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Technique of Russian Trawl-acoustic Survey of the Barents Sea Bottom Fish and Mechanisms to Improve it

by

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ABSTRACT

Present-day trawl survey of the Barents Sea bottom fish has been conducted since 1982, as well as trawl-acoustic survey in October-December since 1986, by minimum two research vessels equipped with the latest hydroacoustic instruments, computer, trawl and hydrographic facilities. To estimate the abundance of next yearclasses the main commercial young species are assessed during trawl survey, as well as flatfish and catfish; the abundance and biomass of cod, haddock and redfish are estimated during trawl-acoustic survey. The survey is conducted by hydroacoustic tracks, occupying trawl stations located with allowance for long-term mean distribution of commercial fish proportionally to the area of the depth surveyed. Each trawl station position is random and is mainly dependent on a necessity of complete and uniform coverage of the area surveyed by them. Density of fish distribution is estimated by method of local areas. The survey technique is constantly improved. To automatize sampling and processing of primary information, calculation of bottom fish abundance and biomass, estimation of errors for calculations the special software packages were developed and used. Special attention is giving to calibration and intercalibration of EK-500 echo-sounders during the survey.

During the trawl-acoustic survey in 1995 separation of echo-intensities by species (cod, haddock, S.mentella and S.marinus) was done with allowance for isolating fish into three length groups, i.e. small, mean and large size. Calculations for abundance and biomass of cod and haddock were done taking into account length-weight relationship derived by analysis of regression for the database on 1cm length groups.

INTRODUCTION

Development of basis for rational fishery under a constantly growing anthropogenic impact on fish stocks is the most topical problem of fisheries science. Settling of this problem is possible in the event provided the sufficiently precise estimates are obtained for status of populations of marine organisms inhabiting this or that area.

Polar Institute was one of the first in Russia which organized large-scale investigations on bottom fish stock assessment. Since 1946 annual trawl survey for young fish assessment has been carried out, as well as trawl survey to estimate relative abundance of adult fish in the Barents Sea area since 1959. In 1970's the acoustic technique and underwater observations to assess bottom fish stocks were introduced.

Applying of different methods for assessment of the Barents Sea bottom fish in 70-80's has revealed their advantages and disadvantages and provided for the lines of their further development and improvement, a realization of which was mainly due to the introduction of the latest methods and hardware, obtaining and efficient exploitation of maximum quantity of biological information at minimum expenses, as well as to optimization of works. In 1982 multispecies trawl survey was conducted in the Barents Sea, during which both the young fish and bottom fish stock were simultaneously assessed for the first time. It was improving with a growth of hardware and methods for investigations and in 1987 it became a multispecies trawl-acoustic survey to assess both the young fish and stocks of bottom and pelagic fish (Shevelev, Mamylov, Yaragina, 1988). To estimate the abundance of fish distributed in 8-meter bottom layer, fished off by sampling trawl, the trawl efficiency coefficients (differentiated by species and length group), the values of which were found by experimental underwater facilities (Zaferman, Serebrov, 1984), were used. In this case, density of fish in pelagial (above 8m from bottom) was determined by standard and acoustic methods.

To determine abundance of fish in a bottom layer an acoustic method was also used along with a trawl one, in spite of limitation of its applying in this case because of a bottom acoustic "shadow zone". A comparison between the abundance of marine organisms, distributed in this layer and registered by different methods, allowed to obtain additional data on fish vertical distribution which could be possible to use for improving the trawl-acoustic method for stock assessment. However, incorrectness of the results obtained by this method for a bottom layer, due to insufficiently reliable differentiated coefficients of sampling trawl efficiency, prevented from applying them in the 1988 survey (Shevelev, Dorchenkov, Shvagzhdis, 1989). Abundance of fish in the zone fished off by a bottom trawl was determined using a trawl or acoustic method depending on a pattern of fish distribution at the bottom, with allowance for regression relationship between catches and mean value for echo-intensity in a bottom channel of integrator along the area swept (Mamylov et al., 1989). As a result of the investigations in 1987-1989 an optimum period (October-December) has been set for assessment of young and bottom fish stocks (Shevelev, Dorchenkov, Mamylov, 1990). The investigations on bottom fish have been conducted during this period since 1990 and still continued at present.

Besides mentioned, other main aspects of methods for multispecies trawl-acoustic survey (MS TAS) have nearly not been changed since 1982. Special attention in the paper (cod as an example) is given to the changes taken place in methods for processing the results from MS TAS in 1995.

METHODS

MS TAS of bottom fish

This survey is conducted during a mass migration of cod and haddock to wintering and spawning grounds from late October to late December. Its total duration is 40-50 days. All the fishing grounds (around 150 thou.mile^2) on the shelf of the Barents, Norwegian and Greenland Seas are covered by the survey. Depth are surveyed from 50 to 900m. MS TAS is carried out by a grid of hydroacoustic tracks, occupying trawl stations located with allowance for long-term mean distribution of commercial fish, proportionally to the area of the depth surveyed with a mean density of about 1 station per 300 mile^2. Total number of sampling hauls decreased from 600 to 400 during recent years. Each trawl station position is taken on random and is mainly determined by a necessity of complete and regular covering of the surveyed area by them (Fig.1). The survey is undertaken regarding fish migrations, i.e. by current flows towards a movement of active migrants (cod and haddock). Operations are performed during 24 hours by 2 or 3 vessels simultaneously. Sampling gear is a fishing bottom trawl with the distance between wings about 30m and 7.8-8.0m opening height. A netting (16mm inner mesh-size) is installed into a trawl codend. Vessel's speed during bottom trawling is 3.2 knots, duration of haul is 1 hour. Echo-integration of mid-water by layers is performed between trawl stations and during hauls. Hydrographic observations are done at each trawl station at all standard depths, as well as zooplankton is collected by a trawl net during hauls.

About 20 fish species are registered, as well as deep water shrimp and benthic organisms occurring in trawl.

Trawl method is used to assess young bottom fish and to obtain relative indices for abundance of next yearclasses (Baranenkova, Drobysheva, Ponomarenko, 1964; Baranenkova, 1967; Trambachev, 1981) simultaneously with stock assessment. Yearclass abundance is estimated by mean catches of young fish from the yearclass preset per 1 trawling hour in comparison with long-term series of similar observations (Melyantsev, Salmov, 1985). Trawl method is also used to assess the stocks of Greenland halibut, flounder, plaice and of three species of the Barents Sea catfish. For stock assessment of cod, haddock, S.marinus a trawl-acoustic method is applied. When estimating stocks by trawl method the mean coefficients of a sampling trawl efficiency are used which are constant from year to year and specific for each species, allowing to obtain only indeces for abundance and biomass. Ideally, the trawl-acoustic method gives a possibility to estimate absolute abundance and biomass of fish. Density of fish distribution over the area is estimated by method of local areas.

As a rule, the estimates obtained by TAS method are lower than those calculated by VPA method due to a constant underestimation of stocks because of imperfectness of the first method and some reasons concerning arrangement. On the other hand, both the trawl and trawl-acoustic methods produce estimates, the year-to-year dynamics of which well agrees with those estimated by VPA method. Agreement of trends revealed on the basis of estimates obtained by different methods allows to consider the results from MS TAC to reflect a status of the stocks investigated sufficiently well. At the same time, enhancement of reliability of estimates for fish stocks remains to be actual.

To improve technique of the surveys the following trends could be isolated:

- to optimize a location of hydroacoustic tracks and trawl stations;
- to develop more stable operating trawls for assessment surveys;
- to elucidate methods for differentiation of bottom and pelagic components of aggregations of marine organisms based on studies on their behaviour regularities;
- to develop more reliable facilities for quantitative estimation of bottom fish aggregations based on underwater television;
- to expand and elucidate data on differentiated coefficients of trawl efficiency;
- to improve methods for sampling and processing of data;
- to improve survey arrangement.

Such works are performed by the Polar Institute, however financial difficulties prevent from fulfilling them completely. Meanwhile, two last trends can improve quality of surveys rapidly and essentially without any additional financial expenses. For example, let's consider one of them, i.e. improving of methods for hydroacoustic data processing.

Peculiarities of processing of hydroacoustic data from MS TAS in 1995.

To calculate bottom fish abundance and biomass to 1995 a known method of local areas (Yudanov et al., 1984) was used with total length frequency of fish from bottom hauls and Sa echo-intensities averaged by subareas for fish aggregations in pelagial and at the bottom. A constant error, when estimating species and length composition of pelagic component of fish aggregations, as well as accidental error due to a scanty quantity of biological samples in the beginning and in the end of length frequency (especially for large specimens) were the disadvantages of this method. During the MS TAS of bottom fish in October-December 1995 an attempt was undertaken to reduce these errors when calculating abundance and biomass of main marine organisms.

Separating of summarized echo-intensities by marine organisms species during an integration interval is the main point in obtaining of acoustic data and in their subsequent processing. To obtain biological information necessary for this (species and length-age composition of aggragations) check hauls are performed. After processing and averaging of biological characteristics, with the latter being done with allowance for each biological sample "statistical weight", the total length frequency by subarea is determined.

Apparently, and as indicated by the experience from hydroacoustic surveys and biological peculiarities of behaviour and distribution of fish (cod, haddock, redfish), that in most cases a pelagic component includes fish of smaller size than specimens distributed in bottom layers. So far as a gear of assesment in the MS TAS is only a bottom trawl, reliability of information about pattern of distribution of marine organisms investigated in pelagial is insufficient. Therefore, the main task when processing hydroacoustic data is a thorough analysis for echo-sounder recodrs when the following factors could be considered:

- characteristics of trawl catches including those taken by other vessels, as well as by commercial, in the area preset;
- distribution of TS-values for single pelagic objects by depth;
- geographical position of the area surveyed including its bathymetric characteristics;
- thermal state of water both in pelagial and at the bottom;
- status of food supply in the area and qualitative structure of fish feeding;
- peculiarities of behaviour and distribution of marine organisms;
- results from previous analogous investigations.

Naturally, such work should be performed by a specialist rather experienced in conducting hydroacoustic surveys and knowing peculiarities of behaviour and distribution of fish in the area preset.

Processing of the hydroacoustic data from MS TAS had the following peculiarities:

- modified method for calculating acoustic shadow zone (Mamylov, Ratushny, 1996)was used to estimate ech-intensity (Sa) in a bottom channel of integrator;
- mean echo-intensity by tracks with further calculation of abundance and biomass was estimated separately for each of three size ranges of main bottom fish species (small, mean and large);
- to estimate length frequency of fish distributed in pelagial the data on distribution of TS of single specimens by depth, obtained with EK-500 echo-sounder, were used;
- when separating mean echo-intensities along tracks by marine organism species with allowance for results from check hauls the differentiated coefficients of trawl efficiency were used for specimens below 12cm long (Mamylov, 1988; Mamylov et al., 1989);
- to reduce error due to insufficiency of biological samples in separate length groups the regression relationship between fish weight and its length was used;
- abundance and biomass were calculated by 1cm-length groups with a further grouping of the data obtained into class intervals - 5cm for cod and haddock and 2cm - for redfish.

As indicated by the analysis for EK-500 echo-sounder records, a relationship between the density of distribution of large, mean and small fish in a bottom layer and in pelagial differed essentially from each other in most events, that was due to peculiarities of behaviour of fish at different stages of ontogeny. Therefore, to obtain more real length composition of fish distributed in pelagial, length frequencies were separated into three ranges. A choice of these ranges limits is determined by a length frequency pattern, is individual for each fish species and somewhat conventional. During the MS TAS in 1995, 16 and 40cm were assumed to be such limits for cod and haddock (mean TS-values in situ for fish at this size make up about -46 and -38dB, respectively).

Relationship between echo-intensities for small, mean and large fish in a bottom channel was assumed on the basis of length frequencies from catches taken by bottom trawl, and for pelagic component this relationship was corrected in accordance with a distribution of TS of single specimens by depth reflected on EK-500 echo-sounder.

The method suggested for estimation of echo-intensity separately for each of three size ranges of fish, compared to the that for the calculation used previously (by single length frequency for bottom and pelagic components), in our opinion, allows to enhance precision of estimation for abundance and biomass of fish from different yearclasses and, mainly, from recruitment.

Two methods for estimating cod abundance and biomass by one of the areas surveyed are presented as example in Tables 1 and 2. As can be seen in the figures, using of total length frequency and echo-intensities non-separated for large, mean and small fish, results in overestimation of biomass (2.6 times) and in more essential underestimation of abundance (10.5 times). These differences in the results for one area, conditioned by applying of different methods for estimation, do not mean that they will be essential for all the areas. In those areas where no small-size fish were predominant such effect will not be observed.
Besides method of separating summarized echo-intensities considering vertical distribution of fish at different length, to estimate biomass of cod, haddock, S.mentella and S.marinus the regression length-weight relationship was used:

$w=a*L^b$
where:
w is mean weight of fish by 1cm length groups;
L is fish length.

It is due to the biological samples collected are often insufficiently representative regarding the length frequency left and wright parts. Fig.2 gives some diagrams of length-weight relationship for cod, derived by results from regression analysis for a rather large base of biological data (about 5 thou.spec.) collected during TAS of bottom fish in the Barents Sea in autumn-winter 1993-1995. In each diagram the fish length is given along X axis and its mean weight - along Y axis. Curves demonstrate the relationship derived w(L). For fish 25-80cm long the regression relationship has a very high coefficient of correlation (R=0.9996) and values for fish mean weight obtained during observations are well agreed with the data calculated. This is due to the fact that the length class mentioned is represented by the highest amount of fish taken for analysis. Lower coefficient of correlation and wide range of mean weight by length indicate an obvious insufficiency of the material collected for two other length classes. Using the observed mean weight of these fishes in calculations results in overestimation or underestimation of stock. Therefore, in biomass calculations, using of weight calculated by regression equations for each of three length classes, the limits of which are determined from a maximum correlation regression relationship $w=a*L^b$ for each of them, will be more correct.
When conducting surveys during other periods and considering that fish weight experiences considerable fluctuations during a year, the regression equations should be done for each season separately.

CONCLUSIONS

Undoubtedly, the changes suggested for processing hydroacoustic data do not exhaust all possibilities of improving methods for sampling and processing the MS TAS data. They are only an example of that how essentially the small changes in methods for data processing influence a final result.

Therefore, it is extremely important to follow the methods adjusted for sampling and processing data and to analize all changes taking place in them in order to provide for a comparison of results obtained during different years. Just in such approach to conducting investigations, which is in practice realized insufficiently consistently, considerable reserves are available for enhancement of reliability of the results obtained.

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TS:			
L<=10	14.4	* lg(L)	-65.2
L > 10	21.8	* lg(L)	-72.7

COD
1995

Av. Sa *Pel* 18.08 *sq.m/sq.n.m.*
Bot 5.69 *sq.m/sq.n.m.*

Area, sq. n.m. *19352.3*

Subarea H

Length L	*Av.weight* w	*Frequency* *(from trawl samples)*		*Abundance* *mil.sp.*			*Biomass* *thous. tonn*		
cm	*g*	*sp.*	*%*	*pelagic*	*bottom*	Σ	*pelagic*	*bottom*	Σ
5 -10	6.6	7	0.55	330.319	42.522	372.840	2.175	0.280	2.454
11-15	11.6	561	43.93	1606.210	209.458	1815.668	18.627	2.451	21.078
16-20	49.1	28	2.19	4.485	3.052	7.537	0.220	0.150	0.370
21-25	91.8	59	4.00	7.783	5.296	13.079	0.715	0.486	1.201
26-30	187.9	81	4.62	12.928	8.796	21.724	2.429	1.653	4.082
31-35	287.2	141	11.04	17.150	11.668	28.818	4.926	3.351	8.277
36-40	446.3	51	3.99	5.673	3.860	9.532	2.532	1.722	4.254
41-45	622.7	40	3.13	0.273	0.535	0.807	0.170	0.333	0.503
46-50	910.0	19	1.49	0.196	0.384	0.580	0.178	0.350	0.528
51-55	1195.0	32	2.51	0.290	0.568	0.858	0.346	0.679	1.025
56-60	1549.4	38	2.98	0.298	0.585	0.883	0.462	0.906	1.368
61-65	2026.4	40	3.13	0.358	0.702	1.060	0.725	1.422	2.147
66-70	2488.2	47	3.68	0.418	0.819	1.236	1.039	2.037	3.076
71-75	3071.7	41	3.21	0.324	0.635	0.959	0.995	1.950	2.945
76-80	3776.0	35	2.74	0.281	0.551	0.832	1.062	2.082	3.143
81-85	4496.9	23	1.80	0.170	0.334	0.505	0.766	1.503	2.269
86-90	5603.5	13	1.02	0.136	0.267	0.404	0.764	1.498	2.262
91-95	6838.0	13	1.02	0.085	0.167	0.252	0.583	1.142	1.725
96-100	8447.4	4	0.31	0.026	0.050	0.076	0.216	0.423	0.639
101-105	9851.8	3	0.23	0.017	0.033	0.050	0.168	0.329	0.497
106-110	11849.8	1	0.08	0.009	0.017	0.025	0.101	0.198	0.299
12.45	28.16	1277	100	1987.426	290.299	2277.725	39.198	24.944	64.142

Table 1. The calculation example when **Sa**-values are separated for big, middle and small fish.

TS:			
L<=10	14.4	* lg(L)	-65.2
L > 10	21.8	* lg(L)	-72.7

COD
1995

Av. Sa *Pel* 18.08 *sq.m/sq.n.m.*
Bot 5.69 *sq.m/sq.n.m.*

Area, sq.n.m. *19352.3*

Subarea H

Length L	*Av.weight* w	*Frequehcy* *(from trawl samples)*		*Abundance* *mil.sp.*			*Biomass* *thous.tonn*		
cm	*g*	*sp.*	*%*	*pelagic*	*bottom*	Σ	*pelagic*	*bottom*	Σ
5 -10	6.6	7	0.55	11.833	3.727	15.560	0.078	0.025	0.103
11-15	12.2	561	43.93	62.124	19.566	81.690	0.757	0.238	0.995
16-20	49.2	28	2.19	4.373	1.377	5.750	0.215	0.068	0.283
21-25	91.8	59	4.62	7.589	2.390	9.979	0.697	0.219	0.916
26-30	187.9	81	6.34	12.605	3.970	16.575	2.368	0.746	3.114
31-35	287.3	141	11.04	16.721	5.266	21.987	4.803	1.513	6.316
36-40	446.2	51	3.99	5.531	1.742	7.273	2.468	0.777	3.245
41-45	622.7	40	3.13	4.116	1.286	5.412	2.563	0.807	3.370
46-50	910.0	19	1.49	2.958	0.932	3.890	2.692	0.848	3.540
51-55	1195.1	32	2.51	4.373	1.377	5.750	5.226	1.646	6.872
56-60	1549.3	38	2.98	4.502	1.418	5.920	6.975	2.197	9.172
61-65	2026.6	40	3.13	5.402	1.701	7.103	10.947	3.448	14.395
66-70	2488.4	47	3.68	6.302	1.985	8.287	15.682	4.939	20.621
71-75	3071.6	41	3.21	4.888	1.539	6.427	15.013	4.728	19.741
76-80	3776.2	35	2.74	4.244	1.337	5.581	16.027	5.048	21.075
81-85	4496.3	23	1.80	2.572	0.810	3.381	11.568	3.643	15.211
86-90	5603.8	13	1.02	2.058	0.648	2.706	11.532	3.632	15.164
91-95	6839.1	13	1.02	1.286	0.405	1.691	8.795	2.770	11.565
96-100	8455.6	4	0.31	0.386	0.122	0.507	3.260	1.027	4.287
101-105	9858.0	3	0.23	0.257	0.081	0.338	2.534	0.798	3.332
106-110	11858.0	1	0.08	0.129	0.041	0.169	1.524	0.480	2.004
31.11	765.45	1277	99.99	164.249	51.720	215.978	125.724	39.597	165.321

Table 2. The calculation example when **Sa**-values are not separated for big, middle and small fish.

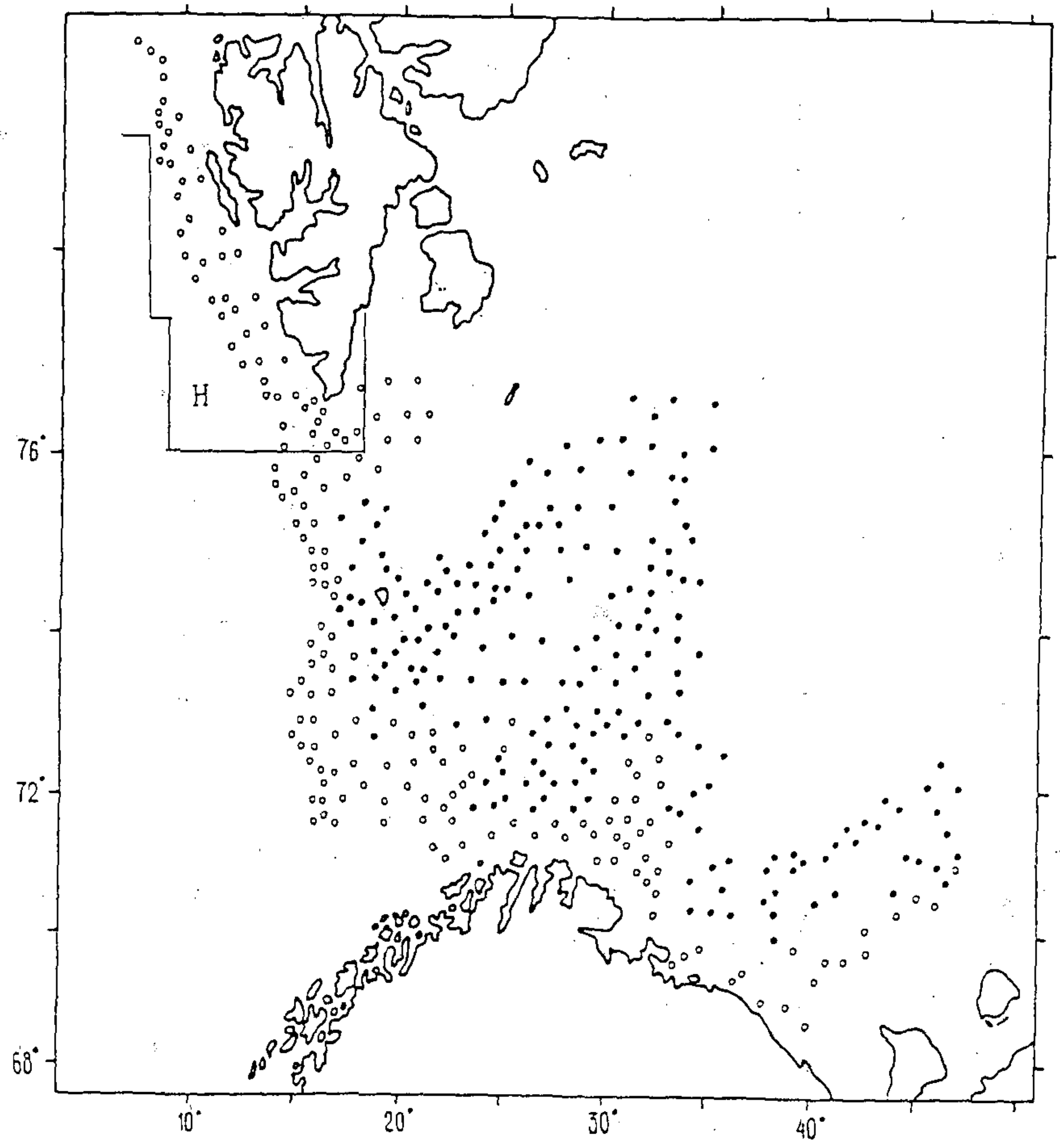
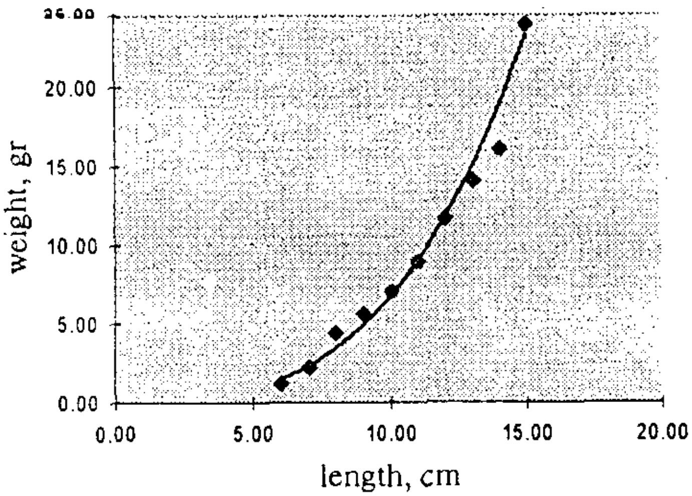


Fig.1 Trawl stations made in October - December 1995

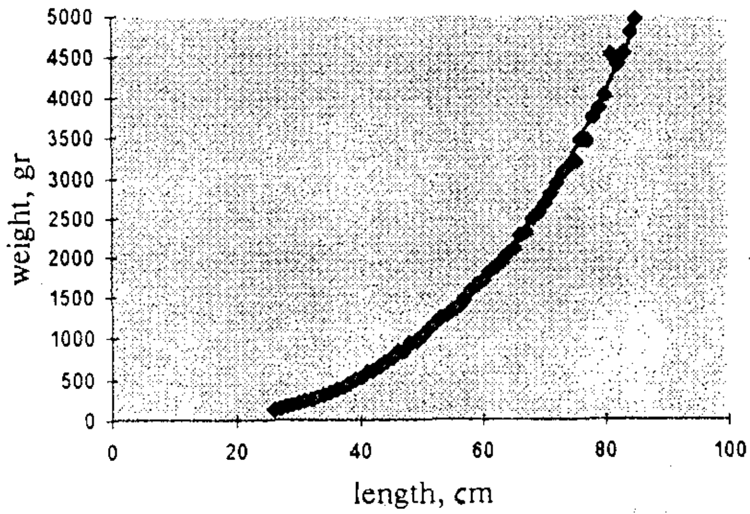
● - R/V "F.Nansen"

○ - R/V "Professor Marti"

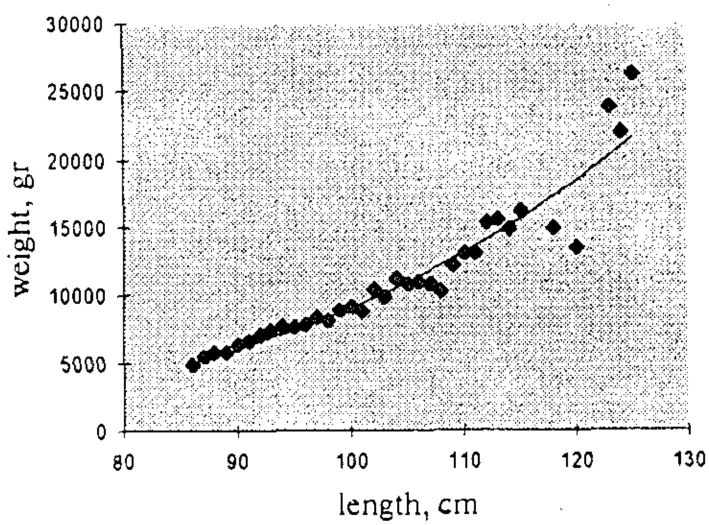
H - Western Spitsbergen area



$w = 5.537 \times 10^{-3} \times L^{3.0777}$
$R = 0.9906$



$w = 8.230 \times 10^{-3} \times L^{2.9916}$
$R = 0.9996$



$w = 1.645 \times 10^{-4} \times L^{3.8715}$
$R = 0.9761$

Fig.2. Regression length-weight relationship of cod.
R - coefficient of correlation