Theme Session (Y29): Synthesis and critical evaluation of Research Surveys

Icelandic Groundfish Survey

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Abstract

The objective of the Icelandic Groundfish Survey (IceGFS) is to improve the scientific basis of fisheries management and thus increase consistency and reliability of management advice for demersal fish stocks in Icelandic waters. The survey has been carried out annually in March since 1985, covering the continental shelf waters around Iceland with 540-600 "semi-randomly" distributed tows. Biological data are collected for all fish species although sampling effort is basically related to economic importance of each species. At present length data are collected for all species, age data for 11 species and weight data for 3 species (cod, haddock and saithe). Stomach content is analyzed for cod. Standard environmental information (weather, sea conditions, etc.) including sea temperature is collected on every tow. Survey results have been used to monitor biological status (weight at age, maturity status), to predict recruitment and for assessment calibrations of cod and haddock. For several other demersal species indices for catchable stock and recruitment have been used to monitor status of the stocks and to support management advice. Analysis of trends in catchability of cod in the survey have given negative results, i.e. significant trends have not been observed. In general the survey has met its objectives quite well. However, an important critique relates to reduced catchability of mature cod in the main spawning area off the southwestern coast and, therefore, less weight of spawning stock indices in assessments calibrations. Another critique is the fact that saithe is not adequately covered in the survey due to the pelagic behavior of the species. Two important demersal species, deep-sea redfish (*Sebastes mentella*) and Greenland halibut, are not covered in the survey due to their spatial distributions outside the continental shelf area.

1. Introduction

Objectives and methodology of the Icelandic groundfish survey (IceGFS) have been described in detail in an earlier publication by the authors (Pálsson et al. 1989). The selection of tows has been described as "semi-random" since only half of the tows were randomly selected and the other half were selected by fishermen (figure 1). From the beginning the goal has been to keep changes in the survey minimal and try to take the same tows every year. In spite of that some changes have been made from the original configuration some unavoidable but other on purpose.

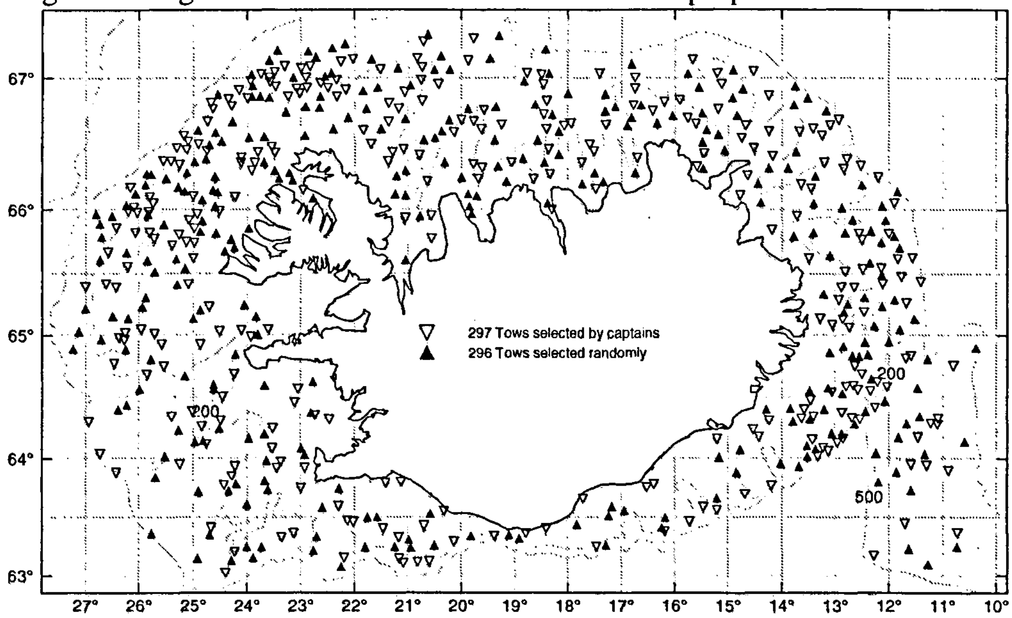

Figure 1. Tows taken in the first survey 1985

In the following sections survey design is broadly described, mainly focusing on changes in the design which have been made during the period 1985-97. Collection of environmental and biological data is then described and, finally, the use and quality of the data is evaluated mainly with respect to application in stock size estimates.

2. Survey design

2.1 Original allocation of tows

The survey area (60 000 nm^2) remained unchanged from 1985 to 1995. Since 1996 the area in the Iceland-Faroes ridge has not been covered in the survey (figures 1 and 3). This change resulted from an attempt to reduce the cost of the survey without significant change in the quality of the data. The area dropped corresponds to approximately 10% of the total area but only 24 tows out of approx. 600 (4%) were located there. Of commercially important species deep sea redfish *(Sebastes mentella)* and tusk are the only ones where a significant proportion is found in this area but the survey is anyway not considered to cover deep sea redfish properly.

All the 600 tows initially planned have never been taken. A number of these tows were removed during the first 3 surveys due to rough bottom that caused heavy gear damage or loss of fishing gear. In 1988 30-40 tows had been dropped due to these causes. In 1988 additional 15 tows were not taken due to ice conditions, resulting in only 545 tows in the survey that year . In 1993 30 shallow water tows were added to the survey area in response to critiques by fishermen. They claimed that the abundance of cod was increasing in shallow water areas. The variance in the number of fishes caught in shallow water tows is high so it is difficult to see if the number of fishes caught there is increasing.

Table 1. Number of tows taken in the IceGFS 1985-97.

Year	85	86	87	88	89	90	91	92	93	94	95	96	1997
Tows	593	585	566	545	568	567	570	571	597	596	600	540	533

2.2 Survey revision.

In 1996 the number of tows was revised in order to reduce the cost of the survey. The goal was to see if the survey could be carried out by 4 trawlers instead of 5 without reducing the quality of the survey. The first step was to look at data from the tows in the Iceland-Faroes ridge. The number of tows there was small (24) but large distance between tows so the time saved by removing the tows was considerable. After looking at the species composition in the area it was decided not to cover it.

The next step was to investigate the effects of reducing the number of tows on the abundance indices of 3 of the most important species, cod, haddock and redfish (*Sebastes marinus*) by bootstrapping (Efron 1979) From the tows taken in each survey (N) n tows were selected at random with replacement and abundance indices calculated. The selection process was repeated 500 times and the distribution of the abundance indices recorded. The species were split in length group as shown in table 2.

Table 2 Length groups used in bootstrapping.

Cod	<20	20-29	30-49	50-69	70-89	>89	All
Haddock	<20	20-29	30-39	40-49	50-59	>59	All
Redfish	<20	20-29	30-39	>39	All		

The process was repeated with n = 100, 200, 350, 400,450, 500, 600, 700, 800, 1000, 1500 and 2000. What is of primary interest in the bootstrapping is the CV of the distribution of the abundance indices. According to statistical theory the equation $CV = \frac{a}{\sqrt{n}}$ describes CV as function of sample size. Table 3 shows CV in % for some selected length groups. The numbers in the table are based on n=400 but the coefficient a in the equation can be found by multiplying the number in the table by 0.2.

Table 3. CV in % for some selected length groups based on n=400.

	85	86	87	88	89	90	91	92	93	94	95
cod <20cm	10.5	11	10.6	23	12	12.5	12	11.8	17.2	16.1	13.3
cod 20-29cm	44.7	15.3	9.8	11	12.4	11.3	10.3	9.9	9.3	11.6	14.2

cod 50-69cm	16.4	11.4	11.5	16	17	11.6	12.6	19.4	26.2	22.3	13.1
cod >89cm	29.5	11.9	18.8	15.2	16.1	26	38.5	19.1	17.9	17.7	18.6
All cod	16.6	9.6	9.8	12.4	15.3	8.9	9.4	21.5	16.2	13.1	8.2
All haddock	10.7	12.8	22.5	20.2	11.3	15.3	14.9	15.1	14.3	13.8	13.1
All redfish	10.7	12.8	22.5	20.2	11.3	15.3	14.9	15.1	14.3	13.8	13.1

As may be seen the CV varies a lot from year to year. For cod it is highest 21.5% in 1992 but lowest 8.2% in 1995. High values of CV are usually related to one or few tows responsible for high percentage of the total abundance. The high CV values in 1985 and 1992 are associated with tows with more than 10,000 cod of age 2.

The mean CV for all cod is 12.8% with n=400 corresponding to a=2.56 in equation 1. Figure 2 shows a plot of the CV for cod in various years with CV according the equation $CV = \frac{2.56}{\sqrt{n}}$. added to the plot.

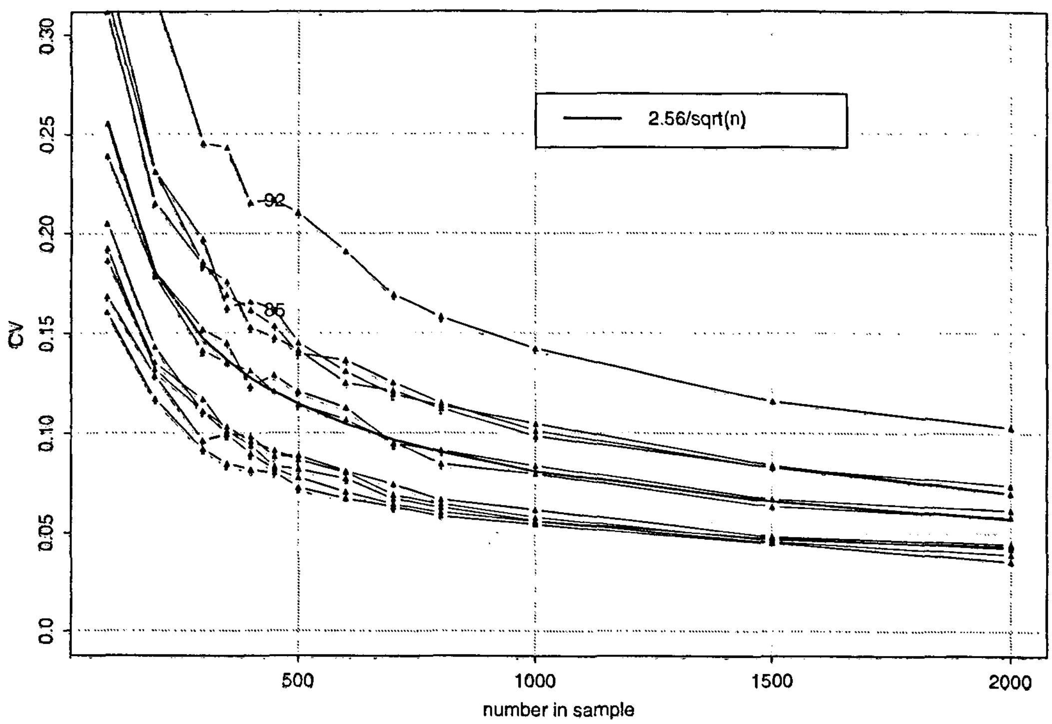

Figure 2. CV for cod survey indices as function of sample size. Indices based on total number of cod.

Finding a criteria for selecting the number of tows based on CV of abundance indices is not straightforward. If the number of vessels in the survey was to be reduced to 4 the number of tows would have to be lowered to approximately 520 compared to 600 in 1996. The increase in CV is 7% if all tows were used in calculating the survey indices. It can also be argued that abundance indices used as a time series should always be based on the same tows (482) which puts the number of "used" tows down to 482, which can easily be done by 4 vessels.

The final conclusion was to take the 482 tows that had always been taken. In addition to them the following tows were included in the revised tow list:

1) 14 shallow water tows in the southern area added in 1993. 16 shallow water tows in the northern area that were added in 1993 were dropped.
2) 26 tows in the southern area taken in all surveys from 1985-95 except 1.
3) 11 tows deep off the northern coast. These tows had always been taken except in 1988 when they could not be taken due to sea ice.

This resulted in 533 tows in a revised list of tows (figure 3). In 1996 and 1997 540 and 533 tows, respectively, were taken.

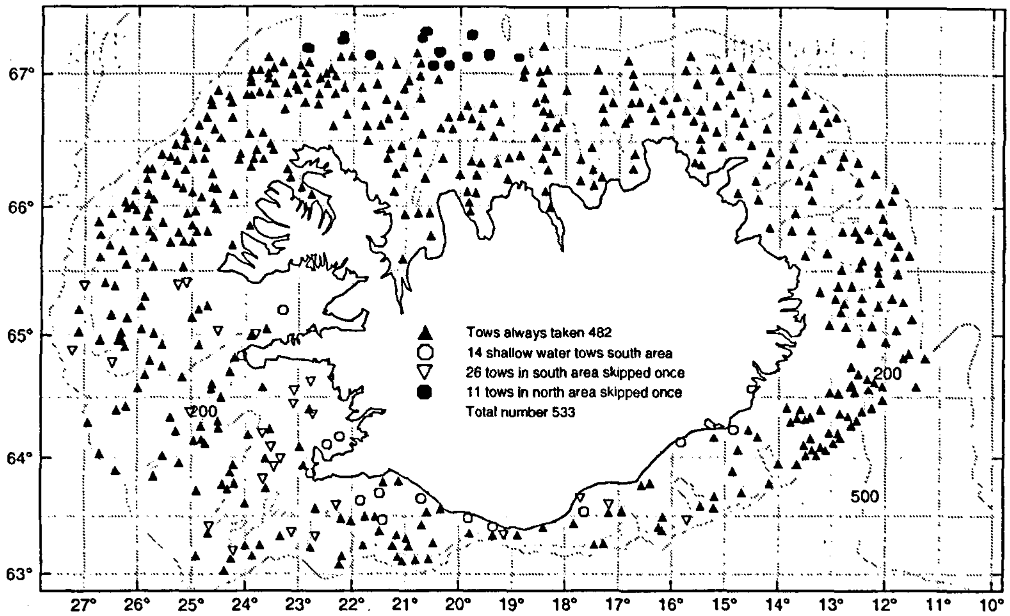

Figure 3 IceGFS after redesign

2.3 Other aspects of survey design

The fishing gear of the survey is a bottom trawl with the following main specifications: Headline 105', fishing line 63', bobbins footrope 60' weighing 4.0-4.2 tones, bridles 25 & 35 fm (above and below 100 fm depth), otter boards 1750 kg and 7.65 m^2. Mesh size: 135 mm in the front section, 80 mm in the belly, 135 mm in extension piece and 155 in codend, codend cover (+ extension piece) 40 mm. The vertical opening of this trawl is rather limited or approximately 3 m (for further details see Pálsson et al.1989).

Standardization of the bottom trawl has been regarded as an essential condition for a proper fulfillment of the objectives of the survey. Thus, the same gear has been used unchanged throughout the survey period. However, minor increase in the weight of the otter boards (doors) has not been avoided since the doors used by the research trawlers during commercial fishing have in some instances been used in surveys. The initial weight of the doors was set at 1750 kg each. During the first years the weights were in the range 1720-1830 kg with an average close to 1750 kg. In later year the weights of the doors have increased somewhat and are at present in the range 1880-1970 kg with an average of approximately 1900 kg.
Furthermore, standardization of survey vessels has been considered equally important. Therefore, since research vessels were not available, 5 identical commercial trawlers,

out of a set of 10 such vessels, were leased for the first research cruise. However, all but one of these trawlers have gone through some changes in the past years with respect to length and engine power. The initial overall length of the vessels was 47.1 m and engine power was 200 hp. During 1986-88 most of the vessels were increased in length up to 53.78-60.32 m. In addition, larger engines (2300 hp) with more efficient power utilization (pull) were substituted. These trawlers are still used as research vessels in the survey along with one trawler of the initial length.

Clearly, the survey design has not remained without changes in the course of time. However, changes in survey area, number of tows as well as the increase in the weight of doors are considered as minor. These changes are not considered having had any significant effect on survey results. The inevitable changes in research vessels, on the other hand, may have had larger effect on survey results, although this is difficult to evaluate. Larger vessels are more stable in rough weather and, therefore, the effect of increased size and power will become larger under such conditions. These condition differ markedly from year to year. Modeling effects of vessel size is therefore difficult as it interacts with weather conditions. The fact that the effects of vessel size is difficult to model makes it also more important to minimize changes in vessel size.

3. Data collection

3.1 Introduction

A large number of variables like position, depth and sea temperature is registered with each tow. Table 4 gives a complete list of the variables registered with each tow. This registration has remained unchanged throughout the survey period. In the last 2 surveys an attempt has been made to attach continuously recording thermometers to the research trawl. Some of the thermometers have been damaged or lost in the surveys but the goal is to keep on with this kind of work.

Table 4. Variables registered with each tow.

Cruise id. number	Station number	Nr. of statistical square
Gear id. nr.	Mesh size	Length of warp (towing wire)
Length of bridles (in trawl)	Position at beg. & end of tow	Date
Duration of tow (min.)	Bottom depth at beg. & end of tow	Sea-ice conditions (coverage)
Vertical/horiz. opening of trawl	Tow direction	Tow length (nm)
Towing speed	Wind direction	Wind speed
Sea state (wave height)	Near-bottom temp.	
Weather cond. (clear, rain, fog. etc.)	Cloud coverage	Barometric pressure
Air temperature	Sea surface temp.	

Biological data collected includes
1. Sampling of otholiths
2. Weighing of fish
3. Collection of stomach samples
4. Determination of sex and maturity stage
5. Length measurements
6. Counting

Table 5 gives and overview of the biological sampling in the groundfish survey 1997.

Table 5. Biological sampling (number of individual fish) by species in IceGFS 1997.

counted=A, measured=B, otoliths, weighed, stomachs, sex det.=C

	A	B	C
Cod, *Gadus morhua*	25.704	47.937	4.170
Haddock, *Melanogrammus aeglefinus*	57.157	34.074	3.501
Saithe, *Pollachius virens*	694	1.482	474
Whiting, *Merlangius merlangus*	4.426	2.677	
Golden redfish, *Sebastes marinus*	106.130	35.630	212
Ling, *Molva molva*		223	98
Blue ling, *M. dypterygia*		107	34
Cusk, *Brosme brosme*		847	323
Catfish, *Anarhichas lupus*	1.711	19.789	1.517
Stary ray, *Raja radiata*	715	10.315	
Spotted wolffish, *Anarhichas minor*		2.681	
Angler, *Lophius piscatorius*		30	
Common skate, *Raja batis*		14	
Piked dogfish, *Squalus acanthias*		12	
Greater argentine, *Argentina silus*	2.825	1.117	88
Halibut, *Hippoglossus hippoglossus*		66	63
Greenland halibut, *Reinhardtius hippoglossoides*		272	
Plaice, *Pleuronectes platessa*	119	1.998	298
Lemon sole, *Microstomus kitt*	90	1.556	2
Witch, *Glyptocephalus cynoglossus*	173	1.522	1
Megrim, *Lepidorhombus whiffiagonis*	20	64	
Dab, *Limanda limanda*	15.194	1.860	
Long rouch dab, *Hippogl. platessoides*	80.800	21.027	200
Herring, *Clupea harengus*	3.534	444	
Capelin, *Mallotus villosus*	19.571	485	
Norway pout, *Trisopteus esmarki*	3.893	743	
Blue whiting, *Micromesistius poutassou*	5.187	501	
Sandeel, *Ammodytes sp.*		1	
Ratfish, *Chimaera monstrosa*		69	
Norway lobster, *Nephrops norvegicus*	95		
Deep water prawn, *Pandalus borealis*	1.295		
Arctic wolffish, *Anarhichas denticulatus*		43	
Lumpfish, *Cyclopterus lumpus*		1.101	
Moustace sculpin, *Triglops murrayi*	383	877	
Atlantic poacher, *Leptagonus decagonus*	263	577	
Fourbeard rockling, *Rhinonemus cimbrius*	58	416	
North Atlantic codling, *Lepidion eques*		8	
Arctic eelpout, *Lycodes reticulatus*	321	234	
Norway haddock, *Sebastes viviparus*	14.550	5.788	
Deepwater redfish, *Sebastes mentella*	2.462	501	
Roughead grenadier, *Macrourus berglax*		1	
Esmark's eelpout, *Lycodes esmarki*	346	344	
Spotted snake blenny, *Leptoclinus maculatus*		28	
Twohorn sculpin, *Icelus bicornis*	1	21	
Gymnelus retrodorsalis		29	
Lycodes seminudus	250	120	
Longfin snailfish, *Careproctus reinhardti*		145	
Polar cod, *Boreogadus saida*		24	
Five bearded rockling, *Ciliata mustela*		1	
Atl. hookear sculpin, *Artediellus atlanticus*	3.277	604	
Forkbeard, *Phycis blennoides*		7	

Vahl's eelpout, *Lycodes vahli*	9.394	3.645
Bullrout, *Myoxocephalus scorpius*	15	70
Arctic sculpin, *Cottunculus microps*		120
Eelpout, *Lycodes sp.*	145	
Round ray, *Raja fyllae*		1
Silver rockling, *Onogadus argentatus*	83	222
Hook nose, *Agonus cataphractus*		2
Arctic skata, *Raja hyperborea*		4
Threespot eelpout, *Lycodes rossi*	123	10
Snake blenny, *Lumpenus lampretaeformis*	1.840	674
Greater sandeel, *Hyperoplus lanceolatus*	1	
Lycodes eudipleurostictus	473	286
Grey gurnard, *Eutrigla gurnardus*	452	95
Lycenchelys muraena		2
Pale eelpout, *Lycodes pallidus*	1.260	347
Cephalopoda	2	8
Velvet belly, *Etmopterus spinax*		1
Spiny stone crab, *Lithodes maia*	1	
Bathypolypus arcticus		3
Checkered wolf eel, *Lycenchelys kolthoffi*		2

3.2 Length measurements and counting.

In 1985-1995 27 relatively abundant species were length measured but other species were just counted by numbers. The maximum number measured was 5 times the range of the length distribution of the species in the tow. In 1996 the maximum number was reduced to 4 times the range but length measurements of fishes that in earlier years had been counted were added. The maximum number measured of these species was set to 20. If the number of fishes caught exceeds the maximum number the remaining fishes are counted by numbers.

Invertibrate species have not been systematically recorded except for northern shrimp (*Pandalus borealis*) where the weight of catch has been recorded.

3.3 Otholith sampling.

Otholiths for ageing have been sampled from 10 species as shown in table 7.
Two different sampling schemes have been used to collect otholiths in the survey.
In 1985-1988 sampling of otholiths was stratified. The survey area was split up in 10 areas and each species in 5-15 cm length intervals. For each species, length interval and area of maximum number sampled in each length group was then specified. The experience with this sampling scheme was bad, mainly because the areas were too large.

Since 1989 sampling has been carried out randomly sampling from 2 to 33% of the caught fishes A maximum limit has also been on the number of fishes sampled per tow. This ceiling has gradually been reduced and is now 25. For cod the proportion of fishes taken for otholith sampling has been higher in the southern area than in the northern area (Table 6). This difference relates to less catchability of cod in the southern area than in the northern area (Thorarinsson and Jóhannesson 1994).

Table 6. Sampling for otoliths by species and years in IceGFS. % sampled during the period of random sampling is indicated.

Species	% sampled	Period	Remarks
Cod	5 and 33	1985-97	Northern and southern area
Haddock	2	1985-97	5% in 1997
Saithe	33	1985-97	
Catfish	7	1985-97	
Ling	25	1985-97	
Blue ling	25	1985-97	
Brosme	25	1985-97	
Halibut	25	1985-97	
Plaice	5	1985-97	
Silver smelt	3	1985-97	

3.4 Registration of sex and maturity.

Sex and maturity stage of all fishes taken for otolith sampling is registered. In addition sex of length measured fishes is also registered for some species with length specific growth (table 7). In 1997 3 flatfish species were added to this list.

Table 7 Species where sex of length measured fishes is registered.

Species	Period
Greenland halibut	1985-97
Lumpsucker	1985-97
Roundnose grenadier	1985-97
Rough head grenadier	1985-97
Plaice	1985-97
Dab	1996-97
Halibut	1997
Megrim	1997
Witch	1997
Long rough dab	1997
Starry ray	1985-97

3.5 Sampling. of stomach content

Stomach content of cod has been sampled in all surveys. During most of the period the sampling was stratified by predator length (5 and 10 cm length groups) and area.

Prior to 1993 the content of the stomachs was put in a container and stored in isopropanol for later analysis. With the purchase of electronic on-board scales in 1993 the stomach content was analyzed at sea and the stomach content not stored.

Since 1996 the same species have been sampled for stomachs content and otoliths. The sampling of stomach content is then random.

In 1992 as part of a multi-species project an intensive stomach sampling program was carried out covering most demersal fish species encountered in the survey. The sampling was stratified on length and area basis. Approximately 57 thousand from 51 species were collected in this survey.

3.6 Weighing

Weighing of individual fishes at sea became feasible with the introduction of electronic sea balances. Since 1993 cod, haddock and saithe sampled for otoliths have been weighed. Currently the following measurements are done on specimens of these species sampled for otoliths.

1. Length measurement
2. Registration of maturity and sex.
2. Ungutted weight
3. Gutted weight.
4. Weight of liver
5. Weight of roes or gonads (if mature)
6. Otholiths taken.

For cod the stomach content of these fishes has also been sampled since 1996.

Prior to 1993 cod in a small portion of the northern area was weighed gutted.

3.7 Registration.

Until 1993 the results of a typical groundfish survey came as a large quantity of paper. The data on this paper then had to be typed on a computer.

In 1992 the Marine Research Institute bought a number of electronic on-board scales from Marel ltd. These scales were interfaced to portable computers. Writing and testing of necessary software was finished prior to the survey in 1993 when the system was used for a first time in the survey. Introduction of this system meant some major changes in the work carried out in the survey.

1. Fish from which the otholiths were taken was weighed.
2. A keyboard was attached to the scale. The length measurements and the number of fishes were entered through this keyboard but not written on a sheet of paper.

With these changes weighing of fish, length measurements and counting were collected on a computer and could be loaded into a database immediately after the survey. The computer finds when enough fishes have been length measured.

Registrations regarding the tow (table 4) were computerized in 1996 and are now entered on a computer while towing.

Stomach samples have been analyzed on sea since 1993 but the results were registered by means of pencil and paper until 1997 when a program to register stomach data was tested for the first time.

The status today is that all data from a survey comes on a computer ready to be loaded in the database.

The experience with the computer system is good. It saves a lot of labor and the chance of errors decreases. Furthermore most data from the survey is available immediately after the survey which is of importance in the case of IceGFS.

4. Calculation of indices

4.1 Introduction

One of the main use of the survey in assessment is through the use of abundance indices.

The first step in calculations of abundance indices is usually to calculate some quantity for each tow (station). This quantity can be catchable biomass, spawning stock biomass, number in a agegroup or number in a length group depending on what type of indices are to be calculated.

4.2 Calculating the amount for each tow.

Calculations of amount in each tow are trivial except when age disaggregated indices are needed. When calculating an index of catchable stock an ogive and a length-weight relationship are specified. The length distribution in the tow is multiplied by the ogives and the length-weight relationship to get catchable biomass for each tow. The ogives used for 5 important species are shown in figure 4. These ogives were estimated by comparison of length distributions from commercial catch and survey. Indices of recruitment have been calculated in numbers. The ogive used has usually been the inverse of the ogive for the catchable stock. (the sum of the 2 ogives is always 1).

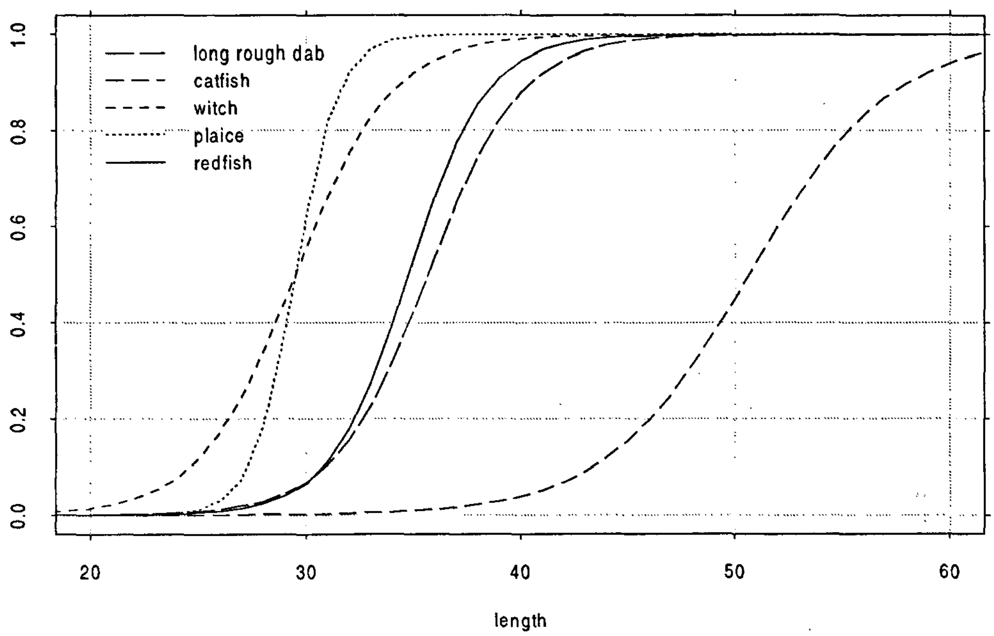

Figure 4. Ogives used to split the data into catchable stock and young fish.

Calculating the number in each tow disaggregated by age is more complicated. The traditional method is based on calculating a matrix of conditional probabilities p(a|L) and multiplying the length distribution in each tow by the conditional probabilities. For cod and haddock the conditional probabilities have been calculated using 5 cm length groups and 2 areas, north and south. In recent year a based on the use of glm models (Björnsson 1994, Jóhannesson 1994) has been used. A method based on the use of a multinomial glm model (Venables and Ripley 1994) has also been tested.

Which method is used does not make a lot of difference for the surveys after 1988. In the surveys from 1985 to 1988 when otholith sampling was stratified using too large areas the glm models (Björnsson 1994, Jóhannesson 1995) seem to be superior to the other methods.

4.3 Calculations of indices from amount per tow.

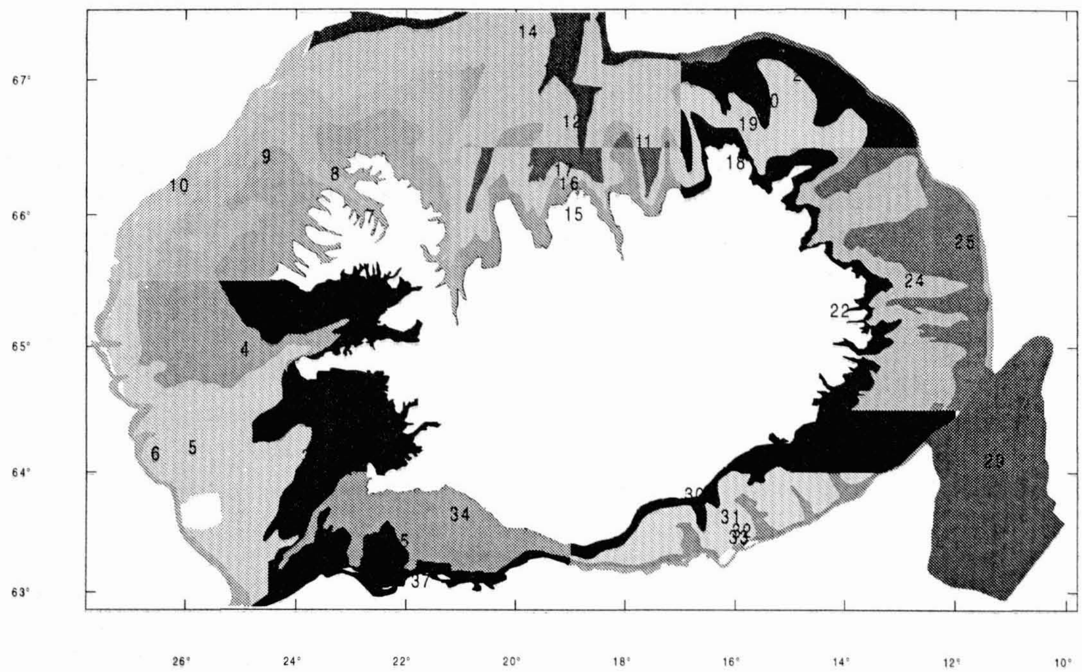

Figure 5 The post-stratification scheme used to calculate the stratified mean indices.

For calculation of stock indices of stock size various methods have been tested eg. stratified means, geostatistical methods (kriging), generalized linear models (glm) and generalized additive models (gam). Foote and Stefánnson (1993) discuss some advantages and disadvantages of different methods.

The classical method to calculate survey indices is stratified random mean(Cochran 1953). It has been used for other species than cod. In recent year the 36 stratas shown in figure 5 have been used.

For cod more "advanced" method have been used. The DG model of Stefánsson (1996) was used for some time and in the last 3 year a spatial GAM model described in Björnsson (1994) has been used. This model has given good results mainly due to down weighting of tows near the edges of the survey area.

It turns out that with a survey as extensive as the IceGFS it does not matter what method is used to calculate survey indices, they give all similar results. Therefore the simplest method which in this case is stratified mean is what should be used.

5 Use of survey data

5.1 Introduction

The main motivation for starting the survey was to get better information on the cod stock most notably the younger age groups which do not show up in the commercial catch (Pálsson et.al. 1989). The survey was designed for cod but in recent year the survey has been used to help in the stock assessment of a number of other species.

Much of the use of the survey in assessment involves the use of survey indices. For species where age readings are available age disaggregated indices are calculated but for most other stocks an index of catchable stock and an index of recruitment is calculated. Length disaggregated indices have not been used but their use will possibly increase with use of length based assessment model.

5.2 Use of aggregated indices

The target species of the IceGFS is the Icelandic cod. The allocation of tows in the IceGFS is based on pre-estimated cod density patterns and accordingly the gear used and towing speed is designed for cod. Hence, the survey does not cover the distributional areas of all demersal fishes and the catchability can be quite low for some species such as flatfishes. But assuming that the distributional pattern does not change much with stock size and catchability remains more or less stable, indices calculated from these data can give a fairly good picture of the annual changes in the size of these stocks

For species where age-readings are not available aggregated survey indices are an important part of finding harvesting strategies for the species. The survey indices do often indicate reduction in stock size when CPUE from the fleet is stable due to technological changes. The survey also gives an indication of recruitment to the stocks.

The species for which aggregated survey indices have been used in assessment are catfish, redfish, plaice, long rough dab,witch, ling, blue ling, brosme, halibut, dab and lemon sole.

The indices of redfish, catfish, long rough dab, witch and plaice are shown in figure 6 with the selection patterns used to calculate the indices shown in figure 4.
The shaded areas in figure 6 indicate ± two times the standard error of the stratified mean. The same data is also shown in tables 8 and 9.

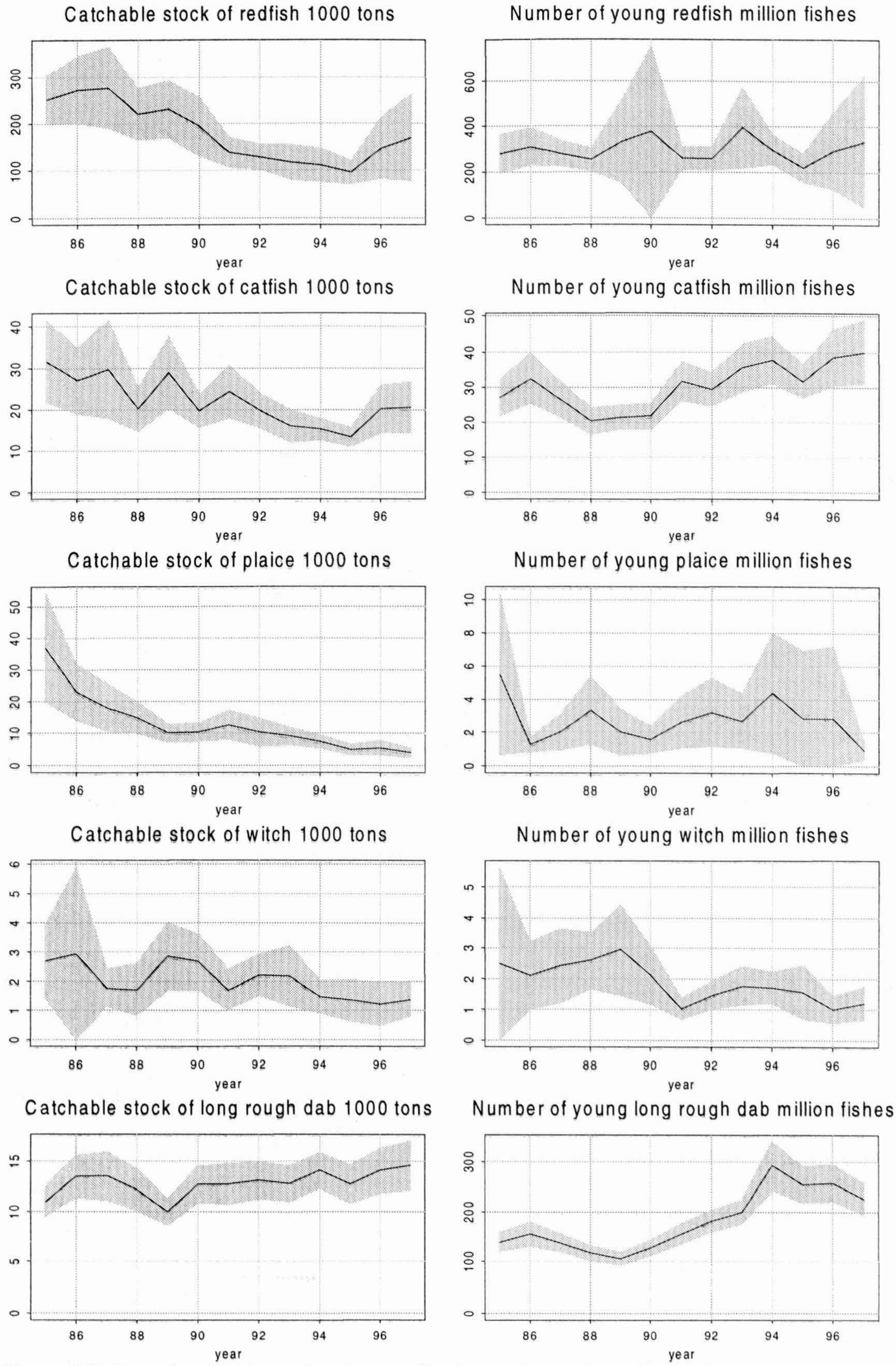

Figure 6. Indices of catchable stock and young fish for redfish, catfish, plaice, witch and long rough dab (shaded areas indictae ± two times the standard error of the stratified mean).

Table 8. Indices of catchable stock biomass

	Redfish		Catfish		Plaice		Witch		Long rough dab	
Year	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
85	251.86	0.11	31.54	0.16	36.86	0.23	2.69	0.24	11.00	0.07
86	272.50	0.13	27.10	0.15	22.95	0.19	2.91	0.52	13.51	0.08
87	277.37	0.16	29.72	0.20	17.97	0.21	1.77	0.18	13.56	0.09
88	220.91	0.13	20.13	0.13	14.77	0.17	1.71	0.26	12.17	0.09
89	230.78	0.13	29.04	0.15	9.99	0.15	2.85	0.20	10.00	0.07
90	194.61	0.16	19.70	0.10	10.31	0.14	2.67	0.18	12.72	0.07
91	138.60	0.12	24.46	0.13	12.62	0.18	1.70	0.21	12.77	0.08
92	128.80	0.11	19.80	0.11	10.30	0.22	2.21	0.16	13.12	0.07
93	117.86	0.16	16.01	0.13	9.02	0.15	2.17	0.24	12.81	0.07
94	111.84	0.16	15.28	0.08	7.25	0.15	1.47	0.19	14.15	0.06
95	96.32	0.13	13.41	0.09	4.80	0.18	1.35	0.26	12.73	0.08
96	147.24	0.22	20.20	0.14	5.29	0.22	1.23	0.30	14.14	0.08
97	170.38	0.27	20.52	0.15	3.81	0.20	1.38	0.21	14.65	0.09

Table 9. Indices of young fish (in numbers)

	Redfish		Catfish		Plaice		Witch		Long rough dab	
Year	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
85	279.54	0.15	27.06	0.09	5.49	0.45	2.48	0.63	138.96	0.07
86	312.77	0.13	32.51	0.11	1.26	0.18	2.10	0.26	155.14	0.08
87	280.58	0.10	26.48	0.10	2.03	0.27	2.42	0.25	138.09	0.07
88	255.32	0.10	20.31	0.09	3.33	0.31	2.59	0.18	116.78	0.07
89	334.55	0.27	21.37	0.08	2.00	0.36	2.94	0.25	105.40	0.06
90	377.53	0.50	21.78	0.09	1.57	0.26	2.12	0.22	127.20	0.06
91	261.29	0.10	31.66	0.09	2.64	0.30	1.03	0.17	155.92	0.07
92	260.82	0.10	29.38	0.08	3.21	0.33	1.46	0.16	181.59	0.06
93	395.84	0.23	35.54	0.10	2.70	0.31	1.78	0.17	200.77	0.06
94	299.00	0.11	37.79	0.09	4.37	0.41	1.72	0.15	292.89	0.08
95	220.09	0.14	31.73	0.07	2.86	0.71	1.57	0.28	254.59	0.07
96	293.06	0.29	38.32	0.10	2.86	0.76	1.01	0.22	258.03	0.07
97	335.15	0.43	39.99	0.11	0.89	0.30	1.21	0.23	225.92	0.07

Redfish

The stock index of catchable golden redfish (*Sebastes marinus*) declined sharply in the period 1988-1995 but indicates an increase in the catchable biomass in1996 and 1997 with a relatively high CV. CPUE indices, using data from Icelandic trawlers in January-March, show a similar trend. The young fish index has fluctuated considerably with a relatively high CV over the period. A weak indication of increasing recruitment to the catchable stock is observed in the last two years.

Catfish

The index for the fishable stock decreased by over 50% in the decade 1985-1995, showing a considerable increase in 1996 and remaining stable in 1997. However, the abundance index of the younger component of the stock indicates increasing recruitment to the fishable stock since 1991. The CV of the indices is usually low.

Plaice

Indices indicate that the fishable stock of plaice has been declining sharply since 1985. The observed 1997 index is only about 1/7 of that observed in 1985. The young fish index has been declining since 1994 and was at the lowest level observed in 1997. A relatively few hauls with big catches of young plaice are observed resulting in a relatively high CV of the young plaice index.

Witch
Stock abundance indices of witch have decreased substantially in the last 10-13 years and are now at about half of the level observed in the beginning of the period. This is in accordance with observed CPUE series from seiners and preliminary VPA analysis. The young fish index was relatively high in 1985-1989 but decreased sharply in 1990 and 1991 and has since been at much lower level indicating poor recruitment in recent years.

Long rough dab
Stock indices indicate little changes in the fishable stock biomass in the decade 1985-1995 but an increase in 1996 and 1997. Thos is in contrast with CPUE indices from seiners which show a decrease in recent years. These discrepancies may be explained by the behaviour of the seiner fleet where the bulk of the catches are females caught in spawning time at spawning concentrations. Long rough dab is relatively evenly distributed over the hole survey area resulting in an index with the lowest calculated CV. Indices for young fish increased sharply in 1989-1994. Although they have declined somewhat since 1994 they are still at relatively high level indicating good recruitment in this stock

5.3 Tuning of catch at age data for cod and haddock

In recent years indices from the IceGFS have been used combined with commercial CPUE data for the trawler and gillnet fleets to tune the XSA for both cod and haddock.

Indices for cod used in XSA tuning are calculated by the method described by Björnsson (1994.) The indices used for cod tuning are both area and age disaggregated. The age groups used are 3 to 11 years and the areas are north, south-west and south-east, Disaggregation in 3 areas comes from reduced catchability of mature fish compared to immature (Thorarinsson 1994) The indices used for haddock are age disaggregated with ages 2 to 9 used. To use the latest information available in the XSA the 1997 survey abundance indices were moved back in time setting 3 years old (1997) as 2 years old in 1996 etc. for all age groups. The same applies for the abundance indices for other survey years.

Figure 7 shows the scaled weights in the estimation of fishing mortality by age for survey indices, commercial CPUE and the shrinkage mean for cod resulting from the 1996 XSA-tuning. For the younger age groups (3 to 5) the weight of the survey predominates but by increasing age its importance decreases gradually. This is to some extent connected to the fact that the mature fish is less available to the survey than the younger immature fish. For the oldest age groups (11 to 14) that are few in number the shrinkage to the mean predominates the estimation of fishing mortality.

The same picture also applies for haddock (Figure 8). For age groups 2 to 4 indices from IceGFS have largest weight in XSA tuning but CPUE from commercial fishing fleets has the largest weight for age 6 and older.

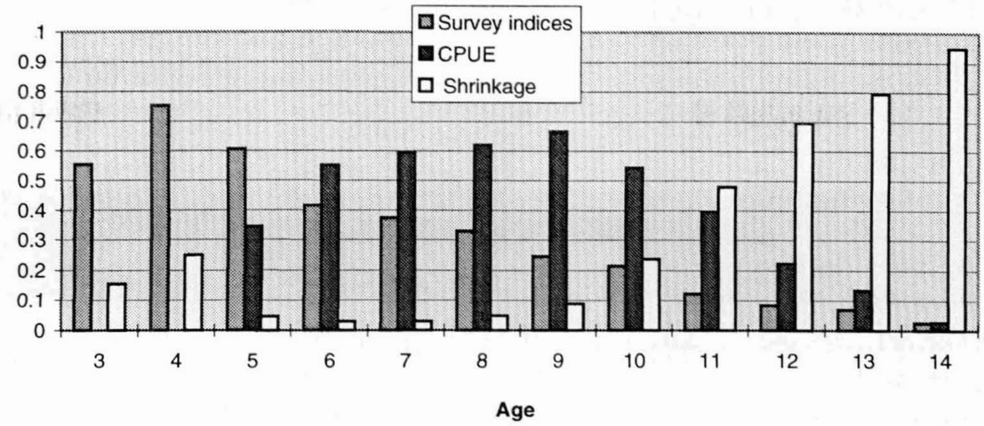

Figure 7. XSA tuning of cod. Scaled weights by age for survey (3 different indices), commercial CPUE (5 fleets) and shrinkage mean.

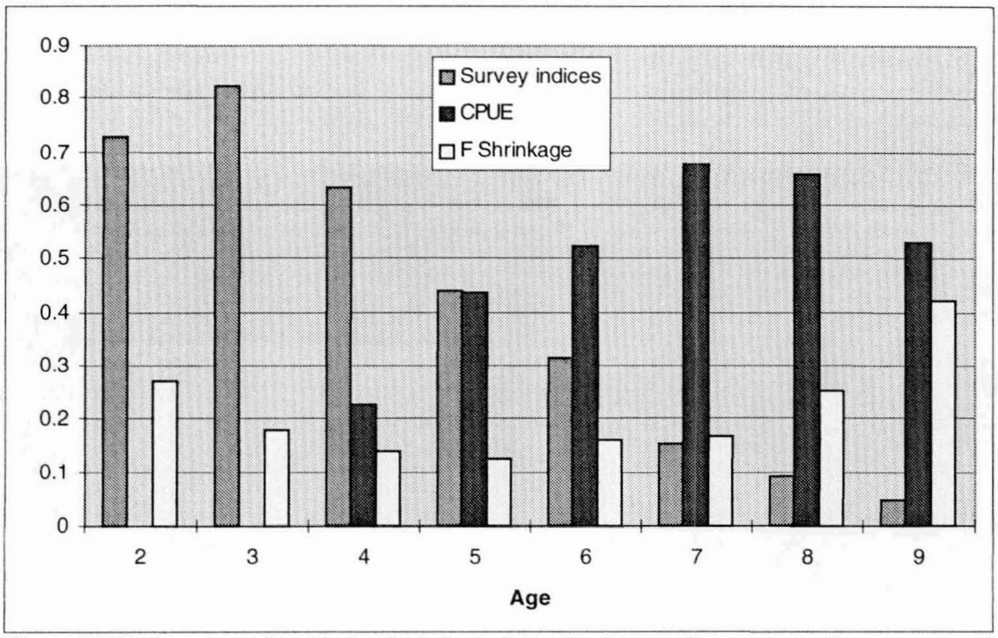

Figure 8 XSA-tuning of haddock 1996. Scaled weights by age for survey indices, commercial CPUE and shrinkage mean

5.4 Recruitment predictions of cod and haddock.

Annual predictions of recruitment to fish stocks sustaining commercial fisheries are standard routines in fisheries management. However, the methods underlying these routines have changed markedly during the last few decades. In the early seventies 0-group indices were used as predictors of cod recruitment with rather poor results. In the late seventies and the early eighties indices of demersal juvenile cod were used and were found to perform considerably better but still not without extreme outliers.

A major objective of the Icelandic groundfish survey was to improve predictions of cod. Recruitment. During 1985-93 recruitment predictions of cod and haddock were based on simple linear regressions of age group indices versus VPA recruitment. Since 1994 the RCT routine has been used for this purpose. The RCT routine carries out a log linear regression of the age group indices in question (ages 1-4 for cod and haddock). The squared inverse of the standard error of the predicted value is used to determine the weight of the respective relationship in the overall prediction for that year class. The VPA values are also taken into account in the prediction in relation to their standard errors. The most recent (1997) RCT data are shown in figures 9 and 10 for cod and haddock respectively. The results show that regressions of cod age group indices versus VPA recruitment of cod have R^2-values close to 0.8 for age groups 2, 3 and 4 but a considerably poorer fit for age 1. In the case of haddock the R^2-values are markedly higher for all ages and year classes or close to or larger than 0.9. Also the relationship between survey indices and VPA estimates in nearly linear for haddock but far from linear for cod. Highest values were observed for haddock age group 2 and lowest for ages 3 and 4. This clearly indicates that not only cod is well covered by the survey although survey design was made in view of the biological features of cod.

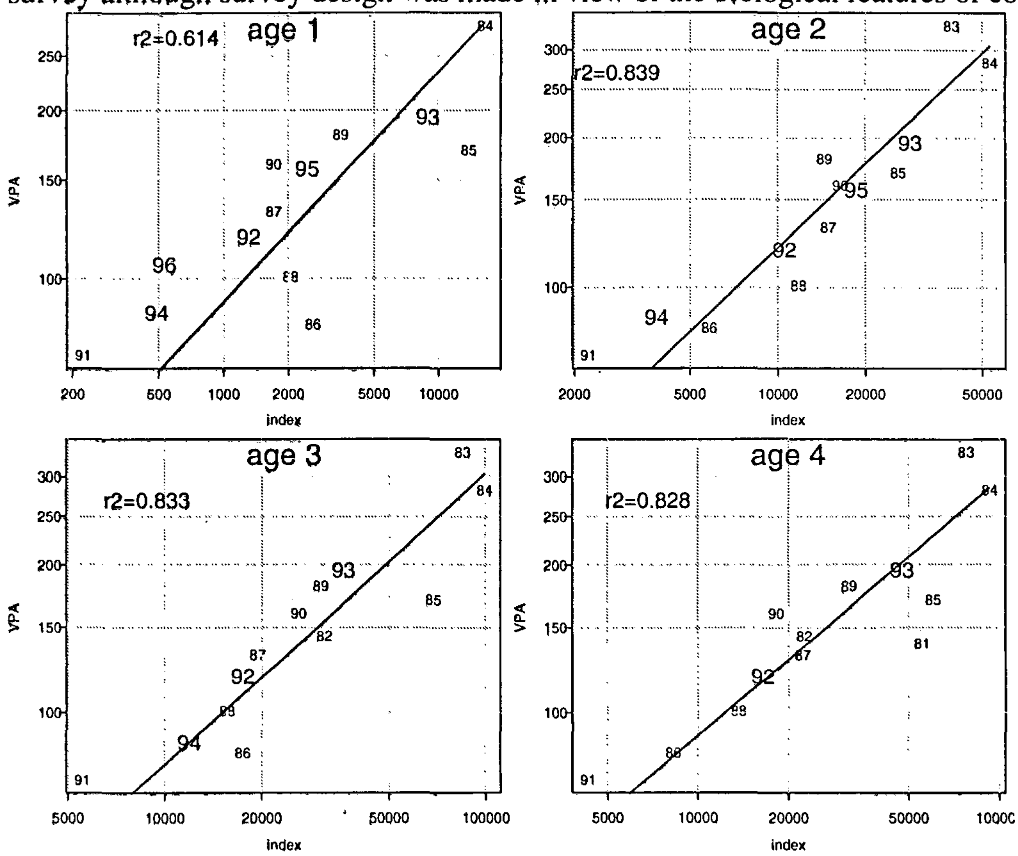

Figure 9. Stockindices and VPA estimate for cod. Estimates from RCT3 also shown with estimated r^2 from RCT3.

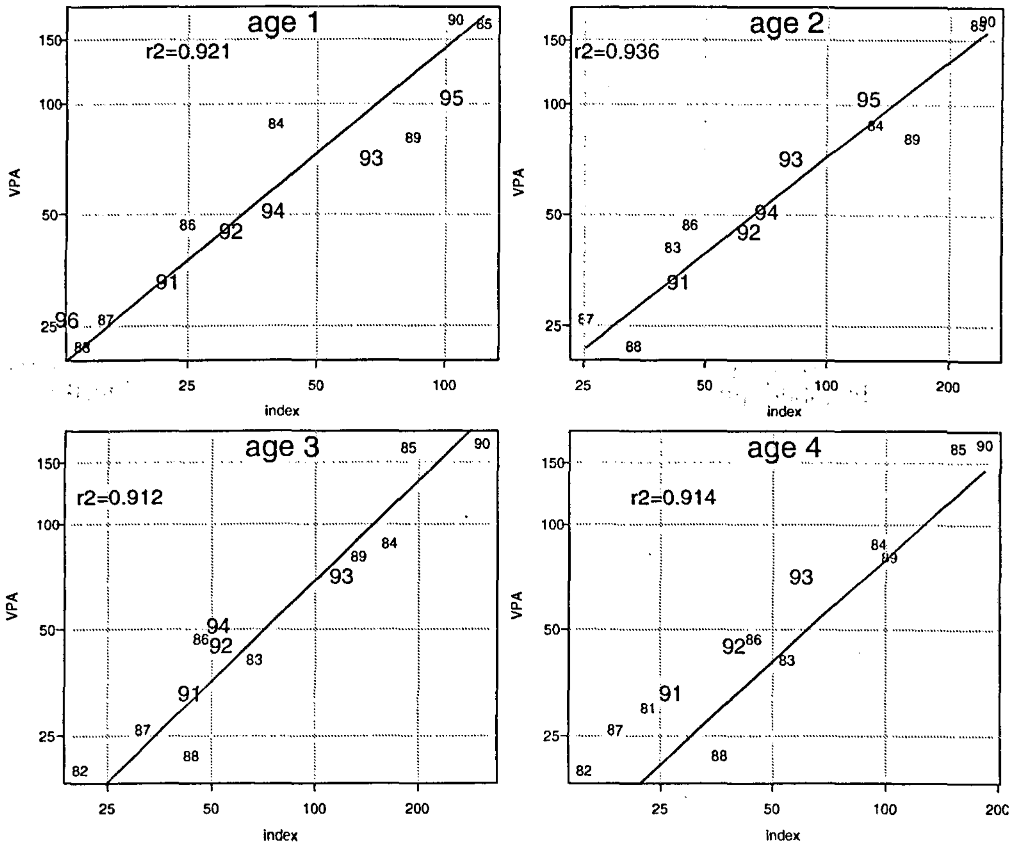

Figure 10. Stockindices and VPA estimate for cod. Estimates from RCT3 also shown with estimated r^2 from RCT3.

A quality analysis of recruitment predictions is shown for cod and haddock in tables 10 and 11 respectively. It is seen that during the first years of the IceGFS-survey recruitment predictions (year classes 1981-1988) deviated (average absolute deviation), in majority of cases, from the VPA recruitment by more than 20% (Table 10). In these years the predictions were mainly based on previous demersal studies and 0-group surveys. On the other hand, for year classes 1989-1993 the average absolute deviations was in all but one instance less than 20% and less than 10% for year classes 1992 and 1993. Thus, it seems justified to conclude that the objective stated above has been reached as far as cod is concerned.

Table 10. Quality analysis of cod recruitment predictions by age group and year class since 1985 (Anon. 1985, 1986, 1987a, 1987b,1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997) and current VPA recruitment estimates (Anon. 1997). Recruitment figures in millions of fish at age 3.

Year-class	Recruitment predictions Age 1	Age 2	Age 3	Age 4	VPA recr.	Deviations from VPA value (%) Age 1	Age 2	Age 3	Age 4	Av. abs. deviations (%)
1981			160	160	139			15.1	15.1	15.1
1982		100	120	125	144		-30.6	-16.7	-13.2	20.1
1983	190	220	300	280	336	-43.5	-34.5	-10.7	-16.7	26.3
1984	300	280	300	300	331	-9.4	-15.4	-9.4	-9.4	10.9
1985	220	220	220	190	169	30.2	30.2	30.2	12.4	25.7
1986	140	140	150	110	82	70.7	70.7	82.9	34.1	64.6
1987	140	150	140	150	131	6.9	14.5	6.9	14.5	10.7

1988	150	140	125	125	100	50.0	40.0	25.0	25.0	35.0
1989	170	160	150	155	180	-5.6	-11.1	-16.7	-13.9	11.8
1990	130	155	137	155	168	-22.6	-7.7	-18.5	-7.7	14.1
1991	100	73	60	60	79	26.6	-7.6	-24.1	-24.1	20.6
1992	130	130	110	115	125	4.0	4.0	-12.0	-8.0	7.0
1993	180	210	195	195	195	-7.7	7.7	0.0	0.0	3.9
			Av. abs. dev. (%)			25.2	22.8	22.3	16.2	

Prior to the IceGFS haddock recruitment was evaluated in view of 0-group indices and VPA catch at age results. The extensive data yielded by the IceGFS on haddock were quickly used for recruitment predictions and seem to have performed quite well already in the first years when average absolute deviations below 20% were the rule. During this period (year classes 1984-87) recruitment was generally underestimated with respect to VPA results. The year classes of 1988 and 1989 were exceptionally poorly predicted and grossly overestimated. Later year classes (1990-93) have mostly been predicted with average absolute deviation below 20% and have been overestimated in later years. Thus, somewhat surprisingly, the haddock predictions have remained rather stable throughout the period, with exception of year classes 1988 and 1989, and do not show the trend in improvement observed for cod.

Table 11. Quality analysis of haddock recruitment predictions by age group and year class since 1986 (Anon. 1987a, 1987b,1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997) and current VPA recruitment estimates (Anon. 1997). Recruitment figures in millions of fish at age 2.

Year-class	Recruitment predictions Age 1	Age 2	Age 3	Age 4	VPA recruitm.	Deviations from VPA values (%) Age 1	Age 2	Age 3	Age 4	Av. abs. deviations
1984		80	80	110	88		-9.1	-9.1	25.0	14.4
1985	100	180	110	134	166	-39.8	8.4	-33.7	-19.3	22.8
1986		50	34	40	47		6.4	-27.7	-14.9	16.3
1987		30	30	24	26		15.4	15.4	-7.7	12.8
1988	40	40	31	31	22	81.8	81.8	40.9	40.9	61.4
1989	100	110	110	107	81	23.5	35.8	35.8	32.1	31.8
1990	110	160	162	167	170	-35.3	-5.9	-4.7	-1.8	11.9
1991	44	41	40	35	35	25.7	17.1	14.3	0.0	14.3
1992	54	50	50	44	40	35.0	25.0	25.0	10.0	23.8
1993	100	78	73	71	71	40.8	9.9	2.8	0.0	13.4

6. Quality of survey data used for assessment.

6.1 Introduction

Those using survey data for assessment have preferably to have some method to estimate the quality of their data. This is often a difficult job for the truth is not known. There are 3 possible error sources in survey data.

1. Variance due to limited number of tows.
2. Fluctuations in catchability from one year to another.
3. Long term changes in catchability. This can be due to change in distribution of the species and/or maturity ogives.

6.2 Variance due to limited number of tows

The CV in the survey data was discussed in section 2 in connection with redesign of the survey. For cod the CV was 11% but 13% for haddock and redfish. (Numbers based on 530 tows and an index of total number of fishes).

Tables 8 and 9 show the CV of the survey indices for 5 selected species. This CV is similar to the CV obtained from the bootstrap, i.e. reflects the variance due to insufficient number of stations. As may be seen in the tables the CV of the indices for Catfish and long rough dab is very low indicating even distribution of these species while the indices for plaice are somtimes quite bad with a CV up to 0.76.

6.3 Fluctuations in catchability from one year to another

Catchability of a species can change from between years. This is well known in commercial catches where there is little catch for some time but then the catch is quite good for some time

Environmental factors like weather, tidal current and ocean temperature have important effect on the catchability in the survey. The effect of these factors is though difficult to quantify but as the survey series gets longer possibilities increase to investigate the effect of these factors.

Difference in maturity from one year to another (due to feeding conditions) can affect obtained survey indices of some species. It has been shown (Thorarinsson and Jóhannesson 1994) that mature cod is much less available to the survey than immature cod.

Reasonable short term fluctuations in catchability are usually not a major problem in assessment when using stock assessment methods like XSA or related method.

6.4 Long term trends in catchability of cod.

Long term trends in catchability are the most difficult one to handle. They can be more or less due to the same reasons as the short term fluctuations i.e. environmental conditions or change in maturity ogives. In this case the effects are more of permanent character.

Joint time series analysis of catch-at-age observations and survey results described by Gudmundsson (1994) has been used in assessment of the Icelandic cod stock for a number of years. The method allows to test statistically if there is a trend in catchability of a fleet used for tuning.

The aim of the survey is to obtain annual indices for each age, proportional to the stock at the time of the survey. The catches are subject to random variations, and environmental changes could affect several age groups in the same way. But most applications of survey results are based on the assumption that the variations are transitory. However, environmental effects could be of a permanent character and so would variations produced by changes in the conduct of the survey. In order to test for such variations a model must allow for their presence. Let us call the survey result for age a in year y U_{ay} and the stock at the time of the survey N_{ay}. The relationship is then

$$U_{ay} = \varphi_y q_a N_{ay} + \varepsilon_{ay}$$

where catchability at respective age is given by q_a and ε_{ay} represents measurement errors and random transitory variations in catchability. The variance of ε_{ay} is $\sigma^2 \tilde{U}_{ay}$ where $\tilde{U}_{ay}$ is an estimated mean value for respective age and cohort. Joint variations in catchability are represented by φ_y and modeled as

$$\log \varphi_y = \xi_{y-1} + \delta_{1t},$$

$$\xi_y = \xi_{y-1} + b + \delta_{2t}.$$

Transitory variations, common to all ages, are denoted by the residuals δ_{1t} with variance σ_1^2. Permanent variations are represented by ξ_y; b introduces trend and the residuals δ_{2T}, with variance σ_2^2, random walk.

The survey results for ages 4-9 from the years 1985-1997 were analyzed by this model together with catch-at-age data for ages 4-11 years from 1984-1996. The survey results for 3 years old fish were also included as a recruitment index.
In order to test the hypothesis that there are no permanent variations, we compare the maximum of the likelihood function when both b and σ_2 are fixed at zero with the maximum obtained when these parameters are estimated. With the present data there is negligible increase in likelihood when b and σ_2 are freely estimated so that there is no evidence against the hypothesis that variations in catchability are transitory.

The estimated values of σ and σ_1 are 0.23 and 0.29 respectively.

6.5 Comparison of tows selected by captains and tows selected randomly.

As mentioned earlier half of the original tows were selected randomly but the other half selected by fishermen. An interesting question that came up when allocating tows for a survey in the autumn was if there was any difference in the quality of data from the two types of tow. To answer that question 2 XSA runs were done. The species used was cod but cod was probably the target species for most captains in the original selection of tows. The tuning data in the XSA runs was as follows.

1. Only tows selected ~~randomly~~ by captains used to make indices for tuning.
2. Only tows selected randomly used to make indices for tuning.

The result is shown in table 12. The random tows are better for age 3 and 4 but worse for age 5 and older with the difference increasing with age of cod. This is more or less as expected, the captains select spots where they find large fish but avoid spots with small fish (or the smaller fish does not survive in locations with abundance of larger fishes).

Table 12. Regression statistics from XSA runs using tows selected by captains and random tows. The table shows r^2.

	Age					
	3	4	5	6	7	8
Tows selected by captains	0.83	0.88	0.89	0.91	0.82	0.77
Tows selected randomly	0.88	0.89	0.87	0.85	0.74	0.58

7. Other data obtained from the groundfish survey.

7.1 Introduction

Most of the description of the use of survey data has been about the use of abundance indices in tuning. Many other information can be obtained from the survey although their use in assessment is probably not as direct. Among information of interest are:

- Distribution of sea temperature
- Changes in sea temperature
- Distribution of mean length and weight at age
- Maturity at age
- Changes in mean length and weight with time
- Distribution of species

This list is far from complete. What will be looked at is the meanl weight and maturity at age for cod and haddock as well as distribution of some species.

7.2. Weight and maturity at age of cod and haddock

Mean weight at age of cod in southern and northern areas is presented in figures 11 and 12 There are considerable fluctuations. in the mean body weight especially in the southern area. Fluctuations of cod 8 years or older are not considered reliable due to scarce data. During the first years of the survey cod was generally in good condition and gaining weight. This situation culminated in 1987. After that body weight decreased gradually until 1991 when this development stopped and body weight reached it's lowest level. Since then it can be stated that weight at age has been increasing. This development has in general been somewhat similar in the southern area, the trends of body weight fluctuations in that area being more vague than in the northern area. Body weight of cod in recants years seems, however, to have culminated in the year 1995 in the northern area while it is still rising in the southern area.

Mean weight of haddock can also fluctuate considerably (Fig. 13 and 14). These fluctuations do not coincide with those of cod but there are, however, some similarities. In the southern area haddock was also in good condition and gaining weight at the beginning of the survey series although no single year can be pointed out as the year of culmination in this development when looking at all year-classes. Leaving out 2 year old haddock there has been a general trend of falling body weight since the end of the last decade until 1995 when this development mainly came to a halt or even was reversed. As is the case with cod mean weight of haddock in the northern area fluctuates more from year to year making it difficult to see trends. However, low body weight of haddock has been the general rule in both areas during the last 5 to 6 years.

Maturity at age of cod is presented in figures 15 and 16 separately for north and south area. Not regarding the oldest age groups which due to scarce data are hardly reflecting true situation, there are clear fluctuations and changes in maturity both from year to year and long time trends. In the southern area there has been a general upward trend in maturity since 1991 up to present date (1997). For 4 and 5 years old cod this trend, however ,culminated in 1994 and has mostly be en declining since then for three age groupes. In the northern area fluctuations seem to be more sporadic. However, there seems to be a general slow downward trend in maturity of 5 to 7 year old cod since 1987 up to present date but this trend is not without exceptions.

Maturity at age of haddock is presented if figures17 and 18 separately for area north and south. In the southern area some fluctuations of older haddock are visible from year to year but long term trends are not seen . However, constant rising of maturity of young haddock (2 and 3 years old) is very clear. Fluctuation in maturity of haddock in the northern area are more sporadic from year to year and long term trends are mostly unclear.

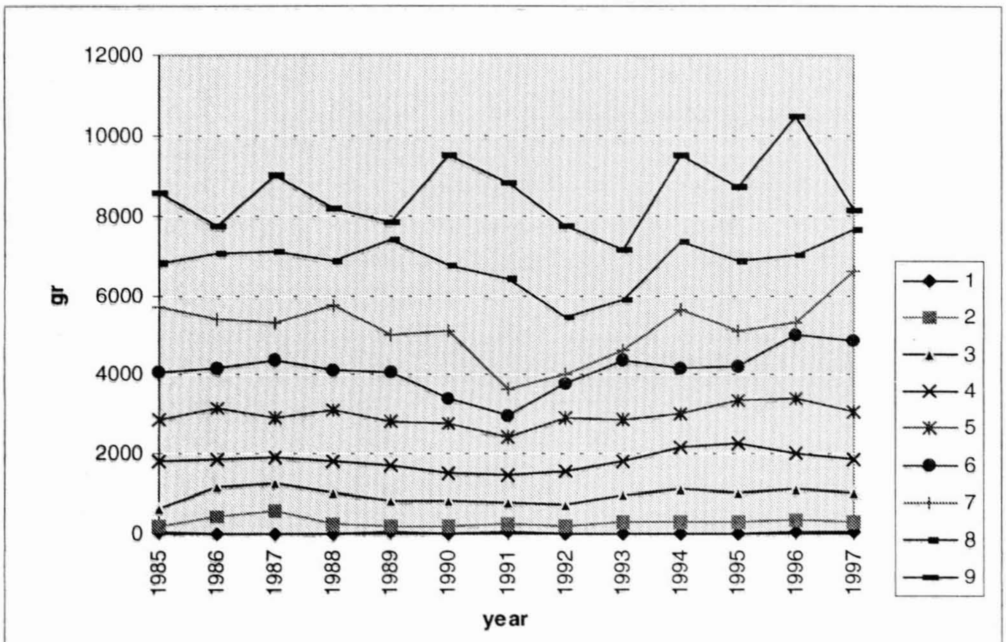

Fig. 11. Average weight at age of cod in groundfish surveys, southern area 1985-1997

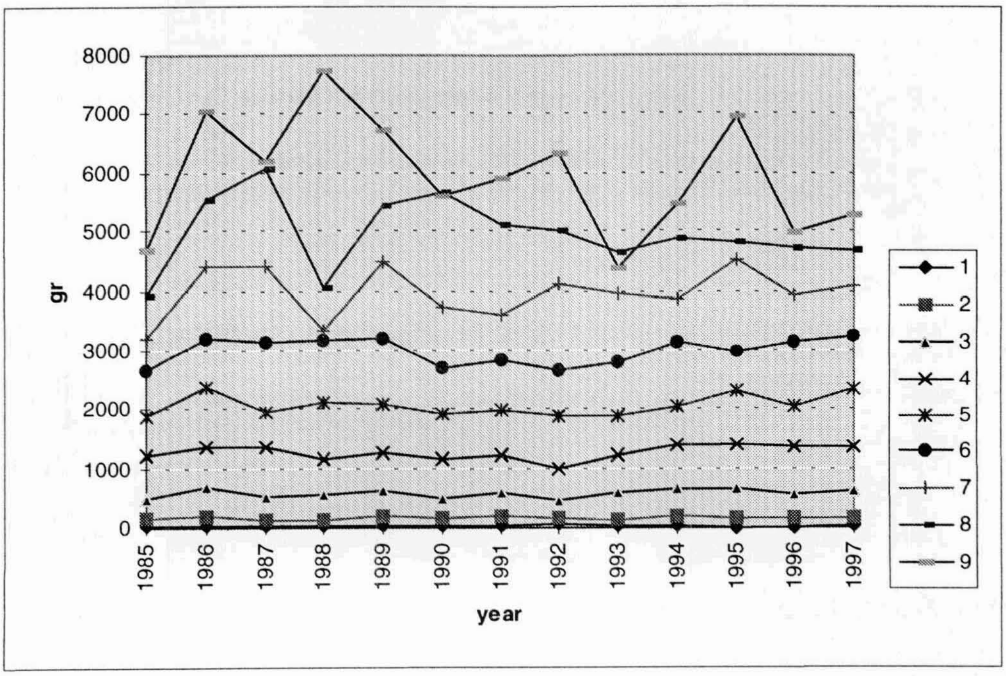

Fig. 12. Average weight at age of cod in groundfish surveys, northern area 1985-1997

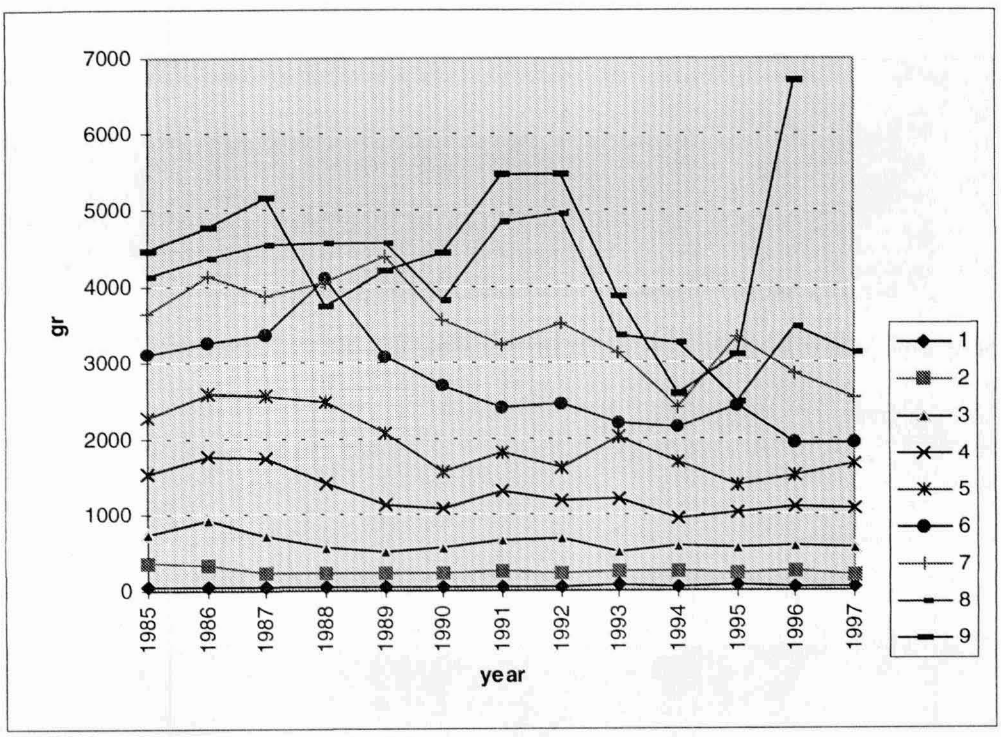

Fig. 13. Average weight at age of haddock in groundfish surveys, southern area 1985-1997

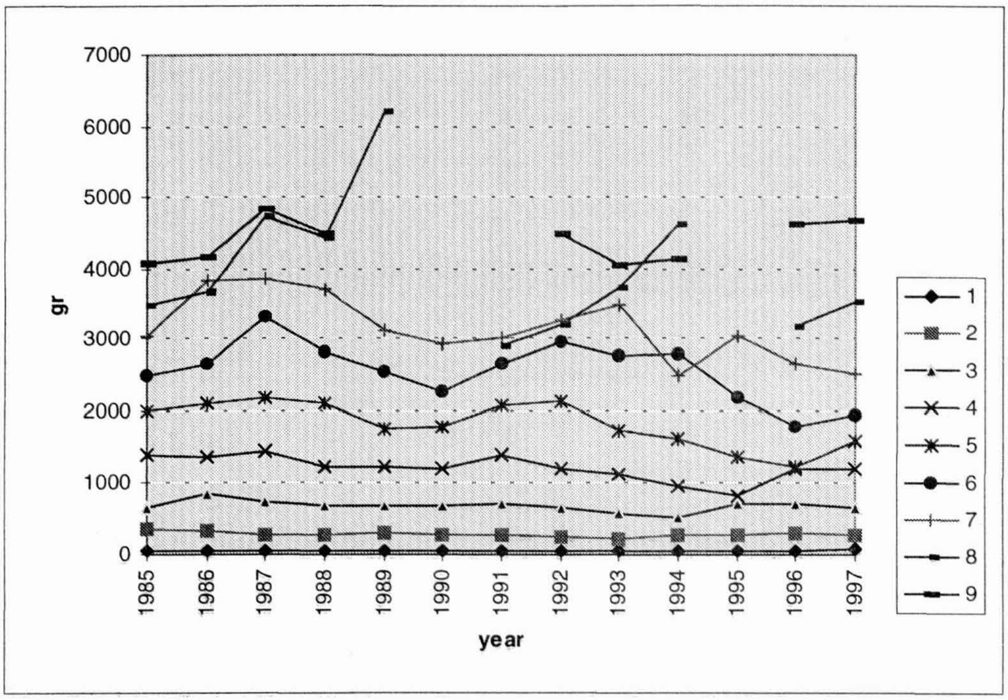

Fig. 14. Average weight at age of haddock in groundfish surveys, northern area 1985-1997

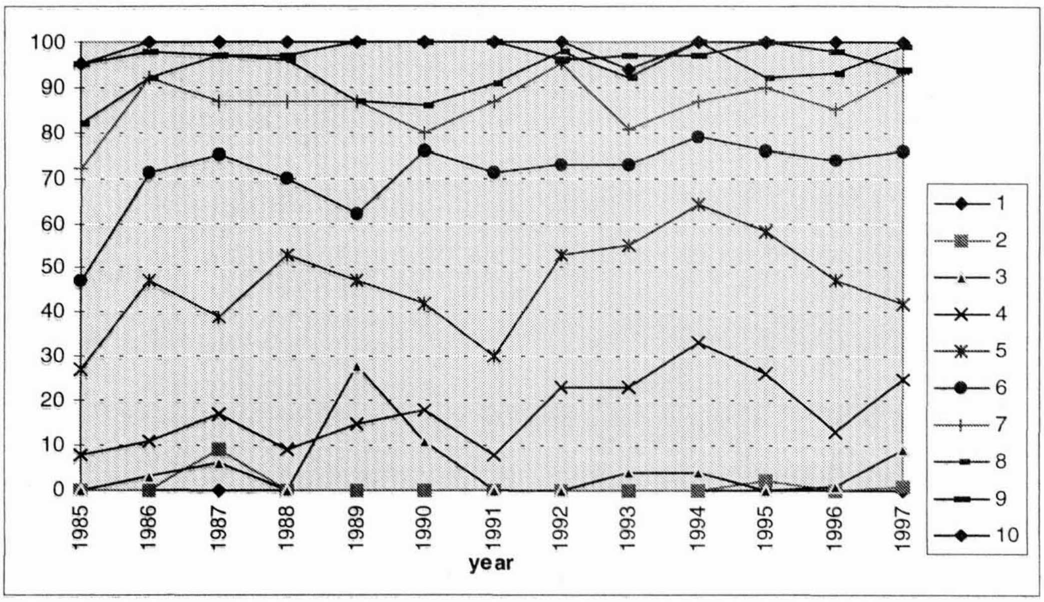

Fig. 15. Maturity (%) at age of cod in groundfish surveys, southern area, 1985-1997

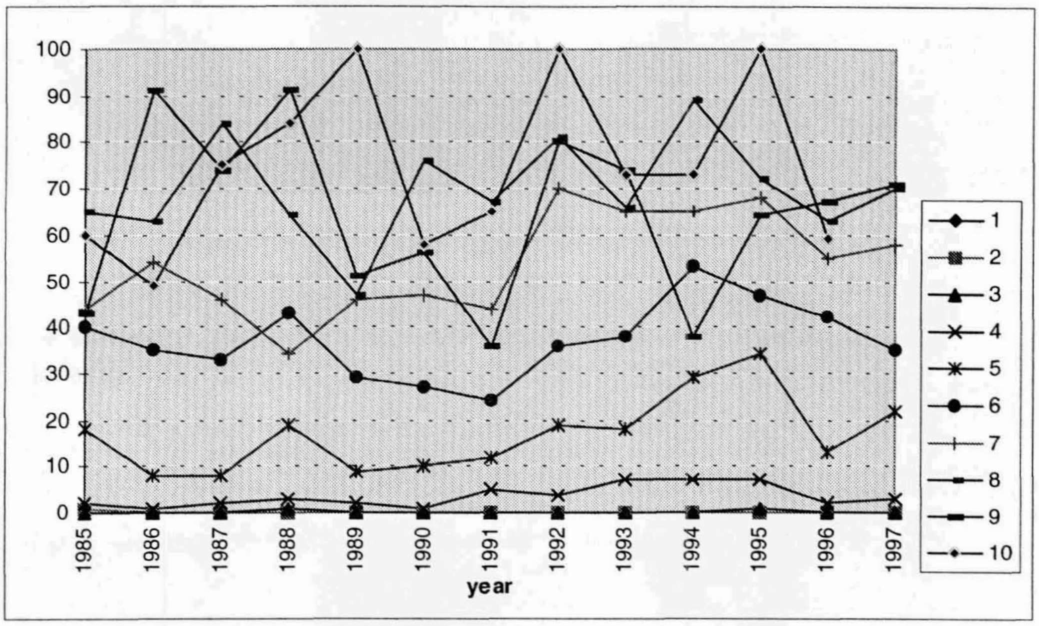

Fig. 16. Maturity (%) at age of cod in groundfish surveys, northern area, 1985-1997

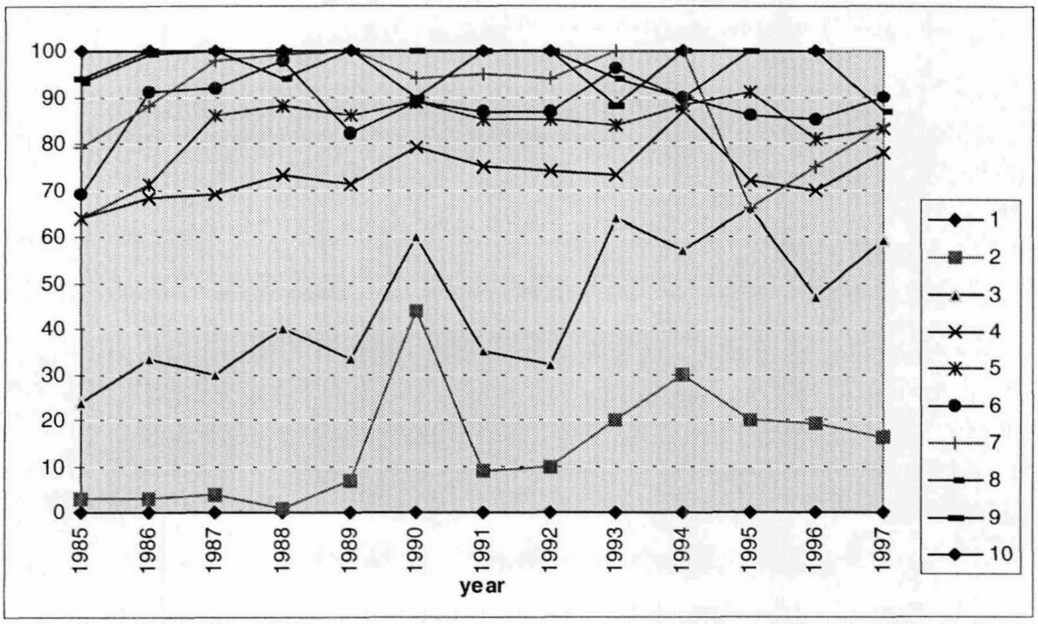

Fig. 17. Maturity (%) at age of haddock in groundfish surveys, southern area, 1985-1997

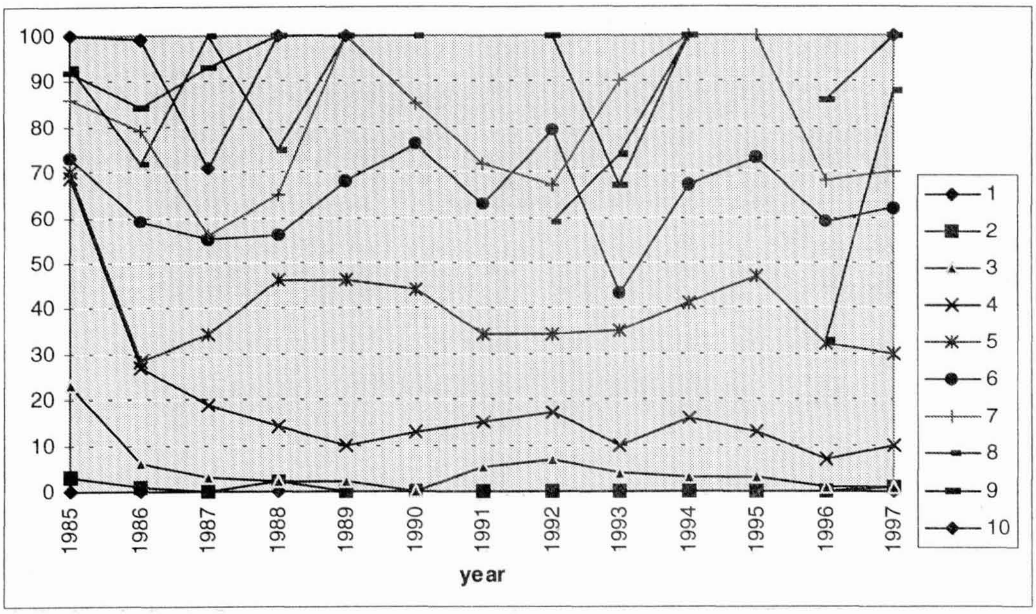

Fig. 18. Maturity (%) at age of haddock in groundfish surveys, northern area, 1985-1997

7.3 . Spatial distributions of selected stocks

In figures 19 to 22 the spatial distribution of several selected species is presented as mean catch (1985-1997) per tow in number or kg. As nursing grounds (small fish) of many species are frequently in different localities than the fishing banks of the adult stock spatial distribution of many species is closely connected to length (of individual fish). In order to apprehend this situation the spatial distribution of some species is looked at according to different size.

Cod is distributed all around Iceland (Fig. 19). Small cod (< 20 cm) is mainly distributed off the northern part of Iceland both in shallow and deep waters. Medium size cod (55-65 cm) has much larger spatial distribution. However the highest concentrations occur off the north coast while the banks off the south coast are practically void of medium size cod. Large cod (> 90 cm) is mainly distributed in waters off the southern part of Iceland.

Haddock has little distributions on deeper grounds but close to coast concentrations are quite common (Fig. 20). Small haddock (< 20 cm) is always found in high concentrations off the south coast. Medium size haddock (25-35 cm) is fairly evenly distributed around Iceland, the largest catches, however, most often occur of the south coast. Haddock larger than 50 cm is most common at SA and SW Iceland. Amount of haddock in the northern area correlates more with temperature than the amount of cod, in cold years much less haddock is caught there.

Redfish is not found in shallow waters (Fig. 21). Young redfish less than 15 cm is only caught in the northern part of the survey area. Medium size redfish (25-30 cm) is mainly caught on deep grounds W of Iceland while highest catches of large redfish (> 40 cm) are mainly in deep water SW and to some extent SE off Iceland.

Catfish is found all around Iceland to some extent (Fig. 22) the highest concentrations being at NV and SE Iceland.

Plaice is a shallow water species and found to some extent close to the coast all around Iceland (Fig. 22). The highest catches, however, are always in the bays west of Iceland.

Whiting is with few exceptions only found off the south coast of Iceland (Fig. 22).

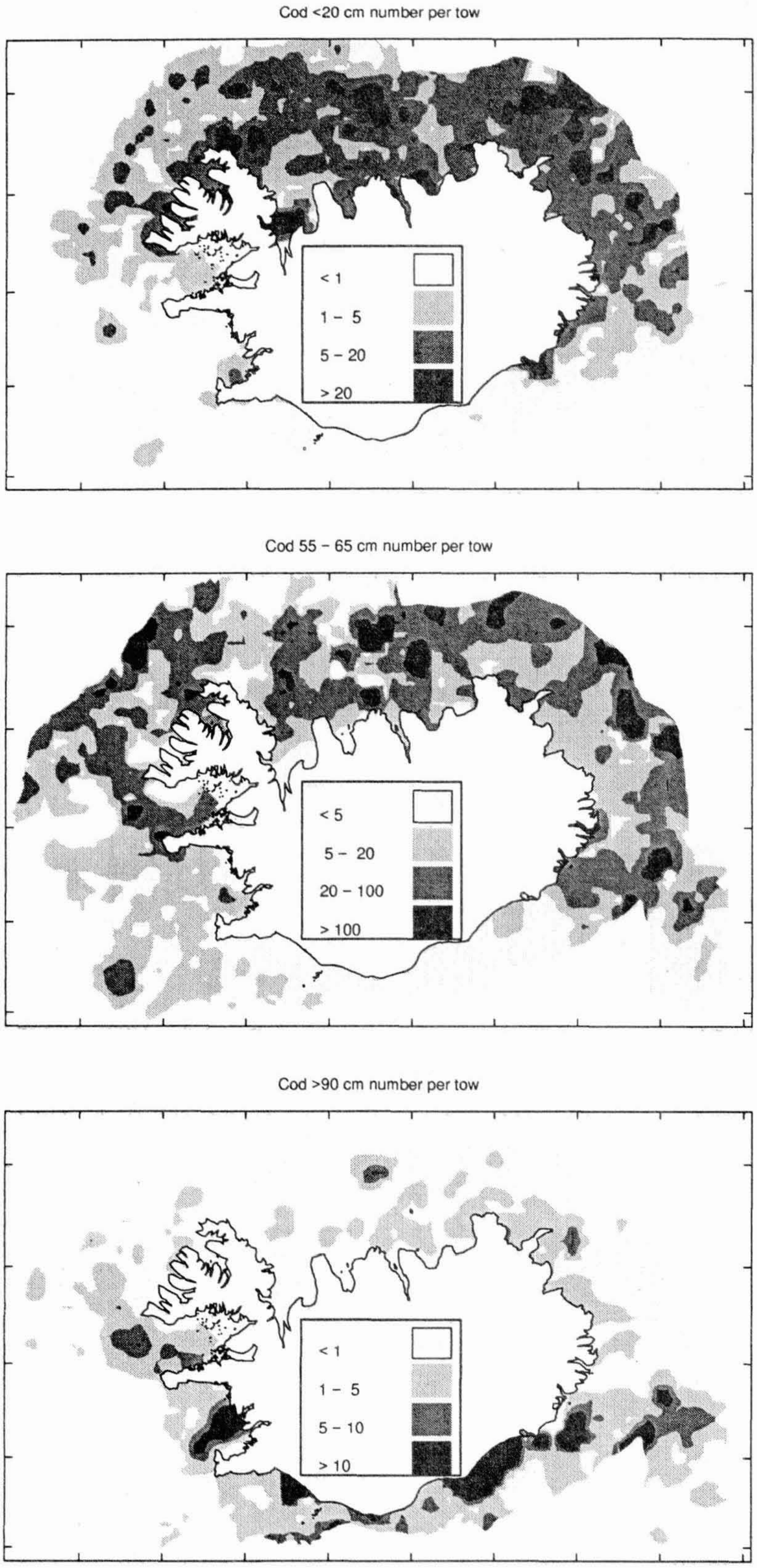

Figure 19. Distribution of cod in the groundfish survey 1985 to 1997. (Number per tow).

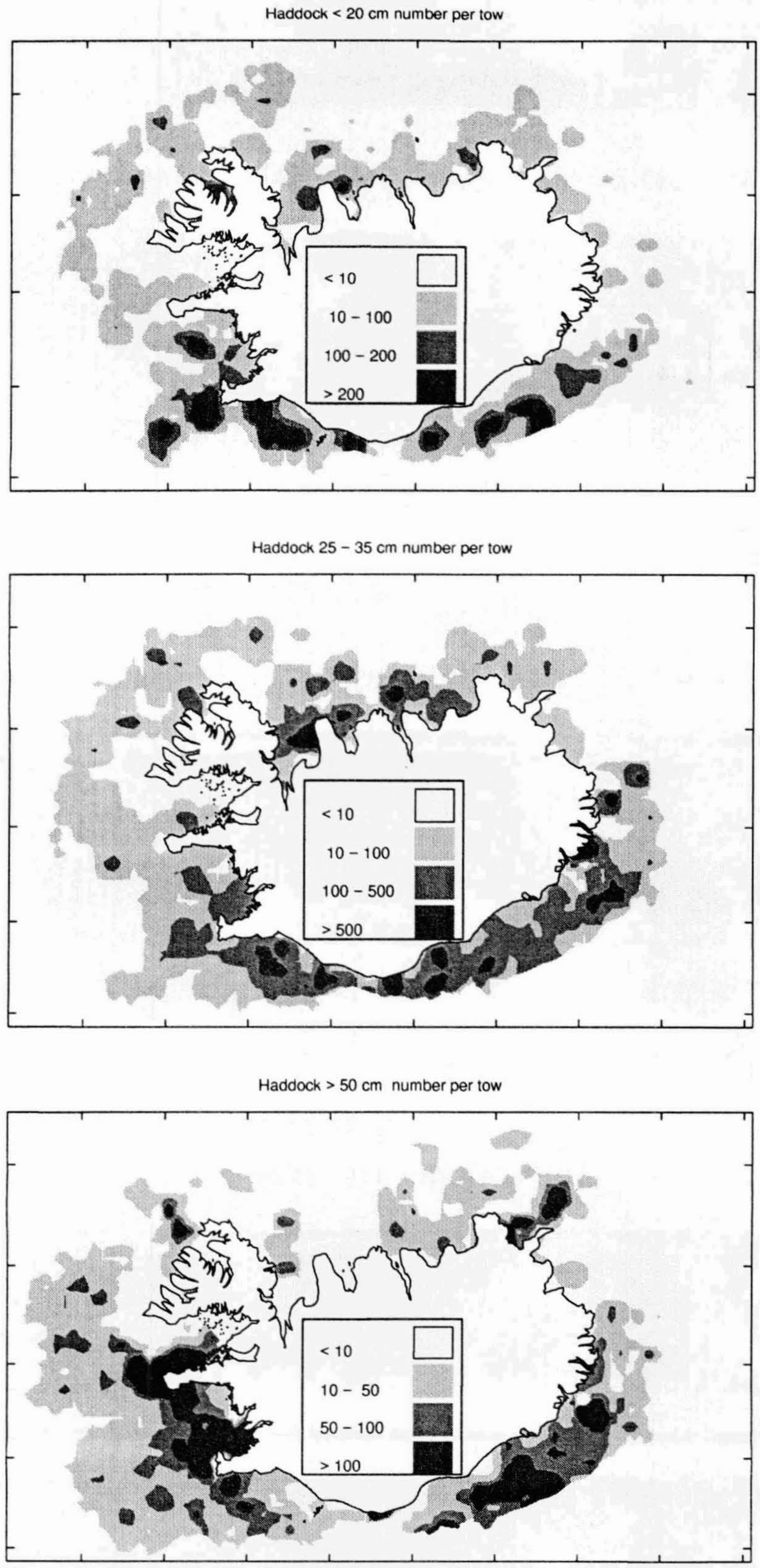

Figure 20. Distribution of haddock in the groundfish survey 1985 to 1997. (Number per tow).

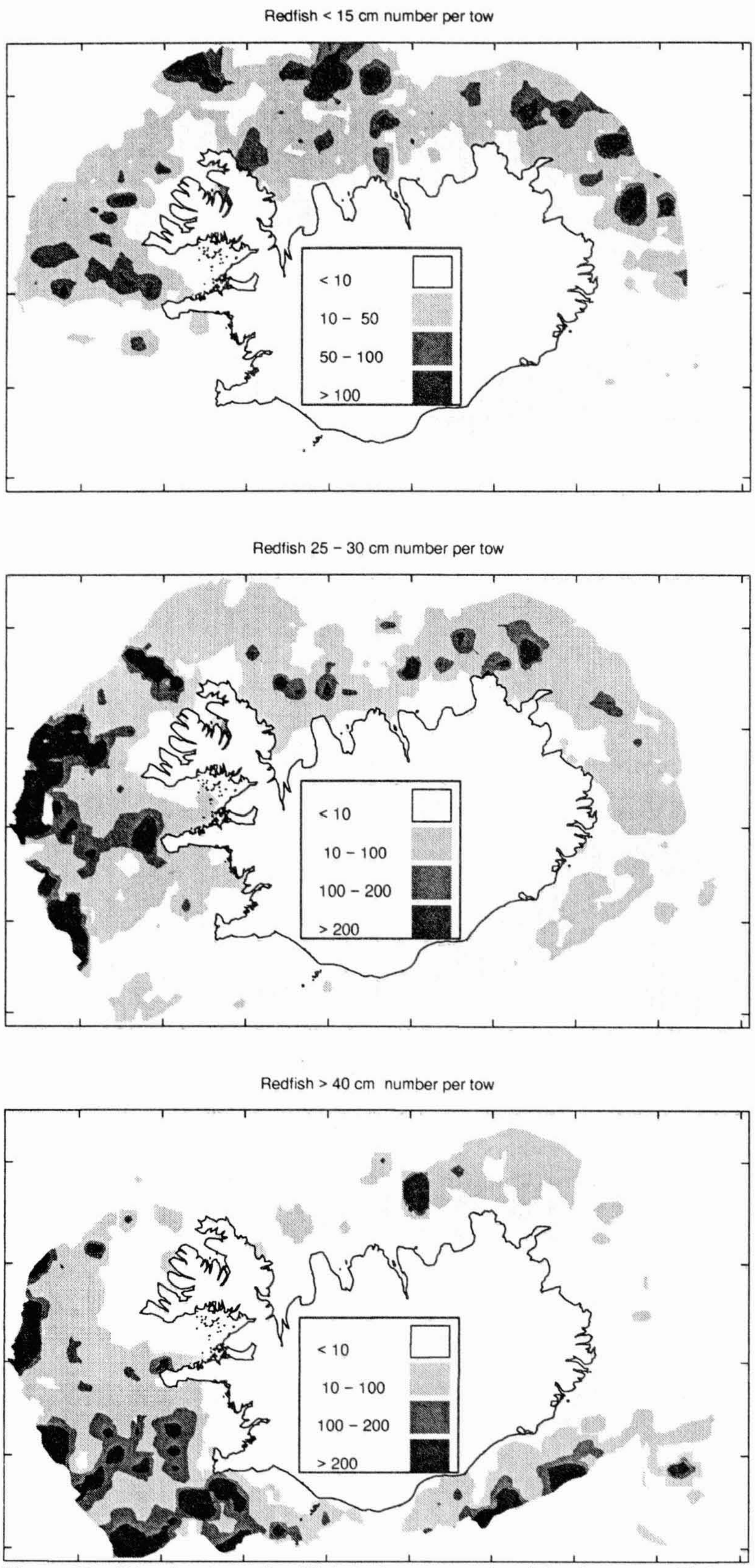

Figure 21. Distribution of redfish (Sebastes marinus) in the groundfish survey 1985 to 1997. (Number per tow).

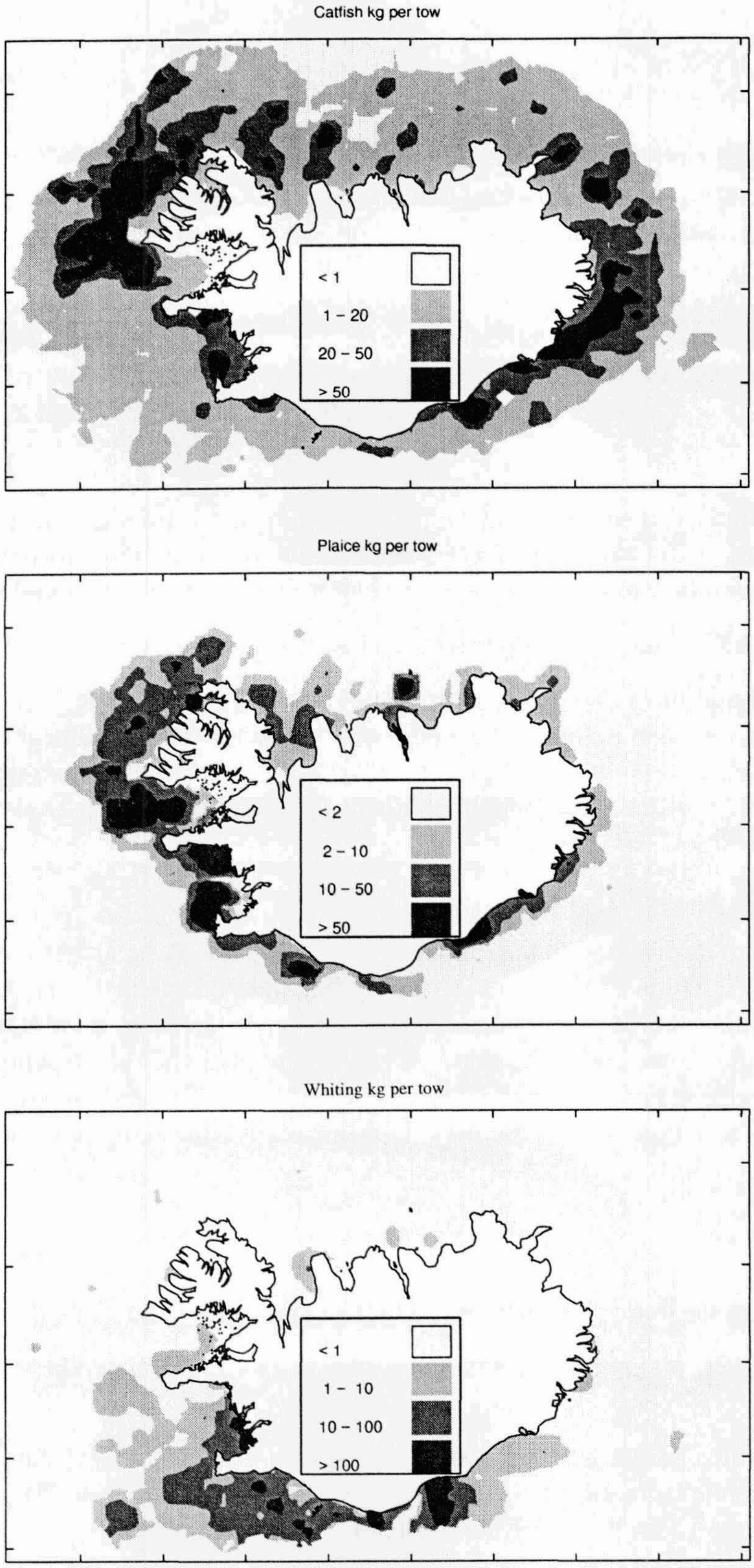

Figure 22. Distribution of catfish, plaice and whiting in the groundfish survey 1985 to 1997. (kg per tow).

8. Conclusions

This paper has provided an outline of some of the present uses to which data from the Icelandic groundfish survey is put. It is seen that the survey has found its main place as the provider of indices of abundance, used to monitor several of the most important fish stocks on the shelf around Iceland. The survey has been conducted in as standard a fashion as possible. In particular, attempts have been made to maintain the same set of stations every year, as well as maintaining the same gear. Some changes have been inevitable, however, given that the survey is conducted using commercial trawlers, but in spite of these, the survey correlates well with other abundance measures such as VPA.

This groundfish survey is also an important source of biological information since every attempt has been made to maintain and enhance on-board biological information collection. Thus, randomly sampled fish are aged, length-measured and weighted and stomach samples are taken in a more selective manner from aged fish.

In spite of the overall optimistic view several questions remain. These range from the nature of the relationship between stock and index, which appears to be nonlinear in many cases to unresolved methodological problems computing global indices in light of what appear to be very different catchabilities for several demersal species in the southern and northern areas.

Given the success of the survey it is clear that there is little incentive to modify it in any way, since that will destroy the standardization. In particular, gear changes and corrections through calibration experiments have not been undertaken since it is quite clear that such experiments have very high associated variances. In order to move technology forward, therefore, a separate survey has been initiated and the present survey will not be modified until the new survey proves adequate for assessment purposes as a bridge during the initial time period when a modification of the present survey will cause uncertainty in computed indices.

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