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Exploration of the Sea

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REPORT OF THE SAITHE STUDY GROUP

Aberdeen, 30 May - 2 June 1995

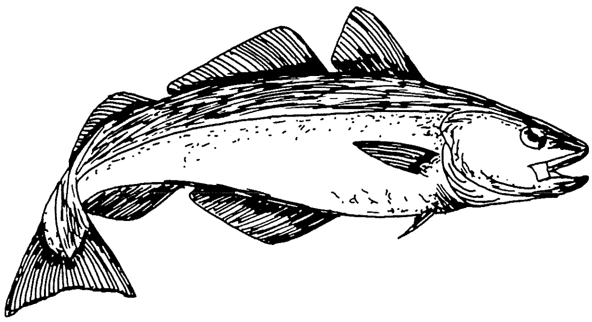

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TABLE OF CONTENTS

1 INTRODUCTION

1.1 Participants

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An address list of participants is given in Appendix A.

1.2 Terms of Reference

It was decided at the 1994 Statutory Meeting, Demersal Fish Committee (C.Res. 1994/2:29) that "a Saithe Study Group will be established under the chairmanship of Dr. K. Nedreaas (Norway) and will meet in Aberdeen, UK from 30 May to 2 June 1995 to:

a) review the information on the distribution and migration of saithe in the ICES area and advise on the need for any changes in stock assessment units;

b) review the assessment methods used for saithe with particular reference to the use of catch-per-unit-effort and recruitment indices;
c) review the experience with research surveys and consider possibilities for improving the collection of fishery-independent assessment data."

1.3 Working Documents

Working Documents were presented on all of the three terms of reference. In addition, information was presented on North-West Atlantic Saithe, which is summarized for comparison here. These, along with other documents available to the meeting, are presented in Appendix B. Compendia of former Assessment Working Group reports for each of the current five stock units were made for the meeting.

2 BASIS FOR CURRENT MANAGEMENT

2.1 Present stock assessment units

At present, there are five different stock assessment units of saithe (*Pollachius virens* (L.)) in the north-east Atlantic.

The origin for splitting the north-east Atlantic saithe into five stocks goes back to the first saithe (or coalfish) Working Group Meetings in 1962 (Anon. 1962, 1965). The Working Group based the separation on knowledge about location of spawning grounds and important fishing areas. The exact borders between the stocks were, however, solely based on the already established ICES Sub-areas and Divisions. Due to the awareness of larval drifts and migration of saithe across these borders, the Saithe Working Group in 1974 (Anon. 1974) also made a VPA combining data for all areas, but apart from this attempt all later ICES Working Groups have assessed the North-East Atlantic saithe as five separate stock units without any account taken of immigration or emigration. These stock assessment units are:

North-East Arctic Saithe in Sub-areas I and II
North Sea Saithe in Sub-areas IV and III
Saithe west of Scotland in Sub-area VI
Faroe Saithe in Division Vb
Icelandic Saithe in Division Va

Landings of saithe have also been reported from Sub-area VII (Celtic Sea, Irish Sea and West of Ireland), varying between 5,000 and 12,000 tonnes during the mid 1980-ies (Anon. 1992, see also Working Doc. no.13). However, almost no saithe were reported in Division VIId (Anon. 1993). The saithe from the Celtic Sea, Irish Sea and West of Ireland have not been included in any stock assessment unit as yet.

For comparison, the North-West Atlantic saithe (or pollock which is the common name of the species in this area) are distributed from southern Labrador, Canada, south to about Cape Hatteras, USA, and are considered as belonging to one stock. Canada manages the resource as a single management unit encompassing the Scotian Shelf and the Bay of Fundy. Saithe are occasionally found on the Grand Banks (NAFO Div. 3Ps) outside the management area. The USA views the management unit as extending from Cape Hatteras to Cape Breton (Nova Scotia).

2.2 Summary of biology for each stock

Typical for all saithe stocks are the inshore nursery grounds. Due to this behaviour, 0-1 year old saithe are not so much exploited compared to other gadoid species which are taken as bycatches and/or discarded at these ages.

In the north-east Atlantic, saithe mainly spawn in January-March in all areas. The size of the spawning stock biomass (SSB) in the period 1970-1994 is shown in Figure 2.1 for each stock assessment unit. The spawning stock at Iceland (Va) has since 1982 been the biggest at around 200,000 tonnes. The figure also shows that both the North-East Arctic and the North

Sea stocks have greater potential than the Icelandic stock. The smallest spawning stock is that west of Scotland (VI) which at present is close to the lowest recorded level (less than 15,000 tonnes).

Catch weight-at-age is shown for age 5 in Figure 2.2 and for mature fish at age 7 in Figure 2.3. Mean weight-at-age 5 has developed similarly for all stocks during the last decade. For age 5 the highest mean weights are observed at Iceland, and the lowest in the North Sea and the North-East Arctic saithe stocks.

In the north-west Atlantic growth is variable by region, with those on the western side of the management unit growing quicker than those to the east.

In some years mean-weight-at-age in one stock unit area is closer to mean-weight-at-age in other areas. This can for example be seen in Figure 2.3 for age 7. Explanations could be density dependent growth which has been suggested for saithe (Olsen 1966, Anon. 1973), environmental (e.g., food availability, hydrographical conditions) or simply the quality of age readings. Nevertheless, sudden changes in mean-weight-at-age in one stock unit area may also indicate migration.

Recruitment at age 3 (as estimated by VPA) has been presented for the different stocks in Figure 2.4. Good or bad recruitment does not affect all stocks simultaneously. Also the extent of recruitment variability is different from one stock to another. The North-East Arctic and the North Sea saithe stocks show the greatest recruitment, although very variable. In Sub-areas II, IV and VI the saithe yearclasses have already as 2 year olds been somewhat reduced due to purse-seine fishing, and the recruitment capability of the stocks are therefore not fully comparable when measured at age 3. This was taken into account when running a multilinear regression analysis with yearclass strength in one stock unit area as the dependent variable and the strength of the same yearclass in the other areas as independent variables. The results are shown in Table 2.1. Strong and weak yearclasses were, with significance, observed occurring at the same time for the North Sea (IV) and the west of Scotland saithe (VI) ($p < 0.001$), and for the Faroes (Vb) and Icelandic (Va) saithe stocks ($p < 0.01$).

Maturity ogives used in the most recent assessment are shown for each stock in Figure 2.5. Ogives are not available for the North-East Arctic and the west of Scotland saithe where knife-edged maturity at age 6 and 5, respectively, have been used. From the available maturity-ogives we see that the saithe belonging to the North Sea mature earlier than the saithe at the Faroes which again mature earlier than Icelandic saithe.

In the north-west Atlantic maturity is achieved, on average, at a length of approximately 45 cm for females. For assessment purposes a knife-edged maturity at age 5 is used.

Figure 2.6 shows the most recent estimates of the biological reference points Fmed and Fmax for the five ICES stock assessment units. Different fishing patterns and mean-weight-at-age are reasons for higher Fmax than Fmed at the Faroes and Iceland.

2.3 The Fishery

Total international landings in all stock unit areas together are presented in Figure 2.7, and for each stock unit area in Figure 2.8. Very big catches were landed in 1969-1976, especially from Sub-areas II and IV. As a result of the introduction of national EEZs and regulation of the industrial fishery in the North Sea, the catches decreased in 1977.

The fishery in the north-east Atlantic is conducted by purse-seiners on the youngest age groups (only along the Norwegian coast in Sub-areas I-IV); by trawlers of various size, handliners and Danish seiners on the whole age range from juvenile to mature and spawning saithe; and by gillnetters almost solely on mature and spawning saithe.

Current fishing pattern, illustrated by the fishing mortality at age used as input to the most recent predictions, is shown for each stock unit in Figure 2.9. Fishing mortality at the reference age is shown for each stock from 1983 and onwards in Figure 2.10.

The fishery in the north-west Atlantic is prosecuted by trawlers of various sizes and fixed gear, principally gillnets, handlines and also longlines. The contribution of larger trawlers to total landings has diminished considerably compared with the 1970's and early 1980's. Total landings decreased to 15,250 tonnes in 1994 (Figure 2.11).

3 DISTRIBUTION, MIGRATION AND STOCK UNITS

3.1 Overview of the distribution and migration of saithe in the North Atlantic

During most of their life, saithe in the north-east Atlantic live on the shelves and continental slopes in depths between 80 and 450 m. They are found in the ICES areas IIa, Va and Vb, IIIa, IVa and northern part of IVb, VI and VII (Figure 3.1). Another stock of saithe (pollock) is found off the coasts of Canada and the USA.

Occasionally, especially in summer, a few saithe can be found in the waters south of Bear Island (IIb), the eastern part of the Barents Sea (I) and in the waters of East Greenland (XIVb).

In some years saithe migrate into the western Baltic Sea (IIIb/c) (Weber and Reinsch 1992) and into the German Bight (IVb). Larvae and young saithe up to age 3 or 4 are living in coastal and inshore waters of Norway, Scotland, Iceland and Faroe Islands. From there, they migrate into the open sea (Fig.3.2)

Spawning grounds are situated along the 200 m depth contour off south-west Iceland, north-east of the Faroe Islands, on Swinøy- and Haltenbank and also south-west of the Lofoten in Norwegian waters. Other spawning grounds can be found in the waters north of the Hebrides and following the 200 m depth line to Shetland Islands and eastwards along the northern border of the North Sea to "Tampen" on the west side of the Skagerrak Deep (Fig.3.3). Spawning takes place between January and March. Migrations between spawning and feeding grounds are shown in Fig. 3.4.

In the north-west Atlantic, pollock spawn in November through March, with concentrations of eggs found off South-West Nova Scotia and the Central Scotian Shelf. Similar to the eastern Atlantic, saithe are found inshore for the first years of their life. They then undertake migrations to offshore banks. These migrations sometimes are rather lengthy.

Tagging experiments by various countries showed that exchange between all saithe stock components in the north-east Atlantic takes place to a variable extent. However, the rate of intermixing between the stocks is not quantified due to limited effort data available (Table 3.1). The Norwegian tagging experiments are reviewed in Working Doc. no. 1 by T. Jakobsen, the German taggings by Reinsch (1976), the Icelandic / English taggings by Jones and Jónsson (1971), the Scottish by Newton (1984) and Hall *et al.* (Working Doc. no. 6), the Faroese in Working Doc. no. 2 by Á. Nicolajsen and the few French taggings of saithe are reported by Fontaine *et al.* (1985). English taggings have been performed in most years in the period 1957-80. The major part of these taggings (in number of saithe tagged) are reported and analysed by Jones and Jónsson (1971).

3.2 Methods of separating stocks and quantifying migration

3.2.1 Stock discrimination techniques

A wide range of established and recently-developed techniques (involving different scientific disciplines) are available for discriminating and differentiating fish stocks. The following are potentially useful tools for the study of geographic variation in saithe.

3.2.1.1 Morphometrics and meristics

The use of morphometrics and meristics to study geographic variation in fish populations is well established. Numerous fin-fish body parts are suitable for measuring or counting in this type of study (eg. fin rays, gill rakers, otoliths, vertebrae and other bones). This approach to identifying stocks is very laborious and slow and is rarely attempted on a large scale.
Scale and otolith measurements are probably the most commonly used characteristics in this group; the theory being that there are natural variations in seasonal growth between stocks and that this is reflected in the scales and otoliths of fish from different areas. Otolith morphometrics in particular, have been used recently in stock discrimination exercises for several commercially important species.

Currently, there are no documented studies of saithe stocks involving analyses of morphometric/meristic characters. Given the known distribution and movements of saithe in the northern Atlantic (see section 3.1), it is unlikely that small, restricted studies of this nature would be very useful.

3.2.1.2 Chemical composition of otoliths

Research is currently being conducted worldwide to investigate whether natural variation in minor and trace elements in teleost otoliths can be used for stock and population discrimination (ref. International Symposium on Fish Otolith Research and Application, South Carolina, USA, 1993). Elemental analyses may also be used to determine the past temperature history and migratory history of the fish. Different decay rates of natural occurring radionucleids in otoliths may also be taken advantage of in stock discrimination and age validation. By other words, the otolith is like a "flight recorder". The analyses are, however, rather laborious and expensive.

3.2.1.3 Genetics

The genetic affinity between and within fish populations, giving some measure of stock mixing and relatedness, can be assessed in a number of ways, including; 1) genetic analysis of isozyme polymorphism (enzyme electrophoresis and histological techniques), and 2) polymerase chain reaction (PCR) sequencing of the nuclear and mitochondrial DNA (nu/mtDNA) genes.

Electrophoretic separation and histochemical staining of structural proteins and enzymes provide the simplest method of analysing the gene products of an individual, and is described for saithe a.o. in Child (1988). These techniques have been used, with varying degrees of success, to discriminate fish stocks.

A small amount of work has been done on saithe. Møller and Nævdal (1973) compared the blood proteins (serum transferrins) of saithe from Icelandic and Norwegian waters and found clear within-area variation but little between-area variation in the distributions of phenotypes. In 1985, 50 saithe from Trondheimsfjord in mid-Norway, 50 saithe from Tromsø in northern Norway, and 23 saithe from Reykjavik (Iceland) were analysed for 6 enzymes. Two enzymes (LDH and PGM) were found to be polymorphic, but no significant differences between the areas were detected in this small sample (prof. Jarle Mork, Biological Station, Trondheim, Norway, pers. comm.). In a similar genetic study comparing skeletal muscle samples of saithe from the northern North Sea and west of Scotland and Ireland (including Rockall), Child (1988) concluded that "It appears from the results of the genetic analysis of saithe that this species is homogeneous. The motivation for this study originated in a request to discover if there was any genetic method which would separate the saithe caught in EC and Norwegian territorial waters. Fish do not respect political boundaries and the major North Sea spawning area appears to enclose the international limit of EC and Norwegian waters. Saithe are known to undergo considerable migrations and the lack of variation between saithe from Rockall Bank and the North Sea may reflect this behaviour" (Child, 1988).

Child's findings, if valid, certainly throw into question the justification for conducting large-scale biochemical-genetic research on saithe 'stocks', at least in the northeastern Atlantic. However, since these three limited studies represent the sum of such work done to date, more investigation is required for; 1) to validate previous results by repetition, and 2) to test other genetic-biochemical techniques (of different sensitivities) on saithe stocks (e.g., nuclear or mitochondrial DNA), and assess if the results are in agreement.

3.2.1.4 Tagging and marking experiments

Studies involving fish marking or tagging and subsequent recovery by commercial fisheries have been widely used for many years as a means of elucidating the migration routes of fish and thereby interpretating the stock structure. The most valuable approach from this point of view is to tag fish in spawning condition so that the pattern of recoveries will provide information on the extent of homing to the same spawning area in subsequent years.

Unfortunately, fish in spawning condition are particularly susceptible to handling damage during first capture. This is particularly true for large saithe, which are very difficult to recover in good condition due to their (deep-water) spawning habits. For these reasons previous tagging studies of saithe have targeted smaller, immature fish (as described in sections 3.1 and 3.4). Remote (*in situ*) tagging techniques for deep-water species, involving ingestible transmitters concealed in bait (fish identified by photography) have recently been developed (see Priede *et al.* 1991). These may be of potential value to qualitative research. However, unless new economical 'fish friendly' remote tagging techniques for larger quantitative studies of spawning adults are developed, it is unlikely that tagging will be a useful tool for stock separation of saithe by reproductive patterns.

3.2.1.5 Parasitological studies

Distributions of fish species infested with certain parasites have been used to describe stocks. This method is particularly useful in a situation where an adult stock is receiving recruits from several widely separated nursery areas, each carrying different levels of parasitic infection. Although no work of this kind has been done on saithe, the feasibility of a parasitological study of this species, for stock discrimination purposes, warrants investigation and serious consideration. Some preliminary screening of the total parasite fauna in young saithe have been done in a fjord in western Norway, and altogether 39 different parasite species were detected (Frank Nilsen and Kjartan Hodneland, thesis, University of Bergen, Norway).

3.2.1.6 Growth and recruitment patterns

Differences in growth rates have also been considered as evidence of mixing and origin of different fish populations. Detailed analyses of length-frequency distributions of several demersal species (including saithe), for example, have detected distinctly bimodal patterns which cannot easily be explained in any other way. In Norwegian waters there are often large differences in weights-at-age between saithe from certain localities, due to different growth rates and feeding regimes. Furthermore, sudden changes in mean-weight-at-age in one stock unit area may indicate migration (see Figures 2.2 and 2.3).

Another area of interest (still to be properly developed and evaluated) involves the comparison of recruitment trends of different assessed fish stocks in order to examine possible linkage and hence possible strength of mixing between stocks. A crude comparison of saithe recruitment trends, (see correlation matrix in Table 2.1), suggests that some stocks, for example IV/IIIa and VI, Va and Vb, are closely linked, whilst others are not. It is not possible at present, to quantify any results from these analyses, but nonetheless, it may be a useful tool in future, particularly if used in conjunction with other types of study of stock interactions (compare Tables 2.1 and 3.1).

3.2.1.7 Catch-at-age data

Catch at age data can be used to analyse migration between areas. In a preliminary study (Working Doc. no. 4) comparative assessments between two saithe stocks (IV/IIIa and VI) have been made by running a VPA for each stock separately and combined. Recruitment and SSB are compared using regression analysis and results from retrospective VPA can be compared for each stock and the combined stock. This area of study is also of potential value in determining stock-structure. Catch at age data can also be analysed for migration by following the catch at age of a yearclass. Schopka (1993) has done this for several yearclasses of Icelandic Cod. When analysing migration it can be very useful to compare the catch at age for the same yearclass in two areas. Haddock from the Canadian side and the American side of George's Bank has been analysed using this method (John Neilson, pers.comm.).

3.2.2 Analysing saithe migration.

When studying migration between fish stocks, it is important to have all available information about each fish stock at hand. These data include:
landings, catch as number at age, length at age, maturity at age, weight at age, tuning data and tagging information for each fish stock.

This data should be analysed to form an overall picture of the migration:

- Assessments (tuning and VPA) should be re-run, focusing on problems that can be related to migration.

- A combined assessment should be made and the results from it should be compared with the results from each individual assessment.

- Growth parameters such as length at age, weight at age and maturity at age should be analysed and compared stock by stock.

- Landings, SSB and recruitment should be compared between stocks.
- Catch at age data for each stock should be analysed and compared between stocks.

- Yearclass specific comparisons of growth data, catch at age data, and tuning data should be made if these are available.

The overall picture may be summarized as in Table 3.1. Hopefully the analysis can indicate whether the migration is systematic with respect to age or spawning or if it is completely random. Perhaps the analysis also can point to specific yearclasses that have migrated and the time of migration. It is doubtful that the analysis can tell anything about the magnitude of a migration unless we have good tagging and CPUE data for all fish stocks. One should also seek to find biological or environmental explanations for the migrations, like changes in water temperatures or changes in food resources. The treatment of tagging-results and how migration rates are computed is a subject of its own and is discussed elsewhere. Working Docs. nos. 3 and 6 deal with this subject.

3.2.2.1 How to incorporate migrations in stock assessments.

Depending on the extent of the migrations one may consider to take this into account when making an assessment. Some assessment methods have been proposed that are capable of dealing with immigrations. TSA, which will be included in the ICES assessment package, is said to be able to deal with migrations. In one method described by Stefansson (1988, 1992), the number of immigrants which minimizes the C.V. of the VPA tuning procedure can be added in the beginning of the immigrating year. Ulltang (1977) treats the problem of migration and its consequences to a VPA, and Jakobsen (1981) assessed the North-East Arctic and the North Sea stocks of saithe taking migrations into account. This was further elaborated by the Saithe Working Group in 1983 (Anon. 1983).

3.2.2.2 Usefullness of modelling

Until now not much work on modelling migrations has been performed. One reason for this may be that the models can be rather complex if they are to be realistic, and therefore also be difficult to implement. A model described in terms of differential equations for example is hard to implement in a spreadsheet. There is one area, however, where modelling has been applied extensively, namely the North Sea Multispecies model. But in this model migration is only an ingredient and is not dealt with in isolation. In a simulation model it is possible to control the migrations and this can be very useful when studying its effect on other stock parameters. Modelling and simulation is about the only way a migration indicator can be tested but any model has to be designed with some specific problem in mind. Working Doc. no. 3 presents a model of a system of N fish stocks between which migration takes place. The simulation model is used to test a migration indicator based on the catch at age of the same yearclass in different areas. It would be beneficial to include effort, or better fleet differentiated effort, in future modelling work. This would make it possible to describe the effect of different fleets operating in an area during the year.

3.3 Implications of changing stock units

As explained in section 2.1, the Saithe Working Group in 1962 established 5 stock assessment units according to spawning and fishing grounds, however, exact borders were set related to ICES areas. As exchange between these stock assessment units is known to occur the question is raised whether to redefine stock boundaries. Changing stock assessment units has both biological and management related implications.

Biological implications

The existing biological knowledge is too limited to allow for any definite conclusions about north-east Atlantic saithe stock identities and delimitations. For instance there is insufficient information on recruitment from the different spawning areas. Furthermore, various tagging experiments have not been co-ordinated and do not give a definite and overall picture of distribution and migration patterns.

Regarding the stock components in Subareas IV, VI and VII there exists mutually separated spawning areas in VIIj, VIb, and VIa / IVa. These spawning areas are believed to be separated by depth.

There seems not to be a direct connection, through the English Channel, between the saithe stock component in Subarea VII and IV as saithe is nearly absent in the southern North Sea. Therefore, if saithe in Subarea VII do not constitute a separate stock it must be related to the stock component in Subarea VI. Besides landing figures, no biological information on saithe in Subarea VII is available. Saithe in Subarea VII has not been dealt with in a Working Group context and it has never been assessed. Despite extensive tagging programs in other areas practically no recaptures have been reported from Subarea VII. Without biological information it is not possible to conclude anything about the identity of saithe in this area, and initiation of coordinated, systematic sampling from the saithe fisheries are therefore recommended in order to obtain further knowledge regarding stock parameters, effort data and catch rates.

Present biological knowledge shows no evidence that saithe in Divisions IVa and VIa belong to separate stock units. There seems to be a similar recruitment pattern (Table 2.1) and the spawning areas in these Divisions are not separated. Regarding recruitment, it is likely that some of the juveniles originating from the spawning grounds in Division VIa recruit to Division IVa since recruits are found along all of the Scottish north coast.

When combining present stock assessment units the existing tuning data time series will only cover part of the new combined stock assessment unit. Another assessment problem here is that potential recruitment differences between stock components within a combined stock assessment unit will be hidden. Furthermore, if two different sized stock components are combined the smaller stock component might suffer due to potential reallocation of effort.

In general, samplings from all stocks should be intensified to obtain more precise estimates of migration and stock delimitations. If using catch at age data to identify migration rates, the sampling of catch at age should be extended and detailed information on fishing fleets and gears is required. Attempts should be made to take account of migration between stocks .

Management implications

Regarding changes in stock units, the management implications should be considered. One should question whether migration between the different saithe stock units creates management problems related to the present managed units, and do we actually gain anything by joining the existing stock assessment units? There is no evidence that any stock assessments suffer under the present management regime.

Changes in stock assessment units would require international cooperation to control the fisheries in the new units. Further, it will be necessary to address the problem of how to reallocate catch in a TAC-system or a fleet-based system related to historical catches, and this may prove difficult as the historical basis for catch allocation is not clear. On the other hand the disadvantages of misreportings between the existing areas could be eliminated by combining stock assessment areas.

3.4 Need for international tagging experiments

The extensive tagging experiments on saithe by Norway, Germany, Faroe Islands, Iceland, England, Scotland and France have not been co-ordinated. An extensive international tagging program with taggings performed simultaneously in different areas (addressing different stock components) would contribute more information on the actual biological stock delimitations. However, before implementing such a resource demanding standardized programme, both the benefit in biological knowledge about the saithe stock units and the benefits for improving management of the stock components should be considered. To elucidate what results such a programme will produce and in what scale the program should be set up, preliminary modelling and sensitivity analyses of variation in stock assessment parameters and thus estimates of stock sizes related to implications of different migration rates between different stock units are recommended. If such a tagging experiment is set up the results will form the basis for modelling migration between stocks. An useful and good quality model of movements between stocks would then request information from a co-ordinated and standardized tagging program.

The following should be taken into consideration:

1) The information one wants to obtain from such a tagging experiment should be clearly described and stated.

For example which stock components and life stages (length groups) should be addressed? Pre- or post-spawning migration? There seems to be a need for tagging of large saithe during spawning to detect post-spawning migrations. Should the program detect both migration routes and migration rates? There seems to be need for knowledge about migration rates for quantifying the impact of migration on stock sizes.

2) Design and standardisation of tagging program (experiments):

The duration of the tagging experiment has to be considered in relation to the results of earlier tagging experiments from which it has been concluded that the magnitude and direction of mixing varies considerably from year to year over a period of years.

The extension/delimitation of geographical area and tagging localities should be exactly defined in relation to the stocks being investigated. Further, the optimal season for tagging of different life stages in different localities should be considered bearing in mind the results of earlier tagging experiments.

The choise of tag type (external, internal, electronic) should reflect the purpose of the tagging experiment in respect of the type of information that is requested. The usefulness of electronic tags giving information about depth and hydrography in a saithe tagging program should in that respect be considered.

The gear used to catch large saithe to be tagged should be considered as large size groups are distributed at considerable depths (~200 m). Experience from previous studies show high immediate mortality on large saithe when caught in bottom trawls fished at great depths. Pressure changes and gear effects are believed to cause mortality and should be minimized if using a bottom trawl. Use of long lines or similar gear with bait is worth considering as saithe is known to eat during the spawning period (T. Jakobsen, pers. comm., Toresen 1991).

When designing the tagging experiments potential recapture should also be taken into account. Based on earlier work it is possible to identify the fleets and types of vessels that are most likely to have most frequent recaptures. To calculate migration rates based on tagging experiments it is necessary to have precise effort estimates from fleets concerned. Related to the different recapture fleets and to the use of effort data the degree of standardisation of the tagging experiments and monitoring should be considered.

Further, the necessary order of magnitude of the tagging experiment , i.e. how many fish of a given size group should be tagged, has to be decided to satisfy the purposes of the tagging experiments and to give significant answer.

4 ASSESSMENT OF SAITHE STOCKS

4.1 Assessment methods

The working groups (Arctic Fisheries WG, Demersal stocks in North Sea WG, Northern Shelf WG, and North-Western WG) assessing the saithe stocks in the north-east Atlantic have for the last 2-3 decades used the analytical approach, *i.e.* VPA or Cohort Analysis.

In the last decade or so tuning methods have been developed for estimating the level of fishing mortality for the last year and terminal ages. These calculations are based on the time series of effort or CPUE data from commercial or research vessels.

In the last couple of years the new methods of Extended Survivors Analysis (XSA) (Darby and Flatman 1994) and Time Series Analysis (TSA) (Gudmundsson 1984) have been introduced. The resulting terminal F-values from these tuning calculations are used to determine the population numbers and exploitation pattern. From information on mean weight at age and proportion mature at age the total stock and spawning stock biomass is calculated.

Short- and long-term predictions of population size and catches are based on assumptions on development of population parameters such as recruitment, mean weight at age, proportion mature at age and exploitation pattern. In recent years RISK analysis have been applied for medium term prediction where an additional assumption of spawning stock biomass-recruitment relationship has to be formulated.

Calculation of Effort and CPUE

Table 4.1 describes the CPUE and effort series used in the tuning of saithe assessments, the duration of the series and the ages employed. The series and their derivations are given below:

Faroes (FAR)	'Cuba' trawlers	The effort from 8 pair trawlers (> 1000 HP) . Numbers of days fishing along with catch in numbers from the same fleet.
Iceland (ICE)	Trawler CPUE, Jan-May Trawler CPUE, Jun-Dec	Individual tows from trawler logbooks where the catch contains over 70% saithe. The two series are age-disaggregated separately based on otolith samples taken from trawlers in the same period..
	Trawler-effort	Calculated by dividing trawler landings with the annual CPUE (=> 70% saithe).
North East Arctic (NEA)	Norway purse seiners - effort	Number of vessels of 20-24.9 m, raised by total purse seine catches
	Norway trawl - effort	Trawlers where individual hauls with more than 50% saithe and only trips with more than 50% saithe in landings. The effort was raised by total trawler catches.
	Norway Acoustic survey	Annual acoustic trawl survey in October-November along the Norwegian Coast.
North Sea (NOS)	French Trawler	Used hours fished according to logbooks along with catch in numbers from the same fleet
	Norway Trawler	As above

West of Scotland (WOS)	Scottish Seiner	As above
	Scottish Light Trawler	As above
	Scottish Nephrops Trawler	As above
	French Trawlers	As above

Other settings and input to the XSA before running the program are given in Table 4.2.

4.2 Input Data

Landings

The landings data used in the most recent assessments are summarized by stock below:

	SA I and II (North-East Arctic)	**SA IV and Div. IIIA (North Sea)**	**Div. Va (Icelandic)**	**Div. Vb (Faroese)**	**SA VI (west of Scotland)**
Years available	1960-1993	1970-1993	1960-1994	1960-1994	1963-1993

Working group estimates of total landings often differed from landings as reported to ICES, but only by a few percent. The largest discrepancies were noted for the West of Scotland stock in the mid-1980s, when the difference between official landings statistics and those used in the assessment was sometimes between 10 and 20%. In this area there are still problems with official reportings from some countries.

Catch at Age

For the North-East Arctic, the recent catch at age was constructed using data from Germany and Norway, which accounted for 98% of the landings. The age composition from the landings by Germany was applied to the landings of the other countries participating in the fishery.

For the North Sea stock, catch at age information is contributed by Denmark, Germany, France, Norway, UK (England) and UK (Scotland), and accounts for 96% of the landings.

For the Icelandic stock, the catch at age was constructed using Icelandic sampling and age information only, but Icelandic landings were 98% of the total in 1994. Similarly, the Faroese catch at age matrix was determined from Faroese samples only, but the Faroese fishery was also 98% of the total landings.

For the west of Scotland stock, age composition data for 1993 were supplied by France, Germany, and UK (Scotland) accounting for more than 90% of the total landings.

Although biological samples are provided by the countries responsible for most of the total landings, the Study Group felt that the quality of these samples has not been evaluated.

Weight at Age
For the North-East Arctic and Icelandic stocks, constant sets of weight at age data are used from 1960-1979. For subsequent years, annual estimates of weight at age in the catches were determined. Weights at age in the landings are assumed to be equal to the weight at age in the stock.

For North Sea saithe, annual estimates of mean weight at age are provided for 1970 and onwards. Weights at age in the landings are assumed to be equal to the weight at age in the stock.

In the case of the Faroese stock, year-specific weight at age data in the landings are available from 1960 onwards, and were also taken to represent stock mean weights.

For the West of Scotland stock, mean weights at age in the landings are available from 1963 onwards, and were also taken to represent stock mean weights.

Maturity Information
The available maturity information varies by management unit, and is summarized below (see also Figure 2.5):

SA I and II (North-East Arctic)	**SA IV and Div. IIIA (North Sea)**	**Div. Va (Icelandic)**	**Div. Vb (Faroese)**	**SA VI (west of Scotland)**
No maturity ogive available, assumed knifed-edged at age 6. Recent information suggests maturity may occur earlier	Age 1 - .000 Age 2 - .000 Age 3 - .000 Age 4 - .150 Age 5 - .700 Age 6 - .900 Age 7 - 1.000	Year-specific maturity ogives are available for 1980-1994. Prior to 1980, published values were used.	Year-specific information is available from 1983 to 1994. For 1960-1982, averages from 1983 to 1992 were used.	No maturity ogive available, assumed knifed-edged at age 5.

Natural Mortality
Natural mortality was assumed to be 0.2 and constant for all ages and for all stocks. The Working Group noted that this parameter was at least as difficult to determine for this species as other marine species, and possibly more so, due to its complex life history.

Discarding
Comparatively little information is available on discarding rates. In the English fishery, anecdotal reports indicate that discarding rates are sometimes quite high on the North Sea stock. Scotland has information on discarding rates since 1975 for Divs. IVa and IVb. Scotland also has information on discarding in Div. VIa since 1978. Denmark is planning a comprehensive program of discard sampling starting in 1995 for all species in all North Sea fisheries. This program should continue for two years. More limited sampling has occurred in Danish North Sea fisheries from 1988 to 1994. Discarding is not thought to be a problem in the Norwegian, Faroese and Icelandic fisheries for saithe.

4.3 Recruitment

4.3 1. Recruitment in the assessment

Age of recruitment to the fisheries varies among the saithe stocks and the youngest age used in the VPA for the different stocks reflects this. Age 1 is used in the North Sea and West of Scotland, age 2 in the North-East Arctic, and age 3 at Iceland and Faroe Islands. Fishery-independent recruitment indices are available only for the North Sea where the English and Scottish groundfish surveys and a Norwegian observer programme are used to estimate the two youngest year classes in the VPA.

For Faroe and North-East Arctic saithe VPA estimates of the two youngest year classes were ignored and substituted by average recruitment figures. For Icelandic and west of Scotland saithe, VPA estimates of only the youngest year class were ignored and substituted by average recruitment figures.

When average recruitment is assumed, it will normally result in errors in the predictions of catch and biomass. The text table below shows the contribution of different age groups to catch and SSB in longterm yield and SSB calculations at the current level of exploitation, using the most recent working group inputs (see Appendix C for how these percentages have been estimated).

Contribution (per cent) to catch and spawning stock biomass by age group.

	Stock									
	NEA		NOS		WOS		FAR		ICE	
Age	C	SSB	C	SSB	C	SSB	C	SSB	C	SSB
1	-	-	0	0	0	0	-	-	-	-
2	3	0	4	0	8	0	-	-	-	-
3	14	0	18	0	19	0	2	2	1	2
4	20	0	25	7	29	0	13	10	7	6
5	21	0	18	23	15	35	28	23	16	11
6	20	44	-	-	-	-	23	22	20	18
7	-	-	-	-	-	-	13	15	18	18

The lines indicate upper limit for age groups which, for the TAC year (two years after the last VPA year), cannot be estimated from commercial data and where a long-term average therefore may be the basis for the prediction.

The size of the error which can be expected is dependent mostly on the exploitation pattern, the variation in the recruitment and the current size of the stock. Keeping in mind that recruitment frequently may deviate by 50% or more from average levels, it is conceivable that there will be errors of more than 20% in short-term catch predictions for all the stocks, especially if consecutive strong or poor year classes occur.

Short-term predictions of SSB will not be affected in the two stocks where knife-edge maturity is assumed and in the North Sea. The probability of a large error is higher at Faroe Islands than at Iceland.

4.3.2. Fishery-independent information on the recruitment

No satisfactory method for estimating early recruitment of saithe has been developed. The main reason for this is the near-shore distribution of the early stages which means that traditional survey techniques cannot be applied. Attempts at estimating recruitment from post-larval surveys have failed, probably because the year class strength is not yet established at this stage of life, although the sampling gear used may not have been the optimal one (Working Doc. no. 9). 0-group surveys are not likely to provide reliable estimates of recruitment because a large proportion of the year class already is inshore when such a survey can be conducted. If such a survey is to be conducted in future, further research on the catchability of the sampling gear and its quantitative impact on the results should be better understood in advance.

In Norwegian inshore waters it has been attempted to use shore seine on 0-group saithe. This was stopped mainly because of the large variation in catches caused by the schooling behaviour of the saithe. To use acoustics on saithe in Norwegian inshore waters with a small vessel has been tried, but this was unsuccessful on 0- and 1-group saithe which were not detected in significant numbers (Working Doc. no. 10). To what extent this method can be useful to estimate abundance of 2-year-old saithe is not known. The acoustic surveys conducted in coastal or offshore waters have failed to detect regular occurrences of 0- and 1-group saithe, confirming their preference for near-shore habitats.

The observer programme in western Norway (Working Doc. no. 8) has given some indication of the recruitment, but cannot be considered very reliable. It is possible, however, that more reliable estimates can be obtained by increasing the number of observers and by improving the design of the programme.

The Study Group can suggest only two approaches that have not been attempted for estimating recruitment of saithe. One is the employment of fixed gear in near-shore areas. Fishing with gill nets for small cod have been attempted at Greenland with promising results. For saithe, an alternative to gill-nets could be traps, but these might have to be specially designed to catch the smallest saithe. The other is to use photographic equipment. The technology is available and could easily be tried on a small scale (e.g., Huntsman *et al.* 1982). However, to obtain abundance indices, both fixed gears and cameras may have to be operated over a longer time interval and at many localities.

4.4. Catch per unit of effort data

CPUE data are used in all the saithe assessments. The success of this can be evaluated only by retrospective analysis of the assessment. Some of the diagnostics from the XSA is given in Table 4.3.

Fishing for saithe is partly directed, but often by vessels fishing for other fish at other times. The CPUE data therefore have to be analysed in order to estimate the part of the effort which has been directly for saithe. This has been done for Icelandic and Norwegian trawlers. The basic principle is to sort out the part of the fishery where saithe has dominated the catches, specifying a percentage as limit. Trials show that the directed effort estimated for saithe is robust to changes in this percentage and the procedure appears to be straightforward if the data are sufficiently disaggregated.

Using data from fisheries where saithe is a by-catch can be problematic since very large catches of saithe may occasionally occur because of the schooling behaviour of the species. Such catches can dominate the total saithe catch for the fleet and are unlikely to reflect stock abundance.

In the North-East Arctic, CPUE from purse seiners is used. In some purse seine fisheries there is evidence that catch rates do not reflect stock abundance because the fish tends to be more concentrated as the stock size decreases. For young saithe which is linked to coastal areas there is no indication of such an effect. However, the measure of effort is crude, given as number of boats by size category participating in the fishery and the performance of the tuning data is not satisfactory.

For other gear types, effort data are in general sparse or crude. CPUE data from gill nets are potentially useful in the assessments, but they are highly selective and use of variable mesh size is a problem.

The use of CPUE data is restricted by deficiencies in the data collection systems. In order to efficiently use available effort data, there has to be appropriate samples to apply to the effort and the catches it has accounted for.

4.5 Sampling

Poor sampling of biological data will obviously affect the assessments directly, but may also restrict the use of CPUE data and the possibility of detecting effects of migration from one stock unit area to another.

From the account given in the assessment working group reports it is not possible to evaluate the extent and quality of the sampling of commercial landings. A more detailed overview and evaluation of the sampling in the different areas would be useful. A guideline for this may be the "Report of the Workshop on Sampling Strategies for Age and Maturity" (Anon. 1994).

The weight-at-age data from the catches appears to be reasonably consistent for the younger fish, but for older fish the data contain some noise. These weights are also used for the stock. For fully recruited fish the difference between observed catch weights and true stock weights is probably not very large, provided that the former are reliably estimated. For the youngest fish the stock weights are in all likelihood lower than the catch weights. The available data should be examined to see if there is a potential for estimating stock weights from other sources.

In the North-East Arctic and West of Scotland knife-edge maturity is assumed. There may be a basis for estimating a maturity ogive for the North-East Arctic stock from survey data, and possibly also from otoliths. The estimation of reliable maturity ogives is difficult even from survey data, but the validity of the data presented is rarely questioned. An evaluation of the basis for the maturity ogives used for saithe would therefore be useful.

Canada and Norway currently, as a routine, record the onset of first maturity from the otoliths themselves, but lack of verification and the possibility of forecasting maturity has prevented the data from being adopted for assessment purposes. The method has been described for saithe by Reinsch (1968) and for cod by Rollefsen (1932).

Saithe is considered an easy species for age determination, but there is no documentation of this. The Study Group feels that a program of saithe otoliths exchange between the different institutes involved in age reading of saithe would represent a quality control on the age reading results and quickly would reveal if there are problems with the ageing.

5 RESEARCH SURVEYS

5.1 Bottom Trawl Surveys

For many years groundfish survey data have been important in the assessment of many managed fish stocks. Groundfish surveys are conducted in all of the saithe stock management areas but, with one or two exceptions, none is specifically designed for this species.

The Barents Sea survey has been conducted annually during January - March since 1981. Saithe catches are small and are generally only made around the North Norwegian coast. The Saithe data have never been used in the assessment of the North-East Arctic stock.

There has been a groundfish survey around Iceland, during March, each year since 1985. Because of the observed variation in catch rates of saithe no attempt has been made to utilise these data in the Iceland stock assessment.

A survey, during February/March, has been conducted around the Faroe Islands each year since 1983. Survey estimates have been compared with VPA. As a consequence of the poor results, survey data are not used in the assessment of Faroe saithe stocks.

Within the West of Scotland area (VIa), a groundfish survey over the continental shelf has been conducted during February/March since 1981. The target species for this survey are haddock and whiting. Saithe data are considered unreliable and are not used in the stock assessment.

A number of groundfish surveys are conducted in the North Sea. These include the International Young Fish Survey (first quarter since the early 1970's), the English Summer Survey (third quarter since 1977), the Scottish Summer Survey (third quarter since 1982) and more recently the International Bottom Trawl Surveys which, with those surveys mentioned, have combined to cover all of the North Sea in each quarter of the year since 1991. The target species for these surveys have been some or all of the following:- cod, haddock, whiting, Norway pout, herring, sprat, mackerel. The surveys have not generally extended into water deeper than 200m. The surveys have not been used for VPA tuning for saithe but have, more recently, been used to provide recruit estimates (Working Doc. no. 13).

For a number of years, during the late 1980's, a German bottom trawl survey was conducted, targeting spawning concentrations of saithe, along the shelf edge in areas IVa and VIa. This survey gave satisfactory results in as much as it described the spawning area and indicated the relative year class strengths within the spawning stock.

The North-West Atlantic saithe stock is shared between Canada and the USA. Both countries conduct extensive groundfish surveys. Canada's, which is made during June/July, dates back to 1970. Survey data have been and still are used for stock assessment purposes by the USA but Canada abandoned the practise after 1992 due to large variations in catch rates.

Small catches of saithe have regularly been made during English groundfish surveys in the Western Channel and the Celtic Sea (VIIg, VIIh, VIIj). The presence of saithe in these and other westerly areas is supported by commercial landings (Working Doc. no.13).

5.2 Acoustic Surveys

5.2.1 North-East Arctic Saithe

Since 1985 an acoustic survey specially designed for saithe has annually been conducted in October-November by the Institute of Marine Research (IMR) on the Norwegian near coastal banks (Working doc. no. 11). Since 1992 the survey has covered the area from the Varangerfjord close to the Russian border and southwards to 62°N. Because of the schooling behaviour of the saithe, the survey has tried to cover known saithe grounds rather than sailing regular survey tracks (Figure 5.1). Generally, bottom or pelagic trawl catches were used to provide length data. Where this was impracticable, for instance due to rough ground, catches made with handlines were used. In addition, the cruise leaders have kept contact by radio/VHF with fishermen fishing in these difficult areas with handline, longline, gillnet or Danish seine as the survey passed. Their reporting on species composition and size was used in combination with the observations on the research vessel. The results of these cruises were used as input in the tuning of the XSA in 1994, but the first three years of the time series were excluded because the distribution area was poorly covered. Table 5.1 shows the indices for the full period, and Figure 5.2 shows a comparison between the acoustic indices and the VPA for the period 1988 to 1994.

The Norwegian Institute of Fisheries and Aquaculture started in 1992 an acoustic survey along the coast of Norway (Working doc. no. 12). The purpose of the investigation program along the fjords and coastal areas from 62°N to the Russian border, was to evaluate the distribution and stock biomasses of the most common commercial fish species and shrimp (*Pandalus borealis*). In 1992 the area from the Russian border to Senja in Troms county was investigated, from the inner part of the fjords and out to 12 n.miles. In 1993 the area from Senja to the South of Nordland County was investigated, and in 1994 the areas from the South of Nordland County to Møre was investigated. In 1993 and 1994 the survey went from the inner part of the fjords and out to a depth of about 900 m. For each year about 300 pelagic trawl, bottom trawl or handline stations were made. In 1992 the saithe were measured for length and weighed. In addition, in 1993 and 1994, age data were collected.

A total biomass of about 700,000 tonnes of saithe was found in the whole area (Table 5.2). Most of the biomass was found in the offshore areas (about 550.000 tonnes; Table 5.2) where the fish were, on average, larger (older) than those caught in the fjords.

5.2.2 North Sea Saithe

The Institute of Marine Research in Bergen has carried out some acoustic work on saithe in the North Sea. In the period 1985 to 1991 a survey specially designed for saithe was conducted on the spawning grounds. The greatest problem with these surveys was the weather conditions, which influenced both the quality of the acoustic data and the coverage of the distribution area. The results from these surveys were therefore very variable (Figure 5.3).

In the period 1984 to 1986 acoustic investigations were made in summertime specifically for herring and 0-group gadoids. Even though these surveys were designed for other purposes they gave promising results for saithe (Figure 5.3).

During the IBTS quarter 4 survey the Norwegian vessel also did some acoustic work. However, the distance between track lines was 30 nautical miles, and this may have been too great considering the schooling behaviour of the saithe. In addition, the stock size of saithe was very small during the early 1990's. Saithe was therefore seldom observed in quantities, and in areas with small amounts of saithe they were almost impossible to distinguish on the echo recordings. Results are shown in Figure 5.3.

The Norwegian research vessels have now mounted the transducers on a keel that can be lowered down to 3 metres below the hull. This has improved the acoustic data tremendously in bad weather conditions. An acoustic survey in wintertime should therefore give better results than previously. However, stock size is still low, and the problems with registration still exist.

In the North Sea an international acoustic survey for herring has been conducted since 1979. It is questionable that saithe has been sampled adequately during these surveys but there may be some information in the survey data.

5.3 Other gears

From commercial landings it may be seen that saithe has been caught, at times, by almost every type of fishing gear. Two gears that indicate regular catching success are gillnets and longlines and these gears may be considered for survey purposes. The greatest disadvantages are that both gears have to be left for sometime to fish, that both, as fixed gears, cause conflict with mobile gears and that both are selective, the former because of mesh size and the latter because of feeding preferences. However, Icelandic fishermen claim that gillnets provide a more accurate estimate of saithe abundance than do bottom trawls. It is intended to use gillnets during a brief annual closure of the Icelandic spawning saithe fishery to attempt to verify these claims.

Egg and larvae surveys have been used to provide fishery independent assessments of spawning stock biomass (e.g. mackerel). Because of the extensive spawning areas of the North-East Arctic and North Sea saithe stocks this option may not be economically viable but it may be possible to experiment with the stocks with smaller spawning areas. It should be noted that experience with this method is limited and results obtained may be unreliable.

5.4 Possibilities for improving the collection of fishery-independent assessment data.

It is clear from experience that general purpose (or saithe non-specific) groundfish surveys do not provide data suitable for VPA tuning or fishery independent stock assessment. Because of the schooling behaviour of saithe it is unclear how a saithe specific groundfish survey may be designed or what its potential effectiveness would be in satisfying these requirements.

Acoustic surveys show more promise. Two such surveys exist for North-East Arctic saithe, one specially designed for saithe and the other designed for several species. A further coordination of these surveys will be made in the future. This will improve the data, especially for the younger ages.

It may be assumed that any type of survey may benefit from being specifically designed for saithe but it should be remembered that because of the peculiar characteristics of this species that very little useful data may be gathered on other important commercial species from such specialised surveys. In addition, it is widely accepted that, at the very least, a five year time series of survey data is needed to be of any use at all.

6 RECOMMENDATIONS

i) Any VPA assessment is totally dependent on reliable information on catch statistics. National institutes are encouraged to obtain complete information on landings and discarding.

ii) Further attempts should be made to obtain fishery independent recruitment indices.

iii) Working Groups assessing the saithe stocks are asked to evaluate the biological sampling of age, weight and maturity which form the basics in all assessment work.

iv) Institutes should obtain CPUE and age-data covering the entire age range in the assessment. Also maturity ogives are required for all saithe stocks.

v) The Study Group recommends that the problem concerning estimating migration of fish between stock assessment units should be further investigated by the ICES Methods Working Group. Particularly, how migrations influence the assessment, and how eventual future tagging experiments should be designed to provide useful information on this subject.

vi) Future tagging experiments should be internationally coordinated. (Conducting a resource demanding international tagging program will nevertheless be dependent on the conclusions and recommendations coming out of point v).

vii) To improve survey data suitable for saithe stock assessment, research surveys and preferably acoustic surveys, should be specifically designed for saithe because of the peculiar characteristics of this species. A five year time series will then be needed.

viii) An exchange of saithe otoliths should be conducted between laboratories as a quality control of the age reading.

ix) Work using different stock discrimination techniques, e.g., DNA, morphometrics, otoliths, should be promoted.

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APPENDIX A

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APPENDIX B

LIST OF WORKING DOCUMENTS (WD) PRESENTED

Related to Terms of Reference No. 1:

WD no. 1. Jakobsen, T. Review of Norwegian Tagging Experiments on Saithe.

WD no. 2. Nicolajsen, A. A note on the wheres and whens of saithe tagged in the Faroes (Division Vb).

WD no. 3. Grastein, J.M. Migration Modelling.

WD no. 4. Hastie, L.C. Saithe in the North Sea and West of Scotland: Effects of combining assessments.

WD no. 5. Ehrich, S., Ratz, H.-J. and Reinsch, H.-H. Historical trend in the mean length of North Sea saithe, landed by Germany.

WD no. 6. Hall, S.J., Fryer, R., Bell, M., Wright, P.J. and Hislop, J.R.G. Movements of saithe: a re-examination of Scottish tagging experiments.

WD no. 7. Neilson, J. Pollock (Pollachius virens) in NAFO Divs. 4VWX5Zc.

Related to Terms of Reference No. 2:

WD no. 8. Smedstad, O.M. Using observers for estimating saithe recruitment.

WD no. 9. Nedreaas, K.H. and Smedstad, O.M. The inability of the postlarvae/0-group saithe survey to forecast the strength of the yearclasses entering the fishery.

WD no. 10. Aglen, A. Preliminary report on a coastal acoustic survey for young saithe during August 1994.

Related to Terms of Reference No. 3:

WD no. 11. Nedreaas, K.H. Annual acoustic surveys on 2-5 year old North-East Arctic saithe in October.

WD no. 12. Berg, E. Resume of the saithe results from three years of survey in coastal areas.

WD no. 13. Boon, T. English data on landings, CPUE and groundfish survey results.

APPENDIX B (cont'd.)

RELATED DOCUMENTS, AVAILABLE TO THE MEETING

Aglen, A. 1994. Surveying the younger age groups of saithe - experiences from a small scale acoustic survey at the coast of western Finnmark. Pp. xx-xx in Hylen, A. (ed.): Precision and relevance of pre-recruit studies for fishery management related to fish stocks in the Barents Sea. Proceedings of the sixth Russian-Norwegian Symposium, Bergen, 14-17 June 1994. Institute of Marine Research, Bergen, Norway.

Nedreaas, K. 1987. Food and feeding habits of young saithe, *Pollachius virens* (L.), on the coast of western Norway. FiskDir.Skr.Ser.HavUnders., 18: 263-301.

Reinsch, H.-H. 1994. Zur Verbreitung der einzelnen Altersklassen des Kohlers, Pollachius virens (L.), in der nordlichen Nordsee (ICES-Div. IVa). Infn Fischw. 41 (3), 124-135.

Compendia containing an extract of former Assessment Working Group reports for each of the current five stock units. Available at the Institute of Marine Research, Bergen, Norway.

APPENDIX C.

The table below shows as an example of how the values in the text-table in chapter 4.3.1 have been estimated. Exploitation pattern (F), weight-in-catch (W), and maturity ogive have in this example been taken from the input to the yield-per-recruit calculations in the most recent assessment of the North-east Arctic saithe stock. Number at age have been calculated using M=0,2 and the Fs from the exploitation pattern. Some differences in the estimated percentage contribution to the SSB between this example and the table in chapter 4.3.1 are due to the latest age-group being handled as a plus-group in the latter case.

Age	N	F	W	Mat.ogive	C	SSB
2	1,000	0,0561	0,450	0	0,022	0,000
3	0,774	0,2487	0,703	0	0,109	0,000
4	0,494	0,3651	1,103	0	0,152	0,000
5	0,281	0,4539	1,717	0	0,161	0,000
6	0,146	0,6391	2,390	1	0,151	0,349
7	0,063	0,6649	2,893	1	0,081	0,183
8	0,027	0,5606	3,253	1	0,034	0,086
9	0,012	0,4413	4,113	1	0,017	0,051
10	0,007	0,5479	5,467	1	0,014	0,036
11	0,003	0,5479	6,490	1	0,008	0,020
				Σ	0,748	0,725

Example:
Contribution of age 4 to the total catch: C_4 = 100% x 0.152/0.748 = 20.3%

Table 2.1. Comparison of recruitment/yearclass strength between stock unit areas. Input data and results from multilinear regression analyses.

SAITHE in the North Atlantic. Recruitment.

Year-class	I/II age 2	IV/III age 1	Va age 3	Vb age 3	VI age 1
1970	275	231	26	24	34
1971	116	242	25	20	33
1972	204	267	26	17	31
1973	369	542	31	20	33
1974	302	188	22	13	25
1975	177	141	49	8	17
1976	281	127	55	9	18
1977	166	104	28	12	20
1978	352	269	20	33	22
1979	151	165	22	15	31
1980	139	197	34	41	30
1981	118	326	50	26	40
1982	136	474	36	22	41
1983	271	394	76	62	43
1984	207	158	120	50	22
1985	100	185	60	45	29
1986	76	95	33	30	30
1987	82	167	26	22	21
1988	323	203	32	26	22
1989	397	128	21	17	15

Correlation matrix

	I/II age 2	IV/III age 1	Va age 3	Vb age 3	VI age 1
I/II	1.000				
IV/III	0.213ns	1.000			
Va	-0.110ns	0.004ns	1.000		
Vb	-0.089ns	0.208ns	0.617**	1.000	
VI	-0.283ns	0.703***	0.062ns	0.400ns	1.000

ns - not significant
** - P < 0.01
*** - P < 0.001

Table 3.1. Exchange of stock components as shown by different tagging experiments on saithe.

Recapture area	Tagging area IIa	IVa	VI	Vb	Va
IIa	+++	+	+	+	++
IVa	+++	+++	++	++	+
VI	+	+	+++	++	+
Vb	++	+	+	+++	++
Va	+	0	+	+++	+++

Frequency of recapture:

+++	++	+	0
abundant	frequent	rare	none

Table 4.1 Tuning series used for saithe stocks in the Nort East Atlantic.

Stock	Data Sources	First year	Last year	First age	Last age	Alpha	Beta	Commercial/ Research
Faroes	'Cuba' trawlers	1982	1994	3	12	0,00	1,00	C
Iceland	Trwl cpue, Jan-May	1980	1994	4	11	0,00	0,42	C
	Trwl cpue, Jun-Dec	1980	1994	3	12	0,42	1,00	C
	Trw-effort	1980	1994	3	12	0,00	1,00	C
North East Arctic	Norw purse seiners	1977	1993	3	7	0,00	1,00	C
	Norw trawl	1976	1993	3	8	0,00	1,00	C
	Norway Ac. surv	1988	1993	2	5	0,75	0,85	R
North Sea	Fratrb	1978	1993	2	9	0,00	1,00	C
	Nortrl	1980	1993	3	9	0,00	1,00	C
West of Scotland	Scosei	1972	1993	2	5	0,00	1,00	C
	Scoltr	1972	1993	2	7	0,00	1,00	C
	Scontr	1972	1993	2	4	0,00	1,00	C
	Fraall	1974	1993	2	9	0,00	1,00	C

Table 4.2 Input parameters to the XSA.

Stock	Catchability independent of stock size	Regression type	Min no of points	Surv. est. shrunk to pop. mean for ages	Catchability independent of age	Shrinkage of no of final years	No of oldest ages	S.E. of mean	Min. S.E.	Ref. age	Fbar
Faroes	All ages				>=9	5	3	0,5	0,3	4-8	0,41
Iceland	>=4	C	5	<4	>=11	5	5	0,5	0,3	4-9	0,27
North East Arctic	>=3	C	5	<3	>=8	5	5	0,5	0,3	3-6	0,41
North Sea	>=4	C	5	<4	>=7	5	5	0,5	0,3	3-6	0,48
West of Scotland	>=3	C	5	<3	>=6	5	5	1,0	0,3	3-6	0,53

Tapered time weighting applied for all stock by a power of 3 for 20 years except for Faroes which used 12 years. No prior weighting was used.

Table 4.3 Standard error of log catchabilities for estimates of abundance of age.

		Ages									
Stock	Fleet	3	4	5	6	7	8	9	10	11	12
Faroes	'Cuba' trawlers	0,52	0,41	0,30	0,19	0,20	0,33	0,51	0,52	0,55	0,44
Iceland	Trwl cpue, Jan-May		0,79	0,69	0,39	0,31	0,65	0,51	0,74	0,67	
	Trwl cpue, Jun-Dec		0,67	0,57	0,26	0,36	0,57	0,78	0,91	1,12	0,94
	Trw-effort		0,48	0,39	0,29	0,27	0,33	0,28	0,52	1,20	0,93
North East Arctic	Norw purse seiners	0,79	0,79	1,14	1,13	1,65					
	Norw trawl	1,06	0,77	0,39	0,42	0,65	0,51				
	Norway Ac. surv	0,56	0,43	0,58							
North Sea	Fratrb		0,41	0,38	0,59	0,68	0,67	0,58			
	Nortrl		0,47	0,37	0,53	0,59	0,89	0,90			
West of Scotland (WOS)	Scosei	1,07	1,37	1,23							
	Scoltr	0,54	0,72	0,83	0,75	0,84					
	Scontr	1,48	1,15								
	Fraall	0,38	0,48	0,41	0,34	0,40	0,32	0,17			

Table 5.1 North-East Arctic Saithe. Results from the acoustic survey in October-November. Numbers in millions. In 1985-1987 the area covered was incomplete.

Year	Age 2	Age 3	Age 4	Age 5	Age 6+	Total
1985	3,1	4,9	2,4	0,5	0,0	10,9
1986	19,5	42,8	3,6	1,8	1,8	70,3
1987	1,8	22,0	48,4	1,8	1,7	75,9
1988	15,7	22,5	19,0	7,1	0,6	64,9
1989	24,8	28,4	17,0	10,1	12,4	92,6
1990	99,6	31,9	14,7	5,1	7,4	158,7
1991	87,8	104,0	4,6	4,0	7,1	207,5
1992	163,5	273,6	57,5	6,2	8,8	509,7
1993	106,9	227,7	103,9	12,7	3,2	454,9
1994	34,4	87,8	112,4	39,5	10,0	284,6

Table 5.2 Biomass (tonnes) by age of saithe in inshore and offshore areas from the Norwegian coastal resource surveys during the period 1992 - 1994.

		Age (year)											
Survey year		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10+**	Total
1992	Inshore												34 716
	Offshore												146 058
	Total												**180 774**
1993	Inshore	2 228	1 568	17 944	26 429	16 078	9 542	5 352	4 101	3 401	3 416	14 884	104 943
	Offshore	6 239	9 309	32 524	53 327	39 212	20 228	15 083	13 611	12 533	10 002	20 725	232 793
	Total	**8 467**	**10 877**	**50 468**	**79 756**	**55 290**	**29 770**	**20 435**	**17 712**	**15 934**	**13 418**	**35 609**	**337 736**
1994	Inshore		12	251	476	474	961	820	247	104	30	218	3 593
	Offshore		358	6 892	18 578	54 492	55 474	19 341	6 299	4 808	1 572	7 336	175 150
	Total		**370**	**7 143**	**19 054**	**54 966**	**56 435**	**20 161**	**6 546**	**4 912**	**1 602**	**7 554**	**178 743**
Total	Inshore	2 228	1 580	18 195	26 905	16 552	10 503	6 172	4 348	3 505	3 446	15 102	143 252
1992-1994	Offshore	6 239	9 667	39 416	71 905	93 704	75 702	34 424	19 910	17 341	11 574	28 061	554 001
	Total	**8 467**	**11 247**	**57 611**	**98 810**	**110 256**	**86 205**	**40 596**	**24 258**	**20 846**	**15 020**	**43 163**	**697 253**

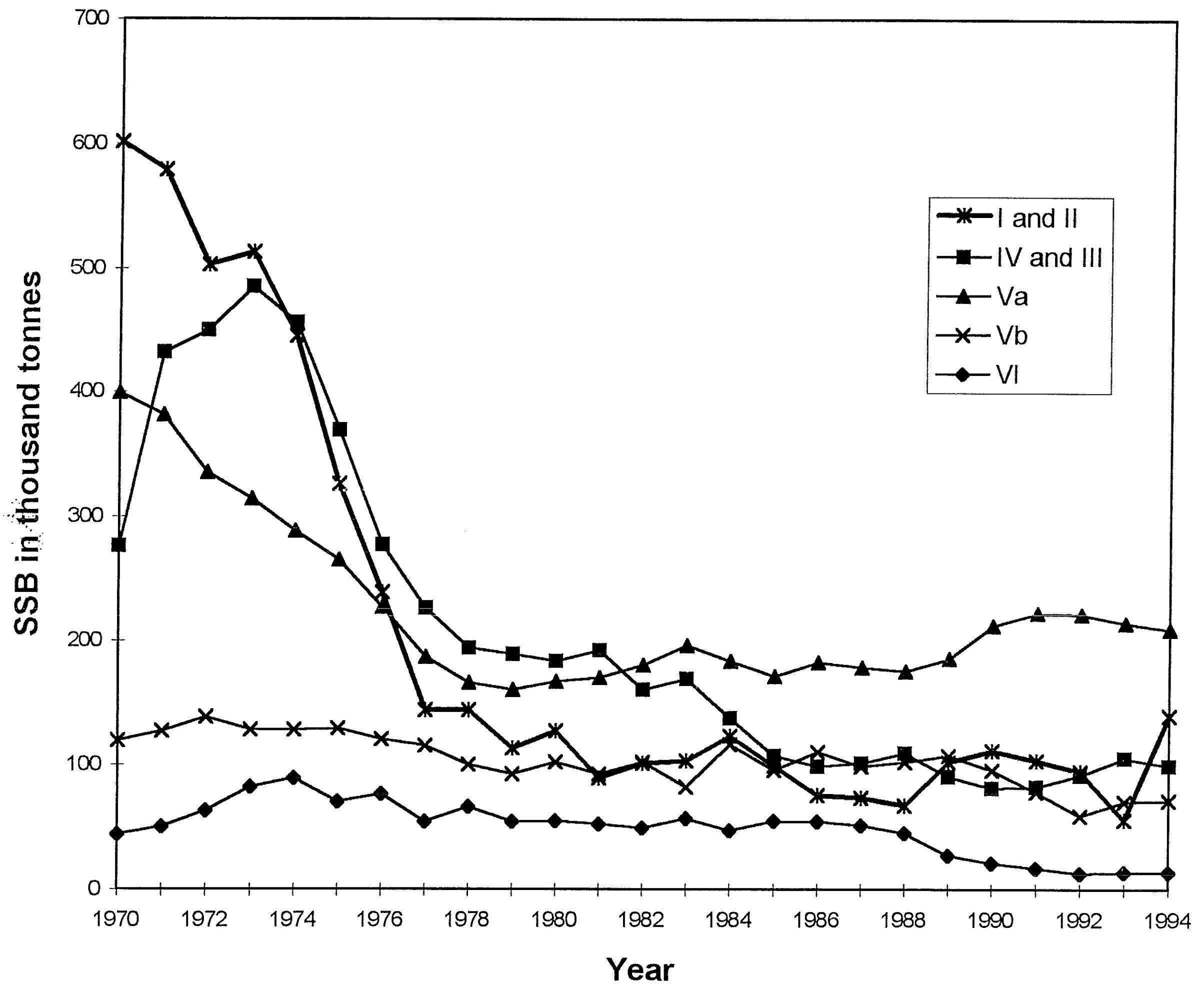


Figure 2.1. Spawning stock biomass (SSB) for the five north-east Atlantic saithe stocks 1970-1994 (in thousand tonnes). Source: most recent ICES Assessment Working Group reports.

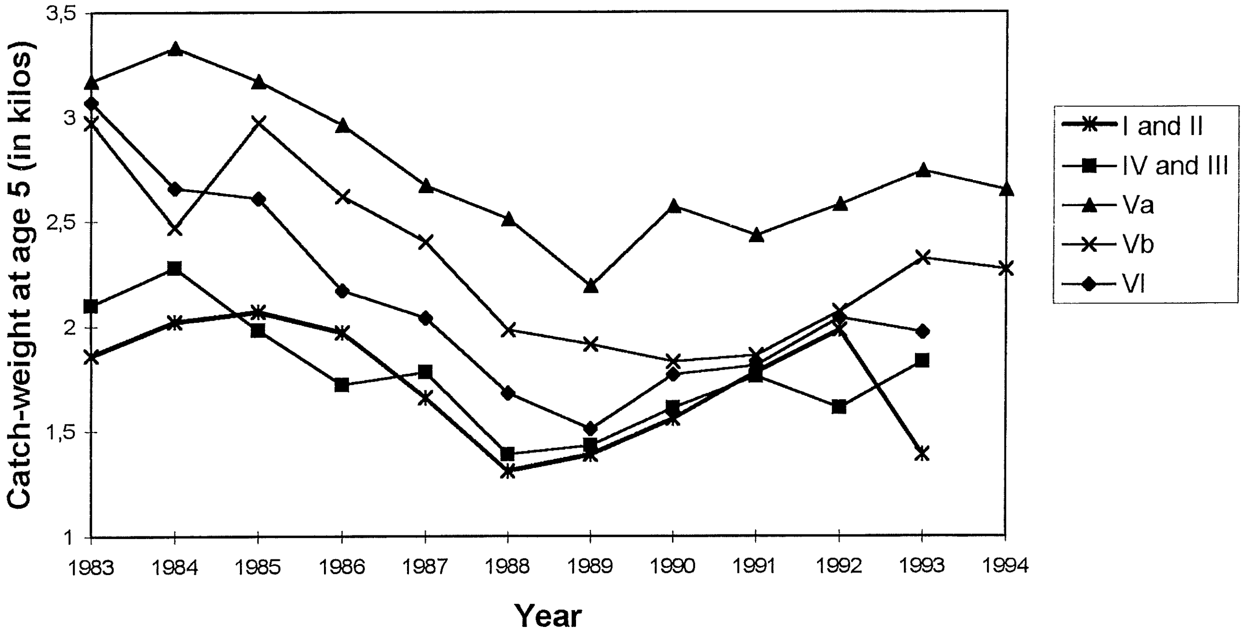


Figure 2.2. Catch weight-at-age 5 for the five north-east Atlantic saithe stocks from 1983 and onwards. Source: most recent ICES Assessment Working Group reports.

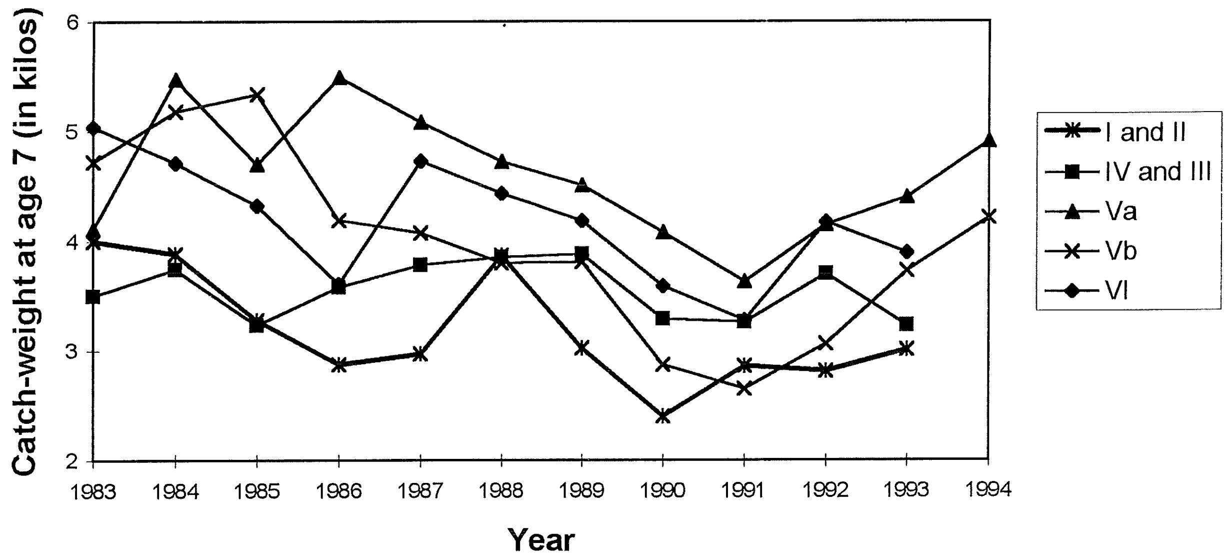


Figure 2.3. Catch weight-at-age 7 for the five north-east Atlantic saithe stocks from 1983 and onwards. Source: most recent ICES Assessment Working Group reports.

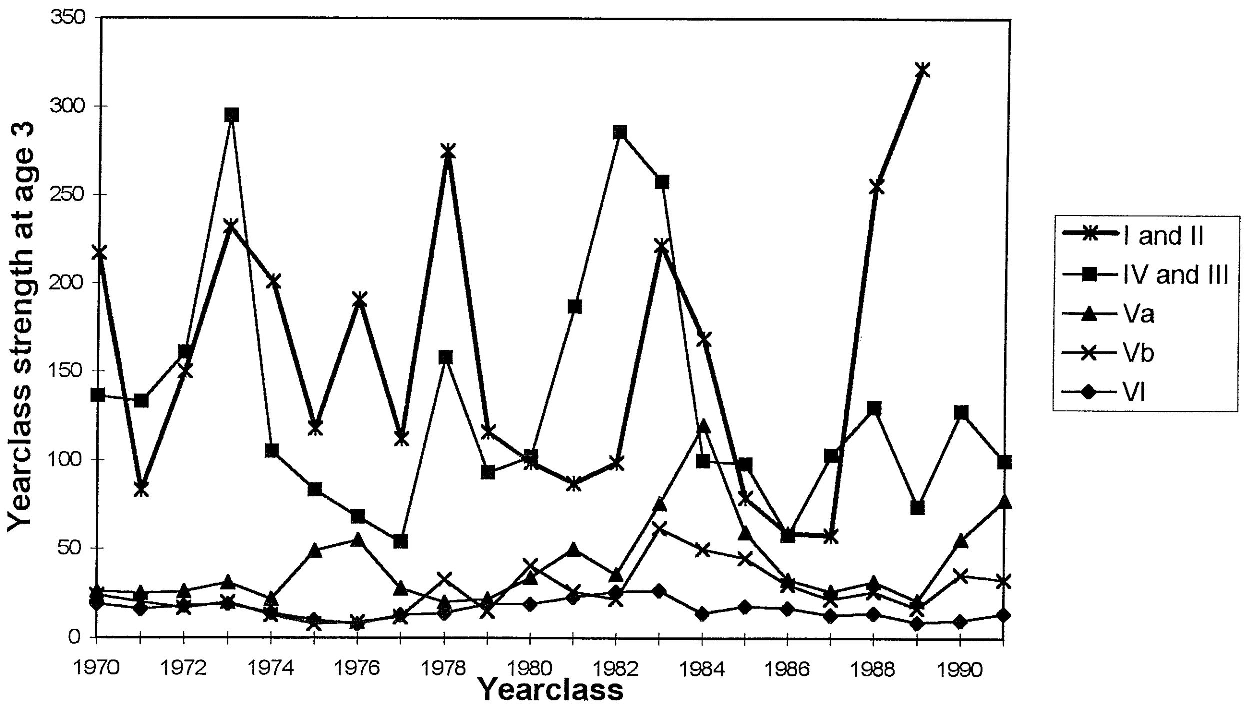


Figure 2.4. Strength (in millions) of the yearclasses after 1970 at age 3 as they have been estimated by VPA for the five north-east Atlantic saithe stocks. Source: most recent ICES Assessment Working Group reports.

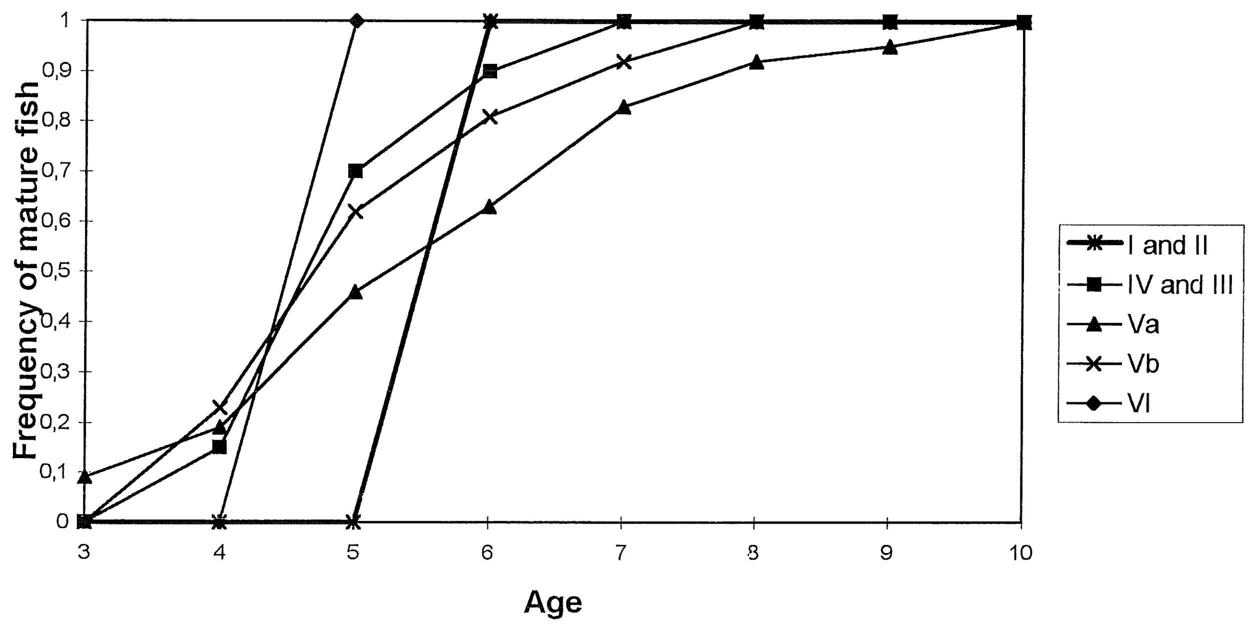


Figure 2.5. Maturity ogives as used for the last year in the most recent assessment. Source: most recent ICES Assessment Working Group reports.

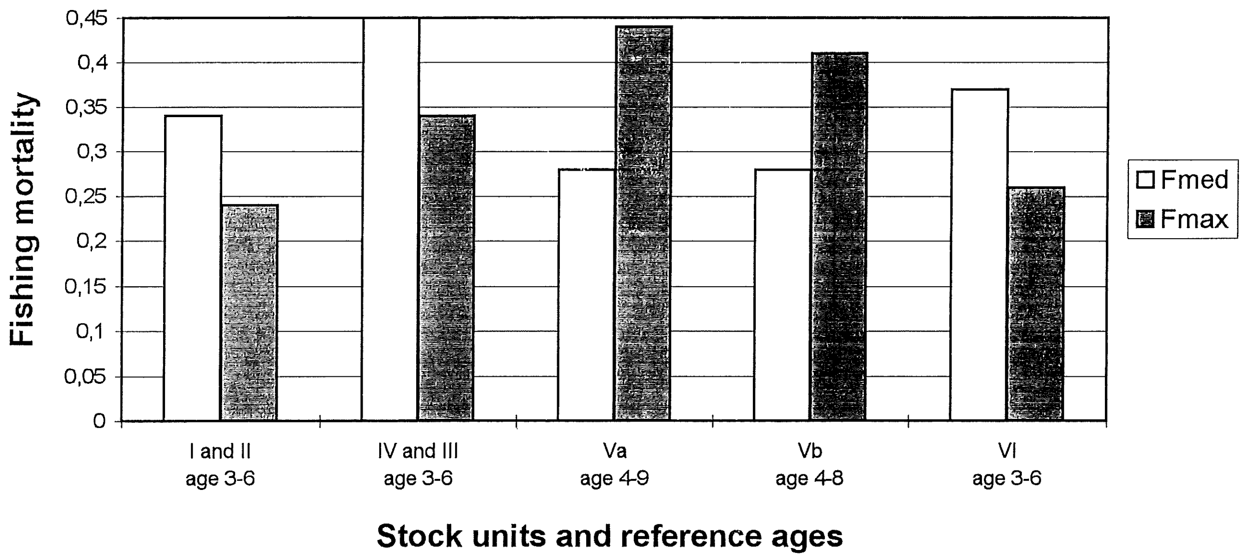


Figure 2.6. The biological reference points F_{med} and F_{max} for each stock unit as esimated in the most recent assessment. Source: most recent ICES Assessment Working Group reports.

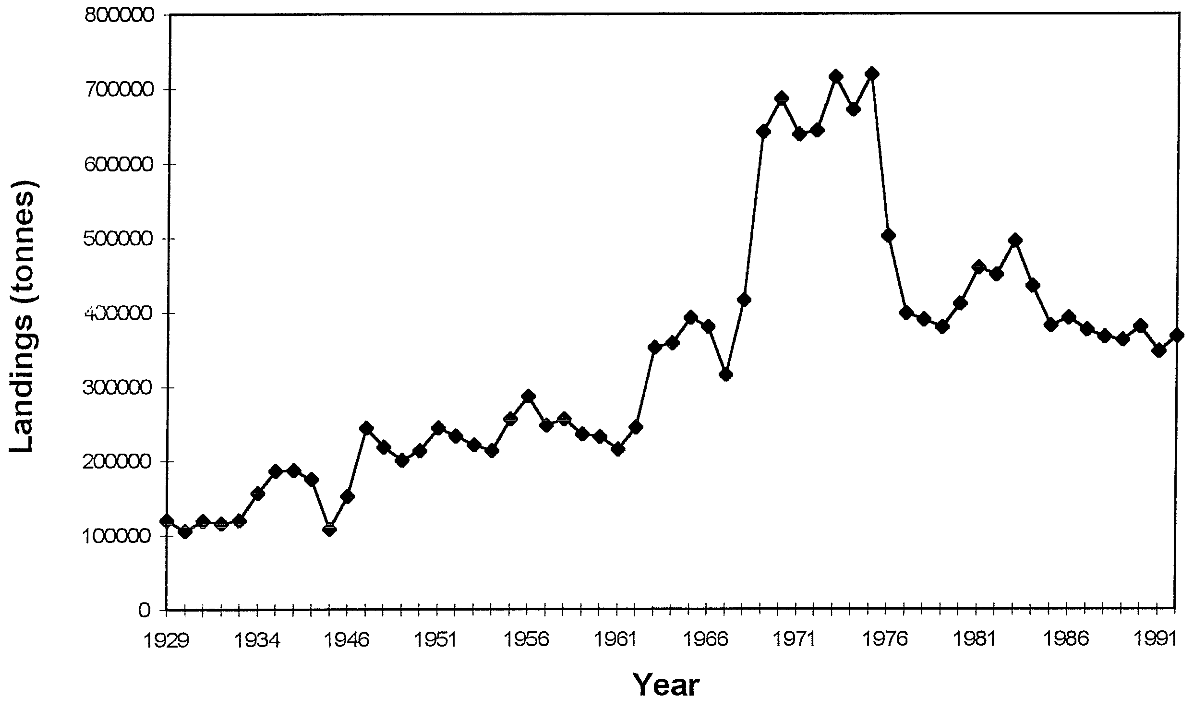


Figure 2.7. Total international landings (in tonnes) of saithe in the north-east Atlantic 1929-1992. Source: ICES Assessment Working Group reports.

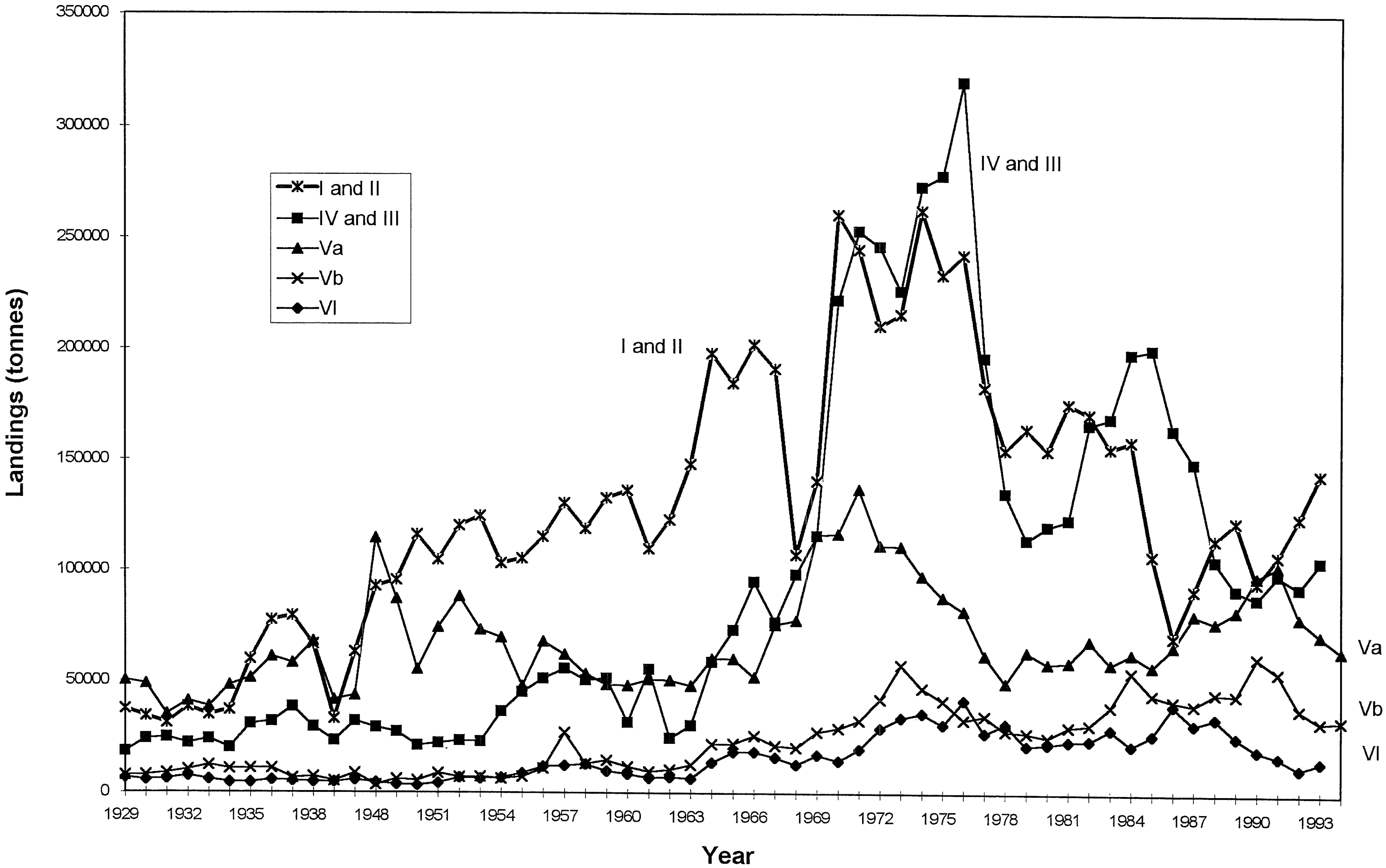


Figure 2.8. Total international landings (in tonnes) of saithe in the north-east Atlantic 1929-1992 splitted on stock units. Source: ICES Assessment Working Group reports.

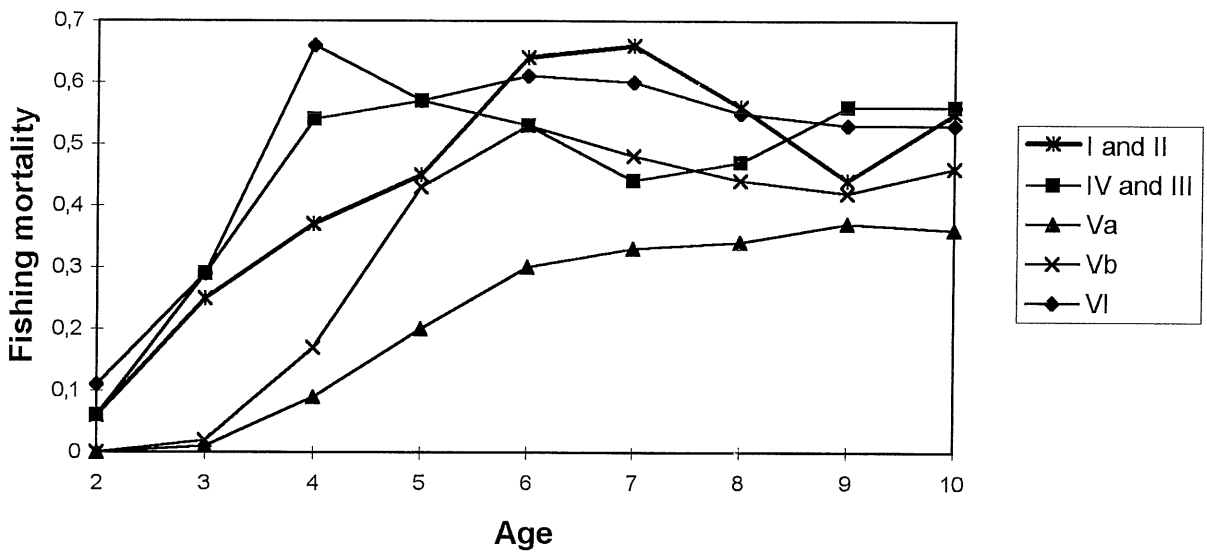


Figure 2.9. Fishing pattern for saithe for each stock unit as used in the most recent prediction. Source: most recent ICES Assessment Working Group reports.

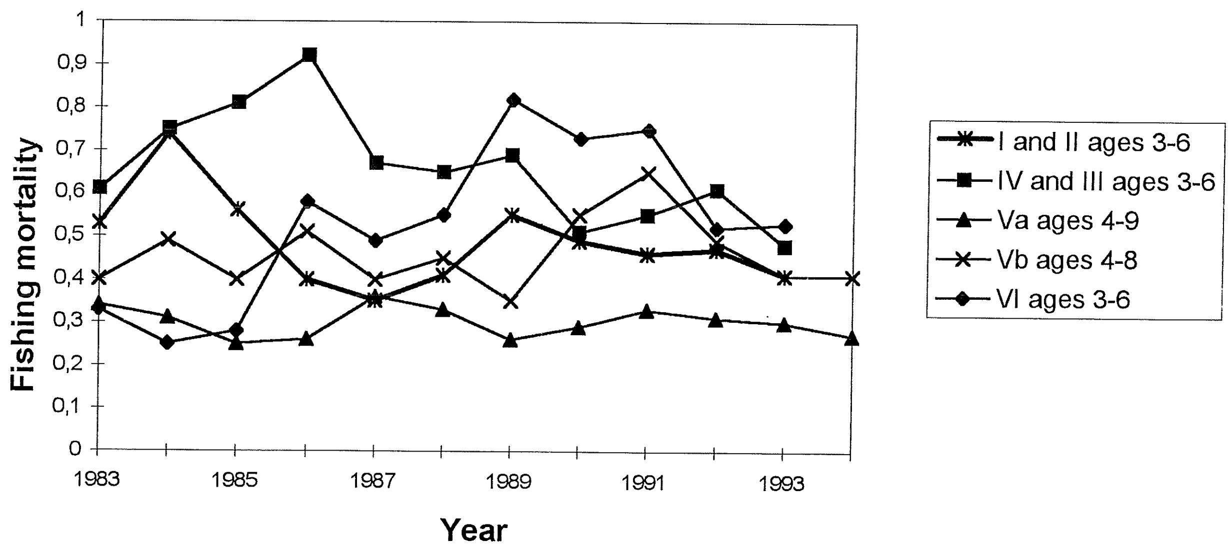


Figure 2.10. Average fishing mortality, 1983 and onwards, for those ages used as reference age in the five saithe stocks in the north-east Atlantic. Source: most recent ICES Assessment Working Group reports.

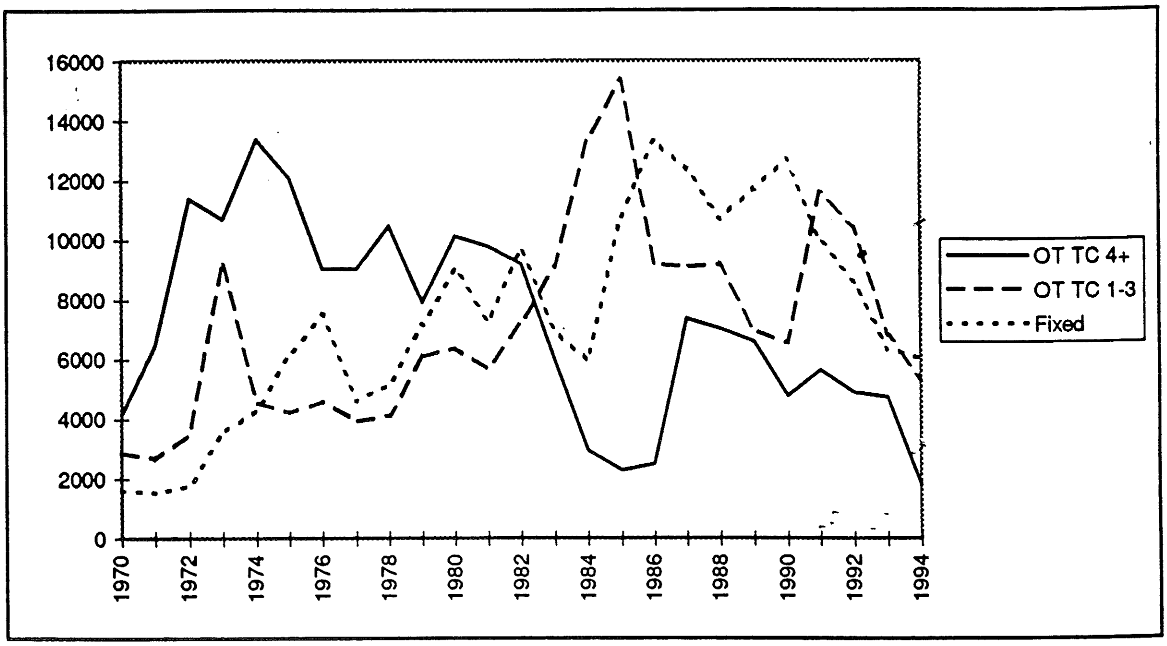


Figure 2.11. Total landings by gear of pollock (=saithe) in the north-west Atlantic (NAFO Divs. 4VWX and Subdiv. 5Zc) 1970-1994 (in tonnes). Larger trawlers (solid line), smaller trawlers (stipled line) and gillnet and longline vessels (pointed line).

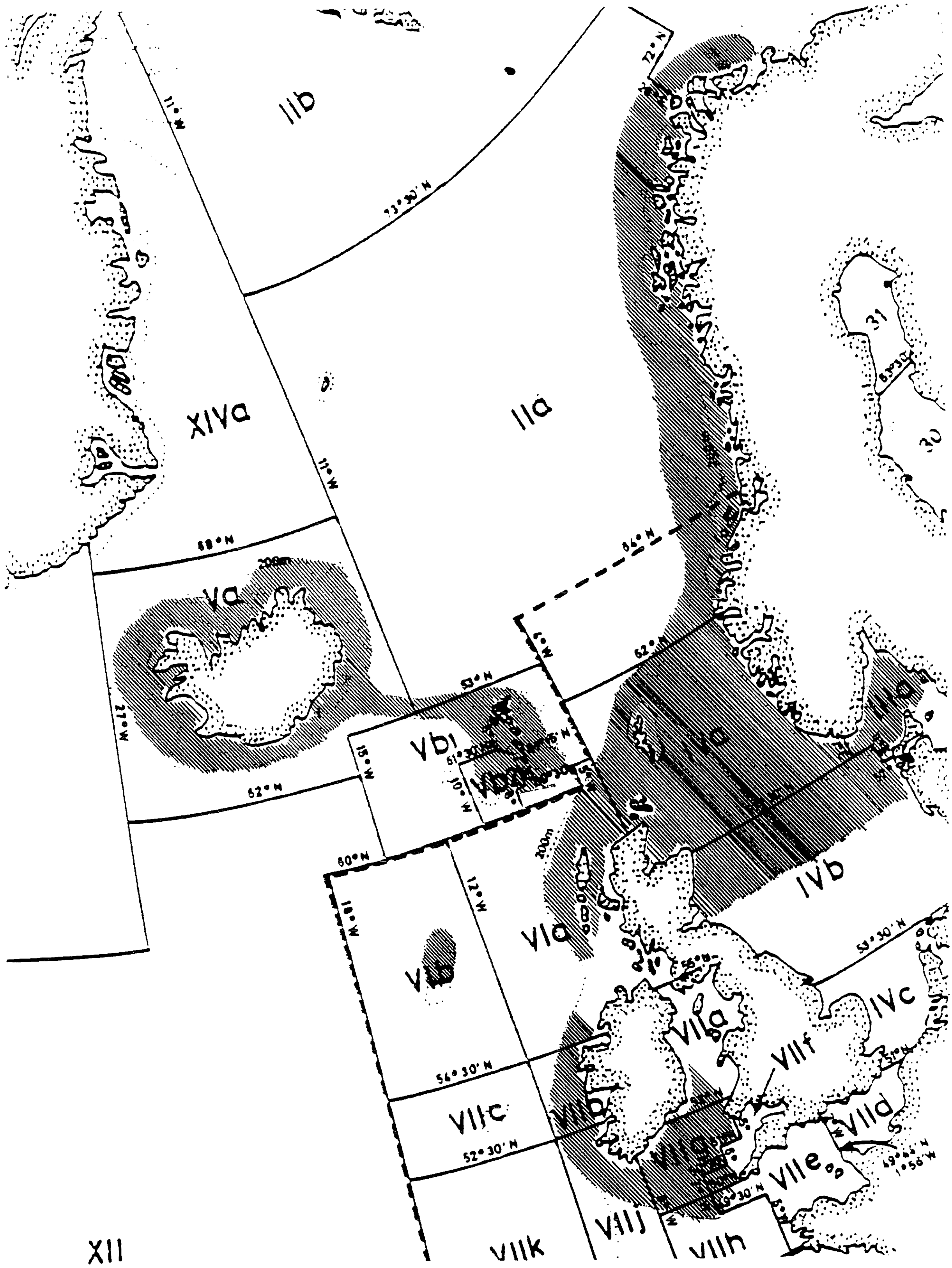


Figure 3.1. Distribution of saithe in the north-east Atlantic.

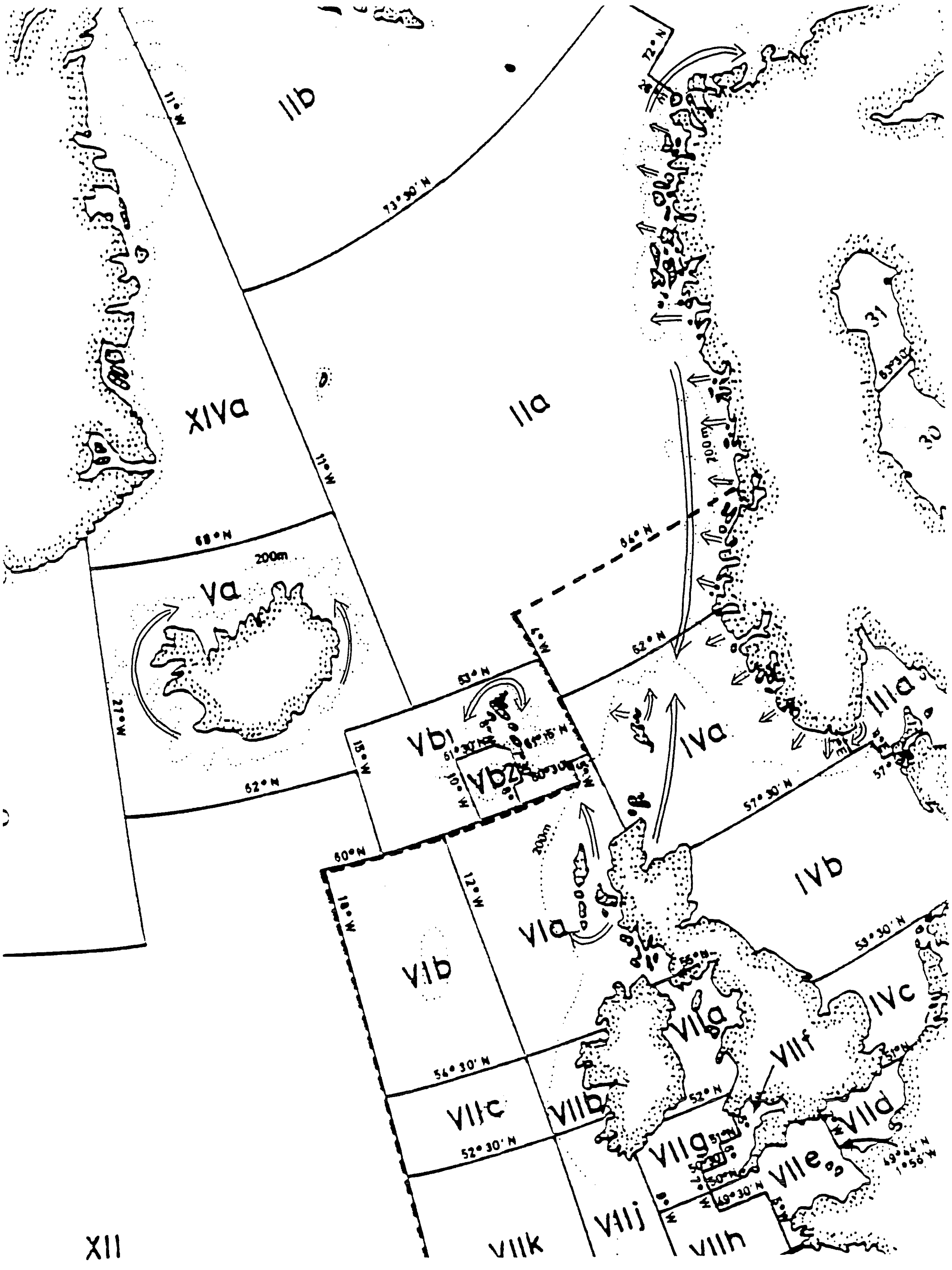


Figure 3.2. Juvenile saithe. Migration from coastal and inshore waters into the open sea.

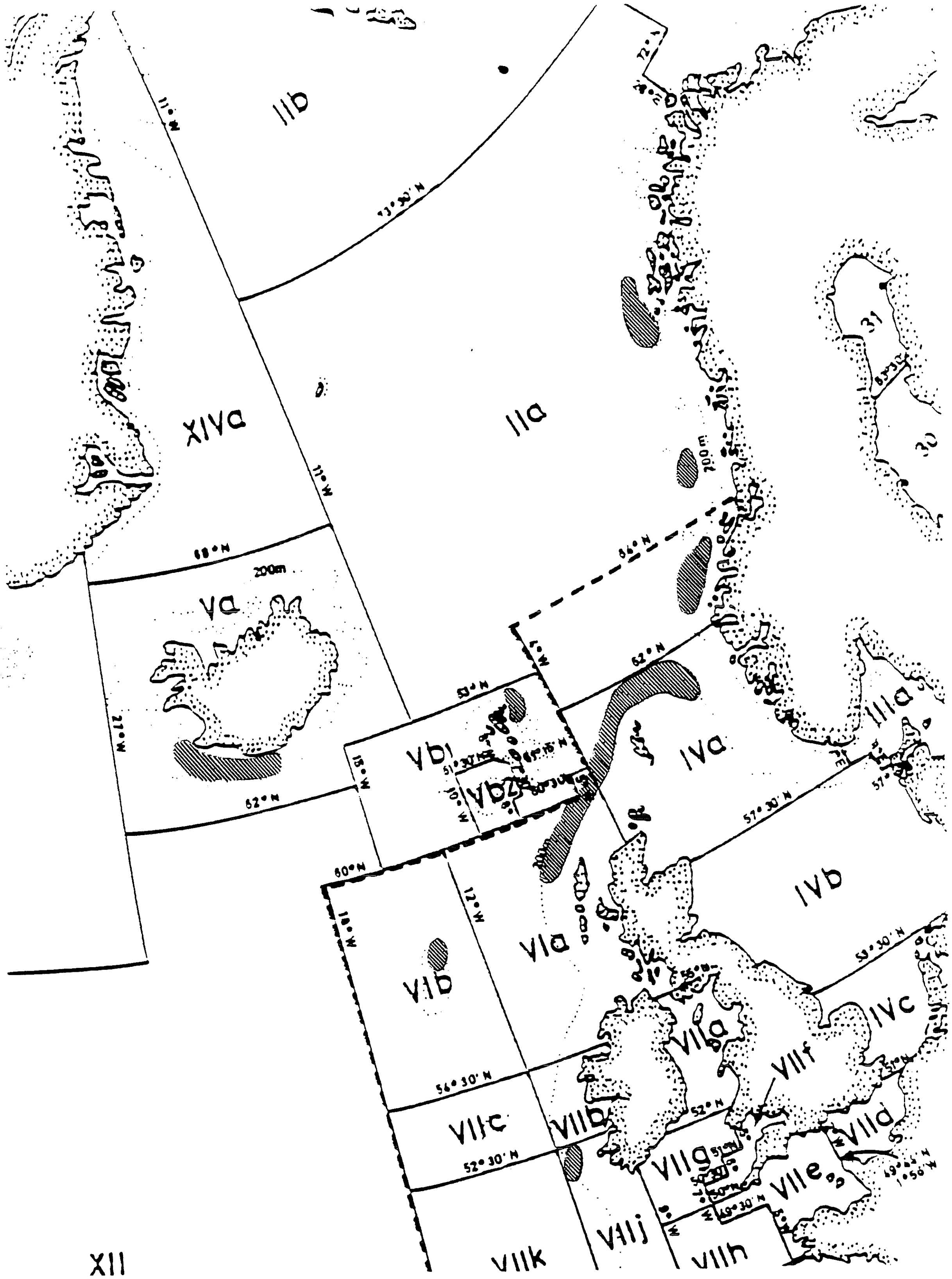


Figure 3.3. Main spawning grounds for saithe in the north-east Atlantic.

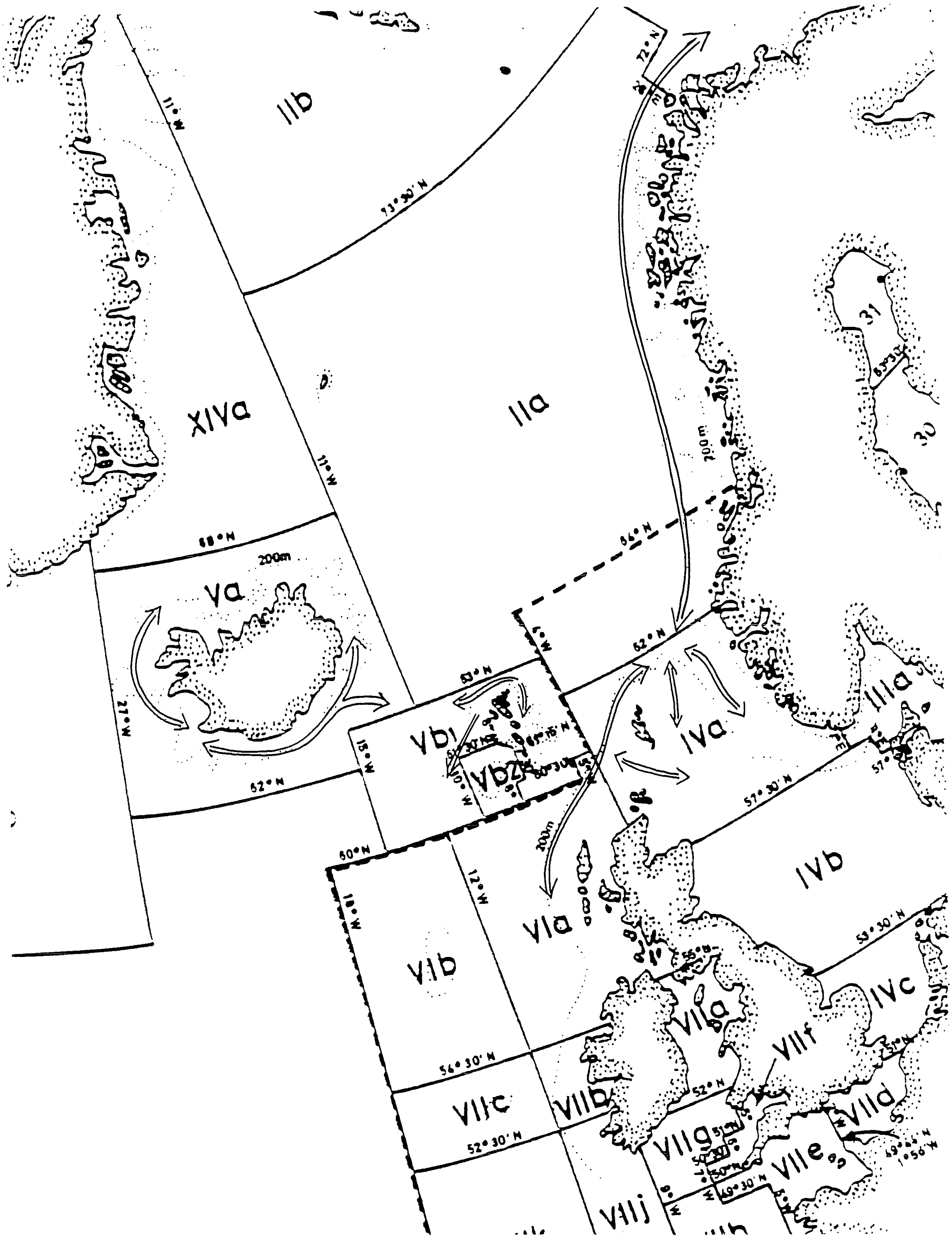
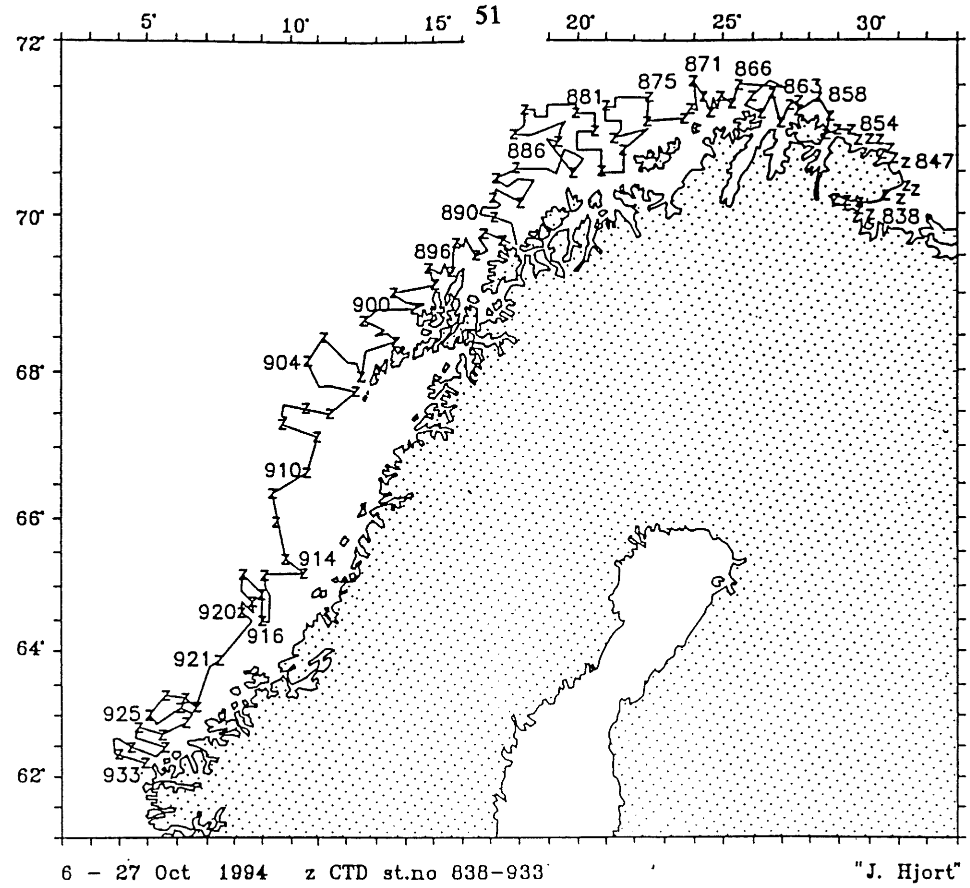


Figure 3.4. Spawning and feeding migration of adult saithe.



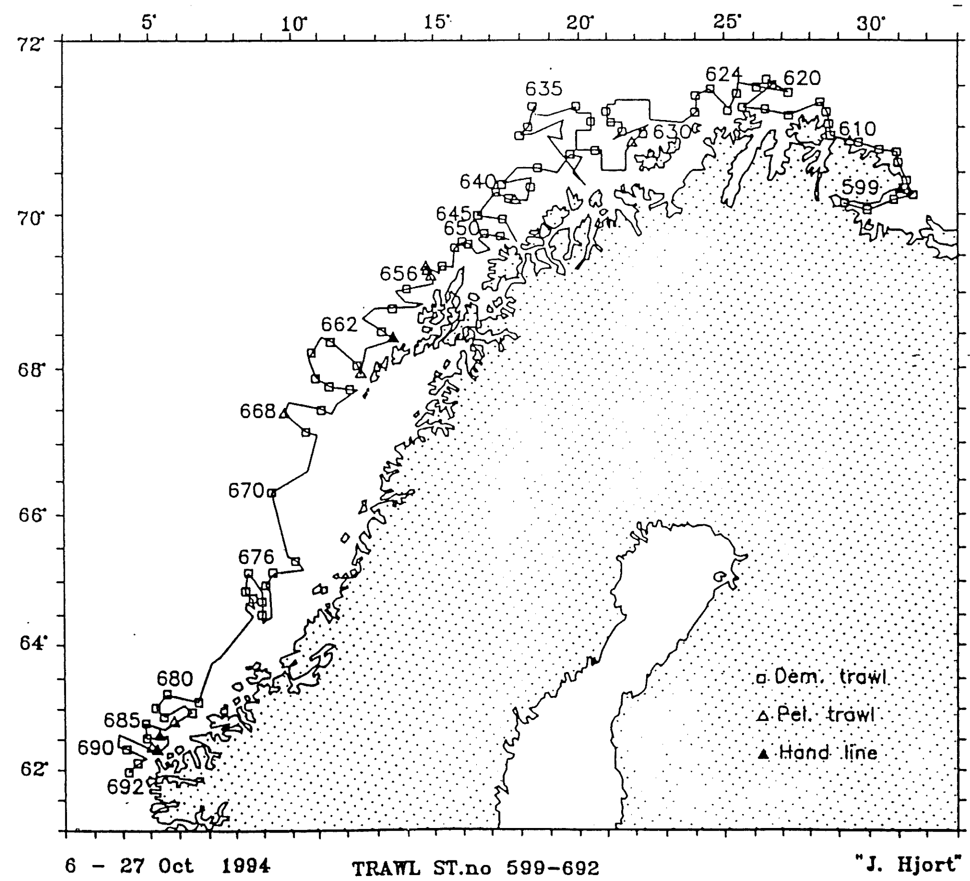


Figure 5.1 Survey tracks, trawl- and handline stations, and CTD stations during the October 1994 acoustic saithe survey north of 62 N.

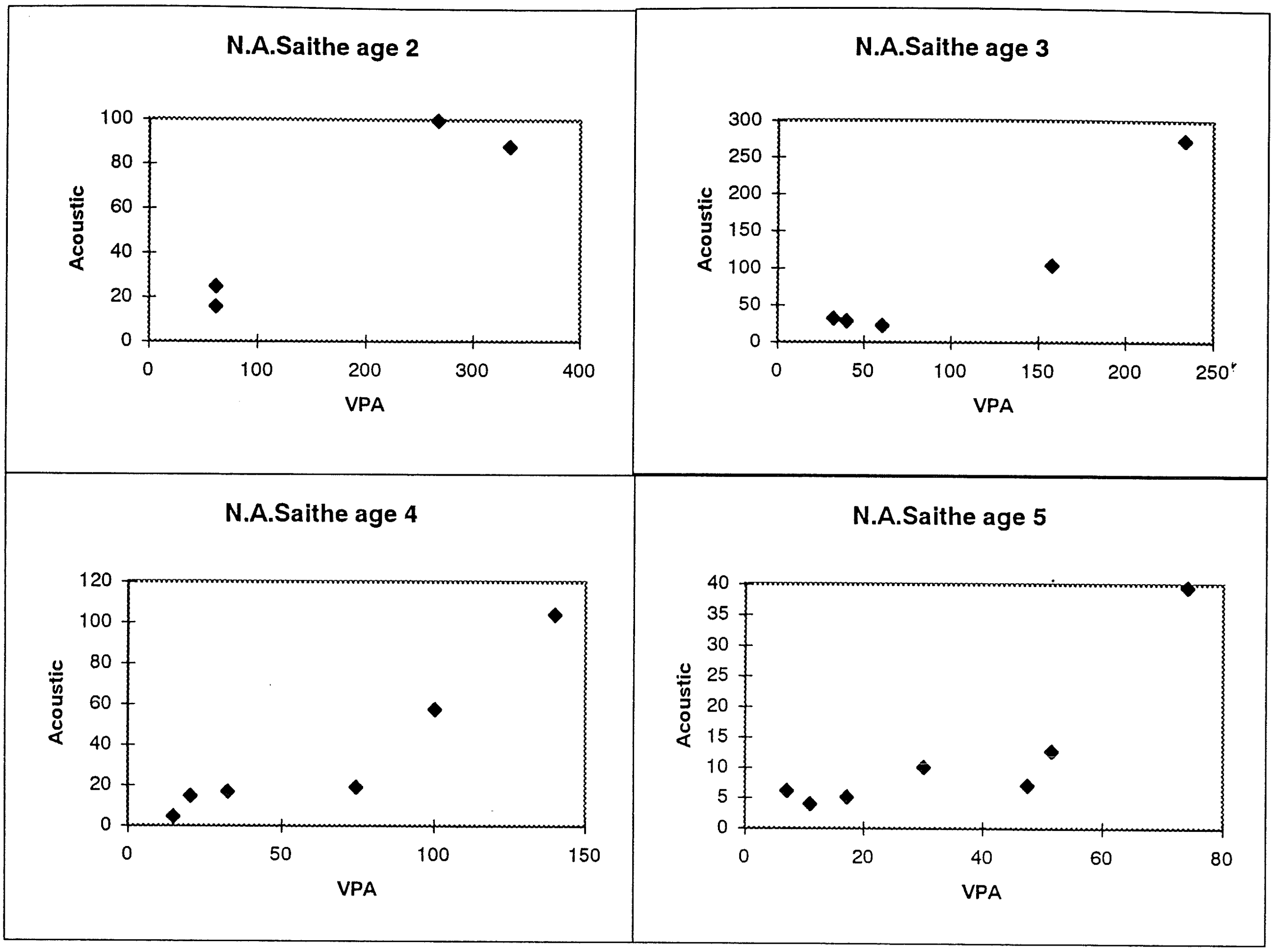


Figure 5.2. Acoustic indices from the IMR survey compared with the VPA values calculated in 1994.
VPA values are time adjusted. Last year class used 1989.

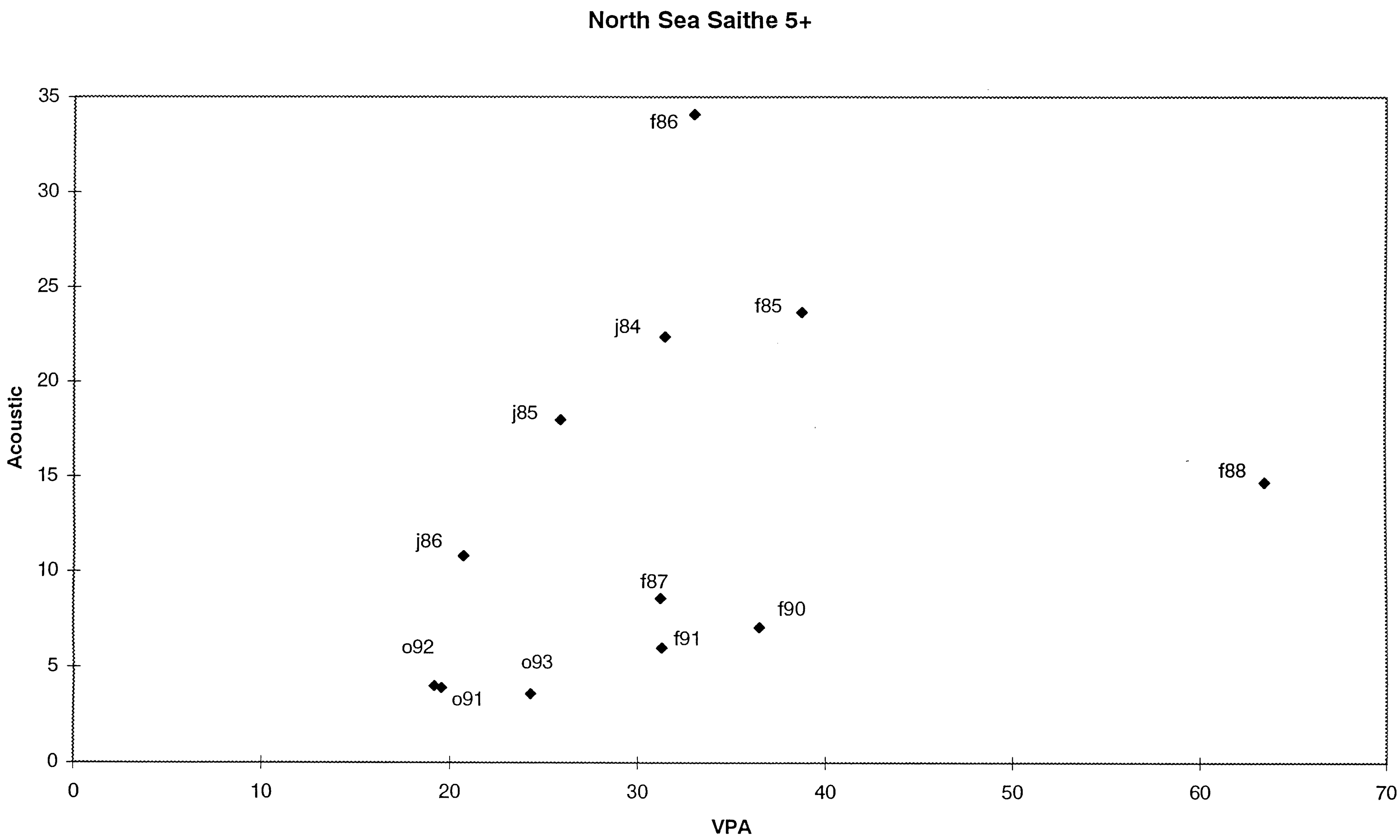


Figure 5.3. Acoustic indices/VPA values. The VPA values are time adjusted. f86= february 86, j86=july 86, o91=october 91.