway and the area under the Spitsbergen Treaty of 1920, which would enable to reduce discards of small North-East Arctic cod.

Introduction

A correct assessment of the status of resources available for the trawl fishery is only possible when full and reliable information on the harvest of the resources is available. However, for a number of reasons this information is difficult to obtain. One of the reasons which hampers the acquisition of reliable information on catch is discards of the fish captured.

The term "discards" means a difference between the catch actually hauled by a commercial vessel and the catch officially reported after it has been processed, in other words there is a part of the catch which is used neither for food nor industrial purposes. As a rule, the catch hauled by vessel is larger than the catch actually declared and recorded in vessel's logbook.

Discards are composed of fish which for various reasons are not in demand in the market and of low commercial value or do not have it at all. For example, small or damaged fish or those highly infested with parasites which deteriorate the exterior of fish can not be used for production of quality food products.

Discards in a fishery targeting a particular species could conventionally be divided into two categories. The first includes discards of non-target species taken as by-catch. The second is composed of small fish of the species, which is targeted in the fishery. While the discards of the first category impact on the total stock of a species, discards of the second category diminish the part of the stock composed of young immature fish which have not fulfilled its productive function and contributed to reproduction of the population.

Discards of small fish lead to decreased abundance of the species, misreporting in catch statistics, and hence to a greater inaccuracy of stock assessment. Valuable, economically more important species, which are harvested in large quantities, are mostly affected by such discards. Therefore, an adverse effect of discards on stock status is hard to overestimate.

First references to discards of small cod and haddock in the Barents Sea and adjacent waters can be found in scientific literature dating back to 50s and 60s. For example, it is known that in 1952 about 25% of cod captured in the Barents Sea by British and German trawlers were discarded (Graham, 1954; Lundbeck, 1954). As reported, British trawlers discarded cod less than 50-60 cm (Lee, 1956) and Norwegian trawlers less than 49 cm (Hylen, 1967). Discards by Soviet vessels were much smaller at that time, because all fish of 40-50 cm were used in production (Ponomarenko, 1965).

A. Hylen (Hylen, 1967) was the author of the first paper dedicated to quantitative assessment of discards of small cod and haddock in the Barents Sea by Norwegian vessels. According to him, in 1967 discards of cod by Norwegian vessels accounted for up to 25% of the total number captured and those of haddock up to 84%. In 1996 a paper was published (McBride, Fotland, 1996) where an attempt was made to assess the discards of cod in the Norwegian trawl fishery for cod. The authors assessed that in 1989 about 7% of all cod captured were discarded by Norwegian vessels. For that assessment results from trawl-acoustic survey of bottom fish, data on selectivity of trawl codend and reported catch were used.

Unfortunately, there are almost no attempts found in the contemporary scientific literature to perform a quantitative assessment of discards of juvenile fish in the Barents Sea and adjacent waters. There is evidence available on discards of small cod by a German trawler which operated in the area between the Bear Island and Spitsbergen in autumn 1998 (Shöne, 1999). The discards of cod at age 2 and 3 years there were as large as 36% in number of all fish captured.

Results of anonymous survey among Norwegian fishermen and fish buyers conducted in December 2000 – January 2001 by experts of the Institute of Marine Research, Bergen, showed that in 1999 about 3-4% of the Norwegian cod catch by weight were discarded which corresponded to approximately 8-12% of the total number of fish captured (Nakken, 2001).

A review of publications dedicated to discards of small fish has shown that the information available is sufficient for their preliminary rough assessment. A feasibility to develop a method for such an assessment was in principle proved more than 30 years ago (Hylen, 1967).

However, a major disadvantage of the methods proposed for assessment of discards of small cod lies in the use of data from trawl-acoustic surveys which unlike the fishery conducted the whole year round are time-restrained. In addition it is not always that survey data reflect the size composition of commercial catch correctly.

There is an extensive database available at PINRO which contains data from length measurements of cod from catches taken by Russian fishing vessels practically in all areas of the Barents Sea and adjacent waters over the whole year, based on which a preliminary rough assessment of discards can be undertaken.

The purpose of this paper is:

- to confirm the feasibility of assessment of discards of small cod in the Barents Sea and adjacent waters;
- to develop a method for estimation of discards in the trawl fishery for cod;
- to assess provisionally discards of small cod in the Russian trawl fishery in 1996-2000;
- to study the dynamics of discards and identify factors behind them.

Material and methods

The paper uses results of massive length measurements of cod from commercial catch done by PINRO observers in 1996-2000 during trips of fishing vessels. Catches were taken with conventional bottom trawls with the mesh size 125-135 mm, which were from 1998 on, rigged with sorting grids. To assess the discards of cod by age size-age keys for cod from catch taken with commercial trawl pooled by year were used.

Russian trawlers fishing for cod are classified into vessels equipped with a freezer and vessels producing fresh cod. Both are as a rule oriented to export of cod. Fish harvested by the first group of vessels are normally exported to EU countries. The second group is oriented to deliveries of fresh cod to Norway. Peculiarities of the markets and possibilities for processing and storage of fish by these vessels dictate a minimal size of "marketable" fish to be retained. For example, vessels landing chilled cod can not store the fish on board for a long time; they have smaller holds than vessels, which produce frozen cod. Therefore, it is in their interest to produce products of larger and correspondingly higher priced fish. As a rule, Norwegian companies refuse to buy small cod, less than 0.5 kg (gutted/headed), and thereby make the fishermen discard these fish. Sometimes when the fishery is good cod of less than 1 kg do not sell.

According to the Russian "Fisheries Regulations" a minimal landing size for cod is set at 42 cm while it is 47 cm under Norwegian "Fisheries Regulations". It is forbidden to fish cod of smaller size. Allowable is a by-catch of undersized cod of no more than 15% of the catch in number. Russian vessels producing fresh cod for deliveries to Norway operate, as a rule, in the economic zone of that country and in the area of joint fisheries and follow the Norwegian "Fisheries Regulations". Other Russian trawlers fishing in areas other than the Economic Zone of Norway follow the Russian "Regulations".

Practical experience of PINRO observers on fishing vessels has shown that to a different extent jettisoned are cod of up to 55 cm with the weight of about 1 kg, however, most frequently discarded are fish of less than 0.5 kg. Weight of cod of 41 cm (gutted/headed) is about 450 g, 46 cm about 600 g. When the catch is graded on board it is difficult to determine weight of each individual fish and, therefore, when discarding cod fishermen rely, as a rule, on the minimal landing size.

For this reason and taking into account peculiarities of operation of the two groups of vessels it was assumed that vessels with a freezer discarded cod of 41 cm and less while vessels which produced fresh fish discarded fish of 46 cm and less.

The distribution of juvenile cod, their densities and, hence, by-catch are related to a variety of factors and differ between years and areas. Therefore, discards of small cod were assessed individually for each area in the Barents and Norwegian Seas as shown in Figure1.

Input data for computation of discards of small cod were:

- yearly catch of cod by Russian trawlers by economic zone and vessel type;
- size distribution of cod in catches by commercial trawl by economic zone and pooled by year;
- long-term mean size-age key for cod for 1996-2000;
- size-age keys for cod from catches by commercial trawl for 1996-2000 pooled by year.

The following symbols were used in the paper:

P - reported catch, tonnes
N –estimated catch of cod of landing size, individuals
p – weight of cod of landing size in observed size distribution, tonnes
n – number of cod of landing size in observed size distribution, individuals
P*-estimated discards of cod, tonnes
p* -weight of undersized cod in observed size distribution, tonnes
N*-estimated discards of cod, individuals
n* - number of undersized cod in observed size distribution, individuals

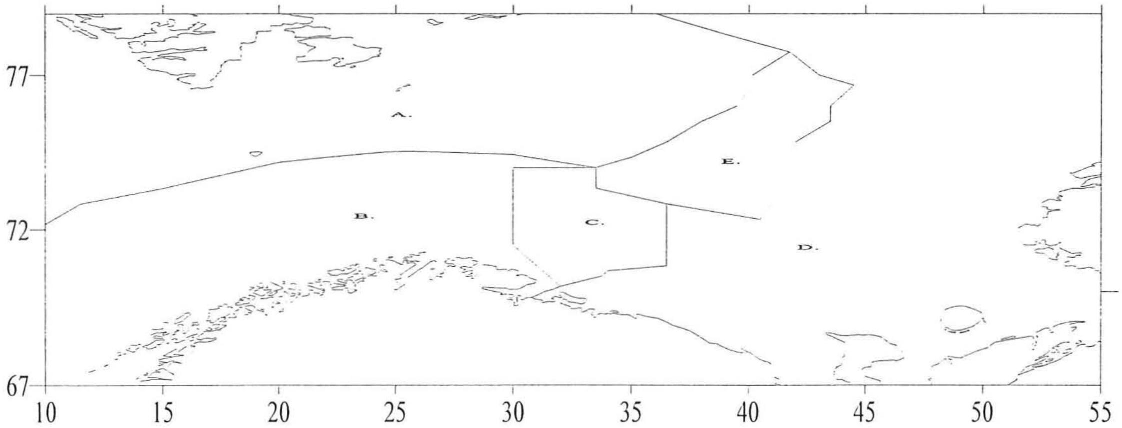

Fig. 1. Division of the Barents and Norwegian Seas into areas:

A – area under the Spitsbergen Treaty of 1920
B – Economic Zone of Norway
C – area of joint fisheries between Russia and Norway
D – Exclusive Economic Zone of the Russian Federation
E – area outside Economic Zones of Russia and Norway (Enclave)

At the first stage of computations of discards the amount of small cod captured in each of the zones in the Barents Sea and adjacent waters was determined. When doing this it was assumed that catch reported by vessels with a freezer did not include cod of 41 cm and less, and catch reported by vessels producing fresh cod – 46 cm and less.

Measurements of fish length were done prior to grading of catch into large (marketable) and small fish. Therefore, size distributions of cod derived by observers on fishing vessels reflected the real size distribution of fish in catch. Therefore, the weight of reported catch was proportional to a sum of weights of fish from the part of the size distribution beginning with size 42 cm (47 cm), while the number of fish measured within that part of the size distribution was proportional to the number of fish in reported catch.

The number of captured cod above minimal landing size by economic zone was computed by the equation:

$$\mathrm{N} = \mathrm{n}\,\frac{P}{p} \tag{1}$$

At the second stage of computations the weight and number of discarded small cod by area were calculated.

To do this a ratio of the total reported weight of fish of 42 cm (47 cm) and more to the total weight of cod less than that size in the observed size distribution was found.
It was further assumed that that ratio reflected the ratio of reported catch weight to the weight of discards of cod below the landing size in one or another area of the sea.
The weight of discarded fish was determined by the equation:

$$\mathrm{P}^* = \mathrm{p}^*\,\frac{P}{p} \tag{2}$$

The same procedure was applied to determine the number of discarded fish:

$$\mathrm{N}^* = \mathrm{n}^*\,\frac{N}{n} \tag{3}$$

Exposed to discarding are cod at age 1 to 5 years including size-age keys for cod from commercial catch pooled by year were used to split the discards by age group.

Results and discussion

According to calculations discards of small cod in the Russian bottom trawl fishery in the Barents Sea and adjacent waters in 1996-2000 varied from 5 362 000 fish in 1996 to 21 678 000 fish in 1998 (Table 1), which corresponded to 3 300 tonnes and 12 700 tonnes by weight, respectively (Table 2).

Table 1. Estimated discards of small cod in the Russian bottom trawl fishery in the Barents Sea and adjacent waters in 1996-2000 (x 10^3 fish)

Year	Area under the Spitsberegen Treaty of 1920	Economic zone of Norway	Economic zone of Russia	Area of joint fisheries between Russia and Norway	Enclave	Total
	A.	B.	C.	D.	E.	
1996	1568	847	1476	1439	31	5362
1997	2494	573	5163	1157	108	9495
1998	2234	1188	12657	5427	172	21678
1999	1929	1925	3146	3401	116	10518
2000	1497	1359	1535	2417	70	6879

Table 2. Estimated discards of small cod in the Russian bottom trawl fishery in the Barents Sea and adjacent waters in 1996-2000 (tonnes)

Year	Area under the Spitsbergen Treaty of 1920	Economic zone of Norway	Economic zone of Russia	Area of joint fisheries between Russia and Norway	Enclave	Total
	A.	B.	C.	D.	E.	
1996	960	512	846	943	21	3282
1997	1478	354	2920	725	74	5551
1998	1335	751	7213	3241	116	12656
1999	1197	1327	1860	2175	74	6633
2000	880	936	882	1438	37	4172

In the course of 1996 to 1998 discards of small cod were noted to be increasing. The most unfortunate was 1998 when according to estimates more than 21 million cod (12 600 tonnes) were discarded. From 1999 on, discards in the Russian bottom trawl fishery have been declining. In our view, one of the reasons behind such a decline was a decrease of abundance of year classes of cod, which occurred as by-catch.

The largest were by-catch and discards of small cod in the Russian Economic Zone. In 1998 more than 50% of the total number of discarded cod were discarded in that zone. On the average, in 1996-2000 discards in that area accounted for 38%. The situation was somewhat better in the area of joint fisheries between Russia and Norway, where in 1996-2000 discarded cod constituted about one fourth of the total discards. Even better was in 1996-2000 the area under the Spitsbergen Treaty. In individual years discards of cod in that area ranged from 10% to 29% of the total number discarded.

Relatively safe areas in respect of by-catch and discards of small cod were the Economic Zone of Norway and enclave in the Barents Sea. For example, discards in the Economic Zone of

Norway fell between 5% and 20% of the total amount discarded and they were about 1% in the enclave.

Such a pattern of distribution of discards of small cod may be due to peculiarities of distribution of the species over the area where fisheries were conducted. As known, Economic Zone of the Russian Federation and areas close to Spitsberegen are areas where predominantly juvenile cod are distributed while the Economic Zone of Norway is the area of distribution of mature and large immature cod.

Harvest and discards of small fish, as its consequence, can significantly reduce the abundance of cod year classes. For example, in 1996-2000 when 1992-1996 year classes were discarded the 1995 year class of cod was most heavily exposed to the adverse impact of discards, out of that year class in the course of 1997-1999 more than 18 million fish at age 2, 3, 4 and 5 years were lost. In 1996-2000 to the highest degree cod at age 3 years were exposed to discarding (Table 3).

Table 3. Estimated discards of small cod in the Russian bottom trawl fishery in the Barents Sea and adjacent waters in 1996-2000 by age (x10^3 individuals).

Year	Age, years					Total
	1	2	3	4	5	
1996	0	795	2017	2226	324	5362
1997	21	901	4296	3488	788	9495
1998	23	1084	12765	7538	269	21678
1999	8	568	4687	4935	321	10518
2000	3	789	2897	3015	175	6879

A comparison of estimated discards of small cod with the number of cod in reported catch by age as estimated by the ICES Working Group (Anon., 2001) has shown that in 1996-1999 potential discards of cod at age 3 years ranged from 25% to 60% of the total number of individuals of the same age retained in the fishery, at age 4 years – from 6% to 10%. Taking into account that the Russian catch of cod in the trawl fishery in those years was about 65% of the international catch taken with trawls the total figure for discards could be even higher.

Analysis of the impact of various factors on discards of small cod has shown that in 1996-2000 the abundance of cod year classes fished as by-catch had the strongest impact on the size of discards. Analysis of the relationship between the strength of various year classes of cod in 1996-2000 and estimated discards has shown that the discards are significantly related to the strength of year classes of cod at age 2 and 3 years (correlation coefficients 0.98 and 0.91, respectively) (Table 4). However, no linear relationship was established between the abundance of 4-year-olds and discards. It could probably be due to that the discards of cod at age 4 years along with the reasons given above are impacted by some other factors. For example, these could be economic reasons resulting from market demands.

Table 4. Statistically significant correlation coefficients between discards of small cod in 1996-2000 (individuals) and various factors impacting on them (significance level 0.10)*

	Area					Barents Sea and adjacent waters
	Area under the Spitsbergen Treaty of 1920	EEZ of Norway	EEZ of Russia	Area of joint fisheries between Russia and Norway	Enclave	
Abundance of cod at age 2 years, individuals						0,98
Abundance of cod at age 3 years, individuals						0,91
Abundance of cod at age 4 years, individuals						-
Abundance of cod at age2-4 years, individuals						0,93
Mean length of cod in catch, cm	-	-0,97	-	-0,84	-	-
Catch by vessels producing fresh cod, t	-	-	-	0,81	-	-
Catch by vessels producing frozen cod, t	-	-	-	-	-	-
Total catch of cod in the Russian trawl fishery, t	-	-	-	-	0,81	-

* dash corresponds to insignificant correlation coefficient

Discards of small cod in those years were also related to the mean size of fish in catch. An inverse relationship between these two can clearly be identified for the fishery in the Economic Zone of Norway and area of joint fisheries. No such relationship was established for the Russian Economic Zone and Spitsbergen area.

The fact which draws attention is that the relationship between the mean size of cod in catch and discards is most prominent for the best area in terms of by-catch of small cod – the Economic Zone of Norway.

In our view this is due to that harvested there are large cod, while in the Economic Zone of Russia, in the area of join fisheries and Spitsbergen area there are areas where a large number of young small cod are distributed over the whole year, which has been confirmed by measurements of cod from catch (Table 5).

Table 5. Mean size of cod from Russian catch by commercial trawl by area in the Barents Sea and adjacent waters in 1996-2000, cm

Year	EEZ of Russia	EZ of Norway	Area under the Spitsbergen Treaty of 1920	Area of joint fisheries	Enclave	All sea
1996	62,3	63,8	61,8	57,9	58,3	60,9
1997	59,2	63,7	59,2	56,4	59,8	58,9
1998	53,2	61,4	56,7	54,2	53,7	55,1
1999	52,7	57,2	55,7	54,2	53,5	54,8
2000	54,5	59,5	58,0	56,0	54,8	56,8

Mean size of cod in trawl catch depends on the strength of year classes of fish taken as by-catch and selectivity of the gear. Therefore the amount of captured and then discarded small fish depends also on trawl specific features such as mesh size in the codend and the use of sorting grid. It could be that a high correlation coefficient between the mean size of cod and discards for the economic zone of Norway (-0.97) resulted from the use of trawls with the mesh size of 135 mm in the codend by Russian trawlers there (in accordance with the Norwegian "Fisheries Regulations"). As for other areas the majority of Russian fishing vessels fish as a rule by trawls with the mesh size of 125 mm (in accordance with the "Regulations for the fishery in the Russian economic zone").

A reduction of discards of small cod in 1999-2000 as against 1997-1998 could be associated with the application of sorting grids implemented in the fishery for cod in the Barents Sea and adjacent waters in 1997. During 1997-1998 experience was gradually gained by Russian fishermen in operating the grids. There were areas in the Russian Economic Zone in those years where it was allowed to fish without sorting grids. From 1999 on, these grids have become mandatory for use by all Russian vessels fishing for cod and haddock.

This reduction showed itself most vividly in the dynamics of discards of cod at age 2 and 3 years (Table 3). For example, in 1999 and 2000 when sorting grids were used by all Russian fishing vessels by-catch of cod from those age groups was reduced by more than 2 times compared to 1996-1998.

No relationship was found between the total Russian catch of cod by trawls and discards in 1996-2000. However, a relationship between the discards of small cod in the area of joint fisheries between Russia and Norway and the catch by vessels producing fresh cod should be noted. In our view, it could be accounted for by that the major catch of cod by that group of vessels was taken in the area of joint fisheries.

No statistically significant relationship between the discards of small cod in various areas of the sea and the catch taken by vessels with a freezer was found.

So, in 1996-2000, major factors which had impact on discards of small cod were abundance of year classes of cod at age 2 and 3 years and mean length of cod in trawl catch.

In the trawl fishery for *Gadidae* in the Barents Sea and adjacent waters by-catch and hence discards of small cod are unavoidable. Therefore, an adverse impact caused by them is, to a certain degree, inevitable.

Based on the reasons behind discards an adverse impact on the status of the cod stock could be reduced by temporary closure for trawl fishery of areas with high concentrations of small fish and through enhancing the fishing gears.

A re-allocation of the fishing effort of the trawl fleet from the Russian Economic Zone and area of joint fisheries to the Norwegian Economic Zone and area under the Spitbergen Treaty of 1920 could also contribute to the reduction of discards of small cod in the Russian bottom trawl fishery. Preliminary computations have shown that by doing so the amount of discarded cod could be nearly halved.

Conclusions

This paper confirms the feasibility of assessment of discards of small cod in the bottom trawl fishery in the Barents Sea and adjacent waters. Methods for computing the discards have been suggested and applied for preliminary assessment of discards in the Russian bottom trawl fishery in 1996-2000.

According to computations done in the course of 1996 to 2000 from 5.3 to 21.7 million small cod were discarded in the Russian bottom trawl fishery in the Barents Sea and adjacent waters, which corresponded to 3300 and 12 700 tonnes, respectively.

The easiest in terms of by-catch and discards of small cod was 1998. In 1999-2000 discards of small cod were observed to decline which along with other reasons was due to mandatory use of sorting grids.

Maximum discards of small cod are typical of the Russian Economic Zone where in certain years up to 60% of the total discards took place. The safest in respect of discards of small cod is the Economic Zone of Norway.

It is cod at age 2 to 5 years, which are jettisoned by fishing vessels. To the greatest extent exposed to discarding are cod at age 3 and 4 years, which have not reached the landing size.

In 1996-2000 discards of small cod were primarily related to the strength of year classes taken as by-catch. A level of the total Russian catch of cod did not have any significant impact on the amount of fish discarded.

As one of the measures to reduce considerably the by-catch and discards of small cod in the Russian bottom trawl fishery in the Barents Sea and adjacent waters a re-allocation of the fishing effort of the Russian fishing fleet from the Russian Economic Zone and area of joint fisheries between Russia and Norway to the Economic Zone of Norway and area under the Spitsbergen Treaty of 1920 could be suggested.

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COMPARISONS BETWEEN SIZE DISTRIBUTION IN SURVEYS AND COMMERCIAL CATCHES – A USEFUL TOOL FOR MONITORING CHANGES IN THE SIZE SELECTION IN THE FISHERIES?

by

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Abstract

A method is proposed for using fish length distributions from standardized research surveys for estimating relative selection in the fisheries. The method is applied on data for North-east arctic cod in the 1990-ies. Survey-related selection for the Norwegian trawl fishery is compared between years and between data covering different seasons and geographical areas. Some uncertainties of the data are recognised and discussed. In spite of this there seem to be a fair consistency among the data sources, leading to the conclusion that the selection on length groups near the minimum catching size increased considerably in 1998 and has decreased in 1999 and 2000. Possible reasons for this development are indicated.

Introduction

In the literature comprehensive studies are available on how technical details of fishing gears influence the size selection. Such studies form the basis for a number of regulations regarding mesh size, sorting devises, gear dimensions and so on. The size selection for a fishery as a whole depends on a number of additional factors that are difficult to predict or measure. Such factors are (among many others); the spatial and seasonal mixing of different size groups of fish, the price difference between size groups, technological development, quota limitations, by-catch regulations and area closures. In addition the temptations to break the regulations may vary, for instance depending on absence/ presence of coast guard vessels. Such effects work on various time scales and geographical scales. Methods for monitoring changes in the size selection of the fishery at various scales are needed, both for evaluating the effects of the existing regulations and for improving the assessment and prediction of the stock situation.

Abundance estimation surveys are aimed at covering the whole stock. They are applying sampling gears that are well documented and standardized between vessels and between years. A change from one year to the next in the size distribution from a survey is expected to reflect some change in the true size distribution of the stock, even though the survey catchability may depend on the fish size. Size distributions from surveys could therefore work as a useful reference to get a kind of relative selection when analysing the size distribution in commercial catches. In this paper data on North-east Arctic cod from demersal fish surveys in the Barents Sea and from the Norwegian trawl fishery have been used to compare survey-related selection between years and to compare survey-related selection at various time scales and geographical scales.

Material and methods

Table 1a gives survey estimates by length for cod in the Norwegian winter (February) bottom trawl survey, for the period 1993-2000. This survey started in 1981, and since 2000 it has been a joint Norwegian-Russian survey. In the late 80-ies and early 90-ies several changes in survey methodology was introduced. Therefore, only the years after 1992 are used here. Jakobsen *et al.* (1997) describe the survey and the changes in methodology. They also describe the functional relationship between fish size and effective fishing width of the trawl assumed in the swept area estimation procedure. For comparisons with other studies based on direct catch rates by length in the research trawl, an attempt was made to remove this length dependent function in the estimates, by applying a factor corresponding to the mid-point in each 5 cm length interval. Since these factors have been applied directly on the total survey estimate, it is an approximation compared to using raw data without length dependent fishing width. These factors and the results are shown in Table 1b.

Annual trawl catch, all areas

Total annual landings by length for the Norwegian trawl fleet are shown in Table 2 for the period 1993-2000. These data are as reported to the Arctic Fisheries Working Group (AFWG), where catch by length is used as input to the “fleksibest” model. When these data were calculated, the samples from catches and the samples from landings were treated equally. Over this period the amount of sampling of catches has increased relative to the amount of sampling of landings.

The ratio between annual catch by length and survey estimate by length can be considered as the relative fishing pressure by length for a given year. Since the fishery reflects the whole year, while the survey only covers one month, the growth of the fish confuses the direct interpretation of this ratio. The ratio by length can, however, be compared between years, if it is normalised for the annual overall fishing pressure. The ratio for the size groups having full selection could be a useful measure of overall fishing pressure. Here it is assumed that fish above 60cm have full selection. Relative selection RS_i for length group *i* is therefore calculated as

$$RS_i = (C_i/S_i) / (C_{>60}/S_{>60}) \qquad (1)$$

Where C is catch in number and S is survey estimate in number.

First quarter catch, Western Barents Sea

Table 3 shows the catches of cod taken by Norwegian trawlers during the first quarter in the area north of 70° N and west of 30° E. These catches are distributed on length according to total number of cod measured by the Norwegian Coast Guard during inspections of Norwegian trawlers in the same area and quarter. Table 4 gives the abundance estimates in the winter survey for the same area (Main Areas A,B,C and S, Jakobsen *et al.* 1997). The Table also includes values where length dependent fishing width is removed, as described above.

Relative selection is calculated by equation (1).

July-August, Bear Island-Region

Another source of information for calculating relative selection in commercial trawl relative to research vessel trawl is the data from the closed area monitoring surveys that are conducted by the Norwegian Directorate of Fisheries. The purpose of these surveys is to evaluate the needs for closing areas for fishing, in order to protect undersized fish. Here a typical commercial cod trawl with 55 mm sorting grid (Sort X) is used. Some of these surveys overlap in time with the Norwegian summer survey (Aglen 1999), where the standard research trawl is used. In July-August 1997 and 1999 there was a reasonable overlap between these two surveys at bottom depths between 100 and 300 m in ICES sub-Division IIb, south of 76°30' north. Table 5 shows the average catch rates (number of fish per n. mile towed) by length for the commercial trawl and the research trawl for those surveys in the overlapping areas.

Relative selection was calculated by equation (1) with the modification that the catch was replaced by the average catch rate for the commercial trawl, and the survey estimate was replaced by average catch rate for the research trawl (Table 5).

Mid August, small area (10 by 16 n.miles)

During the summer survey in 1995 two research vessels were inter-calibrating their research trawls within an approximately 10 times 16 n. mile area to the west of Bear Island (between 74°13' and 74°22' north and 16°50' and 17°50' east), while, during the same week, three commercial trawlers with observers onboard were working in the same area. Table 6 shows average catch rates by length for each vessel in that experiment.

Relative selection was calculated by equation (1) with the modification that the catch was replaced by the average catch rate for the commercial trawl, and the survey estimate was replaced by average catch rate for the research trawl (Table 6).

Results

Relative selection was calculated by equation (1) from the data presented in Tables 1-6. Figures 1 and 2 show survey-related selection by length group for the annual catch and Figure 5 shows survey-related selection for the first quarter catch in Western Barents Sea. The results were not sensitive to whether the survey estimates were based on length dependent or fixed fishing with. This is because the assumed length dependence is rather weak for the size groups with high selection in the commercial fishery, and the scaling factor (ratio for all fish above 60 cm, equation (1)) takes account of the systematic difference in assumed fishing width for large fish.

For the annual catch the between year variation in relative selection is largest for the largest fish (Figures 1 and 2). During the winter survey a large, but variable, proportion of the largest fish is on spawning migration outside the survey area. This fish is available to the commercial trawlers both on its spawning migration and in the Barents Sea during other seasons. When considering only catches taken in the same area and season as the survey (Figure 5) it is seen that this tendency of increased year to year variation for the largest fish is less pronounced. In the size range 42.5 to 62.5 cm the between year variability is larger in the period 1997-2000 (Figure2) than in the period 1993-1996 (Figure 1). The high variability in the last period is also confirmed in the first quarter catches in the Western area (Figure 5). Figures 3 and 6 show that the relative selection for the length groups 47.5 and 52.5 had a peak in 1998, remained fairly high in 1999 and return to the pre-98 level in 2000. A similar development is observed for the age groups 4 and 5 in the relative fishing mortality at age (Figure 4) taken from the last stock assessment (ICES 2001).

The survey related selection calculated from the closed area monitoring survey show large differences between July-August 1997 and July-August 1999 (Figure 7). Below 45 cm the 1997 monitoring survey show higher selection than any of the other cases considered here. These monitoring surveys may spend more effort in areas with concentrations of undersized fish and could be biased compared to an ordinary abundance estimation survey.

The data from the individual commercial trawlers represents few hauls, and it is seen that average catch rates differed largely between the vessels (Table 6), even though all the tows were taken within few days in a quite restricted area. In spite of this, the relative selections for the two vessels not using sorting grid are fairly similar, at least for fish lengths below 50 cm (Figure 8). For the length groups 42.5 – 57.5 cm the relative selection "curve" for the vessel using sorting grid is about 5 cm further to the right than the other two. The two research vessels were in this case towing in parallel (0.3 to 0.5 n.mile between the vessels) and they had a reasonable number of tows. Here it is seen that the average catch rates for these two vessels are quite close for all length groups above 22.5 cm (Table 6).

Discussion

The various data sources have different weaknesses. As mentioned the whole year catch includes catches from other seasons and areas than covered by the survey, and thus lead to some uncertainties relating to the largest fish which is poorly covered by the survey. In addition the growth of the fish confuses the interpretation of the results. These two factors are largely reduced when only considering the first quarter catch in the western area. Here the results are based on the Coast Guard inspections, which could be biased, because the Coast Guard may focus on areas where by-catches are high or there are concentrations of undersized fish. In addition, the amount of inspections has increased during recent years. This could indicate that the sampling strategy has changed over the same period.

The closed area monitoring surveys may be biased towards areas with concentrations of undersized fish. In addition, the data are taken in an area and a season where the cod is known to move around rather quickly. Therefore, some week time-lag between the closed area monitoring and the research vessel survey could involve considerable changes in fish size distribution.

The data on individual commercial trawlers in the small area represents very few catches for two of the vessels.

In spite of these weaknesses it seems that the results from the different data sources within the same year (Figure 9) are in most cases more similar than the results for the same data source compared between years. This indicates that in each of the data sets there are some signals of significant year-effects in the size selection in the Norwegian trawl fishery.

A systematic evaluation of all regulations, control measures, market developments and changes in the fleet would be required to try to explain the between year differences in selection indicated in this study. At this stage only some hypothesis may be raised. One interesting pattern is the development for the selection of the length groups 47.5 and 52.5 in recent years. It decreased from 1996 to 1997 and raised considerably in 1998, then decreasing again in 1999 and 2000. The decrease in 97 could be caused by more extensive use of sorting grids, since it was made mandatory from the beginning of the year. In 1997 and 1998 the total quota was high relative to the fishable stock and the quota was not reached. It seems that the fleet focused on the large fish until it became more profitable to fish in areas with smaller fish. A shift in that respect might have occurred during 1998. During 1998 the Norwegian Coast Guard inspections showed an increased proportion of small fish in the catches, especially in the Grey Zone during the autumn. In 1999 and 2000 large areas with undersized fish have been closed for most of the year. In addition the quotas have been reduced.

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Table 1. Estimated number of cod (millions) by 5 cm length group in the total winter survey. The length groups are labelled by the mid-point of the interval. >60 is the sum of all fish above 60 cm.
a: Estimates based on length dependent fishing width (as in survey reports)
b: Estimates converted to 25 m fishing width independent of length. Factor is the factor by 5 cm group used for conversion.

Length (cm)	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	>60
a														
1993	208.5	175.9	60.0	90.0	109.2	65.1	40.1	59.1	62.6	30.7	12.5	7.6	4.8	61.3
1994	324.4	128.2	153.0	113.5	83.0	114.9	131.3	87.5	45.1	37.0	31.3	17.2	6.6	96.4
1995	315.4	212.8	97.7	84.9	114.3	103.4	98.3	113.8	97.6	51.7	25.2	17.3	10.1	111.8
1996	380.9	328.0	82.9	51.7	54.9	64.0	69.2	59.5	46.7	43.9	28.8	12.8	5.7	96.4
1997	604.4	367.3	141.0	109.9	50.1	31.5	34.9	37.6	34.8	23.8	15.3	10.0	6.1	58.2
1998	366.8	162.2	138.3	171.0	139.8	84.6	42.3	22.9	16.7	14.4	10.4	7.6	3.7	39.0
1999	245.7	96.0	116.7	79.7	78.2	67.4	50.8	29.0	13.4	6.7	5.0	4.1	3.2	21.2
2000	79.8	182.0	131.7	85.7	67.9	55.2	46.2	46.3	31.1	15.9	7.8	3.3	1.7	30.3
2001	41.3	46.1	54.8	97.4	111.3	80.1	59.9	46.0	28.7	19.3	12.7	6.5	3.5	43.9
b														
Factor	0.81	0.90	0.98	1.06	1.12	1.19	1.24	1.30	1.35	1.39	1.39	1.39	1.39	
1993	168.7	158.6	59.0	95.1	122.7	77.2	49.8	76.7	84.5	42.8	17.4	10.6	6.6	85.5
1994	262.5	115.6	150.4	119.9	93.2	136.2	163.3	113.6	60.9	51.6	43.6	24.0	9.1	134.4
1995	255.3	191.9	96.0	89.7	128.4	122.6	122.2	147.8	131.7	72.1	35.1	24.2	14.1	155.9
1996	308.3	295.8	81.5	54.6	61.6	75.8	86.1	77.2	63.0	61.2	40.2	17.9	8.0	134.4
1997	489.2	331.3	138.6	116.0	56.3	37.3	43.3	48.8	46.9	33.2	21.3	13.9	8.4	81.2
1998	296.9	146.2	136.0	180.6	157.0	100.2	52.5	29.8	22.5	20.0	14.4	10.6	5.1	54.3
1999	198.8	86.6	114.7	84.1	87.9	79.9	63.2	37.6	18.1	9.3	6.9	5.7	4.4	29.6
2000	64.6	164.2	129.4	90.5	76.3	65.4	57.5	60.0	42.0	22.1	10.8	4.6	2.3	42.2
2001	33.4	41.6	53.9	102.9	125.1	95.0	74.5	59.6	38.8	26.8	17.7	9.1	4.9	61.2

Table 2. Annual catches of cod (millions) by 5 cm length groups in the Norwegian trawl fishery (all areas). The length groups are labelled by the mid-point of the interval. >60 is the sum of all fish above 60 cm.

Length (cm)	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	>60
1993	0.0	0.0	0.0	0.1	0.4	1.4	1.9	2.9	4.8	5.4	3.6	2.2	1.4	16.9
1994	0.0	0.0	0.0	0.3	0.6	1.5	3.7	6.3	7.7	9.3	10.9	6.2	2.9	34.8
1995	0.0	0.0	0.0	0.0	0.1	0.5	1.9	6.1	13.3	14.0	9.7	6.1	3.6	36.1
1996	0.1	0.1	0.0	0.1	0.3	0.9	2.0	4.3	6.4	8.5	8.3	5.9	3.7	31.5
1997	0.0	0.0	0.0	0.2	0.6	1.0	1.8	3.4	6.0	8.2	9.1	7.8	5.2	36.9
1998	0.0	0.0	0.1	0.4	1.1	2.6	4.7	6.0	5.6	5.3	4.7	3.8	2.7	21.5
1999	0.0	0.0	0.1	0.3	0.7	2.0	4.4	7.5	7.7	5.4	3.6	2.6	2.0	16.3
2000	0.0	0.0	0.0	0.1	0.3	0.9	2.2	4.6	6.7	6.5	4.4	2.5	1.3	16.3

Table 3. Catches of cod (millions) by length in the Norwegian trawl fishery in the first quarter in the Western Barents Sea. The length distributions are based on Coast Guard inspections. N is number of fish measured. The length groups are labelled by the mid-point of the interval. >60 is the sum of all fish above 60 cm.

Length (cm)	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	>60	N
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.28	0.44	0.88	1.16	1.44	1.30	0.75	5.49	589
1998	0.00	0.00	0.00	0.00	0.04	0.20	0.50	0.68	0.64	0.77	0.80	1.09	0.86	0.47	3.81	1110
1999	0.00	0.00	0.00	0.00	0.01	0.03	0.23	0.60	0.93	1.01	0.80	0.68	0.57	0.43	3.00	6421
2000	0.00	0.00	0.00	0.00	0.01	0.04	0.15	0.43	1.28	2.03	3.00	2.14	0.89	0.32	6.61	22618

Table 4. Estimated number of cod (millions) by 5 cm length group in the Western Barents Sea in the winter survey. The length groups are labelled by the mid-point of the interval. >60 is the sum of all fish above 60 cm.
a: Estimates based on length dependent fishing width (as in survey reports)
b: Estimates converted to 25 m fishing width independent of length. Factors by 5 cm group used for conversion are as specified in Table 1b.

Length (cm)	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	>60	N
a																
1997	297.54	6.42	3.27	1.24	1.17	0.73	0.82	1.14	1.42	1.69	1.43	1.06	0.73	0.43	3.91	13075
1998	470.66	6.75	3.48	3.93	5.70	5.44	4.03	2.11	1.16	0.96	0.91	0.71	0.57	0.25	2.74	19134
1999	39.82	2.99	1.22	1.25	1.44	2.60	3.11	2.71	1.68	0.84	0.47	0.39	0.32	0.27	1.67	8547
2000	30.54	2.18	3.83	3.15	2.26	2.65	2.63	2.75	3.24	2.17	1.11	0.57	0.24	0.12	2.21	10505
b																
1997	225.38	5.20	2.95	1.22	1.24	0.82	0.98	1.42	1.85	2.28	1.99	1.47	1.01	0.60	5.45	
1998	356.51	5.46	3.14	3.87	6.02	6.11	4.78	2.62	1.51	1.29	1.27	0.99	0.79	0.35	3.82	
1999	30.16	2.42	1.10	1.23	1.52	2.92	3.68	3.37	2.18	1.14	0.66	0.55	0.45	0.38	2.33	
2000	23.13	1.76	3.45	3.09	2.38	2.97	3.12	3.41	4.20	2.93	1.55	0.79	0.33	0.17	3.09	

Table 5. Average catch rates of cod (number per n. mile towed) in commercial trawl (CT) in the closed area monitoring surveys and in research trawl (RT) in the Norwegian summer survey. All data restricted to the southern part of ICES sub-Division IIb in July-August. The length groups are labelled by the mid-point of the interval. >60 is the sum of all fish above 60 cm.

	Length (cm)	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	>60	# of hauls
CT	1997	0.01	0.46	1.11	4.38	6.20	3.89	3.94	5.12	5.53	6.13	3.74	2.74	1.80	15.76	23
CT	1999	0.01	0.01	0.23	0.70	1.05	2.93	6.97	8.93	8.39	5.02	2.68	1.82	1.12	11.98	33
RT	1997	58.30	26.97	11.82	8.67	9.66	6.83	5.67	4.16	3.83	3.90	3.73	1.88	1.62	11.89	50
RT	1999	35.37	35.76	18.19	21.83	12.73	8.34	12.89	11.77	7.07	3.97	1.54	1.56	1.08	8.84	47

Table 6. Average catch rates of cod (number per n. mile) for individual vessels fishing in the same area in mid-August 1995. RT1 and RT2 are research vessels using research trawl. CT1, CT2 and CT3 are fishing vessels using commercial trawl. CT1 used 55mm sorting grid, the other two fished without sorting grid and their combined catch rates are shown (CT2+3). The length groups are labelled by the mid-point of the interval. >60 is the sum of all fish above 60 cm.

Length (cm)	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	>60	# of hauls
RT1	163.3	17.4	22.5	30.9	26.0	34.1	22.5	17.6	27.0	34.7	21.3	10.2	6.0	77.5	27
RT2	235.3	27.4	28.8	29.2	26.2	35.6	25.0	18.6	28.0	37.6	21.2	11.9	6.7	83.3	27
CT1	0.0	0.0	0.0	1.4	4.5	14.4	20.4	29.4	93.4	141.4	106.4	53.4	41.1	389.1	8
CT2	0.0	0.0	0.0	0.9	1.9	11.8	17.2	23.4	47.1	65.5	40.7	24.1	17.1	169.0	4
CT3	0.0	0.0	5.8	7.7	18.7	23.6	72.5	110.9	316.2	401.5	212.3	80.5	71.3	819.1	3
CT2+3	0.0	0.0	1.4	2.5	5.9	14.6	30.4	44.4	111.6	146.0	81.8	37.6	30.1	324.8	7

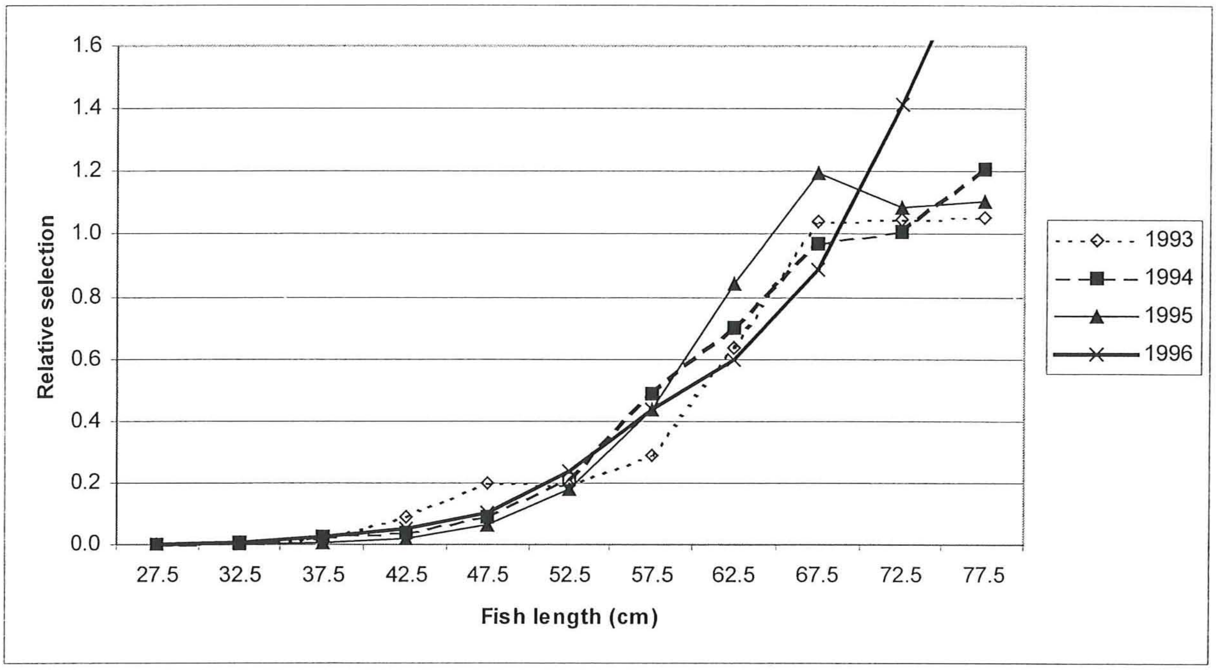

Figure 1. Survey-related selection by length groups for the annual landings by Norwegian trawlers in the years 1993-1996.

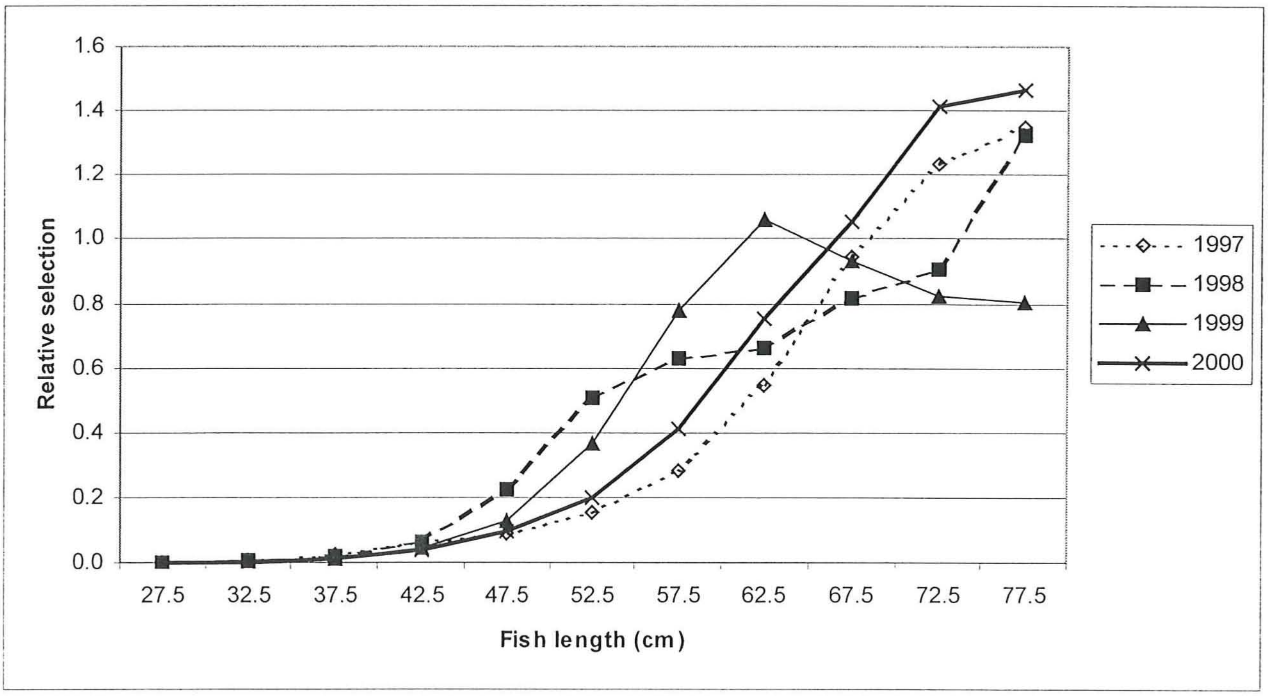

Figure 2. Survey-related selection by length groups for the annual landings by Norwegian trawlers in the years 1997-2000.

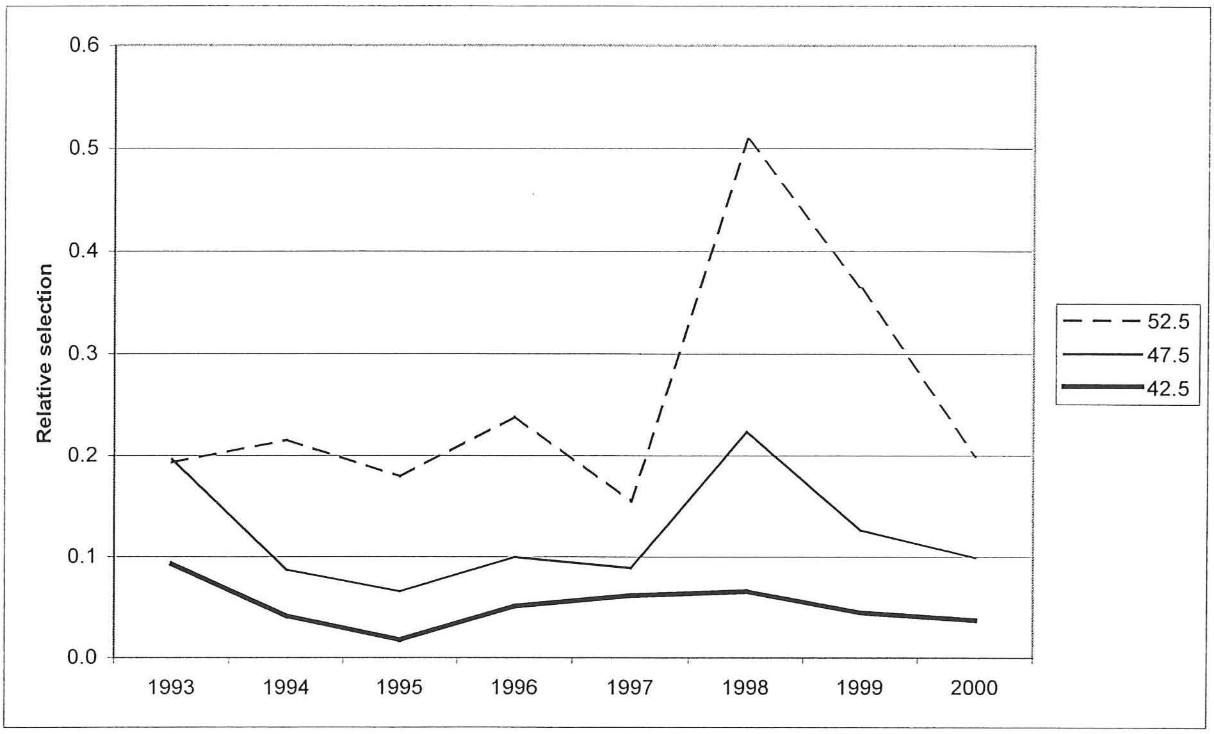

Figure 3. Survey-related selection by years for the length groups 42.5, 47.5 and 52.5 for annual landings by Norwegian trawlers in the years 1993-2000.

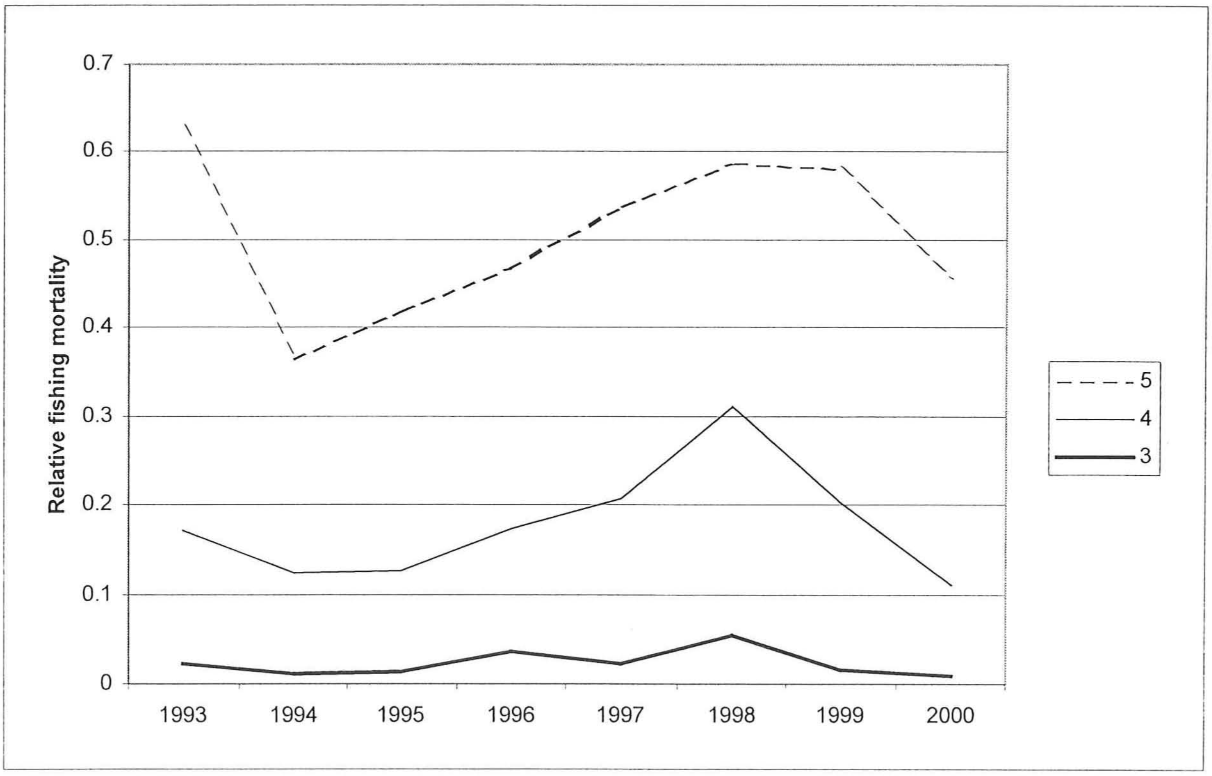

Figure 4. Relative fishing mortality (F) for age groups 3,4 and 5 (F relative to the average F for age groups 5 to 10) for the total fishery of North-east arctic cod, as calculated by the ICES Arctic fisheries Working Group (ICES C.M. 2001/ACFM:19).

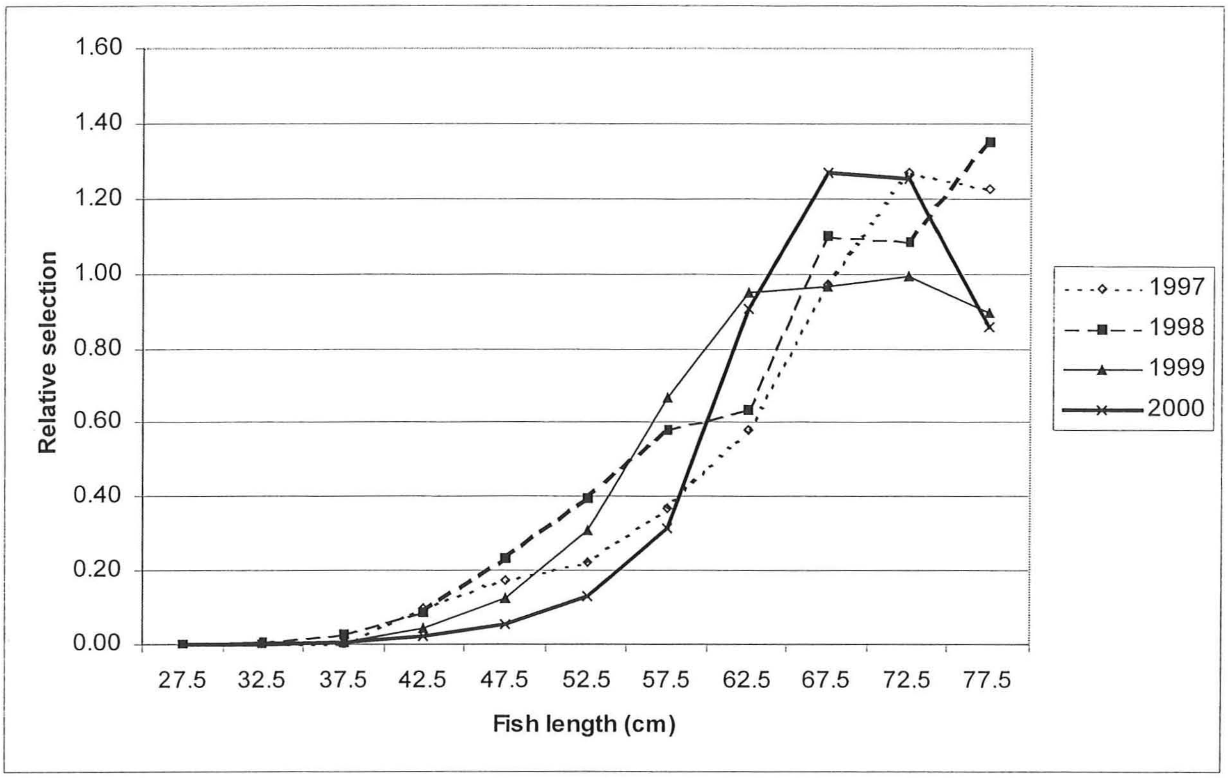

Figure 5. Survey-related selection by length groups for the landings by Norwegian trawlers in the Western Barents Sea during the first quarter.

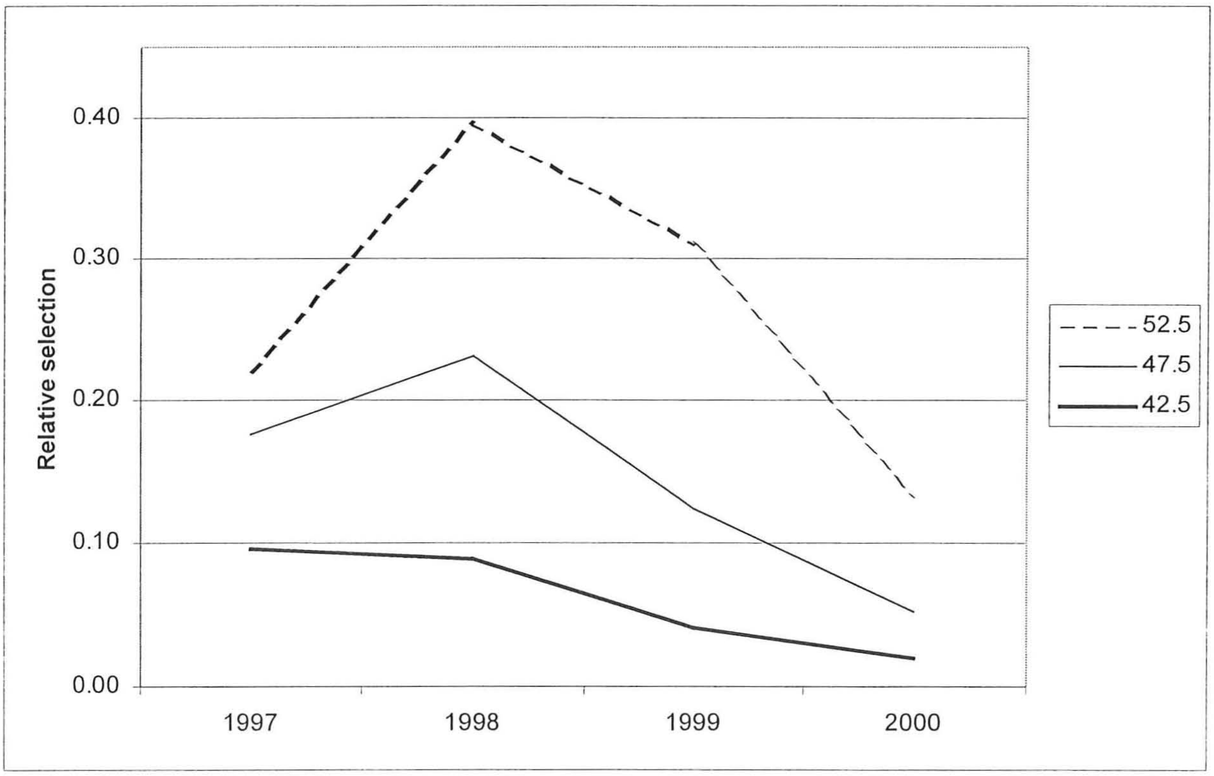

Figure 6. Survey-related selection by year for the length groups 52.5, 47.5 and 42.5 for the landings by Norwegian trawlers in the Western Barents Sea during the first quarter.

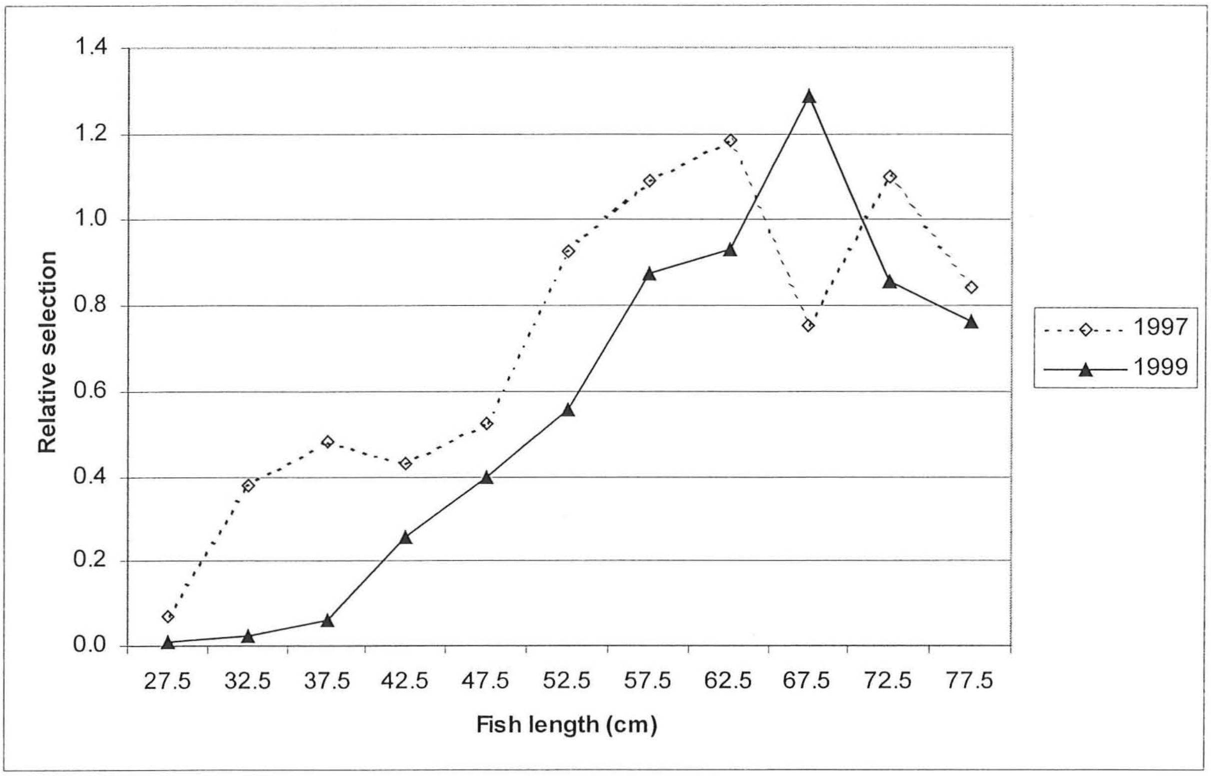

Figure 7. Selection for commercial trawl relative to research vessel trawl based on comparisons in southern part of ICES sub-Division IIb during July-August 1997 and 1999.

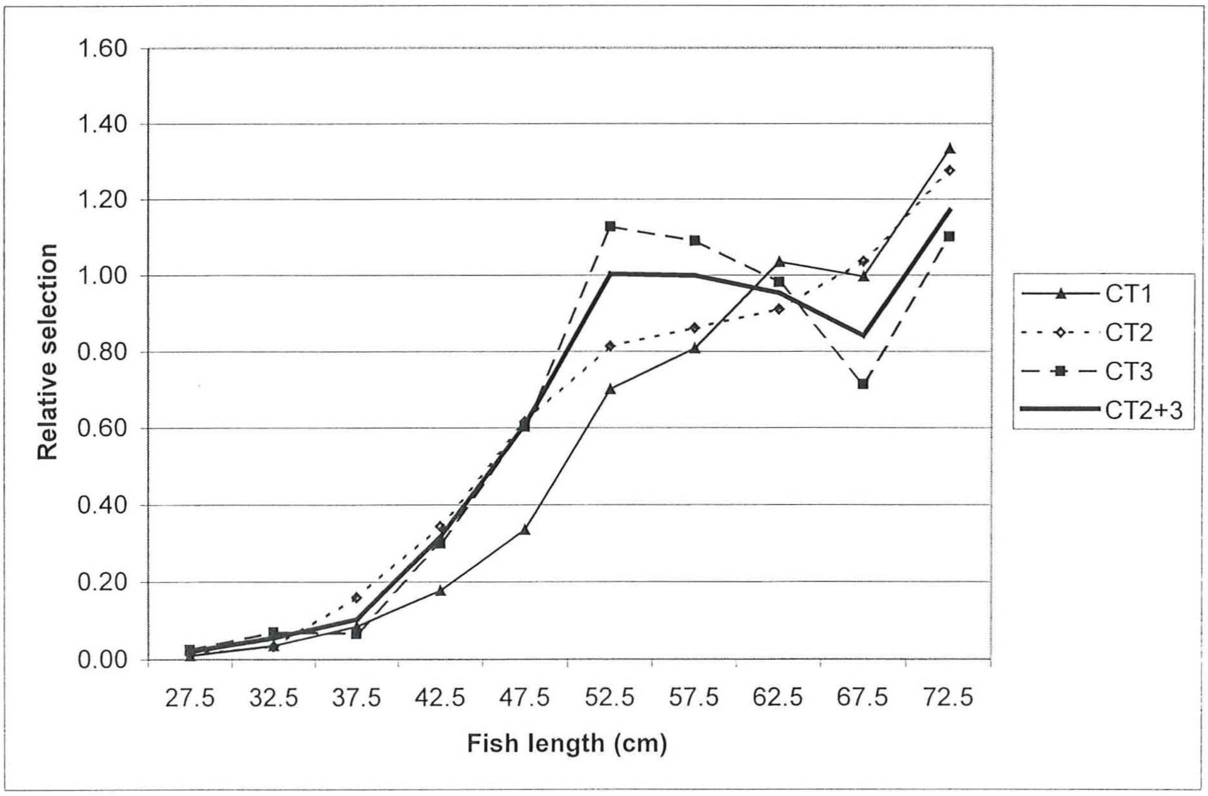

Figure 8. Selection for individual commercial trawlers (CT1, CT2 and CT3) relative to research vessel trawl. CT2 and CT3 fished without sorting grid and their combined results are shown (CT2+3). CT1 used 55 mm sorting grid. The vessels were fishing close to the research vessels during mid August 1995.

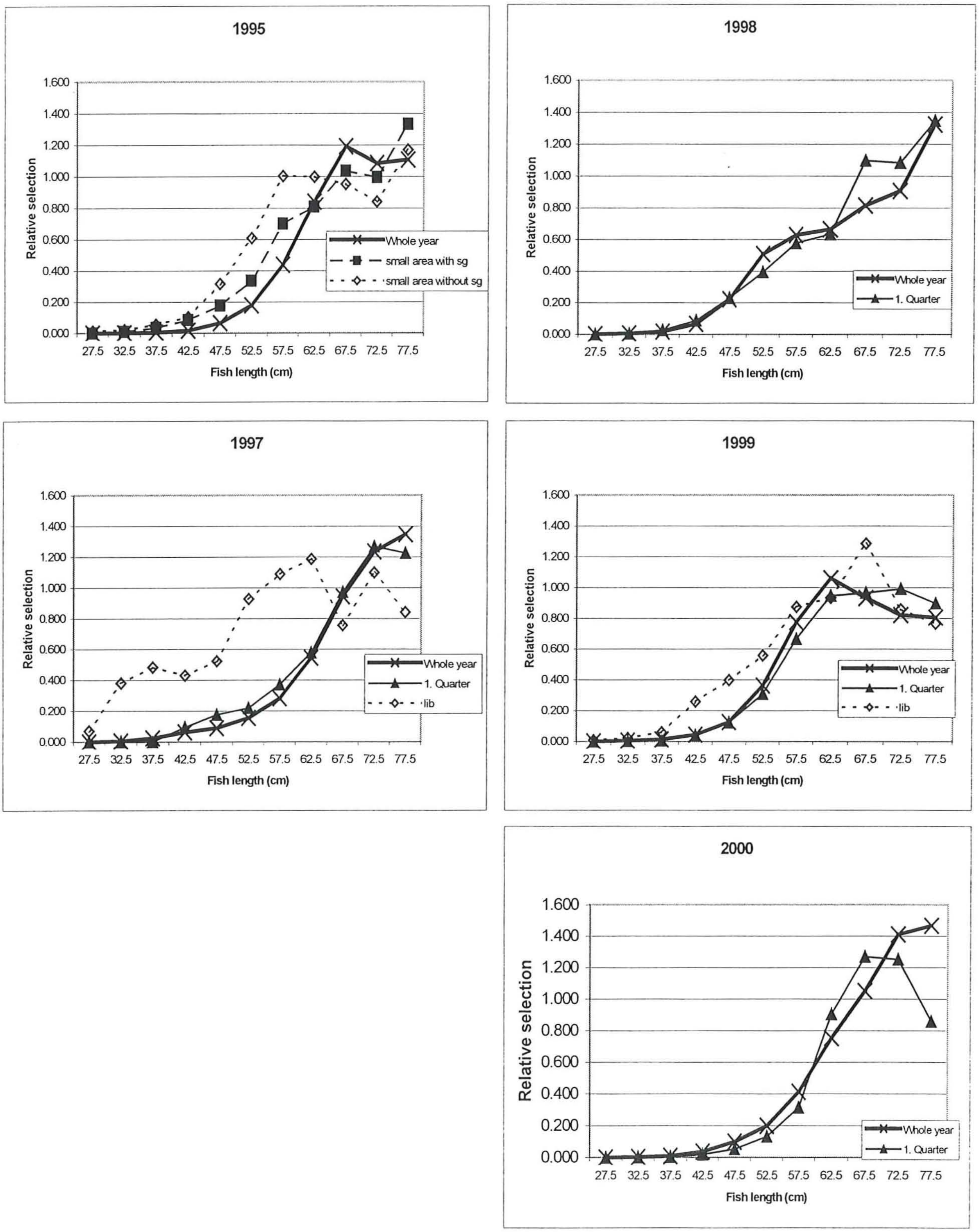

Figure 9. Comparisons of survey-related selections obtained from the various data sources within the same year. IIb represents the closed area monitoring surveys in southern part of ICES sub-division IIb.
sg means sorting grid.

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PROTECTION OF JUVENILES OF COMMERCIAL FISHES UNDER INTERNATIONAL SHRIMP FISHERY IN THE BARENTS SEA AND ADJACENT WATERS

by

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Abstract

Based on the computations of possible bycatches of juvenile cod, haddock and redfish *S. mentella* in the international fishery for shrimp in the Barents Sea and adjacent waters in 1998-2000, a probable impact of shrimp fishery on the future status of commercial fish stocks taken as bycatch is estimated.

The computations show that the highest possible additional recruitment – ca. 1 000 tonnes - to the spawning stock of redfish by juveniles “saved” from catching in shrimp fishery in 1998-2000 would be reached in 2013-2014, which would enhance stock recovery.

Annual possible catches of cod in 2000-2011 would additionally increase by 8 600 tonnes, those of haddock – by up to 2 000 tonnes. The summarised catch of cod and haddock for 2000-2011 would additionally increase by 49 000 tonnes.

Shrimp catches taken in the Barents Sea and adjacent waters in 1998-2000 with bycatch of commercial fishes, as well as the income from their sales, were found to be considerably higher than the additional future catches of cod and haddock and long-term income from fishery on those species supposedly “saved” from catching in shrimp fishery.

Introduction

Under direct trawl fisheries many non-target species are removed from the ichthyocenosis. This results from two factors, the presence of other fish in aggregations of commercial species and the selectivity of fishing gears. Major part of bycatches is generally made up by the usually discarded juveniles of commercial fishes. Large-scale trawl fishery can pose a great threat to commercial and spawning stocks of bycatch species by reducing the future spawning stock and the total allowable catches (TACs) (Clark, 1998; Hylen, Jacobsen, 1987). On the other hand, any measures aiming at bycatch limitation hinder the direct fishery and reduce the total catch of the target species.

The "bycatch problem" is the greatest under trawl fishery for shrimp where the ratio between the weight of shrimp and the weight of other animals can reach 1:10 (Kennely *et al.,* 1998; Pascoe, 1997). About 90% of the bycatch are discarded, causing death of fish. This problem also exists in the trawl fishery on the northern shrimp (*Pandalus borealis* Kroyer, 1838) in the Barents Sea where bycatches contain juveniles of such valuable commercial species as cod, haddock, redfish and Greenland halibut. In the periods when their distribution coincides with the areas of shrimp fishery, mortality of juveniles in these stocks reaches tens of millions fish.

The history of trawl fishery on the northern shrimp of the Barents Sea dates as far back as a century (Rasmussen, 1965; Berenboim, 1972). It originated as a coastal or fjord fishery, but gradually spread to the open sea. Presently, the fishery is conducted primarily by Norway and Russia in a large area of the Barents Sea and adjacent waters (Fig.1).

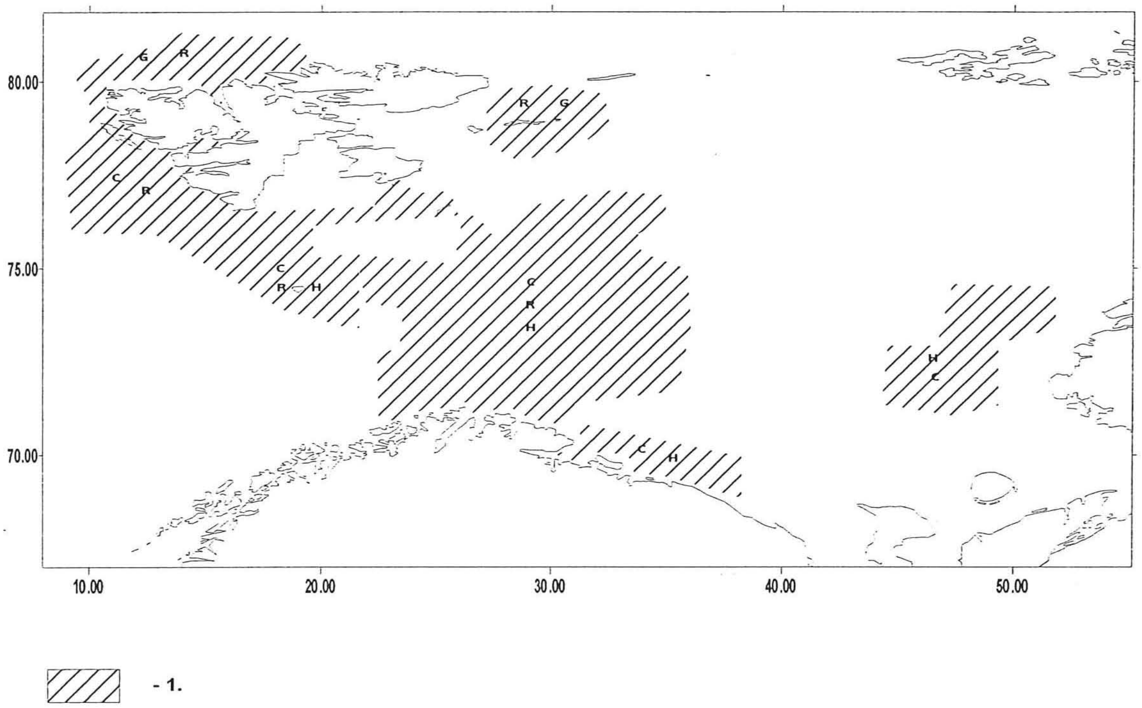

Fig.1. Traditional areas of northern shrimp fishery in the Barents Sea and adjacent waters (1.) and main species occurring in bycatches, cod (C), haddock (H), redfish (R) and Greenland halibut (G)

Until the early 1980s, large-scale trawl fishery had not been regulated and the bycatches had not been limited. The non-regulated total catch of shrimp in some years exceeded 100 thousand tonnes (Fig.2).

Only one regulatory measure was in use, namely the 35-mm mesh size in trawls. At present, the maximum allowable bycatch of shrimp with carapace length below 15 mm in the NEZ shall not be over 10% by weight of the catch (Regulations..., 1986). Since the late 1990s the Norwegian authorities have been unilaterally limiting the number of vessels and vessel-days in shrimp fishery.

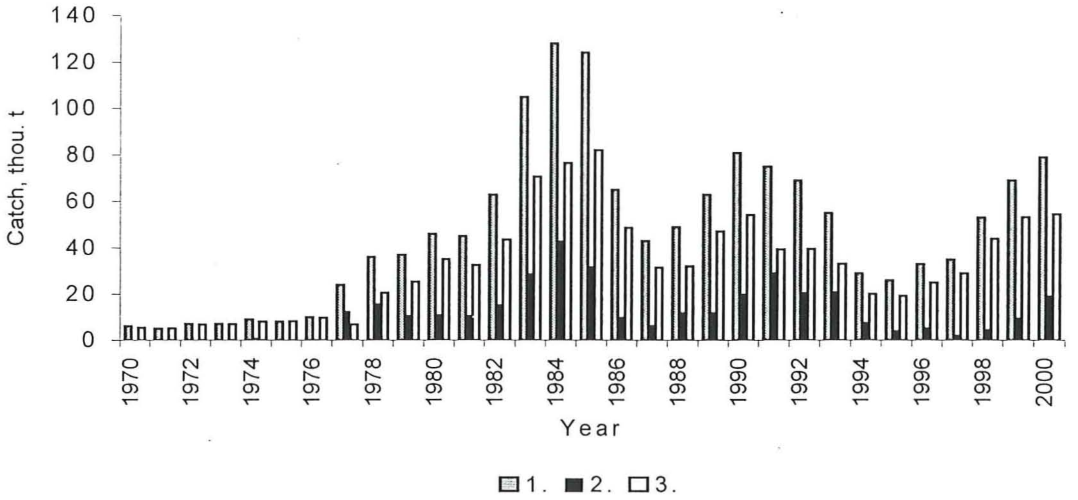

Fig. 2. Total catch of shrimp (1.), catch of shrimp by Russia (2.) and Norway (3.) in the Barents Sea and adjacent waters in 1970-2000, ('000 tonnes)

In 1984, the Joint Russian-Norwegian Fisheries Commission agreed on the limitation of bycatches of undersized cod and haddock to 300 individuals per 1 tonne of shrimp. In July 1992, in view of the critical status of the Greenland halibut stock, Russia and Norway introduced restrictions on bycatches of its juveniles. It was allowed to catch 300 individuals per one tonne of shrimp. The excess of the allowed amount of undersized fish in catches is the reason for closure of shrimp fishing areas. Besides, since 1992 trawls with sorting systems have been mandatory in shrimp fishery. Such trawls are believed to effectively release young fish longer than 20 cm. Their practical use considerably reduced the amount and changed the age composition of bycatches of young cod, haddock and redfish. However, no notable reduction of Greenland halibut bycatches was observed (Isaksen *et al.,* 1992). Due to the sorting systems, cod and haddock of 20 cm length and longer, redfish of 16-18 cm and longer and halibut of more than 30-32 cm length are eliminated from shrimp catches.

Lower amount and changed age composition of juvenile bycatches were the main reasons for the revision of allowed bycatches. Russian and Norwegian specialists developed two methods of calculating allowable bycatches, or bycatch criteria, for juveniles of the mentioned species under shrimp fishery in the Barents Sea and adjacent waters (Veim *et al*., 1994; Tretyak *et al*., 1994). The principal objective of these methods was to minimise the reduction in spawning stocks and TACs caused by excessive catching of juveniles in shrimp fishery, as well as the reduction in shrimp catches due to closure of fishing grounds. Since 1995, bycatch criteria for undersized cod and haddock have been annually established by the Joint Russian-Norwegian Fisheries Commission after the discussion of results obtained by both methods. The allowed bycatch of Greenland halibut has not been revised, making up 300 fish per one tonne of shrimp. In January 2000, due to the low stocks of redfishes (*Sebastes mentella* and *Sebastes marinus*) in the Barents Sea, the existing regulation measures were added by the limitation of bycatch of juvenile fish from the *Sebastes* genus to 1000 fish per 1 tonne of shrimp.

The paper attempts to use the recent data for estimating the impact of shrimp fishery on the stocks of cod, haddock and redfish and defining the efficiency of bycatch criteria for juveniles of these species. A brief economic analysis of shrimp fisheries is given in view of the bycatch criteria for the above species.

Materials and methods

Supposed catches of small cod, haddock and redfish in trawl fishery for shrimp are calculated on the basis of the results from Russian trawl surveys (TS) of shrimp stocks in the Barents Sea and adjacent waters annually conducted in the main areas of shrimp fishery in 1998-2000. Shrimp was caught using trawl with a small-meshed insertion in codend and without a sorting system.

The prescribed fishing gear in shrimp fishery is trawl with a sorting system for release of fish longer than 20 cm and with a 35-mm mesh size in the codend. Occurring in catches are cod below 20-cm length and haddock below 16-cm length. Shrimp catches taken during surveys contain also larger fish. Therefore, for the computation of the supposed bycatch of young fish, cod and haddock above 21 cm and redfish above 17-cm length were excluded from the preliminary survey data. Besides, only catches of near-commercial size, i.e. of more than 50 kg of shrimp per one hour of trawling, were taken into account.

According to earlier studies (Tretyak, Mukhina, 1992), 50% of the shrimp catch in the Barents Sea and adjacent waters contain bycatch of haddock and redfish and 90% - bycatch of cod.

Length of young cod and haddock in bycatches corresponded to the age of 1 year, that of redfish – to the age of 1 and 2 years.

It was assumed that young cod, haddock and redfish fished as bycatch in 1998-2000 did not die and remained in the ichthyocenosis. They would be affected only by natural mortality, providing the recruitment to the commercial stocks in future years. The hypothetical reduction in the abundance of this age group of fish was calculated on the basis of long term means of instantaneous natural mortality coefficients by the MSVPA method (Tretyak *et al.,* 1999) (Table 1). The method was adapted for the commercial part of the Barents Sea community. Natural mortality coefficients for redfish were taken from Tretyak *et al.* (1995) (see Table 1). After the recruitment to the commercial stock the survived fish would increase the biomass of the commercial and spawning stocks and, consequently, the total catch of the mentioned species.

Table 1

Parameters and indices used for computation of a possible recruitment to the commercial stocks of cod, haddock and redfish

Species	Age when fished as bycatch in shrimp fishery, years	Age of recruitment, years	Age	Instantaneous coefficient of natural mortality (M_t)
Cod	1	3	1	0.63
			2	0.30
Haddock	1	3	1	0.65
			2	0.34
Redfish	1 2	7	1	0.30
			2	0.26
			3	0.22
			4	0.18
			5	0.14
			6	0.10

Mean weight of fish in catch and in the stock, natural and fisheries mortality coefficients, as well as the portion of mature fish in each age group are assumed to be equal to the corresponding means for 1995-2000 (Anon., 2001). Considering that redfish is fished very cautiously, the recruitment age is supposed to be the age of maturation beginning, i.e. 7 years.

The expected income from sales of the portion of shrimp catch taken with bycatch of juveniles, as well as the additional income from sales of cod and haddock presumably "saved" in 1998-2000 from catching in shrimp fishery, were calculated with the following prices: NOK 9 for 1 kg of round weight of shrimp, NOK 8.5 for that of cod and NOK 8 for that of haddock (Veim *et al.,* 1994). Discount coefficient was taken as 1.05 (Veim *et al.*, 1994).

Results and discussion

In 1998-2000, 19-39 million individuals of cod, 1-19 million individuals of haddock and 2-6 million individuals of redfish were annually caught in the trawl fishery for shrimp in the Barents Sea and adjacent waters (Table 2). In our opinion, cod bycatches are consistent with the results of earlier studies (Hylen, Jacobsen, 1987), according to which in 1983-1986 the annual catch of cod aged 1 year taken in Norwegian trawl fishery for shrimp and north of 69°N alone amounted to 3-9 million individuals.

Table 2
International catch of shrimp in the Barents Sea and adjacent waters and calculated catch of juvenile cod, haddock and redfish in shrimp fishery in 1998-2000

Year	Shrimp catch* ('000 t)	Catch of juvenile fish, million individuals		
		Cod	Haddock	Redfish
1998	53	27	1	2
1999	69	19	7	3
2000	79	39	19	6

* - Anon., 2001

Annual catch of young fish in 1998-2000 depended on the size of shrimp catches and on the spatial distribution of these fish. In 2000, e.g., the highest catches of juvenile fish were recorded simultaneously with the highest catches of shrimp and wide distribution of juveniles.

In 1998-99, cod and haddock in bycatches were of the average yearclasses, in 2000 – of the below-average ones. Increased catches of juvenile cod and haddock in 2000 when cod stock was on the decline can be explained by a greater overlapping of shrimp fishing areas and distribution areas of small cod and haddock.

Catches of young redfish varied less, which, in our opinion, was due to a steadily low abundance of successive yearclasses.

The additional recruitment to the commercial stock of cod in 2001-2002 by fish "saved" from bycatch would be 7-15 million individuals (Table 3), which could by 2-11% increase the recruitment calculated by the ICES Arctic Fisheries WG.

Table 3
Possible additional recruitment of the commercial stocks of cod, haddock and redfish in the absence of bycatch of their juveniles in shrimp fishery (in million individuals)

Species	Year of catch in shrimp fishery	Year of recruitment to the commercial stock	Possible additional abundance of recruits
Cod	1998	2000	10.7
	1999	2001	7.4
	2000	2002	15.4
Haddock	1998	2000	0.4
	1999	2001	2.6
	2000	2002	7.3
Redfish	1998	2003	0.4
		2004	0.3
	1999	2004	0.6
		2005	0.5
	2000	2005	1.2
		2006	0.9

Recruitment of the commercial haddock stock in 2002 by fish "saved" from bycatch in 2000, could grow by 7.3 million individuals, which, at the average abundance of recruits (96 mill. indiv.) would increase their abundance be almost 8%.

Possible recruitment to the commercial stock of redfish by "saved" specimens could begin only in 2002. In 2005, the abundance of 6-year-old redfish could have increased by almost 2 million individuals.

Cod and haddock "saved" from catching in shrimp fishery in 1998-2000, could be caught in the directed fishery in the period from 2000 to 2011. Computations show that, with the fisheries mortality averaged for 1995-2000, possible catches of cod in 2000-2011 could additionally grow by 100 – 8 600 tonnes a year (Table 4), which makes up 0.01-1.4% of the average catch in 1995-2000. The additional catch for the entire period of fishery on these yearclasses would amount to 40 000 tonnes.

Possible catches of haddock in 2000-2009 could annually increase by 10 – 2 000 tonnes (Table 5). The highest additional catch – ca. 2 000 tonnes - would be attained in 2004.

Summarised shrimp catch taken in the Barents Sea and adjacent waters in 1998-2000 made up 196 000. tonnes, of which 176 000 tonnes were fished with bycatch of commercial fishes. Possible catch of cod and haddock "saved" in those years would reach 49 000 tonnes. Thus, food production obtained in the international shrimp fishery in 1998-2000 would be 4 times higher than that obtained from future catches of "saved" cod and haddock.

It should be noted that in 1998-2000, only a few cases of excessive bycatch (over 1000 individuals / 1 t of shrimp) of young cod and haddock in shrimp fishery were recorded. This indirectly indicates that the limitation on bycatches of young cod and haddock did not pose great difficulties in shrimp fisheries in that period. On the other hand, this limitation did not result in the excess of future possible catch of fish over the actual catch of shrimp.

Table 4

Possible additional catches of cod in absence of bycatch of its juveniles in shrimp fishery in 1998-2000, tonnes

Age, years	$F_{95\text{-}2000}$	Mean weight, kg*	Year											
			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
3	0.101	0.685	705	487	1012									
4	0.198	1.072		1527	1055	2193								
5	0.358	1.613			2585	1787	3712							
6	0.668	2.375				3525	2437	5063						
7	0.798	3.480					2450	1694	3519					
8	0.995	4.925						1465	1013	2105				
9	1.116	6.462							620	429	891			
10	1.267	7.900								217	150	312		
11	1.267	9.183									58	40	84	
12	1.345	12.026										18	13	26
Total			705	2014	4652	7505	8599	8222	5152	2751	1099	370	97	26

* - Anon. 2001

Table 5

Possible additional catches of haddock in absence of bycatch of its juveniles in shrimp fishery in 1998-2000. tonnes

Age, years	$F_{95-2000}$	Mean weight, kg*	Year									
			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
3	0.060	0.668	13	95	269							
4	0.191	0.917		42	299	848						
5	0.437	1.187			74	534	1514					
6	0.613	1.460				63	450	1275				
7	0.659	1.735					35	250	707			
8	0.644	2.022						17	121	343		
9	0.519	2.297							7	51	143	
10	0.567	2.615								4	30	85
Total			13	137	642	1445	1999	1542	835	398	173	85

* - Anon. 2001

Table 6

Possible additional recruitment to the spawning stock of redfish in absence of bycatch of its juveniles in shrimp fishery in 1998-200, tonnes

Age, years	Portion of mature fish*	Mean weight of 1 indiv., kg*	Year														
			2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
7	0.0078	0.196	0.6	1.4	2.6	1.4											
8	0.0060	0.228		0.5	1.1	2.1	1.1										
9	0.0268	0.276			2.5	5.5	10.1	5.5									
10	0.0912	0.338				9.3	20.8	38.2	20.6								
11	0.2258	0.378					23.3	52.1	95.6	51.7							
12	0.3758	0.434						40.2	90.1	165.4	89.4						
13	0.4928	0.490							53.9	120.7	221.5	119.7					
14	0.7352	0.544								80.7	180.9	332.0	179.5				
15	0.8154	0.584									87.0	194.9	357.6	193.3			
16	0.8946	0.622										92.0	206.1	378.1	204.4		
17	0.9746	0.672											98.0	219.5	402.7	217.7	
18	1.0000	0.686												92.8	208.0	381.7	206.3
Total			**0.6**	**1.9**	**6.2**	**18.3**	**55.3**	**136.0**	**260.2**	**418.5**	**578.8**	**738.6**	**841.2**	**883.7**	**815.1**	**599.4**	**206.3**

* - Anon. 2000

In the last years of the 20th century, spawning stock biomass of redfish in the Barents Sea did not exceed 110 000 tonnes, while the minimum biologically acceptable level (MBAL) advised by the Arctic Fisheries WG was 300 000 tonnes.

A critically low status of the commercial and spawning stocks of redfish in the Barents Sea necessitated cautious fishery on this species. Considering this fact and low bycatch of juvenile redfish in shrimp fishery, the possible additional recruitment to the spawning stock by juveniles "saved" from bycatch in shrimp fishery in 1998-2000 was calculated. Computations showed that the highest additional increase in biomass of the spawning stock of redfish – 1 000 tonnes – could be attained in 2013-2014 (Table 6).

Since the spawning stock of redfish is presently below MBAL, even such a slight increase would enhance stock recovery.

According to the computations, the income from shrimp catches in 1998-2000 taken with bycatch of juveniles would be 3-7 times higher than the long-term income from possible additional catch of cod and haddock (Table 7). In other words, in 1998-2000, with the observed catches of young cod and haddock, it would be economically more profitable to fish for shrimp rather than to protect cod and haddock juveniles.

Table 7

Income from shrimp fishery and possible long-term income from catches of cod and haddock in absence of bycatch of their juveniles in shrimp fishery in 1998-2000, million NOK

Shrimp		Cod		Haddock	
Fishing year	Income, mill. NOK	Period of commercial exploitation	Long-term income, mill. NOK	Period of commercial exploitation	Long-term income, mill. NOK
1998	429	2000 - 2009	90	2000 - 2007	2
1999	559	2001 - 2010	62	2001 - 2008	12
2000	640	2002 - 2011	129	2002 - 2009	34

It should be noted that presently, when no TACs regulate shrimp fishery in the Barents Sea and adjacent waters, the protection of young fish from overfishing poses a very difficult task. Bycatch criteria are calculated on the basis of the predicted shrimp catch which in the recent 5 years has been below the actual catch. In 2000, e.g., the allowable bycatch of small cod and haddock was set at 1000 indiv./1 t of shrimp catch which was predicted to be 50 000 tonnes. However, the actual catch of shrimp by all countries in the Barents Sea and adjacent waters exceeded 79 000 tonnes. Therefore, the actual catch of young fish is often higher than the calculated one. This leads to overfishing of juveniles and aggravates the negative impact of shrimp fishery on commercial stocks.

Conclusions

The computations show that in 1998-2000, 19-39 million individuals of cod and 1-19 million individuals of haddock of 1997-1999 yearclasses at the age of 1-2 years were annually taken in the Barents Sea and adjacent waters as bycatch in shrimp fishery. Catch of redfish aged 1-2 years from yearclasses of 1996-1999 made up 2-6 million individuals.

The highest possible recruitment to the spawning stock of redfish in absence of catching in shrimp fishery in 1998-2000 would be reached in 2013-2014, amounting to ca. 1 000 t, i.e. ca. 1% of the spawning stock biomass in 2000. Considering that the spawning stock of the Barents Sea redfish is presently below MBAL, even such a slight increase would enhance its recovery.

Possible catches of cod in 2000-2011 would annually increase by up to 8 600 tonnes, those of haddock – up to 2 000 tonnes. Summarised catch of cod and haddock in 2000-2011 would additionally increase by 49 000 tonnes.

Catch of the Barents Sea shrimp in 1998-2000 taken with bycatch of small fish was almost four times the possible additional catch of cod and haddock "saved" from catching in shrimp fishery.

The income from shrimp catches taken in 1998-2000 with bycatch of small fish would be 3-7 times higher than the long-term income from possible additional catch of cod and haddock "saved" from catching in shrimp fishery.

Absence of TAC regulation of fishery on northern shrimp in the Barents Sea and adjacent waters increases the complexity of protecting fish juveniles from overfishing in trawl fishery for shrimp.

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BYCATCHES OF KAMCHATKA CRAB (*PARALITHODES CAMTSCHATICUS*) IN THE BOTTOM TRAWL FISHERY IN RUSSIAN WATERS OF THE BARENTS SEA

by

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Abstract

Analysis is done on Kamchatka crab (*Paralithodes camtschaticus*) bycatch distribution in Russian waters of the Barents Sea for 1989-2001. Maximum bycatches of crabs of both sexes were found at 100-200-meter depths. The ratio of males and females in bycatch made up 72% to 28 %. 86 % of males had a 150 mm carapace width and above and 89 % of females were with eggs. The Kamchatka crabs bycatch taken by a bottom trawl increased in 1996-1999.

Introduction

The first reports on Kamchatka crab bycatches during the fishery for fish in Russian waters of the Barents Sea appeared in the mid-70s. Since the late 80s the number of reports on catches of crabs continuously grew and by the end of the 90s crab catches, obviously, exceeded its removals during the trial fishery.

Therefore, the main aims of this report are:

- investigations of geographical distributions of crab bycatches in the Russian part of the Barents Sea ,
- estimation of size of crab bycatches,
- investigations of size composition of crab bycatches,
- survey of crab distribution by depths,
- assessment of crab bycatch dynamics by year,
- presentation of recommendation regarding the criteria of crab bycatches.

Material and methods

Since 1976 all the information about the Kamchatka crab bycatches has been received by PINRO from commercial and research vessels. The database on bycatches was created where the data on geographical reference, fishing gear, depth, total catch and bycatch of crab were included to. If the data on sex, size, moulting stages and other biological features of crabs were available, they were also included into the database.

There are several original methods to assess bycatches (Shevelev et al., 1995; Shevelev, Sokolov, 1997; Sundet, 1998).

The assumption, that the level of crab bycatch is identical both for the vessels with observers onboard and for other commercial vessels operating in the same areas and periods, was put into the basis of calculations of crab bycatches taken in REZ (the Russian Economic Zone). The total catch of crabs (C_{total}) was calculated using the formula:

$$C_{total} = (C_{observed}/E_{observed})*E_{total},$$

where $C_{observed}/E_{observed} = CPUE_{bycatch}$;

$C_{observed}$ - the number of crabs caught at the vessels with observers;
$E_{observed}$ - fishing effort of the vessels with observers;
E_{total} - total fishing efforts.

The data on fishing efforts were taken from PINRO's database compiled on the basis of radio reports. Three types of fishing efforts, i.e. the number of fishing operations, trawling hours and vessel/fishing days were used for the calculations.

Results

Data on crab bycatches (1989 to April 2001) allowed to get an idea of the Kamchatka crab new areas in the Barents Sea (Fig.1) The first expert estimates for the number of crab bycatches in trawls taken in REZ showed that they could attain at least 1% of the total population abundance (Kuzmin & Pavlov, 2000). There are also many crabs in bycatches by bottom trawling in the Pacific Ocean area (Stevens, 1990; Thomson, 1990).

Maximum crab bycatches taken during trawl fishery were usually registered at the depths from 100 to 200 m (Fig.2). The largest depth of catching crabs by trawl was 320 m.

The juvenile crab bycatches attained maximum values of 1000-1500 individuals per a haul (Fig.1).

Most of the crab bycatches from the Murman coastal area were reported in the third quarter. It was, obviously, due to the heating of water in the southeastern Barents Sea and to approaches of demersal fish (mainly haddock) to those areas.

The comparison of length composition of bycatches and crab size, obtained from the results of the surveys, shows that bottom trawl fishing influences the larger crabs of both sexes (Fig.3). In the areas of harvesting fish and scallop in the far distance from the shore (to 50 miles) not only large males, but also roe berrying females were found. The ratio of males and females in bycatch was 72% to 28%. Among the crabs analysed, 86% of males were of commercial size (150 mm by carapace width and above). 89% of females had eggs on abdomen.

No data are yet available from the experiments on crab mortality due to an impact of bottom trawls operating in the Barents Sea. There are different estimations of this parameter, up to ~ 80 % (Armstrong et al., 1993; Stevens, 1990; Witherel & Harrington, 1996), for the other regions.

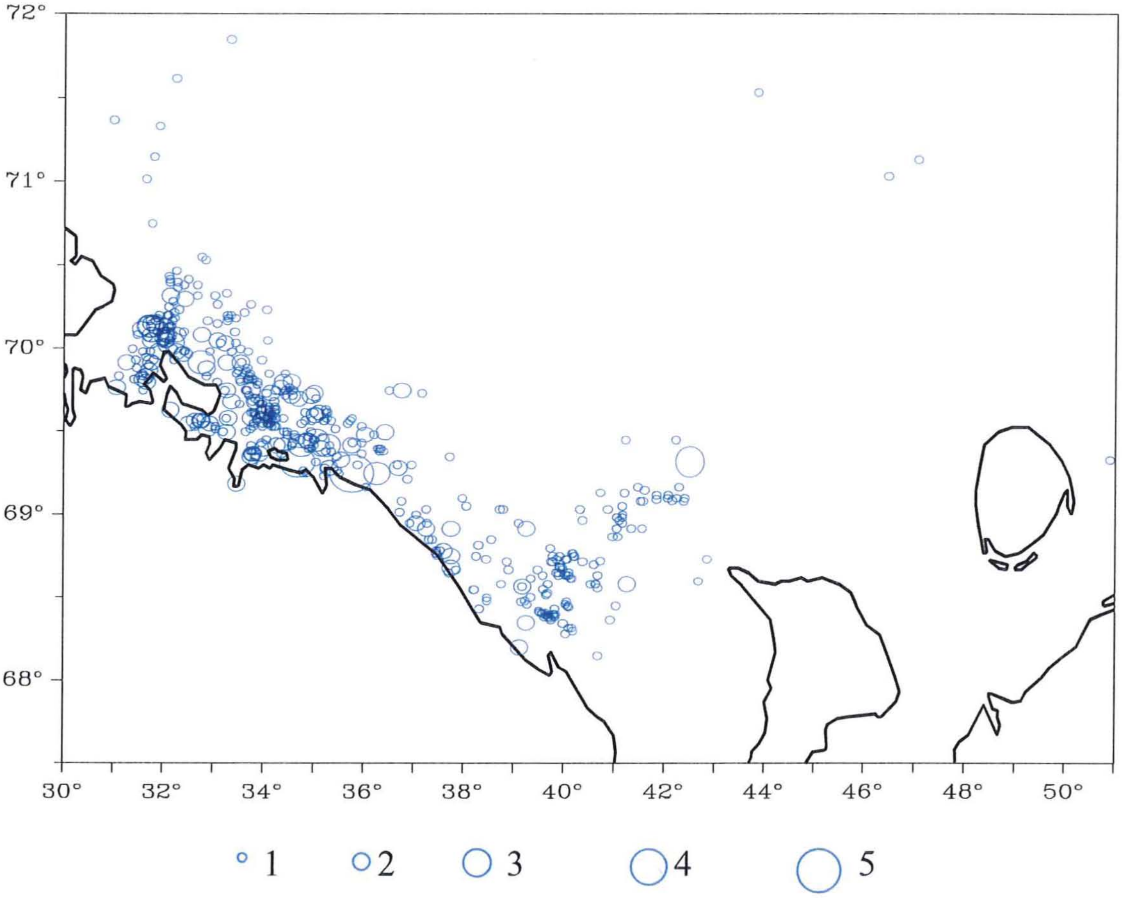

Figure 1. Bycatch of Kamchatka crab (ind./fishing operation) by trawl, long-line and drag fishing from the reports of observers in 1989-2001: 1 - to 10; 2 - from 11 to 100; 3 - from 101 to 500; 4 - from 501 to 1000; 5 - 1001 and above.

In the Murman coastal areas maximum bycatches per effort were taken in 1999 (Tables 1 and 2).

The proportion of analysed fishing operations by the vessels with observers in 1996, 1997, 1998 and 1999 accounted for 2.9%, 1.8%, 6.8%, 3.4%, respectively, and 3.7%, on the average, in the period mentioned. In 2000, due to a lack of information, the bycatches were calculated as the mean value for 1996-1999.

This number of observations should not be considered as optimum and sufficient. These estimates for crab bycatches are therefore of expert character. According to our calculations, about 100 000 crabs were caught during the trawl fishery in the coastal areas of REZ in 1996 - 2000.

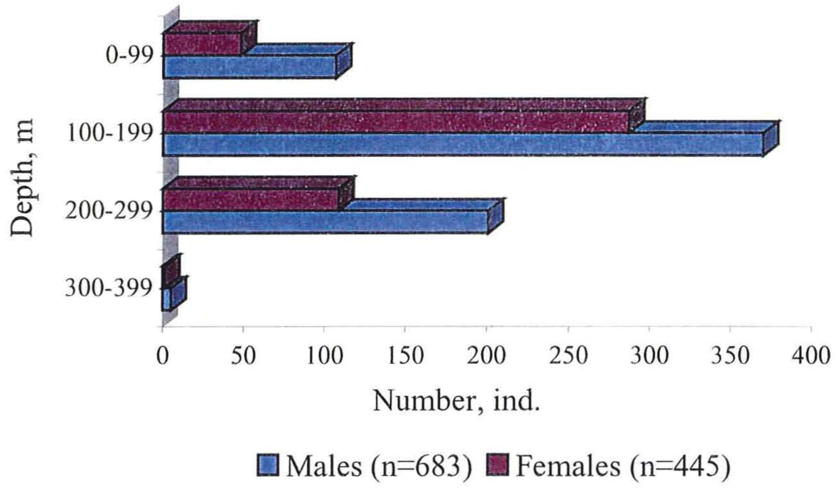

Figure 2. Distribution of Kamchatka crab bycatches by depths in REZ, 1998 (*Kuzmin and Pavlov, 2000*)

Table 1. Kamchatka crab bycatch by bottom trawl in 1996-1999 (vessels with observers).

Year	Bycatch of crabs and effort data					$CPUE_{bycatch}$		
	Number of crabs in by-catch, ind.	Num-ber of vessels	Number of operation	Hours of trawling	Fi-shing days	Per number of operations	Per trawling hour	Per fishing day
1996	51	10	672	1843	192	0,076	0,028	0,266
1997	186	3	395	1114	109	0,471	0,167	1,706
1998	1994	16	2539	8080	661	0,785	0,247	3,017
1999	1045	8	881	2541	190	1,186	0,411	5,500
Average	819	9	1122	3395	288	0,630	0,213	2,622

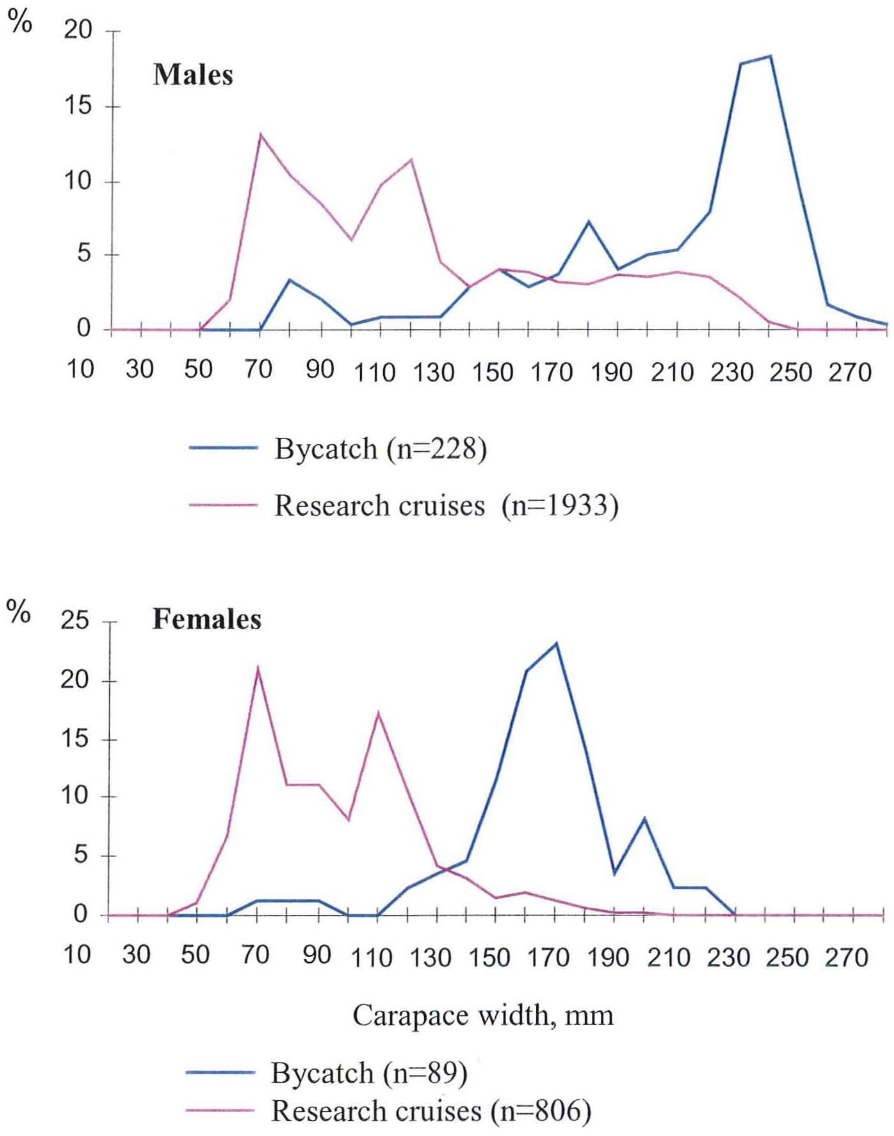

Figure 3. Length composition of the Kamchatka crabs in research surveys and trawl bycatches, REZ 1998 (*Kuzmin and Pavlov, 2000*)

Presented below are the comparisons of variations in commercial abundance and $CPUE_{bycatch}$ for the period mentioned. Their close correlation link is evident (Fig.4).

Thus, under the regular collection of the data on bycatch, which is arranged in the proper way, extra alternative indices of crab commercial stock in REZ may be annually obtained.

Table 2. Effort data and crab bycatch in 1996-1999 (individuals)

Year	Effort data per year			Bycatch of crabs per year (calculated)			
	Number of operations	Hours of trawling	Fishing days	By the number of operations	By hours of trawling	By fishing days	Average
1996	23056	73095	6956	1752	2047	1850	1883
1997	22025	69893	6905	10374	11672	11780	11275
1998	37320	133477	11341	29296	32969	34216	32160
1999	25916	94638	7689	30736	38896	42290	37307

Extra measures should be introduced into fishery regulations in accordance with the investigation results of the Kamchatka crab bycatches in the Barents Sea

The experience of fishery regulation in the Russian Far East demonstrates that it is expedient to restrict crab bycatch by 1-2% to the weight of allowed object when fishing by trawls. This restriction should be applied as a temporary measure.

While conducting further investigations in this direction it is necessary to determine the allowable number of crab bycatch in specimen per unit weight of allowed object.

The development of net fishing lumpsucker and other fishes at the Murman coast may lead to the same problem with crab bycatches as when trawl fishing. In Russian waters when net fishing lumpsucker the bycatches of Kamchatka crab were recorded in all the areas. From the expert estimation in 1996-2000, when net fishing the crab bycatch was from 150 to 3 850 individuals per a season. Not less than 20% of crabs die because of traumatism (Rusyaev, 2001).

To define the economic expediency of closing fishing areas the bioeconomic investigations should be conducted. It is necessary to compare the size of possible losses from the decrease in the catch of fish (cod, haddock, capelin, etc.) due to the closing the areas with increased concentrations of Kamchatka crabs for fishing.

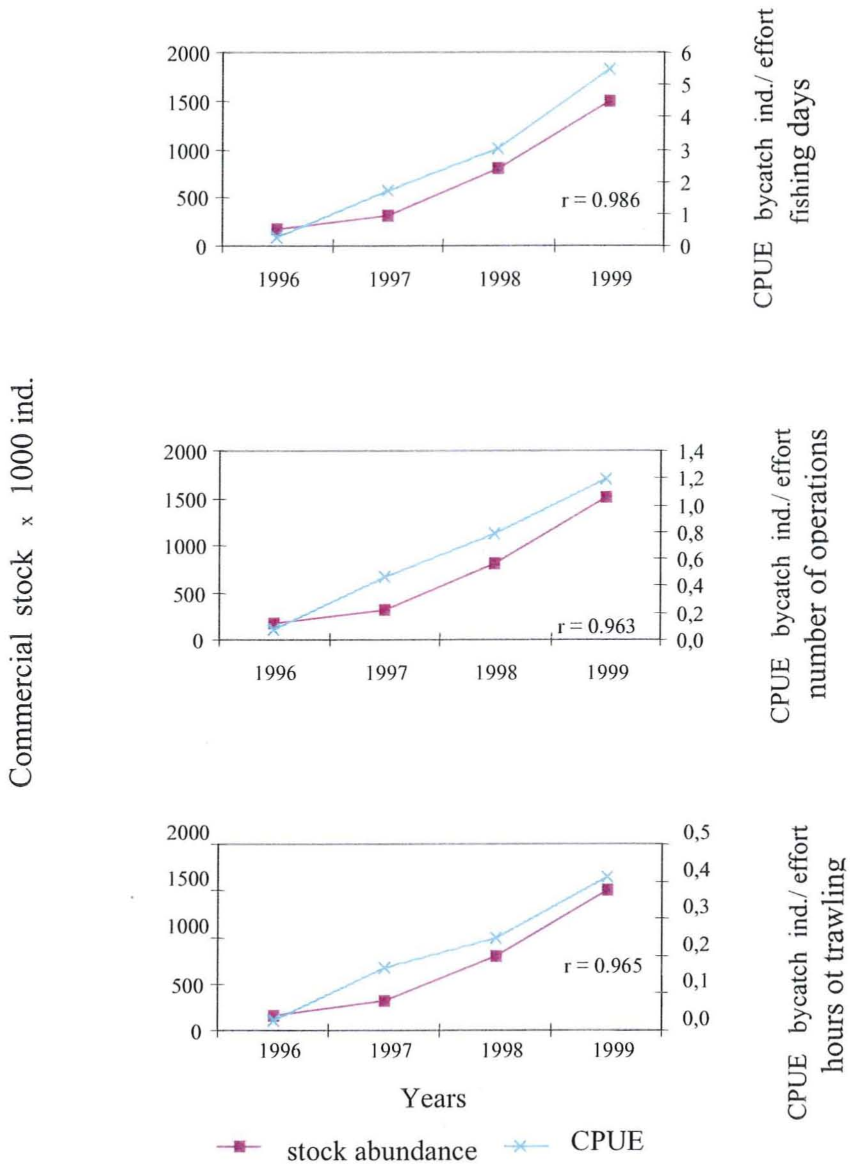

Figure 4. Commercial stock of the Kamchatka crabs in REZ of the Barents Sea and CPUE bycatch, 1996-1999 (*Kuzmin and Pavlov, 2000*).

Conclusions

In 1996-1999, bycatches of Kamchatka crabs when fishing by bottom trawl increased in REZ.

The ratio of males and females in bycatch was close to 3:1. Males of commercial size accounted for 86%, females with eggs on abdomen - for 89%, respectively, from their abundance in bycatch.

Year-to-year variations of crab bycatch indices ($CPUE_{bycatch}$) agree well with the dynamics of their commercial stock.

With the object of crab stock conservation it is necessary to introduce the allowable number of crab bycatch in specimen per unit weight of allowed object into the fishery regulations.

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ON THE REGULATORY MEASURES FOR GREENLAND HALIBUT IN THE BARENTS SEA

by

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Abstract

The paper in brief presents results from the investigations on Greenland halibut *Reinchardtius hippoglossoides* (Walbaum) from the Norwegian-Barents Sea population. The investigations were carried out by the vessels of ZAO NPP "Vega" in 1996-2000. In the course of the specialised investigations, including the monitoring of aggregations on the all-the-year-round basis, assessment trawl and fry surveys, the investigations using autonomous video recorder, the data on biological and fishing characteristics of halibut aggregations were obtained.

Results of the investigations, as well as the data from surveys and experimental works, have indicated that a ban on trawl fishery had a general positive effect on the status of the Greenland halibut population. Commercial and spawning stocks increased to 120 000 and 89 000 tonnes, respectively.

Positive variations in the stock structure, growth of biomass of older fish fish, as well as increase in the density of aggregations, are noted. Along with this, a directed fishery for halibut with passive fishing gears is continued, due to which larger fish are removed, that adversely influences the growth rates of the spawning stock.

Introduction

Greenland halibut *Reinchardtius hippoglossoides*_(Walbaum) is an important commercial species in the European North seas. The eastern Norwegian Sea and the most area of the Barents Sea are inhabited by the Norwegian-Barents Sea population of Greenland halibut, the systematic investigations on which have been carried out since 1965 (Nizovtsev, 1968, 1989). As any other population of the long-cycle fish species with a multi-age structure of the stock and long period of maturation, the Norwegian-Barents Sea population of Greenland halibut is subject to considerable fluctuations in its abundance. The highest biomass of the Greenland halibut spawning stock was estimated as 226 000 - 261 000 tonnes for 1969-1970 (Anon., 2000). The maximum catch of Greenland halibut was taken in the Barents Sea in 1970, when the catch by all countries made up

89 500 tonnes. Regulatory measures for Greenland halibut have been introduced since 1977 (annual establishment of TAC and allocation of national quotas), which had allowed to stabilise catch at 20 000 tonnes. However, the fishing intensity remained to be rather high for the existing level of the stock and made up on the average 21% of the total stock (Nizovtsev, 1989; Anon., 1998, 2000). In 1992, the Joint Russian-Norwegian Fisheries Commission, by the recommendation of ACFM, introduced the ban on directed trawl fishery for Greenland halibut. In 1992-1996, halibut by-catch taken by Russia during fishery for other species constituted 1 000-2 000 tonnes (Gotovtsev *et al.*, 1998). From 1997 to 2000, the Russian catch of Greenland halibut somewhat increased owing to the monitoring carried out on the all-the-year-round basis within the research programs. Directed fishery for halibut using the passive fishing gears was continued by Norway; the annual catch constituted 8 000-15 000 tonnes (including by-catch during the trawl fishery for other species and in the course of research experimental fishery) for 1992-1999.

Materials and methods

The results from more than 15 research cruises undertaken by "Nerey" (MI-0352) (ZAO NPP "Vega") during 1996-2000, are used in the paper. Some data were collected during the cruises performed by MB-1202 "Persey-III" and MI-617 "Persey-IV" (ZAO NPP "Vega"). All the vessels operated in accordance with the annual research programmes of PINRO and VNIRO, approved by the State Committee for Fisheries of the RF. Along with the all-the-year-round monitoring of Greenland halibut aggregations in the period 1996-2000, 5 trawl assessment surveys for Greenland halibut stocks were carried out by MI-0352 "Nerey" together with the RVs "Atlantida", "AtlantNIRO", "Nansen", "Persey-III" and "Persey-IV"; 2 trawl assessment surveys for young halibut were performed together with Norwegian RVs. The data from parallel trawl-longline experiments carried out by the research-scouting vessels "Kozlovo" and "K.Konstantinov", the data derived from the autonomous video recorder (AVR), catch statistics from the trawl and longline fishing, as well as the ICES data, were considered.

To conduct the surveys mentioned above, valid hauls were used; a bottom trawl (drawing 1953) with a rockhopper and Danish boards of Nerey-type - to monitor aggregations of halibut. Hydrographic observations were done with echosounder SBE "Sea-bird electronics" (USA) and biological data were collected in accordance with the methods used by PINRO and VNIRO.

To perform experimental works on intercalibration of trawls, to study the behaviour of Greenland halibut in the area of operation and to estimate the density of its aggregations, autonomous video recorder (AVR), developed at PINRO (Serebrov, 1997), was used. The intercalibration of the trawl (drawing 2283-02), used onboard RV "Persey" (MB-1202) and trawl (drawing 1956) - onboard RV "Nerey" (MI-352), was performed on the Bear Island Bank Western slope. To estimate the density, two methods were tested, i.e. underwater video survey using AVR and the method of repeated fishing of fixed grounds.

Results and discussion

The Norwegian-Barents Sea grouping of Greenland halibut inhabits the vast area of the Barents and Norwegian Seas; large amount of juveniles occur along the difficult for access marginal sites of the area of its distribution in the Barents Sea areas and adjacent waters. Halibut of commercial size - 50 cm length and above - aggregate mostly along the continental slope from the coast of

Norway to the West Spitsbergen (in the Norwegian economic zone and Bear Island-Spitsbergen area) at 100-900 m depths.

A considerable extension of the area of commercial halibut aggregations was recently noted to the east along the continental shelf of the Kola Peninsula to the Murman Shallows. Thus, in 2000-2001, by the reports of masters from the vessels which operated there, the proportion of halibut in catches taken by longline attained 30% and above; compared to the last years, an increase in by-catch should also be noted for the trawl fishing vessels. Nearly insurmountable situation formed for the longliners with a restricted cruise duration (8-10 days) and without freezers, when masters, in order to provide a 7% allowable by-catch of halibut, had to infringe a law by leaving the excessive halibut by-catch onboard or discarding it, or by prolongation of cruise duration resulting in a violation of the chilled product storage period.

Analysis of major biological and fishing characteristics for the sites with different geographical, topographical and hydrographic conditions has revealed variations in the length-age composition of the Norwegian-Barents Sea stock of halibut which occurred since the ban of a directed trawl fishery. While in 1996-1998 the bulk of trawl catches consisted of specimens of 40-60 cm length (modal group 46-50 cm), in the catches taken in 1999-2000, specimens of 45-65 cm length (modal group 51-55 cm) were predominant. Large-size fish of 50-70 cm length are fished during longlining, however, a decrease (on the average by 10%) in catches of proportion of the large-size fish above 60 cm was noted from 1996 to 2000. The comparative analysis of the catch composition from trawl and longline has indicated fish caught by longline to be larger than that fished by trawl. Besides, 70% of catch taken by trawl was made up by males, while in longline catches approximately the same portion was constituted by large females. Lower impact of longlining upon the Barents Sea grouping of Greenland halibut would allow to preserve large-size spawners. The 30-40% restriction on halibut by-catch appears to be optimal. This would allow to increase the proportion of large mature females on spawning grounds, thus enhancing the reproductive capacity of the population.

The dynamics of mean catches taken by trawl for a period passed from the ban introduction corresponded to the seasonal cycles in halibut distribution. In the beginning of the ban period the maximum mean monthly fishing efficiency (to 1.3 t/hr. or 14.0 t/day) was observed during spawning and wintering. In summer the density of aggregations was the lowest (0.6 t/hr. or 9.6 t/day). By 2000, mean trawl catches increased by 2-2.5 times and attained 2-3 t/hr. and 15-20 t/day depending on the season and site of fishing.

The ban on trawl fishery allowed to reduce the proportion of immature specimens in the total catch from 10-20% to 5-10% (Smirnov, 1999; Anon., 1998-2000). An increased amount of young fish to 40 cm length, which constituted on the average 8-15 fish/trawling hr. when using trawls without selective devices, was observed in some sites. A general upward trend of its abundance is traced to the north and at small depths. Sites with maximum aggregations of young fish, the density of which reached 30-50 fish/trawl.hr.and above, were identified.

Already the first results from monitoring conducted in October 1996 by R/V "Nerey", produced two opposite opinions about the status of the Greenland halibut commercial stock and a possibility of its utilisation; however, a lack of systematic investigations for 1992-1996, as well as changing of fishing gears applied for the assessment surveys created a number of additional difficulties in the analysis of the data derived. During the ban period, with the stabilisation and gradual growth of the halibut stock, considerable changes occurred in the stock structure dynamics, which were used by

Nizovtsev (1989) to estimate possibilities of rational exploitation of Greenland halibut stocks. From 1984 to 1991, due to the intensive fishery, a decrease in the stock abundance of Greenland halibut occurred, which, because of a low abundance of the spawning stock, persisted into 1992-1994 (Smirnov, 1995). Steady growth of biomass of the older fish was observed during our investigations. It was the most conspicuous in fish at age 7-12, the proportion of which at the first stage of our studies decreased from 52 to 31%, with a further increase to 67%. A gradual increase in the halibut abundance in 1996-2000 occurred due to the males which accumulated on spawning grounds under a restricted fishery. Low abundance of females observed during recent years remains unchanged that is probably explained both by the intensive withdrawal of mainly large females using passive fishing gears and also by their underestimation at the depths below 800 m.

By the data from the ICES Arctic Fisheries Working Group, in 1992-1999 the commercial and spawning stocks of Greenland halibut from the Norwegian-Barents Sea population increased from 45 300 and 29 000 tonnes to 73 900 and 50 300 tonnes. In 2000, the absolute values for stocks somewhat decreased. According to our data, the commercial and spawning stocks of Greenland halibut from the Norwegian-Barents Sea population in the area surveyed increased, reaching 119 800 and 88 700 tonnes, respectively, in 2000. Such figures for the stock were obtained at the maximum (since 1965) intensity of experimental trawl fishery carried out by Russian and Norwegian RVs in 1999-2000.

The intercalibration of trawls allowed to compare the data from assessment surveys for the period before 1995 with those obtained in 1996-1998. By the video-survey data and catch analysis, the mean and differentiated by size groups of fish coefficients of trawl efficiency were calculated; the mean value for the fishing efficiency of the trawl (drawing 2517) were 13% and 22% - for the Box-trawl. Ratio of the fishing efficiency of the trawls used before and after 1995 constituted 1:1,7 when recalculating per a mile and 1:1,4 - per trawling hour. The density of Greenland halibut aggregations varied from 6.500 to 10.600 fish/mile (on the average 7,6). Positive correlation r=+0,716 was observed between density and catches.

In our opinion, both Parties (Russia and Norway) should be concerned in a qualitative research of Greenland halibut in order to reveal the processes occurring in its population in the current period. According to Appendix 10 of the Protocol of the 29th Session of the Joint Russian/Norwegian Fisheries Commission, when monitoring the demersal fish stocks in 2001-2003, Russia will be able to fish 1 000 tonnes of halibut that is much lower than the annual catch taken by the RVs in 1997-2000. Taking into account a necessity of monitoring of the most part of the distribution area for Greenland halibut, as well as experimental fishing, a participation of 2 or 3 research vessels using active and passive fishing gears will be required throughout a year and the catch of fish taken during such investigations should not be limited.

Conclusions

The ban introduced on trawl fishery in 1992, played a positive role by reducing the proportion of immature fish in catch and provided for an upward trend of the total stock.

To maintain a mature proportion of the population, it is necessary that a ban should be introduced on Greenland halibut directed fishery with passive fishing gears throughout the year. It is suggested that the halibut by-catch in fishery by passive gears should be established at 30-40% of the catch taken in the entire Barents Sea. As for the trawl fishery, it would be reasonable to use the regulatory measures adopted at the 29th Session of the Joint Russian/Norwegian Fisheries Commission.

To derive more precise data on the trawl efficiency, density of fish aggregations and their length composition, it is necessary to continue investigations using the autonomous video recorder. Experimental trawl fishery with a participation of 3-5 medium-size vessels equipped for research works with an annual catch of 10 000-12 000 tonnes should be arranged in order to continue monitoring of Greenland halibut aggregations.

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APPENDIX

Proposals of the 9th Russian-Norwegian Symposium to be addressed to the 30th Session of the Joint Russian-Norwegian Fisheries Commission

Having discussed the existing and suggested technical regulations in the Barents Sea fisheries, scientists and fishermen have come to a conclusion that it is required to introduce common biologically substantiated and mutually acceptable limits:

- minimum catching size for cod and haddock;
- corresponding minimum mesh size in the codend for all areas of trawl fishery;
- limit allowable by-catch of undersized fish to a minimum;
- areas where concentration of undersized fish is above the allowable percentage are to be closed in accordance with the joint Russian-Norwegian procedure for closure of bottom fish and shrimp fishing grounds.

The participants of the Symposium urge the Permanent Russian-Norwegian Committee to continue the work and come up with agreed limits as soon as possible.

An analysis of technical regulations back in history shows their inadequate efficiency due to few observers and poor control of the scientifically advised TAC. This, together with possible methodological problems, made fairly high errors of stock estimates, on which TAC depends on, and which may constitute approximately 20%. This error should be taken into account by the managers when setting the quota. With the aim to improve the main regulation measure in fishery, i.e. the TAC, participants of the Symposium have agreed upon the necessity to estimate the uncertainty when establishing the TAC.

The estimations presented by scientists have shown that sorting grids used in cod trawls reduce by-catch of young fish, which yields significant advantages in the long term.

The participants of the Symposium recognised the need for continuous evaluation of the effect of area closures and gear selectivity (incl. new sorting grids) in the commercial fishery.

Scientists, fishermen and managers believe that in the future technical regulations in fishery should be improved and that comprehensive analyses and their comparability for the whole distribution area of target species, taking into account their availability for fishermen of both countries, should be achieved.

TECHNICAL REGULATIONS AND BY-CATCH CRITERIA IN THE BARENTS SEA FISHERIES

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