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Evaluation of the North-East Arctic saithe (*Pollachius virens*) acoustic survey.

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ABSTRACT

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. 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. This paper describes and tries to make a critical evaluation of this research survey with regards to survey design, timing, cruise tracks, stratification, fishing ground selection, and attribution of species composition to acoustic data. Including the acoustic survey in the XSA-tuning will slightly improve the statistical diagnosis of the assessment, and will lead to a small reduction in fishing mortality and a 3-10% larger juvenile biomass the four most recent years. For the prediction, however, the consequences are bigger. The input fishing pattern to the prediction and the stock size in numbers will lead to 10-12% larger total biomass, up to 40% higher SSB and up to more than 80% larger catches in the short term when the survey is included in the XSA-tuning. Out of presently three XSA tuning series, the acoustic survey is the only fishery independent one, it both improves the reliability and has a significant impact on the results. It is therefore concluded that the survey should continue to be conducted annually at more or less the same time of the year.

Keywords: acoustic, assessment, Norwegian coast, saithe, survey.

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INTRODUCTION

Lack of information about recruitment has always been a problem for the saithe assessments in the north Atlantic (Anon. 1995). The main reason for this is the near-shore distribution of the early stages. The aim of conducting an acoustic survey targeting north-east Arctic saithe has been to support the analytical stock assessment with fishery independent data of the abundance of as young saithe as possible. The survey has been specially designed to cover the grounds where the trawlfishery takes place. These fishgrounds are normally dominated by 3-5 year old saithe in favourable conditions for acoustic measurements, but also 2 year old saithe, mainly inhabiting the fjords and more coastal areas, may recruit to these banks. Therefore, in the most recent analytical assessments, abundance indices of ages 2-5 have been used for tuning.

The present paper presents a synthesis and critical evaluation of this acoustic survey. The usefullness of the survey and the impact it has on the analytical assessment are discussed.

MATERIALS AND METHODS

Survey timing.

The timing of this survey is dictated by vessel availability rather than being specifically selected for biological reasons. A fall survey is appropriate in light of assessment timing and the recruitment of age 2 fish to the survey area, which increases over the year. In general a time when good weather can be anticipated is preferrable to stabilize the accoustic platform, but due to more established survey time series for other species, the saithe survey has so far been postponed until October. This survey is intended as a recruitment survey aiming at covering 2-5 year old saithe, so selecting a time when adults might be concentrated was not crucial. If a survey of a greater age range was desireable, the spawning season in February -March might be better. However, a smaller proportion of age 2 fish would then probably be covered, and one may run the risk of a variable proportion of fish inhabiting the spawning grounds during the survey time each year due to variation in spawning time. However, changing the survey time from October to September would certainly have decreased the chances of bad weather hampering the survey progress and the data collection.

Selection and design of cruise tracks.

The fishgrounds included in the survey have increased during the time series, but have been the same since 1992. The same grounds are surveyed each year. The areas to cover are pre selected, but may be modified during the survey if time requires. The pre selected cruise tracks are also dynamic to a certain degree. If commercial fishing activity is localized outside of the selected track, or between transects, the cruise track may be modified to include these areas. If the sa values are extreme, or the fish length composition differs from surrounding areas, this might then result in a small "stratum" incorporating only the area of abundance.

Similar tracks are followed from year to year. It is not specifically parallel random tracks, although parallel swaths across a bank are common, rather the intention of a track is to crisscross much of the expected area of abundance, and then to traverse intervening areas quickly.

The bridge is tied into the computer. Each time the Captain changes course, this is enterred into the track file, and this assists with the data analysis. Similarly, the beginning and end of each trawl set is enterred in the acoustic file, and results in a note on the real-time echogram print-out.

Fishing sets.
Since on some grounds it is only possible to trawl on specific locations, some trawlstations are pre-selected, but generally stations are selected as deemed necessary. Sets will be made every few hours when in areas where fish are reasonably abundant, or when a persistent change is noted in the general pattern of echo signals. Thus if the abundance of fish, as represented both by vertical spread and strength of echo, changes, or if the style of signal changes (between individual targets and a general band of signal, or patchy aggregations) then a set will be made to characterize the new acoustic pattern. The goal of the net sets, as well as giving species composition, is to get a representative length frequency of the target species. If a set cannot be made due to bottom type or commercial gear conflicts (gill nets or long-lines), then information from other sources (e.g., commercial catches) may be used to characterize the species composition and length frequency. The cruise leader keep contact by radio/VHF with fishermen fishing in these difficult areas with handline, longline, gillnet or Danish seine as the survey passes. Their reporting on species composition and size is used in combination with the observations on the research vessel. Generally this would result in a decision of which of the near-by sets is most likely to be representative, and this set will then be applied to the accoustic data. However, during daylight automatic handline machines have been used with success.

Duration of fishing sets varies, depending largely on density of acoustic signals. The median would be about 20 minutes, with maximum duration of 60 min. If the trawl hits a school of fish the tow may suddenly be abrupted although the towing time is less than 5 minutes.Trawl sets need not be directly comparable, since their purpose is only to provide species composition and length frequency. Mid-water tows are less common. Saithe are difficult to catch in mid-water, and seem to dive in response to ship noise, so even those well above bottom may be sampled with a bottom trawl, however in areas where the bottom is unsuitable, or the fish signals are entirely pelagic, a mid-water trawl may be appropriate. Mid-water trawls may, however, be more succesful at night (less trawl avoidance). Even in cases where the catch is small, information from a midwater set may corroberate the initial species identifications from acoustic data, as well as indicating what size range of saithe are present, which can be used for stratification, and, along with information from nearby bottom trawls, can assist in the scrutinization of the acoustic data.

Stratification.
The survey area is divided into 4 sub-areas with different age-length keys (ALK's) used in each.

The areas are:

Sub-area A: the area north of 69°30'N, i.e., north of Lofoten/Vesterålen
Sub-area B: 67°00'N - 69°30'N, i.e., offshore of Lofoten/Vesterålen
Sub-area C: 63°30'N - 67°00'N, i.e., the banks between Lofoten and Møre
Sub-area D: 62°00'N - 63°30'N, i.e., the coastal banks of Møre

The depth range included varies slightly within these areas due to differences in saithe distribution within these areas. In the northern area, for example, only a narrow band along the coast is included (north to approx. 71°30'N). Although much ground exists in the 200-300 m depth range in the Barents Sea, saithe are not generally found there.

Within each of these areas, the survey track is post-stratified. Based on net catches, acoustic readings, information from the fishery, and bottom topography, the saithe grounds are divided into polygonic strata. A single bank may all be included in one stratum, or it may be divided into more than one if variation in fishlength distribution seems to warrant it (Figure 1). Where this is done information from fishermen active in the area can be very helpful in determining roughly where the boundaries lie for assemblages containing different length frequencies. The area of the stratum is then determined with a planimeter. Once the strata boundaries are established, the Sa, species, and length composition from within that area are applied against the entire area of the unit area for estimation which is a rectangle of 1 degree longitude and 0.5 degree latitude. For further description of the calculations, see page 6.

Not all of the area through which the ship passes is included in the strata. Between the major saithe grounds the track followed does not contribute to the survey total. The depth in these areas is generally outside the range inhabited by the target fish.

Attribution of species composition to acoustic data.
The species composition from the net set is scaled by the target strength of each species. A proportional allocation to the acoustic data can then be made. Simrad EK-500 echosounder is used working at 38kHz, and this is attached to the BEI (Bergen Echo Integrator) (Knudsen 1990). The most common instrument settings of the acoustic equipment are given in Table 1. The "screen" of acoustic data on BEI is editted (Foote *et al.* 1991). The bottom channel (from bottom to 10 meters above bottom) and the pelagic zone are treated seperately. Any bottom spikes are cut out (note: a cumulative plot of Sa is visible across the bottom of the screen. This is used to help identify places where some bottom signal is being included in the integration; the cumulative plot gives a sudden jump if strong bottom signal is being incorporated). A line occluding most of the pelagic plankton is set, and then the minimum target strength threshold is raised until all the plankton is eliminated. What remains is considered fish.

The acoustic registrations by BEI are scrutinized according to the pattern observed on the echogram and the species composition in the trawl hauls. Saithe, cod and haddock are scrutinized as separate groups, while Norway pout, blue whiting and redfish usually are lumped together and scrutinized as a demersal fish group. In areas with few registrations of cod and haddock these species are scrutinized as demersal fish only, and where redfish are very frequent this species group is scrutinized as redfish. Where species are only scrutinized into bigger categories, e.g., demersal fish or pelagic fish, the final splitting of these categories is done according to the relative species composition in the trawl catch(es).

Biological sampling.

When catch is large and/or includes lots of small fish, the catch is subsampled. Species composition and length frequency data are collected for all species. Collection of otoliths along with sex, maturity stage and individual weight are stratified for saithe, haddock and cod, usually 5 specimens per 5 cm length group. For redfish representative, not stratified, samples of maximum 50-100 otoliths are taken. The otoliths are read at sea. They are snapped and set in plasticine. During the survey the catches are composed of many gadids (saithe, cod, haddock, whiting, tusk, ling), along with redfish, herring, copious Norway pout (especially south of Vesterålen), and an assortment of occasionals.

Personnel requirements

The cruise track is essentialy constant from year to year, so no time is required to select this prior to the survey. The responsibility for equiment maintenance and calibration lies with others, so the chief scientist needs only ensure that it is being done. Time prior to a cruise is allocated for keeping in touch with industry, both individually and through their periodicals, regarding the fishery in various areas. It is also necessary to determine where conflicts with fixed gear may occur.

During the survey the scientific crew usually number 7. This includes 1 equipment specialist and 2 biological staff for conducting sampling for each watch, and the chief scientist. The acoustic data are analyzed at sea, the ageing is completed, the attributing of species and age information to the acoustic data is complete, and for most of the survey area, the strata boundaries are established. Thus, when the survey is completed the acoustic estimation of the age disagregated abundance indices are near completion. An additional week on shore is nevertheless required to finalize this.

Approximately two weeks of analysis is reqiured to obtain all the results after the survey. Personell among the scientific crew are allocated to aid in this post-survey work and to assist in writing the report.

Abundance estimation.

Mean echo abundance ($\overline{S_A}$) is estimated for each rectangle of 1 degree longitude and 0.5 degree latitude (Figure 1). Very often the mean echo abundance measured along the survey track(s) through a rectangle cannot be taken as representative for the whole rectangle due to e.g., patchiness and depth (Figure 1). We try to improve the estimate by drawing isolines around more or less homogenous (with regards to length and age) fish registratons. Hence it is therefore necessary to calculate how big part of the rectangle, k, the mean echo value should represent, so that the equation

$$\overline{S}_A \cdot k \cdot a = E \qquad \text{(I)}$$

where a is the area of the entire rectangle, represent the echo abundance (E) in the rectangle.

Number of fish, N, of the actual species within the rectangle is then:

$$N = \frac{E}{\overline{\sigma}} \qquad \text{(II)}$$

where $\overline{\sigma}$ is the mean value of the species specific echo back scattering ability in the rectangle.

For the echo back scattering, σ, the same formula as for cod , 10 log $\frac{\sigma}{4\pi}$ = 20 log L-68, was used for both saithe, haddock and redfish (Foote 1987).

From this we get the following equation for the number of fish:

$$N=5{,}02\cdot 10^5 \cdot \frac{E}{\overline{L^2}} \qquad \text{(III)}$$

where L is the total fishlength. The mean squared fishlength was estimated as follows:

$$\overline{L^2} = \frac{\sum_{L=1}^{L\max} f_L \cdot L^2}{\sum_{L=1}^{L\max} f_L}$$

To every rectangle a set of trawlstations with lengthdistributions, judged to be representative for the fish within the rectangle, were allocated. The lengthdistributions from these stations were summed to give a representative lengthdistribution for the rectangle, and the mean squared fishlength, $\overline{L^2}$, was calculated for this distribution and used in equation III. Then the total number N was distributed on 5 cm length-groups using the same lengthdistribution.

Input data to the VPA (XSA) and prediction.
The input data are those used by the Arctic Fisheries Working Group (Anon. 1997). The only new data sets are the stock size in numbers at age at the beginning of the first prediction year (which was taken from the XSA-run with the survey excluded) and the fishing pattern (which was taken as the average 1993-1995 and scaled to the 1995 level) necessary for running the prediction when not taking the acoustic survey into account. For 1996 a TAC constraint of 163000 tonnes has been used, while for the other years in the prediction catches based on a fishing mortality of F=0.33 (= F_{med}) were used.

RESULTS AND DISCUSSION

Abundance and biomass.
The results from the 1996-survey are shown as an example. The survey tracks, fishing stations and hydrographical stations are shown in Figure 2. Altogether 80 hauls with bottom trawl, 5 with pelagic trawl, 22 handline stations and 116 hydrographical stations (CTD-sonde) were made. About 4000 nautical miles were sailed. Mean echo abundance in the rectangles and the most important distribution pattern are given for each sub-area in Figures 3-6. The acoustic abundance time series is presented in Table 2. In addition the survey may provide us with general biological information such as growth and nutrition. Data collected on other species have also to some degree been analysed, and do provide useful additional information to other surveys (e.g., haddock, cod and herring). It can be mentioned that the estimated number of 1 year old haddock in 1996 was almost equal to the abundance of the same yearclass in the open Barents Sea.

The biological sampling provides growth data. Table 3 shows the mean length at age from the survey since 1988. A greater overlapping of the length distributions of 3, 4 and 5 year old saithe the two most recent years may raise the question whether the age samples have been sufficient representative. Thus, although the total abundance estimate of these age groups may be correct, the estimate of each of the age groups may be biased. Stratification of the otolith sampling (e.g., 5 specimens in each 5 cm length group) should therefore take into account the acoustic registrations and increase the number of specimens sampled when the echo registrations are high.

The importance as tuning data for the analytical assessment (XSA).

XSA-diagnostics.

The three XSA-tuning series, i.e., the acoustic survey, commercial purse seine and trawl CPUE, have different capabilities to cover and give a reliable index of the abundance of the different saithe age groups. This is illustrated in Figure 7 by the mean logaritmic value of the catchability for each of the three series. The acoustic survey shows a relative stable catchability for the age-groups 2-5, although the efficiency seems to increase towards 3 year old saithe before it slightly decreases towards 4 and 5 year olds. Of the three tuning series it is the acoustic survey that shows the higher catchability of 2 year old saithe. The purse seine catchability shows a dome-shaped pattern with the peak at age 4. The catchability of the trawl is similar to the survey and the purse seine at age 3, but increases then towards age 6 from whereon it is rather stable.

Figure 7 also shows that including the acoustic survey in the XSA-tuning or not did not affect the estimated catchability of the purse seine and commercial trawl.

The internal and external standard error of the overall mean estimate of survivors at the end of the final year as well as the variance ratio (see Appendix 8 in Darby and Flatman (1994)) were looked upon from the XSA output diagnostics. While the external standard error and the variance ratio did not show any systematic differences whether the acoustic survey was included or not, the internal standard errors became less when including the survey in the tuning series (Figure 8). The tuning diagnostics for the survey at age 2 showed high standard error (this was even more outstanding when looking at the external standard error of the survivors estimate and the standard error of the resulting logaritmic VPA-population). This high value at age 2 is probably caused by the very low and probably underestimated catch figure at age 2 in 1995 (Anon. 1997).

Retrospective analyses were run for both XSA alternatives, i.e., with the survey included and not. Figure 9 shows only minor changes in the retrospective pattern when excluding the survey from the tuning. In fact, however, not using the survey in the tuning slightly improved the consistency of the fishing mortality. Reasons for this may be noise in the survey time series and not complete area coverage until 1992 on one side, and on the other side, the fact that the commercial purse seine and trawl series may better fit with the commercial catch data.

Comparisons of survey data versus VPA-results.

Figure 10 shows a good fit between the numbers of 3-5 year old saithe from the acoustic survey and that estimated by the VPA. It is surprising how well it fits in absolute numbers since no scaling of either of the two series has been done. This may be due to either an underestimate of the natural mortality in the VPA and/or an overestimation in the acoustic survey since it is hard to believe that every 3-5 year old fish could have been detected. The VPA estimate may also have been underestimated due to wrong landings statistics and/or the survey indices may have been overestimated due to wrong species scrutinizing, bad allocation of length distributions to acoustic data and the target strength. The less good fit is seen in the two most recent years, which may have to do with the VPA having not converged.

Figure 11 shows the relation between the numbers of 2 and 3 year old saithe from the survey and that estimated by the XSA. The fit is better for 3 year olds than for 2 year olds, but this may be due to rather poor catches and/or statistics of 2 year olds instead of poor survey results. VPA-survey comparisons are shown for all ages in the report from the Arctic Fisheries Working Group (Figure 5.2A in Anon. 1997).

Results from the VPA (XSA) and prediction runs including the acoustic survey and not.

The fishing mortalities at age in the last year are reduced for most of the ages when the survey is included (Figure 12), while the estimated reference fishing mortality (ages 3-6) for each year is only reduced in the two most recent years (Figure 13). For the years prior to this the convergency inherent in the VPA has smoothed out any differences.

Figure 14 shows the total biomass (BIOM 2+) and the spawning stock biomass (SSB) as estimated by the XSA up to 1 January 1996 and predicted for the years up to 1999 having the survey included and not. A 3-10% larger juvenile biomass is seen for the four most recent years in the XSA. Prior to this the convergency of the XSA has smoothed out any differences.

For the prediction, however, the consequences are bigger. The prediction shows that including the survey in the assessment will lead to 10-12% larger total biomass (2+), up to 40% higher SSB and up to more than 80% larger catches in the short term (Figures 14 and 15).

Other comments.

The acoustic estimation does not include any measure of variance. This could be done "with a handful of assumptions," and it is the plan to move towards including a variance measure for the acoustic surveys in general. Neither has spatial techniques been used to analyze the survey data (MacLennan and Simmonds 1992, Foote and Stefansson 1993). Foote and Stefansson (1993) define the problem of estimating fish abundance over an area from acoustic line-transect measurements of density, and present some candidate methods for solving these problems.

The distribution maps (Figures 3-6) which are based on average s_a values for each nautical mile do not give the details in the distribution since saithe schools extending less than 1/10 of a nautical mile are smoothed out along the whole mile. A high nautical mile value is therefore very often a result of a single dense school being registered on a short part of the mile only. This will give a high variance and low precision to the abundance estimate. Likewise, care should be taken when making an average of all the nautical miles within the smallest unit for density estimation, i.e., the 0.5 x 1.0 degrees rectangle. It is the opinion of the author and colleagues at the Institute of Marine Research that this variance is reduced when only averaging miles with more or less homogenous length distributions. This has already been done for the present saithe estimations. Nevertheless, this could be further improved by allocating a trawl station with corresponding length distribution to each scrutinised nautical mile s_a, of course, dependent on the quality of the trawlcatch and how frequent the trawlhauls are made.

In situ target strength (TS) information is not used for determining fish size frequency, but it is used in scrutinising the acoustic data to the extent that it indicates large versus small fish or plankton. A histogram of TS in one corner of the screen is used as an indicator of size frequency within the screen. The weaker echoes may to a certain extent be isolated by using a specific thresholding of small signals, i.e., threshold limit of the volume backscattering strength, $S_{vol.}$ This is generally how plankton contributions are removed from the acoustic recordings today. Thresholding, however, may affect the effective acoustic sampling volume of the acoustic beam, also for the fish involved, and a bias in the density estimate of fish may be introduced at greater depths (e.g., Egil Ona, Institute of Marine Research, pers. comm.). However, it is believed that it would have no significant impact on saithe which mostly are registrated shallower than 200-300 meters.

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Table 1 . Instrument settings of the acoustic equipment.

Echo sounder/integrator	Simrad EK500/BEI
Frequency	38 kHz
Transducer type	ES38B-SK
Transducer depth	5 to 8 meters (center board)
Absorption coeff.	10 dB/km
Pulse length	Medium (1.0 ms)
Bandwidth	Wide (3.8 kHz)
Max. transmission power	2000 W
2-way beam angle	-21.0 dB
3 dB beamwidth	7.2 deg.
S_{vol} *threshold*	-79 dB
Bottom offset and detection level	0.5 meters and -40 dB

Logging by BEI is done for a 250 meters or 500 meters depth range. The bottom channel is defined as the distance from bottom to 10 meters above. Scrutinized values are stored with 50 meters vertical breaking up in the pelagic channels and 2 meters breaking up in the bottom channel. Scrutinized values are saved for each nautical mile.

Table 2. North-east Arctic Saithe. Acoustic abundance indices from surveys in October-November. In 1985-1987 the area coverage was incomplete, and the present area coverage was not fully achieved until 1992. Numbers in millions.

Year	Age					Total
	2	3	4	5	6+	
1985	3.1	4.9	2.4	0.5	0.0	10.9
1986	19.5	40.8	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
1995	38.7	165.2	87.0	46.8	20.0	357.7
1996	37.0	118.9	214.7	32.1	19.3	422.0

Table 3. North-east Arctic Saithe. Mean length (cm) at age in the annual autumn surveys. For 1988-1994 mean lengths are computed from the aged invividuals only.

Year	Age							
	1	2	3	4	5	6	7	8
1988	28.7	34.8	41.5	47.2	54.8	65.8	69.0	72.0
1989		37.7	41.9	48.9	54.7	61.4	79.0	
1990	29.0	35.5	45.5	51.5	56.9	64.3	70.1	
1991		34.5	44.2	56.8	62.3	67.5	72.7	74.8
1992		34.8	42.6	54.3	64.1	68.2	71.3	72.0
1993	27.2	34.3	40.3	49.4	61.0	72.5	76.3	81.1
1994	29.0	32.3	40.2	46.8	55.9	68.5	75.8	79.8
1995	27.5	34.1	38.2	48.2	52.9	61.6	70.5	77.5
1996		34.2	38.9	44.1	52.4	58.4	68.8	73.5

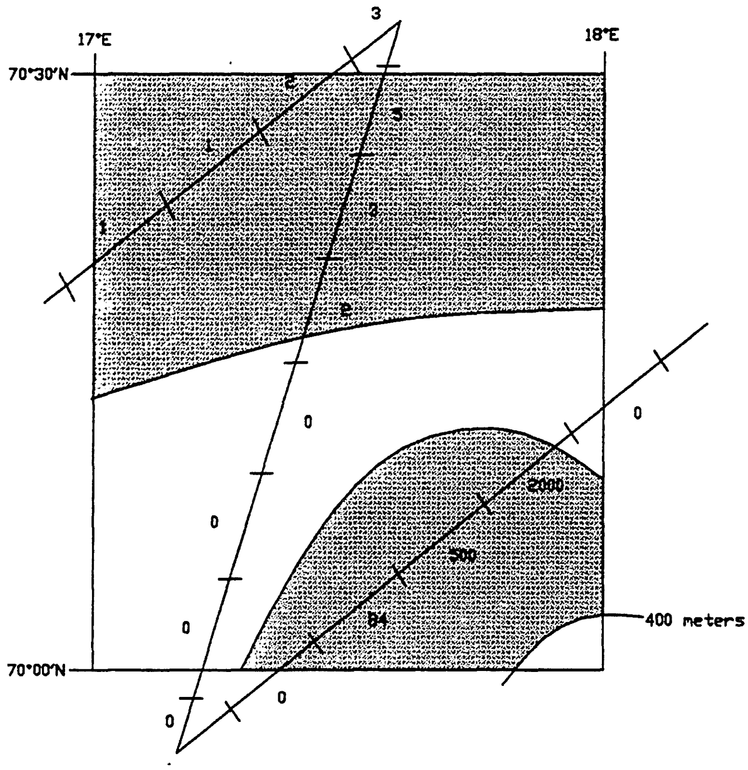


Figure 1. Illustration of a 1 degree longitude and 0.5 degrees latitude rectangle with a survey track going through it. Sa values for each 5 nautical mile have been shown. In order to reduce the variance the rectangle has been further divided into three post-drawn polygons (hatched and white) with more homogenous length distributions and more even Sa values. A small part of the rectangle which is deeper than 400 meters has been subtracted since no saithe are expected to be here.

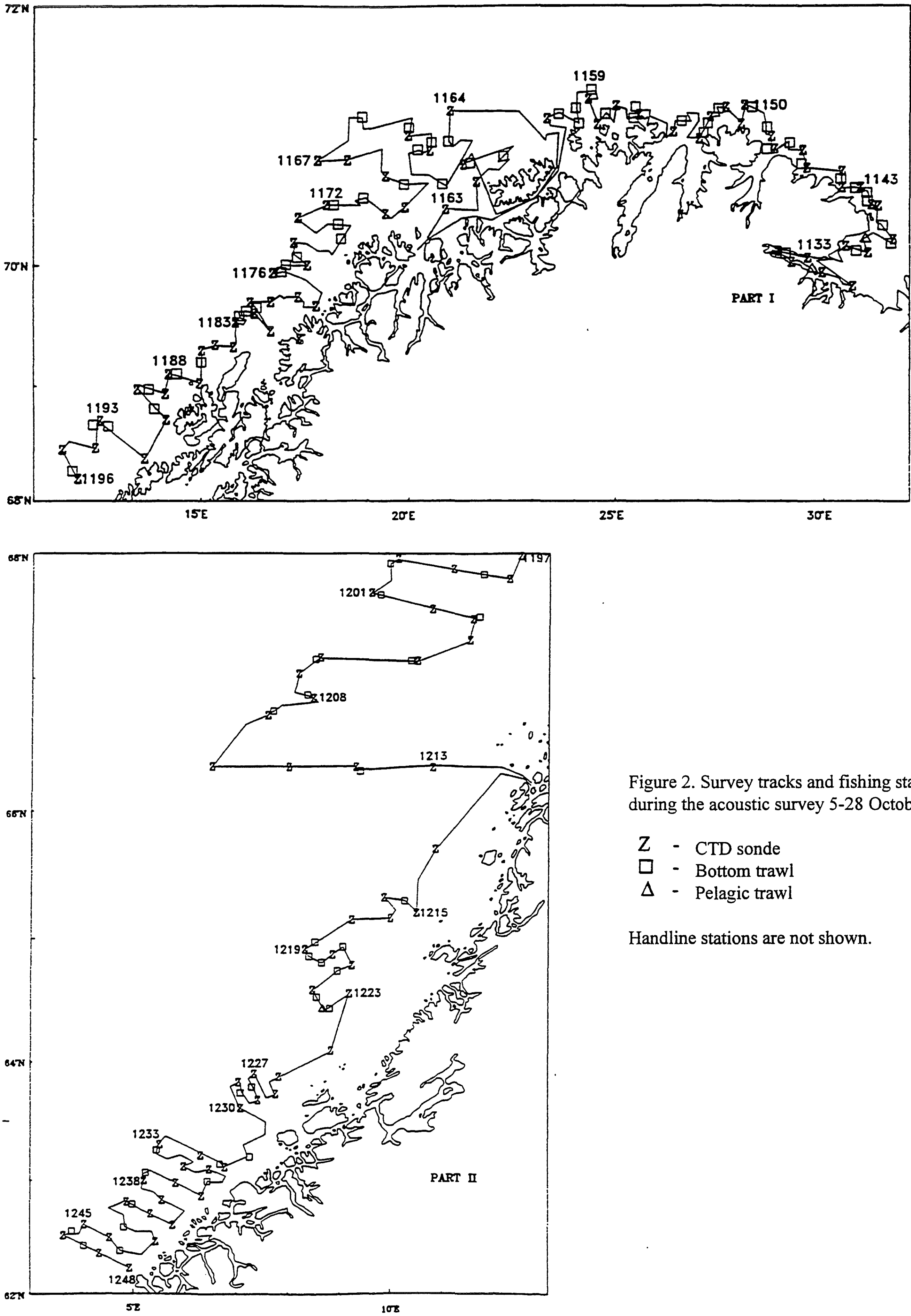


Figure 2. Survey tracks and fishing stations during the acoustic survey 5-28 October 1996.

Z - CTD sonde
□ - Bottom trawl
Δ - Pelagic trawl

Handline stations are not shown.

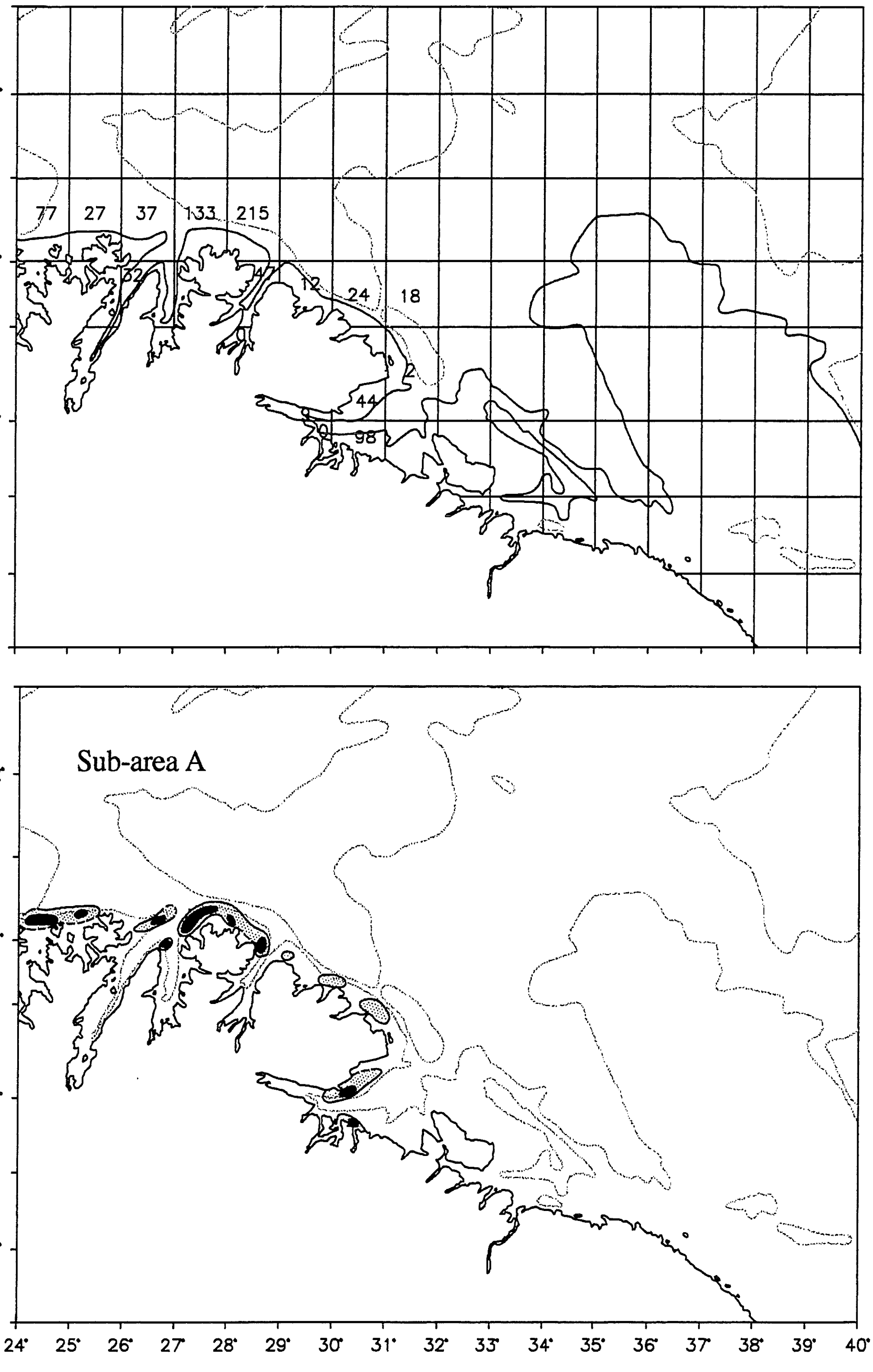


Fig.3. SAITHE. Finnmark 1996. Mean echo abundance ($\overline{s_A}$, m^2 /nm^2) in eacho rectangle and the most important distribution pattern. Integratorvalue >10m^2 /nm^2 (hatched) and >100m^2 /nm^2 (black).

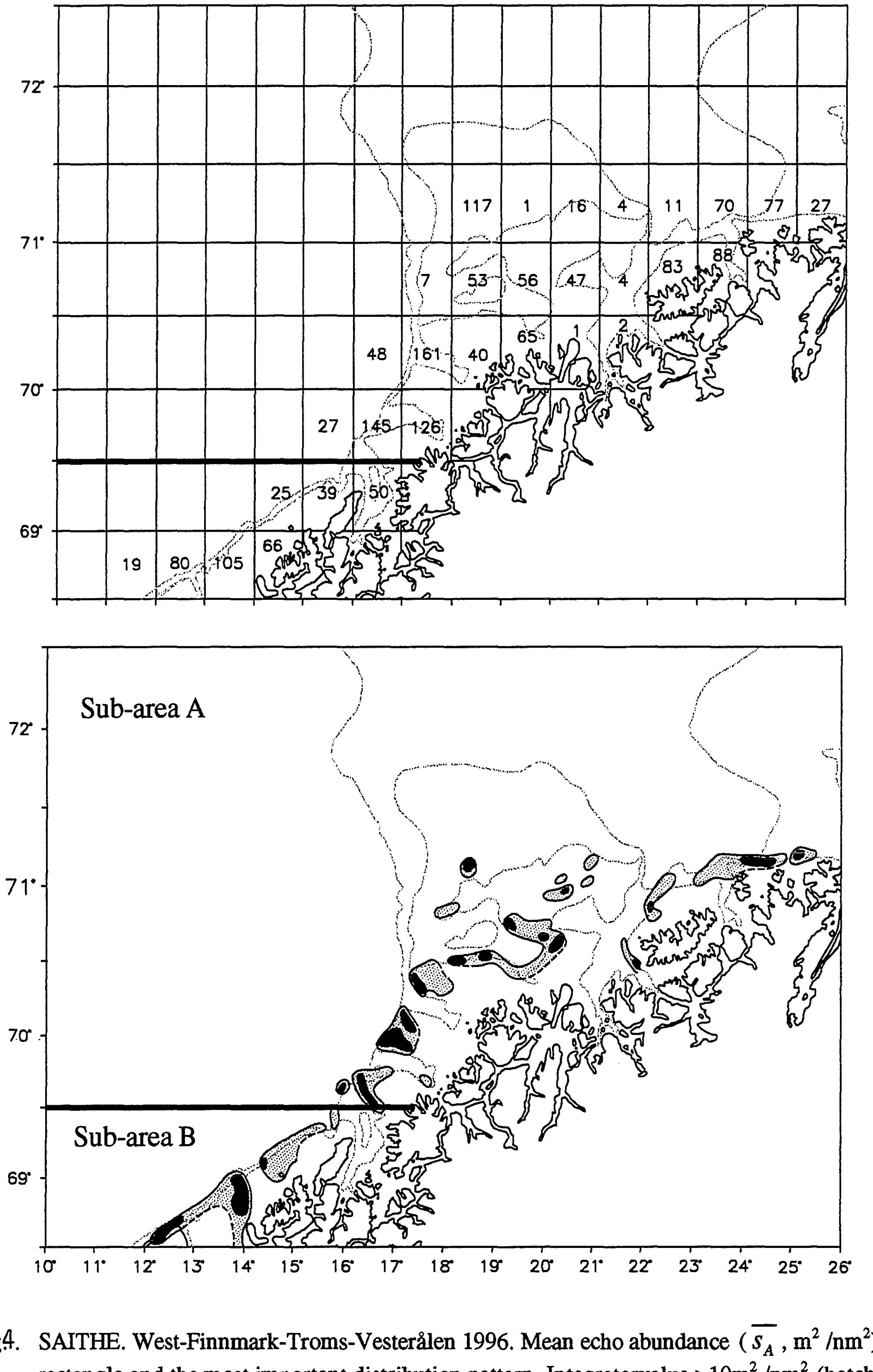


Fig4. SAITHE. West-Finnmark-Troms-Vesterålen 1996. Mean echo abundance ($\overline{s_A}$, m^2 /nm^2) in each rectangle and the most important distribution pattern. Integratorvalue >10m^2 /nm^2 (hatched) and >100 m^2 /nm^2 (black).

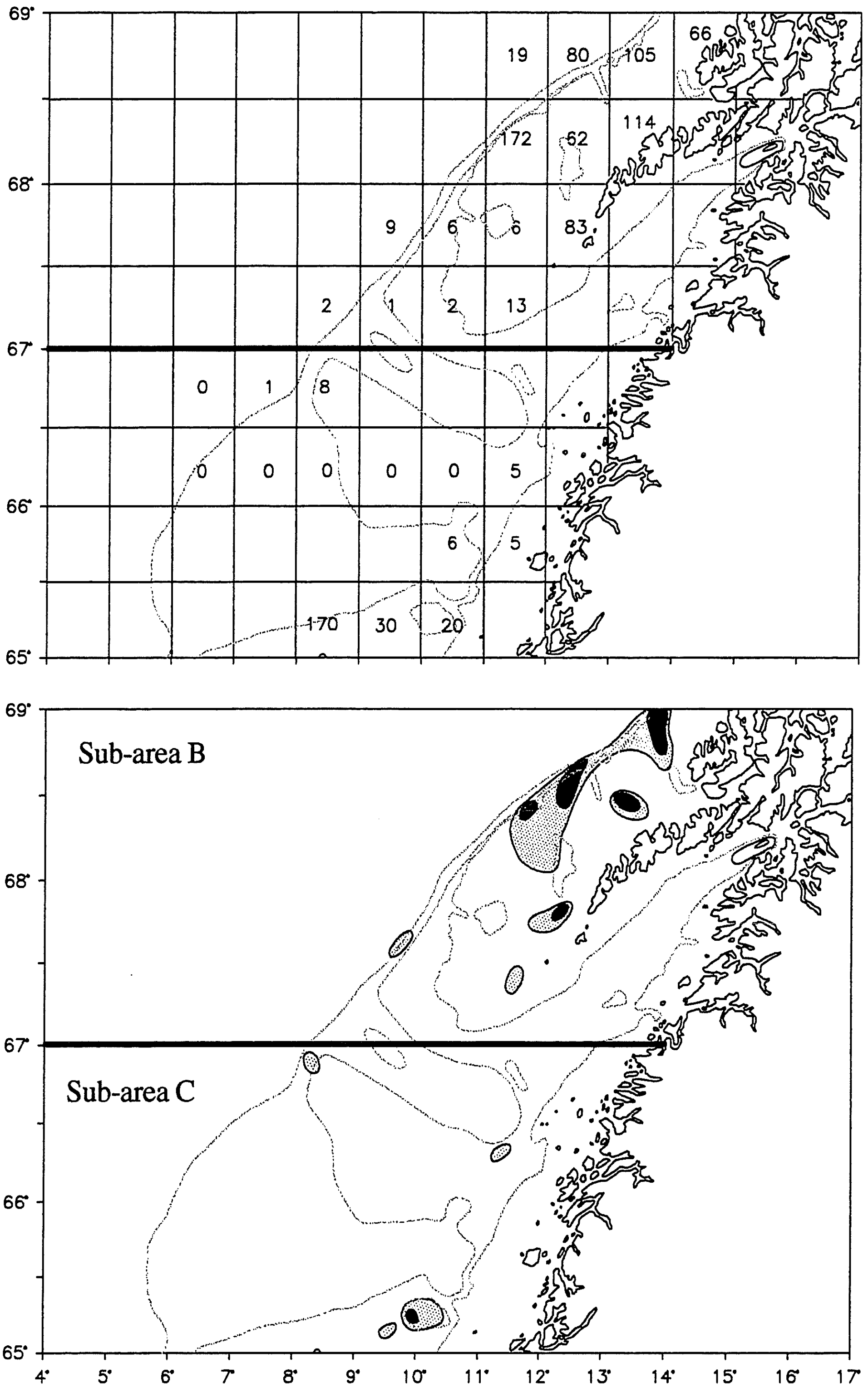


Fig5. SAITHE. Vesterålen-Helgeland 1996. Mean echo abundance ($\overline{s_A}$, m^2/nm^2) in each rectangle an most important distribution pattern. Integratorvalue >10m^2/nm^2 (hatched) and >100m^2/nm^2 (bla

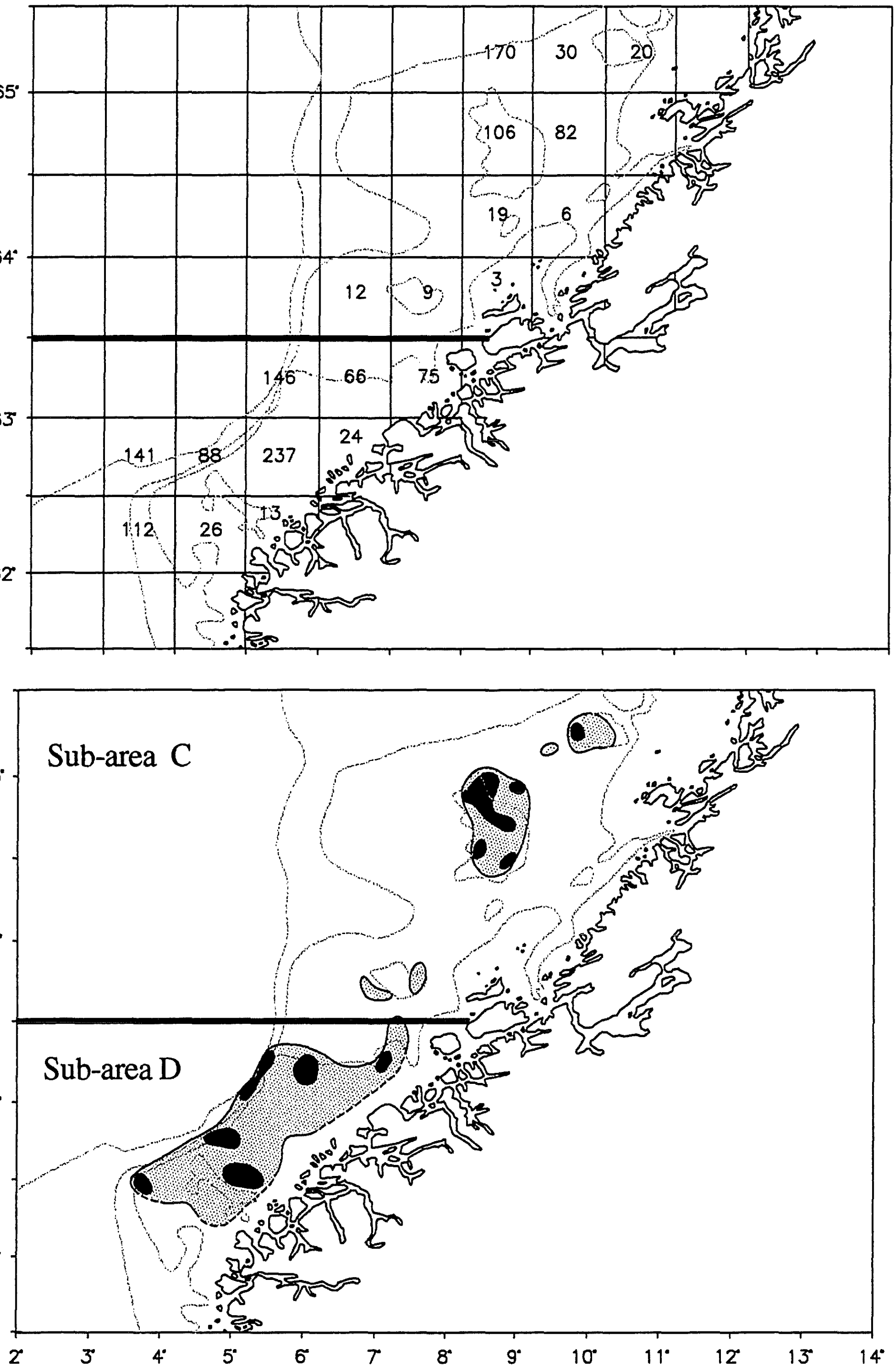


Fig.6 SAITHE. Trøndelag-Møre 1996. Mean echo abundance ($\overline{s_A}$, m^2/nm^2) in each rectangle and the most important distribution pattern. Integratorvalue $>10m^2/nm^2$ (hatched) and $>100m^2/nm^2$ (black)

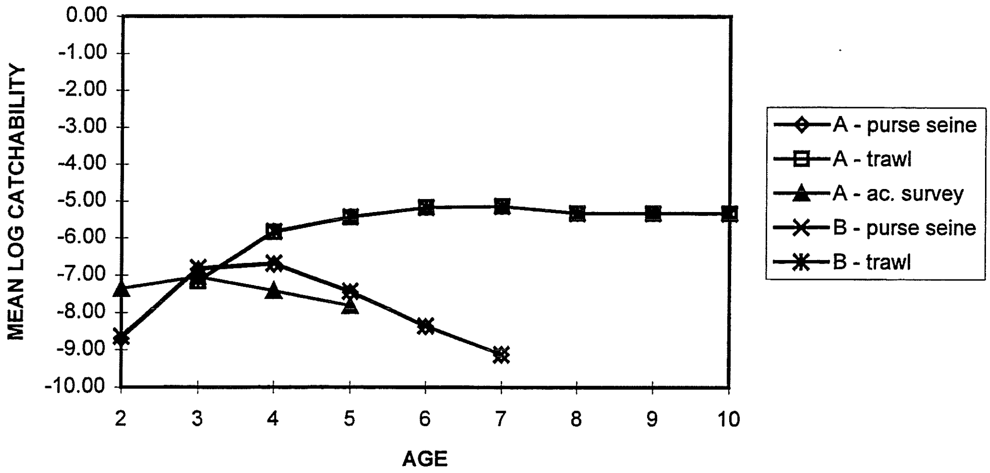


Figure 7. Mean logaritmic catchability of each of the three tuning series. A - from XSA diagnostics when acoustic survey included, B - from XSA diagnostics when acoustic survey NOT included.

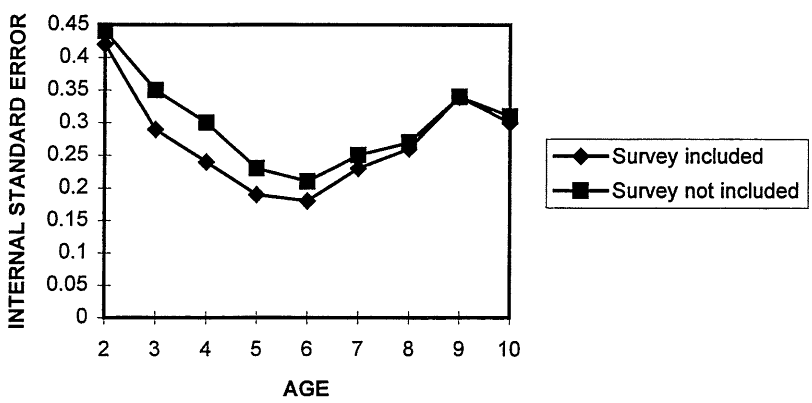
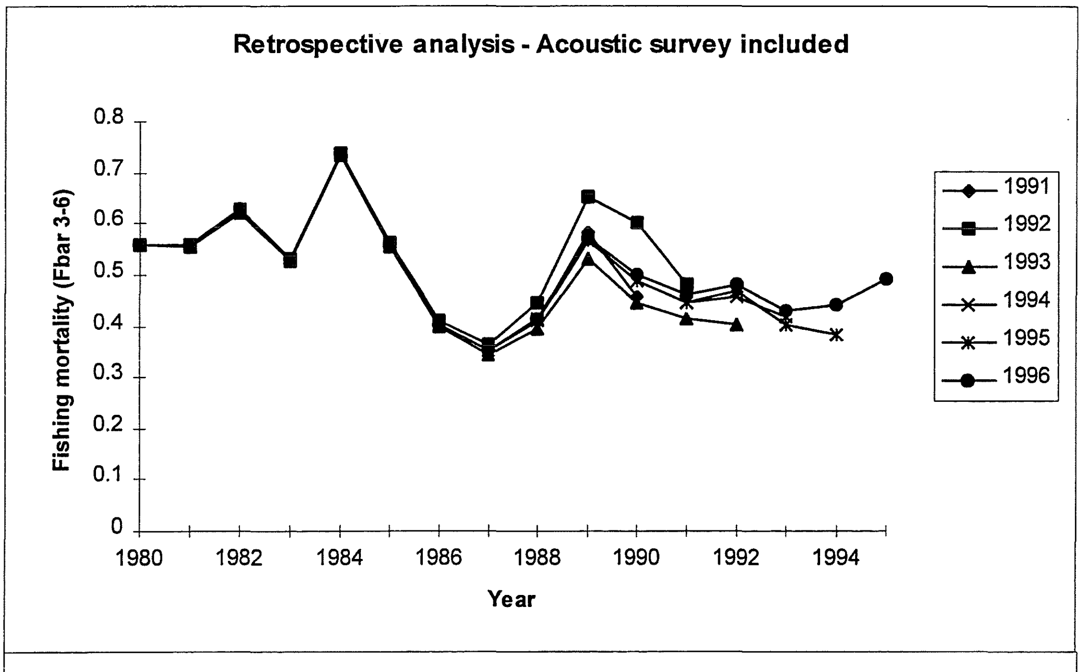


Figure 8. Internal standard error of the overall mean estimate of survivors at the end of the final year as given by the XSA diagnostics.



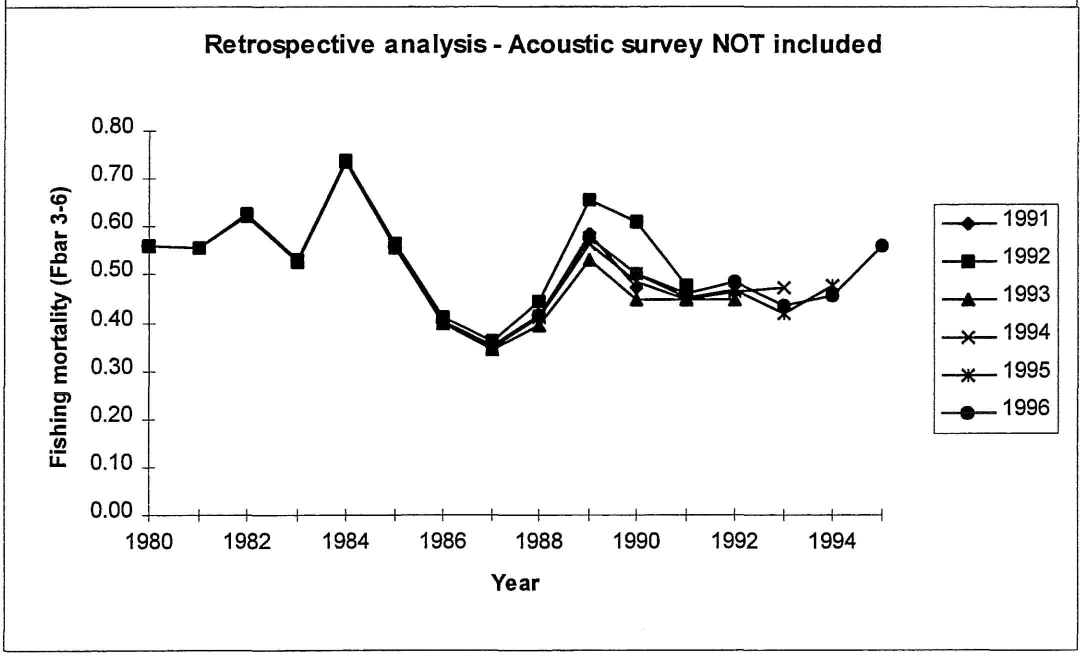


Figure 9. Retrospective analyses for both XSA alternatives.

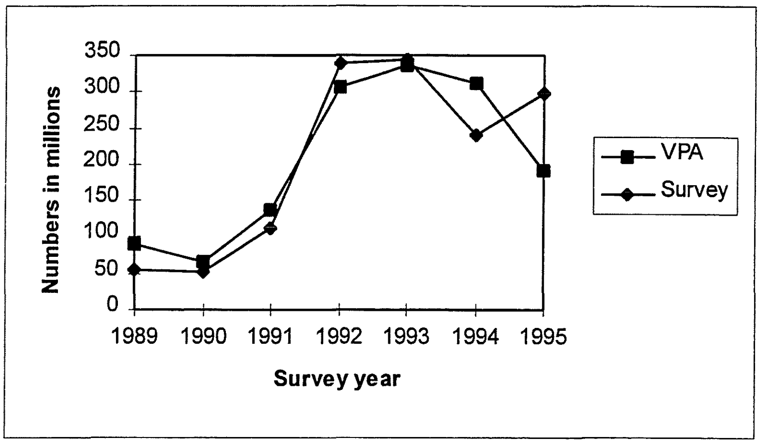


Figure 10. Numbers of 3-5 year old saithe (the VPA estimate is from 1 January two months after the survey when the saithe has become 4-6 years old) as estimated by the acoustic survey and the VPA.

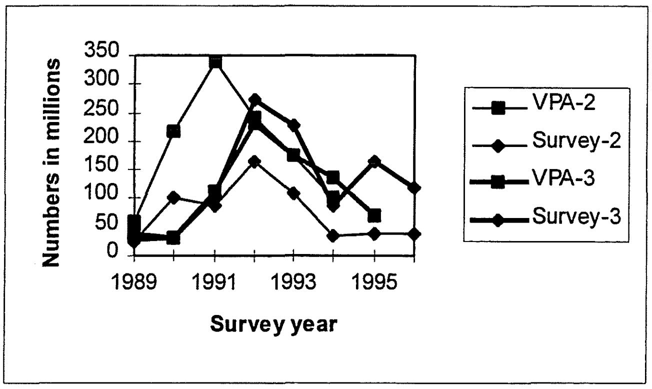


Figure 11. Numbers of 2 and 3 year old saithe (the VPA estimate is from 1 January two months after the survey when the saithe has become 3 and 4 years old, respectively) as estimated by the survey and the VPA.

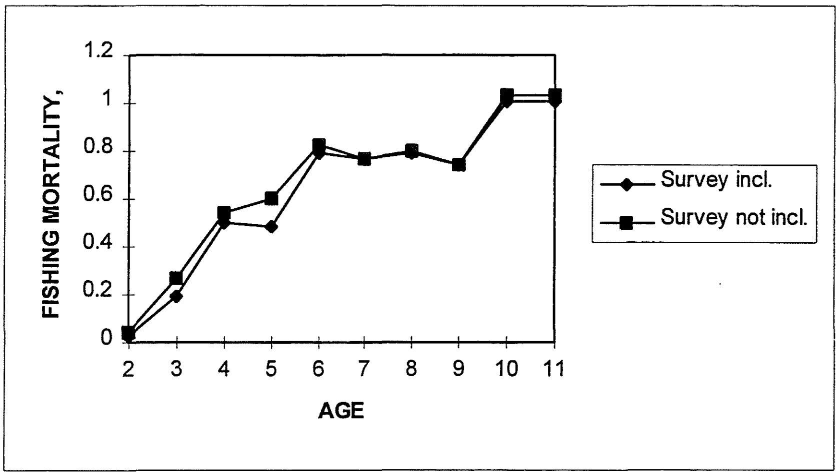


Figure 12. Fishing mortality at age in the last year in the XSA assessment.

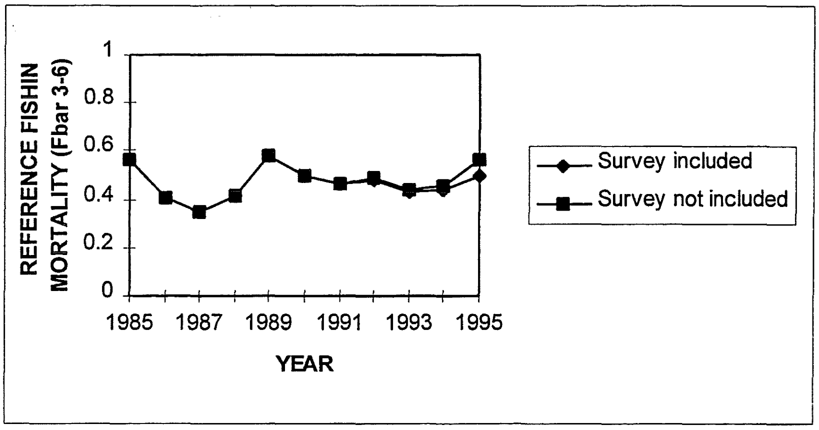


Figure 13. Reference fishing mortality (ages 3-6) from the XSA.

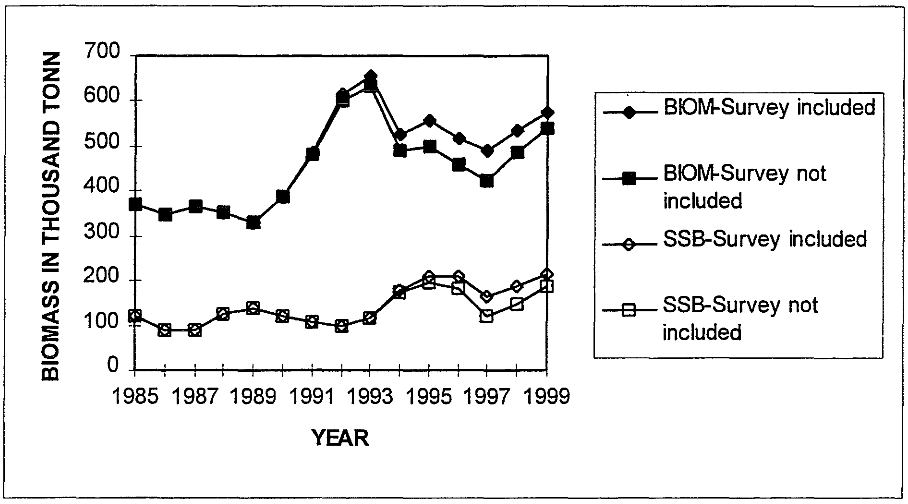


Figure 14. Total biomass (BIOM 2+) and spawning stock biomass (SSB) as estimated by the XSA up to 1 January 1996, and as predicted for the years up to 1999 with the acoustic survey included in the analysis and not.

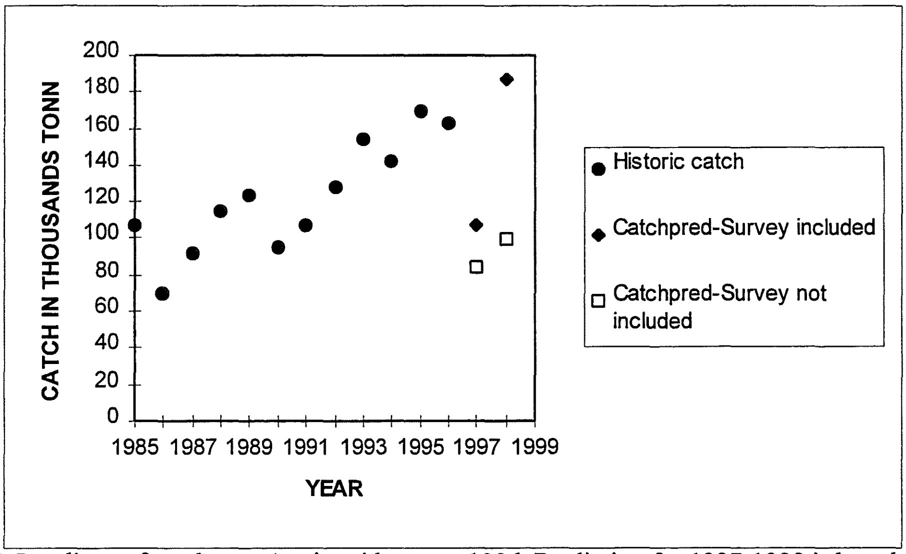


Figure 15. Landings of north-east Arctic saithe up to 1996. Prediction for 1997-1998 is based on a fishing mortality equal to Fmed.