IMR/PINRO
JOINT REPORT SERIES
5
2002

JOINT
REPORT

MANAGEMENT STRATEGIES FOR THE FISH STOCKS IN THE BARENTS SEA

Proceedings of the 8th Norwegian-Russian Symposium, Bergen, 15-16 June 1999

Edited by
Tore Jakobsen

ISSN 1502-8828, ISBN 82-7461-057-1

Institute of Marine Research - IMR

Polar Research Institute of Marine
Fisheries and Oceanography - PINRO

This report should be cited as:
Jakobsen, T. (ed.) 2002. Management strategies for the fish stocks in the Barents Sea.
Proceedings of the 8th Norwegian-Russian Symposium, Bergen, 15-16 June 1999.
IMR/PINRO Joint Report Series, No. 5/2002.
ISSN 1502-8828, ISBN 82-7461-057-1.

PROCEEDINGS OF THE 8TH NORWEGIAN-RUSSIAN SYMPOSIUM

MANAGEMENT STRATEGIES FOR THE FISH STOCKS IN THE BARENTS SEA

Institute of Marine Research, Bergen Norway
15-16 June 1999

Editor: Tore Jakobsen, IMR

Foreword

These proceedings contain a fairly detailed résumé of the discussions during the symposium including the opening addresses, and edited versions of the written contributions to the symposium. The presentations and other spoken contributions (comments, questions, answers) were given in Russian, Norwegian or English with the aid of interpreters. The proceedings are in English and it is hoped that those contributions that have been translated, either by the interpreters or by the editor, have retained their original meaning and flavour.

The written contributions represent a wide range in terms of details. Some are comprehensive, others are only copies of the overheads presented. In the résumé there is no summary of the contents of the contributions. The readers are advised to read the contributions before referring back to the résumé for comments and discussion.

The scientific contributions in these proceedings have not been subject to peer review and should not be quoted in scientific literature without permission of the authors.

Although the résumé was written immediately after the symposium, the distribution of the proceedings have been delayed because some of the contributions needed a check on errors and in one case a translation was needed.

Bergen 22 March 2000

Tore Jakobsen

Contents

1. Background and Aim

This is the 8th Norwegian-Russian Symposium on Fisheries Research arranged in co-operation between the Institute of Marine Research (IMR), Bergen, Norway and the Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk, Russia. These symposia are normally attended by scientists only, while this symposium also addresses Fisheries managers and representatives from the Fishing industry as well as Fisheries scientists.

Recognising the need to develop long term strategies for the management of the joint fish stocks in the Barents Sea, the mixed Russian-Norwegian Fisheries Commission decided that the theme for the symposium should be: “Management Strategies for the Fish Stocks in the Barents Sea”, aiming at

- increasing the knowledge and stimulating discussion about the fish stocks in the Barents Sea,
- transmitting knowledge on the medium and long term consequences of fishing on:
    a) average yield (catch in tonnes),
    b) economic yield (net value of catch),
    c) stability in yield.

2. Opening of the Symposium

Research Director Åsmund Bjordal, IMR opened the symposium with wishing everyone welcome and introduced his co-chairman Deputy Director Valery Shleinik, PINRO. He then gave the floor to Permanent Under-Secretary of State Jørn Krog, The Royal Norwegian Ministry of Fisheries and 1st Vice-Chairman Vladimir A. Izmailov, State Committee of Fisheries of the Russian Federation, for opening addresses.

In his opening address Jørn Krog started with greeting everybody welcome to IMR and to the 8th Norwegian-Russian Symposium. In Norway and in the Ministry of Fisheries we are proud of and satisfied with the IMR and what they represent in competence and insight, even if it is difficult to keep a full view of the world around, and especially the part under water.

This is the 8th Symposium and this means that a tradition is established. These symposia are an important component in the co-operation between Norway and Russia. Aiming at the best possible fishery management has always been highlighted in our co-operation. On the scientific side there has always been good co-operation between our two countries. On the Norwegian side great importance is attached to a good dialogue and to be able to learn from each other.

There have been some problems in the co-operation recently, especially concerning research surveys. We hope for a solution so that our scientists get optimal conditions for their work.

The present resource situation in the Barents Sea represents bigger challenges than for many years. We hope that we jointly will be able to halt the decline and improve the exploitation pattern. If we succeed, conditions for the people working in the fisheries will improve.

Management of living resources has not been made simpler over the years. New concepts like "the precautionary approach", sustainability, and ecosystem management require better knowledge, insight, and inclusion of more academic disciplines, and will give a more complex existence for those of us who have to make management decisions.

A long-term strategy is needed to obtain more stability. This symposium will surely reflect some of the complexity of management, but should be a good basis at the next Commission meeting. The symposia have previously been pure scientific meetings and it is positive that we this time also have gathered representatives from fishery management and the fishing industry to be able to look at the problems from different angles.

It is my hope that we after this conference can state that the goals have been achieved: to stimulate discussion about the Barents Sea fish stocks and to spread knowledge about temporary and long-term management of fish stocks with the aim of optimising economic yield and improve stability. I wish all participants good luck with the symposium.

Vladimir Izmailov, in his opening address, thanked for the invitation to the symposium. In particular, it is satisfactory that representatives from management and industry are invited. The management situation is complicated and there are serious problems with the fish stocks in the Barents Sea, especially cod. Although there has been research on this stock for almost 100 years, there are significant problems that have not been dealt with. A special problem previously discussed many times is a total stock assessment for the cod. Also issues relating to many other stocks, e.g. herring and blue whiting, will be raised, although not answered at this meeting.

I wish all participants and those presenting papers good luck and will finally again thank for the invitation to participate in the symposium.

3. Sessions, Contributions and Discussions

Session 1. The Ecosystem of the Barents sea.

Oceanography, primary and secondary production. Overview of the commercially important fish stocks of the Barents Sea. Pollution levels in the Barents Sea and possible consequences for marine life. Description of the capelin and herring stocks as key stocks in the ecosystem.

"A review of the physical and biological conditions in the Barents Sea" by V.Borovkov, PINRO and H.Loeng, IMR. Presented by H.Loeng.

Discussion

O.Nakken: The figures show opposite trends in the development of water temperatures in the eastern and western parts of the Barents Sea: cooling in the east and warming in the west.

H. Loeng: This impression might be due to more updated information (up to April this year) in the figure showing the development in the west and a warmer trend now also starts to show up in the Kola section in the east.

V.A.Izmailov: Anthropogenic effects were not discussed. Comments?

H.Loeng: There has been a lot of discussion internationally, especially concerning the greenhouse effect. Some global models indicate increased temperature in the Arctic in the next 40-50 years. However, these models do not deal much with air/sea interactions and therefore tell little about the effect on the oceans. There is much uncertainty about the oceanic circulation, which is the subject of large international research programmes. It is hoped that in 5-10 years more will be known about anthropogenic effects on the oceanic climate.

"Overview of fish stocks in the Barents Sea and adjacent areas" by M.Shevelev, PINRO and H.Gjøsæter, IMR. Presented by H.Gjøsæter with supplement by M.Shevelev.

Discussion

In his supplementary comments, M.Shevelev referred to coastal cod. The existence of this stock is not firmly proved. The current procedure of management in the Russian-Norwegian Commission can lead to unjustified increase in the exploitation of Northeast Arctic cod, especially when this stock is declining. Regarding Greenland halibut, which is a joint stock dealt with by the Commission, Russian investigations continue even if the ban on directed trawl fishery has resulted in a loss primarily to Russian fishermen. Russian surveys show increase in all components of the stock and in particular mature females, which nearly have doubled since 1996. The increase is in accordance with observed increase of Russian by-catches. However, the catch per unit of effort has decreased and this is a contradiction that can be explained by the limited information resulting from the Norwegian research fishery, which is carried out by isolated vessels. To obtain more reliable data it is suggested to have a trawl fishery in autumn 1999 with up to 10 units. Regarding juvenile Greenland halibut the joint acoustic/trawl survey in the Frans Josef Land-Spitsbergen area in September is very important.

"Capelin and herring as key species for the yield of cod. Results of multispecies runs" by J.Hamre, IMR. Presented by the author.

Discussion

H.Loeng: I am glad to see that the environment was included in the model, but using a longer historical period as basis would improve the prognostic properties of the model.

J.Hamre: The extension backwards in time is limited by the available data on cod predation.

J.Krog: Shrimp and marine mammals are not included in the model. Would the conclusions still be valid if they were?

J.Hamre: The mammals, being top predators, would not influence the natural cycles. But they would prey on both cod and capelin, and it is difficult to foresee the effect in the model. The aim is to include marine mammals in the future. Shrimp is indirectly dealt with in the growth model.

O.Bye: This was an interesting lecture, but the figures for cannibalism do not fit the fishermen's observations. They found it higher in the 1980s than in the 1990s, opposite to the figures presented.

B.Bogstad: This is at least partly because the figures shown by Hamre refer to cannibalism on the stock, whereas the fishermen observe the number of cod in individual stomachs. Even if each cod ate much in the 1980s, the stock was smaller and therefore also the total effect. Russian observations show the same level of cannibalism in the 1950s as in the 1990s.

V.Tretyak showed some tables to illustrate how the sea temperature affects mortality on the young cod. Based on data from 1964-1993 it is found that mortality is inversely proportional to temperature. Furthermore, mortality is also in inverse proportion to the biomass of capelin. The periodicity created by these relationships might be applied to survey results to improve predictions. V.Tretyak confirmed B.Bogstad's statement about high cannibalism in the 1950s.

J.I.Maråk: Hamre's model shows aspects which are new relative to the management and that there is a need for new thinking. The management in recent years has not been successful. We are managing the cod without taking the situation in other stocks, e.g. capelin, into account. Having a large spawning stock of cod when there is a lack of capelin increases cod cannibalism, prevents rebuilding of the capelin stock and reduces the shrimp stock. Hamre's presentation raises a number of questions: Is it right to have a fixed fishing mortality on cod? Considering the large environmental impact, is the spawning stock's effect on recruitment exaggerated? Do the existing rules for protection of young fish counteract rebuilding of the capelin stock in certain periods?

W.Sørensen: To harvest cod and capelin in periods of high production, is the aim pure catch or catch to provide food for the cod? What is a good precautionary management of capelin and what types of uncertainty should be considered?

J.Ramberg: Director Olav Orheim of the Norwegian Polar Research Institute recently said that Norway directs a lot of effort towards climatic research, but that this is concentrated on atmospheric research and it would be more natural for Norway as a marine power to concentrate on oceanography. My question is: Would not this type of research be useful to increase our knowledge of environmental processes in the ocean? A central theme would be the importance of the ocean currents.

J.Hamre: I have not presented my personal meanings or beliefs, but the results of the model. There are many uncertainties in such a complicated system which we today do not fully comprehend. But the model says: You shall catch when the production is high. Lowering the fishing mortality when the stock is large accumulates a large cod stock when the capelin stock is low and this will result in little food for the cod.

Session 2: Management advice

"State of the advice" from ICES with Northeast Arctic cod as case stock. How do scientists produce their advice: which surveys are conducted, which indices are calculated, what are the major uncertainties and risks involved in a stock assessment? Consequences of short-term versus long-term choice of exploitation rate (TAC).

"Retrospective review of management advice and TACs for some stocks" by O. Nakken, IMR. Presented by the author.

Discussion

S.Tjelmeland: The spawning stock of Northeast Arctic cod has been generally overestimated after 1990. Would the conclusion be the same 10-15 years from now?

O.Nakken: This is difficult to answer.

J.I.Maråk: Nakken says that the TACs have been too high but quotas now are lower than in the period 1946-1976 when the average catch was more than 800,000 t. Should not this give cause for some reflections?

O.Nakken: I do not see the difficulty in Maråk's problem, but I need at least a quarter of an hour to give an adequate answer.

"Basis for stock assessment and management advice" by N.Yaragina, PINRO and A.Aglen, IMR. Presented by N.Yaragina.

Discussion

B.Kotenev: How well can you estimate the precision of our fishing statistics? And how do you explain the discrepancy between long-line and trawl estimates?

N.Yaragina: This is difficult to answer. We do not know the uncertainty of the catch data. The same applies to the surveys that have been conducted for 20 years and where much has been changed, e.g. trawl equipment, acoustics, methods of sampling. Trawl and long-line have different catchabilities. The long-line catches bigger fish. The trawl survey aims at estimating young fish abundance and therefore uses a small mesh size.

"Harvesting control rules and future development of the precautionary approach - Northeast Arctic cod as an example" by S.Tjelmeland, IMR and V.Tretyak, PINRO. Presented by S.Tjelmeland.

Discussion

O.Nakken: Multispecies interactions have always existed, even if data may not exist. But this presentation shows that there is nothing to gain by increasing fishing mortality above 0.4 and a multispecies model would have shown the same.

B.Bogstad: Managment advice is in this paper given as a figure, which is too simple. The mangers need to look a few years into the future before making decisions. Known recruitment needs to be taken into account in a short and medium term analysis.

J.Ramberg: Even if Bogstad thinks that this model is too simple, this is not the reason why the Norwegian Ministry of Foreign Affairs this year did not find it possible to give grants to the project of preparing a historical Russian data base, which everybody here regret. The Ministry of Foreign Affairs has supported this project with several million NOK. The work is important and I hope that it will be possible to get grants through what is now the appropriate institution: The Centre of International University Co-operation, located here in Bergen.

B.Kotenev: The codex for responsible fisheries says that we must take the experience up to the present into account. Today I have heard something fantastic: The author claims that if the management model is followed, we will in a few years have a cod spawning stock of 2.5 million t. Historically we have seen low levels of the stock. Therefore, I agree much more with the first presentation (Borovkov and Loeng). Even if we stop fishing now, the stock will be at a minimum in 2003. We must learn from experience.

S.Tjelmeland: The period Kotenev refers to concerning the expected stock increase is 20 years. I agree that we must look at past experience and this comprises multispecies interactions that are not included in this model. I hope we soon can get the multispecies model operational. I also agree with the comments made by Nakken and Bogstad.

P.Gullestad: I agree with Bogstad's comments concerning the presentation of advice. I am surprised at the high spawning stock level in this standard assessment and note that there is are large differences in the annual catch levels. I also note that fishing mortality in the range 0.2 - 0.4 is optimal

S.Tjelmeland: Different models can still give small differences in the conclusions about what is sensible management. I am not surprised that a large reduction in fishing mortality can give a spawning stock of more than 2.5 million t.

J.Krog: I can support Tjelmeland's wish to have a forum where managers and scientists can meet, exchange viewpoints and learn from each other. One of the most important achievements would be to arrive at a conclusion that more clearly than others points in a certain direction for management. For me it is essential to be confident that the main conclusion has a sound scientific basis. It was shown that low fishing mortality gives a large spawning stock, but there must be a maximum biological production. It would be interesting to get an evaluation of how large the maximum biological production is in the Barents Sea. Both scientists and managers have been evaluated and given medium ratings. But how about the people in the fishing industry?

J.Hamre: Nakken said that multispecies interactions always had existed. This is a fair statement if the development in the Barents Sea had been "normal", i.e. not influenced by human activity. However, we fished down the herring and have experienced a period where the capelin stock has carried the production plus a fishery. This represents the biggest uncertainty in the present analysis.

K.Nedreaas: Can Tjelmeland comment on the development of natural mortality, which has declined towards 0.2? This development is not consistent with the surveys where catch plus a natural mortality of 0.2 fail to account for the total mortality.

V.Tretyak: Many years of intensive fishing have changed the population of Northeast arctic cod. There are changes in growth, life span, age at maturity and other parameters. For a given size of cod we also observe more mature fish. This was first seen in the 1980s and in the 1990s it became statistically significant. Our estimation of natural mortality is based on the model and existing parameters for growth etc.

J.I.Maråk: The observation of Nakken that fishing mortality should not exceed 0.4 is derived from the model, but this leaves a large stock in the sea. This stock will feed on other commercially interesting stocks. It must be taken into consideration what the cod stock consumes of other species. E.g., when capelin can be fished for human consumption, will this change the view on the optimum fishing mortality for cod?

O.V.Lebedev: Old cod make up a population of predators. Are there data on this?

S.Tjelmeland: We have numbers for the cod's consumption, but they are based on information from recent years only. It has been said that we must learn from experience, but then the experience, in the form of historical data, must be made available to us. The process of obtaining this experience has now been stopped.

O.V.Lebedev: How far back do the Norwegian data go?

K.Nedreaas: Norwegian data exist back to 1984.

O.Nakken: There is a dilemma concerning old cod. Large cod eat shrimp, haddock, capelin, but they also produce the most viable offspring. It has been shown by Russian and Norwegian scientists that large cod spawning for the second time or more produce more viable offspring than first time spawners. This is a difficult balance to consider in management.

O.V.Lebedev: If old, large cod produce good offspring, one might suggest that it should not be caught.

B.Kotenev: But are there also data showing that large cod do not participate in the spawning?

O.Nakken: It has been shown that cod, especially in years with shortage of food, skip one year of spawning.

Session 3: Management objectives

Which objectives do representatives from the fishing industry/fleet find important to fulfil when deciding on TAC levels? Which objectives do fisheries managers find important when fixing management strategies?

The first part of this session comprised speeches given by Director of Fisheries P. Gullestad, and 1st Vice-Chairman V.A.Izmailov as representatives of the management.

P.Gullestad talked about management objectives for cod and the outline of a management strategy. There are many examples of management objectives, e.g.:

- preservation of fish stocks to ensure good recruitment
- maximum sustainable yield
- maximum economic yield
- job-security
- stability in supply of fish
- preservation of pattern of settlement in coastal areas

Major tools to further the objectives are exploitation rate (level of TAC) and exploitation pattern (size when fish are caught).

In obtaining the objectives, important factors are the trade-off between long-term and short-term consequences, the discount rate and the attitudes towards risk.

The exploitation rate can be based on biological reference points, e.g. for Northeast Arctic cod:

- SSB must be higher than depletion/extinction level ($SSB>B_{lim}=112,000$ t)

- Probability that the measured SSB actually is lower than B_{lim} must be small ($SSB>B_{pa}$ where $B_{lim}<B_{pa}=500{,}000$ t)
- SSB must be large enough to secure good recruitment when environmental factors are favourable (SSB>MBAL=500,000 t)

Management advice should contain tables showing expected development of the stock in the medium term (5-6 years) for various management strategy options (e.g. constant F or constant TAC), and the corresponding probabilities that SSB falls below B_{lim} in a given year.

Relevant economic factors are:

- harvest costs pr kilo;- dependent on stock size
- demand curve for cod
- multispecies-effects; cod-capelin-sea mammals

Measures to improve the exploitation rate are contained in a management strategy for the period 2000-2004:

The aim is to maximise the total physical outtake of cod over the next five years and at the same time also aim at:

- stability in annual TAC by assuming constant TACs
- a high possibility of good recruitment and a moderate risk of bringing SSB outside safe biological limits by keeping SSB above 500,000 t during the whole period
- a target value of SSB after five years of 700,000 t
- every year recalculate the level of annual TAC for a new five year period, based on updated scientific information
- in the event that the SSB for the next year falls below 500,000 t, the TAC for that year shall be limited by an F-value not higher than 0.8x0.SSB

The factors determining the optimum exploitation pattern for cod are

- natural mortality
- individual growth
- size-dependent prices

It has been calculated that economic yield per recruit reaches a maximum if the fish is caught when it is 9 years old and therefore there would be an economic gain by improving the exploitation pattern. This can be done by the following measures:

- Gradually increase the allowed minimum spacing between bars in sorting grids from 55 mm to, say 80 mm in 2002.
- Continue research to improve selectivity in fishing gears
- Continue biological and economical research to more precisely determine the optimal exploitation pattern for cod
- Further improve technical regulations when indicated by scientific information and advice

V.A.Izmailov gave a short overview of the main principles of Russian management of natural resources. There are two basic goals: Sustainable utilisation of the resources and securing food supplies to the Russian internal market. About 40% of the animal protein in Russian food is from fish.

To get us out of the present difficult situation and to ensure sustainability and stability we need prognoses and TACs for longer periods. There are of course scientific problems in making prognoses for longer periods and it will require more research, but we think this is justified. Management of single resources is difficult. Yesterday we learned about the interactions between cod, capelin and sea mammals.

One socio-economic aspect of Russian management is to preserve work-places in outlying districts where the main outcome is from fishing. This is stated in Russian law. Another aspect is the distribution of food, in this case fish, to the Russian population. To achieve this, it is necessary to make fishing profitable for the fishermen. And some times it may actually be economically advantageous to stop fishing for a period. An example is crab where the catch has been doubled, but the prices reduced to half. Another example where market mechanisms play an important role is in the fishery for sturgeon to obtain black caviar.

Discussion

J.I.Maråk: Stabilisation of TACs is a goal for Russia and if you ask a fisherman, he wants stability. But how much are the fishermen willing to pay for this stability? For the catches will on the average be lower and the cost for other stocks will be large.

V.A.Izmailov: On the Russian side it is not necessarily a wish to have constant TACs, but we want long-term forecasts and through management decisions and implementations we will try to reduce the impacts of changes in stock size.

W.Sørensen: I agree with Gullestad's objectives. But it is not possible to talk about management of cod without talking about management of capelin. How will you manage the capelin stock? Another point: If we only catch large fish, we get poor flexibility in the products we can deliver to the markets, but the same is true if we only catch small fish. At present we are at a historically low level in demersal fish TACs, but we nevertheless have a large quantity of blocks stored because small fish only can be used for two products. The price difference between small and large fish is actually too small.

P.Gullestad: The figure I showed (on price against age) was meant to give a message: It is generally profitable to shift the exploitation towards older fish. If the cod is managed to keep the stock at a reasonable level, the cod will eat what it needs. We then must manage what remains of the other stocks, but I think that more research is required to check the spawning stock limit of 500,000 set for the capelin. And what is the ecological significance of spawned capelin. If this is bigger than assumed, we might want a more cautious management.

O.Nakken: Izmailov said that it is sometimes profitable not to fish and gave examples, but how much weight has been put on such aspects in the management of the large stocks in the northern oceans?

V.A.Izmailov: Since I used black caviar as an example, the world market demand is 200-250 t. On the basis of outcome per fish it is possible to calculate how large stock is needed to give maximum economic yield. But it might also be necessary to reduce a stock if it has become too large, so there are many aspects that need to be taken into consideration.

O.V.Lebedev: P.Gullestad mentioned spawning stocks of 500,000 t and 700,000 t. What age groups will you then have in the catches and in the stock?

P.Gullestad: I have used the existing exploitation pattern, but the point was to emphasise the desirability of "increasing" the exploitation pattern.

V.M.Bondarenko, Murman Trawl Fleet and K.W.Hansen, Norwegian Fishermen's Association, as representatives of the fishing industry, presented their views in speeches which are reproduced among the scientific contributions to the symposium.

Discussion

B.Kotenev: Yesterday I liked the presentations by Loeng and Hamre best. They went into the mystery the ocean is. Others had a black box which they put into another black box. But today we have started to open them. From what the fishermen said it became clear what we are doing at sea. We do things we should not do. I have experience from the Far East where dumping sites in the ocean have got their own societies. If we can salvage the fish that today is being discarded, we all deserve a monument. It is shown that a high stock of cod gives a low stock of capelin. Overfishing of cod in the Barents Sea? This we cannot understand. In the northern Atlantic we see 100-year cycles. The reduction in the cod stock is due to natural fluctuations. The next symposium should deal with regulatory techniques and sorting equipment.

A.Aglen: The precautionary approach was dealt with in our paper. It shows the conceptual basis for fishing mortality and biomass reference points. ICES sets the limits for responsible fishing, but does not advice on optimum levels.

S.Tjelmeland: If new management regimes shall be respected, they must be understood and Krog touched on this yesterday. But we have a long way to go. The scientific framework is today far from sufficient for communication of results. My work is to work out management strategies for capelin, herring and in this meeting also for cod and we are willing to have a dialogue with the users. This will demonstrate that there are severe scientific problems. Many of the reference points are poorly defined. And I am looking forward to have the reference point for capelin, which up to now has been my personal problem, promoted to an official problem. Managers and bureaucrats have a responsibility to ensure that research funds are used in the most rational way. I look forward to the establishment of a suitable forum for co-operation.

J.Krog: Representing the management, I would like to thank the two representatives of the fishing industry for constructive contributions. They were characterised by frankness and a good ability to discuss relevant problems. It was interesting to note that there were concurrent views on important issues. This is important and heightens expectations for the future development. Finally, the precautionary approach, which I personally find difficult. What shall a fishery be responsible in relation to? Is it a biological collapse, is it an optimum stock level, or perhaps economical parameters? Here we still have some intellectual challenges.

Session 4: Simulation scenarios for harvesting the Barents Sea

Focus on simulation studies with the aim to show biological and economic consequences of different management strategies (fixed F, fixed TAC etc.)

"Some consequences of long-term management strategies" by T.Jakobsen, IMR, "Economic consequences of various Exploitation rates" by P.Sandberg, Directorate of Fisheries, Norway and "Bioeconomic consequences" by S.I.Steinshamn, Centre for Fisheries Economics. Presented by the respective authors.

Discussion

P.Gullestad: The main message emerging after these three presentations is that bioeconomic principles point to a more conservative management than biological considerations. This raises interesting problems, not least when multispecies interactions are included, and I would encourage both biologists and economists to have a closer look at this.

4. Summary discussion

Å.Bjordal: Many of us present have met at The Joint Norwegian-Russian Fishery Commission where the main task is to make decisions. This symposium, on the other hand, is a forum for a dialogue that promotes understanding and creates a basis for decisions. In this respect, I think the symposium has been useful. I will attempt a brief summary: Multidisciplinary fora (fishermen, managers, scientists) are both useful and necessary to improve management, not least when new concepts like precautionary approach, ecosystem management and biodiversity are introduced. There is a clear need for extended prognoses (up to 5 years). This requires more research on climate/fish relations, but also different models, e.g. like the one presented by J.Hamre. For cod it is bioeconomically correct to shift the exploitation towards bigger fish, even if, as expressed by P.Gullestad, there is a "feeding cost" of having a large stock. Another important point is that it is the responsibility of the fishing industry to provide more reliable data from the fisheries. And finally, it is important to continue working towards a harmonisation of Norwegian and Russian management regulations. Are there comments or additions to this?

B.Bogstad: P.Gullestad wants more multispecies research. We hope to create a basis for multispecies management in the future, but he and the fishing industry must realise that after a model is operational, it requires a lot of effort both from scientists and from the industry to translate this into a successful multispecies management. I fear that the amount of scientific work required is underrated. It is substantial, but also inspiring.

O.Nakken: I agree that work on multispecies models and economy is important, and I can understand that there is uncertainty about the basis for the present advice. But I do not doubt for a moment that there is sufficient knowledge in many stocks to manage them better than we have done so far. We have knowledge to establish harvest control rules for many stocks and it is necessary that this is done quickly if the problems facing us in coming years shall be dealt with

P.Gullestad: I agree that we have enough knowledge to be able to make a choice. And then there will have to be a learning process where we gradually make improvements. An important point that has not been mentioned is the psychological effect. Experience has shown that when IMR tells us that stocks are improving, this creates optimism which leads to investments, which later turn out to be over-optimistic and then it is too late. The investments are already made. Long-term prognoses will give a better insight in the situation and will give a better basis for deciding on investments. ACFM is a conservative institution. When I at the ICES Dialogue meeting requested 5 year prognoses, managers gave a very positive response, but not all the scientists. Do we have to write to ACFM and require long-term prognoses in their advice?

Å.Bjordal: It would at least not do any harm to write.

O.Nakken: This is something ACFM should do.

A.Aglen: In the formal procedures of ACFM, most stocks have a fixed set-up. If there are particular demands for certain stocks, a formal request is needed.

B.Bogstad: The ICES working groups already produce such prognoses for cod and herring.

O.V.Lebedev: I want to return to ground level and point to a tendency seen in the last 3-4 years. Previously Norwegian-Russian meetings have been dominated by scientists, whereas fishermen have been rare birds, but this group and other representatives of the industry are now more eager to take part. That I am present means that I can reach the right management decisions. We are not making decisions here, but I have a wish: That in half a year there will be available a scientific basis for practical solutions at the Commission meeting. After listening to Steinshamn, I conclude that the cod TAC must be seen in context with TACs for saithe, redfish and Greenland halibut which is of particular interest to Russia. In our trawl fleet, the catch of these species have increased, which was pointed out also at the seminar in Murmansk in March. I wish that others could see this from a practical point of view and increase the TACs. We must also reach a joint decision concerning sorting grids: Either by having sorting grid plus reduced mesh size or no sorting grid and the old mesh size.

5. Closing of the Symposium

Å.Bjordal: Then I will on behalf of my co-chairman V.Shleinik and the organising committee thank especially those who have given presentations, but also all other participants and perhaps in particular the two interpreters. With a wish for a good journey home and in the symposium spirit a good future for the fisheries in the Barents Sea, I give the word to J.Krog for closing remarks.

J.Krog: On behalf of the participants, I thank the organisers, Å.Bjordal and V.Shleinik, for their preparatory work and for the way they have chaired the meeting. For me this has been an interesting and useful experience. My head is now starting to getting tired, which indicates that the meeting has been timed correctly. There exists a lot of knowledge and new knowledge is being developed. It is a challenge for the managers to use this knowledge and competence, even if we perhaps, as O.Nakken says, know enough already. This gathering of representatives from all parts of the industry has been inspiring and is tempting to repeat. The discussion has shown that there are a number of themes that could be on the agenda in a symposium. This we will have to discuss in the Commission. I thank all participants for their engaged involvement and let us give a hand to the organisers. I wish all Russian guests a safe journey home.

APPENDIX

SYMPOSIUM PROGRAMME

Co-conveners: Å. Bjordal and V. Shleinik

MONDAY, 14 JUNE

1900-2100 *Welcome reception at the Institute of Marine Research*

THUESDAY, 15 JUNE

0900-0930 Opening addresses:
J. Krog The Royal Norwegian Ministry of Fisheries
V. A. Izmailov The State Committee of Fisheries of the Russian Federation

Session 1: The Ecosystem of the Barents Sea

Focus on: oceanography, primary and secondary production and overview of the commercially important fish stocks of the Barents Sea. Pollution levels in the Barents Sea and possible consequences for the marine life. Description of the capelin and herring stocks as a key stock in the ecosystem.

0930-1000 Oceanography, primary/secondary production
V. Borovkov, H. Loeng

1000-1030 *Coffee/ tea break*

1030-1100 Overview, fish stocks.
M. Shevelev, H. Gjøsæter

1100-1130 Capelin and herring as key species for the yield of cod.
J. Hamre

1130-1200 Summarizing questions and discussion

1200-1300 *Lunch*

Session 2: Management advice

Focus on: "state of the art advice" from ICES with Northeast Arctic Cod as case stock. How do scientists produce their advice: which surveys are conducted, which indices are calculated, what are the major uncertainties and corresponding risks involved when presenting a stock assessment. Consequences of short term versus long term choice of exploitation rate (TAC).

1300-1330 Retrospective review of management advice and corresponding TACs
O. Nakken

1330-1400	Basis for stock assessment and management advice A. Aglen, N. Yaragina
1400-1430	Coffee/ tea break
1430-1500	Exploitation strategies and harvest control rules. S. Tjelmeland, V. Tretyak
1500-1600	Summarizing questions and discussion
1900	*Symposium dinner*

WEDNESDAY, 16 JUNE

Session 3: Management objectives

Which objectives do representatives from the fishing industry/fleet find important to fulfill when deciding on TAC levels? Which objectives do fisheries managers find important when fixing management strategies?

0900-1000	From the management: P. Gullestad, V. A. Izmailov.
1000-1030	*Coffee/ tea break*
1030-1130	From the fishing industry: V. Bondarenko, K.W. Hansen
1130-1200	Summarizing questions and discussion
1200-1300	*Lunch*

Session 4: Simulation scenarios for harvesting the Barents Sea

Focus on simulation studies with aim to show biological and economic consequences of different management strategies (fixed TAC, fixed F etc.).

1300-1330	Consequences of various TAC strategies T. Jakobsen, P. Sandberg
1330-1400	Bioeconomic consequences S.I. Steinshamn, A. Vasilyev
1400-1430	*Coffee/ tea break*
1430-1500	Summarizing questions and discussion
1500-1600	Concluding statements and recommendations

SCIENTIFIC PROGRAM COMMITTEE

- Fisheries research: Å. Bjordal, V. Shleinik (co-conveners)
- Fisheries management: A. Okhanov, P. Sandberg
- Fishing industry: V. Gorokov, J.B. Jørgensen
- Secretary: Å.L. Pedersen

SYMPOSIUM STEERING COMMITTEE

J. Krog
P. Gullestad
O. Bye
V. Sokolov
Y. Myasnikov
V. Bondarenko

LOCAL ORGANIZING COMMITTEE

S. Mehl, K. Østervold Toft, B. Røttingen, V. Eriksen

PROCEEDINGS EDITORS

The papers and summaries of discussions will be published as proceedings from the symposium, edited by T. Jakobsen

LOCATION

The symposium will be held at The Institute of Marine Research, at Nykirkekaien 1, Bergen, Norway.

LANGUAGE

The symposium will be held in English, with translation to Russian.

INFORMATION TO SPEAKERS

The speakers should aim at restricting their talk to half the time allocated in the program, to leave time for translation and clarifying questions. A paper copy and preferably a disc-version of the manuscript should be delivered to the symposium secretariat, latest by 15 June.

LIST OF PARTICIPANTS

RUSSIA	
V. A. Izmailov	State Committee of Fisheries of the Russian Federation
S. V. Simakov	State Committee of Fisheries of the Russian Federation
A. V. Zelentsov	The Embassy of Russia in Norway
V. Shleinik	PINRO
M. Shevelev	PINRO
N. Yaragina	PINRO
V. Tretyak	PINRO
E. Beloous	PINRO - Interpreter
B. Kotenev	VNIRO
V. M. Bondarenko	AOOT Murmansk Trawling Fleet
V. P. Gusenkov	Association of fishermen of the North, Murmansk Regional Duma
O. V. Lebedev	"Karelrybflot"
NORWAY	
J. Krog	The Royal Norwegian Ministry of Fisheries
C. Elvestad	The Royal Norwegian Ministry of Fisheries
P. Gullestad	Directorate of Fisheries
J. Ramberg	The Royal Norwegian Ministry of Foreign Affairs
C. A. Mordal	The Royal Norwegian Embassy, Moscow
P. Sandberg	Directorate of Fisheries
O. Midttun	Directorate of Fisheries
A. Gilja	Directorate of Fisheries
A. Kjos Veim	Directorate of Fisheries
O. Bye	Norwegian Fishermen's Organization
J. B. Jørgensen	Norwegian Fishermen's Organization
K. W. Hansen	Norwegian Fishermen's Organization
J. I. Maråk	The Norwegian Fishing Vessel Owners Association
O. Strand	The Norwegian Fishing Vessel Owners Association
A. Aarseth	Norwegian Fishermen's Sales Organization for Pelagic Fish
W. Sørensen	Norwegian Rawfish Organization
R. Vaage	Institute of Marine Research
Å. Bjordal	Institute of Marine Research
A. Aglen	Institute of Marine Research
B. Bogstad	Institute of Marine Research
H. Gjøsæter	Institute of Marine Research
J. Hamre	Institute of Marine Research
T. Jakobsen	Institute of Marine Research
H. Loeng	Institute of Marine Research
O. Nakken	Institute of Marine Research
K. Nedreaas	Institute of Marine Research
S. Tjelmeland	Institute of Marine Research
Å. L. Pedersen	Institute of Marine Research - Organizing Committee
S. Mehl	Institute of Marine Research - Organizing Committee
B. Røttingen	Institute of Marine Research - Organizing Committee
K. Østervold Toft	Institute of Marine Research - Organizing Committee
V. Eriksen	Institute of Marine Research - Organizing Committee
S. I. Steinshamn	Centre for Fisheries Economics, Bergen
E. Berg	Norwegian Institute of Fishery and Aquaculture Ltd.
D. Klaastad	Interpreter

CONTRIBUTIONS

V.Borovkov, PINRO and H.Loeng, IMR: “A review of the physical and biological conditions in the Barents Sea.”

M.Shevelev, PINRO and H.Gjøsæter, IMR: “Overview of fish stocks in the Barents Sea and adjacent areas.”

J.Hamre, IMR: “Capelin and herring as key species for the yield of cod. Results of multispecies runs.”

O. Nakken, IMR: “Retrospective review of management advice and TACs for some stocks.”

N.Yaragina, PINRO and A.Aglen, IMR: “Basis for stock assessment and management advice.”

S.Tjelmeland, IMR and V.Tretyak, PINRO: “Harvesting control rules and future development of the precautionary approach - Northeast Arctic cod as an example.”

V.M.Bondarenko, Murman Trawl Fleet. Views on the management of Barents Sea fish stocks.

K.W.Hansen, Norwegian Fishermen’s Association: Thoughts about management strategies for the Barents Sea stocks seen from the perspective of Norwegian fishermen

T.Jakobsen, IMR: “Some consequences of long-term management strategies.”

P.Sandberg, Directorate of Fisheries, “Economic consequences of various Exploitation rates.”

S.I.Steinshamn, Centre for Fisheries Economics: “Bioeconomic consequences.”

A review of the physical and biological conditions in the Barents Sea

Vladimir Borokov[1] and Harald Loeng[2]

The Barents Sea represents the most important shelf sea connection between the Arctic Ocean and the Nordic Seas, and the amount of Atlantic water entering the Arctic Ocean through the Barents Sea is believed to be comparable to what is entering through the Fram Strait. Atlantic water, with relatively high temperature, is also an important factor contributing to the high biological productivity of the Barents Sea.

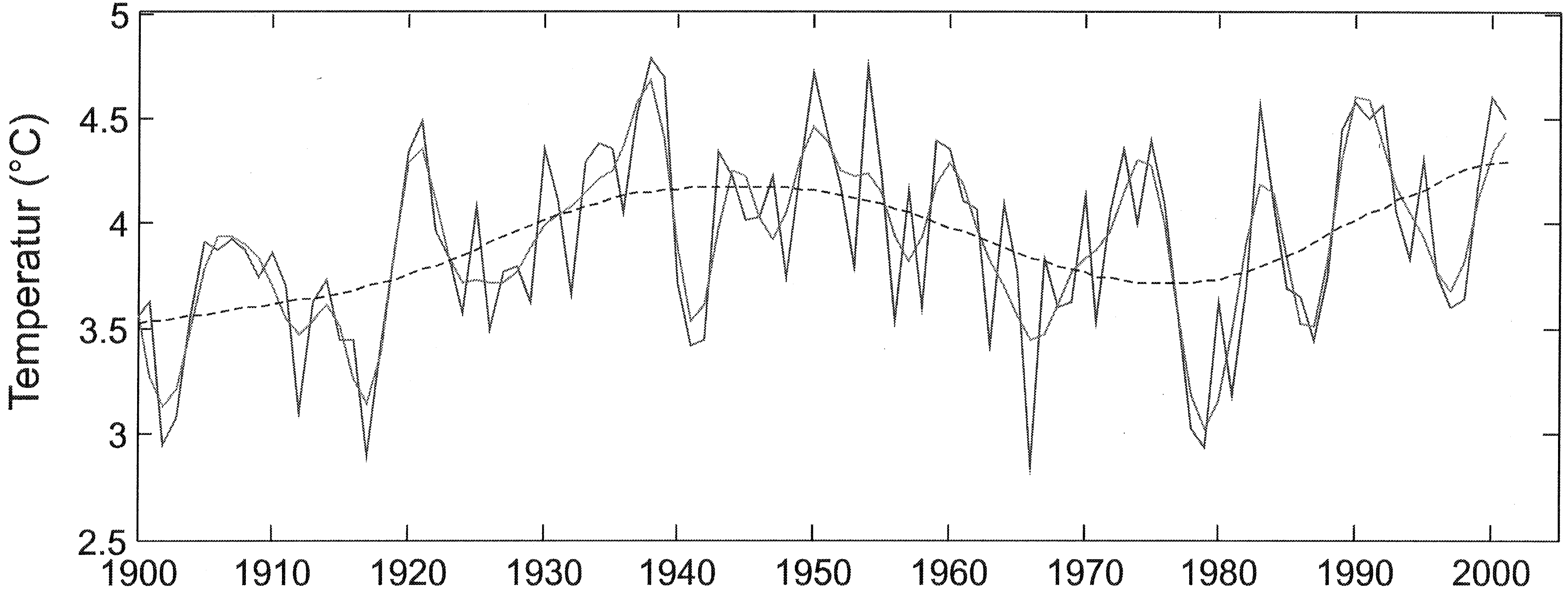
Time series of temperature in standard sections in the Barents Sea reveal that the Barents Sea climate has both long and short-term regular periods. (Fig. 1). After a warm period in the 1930s and 1950s, the Barents Sea cooled in the 1960s and 1970s. Since then there has been an increasing trend in the temperature. The 1990s started out warm, followed by a short relatively cold period in 1996-1998. During the last years of the decade there was a gradual build-up towards higher temperatures, with very high anomalies during late autumn and early winter. In comparison with other decades during the last century, the 1990s were colder than both the 1930s and 1950s.

The temperature variability in the standard sections may be compared with the horizontal distribution of temperature and reveals that all sections give a fairly good representation of the climate fluctuations in the areas occupied by Atlantic water masses. The relation between the climate variability in the Barents Sea and the North Atlantic Oscillation (NAO) is important in some periods. Although the NAO has a significant effect on the Barents Sea, especially during extreme NAO events, local forcing seems to be dominating. The local sea level pressure distribution influences both the total inflow to the area and the distribution of the waters within the Barents Sea. Different phases of sea level pressure may cause an alternation between the amount of water carried in the two branches going respectively east and north, and thereby have a significant effect on the climate of the Barents Sea.

Time series of sea temperature are statistically analysed and compared. Comparing statistical analyses of the Kola section with analyses of Norwegian coastal stations shows that synchronies, anti-synchronies, and similar cyclic patterns in time series from different regions may be responses to large-scale atmospheric fluctuations, as represented by the NAO. The results indicate antisynchrony between northeast and northwest Atlantic sea temperature fluctuations. Furthermore, since the mid 1960s/early 1970s and into the mid 1990s, Barents Sea temperature has been closely linked to the NAO, while the connection during the preceding decades was a lot weaker. If heat transport in the ocean, e.g. northwards along the Norwegian coast, is an important cause of sea temperature variability, one would expect time series from downstream locations to lag those earlier in the current system. The advective signals found are, however, weak.

[1] Polar Institute of Fisheries and Oceanography, Knipovich Street 6, Murmansk, Russia
[2] Institute of Marine Research, P.O.Box 1870 Nordnes, N 5817 Bergen, Norway

Figure 1. Temperature in the Kola Section, with 5 and 30 years running means



Contribution to the symposium

Management Strategies for Fish Stocks in the Barents Sea

Bergen June 14-16 1999

OVERVIEW OF FISH STOCKS IN THE BARENTS SEA AND ADJACENT AREAS

by

Michail Shevelev[1] and Harald Gjøsæter[2]

Abstract

The papers deals in short with the stock and catch history of the most important fish stocks in the Barents Sea and the adjacent area.

---

[1] Polar Institute of Fisheries and Oceanography, Knipovitch Street 6, Murmansk, Russia

[2] Institute of Marine Research, P.O. Box 1870 Nordnes, N 5817 Bergen, Norway

1. INTRODUCTION

Fish stocks in the Barents Sea and adjacent waters include abundant straddling and highly migratory fish species, which are target species for both Russia and Norway. Heavy fishery and other anthropogenic activities necessitate a rational exploitation and effective management of these stocks, which is possible only when a reliable information about the status and probable dynamics of the stocks is available.

The Barents Sea is situated at the border between the boreal and the arctic zoogeographic zone. One effect is that relatively few fish species are found there and, of these, only a few constitutes the bulk of the total biomass. Another effect is that climate and changes in climate play an essential role for the biology of the species living there. Borovkov and Loeng have dealt with the climate in a paper to this symposium, and the biology and interactions between species will be dealt with by, among others, Hamre in another paper. The present paper deals in short with the history of stock and fishing for the most important fish stocks in the area, and can serve as a basis for further discussion of management strategies for these stocks.

2. OVERVIEW OF IMPORTANT FISH STOCKS

2.1 Pelagic fish

2.1.1 Capelin (*Mallotus villous*)

The history of the Barents Sea capelin stock is poorly known before 1970. The knowledge of the earlier history is fragmentary and partly of anecdotic character. Although both the Norwegian and Russian capelin fishery have a long history, this fishery was of relatively minor importance. The capelin were fished with beach seines at the coast during the spawning season, and mainly used as bait, fertiliser or animal food (Nitter-Egenæs 1967; Prokhorov 1965). From 1916 capelin were used for meal and oil production in Finnmark, but it was not until the 1930s that a fishery for industrial purposes became important (Møller and Olsen 1962). From the late 1960 an oceanic fishery with pelagic trawls and purse seines developed rapidly when the fishing fleets, following the rapid decline in the herring stocks focused their effort on the capelin. In the early 1970s the catches rose to a record level of 3 million tonnes, surpassed by few other fisheries in the world (Figure 1).

From 1972 there are stock size estimates from annual acoustic surveys conducted during autumn (Figure 1). It is seen that the stock size has fluctuated considerably during this period, with two stock collapses in 1983-86 and in 1992-94. There are various apprehensions of the reasons for the collapses but, obviously, the main mechanism involved was recruitment failure (Hamre 1991; Tjelmeland and Bogstad 1993; Gjøsæter 1995; Gjøsæter 1998). During the last phase of the first collapse (autumn 1985 and winter 1996) the exploitation may have played a role by reducing the spawning stock beyond a critical level. However, the main reason for the observed recruitment failure was probably a heavily predation pressure on the larvae from the large stock of young herring residing in the Barents Sea from 1984-1986 and from 1992-1995. The ecological role of the capelin and the interaction with other stocks are further discussed in the paper "Capelin and herring as key species for the yield of cod" by J. Hamre, presented to the present symposium. During the three last years, the capelin stock has been found to increase rapidly, and in winter 1999 the stock was sufficiently large for the Russian-Norwegian Fishery Commission to open for a capelin fishery of 80 000 tonnes.

2.1.2 Herring (*Clupea harengus*)

The herring of the Norwegian spring-spawning stock also plays an important role in the Barents Sea, although it is not always present there, and the year classes spend maximum 4 years there.

The recruitment to the stock of Norwegian spring-spawning herring is extremely variable; very numerous year classes emerges at about 10 year intervals, the recruitment in the intervening periods is variable but mostly poor (Hamre, 1988). When the larval survival of herring is good, most of the larvae are transported into the Barents Sea and stay in the southern parts of the area until they reach about 25 cm length at age three or four. In years of poor herring recruitment practically no herring larvae enter the Barents Sea.

In periods when the herring is abundant in the Barents Sea this species may have a considerable impact on the ecosystem. The reason is that the young herring may consume considerable amounts of capelin larvae (see paper by J. Hamre to this symposium), thereby causing recruitment failure to the capelin stock. In addition, the herring may constitute an important contribution to the food for cod.

2.1.3 Polar cod (*Boreogadus saida*)

In the beginning of the 1970s both Russian and Norwegian fishermen landed considerable amounts of polar cod (Figure 8). During the rest of the 1970s and till present the catches were variable but mainly low. After 1975 only Russia has landed polar cod from the Barents Sea. The size of this stock is uncertain. From 1986, acoustic estimates were made during the joint capelin surveys in autumn (Figure 2). These estimates probably represents a reliable index of stock size, but it is unknown whether the also give reliable absolute stock size measurements (Gjøsæter and Ushakov 1997).

2.1.4 Other species

Other pelagic fish stocks of commercial importance in the Barents Sea are the lumpsucker (*Cyclopterus lumpus*) and the blue whiting (*Micromesistius poutassou*). The lumpsucker is fished with nets when it approaches the coast to spawn. Only the roe is used for caviar production. Blue whiting are found in the western parts of the Barents Sea. A large stock of blue whiting feeds in the Norwegian Sea and spawns to the west of the British Isles. It is not clear whether the blue whiting in the Barents Sea belong to this stock. No fishing takes place on blue whiting in the Barents Sea.

2.2 Demersal fish

2.2.1 Cod (*Gadus morhua*)

Northeast Arctic cod plays a key role in the Barents Sea ecosystem. It is the most important predator, which to a great extent defines interspecific interactions and, at the same time, is a major object of international fishery (Boitsov *et al.*, 1996).

In 1988-1989, the commercial and the spawning stocks of the Northeast Arctic cod were on the minimum level for the period from 1946 to 1997 (Fig.3). After that the stocks started to improve owing to the appearance of the year classes of high (1990) and medium (1989, 1991, 1992) abundance, high growth rate in 1992-1993 and cautious stock exploitation. Commercial (2.4 million tonnes) and spawning stocks reached their local maximum in 1993. This was followed by a gradual decline of stocks due to an intensive exploitation, lower growth rate and poor recruitment resulting from the limited food supply and increased cannibalism. By the beginning of 1998, the commercial stock biomass reduced to 1.6 million tonnes; by the beginning of 1999 to 1.4 million tonnes (PINRO, 1999).

In 1991-1999, the spawning stock biomass was higher than or close to the long-term mean (590 thousand tonnes) that was related mainly to the maturation of the strong 1983 year class. In 1998, the spawning stock made up 0.63 million tonnes, by the beginning of 1999 - 0.58 million tonnes (Overwiew, 1999). This stock also shows a downward trend and the results of the recent investigations give good grounds to believe it to be below safe biological limits (500 thousand tonnes).

The bulk of the commercial stock is at present made up by medium-sized specimens represented mainly by the 1995 year class (Fig.4), a major portion of which has not reached the commercial size. The abundance and biomass of older ages of cod declined. Therefore fishery is based on smaller cod as compared to 1998 that causes higher mortality of these size groups. This will, in turn, result in the weaker recruitment to the spawning stock the decline of which will consequently be faster.

Considerable variations in cod catch by all nations were noted in the last decade (Fig.3). Minimum catch (212 thousand tonnes) was taken in 1990, maximum catch (771 thousand tonnes) reached the long-term mean for the period 1950-80s (780 thousand tonnes) in 1994 (Kovtsova et al., 1991). After that catches started to decline. However, in 1997 the second local catch maximum (755 thousand tonnes) was observed. By the preliminary data, in 1998 the catch sharply decreased by almost 100 thousand tonnes. A similar reduction in total catch of cod is also expected in 1999.

To slow down stock decline, fishing mortality must be lower. On account of the uncertainty in cod stock assessment during 1996-1998, ICES Advisory Committee for Fisheries Management (ACFM) proposed to apply the precautionary approach to stock exploitation, i.e. to set fishing mortality at the level not exceeding $F_{pa}=0.42$ and TAC at 360+40 thousand tonnes. However, the TAC approved at the 27th Session of Mixed Russian-Norwegian Fisheries Commission amounted to 480+40 thousand tonnes and was higher than that recommended by ICES. In case such fisheries regime is maintained, the spawning stock biomass of cod will decline in the coming years whereas the commercial stock biomass will remain at the previous level due to the recruitment by the year classes of high (1995) and medium (1996) abundance to the commercial stock, as well as due to an increase in the growth rate related to the improved food supply (Fig.3).

2.2.2 Haddock (*Melanogrammus aeglefinus*)

Stock size of Arcto-Norwegian haddock depends primarily on the variations in the abundance of separate year classes, which prevail over the influence of all other factors, including fishery (Kovtsova *et al.*, 1991).

The dynamics of haddock stocks over the 1990s resembled that of cod stocks and was associated with similar causes, with the exception that they reached their maximum later, the commercial stock in 1994-1995 and the spawning stock in 1996-1998, that was followed by a rapid decline (Fig.5).

By PINRO data, the commercial and the spawning stocks of haddock declined by the beginning of 1999 to 280 and 202 thousand tonnes, respectively. Thus, the commercial stock is below the long term mean for the period 1950-1997 (395 thousand tonnes) and the spawning stock is far above the long term mean (125 thousand tonnes).

The bulk of the spawning stock (ca. 65% of the biomass) is made up by specimens from strong year classes (1989-1991) at age 8-10 years. Recent recruitment to the spawning stock is poor (Fig.6). Despite the fact that 1992-1995 year classes at age 1 yr. old were regarded as strong, by the moment of recruitment to the commercial stock they were less abundant than the average year classes because of high mortality. 1996-1997 year classes were below average or weak.

Actual exploitation level in 1998 was $F_{98}=0.226$. In the coming years, at any exploitation level, except F_{low}, the commercial and the spawning stocks, as well as catch, will show a downward trend. TAC on haddock for 1999 was established at 78 thousand tonnes that corresponds to a higher exploitation level (F=0.249) than F_{low}.

In 1990-1996, haddock catch by all nations increased steadily from 26 to 187 thousand tonnes (Fig.5). After that it declined reaching 98 thousand tonnes in 1998 (preliminary data) (PINRO, 1999). In 1994-1997 it exceeded the long term mean for the period from 1951 to 1998 (120 thousand tonnes). In 1999 a further reduction in haddock catches is expected.

2.2.3 *Sebastes mentella* of the Norwegian-Barents Sea stock

In 1984-1998, the commercial and the spawning stocks of *Sebastes mentella* stabilised at a low level, 160-240 and 60-90 thousand tonnes, relatively (Fig.7), that was twice as low as the long term mean. In the beginning of 1999 the commercial stock amounted to 225 thousand tonnes, and the spawning stock to 101 thousand tonnes (PINRO, 1999). This situation is expected to continue into the nearest future because, since 1991, all year classes of *S.mentella* have been weak (Fig.8).

According to ICES advice, in order to enhance the spawning stock and production capacity of the population, directed fishery on *S.mentella* should be reduced and bycatch of this species in other fisheries, including bycatch of young redfish in shrimp fishery, should be minimised.

In the period 1987-1991, catch of *S. mentella* by all nations increased from 11 to 49 thousand tonnes. In the subsequent years, as more stringent regulation measures were introduced for fishery on this stock in the Norwegian economic zone and quotas for directed trawl fishery were reduced, the catch of *S. mentella* decreased in 1996 to 8 thousand tonnes. In the recent years total catch of this species somewhat grew (by the preliminary data, to 11 thousand tonnes in 1998) owing to the increase of redfish bycatches (PINRO, 1999).

2.2.4 Greenland halibut (*Hippoglossus hippoglossus*) of the Norwegian-Barents Sea stock

ICES data show the commercial and the spawning stocks of Greenland halibut to have declined to respectively 80 and 60 thousand tonnes by the early 1980s. By 1992, when fishery restriction regulations were introduced for this species, biomass of the stock was estimated at 43 and 30 thousand tonnes (Fig.9).

According to the calculations of the ICES Arctic Fisheries Working Group, halibut stocks in 1992-1997 stabilised at a low level that contradicted the results of the trial trawl fishery, which was very efficient.

Owing to the absence of reliable fisheries and biological data, especially on age groups younger than 5 years old, the ICES Arctic Fisheries Working Group did not calculate the size of Greenland halibut stocks in the beginning of 1999. Nonetheless, 1998 investigations showed some positive changes in the status of this stock, including the enhanced recruitment to the commercial stock and the increased number of females in the spawning stock. The strength at age 5 of the year classes of Greenland halibut is shown in Figure 10.

Due to the uncertainty relating to the status of Greenland halibut stocks, it was agreed at the 27th Session of the Mixed Russian-Norwegian Fisheries Commission that the ban on the directed trawl fishery for this stock should be continued into 1999.

In 1980s, annual catch of Greenland halibut by all nations, due to a high fishing effort, remained at a relatively stable level at ca. 20 thousand tonnes (Kovtsova et al., 1991). In 1991, a record catch for the last two decades was taken - 33 thousand tonnes. After that the Mixed Russian-Norwegian Fisheries Commission imposed a ban on directed trawl fishery for halibut. As a result of this restriction, halibut catches in 1992-1998 varied between 9 and 14 thousand tonnes (Anon., 1999). The main portion of halibut catches is being taken by Norway.

2.2.5 Conclusion – demersal fish

Thus, the current tendencies in the dynamics of cod and haddock stocks arouse concern about the resources available for trawl fishery in the coming years. A suspended decline of *S.mentella* and Greenland halibut stocks and their stabilisation at a low level do not allow us to be too optimistic. Therefore the fisheries strategy for the Barents Sea and adjacent waters in the coming years should keep to strict regulation measures.

3. REFERENCES

Anon., 1999. Report of the Arctic Fisheries Working Group. ICES C.M.1999/ACFM:3. 276 p.

Boitsov V.D., Lebed N.I., Ponomarenko Ya.I., Tereshchenko V.V., Tretyak 1996. The Barents Sea cod (biological and fisheries outline). Murmansk: PINRO Press, 285pp. (In Russian).

Gjøsæter, H. 1995. Pelagic Fish and the Ecological Impact of the Modern Fishing Industry in the Barents Sea. –*Arctic* 48:267-278.

Gjøsæter, H. 1998. The population biology and exploitation of capelin (*Mallotus villosus*) in the Baretns Sea. Sarsia 83(6):453-496.

Gjøsæter, H. and N.G. Ushakov 1997. Acoustic estimates of the Baretns Sea Arctic cod Stock (*Boreogadus saida*). Forage Fishes in Marine Ecosystems. Proceedings of the International Synposiym on the Role of Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program Report No. 97-01:485-504. University of Alaska Fairbanks.

Hamre, J. 1988. Some aspects of the interrelation between the herring in the Norwegian Sea and the stocks of capelin and cod in the Barents Sea. –*ICES C.M.* 1988/H:42 15 pp.

Hamre, J. 1991. Interrelation between environmental changes and fluctuating fish populations in the Barents Sea. –Pp. 259-270 in: Kawasaki, T., S. Tanaka, Y. Toba & A. Tanaguchi (eds.): *Long-term variability of pelagic fish populations and their environment.* Proceedings of the International Symposium, Sendai, Japan, 14-18 November 1989. Pergamon Press.

Kovtsova, M.V., Shevelev, M.S., Yaragina; N.A. 1991.Bottom fish stocks and prospects of their fishery in the Barents Sea. PINRO complex fisheries research in the Borth Basin: Results and outlooks. Selected Papers. PINRO, Murmansk. Pp145-165. (In Russian).

Møller, D. and S. Olsen 1962. Lodda og loddefisket (The capelin and the capelin fishery). Fiskets Gang nr 3 1962:27-36.

Nitter-Egenæs, W. 1967. The capelin fishery. –*Norwegian Fishery and Maritime News* 14(1):11-15.

PINRO, 1999. Overview of resources of the Barents Sea and the North Atlantic for 1999. Murmansk: PINRO Press. 58pp (In Russian).

Prokhorov, V.S.1965. Ecology of the Barents Sea Capelin (*Mallotus villosus villosus*) and prospects for its commercial utilization. *–Fishery Research Board of Canada Translation Series* No. 813. 131 pp.

Tjelmeland, S. & B. Bogstad 1993. The Barents Sea Capelin Stock Collapse: A Lesson to Learn. –Pp 127-139 in: Smith, S.J., J.J. Hunt, D. Rivard (eds.) Risk Evaluation and Biological Reference Points for Fisheries Management. *Canadian Special Publications on Fisheries and Aquatic Sciences*. 120.

Contribution to the symposium

Management Strategies for Fish Stocks in the Barents Sea

Bergen June 15-16 1999

Capelin and herring as key species for the yield of cod
Results from multispecies model runs

by

Johannes Hamre

Institute of Marine Research, P.O. Box 1870 Nordnes, N 5817 Bergen, Norway

Abstract

A conceptual multispecies model for the fishery of capelin, cod and herring (Systmod) in the Norwegian Sea-Barents Sea region has been developed and used in analysing the impact of different fishery management strategies on stock and yield. The study shows that the biomass production of capelin is the most important factor for the obtainable yield of cod, and the recruitment and life pattern of the herring govern the recruitment of capelin. The recruitment of herring and cod is linked to the ocean climate, which may alternate with warm and cold periods. Cannibalism is also an important factor for cod in adapting to the periodic changes of the system. Most of the production takes place in the warm periods, and capelin and cod have to be harvested when the stocks are large in order to obtain an optimal sustainable catch. The stocks cannot be accumulated in their most productive phase for the benefit of increased catches when the biomass production is low, due to the short life span of capelin, and to the stock interrelationship between the two species. The sustainable yield of herring is more dependent on climate changes than on the stock interrelationships and may be harvested with constant yearly catch quotas if the time lags between the warm periods are short. A high frequency of warm periods is favourable for the herring, but has a negative effect on the obtainable yield of capelin and cod. Long time lags between strong herring year classes in the Barents Sea provide more time for rebuilding and growth of the capelin stock, which is the condition for high biomass production of cod.

Introduction

Capelin was the dominating plankton feeder in the Barents Sea in the 1970`s and first half of the 1980's. The stock formed the basis for the largest fishery in Europe with a record catch in 1977 of nearly 3 mill. tonnes, and the total biomass production is estimated to be some 8 mill. tonnes (Hamre and Tjelmeland 1982, Gjøsæter 1997). In 1983-86 a strong herring year class occurred in the southern part of the Barents Sea, and coincided with a dramatic fall in the recruitment to the the capelin stock, which collapsed in 1986. The lack of prey fishes in subsequent years caused mass mortality in the fish-eating stocks of fish, sea birds and marine mammals. It is assumed that the collapse of the capelin was associated with the occurrence of the herring (Hamre 1985,Anon., 1987, Moksnes and Øyestad, 1987, Gjøsæter and Bogstad, 1998). The present author (Hamre 1988, 1994) suggested a conceptual model, which links the observed interrelationships between herring and capelin to climatic changes in the ocean.

The stock evolution in the Barents Sea in the 1980's was the background for the development of a conceptual model for the fisheries in the Norwegian and Barents Seas (Hamre et al. 1993). The model "Systmod" was developed in cooperation between The Institute of Marine Research (IMR) and Norsk Regnesentral (Norwegian Computing Center). So far it includes herring, capelin and cod.

The conceptual hypothesis of the model presupposes that the herring has a decisive impact on the recruitment of capelin and that this stock interaction is governed by periodic changes in the ocean climate. A warm climate provides good recruitment of herring and cod, but the presence of strong year classes of herring in the Barents Sea entail mass death of capelin fry. These ecological interrelations are the most powerful dynamic factors in the system, which "Systmod" is supposed to simulate. The main evidence, which supports the hypothesis of the model, is summarised below.

1.2 The concept

The physical conditions in the Norwegian Sea - Barents Sea region are governed by the inflow of Atlantic water through the Faroe-Shetland Channel (Figure 1). Two main branches of the Atlantic Current create two separate ecosystems, one in the North Sea and one in the Norwegian Sea - Barents Sea. . In the latter area, the interface between the inflow of warm Atlantic water and the cold Arctic water, provides upwelling and the physical basis for two highly productive areas, one in the Norwegian Sea along the Polar front, and one in the marginal ice zone of the Barents Sea.

Relevant features of the general biology of the main fish stocks are illustrated in Figure 2. Most of the rich plankton production in the upwelling areas has been harvested by the adult Norwegian spring-spawning herring *Clupea harengus* in the Norwegian Sea, and the capelin *(Mallotus villosus)* in the Barents Sea. The capelin is the main plankton feeder in the Barents Sea, but in years with strong herring year classes the juvenile herring plays an important part as prey species in the area. The capelin has a short life span and most of the fish spawn only once. Herring and capelin are the main food sources for a large variety of stocks, but the northeast Arctic cod *Gadus morhua* is the largest predator and plays a decisive role in the balance of predators and prey (Bogstad and Mehl, 1987). The stocks spawn on the Norwegian coast, and the spawning migrations of the plankton feeders transfer huge quantities of fish biomass from distant waters to the Norwegian continental shelf and to the southern parts of the Barents Sea.

The adult herring stock wintered in Icelandic waters prior to the 60's. This has changed in later years. The adult herring as well as the juveniles are now feeding in the eastern Norwegian Sea, and are wintering in Norwegian fjords.

Two large semipelagic stocks occur in the region, blue whiting and polar cod. The semipelagic stocks are however of marginal importance as prey species in this system because they spawn in other areas.

Details on stock distribution and interaction in the Barents Sea are illustrated in Figure 3. During summer the capelin feed in the marginal ice zone but accumulates in front of the south moving ice boarder during autumn. In winter the maturing stock migrates towards the coast for spawning, and it is during this spawning migration the capelin spawners become available to the immature cod (the mature cod is elsewhere for spawning). In the southern part of the Barents Sea the distribution of juvenile herring overlaps the distribution of the capelin larvae, which affects the survival of capelin frey. These stock interactions are the most powerful conceptual factors of the model and together with climate interaction determine the dynamics of the system.

The mean temperature in the Barents Sea in the period 1900-1994 is shown in Figure 4. The temperature shows abrupt increases in the about 1905, late 1910s, late 1930s, 1940s, 1950s, late 1960s and early 1970s, early 1980s and 1990s. These periods of warm climate coincide with strong year classes of herring and cod. (Marty and Federov, 1963; Sætersdal and Loeng, 1984).

In conclusion, the evidence indicates that the herring and capelin are the key prey species at fish level of the food chain in the Norwegian Sea - Barents Sea ecosystem, and the cod is the dominant predator. The abundance of immature herring determines the survival of 0-group capelin, whereas the abundance of immature cod determines the mortality of maturing capelin. The dynamics of the system are governed by the inflow of Atlantic water, which determines distribution, recruitment success and growth of the main species involved. Based on this knowledge, the structure of climate and stock interrelationships is modelled, and a technical version of the model was published in a paper by Hamre and Hatlebakk (1998): SYSTEM MODEL (Systmod) FOR THE NORWEGIAN SEA AND THE BARENTS SEA. Input data for "Systmod" are stock data and parameter data files, and the model parameters are estimated by comparing model results to data. A brief description of the model structure is outlined below.

1.6 Model structure

The model is length-based, and the growth in length per month is modelled with the following equation (von Bertalanffy, 1938):

$$dL(t) = l(t+T) - L(t) = (L_\infty - L(t)) \cdot (1 - e^{-KT}) \cdot M(t)$$

where t is a time variable and T an interval of fixed length. L is the maximum length of the fish. M(t) is a factor, which distributes the yearly growth on the different months. K is the growth parameter, which determines the growth related to the size of the stock and environmental factors (capelin and herring). K is determined by the following equations:

$$K = (a + b \cdot e^{-d \cdot B(t)}) \cdot g$$

B(t) is the stock abundance at time t.The exponential term regulates the density dependent growth. For cod the parameter K is computed according to the equation:

$$K = a(2.2 - 0.4 \cdot \frac{CCODC}{COD}) + b \cdot \frac{CCOD}{COD}$$

CCOD is the food consumption for cod, CCODC the consumption of capelin, and COD the stock biomass.

g is a function to regulate the growth according to environmental factors.

The juveniles are recruited to the stock in January at age 1. To describe the relation between the spawning stock in the springtime and the number of recruits in January the following year, the Beverton-Holt function is used:

$$R = \frac{M \cdot B}{H + B} e^{a \cdot T}$$

where R = recruitment; M = maximum recruitment; B = spawning stock biomass; H = the half- value; T = temperature deviation; a is a parameter. Two levels of M are used for simulating herring recruitment, one low and one high, when T exceeds a given value.

The affects of juvenile herring on the survival of capelin fry is modelled by a reduction factor proportional to the strength of the age groups 1 to 3:

$$R = R_o \cdot (1 - (a_1 \cdot HER_1 + a_2 HER_2 + a_3 \cdot HER_{3+}))$$

HER_1 denotes 1-group herring, HER_2 2-years herring, HER_3 3 years herring,.

All the species mature at the turn of the year. The maturity ogive in each length group is computed from a logistic function (Tjelmeland, 1987):

$$M(l) = \frac{1}{1 + e^{4P_1(P_2 - l)}}$$

where l denotes mean length in the length group (midpoint in length interval), P_1 and P_2 are parameters.

In computing mortality per month the following variables are used:

$$N_{i,t+1} = N_{i,t} \cdot (1 - G) \cdot (1 - M) \cdot (1 - P_i) \cdot (1 - F_i)$$

- spawning mortality (G) (capelin only)
- fishing mortality (F)
- predation (P)
- natural mortality (not including predation) (M)

A parameter in the model determines the fraction of mature capelin, which survives after spawning (1April).

The monthly mortality rate caused by the predation is computed by species. For capelin this is:

$$P_i = K \cdot (a_0 \cdot COD_{im} + a_1 \cdot COD_m),$$

for Barents Sea herring: $P_i = K \cdot COD/(1 + b_1 \cdot CAP)$,

for cod: $P_i = K \cdot COD/(1 + b_1 \cdot CAP + b_2 \cdot HER_{im})$,

where
P_i - predation mortality rate for length group i
K - K is a constant
a_i(COD) - weighted sum of the predator stock (m/im = mature/immature)
b_i(CAP, HER) - reduction in mortality rate due to preference of prey species

Parameter estimation has been effected by a step-by-step procedure based on biological knowledge of the system and experiences gained in the model runs. The impact of changes in the climate is modelled by a sine curve fitted to observed temperature anomalies in the Kola section (Figure 5). The recruitment parameters of capelin are determined by comparing modelled numbers of 2 years old to acoustic estimates of the age group in autumn, and the parameters of herring and cod by comparing modelled numbers of 3 years old to the corresponding VPA-estimates of the stocks The stock in numbers is converted to stock biomass by observed weight by length-groups.

The predation parameters of cod are derived from the estimates of the yearly consumption of cod by prey species (Bogstad and Mehl, 1997). Such data are available from 1984 onwards. The predation parameters of cod are of basic importance and the period after 1982 is selected for fitting the model results to data. The results of fits of stock abundance in number and weight are shown in Figure 6. The fits are reasonably good whether the sine curve or the observed temperature anomalies are used as basis for the simulation. This supports the underlying theory of the dynamics of the system, that recruitment and growth are governed by the ocean climate, and that the stock interrelationship determines mortality and stock abundance. Assuming a cyclic change in the ocean climate, the model is used in analysing the impact of different fishery management strategies on stock and yield.

2 Management strategy analysis

In the model the fisheries may be regulated by the fishing mortality rate (F) and by fishing quotas by season and year. This means that for a given F the fishery is closed if and when the quota is taken. In addition the capelin winter fishery may be closed if the maturing stock is reduced to a predetermined lowest acceptable level. If no autumn fishery is allowed, this strategy is similar to the management strategy in use for capelin, and termed the conventional strategy in the text of the figures.

Warm periods with a cycle of approximately 8 years are observed in recent years and a sine curve with corresponding amplitude and frequency is chosen as basic for the first set of model runs. For the purpose of comparing model results for different time lags between warm periods, some runs are made with a cycle frequency of 11 years as shown in Figure 7.The stock estimates as of 1 January 1995 are chosen as terminal stocks, and the runs cover periods of 40 years. Output files of catch, stock biomass and recruitment are processed on spreadsheet and the results illustrated in Figures 8 to 18.

2.1 Results of runs with 8 years between warm periods

First set of runs. The first two runs compare estimated yield, stock and recruitment with and without a conventional capelin fishery, when the cod fishery is regulated by a constant F of 0.8, the herring fishery by a F of 0.2 and a yearly catch quota of 1.2 mill. tonnes, equally distributed on seasons.The simulated catches are shown in Figure 8. The capelin catches fluctuate between 0 and 0.8 mill. tonnes, with an average catch of close to 0.3 mill. tonnes. In about half the period (3-4 years) the maturing capelin stock is below the lowest acceptable level for fishing, which is set to 0.5 mill.tonnes. The fluctuation in the catches by periods is related to the pattern of the sine curve (differences in the amplitudes), and the stock interaction between the maturing capelin and the immature cod.

The cod catches fluctuate between 0.3 and 1.0 mill. tonnes with an average of some 0.55 mill.tonnes. Since this is a F-regulated fishery the catches fluctuate in relation to the stock size shown in Figure 9, and the pattern of the stock development is a combined effect of the pattern in the climatic changes and the interaction between the spawning stock of capelin and the immature cod stock. The immature terminal cod stock (1995) is relatively numerous due to recruitment of more then one abundant year class (contrary to the situation in 1983). This may delay rebuilding of the capelin stock, which has suffered from recruitment failure in several years (abundant herring year classes 1991-92). The reduced availability of capelin has consequences for the next generations of cod, for which the growth in biomass is correspondingly reduced. This will in turn results in an increased stock of capelin in the next period and so on. This alternation in stock size between a predator and its prey is a well-known phenomenon and is known as the Lotka – Volterra predator-prey relationships.

The strategy of regulating the herring fishery presupposes a yearly catch quota of 1.2 mill. tonnes, equally distributed on seasons, but not allowing F to exceed 0.2. The run shows that this strategy for managing the herring fishery may yield a constant yearly catch of 1.2 mill. tonnes, although the recruitment of herring fluctuates with 1 or 2 abundant year classes every 8 years (Figure 10).

The dotted lines in Figures 8 to 10 illustrate the estimated effects of a total band on the capelin fishery, keeping the regulating strategy of cod and herring unchanged. The simulations indicate that this restriction may have little effect on the recruitment and abundance of the stocks, but may increase the average catch of cod by about 30 000 tonnes. This is the gain in yield of cod, obtained by a corresponding loss in the yield of capelin of 300 000 tonnes.

Second set of runs. The next set of runs compares the effects of an additional constraint on the cod fishery in order to equal out the fluctuation in the yearly cod catches (Figure 8). The average yearly catch of cod in the previous runs approached 0.6 mill. tonnes, which in the present runs is chosen as the yearly catch quota of cod, keeping the fishing strategies on the other stocks unchanged. The results are shown in Figures 11 to 13. The simulation shows that a catch quota regulation of the cod fishery, which restricts the yearly catch of cod to a level close to the optimum average sustainable yield, may create a new cycle in the abundance of cod (Figure 12), with a frequency of 16 years or twice the frequency of the cycle of changes in the climate. The catches may be kept at the quota level when the stock is abundant (half the period), but have to be reduced considerably when the stock is declining. The estimated average catch is reduced by some 5%, compared to the strategy of no quota regulation of the fishery. In addition, the accumulated stock of cod increases the predation on the stock of herring, which is slightly reduced (Figure 12).

This model result may also be explained as a Lotca-Voltera phenomenon of predator-prey relationship. The additional restriction on the catch of cod when the stock is abundant will accumulate a large immature cod stock, which may delay the rebuilding of the capelin stock. This will in turn reduce the food supply for the next generations of cod for a whole period, i.e. 8 years, and a new cycle of 16-years period may occur.

Third set of runs. These runs compare the results of the previous strategy with the same strategy but without a capelin fishery (Figure 14). The closure of the capelin fishery, which yielded some 220 000 tonnes a year on an average, may result in a slight improvement of the catch of cod, especially in prolonging the period of optimum catch. The gain in the average catch of cod is estimated to some 10 000 tonnes.

2.2 Results of runs with 11 years between warm periods

In this century strong herring year classes have occurred with periods from about 15 years in the early 1900's, to 8 years in recent time. In order to study the effect of a prolonged time leg between the warm and favourable recruitment periods of herring and cod, the model runs in this section are based on a sine curve with the same amplitude as in the previous runs, but with a cycle of 11 years (dotted line in Figure 7).

Fourth set of runs. These runs compare results of a standard management strategy with 8 and 11 years of time lags between warm periods. The strategy is defined by the conventional fishing strategy for capelin, a catch-quota-regulated cod fishery of 0.8 mill. tonnes a year and F = 0.8, and the herring fishery regulated as in previous runs. Results are shown in Figures 15 – 17. The effect of a longer period without interruption of the herring is favourable for the capelin, which may recruit 3 more abundant year classes to the stock and the fishery compared to the 8-years-cycle regime (Figure 17). The capelin catch may be doubled, from 0.22 to 0.44 mill. tonnes on average (Figure 15), and the impact on the cod stock is also favourable in the way that a longer period with no herring in the Barents Sea results in a more stable supply of food for the cod, and may thus level out the fluctuation in the stock abundance. The average yield of cod is however only slightly increased. The effect on the herring is on the other hand significantly negative (Figure 16) and may reinforce the fluctuation in the stock size and reduce the average yield of herring by about 20%.

Fifth Set of runs. This final set of model runs compares the estimated yield of the standard strategy with the yield without a capelin fishery. The results are shown in Figure 18. A closure of the capelin fishery will increase the estimated average catch of cod to 0.6 mill. tonnes a year, corresponding to a gain in the yield of about 30 000 tonnes or 5 %. The corresponding loss in the yield of capelin is estimated to 440 000 tonnes. The effect on herring is an increased predation of cod, which will result in a decrease in the herring recruitment. This may reduce the average yield of herring by about 25 000 tonnes a year.

3. Discussion

In evaluating the reliability of the output from this model it should be borne in mind that in a context of multispecies interactions with a large number of mutually dependent parameters, no unique solution exists in fitting model results to data. The parameter estimates used in this study are moreover preliminary, because some are only roughly estimated and not systematically tuned to data. Slight changes in the yield estimates may also occur if or when the herring resume theirs traditional migration pattern. The validity of the model may thus be improved with respect to the magnitude of the estimates. However, the trends of development in stock and yield reflected by this model under different management regimes are probably more dependant on the validity of the concept on which the model is built than the accuracy of the parameter estimates. Provided that the concept is valid, the model should be a valuable tool to quantify the dynamic processes of the system. With this reservation in mind, some details of the model results will be commented on and discussed.

The goodness of fit of the temperature curve to data (Figure 5) is acceptable in the warm periods, but low in the cold period from 1993 to 1996. In spite of this the modelled stock in the past fits equally well to data, whether the simulated temperature curve or the actual temperature measurements are used (Figure 6). There is a double explanation for this, one related to the impact of the climate on the recruitment figures and one related to the survival of the fray.

The impact of the climate on capelin recruitment seems to be negligible but the effects of herring recruits on the capelin are the most powerful dynamic element in the model. This takes place in warm periods when the fits of the sine curve to data are reasonably good. The strong herring year classes are triggered by high-temperature anomaly (T), and the model selects a high maximum recruitment level (M in the recruitment formula, page 4), when T exceeds a predefined value (0.4). When 3 strong herring year classes occur, the first one is reduced by 80%. For herring the high recruitment level is determined to be 20 times higher than the low M value, and the exponential factor in the recruitment formula for herring is found to be negligible. Since the observed T in 1995 is below the value, which triggers the high-level M, the model estimates of recruitment for herring will be the same whether based on the sine curve or the observed values.

The recruitment relationship of cod to climate is different. The recruitment figures of 1-group cod seems to be closely related to the temperature and less dependent on a peak value T, which triggers a strong year class, as for herring. This relationship is modelled by selecting relatively high parameter value in the exponent of the recruitment formula for cod. This results in good recruitment of cod in 1994-1995 as 1- group, but due to cannibalism in the subsequent years, estimated according to the formula of cod predation on cod (page 5), these age groups are depleted as 3-year olds. The cod cannibalism in 1995 and 1996 is estimated to 0.4 and 0.6 mill. tonnes of young cod, respectively (Anon. 1998), and the cod predation parameters (page 5) are tuned against these data. When the recruitment of cod as 1-group and survival of the recruits as 3-group is modelled in this way, the final results of recruitment to the stock will be approximately the same whether the sine curve or the observed values of the temperature anomalies are used as a basis for the simulation (Figure 6).

The ecological interpretation of this phenomenon is interesting and indicates that the cod has adapted to the cyclic recruitment pattern of capelin by eating its own progeny when the capelin stock is down and in a state of rebuilding. It seems obvious that if the 1 mill. tonnes of young cod eaten by older brothers and sisters in 1995-1996 had survived, this would have delayed rebuilding of the capelin stock in the subsequent years and thus threatened the food supply for the coming generations of cod.

The above interpretation of the role of cod cannibalism in the system also supports the findings that a constant yearly catch-quota regulation of cod cannot manage the cod fishery on a sustainable basis. The mechanism behind this is the same as the assumed reason for the cod cannibalism in 1995 onwards. A constant catch-quota regulation of cod will reduce the fishing mortality in periods when the stock is large, accumulating a more abundant stock during cold periods. This is after a period when the capelin has suffered from recruitment failure for several years and the spawning stock is in a state of rebuilding because the herring may have left the Barents Sea. In this situation a numerous stock of cod in the Barents Sea will increase the predation on capelin and thus delay the rebuilding of the spawning stock. This in turn will reduce the availability of food for the new generations of cod, which are expected to be recruited when the climate changes. In other words, the improved basis for the cod fishery in a cold period obtained by cutting the catches in the preceding years, may result in a low production of capelin biomass throughout the next cycle and thus reduce correspondingly the obtainable catch of cod.

In conclusion, the present study shows that the biomass production of capelin is the most important factor for the obtainable yield of cod, the former being governed by the recruitment and life pattern of the herring. The superior steering factor of the system is linked to the ocean climate, which may alternate with warm and cold periods. Most of the production takes place in the warm periods, and has to be harvested when the stocks are large in order to obtain an optimal sustainable catch. This refers especially to capelin and cod, which cannot be accumulated in their most productive phase for the benefit of increased catches when the biomass production is low. This is due to the short life span of capelin and to the stock interrelationship between the two species. The sustainable yield of herring seems to be more dependent on climate changes than on the stock interrelationships and may be harvested with constant yearly catch quotas if the time lags between the warm periods are as short as have been experienced in resent years. A high frequency of warm periods is favourable for the herring, both with respect to level and stability of the catches, but has a negative effect on the obtainable yield of capelin cod. This is because longer time lags between strong herring year classes in the Barents Sea leave more time for the rebuilding of the capelin stock, which is the basis for high biomass production of cod.

6 REFERENCES

Anon., 1987. Report of the Atlanto-Scandian Herring and Capelin Working Group, Copenhagen 27-31 October 1986. ICES C.M. 1987/Assess:8.

Bogstad, B. and Mehl, S. 1997. Interaction between Atlantic cod (Gadus morhua) and its prey species in the Barents Sea. In: Forage Fishes in Marine Ecosystems. Alaska Sea Grant Report 97-01.University of Alaska Fairbanks, Fairbanks, AK.

Gjøsæter, H. 1997. The Barents Sea Capelin Stock (*Mallotus villosus*): A Brief Review. - Proceedings. Forage Fishes in Marine Ecosystems. Alaska Sea Grant College Program. AK-SG-97-01, 1997: 469-484.

Gjøsæter, H. and Bogstad, B., 1998. Effects of the presence of herring (*Clupea harengus*) on the stock-recruitment relationship of Barents Sea capelin (*Mallotus villosus*). Fisheries Rsearch 38, 57-71.

Hamre, J. 1985. Assessment and management of Barents Sea capelin. In proc. Soviet-NorwegianSymp. Barent Sea capelin, 14 –17 August 1984. H. Gjøsæter, ed. Pp 5-24. Bergen: Institute of Marine Research.

Hamre, J,. 1994. Biodiversity and exploitation of the main fish stocks in the Norwegian Sea - Barents Sea ecosystem. *Biodiversity and Conservations 3 (1994):* 273-292.

Hamre, Hatlebakk, Hagen, Merckoll, 1993. System-modell for havfiske, NR-notat, STAT/5/1993.

Hamre, J. and Hatlebakk, E., 1998. System Model (Systmod) for the Norwegian Sea and the Barents Sea. Pp. 93-115 inTor Rødseth (ed.). Models for Multispecies Management, Physica-Verlag Heidelberg New York

Hamre, J. 1988. Some aspects of the interrelation between the herring in the Norwegian Sea and the stocks of capelin and cod in the Barents Sea. ICES C.M 1988/H:42: 1-15. (Mimeo).

Hamre, J. and S. Tjelmeland 1982. Sustainable yield estimates of the Barents Sea capelin stock. ICES C.M. 1982/H:45: 1-24. (Mimeo).

Marty, J.J. and S.S. Fedorov, 1963. Features of the population dynamics of marine herring as seen from the Atlanto-Scandian stock. Rapp.P.-v.Reun.Cons.perm.int.Explor.Mer, 154: 91-97.

Moksnes, E. and Øyestad, V. 1987. Interaction of Norwegian sprin-spawning herring larvae (Clupea harengus) and Barents Sea capelin larvae (Mallotus villosus) in a mesocosm study. J. Cons. int. Mer., 44: 32 –42. 1987.

Ponomarenko, V.P. and I.Y. Ponomarenko, 1975. Consumption of the Barents Sea capelin by cod and haddock. ICES C.M. 1975/F:10: 1-6. (Mimeo).

Sætersdal, G. and H. Loeng, 1984. Ecological adaption of reproduction in Arctic Cod.Pp.13-35. Proc. of the Soviet-Norwegian Symp. Reproduction and Recruitment of Arctic Cod. Inst. of Mar. Research, Bergen, 1984.

Tjelmeland, S. 1987. Mortality on Barents Sea Capelin calculated by the IMR Multispecies Model for the Barents Sea. ICES C.M. 1987/H:55: 1-21 (Mimeo).

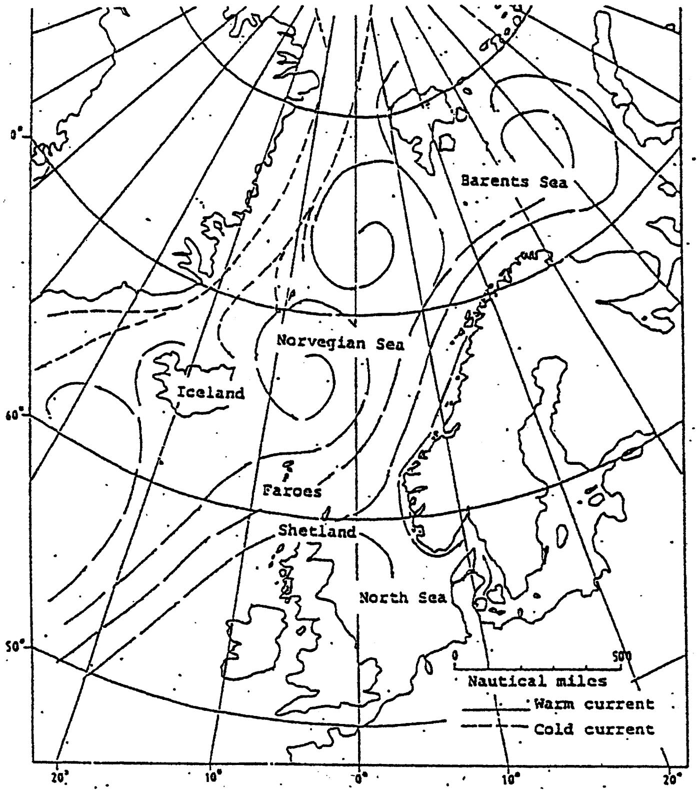


Fig. 1. The circulation of the Norwegian Sea.

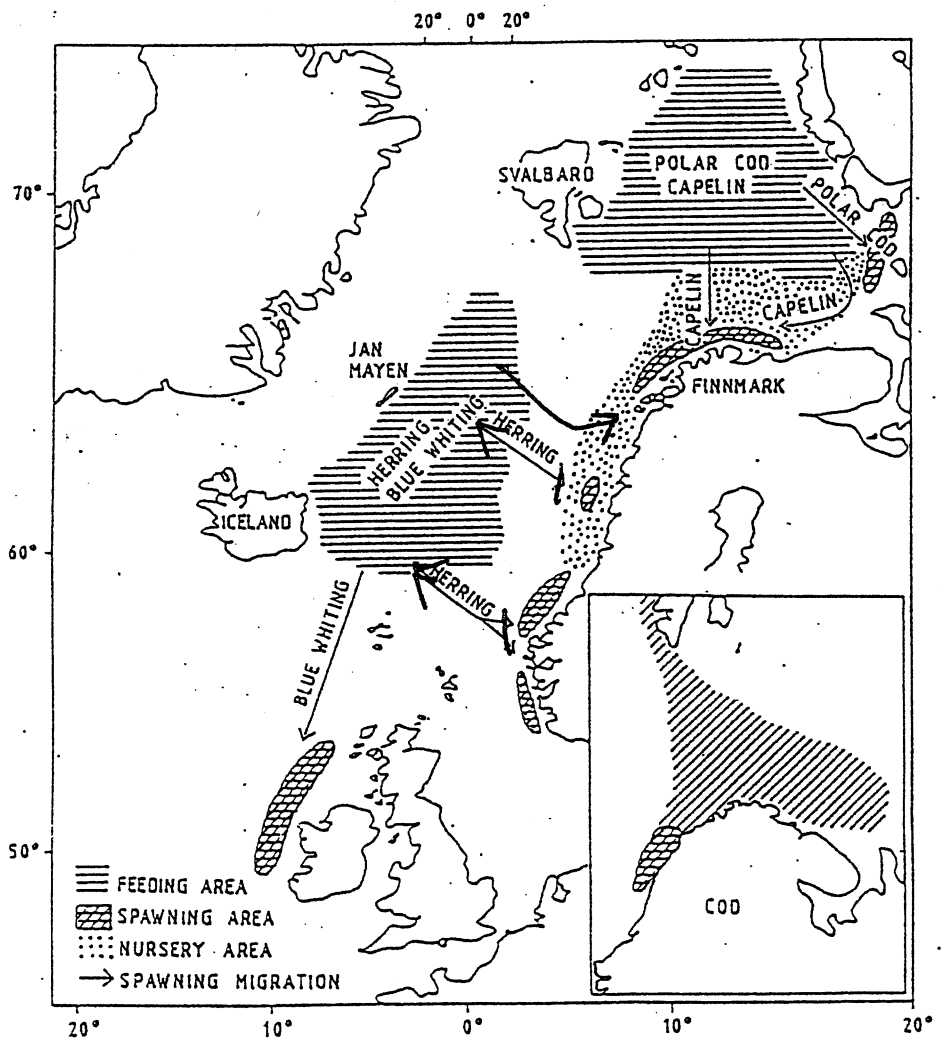


Figure 2. Distribution and migration of the most important fish stocks in the Norwegian-Barents Sea ecosystem.

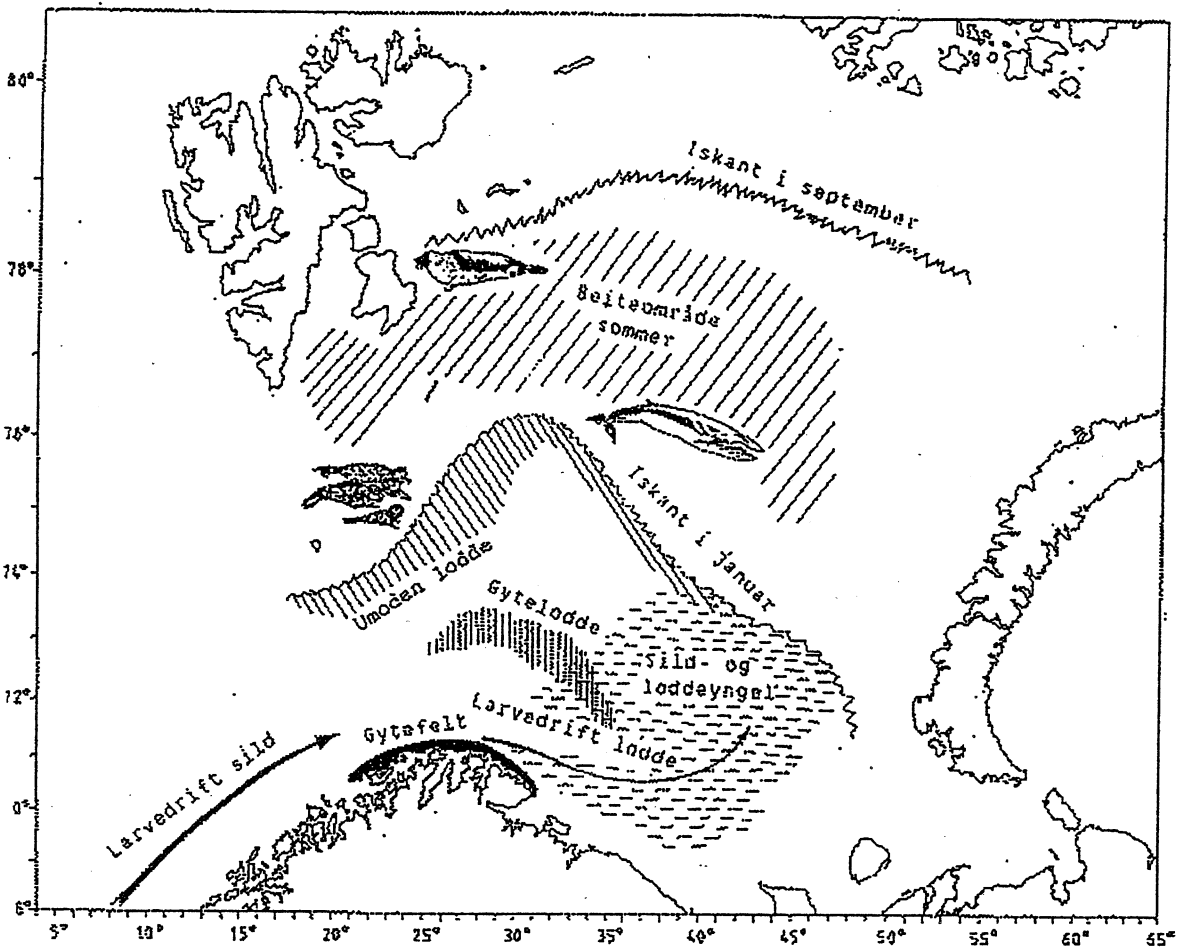


Figure 3. Stock distribution and interaction in the Barents Sea.

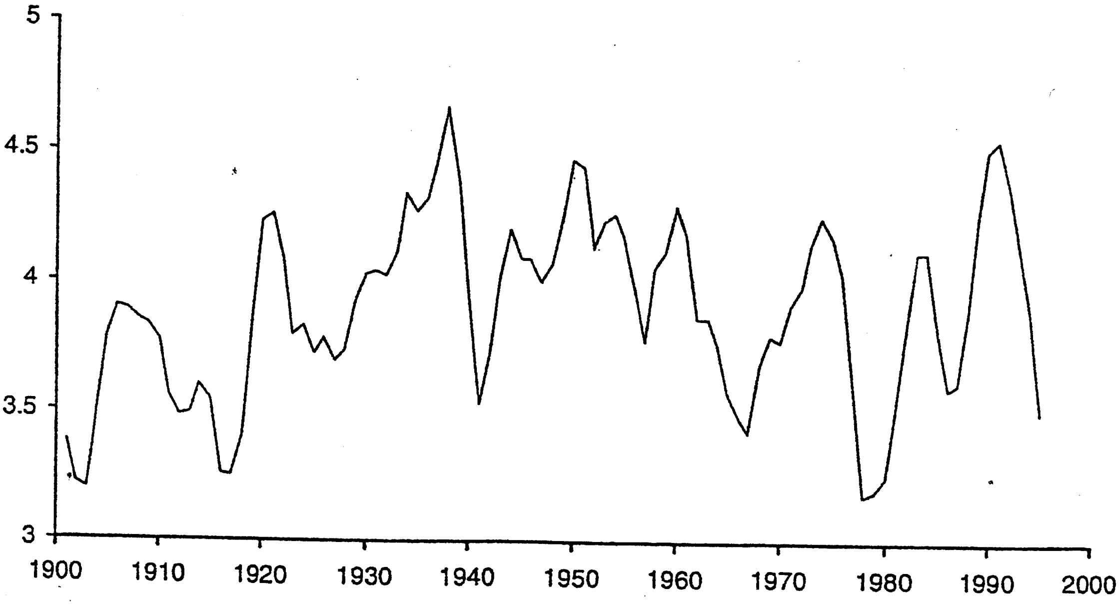


Figure 4. Mean annual temperature in the Barents Sea (Kola section), in1900-1994 (smoothed over 3 years).

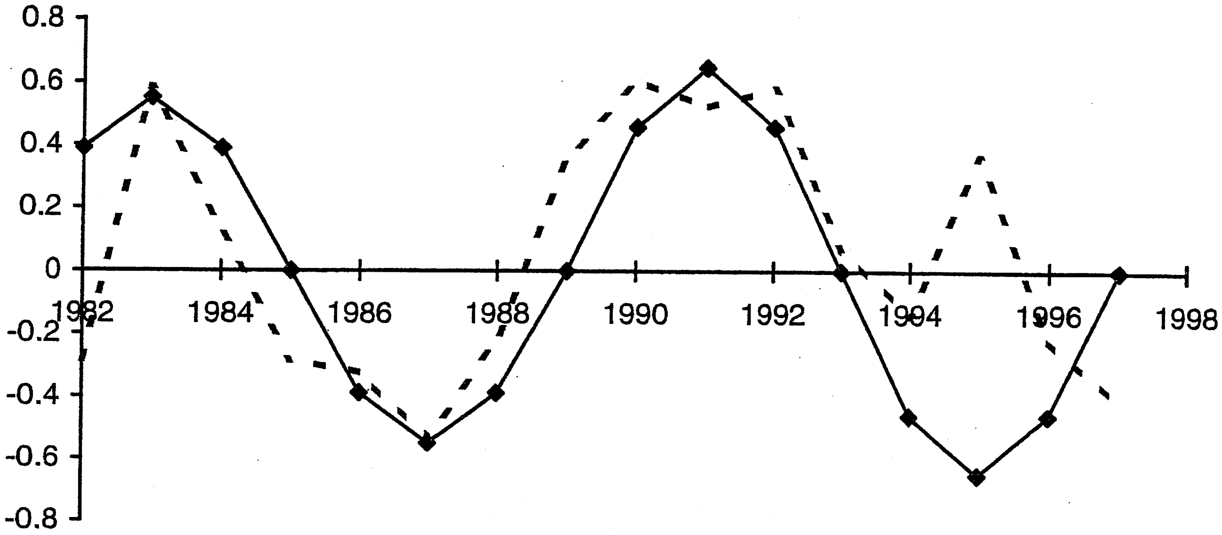
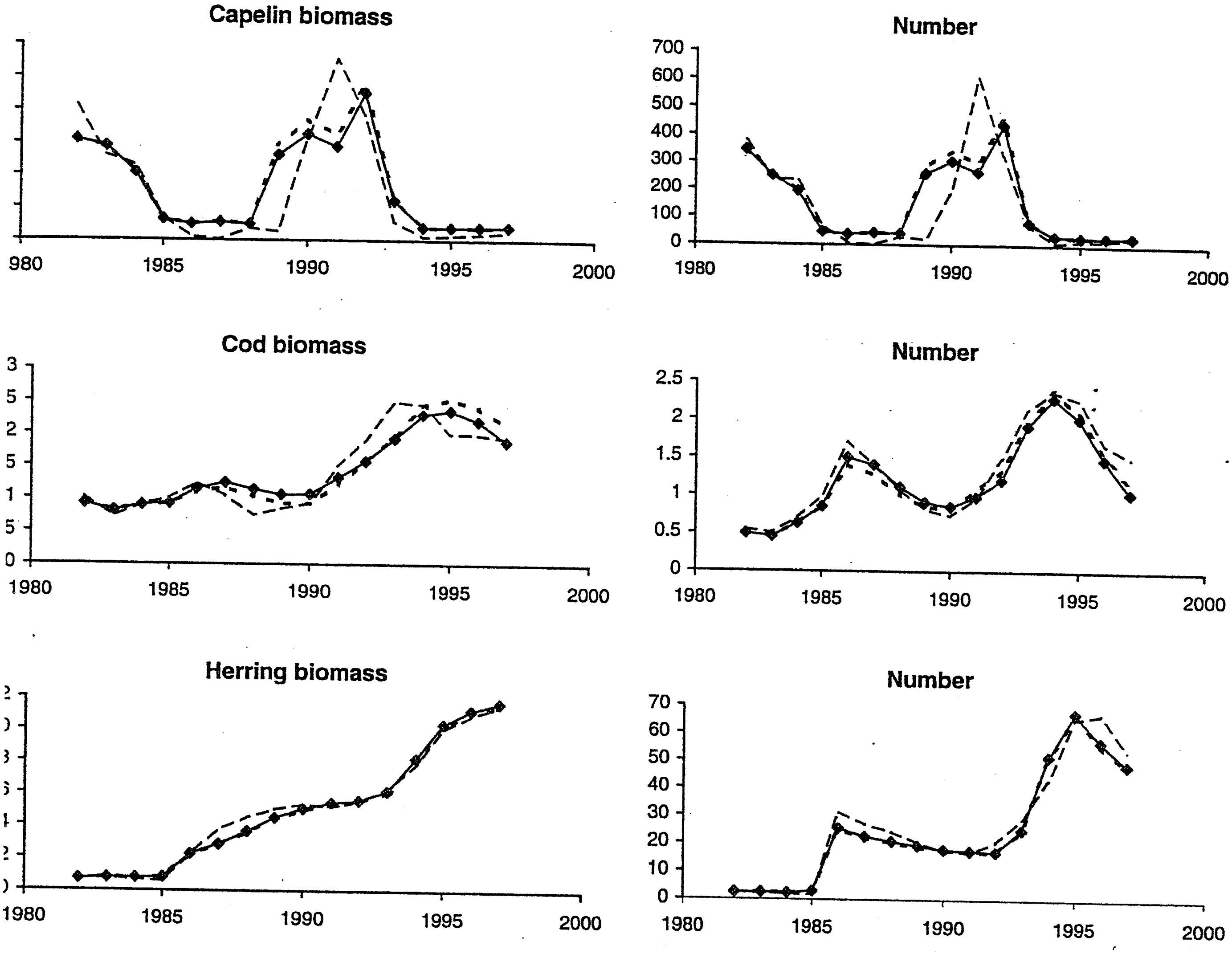


Figure 5. Simulated and observed (dotted line) temperature anomalies with 8 years between warm ocean climate periods in the Barents Sea.



gure 6. Simulated and observed (broken line) stocks of capelin (2+), cod (3+) and herring (3+) using the sine curve and observed temperature anomalies(dotted line) as climate control.

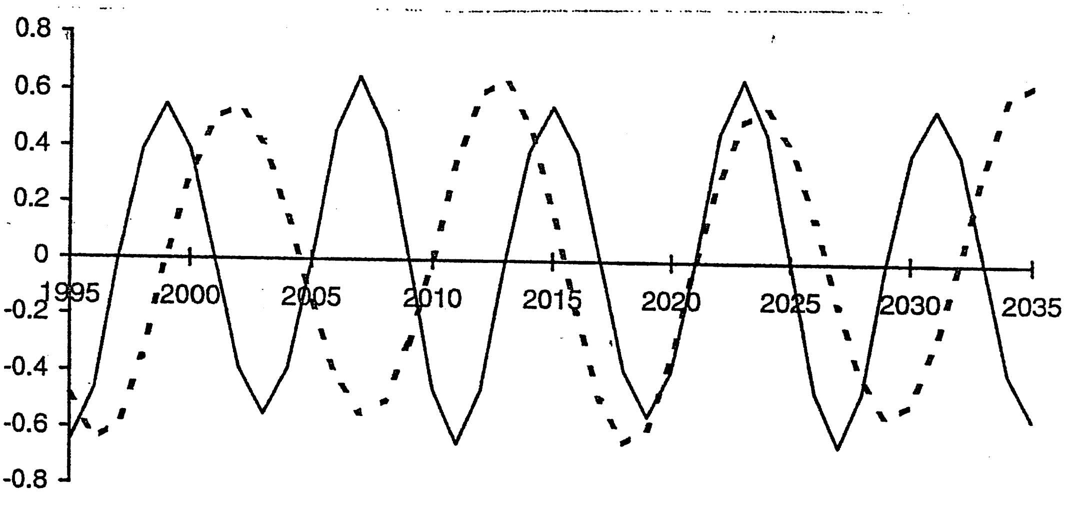


Figure 7. Simulated temperature anomalies with 8 and 11(dotted line) years between warm ocean climate periods in the Barents Sea.

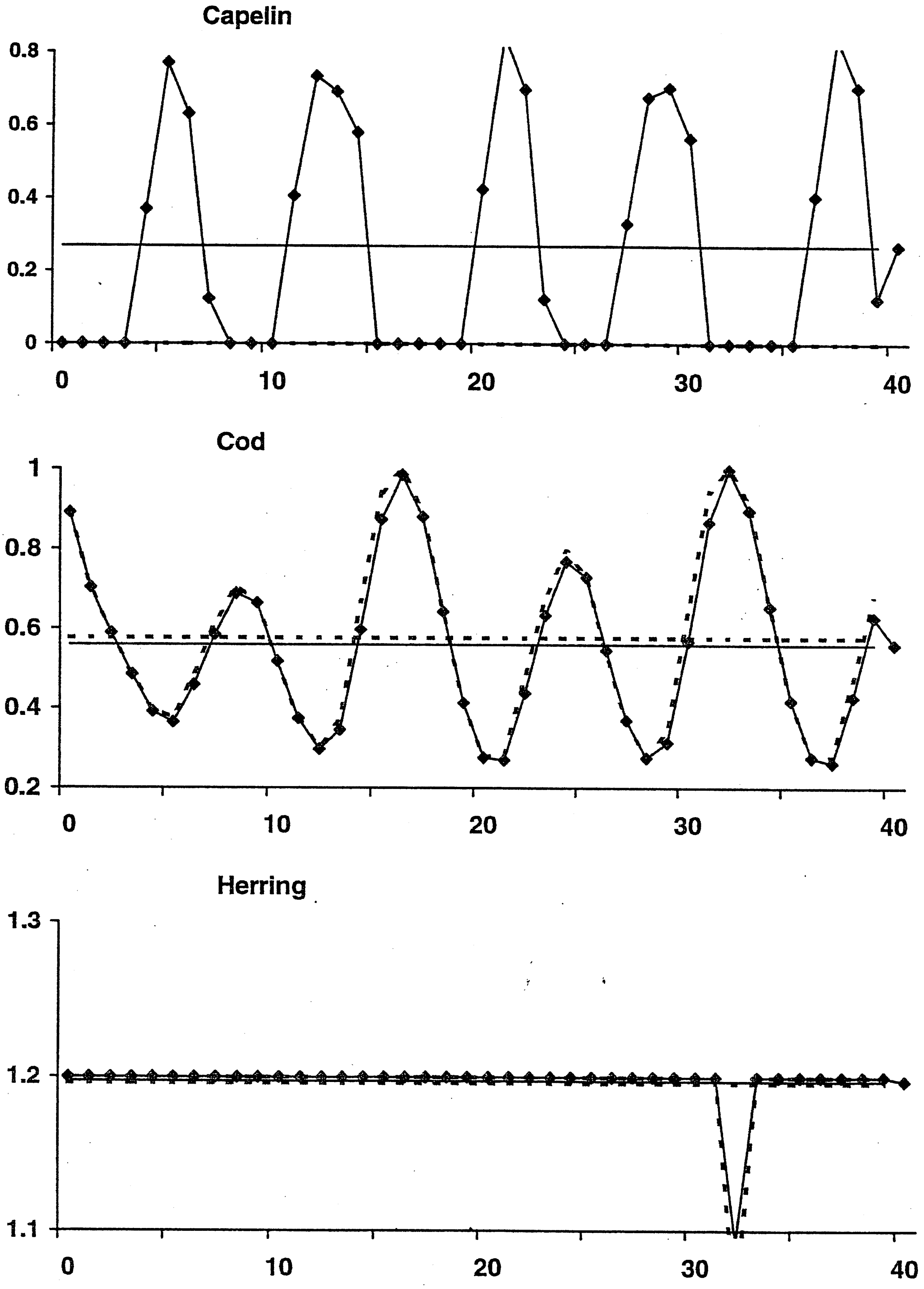


Figure 8. Simulated catches (mill.tonnes) of capelin, cod and herring in 40 years.Parallell lines to the x-axis show average catch.Temperature cycle 8 years.Fishing strategy for capelin as conventional (see text), for cod F = 0.8, and for herring F =0.2, catch quota = 1.2 mill. tonnes. Dotted lines show results for capelin catch quota = 0.

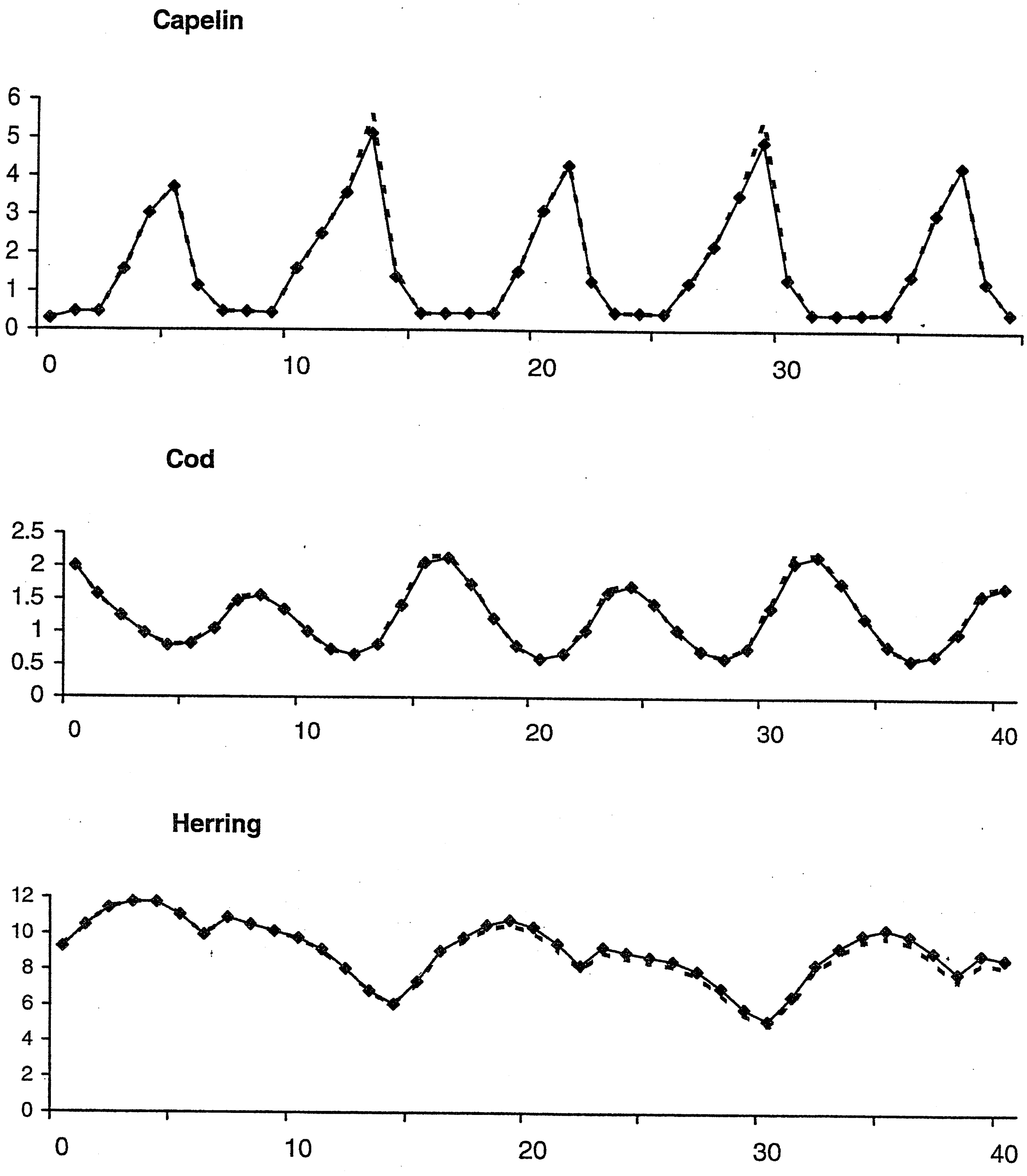


Figure 9. Stocks of capelin (2+), cod and herring (3+) in mill.tonnes. Strategy as in Figure 8.

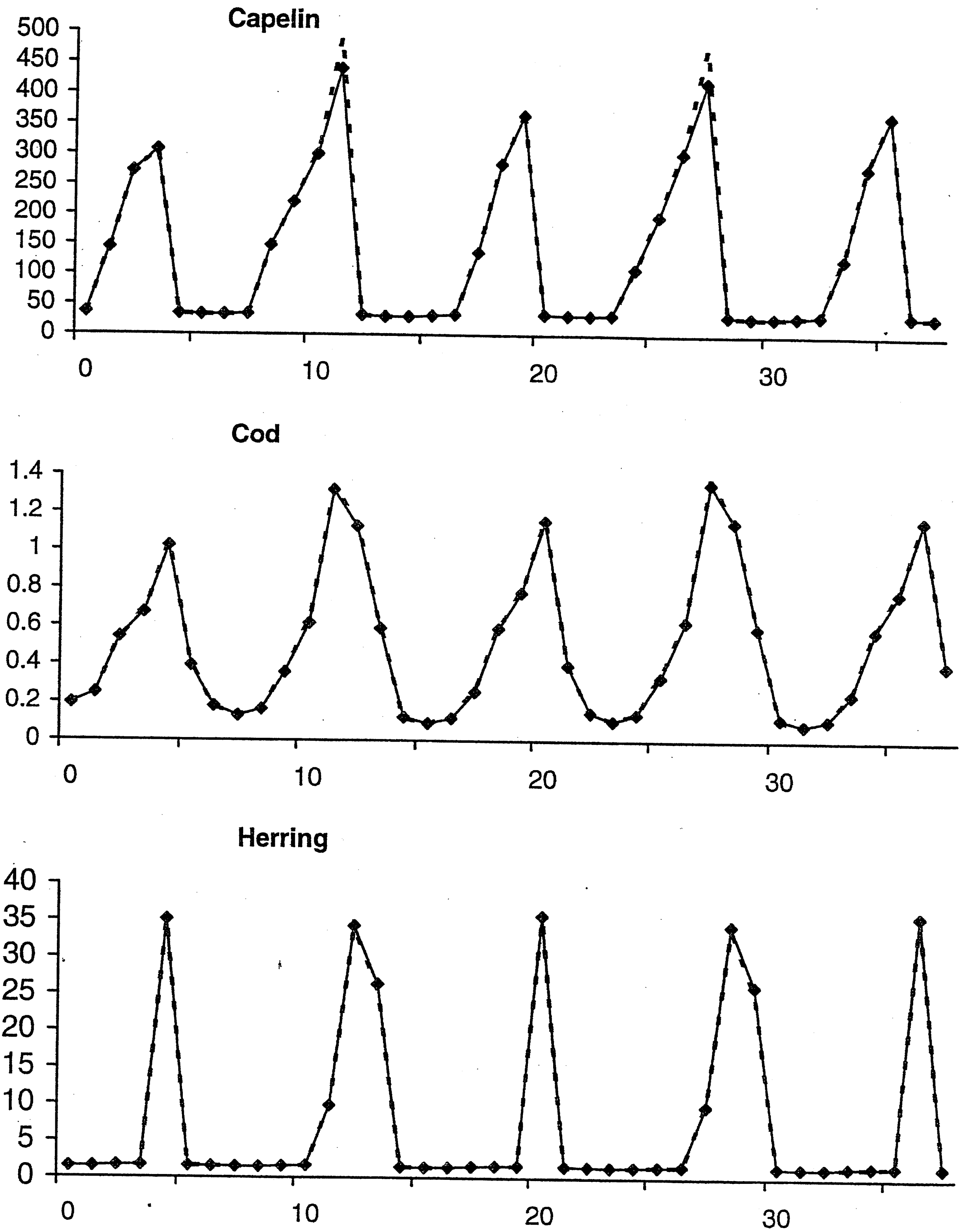


Figure 10. Simulated recruitment by year class from year 0 in bill. ind. for capelin (2-group), cod and herring (3-group). Strategy as in Figure 8.

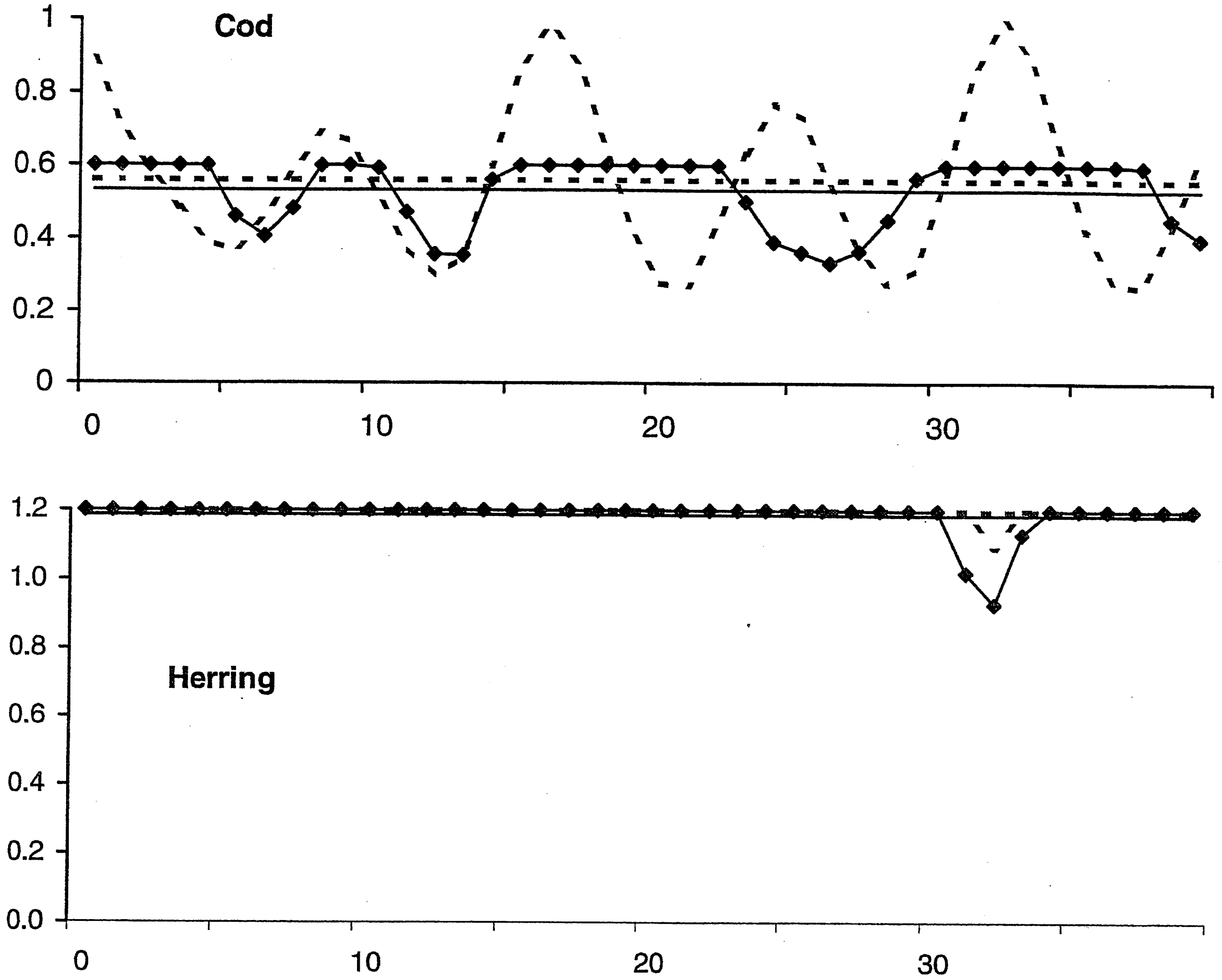


Figure 11. Simulated catches (mill.tonnes) of capelin, cod and herring in 40 years. Parallel lines to x-axis show average catch. Temperature cycle 8 years. Fishing strategy for capelin: F =0, for cod: F = 0.8, catch quota = 0.6 mill. tonnes, and for herring F = 0.2. Dottet lines show fishing strategi as in fig. 8.

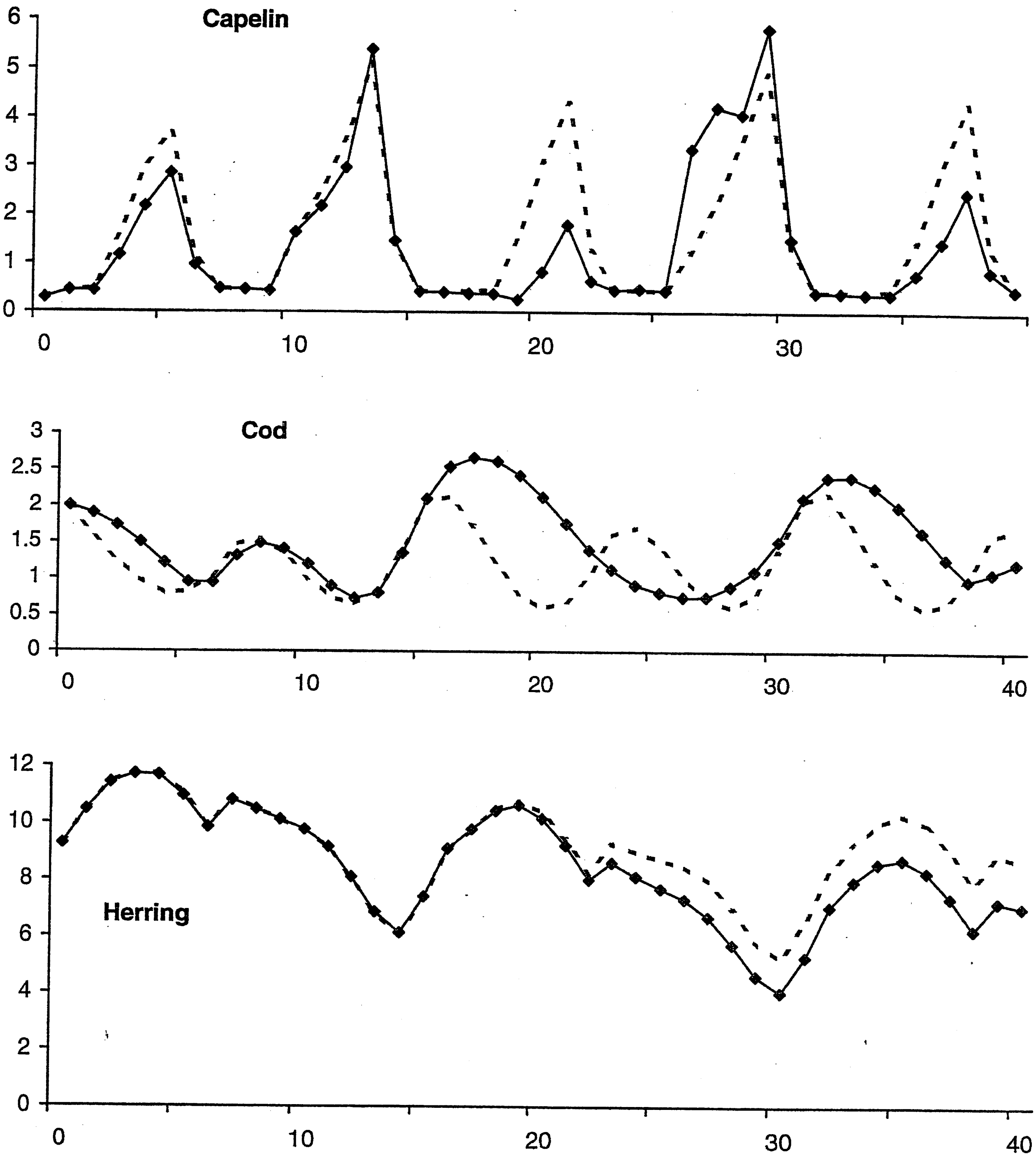


Figure 12. Stocks of capelin (2+), cod and herring (3+) in mill.tonnes. Same strategy as in Figure 11

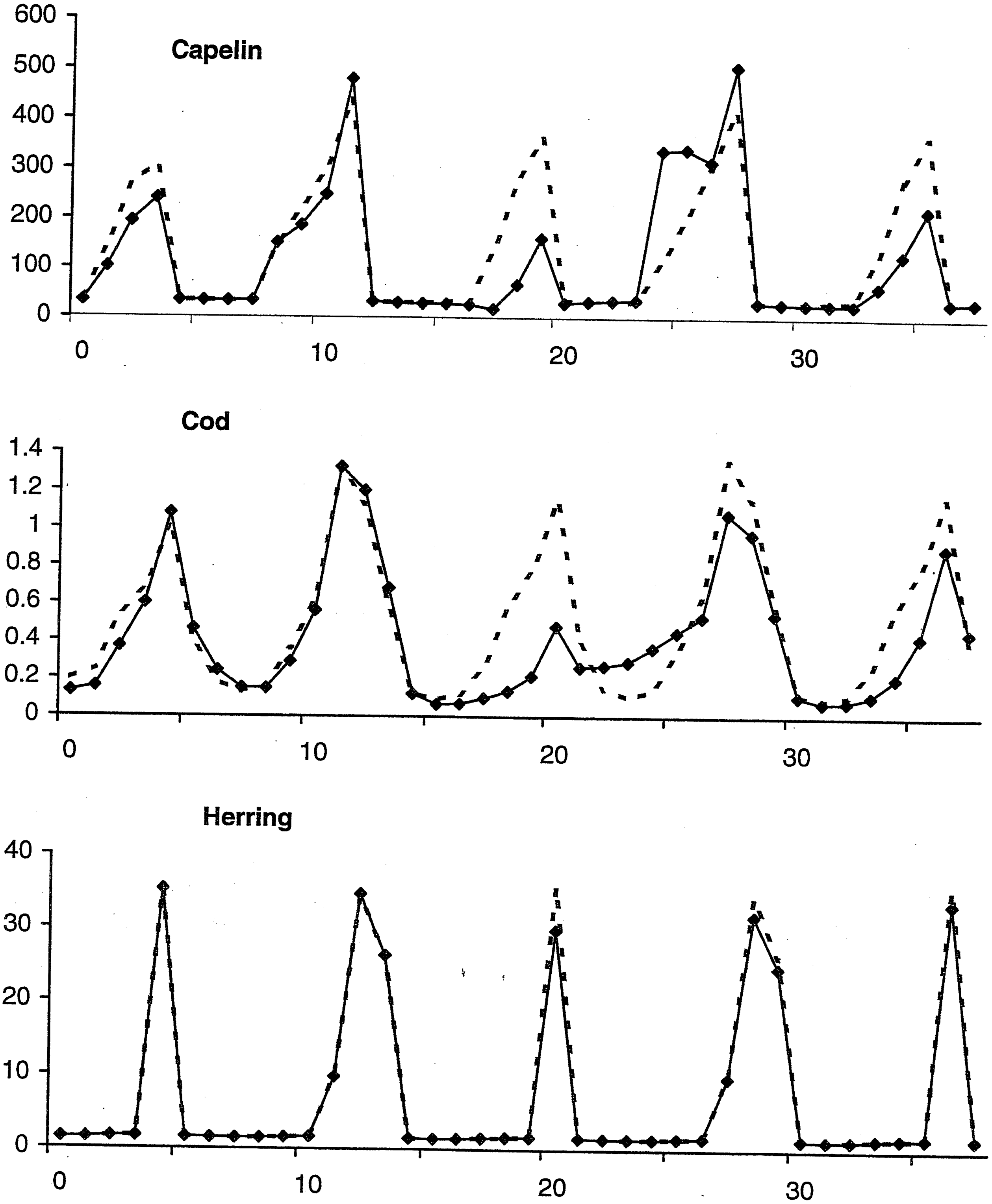


Figure 13. Simulated recruitment by year class from year 0 in bill. ind. for capelin (2-group), cod and herring (3-group). Strategy as in Figure 11.

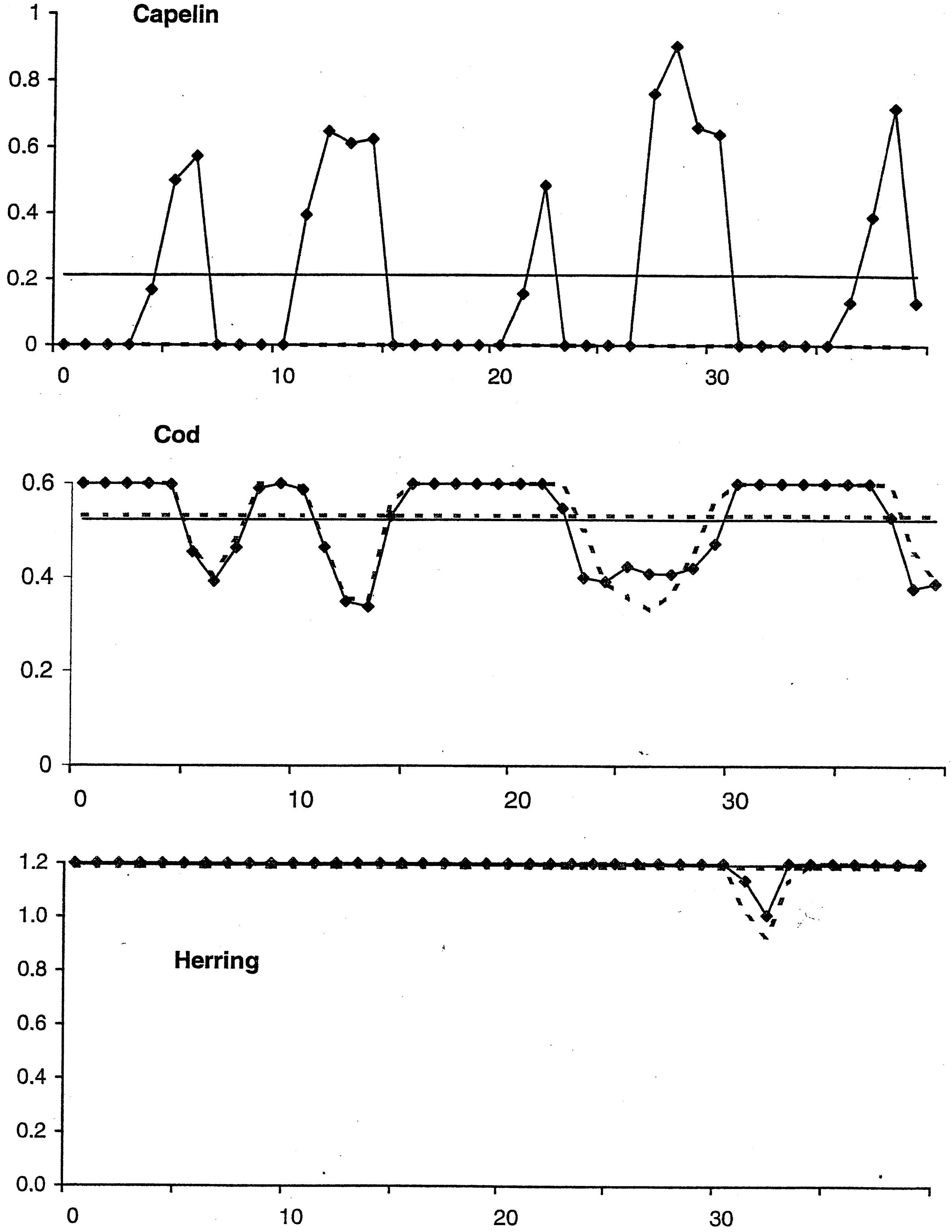
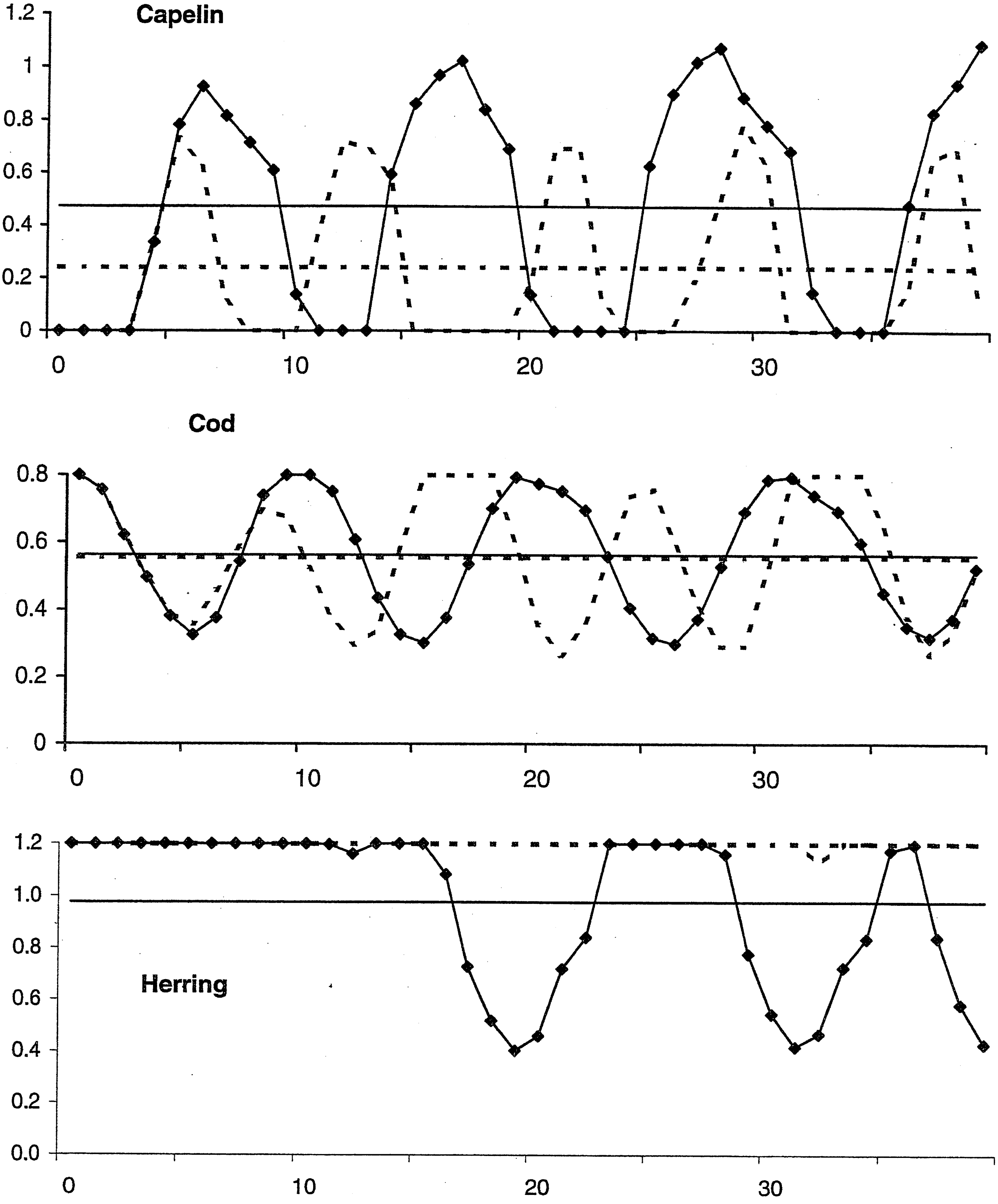


Figure 14. Simulated catches (mill.tonnes) of capelin, cod and herring in 40 years.
Parallel lines to x-axis show average catch.Temperature cycle 8 years.
Fishing strategy for capelin: F = conventional, for cod: F = 0.8, catch quota = 0.6 mill. tonnes.
Herring: F = 0.2, catch quota 1.2 mill. tonnes. Dotted lines show the same strategi but capelin F = 0.



igure 15. Simulated catches (mill.tonnes) of capelin, cod and herring in 40 years. Parallel lines to x-axis show average catch.Temperature cycle 11 years. Fishing strategy for capelin: conventional (see text), for cod: F = 0.8, catch quota = 0.8 mill. tonnes Dotted lines show results for 8 years cycle.

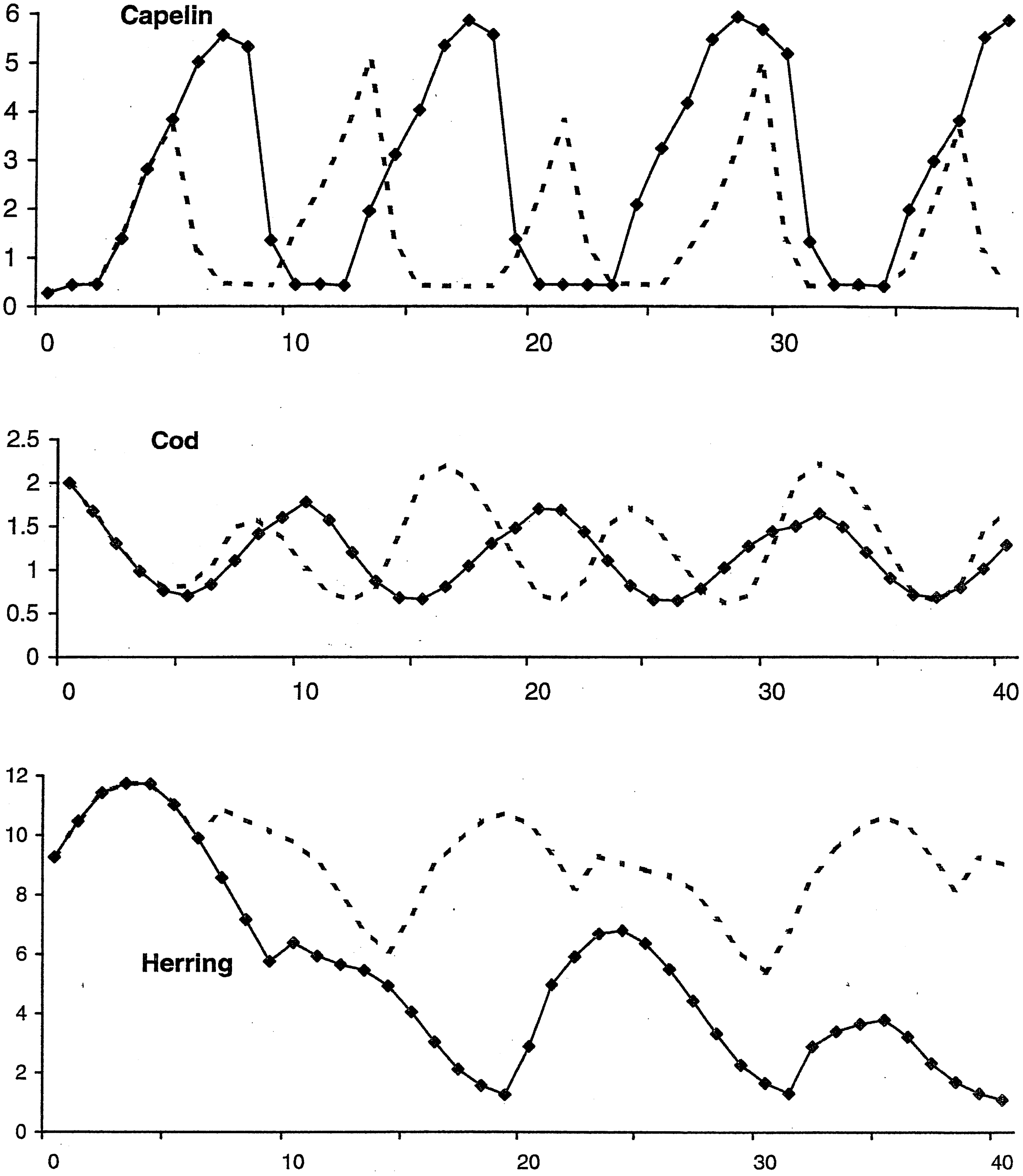


Figure 16. Stocks of capelin (2+), cod and herring (3+) in mill.tonnes. Same strategy as in Figure 15

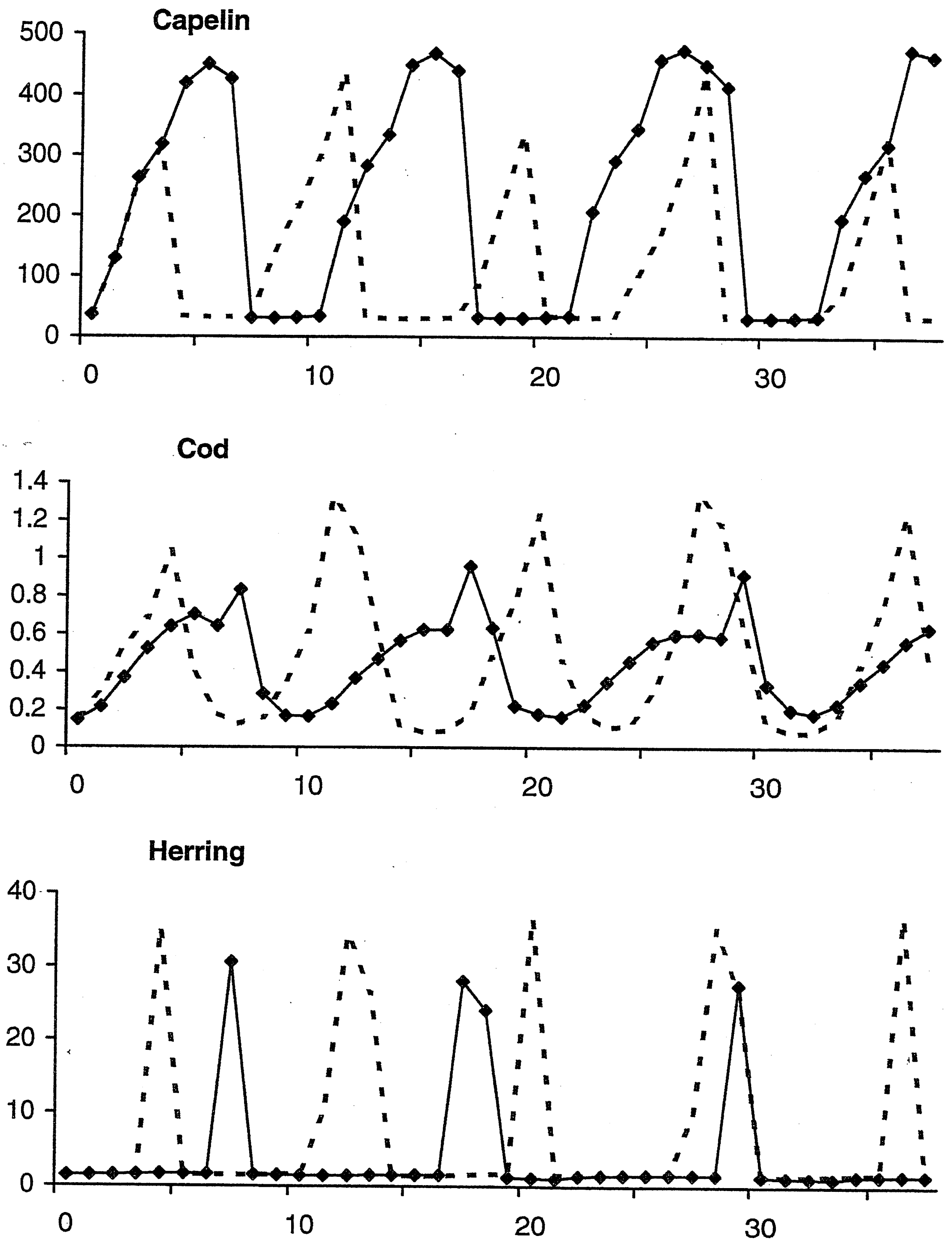


Figure 17. Simulated recruitment by year class from year 0 in bill. ind. for capelin (2-group), cod and herring (3-group). Strategy as in Figure 15.

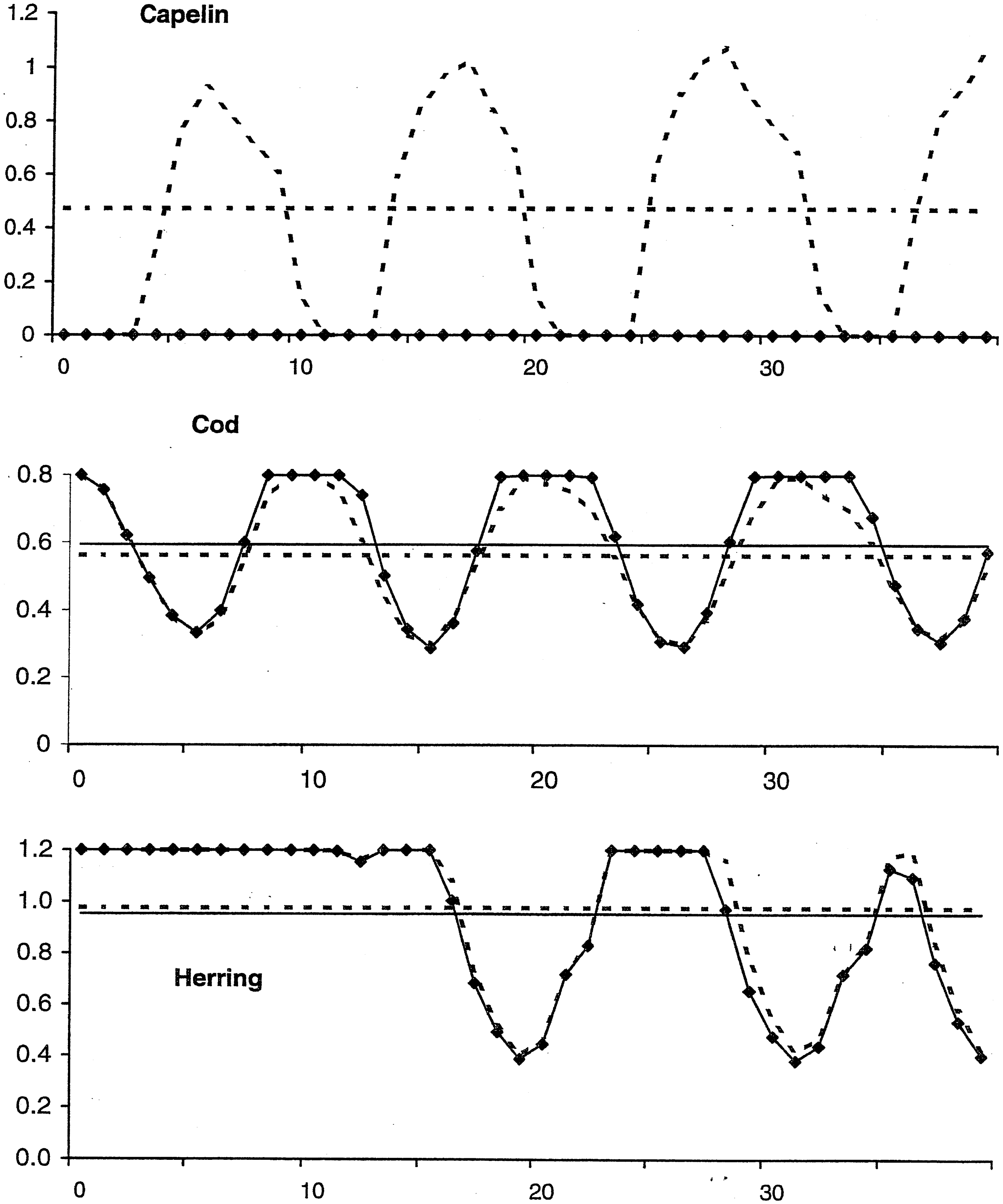


Figure 18. Simulated catches (mill.tonnes) of capelin, cod and herring in 40 years. Parallel lines to x-axis show average catch.Temperature cycle 11 years. Fishing strategy as in Figure 15. Dotted lines shows results for capelin F = 0

8th Norwegian-Russian Symposium
Management strategies for the Fish
stocks in the Barents Sea
Bergen, 15-16 June 1999

RETROSPECTIVE REVIEW OF MANAGEMENT ADVICE AND TAC's FOR SOME STOCKS

by

Odd Nakken
Institute of Marine Research

ABSTRACT

During the past 20 years fisheries management in the Barents Sea and adjacent waters has been based on annual advice provided by The International Council for the Exploration of the Sea, ICES. In the present paper the discrepancies between advised, agreed and actual annual catches were investigated for some stocks in the period 1978-1998. The study showed that the agreed, and particularly the actual catches have frequently exceeded the advised ones. In addition the annual advice, particularly for northeast arctic cod, was found to be based on stock assessments which have given biased results; the annually estimated mortalities have as a rule been too low.

These findings call for considerably more caution when TACs are decided on in future as compared with past and present experience.

INTRODUCTION

During the past 20-25 years management advice has been given annually for all main stocks in the Barents Sea and adjacent areas, largely based on stock monitoring and science carried out at IMR and PINRO. The stock assessments and predictions which form the basis for advice are undertaken within the framework of ICES (assessment working groups and ACFM) and advice is forwarded to Norwegian and Russian management authorities each year in May or/and November by ICES. Nakken (1998) reviewed the exploitation and management of marine resources in the area and attempted to answer two questions:

1. Has the advice been used properly by the managers?
2. Has the advice been based on reliable stock assessments and communicated to the managers in a way that forwards adequate management measures?

In the present paper a brief summary of his findings regarding the first of these questions is given. The second question is addressed in some more detail than in the original paper, particularly regarding the stock of Northeast Arctic cod. The main purpose is to give some guidelines to managers on how the advice ought to be used.

Has the advice been used properly?

In order to throw light on the question, table 1 was prepared. The table shows advised, agreed and actual catches as tabled in the annual reports of ACFM. The figures need some comments. ICES has not directly provided advice on TAC every year. In some years a certain fishing mortality rate which should not be exceeded has been recommended and the TAC corresponding to that mortality rate has been calculated at a later stage and on the basis of slightly revised stock size. This will to some extent invalidate the comparability between advised and agreed catches.

The wording "agreed" catches is not strictly correct for saithe and redfish, nor in many of the years for herring since Norway alone has set the TACs. For some years it is unclear whether a TAC was decided on particularly for saithe and the two redfish stocks. The figures for actual catch are the ones used by ICES. In most years these figures correspond to the reported landings for haddock, saithe, redfish and capelin. For cod and herring ICES has in some years used actual catches which were higher than the reported landings. Discards are not included although substantial amounts of discarding of small specimens at times have taken place, particularly of small sized redfish in the shrimp fisheries, a matter that certainly contributed to the decline in redfish stocks and fisheries about a decade ago.

In order to investigate to which extent the advice has been used tables 2A and 2B were made from the data in table 1. Table 2A shows how the agreed TACs relate to the advised ones; i.e. to which extent the advice was used when the quota was decided on. It appears that there has been a general tendency to decide on TACs at or above the advised level for all stocks. This is particularly pronounced for cod and herring (Table 2A). For herring zero catch was recommended for quite a number of years, yet Norway decided to fish a limited quantity. However, the apparent "negligible" fishery which took place in the 1970s and early 1980s contributed to delay the recovery of the spawning stock (Gjøsæter 1995, Nakken 1998).

For cod the Norwegian-Russian mixed commission quite often has agreed that catches should be higher than the stock could sustain. Even in the early 1990s when the spawning stock was recovering from its record low level, the agreed TACs (1992, 1993, 1994) were substantially higher than those which would have made the stock sufficiently robust to fishing at the end of the 1990s: Was the advice misunderstood in the early 1990s? ICES changed its advisory practice in 1991-1992, from recommending a certain TAC regardless of stock size to a presentation of options of catch and future stock development. Thus leaving managers to decide which option to choose when the stock was considered to be within "safe biological limits". I have the impression that many people involved in the discussion prior to the decision on TAC, have held - and still hold - the opinion that any option given by ICES can be considered an ICES recommendation, which it can not. Since one or more of the TAC options presented were above the level that would have been recommended based on sustainability considerations, this might have contributed to TACs in excess of the advisable ones for cod in the early 1990s. On the other hand, the distributions in table 2A are all clearly skewed towards the right hand side for all stock. Thus indicating that the agreed TACs were based on a perception that the advised figures generally were too low. In other words, managers usually have assumed that the scientists have underestimated either the stock size or the production capacity of the stock.

The distributions in table 2B might be taken as an indication of the managers capability to limit the catches to the level they found necessary when the TAC was decided on. Except for capelin and haddock, overfishing of TACs has taken place for all stocks. To some extent this may reflect the lack of jurisdiction in parts of the area, but in most cases it is caused by lack of enforcement in the national zones. The relatively high number of "belows" for cod and haddock simply shows that the fleets have not managed to take the agreed and/or advised TAC because of lack of fish in many of the years, indicating that advised TACs might have been too high or to optimistic.

Has advice been too optimistic?

Fortunately, this question can be investigated since ICES each year produces an updated an corrected version of the main results of previous years stock assessments. In table 3 are listed two estimates of spawning stock biomass each year for cod, haddock, saithe and herring. The figures generated by the 1998 assessment (1999 for herring) are regarded the most reliable ones. The ratios between the two yearly estimates are shown in Fig. 1. For all 4 stocks the ratio varies in a rather systematic manner with time and it deviates quite substantially from unity. Spawning stocks of haddock and saithe were grossly overestimated in the annual assessments in the 1980s. In the 1990s the amount of spawning haddock has been underestimated while saithe appears to be adequately assessed with exception of 1993. The spawning stock of cod has been overestimated in nearly all assessments which have been carried out in the period while the annual assessments of herring have generated considerably lower spawning stocks estimates than the 1999 assessment in all years since the 1983-yearclass recruited and caused an extensive growth in spawning stock biomass at the end of the 1980s.

Estimates of spawning stock biomass depend on number at age and weight at age as well as percentage mature at age. Which of these three variables have contributed to the discrepancies appearing in table 3 and Fig. 1? Fig. 2 shows a plot of estimated annual fishing mortalities for cod for the period 1982-1997. The straight line has slope 1 and runs through origin. If there were no differences between the two estimates of fishing mortality all points would appear on the line, which they do not. The 1998 assessment which is considered to be the most reliable one for the years 1995 and backwards, but not necessarily for more recent years - generated fishing mortalities which were systematically higher than those produced in the annual assessments. Thus, it seems reasonable to conclude that the annual assessments of cod have underestimated the fishing mortality and overestimated stock numbers available for the fishery. Hence, the annually advised TAC which has been based on these figures has been too optimistic, i.e. too high.

How much is the mortality rate biased?

In Fig. 3 are shown the time series of the same data as used in Fig. 2. Fig. 3 indicate that the underestimation of $\overline{F}_{5\text{-}10}$ in the annual assessments is more pronounced in the periods, 1982-1986 and 1991-1995, when the mortality was increasing, than in 1987-1990,when the mortality was reduced. The figure (Fig. 3) also demonstrate that the fishing mortality rate during most of the investigated period has been far in excess of the levels recommended for maximum sustainable yield (Nakken et. al. 1996).

The time series of the ratio between the two estimates of fishing mortality, F(Ass)/F(98), is given in Fig. 4. The tendency towards lower ratios in the mid-1980s and early 1990s than for the years in between is early seen. However, it should be noted that the mortalities arrived at in the assessments for 1990-1992 were based on too low catches. The catches for 1990-1994 were raised in order to compensate for underreporting in those years, and this was done in autumn 1994 when the assessment for 1993 was carried out.

Fig. 5 is an attempt to illustrate the development of the range and average of the "underestimation" in successive assessments (years). It takes 5-6 years before the mortality estimate for a certain year converge and stabilizes and the average underestimation in the actual assessment year (year 0) is about 20 percent, which corresponds to a similar overestimation of the stock of fish aged 5-10 years..

Consequences for future advice and management

In the scientific literature focus is often directed towards the uncertainties related to the prediction of stock size (Ulltang 1996); i.e. to the recruitment in coming years. The brief comparisons made above indicate that at least for the gadoid stocks and in particular for northeast arctic cod, TACs are often based on wrong perceptions of current mortality in the stock. Fish are removed from the stock at a higher rate that the scientists expect from their analyses at the time the advice is given. In order to throw light on this problem in-depth investigations of the reliability of catch statistics as well as careful reviews of the assessment methodology are needed.

However, until the causes of the discrepancies are known management authorities ought to take a more precautionary approach when setting TACs than hitherto. The general tendency for northeast arctic cod as well as for the other demersal stocks has been to decide on TACs at or above the advised level. The finding above call for a change in this practice towards deciding on TACs at and below the advised level. This would lower the rates of exploitation and increase and stabilize the yields for most stocks as demonstrated for the Barents Sea cod by many authors (see Nakken et. al. 1996 for references).

REFERENCES

Gjøsæter, H. 1995. Pelagic fish and the ecological impact of the modern fishing industry in the Barents Sea . *ARCTIC 48(3),* 267-278.

ICES, 1980-1989. Reports of the Advisory committee on Fisheries Management (ACFM), and Rerports of the Arctic Fisheries Working Group.

Nakken, O. 1998. Past, present and future exploitation and management of marine resources in the Barents Sea and adjacent areas. *Fisheries Research 37(1998):* 23-35.

Nakken, O., Sandberg, P., Steinshamn, S.I. 1996. Reference points for optimal fish stock management. A lesson to be learned from the northeast arctic cod stock. *Mar.Policy 20(6),* 447-462.

Table 1. Advised (Adv), agreed (Agr) and actual (Act) catches (000 tonnes) from 6 stocks in the Barents Sea and adjacent waters from 1978 to 1999. (Source: ICES - Reports of the Advisory Committee for Fisheries Management, 1978-1999).

Year	Cod			Haddock			Saithe			Redfish			Herring			Capelin		
	Adv.	Agr.	Act.	Adv.	Agr.	Act.	Adv.	Agr.	Act.	Adv.	Agr.	Act.	Adv.	Agr.	Act.	Adv.	Agr.	Act.
1978	850	850	699	150	150	95	160	-	154	150	-	125	0	7	10			
1979	600	700	441	206	206	104	153	-	166	157	-	113	0	0	13	1800	1800	1783
1980	390	390	382	75	75	88	122	-	145	100	-	103	0	10	18	1600	1600	1649
1981	-	300	399	110	110	77	123	-	172	89	89	101	0	9	13	1900	1900	1987
1982	<432	300	365	110	-	47	130	-	175	84	84	130	0	12	17	1600	1700	1759
1983	<380	300	290	77	-	22	130	-	155	85	85	125	0	21	23	2300	2300	2309
1984	150	220	278	20	-	17	103	-	150	85	107	101	38	38	53	1100	1400	1434
1985	170	220	308	50	50	41	85	-	107	100	100	92	50	60	81	1000	1100	851
1986	<446	400	430	100	100	97	74	-	70	100	100	53	150	126	137	0	120	123
1987	<645	560	518	160	250	151	90	-	92	-	-	34	150	115	123	0	0	0
1988	(530)[1]	590	459	<240	240	92	<83	-	114	26	-	42	150	120	135	0	0	0
1989	335	300	351	69	83	56	120	120	123	36	-	47	100	100	104	0	0	0
1990	172	160	212	-	25	26	93	103	95	41	-	63	80	80	86	0	0	0
1991	215	215	319	-	28	34	90	100	107	36	-	68	0	76	85	1000	900	933
1992	250	356	513	35	63	54	115	115	128	47	-	32	0	98	104	1030	1100	1123
1993	256	500	582	56	72	78	132	132	154	30	30	29	119	200	232	600	630	586
1994	649	700	771	97	120	121	158	145	142	R.C.	-	28	334	450	479	0	0	0
1995	681	700	740	122	130	138	221	165	169	L.p.	-	25	513	None	905	0	0	0
1996	746	700	732	169	170	173	158	163	171	L.p.	-	25	-[6]	None	1226	0	0	0[x]
1997	<993	850	766	<242	210	146	107	125	143	L.p.	-	25	-[6]	1500	1426	0	0	0
1998	514	654	561	120	130	95	117	144	153	N.d.f.	-	30	≤ Hcr	1300	1223	0	0	0
1999	360	480	-	74	78	-	N.a.	145	-	N.d.f.	-	-	1263	1302	-	79	-	-

[1] Revised advice May 1988: 320-360, Agr: May 1988: 451.

L.p.: Lowest possible, N.d.f.: No directed fishery, N.a.: No ICES advice, Hcr: Harvest control rule

[2] Keep SSB > 2.5 mill. tonnes

Table 2A. Occurrence of cases when agreed TAC was set below, at or above the advised one. The two TACs were considered to be equal (i.e. At) when the ratio between them was in the range 0.9-1.1. Data from table 1.

Stock	Below	At	Above	Total
N-E Arctic cod	3	10	8	21
N-E Arctic haddock	0	12	5	17
N-E Arctic saithe	1	6	4	11
Redfish (two stocks)	0	6	1	7
Nss Herring	3	6	11	20
Capelin	0	19	2	21
Total	7	59	31	97
Total (Herring excl.)	4	53	20	77

Table 2B. Occurrence of cases when the actual catch was below, at or above the agreed TAC. Catch and TAC were considered equal (i.e. At) when the ratio between them was as in 2A.

Stock	Below	At	Above	Total
N-E Arctic cod	5	6	10	21
N-E Arctic haddock	10	7	1	18
N-E Arctic saithe	0	8	2	10
Redfish (two stocks)	1	3	3	7
Nss Herring	0	10	9	19
Capelin	1	19	0	20
Total	17	53	25	95
Total (Herring excl.)	17	43	16	76

Table 3. Estimates of spawning stock biomass (000 tonnes) for cod, haddock, saithe and herring 1984-1994.
A 98: from the assessment carried out in 1998
Ann: from the annual assessments 1985-1997

	Cod			Haddock			Saithe			Herring		
Year	A 98	Ann	ratio	A 98	Ann	ratio	A 98	Ann	ratio	A 99	Ann	ratio
1984	259	354	0.73	37	87	0.42	150	179	0.84	593	840	0.71
1985	212	407	0.52	32	69	0.46	121	171	0.71	492	579	0.85
1986	166	393	0.42	47	77	0.61	89	157	0.57	414	477	0.87
1987	112	275	0.41	32	32	1.00	90	539	0.17	1011	491	2.06
1988	187	189	0.99	55	110	0.50	125	193	0.65	3268	1336	2.45
1989	196	151	1.30	70	89	0.79	139	255	0.54	4151	1497	2.77
1990	350	327	1.07	76	141	0.54	122	186	0.66	4848	1482	3.27
1991	679	680	1.00	94	79	1.19	108	102	1.06	5119	2183	2.34
1992	882	1047	0.84	117	82	1.43	103	79	1.30	5016	2396	2.09
1993	751	1024	0.73	163	117	1.39	120	56	2.14	4868	2314	2.10
1994	604	774	0.78	94	78	1.21	195	174	1.12	5605	3841	1.46
1995	537	704	0.76	146	100	1.46	231	238	0.97	5948	5041	1.18
1996	651	832	0.78	212	242	0.88	231	211	1.09	6652	5557	1.20
1997	727	839	0.87	215	255	0.84	226	223	1.01	11998	12585	0.95

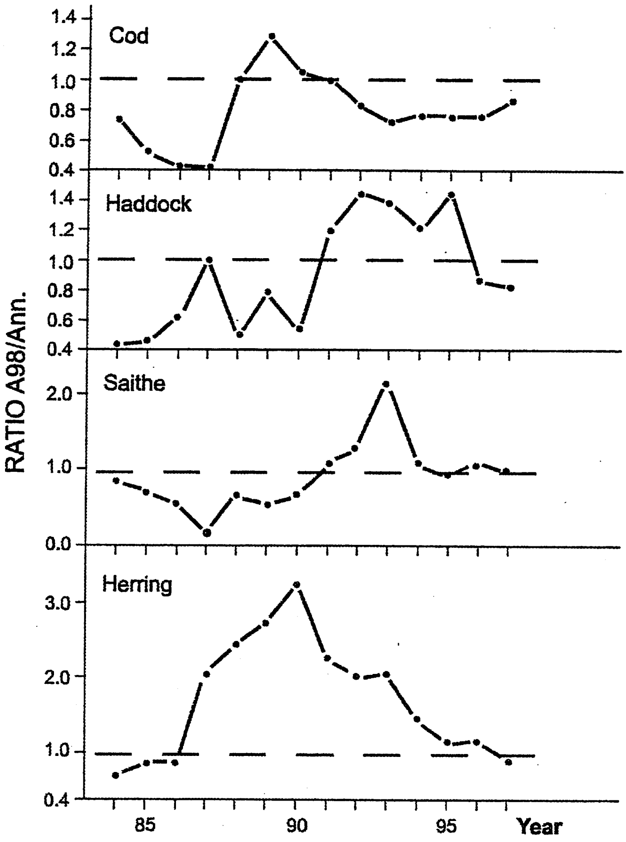


Fig. 1. Ratio between corresponding estimates of spawning stock biomass for northeast arctic cod, haddock and saithe and Norwegian spring spawning herring. A98: Estimates from the assessment carried out in 1998. Ann: Estimates from the annual assessments 1985-1998.

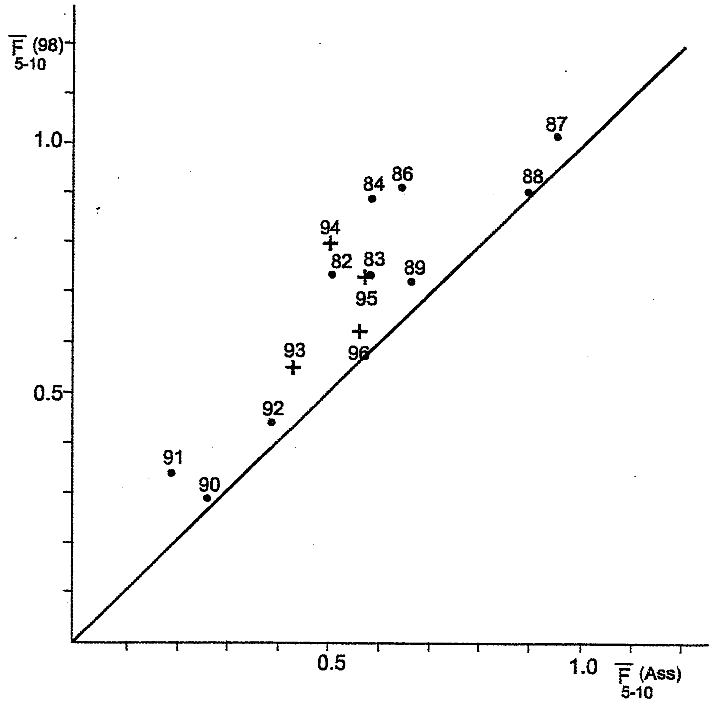


Fig. 2. Northeast arctic cod. Annual fishing mortality rates (F_{5-10}) in 1982-1996 for 5-10 year old fish. The values estimated in the 1998-assessment (ordinate) are plotted against the corresponding values arrived at in the annual assessments 1983-1998.

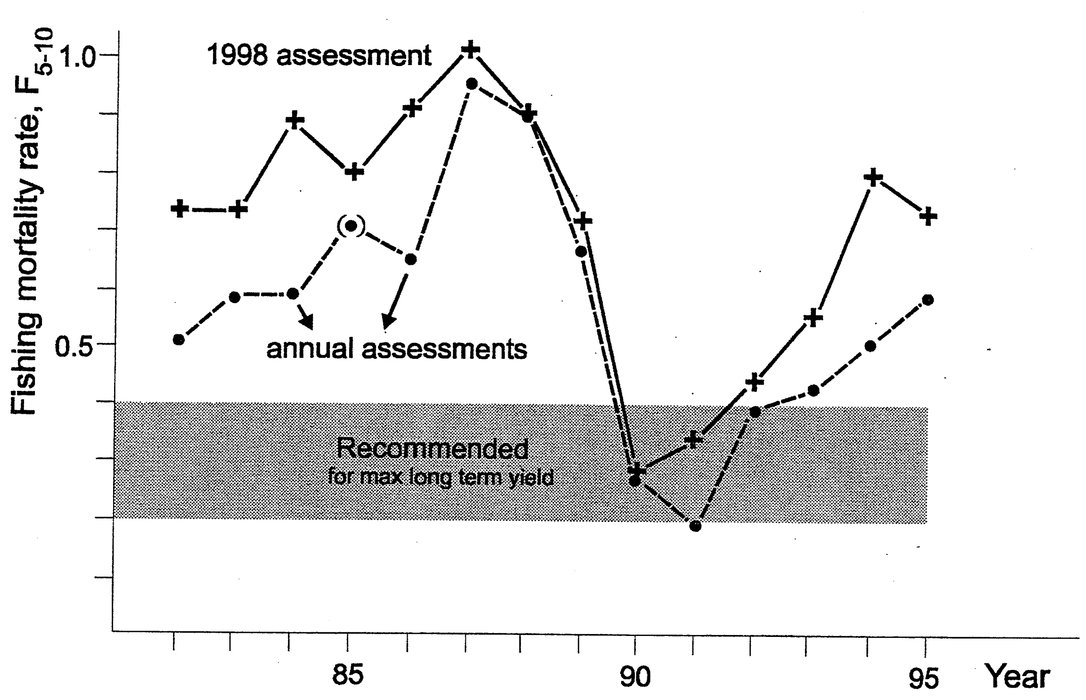


Fig. 3. Northeast arctic cod. Annual fishing mortality rates, F_{5-10}, in 1982-1995 for the cohort aged 5-10 years. Estimates from the assessment made in 1998 compared with those obtained in the annual assessments 1983-1996. The shaded area shows levels of F_{5-10} corresponding to maximum long term yield.

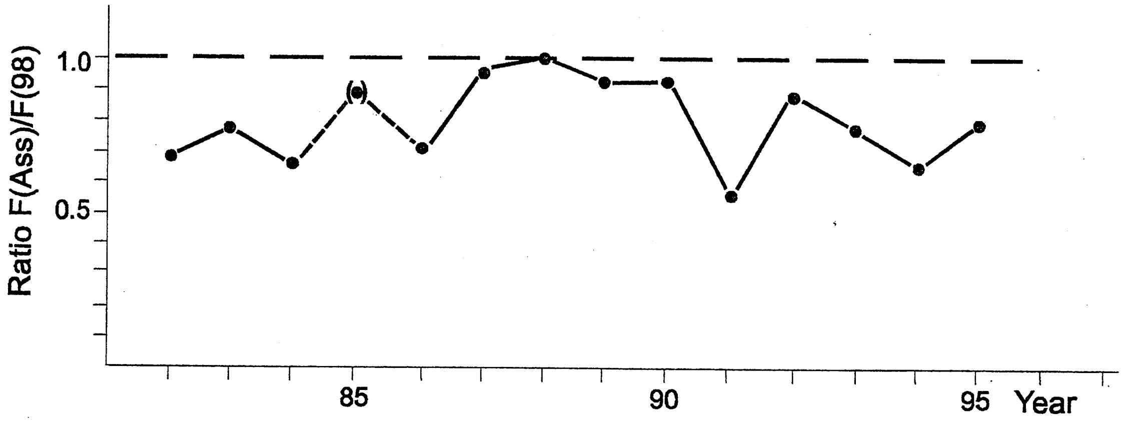


Fig.4 Northeast arctic cod. Ratio between corresponding estimates of annual fishing mortalities. F(ass.) is the estimate arrived at each year (1983-1996), F(98) is from the 1998 assessment.

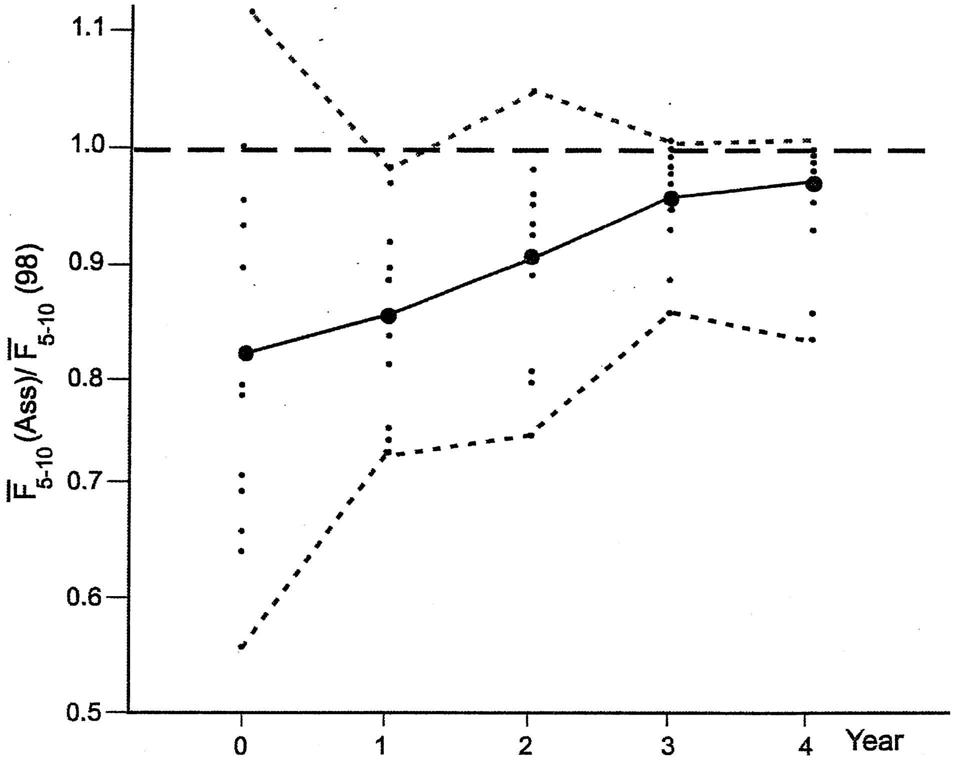


Fig. 5. North east arctic cod.
Ratios between annual mean fishing mortality rates
$F_{5\text{-}10}$(ass.): is estimated each particular year.
$F_{5\text{-}10}$(98): is estimated for the same years in 1998.

The 8th Norwegian-Russian Symposium
14-16 June 1999, Bergen, Norway

Basis for stock assessment and management advice

By
Natalia Yaragina (PINRO) and Asgeir Aglen (IMR)

ICES working procedures and form of advice

For most stocks of any commercial interest in the ICES area, ICES is asked for annual advice on fisheries management (catch levels). The normal working procedure is that each fisheries laboratory reports its research regarding each stock to the relevant ICES working group. In many cases this is reported through a stock co-ordinator appointed by the working group. In addition each member country reports (to ICES) the annual official landing statistics by species and ICES area. Most working groups meet annually for about 5-10 days. Here the research is critically reviewed and combined to give a best assessment of the state of the stock and the potential harvest in both short term and long term. The working group compiles a report where the analyses are documented in detail and an advice for management is suggested. This report forms the basis for the final advice, which is formulated by the ICES Advisory Committee on Fishery Management (ACFM). In this committee each member country has one representative. The main tasks of ACFM are;

- -Critical review of the working group report
- -Formulate an advice in accordance with the established ICES Form of Advice
- -Assure that the advice properly relates to objectives formulated by the management agencies and that items raised in requests from management agencies are covered.

The ICES Form of Advice defines the general objectives for the advice, and specifies the type of biological reference points related to these objectives. This is, therefore, an important basis both for the fisheries scientists formulating the advice and for the managers receiving the advice. This Form of Advice applies to all stocks and it is designed to give consistent advice between stocks.

The main objective is to have the stocks within safe biological limits. In recent years the Form of Advice has been revised for the purpose of giving advice in accordance with the Precautionary Approach. In that context it has become particularly important to focus on uncertainties in the assessments, and safe biological limits are now defined in terms of probabilities. As a result, new reference points have been defined as criteria for evaluating stocks and fisheries in relation to the Precautionary Approach. The conceptual basis for those are given in the present Form of Advice (ICES 1999a):

> *In order for stocks and fisheries exploiting them to be within safe biological limits, there should be a high probability that 1) the spawning stock biomass is above the threshold where recruitment is impaired, and 2) the fishing mortality is below that which will drive the spawning stock to the biomass threshold which must be avoided. The biomass threshold is defined as* $\boldsymbol{B}_{lim}$ *(*$_{lim}$ *stands for limit) and the fishing mortality threshold as* $\boldsymbol{F}_{lim}$*. In order to have a high probability to avoid the thresholds, management action must be taken before the thresholds are approached. The precision with which the thresholds and current status of the stocks are known, and the risk which is tolerable, are important factors in determining the distance away from the threshold that management action is required. The greater the precision of the assessment, the smaller the distance between limit and precautionary reference points. If the assessment is less reliable, the distance will be greater. ICES has defined* $\boldsymbol{B}_{pa}$ *(*$_{pa}$ *stands for precautionary approach) as the biomass below which action should be taken and* $\boldsymbol{F}_{pa}$ *as the fishing mortality above which management action should be taken. The distance between the limit and the precautionary approach reference points is also related to the degree of risk that fishery management agencies are willing to accept. Therefore, although ICES sees its responsibility to identify limit reference points, it will suggest precautionary reference points. The adoption of precautionary reference points requires discussion with fishery management agencies.*

ICES considers its main responsibility to give advice relating to these precautionary reference points. Therefore, the ICES advice does not usually attempt to define optimum management targets, but rather defines the limits of responsible management. In cases when the management agencies have defined clear objectives, ICES evaluates whether those are in agreement with the Precautionary Approach, and the advice is formulated in relation to those objectives.

Basis for stock assessment

To develop advice for fish stock management, a sufficient body of reliable information is necessary, and also the instrument of its analysis, first of all - theoretical models that would more or less entirely and adequately describe the processes occurred in marine ecosystem, such as species distribution, spawning, wintering and feeding migrations, response to fishery, links with climatic conditions and ecological interrelations between the species. Fairly many theoretical models applied in fisheries management are presently available. Single-species models, for instance, the VPA (Baranov, 1918, 1960; Beverton and Holt, 1957; Gulland, 1965) were the first to be developed and used in practice. Complex multi-species models have been developed during recent decades (Andersen and Ursin, 1977; Tjelmeland and Bogstad, 1998; Stefanson and Palsson, 1997).

The most important processes are reflected in the models with the appropriate equations in use:

- growth of marine organisms;
- maturation;
- fluctuations in recruitment;
- consumption of certain species by others;
- natural mortality;
- fishery.

Estimation of modelling parameters requires a large number of various reliable data. The data are collected by regular systematic, sometimes routine work performed by technicians and other specialists.

Data sources and assessment methods for Northeast Arctic cod

This section describes the types of data required for the models applied presently within the frames of ICES for stock assessment and for development of management advice. Uncertainties are discussed both regarding data and assessment methods. These are summarised in Tables 1 and 2.

Fisheries statistics

Fishery for the Northeast Arctic cod is known to be carried out by vessels from many countries. A major role in the fishery was played by Norway, Russia (previously the USSR), Great Britain and Germany. Cod catches taken in the period 1946-1997 varied considerably around the mean level, i.e. 700 thousand tonnes. Maximum catch (1343 thousand tonnes) was taken in 1956 and minimum one (212 thousand tonnes) - in 1990.

The stock size is calculated by annual catch (in number) of fish at age (year class). To obtain these values, the data on catch (tonnes) from appropriate departments of fisheries are used. Catch statistics is pooled by the data from fisheries organizations which are obliged to report back to the regulatory bodies. However, the statistics is not always complete, with the catch size, fishing areas and exceeding of quota allocated for catch being sometimes misrepresented (Table 2). Thus, by the data from the ICES Arctic Fisheries Working Group, the catches unreported in 1990-1994 varied from 25 to 130 thousand tonnes, with the maximum in 1992; the catch taken by the countries having no quota made up from 10 to 60 thousand tonnes during the same years (ICES, 1994, 1995, 1996). Few information is usually available about discards. The discards reported for 1946-1990 are believed to have decreased much (Nakken, 1994) owing to some modifications in mesh size and to a number of other management measures.

To recalculate catch weight into the number of fish by age, data on length, weight and age composition are required. To that end, specialists of scientific institutions perform mass measurements of fish (both at the sea and onshore when landing), collect age samples and read age. It should be noted that high variation in growth is typical of the Northeast Arctic cod. Range in value from maximum and minimum mean weight varies from 0.49 kg in cod at age 3 to 3.49 kg in specimens at age 9; standard deviations of mean weight increase from 0.1 kg to 0.65 kg for the same age groups, respectively (Ozhigin et al., 1997). Variability in growth is caused by a combined influence of a number of factors, the major of which are water temperature, feeding conditions and population density (Dementyeva and Mankevich, 1965; Ponomarenko et al., 1985; Nakken and Raknes, 1987; Jørgensen, 1992; Nilssen et al., 1994).

Precise estimation of stock biomass requires actual data on fish weight for the entire study period. However, only the data from 1983 are presently available for the ICES Working Group (Table 2).

Another important challenge is age reading. Earlier, cod were aged by scales, further - by otoliths (Rollefsen, 1933; Mankevich, 1966). The co-operation between age readers (exchange of samples and specialists on a regular basis) has been developed since 1992. However, the Norwegian and Russian methods for age reading have similarities and differences, which can have significant consequences. Thus, the yearly catch calculations using only Russian data on age determination have resulted in a difference in catch from 30 to 80 thousand tonnes, compared to those done when using both the Russian and Norwegian data (Yaragina et al., 1998).

Stock surveys

Instrumental survey for fish stocks is an integral part of research during which a large body of information on stocks, including fish abundance and on other parameters of the stock, is accumulated.

Hence, some words about a history of the surveys conducted in the Barents Sea. Quantitative assessment of cod and haddock at age O+ and 2+ with a small-meshed bottom trawl has been initiated by PINRO since 1946 and since 1978 - abundance and biomass of demersal fish in the Barents and Norwegian Seas were assessed during these surveys (Shevelev et al., 1996; Lepesevich and Shevelev, 1997). The attempts to estimate the recruitment of cod and haddock using acoustic methods were first undertaken by IMR in 1970 (Jakobsen et al., 1997). Full-scale acoustic survey has been performed by IMR since 1981, and since 1987 by PINRO. A number of other surveys (Table 3) are also carried out in the Barents Sea and adjacent areas and their basic aim is to assess abundance of recruitment at different stages of life cycle. This task remains one of the most difficult aspects of mathematical modelling.

Fluctuations in abundance of the Northeast Arctic cod inhabiting the Barents Sea, within the margin of its area, are known to be rather significant. By the data from the VPA calculations, the abundance of rich year classes exceeds that of the poor ones by 16 times (for comparison: the 1970 year class at age 3 amounted to 1818 million individuals and 112 million - from the 1966 year class) (ICES, 1999b).

Analysis and processing of survey data allows to obtain abundance indices of fish at different age, both relative (catch per hour, logarithmic indices, etc.) and absolute. Besides predicting recruitment, these data are also used to tune the VPA and estimate the total mortality of different year classes in order to define a regime of stock exploitation.

The survey areas are chosen to cover the sites of fish distribution. However, this is not always achieved in each specific survey. The area of cod distribution is known to be linked with those where the Atlantic and coastal waters are distributed. In connection with the variations in oceanographic conditions a distribution of cod can vary from year to year. Abundant year classes are usually distributed over a vaster area, compared to the poor ones. This variability may be illustrated by the charts showing the distribution of O-group cod during 1987 and 1992. It is therefore necessary sometimes to correct the areas to be surveyed. Thus, the Norwegian winter survey area was extended in 1993 (Jakobsen et al. 1997). Serious problems with the surveys occurred during 1996-1998 that had disrupted the time series. In 1996, due to some financial difficulties PINRO could not carry out the survey in the ICES Division IIb; no survey was conducted in Subarea I in 1997. A part of this area was further covered by a grid of stations, however, not during traditional period of time, but in February-March 1998. In 1997-1998, only the Norwegian economic zone was covered by the Norwegian trawl-acoustic surveys, as far as the Russian authorities did not allow to conduct the survey in the Russian economic zone, where a considerable proportion of cod stock is distributed in February-March. Therefore, the ICES Working Group had to make interpolations, that resulted in essential uncertainty in the stock estimates.

Monitoring of the stock biological status

Data on fish maturity, usually used to calculate the spawning stock, are the supplementary data necessary for a development of advice. One of the main criteria for stock management is the spawning stock biomass. Actual data on cod maturity are available only from 1982; earlier, fixed values, i.e. knife-edge ogive (all fish at age below 8 were assumed to be immature and those at or above 8 - mature), were used. However, a period of cod maturity is known to be prolonged, with rather essential variations in the maturity rate being observed during a 50-year period of observations. The maturity rate has increased during that period (Ponomarenko and Yaragina, 1994; Jørgensen, 1990). Besides, the spawning stock value is not always precise and flexible parameter of cod reproductive potential (Marshall et al., 1998). Others, more precise parameters, are necessary to be found.

In connection with a development of multispecies approach to modelling, it was necessary to have a detailed database on fish feeding. It was developed owing to joint efforts of scientists from IMR and PINRO (Mehl and Yaragina, 1992) and it is one of the examples of successful co-operation between the scientists of both countries. Based on it, the abundance of young cod (and of other marine organisms) consumed by the cod itself is being calculated, and the stock recruitment corrected. Cannibalism grows when the abundance of major food objects (capelin, young herring) is low. The cannibalism was especially high in 1994-1997, when the biomass of juveniles consumed by the cod itself attained 230-520 thousand tonnes, compared to 10-45 thousand tonnes in the mid-80-ies (Korzhev and Tretyak, 1989; Bogstad et al., 1994; ICES, 1999b) (Figure 1).

The considered stock inhabits the margin of its area, no other cod stock is distributed so far northward. Therefore, natural fluctuations in the abundance of cod, its food objects, competitors and predators, are rather significant in the Barents Sea ecosystem. Large-scale mixed species fisheries in the area surveyed is a major factor of population dynamics. To manage the stocks it is necessary to have objective, complete fisheries statistics and reliable data on catch composition. In addition it is important to have regular monitoring of stock size and population biological parameters, as well as monitoring of oceanographic conditions, food supply and feeding of fish. Theoretical models of commercial communities should also be improved.

Summary of uncertainties relating to assessment methods and management advice

In the scientific community there has been a lot of discussions and analyses relating to the problems with the assessment of Northeast Arctic cod in recent years (Pennington 1999). Besides the methodological problems of properly treating the large variability in cannibalism, growth and maturity (Table 1), there also seem to be problems related to some of the data from surveys and landings. The variation between neighbouring years ("random noise") does not appear to be particularly large, but there could be biases that changes over longer periods. It seems to be a common understanding that an important part of the problem is that the surveys and the landings show different time trends or periodic cycles. This could be caused by changes in the part of the mortality not explained by landings and cannibalism (other predators and/or misreported catch). It could also be caused by changes in survey methodology and/ or the availability of the stock to the survey method. It is likely that there has been a general increase in the overall "survey catchability" due to changes in survey methodology. In the late 80-ies and early 90-ies improved acoustic equipment and equipment for monitoring trawl performance were introduced, and the investigated areas increased. For some of the survey time series the ratio between survey estimates and the estimates based on landings at age analysis (VPA) show periodic changes which are negatively correlated with the size of the capelin stock (Figure 2). This indicates that some biological processes might be involved (mortality and/or fish availability to the survey method). Until the underlying mechanisms are fully understood, it is difficult to take such patterns fully into account in the assessment.

The reference points, defined in the first section of this document, are strongly related to the stock –recruitment relationship. Figure 3 shows the scatter-plot of corresponding values of recruitment and parent stock for Northeast Arctic cod. As can be seen the "biomass threshold where recruitment is impaired" (B_{lim}) is not very obvious. It has been set at 112 000 tonnes, the lowest biomass observed. By a standard calculation procedure, data on stock, recruitment and fishing mortality have been used to obtain the value of 0.7 for F_{lim} ("the F which will drive the spawning stock to B_{lim}"). The obtained values of B_{lim} and F_{lim} are regarded to be rather uncertain, both due to the large scatter of the observations and due to the uncertainties mentioned regarding historic values of natural mortality, weight at age, maturity and spawning potential. It is worth noticing that the average recruitment close to B_{lim} is somewhat lower than at higher biomass.

The proposed value of $F_{pa} = 0.42$ is obtained by setting a safety margin towards F_{lim} corresponding to the estimated uncertainty of F_{lim}.

The proposed value of B_{pa} (500 000 tonnes) is equal to the value of the formerly used MBAL (Minimum Biological Acceptable Level). When the stock is below this value action should be taken to prevent further decline towards B_{lim}. In this case with large uncertainty both for the assessment and for the estimate of B_{lim} it is important to have that large "buffer" between B_{pa} and B_{lim}.

It might be argued that in view of the stock history, the proposed reference points appear to be rather restrictive, since the stock still exists after long periods with a spawning stock below B_{pa} and a fishing mortality above F_{pa} (Figure 4). It should be noticed that the spawning stock showed a steady decreasing trend, only interrupted by some temporary peaks, over the period 1946-1987. This means that the stock did not sustain the high fishing mortality, and the risk of a severe collapse would have increased if not action had been taken in the late 80-ies.

Another weakness of the reference points in general is that in many respects they reflect average conditions over the time series. In theory, changes in environmental conditions like food availability, predator abundance and temperature could alter the reference points. At the present state of the art the ability to predict such conditions and the knowledge on how they influence the reference points are too poor to contribute to any improvement of the advice on management.

For the short term advice the uncertainty of the assessment is much more critical than the uncertainty of the reference points. Therefore, the research needs to focus on improving the assessment. As indicated above an improved statistical and biological understanding of the data is important for an improved assessment. A new assessment model has been developed for the purpose of making progress in that respect.

List of references

Andersen K. and Ursin E., 1977. A Multispecies Extension to the Beverton and Holt Theory of Fishing, With Accounts of Phosphorus Circulation and Primary Production. Medd. Dan. Fisk. Havunders. , V. 7, p. 319-435.

Baranov F.I., 1918. On the question of the biological basis of fisheries. Izv. otdela rybovodstva i nauchno-promyslovykh issledovanij, 1 (1), 21 pp.(in Russian).

Baranov F.I., 1960. On optimal intensity of fishing. Proceedings of Kalinigrad institute of fisheries, V. 11:3014(in Russian).

Beverton R.J. and Holt S.J., 1957. On the dynamics of exploited fish population. Fish. Inv., ser.2, v. 19, 533 pp.

Bogstad B., Lilly G., Mehl S., Palsson O.K.and Stefansson G. Cannibalism and year-class strength in Atlantic cod (*Gadus morhua* L.) in Arcto-boreal ecosystems (Barents Sea, Iceland, and eastern Newfoundland). *ICES mar.Sci.Symp.*, 198:576-599.

Dementyeva T. F. and E. M. Mankevich, 1965. Changes in the growth rate of the Barents Sea cod as affected by environmental factors. ICNAF. Special publ., No 6 : 571-577.

Gulland J.A., 1965. Survival of the youngest stages of fish and its relation to year-class strength . ICNAF, Special Publication, N 6:363-371 .

ICES, 1994. Report of the Arctic Fisheries Working Group. ICES C.M.1994/Assess:2, 240 pp.

ICES, 1995. Report of the Arctic Fisheries Working Group. ICES C.M.1995/Assess:3, 252 pp.

ICES, 1996. Report of the Arctic Fisheries Working Group. ICES C.M.1996/Assess:4, 311 pp.

ICES 1999a. Report of the ICES Advisory Committee on Fishery Management, 1998. ICES Cooperative Research Report no. 229, part 1.

ICES, 1999b. Report of the Arctic Fisheries Working Group. ICES C.M.1999/ACFM:3, 276 pp.

Jakobsen T. 1993. Managment of Northeast Arctic Cod: Past, Present - and Future?. Proceedings of the International Symposium on Managment Strategies for Exploited Fish Populations, Alaska Sea Grant College Program, AK-SG-93-02, p.321-338.

Jakobsen T. , Korsbrekke, Mehl S. and O. Nakken, 1997. Norwegian combined acoustic and bottom trawl surveys for demersal fish in the Barents Sea during winter. ICES CM 1997/Y:17.

Jørgensen T., 1990. Long term changes in age at sexual maturity of Northeast Arctic cod (*Gadus morhua* l.). J.Cons. int. Explor. Mer.,V. 46: 235-248.

Jørgensen T., 1992. Long term changes in growth of Northeast Arctic cod (*Gadus morhua* l.) and some environmental influences . ICES J. mar. Sci., V. 49: 263-277.

Korzhev V.L., Tretyak V.L., 1989. The effect of cannibalism on the strength of recruitment to commercial stock of Arcto-Norwegian cod. ICES Symp. on Multispecies Model. Paper N 37, 16 pp.

Lepesevich Yu. M. and Shevelev M.S., 1997. Evolution of the Russian survey for demersal fish: From ideal to reality. ICES CM 1997/Y:09, 10pp.

Mankevich E. M., 1966. Methods of taking and reading the age samples of cod. Materialy rybochoz. issledov. Severnogo basseina, Murmansk, v. 7 p.53-56 (in Russian).

Marshall , C.T., Kjesbu O.S., Yaragina N.A., Solemdal P., and Ulltang O.,1998. Is spawner biomass a sensitive measure of the reproductive and recruitment potential of Northeast Arctic cod? Can. J. Fish. Aquat. Sci. 55: 1766-1783.

Mehl, S. and N. Yaragina, 1992. Methods and results in the joint PINRO-IMR stomach sampling program. Proceedings of the fifth PINRO-IMR Symposium, Murmansk, 12-16 August 1991, B.Bogstad and S.Tjelmeland editors, IMR 1992.

Nakken O., 1994. Causes of trends and fluctuations in the Arcto-Norwegian cod stock. ICES mar. Sci. Symp., 198: 212-228.

Nakken O. and Raknes A., 1987. The distribution and growth of Northeast Arctic cod in relation to bottom temperatures in the Barents Sea, 1978-1984. Fisheries Res., No. 5: 243-252.

Nilssen E.M., Pedersen T., Hopkins C.C.E., Thyholt K., and J.G. Pope. 1994. Recruitment variability and growth of Northeast Arctic cod: influence of physical environment, demography, and predator-prey energetics. *ICES mar.Sci.Symp.*, 198: 449-470.

Ozhigin V. K., Yaragina N.A., Tretyak V.L., and V.A. Ivshin, 1996. Growth of Arcto-Norwegian cod. Murmansk, PINRO Press, 59 p. (in Russian).

Pennington, M. 1999. Report of the Workshop on Comparison of Stock Assessment Model Strategies, with Application to North-east Arctic Cod, Bergen, 1-4 Dec. 1998. Fisken og Havet no.4, 1999, IMR, Bergen, Norway.

Ponomarenko V.P., Ponomarenko I. Ya. and N.A. Yaragina, 1985. Changes in growth and maturation of the Barents Sea cod . A theory of formation of abundance and rational exploitation of commercial fish stocks. Moscow, Nauka: 73-82 (in Russian).

Ponomarenko I. Ya. and N.A.Yaragina, 1994. Maturity rate of the Lofoten-Barents Sea cod in 40's and 90's. ICES CM 1994/ G:30, 17pp.

Rollefsen G., 1933. The otoliths of the cod. FiskDir. Skr. ser. HavUnders., N 4 (3):1-14.

Shevelev M.S., Mamylov V.S., Ratushny S.V. and E.N. Gavrilov , 1996.Technique of the Russian Trawl-acoustic Survey of the Barents Sea Bottom Fish and Mechanisms to Improve it. NAFO SCR. Doc 96/91, 91 pp.

Stefanson G.and O. Palsson (Edc.), 1997. BORMICON. A Boreal Migration and Consumption model . Marine Research Institute Report 58, 223 pp.

Tjelmeland S. and B. Bogstad, 1998. Biological Modeling. Models for Multispecies Managrment. Tor Rodseth.- Heidelberg: Phisica-Verlag, p. 69-91.

Tretyak V.L., 1984. A method of estimating the natural mortality rates of fish at different ages (exemplified by the Arcto-Norwegian cod stock). The Proceedings of the Soviet-Norwegian Symposium on Reproduction and Recruitment of Arctic cod, P.241-274.

Yaragina N.A., Nedreaas K.H., Mjanger H., Koloskova V.P. and P. Aagotnes, 1998. Differences in age determination of North-East Arttic cod. Consequences and improvements through regular exchange of material and personnell. Symp. “Fish Research and Application “ Bergen, Norway, June 1998, Poster 214.

Table 1. Uncertainties related to cod assessment methods

Method	Uncertainties
Using the analytical mathematical methods (VPA) adopted within the framework of ICES	Methodological problems: - XSA tuning method is very sensitive to choosing the age at which the catchability (q) depends on year-class abundance - natural mortality coefficient varies by age groups (Tretyak, 1984) and is not constant (M=0,2)
Using the elements of multispecies modeling to estimate cod cannibalism	Methods of calculating rations have not been completely agreed and are at the stage of elaboration. There are problems of including cannibalism in the standard VPA calculations
Using long-term/running means for short- and long-term forecasts	There no adopted models of forecasting recruitment, growth, maturation, temperature, abundance of food organisms, cannibalism included in standard VPA calculations

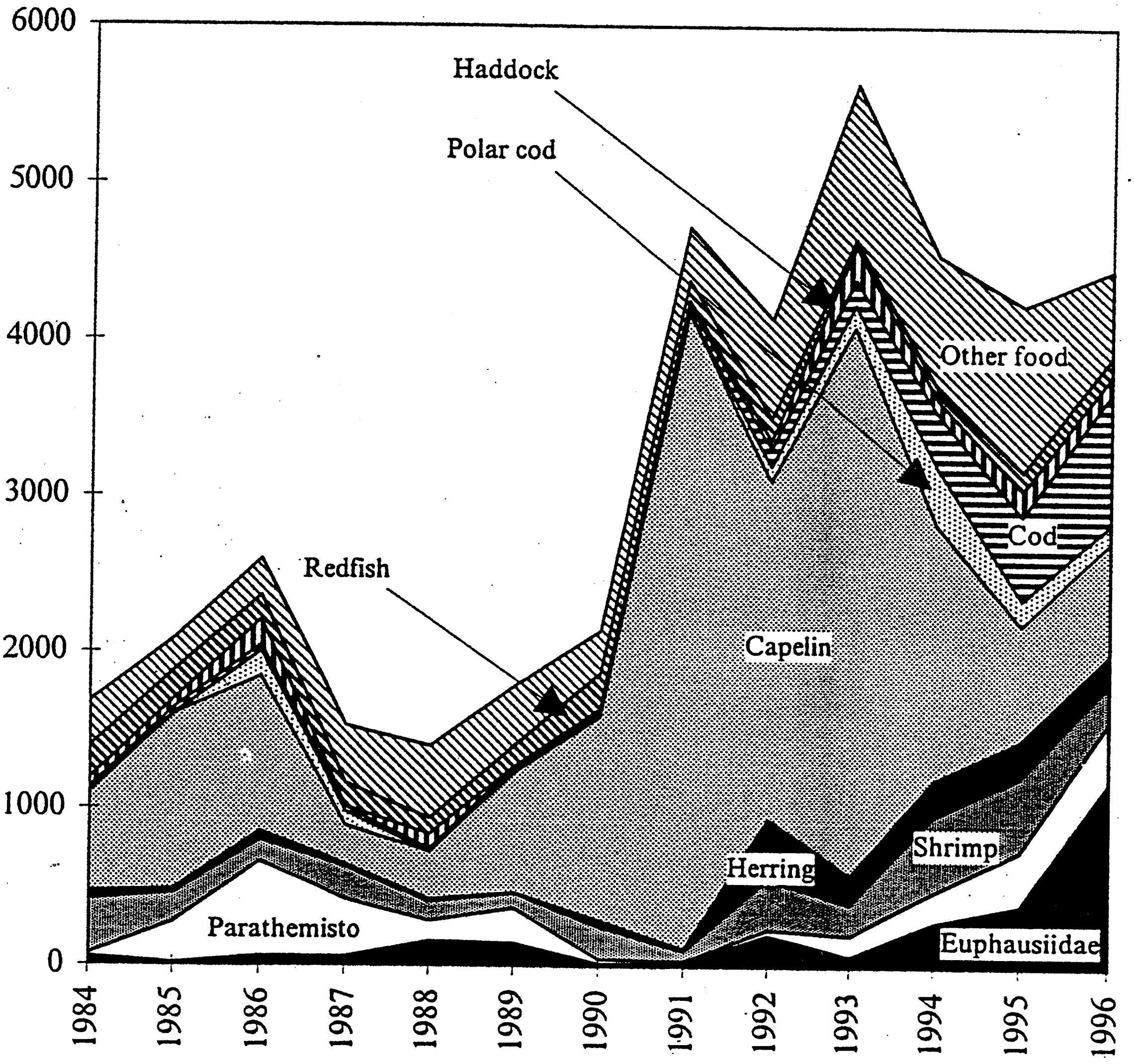
Table 2. Uncertainties related to the data used to assess the cod stock

Routine activities	Uncertainties
Fisheries statistics National and international systems of collecting statistical data on fishing National systems of control over the observance of fishing regulations	It is impossible to control fishing activities of each vessel Illegal catch (including International waters) Unreported catch (from unknown areas and in unknown size) Undersized fish discards are unknown By-catch size in other fisheries is unknown
Monitoring of stock biological parameters Systems of collecting fisheries and biological data on age composition, length and weight of fish caught	Applying actual data on fish weight since 1983 and fixed values for 1946-1982 Differences in methods and results of cod age reading by IMR and PINRO Using actual data on ogives of fish maturation since 1982 and fixed values (knife-edge curve) for 1946-1981 Using actual data on cod feeding since 1984. The lack of data for previous (1946-1983)
Stock surveys Carrying out annual instrumental stock surveys to estimate abundance and collect biological data	Heterogenity of survey time series as a result of: - change of survey techniques - acoustic problems - incomplete coverage of fish distribution areas due to climatic changes, as well as political and financial problems

Table 3. List of surveys used in cod stock assessment

Name	**Place**	**Season**	**Years**	**Indices**
International 0-group survey	Barents sea and adjacent waters	August	1966-1998	Abundance indices
Russian trawl young fish survey	Barents sea and adjacent waters	Autumn-Winter	1949-1980	Numbers per hour trawling
Russian bottom trawl	Barents sea and adjacent waters	October-December	1981-1998	Numbers per hour trawling
Russian acoustic	Barents sea and adjacent waters	October-December	1985-1998	Stock numbers by age in millions
Norwegian bottom trawl	Svalbard	September-October	1983-1998	Abundance indices (millions)
Norwegian bottom trawl	Barents sea	January-March	1981-1999	Abundance indices (millions)
Norwegian acoustic	Barents sea	January-March	1981-1999	Stock numbers by age in millions
Norwegian acoustic on the spawning grounds	Lofoten	March-April	1984-1999	Stock numbers by age in millions
Russian ichthyoplankton	Norwegian and Barents sea	April- July	1959-1993	Numbers per net
Norwegian bottom trawl	Barents sea and adjacent waters	August-September	1990-1998	Abundance indices (millions)

Figure 1. **Biomass of preys consumed by cod in 1984-1996**



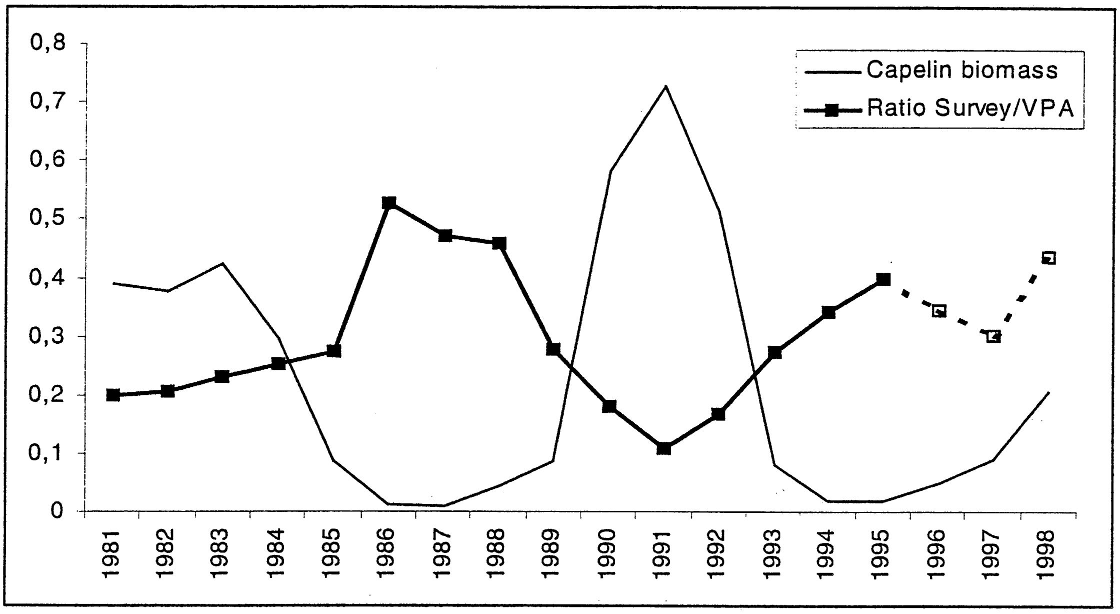


Figure 2. The ratio between survey estimates and VPA estimates of Northeast Arctic cod (number of fish at age 3 and older), compared to the biomass of capelin (as estimated in the autumn capelin survey, unit 10 mill. Tonnes). The survey estimates of cod are from the Norwigian bottom trawl survey during winter.

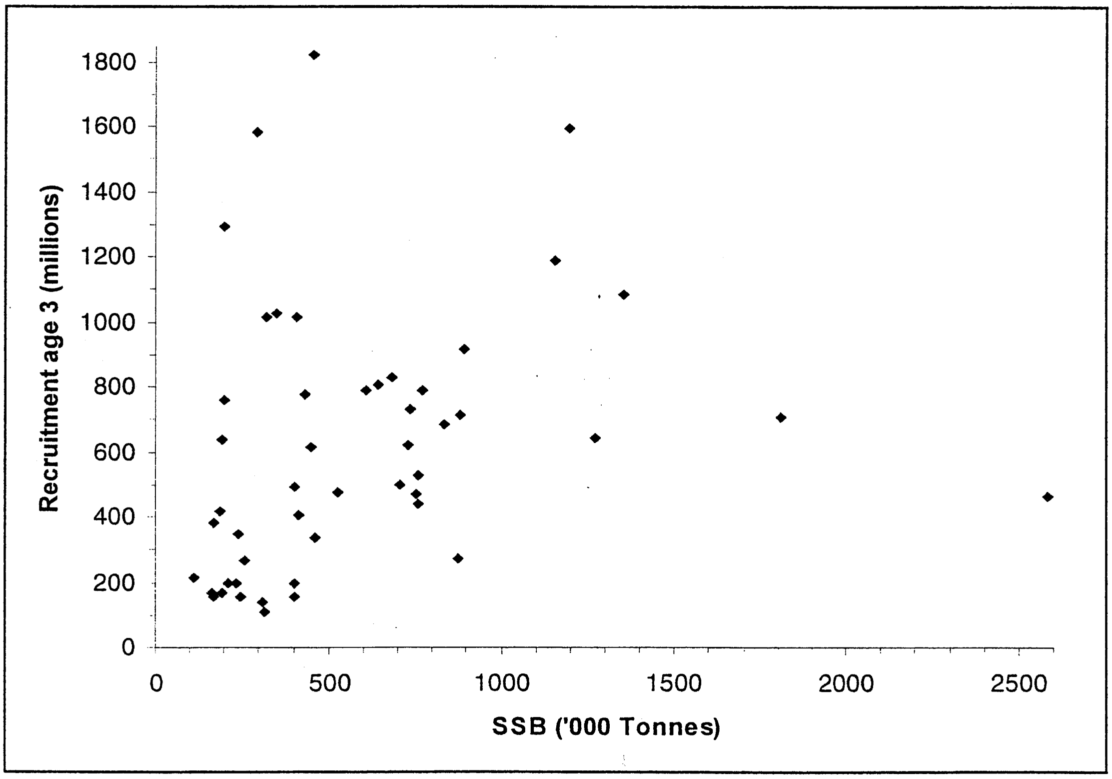


Figure 3. Corresponding values of recruitment and parent stock for Northeast Arctic cod for the year classes 1943-1994.

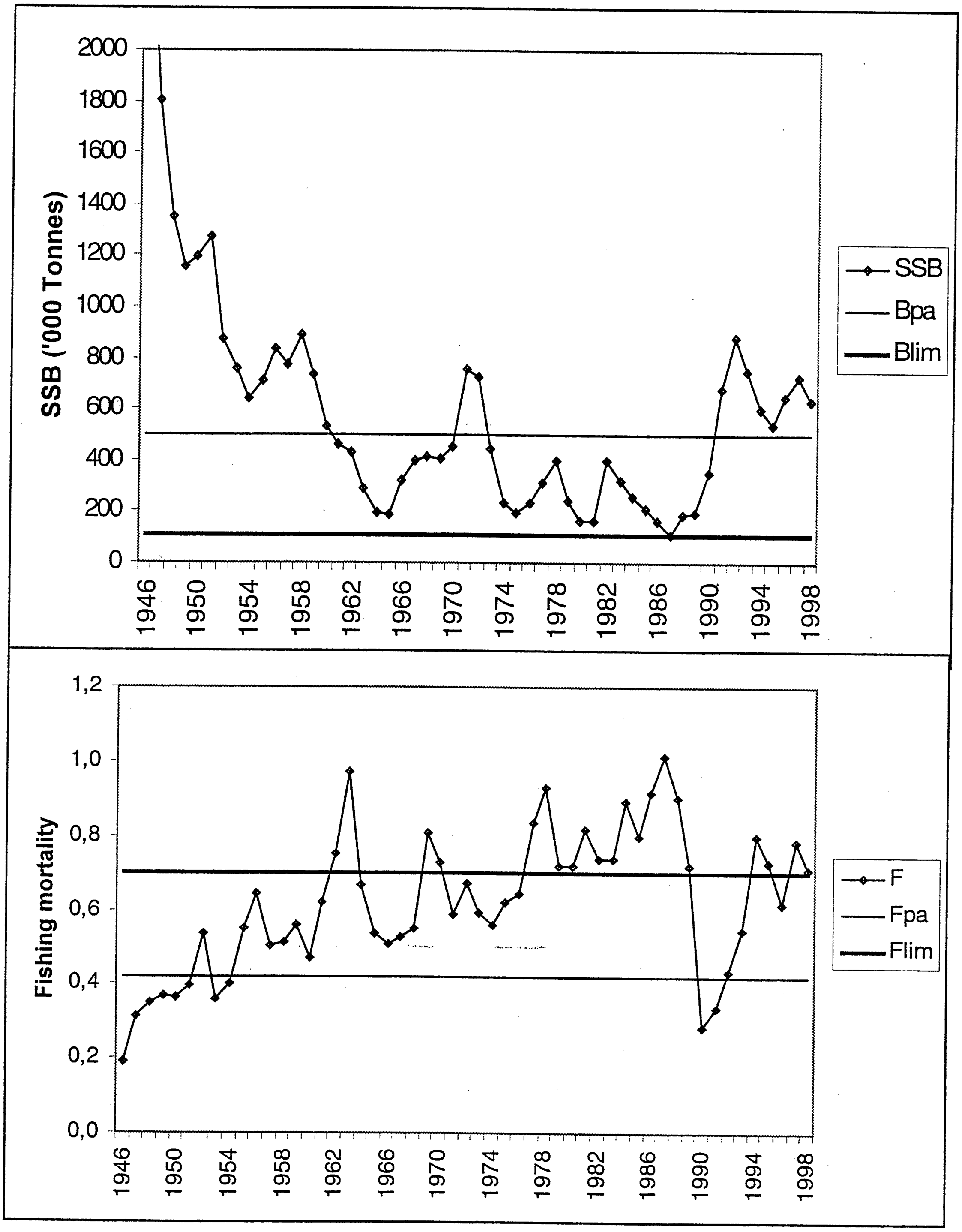


Figure 4. Historical development of spawning stock (upper panel) and fishing mortality (average for age groups 5-10, lower panel) compared with the proposed reference points (straight lines).

Paper to the 8th Norwegian-Russian symposium Management strategies for the fish stocks in the Barents Sea

Harvesting control rules and future development of the precautionary approach – Northeast arctic cod as an example

Sigurd Tjelmeland, IMR
Viktor Tretyak, PINRO

Introduction

There are basically two different considerations in management of straddling and highly migratory fish stocks. On the one hand, these stocks should be managed in compliance with international demands that the stocks are not put into jeopardy by excessive fishing (Anonymous 1995). To this end a set of criteria based on the precautionary approach has been developed, although their basis in scientific knowledge are often obscure. On the other hand, merely complying with precautionary approach in the sense that the stock should have a small risk of immediate collapse or recruitment failure is in itself a long-term management rule that could be sub-optimal. Thus, the question arises what is the "best" management. For many stocks an initial lowering of quotas may lead to a growth that would yield higher quotas in the long term than would have been obtained just by keeping the stock above the danger level.

The effect of fishing in the long run is to diminish the spawning stock and thereby reducing the expectation value of the number of recruits. The single most important problem to solve for an optimal harvesting control rule to be established is therefore that of estimating a stock-recruitment relation from data. The difficulties associated with inferring such a relationship from erratic "shot-gun" plots have precluded the establishment of an optimal harvesting control rule for most fish stocks. For the stocks in the Barents Sea one have until present day tried to regulate only the capelin stock by a management rule based on the principle of maximising long-term yield and using a simulation model and a stock-recruitment relation estimated from data (Hamre and Tjelmeland 1982).

In autumn 1991 ICES changed the form of management advice. ACFM now defines its objective to be: "To provide the advice necessary to maintain viable fisheries within sustainable ecosystems" (Serchuk and Grainger 1992). If the stock is considered "within safe biological limits", ICES only provides options, i.e. calculations of stock and catch trajectories a few years into the future. The strategy for keeping the stock on safe grounds is to try to maintain an F-value low enough for the stock not to be driven into collapse. A "dangerous" F-value – referred to as F_{lim} is defined as the F-value that will lead to a collapse or the F-value that will during static conditions produce the smallest observed spawning stock biomass. Then the quota is set at a level that gives a small probability for this F-value to be realised taking into account the uncertainties connected to the assessment and the population dynamics in the short run. See the work of the ICES study group on the precautionary approach (Anonymous 1998) for technical details.

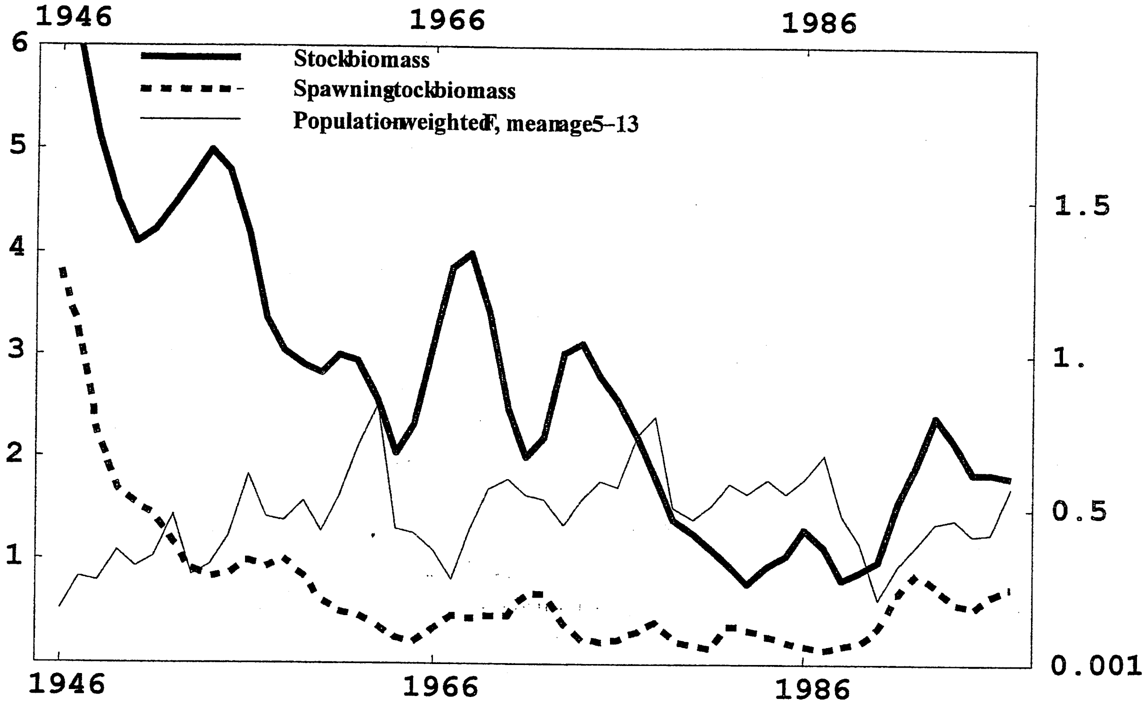
Corten (Corten 1993)strongly argues that managers may tend to regard MBAL (Minimum Biologically Accepted Level, a forerunner to the present-day B_{lim} , which is a biomass equivalent of F_{lim}) as a lower bound on management objectives, rather than as a limit below which great damage to the stocks can occur. This should be avoided at all costs.

The present paper focuses on the discrete uncertainty from conflicting but plausible assessments and on the generalised method for evaluating harvesting control rule.

Management of the Northeast arctic cod stock

Figure 1 shows the recent stock history of the Northeast arctic cod stock . Since the 1950s there was a gradual although fluctuating downwards trend until the rich 1983 yearclass gave rise to a recovery of the stock. The downward trend is concurrent with an increasing trend in fishing mortality. This may be interpreted as evidence of mis-management, too high catches led to stock decline through recruitment overfishing.

Figure 1. Recent stock history of Northeast arctic cod. Stock biomass (million tonnes) left axis, F-values right axis



Part of the problem has been that recommendations have not been strictly adhered to (Nakken 1998). The advice from ICES was to bring the F-value down towards F_{max}, which is the fishing mortality that gives the optimal catch if the recruitment is independent of the spawning stock. The F-values actually generated on the stock were substantially larger. However, the philosophy behind F_{max} only deals with optimising a balance of gain from increased weight and loss through natural mortality. The real danger is recruitment overfishing, which never was signalled from ICES bodies. The reason for this is that the spawning stock-recruitment plots at the time gave little evidence for larger recruitment with larger spawning stock, such an effect was totally masked by recruitment fluctuations due to random change of environment.

If the declining trend is due to recruitment overfishing the rationale behind using F_{med} as a guideline for management fails. F_{med} is thought of as the fishing mortality that in the long run will lead to the stock replenishing itself. But if F_{med} is calculated using data from a period when the stock did not replenish itself the calculated F_{med} would probably be too high. However, the stochasticity in the spawning stock – recruitment relation works the opposite way: the strong year-classes influences more on the positive side than do the weak year-classes on the negative side, which can be shown by simulation. It is therefore difficult to a priori judge how the F_{med} calculated from the above time series will work in the long run.

The precautionary approach

With the UN convention on straddling fish stocks and highly migratory fish stocks agreed biological reference points are important for a successful international management. The UN convention defines a precautionary reference point as "- an estimated value derived through an agreed scientific procedure, which corresponds to the state of the resource and of the fishery, and which can be used as a guide for fisheries management" (Anonymous 1995). The FAO document divides reference points into limit reference points "within which the stocks can produce maximum sustainable yield" and target reference points that are intended to meet management objectives.

The precautionary approach to management of fisheries states in essence that the more uncertain the assessment is, the lower the quota should be. This is achieved by demanding that the probability that the stock falls below a certain limit does not exceed some prescribed value. Thus, it is essential to evaluate the uncertainty both in the perceived stock and in the processes that affects the stock development. In addition, the limit value of the stock and the associated probability should be based on simulation experiments. In summary, the following entities must be determined:

1. The probability distribution of the present stock
2. The probability distribution connected to parameters in the equations that describe the stock dynamics, such as natural mortality, weight at age, exploitation pattern
3. The length of the prognostic runs
4. The limiting value and the associated probability

Methods for developing the necessary probability distributions for cod has not yet been developed, although this process has started in the ICES Arctic Fisheries Working Group (hereafter called WG) in that the medium-term forecast made the autumn 1998 was made probabilistic with an assume CV on the assessment of 0.3 on log-scale.

In order to elucidate the significance of a precautionary approach to the management of the cod stock in the present paper several of the necessary probability distributions will be developed. Also, uncertainties connected to the model formulation will be dealt with, i.e. the assumption made in the WG that the natural mortality for fish of age 3 and older is constant for all ages, for all years and equal to 0.2 will be challenged.

Changing role for managers?

Broadly speaking, the role of the scientists may by the managers have been perceived as suggesting a quota based on biological criteria, while the managers' role has been to adjust the quota if they have found it appropriate to take into consideration other non-biological factors or biological factors other than those considered by the scientists. An example of the former is that for many years ACFM kept giving advice on reducing the F-level of Northeast arctic cod to F_{max} while the quota set by the Mixed Russian-Norwegian Fishery Commission corresponded to a considerably higher F. This can be perceived as discounting the stock on socio-economic grounds. An example of the latter is the quota on capelin set by the Commission in 1986, where the quota was reduced with respect to that proposed by the scientists, probably because the capelin's role as source of food was considered.

With the inclusion of the precautionary approach the role of the managers changes even deeper, and the new paradigma poses large challenges to managers. Because the managers should be responsible for formulating the objective function underlying target reference points and for the maximum allowed probability for exceeding reference points, they should acquire a deep understanding of the methods and models underlying the reference points. A better dialogue between managers and scientists is called for.

Uncertainties in the assessment

The uncertainties associated with the yearly assessment fall into two categories: uncertainties in parameters estimated through the tuning procedure and uncertainties regarding the models chosen for the population dynamics and for the observation model.

The uncertainties associated with estimated parameters are expressed in the form of probability distributions that are easily implemented into procedures for evaluating harvesting control rules and performing medium-term predictions. Uncertainties as to which models for the population dynamics and observations are the most appropriate are more difficult to handle. If not convincing arguments can be given from inspection of residuals or from independent information one inevitably is left with different scenarios.

The assessment model

The assessment model XSA (Darby and Flatman 1994) that has been used for Northeast arctic cod is based on calculating the catchability parameters and the F-values in the terminal year and for the oldest age group by least-squares after taking logarithms. This method has advantages as to computer speed, but since it does not use a likelihood function it is difficult to evaluate the statistical properties. In the present paper the assessment model is the same as was used for tuning Norwegian spring spawning herring in 1998, which enables a comparison between different assumptions about the error structure of the observation model. Two different structural assumptions will be used: gamma with constant CV and lognormal, where the latter should give comparable solution to the XSA. A change from basic XSA assumptions were made regarding how the catchability depends on age. XSA uses a power function in addition to a subjectively determined age above which the catchability is independent of age. In the present implementation the function 1 – Exp(-age/par) was used which achieves approximate linearity with age for old fish without the subjective assumption of a cut-off age. This formulation is an advantage that cannot be implemented in XSA where parameters are by taking logarithms and solving a linear system of equations, but at the cost of greatly increased computer time because of the comparably slower process of parameter estimation. XSA uses also dependence on abundance, which was not tested in the present implementation.

The XSA has proved to be unstable, giving very different results for different plausible parameter settings. Because of this work has been undertaken to improve the assessment by constructing a length-based assessment model based on maximising a likelihood function, where also the catches are modelled. The basic analytical tool for the cod assessment is therefore likely to be changed in the near future. .

Natural mortality

The perhaps most unsatisfying feature of the current assessment of the stock is that the natural mortality – decided to be 0.2 – is assumed constant for all fish of 3 years and older, and constant for all years. Furthermore, this value is not based on any estimation from data. Based on research work done at PINRO (Tretyak) we have substituted the constant natural mortality of 0.2 with estimated values (Table 1). Consequently, we have performed 4 different assessments, using to different assumptions on the distribution of the surveys and two different assumptions on the natural mortality.

The variable M is based on the assumption that the natural mortality changes throughout the life of a fish according to the formula

$$\frac{dM(t)}{d(t)} = -a\,\frac{\left(t - \overline{t}_s\right)}{\left(t - t_e\right)}$$

where t_s is the mean age of spawners and t_a is the oldest attainable age. a is a constant to be estimated. The solution is the function

$$\mathbf{M(t) = a \cdot (- t - (t_e - \overline{t}_s) \cdot \ln(t_e - t)) + b}$$

Which is dome-shaped, with a minimum at t_s. Table 1 gives the estimated values.

Table 1. estimated natural mortality for Northeast arctic cod

Age, years	Generation, years	Fishing years												
	1950	1952	1951-1953	1968-1970	1987-1989	1988-1990	1989-1991	1990-1992	1991-1993	1992-1994	1993-1995	1994-1996	1995-1997	1984-1997
3	0.230	0.225	0.245	0.251	0.159	0.165	0.162	0.112	0.099	0.079	0.060	0.041	0.050	0.077
4	0.219	0.214	0.234	0.238	0.139	0.153	0.151	0.101	0.087	0.065	0.043	0.024	0.032	0.060
5	0.210	0.204	0.224	0.227	0.123	0.143	0.143	0.093	0.078	0.055	0.031	0.011	0.019	0.049
6	0.203	0.197	0.217	0.218	0.111	0.137	0.139	0.088	0.073	0.050	0.025	0.004	0.011	0.042
7	0.199	0.192	0.212	0.211	0.105	0.135	0.138	0.089	0.073	0.050	0.024	0.004	0.010	0.041
8	0.197	0.190	0.210	0.206	0.104	0.138	0.140	0.093	0.078	0.056	0.030	0.010	0.015	0.046
9	0.197	0.190	0.211	0.204	0.110	0.144	0.147	0.103	0.089	0.068	0.044	0.024	0.029	0.058
10	0.201	0.194	0.214	0.205	0.123	0.157	0.159	0.119	0.107	0.088	0.066	0.048	0.052	0.078
11	0.208	0.201	0.222	0.209	0.145	0.175	0.177	0.142	0.132	0.116	0.097	0.081	0.084	0.108
12	0.218	0.213	0.232	0.217	0.176	0.200	0.200	0.173	0.166	0.155	0.140	0.127	0.129	0.148
13	0.232	0.228	0.248	0.228	0.218	0.232	0.231	0.213	0.210	0.204	0.195	0.187	0.188	0.200
14	0.251	0.249	0.268	0.244	0.273	0.274	0.269	0.263	0.265	0.267	0.267	0.263	0.264	0.267
15	0.275	0.276	0.293	0.264	0.344	0.327	0.318	0.326	0.335	0.347	0.356	0.360	0.360	0.352
3-15	0.218	0.213	0.233	0.225	0.164	0.183	0.183	0.147	0.138	0.123	0.106	0.091	0.096	0.117

Based on the above estimates of the natural mortality there seems to have been a declining trend with the declining stock, however not sufficient to counteract the negative impact from the high fishing pressure.

We will thus consider 4 different assessments: 1) an assessment close to the traditional XSA assessment, 2) using gamma distribution with constant CV for the surveys, 3) using the above estimated variation of natural mortality and 4) using both gamma distribution of surveys and variable natural mortality. The first variant is hereafter referred to as the standard assessment.

Future: Optimal F in addition to precautionary measures?

The present management situation for Northeast arctic cod is that – as for most stocks – ICES recommends an F-value in a range that will bring the spawning stock below B_{lim} only with a low probability. B_{lim} is by definition a limit value below which there is a noticable probability of recruitment failure. Based on an inspection of the stock-recruitment plot from the assessments made by the Arctic Fisheries Working Group (hereafter Arctic WG) B_{lim} has been set to 400 000 tonnes. For spawning stocks above this level there seems not to have been recruitment failure (Jakobsen 1993). Mace (Mace 1994) suggested that the spawning stock that yields half the maximum recruitment in a theoretical stock-recruitment model should be used as a reference point that should be exceeded with a very small probability. Myers et al (Myers; Rosenberg; Mace; Barrowman, and Restrepo 1994) studied a wide range of reference points and found that $B_{50\%}$ was most reliable and robust. This reference point, although somewhat arbitrary is clearly understandable and operational and will be used in the present paper for that reason. However, some words of caution may be needed. Stocks for which there have been very good recruitment at low values of the spawning stock (Barents Sea capelin is an example) may have the $B_{50\%}$ estimated close to zero, which renders this reference point useless.

However, complying to this rule every year taking as high a catch as possible would be a suboptimal management in terms of maximising yield, the stock would never get a chance of rebuilding to a size where good catches can be expected.

Rule-based management

The yearly objective for management is to achieve certain numerically expressed goals, i.e. the spawning stock should be above 500 000 (Bogstad; Sandberg; Steinseide, and Steinshamn). However, if one is faced with different scenarios giving radically different perceptions of the stock development, expressing the management goal in numeric terms may become a problem because the different scenarios will be conflicting. However, if the management goal is expressed as a rule, the conflict may be greatly reduced. For instance, two scenarios where the stock development differ by a factor of 2, will give management goals that also differ by a factor of 2. But if the management goal can be expressed as a rule, for instance the F-value that in the long run gives the highest yield, the numerical value between the different scenarios will still be large, but the corresponding quotas may be close to each other. The reason for this is that the historic catch that generated the two different historic developments is the same.

Similarly, there may be uncertainties in the assessment due to decisions that must be taken with regard to choice of models for the stock dynamics and error structure of the tuning indices, leading to several alternative assessments that may be equally valid. The perception of the stock situation may thus be conflicting. However, if the management is conducted using a rule, the parameters in the rule may differ accordingly and the final decision of the quota may not necessarily differ so much.

Finally, the present management is presented to the managers in terms of technical terms like F that carry little or no meaning to the decision makers. In contrast a rule-based management will be more easily understood. Continuous development of methods on the scientific level may thus be transparent to the manager, who only needs to consider the rationale behind the management rule.

Maximum sustainable yield

The concept of maximum sustainable yield has been one of the more important guidelines for management, although in recent years guidelines intended to safeguard the stock against collapse in the medium-term have got more attention. However, for reasonably healthy stocks this does not give much advice to the managers, that possibly will tend to advice catches that on the long run are too high for the stock to be maintained at the most productive level.

Maximum sustainable yield is traditionally based on calculations using the replacement line and the stock-recruitment relationship and ignoring trends or fluctuations in the data that are used to calculate these two entities. Instead we will base the calculations on a stochastic model.

A formal optimal management rule based on first principles has not yet been established for the Northeast arctic cod stock. Using a multispecies model Tjelmeland (Tjelmeland 1995) found an optimal F-value of about 0.4, this was however based on outputs from the standard assessment of the stock using XSA. In the present paper the assessment model is made more realistic by introducing an age-dependent natural mortality, which also is used in the simulation model.

In a real management situation the goal of maximum long-term yield should be modified by taking into account price elasticity, which was done by Sandberg et al (Sandberg; Bogstad, and Røttingen 1998) in the medium term. The method and model used in this paper lend themselves readily for such an analysis, but this will not be pursued here, it is the general principles of establishing an optimal rule that is of primary interest.

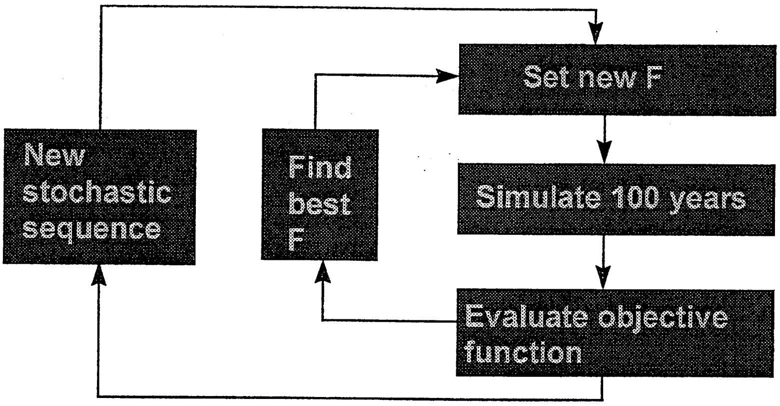
Managing through F

Walters and Parma (Walters and Parma 1996) showed using simple stochastic models that a fixed F policy in general will achieve at least 85% of what would have been achieved if the fluctuations in environmental conditions were known in advance and is thus a fairly robust harvesting control rule. In this paper the optimal F for Northeast arctic cod will be found for 4 different situations: assessment made with gamma or log-normal distribution of tuning series indices and with the natural mortality be constant and equal to 0.2 or being estimated exogeneously.

Scheme for evaluating a harvesting control rule through simulations

The evaluation of a harvesting control rule is outlined in figure 2. The simulation model is started using a fixed initial stock and conducted using a fixed value of the fishing mortality. In the present paper the simulations were run over 300 years and data during the first 30 years were not used to avoid effects of the arbitrary initial stock. Then the objective function is evaluated and another run is made for a new value of the fishing mortality but using the same sequence of stochastic events, i.e. the spawning success is the same in all years. By varying F systematically the F-value that in the long run gives the best outcome is found. In the present paper the best outcome is simply the highest long-time catch, but the method readily lends itself to an elaboration of the success criterium. For instance, a high stability of catches could be valued. Also, the proposed harvesting control rule, which in fact merely is a biological reference point and the stochastic equivalent of F_{MSY} could be elaborated. For instance Scweder et al (unpublished manuscript) have shown that setting a catch ceiling increases the economic benefit of the fishery.

Figure 2. Scheme for evaluating harvesting control rules



Having found the optimal F-value for one set of stochastic events the procedure is re-iterated for another set of stochastic events. A set of optimal Fs are thus found, making it possible to control the uncertainty level of the calculations.

Simulation model

The basic simulation model is the same as used in the assessment. The dependence of F on age is taken as that of the last year in the assessment. The weight at age and proportion mature at age are considered dependent on abundance and interpolated between historic values using the total number of fish in the age range 8-13. Thus, the only major source of uncertainty is the spawning stock – recruitment relation.

Recruitment is modelled by a Beverton-Holt function:

$$\mathrm{Re}\,cruitment = Max\,\mathrm{Re}\,cruitment \frac{SpawingStock}{SpawningStock + B_{50\%}}$$

The number of recruits calculated using the above formula are further modified by cannibalism, temperature effect and the effect of the mean age of the spawning stock by the expression:

$$Modified\,\mathrm{Re}\,cruitment = \mathrm{Re}\,cruitment \times e^{-\mathrm{Im}\,matureBiomass/Cann}\, e^{-Temperature/Temp}\, e^{MeanAgeSpawningStock/Age}$$

where Cann, Temp and Age are parameters to be estimated. A large value for these parameters means that the corresponding effect is not important. The parameters are estimated by assuming lognormal errors. The parameters and the percent variation explained (R2) are shown in Table 2.

Table 2. Estimates of parameters in the spawning stock - recruitment relation for 4 different assessment scenarios

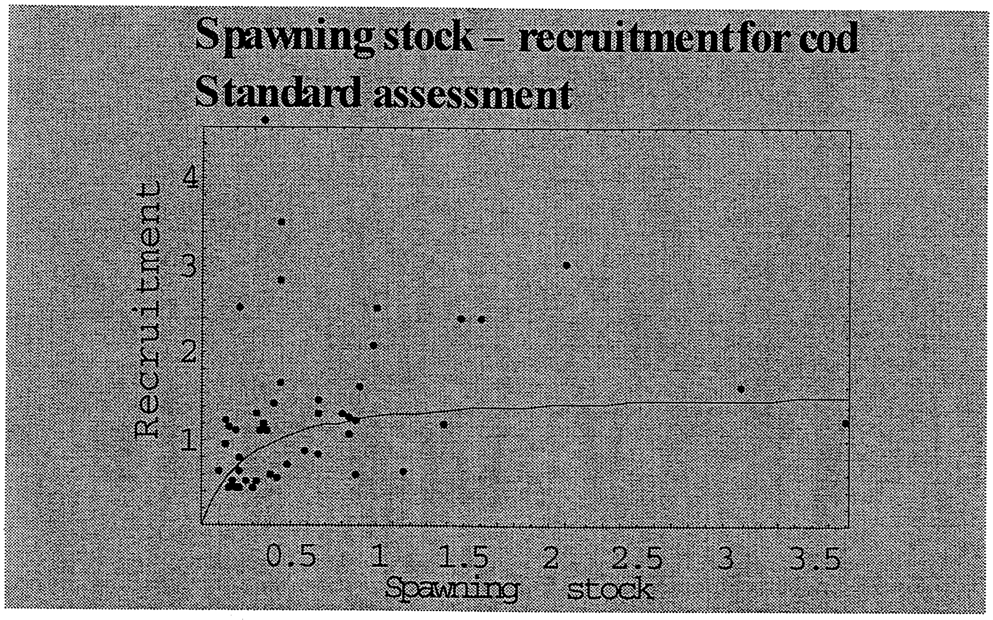
Summary of different cod assessments

	B50	Cann	Temp	Age	R2	B98
						rel. stand.
Standard	0.256	16.718	1.711	97.693	0.355	1.000
Gamma surveys	0.201	8.658	1.638	8.883	0.370	0.923
Variable M	0.234	2397.975	2.067	4.009	0.454	0.999
Gamma surveys, variable M	0.324	5.266	1.777	2.890	0.509	1.023

Generally, the variation in the recruitment is poorly explained by the model. Using variable M gives a clearly better fit. The low values of the parameters for cannibalism, temperature effect and mean spawning stock age effect shows that all these effects are important, with the exception of the age effect in the standard assessment and the cannibalism effect in the assessment using log-normal distribution of surveys and variable M. $B_{50\%}$ is close and in the range 200 to 250 thousand tonnes, with the exception of the assessment with gamma distribution of surveys and variable M, where $B_{50\%}$ is markedly higher. B98 is the 1998 spawning stock biomass relative to what it is in the standard assessment. It is seen that the present perceived stock situation differ little among the different assessment scenarios.

Figure 3 shows the spawning stock – recruitment points in the standard assessment, corrected for cannibalism, temperature effect and mean spawning age effect together with the estimated Beverton-Holt relationship.

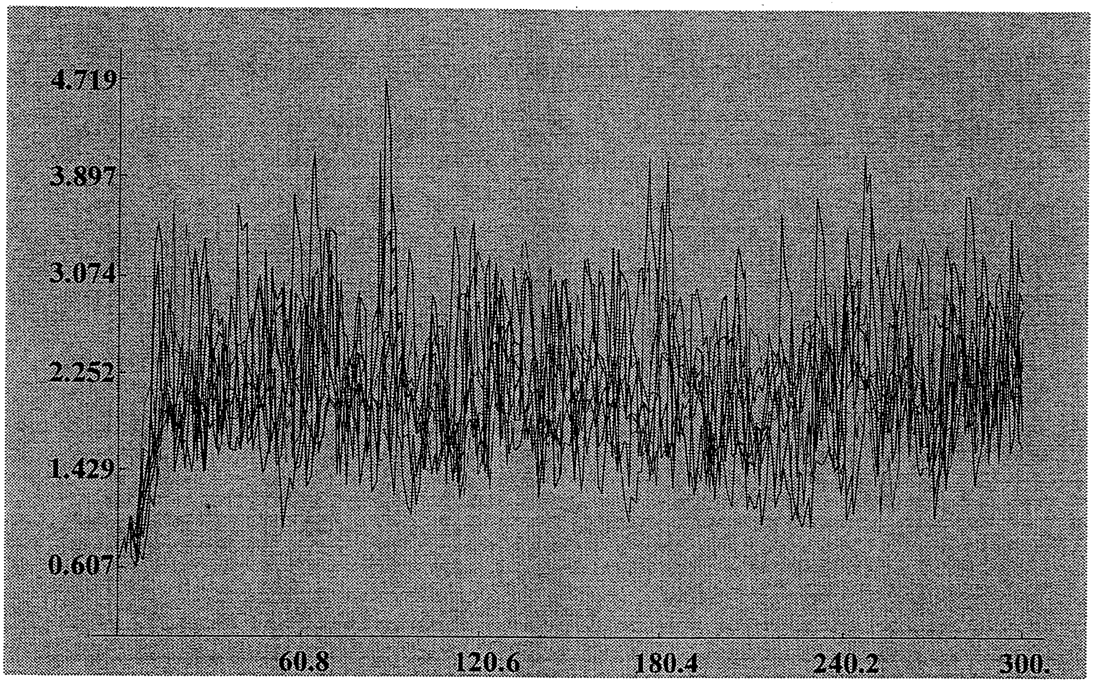
Figure 3. Spawning stock - recruitment points and estimated Beverton-Holt relationship for the standard assessment



There is clearly an increase of recruitment with increasing spawning stock, but the signal is not very strong. Since the above relation is of paramount importance for defining harvesting control rules research into finding improved models should be encouraged.

Figure 4 shows an example of the typical variation for the spawning stock over the simulation period, taken from the standard assessment and for the optimal F-value. It is seen that the spawning stock rapidly builds up to about 2.5 million tonnes and that there is a considerable range of variation.

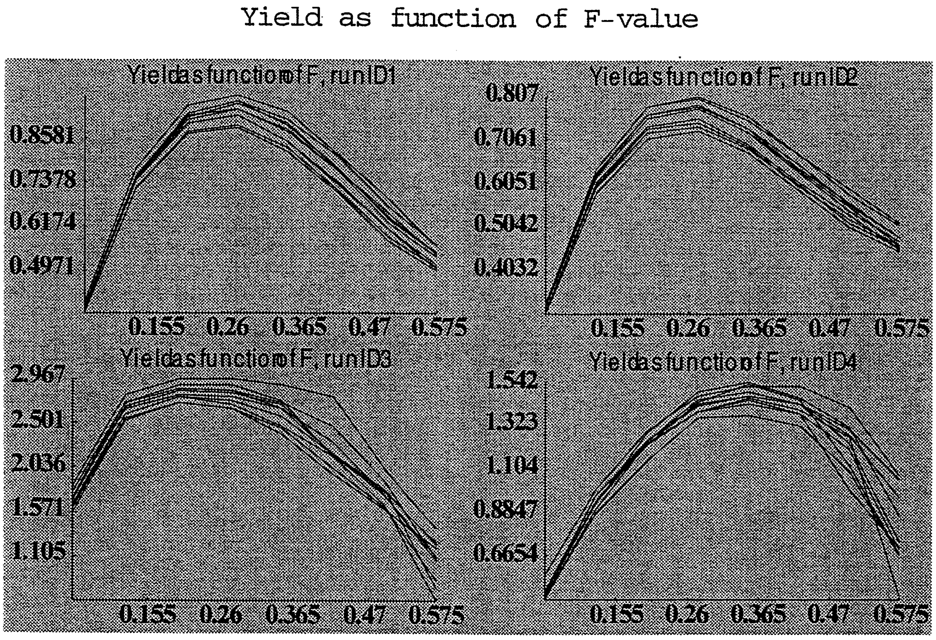
Figure 4. Simulated spawning stock timeseries, standard assessment, optimal F-value



Estimates of F_{opt}

Figure 5 shows the long-term yield as function of F-value for 10 different sequences of stochastic events for the standard assessment (upper left), gamma distribution of surveys (upper right), variable M (lower left) and both gamma distribution of surveys and variable M (lower right).

Figure 5. Yield as function of F for different stochastic sequences and 4 different assessment scenarios



It is seen that the two assessment scenarios with constant M are similar, with an optimal F around 0.27. Using variable M makes the two different assumptions about survey distribution give different perceptions about what is the optimal F-value.

It is interesting to note that the optimal F-values from figure 5 compares favourably with the value of 0.26 obtained by Garrod and Jones(Garrod and Jones), as is the declining trend at F-values above 0.42, which Garrod and Jones maintained would lead to an extinction of the stock in the long run.

Also, the obtained optimal F-values fall into the range 0.25 – 0.45 indicated by Nakken (Nakken; Sandberg, and Steinshamn 1996) using a yield per recruit analysis, an analysis that in addition to the consideration that the spawning stock should be above 500 000 tonnes is used in present-day recommendations for the stock (Bogstad and others).

Simulations made during the 1999 meeting of the ICES Comprehensive Fishery Evaluation WG (Anonymous 1999) indicated an optimal F-value below 0.24. However, cannibalism was not included in the recruitment model used.

Using the harvesting control rules and biological reference points – The short-term simulation

To see how the two reference points will work in practice 200 simulations were made over one year for different quotas. A standard error of 0.3 on the assessment was assumed, in accordance with present practise. It should be noted however that it is possible to evaluate the uncertainty in the assessment using replacement simulation or – when the assessment is statistically based - sampling from the likelihood function using Markov Chain Monte Carlo techniques. The latter method has previously been used in the assessment of Norwegian spring spawning herring (Anon. 1998). For each quota the probability of the spawning stock after one year to be smaller than $B_{50\%}$ and the probability for the realised F-value to be larger than the optimal value found from figure 5 were calculated. The results are shown in figure 6 for each of the 4 assessment scenarios.

Figure 6. Probability of realised spawning stock biomass being smaller than $B_{50\%}$ (broken) and the realised F-value for being larger than the long-term optimum(solid lines) for the standard assessment (upper left), gamma distribution for surveys (upper right), variable M (lower left) and both gamma distribution and variable M (lower right)

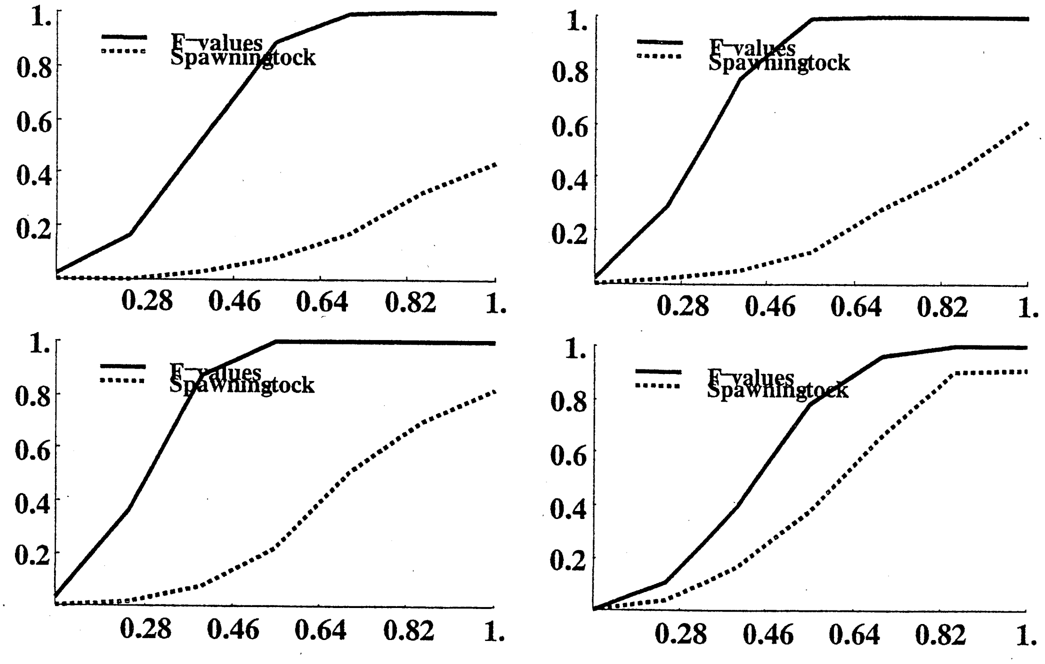


Figure 6 represents the communication of the assessment to the managers. It would be natural to use a 50% probability for the realised F to be smaller than the optimal (target) F and a low probability (less than 10%) for the realised spawning stock to be smaller than the (limit) $B_{50\%}$ spawning stock level. Then it is seen that the target strategy corresponds to the smallest quota in all cases, which one would expect.

All relevant information from the 4 very different assessments are condensed into figure 6. Although the 4 assessment scenarios are based on radically different principles the final outcome of the analysis does not differ very much between the 4 cases.

A note of warning: Multispecies effects

It should be observed that the simulations made in the present paper are strictly single-species. Inclusion of multispecies affects may change the results substantially. When the capelin stock collapsed in the period 1983-1989 the individual growth of the cod decreased (Bogstad and Mehl 1997). Management rules that on the average give a very high stock of cod may thus be too optimistic, in that the average food abundance will not sustain the stock at the perceived level.

PINRO and IMR have conducted joint multispecies research in the Barents Sea since 1985 and several multispecies models have emerged by which species interrelations of importance to managers can be studied (Tjelmeland and Bogstad 1998). These models have not yet resulted in versatile tools for management. Research is ongoing however, and it is expected that the basic philosopy behind the development of harvesting control rules in the future will be essentially multispecies. In view of the biological complexities and parameter estimation difficulties involved, rapid progress in terms of operational harvesting control rules should not be expected.

There has been an attempt of evaluating optimal harvesting control rules for capelin using the capelin-cod model CAPSEX (Anonymous 1998), in which the recruitment to the capelin stock is to a large extent controlled by inflow of occasionally large yearclasses of herring into the Barents Sea. The attempt failed, however, because there was an inconsistency in the input data that led to a vanishing spawning stock of capelin in some years. One of the problems with this model – as with all multispecies models for the Barents Sea that are used for the period before 1984 – is that there are no stomach content data before 1984. If the overlap between the species or the amount of other food were different in, say, the 1970s than from 1984, then errors will be made.

In recent years it has been possible through a joint effort between PINRO and IMR and with sponsoring from the Norwegian Ministry of Foreign Affairs to make parts of the Russian retrospective data base available for joint research (Shleinik; Ushakov, and Tjelmeland 1999). If it is possible to continue this co-operation there may be promise for a future quantification of species interrelations also for the period before 1984. Then multispecies models may come stronger into force when it comes to management of fish stocks in the Barents Sea, resulting in a possibly more rational harvesting from the ecosystem.

Living with discrete uncertainty – a better co-operation between managers and scientists is called for

The decision about what are the most appropriate assumptions to be used in the assessment has been taken by the scientists in the ICES working groups. However, in a precautionary framework the responsibility for decisions and for handling uncertainty is left to the managers, the scientists will decide on what are the most appropriate models and make parameter estimates. If a decision about the error structure of the surveys can be made, this should be viewed as a part of the overall uncertainty in the management and the managers should take responsibility for handling it properly.

Simulation tools can be of great help in this work. In order for the managers to obtain the best possible insight into the uncertainties connected to the assessment and the development of harvesting control rules scientists and managers should find room for to some extent working together using appropriate simulation tools. The suite of simulation tools should contain models that view the ecosystem from different perspectives:

- Single-species models that aim at establishing elementary harvesting control rules, as is the case with the model used in the present paper.
- Multispecies models in which all the parameters are estimated and which are directed towards immediate management use (Tjelmeland and Bogstad 1998),(Tjelmeland and Bogstad 1998).
- Multispecies models that are all-embracing and in which not necessarily all parameters are attempted estimated from data in a formal way (Hamre and Hatlebakk 1998),(Hagen; Hatlebakk, and Schweder 1998). These models may be used in testing "what-if" scenarios.

A working method worth considering is that of setting up a simulation laboratory based on running the models over Internet for certificated users.

References

1. Anon. Report of the Northern Pelagic and Blue Whiting Fisheries Working Group. ICES Headquarters; 1998; ICES CM 1998/ACFM:18.

2. Anonymous. Draft agreement for the implementation of the provisions of the United Nations Convention of the Law of the Sea of 10 December 1982 relating to the conservation and management of straddling fish stocks and highly migratory fish stocks. Sixth session, New Yourk, 24 July-4 August 1995. A/CONF.164/33. 1995.

3. --. Report from the 1998 joint Rssian-Norwegian meeting to assess the Barents Sea capelin stock. Hammerfest, October 6-8, 1998; 1998.

4. --. Report of the comprehensive fishery evaluation working group. 1999; Key Largo, Florida,14-21 January 1999.

5. ---. Report of the study group on the precautionary approach to fisheries management. ICES CM 1998/ACFM:10 Ref.D. 1998.

6. Bogstad, Bjarte and Mehl, Sigbjørn (Institute of Marine Research). Interactions between Atlantic Cod (Gadus Morhua) and its Prey Species in the Barents Sea. Proceedings of the International Symposium of the the Role of Forage Fishes in Marine Ecosystems; 1996 Nov 13-1996 Nov 16; Anchorage. University of Alaska Fairbanks; 1997.

7. Bogstad, Bjarte; Sandberg, Per; Steinseide, Anita Kj., and Steinshamn, Stein Ivar. Beskatningsstrategi for Norsk arktisk torsk. Fiskeridirektoratet; Rapporter og meldinger, 1996 nr. 2.

8. Corten, A. The use of the MBAL concept in management advice. ICES CM 1993/H:19. 1993.

9. Darby, C. D. and Flatman, S. Virtual Population Analysis: version 3.1 (Windows/DOS) user guide. Directorate of Fisheries Research, Lowestoft; 1994.

10. Garrod, D. J. and Jones, B. W. Stock and recruitment relationship in the northeast arctic cod stock and the implications for the management of the stock. J. Cons. Int. Explor. Mer. 36:35-41.

11. Hagen, Gro; Hatlebakk, Einar, and Schweder, Tore. Scenario Barents Sea: A Tool for Evaluating Fisheries Management Regimes. Rødseth, Tor. Models for Multispecies Management. Physica-Verlag; 1998; pp. 173-226.

12. Hamre, Johannes and Hatlebakk, Einar. System Model (Systmod) for the Norwegian Sea and the Barents Sea. Tor Rødseth. Models for Multispecies Management. Physica-Verlag; 1998; pp. 93-115.

13. Hamre, Johannes and Tjelmeland, Sigurd. Sustainable estimates of the Barents Sea capelin stock. 1982; ICES CM 1982/H:45.

14. Jakobsen, Tore (Institute of Marine Research, Bergen, Norway). Management of Northeast Arctic Cod: Past, Present - and Future? Management of Exploited Fish: Alaska Sea Grant College Program; 1993.

15. Mace, Pamela M. Relationships between Common Biological reference Points Used as Thresholds and Targets of Fisheries Management Strategies. Can. J. Fish. Aquat.Sci. 1994; 51:110-122.

16. Myers, R. A.; Rosenberg, A. A.; Mace, P. M.; Barrowman, N., and Restrepo, V. R. In search of thresholds for recruitment overfishing. ICES J. Mar. Sci. 1994; 51:191-205.

17. Nakken, Odd. Past, present and future exploitation and management of marine resources in the Barents Sea and adjacent waters. Fisheries Research. 1998; 37:23-35.

18. Nakken, Odd; Sandberg, Per, and Steinshamn, Per Ivar. Reference points for optimal fish stock management. Marine Policy. 1996; 20(6):447-462.

19. Sandberg, Per; Bogstad, Bjarte, and Røttingen, Ingolf. Bioeconomic advice on TAC - the state of the art in Norwegian fishery management. Fisheries Research. 1998; 37:259-274.

20. Serchuk, F. M. and Grainger, R. J. R. Development of the basis and form of ICES fisheries management advice: historical background (1976-1990) and the new form of ICES advice (1991-?). ICES CM 1992/Assess:2. 1992; 8 pp.

21. Shleinik, Valery; Ushakov, Nikolay, and Tjelmeland, Sigurd. A possible use of frequency of occurrence stomach content data to improve assessment models for Barents Sea capelin. 1999; Working Document to the ICES Northerin Pelagic and Blue Whiting WG, 1999.

22. Tjelmeland, S. The dependence of some management strategies for Barents Sea cod and capelin on the recruitment models. Precision and relevance of pre-recruit studies for fishery management related to fish stocks in the Barents Sea and adjacent waters.; 1994 Jun 14-1994 Jun 17; Bergen. Institute of Marine Research; 1995.

23. Tjelmeland, S. and Bogstad, B. Biological ModellingTor Rødseth. Models for Multispecies ManagementHeidelberg: Physica-Verlag; 1998: 69-91.

24. Tjelmeland, Sigurd and Bogstad, Bjarte. Multspec - a review of a multispecies modelling project for the Barents Sea. Fisheries Research. 1998; 37:127-142.

25. Tretyak, V. L. A method of estimating the natural mortality rates at different ages (exemplified by the Arcto-Norwegian cod stock). Proceedings of the Soviet-Norwegian symposium on reproduction and recruitment of Arctic cod.

26. Walters, Carl and Parma, Ana M. Fixed exploitation rate strategies for coping with effects of climate change. Can. J. Fish. Aquat. Sci. 1996; 53:148-158.

The 8th Norwegian - Russian Symposium

MANAGEMENT STRATEGIES FOR FISH STOCKS IN THE BARENTS SEA

Bergen, 15. - 16. June 1999

Management objectives for cod

Outline of a management strategy

By

Director General of Fisheries, Peter Gullestad

Examples of management objectives

- Preservation of fish stocks to ensure good recruitment
- Maximum sustainable yield
- Maximum economic yield
- Job - security
- Stability in supply of fish
- Preservation of pattern of settlement in coastal areas

Major tools to further the objectives

- Exploitation rate (level of TAC)
- Exploitation pattern (size when fish is caught)

Obtaining the objectives

- Tradeoff between long-term and short-term consequences
- Discount rate
- Attitudes toward risk

Exploitation rate

- Biological reference points
  - SSB must be higher than depletion/extinction - level
    (SSB > B_{lim} = 112.000 tons)
  - Probability that measured SSB actually is lower than B_{lim} must be small
    (SSB > B_{pa} where $B_{lim} < B_{pa}$ = 500.000 tons)
  - SSB must be large enough to secure good recruitment when environmental conditions are favourable
    (SSB > MBAL = 500.000 tons)

Example of extended option table

Option	F / TAC	Year 1	Year 2	Year 3	Year 4	Year 5	Year ....
A	F = 0,1 (constant)	TAC SB SSB P(SSB<Blim)	TAC SB SSB P(SSB<Blim)	TAC SB SSB P(SSB<Blim)	TAC SB SSB P(SSB<Blim)	TAC SB SSB P(SSB<Blim)	TAC SB SSB P(SSB<Blim)
B	F = 0,2 (constant)	TAC SB SSB P(SSB<Blim)	TAC SB SSB P(SSB<Blim)	TAC SB SSB P(SSB<Blim)	TAC SB SSB P(SSB<Blim)	TAC SB SSB P(SSB<Blim)	TAC SB SSB P(SSB<Blim)
C	TAC = 100 (constant)	F SB SSB P(SSB<Blim)	F SB SSB P(SSB<Blim)	F SB SSB P(SSB<Blim)	F SB SSB P(SSB<Blim)	F SB SSB P(SSB<Blim)	F SB SSB P(SSB<Blim)
D	TAC = 200 (constant)	F SB SSB P(SSB<Blim)	F SB SSB P(SSB<Blim)	F SB SSB P(SSB<Blim)	F SB SSB P(SSB<Blim)	F SB SSB P(SSB<Blim)	F SB SSB P(SSB<Blim)

Relevant economic factores

- Harvest costs pr kilo are dependent of stock - size
- Demand curve for cod
- Multispecies - effects; cod - capelin - seamammals

Measures to improve the exploitation rate

- Suggestion for management strategy in period 2000 - 2004:

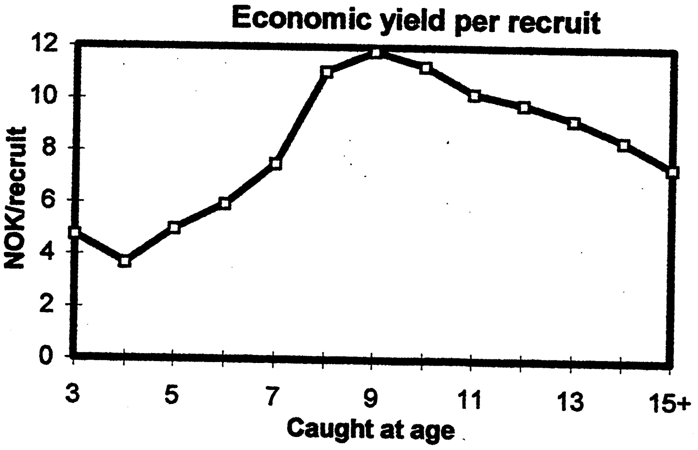
  Maximize the total physical outtake of cod over the next five years and at the same time aim at:

  - stability in annual TAC by assuming constant TAC's
  - a high possibility of good recruitment and a moderat risk of bringing SSB outside safe limits by keeping SSB above 500.000 tons during the whole period
  - a target value of SSB after five years of 700.000 tons
  - every year recalculate the level of annual TAC for a new five year period, based on updated scientific information
  - in the event that the SSB for the next year falls below 500.000 tons, the TAC for that year shall be limited by a F-value not higher than 0,8 x 0,SSB

Factors determining the optimum exploitation pattern for cod

- natural mortality
- individual growth
- size-dependent prices

DIRECTORATE OF FISHERIES


Economic yield per recruit

DIRECTORATE OF FISHERIES

Measures to improve the exploitation pattern

- Improve existing exploitation pattern by gradually increasing the allowed minimum spacing between bars in sorting grids from 55 mm to, let us say, 80 mm in the year 2002
- Continue research to improve selectivity in fishing gears
- Continue biological and economic research to more precisely determine the optimal exploitation pattern for cod
- Further improve technical regulations when scientific information and advice so indicate

Contribution by V.M.Bondarenko,
Murman trawl fleet

Ladies and gentlemen,

Our participation in this symposium is a sign of our rejection of the belief that the interests of research and commercial fishing are mutually opposed to each other. In 1833, the great Russian writer Pushkin wrote a fairy-tale about a fisherman and a fish, and this year we can celebrate the 200th anniversary of his birth. We (the Murman trawler fleet) bear a certain resemblance to the protagonist in Pushkin's story. I represent the Murman trawler fleet which, like the fisherman in the story, has been in operation for 80 years. And fishing provides the only opportunity for us and our families to earn a living. Most of us are shareholders in our company. The company management is responsible for us, so that we do not lose all our fish like the fisherman in the fairy-tale. But this is just what could happen if the resource base is undermined. For this reason, we are ready to play a part in implementing whatever sort of measure might be organised to guarantee efficient catch regulation.

I would like to offer some reflections on this problem, and to ask a number of questions to which we either do not know the answers, or whose answers are not found to be convincing by commercial fishermen.

What is the aim of the owners of fishing vessels as far as total allowable catches (TACs) are concerned? We shall tell no lies: they quite certainly have two figures in mind, the minimum and maximum quotas:
- The minimum quota is the quota that is needed to ensure the maintenance of a fishery on the basis of the bioresources in the ocean, in other words the quota that is capable of protecting us against a contraction of the fishing industry and in the worst case, bankruptcy.
- The maximum quota is the quota that can be exploited if one works at maximum capacity.

Naturally, all fishing vessel owners remember the minimum quota very well, but they work at maximum level. And the level of their efforts depends on how big a share of the profits they receive.

A system of allocating the total catch has developed, and it is a simple matter to calculate the minimum and maximum limits of the total permitted catch for next year. With regard to the danger of undermining our bioresources, they have arrived at a figure near the midpoint. And they defend this quota level with every possible argument. Without a system of distributing the TAC among users, each individual fisherman will try to take the maximum quota in order to insure himself against an unexpected misallocation, and fears for the future will be brushed aside.

Furthermore, the distribution key which will be accepted for regulating our fish resources is controversial and will lead to stops in a fishery if catch capacity and catch effort are not reduced at the same time. Attempts on the part of the Murman Fisheries Council to introduce such additional measures to regulate the fisheries did not have any positive results due to the lack of

- A legal basis for putting them into effect
- A lack of well-founded scientific recommendations for the measures involved
- The local character of the allocations

Among the results of such fishing stops is a rise in the number of new companies whose sole objective is to maximise profits. It is quite certain that such companies will not be fighting for the sensible utilisation of fish resources.

Who will be the best allies in the struggle for the optimal Total Allowable Catch? We believe that they will be:

- companies with many owners, for which profit dividends are less important than the guarantee of work
- companies that exploit all the resources of the ocean, so that a reduction in the quota for one resources will partly be compensated for by other quotas, even in income falls somewhat
- family companies with only a single source of profit, and which are inherited from generation to generation
- any companies that have guaranteed quotas, and which are therefore not dependent on a TAC in a given period.

In this way, the number of allies will be sufficient, given that the fisheries authorities have the possibility of increasing the numbers of the fourth group of companies on the recommendations of fisheries researchers and the fisheries inspectorate.

The more correct the recommendations of fisheries research, the closer will science and fishing be able to approach each other. Unfortunately, it may be that our attitude to scientific recommendations is far too critical, but this is due to the wrong conclusions being drawn from incomplete investigations. One example is the conclusion that Greenland halibut stocks are under threat, while in practice, fishing vessels are being driven out because they are taking more than the permitted bycatch of Greenland halibut in traditional (deepwater) cod and haddock areas. We begin to doubt the correctness of scientific recommendations, and our doubts are reinforced by an analogous case of the evaluation of the state of saithe stocks. And the correctness of our doubts is further confirmed by evaluations of the state of the stocks of cod and other species.

In the course of the past few years doubts have repeatedly been expressed as to the correctness of stock evaluations and the setting of TACs for cod made by the Mixed Russian-Norwegian Fisheries Commission. Such repeated doubts do not increase respect for science. The recommendations are reminiscent of political methods in the way that they regulate fish stocks, and they do not correspond to practical reality. This can be seen in the table and diagram that show comparative average catches by month and year. It is easy to see that the rate of fall in the TAC is higher than the rate of fall in the CPUE for identical vessels, which will be at the same level this year as last year (unfortunately, data from the first six months of the year are processed at the end of the year). The divergence between what is produced (data regarding quantity can easily be checked accurately) and catch quantities can be considerable, and is assuming a serious character. Let us look at some of the possible sources of such divergence and characterise their causes:

1. Discard of fish: basic causes

*Surplus of small fish (cod and haddock). Fish are discarded in an attempt to bring the proportion of small fish down to the permitted level of 15%. The deficiencies of the current method of regulation are a consequence of placing limits on the sizes of fish taken.

*Discard of fish raw materials that fetch poor prices when there is a severe quota shortage, in an attempt to use the quota more efficiently. The difference between the prices of small cod and large cod is more than 50%.

*Fish that do not satisfy the requirements for mechanical processing, for example in filleting machinery.

*Rejection of production from complicated fish-processing machinery, due to technical problems or limited capacity.

*Physical damage to fish caused by stones or sponges in the cod-end of the trawl.

Demands for rules regarding the prevention of ocean pollution hide these problems, because fish waste is ground up. Modern fishing vessels have large-capacity meat grinders which make it quite possible to hide the facts regarding discarded whole fish. The waste from fillet production is probably greater than the production itself and all ground-up fish waste is thrown into the sea. Unfortunately, we have no scientific guarantee that such measures are safe for the ecosystem. We also wish to know the answers to the following questions:

What sort of fish eats ground fish waste?

What is the percentage of ground fish waste in the diet of cod and haddock and why is this not included in the total food availability?

Does this food have any effect, and if so, what sort of effect, on the development of cannibalism in cod?

Would this food not be suitable for new species of fish in the Barents Sea and the Norwegian Sea. Will large amounts of easily available food not disturb the balance of the ecosystem?

2. Uncontrolled fishing by third countries in the open part of the Barents Sea and the Norwegian Sea. Information available in the press gives us the impression of an agreement with potential claimants to such fisheries.

3. Mortality caused by the effects of fishing gear

*Fish mortality resulting from lost fishing gear.

*Mortality resulting from injuries caused by sorting systems (grids)

*Mortality resulting from fish passing through trawl meshes.

We feel that the last two points have not been studied sufficiently. We have not found convincing documentation regarding the useful application of sorting grids to protecting cod larvae, and in our view they only create an illusion of particular areas being good for fishing. I cannot forget something that I observed ten years ago, when the Spanish trawler fleet was working the mackerel stocks in the southeast Atlantic close to the Continental Shelf. Every single ship was followed by a five kilometre-long white wake - the stomachs of dead small hake that had passed through the trawl meshes. Are cod and haddock more hardy than hake? We would like to know the answer to that question.

We can see that there are many problems and questions related to the regulation of fish stocks and their rational exploitation. Solutions can only be found by working together. Leading joint bodies for the fishing nations must organise this work and take responsibility for it. We can assume that the following questions will have to be taken up.

1. Increasing importance of methods for limiting fishing efforts for regulatory and sustainability objectives for fish stocks.
2. A well worked-out key for allocating quotas to users as a guarantee of a long-term commitment to the maintenance of resources.
3. The allocation key must guarantee sufficient quotas so that accepted norms and rules are not violated.
4. A unified method for implementing rapid fishing stops and starts for all fishing areas in the Barents Sea and the Norwegian Sea, as a means of encouraging the reliable supply of information by fishermen.
5. The usefulness of using sorting grids, if these lead to fish mortality and in this way distort the catch pressure picture.
6. The evaluation of fisheries regulations, for example the control and existence of regulatory mechanisms.

This list of questions has an objective, namely, that quota users should not feel that it is necessary to get round fixed regulations and norms in operational fishing. This in turn would ensure the conservation of resources. Limitations and prohibitions as means of regulating fisheries are complicated, expensive and occasionally inefficient methods of achieving our basic objectives.

Thank you!

THOUGHTS ABOUT MANAGEMENT STRATEGIES FOR THE BARENTS SEA STOCKS SEEN FROM THE PERSPECTIVE OF NORWEGIAN FISHERMEN

by

Knut W. Hansen
Norwegian Fishermen's Association

Dear Russian friends and other participants in the meeting!

My task here to-day is to present some views from Norwegian fishermen about management strategies for the stocks in the Barents Sea, this oceanic area with biological resources we all know are crucial for those in our two countries who are making their living from the sea.

Norwegian fishermen are of course concerned that we can succeed in having a sustainable management of all the stocks in the Barents Sea so that we can have the best possible utilisation of the biological resources in the area. This means that all the stocks of demersal fish, pelagic fish, and not least the marine mammals in the ecosystem must be exploited in a way which secures maximum economic revenue from the fisheries. This approach requires that we bring in even more economical considerations in the evaluation of the management strategy in addition to the biological knowledge. This will provide the basis for quota levels and fishing patterns.

Norwegian fishermen have for a long time advocated increased harvesting of the populations of marine mammals in the North Atlantic Ocean and in the Barents Sea, especially seal stocks which for many years have been allowed to increase without being significantly exploited. Conservative estimates of the amount of fish eaten by marine mammals in the Barents Sea exceed by far the annual quotas taken by the fishermen. It is both regrettable and unforgivable that extremist environmental organisations for many years have made propaganda all over the world against harvest of marine mammals, which among other things nearly has totally ruined the market for seal products. It is absolutely necessary that Russia and Norway as soon as possible agree on a strategy to increase the catch of seals and whales.

I see clearly that there could be problems at all times and for all Barents Sea stocks fulfilling the management strategies that in theory give the highest possible economic revenue. Even if refined management strategies for the different stocks were made, I am convinced that the nature will continue to influence the development of the stocks and make it necessary to correct the chosen strategies. In a multispecies perspective I am especially concerned that the different links in the food chain are secured enough food. Some species have a key role in transforming and distributing the production in the ecosystem.

Nearly all stocks in the Barents Sea have their distribution both in the Russian and Norwegian zone in addition to international waters. If we are going to succeed with the management of the Barents Sea stocks, it is therefore absolutely necessary that we can establish uniform management rules for all the fishing areas.

Norwegian fishermen are still concerned that we should have protection of juvenile fish. This can be achieved by a reasonable minimum landing size, minimum mesh size and devices for selection in the trawls. Closing of areas must still be used and the criteria for closure must be the same in the Norwegian and the Russian zone. If this measure shall have the desired effect it is necessary to have a continuous monitoring of closed areas to avoid that they are closed unnecessary long and to ensure that they are quickly closed when needed. In Norway we have experienced that areas have been closed for a long time because of lack of resources to monitor the areas. Norwegian fishermen have therefore asked for better procedures and routines for closing and opening of areas. Both countries must strive to establish common rules also for this management measure for the entire Barents Sea. There is also a need for continuous development of sorting grid construction and technology in particular, but also of fishing gear in general.

In connection with the things I have touched upon, I cannot avoid expressing concern about the increased exploitation of young cod in the Barents Sea. Even with sorting grids in the trawls, I think that Norway and Russia must reach an agreement on common minimum landing sizes for the different stocks in the Barents Sea and on a common mesh size for Norwegian and Russian zone. If we want to have a rational exploitation pattern for our joint fish stocks, both Norway and Russia must be flexible with regard to allowing fishermen to take their quotas in each other's zones.

Solid biological knowledge about the different stocks is of course crucial to succeed in sustainable harvesting. Sufficient economical resources for marine research and stock assessment must therefore be ensured in both countries. I know that there is good co-operation between the marine scientists in our two countries and this should be further developed. Considering that marine research has limited economical resources it is important that co-operation across the boarder continues, e.g. through joint research surveys, and that admission to carry out the surveys in the economical zones is given. Perhaps the research co-operation should be developed even further by having a joint research vessel for the Barents Sea. I also want to mention that Norwegian fishermen have asked that information about catches from the fishing fleet to a larger extent must be used in the fishery research. It is also my opinion that fishermen must be involved more in the process leading to management decisions. It must be better to talk to each other across a table than through the newspapers.

Through different international processes in recent years agreement has been reached on principles linked to the "precautionary approach". ICES has already started to apply this approach, e.g. by defining new reference points for stocks where both the spawning stock and the fishing mortality are used, while previously only a minimum level for the spawning stock was considered. As a result, ACFM last autumn classified many Barents Sea stocks as being outside safe biological limits. I feel that the scientists have not been very good at explaining and inform the opinion about the change to new reference points since the expression "outside safe biological limits" by many groups is understood as a crisis.

Norwegian fishermen can agree that it may be useful to have more reference points for a stock to be able to take suitable management action depending on the size and the composition of the stock. These reference points must, however, be set at a realistic level if the fishing industry shall have faith in them so that they can have the desired effect. I therefore hope that we during this symposium will get the opportunity to discuss sensible levels of fishing mortality and spawning stock for some of the most important Barents Sea stocks.

A central element in discussing management strategies is to give priority to catch levels. Large variations in the quotas from year to year create problems in planning both at sea and land in the industry. All the stakeholders will undoubtedly gain if the catch from a stock can be kept reasonably stable form year to year. I therefore think it is important to focus on the stability of the quotas when we are looking for sensible management strategies.

On behalf of Norwegian fishermen I wish you good luck with the discussions and I am looking forward to the establishment of sensible parameters as guides for the management of the stocks in the Barents Sea.

The 8th Norwegian-Russian Symposium
Bergen 15-16 June 1999

SOME CONSEQUENCES OF LONG-TERM MANAGEMENT STRATEGIES

Tore Jakobsen

Institute of Marine Research
Bergen

Introduction

Management strategies can be divided into three types: Short-term, medium-term and long-term.

A short-term strategy means that management decisions are made only for one year at the time. Usually the decisions are made on the basis of biological management advice, but this is not necessarily followed. Some medium- or long-term considerations may be involved, but they are often vaguely stated and secondary in the decision making. Unfortunately, most stocks are still managed in the short-term perspective.

A medium-term strategy typically deals with a period of 3-10 years. The aim can be rebuilding a stock to a desired level or avoiding a stock decline in the given period. Stability in catches could be another goal. The catch and stock projections usually involve estimates of uncertainty and risk analyses. The risk must be related to some reference point, normally a minimum desirable level of spawning stock biomass, e.g. B_{pa}. Medium-term strategies are gradually becoming more common. An example where it is applied in management is Norwegian spring-spawning herring.

A long-term strategy requires an agreement on the principles for management of the stock. The level of exploitation and the need for stabilisation of catches are important issues that must be addressed. A long-term strategy involves harvest control rules which specify how management actions relate to the state of the stock. Usually this means that pre-agreed management measures are introduced if the stock falls below a given level, e.g. B_{pa}. The strategy should be the result of a process where managers, fishermen, the fishing industry and scientists meet and discuss various strategies. This was done in Iceland where they agreed on the long-term strategy for Icelandic cod now in effect.

Long-term strategies can have many forms, simple or complex, and the advantages of a particular strategy may depend on the biology of the stock. Among the simple forms, a fixed F (fishing mortality) strategy (Figure 1) and a fixed TAC strategy (Figure 2) can be seen as two opposite extremes. The first allows catches to follow the natural fluctuations of the stock, the second, which in practice may be impossible to fully achieve, aims at stabilising the catches. The following discussion deals with some consequences of these two strategies applied to Northeast Arctic cod.

The Model

The large environmental fluctuations in the Barents Sea and their effect on the fish stocks represent one of the main challenges in modelling Northeast Arctic cod. In the present model, changes in the environment are indirectly represented through variation in recruitment. This is done by looking at recruitment success, i.e. actual recruitment compared to what would be expected from a spawning stock-recruitment relationship.

Having used the post war period as basis, stock fluctuations in the model show similarities with those experienced in this period. Density dependent growth, maturation and cannibalism is included, but the effect of a collapse in the capelin stock is not fully implemented. Apart from this, the main problem is how to model the behaviour of the cod stock at extreme high and low levels which are outside our range of experience. The simulations start with the stock from the most recent stock assessment and is projected forward 50 years. However, this is not a stock prediction, but a simulation of how the stock can be expected to react under various management strategies. The model is very preliminary and some of the results should be taken with caution.

The two strategies are run on the basis of the harvest control rules showed in Figure 1 and 2, i.e. fishing mortality and TAC, respectively, are reduced linearly when SSB falls below 500,000 t (B_{pa}) and will be zero if SSB falls below 100,000 t (B_{lim}).

Fixed F strategy

A fixed F strategy is simulated for fishing mortalities of 0.3, 0.4, 0.5 and 0.6 and the resulting catches are shown in Figure 3. Over the range of fishing mortalities from 0,4 to 0,6 there are small differences in average catch, but at 0,3 it is approximately 100,000 t lower. The maximum is reached at about 0.48, i.e. close to the F_{med} value of 0.46 which has been used by the Mixed Russian-Norwegian Fishery Commission. The mean catch level, about 850,000 t, appears to be high compared to historical levels. This seems to be linked to the recruitment level and could indicate some mis-specification in the model.

Figure 4 shows the corresponding levels of spawning stock biomass (SSB). Not surprisingly, low F gives high SSB and vice versa.

Although a fixed fishing mortality is the strategy, the harvest control rule will frequently come in force for F=0.5 and F=0.6 and this will temporarily reduce F (Figure 5). For F=0.4 SSB falls slightly below 500,000 t in one year, while it is always above 500,000 t for F=0.3.

There is also a clear correspondence between fishing mortality and the mean weight of the fish in the catches: Low mortality means more large fish in the catches (Figure 6).

With a stock showing fluctuations like the Northeast Arctic cod, a fixed F strategy will necessarily lead to variations in catches. However, these variations will increase substantially for F>0.4 (Figure 7).

Expected catch rates (e.g. catch per trawl hour) are approximated by the ratio C/F and will vary considerably for all fixed F strategies (Figure 8), although the variations will in practice probably be less than the figure indicates. However, the catch rates are clearly higher when fishing mortality is low.

Fixed TAC strategies.

Three fixed TAC strategies are simulated: For 600,000 t, 700,000 t and 800,000 t. In all cases the harvest control rules will come in force at the start of the period and during the period of poorest recruitment success in the model (Figure 9). It is, however, surprising to see that in the first part of the period 800,000 t can be maintained longer then 700,000 t and 600,000 t. This outcome is dependent on assumptions about recruitment and cannibalism at spawning stocks levels higher than experienced in the historical data and is clearly questionable, but demonstrates that the outcome of a fixed TAC strategy could be difficult to predict.

The SSB will in periods fall well below 500,000 t, but will for long periods be considerably higher for all options, and more than 2 million t for TAC=600,000 t (Figure 10).

Fishing mortality will be at a low level in a large part of the period, but is not as closely linked to the TAC level as might be expected (Figure 11). When the stock declines, fishing mortality will rapidly increase until harvest control rules are enforced. F levels needed to take the TAC may exceed 1.0 in the year before harvest control rules are introduced. Without harvest control rules the stock could at this stage be virtually wiped out in a couple years if the fleet capacity is large enough.

Also the catch rates show a somewhat surprising relation to the TAC levels (Figure 12), but are generally highest with a low TAC.

Discussion and Summary

The model is preliminary and will probably be somewhat adjusted after a closer scrutiny. Furthermore, it does not assume a situation with large fluctuations of the capelin stock which could change the results considerably. However, the main aim of this paper is to compare a fixed F and a fixed TAC strategy and in this respect the model seems satisfactory.

The results indicate that a fixed TAC strategy probably cannot be sustained over a long period even for a relatively low TAC. A fixed F strategy will give higher average catches which are not very dependent on the F level (but will decrease markedly if F is further increased). These simulations therefore clearly indicate that a fixed F strategy is preferable unless there are strong economic arguments for the higher catch stability, at least temporarily, obtained by a fixed TAC strategy.

Less fluctuations in catches, higher mean weight of the fish in the catches and higher catch rates are factors that would favour a relatively low F if economic considerations are taken into account in the fixed F strategies. This will have to be weighted against negative effects on other species by having a large cod stock.

If a long term management strategy is adopted it needs not follow the relatively simple approach outlined here. A number of other strategies are possible. It will, however, have to be based on the information available at the time and new scientific knowledge can change the basis for the strategy. Furthermore, the economic situation can change as well as the objectives of the managers and the industry. Therefore a long-term strategy is not meant to last forever and should at any rate be regularly re-evaluated. If the strategy shall be effective, however, it must not be discarded only because TAC levels start declining. With a stock like the Northeast Arctic cod this is unavoidable in the long run and should be part of the common understanding of how this stock behaves.

Figure 1. Fixed F management

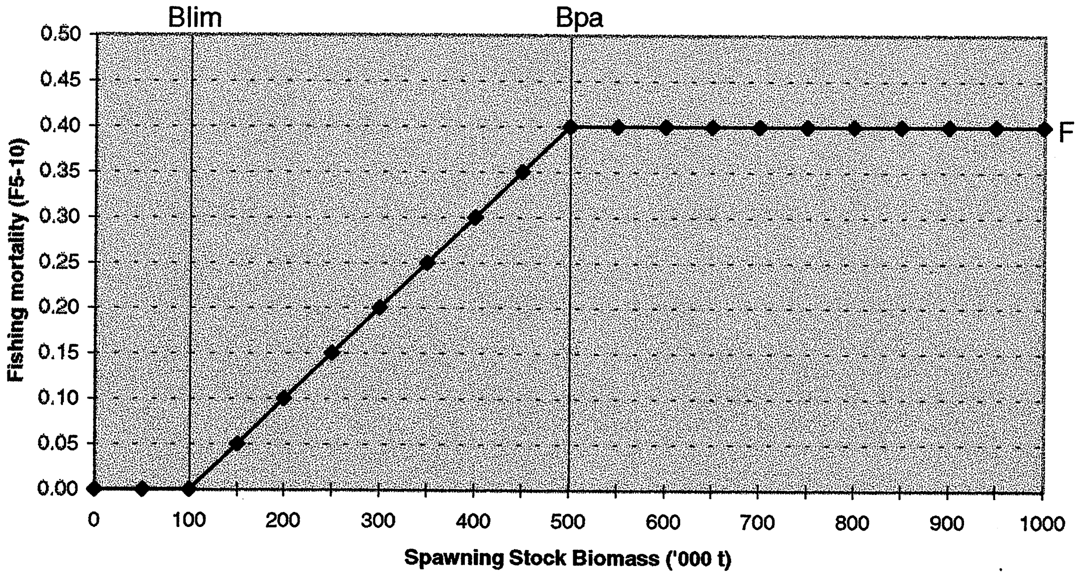


Figure 2. Fixed TAC management

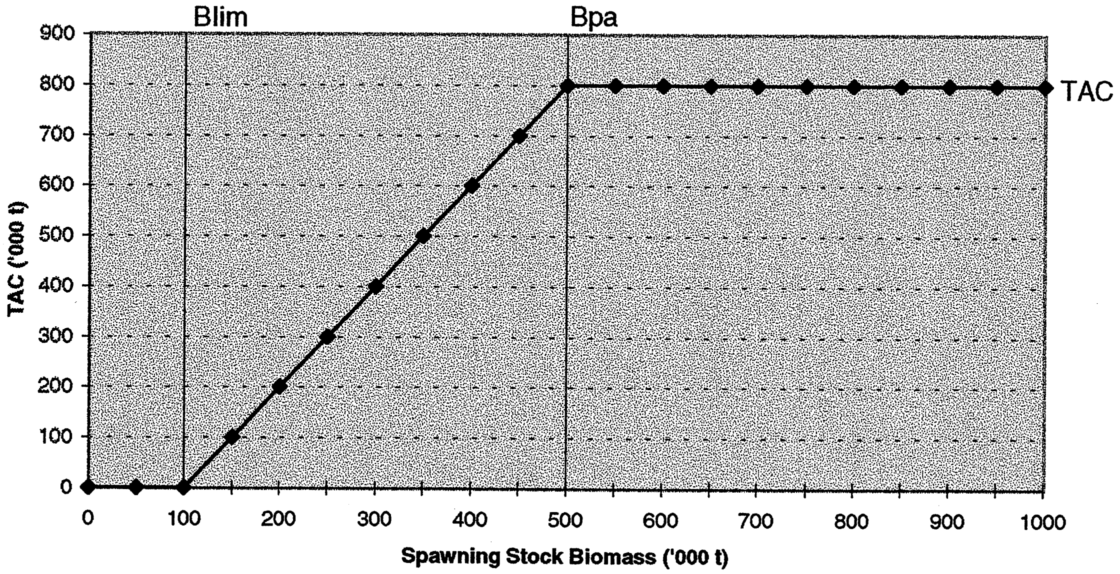


Figure 3. Northeast Arctic Cod - Catch

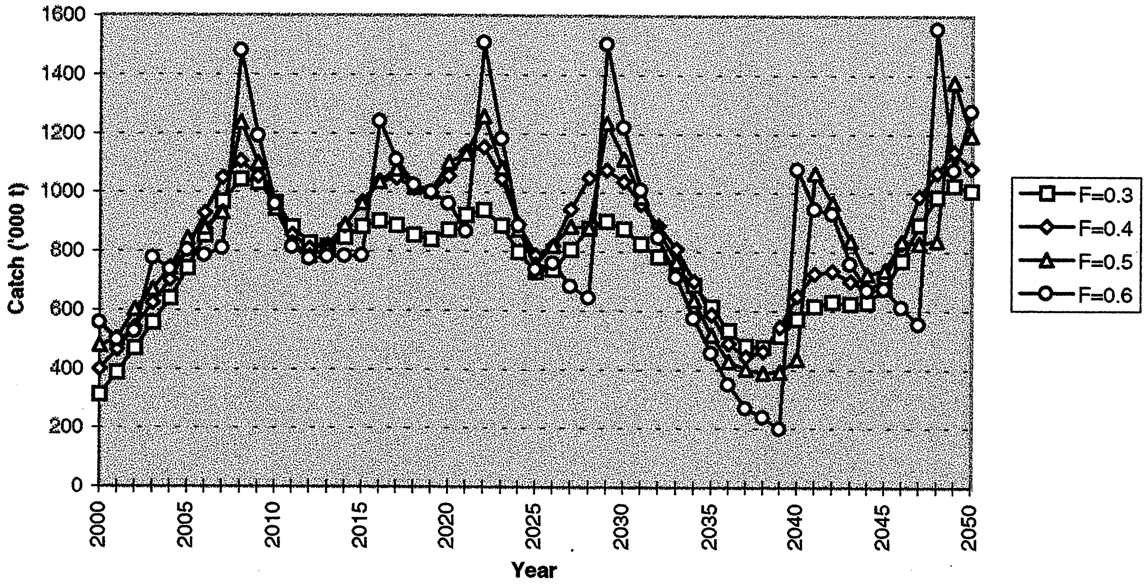


Figure 4. Northeast Arctic Cod - Spawning Stock Biomass

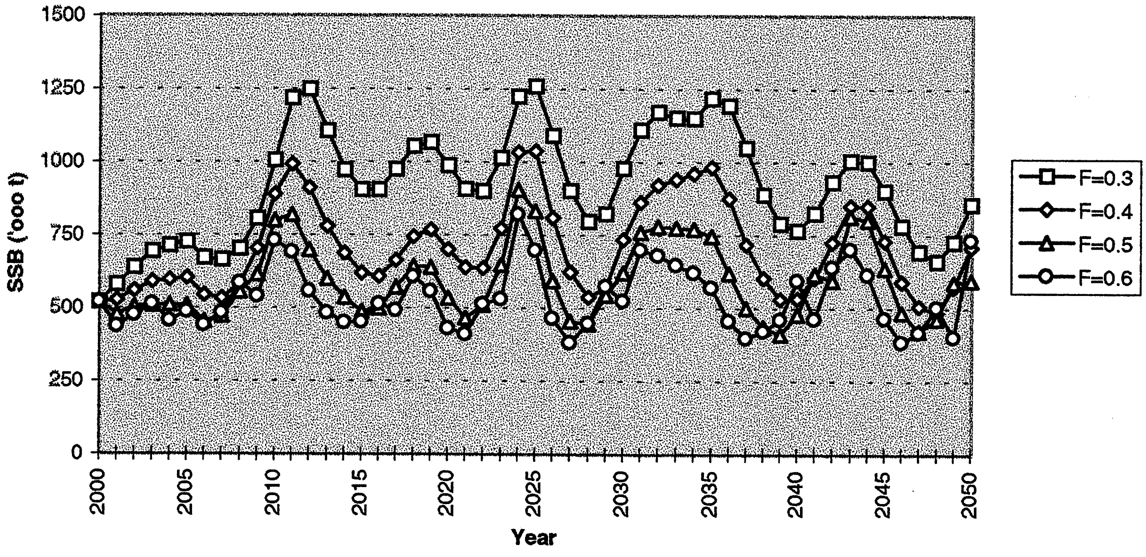


Figure 5. Northeast Arctic Cod - Fishing mortality

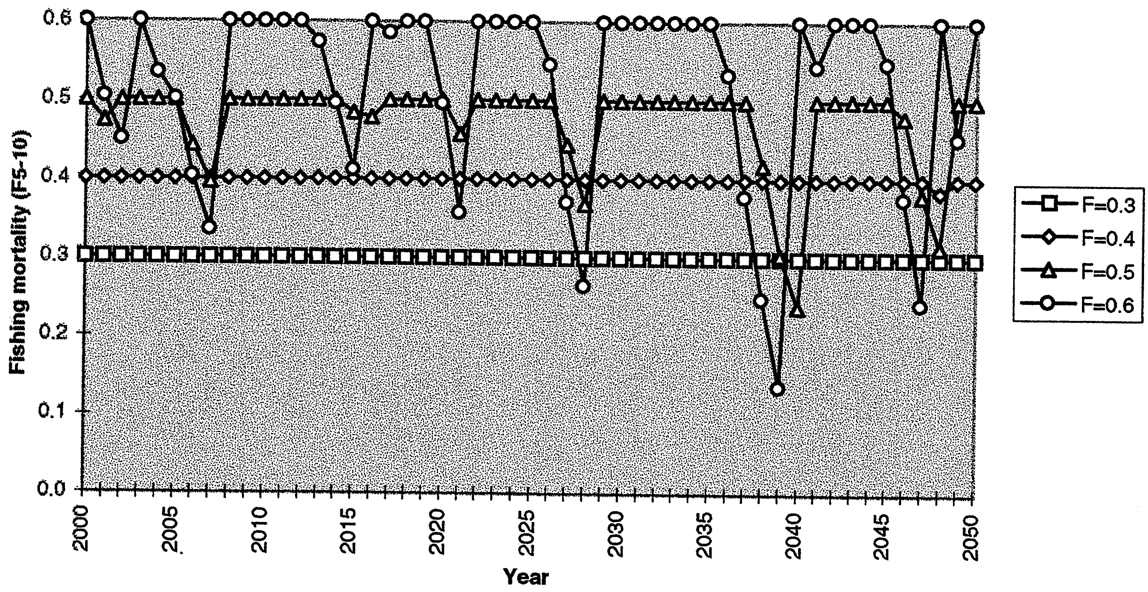


Figure 6. Northeast Arctic Cod - Mean weight in the catch

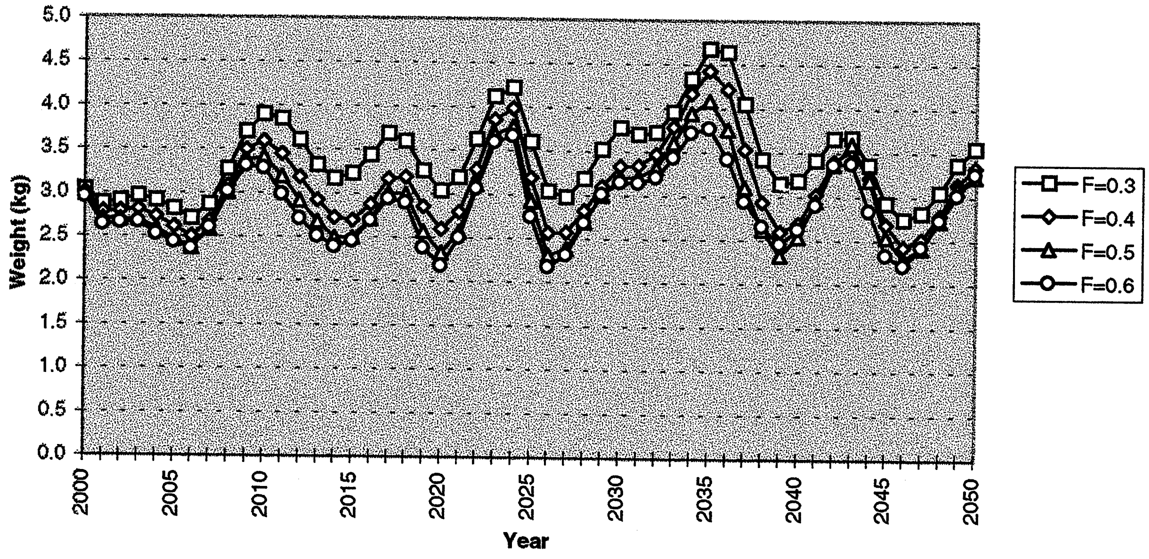


Figure 7. Northeast Arctic Cod - Annual change (%) in catch

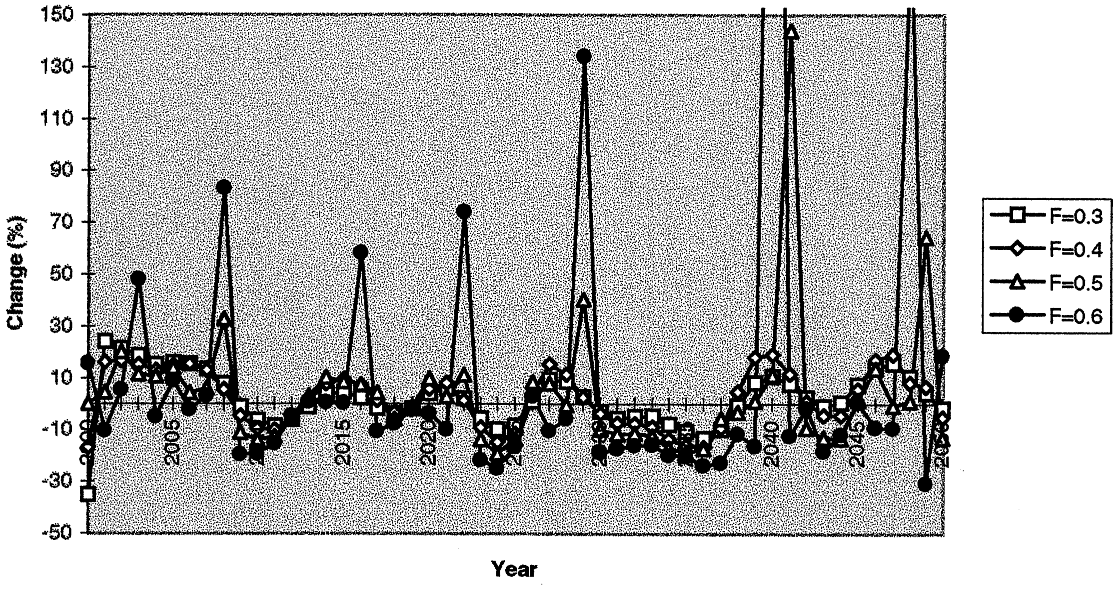


Figure 8. Northeast Arctic Cod - Variation in catch rates (C/F)

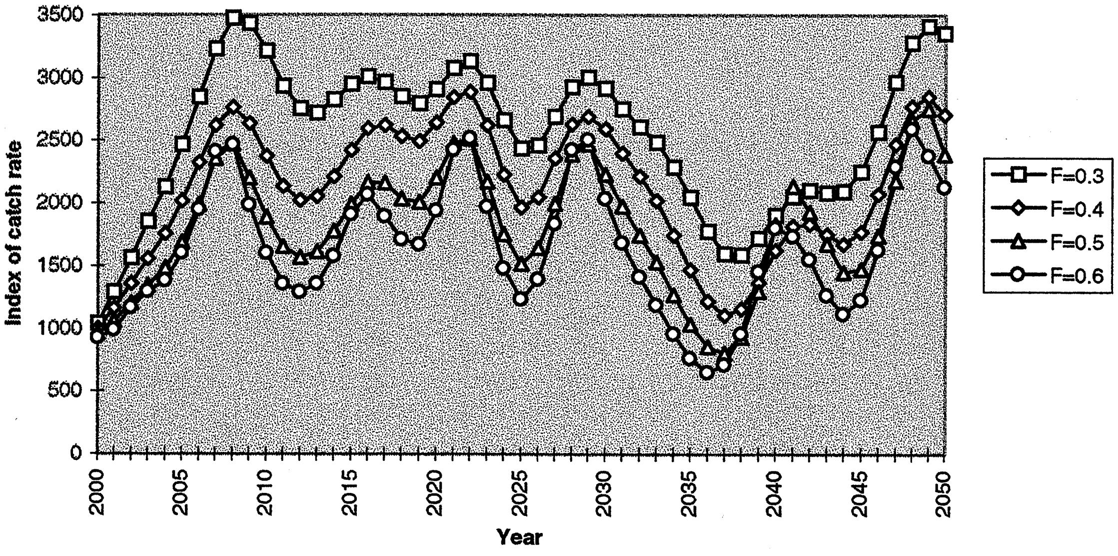


Figure 9. Northeast Arctic Cod - Catch

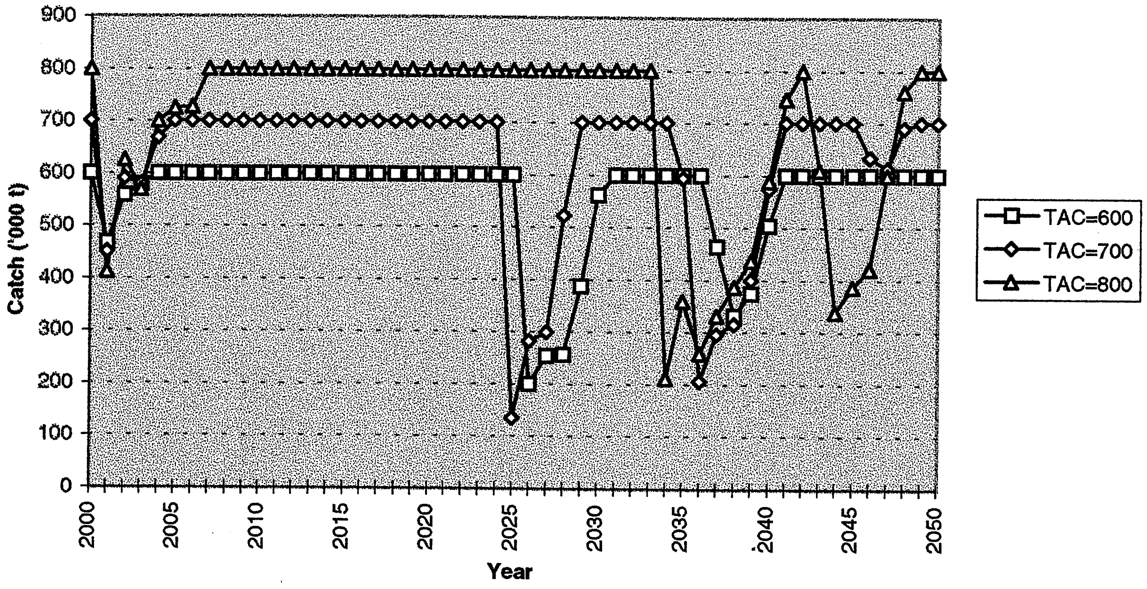
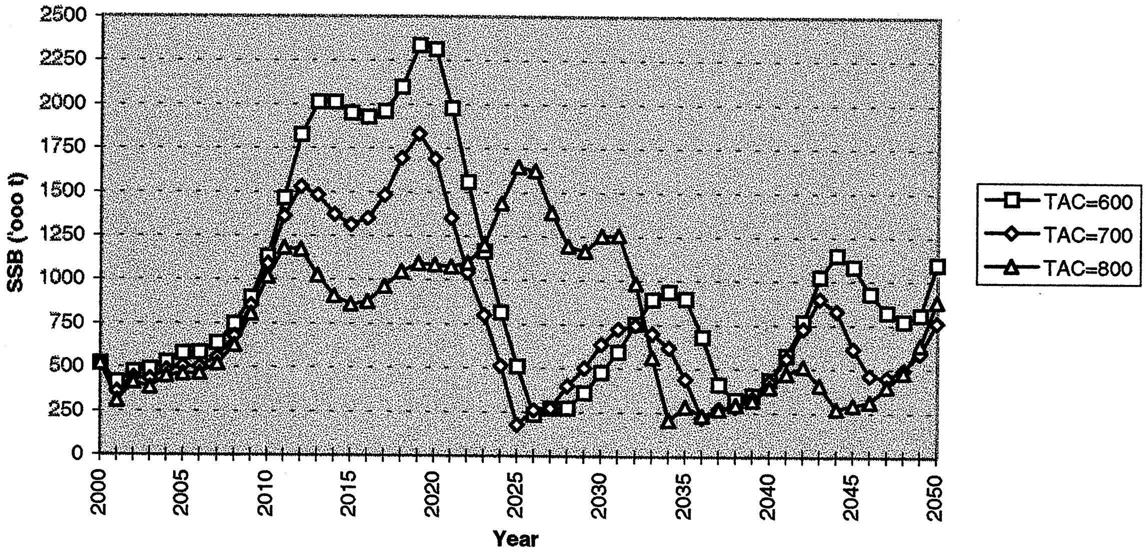


Figure 10. Northeast Arctic Cod - Spawning Stock Biomass



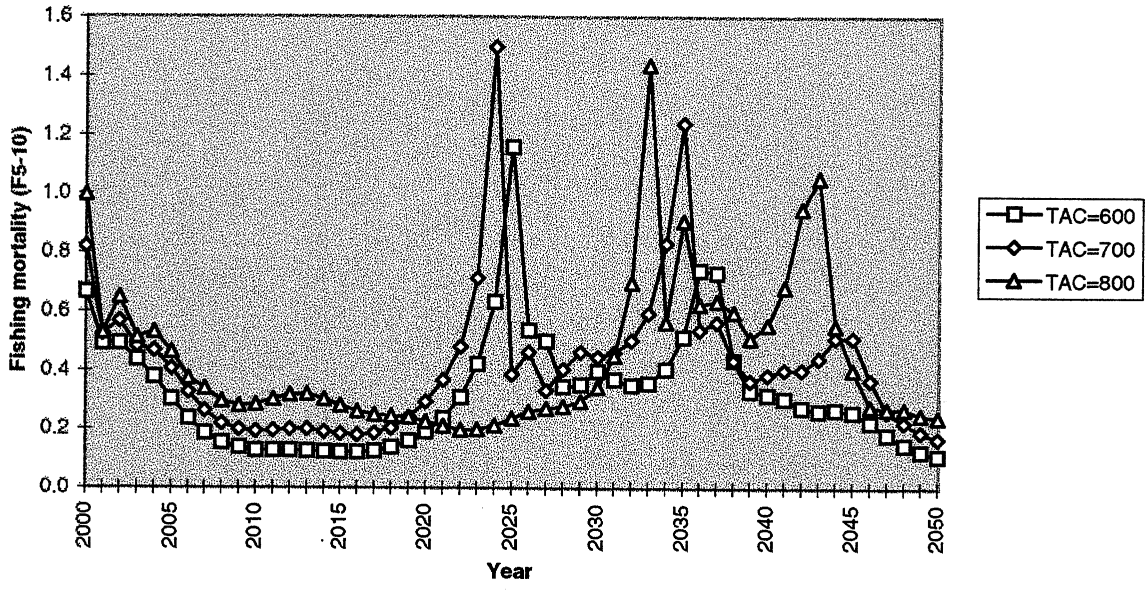


Figure 11. Northeast Arctic Cod - Fishing mortality

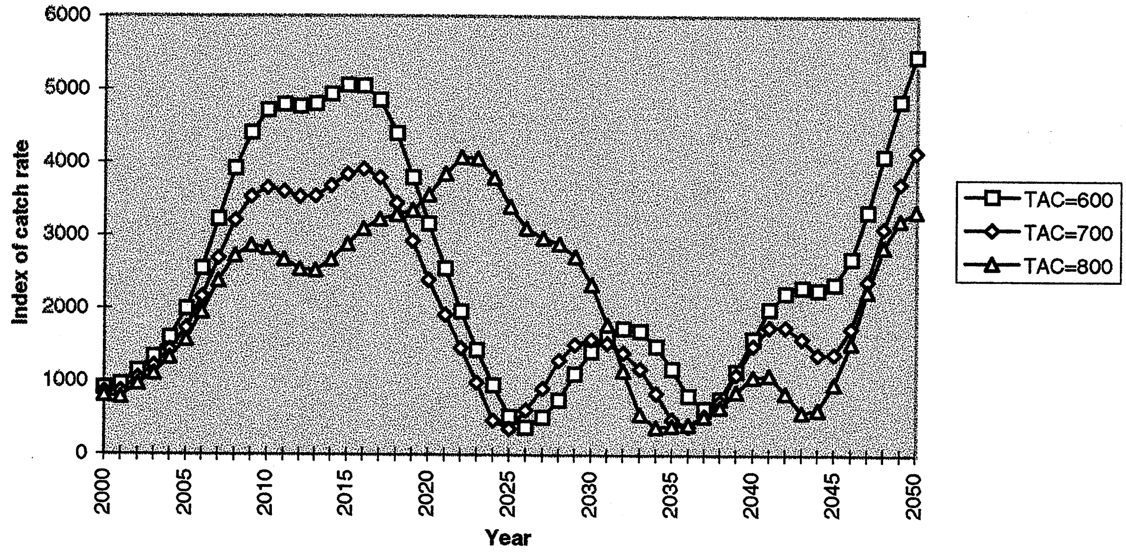


Figure 12. Northeast Arctic Cod - Variation in catch rates (C/F)

Economic consequences of various Exploitation Rates

Which exploitation rate would give highest net economic revenue ?

Discussed in Nakken O. Sandberg P. and Steinshamn S.I.:
Reference points for optimal fish stock management
Marine Policy (Vol 20, no 6, 1996, pp 447-462)

Ladies and gentlemen.

It is a privelege to be asked to speak about management strategies to members of The joint Norwegian-Russian Fishery Commission and to scientists and representatives from industry and management from our two countries.

During the 27.th session of the Commission, the Parties agreed to develop long-term management strategies for the joint fish stocks in the Barents Sea. Until such a strategy is hammered out, the Parties agreed to keep the spawning stock biomass above 500.000 tonnes and at the same time reduce the fishing mortality to Fmed = 0.46.

Management measures are often discussed in terms of their consequences in tonnes. However, the fishermen do not live of the tonnes of fish itself, but of the net value that these tonnes generates.

In my intervention, I will focus on how the net revenue from the cod-fishery can be expected to vary as a consequence of how much we are fishing each year. I will illustrate this by looking at how the net revenue is expected to vary when varying the fishing mortality/exploitation rates for northeast arctic cod.

Highest net economic revenue

Gross value of the catch
- less variable harvesting costs
= Net economic revenue

When measuring economic performance in a fishery, several indicators can be of use. In a long-term perspective, the profitability will be the crucial parameter. If the profitability is negative for several years, ship-owners will go bankrupt and are forced out of the industry.

In the short run however, it is reasonable to assume that the size of the fleet will not vary. Consequently, the fixed costs will not change in a short-term perspective. The net economic revenue can then be an important parameter to measure. The net economic revenue is calculated as gross revenue from the fishery less variable harvesting costs.

In this presentation, I will focus on a situation where the size of the fleet is fixed and have a closer look at how the average net economic revenue per year will depend upon the exploitation rate.

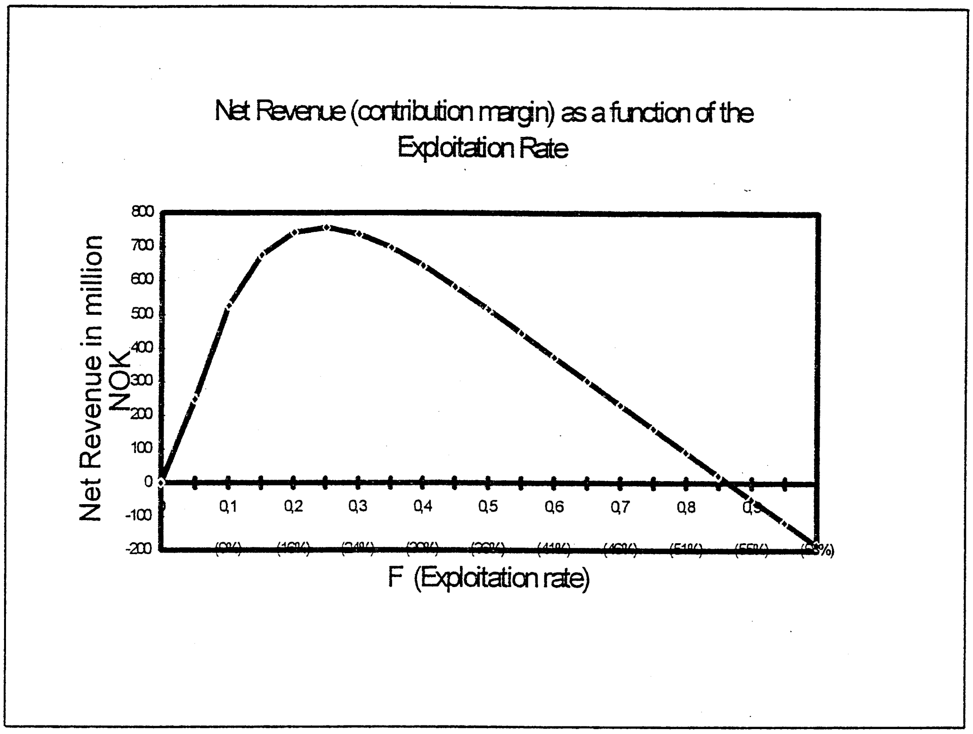
Assumptions

- Period analysed: 1980-1994
- Biological assumptions:
  - Recruitment, growth and natural mortality as in period analysed
- Economic assumptions:
  - Fixed prices during the period
  - Variable costs per ton catch depending upon the size of the biomass

The calculation was done assuming the following:

1. We used ICES' biological data on recruitment, growth and natural mortality from the 15-year period 1980-1994.
2. Having these data, we simulated with the fishing mortality, analysing various levels of fixed fishing mortality during the period.
3. When changing the fishing mortality we let recruitment and natural mortality be unaffected.
4. The only element which varied was numbers of survivors from year to year.
5. The resulting catch was multiplied with a fixed price in order to calculate a gross value of the catch.
6. To be able to calculate the net economic revenue, we had to calculate harvesting costs. It is natural to assume that these costs will vary in response to the size of the stock. We therefore used a relationship where the level of the costs per ton catch increased when biomasses decreased and vice versa.

With these parameters, we simulated the average level of net economic revenue as a consequence of various levels of fishing mortality.



When keeping the fishing mortality constant through the whole period 1980-1994, we found the economic optimal fishing mortality to be 0.24. We found that fishing mortality lower than this would greatly reduce the net revenue and that fishing mortalities greater than this would also reduce the net revenue.

Looking at the fishing mortalities which has characterised the northeast arctic cod stock during the last years, a fishing mortality at 0.24 seems to be very small. When such a level of fishing mortality is found to be the level which gives highest average net revenue, the reasons are twofold:

- First, fishing less will initially build up the stock. Although a low fishing mortality will generate low catches in the beginning of the period, they will increase during the period.
- Second, building up the stock will increase the availability of fish. Hence, harvesting costs per ton will decrease.

Both these factors will increase the average annual net economic revenue.

Factors not accounted for:

1. Predation by cod on capelin, herring and shrimps
2. Recruitment as a function of spawning stock biomass
3. Density-dependent growth
4. Investment related to expected catch

Including 1 and 3 should result in higher exploitation
Including 2 and 4 should result in lower exploitation

Any calculation implies simplification of reality. In this case we would draw attention to the following which, due to lack of knowledge, was not incorporated in the analysis:

1. If a "low F strategy" should be successful in terms of building up the spawning stock biomass, such a biomass would consume more, including commercial interesting species like capelin and herring. Inclusion of such effects could move the "optimal F" to a higher level.

2. Again if a "low-F-strategy" would icrease the spawning stock, it is reasonable to expect that recruitment would increase, making it possible to reap even higher catches than the ones calculated. Inclusion of such effects could move the "optimal F" to a lower level.

3. An increased spawning stock may set the food supply of the cod in jeopardy. Lack of food would eventual reduce the growth of the individual fish. Inclusion of such effects could move the "optimal F" to a higher level.

4. A low-F-strategy could expectedly reduce the future investments. In a situation where there is overcapacity in the fishing fleet, reduction of future investments will have a positive economic effect.

Qualitative, the various factors will draw our conclusion (the optimal F) in opposite directions.

Policy implications:

- Reducing the exploitation rate will build up the stock of Northeast Arctic Cod
- With a higher stock of cod, it should be possible to stabilise the annual TAC
- TAC based on fishing mortalities in the range 0.20 - 0.40 then seems instrumental
- Need for increased research

Management action should be based on the best scientific evidence, as provided by ICES through ACFM. Using this knowledge, and including economic factors, we find that it would be economic efficient to reduce the exploitation rate significantly from the current level.

At higher levels of spawning stock it is easier to stabilise the annual quotas (from year to year). The economic revenue from such a stabilisation is not known, but is also expected to be significant.

ICES has already stated Bpa to 0.42. As shown in this analysis, the economic efficient fishing mortality was found to be at 0.24. In order to keep the annual level of TAC as stable as possible, it is suggested to keep the fishing mortality in the range 0.20 - 0.40.

As mentioned, there are several relevant factors where there is a need for more knowledge in order to use such knowledge when fixing management strategies. It is therefore important to support further research in those areas.

Consequences of economic parameters for optimal management

Stein Ivar Steinshamn
Centre for Fisheries Economics

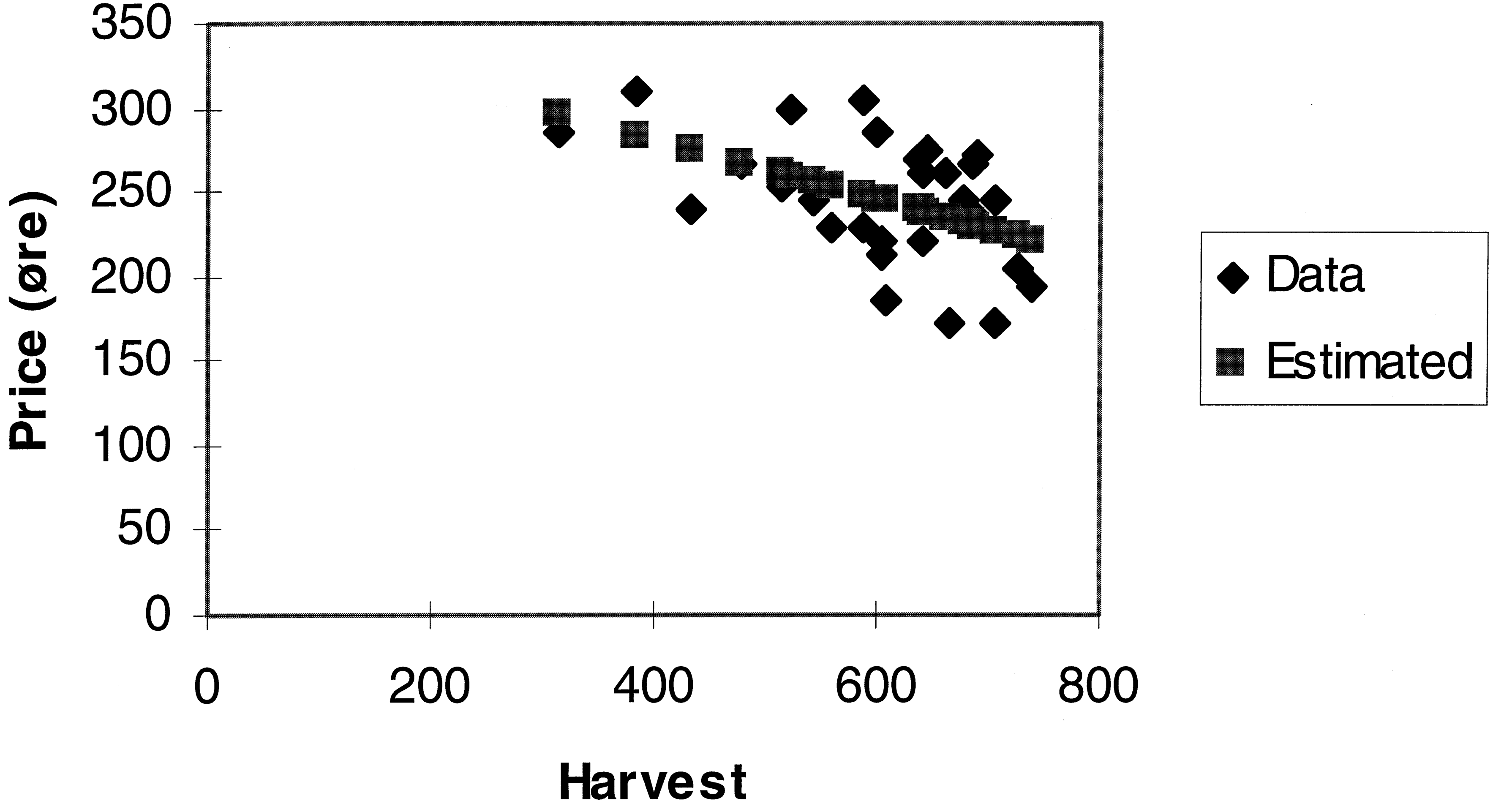
Objective

- Include economic parameters in fisheries management
- Price/quantity relationship
- Increasing marginal costs
- Stock dependent costs
- Discounting of the future

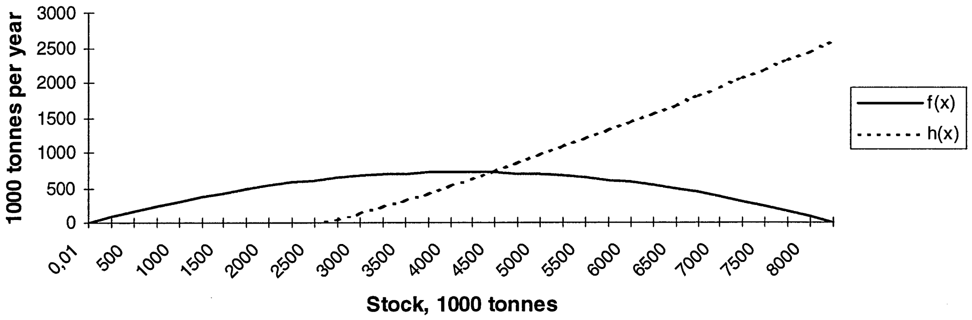
Price/quantity-relationship

- 1998:
- Quantity decreased by 10 %
- Prices increased by 34 %
- Haddock: prices increased by 70%
- Cod: prices increased by 50 %.

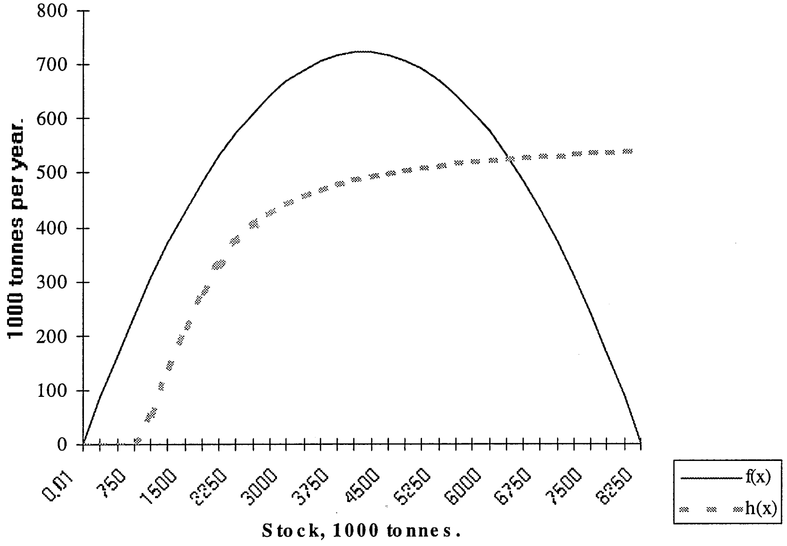
Observed price and estimated demand for cod

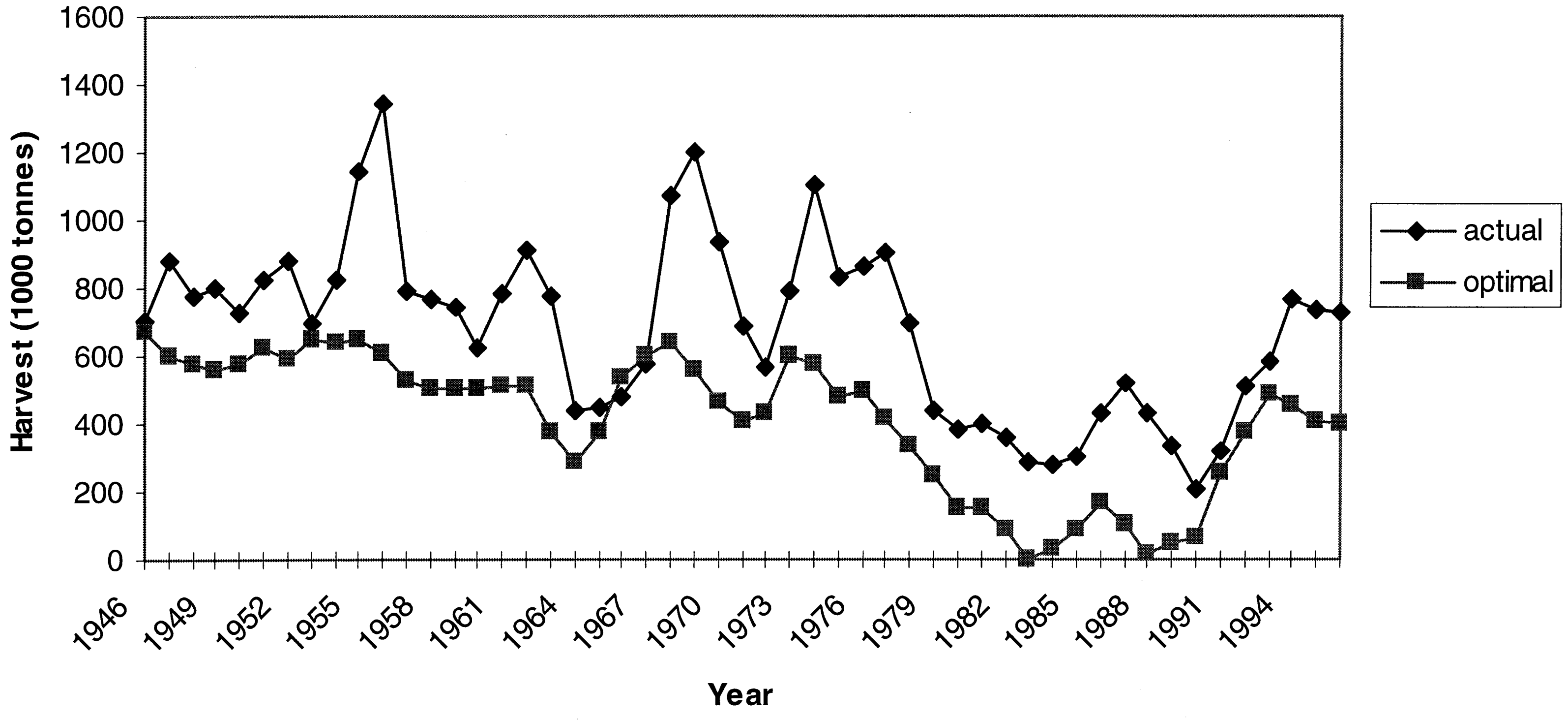


Growth, f(x), and optimal catch, h(x), with constant price.

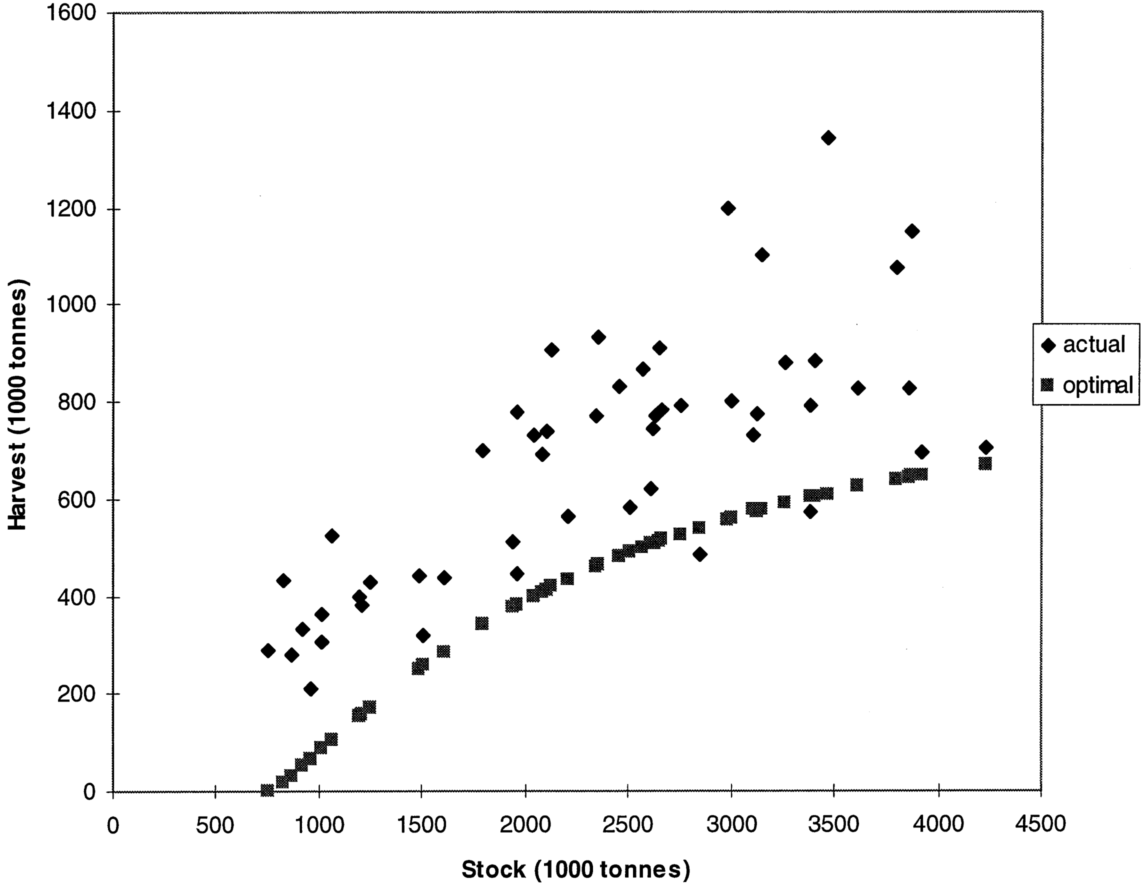


Growth, f(x), and optimal catch, h(x), with downward sloping demand.

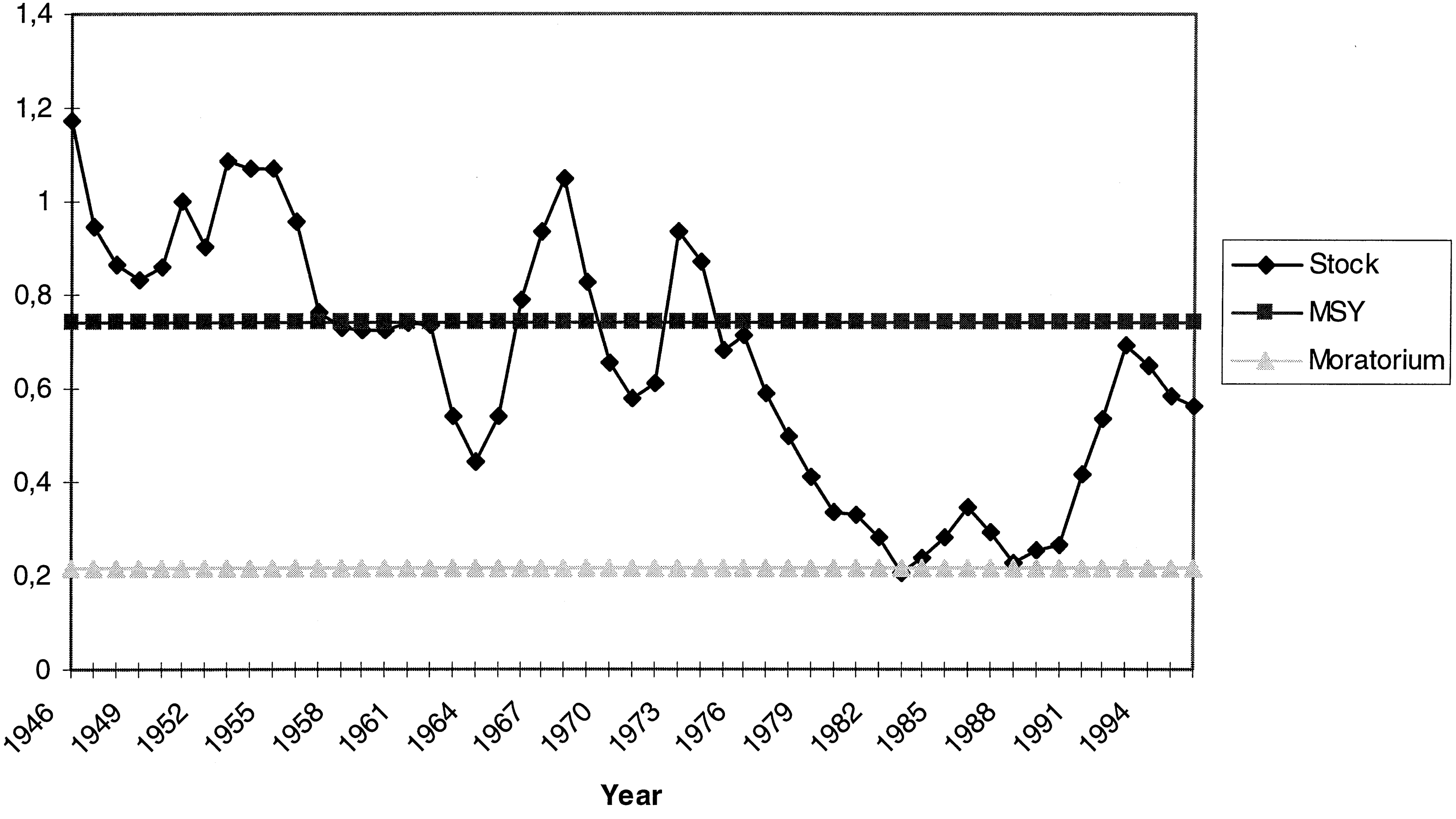



Cod: Actual versus optimal harvest

Cod: Actual versus optimal harvest against stock



Cod: Stock relative to optimal steady state



Conclusions

- Optimal quotas are highly dependent upon the parameters in the demand function.
- The cod stock in the Barents Sea has been heavily overexploited in the postwar period both from a biological and an economic point of view.

IMR/PINRO Joint Report Series 2002

No.1
Anon. 2002. Report of joint Russian/Norwegian aerial surveys in the Barents sea in September 2001.
IMR/PINRO Joint Report Series,No. 1/2002. ISSN 1502-8828. 11pp.

No.2
Anon. 2002. Investigations on demersal fish in the Barents Sea winter 2001. Detailed report.
IMR/PINRO Joint Report Series, No. 1/2002. ISSN 1502-8828. 11pp.

No.3
Anon. 2002. Report of the international 0-group fish survey in the Barents Sea and adjacent waters in August-September 2002.
IMR/PINRO Joint Report Series, No. 3/2002. ISSN 1502-8828.

No.4
Anon. 2002. Report from the joint Norwegian/ Russian acoustic survey of pelagic fish in the Barents Sea,
September-October 2002. IMR/PINRO Joint Report Series, No. 4/2002. ISSN 1502-8828.

No.5
Jakobsen, T. (ed.) 2002. Management strategies for the fish stocks in the Barents Sea.
Proceedings of the 8th Norwegian-Russian Symposium, Bergen, 15-16 June 1999.
IMR/PINRO Joint Report Series, No. 5/2002. ISSN 1502-8828, ISBN 82-7461-057-1.

JOINT REPORT

Institute of
Marine Research
Nordnesgaten 50,
5817 Bergen
Norway

Polar Research
Institute of Marine
Fisheries and Oceanography (PINRO),
6 Knipovich Street,
183763 Murmansk
Russia