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Review of 1983-1996 Russian Trawl Acoustic Surveys to Assess Redfish Stock on the Flemish Cap Bank

by

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Abstract

The paper presents results from 1983-1996 Russian trawl acoustic surveys (TAS) of redfish on the Flemish Cap Bank. Methods of trawl and acoustic survey are described in detail.

Results from trawl survey are given for a combined redfish group including Sebastes mentella and S.fasciatus. Results from acoustic survey are reported for three species, viz. S.mentella, S.fasciatus and S.marinus. Redfish abundance and biomass indices were calculated for two size groups: young fish (L≤15cm) and fish above 15 cm.

Results from 1983-1996 trawl survey show that abundance of juvenile redfish varied from 1.0 to 1237.8 mill. spec., biomass - from 0.03 to 10.3 thou.t. Total redfish abundance varied from 62.3 to 2006.1 mill. spec., biomass - from 10.0 to 309.5 thou.t.

By the results from 1987-1993 acoustic survey, abundance of juvenile redfish in the pelagic and bottom layers was set at 347.9 to 16769.3 mill. spec., the biomass from 6.0 to 187.2 thou.t. In the period of investigations redistribution of juvenile redfish from the pelagial to the bottom layers of the Bank was registered. 1987-1993 acoustic surveys indicated that total redfish stock varied from 1572.8 to 18585.6 mill. spec. by abundance and from 78.6 to 659.1 thou.t by biomass.

Material and Methods

1. Methods of trawl survey

Trawl surveys were carried out according to stratified random method (Doubleday, 1981; Bulatova, Chumakov, 1986; Bishop, 1994).

Hauls were done 24 hours a day using a sampling bottom trawl (drawing 1625) with a small-meshed insertion in a codend (a=10-12mm). Tow duration was 30 min. No less than 3 test hauls were performed in each stratum. Trawl efficiency coefficient was taken as 100%. Sampling area of trawl netting (S_{tr}) was calculated as:

$$S_{tr.} = B * L \qquad (1)$$

where B - distance between trawl wings (14.4m);
L - towed distance.

Calculation of abundance or biomass (N) was done for separate strata, then summarized for the entire area of survey:

$$N = \sum \frac{N_i * S_i}{S_{tr}} \quad , \qquad (2)$$

where N_i - mean catch, stratum index (i);
S_i - area of stratum;
S_{tr} - swept area per one tow.

Data from 1983-1996 Russian trawl surveys carried out on the Flemish Cap Bank (Div.3M) are given in Table 1.

Until 1995 tow depth did not exceed 731m. In 1992 no research were carried out in the strata 504, 509, 513 and 517. In 1996 depth range of survey was 128-914m.

In most surveys redfish of the Sebastes genus were separated into two large groups: S. mentella + S. fasciatus and S.marinus. Some surveys identified S.mentella and S.fasciatus.

2. Methods of acoustic survey

Acoustic methods to assess redfish abundance and biomass on the Flemish Cap Bank have been developed, tested and improved by PINRO since 1983. In 1983-1985 such experimental surveys were attempted in April-June onboard vessels conducting traditional surveys on the Flemish Cap fishing ground.

The surveys were carried out according to traditional FAO acoustic survey methods (Johannesson and Mitson, 1983) using echosounder EK-38A (Simrad, Norway), echo integrators SIORS (USSR) and pelagic as well as bottom test hauls to identify echo recordings. Trawl data were used not only from the survey vessel but also from other research and fishing vessels located in the area. In the course of surveys density of redfish distribution in the pelagial about 1-2m backstep from seabed was estimated without separation into the pelagic and the bottom components. Rectangular survey grid (south-north and east-west directions) with a distance between transects of 20' in latitude and 30' in longitude covered the entire 100-1000m depth range in Div.3M. Averaging of acoustic data was carried out according to the local areas method. Although 1983-1985 acoustic surveys of redfish were experimental, their results provided a substantial supplement to those from traditional trawl surveys of groundfish which were conducted in Div.3M in about the same period.

Since 1987 acoustic survey of redfish in Div.3M using pelagic test hauls has been carried out in spring-summer onboard one vessel simultaneously with the traditional trawl survey of demersal fish and was therefore referred to as "trawl acoustic survey" (TAS). Methods of multispecies TAS in NAFO Divs. 3MKLNO were tested in March-June 1987 onboard the RV "Persey-III" (Mamylov, 1988).

Until 1990 inclusive, echosounders Simrad EK-S-38 and integrators SIORS were used as an echo integrating system. Since 1991 echosounders Simrad EK-400 have been employed. Instrument characteristics of the equipment onboard the vessels used in the course of 1987-1993 TAS are given in Table 2. Positions of acoustic tacks and trawl stations are shown in Figs. 1-7.

Echo intensity (SA) in the course of TAS was measured by 10 depth channels of SIORS integrators one of which operated as the "bottom channel" starting integration at 4m and ceasing it at approximately 1-2m backstep from seabed. It was the backstep from seabed that determined the minimum "acoustic shadow zone" of the echo integrating system. As a result, SA values were obtained for the layer above 4m backstep from seabed (pelagic component) and for 4m bottom layer with the exception of the "shadow zone" (bottom component) mentioned above.

Indicator readings were taken at equal intervals of the distance covered by the vessel. In the course of TAS in NAFO Div.3 readings were taken only when crossing the boundaries of geographic strata, when changing vessel speed, in event of drastic change in density or pattern of fish distribution and, besides, separately during trawling (i.e. from the time when the warps are blocked up until they are released). The integrating interval corresponding to the given reading was registered by the vessel log NL (Simrad). Integrator readings, with regard to the instrumental constant of the echo integrating system and after correcting for the difference between echo sounder TVG and 20logR + 2αR function, were thereupon converted into standard SA units calculated as:

$$SA = 4 \times \pi \times 1852^2 \times 10^{0.1 \times \bar{S}_a} \quad , m^2/n.m.^2 \quad (3)$$

where $\bar{S}_a$ - mean area backscattering strength of the layer per integrating interval, dB

SA values for each integrating interval were classified by species of marine organisms on the basis of a thorough analysis of echograms and results of test hauls separately for the pelagic and bottom channels of the integrator. In the course of work in the Div.3M SA was calculateded separately for 6 species: 1) cod, 2) haddock, 3) young redfish (L≤15cm), 4) redfish (L>15cm), 5) SSL (jellyfish, euphausiids etc.), 6) other demersal and pelagic fish (Myctophidae, Paralepididae etc.). SA division by species using the results from pelagic and bottom trawling was made according to the ratio:

$$SA_1 : SA_2 : SA_3 : \ldots = \frac{P_1 \times \bar{\sigma}_{kg1}}{K_1} : \frac{P_2 \times \bar{\sigma}_{kg2}}{K_2} : \frac{P_3 \times \bar{\sigma}_{kg3}}{K_3} : \ldots \quad (4)$$

where K_i - relative efficiency coefficient of the trawl for species (i);

$$\bar{\sigma}_{kgi} = 4 \times \pi \times 10^{0.1 \times \bar{TS}_{kgi}}$$

- mean scattering cross section per 1 kg of weight, m^2/kg;
P_i - catch of marine organisms of species (i), kg.

Following the experience of using trawls with a small-meshed insertion in the course of TAS in the NAFO Div.3, K_i was taken as =1 for marine organisms with L > 10cm, K_i ≈0.3 for L = 5-10cm, K_i ≈0.1 for L = 3-5cm.

Further procession of survey data consisted in averaging of SA by the strata with regard to integrating intervals. As a result, mean values of acoustic echo intensity ($\bar{SA}$) were calculated for all fish species in each stratum (both the pelagic and the bottom components). Abundance and biomass of redfish at 1cm group intervals and for separate strata were estimated as:

$$W_{jk} = \frac{\bar{SA}_j \times A_j \times q_{jk} \times \bar{w}_{jk}}{\bar{\sigma}_{kgi} \times 10^3 \times \sum_k (q_{jk} \times \bar{w}_{jk})} \quad (5)$$

$$N_{jk} = \frac{W_{jk}}{\bar{w}_{jk}} \quad (6)$$

where N_{jk} - abundance, spec.;
W_{jk} - biomass, t;
q_{jk} - frequency, spec.;
A_j - area of stratum, sq.miles;
$\bar{w}_{jk}$ - mean weight of a single fish, kg;
j - stratum index;
k - size group index.

Abundance and biomass in the entire area of survey was calculated by summation of N_{jk} and W_{jk} for each stratum.

$\bar{\sigma}_{kgi}$ for each species of marine organisms was taken from the developed database (Mamylov, 1988). In respect to redfish target strength ($\overline{TS}_{kg}$) was applied. In different size groups target strength was as follows:

Length, cm	5-8	8-12	12-16	16-20	20-50
$-TS_{kg}$, dB/kg	29.7-33.9	34.0-36.4	36.5-37.7	37.8-38.2	38.3

These data were obtained using the results of TS measurement of redfish by Russian specialists during 1983-1987. For all surveyed fish species total length was used.

In the course of TAS on the Flemish Cap Bank most survey transects were located between random sampling hauls. Despite the fact that survey grid shall ensure regular sampling pattern in each stratum, cases of increase/decrease in grid density as well as crossing of transects occurred sometimes in some strata. Strata with irregular transects were divided into several substrata.

When crossing the transects, the results were averaged to avoid repetitive assessment. The main aim of the survey was to measure statistical parameters of random fields of distribution density (e.g. echo intensity, surface or volume density etc.) for different fish species with a sufficient reliability and to average the parameters for specific strata (or substrata) of the known area for a definite period. Density of transects was practically identical within each stratum (substratum).

Results

Results from 1983-1996 acoustic and trawl surveys of redfish in Div.3M are given in Tables 3 and 4. Compared with the earlier published results from 1983-1996 Russian TAS of redfish in that area (Vaskov, Karsakov, 1996; Vaskov, 1997), recalculation of the results from all those surveys has been done to separately assess young redfish (L < 15cm) and adult fish both in the pelagial and bottom layers. This was connected with the fact that the accuracy of young fish assessment is considerably lower than that of large fish when using both trawl and acoustic methods (owing to fishing gear selectivity, identification difficulties of young redfish echo recordings in the pelagial, etc.).

According to data from 1983-1996 trawl surveys, total redfish stock varied from 10.0 to 309.5 thou.t by biomass and from 62.3 to 2006.1 mill. spec. by abundance. Biomass of young redfish (L < 15cm) in that period generally did not exceed 1 thou.t and varied from 0.03 to 10.3 thou.t, abundance constituted 1.0 to 1237.8 mill. spec. High estimates of juvenile redfish abundance and biomass were obtained in 1991 owing to 1990-1989 strong yearclasses.

By 1987-1993 acoustic survey data, total stock of redfish on the Flemish Cap Bank varied from 78.6 to 659.1 thou.t by biomass and from 1572.8 to 18585.6 mill.spec. by abundance. The bulk of redfish stock in the surveyed area in that period, with the exception of 1993, were distributed in the pelagial.

By the results from 1987-1993 acoustic survey, abundance of young redfish in the pelagic and bottom layers was estimated to be 347.9 to 16769.3 mill.spec., biomass from 6.0 to 187.2 thou.t. In the period of investigations redistribution of young redfish (L<= 15cm) from the pelagial to the bottom layers of the Bank was registered. Obtained in 1993 abundance and biomass estimates of young redfish of the acoustic bottom component exceeded those of the pelagic component.

On the whole, acoustic survey indicated the declining tendency of redfish stock.

Discussion

According to the methods of trawl survey, bottom trawl efficiency (with respect to distance between wings) used to estimate actual density of groundfish distribution is taken as 100%, nominal vertical opening of bottom trawl being 4m and distance between wings 14.4m. Therefore it appears more logical to assess total abundance and and biomass of redfish by summation of the pelagic component of the acoustic survey and the results from the bottom trawl survey. This method to calculate total stock estimates is used in modern practice.

Nonetheless, from our viewpoint (and proved by a series of experiments), the actual fishing bottom trawl efficiency with respect to its 4 - 5m vertical opening, is considerably lower than 100%, and its effective vertical opening is actually about 1.5 - 2m. To obtain the most objective stock estimates for the whole depth range, it would be more correct to sum up acoustic (pelagic and bottom components) and trawl data, since the acoustic bottom "shadow zone" also constituted approximately 1 - 2m. This methodological question will be further discussed in more detail.

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Table 1. An inventory of Russian trawl survey.

Year	Vessel	Valid tows	Dates
1983	MB-2645 "Suloy"	134	06.05-24.05
1984	MB-2645 "Suloy"	165	30.03-30.04
1985	MG-1363 "Genichesk"	129	31.03-16.04
			28.01-01.05
1986	MB-0422 "Kononov"	127	17.06-05.07
1987	MB-1202 "Persey-III"	131	21.06-07.07
1988	MB-1202 "Persey-III"	124	04.06-16.06
1989	MB-1202 "Persey-III"	129	24.06-08.07
1990	MB-1202 "Persey-III"	119	21.06-03.07
1991	MG-1362 "Vilnius"	100	27.04-08.05
1992	MG-1366 "K.Shaytanov"	53	15.04-20.04
1993	MG-1362 "Vilnius"	69	27.06-07.07
1995	MI-0708 "Olenica"	58	20.05-29.05
1996	MI-8339 "Olaine"	76	30.04-12.05

Table 2. Instrument characteristics.

Year	1987	1988	1989	1990	1991	1992	1993
Vessel	"Persey-III"	"Persey-III"	"Persey-III"	"Persey-III"	"Vilnius"	"Capitan Shaytanov"	"Vilnius"
Echosounder	Simrad EK-S-38	Simrad EK-S-38	Simrad EK-S-38	Simrad EK-S-38	Simrad EK400	Simrad EK400	Simrad EK400
Frequency	38 kHz	38 kHz	38 kHz	38 kHz	38kHz	38 kHz	38kHz
Transmitter Power	1.3 kW	1.3 kW	1.3 kW	1.3 kW	2 kW	2 kW	2 kW
Transducer type	38-29/25E	38-29/25E	38-29/25E	38-29/25E	38-29/25E	ES38	38-29/25E
Transducer beam	8.0 x 8.0 deg.	8.0 x 8.0 deg.	8.0 x 8.0 deg.	8.0 x 8.0 deg.	8.0 x 8.0 deg.	6.8 x7.8 deg	8.0 x 8.0 deg.
Range compensation	20 log R	20 log R	20 log R	20 log R	20 log R	20 log R	20 log R
Attenuator	0 dB	0 dB	0 dB	0 dB	0 dB	0 dB	0 dB
Pulse length/Bandwidth	1.0 ms/3.0 kHz	1.0 ms/3.0 kHz	1.0 ms/3.0 kHz	1.0 ms/3.0 kHz	1.0 ms/3.3 kHz	1.0 ms/3.3 kHz	1.0 ms/3.3 kHz
Basic Range	500 m	500 m	500 m	500 m	500 m	500 m	500 m
Integrator	SIORS	SIORS	SIORS	SIORS	SIORS	SIORS	SIORS
Threshold	variable	variable	variable	variable	variable	variable	variable
Gain (output ref.)	10 dB	10 dB	10 dB	10 dB	10 dB	10 dB	10 dB
Bottom channel	4 m	4 m	4 m	4 m	4 m	4 m	4 m
Absolute Calibration							
Date	23/02/87	17/02/88	19/07/89	22/03/90	24/07/91	29/03/92	23/01/93
Reference target	Cu60 -33.6 dB	Cu60 -33.6 dB	Cu60 -33.6 dB	Cu60 -33.6 dB	Cu60 -33.6 dB	Cu60 -33.6 dB	Cu60 -33.6 dB
Instrumental constant//	30.0 $m^2/n.m.^2$	30.0 $m^2/n.m.^2$	31.1 $m^2/n.m.^2$	41.0 $m^2/n.m.^2$	36.0 $m^2/n.m.^2$	44.8 $m^2/n.m.^2$	42.0 $m^2/n.m.^2$
SL+VR	130.3 dB	130.3 dB	128.6 dB	140.0 dB	129.7 dB	127.3 dB	128.1 dB

Table 3 . Trawl survey estimates for S.mentella and S. fasciatus for two size groups in Div. 3M, 1983 - 1996.

Year	L<=15 cm		L>15 cm		Total	
	Abundance, N*10^6,sp	Biomass, W*10^3,t	Abundance, N*10^6,sp	Biomass, W*10^3,t	Abundance, N*10^6,sp	Biomass, W*10^3,t
1983	143.0	3.8	501.0	151.1	644.0	154.9
1984	22.3	0.7	354.4	131.6	376.7	132.3
1985	7.2	0.2	170.1	51.7	177.3	51.9
1986	6.2	0.2	1194.0	309.3	1200.2	309.5
1987	32.4	0.3	430.8	106.1	463.2	106.4
1988	24.7	0.4	158.4	46.6	183.1	47.0
1989	17.6	0.6	266.2	82.7	283.8	83.3
1990	6.9	0.1	67.8	17.6	74.7	17.7
1991	1237.8	10.3	768.3	35.1	2006.1	45.4
1992	40.3	1.0	79.2	17.2	119.5	18.2
1993	64.1	2.3	617.6	67.5	681.7	69.8
1994*	-	-	-	-	-	-
1995	1.2	0.04	136.7	20.06	137.9	20.7
1996	1.0	0.03	61.3	9.07	62.3	10.0

* No investigations were carried out in 1994

Table 4. The redfish acoustic estimation results in NAFO Div. 3M.

Year	Pelagic component				Bottom component				Pelagic+Bottom component				Σ				Total	
	L<=15		L>15		L<=15		L>15		L<=15		L>15		Pelagic *component*		Bottom *component*			
	mill. sp.	thou. t	mill.sp	thou.t	mill.sp	thou.t	mill.sp	thou.t	mill.sp	thou.t	mill.sp	thou.t	mill.sp.	thou.t	mill.sp	thou.t	mill.sp.	thou.t
1983													24800.0	242.0	2600.0	158.0	27400.0	400.0
1984													2300.0	37.0	4050.0	462.0	6350.0	499.0
1985													90.0	3.0	850.0	196.0	940.0	199.0
1986																		
1987	16600.0	186.0	1543.6	393.4	109.3	1.2	272.7	78.6	16769.3	187.2	1816.3	472.0	18203.6	579.4	382.0	79.8	18585.6	659.1
1988	4022.7	99.0	1469.0	292.2	446.7	13.5	163.2	39.8	4469.4	112.5	1632.0	332.0	5491.6	391.2	609.9	53.3	6101.5	441.5
1989	686.1	14.5	1261.2	268.1	39.2	0.8	213.9	64.2	725.3	15.3	1475.1	332.3	1947.3	282.6	253.1	65.0	2200.4	347.6
1990	201.6	3.8	1129.8	224.9	136.7	2.2	571.9	123.3	338.3	6.0	1701.7	224.7	1331.4	228.7	708.6	125.5	2040.0	354.2
1991	1460.1	10.2	389.9	52.1	1304.0	9.2	145.8	28.9	2764.1	19.4	535.7	81.3	1850.0	62.3	1450.0	38.1	3300.0	100.4
1992	669.7	14.2	170.4	25.9	575.1	12.5	157.6	26.0	1244.8	26.7	328.0	51.9	840.1	40.1	732.7	38.5	1572.8	78.6
1993	169.3	6.1	661.7	70.4	178.6	6.6	1072.0	235.1	347.9	12.7	1733.0	305.5	831.0	76.5	1250.1	241.7	2081.1	318.2

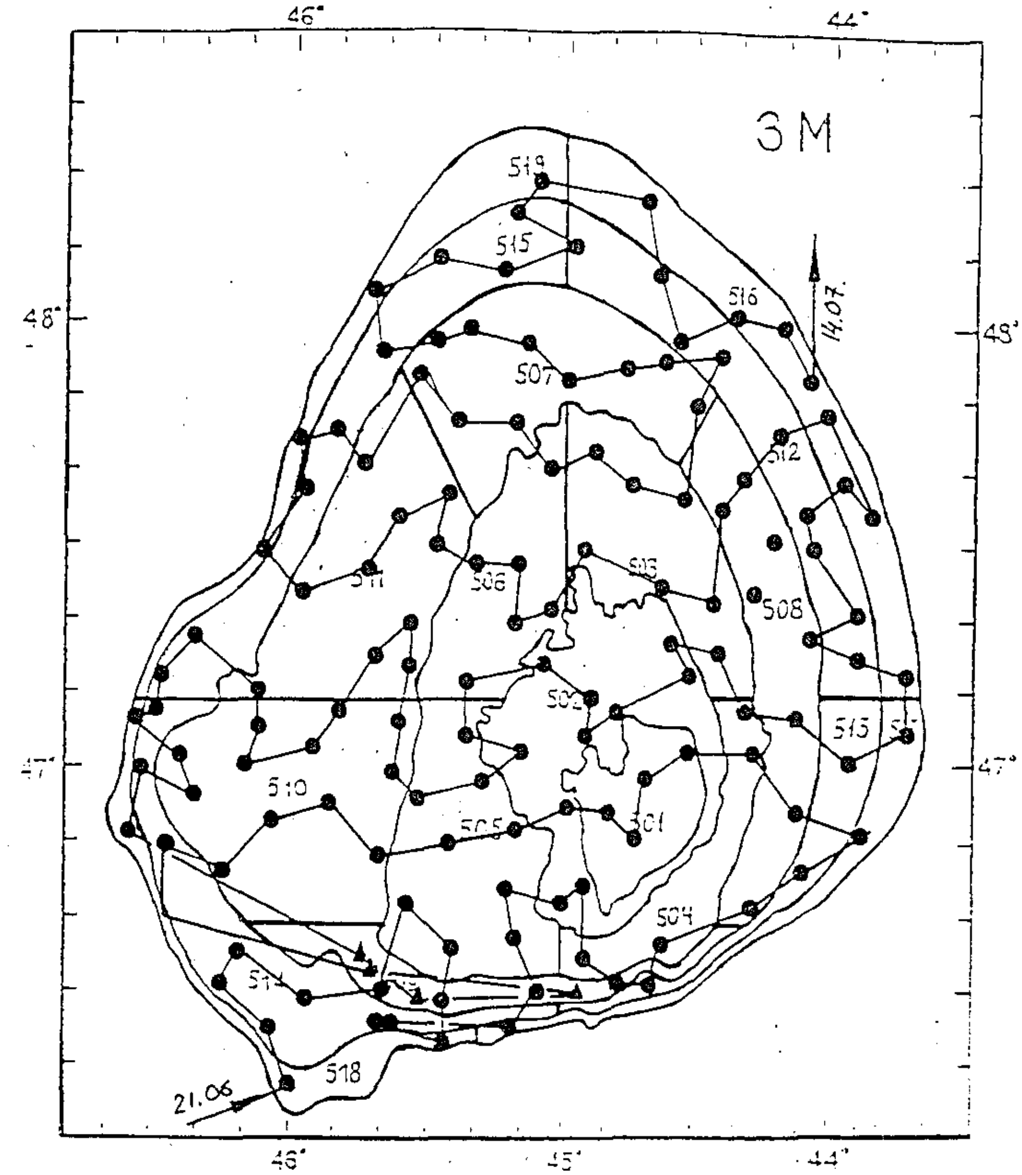

Fig. 1. Position of trawl stations and acoustic tacks
in Div. 3M in 1987.

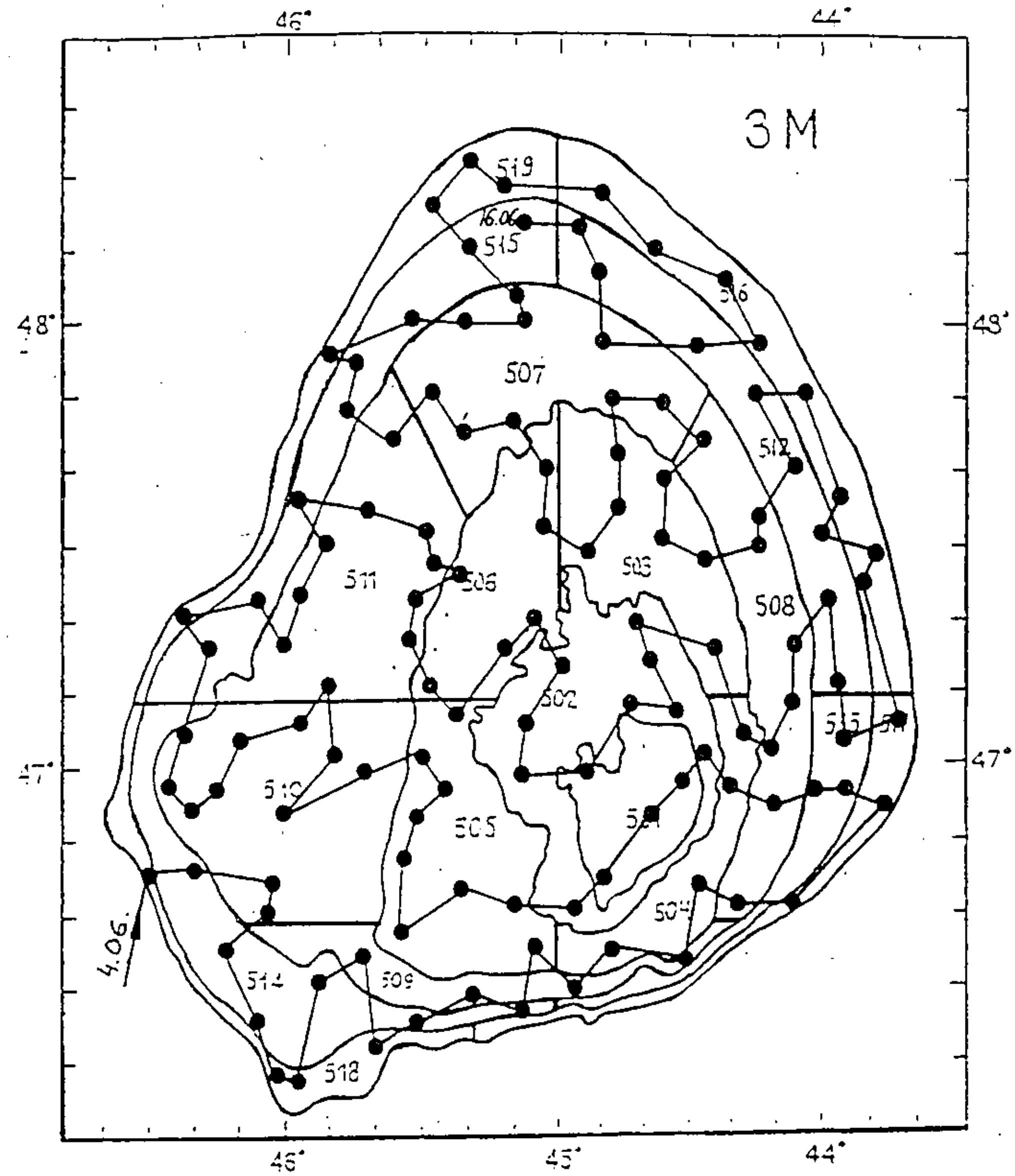

Fig. 2. Position of trawl stations and acoustic tacks in Div. 3M in 1988.

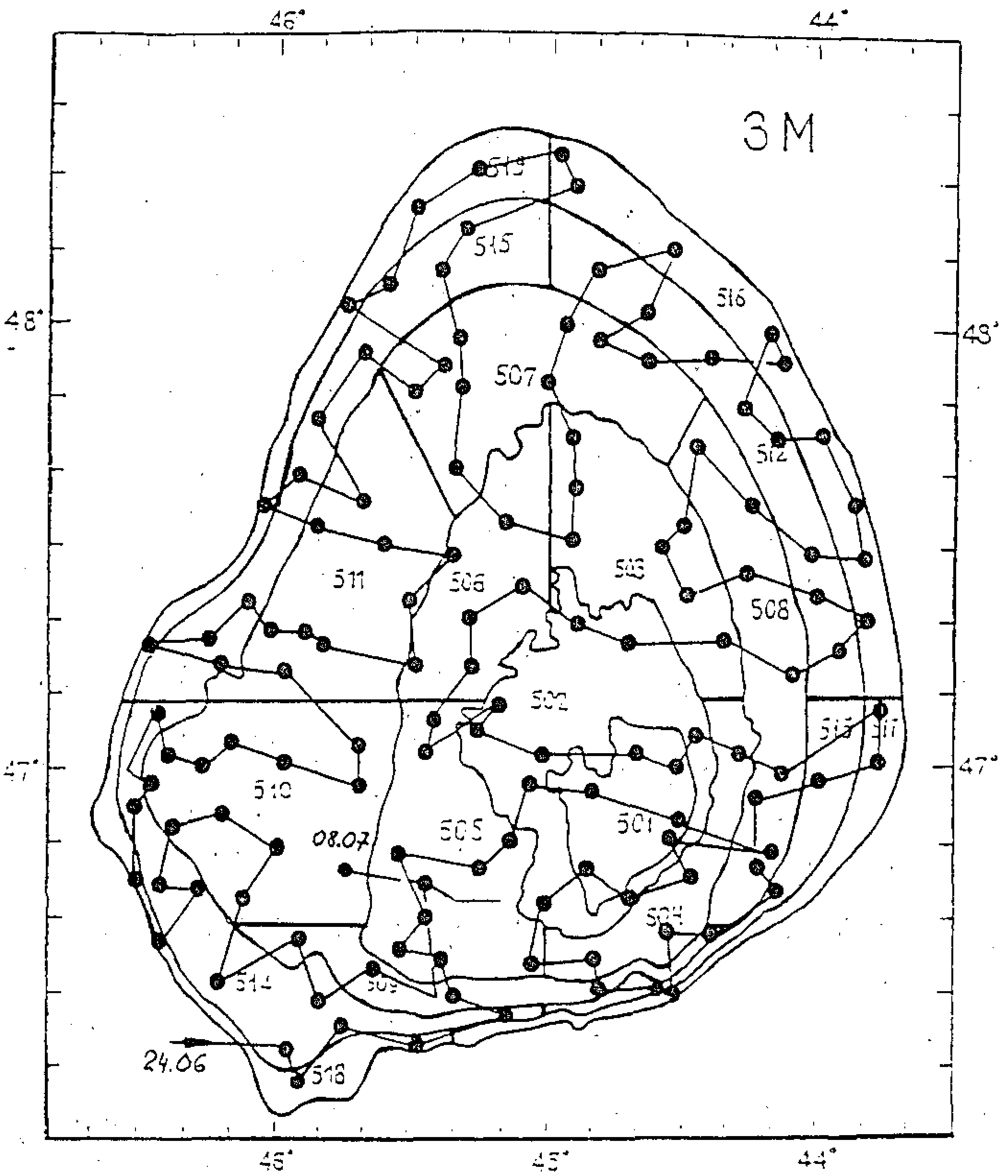

Fig. 3. Position of trawl stations and acoustic tacks in Div. 3M in 1989.

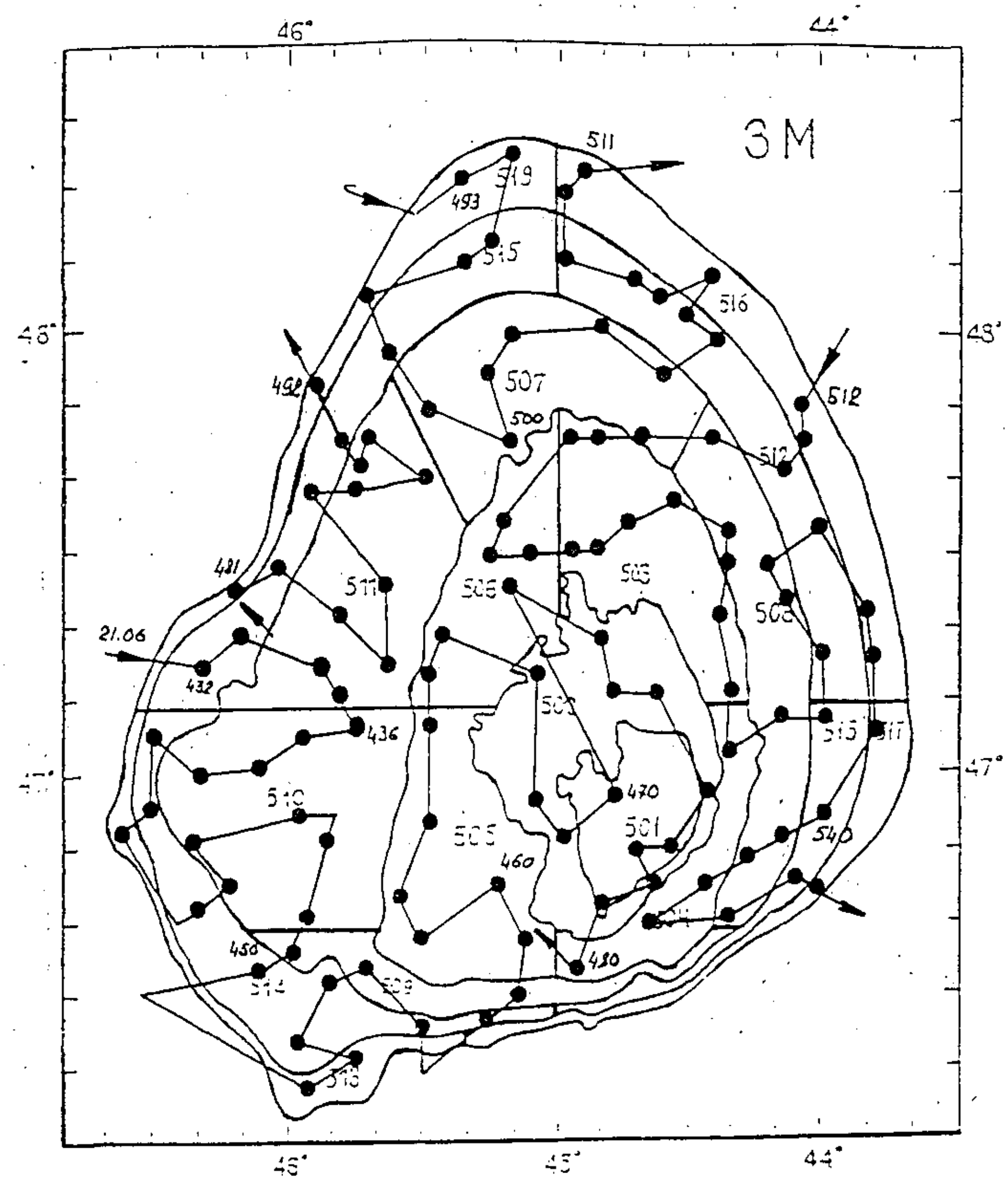

Fig. 4. Position of trawl stations and acoustic tacks in Div. 3M in 1990.

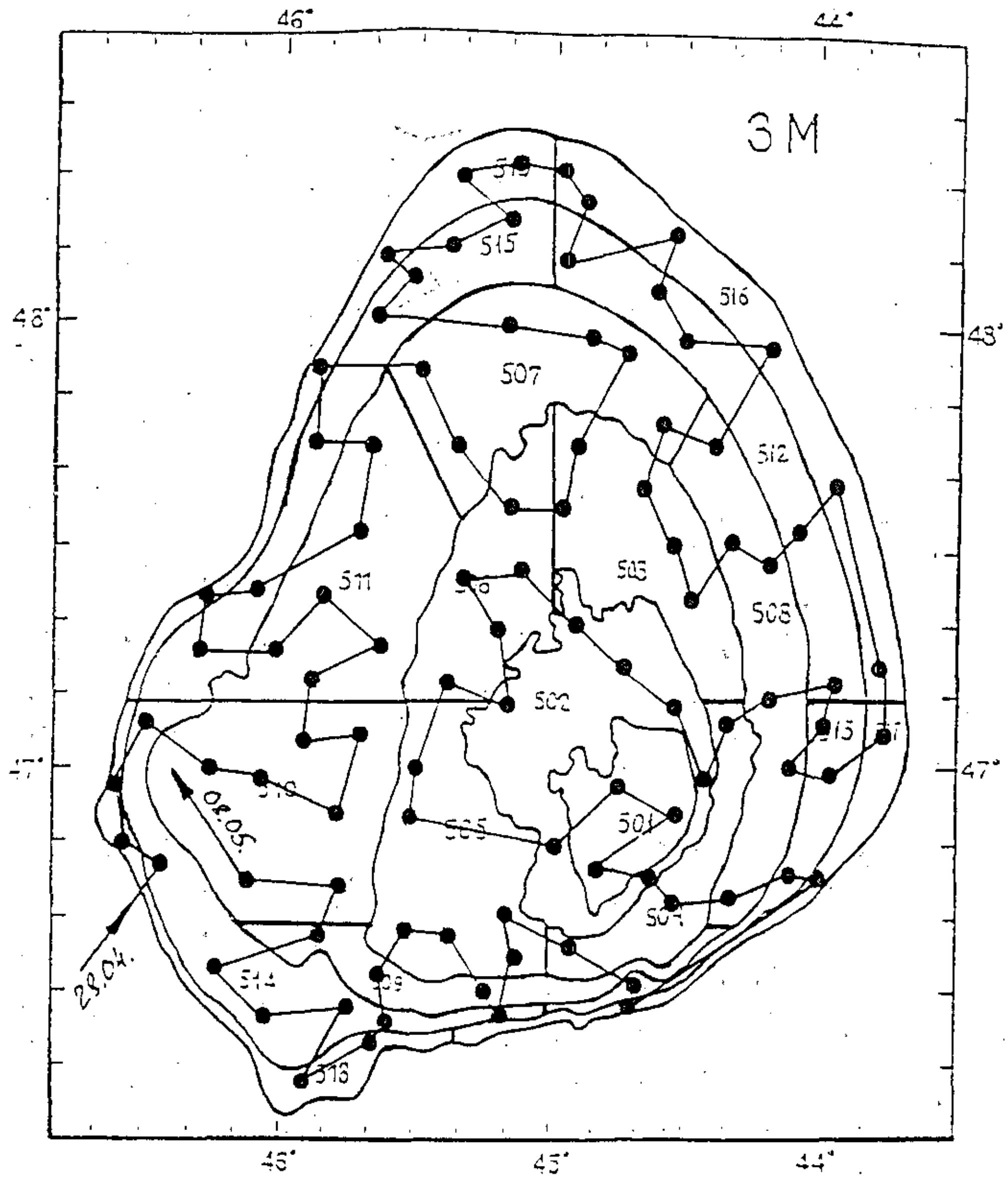

Fig. 5. Position of trawl stations and acoustic tacks in Div. 3M in 1991.

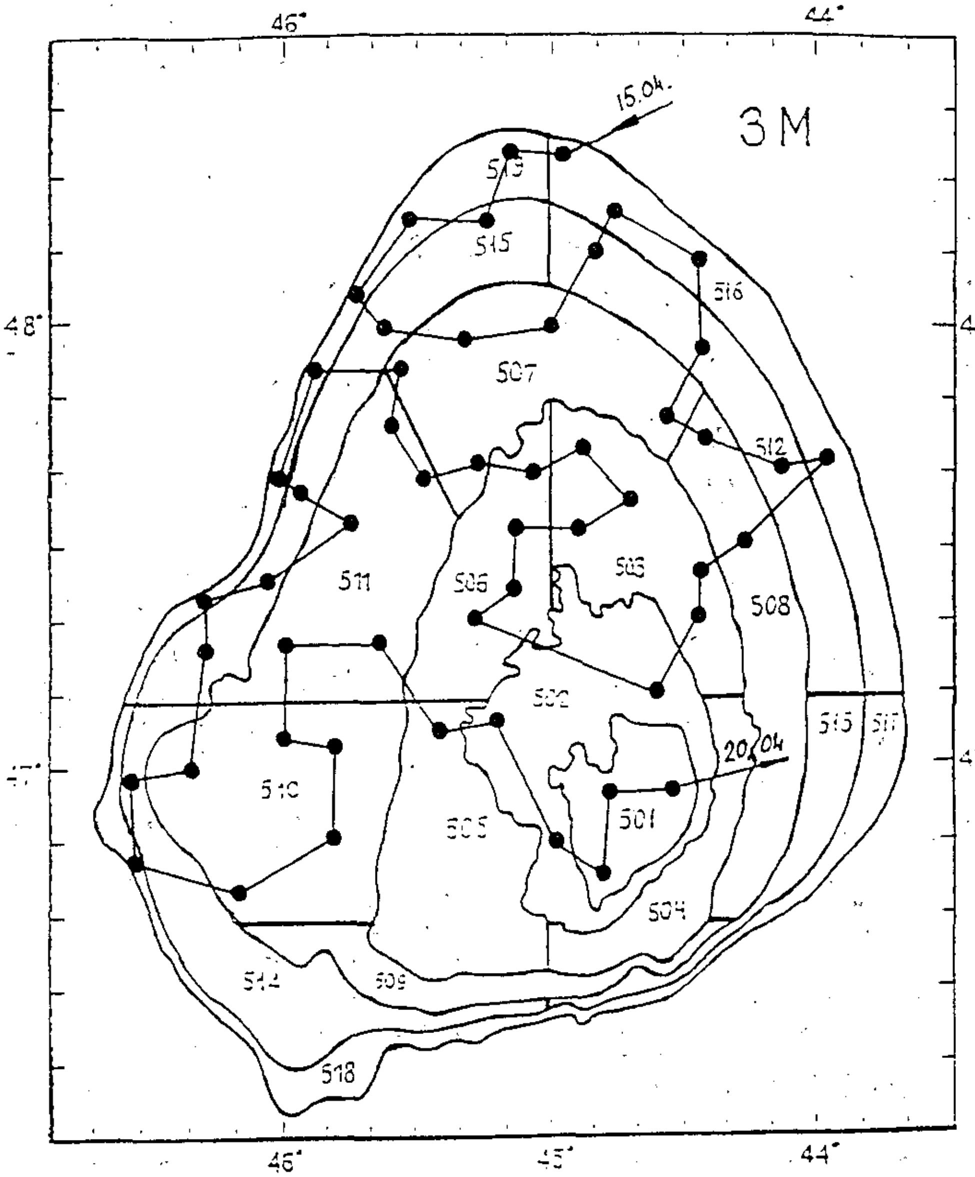

Fig. 6. Position of trawl stations and acoustic tacks
in Div. 3M in 1992.

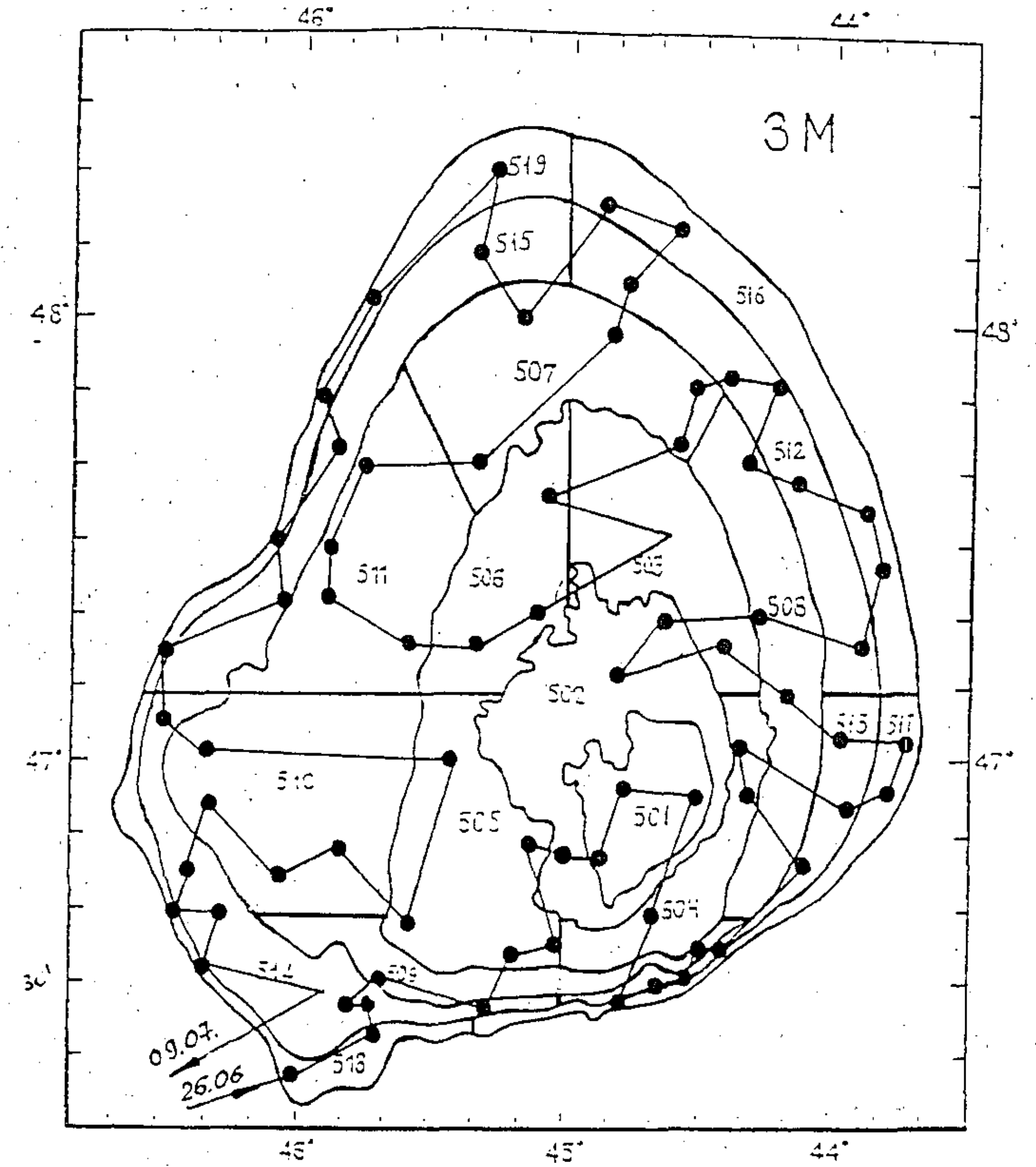

Fig. 7. Position of trawl stations and acoustic tacks in Div. 3M in 1993.