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Analysis of the Faroese Groundfish Surveys 1983 - 1991.

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ABSTRACT

The paper presents the annual groundfish surveys as they have been conducted in Faroese water since they started in 1982. Abundance indices for cod, haddock and saithe are calculated and compared with the corresponding VPA-estimates. Factors, like the length-to-age conversion, allocation of sampling stations, stratification etc., that influence the abundance index are analysed. Some methods for improving the sampling and processing of data from a groundfish surveys are given.

INTRODUCTION

Groundfish surveys have been conducted in Faroese water with the research vessel Magnus Heinason from February to April every year since 1982. The major object of these surveys is to provide annual estimates of the abundance, age composition, information about age-length relation and species compositions of the fishstocks. This information is essential in assessing the current status of the stocks and particularly for predicting the recruitment. The surveys also provide instantaneous pictures of the fishstocks necessary for relating fish distributions and abundances to large scale seasonal and annual changes in environmental factors, and provide information on reproduction, growth and feeding interrelations.

This paper is primarily concerned with using data from earlier surveys in the planning of future surveys. Some method for improving the sapmlings and processing of data are given.

THEORY

There is a tradition to use the *stratified mean catch per standard haul* as an index for the abundance of a fish stock. In stratified theory, it is assumed that the area of interest can be divided into subareas called strata and that the fish density in each of these strata is approximately homogeneous. This roughly means that the fish present in a stratum is not concentrated in a few lumps. The term standard haul refers to hauls conducted under the same conditions (same gear, same speed, same towing time, etc.), therefore the mean catch per standard haul in a stratum is assumed to be proportional to the average fish density in the stratum. The amount of fish present in a stratum is per definition the area times the average fish density and the total amount of fish present in the area is obtained by summing over all strata. If we are just interested in an index for the amount of fish present, it is sufficient to know the average amount of fish present per unit area. To get this we divide the total amount of fish present with the area of all strata together. Mathematically this can be formulated as (Grosslein[71] and Cochran[77]):

$$y_{st} = \frac{1}{a} \sum_{h=1}^{k} a_h \, y_h$$

where

where	y_{st}	is the stratified mean catch per standard haul (trawlhour)
	a	is the area of all strata together
	a_h	is the area of the stratum h
	y_h	is the mean catch per standard haul in stratum h
	k	is the number of strata.

In a stratum the trawlstation should to be selected such that they cover representative areas and this is usually accomplished if they are selected randomly. However, there are at least three methods that can be used to decide how many trawlstations should be taken from each stratum. The simplest one is to say that the number of trawlstations in each stratum is to be proportional to its area, regardless of the amount of fish present. Usually this method leads to over representation of strata with low concentration of fish and under representation of strata with high concentration of fish. A far better method, which is called *proportional sampling*, is to say that the number of trawlstations in each stratum is to be proportional to the amount of fish present. The disadvantage of this procedure is that it requires some a priori knowledge about the concentration of fish in the area. The advantage is that it usually leads to an abundance index y_{st} with much lower variance than the first method. A theoretical optimal method is one that minimizes the standard error of y_{st}. This is achieved when the number of trawlstations in each stratum is proportional to the standard deviation of the stratum mean y_{lt}. However, since there very often will be a close to linar relationship between the estimated mean and its standard deviation, proprotional sampling will perfrom very well.

Once decided on how many trawlstations are to be placed in each stratum, there are basically two ways to pick them out. One is to pick them at random for every survey and the other is to select stations which are believed to be representative for a stratum and keep them fixed for every survey. The first one is called *random stratified sampling* and the second one *stratified sampling with fixed stations*. In the annual Faroese Groundfish Surveys random stratified sampling has always been used.

Stratified sampling is well suited for estimating the number of invertebrates on the bottom of a lake or the number of bacteria in a specimen in a laboratory etc., since these don't move very much. There are however a few drawbacks in applying this method to fish. First, in order to make the division into strata it is necessary to have some knowledge about the fish densities in the area of interests and mostly one has only a vague idea about this, since one can't see the entire area at a time. Secondly, fish are constantly on the move searching for food and many of them swim in shoals. This makes the division of the area into strata and the estimation of the fishdensities very difficult.

THE SURVEYS

In 1981 ICES and NAFO had on several occasions recommended the use of so called "fishery independent data" as a supplement to the regular samplings of landings in order to improve the estimations of the fishstocks. One way to get these data is to make a random stratified survey. In 1981 when the Fisheries Laboratories of the Faroes got the research vessel Magnus Heinason, this recommandation was adopted, in that it was decided that from 1982 this vessel should be used to carry out such surveys (Hoydal[81]).

A grid with mesh sizes 5 min. lat. x 10 min long. was placed on top of the map of Faroes to divide it into rectangles and the area within 500 m depth was divided into 20 disjoint strata (Figure 2), each made up of a whole number of rectangles, each rectangle approximately 25 square miles. Fifteen of these strata are on Faroe Plateau, two on the Faroe Bank, one on each of the Bill Bailey Banks and one on the Iceland-Faroe ridge. It was planned to make three such surveys a year in the period from February to April with approximately fifty trawlstations in each. The tows were to be taken from different rectangles and the catch in a tow was believed to be representative for the whole rectangle. The first survey, with most stations concentrated on Fugloyar Bank and on Sandoyar/Suðuroyar Bank, was aimed at saithe, the second one, with most stations in the area north and west of Faroe Islands, was aimed at cod and the third one, with the stations more scattered around the Faroe

Plateau, was aimed at haddock. It was believed that with these three surveys it was a fair chance to be at the right place at the right time when saithe, cod and haddock are spawning.

In 1991 it was decided that in the future it would be better to move the first survey aimed at saithe to late summer or autumn, since the haul to haul variation for saithe proved to be very large in the spawning season and this resulted in very poor agreement of the stock index with other estimation methods.

VESSEL AND GEAR

R/V Magnus Heinason which has been used for the surveys since they started in 1982 is a 136 feet stern trawler with a 1800 HP engine. The gear is a 116 feet box trawl with 40 mm stretched mesh size in the codend. Two different length of bridless are used dependant on depth and area. 60 meters bridelss are mostly used in the western areas, while 120 meters are mostly used in the eastern area. The trawl is towed for 60 minutes at a speed of 3 knobs. Fishing is done only during daylight.

PROCESSING OF DATA

The catch from a trawlstation is sorted into species, weighed, length measured and samples for otholiths, individual weight, sexes and maturity stage are taken. These data along with data identifying the tow (identification number, start and end position, time, depth, etc.) are fed into a computer on board. When the survey is over, the data is checked, errors corrected and transferred to the ORACLE database on Fiskirannsóknarstovan. The area in ORACLE where data from the surveys is kept is called "veidi-data". The rest of the data processing can be illustrated by the following diagram:

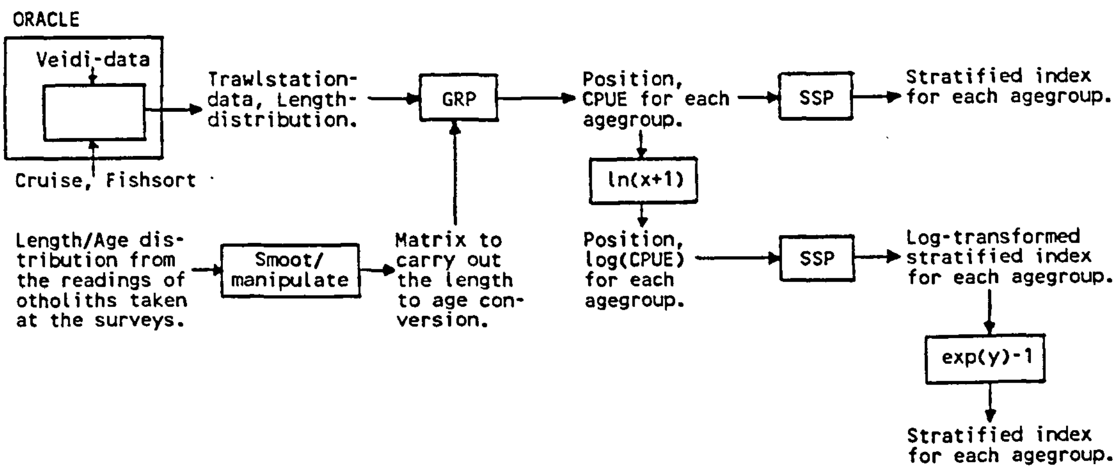


Figure 1 : Processing of data from the groundfish surveys.

Generally the number of otholiths taken during the three groundfish surveys is limited and this leads to unwanted gaps in the length distribution for some low density agegroups. In order to improve the key (matrix) which is used in the conversion, some smoothing of the length distribution for the agegroups is necessary.

It is assumed that the length distribution of a certain agegroup i at time t, originates from a normal distribution with average length $\mu_i(t)$ and standard deviation $\sigma_i(t)$. Given this, the entire length-to-age key can be represented in a (3 x n) matrix

$$K(t) = \begin{pmatrix} f_0(t) & f_1(t) & \cdots & f_{n-1}(t) \\ \mu_0(t) & \mu_1(t) & \cdots & \mu_{n-1}(t) \\ \sigma_0(t) & \sigma_1(t) & \cdots & \sigma_{n-1}(t) \end{pmatrix} \qquad \textit{where} \quad f_0(t) + f_1(t) + \dots + f_{n-1}(t) = 1$$

where the $f_i(t)$ is the *strength* or *frequency* of the i'th agegroup i.e. the fraction of all fish that were i years old. In stead of using the otholith readings directly to make a length-to-age conversion, it is better to use them to estimate the parameters f_i, μ_i and σ_i. Once these parameters have been estimated, it is easy to establish a smoothed length-to-age matrix simply by using the normal distribution function for each agegroup and scaling it with the strength.

Sometimes it is worthwhile to compare $K(t)$ with $K(t-1)$ and $K(t+1)$, especially if one of the $f_i(t)$ are found to be unrealistic for some i. If we assume that the ratio between the strength of two consecutive agegroups is the same in $K(t-1)$ and $K(t)$ and in $K(t)$ and $K(t+1)$, the following approximation formula can be used to adjust $f_i(t)$:

$$\bar{f}_i(t) = \frac{1}{5}\left[f_{i-1}(t)\left(\frac{f_{i-1}(t-1)}{f_{i-2}(t-1)} + \frac{f_{i+1}(t+1)}{f_i(t+1)}\right) + f_i(t) + f_{i+1}(t)\left(\frac{f_{i-1}(t-1)}{f_i(t-1)} + \frac{f_{i+1}(t+1)}{f_{i+2}(t+1)}\right)\right]$$

After using this formula, it is necessary to normalize the f's such that the sum of them equals one. The formula above is only one of many possibilities for smoothing out the f's, and it has only been used where it was found necessary. It ought not to be used for agegroups where heavy gear selection is involved. For the box-traws used in the annual Faroese Groundfish Surveys this means agegroups zero, one and two. By following the yearclasses in the keys, the μ's and σ's can be adjusted by fitting the average length of each yearclass to a theoretical growth equation (Ford-Walford plot). The box called "smooth/manipulate" is a collection of programs and manual procedures which take care of the key manipulation. The output is a matrix that is ready to be multiplied with the length distribution from a trawling station to get the age distribution.

A batch file has been made that, given a cruise identification number and a species as parameters, generates a SQL-select, starts ORACLE with this select, which for all trawling stations on this cruise, generates the data identifying the tow along with the length distributions for the species in the tow. The conversion from length to age is simple matrix algebra and is carried out in a program called GRP. The output from this program is a list containing the position (long., lat.) and the age distribution of the number of fish caught per trawlhour for each station in the cruise. The lists can be appended if desired. For example the three list of age distributions from the annual groundfish survey can be appended to get a list of age distributions for all three surveys together.

In order to make the analysis of data easier and to get a clear picture of the data, an interactive program called SSP (Stratified Sampling Processing) was written. The program computes the abundance index y_{st} along with its variance based on some input data selected by the user. Experimenting with different stratification schemes is easy with SSP, it can also be used to make drawings of the trawlstations and catches in each of them. A brief describtion of SSP is appended.

For shoaling species the haul to haul variation usually is very large, and it is therefore sometimes desirable to $log_e(x+1)$-transform the dataset before an index is computed in SSP and then transform the index back with a the inverse transformation $exp(y)-1$. Two programs named LOGTRANS and INVLOGTR take care of this.

METHODS AND RESULTS

In the analysis only cod, haddock and saithe from the Faroe Plateau are considered. The stratification of the Faroe Plateau out to 500 m can be seen in Figure 2. The indices, which are the stratified mean catch at age in number per trawlhour, for cod, haddock and saithe have been computed for the period 1983 to 1991. The results are given in Table 1, 2 and 3, respectively.

The indices for cod show that the size of the cod stock remained fairly stable in the period 1983 to 1985, but from 1985 to 1986 it was more than doubled. This factor, which is rather high, can partly be explained by the large 1981 and 1982 yearclasses entering the catches. In the period 1987 to 1991 the size of the cod stock was reduced to one sixth of the 1987 value. This alarming result is partly due to the absence of any new large yearclasses in the period and partly due to heavy fishing on all agegroups above 3 years old. All in all, the cod stock has been reduced to one third in the period 1983 to 1991. This is in good agreement with what fishermen say, but not with the 1991 VPA estimates (Table 4). The VPA-estimates for agegroups 2 to 7 years have been plotted against the stratified indices for the same agegroups for the period 1983 to 1988 (top of page 14). The VPA needs a couple of years to stabilize due to its retrospective nature, therefore results for 1989, 1990 and 1991 have not been used.

The indices for haddock (Table 2) tell us that the size of the haddock stock was more than doubled from 83 to 84. This seems unrealistic, but can be explained by an under estimation of the 1982 yearclass in 1983. In 1983 the index for this yearclass was 48.09 and in 1984 it was 116.4. In the period 1984 to 1986 the size of the haddock stock remains fairly stable, but later, in the period 1986 to 1991, there are some pretty heavy fluctuations. It is unrealistic that the stock is reduced to one seventh from 1989 to 1991. Following the yearclasses in the indices shows that the 1989 index generally is too high and the 1991 index perhaps too low. It can be seen from the indices that the 1977, 1978 and 1979 yearclasses were very small, while the 1982, 1983, 1984 and 1986 seem to be pretty large. On the middle of page 14 the VPA estimates from Table 5 for two to seven years old haddock have been plotted against the same agegroups from the stratified indices for 1983 to 1988. Apart from agegroup 2 and 7 the correlation between the two estimates is as good as can be expected. The bad correlation for agegroup 2 can be explained with the insufficient sampling of small haddock. Most of the small haddock comes from the unsorted samples, which only partly are measured and therefore the data for agegroup 1 and 2 are pure conjecture.

Saithe is much more difficult to analyze, since there are very heavy fluctuations on the indices. From the indices (Table 3) it can be seen, that saithe does not enter the catch before is three years old. This is because saithe spends the first two years of its life in shallow water near the coast, where it is not possible to trawl. Furthermore, it can be seen that the

1978, 1983 and 1984 yearclasses were pretty large. The VPA estimates from Table 6 for three to eight years old saithe have been plotted against the same agegroups from the stratified indices for 1983 to 1988 on the bottom of page 14. The correlation between these two estimates is bad for all agegroups except for agegroup five. No doubt, this is because the fluctuations on the indices from year to year are so large. This obviously has something to do with the spawning behavior of saithe, which makes the haul to haul variations in the survey so large. Hopefully, better indices for saithe can be achieved from the summer/autumn groundfish surveys, which was started on in 1991.

Cruises

From 1983 to 1990 three groundfish surveys were conducted a year in the period from February to April. The first cruise was aimed at saithe, the second at cod and the last at haddock. Different strata weighting, that is the number of stations picked in each stratum, has been used in the surveys (Table 9). Therefore one might expect that one of the cruises or a combination of them gives a better indices for a specific species than the others. Now, there are very few ways to test how good an index is, other than to compare it with something that one believes is right. Therefore the indices from every single cruise and combination of them for six selected agegroups for cod, haddock and saithe have been compared with the VPA estimates for the corresponding agegroups. In Table 7 the correlationcoefficients (r^2) between stratified indices and the VPA estimates for agegroup 2 to 7 for cod and haddock and agegroup 3 to 8 for saithe have been computed for all combinations of cruises. Let us say, that the best cruise for a species is the one that gives the highest corrolation coefficient for all agegroups. We then see from the table, that the best single cruise for cod is Cruise 3, the one aimed at haddock and the best combination of cruises for cod is Cruise 2+3, i.e. the cruises aimed at cod and haddock combined. This combination is even better than all three cruises joined together. The worst single cruise for cod is not surprisingly Cruise 1, the one aimed at saithe. For haddock the best single cruise is Cruise 2, the one aimed at cod, and the best combination of cruises is again Cruise 2+3, a little bit better than all three cruises joined together. Surprisingly, the worst single cruise for haddock is Cruise 3, the one aimed at haddock. For saithe, non of the cruises give indices that are very well correlated to the VPA, but the best single cruise is not surprisingly Cruise 1, the one aimed at saithe. The worst single cruise for saithe is Cruise 3, the one aimed at haddock. Because the indices for saithe are so bad, it seems to be a good idea to move the cruise aimed at saithe to some other time of year, outside the spawning season and since the best results for cod and haddock are obtained from Cruise 2+3, it also seem a good idea to join these two cruises into a single cruise with the same amount of trawlstations as both of them together.

Poststratification

The aim of a stratification is to define a limited number of strata in which the variation in fish densities is minimal. A poststratification therefore is a redefinition of strata that seeks minimize the variation in fish densities in each stratum. It is possible to get a picture of the concentration of fish in an area by looking at the mean catch per trawlhour in a trawlstation for a period of time. However, it is necessary to compensate for variations in the sizes of the fishstocks in the period. What is needed is a measure for the quality of each rectangle in the target area which is independent of variations in stocksize. Let us define the *quality of a rectangle* as the ratio between the amount of fish present in the rectangle and the amount of fish present in an average rectangle. If we assume that the spatial distribution of a species is independent of the variation in the stocksize, we have a quality measure that also is independent of the variation in the stocksize. What we mean by this is, that the fraction of fish present in a subarea is the same whether the fishstock is small or large. If a rectangle is selected in a number of surveys, we can estimate the quality of the rectangle, simply by taking the average over the surveys of the catch in the rectangle divided by the average catch per rectangle in the survey. This sounds complicated, but it can be formulated very simply mathematically, if we have an enumeration of all rectangles in the target area. If the i'th rectangle is selected in n survey conducted at time $t_1, t_2 \dots t_n$ and $C_i(t)$ and $\overline{C}(t)$ is the catch in the i'th rectangle and the average catch per rectangle at time t respectively, we can estimate the quality Q_i of the i'th rectangle as follows

$$Q_i = \frac{1}{n}\left(\frac{C_i(t_1)}{\overline{C}(t_1)} + \frac{C_i(t_2)}{\overline{C}(t_2)} + \dots + \frac{C_i(t_n)}{\overline{C}(t_n)}\right)$$

perhaps a geometrical mean is preferable if none of the $C_i(t)$ or $\overline{C}(t)$ is zero

$$Q_i = \left(\frac{C_i(t_1)}{\overline{C}(t_1)}\,\frac{C_i(t_2)}{\overline{C}(t_2)} \dots \frac{C_i(t_n)}{\overline{C}(t_n)}\right)^{\frac{1}{n}}$$

Having an estimate of the quality of most of the rectangles, we are able to optimize the stratification by grouping together adjoining high concentration rectangles, medium concentration rectangles and low concentration rectangles.

This procedure has been used to make poststratification schemes for cod, haddock and saithe. Since the catch is zero for many trawlstations, only the first formula with the arithmetical mean has been used. For cod and haddock some improvement on the stratified abundance indices have been observed, but not for saithe. In fact for saithe a simple mean is better than any of the stratification schemes. However, to get a perceptible improvement, one has to plan the survey in accordance to the stratification, that is the number of stations allocated in a stratum is to be proportional to the amount of fish present, and this cannot be done in a poststratification unless some stations are discarded. The rectangle quality can be used in the planning of a groundfish survey to set the number of stations to be picked from each stratum, simply by letting the number be proportional to the product of the area and average rectangle quality for each stratum.

Figure 4 on shows a map of the Faroes, made with the SSP program, where the rectangle qualities for all agegroups of cod are depicted. From this map it can be seen, that in the spawning season there are two high concentration areas for cod north and west of the Faroes and one medium concentration area east of the Faroes. This has lead to a cod stratification of the Faroese Plateau with nine strata shown in Figure 5. Actually, one could do with five or six strata, but it was considered convenient to have a north-south and east-west division of the area.

In Figure 6, the rectangle qualities for all agegroups of haddock are shown. From the map it can be seen that there ar two high concentration areas east and southwest of the Faroes and two medium concentration areas northeast and southeast of the Faroes. This has lead to a haddock stratification of the Faroese Plateau with eight strata shown in Figure 7. Again, it was found convenient to have a north-south and east-west division of the area.

In Figure 8, the rectangle qualities for all agegroups of saithe are depicted. From the map it can be seen, that saithe is mostly found in areas where the depth is between 200 and 500 meters. Within the 100 meter zone saithe is occasionally found in large shoals, this is probably fish that for a very short period of time enters shallower waters to spawn. It is difficult to allocate strata that covers the high concentration areas for saithe other than to lay a zone around the 200 meter depth line, but it seems that there is a little higher concentration north and south of the Faroe Islands. The saithe stratification in Figure 9 divides the Faroe Plateau into seven distinct strata with two high concentration strata north and south of the Faroes, two small medium concentration areas east and west of the Faroes and three low concentration areas. No doubt, there exists better stratification schemes for saithe.

In order to see the effect of the restratifications, three series of indices for the period 1983 to 1989 have been made. In the first series the entire Faroe Plateau was made into one single stratum, after which indices for cod, haddock and saithe have been computed. This amounts to having no stratification of the area, and the indices being a simple mean of the catches in the area. In the second series the original stratification of the Faroe Plateau (Figure 2) has been used. In the third series the cod stratification (Figure 5) has been used to compute the indices for cod, the haddock stratification (Figure 7) to compute the indices for haddock and the saithe stratification (Figure 9) to compute the indices for saithe. For each of these three series of indices, six agegroups of cod, six of haddock and six of saithe have been selected for comparison with the corresponding agegroups in the VPA estimates. In Table 8 the correlation coefficients (r^2) between agegroups 2 to 7 for cod and haddock and agegroups 3 to 8 for saithe from the VPA estimates and the same agegroups from the three series have been computes. Let us say, that the best stratification for a species is the one that gives the best correlation for all agegroups. From Table 8 it can be seen that the restratification for cod in Figure 5 gives an unmistakable improvement to the cod-indices for almost every agegroup. Furthermore, it can be seen that the original stratification for many agegroups of cod is worse than no stratification at all. For haddock and saithe some improvement are observed with a restratification on the youngest agegroups, but all in all, it makes little difference for the correlation between VPA and the indices whether no stratification, the original stratification or a restratification is used. One reason for this might be, that there is an unbalance between the allocation of trawlstations and the spatial distribution of fish in the area. Too many trawlstations are in low concentrations areas and too few in high concentration areas. It is therefore worthwhile to investigate how trawlstations are allocated and how they ought to be allocated.

The rectangle quality can be used in the planning of a groundfish survey to set the weighting of strata, that is the number of trawlstations to be picked form each stratum. Let us say, that *the weighting of strata is optimal for a species* when the number of trawlstations in each stratum is proportional to the average rectangle quality for this species times the area of the stratum. If all rectangles are of equal size, the number of rectangles in a stratum can be used as a measure for the area of the stratum. So to compute the optimal strata weighting for a species, we compute the average rectangle quality for each stratum, multiply it with the area (or number of rectangles in the stratum). The numbers thus obtained are then divided with the sum of them to produce the optimal strata weighting for the species in question. The actual weighting of strata used in the surveys can be found by looking through the list of trawlstations for every cruise in the period from 1983 to 1991 and count how many of them there are in each stratum.

The optimal strata weighting in percent for cod, haddock and saithe along with the actual weighs used in the surveys in the period from 1983 to 1991 are given in Table 9 for each cruise separately and for all of them together. From the table it can be seen, that for cod, stratum 1 and 2 have been underweighted, while stratum 5 and 7 have been overweighted for all cruises. For haddock the weighting is more balanced, although stratum 3 has been a little underweighted and stratum 4 and 14 have been overweighted for all cruises. For saithe stratum 6 and 15 have been underweighted, while stratum 1, 5 and 12 have been overweighted. Unfortunately the correct weighting of strata doesn't help very much if the strata aren't correctly allocated, therefore the optimal strata weighting for the restratifications for cod, haddock and saithe have been computed in Table 10, along with the actual weighting of these strata used in the surveys. From this it can be seen, that the distribution of trawlstations could be better for all species.

DISCUSSION

An interesting question is, how are we to pick the trawlstations for a groundfish survey aimed at more than one species. The question is very relevant, since one is interested in getting as much information about as many species as possible from a survey. Well, there are many answers to this, but here is one that is simple to implement.

Let us say that we are interested in making a random stratified survey aimed 45 percent at cod, 40 percent at haddock and 15 percent at saithe. If we have one month to conduct the survey, there is time enough to do about 100 one-hour tow in daylight, sailing time included. Given this, we proceed as follows. 45 trawstations are picked randomly using the cod stratification (Figure 5) and corresponding optimal weighting of strata (Table 10), 40 trawlstations are picked randomly using the haddock stratification (Figure 7) and the corresponding optimal weighting of strata and 15 stations are picked randomly using the saithe stratification (Figure 9) and the corresponding optimal weighting of strata. If we insist on having no trawlstation being selected more than once, we simply pick a new one if it has been selected earlier.

There are at least two drawbacks in using the rectangle quality to make the stratification and the corresponding optimal weighting of the strata. The first is, that in order to get the rectangle qualities for the area of interest, some knowledge about the catch data in the area has to be available. So, if no such data is at hand, it is necessary to conduct (unstratified random) surveys until these data become available. The second drawback is, that the rectangle quality might change with time. If one subarea becomes exhausted due to overfishing, the rectangle quality as defined earlier will not give a correct picture of the spatial distribution of fish in the area at the moment, since the data used to find the rectangle qualities is from a period when there was plenty of fish in the subarea. This situation is depicted in Figures 10, 11, 12 and 13, which show the rectangle qualities for cod and haddock for the period 1983 to 1987 and the period 1988 to 1991. It is evident form these pictures, that the high concentration of cod north of the Faroe Islands in the spawning season found in the period 1983 to 1987 is not so distinct in the period 1988 to 1991, while there seems to be a much higher concentration of haddock in the areas east and south-west of the Faroes in the period 1988 to 1991 than in the period 1983 to 1987.

The large variance of the abundance indices for saithe (not included in this paper) indicates a large haul to haul variation. This can be interpreted as shoaling behaviour of saithe the spawning season. The spawning pattern for saithe is not very well known, but one explanation for the large haul to haul variation might be, that it enters shallow water just to spawn. Since the spawning period for saithe very short and varies form year to year, it is impossible in advance to say when the survey aimed at saithe is to be carried out in order to cover the spawning. Some surveys aimed at saithe are conducted in the middle of the spawning and others before and after. The consequences are large fluctuations in the level of the indices. Therefore, if the purpose of a groundfish survey is to get an index for the abundance of saithe, it is not advisable to carry it out in the spawning season. Another explanation might be that saithe migrates between contries. Tagging experiments carried out in the late fifthies showed that old saithe migrates between Norway, Faroes Islands and Iceland (Olsen[59]).

The faroese cod concentrates in two areas north and west of the Faroes in the spawning season and this makes the division into strata and the estimation of the fishdensities relatively easy. The same concentration is not found for haddock, but the spatial distribution of haddock seems to be pretty stable, so also here the allocation of strate goes smoot. But the numbers for small haddock indicates some irregularities that might come from poor sampling. Much of the small haddock comes from the unsorted samples which only partly is measured.

For saithe it was tried to log-transform the data before computing the indices and to transform the index back using the invers transformation. This facillity reduced the variance of the abundance indices, but it did not make the agreement with the VPA estimates any better. To log-transform data before an index is computed and to transform the computed index back using the invers transformation, corresponds to computing the geometrical stratified mean rather than the arithmetical stratified mean.

REFERENCES

Cochran, W. G. (1977) : Sampling Techniques, third edition
John Wiley and Sons, Inc.

Hoydal, K. (1981) : Yvirlitstrolingar við Magnus Heinason.
Internal report by the Fisheries Laboratory. 10 pp. (In faroese).

Kristiansen, A. (1988) : Results from tha groundfish surveys at Faroes 1982 - 1988.
ICES C.M. 1988/G:41. 16 pp.

Olsen, S. (1959) : Migrations of Coalfish from Norway to Faroe Islands and Iceland.
ICES C.M. 1959/No12. 5 pp.

Pennington, M. R.,
Grosslein, M. D. (1978) : Accuracy of abundance indices based
on stratified random trawl surveys
ICES C.M. 1978/D:13. 35 pp.

APPENDIX

A brief description of the SSP program.

SSP is an interactive program to assist the user in analyzing the data. Basically this program is an electronic version of the map of the area around Faroe Islands. But it is more than that, the map is divided into rectangles, the same rectangles that are used in the stratification of the area around the Faroes. Each of this rectangles can contain a sample, which doesn't have to be a single value. In the program a sample is represented as a 15 dimensional vector, in order to contain the age distribution from a trawlstation. When the position and the sample from a trawlstation is loaded, SSP uses the position to place the sample in the rectangle where it belongs. A dot on the map indicates that this rectangle contains a sample, and the size of the dot shows the size of the sample. Actually, it is only possible to view one entry of the sample vectors at a time, but with a single keystroke another entry can be viewed. In this manner the spatial distribution of a certain agegroup (or all of them together) from a survey can be viewed. Figure 3 shows the user interface of the SSP program.

SSP gives the user the possibility to built and change a stratification. A stratification is a set of strata, and each stratum is simply a set of rectangles, so by specifying which stratum a rectangle is to belong to, a stratification can be built up. Once the user is satisfied with the stratification, it can be given a name and saved for later retrieval. Based on this stratification SSP can compute a the stratified index. This index and its variance is displayed on the screen and saved in a result file. The format of this result file is such, that it is ready to be imported in a spreadsheet, where graphs, diagrams, comparison with other data such as results from VPA can be made.

In a typical analyses session with the SSP program, the user select a stratification to be used, reads a dataset (the age distributions for all trawlstations in a survey), computes the abundance index, clears the data, read another dataset, computes the index and so on. Datasets can be combined simply by reading them one after another.

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Sum
1983	0.066	4.719	26.02	17.93	14.49	5.318	1.476	0.512	0.079	0.521	0.296	0.000	0.000	0.000	71.43
1984	0.326	11.57	22.65	16.85	5.341	3.472	1.398	0.142	0.000	0.192	0.000	0.000	0.000	0.000	61.94
1985	0.119	3.962	43.99	16.34	6.718	1.431	1.776	0.673	0.000	0.000	0.000	0.000	0.000	0.016	75.02
1986	0.000	0.840	27.80	101.6	29.68	12.90	6.398	4.409	1.366	0.000	0.000	0.000	0.000	0.015	185.0
1987	0.000	1.277	20.38	46.80	66.15	10.38	1.129	1.499	0.000	0.179	0.000	0.000	0.000	0.000	147.8
1988	0.056	1.977	14.14	25.31	17.83	19.00	3.704	0.922	0.280	0.157	0.000	0.025	0.000	0.009	83.41
1989	0.000	4.462	6.165	10.65	8.939	4.420	7.196	0.709	0.000	0.161	0.000	0.000	0.000	0.000	42.70
1990	0.000	0.000	8.902	16.99	15.15	4.861	6.131	4.119	0.690	0.000	0.119	0.000	0.000	0.000	56.96
1991	0.000	2.546	3.550	12.32	3.173	1.514	0.517	0.117	0.230	0.072	0.000	0.000	0.000	0.000	24.04

Table 1 : Stratified mean catch in number per trawlhour of cod.

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Sum
1983	48.09	27.82	16.75	2.337	1.735	0.000	6.243	2.188	2.529	0.862	0.236	0.000	0.000	0.000	108.8
1984	114.8	116.4	23.12	10.31	0.470	0.573	0.212	1.994	0.720	1.654	0.667	0.195	0.000	0.090	271.2
1985	200.6	67.25	35.04	6.681	2.151	0.000	0.285	0.181	1.019	0.208	0.000	0.419	0.000	0.000	313.8
1986	26.60	114.6	48.54	22.35	4.322	0.804	0.000	0.100	0.328	0.581	0.401	0.611	0.000	0.000	219.2
1987	42.25	11.65	26.88	17.19	8.914	1.582	0.000	0.000	0.000	0.000	0.134	0.000	0.000	0.000	108.6
1988	41.00	88.49	15.83	22.53	11.46	3.721	0.951	0.131	0.097	0.052	0.054	0.100	0.000	0.000	184.4
1989	42.71	150.0	115.2	8.691	24.28	33.33	20.29	2.460	0.000	0.000	0.000	0.000	0.000	0.018	397.1
1990	3.109	47.96	65.52	24.74	2.591	7.939	8.057	3.905	0.896	0.140	0.000	0.000	0.000	0.000	164.9
1991	5.189	19.97	14.05	10.16	4.012	1.555	1.165	0.322	0.106	0.000	0.000	0.000	0.000	0.015	56.54

Table 2 : Stratified mean catch in number per trawlhour of haddock.

Year\Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Sum
1983	0.908	0.000	38.85	8.226	21.49	3.075	1.043	0.000	0.760	0.000	0.000	0.734	0.000	0.209	75.30
1984	0.000	0.000	10.02	41.58	7.782	6.467	0.856	0.455	0.427	0.159	0.166	0.145	0.077	0.533	68.67
1985	0.076	0.000	5.930	48.43	25.53	3.942	4.877	0.494	0.584	0.274	0.000	0.311	0.000	0.223	90.68
1986	8.672	0.000	19.03	6.144	5.558	4.377	0.894	0.778	0.287	0.162	0.067	0.000	0.000	0.188	46.15
1987	0.000	5.481	19.71	26.99	7.177	3.463	0.874	0.759	0.137	0.196	0.000	0.000	0.000	0.137	64.91
1988	0.331	0.000	19.41	27.28	48.58	5.063	1.925	0.838	0.279	0.529	0.030	0.000	0.000	0.055	104.3
1989	0.000	0.000	8.880	31.62	14.87	14.38	1.772	0.727	0.000	0.000	0.000	0.000	0.000	0.000	72.25
1990	0.275	0.000	8.753	42.09	41.64	13.27	4.408	0.488	0.000	0.108	0.000	0.095	0.000	0.037	111.2
1991	0.354	0.000	2.408	6.492	6.188	5.146	2.083	1.065	0.295	0.157	0.000	0.300	0.000	0.000	24.49

Table 3 : Stratified mean catch in number per trawlhour of saithe.

Year\Age	2	3	4	5	6	7	8	9	10+	Sum
1983	25310	17238	7194	6403	2484	865	307	245	240	60649
1984	49891	19080	8940	3419	2788	959	255	112	217	85661
1985	18690	36883	10822	4198	1493	1465	504	136	167	74457
1986	10681	14402	21677	5541	1943	536	425	138	112	55455
1987	12781	8555	8569	10174	2415	781	228	216	81	43800
1988	12992	10232	5778	4673	5563	1249	439	126	95	41146
1989	31295	10177	6469	2987	2495	2605	582	209	33	56842
1990	8326	23484	6291	3228	1387	1074	1192	269	140	45392
1991	0	6588	16550	3763	1846	758	604	704	264	

Table 4 : Yearclass strength (thousands) for cod from the VPA (NWWG 1991).

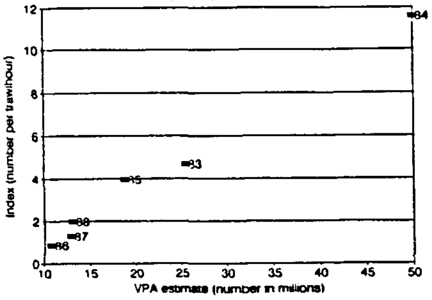
Year\Age	2	3	4	5	6	7	8	9	10+	Sum
1983	28615	18638	2205	2445	821	8515	4274	5168	4339	75020
1984	69521	23029	13484	1460	1622	589	5671	2833	7068	125278
1985	66602	55839	17447	8824	1063	1117	444	3868	7482	162687
1986	43149	53639	41611	12305	6106	718	833	309	3094	161764
1987	12998	35120	41616	30055	8703	4334	553	565	3929	137873
1988	34827	10387	27203	30857	21927	6122	3072	378	2708	137480
1989	14623	27917	8100	20031	22502	16006	4580	2378	1455	117592
1990	8978	11914	21474	6032	13866	16100	11308	3258	1301	94232
1991	0	7239	8399	15536	4123	9506	11152	8317	3331	

Table 5 : Yearclass strength (thousands) for haddock from the VPA (NWWG 1991).

Year\Age	3	4	5	6	7	8	9	10	11	12	13	14+	Sum
1983	39628	11335	17976	4021	1663	877	555	618	446	221	99	1649	79087
1984	24496	30204	8286	10182	2088	846	415	211	418	277	93	907	78421
1985	20279	19723	14816	4666	4674	927	448	195	126	283	174	686	66997
1986	59195	15498	12559	7131	2758	2129	514	274	126	80	167	206	100638
1987	42949	47411	10890	6275	2515	1404	783	202	131	43	36	264	112903
1988	45448	33737	33597	5486	2649	1173	673	343	93	69	31	0	123298
1989	21038	36426	24957	18917	2006	1007	407	228	139	52	18	246	105442
1990	6756	16811	24360	15598	9006	923	332	166	112	64	33	74	74235
1991	0	5266	10313	10882	4570	2858	330	161	81	38	36	34	

Table 6 : Yearclass strength (thousands) for saithe from the VPA (NWWG 1991).

Cod 2 year (1983 - 1988)



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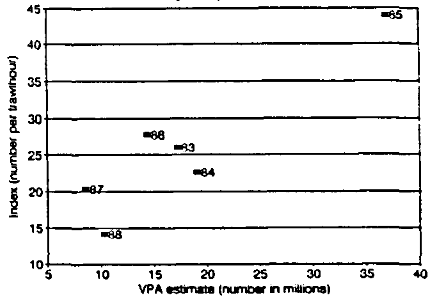

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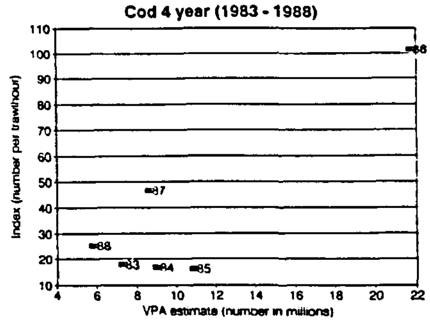
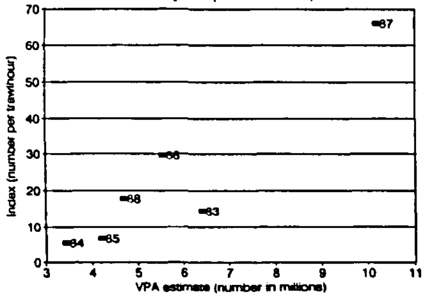


Cod 5 year (1983 - 1988)



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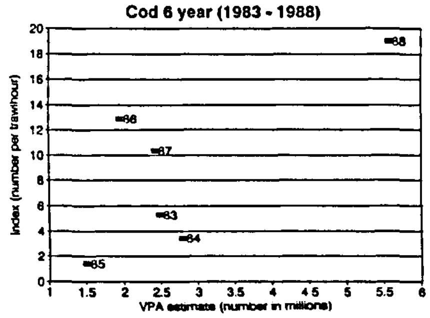
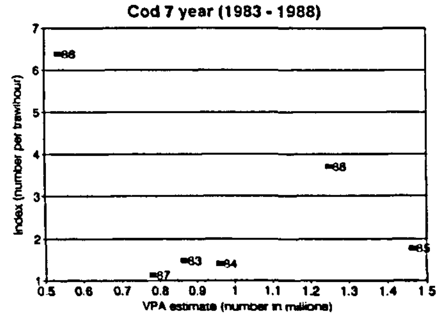
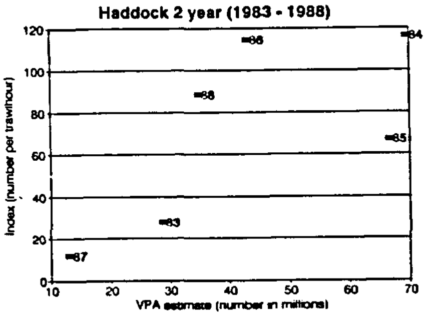


Cod 7 year (1983 - 1988)



Haddock 2 year (1983 - 1988)



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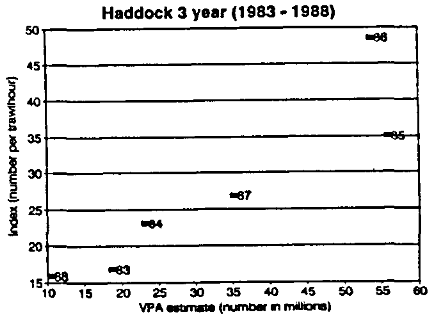

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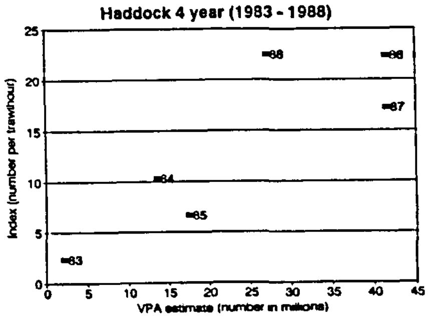

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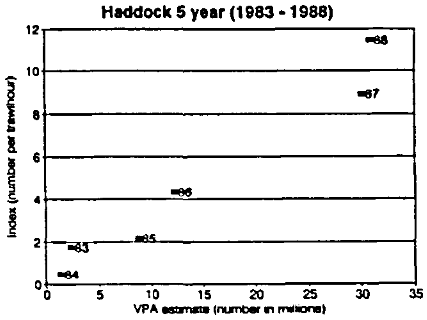

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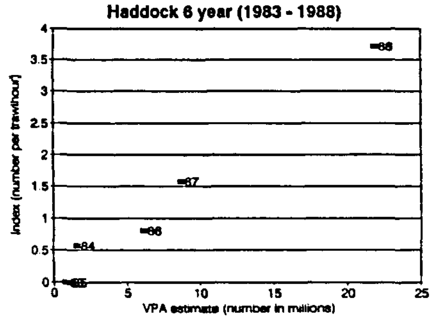
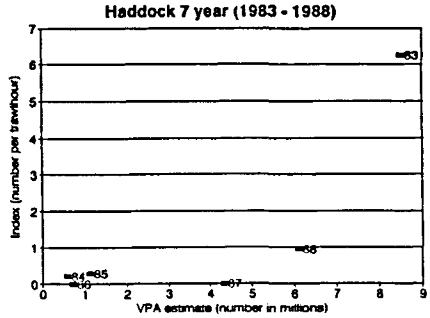
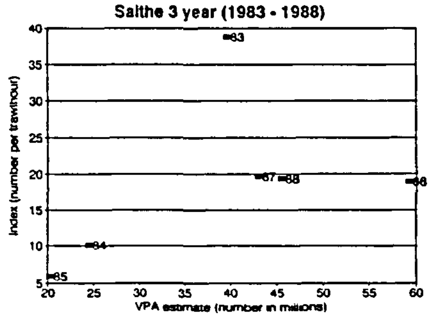


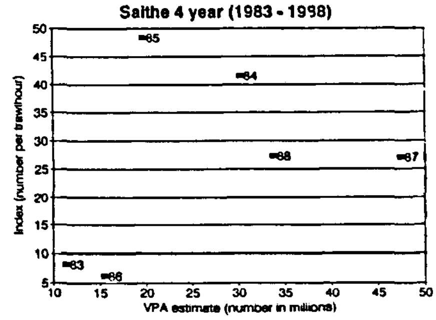
Haddock 7 year (1983 - 1988)



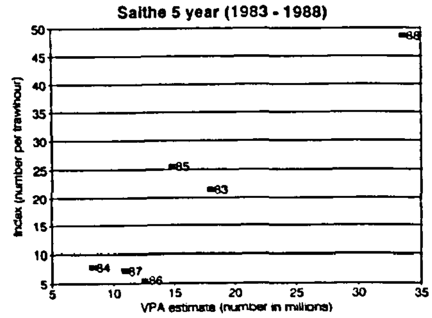
Saithe 3 year (1983 - 1988)



Saithe 4 year (1983 - 1988)



Saithe 5 year (1983 - 1988)



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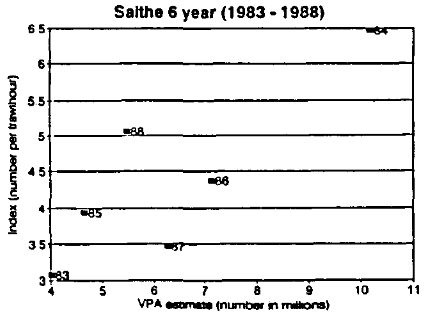
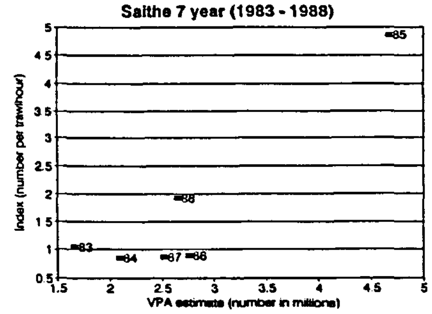
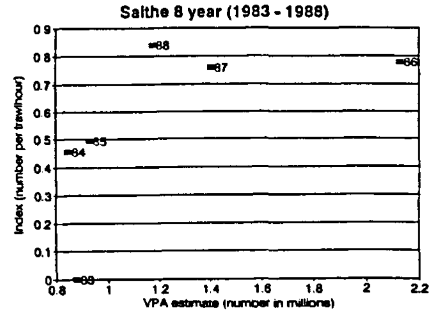


Saithe 7 year (1983 - 1988)



Saithe 8 year (1983 - 1988)



Fishsort	Agegroup	Cruise 1	Cruise 2	Cruise 3	Cruise 1+2	Cruise 1+3	Cruise 2+3	Cruise 1+2+3
Cod	2	0.93	0.85	0.98	0.91	0.98	0.94	0.98
	3	0.00	0.60	0.37	0.55	0.24	0.95	0.74
	4	0.90	0.69	0.54	0.85	0.86	0.80	0.87
	5	0.00	0.03	0.87	0.03	0.85	0.78	0.68
	6	0.42	0.47	0.02	0.41	0.30	0.33	0.38
	7	0.09	0.20	0.20	0.19	0.15	0.23	0.20
Haddock	2	0.53	0.71	0.06	0.72	0.22	0.25	0.38
	3	0.44	0.81	0.59	0.85	0.75	0.74	0.81
	4	0.58	0.88	0.59	0.77	0.57	0.86	0.73
	5	0.90	0.98	0.85	0.93	0.89	0.94	0.91
	6	0.95	0.93	0.96	0.98	0.97	0.98	0.98
	7	0.62	0.57	0.80	0.61	0.68	0.70	0.66
Saithe	3	0.36	0.05	0.00	0.24	0.18	0.06	0.18
	4	0.01	0.63	0.02	0.00	0.00	0.34	0.01
	5	0.87	0.79	0.85	0.87	0.91	0.93	0.93
	6	0.44	0.23	0.00	0.60	0.24	0.25	0.64
	7	0.83	0.32	0.14	0.90	0.78	0.31	0.79
	8	0.62	0.15	0.50	0.67	0.77	0.72	0.70

Table 7: Correlation (r^2) between VPA estimates and stratified indices from groundfish surveys 1983 - 1988 for various cruise combinations (original stratification).

Fishsort	Agegroup	No stratification	Original stratification	restratified
Cod	2	0.95	0.95	0.88
	3	0.59	0.72	0.82
	4	0.84	0.88	0.82
	5	0.91	0.70	0.82
	6	0.74	0.38	0.85
	7	0.48	0.07	0.61
Haddock	2	0.12	0.02	0.18
	3	0.13	0.05	0.15
	4	0.69	0.72	0.64
	5	0.37	0.38	0.49
	6	0.51	0.52	0.54
	7	0.88	0.87	0.88
Saithe	3	0.27	0.25	0.54
	4	0.01	0.02	0.00
	5	0.73	0.74	0.69
	6	0.92	0.93	0.90
	7	0.65	0.70	0.82
	8	0.51	0.60	0.49

Table 8: Correlation (r^2) between VPA estimates and stratified indices from groundfish surveys 1983 - 1988 for various stratification schemes (all cruises combined).

Strat No.	Cruise 1	Cruise 2	Cruise 3	Cruise 1+2+3	optimal for Saithe	optimal for Cod	optimal for Haddock
1	2.9	11.3	11.9	8.5	2.3	42.7	12.0
2	0.0	3.8	3.3	2.2	0.1	9.3	5.9
3	7.3	15.2	7.4	9.9	10.1	8.8	3.3
4	5.6	5.9	1.6	4.5	6.1	0.3	1.0
5	15.7	9.8	8.8	11.6	3.7	2.1	6.9
6	7.2	3.6	2.4	4.4	12.5	0.6	5.4
7	17.6	10.6	18.0	15.3	7.1	3.2	24.7
8	15.4	2.1	5.5	7.7	8.5	1.2	8.1
9	2.9	6.2	4.9	4.8	5.8	1.1	4.3
10	7.4	6.7	9.6	7.9	12.4	5.6	6.6
11	0.0	2.5	0.5	0.9	5.8	1.3	3.8
12	6.7	10.0	8.5	8.4	2.3	14.6	12.1
13	5.2	4.1	7.4	5.8	4.3	0.4	2.6
14	5.1	6.5	8.3	6.7	5.8	6.8	1.7
15	0.8	1.8	2.2	1.5	13.1	2.1	1.5

Table 9 : Weighting of strata in the groundfish surveys 1983 - 1991 (original stratification). An explanation on how the optimal weights are computed is found on page 9.

Strat No.	Cod (cod-stratification)		Haddock (had-stratification)		Saithe (sai-stratification)	
	used	optimal	used	optimal	used	optimal
1	10.5	8.2	5.6	18.3	5.5	3.1
2	7.0	32.8	19.5	12.4	22.4	29.9
3	5.5	31.0	10.6	19.3	10.3	4.0
4	3.5	3.4	6.8	7.5	9.8	10.8
5	22.1	4.3	8.2	7.4	7.8	26.6
6	16.6	12.2	16.4	5.0	40.2	20.1
7	12.6	3.2	9.6	5.4	4.0	5.3
8	6.8	2.2	23.4	24.6		
9	15.5	2.6				

Table 10 : Weighting of strata in the groundfish surveys 1983 - 1991 (restratified). An explanation on how the optimal weights are computed is found on page 9.

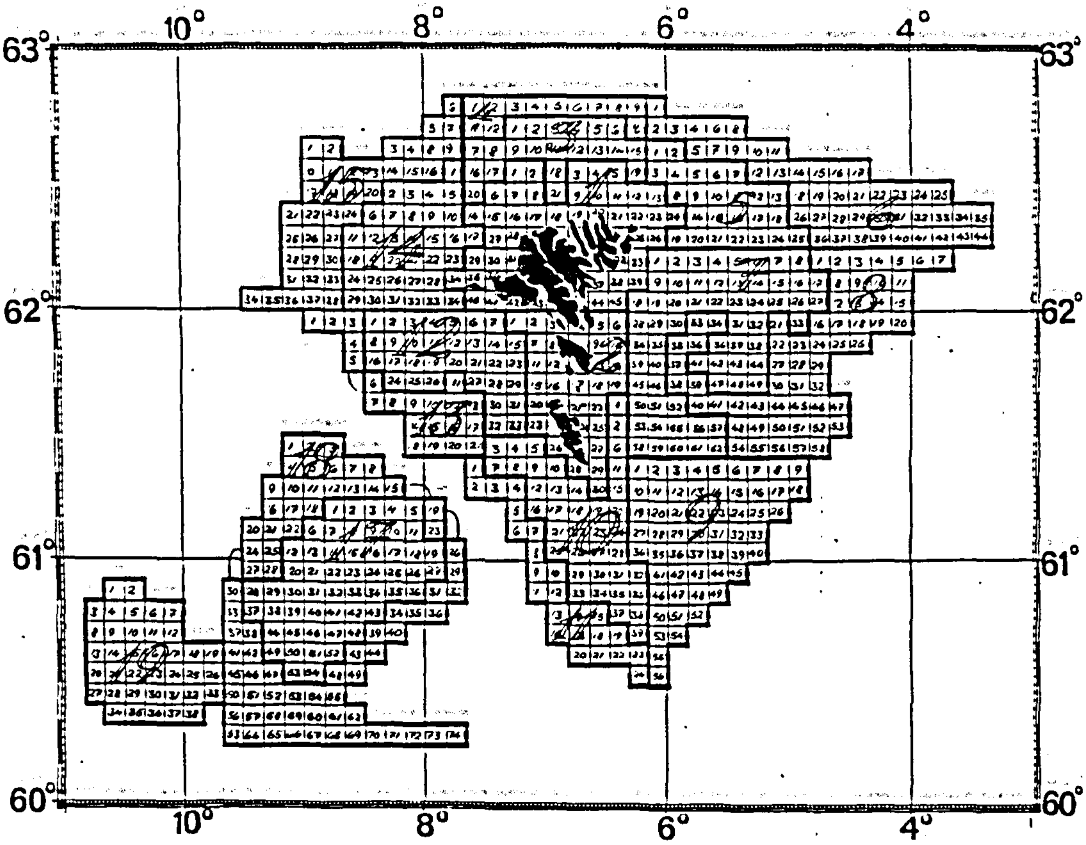


Figure 2 : Original stratification of the Faroe Plateau.

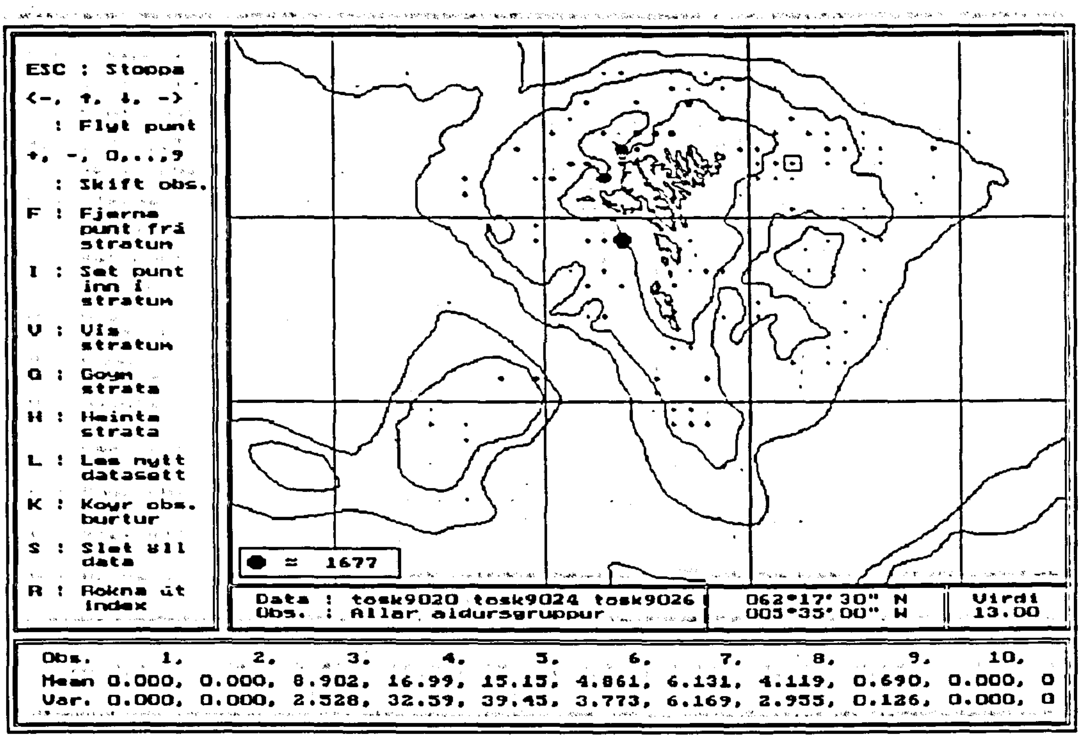


Figure 3 : The user interface of the SSP-program.

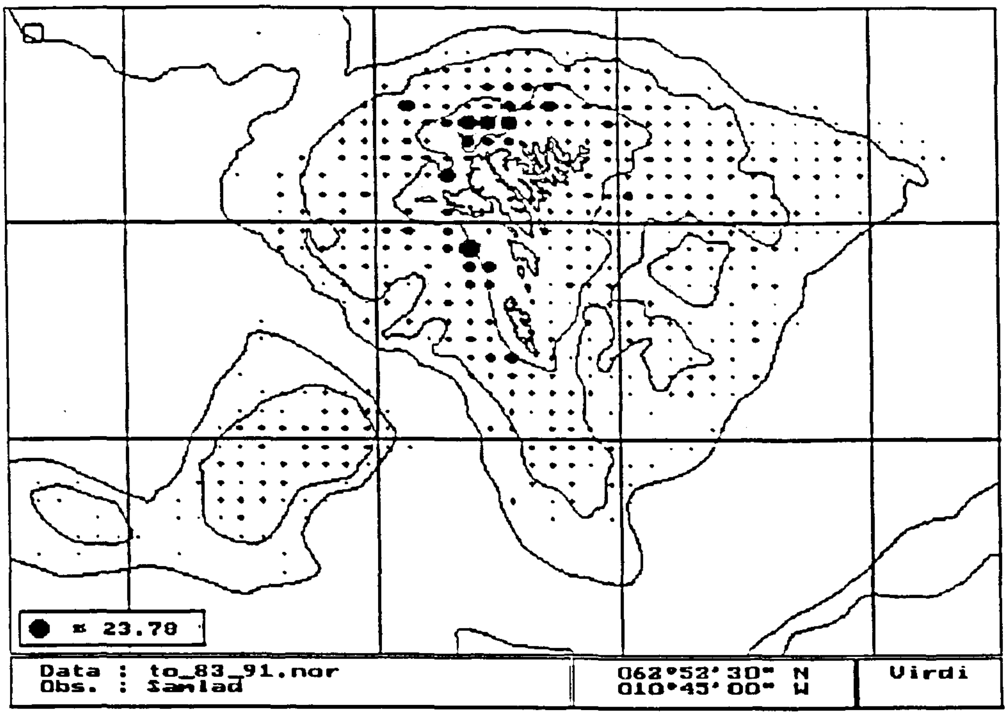


Figure 4 : Rectangle qualities for all agegroups of cod (1983 - 1991).

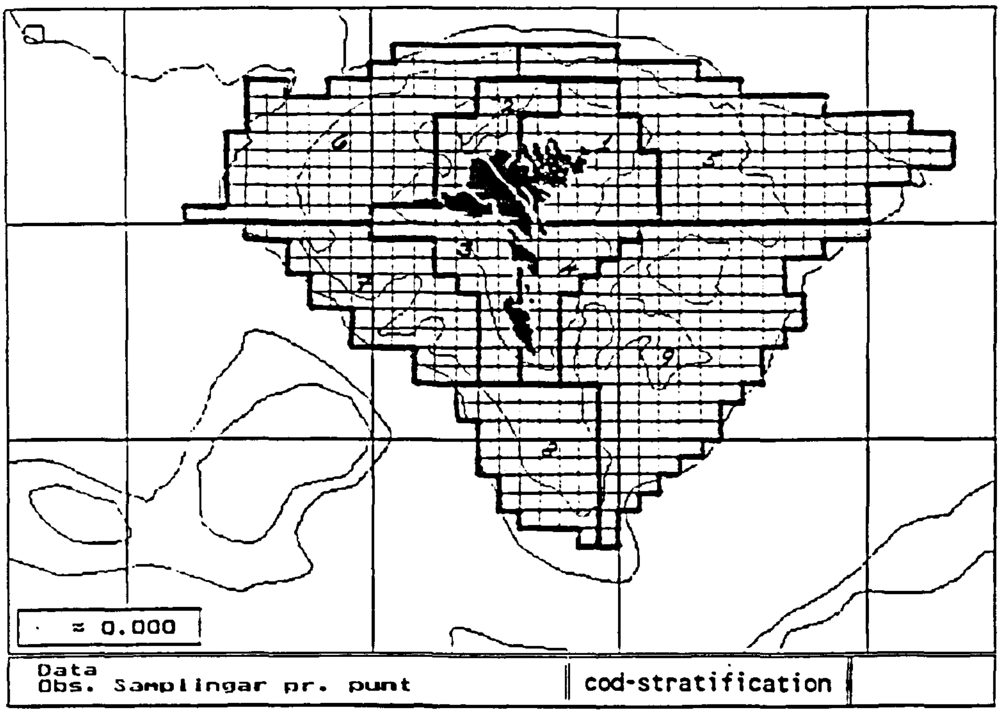


Figure 5 : Cod stratification of the Faroese Plateau.

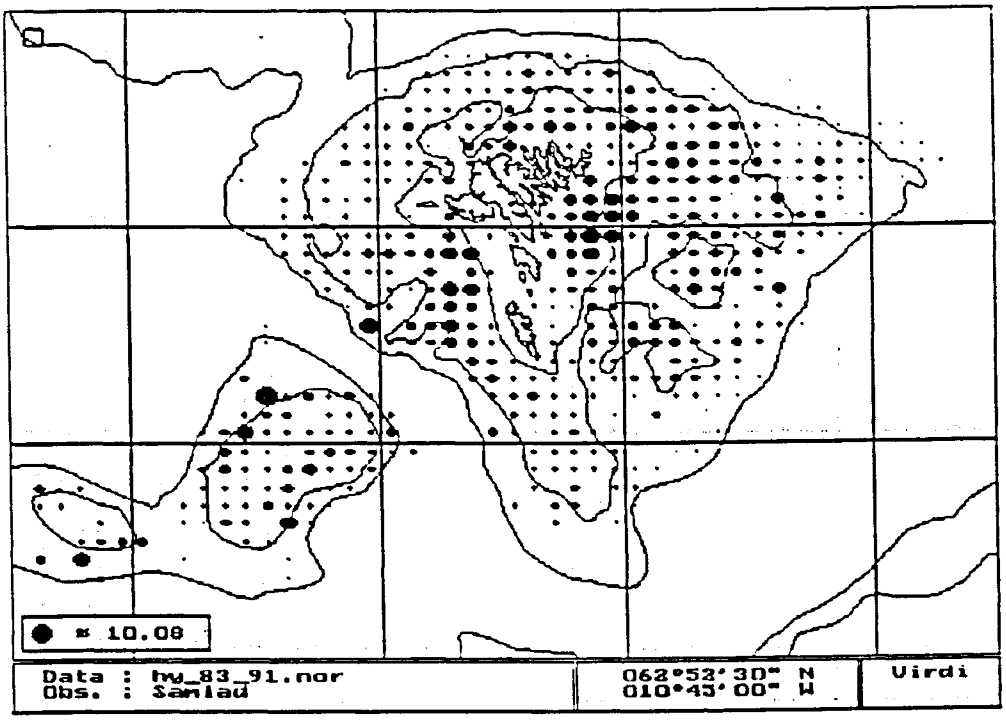


Figure 6 : Rectangle qualities for all agegroups of haddock (1983 - 1991).

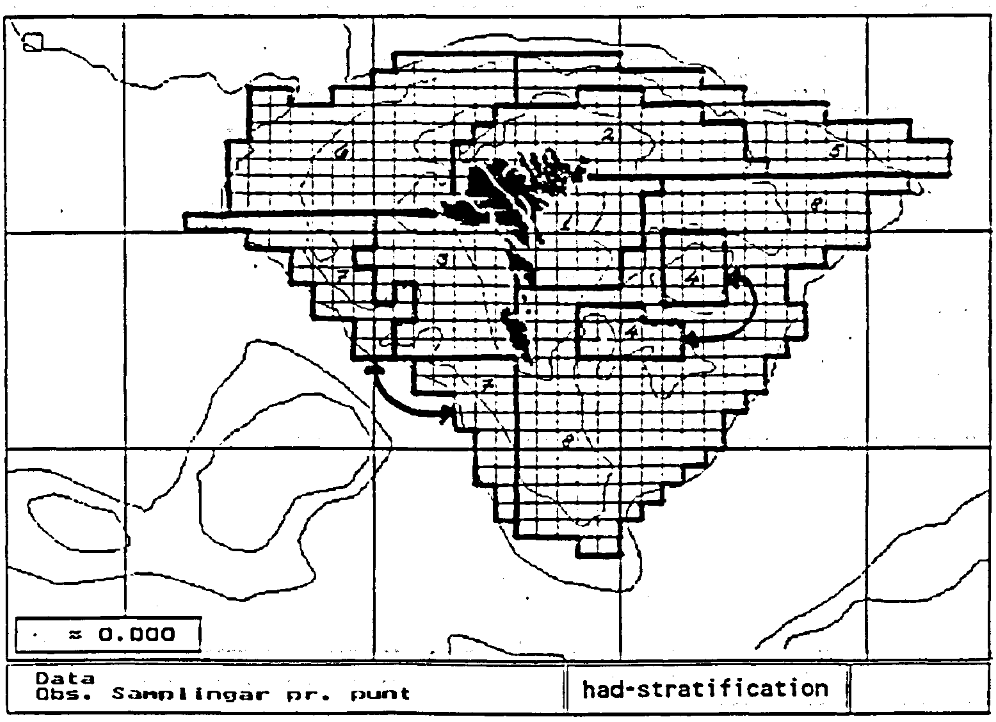


Figure 7 : Haddock stratification of the Faroese Plateau.

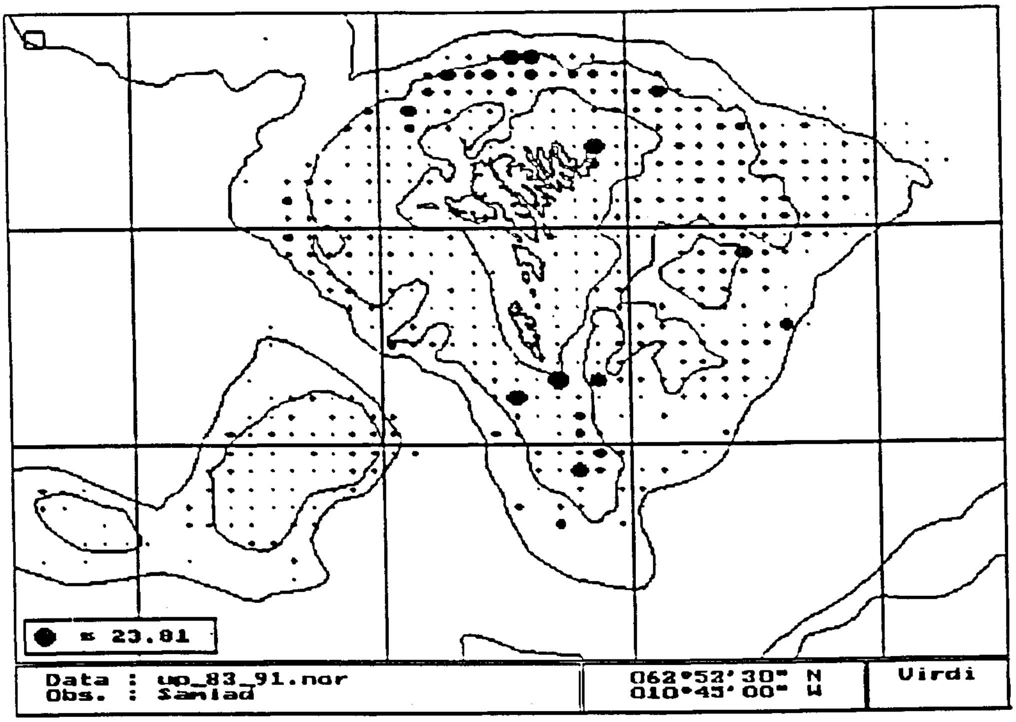


Figure 8 : Rectangle qualities for all agegroups of saithe (1983 - 1991).

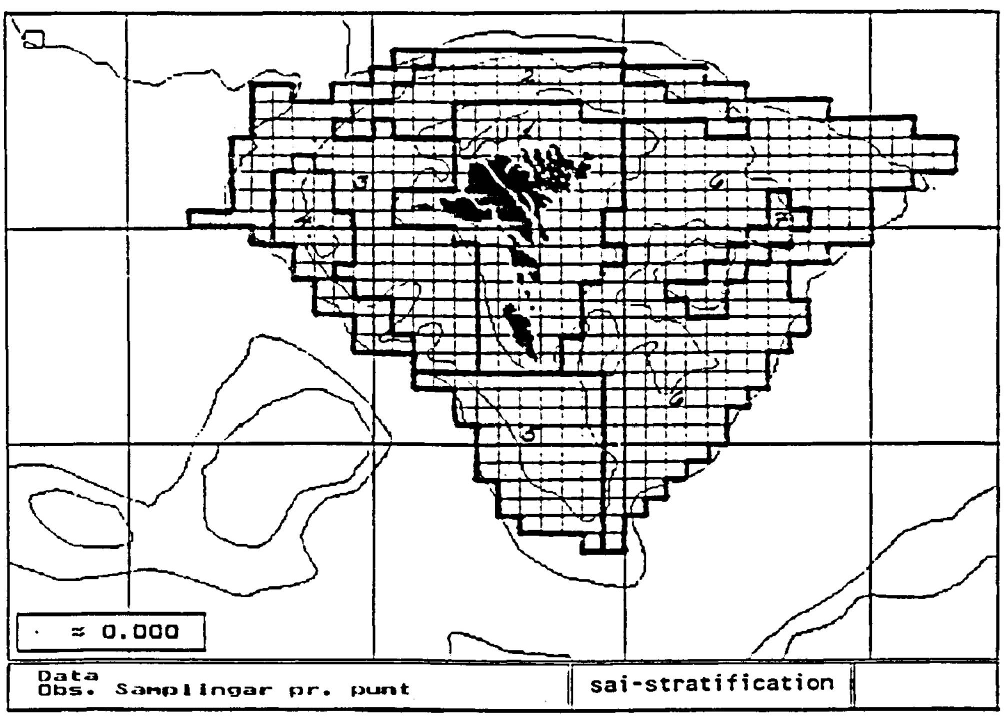


Figure 9 : Saithe stratification of the Faroese Plateau.

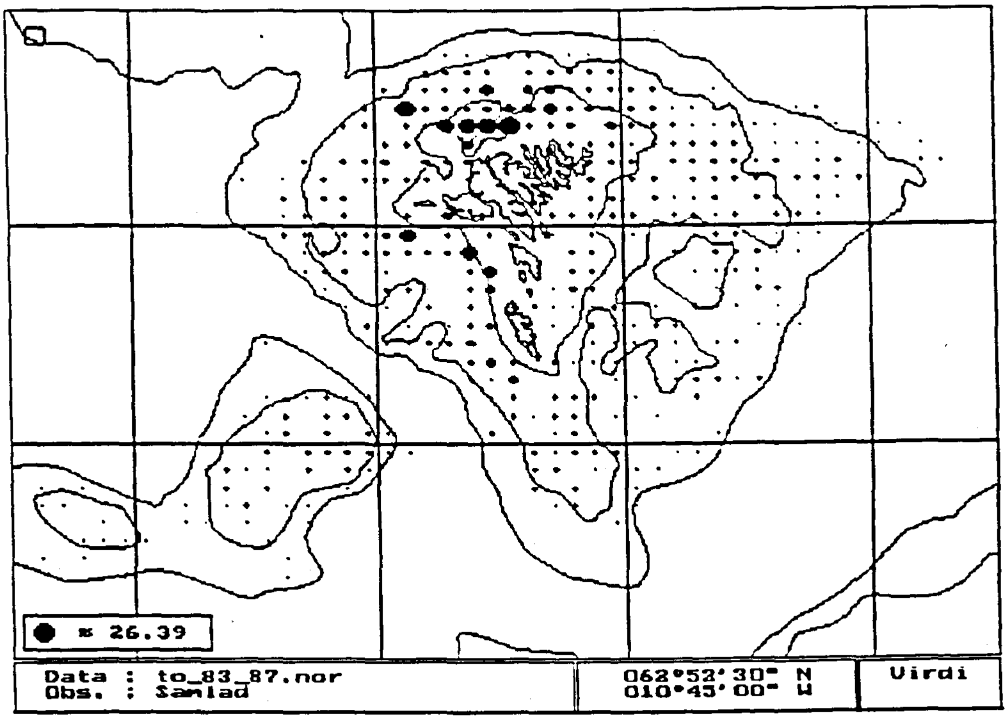


Figure 10 : Rectangle qualities for all agegroups of cod (1983 - 1987).

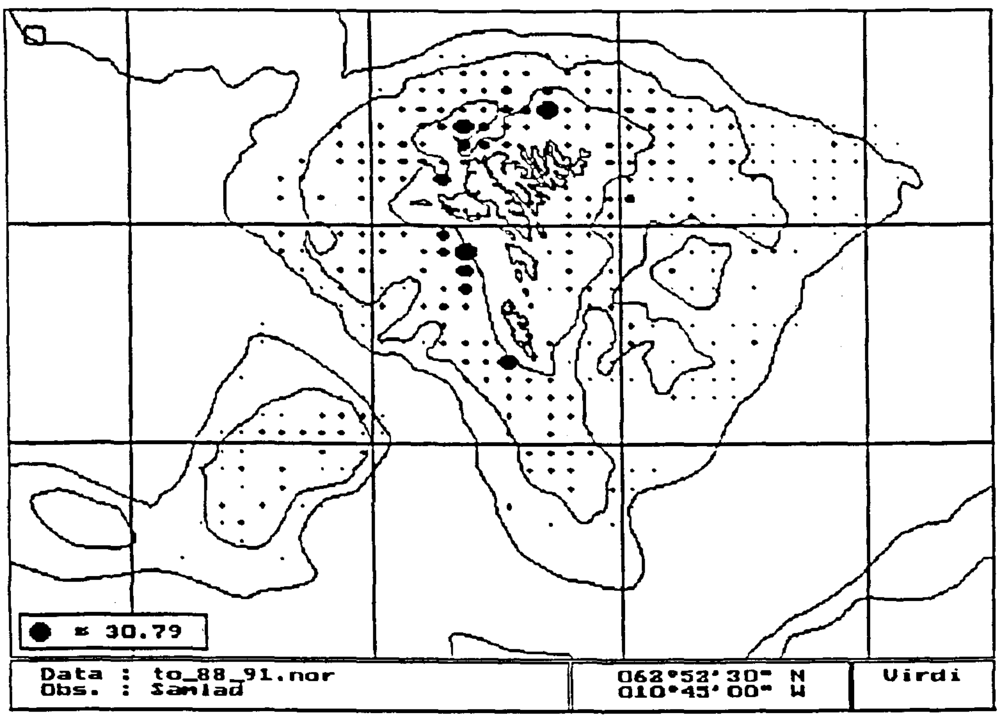


Figure 11 : Rectangle qualities for all agegroups of cod (1988 - 1991).

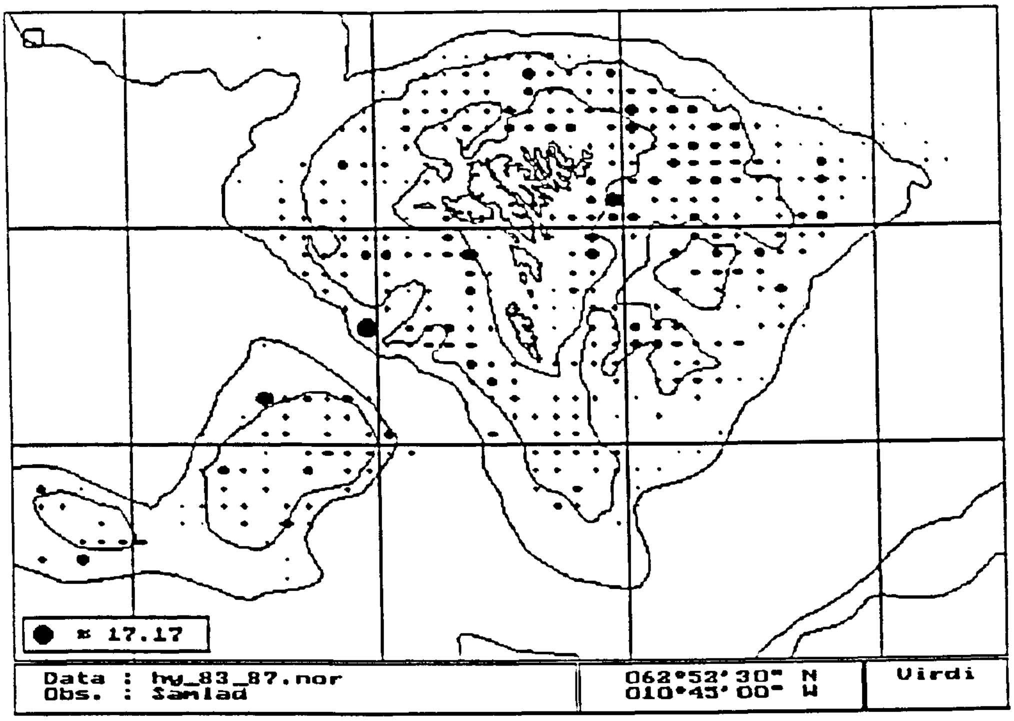


Figure 12 : Rectangle qualities for all agegroups of haddock (1983 - 1987).

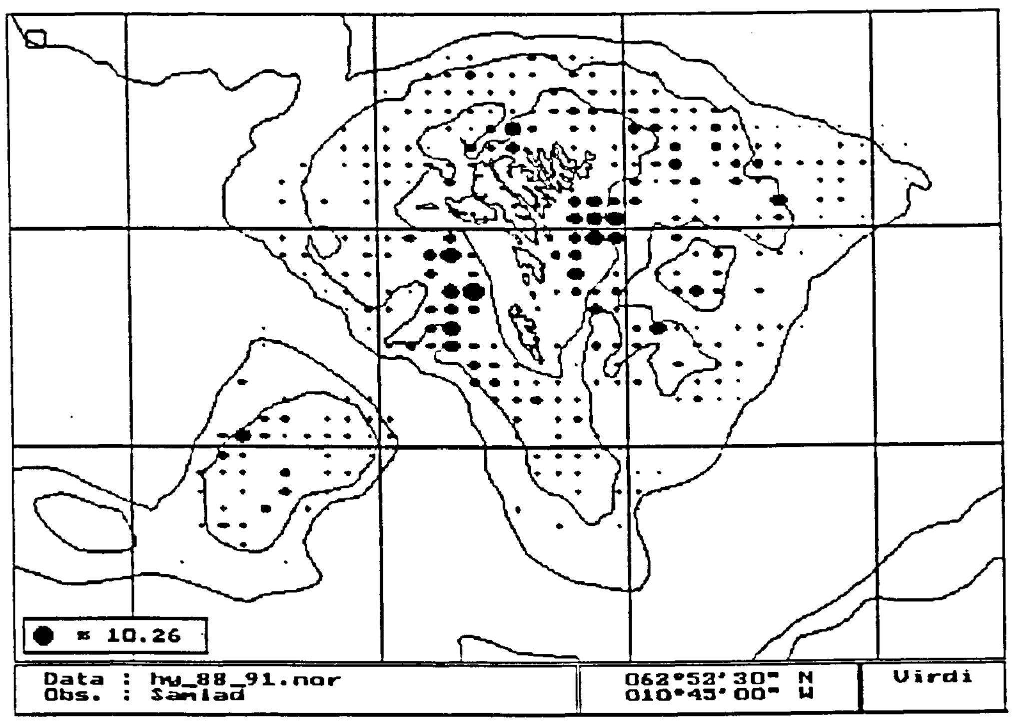


Figure 13 : Rectangle qualities for all agegroups of haddock (1988 - 1991).