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Seminar report:
THE PRECAUTIONARY APPROACH TO NORTH SEA FISHERIES MANAGEMENT

Oslo,
9 - 10 September 1996

HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH
BERGEN, NORWAY

Norwegian Ministry of Fisheries

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1. INTRODUCTION

- The North Sea Conferences

In the early 1980s some countries were dissatisfied with the lack of progress achieved in the protection of the marine environment. In part this was due to the wider geographical coverage of the bodies concerned and the lack of focus on the North Sea. It was in this climate that the Government of the Federal Republic of Germany in 1983 took the initiative of inviting the North Sea coastal states to an International Conference on the Protection of the North Sea at ministerial level. It was not the aim of the conference to create a new set of international agreements, but rather to ensure more effective implementation of the existing international rules in all the North Sea states.

During the preparation phase in 1983, agreement was reached that the Conference should not restrict itself to general principles but that it should examine all pollution sources and adopt definite decisions. The decision to address all pollution sources ensured that a holistic approach to the North Sea environmental problems would be followed. The Conference itself was then held in Bremen from 31 October to 1 November 1984 and was attended by the responsible ministers from the all the states bordering the North Sea. Although the Bremen Conference was initially envisaged as a unique event, the ministers welcomed the invitation of the United Kingdom Government to host a Second International Conference on the Protection of the North Sea for the purpose of reviewing the implementation and effectiveness of the decisions taken in Bremen and to adopt further concrete measures for the maintenance of the quality of the North Sea.

The United Kingdom set out with the intention that the London Conference in 1987 should reach conclusions about the state of the North Sea having regard to the best scientific evidence available. The preparatory work therefore included the production of a comprehensive quality status report (QSR) on the North Sea environment. This QSR showed that there still were shortcomings in the data and that it was not possible to make links between contaminant levels and environmental changes. Therefore, a North Sea Task Force(NSTF) was established to organise a co-ordinated scientific programme leading to enhanced knowledge. It was also decided that a Third Conference should be held in the Hague in 1990.

The conference in the Hague reviewed the implementation of the commitments entered into at the First and Second North Sea Conferences and evaluated the measures agreed in London from a policy point of view. An offer from the Danish Government to host a Fourth International Conference on the Protection of the North Sea in 1995 was accepted. It was also agreed to hold an Intermediate Ministerial Meeting(IMM) in Copenhagen in December 1993. This was essentially a review meeting to determine at ministerial level what issues needed to be addressed in the preparations for the Fourth North Sea Conference. The IMM-93 provided the first opportunity for a cross-sectoral approach at political level to certain environmental problems in the North Sea. The ministers drew attention to the need for suitable regimes for the protection of the coastal and marine areas including species and habitats and the importance of fisheries management for safeguarding the sustainability of the North Sea ecosystem as a whole.

The Fourth International Conference on the Protection on the North Sea was held in Esbjerg (8 - 9 June 1995) and now fisheries were included in the priority issues to be addressed. In the

Ministerial Declaration, article 13, it is stated that « a further integration of fisheries and environmental policy must be elaborated in order to protect the North Sea environment and ensure the sustainability of the fish stocks and the associated fisheries.»

During the Esbjerg Conference the ministers agreed to arrange an Intermediate Ministerial Meeting on the Integration of Fisheries and Environmental Issues in Norway (IMM 97) in March 1997. They further agreed to establish the Committee of North Sea Senior Officials (CONSSO) to prepare for this meeting. The ministers also recommended that the precautionary principle should be applied in North Sea fisheries management.

At its meeting in Bergen, Norway (13 - 14 June 1996), CONSSO adopted a Norwegian proposal to arrange a seminar on the precautionary approach to North Sea fisheries management as a part of the preparations for the IMM-97. The Institute of Marine Research in Bergen was asked by the Norwegian Ministry of Fisheries to organise the seminar which took place in Oslo (9 -10 September 1996).

The aim of the seminar was, with special emphasis on the North Sea fisheries, to:

- Clarify the different views on the application of the precautionary principle to practical fisheries management, and to identify areas of consensus.

- Discuss the precautionary approach in case exercises for three different North Sea fisheries.

A planning group consisting of the following were responsible for organising the seminar:

David W. Armstrong	- DG XIV, EU, Brussels
Åsmund Bjordal	- Institute of Marine Research, Norway, Seminar Convener
Arne Bjørge	- Norwegian Institute of Nature Research
Eskild Kirkegaard	- ICES
Per Sandberg	- Directorate of Fisheries, Norway

An editorial board was given the responsibility for the preparation of the seminar report. This group consisted of the following:

David W. Armstrong	- DG XIV, EU, Brussels,
Roger Bailey	- ICES
Åsmund Bjordal	- Institute of Marine Research, Norway, Editor
Armin Lindquist	- Institute of Marine Research, Sweden
John Pope	- Fisheries Laboratory, UK
Sigmund Engesæter	- Directorate of Fisheries, Norway

The programme for the seminar and a list of participants is given in APPENDIX 1.

- The Precautionary Principle

In June 1980 the Council of Environmental Advisors, an independent body of experts appointed by the German Government, presented its report on the environmental problems of the North Sea. The report concluded that a successful environmental protection policy for the North Sea had to be based on the "precautionary principle" (Vorsorgenprinzip) or the principle of precautionary action. This principle allows the pollutant emissions to be reduced at source even where there is no scientific evidence to prove a causal link between emissions and environmental effects. The adoption of the precautionary principle was indisputably accepted by all the North Sea states at the London Conference in 1987 and is one of the most important decisions emanating from the North Sea Conferences. The influence of the London Declaration decision has spread far beyond the North Sea and has become a generally accepted basic principle for the protection of the environment.

The scope of application of the precautionary principle was successively broadened from toxic substances to natural substances released in large quantities such as nutrients, and further to all emissions responsible for global warming. In the early 1990s, the precautionary principle has been progressively further accepted and widened to encompass the management of renewable resources, including fisheries. Sometimes it seems difficult to distinguish between the precautionary principle and the precautionary approach. Usually the latter is considered as more flexible including also socio-economic implications of its application.

The need for a precautionary approach to ocean development was stressed in the Rio Declaration and in Agenda 21. Principle 15 of the Declaration states that « *in order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*». The agreement from the UN Conference on Straddling Fish stocks and Highly migratory Fish Stocks 1992 - 1995, Article 6 is devoted entirely to the precautionary approach. FAO started the preparations of a Code of Conduct for Responsible Fisheries in 1993 and finalised it in 1995. The code includes a section on the precautionary approach as a part of Article 6 on Fisheries Management which is being progressively reflected in the fishery sector.

In direct relation to the process of development of the FAO International Code of Conduct, the Government of Sweden, in close co-operation with FAO, held a Technical Consultation on the Precautionary Approach to Capture Fisheries and Species Introduction (Lysekil, Sweden, 6 - 13 June 1995). The report from the meeting proposed a definition of the precautionary approach to fisheries as well as an elaboration on the burden of proof. It also contained guidelines on how to conduct fishery management and research and how to develop and transfer fishery technology in a precautionary context. The guidelines are aimed at governments, fisheries authorities, fishing industry, regional fishery management bodies, NGOs and other interested parties in order to increase their awareness of the need for precaution in fisheries as well as to provide practical guidance on how to apply such precaution.

- Assessment of the North Sea Fisheries

In the preparation of the IMM-97 , CONSSO felt it necessary to establish a report covering the status of the North Sea with regard to fisheries and fisheries-related species and habitats issues. The intention is that the report will address the main challenges with regard to further integration of fisheries and environmental management. It should establish an important basis for the Ministers` discussion on how to make progress with regard to improvement in the management of the fish stocks, ensuring the sustainability of the stocks and reduction in the negative impact of fisheries on the ecosystem as well as in adverse effects on fisheries from other human activities.

Most commercial fish stocks of the North Sea, especially those landed for human consumption, are heavily exploited and the fishery lands mainly juvenile fish. The spawning stock sizes are below or close to the minimum biologically acceptable level(MBAL) below which the probability of poor recruitment increases. Survey data indicate a change in the length composition of the North Sea fish stocks: the quantity of larger fish has decreased and the number of smaller fish has increased. To rebuild the stocks above MBAL, a significant and sustained reduction in fishing effort is required.

The annual removal of about 3 million tonnes of fish and shellfish alters the structure of the ecosystem by changing the relative and absolute levels of biological material that pass along each of the trophic pathways in the North Sea food web. Harvesting fish and shellfish directly affects the target species, the non-target species and in a number of cases the abiotic environment. These direct effects of fishing can be: mortality of the target fish and other biota; an increase or decrease in food availability for other species in the ecosystem and disturbance of the seabed.

Fish stocks may also be impacted by all human activities that alter the marine environment; pollution by nutrients, hazardous substances, oil and radioactive contamination as well as introduction of alien species and physical habitat changes.

One of the fundamental problems in fishery management is to obtain a balance between the fishing effort and the availability of fish resources. The fisheries in the North Sea are managed under a system of Total Allowable Catches (TAC) established each year on the basis of scientific advice from the International Council for the Exploration of the Sea (ICES). The TAC system has suffered from enforcement problems which have resulted in an overshooting of quotas and in deterioration of catch statistics.

Until recently ecosystem considerations played only a minor role in the management objectives and decisions. The North Sea fish stocks are still mainly managed as though each species existed in isolation. A further integration of fisheries and environmental management must be elaborated in order to protect the North Sea environment and ensure the sustainability of the fish stocks and the associated fisheries.

2. THE PRECAUTIONARY APPROACH: INTERPRETATION OF THE CONCEPT AND ITS APPLICATION TO THE NORTH SEA FISHERIES

This session of the seminar was introduced by a presentation by J.J. Maguire (Appendix 2) , entitled "The Precautionary Approach - with special emphasis on the Report of the Lysekil (Sweden) Technical Consultation (6-13 June 1995)". The talk was followed by views on the precautionary approach concept and its application presented by representatives from fisheries research, fisheries management, the fishery industry, environmental management and environmental organizations.

There was a general agreement that the guidelines given in the "Lysekil-report" are a good theoretical basis for a precautionary approach to fisheries management, and the importance of their application to practical North Sea fisheries management was emphasized.

Given that fisheries will be an important part of human activities in the future, it should be realized that fishing cannot be undertaken in accordance with the precautionary principle - when using a very restrictive interpretation of the concept.

The precautionary principle is regarded as very restictive and prescriptive, while the precautionary approach is regarded as a more flexible concept including also socio-economic effects of its application. The precautionary approach may thus be regarded as a set of practical guidelines on how to deal with uncertainties in fishery management in a responsible way.

Although the seminar did not provide a forum for creating consensus, there seemed to be general agreement on the above differentiation between the principle and approach concepts.

Fishing should, therefore be conducted according to a precautionary approach, with extensive application of proper guidelines (as given in the "Lysekil-report") in fisheries management.

The session was summerised as a list of statements and recommendations (see section 4). These general conclusions were further supported by the case exercises on the management of different North Sea fish stocks.

3. CASE EXERCISES ON THE APPLICATION OF THE PRECAUTIONARY APPROACH TO THE CURRENT MANAGEMENT OF SOME NORTH SEA FISH STOCKS

The North Sea Herring Stock.

A paper titled "North Sea Herring: A Case study in Precautionary Approach" was presented by Dr. R. Toresen (Appendix 3) . After an introduction to the biology and fisheries of the North Sea herring stock and a history of its exploitation the author asked the question why the situation is as bad as it is. The answers are that fishing mortality is too high and the exploitation pattern is too focused on juvenile fish.

The author then detailed how the advice and management had progressed over the last 5 years. This showed a pattern of the science being overly optimistic about the state of the stock in 1991 and only gradually adapting to the more realistic, pessimistic view as time progressed. Management appeared to have no objective beyond the maintenance of the status quo, did not always take the management advice and had no action plan to apply when limit reference points were approached. Neither scientists nor managers heeded the warning of increased juvenile components in the catch.

In the discussion it was noted that the behaviour of fishermen was not included in the model and nor were other possible factors such as the fungus disease *(Icthyophonus)*. It was particularly noted that MBAL should not be treated as a target since this would guarantee the stock running into problems.

The North Sea Sandeel Stock.

A paper titled "The industrial fishery and the North Sea Sandeel Stock" was presented by Dr. H. Gislason (Appendix 4). The author provided an introduction to the biology and fisheries of the North Sea sandeel stocks and a history of their exploitation and the spatial and temporal distribution of fishing activities. The spawning stock biomass fluctuates around without trend about 800,000 tonnes. The author made calculations suggesting that MBAL might be between 324,000 and 750,000 tonnes. The stock seems fully exploited, but not overexploited from a fisheries view point. The author explained the status of sandeel as a prey to many species. Calculations of changes in yield of its important commercial fish predators did not indicate that large gains would be made in their catch by closing the sandeel fishery. He noted however there had been a link between sandeel abundance at Shetland and breeding success of Arctic terns. He noted that very little was known about interrelationships of sandeel and birds at other coastal sites but a precautionary approach might lead to the closure of fisheries in some sensitive areas.

With respect to the precautionary approach the author noted that there were no objectives for the fishery and no direct management. However, *perhaps because of this* there were good data to monitor the fishery. He thought that effort controls were more likely to be feasible than TACs.

In discussion of the paper it was noted that a precautionary TAC would not prevent overfishing of the stock, it was also noted that the fishery would be driven by the economics of fish meal production. Audience members speculated that the spatial distribution might act as a stock health indicator of overfishing and that the resilience of seabird populations should not be underestimated. In summery it seemed there was need for some sort of control of the fishery and that objectives needed to be agreed.

The North Sea Roundfish Stocks.

A paper titled "North Sea Roundfish" was presented by Dr. R. Cook (Appendix 5). After an introduction to the fisheries of the North Sea cod, haddock, whiting, and saithe stocks and a history of their exploitation the author concentrates on the possible stock recruitment relationships of the 4 stocks and addresses the question of whether the current fishing mortality is greater than F_{loss}, the level of fishing mortality which would generate the lowest observed spawning stock given the stock recruitment relationship. The author also asks the question of "F_{loss} close to the level of fishing mortality which would cause the stock to collapse given the stock recruitment relationship ?" If the answer to both questions is yes then the stock is in grave risk of collapse. This appears to be particularly the case for North Sea cod. However, due to uncertainties in the fitting of the stock recruitment relationships and other parameters of the model the answer can only be given in probabilistic terms.

It was noted in discussion that this paper illustrates two important features that would form part of a future precautionary approach for these and for other stocks. These are the null hypotheses that a stock recruitment relationship exists even if it cannot be established with statistical rigor and that management will have to learn to operate with probabilities rather than certainties that undesirable outcomes will occur and react to these in a rational way (i.e. by taking a precautionary as opposed to a reckless strategy).

Summary of Case Studies

The following general conclusions were noted:

NONE OF THE THREE FISHERIES COULD BE REGARDED AS BEING MANAGED IN ACCORDANCE WITH THE PRECAUTIONARY APPROACH.

Administrators MUST set objectives and scientist must take a more proactive role in assisting them to do this.

Herring and roundfish NEED recovery plans agreeing urgently.

For sandeel fisheries NOW would be a good time to develop pre-agreed future emergency measures.

All three fisheries need targets and limits setting.

All need more effective controls.

Understanding the economic and social drivers of overfishing are critical if a precautionary approach is to work.

Scientists need to provide administrators maximum lead time to help them exhibit prudent foresight.

Improvements in exploitation pattern (i.e. catching less young fish) will improve management foresight, by providing a longer lead time.

Assessment scientists need to assume a stock recruitment model as the null hypothesis.

Assessments need to incorporate uncertainty and management needs to learn how to interpret uncertainty in a prudent (as opposed to reckless) fashion.

Management measures need to be chosen that are robust to uncertainty.

There is a need for broad consultations with interested parties for a precautionary approach to work.

4. GENERAL CONCLUSIONS AND RECOMMENDATIONS

- There was general agreement that the Report of the Technical Consultation on the Precautionary Approach to Capture Fisheries (including Species Introductions) held in Lysekil in June 1995 formed an acceptable basis for a discussion on the application of the precautionary approach to the management of North Sea fisheries. This report makes specific reference to the need for a precautionary approach outlined in the FAO Code of Conduct for Responsible Fishing.

- It was agreed that discussion at the seminar should be limited to the management of capture fisheries and not extend to other aspects such as mariculture and introductions.

- The following summary is based on the guidelines for implementation of the precautionary approach in fishery management presented to the seminar.

1. *The status of North Sea fish stocks and the need for action*

Most of the important commercial fish stocks in the North Sea are fully exploited or overexploited, the only possible exceptions being a number of deepwater stocks at the boundary of the North Sea and certain stocks with developing fisheries, such as *Nephrops* in localised areas. As most stocks are already subject to heavy fishing pressure, a precautionary approach must be applied urgently in two ways:
a) by avoiding further depletion of fully exploited stocks, and
b) by rebuilding depleted resources.

In the case of fully exploited stocks an immediate capping of fishing mortality is required. In the case of depleted resources, the development of explicit rebuilding strategies is needed.

For those stocks that are overexploited, it was agreed that restoration programmes should be developed as a matter of urgency. In this context it was recognised that programmes involving an immediate and severe reduction in fishing effort will have major socio-economic effects - at least in the short term. It was also recognised that initiatives to reduce fishing mortality had failed at the implementation stage because of their socioeconomic consequences and that any new initiatives must address these problems in a direct manner.

2. *Management objectives*

As no long-term management objectives for the North Sea have yet been universally agreed, it was suggested that provisional or working objectives should be formulated. While the setting of management objectives is the responsibility of managers, it was recognised that the scientific advisory bodies can play an important role in this process by identifying and analysing the most reasonable types of objectives and targets available to managers, particularly those which would accelerate rebuilding and enhance sustainability. In this process, precaution must be reflected in any targets and objectives set and these objectives must be both quantifiable and quantified.

3. *Involvement of interested parties*

Increased dialogue between all those with a legitimate interest in a fishery is an important ingredient of the precautionary approach. To ensure a better understanding of, and compliance with, management action, it was agreed that better communication between managers, scientists and interested parties is essential. This should involve consultation with fishermen at the grass roots level in national fora and with representatives of the industry and other interested parties in national and international fora.

4. *Limitation and control of access*

Free or open access to a resource usually leads to overfishing and is therefore not precautionary. The seminar noted that there had been a realisation of the need for limitation of access to fisheries if they are to be fully productive. This could be achieved by requiring prior authorisation for all fishing activities.

5. *Target and limit reference points and triggers for the application of pre-agreed measures*

MBAL, (minimum biological accaptable level of spawning stock) which has so far been established for very few stocks, is a reference point that should be avoided wherever possible by taking action before it is reached. It should never be considered as a target reference point. For stocks that are below MBAL, action is needed to rebuild them as rapidly as is compatible with socio-economic constraints. In this situation, MBAL should be considered only as a first step towards rebuilding the stock biomass to at least a level corresponding to the Maximum Sustainable Yield (MSY) level.

In accordance with the precautionary approach, target and limit reference points (based on fishing mortality, biomass and other relevant factors) should be agreed and mechanisms established for applying pre-agreed measures when stock levels approach these reference point With any measures that are agreed before they are needed it is essential to prescribe exactly what is going to be done, when, and by whom.

It was also agreed that a number of existing measures need to be strengthened or extended including the MAGP (Multi Annual Guidance Program) and technical measures. In addition, effort control should receive further consideration.

6. *Means of controlling capacity and fishing mortality*

It was noted that overcapacity is the main reason why fisheries management has been ineffective and why a precautionary approach has not been followed. Although schemes to reduce capacity have already been applied, the decrease achieved has been compensated by a concomitant increase in efficiency with the result that there has been no reduction in fishing mortality rate. Fishing effort by the existing fleets is also not regulated under the present system in which outputs (catches) are the basis for control.

7. *The effectiveness of fishery regulations*

It was agreed that it is essential to establish why many fishery regulations have been ineffective. For this purpose a study is urgently needed in which both the scientific advisory bodies and the decision makers take part.

8. *Recovery plans for overutilised stocks*

In the present situation in which many stocks are heavily exploited and outside safe biological limits, it is essential to prepare and implement restoration plans as soon as possible. For such overexploited stocks, pre-agreed procedures are needed to ensure timely and effective restoration. For other less heavily exploited stocks, pre-agreement on procedures to follow in the event of approaching limit reference points is essential if stock depletion is to be avoided.

9. *Collection of data*

The poor reliability of reported catch and effort data has been recognised as a major problem in providing scientific advice on fisheries in recent years. This issue will require continued attention by the authorities involved.

There is also at present a paucity of data on socioeconomic factors and on the effect of fishing on non-target species and other components of the ecosystem. A number of economic studies have been carried out but there is a need for further work in this area. It is important that such data and analyses are incorporated into the advisory process, and that estimates of the reliability of the outputs are provided.

10. *Application of management measures*

Management measures such as catch controls, area closures and other technical measures are already in widespread use although their effectiveness in reducing fishing mortality and improving the exploitation pattern has been very limited. The need for real-time management (i.e. short-term closures in response to particular problems such as excessive by-catches of young fish) should also be explored and exploited wherever possible. In addition, there is a need to improve the selectivity of gears both by enhancing the selectivity of existing gears and by introducing novel types of gear.

Considering that many fisheries, particularly those on roundfish and flatfish will remain poorly selective multispecies fisheries. It was agreed that research in new approaches in the management of those multispecies fisheries is needed.

11. *Early warning signs of impending problems*

Further advice should be given on what to look for to prevent the effects of overexploitation. Relevant pointers are:

a) changes and trends in key environmental factors;
b) changes in spatial distribution, and not only changes in catch-per-unit-effort;
c) localisation/extension of spawning areas;
d) oscillations in some indicator species.

12. *Artificial propagation*

Although stock enhancement and stocking may be appropriate in some situations, it is important that they should not be used as a substitute for effective adjustment of fishing capacity and practices.

13. *Ecological effects of fishing*

It was generally agreed that many undesirable ecological or environmental effects of fishing are one of the manifestations of the general problem of overfishing. It is therefore likely that many of the effects of fishing activities on the ecosystem will be reduced or eradicated if the more general problem of overcapacity and excessive fishing effort is solved by a general reduction in fishing over all fishing methods. Certain specific problems will still remain, however, and these should be covered by precautionary action, where necessary by measures additional to those needed to protect the target species.

APPENDIX 1

The Precautionary Approach to North Sea Fisheries management

Oslo, 9 -10 September 1996

- Seminar Program

- List of Participants.

APPENDIX 1

- SEMINAR PROGRAM AND LIST OF PARTICIPANTS

SESSION 1: THE PRECAUTIONARY APPROACH INTERPRETATION OF THE CONCEPT AND ITS APPLICATION TO THE NORTH SEA FISHERIES

(Chairman: Armin Lindquist, rapporteur: Roald Sætre)

- Halvard P. Johansen
Opening Statement

- Jean Jacques Maguire:
The Precautionary Approach to fisheries: presentation of the Lysekil Report (FAO.Fish.Tech. paper 350/1)

Different views on the precautionary principle in the North Sea fisheries management.

- Eskild Kirkegaard:
The International Council for the Exploration of the Sea (ICES)

- Sigmund Engesæter:
The Norwegian Directorate of Fisheries

- Wiebke Schwarzbach:
German Federal Environmental Agency

- David W. Armstrong:
DG XIV, European Commission

- Niels Wichmann:
Danish Fishermens Association/Europeche

- Malcolm MacGarvin:
Greenpeace International

- General discussion

- Lene Buhl-Mortensen:
Statistical Errors in Environmental Science and the Precautionary Principle

- Åsmund Bjordal:
Presentation of the Summary and Conclusions from Session 1.

SESSION 2: CASE ECERCISES ON THE APPLICATION OF THE PRECAUTIONARY APPROACH TO THE CURRENT MANAGEMENT OT THE NORTH SEA FISH STOCKS.

(Chairman: John Pope, rapporteur: Jacques Bastinck)

- Management and development history of the stock versus a retro-spective precautionary scenario.
- Present state of the stock and projections.
- Management according to the precautionary approach.

- Reidar Toresen,
(Institute of Marine Research, Norway)
The North Sea herring stock

- Henrik Gislason,
(Danish Institute for Fisheries Research):
The North Sea sandeel stock

- Robin M. Cook,
(Marine Laboratory, Aberdeen):
The North Sea roundfish stocks

- Concluding discussion

- Closure of seminar

- LIST OF PARTICIPANTS

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APPENDIX 2

The Precautionary Approach: With special emphasis on the Report of the Lysekil (Sweden) FAO Technical Consultation (6-13 June 1995)

By: J.J. Maguire and A. F. Sinclair

The Precautionary Approach

With special emphasis on the Report of the Lysekil (Sweden) Technical Consultation (6-13 June 1995)

by

Jean-Jacques Maguire and Alan F. Sinclair

I would first like to thank the organisers for inviting me to this seminar. I am very happy to be here, my first time in Norway, and I am sure our discussions will be very stimulating and interesting.

Structure of the Presentation

- Popular Concept
- Precautionary Approach vs Precautionary Principle
- Report of the Technical Consultation
- Shortcomings

The structure of the presentation will be as follows:

I will first give a few indications of how popular the precautionary approach has been recently.

Then, I will distinguish between the Precautionary approach and the precautionary principle. The two are often used interchangeably, but they are very different and they carry very different baggage as well.

The majority of the talk will be on the report of the technical consultation. Originally, I wanted to only give a brief introduction to the FAO Fisheries Technical Paper 350/1 and put more emphasis on my own interpretation of what the precautionary approach is. However, I expect that this is what most of the speakers at the Seminar will do and I will have several chances to state my views on the precautionary approach during the seminar. Several of the participants at the technical consultation where this report was written are here today, and they will no doubt correct any misinterpretation I may make. In total, about 35 scientists participated in the technical consultation.

I will end the presentation with a few pitfalls to be avoided.

Popular Concept

- Rio Declaration
- United Nations Conference on Highly Migratory Fish Stocks and Straddling Fish Stocks
- FAO Code of Conduct for Responsible Fisheries

OK, how popular is the precautionary approach? Well, the report of the Lysekil technical consultation is only one element of the several initiatives currently going on at the international level. Some of the others are

the Rio Declaration and Agenda 21,

the United Nation's Conference on HMFS and SFS, and

the FAO Code of Conduct for Responsible Fisheries. (In fact the Guidelines I am introducing to you are in support of the Code of Conduct for Responsible Fisheries).

Countries involved in these events are supposed to follow-up on the resolutions and conclusions of these various meetings. In fact, this Seminar in Oslo is a follow-up by Norway and the European Union to implement some of the ideas and concepts included in those texts.

The FAO Code of Conduct for Responsible Fisheries is a voluntary code of conduct. Once ratified by a sufficient number of countries, the UN Agreement on HMFS and SFS will be incorporated in the Law of the Sea, if I understand this correctly.

Rio Declaration

- *"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation"*

On the precautionary approach, the Rio Declaration says:

UN Conference on HMFS and SFS

- Article 6 and Annex II entirely devoted to Precautionary Approach
- Points covered, among others:
  - ✓ More cautious when uncertainties are greater
  - ✓ Define cautious reference points and ensure they are not exceeded
  - ✓ If reference points are exceeded take quick pre-agreed actions
  - ✓ If a natural phenomenon has significant adverse impact, take measures to ensure that fishing does not exacerbate such adverse impact

In the UN Agreement on HMFS and SFS, article 6 and Annex II are entirely devoted to the Precautionary approach.

Among the points covered are: read the second point...

The last point says that it is not a good idea to catch the last fish, even if we knew they were disappearing because of a natural phenomenon.

One of the important concepts in the HMFS and SFS agreement, is that FMSY is now defined as a limit reference point, that is a zone to avoid rather than an objective to seek. MSY and FMSY are the only reference points mentioned in UNCLOS. Negotiators of the Agreement on HMFS and SFS had the choice of negotiating the inclusion of other reference points, or refer to those already in UNCLOS. They chose the later which obliged them to be rather imaginative. The idea now is that the biomass should be kept above or restored to a level capable of producing MSY. The difference between target and limit reference point is an important concept.

Results on southern Gulf of St. Lawrence cod, show that this is not a unique level while those on North Sea cod and Barents Sea cod suggest that several cod stocks are currently exploited above MSY,and that the biomass is lower than that capable of producing MSY. Northern cod Fmsy in the order of .09 to .13, lower than F0.1.

FAO Code of Conduct (General Principle (6.5) and Article 7.5)

- "*States and subregional and regional fisheries management organizations should apply a precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment, taking account of the best scientific evidence available. The absence of adequate scientific information should not be used as a reason for postponing or failing to take measures to conserve target species, associated or dependent species and non-target species and their environment*"

The FAO Code of Conduct for Responsible Fisheries now. General Principle 6.5 and Article 7.5 deal with the precautionary approach. The Code says that...

The reason I have mentioned the Rio Declaration, The UN Conference and the FAO Code of Conduct, is to convey to you that the Precautionary Approach has become a concept which has been widely used in international fisheries discussions. It was anticipated in those international discussions that mechanisms would be put in place to apply the Precautionary Approach within national jurisdictions as well. This meeting in Oslo is an example of such mechanism.

Precautionary Approach vs Precautionary Principle

- Precautionary Principle Applied in Chemical Industries w/r to Pollution
- Precautionary Principle Very Restrictive and Prescriptive
- Precautionary Approach More Flexible
- Problems with the word “Approach” in some languages

Turning to the difference between the Precautionary Principle and the Precautionary Approach.

In some languages, approach, with the meaning used here, does not exist, and interpreters have had problems finding a synonym. Therefore, the word principle is sometimes still used. And this scares some of the people who are familiar with what the precautionary principle implies.

Precaution Applies to All Elements of Fishery System

- Development Planning
- Management
- Research
- Technology Development and Transfer
- Legal and Institutional Frameworks
- Fish Capture, Processing and Marketing

The Precautionary Approach should be applied to all elements of the fishery system, from the development stage to the marketing stage. Precaution is particularly important at the development stage because many serious mistakes can be avoided at that stage.

In a paper on the "Lessons for stock assessment from the northern cod collapse" Carl Walters, argues that the collapse of northern cod was made inevitable as early as the late 1970s - early 1980s, when the Canadian and Provincial governments subsidized Canadian companies to gear up to go fishing in the northern areas. Without using those specific words, Walters implies that Precautionary development would have been much slower than governments of the time encouraged. As a co-author on the paper, I tend to agree with him.

The FAO reports does not cover directly all those aspects but it does indirectly. The main themes covered are:

Report of the Technical Consultation

- Precautionary Approach (PA) and Burden of Proof
- PA to Fisheries Management
- PA to Fisheries Research
- PA to Fishery Technology
- PA to Species Introduction
  - ✓ Not covered in this presentation

The first item, Precautionary Approach and Burden of Proof was extensively discussed in plenary, and can be regarded as a consensus of the principal elements which should be taken into account in applying the Precautionary Approach. It covers less than one and a half page, and could be used as a checklist to find out if a measure is precautionary.

The other items cover some of the same points in greater details under the headings of

Fisheries Management

Fisheries Research

Fishery Technology

Species Introduction.

Only the first three topics will be covered here, and I will not present material on species introduction.

Precautionary Approach Requires

- ✓ needs of future generations + irreversible changes
- ✓ prior identification of undesirable outcomes and measures to avoid or correct
- ✓ efficient and effective corrective measures
- ✓ when uncertain, benefit of doubt to the resource
- ✓ avoid overcapacity
- ✓ prior authorization and review
- ✓ legal and institutional framework

The precautionary approach requires to take into account the needs of future generations, which implies taking a long term view. This includes the concept of inter-generational equity, which implies that we should leave to our children at least as much natural richness as we have inherited from our parents. In this context, it is necessary to avoid irreversible damages.

To do so requires the prior identification of undesirable outcomes, in order to avoid them, or correct them when we get there.

It requires efficient and effective measures. Here, the report talks about having corrected the situation, that is having reverted to a desirable state in less than 2 or 3 decades.

When we are uncertain, we should give the benefit of the doubt to the resource, that is be more conservative. We do not always do that and we will come back briefly on this later.

Overcapacity is seen as a major problem, and the report implies that the existence of overcapacity is not precautionary.

In order to be precautionary it is necessary that fishing activities have prior authorization and be reviewed periodically. It is also necessary to have appropriate legal and institutional frameworks. However, these need not be centralized nor bureaucratic (my emphasis).

Burden of Proof

- ✓ all fishing activities have environmental impacts
- ✓ not necessary to prevent fishing until all impacts assessed
- ✓ authorization, management plan includes objectives, assessment, monitoring and rehabilitation
- ✓ standard of proof proportional to risks, taking into account potential benefits

With respect to the burden of proof, the Precautionary approach has often been taken as meaning a reversal of the burden of proof. Canadian Fisheries Minister John Crosbie, used this approach in February 1992, a little too late perhaps, when he banned fishing during spawning for northern cod. Nobody had proven that it was detrimental, but he asked to be convinced that it was not detrimental.

Therefore, with respect to the burden of the proof, the report notes that...

The precautionary approach to fisheries requires that all fishing activities be subject to prior review and authorization; that a management plan be in place that clearly specifies management objectives and how impacts of fishing are to be assessed, monitored and addressed; and that specified interim management measures should apply to all fishing activities until such time as a management plan is in place.

The standard of proof should be...

great risks, small benefits - forget it

small risks, great benefits - go for it

PA in FM - Introduction

- ✓ Prudent foresight, changes slowly reversible, difficult to control, not well understood
- ✓ Establish legal, social, institutional frameworks for fisheries management
- ✓ Pre-agreed measures to avoid or mitigate undesirable outcomes

Management according to the precautionary approach exercises prudent foresight to avoid unacceptable or undesirable situations, taking into account that changes in fisheries systems are only slowly reversible, difficult to control, not well understood, and subject to change in the environment and human values.

The frameworks referred to in the second point need not be overly bureaucratic nor centralized. There are examples of successful fisheries management around the world, and these normally imply a large degree of co-management and delegation of decision-making to local authorities. It would be against the intent of the precautionary approach to bureaucratize fisheries management any more than it already is in most areas of the developped world.

The pre-agreement on measures is a key element of the precautionary approach. It is much easier to agree on what to do in case of problem, before the problem arises. I use the space shuttle example here: engineers, astronauts and all other interested parties agree ahead of time that launching procedures will be stopped when such and such happens. It is not time to convene a meeting to discuss actions to be taken when the temperature in a booster exceeds a certain threshold. Similarly, it is not when the fishery is clearly collapsing that we should discuss what to do. We should have done that much ahead of time, and agree on measures to be taken to avoid the collapse.

PA in FM - Management Planning

✓ Ability to monitor and control capacity
✓ All plans should explicitly incorporate precaution
✓ Interested parties to choose from alternatives
✓ Linked to ICAM
✓ Management objectives
✓ Targets and constraints (SBL)
✓ Management procedure - decision rules
✓ Internal consistency
✓ Prospective evaluation

At the planning stage, it is important to ensure that the ability to monitor and control capacity exist. I am not sure that this is the case in many areas of the world. We are still not sure how to define or measure capacity.

All fishery management plans should explicitly state how precaution is implemented.

In order to gain support for the plan, a range of alternatives should be considered and interested parties should choose amongst those. This implies that there is someone, in the interested parties, to speak for the fish.

Planning should be linked with Integrated Coastal Area Management.

An explicit discussion of quantified social, economic and biological objectives, and a consensus adoption of them by all interested parties may seem a little utopic, but it would go a long way in facilitating fisheries management.

It is also useful to define safe biological limits, to define and test (by simulation or otherwise) management procedures and decision rules, this is linked with the pre-agreement. Above all, the management measures, the objectives and the constraints should form a consistent package - high F and high SSB are normally not compatible.

PA in FM - Implementation, Monitoring and Enforcement

- ✓ Detailed instruction for compliance, monitoring of the fishery, and enforcement tactics
- ✓ Involve interested parties in implementation
- ✓ Need data to evaluate and make decisions
  - On side effects too
- ✓ Mechanism to revise/react to unexpected events
- ✓ Re-evaluation of management systems

Implementation puts in place all planned decision rules. This involves the practical interpretation of objectives and procedures, and the implementation of detailed instructions for compliance, monitoring of the fishery, and enforcement tactics.

Here, like at the other stages, it is useful to involve the interested parties.

A very important aspect, often taken for granted, is that if we want to be able to make decisions, we need data and information. Not only on the direct effects of fishing but also on the side effects.

We need to have mechanisms in place to react quickly to unexpected events and we also need periodic review or re-evaluation of the management systems.

PA in FM - Implementation Guidelines - Slide 1 of 3

- ✓ New or developing, Overutilized, Fully Utilized, Artisanal
- ✓ Establish objectives
- ✓ close involvement of interested parties
  - co-management
  - responsible fishing
  - delegate decision-making
  - tenure of fishing rights
- ✓ Limit/Control access,
- ✓ Establish target and limit reference points (SBL)
- ✓ Means to control capacity and fishing mortality

The report lists precautionary measures for four fishery types,

New or developing, Overutilized, Fully Utilized, Artisanal,

stating that "*some of the measures listed [...] will also apply to the other types.*[and that] *Most of these recommendations also apply to existing fisheries that are not yet managed.*"

In fact, the same sort of measures would apply to all fishery types, it is only a question of scope and degree of application. Therefore, I have not separated the measures into those four fishery types. I provide the list of more or less common measures one would expect to find in fisheries.

PA in FM - Implementation Guidelines - Slide 2 of 3

- ✓ Pre-agree on what to do when target reference points are missed and limit reference points are approached
  - includes recovery plan for overutilized fisheries
- ✓ Collect data to monitor fishery and fleets and make decisions
  - Study factors which affect fishers behavior
  - Study economic viability
- ✓ Apply management measures
  - wide use of area closures
  - cap effort and/or catch

Mention undereporting, misreporting, discarding as a result of TAC management of multispecies groundfish trawl fishery.

PA in FM - Implementation Guidelines - Slide 3 of 3

- ✓ Early warning signs, spawning biomass, age-structure of spawners, shrinking spatial distribution, species composition (define recovery in same terms)
- ✓ Trigger application of pre-agreed measures (generally not if, when)
  - reduce F, reduce fishing capacity (allow vessel to move to other fisheries, be flexible - phase out vessels), apply recovery plan, use recruits to rebuild spawning stock biomass
- ✓ Do not use artificial propagation as substitute

The last point, on artificial propagation, I suppose is subject to discussion, but personally I agree entirely with it. I remember a description of the rehabilitation of a striped bass fishery in the USA. This was described as a great fishery management success. Very little had been done in terms of fishery management, the key to stock rebuilding was artificial propagation. This may be only postponing the problem. It also has a flavor of playing god.

PA to FR - Role in Establishing Management Objectives

- Evaluation of Consequences of Management Actions
  - ✓ Operational targets, constraints and criteria
- Until specific research
  - ✓ Biomass above 50% of unexploited
  - ✓ F below natural mortality rate
  - ✓ Avoid immature fish
  - ✓ Protect Habitat

The link between how much precaution is required and research, is quite clear when one thinks about it, the less we know the more precautionary we must be, but in reality it often goes the other way. In many cases, particularly for little known small stocks of groundfish, the less is known, the less precautionary we are. This applies to a number of stocks in many areas.

In a precautionary approach the role of fisheries research in defining management objectives is to evaluate the consequences of various management actions. This implies the definition of operational targets, of constraints and of criteria to implement decision-rules. The objectives must also be quantifiable and quantified - maximum benefits to society does not fit the bill.

In new fisheries or where no specific research has been conducted, the following reference points and constraints should be used...

PA to FR - Observation Processes and Information Base

- Like any other Business
  - ✓ Need information to make decisions
- Revise Periodically Needs for Info
- Use Fishermen and their Knowledge in Research
- Quantify Uncertainties
- Historical Experience (Northern Cod)
- Research on Management Processes

Fisheries is like any other business - I have said that at least once before today and I want to expand a little here, because it is particularly relevant to fisheries research. In any business or human endeavor we need information to make decisions. Without data or information there is no basis to make decisions. Scientists often provide "advice" based on very little information. This does not help their credibility, and the identification of critical gaps in knowledge is an important element of fisheries research. When scientist know little, they should say so, and decisions should be based on other criteria, perhaps.

Because things can change so fast in fisheries, it is necessary to periodically revise what information is needed. It is also necessary to include and use the knowledge of the fishermen in research. This is not as simple as it seems though, and it might be better to incorporate their input at the management procedure stage, rather than at the assessment stage.

It is also necessary to quantify uncertainties. There are few cases where we have done that explicitly. Many of us seem to think that the uncertainties are not that big. We will have surprises when we start really quantifying them.

There is certainly a need to study, identify and implement management processes which have greater likelihood of success.

PA to FR - Assessment Methods and Analysis

- Comprehensive Treatment of Uncertainties
- Assessment Process
  - ✓ Standards of evidence
  - ✓ Transparent process
  - ✓ Periodic independent peer-review/audit
- Realistic Range of Outcome
- Ability to Detect Trend

Often the uncertainties are understated. In Faroe cod, the average weights at age from one year to the next can change by as much as 30%. How can we expect to calculate an appropriate TAC in a case like that? The coefficient of variation, assuming that M is constant over time, that the relationship between the indices of stock sizes and the stock are as assumed (linear, proportional or others), that the growth will be as assumed, that the management plan will be applied, that fishermen will obey the rules etc.. is in the best cases in the order of +/- 20%. Few of these assumptions are likely to hold all the time, therefore, the real uncertainties are probably considerably bigger.

The standard of evidence relates, for example, to the question of when do you provide advice using VPA? What kind of CV do you need to use a given method and approach to provide advice. If there are no indices of recruitment and recruiting year-classes will form a sizable portion of the catch, should we provide TAC advice? I think not.

Independent peer-review - O'Boyle and I last year. Alverson and Harris

Realistic range of outcome (when all uncertainties, not really considered useful) BFT, implies need to collect data, not to do nothing.

The monitoring must also have the ability to detect trend. If we only use commercial cpue, there is a possibility that we will not be able to detect trends.

PA to FR - Implementation Guidelines

- Reduce Uncertainties
- Analyze Possible Management Options
- Study Decision-Making Process
- Define Safe Biological Limits
- Define Safe Economic Limits

The implementation guidelines for the precautionary approach to fisheries research are relatively straightforward. After the main sources of uncertainties have been identified, of course research should be initiated to reduce the uncertainties.

Whenever possible, the possible effects of management options should be carefully studied. When possible by computer simulations.

There is a valid role for fisheries research in studying the decision-making process in order to identify features which have a high likelihood of success. There are very few successes, and these are fragile.

The definition of safe biological limits, incorporating such things as maximum F, minimum SSB, age range and distribution, geographical range and distribution etc.. would also help in evaluating management procedures. We have made progress here, but there is still a little way to go.

There is more work required in defining safe economic limits. Economic reference points need to be defined and accepted. However, it would be very useful to make progress here, because in many cases, staying within safe economic limits will ensure that we stay within safe biological limits as well.

Fishery Technology - Objective
Slide 1 of 2

- "Recognizing that many aquatic resources are overfished and that the fishing capacity presently available jeopardize their conservation and rational use, technological changes aimed solely at further increasing the fishing capacity would not generally be seen as desirable.

There is little discussion on Research and Development, the report simply states that satellite tracking may help implement precautionary fisheries management. The report also says that R&D should not be limited to gears used to capture fish, but also post-harvest losses and improvement of product quality and safety.

This is an important statement, and it relates back to the requirement of consistency mentioned earlier. In most management plans we are trying to constrain, to limit fishing mortality. And still, there are efforts which aim at increasing the fishing efficiency of individual fishing units. We should always keep this in mind.

Fishery Technology - Objective Slide 2 of 2

- Instead, a precautionary approach to technological changes would aim at:
  - ✓ improving the conservation and long term sustainability of living aquatic resources
  - ✓ preventing irreversible or unacceptable damage to the environment
  - ✓ improving the economic benefits derived from fishing and
  - ✓ improving the safety an working conditions of fishery workers

Fishery Technology - Introduction

- Effects
  - ✓ ecosystem, social structure, safety of workers, management of fishery
- Amount and Context
- Increasing Efficiency
- Unacceptable effects (Sorting at Sea vs Discards)
- Best Current Practice Encouraged

The fishery technology used effects the ecosystem in which it is used, the social structure of the communities, the safety of workers and the fishery management measures to be applied.

The fishery technology is not intrinsically good or bad. It is the amount and the context in which the technology is used which make it good or bad.

Increasing efficiency has characterized fisheries and will continue to do so in the future. A small increase in fishing efficiency of 4% per year will lead to a doubling of the fishing mortality in less than 20 years. This seems like a long time away, but remember that several of us started working in fisheries about 20 years ago.

Technologies which have unacceptable effects should not be authorized...

Where a mix of fishery technology exist, it's use should be encouraged as best current practice (FAO endorsement of gillnets some years ago).

Fishery Technology - Evaluating Impacts

- Consider Effects on
  - ✓Target fishery, environment and ecosystem, socio, economic and legal factors
- Desk vs Pilot Studies

In evaluating the impacts of fishery technology, it is necessary to consider the effects on the target species, but also on the environment and on the ecosystem, on the social and economic conditions, on the legal aspects and on the influence on the ability to reach management objectives.

Some evaluation can be done by literature reviews or by comparison with other areas. However, in some cases, pilot studies may be required and may be a cost effective way of obtaining the desired information.

Fishery Technology - Implementation Guidelines

- Single Authority - Right to Appeal
- Periodic Reviews
  - ✓Cumulative effects of small improvements
- Requires Training (Dolphin in Tuna Fisheries)
- Obligations and Rights of Interested Parties
- Gradual Implementation

The process suggested for the implementation of the precautionary approach to fisheries technology is very much modeled after the environmental impact assessments process.

It requires that there be a single authority making decisions on approving or not, but it also requires that there be an appeal process. Both the original request and the appeal should be transparent processes.

Because many of the changes will be small, it will be necessary to do periodic reviews of the technologies to assess the cumulative effects of those small improvements.

Much of the negative aspects of particular technology can be remedied by training of the people who use it. This is quite convincingly demonstrated in the Pacific tuna fisheries where the by-catch of dolphin is now close to zero. In fact the mortality rate imposed on dolphin by purse seining is now probably much less than the infant mortality rate in Mexico, one the main fishing nations.

As with education and training, it is equally important that interested parties be made aware of their obligations and of their rights.

New fishery technology should be implemented gradually in order to be able to stop the introduction if negative effects are detected.

Shortcomings

- States and Public Servants
- Interested Parties
- Deckhands to Ministers of National Governments

Most of the legal instruments and texts discussed here have been drafted by bureaucrats and adopted by the same or by politicians. The Precautionary Approach is not well served by a bureaucratic approach, and it requires a real commitment of all interested parties, from the deckhand on every type of vessels to the Minister of Fisheries of National governments if it is to be expected to work.

The precautionary approach implies applying the spirit of the various agreements, not the letter. When fisheries management gets into the fine interpretation of the texts, it is a sign that we are straying from being precautionary.

Thank you for your attention. I will answer questions if you have any.

APPENDIX 3

North Sea herring

By: R. Toresen
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North Sea herring
A case study study in Precautionary Approach

by

Reidar Toresen

Biology

Herring in the North Sea consists of several smaller stocks of herring (Figure 1). They are mostly autumn spawners and spawn at different sites along the east coast of United Kingdom. The juveniles are distributed in the south and east parts of the sea, in the German Bight and off the west coast of Denmark and in the Skagerrak/Kattegat area. After 2-3 years they join the adult stock in the central parts of the sea. They are managed as one stock unit and shared stock between the EU and Norway.

Fishing fleets

Two fishing fleets exploit the North Sea herring (Figure 2); the human consumption fleet exploiting mainly adult herring and the industrial fleet using small meshed trawls aiming for sandeel or norway pout, but catching herring as bycatch. The human consumption fleet exploit mostly adult herring of more than 20 cm while the industrial fleet catch small and juvenile herring as bycatch.

Status of the stock

The spawning stock biomass (SSB) of North Sea herring has been estimated to about 5 mill t just after the second wourld war (Figure 3). Since then, the level decreased drastically and it was estimated to be less than 1 mill t in 1967. During the seventies the stock continued to decrease and later this decade (1977) the human consumption fishery was stopped. The SSB level was estimated to be less than 100 000 t in the years 1975-1978. The stock recovered through the 80-ies and reached and reached a level of 1.3 mill t in 1989. Since then it has decreased again to the present low level of less than 500 000 t.

The yield of this stock has been very stable around 500-700 000 t, except for a severe decline in the mid seventies to the mid eighties (Figure 3). The fishing mortality increased through the eighties and is now estimated to be 0.8 which is more than double the level of 0.3 recommended by ACFM for this stock. The present exploitation level seems to be too high for this stock especially when most of the catch (in numbers) are taken as juveniles. In the years 1991-1996, about 80 % of the catch were small herring (Figure 4). The MSY for this stock has been estimated to 800 000 t with an F of 0,6. However, based on an exploitation pattern where no juvenile herring are caught.

Recent development

Through the recent 5 years the development of this stock has turned from beeing positive to negative. The abundance indeces and data from the fisheries show that this is the case. However, the yearly assessments of the stock as done by the ICES working group dealing with this stock also shows that there are severe problems with the fishery related data for this work (Figure 5). The status of the stock is reviced every year and in general, we can see that the stock situation is overestimated while the exploitation level (F) is underestimated. This strongly indicate that there may be something wrong with the catch statistics and that there is probably removed fish from the stock which is not acounted for. This may be explained by misreportings or black landings of fish, which are not uncommon phenomens in fisheries.

An interesting question is if the information about the stock development was given to the managers in an appropriate way and if the managers reacted to this information adequately. If the answer to these question are positive we have a reason to believe that something may be wrong either with the quality of the advice or the underlying assumptions for it.

First, we need to examine whether the advice was good enough each year, based on the known stock situation and if the reactions to this were appropriate. In the following, the status of the stock, the advice and the reaction by managers in each year from 1991 - 1996 is presented.

What we "knew" each year, the advice and the reaction by the managers.

1991

Status of the stock (Figure 6):

> Positive development through the eigthies with a peak on the curve of SSB in 1989 of about 1.5 mill t. Fishing mortality decreasing and estimated to a level of about 0.35 in 1990.

Advice:

> To aim for a fishing mortality of 0.3. Concern about the fishery for juveniles in div IIIa.

Management:

> TAC 420 000 t corresponding to a status quo fishing mortality.
> No attempt to regulate the bycatch of juvenile herring.

1992

Status of the stock (Figure 7):

A small downwards revision of the stock, but still estimated to be more than 1.2 mill t. Leveling out since 1989. Fishing mortality revised upwards and estimated to 0.39 in 1991.

Advice:

To aim for a fishing mortality of 0.3. The consequences of the fishing for juveniles are pointed at.

Management:

TAC regulation of 430 000 t corresponding to a small increase of fishing mortality.
No attempt is made to regulate the bycatch of juveniles.

1993

Status of the stock (Figure 8):

The stock shows a downward trend in the development of the SSB. From a maximum level of more than 1.4 mill t in 1989 the stock is estimated to be on a level of 1.2 mill t in 1992. The fishing mortality is estimated at the same level as the year before (0.39) and it seems stable.

Advice:

To aim for a fishing mortality of 0.3. The consequences of the fishing for juveniles are pointed at.

Management:

TAC regulation of 440 000 t corresponding to a status quo fishing mortality .
No attempt is made to regulate the bycatch of juveniles.

1994

Status of the stock (Figure 9):

The stock has shown a downward trend in the development of the SSB since 1989. The stock is revised downwards and the SSB is was estimated to less than 800 000 t (MBAL) in 1993. However, it was believed to be above this level in 1994. The fishing mortality is estimated to be greater than last year and estimated to be 0.42.

Advice:

To reduce the fishing mortality. The consequences of the fishing for juveniles are pointed at.

Management:

TAC regulation of 440 000 t corresponding to a status quo fishing mortality No attempt is made to regulate or reduce the bycatch of juveniles.

1995

Status of the stock (Figure 10):

The stock has shown a downward trend and is no estimated to be below MBAL. The fishing mortality is revised upwards and is now estimated to 0.52.

Advice:

To reduce exploitation significantly and reduce F by at least 50% of levels observed last year. Reiterates concern about the negative impact of juvenile bycatch on loss of yield in directed fisheries and on the spawning stock biomass.

Management:

A TAC of 313 000 t was agreed upon corresponding to a reduction of F of 30%. Still, no attempt is made to do anything on the bycatch of juveniles.

1996

Status of the stock (Figure 11):

The stock is assessed to be at a very low level (<500 000 t). The fishing mortality is revised upwards and estimated to be 0.8.

Advice:

To reduce the TAC in 1996 by 50%. To aim for a very low fishing mortality (0,2) in 1997. To reduce the fishing mortality exerted on juveniles by 50% in current year and in 1997.

Management:

The parties agreed to follow the ACFM advice for the stock.

Can we say that the precautionary implementation guidelines drawn up for stocks in this situation (fully utilized), as described in FAO Fisheries Technical Paper 350/1 are followed? These are as follows:

a. ensure that there are means to effectively keep fishing mortality rate and fishing capacity at the existing level;

b. there are many "early warning signs" that a stock is becoming overutilized (e.g. age structure of the spawners shifting to an unusually high proportion of young fish, shrinking spatial distribution of the stock or species composition in the catch). These warning signs should trigger investigative action according to prespecified procedures while interim management actions are taken, as noted below;

c. when precautionary or limit reference points are approached closely, prespecified measures should be taken immediately to ensure that they will not be exceeded (i.e., do not wait until violation of a limit point is imminent to start deciding what to do about it);

d. if limit reference points are exceeded, recovery plans should be implemented immediately to restore the stock. The recommendations for overutilized stocks should then be implemented;

e. to prevent excessively reducing the reproductive capacity of a population, avoid harvesting immature fish, unless there is strong protection of the spawning stock. For example, if immature fish exceed a specified percentage of the catch, close the local area to all harvesting.

On the basis of these implementation guidelines and what we know about the management decisions in the recent years, the comments are as follows:

In the years 1991-1993, the advices and reactions to these seems appropriate. The stock situation was fairly good and no severe decline in the stock level could be seen so far. However, something could be done about the high levels of the bycatches of juveniles which the managers have been aware of through all these years. In 1994 it was concluded that the SSB was within safe biological limits. However, the trend had been negative for 5 years in succesion and the SSB level in 1993 was estimated to be below MBAL. The message of a stock in decline and approaching the limit reference point of 800 000 t didn't get through to the managers, and both ACFM and the managers are probably worth blaming this year. In 1995 the stock was estimated to be at a lower level than MBAL and the managers reacted in an appropriate manner to the advice from ACFM and aimed to go for a reduction in F in the following year. In 1996, the assessment of the stock showed a further decline and a new revision of the stock which showed that the stock is in a worse state and that F levels are probably a lot higher than we have believed before. A firm advice from ACFM on a 50%

reduction in the TAC in the current year and a 50% reduction of F on the exploitation of juveniles was followed up by the managers who have agreed to reduce the level of exploitation in accordance with the advice. The managers have also agreed on a reduction of the outtake of juveniles.

Even though the management reactions have seemed to be appropriate in each year, they are definitely not so with regard to the precautionary implementation guidelines. Several of the guidelines are directly broken with , especially the once described in points **a**), **c**) and **e**).

- there are probably not means of keeping fishing mortality rate at existing levels, as shown by the revisions of the state of the stock and fishing mortality (especially in most recent years).

- when the limit reference point (MBAL) of 800 000 t was approached nothing was done . Only when this point was exceeded, we saw some kind of reaction.

- nothing was done about the juvenile fishery until after the stock is "prooved" to be below MBAL.

It is of course a question whether it is appropriate to use a knife edge limit reference point with an exact value of 800 000 t when we see so clearly that there are severe problems with the data causing large uncertainties in the assessment. It is likely that we have to live with such an uncertainty for some time and it may therefore be more appropriate to relate to another kind of reference point system. Instead of a knife edge limit reference point on stock level (MBAL) one could relate to danger zones system for the stock (Figure 12). The green zone beeing the zone in which the stock is safe (well buffered against a collapse) and chances of bad recruitment is reduced. The aim could be to try to keep the exploitation at a certain level over time and try to optimize the yield from the stock. The yellow zone beeing the one in which somewhat more precautionary principles could be in work e.g. keeping the F- rate under certain prespecified levels and avoiding catching juveniles. The red zone could be the most restrictive zone with a total ban on fisheries for this stock.

Conclusion

It may be concluded that the North Sea herring is not managed in accordance with the precautionary principles drawn up in the FAO technical paper and that if it were, it would have a much higher chance to develop in a positive direction.

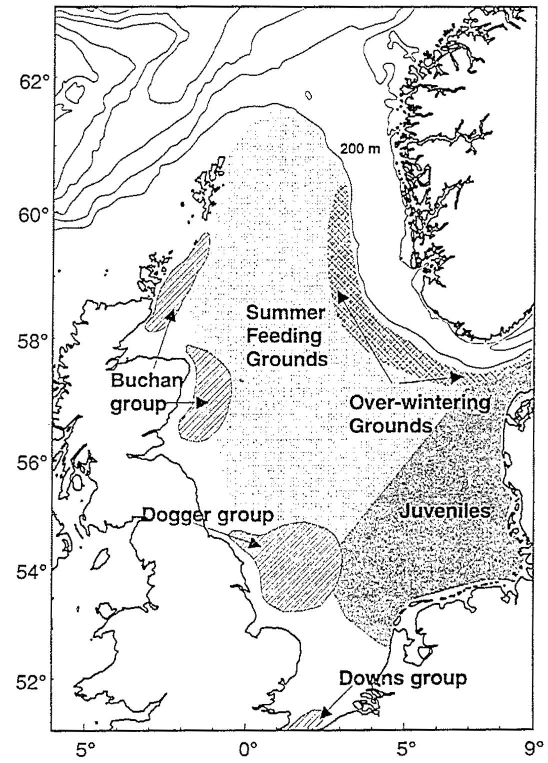

Figure 1. Location of spawning, feeding, over-wintering and adolescent grounds of herring in the North Sea.

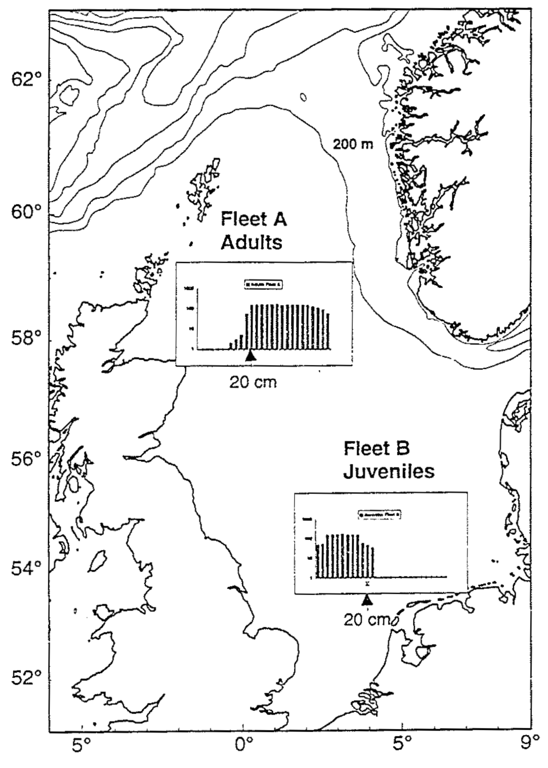

Figure 2. Fishing fleets of herring in the North Sea.

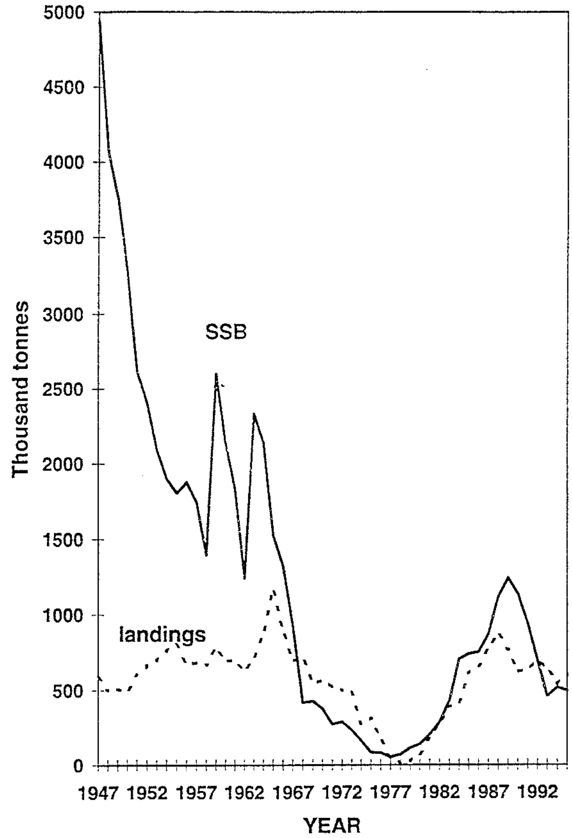

Figure 3. SSB and landings, 1947-1995.

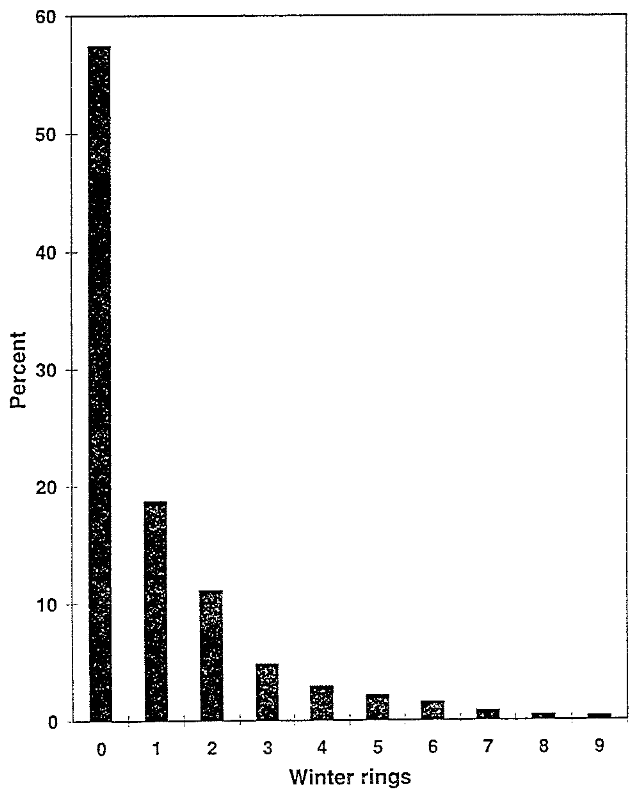

Figure 4. Fishing pattern.

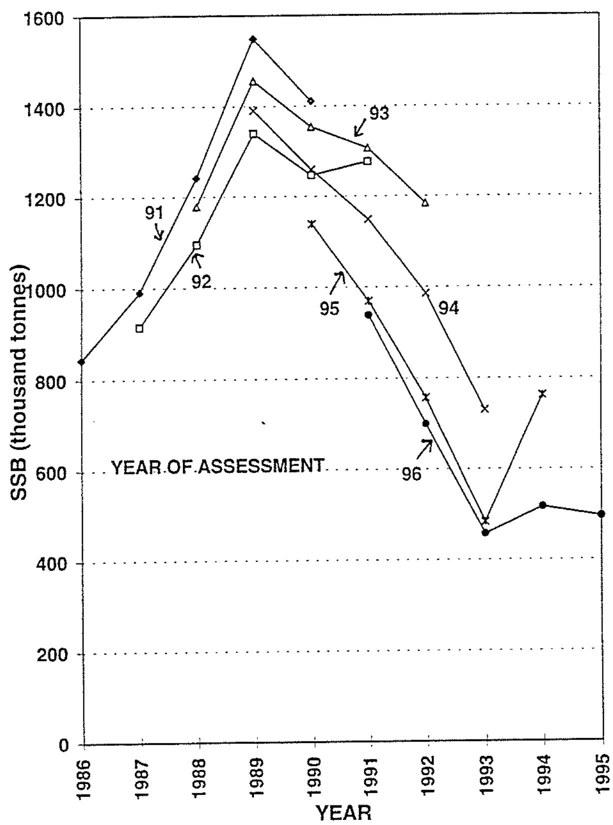

Figure 5. Estimates of SSB in successive years.

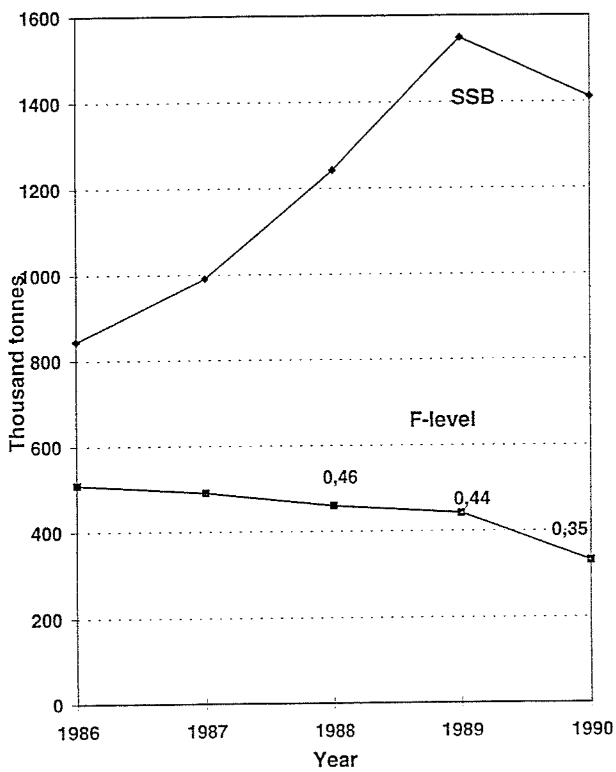

Figure 6. Status as believed in 1991.

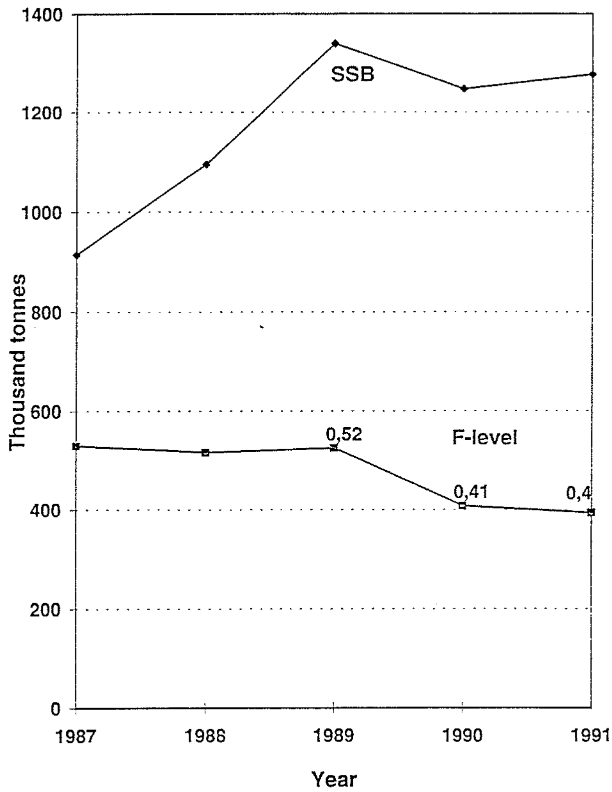

Figure 7. Status as believed in 1992.

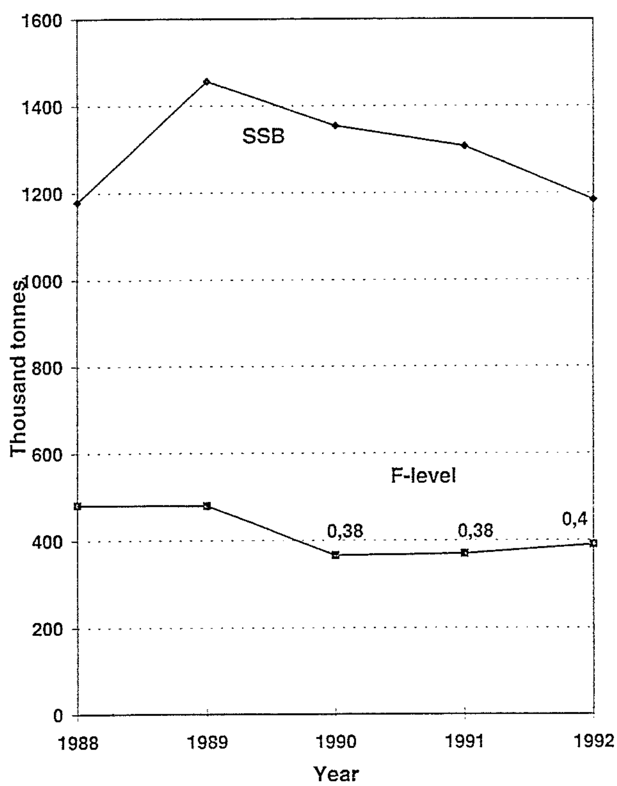

Figure 8. Status as believed in 1993

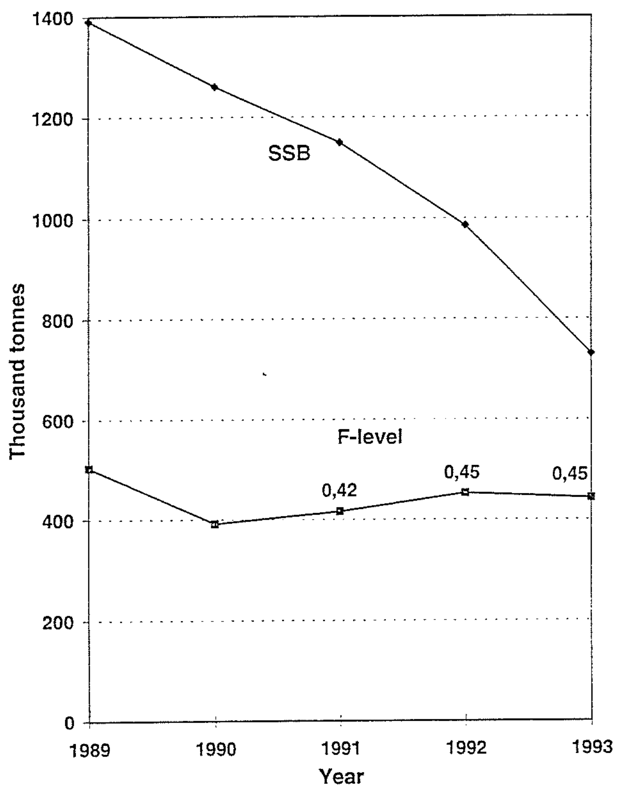

Figure 9. Status as believed in 1994.

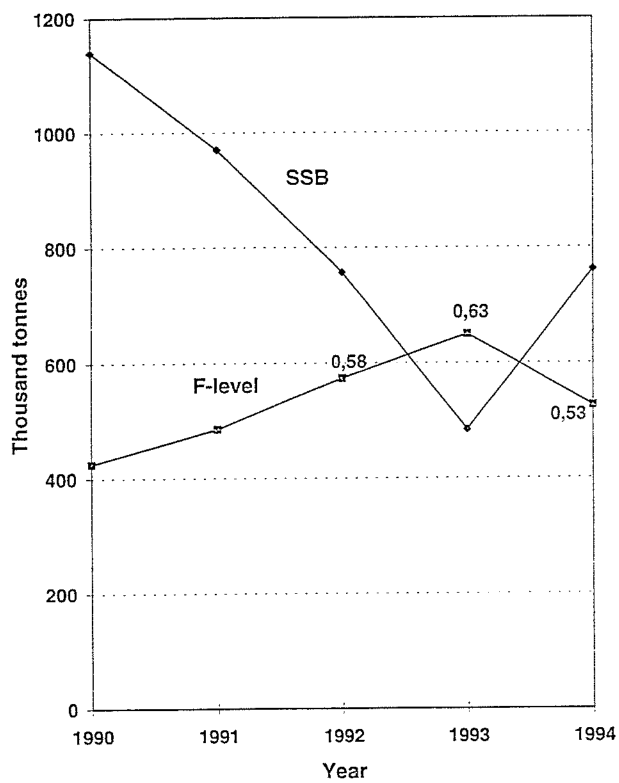

Figure 10. Status as believed in 1995.

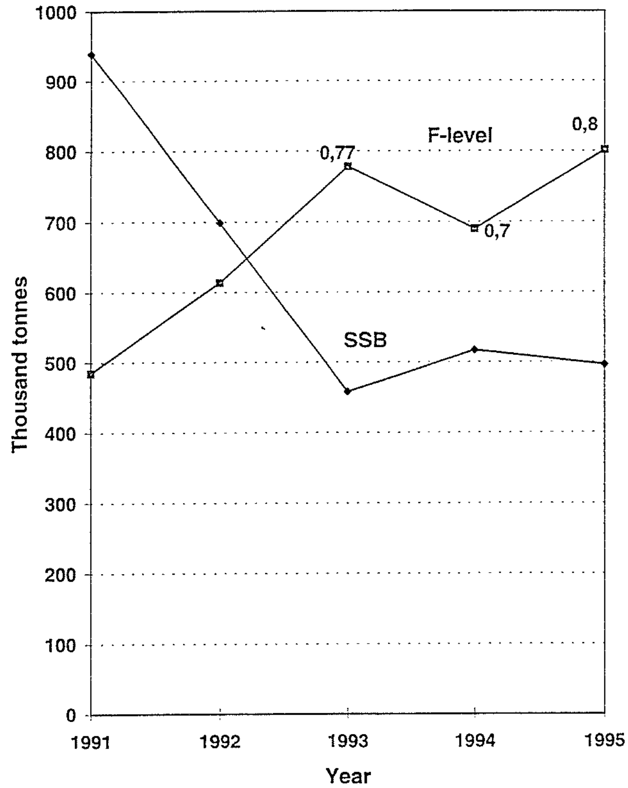

Figure 11. Status as believed in 1996.

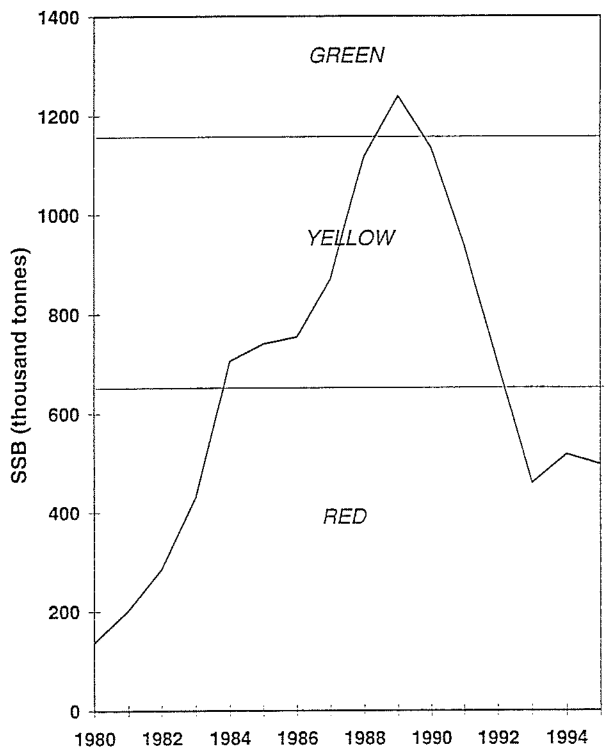

Figure 12. The idea of danger zones.

APPENDIX 4

The industrial fishery and the North Sea Sandeel Stock

By: H. Gislason and E. Kirkegaard
(Danish Institute of Fisheries Research)

Summary of presentation at the Seminar on the precautionary approach to North Sea Fisheries Management, Oslo, 9-10 September 1996

The industrial fishery and the North Sea Sandeel Stock.

by

Henrik Gislason and Eskild Kirkegaard

Introduction

The industrial fishery in the North Sea began in the early 1950s and has since then developed into one of the most important fisheries in the area. In terms of landings it accounts for approximately two thirds of the total landings of fish from the North Sea. The landings are processed to fish meal and oil or used directly as animal foodstuff.

Since its start the fishery has been subject to intense debate and discussions. On one hand it has been argued that the fishery provides a good way to harvest resources that otherwise would remain untapped. On the other hand it is argued that the large amounts of small fish caught deplete the food supplies of human consumption fish stocks and other predators such as seabirds, seals and cetaceans. Recently the sandeel fishery has attracted considerable public attention due to campaigns such as the one conducted by GREENPEACE in the summer of 1996.

With the increasing acknowledgement of environmental conservation and sustainable use of natural resources the idea of precaution has begun to be incorporated in fisheries management (e.g. FAO(1995)). This paper describes the industrial fishery for sandeel, its impact on the North Sea sandeel stock and its competition with the natural predators of sandeel. Our intention has been to provide the input for discussions of how the precautionary approach can be applied in the management of the sandeel fishery.

The industrial fishery

The historical development of the landings from the industrial fishery is shown in Figure 1. The figure is based on a combination of landings data from ICES Working Groups reports and for the earlier years on the information presented by Popp Madsen (1978). The industrial landings increased exponentially from the start of the fisheries in the late 1940s until the mid 1960s where they reached two million tonnes. In the last 15 years the landings have fluctuated between one and 1.6 million tonnes without any particular trend. Denmark accounts for approximately 80% of the total catches and Norway takes most of the remaining.

In the early years herring made up the bulk of the industrial landings, but gradually small short-lived species such as sandeel and later Norway pout and sprat became the most important species caught by the fishery. From the beginning of the 1970's most of the landings have consisted of sandeel, Norway pout and sprat. At present sandeel constitutes approximately 60% of the landings. In addition a number of other species, mainly herring, whiting and blue whiting, are taken as by-catch.

The industrial fisheries are highly seasonal and can be divided into distinct fisheries based on the species composition of the landings. In Table 1 the Danish industrial landings in the period 1990 to 1994 have been classified to fisheries based on the criteria that the target species should make up 50% or more of the landings in a particular month and ICES statistical square ($30*30\ nm^2$).

The relative impact of the industrial fishery and the fishery for human consumption purposes on the target species can be evaluated by comparing the proportion of the annual production harvested by the two fisheries, Figure 2. The industrial fisheries take less than 25% of the total annual production of the industrial species sandeel, Norway pout and sprat. In comparison the proportion of the production taken by the human consumption fishery is generally much larger. For cod and sole about 80% of the annual production is removed by the human consumption fishery and only 20% is left for predation and other sources of natural mortality.

Regulation and control of the industrial fisheries.

The industrial fishery is regulated by precautionary TAC's for Norway pout and sprat while there is no TAC for sandeel except in the Norwegian part of the North sea. Besides precautionary TAC's a suite of technical measures has been implemented aimed at reducing the bycatch of protected species, ie species for which a minimum landings size is in force. In the fisheries for sandeel and sprat the bycatch of protected species is not allowed to exceed 10% of the total catch, while in the fishery for Norway pout a 15% bycatch limit is in force. Fishing for herring for industrial purposes has been banned in all EC North Sea and Div. IIIa waters since 1977 and a maximum allowed herring bycatch of 5% has been adopted in the sandeel and Norway pout fisheries. However, in the sprat fishery a bycatch of herring of 10% is allowed. Due to the low spawning stock size of herring in recent years a bycatch TAC for herring in all industrial fisheries was introduced in 1996. In addition to these regulations special areas have been closed to certain types of industrial fishing. In the so-called "Norway pout box" in the north western North Sea fishing with small mesh trawls for Norway pout is forbidden and in the "Danish sprat box" along the Danish west coast fishing for sprat is forbidden between July and October. Special regulations also pertain to the Norwegian zone of the North Sea.

At a national level a number of additional regulations have been introduced. All Danish vessels participating in the industrial fishery must notify the authorities before they are allowed to land their catch. The vessels are also obliged to keep a logbook where the position of the vessel and the weight and composition of the catch is recorded on a daily basis. At landing the fish meal plants have to report the total amount bought from each fisherman to the authorities. The information is controlled by the Danish fisheries inspection who also takes samples to control the species composition of the catches. The number of inspected landings has varied over the years. In the period 1990-1992 between 13 and 21% of the total landings by weight were sampled by the inspectors. The information is combined and used to estimate the total industrial catch by species, month and area on a 30x30 nm resolution. Additional biological samples are collected and used to determine the size and age composition of the catches.

The quality of the landings statistics for the different species caught in the industrial fisheries has been questioned. The Danish and Norwegian sampling systems of industrial landings were evaluated by a Working Group set up by the European Commission and Norway (Anon. 1993). The Working Group concluded that the sampling systems in use provide a reliable and unbiased description of the species composition of the landings, and that little is gained in precision by increasing the sampling intensity. Lewy (1995) came to the same conclusion in his investigations of the sampling scheme for the Danish industrial fisheries.

The sandeel fishery

The sandeel fishery peaks during spring and early summer and is conducted with bottom trawls with a mesh size less than or equal to 10 mm. The distribution of the fishery in the North Sea by quarter in the period from 1990 to 1995 is shown in Figure 3. As reflected by the distribution of the catches the distribution of sandeels in the North Sea is patchy. Adult sandeels are mostly caught in areas of coarse sand often in association with high current velocities. The largest catches are taken along the Norwegian Deep, along the Danish coast, in the southeastern part of the Dogger Bank and recently also in the Firth of Forth. In addition sandeel is caught in lower quantities in several other areas. Because sandeel is not caught by the gear used by the regular bottom trawl surveys conducted by the various fisheries laboratories around the North Sea, there is little information on the distribution of sandeel and it is not known to what extent the distribution of the fishery reflects the distribution of the stock. Data on the occurrence of sandeel in whiting stomachs collected during the ICES International Stomach Sampling programmes (Jensen et al, 1994) and the occasional discovery of new fishing areas, such as the development of a fishery in ICES stat. sq. 43E9 and 43F0 in 1994 (ICES 1995), would suggest that sandeel is likely to have a wider distribution than reflected by the present fishery.

In the years from 1956 to 1970 the annual sandeel landings fluctuated between 100 and 200 thousand tonnes, Figure 4. In the period from 1971 to 1976 the landings increased and from 1977 onwards the annual landings have been fluctuating between 0.5 and one million tonnes without any trend. Fishing mortality was initially in the order of 0.1 but increased then in parallel with the landings to fluctuate around a level of 0.6 from 1976 onwards. The sandeel fishery has thus been at the same level for the last 20 years and if anything fishing mortality appears to have declined somewhat in the most recent years. Recruitment has varied without a definite trend, and is characterized by alternating good and bad year classes, Figure 5. Since 1976 the spawning stock has fluctuated between 500,000 and 1,200,000 tonnes. However, in 1987 and 1988 the strong 1985 year class increased the SSB to around 1,700,000 tonnes. The average SSB from 1976 onwards is 870 thousand tonnes. Figure 6 shows a plot of SSB versus recruitment. As is the case for many fish stocks there is no significant correlation between spawning stock and recruitment (t=.91, 16 df).

The assessment is, however, subject to some uncertainty. The biology of sandeel makes it difficult to use the traditional fish population models to assess the state of the stock. Sandeel is not caught regularly in trawl surveys such as the International Bottom Trawl Survey and no fishery independent estimates of stock size are therefore available. Tagging experiments have shown that sandeel once they are settled tend to remain on the same ground (Kunzlik *et al.* 1986). The information collected from the commercial fishery will therefore reflect the changes in the size of the exploited population, but it is unlikely to provide information about what is happening outside the fishing areas. Most likely this will lead to an underestimate of the total stock size of sandeel and an overestimate of the fishing mortality.

There is also considerably uncertainty about the stock structure of sandeel in the North Sea. We do not know to what extent the sandeel populations at different fishing grounds are reproductively isolated. Preliminary studies of differences in sandeel allozymes show little difference within the North Sea (Eric Verspoor, pers. comm.), but cannot be used to prove that separate substocks do not exist. Berntsen *et al.*(1994) used a 3-D hydrographic model to predict the drift of sandeel larvae. In the model the larvae were released in the major fishing areas and their drift was simulated assuming that the larvae would behave like passive tracers. The results suggested that the larvae could be transported over large distances. However, the transport of the larvae proved to be sensitive to their vertical distribution, to the location of presumed spawning grounds, to hatching time and to the length of the drifting period. Additional information is necessary before hydrographic models can be used to identify the origin of sandeel larvae recruiting to a specific area within the North Sea.

ICES has been assessing the state of the North Sea sandeel stock on an annual basis and concludes that the stock at present is within safe biological limits, but actual limits have not been explicitly specified (ICES 1996a). The level of fishing mortality expressed as the average fishing mortality for ages one and two over the period from 1990 to 1993 is 0.55 and below Fmed which has been estimated to 0.63 ICES(1996b). However, as ICES(1996a) points out, the stock is variable due to the short life span of the species and variable recruitment. This raises the question of whether the sandeel spawning stock by a combination of low recruitment and high fishing mortality could be reduced to a level where recruitment would be adversely affected. In order to assess this possibility it is necessary first of all to define a lower limit of spawning stock biomass and subsequently to assess the probability that the stock would fall below this limit.

Lower limits of spawning stock size.

No estimate of a lower safe biological limit of spawning stock is available for sandeel. Given the lack of indications of a reduction in recruitment due to reductions in the spawning stock in the historic time series such a limit is difficult to define. Various proposals have been made on how to tackle this situation, some of which are summarised in Myers *et al.*(1994).

The method suggested by Serebryakov(1991) estimates a lower threshold of spawning stock by calculating the upper 90th percentile of the recruitment observations, thus defining a high level of recruitment, and the upper 90th percentile of the observed survival rate, defining a high survival rate of the pre-recruits. If the spawning stock is above the level indicated by the intersection of these lines in a stock and recruitment plot, see Figure 7, the stock would based on the historic evidence be capable of producing a good yearclass provided environmental conditions were favourable for survival. For North Sea sandeel the Serebryakov method produces an estimate of the lower limit of spawning stock biomass of 750 thousand tonnes.

Another method was described by Mace(1994) who suggested that a lower level of spawning stock biomass might be defined as the biomass where recruitment was reduced to half its maximum value. This level of biomass can be estimated by fitting a model of stock and recruitment to the observations. We have fitted the Ricker and the Beverton & Holt stock/recruitment models to the sandeel data. Figure 7 shows the result. The two models produce virtually identical results for spawning stocks below 1.5 million tonnes. The SSB producing 50% of maximum recruitment is estimated to be 320 thousand tonnes for the Ricker and 460 thousand tonnes for the Beverton & Holt model.

In order to estimate the probability (or risk) of falling below these limits we have constructed an EXCEL spreadsheet model of the sandeel stock and added uncertainty to the parameters. In the predictions fishing mortality at age was selected at random from the Working Group estimates of fishing mortality at age (and half-year) giving equal probability to each of the historical values. Recruitment was assumed to follow a lognormal distribution with the same mean and standard deviation as the historic time series from 1976 to 1993. Natural mortality was assumed to be normally distributed with the same mean as used by the Working Group (ICES 1996b) and a coefficient of variation equal to the coefficient of variation of the predation mortalities (M2's) estimated by the Multispecies VPA over the period from 1987 to 1992. The weight at age was taken as the average weight at age over the period from 1987 to 1993 and maturity at age was assumed to be constant as used by the Working Group.

The cumulative distribution of the predicted sandeel SSB is shown in Figure 8. The lower and upper 95% confidence limits of the predicted SSB are 588 and 1975 thousand tonnes, respectively, The probability of generating spawning stock biomasses below the limits are .27, .04 and .003 for the Serebryakov, the Beverton & Holt and the Ricker estimates, respectively. Our calculations in other words suggest that there would be a 27% change of observing a spawning stock biomass below 750 thousand tonnes with the present level of fishing effort.

From a technical point of view it is clear that our estimates of the probability of falling below the limits should be considered as preliminary. First of all our model does not include the uncertainty in the estimates of the catch at age and fishing effort data collected from the sandeel fishery. Secondly the model does not include the covariance between the parameters and thirdly it is a simple single species model and the effect of changes on sandeel predation mortality due to changes in the population sizes of sandeel and its predators has not been included. A more complete analysis will have to await a thorough investigation of the statistical properties of the input parameters and should include alternative assumptions about the population structure of sandeel in the North Sea. However, the reason for presenting the estimates in this context has been to highlight some of the steps involved in defining a sustainable level of sandeel fishing and to point out the inherent uncertainty involved in predicting the impact of the fishery. We have not attempted to provide a final answer.

Considering the lack of a clear relationship between stock and recruitment it is evident that the selection of particular limit reference points involves a large subjective element. Providing biological arguments for choosing one reference point in favour of another is difficult. Given our limited ability to foresee the future, the probability of falling below a certain level of spawning stock will never be zero even in the absence of fishing. The choice of a particular reference point and of an acceptable probability of falling below this point is therefore likely to be based on political considerations in which the perceived risk of what will happen below the reference point will play a major role.

The effect of the sandeel fishery on fish predators

Sandeel is an important prey for many fish species. For some of these species detailed information on their diet composition has been collected by the ICES Stomach Sampling Programme. The diet composition has subsequently been used in the ICES Multispecies VPA to derive estimates of the total intake of different prey species. Figure 9 shows the proportion of exploited fish species in the diet of the five predators covered by the Stomach Sampling Programme in 1981. Approximately 8% of the food cod and haddock, 19% of the food of North Sea mackerel and 25% of the food of whiting consists of sandeel. For 1981 the estimated total consumption of sandeel by the five predators amounts to approximately 900 thousand tonnes, a figure comparable to the total landings from the sandeel fishery. However, a number of other fish species also prey upon sandeel in the North Sea, eg. herring (Hardy, 1924), plaice (Ritchie, 1938), grey gurnard (de Gee and Kikkert, 1993) and salmon (Fraser, 1987), and the total predation of sandeel by fish is therefore likely to be much higher. It is therefore important to include considerations of the likely changes in the interactions between sandeel and its predators if we want to predict the effect of a change in the sandeel fishery.

We have used the ICES Multispecies forecast program (MSFOR) to predict the long term effect of a 40% reduction in industrial fishing effort on sandeel. The MSFOR program is a predictive version of the Multispecies VPA, and can be used to evaluate the likely changes in sandeel stock size and yield resulting from changes in fishing mortality. The model takes account of the changes in predation mortality caused by the other commercially exploited fish predators and the predictions are given by species and fleet. Assuming the industrial fishery to be reduced by 40% the model predicts that the yield of sandeel will decrease by 19% compared with the status quo situation, while the spawning stock biomass will increase by more than 50%, Figure 10. Reducing the fishing mortality and hence increasing the sandeel stock will have some knock-on effects on other species. However, these effects are predicted to be small. Reducing the fishing mortality of sandeel the biomass of its predators (haddock, cod and whiting) is predicted to increase slightly and so is the biomass of their alternative prey (Norway pout, sprat and herring). Overall the predictions suggest that the indirect effects on the sandeel predators are small and that only minor changes in the biomass of other fish species are to be expected by reducing the sandeel fishery.

It has often been suggested that the biomass of the industrial species increased in the late 1960's, but there is little evidence to support this view (Daan et al., 1990). Regular biological sampling programmes of the industrial landings were not implemented before the beginning of the 1970's and there is no information on the size and productivity of the sandeel stock from the period prior to the onset of large scale industrial fishing.

Multispecies models predict that the biomass of sandeel, Norway pout and sprat would decrease if the biomass of their predators increased. The output of the multispecies model of Andersen and Ursin(1978) suggested that the large reduction in the mackerel stock in the late 1960's would have led to an increase in the biomass of sandeel. In the northwest Atlantic a rapid increase in the abundance of sandeel larvae followed a sharp decline in the mackerel and herring stocks (Sherman *et al.* 1981, Fogarty et al. 1991). Results from the MSFOR model point in the same direction. If the biomass of fish predators such as cod, whiting and saithe is reduced the biomass of small fish will increase. It is thus likely that the general reduction in the abundance of fish predators in the North Sea to some extent has counteracted the impact of industrial fishing.

Effects on mammals and seabirds

Very little is known about the importance of sandeel as food for small cetaceans, but sandeel has been recorded in the stomach contents of stranded individuals (Santos *et al.* 1994). More information is available for seals. In the Orkney area sandeels accounted for almost half the weight of the fish consumed by grey seals (Hammond et al, 1994) and in the south-western North Sea analysis of fecal samples also showed that sandeel was important as food (Prime and Hammond, 1990). In the Moray Firth, north-east Scotland, sandeels predominated the diet of common seals in summer (Pierce et al., 1991). Furness(1990) estimated that seals would have consumed in the order of 9 thousand tonnes of sandeels annually at Shetland in the beginning of the 1980's. However, there are no studies available on the interactions between the sandeel fishery and marine mammals in the North Sea.

For seabirds the ICES Study Group on seabird/fish interactions combined information on diet composition, energy requirements and spatial distribution of seabirds in the North Sea. The nine most abundant seabirds in the North Sea were found to be responsible for 94% of the seabirds total energy demand. Annually these species would consume app. 200 thousand tonnes of sandeels (ICES 1994). There were, however, large differences in the intake of sandeel in different areas of the North Sea. Sandeels were most important as prey in the northwestern North Sea where the estimated intake amounted to 112 thousand tonnes.

Jensen *et al.* (1994) compared the spatial distribution of guillemot, puffin, and razorbill in the North Sea with the spatial distribution of the sandeel fishery and found in general little spatial overlap. Using the proportion of sandeel in whiting stomachs as an indication of the local abundance of sandeel resulted a significant positive correlation between bird distribution and sandeel abundance in seven out of twelve cases in the third quarter of the year, but not for any other quarter. The positive correlation was mainly due to overlaps in distribution off the northeast Scottish coast and around Shetland.

On a worldwide scale there are a number of cases where collapses in fish stocks have had dramatic consequences for seabird populations (Montevecchi, 1993). Within the North Sea a reduction in the abundance of sandeels at Shetland in the 1980's resulted in a marked decline in the breeding success of many of the seabirds in this area.

The sandeel fishery at Shetland takes place at a small number of inshore grounds and is small compared to the other sandeel fisheries in the North Sea. The fishery started in 1974, figure 11, and reached a peak of 52 thousand tonnes in 1982 after which it declined due to a decline in the stock and in the economic value of sandeel (Goodlad 1989). In June 1990 the fishery was closed because the spawning stock had reached a level where the probability of producing a good yearclass was likely to have been reduced. The assessment of the Shetland sandeel stock is based on a combination of survey data and commercial catch and effort and is subject to a high uncertainty (ICES 1995). Prior to 1982 fishing mortality fluctuated around a level of 0.4. After 1982 it declined in parallel with the landings. Recruitment declined from 1982 onwards and was at a very low level in the period from 1987 to 1990. More recently recruitment has again increased and the 1991 yearclass is estimated to be the highest on record. The spawning stock biomass of sandeel increased up to 1984 after which it declined due to the combined effect of the fishery and poor recruitment.

The Shetland Isles support a number of breeding colonies of seabirds and for many of these sandeels are important as food. During the 1980's the breeding success of several seabirds declined markedly in response to the decline in sandeel recruitment. Seabirds such as artic tern and kittiwake who feed on 0-group sandeel close to the surface were most affected, while seabirds able to dive deeper for their food did not show a comparable decline in breeding success. Arctic tern suffered from almost complete breeding failure between 1984 and 1990 (Phillips *et al.* 1996) and many of the other species suffered from breeding failure in one or several years.

There has been much controversy over the impact of the fishery on the Shetland sandeel population and on the causes of the changes in sandeel yearclass strength (eg. Avery and Green 1989, Monaghan 1992). The accuracy of the assessment has been questioned as well as its appropriateness for describing changes in sandeel abundance within the localised areas where the seabirds feed. There is apparently little direct competition between the sandeel fishery and the seabirds for 0-group sandeels during the main chick rearing period in June. Most of the fishing on the 0-groups takes place after 1. July (Bailey 1991). The main impact is thus likely to be indirect through reductions in sandeel spawning stock size and subsequent reductions in yearclass strength. Because the decline in sandeel recruitment at Shetland started before the spawning stock was reduced it is unlikely that fishing was responsible for the decline in recruitment. Rather it seems likely that hydrographic changes resulting in a reduction in the advection of sandeel larvae into the area and/or changes in their survival caused the changes observed (Wright 1996).

Recently a sandeel fishery has developed on the Wee Bankie in the Firth of Forth on the east coast of Scotland. The fishery started in 1989 with catches reaching a peak of app. 115 thousand tonnes in 1993 (ICES, 1995), after which they subsequently declined. This area is also important for a number of seabirds during their breeding season, but little is known about the competition between the seabirds and the fishery for sandeels. If the local sandeel stock is selfsustained the fishery could lead to depletion of sandeel in the area and this could adversely affect the breeding success of the seabirds. Without further information on sandeel stock structure and seabird predation this possibility cannot be discounted.

The sandeel fishery in a precautionary context

As outlined by the FAO Technical Consultation on the Precautionary Approach (FAO 1995) a precautionary approach to fishing requires the use of prudent foresight to avoid unacceptable or undesirable situations. In order to be precautionary it is first necessary to elaborate a detailed management plan. The FAO report provides the guidelines for how this could be done. The management objectives should be clearly specified in the plan and should consider both the benefits of the fishery and the possible undesirable outcomes that are to be avoided. Once the overall objectives have been agreed upon operational targets and constraints should be specified for example in the form of limit and target reference points. The reference points should be expressed as measurable quantities (e.g. fishing mortality, spawning stock biomass, economic and social value) useful for the management of the stock in question. A precautionary approach also involves controlling access to the fishery. Such a control is necessary to limit fishing mortality before problems arise. In order to limit access the necessary means to control capacity and fishing mortality should be specified and implemented, eg in the form of a license system. The management plan should include specific pre-agreed actions that will need to be taken when it is likely that target reference points are missed or limit reference points approached. Consideration needs to be given to how uncertainty and ignorance can be taken into account when managing the fishery. Specification of early warning signs such as shrinking of the spatial distribution of the stock, changes in the age structure of the spawning stock or, in the case of sandeel, reductions in seabird breeding success should be given a high priority. Last, but not least, it is evident that sufficient data to monitor the development of the fishery and its impacts must be available.

In the light of these criteria the present management of the sandeel fishery is clearly far from being precautionary. A management plan has not been elaborated and there is no limit on the access to the fishery, no stated agreed objectives and no target reference points available. Early warning signs have not been identified and pre-agreed management measures have not been established. On the positive side the necessary data to monitor the fishery are being collected and perhaps because no TAC regulation is in force, and bycatches are small, data on total landings and effort are of a better quality than for many other North Sea fisheries.

Given the comparably low level of fishing mortality experienced by the sandeel stock and the fact that the fishery has been at the same level for the last 20 years the need for reductions in overall fishing effort to safeguard the spawning stock does not seem compelling. As was the conclusion of ICES(1996a) the sandeel fishery seems to be sustainable with regard to its effect on the overall North Sea sandeel population. However, this conclusion depends to some extent on the level of predation mortality experienced by the stock. If the stock sizes of the fish predators should increase, for example due to an overall decrease in fishing effort in the human consumption fishery in the North Sea, it may be necessary to decrease the fishing mortality of sandeel as well.

The indirect effects of the sandeel fishery in local areas, and in particular the effect on seabird breeding, could be important, but they are difficult to evaluate due to the lack of knowledge about the stock structure of sandeel. If the sandeel population in these areas are reproductively isolated from spawning populations in other parts of the North Sea, the possibility of local recruitment overfishing cannot be discounted.

In order to follow a precautionary approach a management plan for the fishery should be elaborated in which an upper limit on the total fishing effort and other reference points related to eg. spawning stock size and impact on seabirds are specified. Given the uncertainty about the exchange of larvae between local populations of sandeel it cannot with the present scientific knowledge be ruled out that fishing in areas close to seabird breeding colonies could adversely effect the breeding success of the birds. It would therefore seem precautionary to close areas in the vicinity of these colonies to fishing until more is known about sandeel stock structure and the interactions between sandeels and seabirds.

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Composition of landings	Norway pout fishery	Sandeel fishery	Sprat fishery	"Other species" fishery	Total landings
Norway pout	89	2	0.1	6	97
Sandeel	0.3	581	5	21	607
Sprat	0.2	10	93	31	134
Herring	4	11	15	66	96
Other	18	11	4	32	65
Total	111	615	117	156	999

Table 1. Average Danish industrial landings ('000 tons) in 1990 - 94 by major fisheries and species. The classification of fisheries is based on the criteria that the target species should make up more than 50% of the landing by month and ICES statistical rectangle.

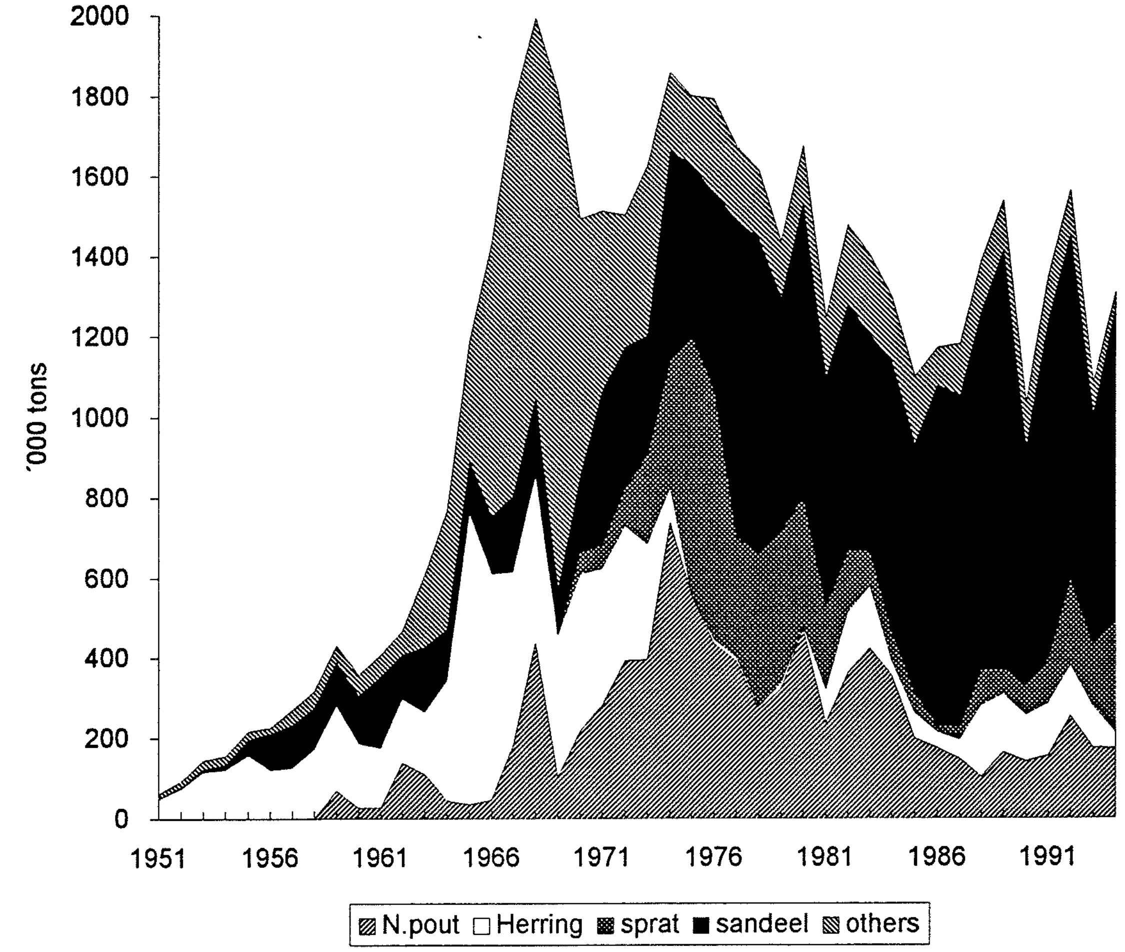

Figure 1. Landings from the industrial fisheries in the North Sea, 1951-1994. Data from ICES Working Group reports and Popp Madsen(1978).

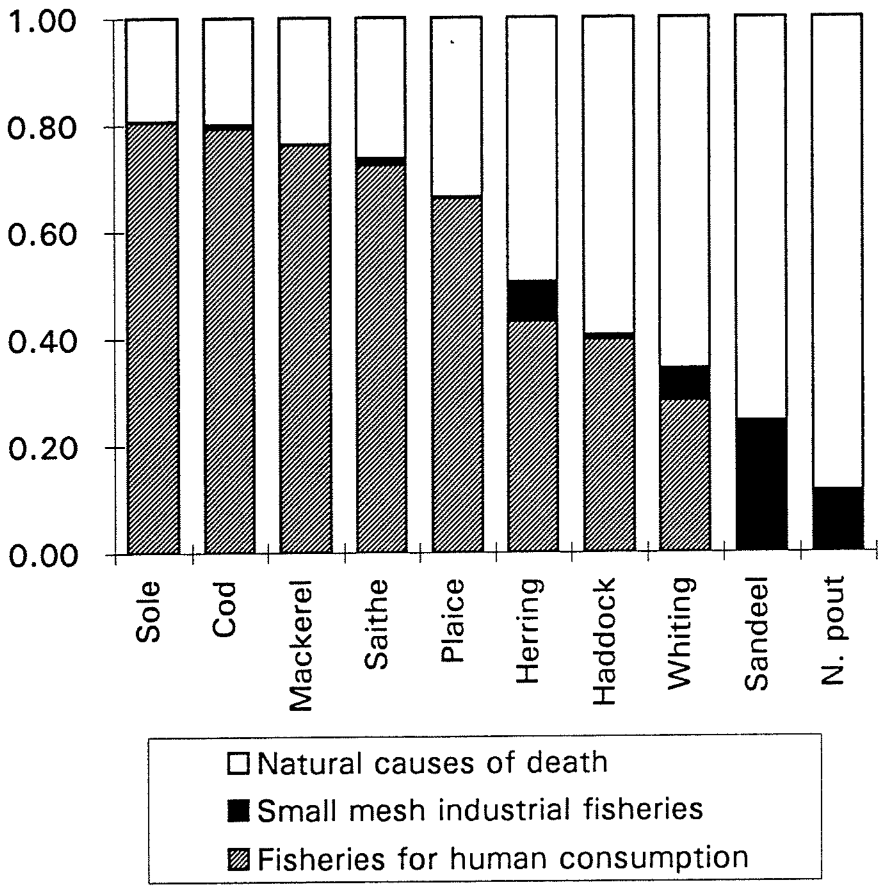

Figure 2. Proportion of the total production of various exploited North Sea fish species harvested by the fishery for human consumption purposes, the industrial fishery and the removed due to natural mortality. Data from MSVPA, 1985-1989.

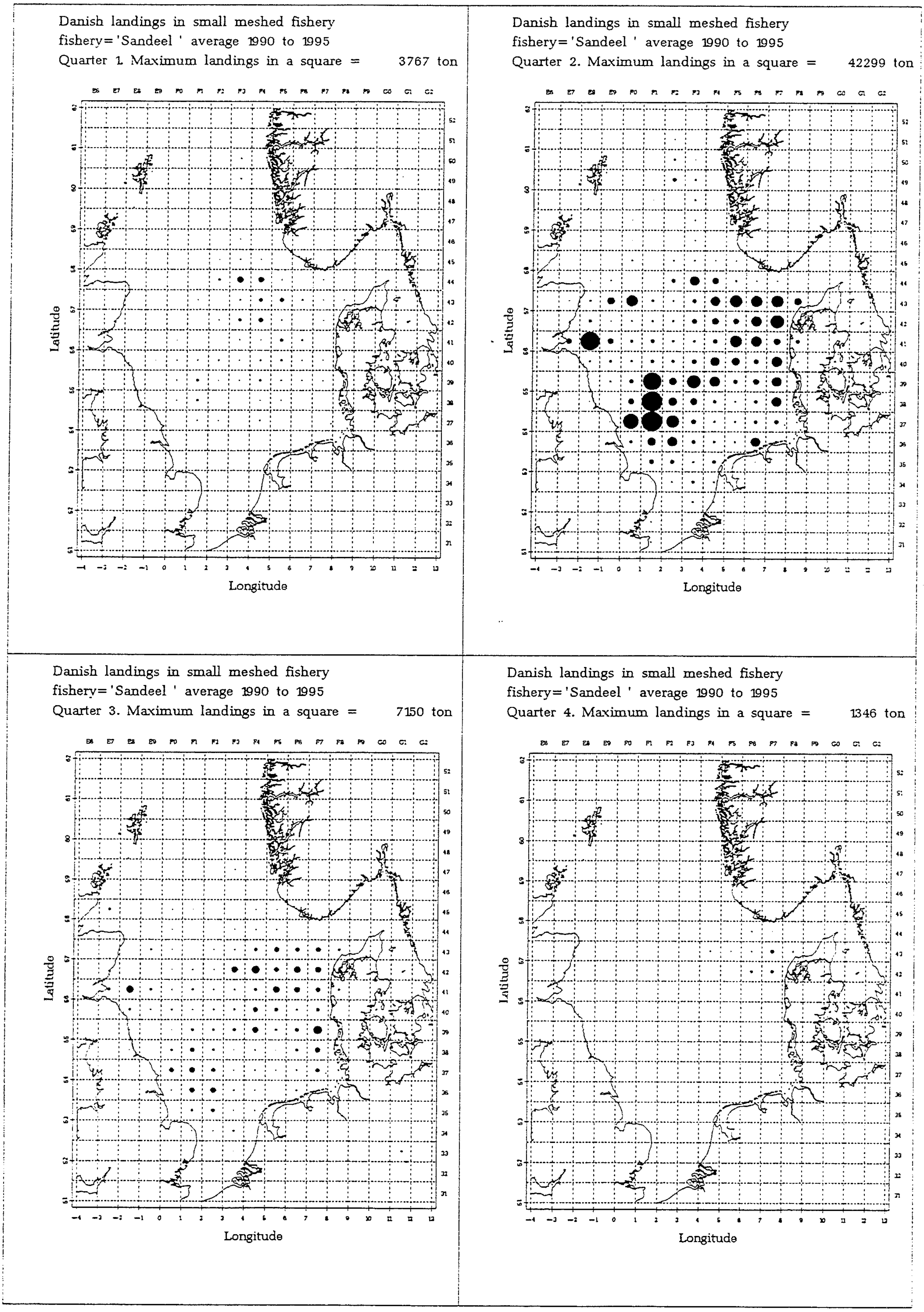

Figure 3. Average landings of sandeel from the Danish industrial fishery by quarter and ICES statistical rectangle, 1990-1995.

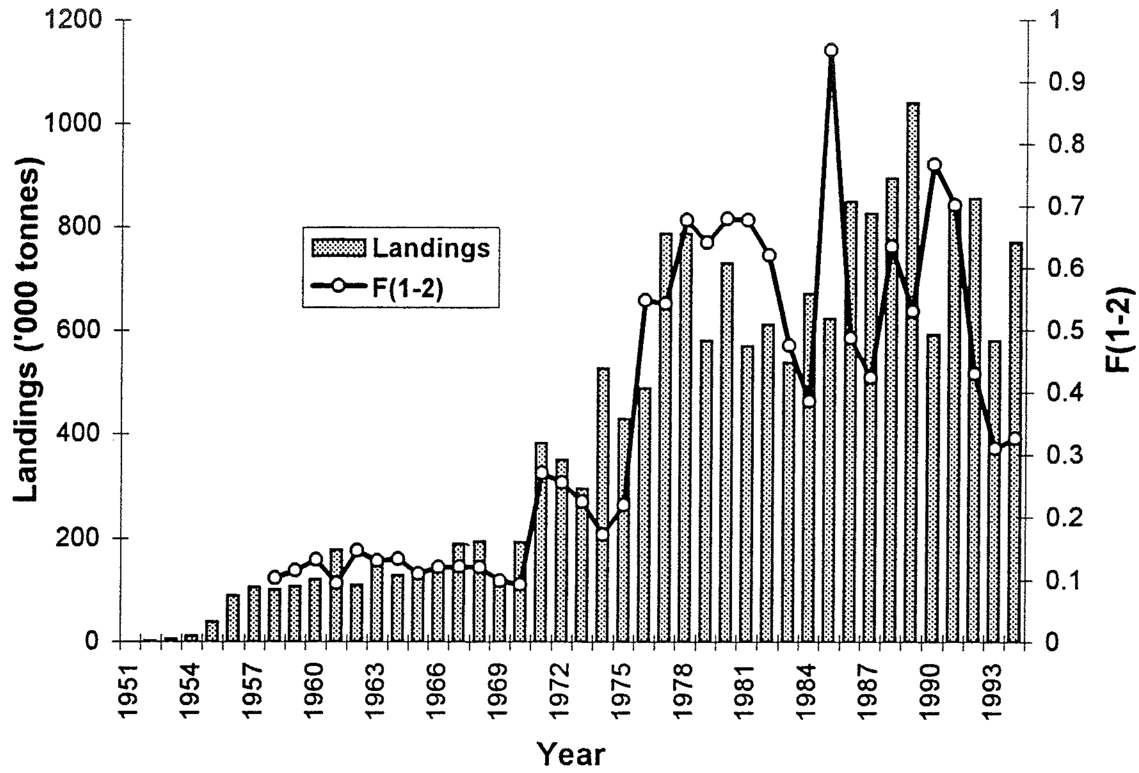

Figure 4. Landings of sandeels from the North Sea and fishing mortality averaged over ages 1 and 2. Data from ICES Working Group reports. Fishing mortalities 1958-1971 derived from Danish effort data.

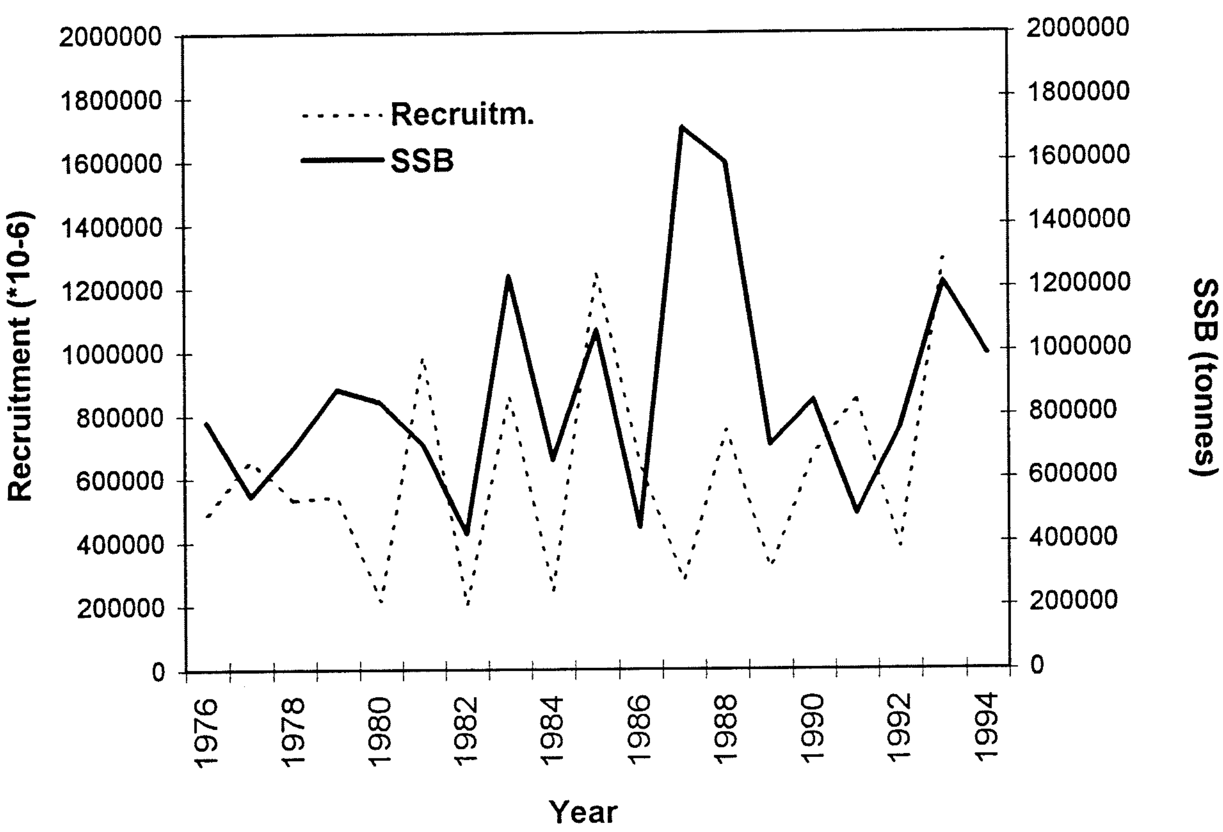

Figure 5. Spawning stock biomass (SSB) and recruitment of North Sea sandeel. Data from ICES(1995).

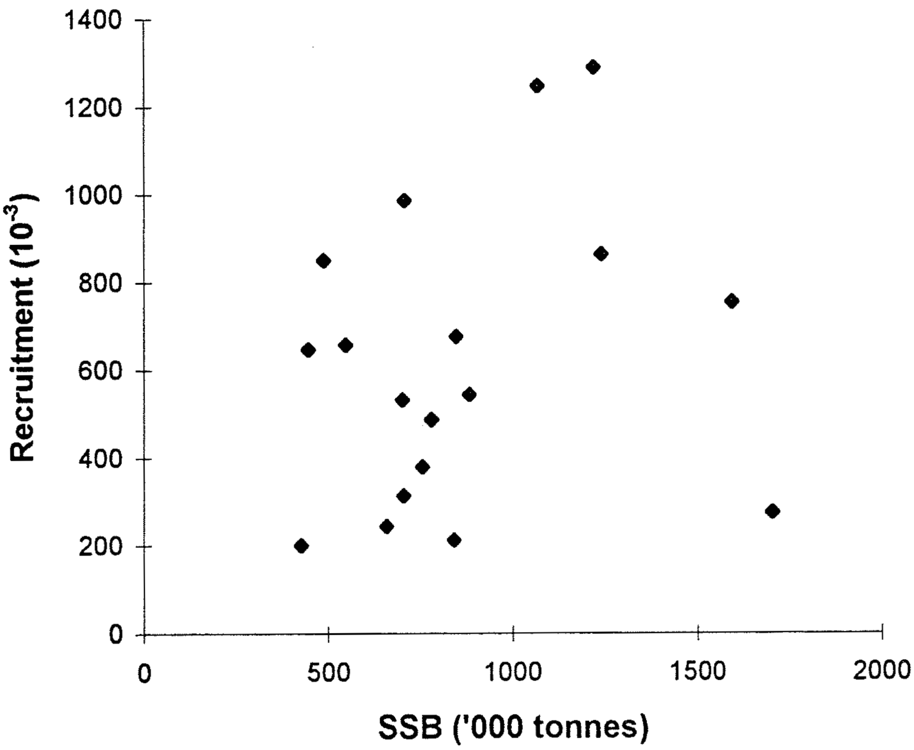

Figure 6. North Sea sandeel. Recruitment versus Spawning Stock Biomass (SSB). Data from ICES(1995).

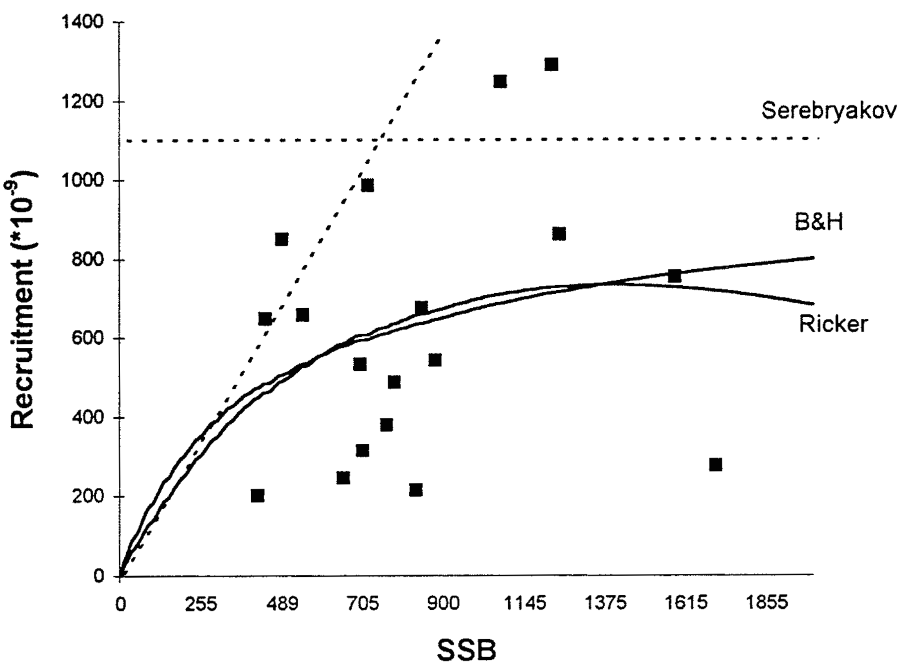

Figure 7. North Sea sandeel. Ricker and B&H stock recruitment curves and an illustration of Serebryakovs method for estimating the lower limit of spawning stock size.

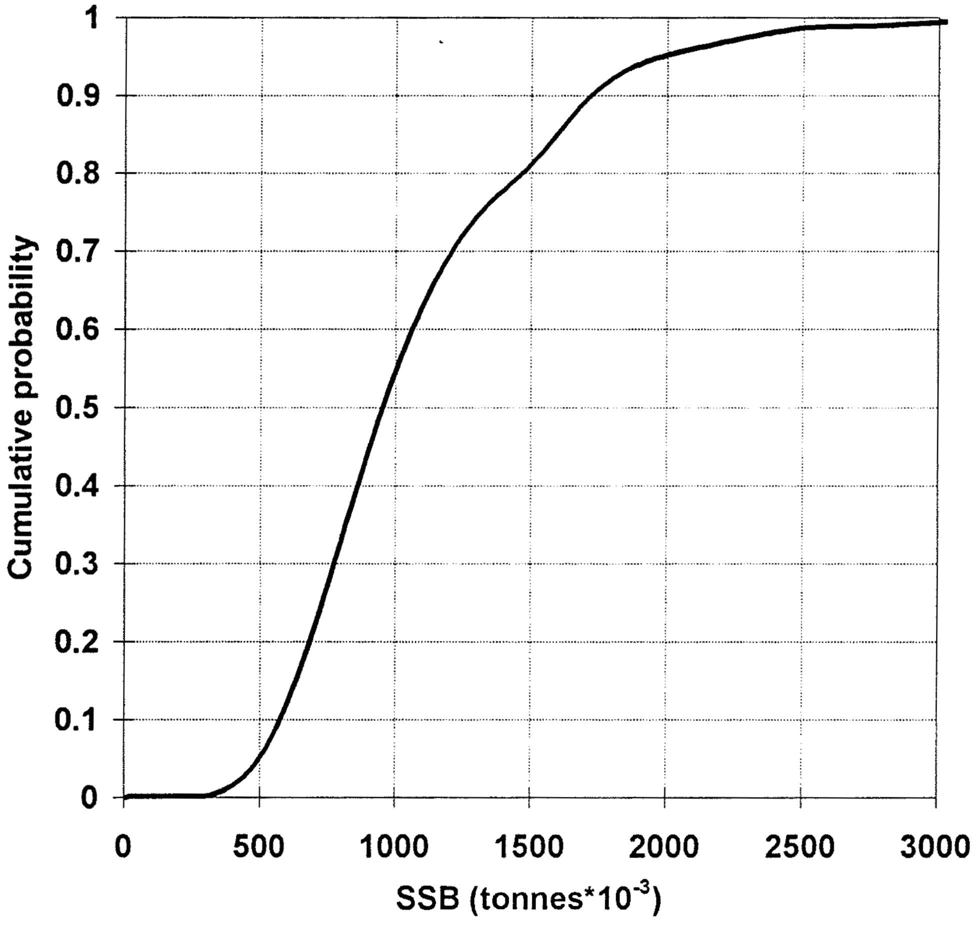

Figure 8. Predicted cumulative probability of sandeel SSB.

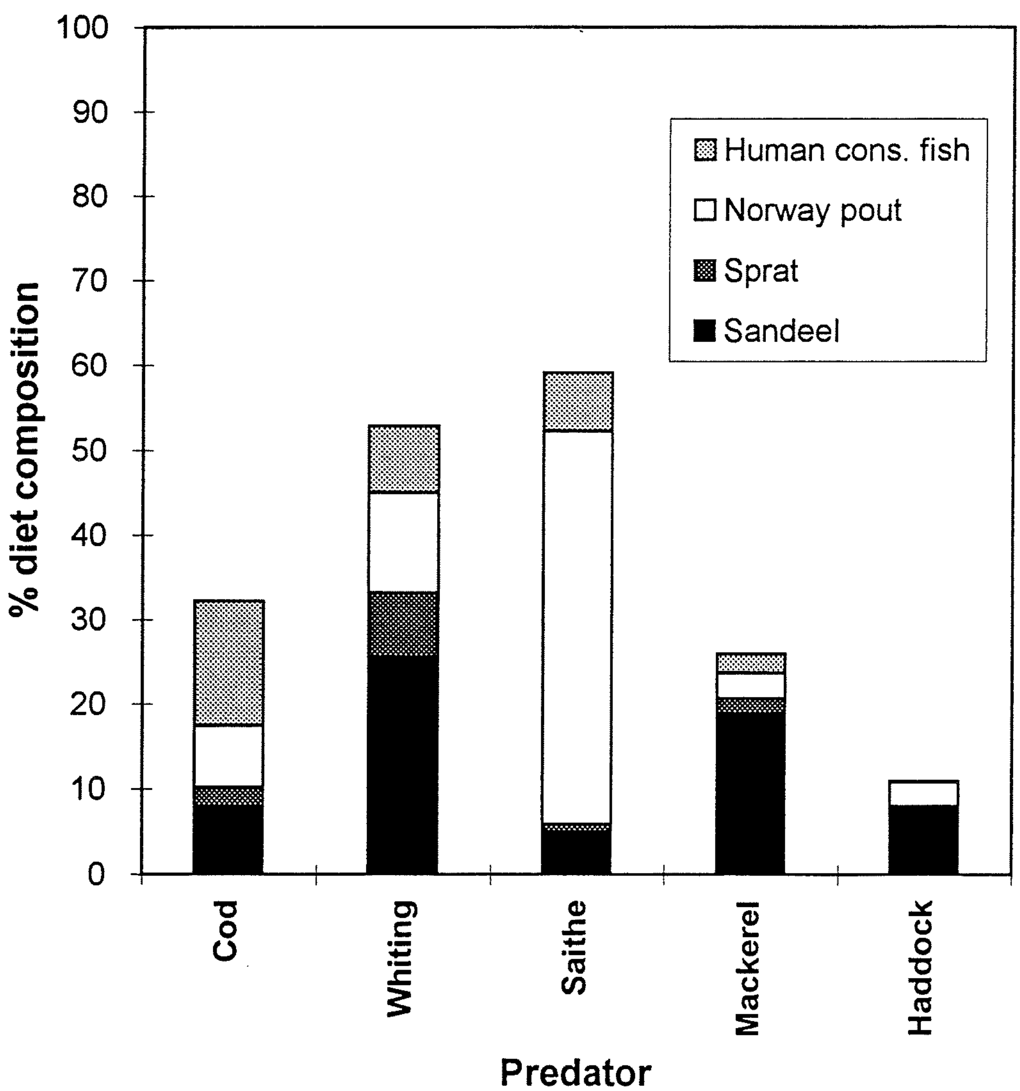

Figure 9. Percentage diet composition of five commercially exploited fish predators in 1981. Data from MSVPA.

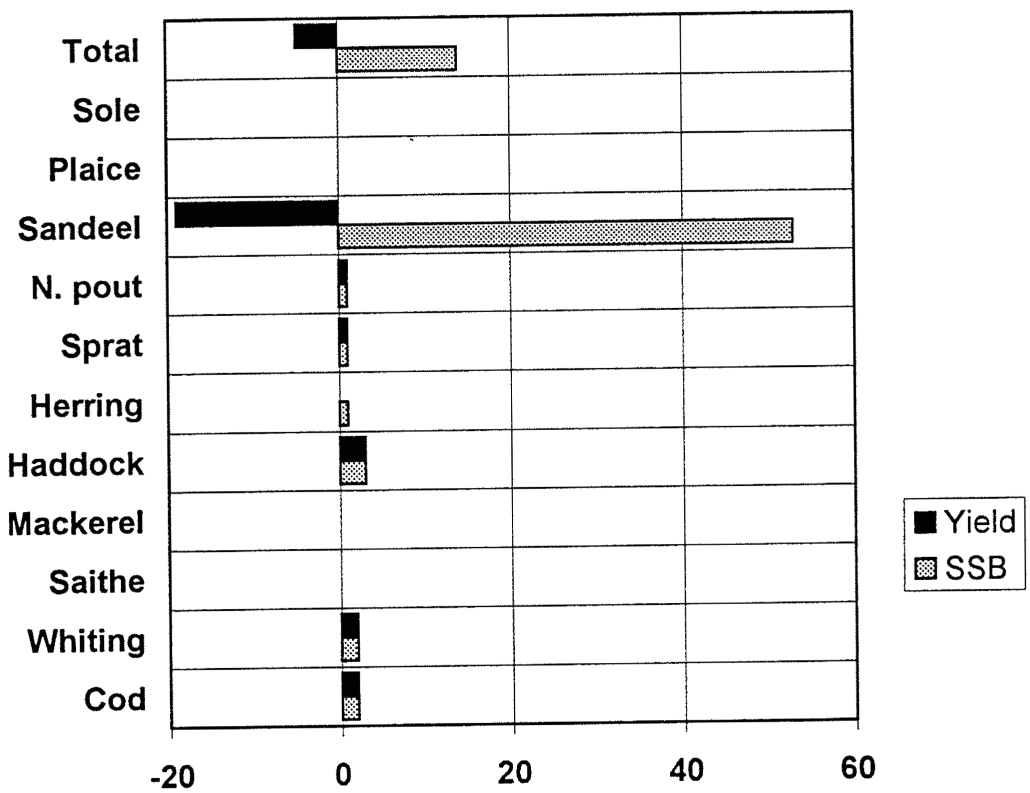

Figure 10. MSFOR predictions of the change in yield and SSB of 11 North Sea species upon a 40% reduction in sandeel fishing mortality

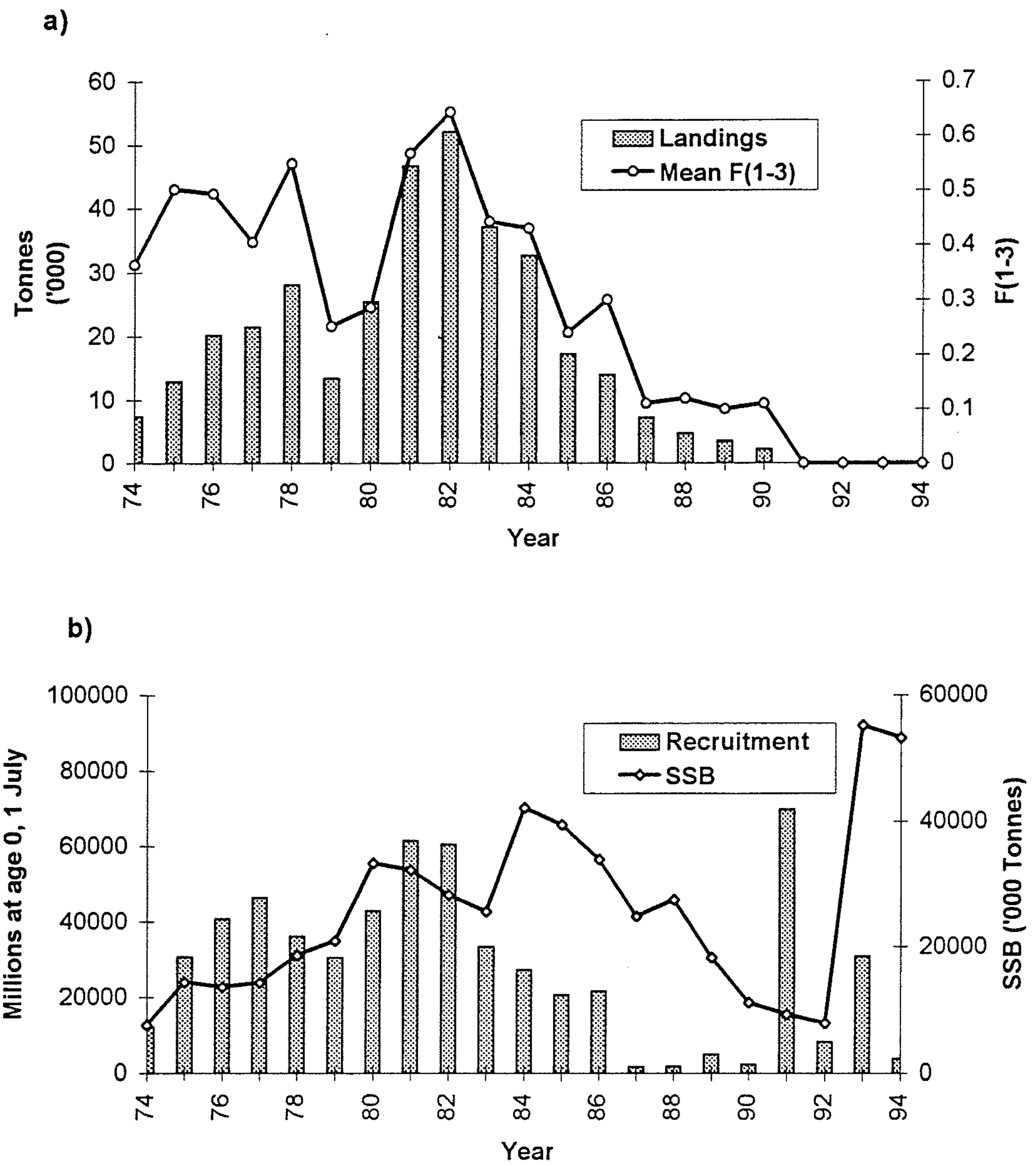

Figure 11. Shetland sandeel. a) Landings and average fishing mortality (ages 1-3). b) Recruitment and Spawning Stock Biomass. Date from ICES Working Group reports.

APPENDIX 5

North Sea Roundfish

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NORTH SEA ROUNDFISH

BY

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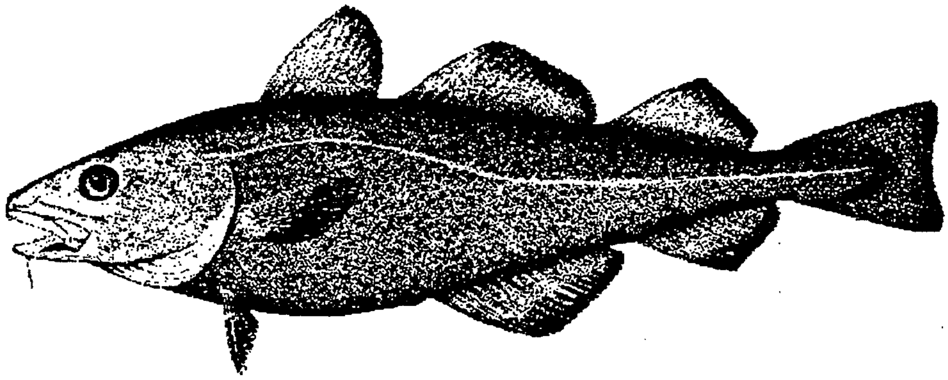

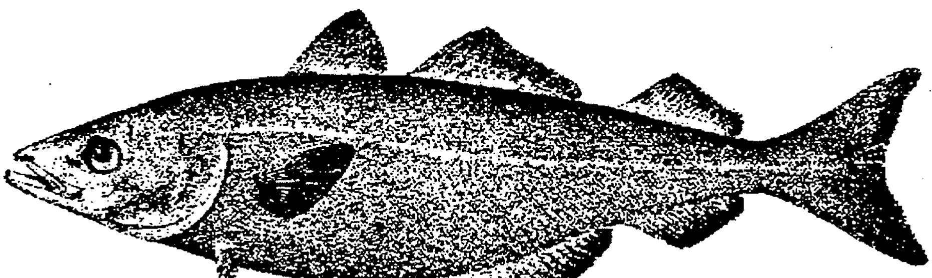

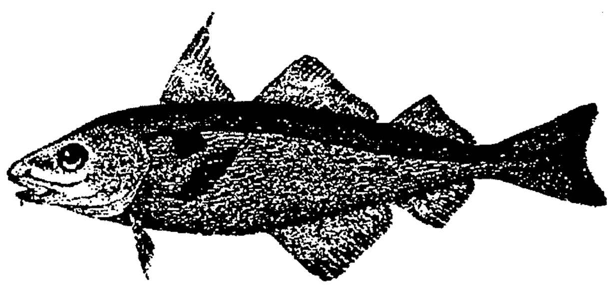

THE PRECAUTIONARY
APPROACH TO NORTH SEA
FISHERIES MANAGEMENT

OSLO 9-10 SEPTEMBER
1996

Summary

North Sea roundfish stocks, cod, haddock, whiting and saithe, have been exploited for many years. In the latter part of the century the fisheries have been dominated by mechanised otter trawlers which are relatively non-selective. The fishries are mixed although a directed saithe fishery near the shelf edge can be distinguished. With the exception of whiting, all roundfish show long term stock declines which can be related to high exploitation rates. The exploitation rate for cod appears high enough to cause a stock collapse and immediate measures are required to reduce fishing mortality by at least 30%. The probability of further stock decline for haddock is moderate and it would be desirable to reduce exploitation rates accordingly. Saithe exploitation rates have recently declined to sustainable levels but the stock is very vulnerable to recruitment over-fishing if exploitation rates rise.

Historical Perspective

Roundfish in the North Sea have been exploited for hundreds of years. In this century the introduction of steam and diesel power has allowed a substantial increase in the fishing power of vessels. However, it is only since the second world war, when comprehensive data collection programmes were set up, that it has been possible to monitor, in detail, the development of stock size and exploitation rate in a systematic way. Although there are a few studies which have been able to reconstruct the population history back to the early part of this century, most conventional ICES assessments go back only to the early 1960s. This paper concentrates on the stock history from this period up to the present on the four main roundfish species, cod, *Gadus morhua*, haddock *Melanogrammus aeglefinus*, whiting, *Merlangius merlangus* and saithe, *Pollachius virens.*

The fisheries for roundfish are predominantly in the northern North sea although cod and whiting are taken in large quantities in the southern area. The fleets are dominated by otter trawlers which have tended to replace more traditional but labour intensive methods such as lines. Seine nets are also widely used primarily with haddock as the target species. In some parts of the North sea, gillnets are becoming a more popular fishing method, particularly for cod.

Trawls are relatively non-selective gears and their dominance in the fleets means that the four main roundfish are caught in a mixed fishery. However, the principal fisheries for saithe take place near the shelf edge on spawning aggregations and this is generally recognised as a distinct targeted fishery with a minor by-catch of other species. The other three species are to some degree or other also the subject of species specific fisheries but the nature of the fish distribution and the need by fishermen to maximise their catch value means that most demersal fishing vessels take a mixture of species on any trip.

The non-selective nature of trawls both by species and size means that non-target low value species and small fish of the target species are discarded. The rates of discarding vary widely and affect all roundfish species. For haddock and whiting typical values are about 30-50% by weight. For some fleets, where there is no human consumption market for whiting, all fish of this species are discarded. This latter point underlines that fact that most discarding is done for economic reasons and is not related to inappropriate minimum landing sizes or quota restrictions, contrary to common belief.

While the fisheries are inescapably mixed, it is simpler from a biological standpoint to consider each species separately before synthesising the more general fisheries management implications of the characteristics of the stocks. First of all let us examine the recent historical trends of the four roundfish as revealed by the conventional ICES assessments. These assessments summarise the stock history in terms of the catch, fishing mortality rate, spawning stock biomass and recruitment.

Cod (Figure 1)

Since the early 1960s fishing mortality rate has increased steadily and has more or less doubled over the past three decades. This continual rise is associated with a steady decline in both catches and the spawning stock biomass. While it is not a marked effect, it appears from the histogram of recruitment, that in the past decade, year classes have on average been smaller than earlier periods. There is reason to believe that this decline in recruitment may be related to the decline in the spawning stock and is an indication of possible recruitment over-fishing.

Something not shown in these trends is that much of the catch consists of juvenile fish. Cod mature at about the age of four but the fishery exploits fish from age two. It means that few fish reach spawning age. In fact the spawning stock represents less than a quarter of the total exploitable biomass. It is one of the reasons why an apparently large stock biomass is not a good indicator of the true health of the stock.

Haddock (Figure 2)

The biological characteristics of haddock are rather different to cod. It is a smaller fish which matures at an earlier age. The earlier age of maturity means that fish potentially have a greater chance of reaching spawning age and the stock is less vulnerable to recruitment over-fishing. Nevertheless as the trend in fishing mortality shows, the exploitation rate has tended to increase and has been at a high level for many years. Although there has been a recent increase in the spawning stock, the long term trend has been downward and the low levels reached in the early 1990s appears to have been the lowest recorded this century. It is more difficult to judge any trends in recruitment. Haddock recruitment is very variable and the large year classes of the 1960s appear to be exceptional. Since the 1980s, recruitment has typically been lower but it is more difficult to relate this to spawning stock declines.

Whiting (Figure 3)

Whiting are slower growing and mature younger than haddock. Their smaller size means that fish reach their highest rates of exploitation at a late age, perhaps age five or six. This characteristic means they are even less vulnerable than haddock to high exploitation rates. Long term trends, while showing an overall high level of exploitation do not show any notable trends in fishing mortality or spawning stock. Recent recruitment has been lower than earlier periods but this does not appear to be related to spawning stock size.

Unlike the other three species considered here, whiting are the subject of an industrial fishery. This accounts for about a third of the total landings but the size of this fishery has declined and accounts for much of the apparent decrease in total landings since the 1980s.

Saithe (Figure 4)

In terms of growth and maturity, saithe are similar to cod. This means they are vulnerable to recruitment over-fishing. The main fisheries for saithe developed in the 1970s and the exploitation rate increased substantially reaching a peak in the mid 1980s. This is associated with a simultaneous sustained decline in the spawning stock biomass. More recently the exploitation rate has declined and the spawning stock has stabilised.

Present State of the Stocks

While long term trends reveal the historical development of exploitation they do not help greatly in identifying the implications of the present state of the stocks. Characterising the state of the stocks requires a more analytical approach and to proceed we need to digress a little into some basic theory of the dynamics of exploited populations. In doing so we emphasize the conditions of sustainability since this underpins much of the debate surrounding the precautionary approach.

The sustainability of harvesting is largely determined by two factors, the relationship between the size of spawning stock (SSB) and the annual number of offspring (the recruits) produced, and the subsequent survival of the recruits on entering the fishery. This is illustrated in Figure 5 which shows a theoretical stock-recruitment curve and a recruit survivorship line. Where the two lines intersect is an equilibrium point to which the population is attracted . If the survivorship line lies above the stock recruitment curve there is no non-zero equilibrium point and the population is attracted to the origin (i.e. it collapses). The slope of the survivorship line is affected by the fishing mortality rate. The more heavily the stock is exploited, the steeper the slope. This line is also called the replacement line since it defines the survivorship needed to replace the spawning stock in the future.

Given adequate data to define a stock-recruitment relationship, it is possible to examine the equilibria corresponding to a range of replacement lines (and hence fishing mortality rates). It means we can examine the expected spawning stock biomass and yield for any particular exploitation regime. This is explored in the following figures.

Cod (Figure 6)

As indicated earlier when examining stock trends, there appears to be a decline in recruitment as spawning stock size is reduced. The wide range of stock-recruit data for cod enables the fitting of a reasonable stock-recruitment curve. The particular curve fitted is a 'lowess' curve which allows the data to dictate the shape of the line. Using this curve it is possible to construct the equilibrium yield and spawning stock curves for a range of different fishing mortality rates. These are also shown in Figure 6. Super-imposed on these equilibrium lines are the observed yield and biomass figures taken from the long term trend graphs.

It is important to understand that the annual observations plotted in this way would only be expected to track the equilibrium curve if the recruitment values are adequately described by the fitted curve and that the fishery has only changed gradually over time. For cod this appears to be the case and the results are a cause for grave concern. The equilibrium spawning stock curve shows a rapid decline as fishing mortality rate increases. The decline is accelerated at higher levels. The observed annual data are entirely consistent with this decline which, if extrapolated, would imply a stock collapse at current rates of exploitation.

The decline in the spawning stock is also reflected in the trajectory of equilibrium yield. This too shows an accelerated decline at high exploitation rates. The observed catches track this decline and re-enforce the perception of a collapsing stock.

Haddock (Figure 7)

Relating recruitment to spawning stock is more difficult for haddock, partly as a result of a few exceptionally large year classes. However, the fitted lowess curve indicates a decline over the range of stock sizes observed. Translating this curve into equilibrium spawning stock and yield does not reveal any dramatic problems as seen for cod. The yield curve is very flat which does not suggest major gains by reducing the exploitation rate. Spawning stock biomass has cycled around an equilibrium at a relatively high fishing mortality rate. However, as will be seen later it would be dangerous to conclude that the present fishing mortality rate is 'safe' particularly in view of the low levels the stock has been observed to reach.

Whiting (Figure 8)

Unlike cod and haddock, whiting have not reached particularly low levels during the period of detailed monitoring. There is very little detectable change in mean recruitment with spawning stock size but the fitted curve indicates a possible maximum at intermediate stock sizes. The equilibrium spawning stock and yield curves do not suggest anything more than that the stock is cycling around an equilibrium value which corresponds approximately to a maximum sustainable yield.

Recent annual values lie below the equilibrium curves which would imply lower than average recent recruitment and this is perhaps a reason for caution. Whiting assessments are not regarded as very reliable and stock trends from trawling surveys are not entirely consistent with the conventional ICES assessments. There is a need to investigate this inconsistency further.

Saithe (Figure 9)

The saithe stock has been reduced to low levels by fishing and there are some indications that this has resulted in reduced recruitment. Using the stock-recruitment data to construct equilibrium yield and biomass curves reveals a classic example of a fishery which has been living beyond its means for a number of years. In both the equilibrium plots, the observed annual data lie above and to the right of the expected equilibrium. It means that for most of the history of the fishery, the high catch rates have been generated by eroding 'capital', the spawning stock biomass, and that these catch rates are almost certainly not sustainable. If the spawning stock curve was extrapolated, it would be reasonable to expect a zero spawning stock at fishing mortality rates observed in the mid 1980s. Fortunately, recent fishing mortality rates have declined and present values appear to be close to sustainable levels. It should be borne in mind, however, that the most recent fishing mortality and spawning stock biomass estimates will be the least reliable and care should be taken in judging the stock to be 'safe' from over-exploitation.

Future Exploitation Rates

So far we have considered the historical development of the stocks and placed this history in the context of expected equilibrium states. This also provides and insight into what to expect from the present exploitation regimes. For one stock at least, North sea cod, there is good reason to expect serious consequences if the existing exploitation regime is maintained. For the other stocks, present exploitation rates appear to correspond to sustainable levels but there is a need to consider at least some of the uncertainties in making this judgement. In this section an attempt is made to evaluate the present exploitation rates in relation to uncertainties surrounding the estimation of vital parameters and the uncertainties in the stock-recruitment data. This can be used to suggest appropriate future exploitation rates.

In Figure 5 an idealized stock-recruitment curve was illustrated with example replacement lines. With perfect information of this type it is easy to define conditions of sustainability and collapse but this pays no regard to estimation errors or the limitations of real data. Crucial to our goal is the need to establish a criterion related to sustainability which is estimable and related to the precautionary approach. Consider the stock recruitment data illustrated in Figure 10. This shows the typical problem where data are scattered and are inadequate to define the left hand part of the stock-recruitment curve (the broken line). If we knew the stock recruitment curve we could define F_{crash}, the fishing mortality which results in stock collapse. However, the best we can do is to define F_{loss}, the replacement line which corresponds to the lowest observed spawning stock (LOSS). Although this is not the replacement line we seek it has certain value because;

a) F_{loss} is a minimum estimate of F_{crash},
b) any fishing mortality which corresponds to a replacement line to the right of F_{loss} should be sustainable and,
c) any fishing mortality which corresponds to a replacement line to the left of F_{loss} should result in and equilibrium stock size below the lowest observed value.

Given these properties what we wish to know is, does the present level of fishing mortality lie to the left of F_{loss}, and if so, is F_{loss} likely to be a good estimate of F_{crash}? If the answer is yes to both questions the stock is in trouble. Clearly we wish to establish a fishing mortality rate which is below F_{crash} with some degree of confidence. To do this requires;

i) the estimation of the uncertainties in replacement lines calculated for any fishing mortality rate.
ii)the estimation of the uncertainties in F_{loss} and
iii)how close F_{loss} is to F_{crash}.

This paper does not offer the opportunity to discuss in detail how (i) and (ii) are dealt with in the analysis which is reported below. What has been done, however, is to calculate the range of replacement lines which correspond to F_{loss} and the present level of fishing mortality. The variability in the estimate of F_{loss} has been made using bootstrapping methods, while the variability in replacement lines corresponding to the present value of fishing mortality rate considers estimation errors in fishing mortality rate, natural mortality rate, growth and maturity. Given estimates of the distribution of these two replacement lines it is possible to calculate the probability that the present level of fishing mortality is equal to or greater than F_{loss} and hence the probability that the stock will decline to an equilibrium below the lowest observed value. It is also possible to perform the same analysis to calculate a value of fishing mortality for each stock which gives a low probability of being at or above F_{loss}. This is a minimum requirement to avoid long term stock decline. It is easier to understand this analysis by examining specific examples.

Cod (Figure 11)

This figure shows the stock-recruitment data with the range of F_{loss}(vertical shading) and present fishing mortality (horizontal shading) plotted. It shows substantial overlap in the distributions with a tendency for the present fishing mortality to lie above F_{loss}. The probability that the present fishing mortality lies above F_{loss} is high (Table 1) and by implication means that the stock would be expected to decline further from its present low level. It seems likely that F_{loss} is a good estimator of F_{crash} because the lowest observed spawning stock lies relatively close to the origin. This means that stock collapse is likely.

It is difficult at the present stage of development of the analysis to quantify an appropriate probability level for a replacement line to lie below F_{loss} to be reasonably sure of avoiding stock collapse. For this paper an arbitrary value of about 0.1 has been chosen. A fishing mortality rate which would satisfy this probability level for cod is 0.6 (Table 1). This represents a 30% reduction from the present levels and would be expected to lead to significant increases in equilibrium yield and spawning stock biomass.

Haddock (Figure 12)

Unlike cod, the distribution of F_{loss} lies mostly above the present fishing mortality rate. However, the probability that present fishing mortality lies above F_{loss} is still fairly high at 0.18 (Table 2). Since the lowest stock sizes are close to the origin, is seems likely that F_{loss} will be close to F_{crash}. The probability level is therefore rather too large to be complacent and it would be desirable to reduce fishing mortality rate accordingly. A 20% reduction in fishing mortality rate to 0.7 would reduce the probability to 0.11. Such a reduction would not be expected to increase average yield significantly but would improve the equilibrium spawning stock level (Table 2).

Whiting (Figure 13)

Present levels of fishing mortality produce replacement lines which have a probability of 0.12 of being above F_{loss} (Table 3). Given that observed stock sizes have not reach particularly low levels, it is likely that F_{loss} lies below F_{crash}. Thus there are no strong reasons, on the basis of this analysis, for suggesting a fishing mortality rate target below the present level. However, the reliability of the assessment needs to be considered when making this judgment.

Saithe (Figure 14)

As with whiting, the present level of fishing mortality gives replacement lines with a low prbability of being above F_{loss} (Table 4). However, F_{loss} may well be close to F_{crash} so some caution is necessary. If the present level of fishing mortality is correctly estimated then there seems no need to define a lower target level on the basis of this analysis. It is worth noting that the highest 'safe' level of fishing according to the probability level chosen here is quite low, 0.45. This can be compared with typical roundfish exploitation rates which are about double this value at present. It illustrates the problem that late maturing fish such as saithe and cod are much more vulnerable to heavy exploitation than early maturing fish such as whiting.

Conclusions

There are many aspects of fishing which may be of concern to interested parties, such as the effects of discarding, the disturbance to benthic communities or the alteration of ecosystem structure. This paper does not address these issues but concentrates solely on a minimum requirement that exploitation regimes should be sustainable. The analysis presented suggests strongly that the exploitation rate for cod is not sustainable and that a reduction in fishing mortality of at least 30% is required. It is important to appreciate that in attempting to reduce fishing mortality it will almost certainly be necessary to reduce fishing effort by much more than this since there will inevitably compensating behaviour by exploiting fleets. However, the rate of decline at present levels of exploitation is sufficiently high to require decisive action.

Haddock and whiting appear less vulnerable to heavy fishing but present levels on haddock carry a moderate risk of being above sustainable levels. It would be prudent to reduce fishing mortality on this stock by about 20% to be more confident of avoiding dangerous levels.

The exploitation rate on saithe appears to satisfy the minimum criteria for sustainability but only if the present estimates of fishing mortality rate are reliable. Furthermore, this stock is the most vulnerable of the roundfish to heavy exploitation, making it even more important to maintain low levels of exploitation.

Although the analysis described in this paper provides a basis for choosing potential target fishing mortality rates by stock, any management measures designed to achieve such targets will utlimately have to operate at the fleet level. The constraints of mixed fisheries means that all target rates may not be achievable simultaneously. Given the particular vulnerability of cod and saithe to recruitment over-fishing, it seems sensible to allow these stocks to define the level of fishing in the mixed fisheries. By implication this would mean that the achieved fishing mortality rates on haddock and whiting are likely to be less than the suggested target rates in Tables 2 and 3 if the target rate for cod is satisfied. However, even such a scenario is likely to improve still further the equilibrium spawning stock and yield for haddock. Whiting spawning stock biomass (but not yield) would also benefit from such a reduction.

Table 1

Cod

Mean Yield 85-94	128,000 t	
Lowest Observed SSB (LOSS)	57,000 t	
Current SSB	59,000 t	Expected Eq. SSB=0
MinSSB/Max SSB	0.20	
Current F	0.85	
Prob. Fnow>Floss	0.63	Floss probably = Fcrash
Suggested Max F	0.60	
Prob. maxF>Floss	0.11	
Equil. SSB	260,000 t	
Equil. Yield	250,000 t	

Table 2

Haddock

Mean Yield 85-94	154,000 t	
Lowest Observed SSB (LOSS)	62,000 t	
Current SSB	158,000 t	Expected Eq. SSB=135
MinSSB/Max SSB	0.08	
Current F	0.90	
Prob. Fnow>Floss	0.18	Floss probably close to Fcrash
Suggested Max F	0.70	
Prob. maxF>Floss	0.11	
Equil. SSB	190,000 t	
Equil. Yield	160,000 t	

Table 3

Whiting

Mean Yield 85-94	120,000 t	
Lowest Observed SSB (LOSS)	231,000 t	
Current SSB	256,000 t	Expected Eq. SSB=380
MinSSB/Max SSB	0.38	
Current F	0.73	
Prob. Fnow>Floss	0.12	Floss probably < Fcrash
Suggested Max F	0.70	
Prob. maxF>Floss	0.10	
Equil. SSB	390,000 t	
Equil. Yield	155,000 t	

Table 4

Saithe

Mean Yield 85-94	122,000 t	
Lowest Observed SSB (LOSS)	78,000 t	
Current SSB	99,000 t	Expected Eq. SSB=110
MinSSB/Max SSB	0.16	
Current F	0.45	F may not be reliably estimated
Prob. Fnow>Floss	0.11	Floss probably close to Fcrash
Suggested Max F	0.45	
Prob. maxF>Floss	0.11	
Equil. SSB	110,000 t	
Equil. Yield	110,000 t	

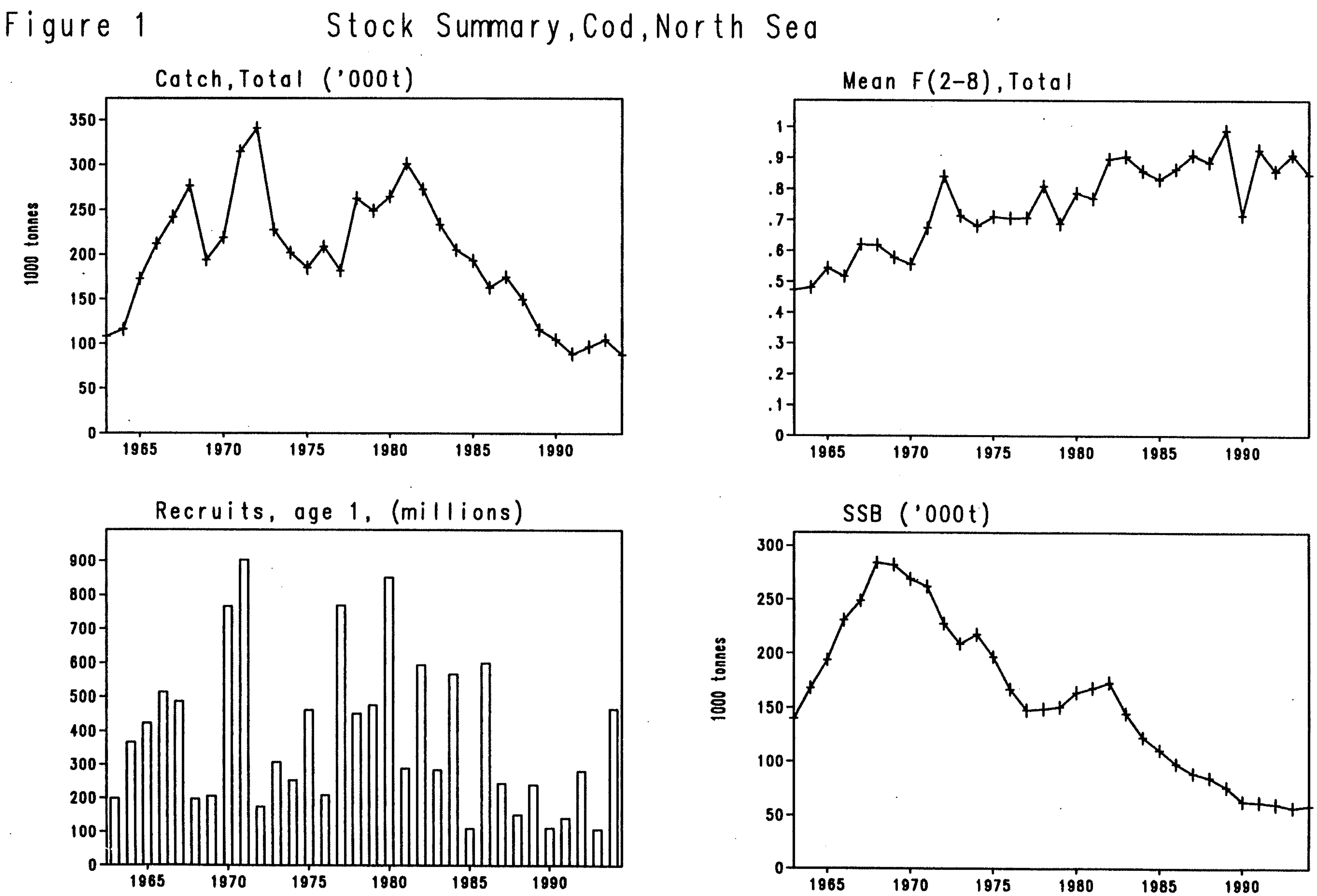

Figure 1. North Sea Cod. Long term trends in yield (total catch), fishing mortality, recruitment and spawning stock biomass as estimated by ICES.

Figure 2

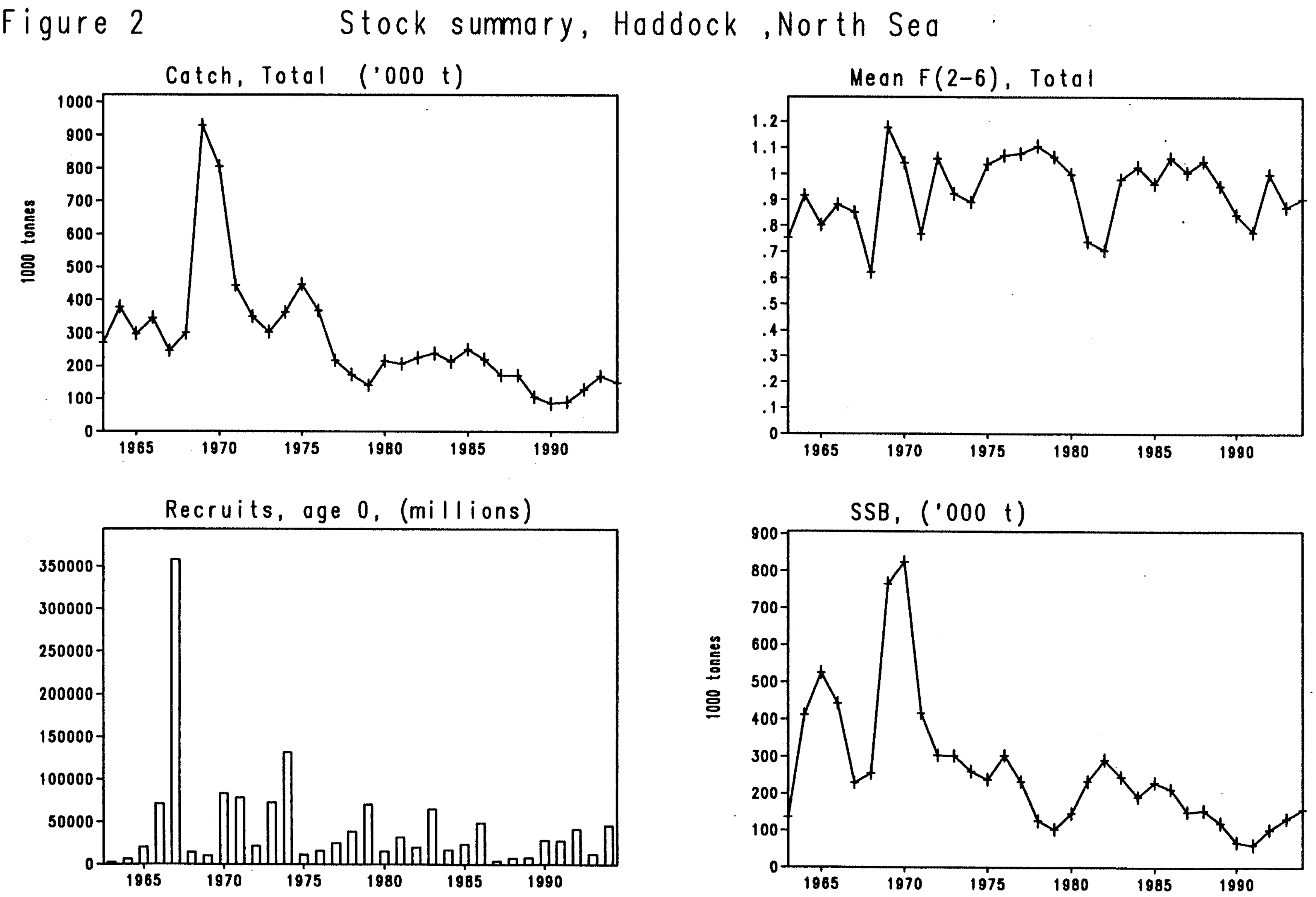

Figure 2. North Sea haddock. Long term trends in yield (total catch), fishing mortality, recruitment and spawning stock biomass as estimated by ICES.

Figure 3 Stock summary, Whiting ,North Sea

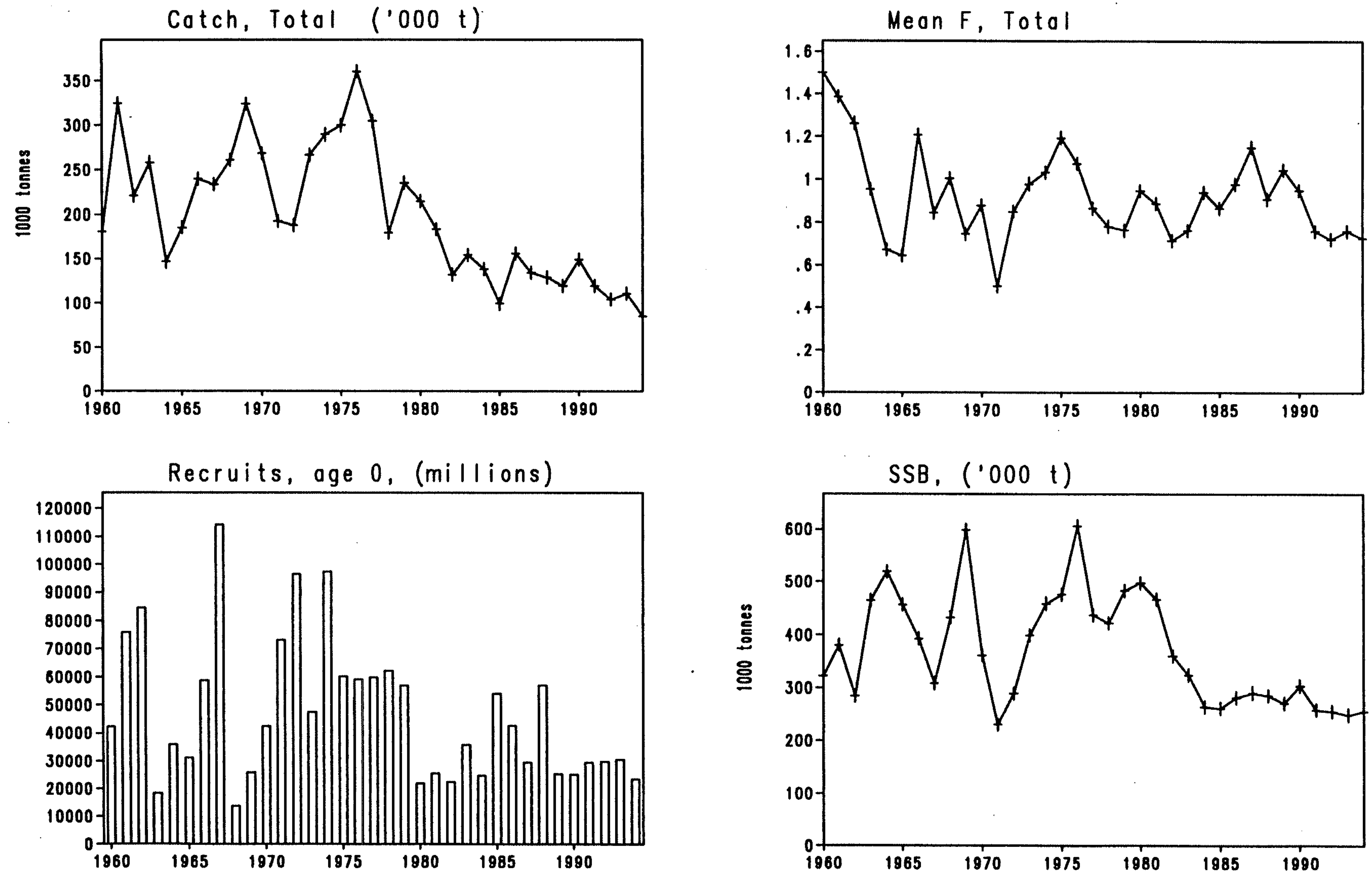

Figure 3. North Sea whiting. Long term trends in yield (total catch), fishing mortality, recruitment and spawning stock biomass as estimated by ICES.

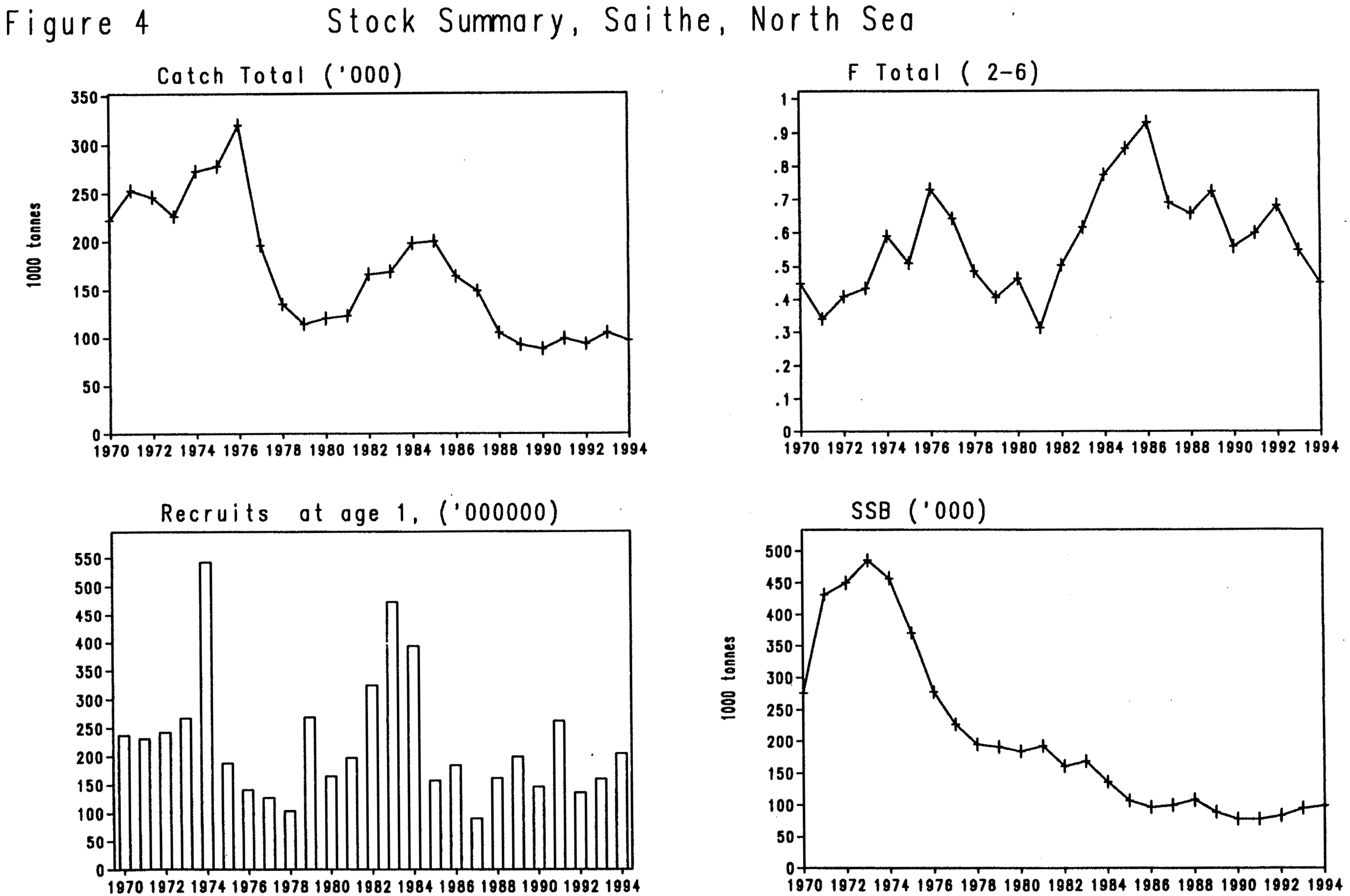

Figure 4. North Sea saithe. Long term trends in yield (total catch), fishing mortality, recruitment and spawning stock biomass as estimated by ICES.

Figure 5

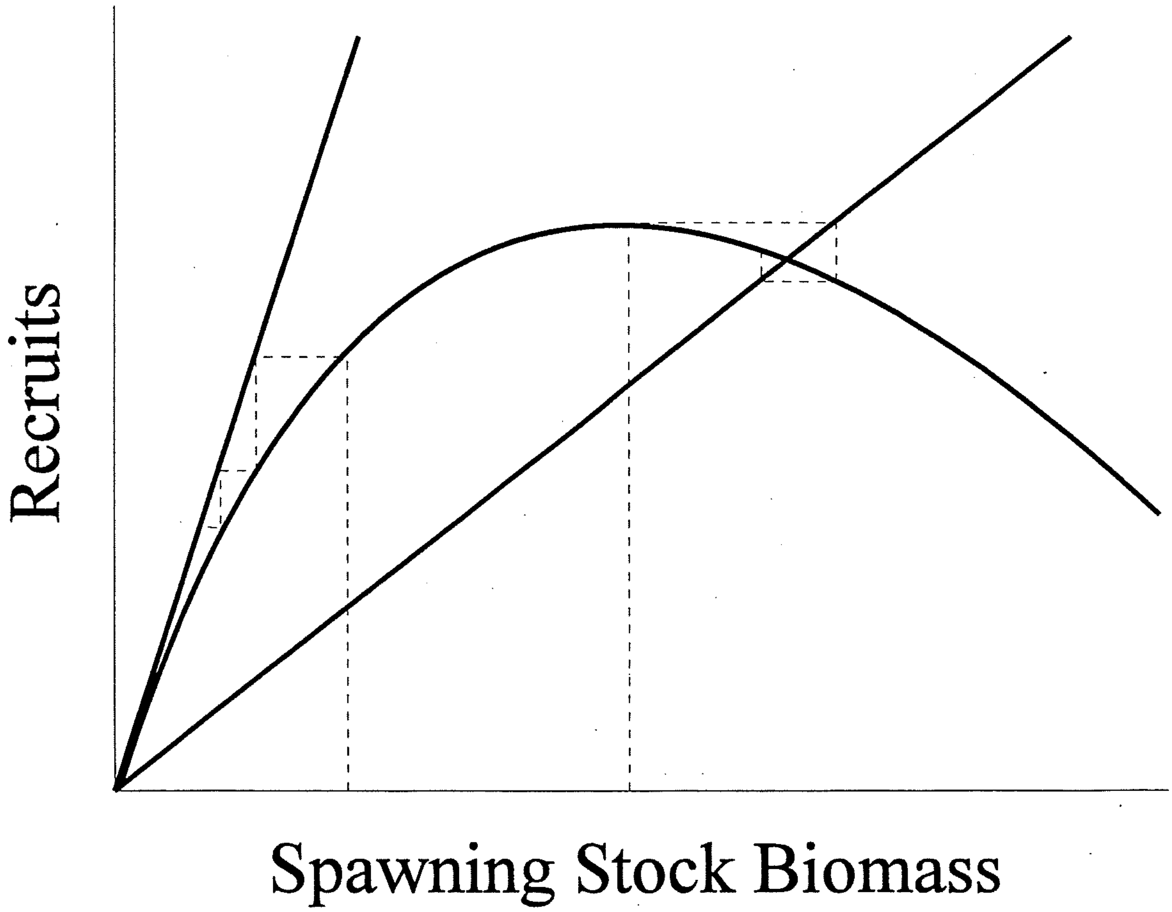

Figure 5. Theoretical stock-recruitment relationship for a fish stock. The curve predicts recruitment given stock size, while the straight lines are the replacement lines. These lines predict expected spawning stock from recruitment for two levels of exploitation. At a low exploitation rate, the dotted line indicates the population trajectory expected which cycles towards an equilibrium point. For high exploitation the dotted line shows the expected population trajectory collapsing towards the origin.

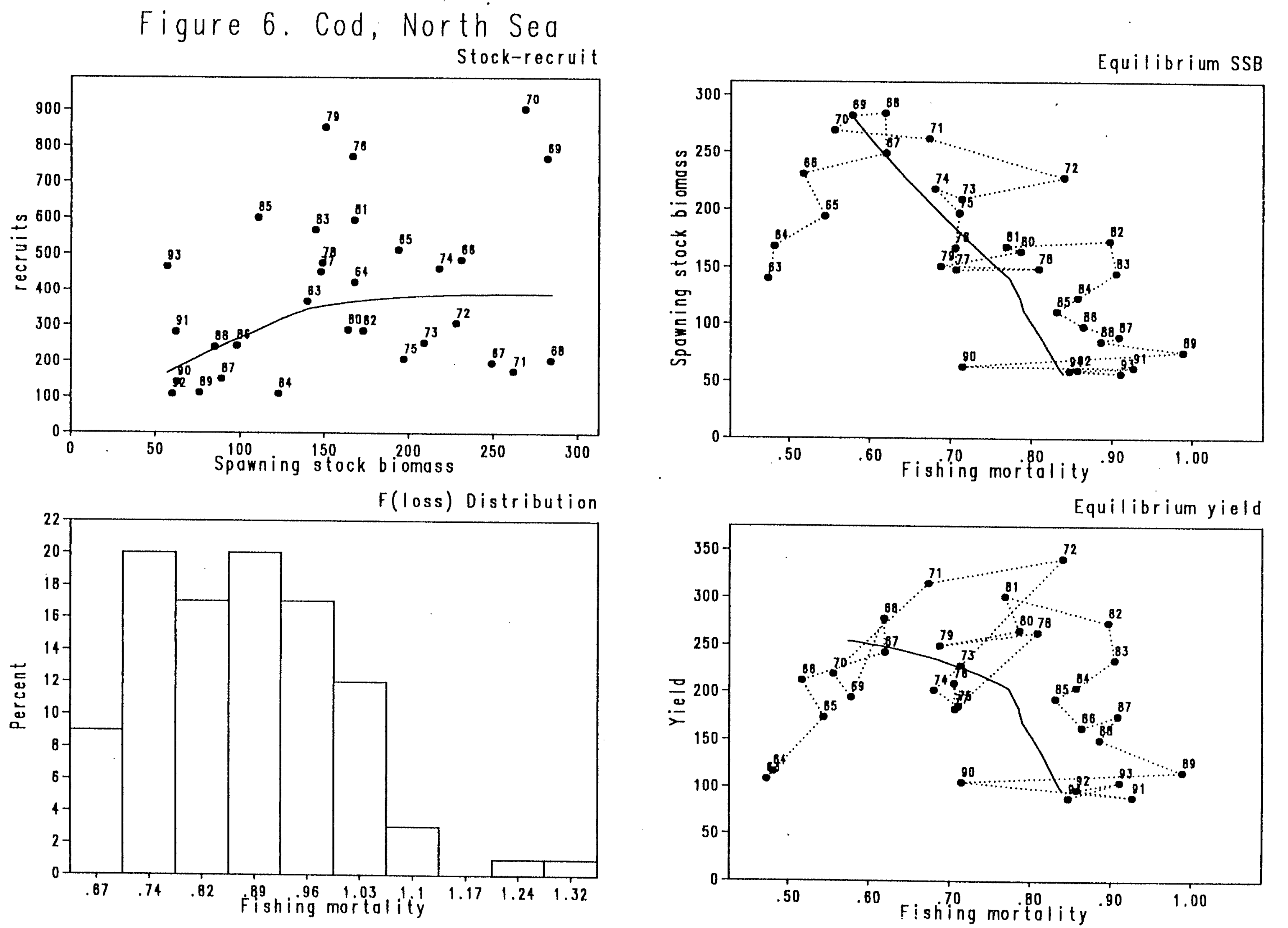

Figure 6. North Sea cod. The panels in clockwise direction show the stock recruitment data with fitted lowess curve, the equilibrium spawning stock biomass, equilibrium yield and the distribution of fishing mortality, which corresponds to F_{loss}. In the case of yield and spawning stock biomass the plotted data points are the annual observations of the quantity estimated by ICES.

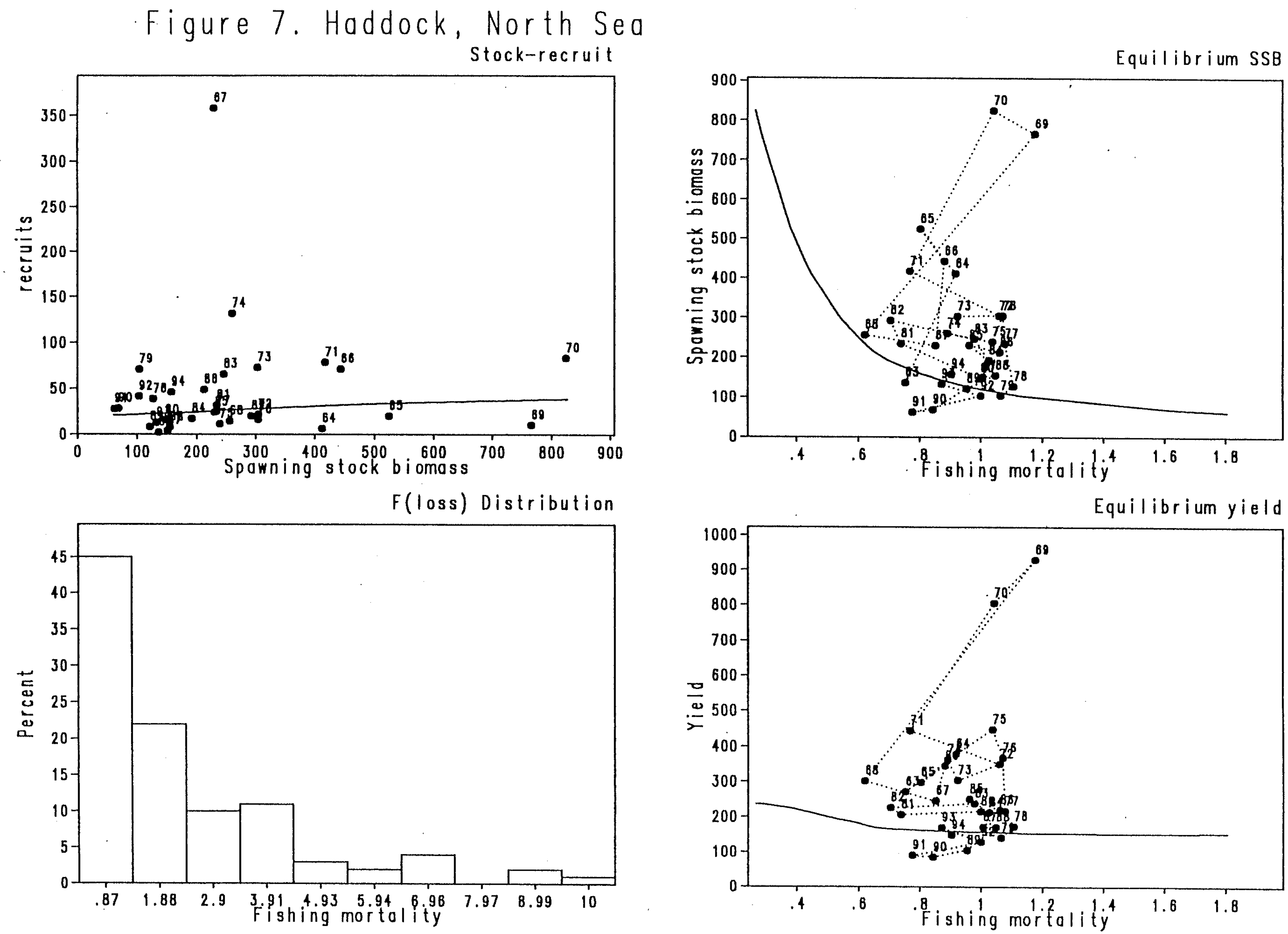

Figure 7. North Sea haddock. The panels in clockwise direction show the stock recruitment data with fitted lowess curve, the equilibrium spawning stock biomass, equilibrium yield and the distribution of fishing mortality, which corresponds to F_{loss}. In the case of yield and spawning stock biomass the plotted data points are the annual observations of the quantity estimated by ICES.

Figure 8. Whiting ,North Sea

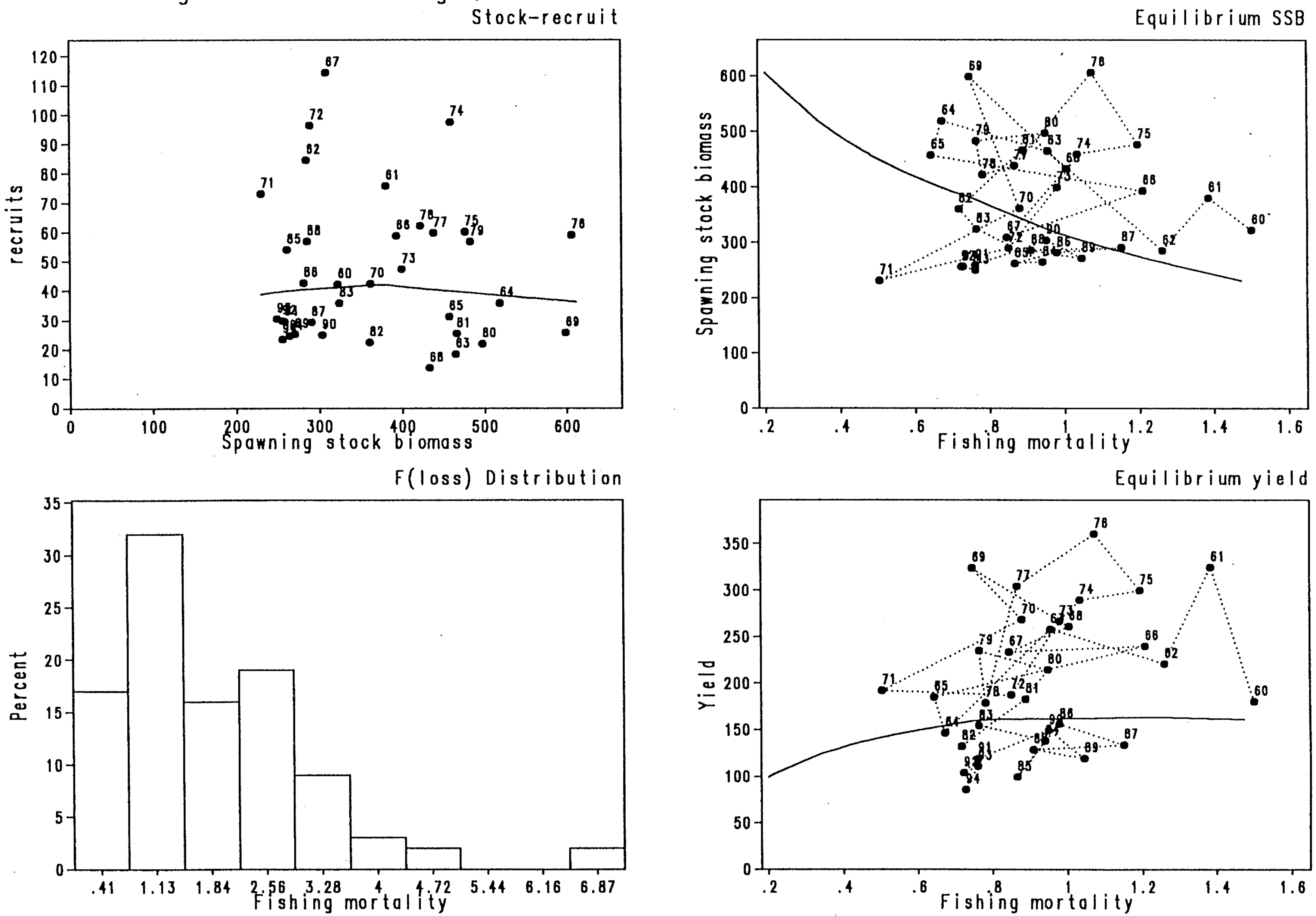

Figure 8. North Sea whiting. The panels in clockwise direction show the stock recruitment data with fitted lowess curve, the equilibrium spawning stock biomass, equilibrium yield and the distribution of fishing mortality, which corresponds to F_{loss}. In the case of yield and spawning stock biomass the plotted data points are the annual observations of the quantity estimated by ICES.

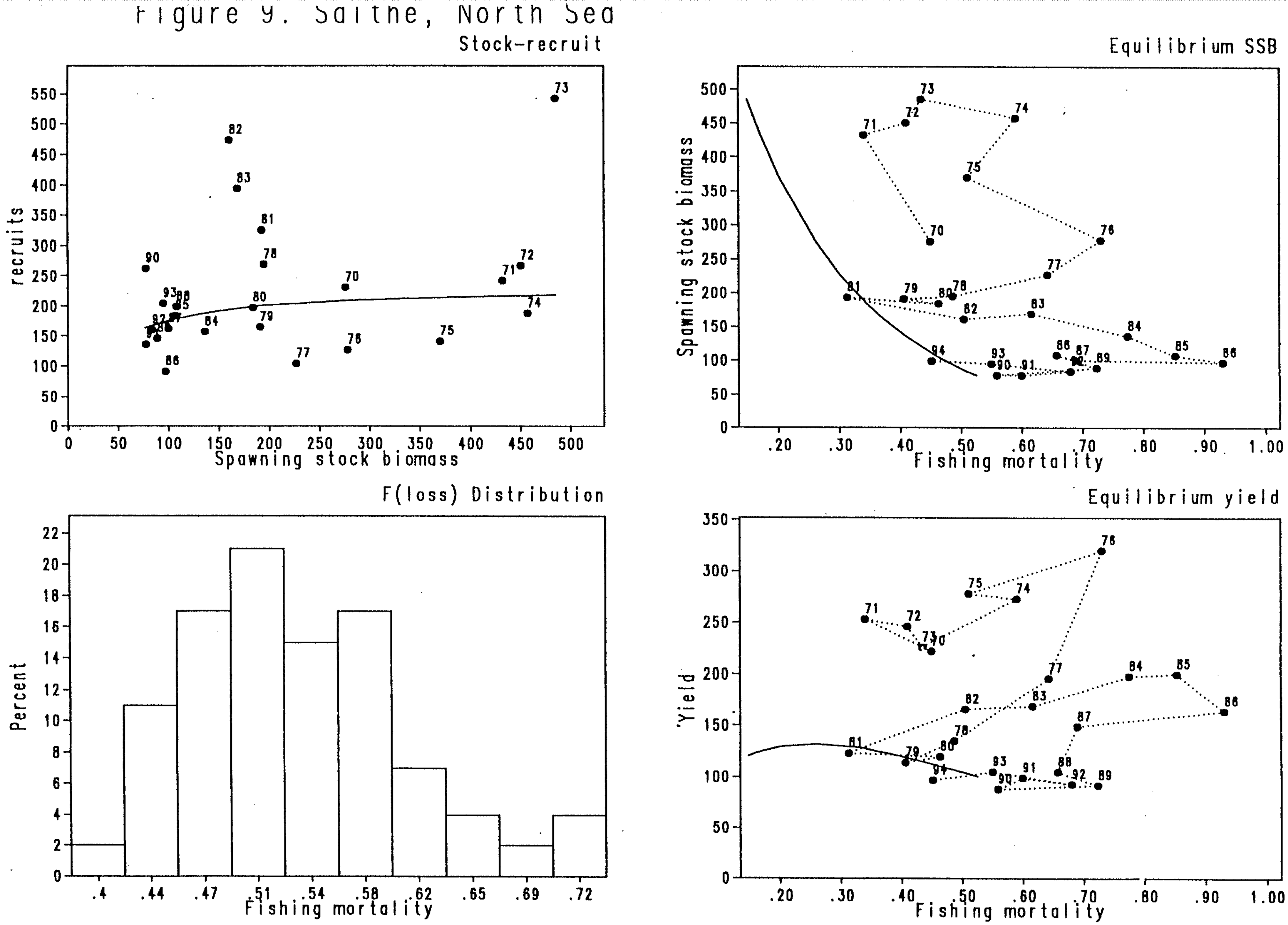

Figure 9. North Sea cod. The panels in clockwise direction show the stock recruitment data with fitted lowess curve, the equilibrium spawning stock biomass, equilibrium yield and the distribution of fishing mortality, which corresponds to F_{loss}. In the case of yield and spawning stock biomass the plotted data points are the annual observations of the quantity estimated by ICES.

Figure 10

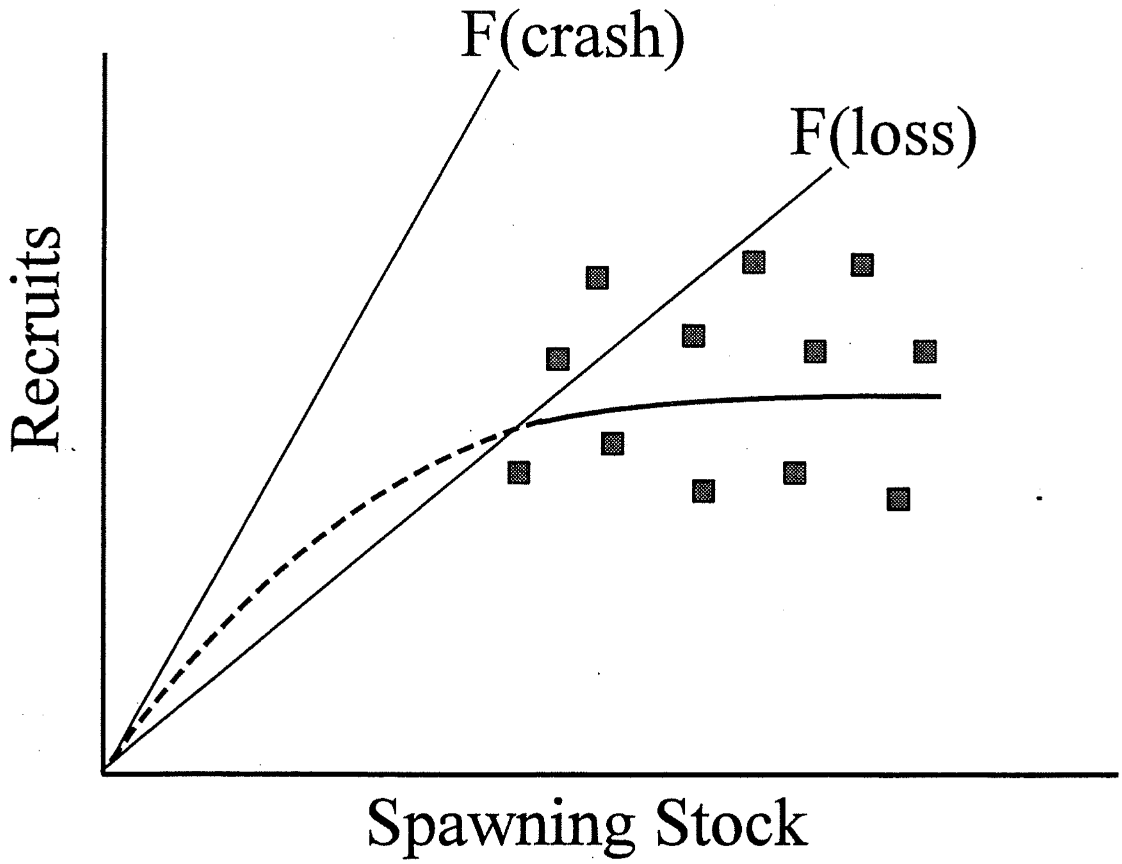

Figure 10. An illustration of a typical stock-recruitment plot where data are variable and insufficient to define the left hand limb of the stock-recruitment curve. F_{crash} is the replacement line at which the stock would collpase. F_{loss} is the replacement line corresponding to the lowest observed spawning stock biomass.

Figure 11. Cod, North Sea

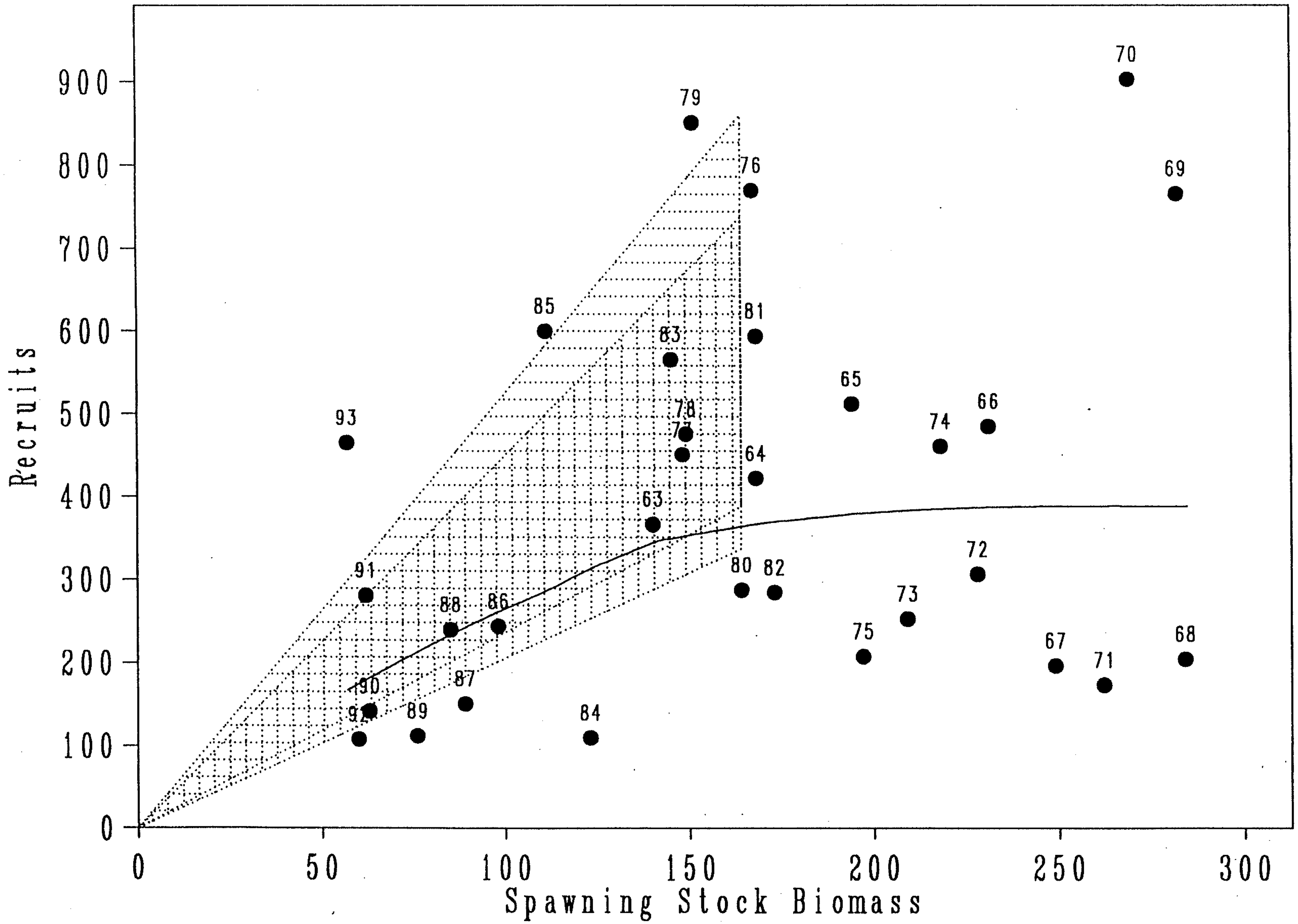

Figure 11. North Sea cod. Stock-recruitment plot showing the 5 and 95 precentiles of F_{loss} (vertical shading) and current fishing mortality rate (horizontal shading).

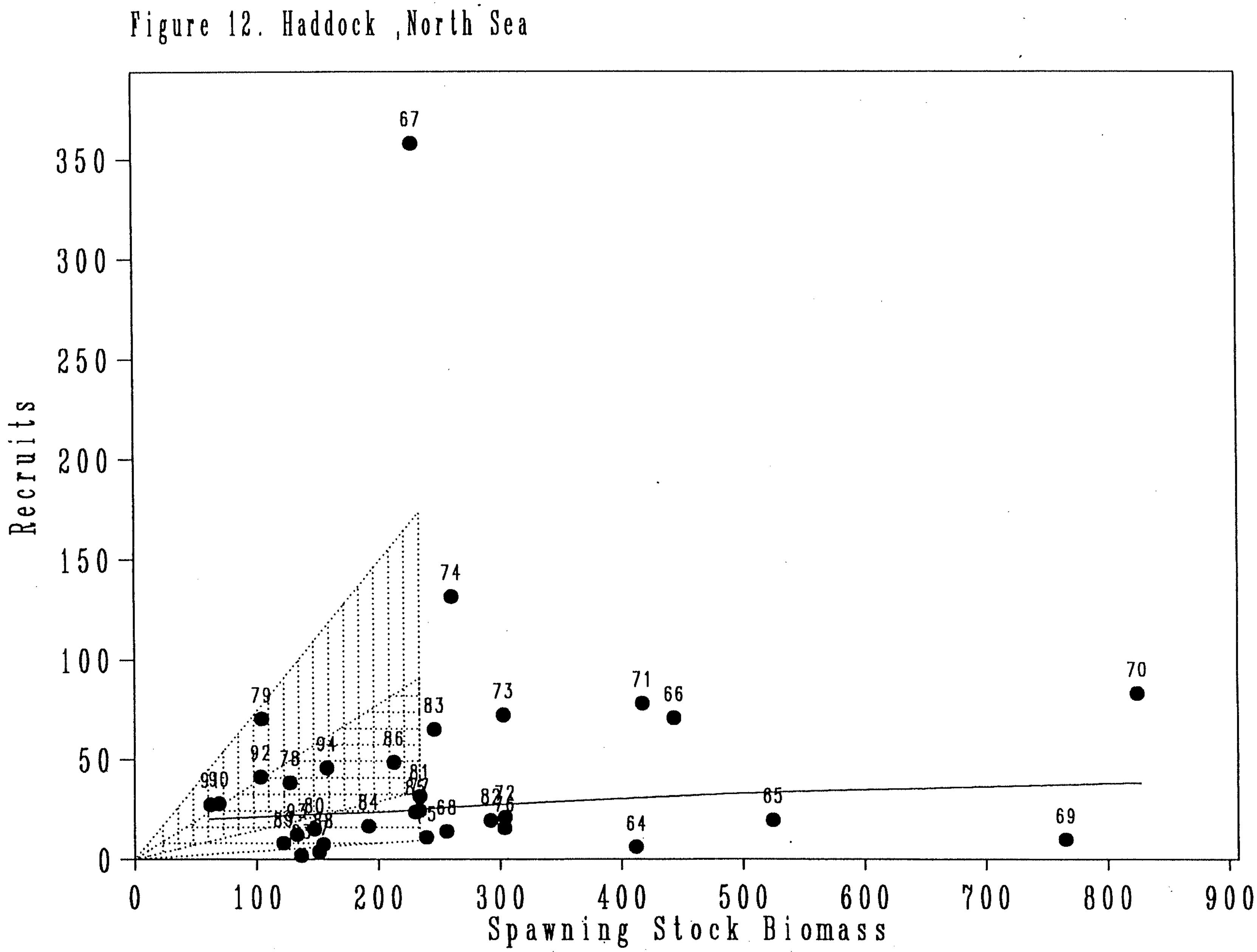

Figure 12. North Sea haddock. Stock-recruitment plot showing the 5 and 95 precentiles of F_{loss} (vertical shading) and current fishing mortality rate (horizontal shading).

Figure 13. Whiting ,North Sea

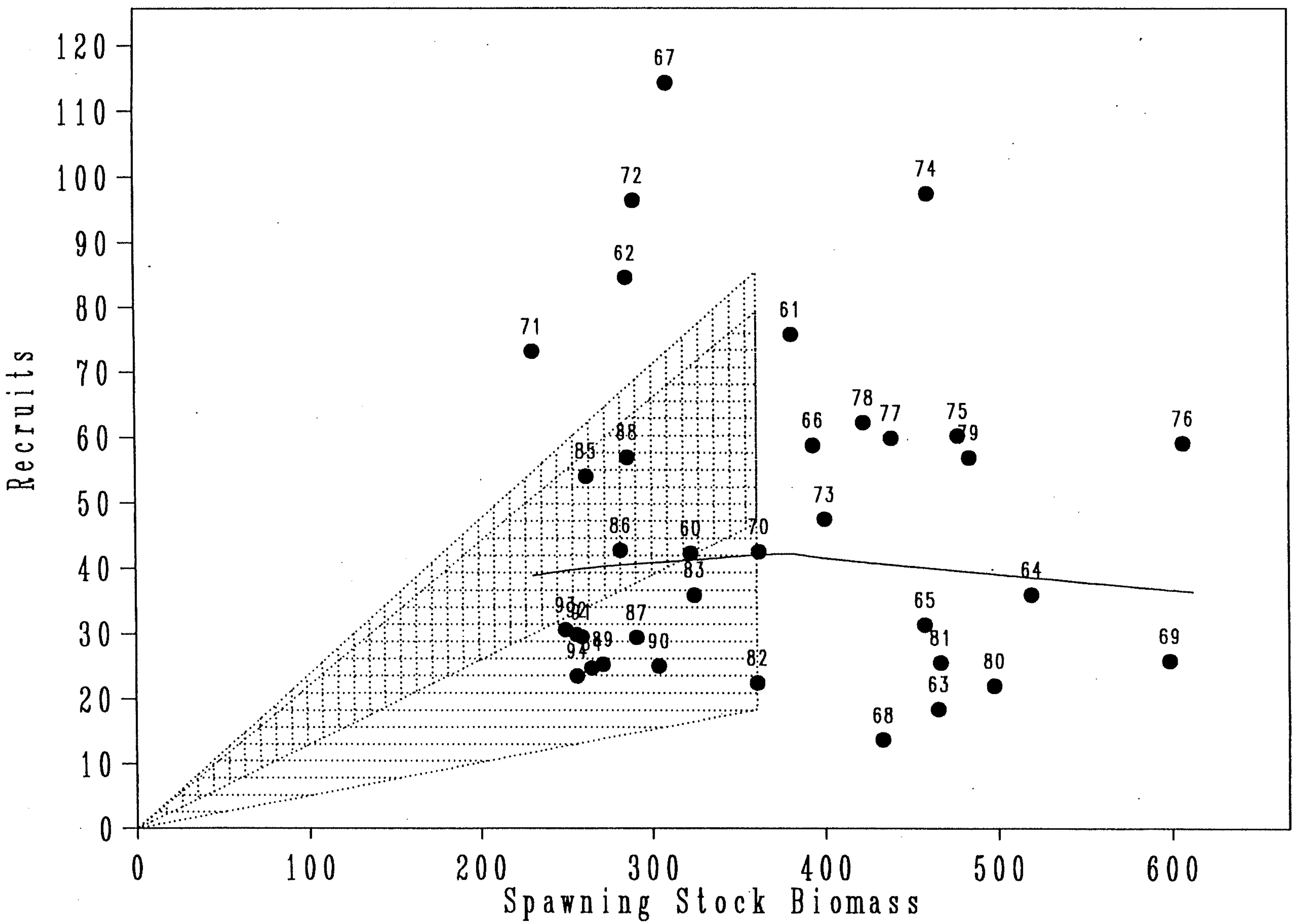

Figure 13. North Sea whiting. Stock-recruitment plot showing the 5 and 95 precentiles of F_{loss} (vertical shading) and current fishing mortality rate (horizontal shading).

Figure 14. Saithe, North Sea

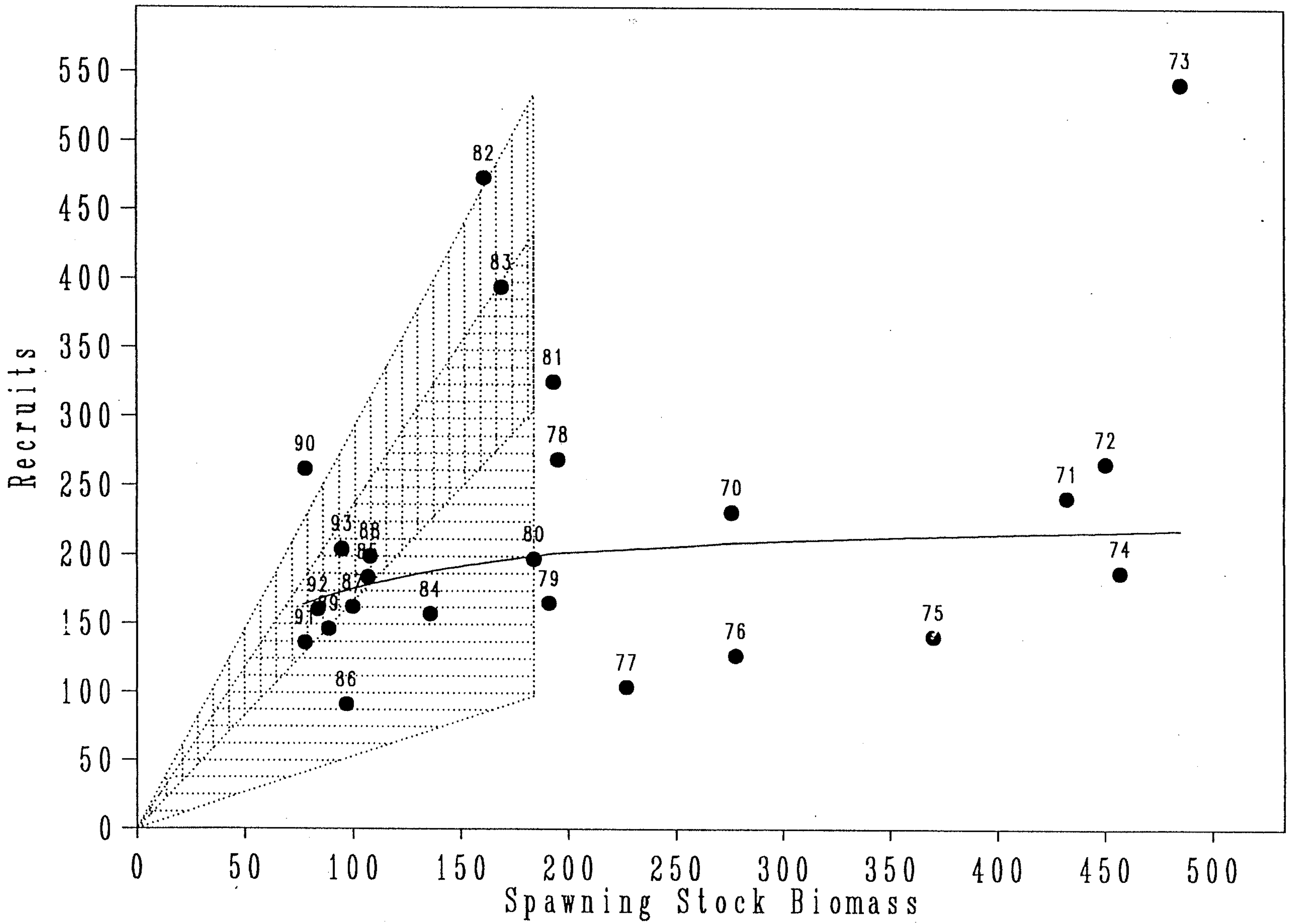

Figure 14. North Sea saithe. Stock-recruitment plot showing the 5 and 95 precentiles of F_{loss} (vertical shading) and current fishing mortality rate (horizontal shading).