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Technique of Russian Bottom Trawl and Acoustic Surveys of the Barents Sea and How to Improve Them

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Abstract

The present-day bottom trawl surveys of the Barents Sea have been conducted since 1982, along with the trawl-acoustic surveys in October–December since 1986, by a minimum of two research vessels equipped with the latest hydroacoustic instruments, computer, trawl and hydrographic facilities. The data are used to estimate the abundance of juvenile year-classes of the main commercial species as well as flatfish and catfish, and the abundance and biomass of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and redfish (*Sebastes mentella* and *Sebastes marinus*) are estimated. The survey is conducted by hydroacoustic tracks, occupying trawl station locations based on the long-term mean distribution of commercial fish and proportioned to the area of the depth stratum. Each trawl station position is randomly selected and designed for complete and uniform coverage of the area surveyed. Special attention is given to calibration and intercalibration of EK-500 echo-sounders during the survey, and the survey technique is constantly reviewed for improvement. Density of fish distribution is estimated by areal expansion. Special software packages were developed for processing of primary information, calculation of bottom fish abundance and biomass and estimation of errors in calculations. During the trawl-acoustic survey in 1995 separation of echo-intensities by species (cod, haddock, and the redfish) was done by isolating fish into three length groups, small, mean and large size. Calculations of abundance and biomass of cod and haddock were done taking into account the length-weight relationships derived by regression analysis of the database on 1 cm length groups.

Key words: acoustic survey, assessment, Barents Sea, biological information, bottom trawl survey, cod, haddock, redfish, surveys

Introduction

A basis for rational fisheries development under constantly growing anthropogenic influences on fish stocks is one of the most topical problems of fisheries science. Addressing this problem is possible provided sufficiently precise estimates are obtained for the status of populations of marine organisms inhabiting a given area.

Polar Research Institute of Marine Fisheries and Oceanography (PINRO) was one of the pioneers in Union of Soviet Socialist Republics (USSR) which organized large-scale investigations on demersal fish for stock assessments. Since 1946 annual trawl surveys for the assessment of young fish has been carried out, while trawl surveys to estimate relative abundance of adult fish in the Barents Sea area began in 1959. In the 1970s acoustic techniques and underwater observation methods were introduced to assess bottom fish stocks.

The application of different methods for the assessment of the Barents Sea bottom fish in 1970–80s has revealed many of their advantages and disadvantages, and has provided for methods for further development and improvement. This possibility was mainly due to the introduction of the latest survey methods and hardware, and the obtaining and efficient processing of the maximum quantity of biological information at minimum expenses and optimal work levels. In 1982 a multispecies trawl survey was conducted in the Barents Sea, during which both the juvenile fish and commercial fish stock were simultaneously assessed for the first time. The improvement of hardware and methods for investigations continued and in 1987 it became a multispecies trawl-acoustic survey to include pelagic fish (Shevelev *et al.*, MS 1988). To estimate the abundance of demersal fish distributed in the 8-m bottom layer fished by the sampling bottom trawl was used. The trawl efficiency coefficients, differentiated by species and length groups, were found by underwater experiments (Zaferman and Serebrov, 1984). In the case of pelagic fish above 8 m from bottom, abundance and distribution was determined by the standard trawl and acoustic methods.

The acoustic method was also attempted to determine abundance of fish in the bottom layer, in spite of its limitation in this case because of the bottom acoustic "shadow zone". This permitted a comparison between the different methods, and to obtain additional data on the vertical distribution, which could be useful for improving the trawl-acoustic method for stock assessment. However, the results obtained by this method for the bottom layer were not reliable enough to differentiate coefficients of sampling trawl efficiency, and prevented from applying them in the 1988 survey (Shevelev *et al.*, MS 1989). Abundance of fish in the depth zone was therefore determined using either the trawl or acoustic method depending on a pattern of fish distribution with allowance for a regression relationship between catches and mean value of echo-intensity along the area swept (Mamylov *et al.*, 1989). As a result of the investigations in 1987–89 an optimum period of October–December was set for assessments (Shevelev *et al.*, MS 1990), and investigations have been conducted since 1990. Besides these, the other main aspects of methods for multispecies trawl-acoustic survey (MS TAS) have not been changed much since 1982. [In the paper, special attention is given to the changes taken place in the survey methods and for processing of the results; cod (*Gadus morhua*) is taken as an example, and special attention is given to data from MS TAS in 1995.]

Methods

MS TAS of bottom fish

This survey is conducted during the 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 150 000 nm^2) on the shelf of the Barents, Norwegian and Greenland Seas are covered by the survey. Depths are surveyed from 50 to 900 m. 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. Therefore survey stations are distributed proportionally to the area of the depth surveyed with a mean density of about 1 station per 300 nm^2. Total number of sampling hauls decreased from 600 to 400 during recent years. Each trawl station position is taken at random and is mainly determined by the necessity to have a complete and uniform coverage of the survey area (Fig. 1). Operations are performed on a 24 hr basis by 2 or 3 vessels simultaneously. Sampling gear is a bottom trawl with the distance between wings about 30 m and 7.8–8.0 m opening height. A 16 mm inner mesh-size netting is installed into a trawl codend. The vessel speed is 3.2 knots and duration of haul is 1 hr. 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. A plankton trawl is done during hauls.

About 20 fish species are registered, in addition to the deep water shrimp and benthic organisms occurring in trawl.

The survey is used to assess juvenile bottom fish and to obtain relative indices of abundance of recruiting year-classes (Baranenkova et al., 1964; Baranenkova, 1967; Trambachev, 1981) simultaneously with assessment of commercial stocks. Year-class abundance estimate of juveniles is done by comparing the mean catch of a year-class in a 1 hr trawl with the long-term mean of the survey series (Melyantsev and Salmov, MS 1985).The 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, *Sebastes marinus*, a trawl-acoustic method is applied. When estimating indices of abundance of stocks by the trawl method, the mean coefficients of efficiency are used, which are constant from year to year and specific for each species. Ideally, the trawl-acoustic method gives a possibility to estimate absolute abundance and biomass of fish by taking density of fish distribution over specific areas.

As a rule, estimates obtained by the TAS method are lower than those calculated by the VPA method due to a constant underestimation of stocks because of imperfections of the TAS method. On the other hand, both the trawl and trawl-acoustic methods produce good estimate values, and the

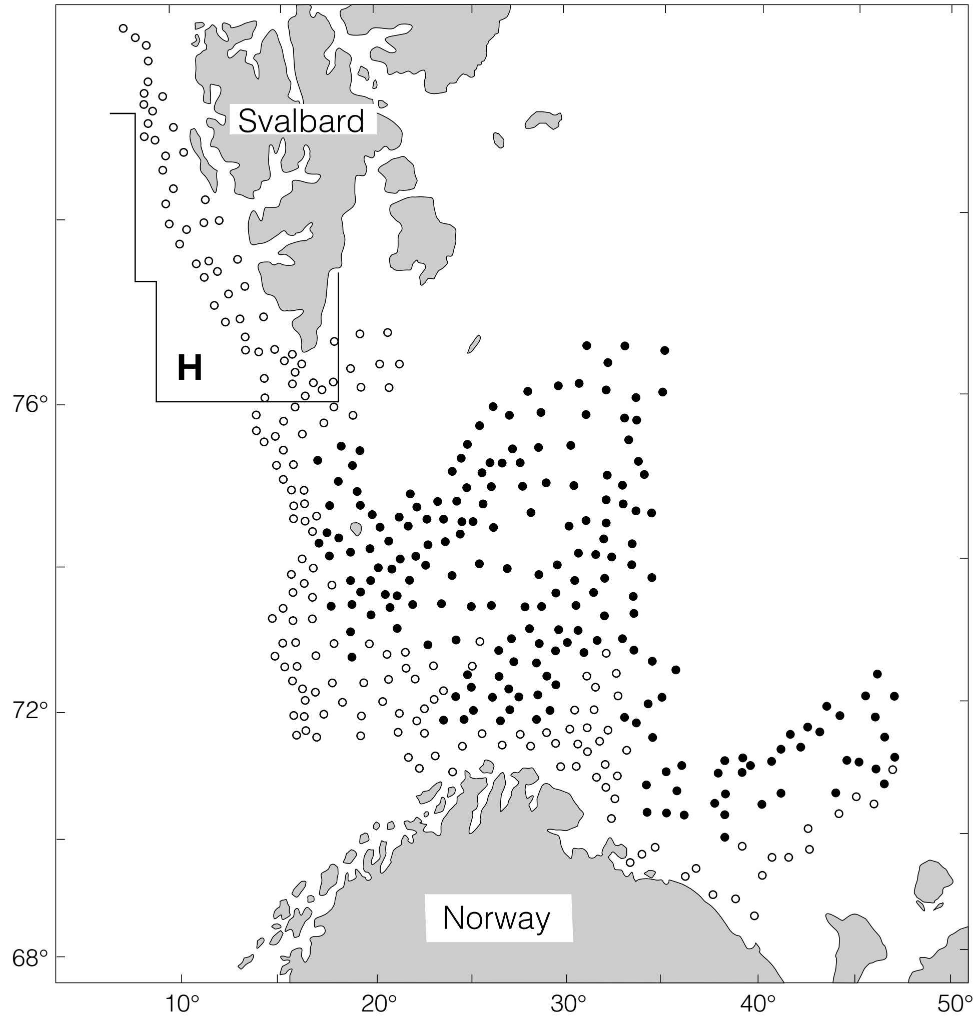

Fig. 1. Trawl stations made during October–December 1995.

year-to-year dynamics which agrees well with the trends estimated by VPA method. Agreement of trends obtained by the different methods allows us to consider the results from MS TAC to reflect the status of the stocks sufficiently well. At the same time, the need to improve the reliability of estimates from the survey methods have been highlighted. To improve the survey technique, the following isolated trends could be addressed:

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

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

Hydroacoustic data from MS TAS in 1995

To calculate bottom fish abundance and biomass to 1995 a known method of selecting local areas (Yudanov *et al.*, 1984) was used, along with the total-length frequency of fish from bottom hauls and echo-intensities averaged by the areas for fish aggregations in pelagial and at the bottom. A persistant error was observed when estimating the species composition and the length composition of the pelagic component of fish aggregations. Error also occurred due to the small quantity of biological samples, resulting in uneven length frequency distributions (especially for large specimens). During the MS TAS of bottom fish in October–December 1995, an attempt was undertaken to reduce these errors.

The main advantage of MS TAS acoustic data is the ability to separate the recorded echo-intensities by the particular marine organisms in an integration interval. To cross check these and to obtain biological information necessary for the species and length-age composition of the aggregations, check hauls are performed. The total-length frequency for each species by subarea can then be determined by averaging the biological characteristics and applying the appropriate statistical weighting for each biological sample.

Information from the hydroacoustic surveys and known biological characteristics of behaviour and distribution of cod, haddock, and redfish, suggest that in most cases, the pelagic component consist of fish smaller in size than specimens distributed in bottom layers. Since the gear in the MS TAS assessments is only a bottom trawl, information about pattern of distribution of marine organisms investigated in pelagial is insufficient. Therefore, a future task when processing hydroacoustic data is a thorough analysis for echo-sounder records, when the following factors could be considered:

– characteristics of trawl catches, including those taken by other vessels, including commercial vessels, in the area,
– distribution of pelagic species in relation to echo-sounder profiles,
– bathymetric characteristics of the area,
– status of food supply in the area and feeding patterns,
– behaviour and distribution of marine organisms.

Advancements made by Russian scientists in the processing of the hydroacoustic data from MS TAS are as follows:

– modified method for calculating acoustic shadow zone (Mamylov and Ratushny, 1996) was used to estimate echo-intensity (Sa),
– the mean echo-intensity by track was estimated separately for each of three size ranges (small, mean and large) of main bottom fish species, and used to calculate abundance and biomass – the EK-500 echo-sounder data were used to estimate length frequency of individual pelagic species, by depth,
– when separating mean echo-intensities along tracks by species the differentiated coefficients of trawl efficiency were used for specimens below 12 cm (Mamylov, MS 1988; Mamylov *et al.*, 1989),
– to reduce error due to insufficiency of biological samples in separate length groups, the regressed lengh-weight relationship was used,
– abundance and biomass were generally calculated by 1-cm length groups, with further groupings of 5-cm for cod and haddock and 2-cm for redfish.

As indicated the relationship between the density of small, mean and large fish in the bottom and in the pelagial layers differed from each other in most events due to behaviour of fish at different sizes. Therefore, to obtain more realistic length compositions of fish distributed in the pelagial, they were separated into three ranges. The choice of these ranges was determined by the conventional length frequency pattern of each species. During the MS TAS in 1995, 16 and 40 cm were assumed to be such limits for cod and haddock (mean echo-sounder values *in situ* for fish at this size were about -46 and -38 dB, respectively). Thus the relationship between echo-intensities for small, mean and large demersal fish 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 the distribution of single species by depth reflected on EK-500 echo-sounder. The method, in our opinion, allows to enhance precision of estimation of abundance and biomass of fish from different year-classes and, hence recruitment.

Two methods for estimating cod abundance and biomass for an area surveyed are presented as examples in Tables 1 and 2. Using total length

TABLE 1. The calculation example of when echo-intensity sounding values are separated into small, mean and large sized fish of the surveyed area: Barents Sea Cod survey in 1995 (area = 19352.3 nm^2, pelagic = 18.08 m^2 per nm^2 and bottom = 5.69 m^2 per nm^2).

Length L	Av. Weight w	Weight Frequency (from trawl samples)		Abundance (in millions)			Biomass (in thousand tons)		
cm	g	No. of samples	%	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	1 277	100	1987.426	290.299	2277.725	39.198	24.944	64.142

TABLE 2. The calculation example of when echo-intensity sounding values are NOT separated into small, mean and large sized fish of the surveyed area: Barents Sea Cod survey in 1995 (area = 19352.3 nm^2, pelagic = 18.08 m^2 per nm^2 and bottom = 5.69 m^2 per nm^2).

Length L	Av. Weight w	Weight Frequency (from trawl samples)		Abundance (in millions)			Biomass (in thous. tons)		
cm	g	No. of samples	%	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	3.383	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
31.11765.45	1 277	99.99	164.249	51.720	215.978	125.724	39.597	165.321	

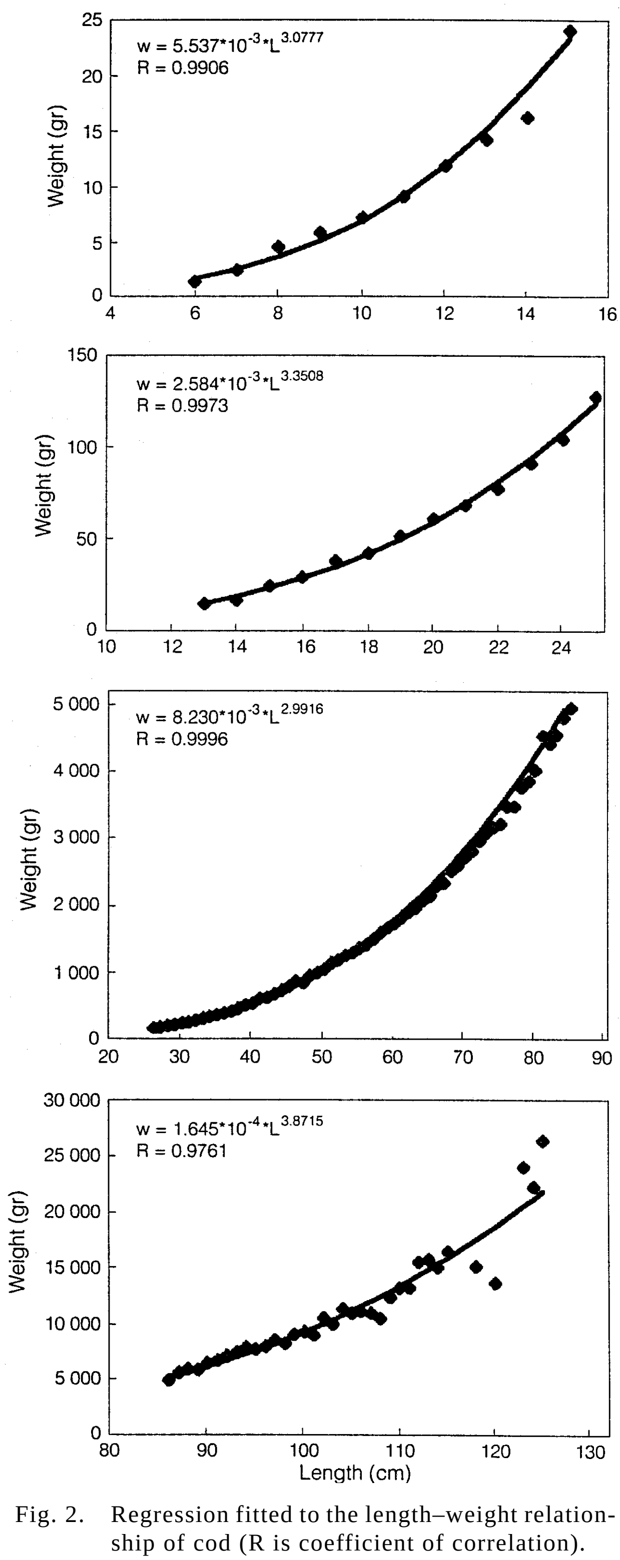

Fig. 2. Regression fitted to the length–weight relationship of cod (R is coefficient of correlation).

frequency and echo-intensities for combined mean and large fish (not separated), results in overestimation of biomass (2.6 times) and underestimation of abundance (10.5 times). These differen·ıs in the results for one area do not mean, however, that they will be applicable for all areas. In those areas where no small-size fish were predominant, such effects will not be observed.

Besides the above methods to estimate biomass of cod, haddock, *Sebastes mentella* and *S. marinus*, the following regression for the length-weight relationship was used:

$$w = aL^b$$

where w is mean weight of fish by 1 cm length groups, and L is fish length.

Figure 2 gives some diagrams of the length-weight relationship for cod derived by regression analysis for a large data base (about 5 000 specimens) collected during surveys in the Barents Sea in autumn–winter 1993–95. In each diagram the fish length is given along X axis and mean weight along Y axis. Curves demonstrate the derived relationship. For fish 25–80 cm long, the regression had a very high coefficient of correlation (R = 0.9996) and the observed mean weight values agreed well with the calculated values. This was due to the fact that the length-classes were well represented in the data. Lower coefficient of correlation and wide range of mean weight by length indicate an obvious insufficiency of the samples collected for the two other length-classes. Using the observed mean weight of these fish in calculations can result in the overestimation or underestimation of stock. Therefore, in biomass calculations, using weights calculated by regression equations for each of the three length-classes, the limits of which are determined from the best correlation regression relationship $w = aL^b$ for each of them, will be more correct.

When conducting surveys during other periods and considering that fish weight exhibit considerable fluctuations during the year, the regression equations should be done separately for each season.

Conclusion

Undoubtedly, the suggested changes for processing hydroacoustic data do not exhaust all possibilities of improving methods for sampling and processing the MS TAS data. This paper presents only an example of how small changes in methods for collecting and data processing can influence final results. It also demonstrates that it is extremely important to follow the adjusted methods for sampling and processing data and to analyze all changes taking place in order to provide for a comparison of results obtained during different years. In such an approach to conducting investigations, it soon becomes apparent that considerable options are available for improving the reliability of results obtained.

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