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Herring spawn volume at Fisherman's Bank, Prince Edward Island, in 1994

by

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ABSTRACT

Thicknesses of herring eggs deposited at Fisherman's Bank in eastern Northumberland Strait were measured by underwater video and egg volumes were estimated by geostatistic analysis. In 1994, herring deposited an estimated 11,619 m^3 of spawn on Fisherman's Bank. This value is in the mid-range of records since 1985. No eggs were found on the Ridge, an underwater promontory near Fisherman's Bank, but surveys there were infrequent and herring might have spawned there without detection.

RESUMÉ

On a mesuré les épaisseurs des oeufs d'hareng déposés au Fisherman's Bank dans l'est du Détroit de Northumberland à l'aide d'un appareil vidéo à distance. En 1994, les harengs ont déposé 11619 m^3 d'oeufs, selon l'analyse géostatistique. Cette déposition est dans le milieu des estimations rapportées depuis 1985. Aucun oeuf n'a été trouvé sur le Ridge, une crête sous-marine près du Fisherman's Bank, mais les relevés à cet endroit étaient peu fréquents et les harengs auraient pu y frayer sans détection.

INTRODUCTION

Populations of herring (*Clupea harengus*), like those of most pelagic fishes, are difficult to estimate. In the southern Gulf of St. Lawrence, herring stock assessments have traditionally relied on sequential population analysis. This method has met with reasonable success in autumn-spawning herring of the southern Gulf, but its accuracy is affected by uncertainties in abundance trends and seasonal spawning affinities.

Since 1985, surveys of herring spawning beds have been conducted at Fisherman's Bank, a fall spawning ground off southeastern Prince Edward Island (Messieh 1986, 1987, 1988; Messieh et al. 1987; Lambert and Messieh 1989; Messieh and Rosenthal 1989; Cairns et al. 1993). These surveys are intended to provide an independent indicator of the size of the southeastern Gulf component of the 4T fall spawning stock.

This report presents estimates of egg deposition at Fisherman's Bank for 1994.

STUDY AREA AND METHODS

STUDY AREA

Fisherman's Bank ($46^{o}01'N$, $62^{o}16'W$) is an underwater dome located 16 km east of the southeastern tip of PEI (Fig. 1). The bank measures 3.1 x 5.3 km within the 20 m contour, and rises to 9 m depth at its shallowest point. A broad shelf 25-30 m in depth lies between Fisherman's Bank and Prince Edward Island. Water depths to the east are about 45 m, but an elongated promontory known as the Ridge extends northeast from Fisherman's Bank (Fig. 1). Depths on the Ridge are about 24-32 m.

EGG ESTIMATES

Field surveys

Volume estimates in 1988-1994 were derived from egg bed thickness measurements made by plunging a sharpened ruler into the eggs until it reached the substrate. A video camera was used to monitor the depth of penetration of the ruler into the eggs. A DeepSea Power and Light camera was used in all years, but in 1993-1994 a Sony Handycam video camera, mounted inside a pipe capped by Plexiglas plates, was also used. Mounting systems and camera operation are described by Cairns et al. (1993).

Spawning bed surveys in 1988-1989 proceeded in three stages: exploratory surveys (Phase I), bed delineation (Phase II), and volume estimation by random sampling (Phase III). In 1990-1991 an additional phase (IV) was added to intensify sampling for geostatistical analysis. At each camera station the vessel stopped at pre-determined Loran TDs where the survey crew lowered the camera to the bottom. The camera was hauled clear of the bottom for a few seconds and then dropped until at least three clear measurements were obtained. Five measurements were taken at each Phase III and IV station.

Surveys in 1988 and 1989 were based on a 193 m grid. In 1990 a new 200 m grid was introduced with $46^{o}00'N$, $62^{o}18'W$ as its base point. In 1988-1989 and in 1990-1992 twin arrays of Phase I stations were established, each of which used every second point of the 193 or 200 m grid. These arrays were diagonally offset from each other by 273 m in 1988-1989 and by 283 m in 1990. Phase I arrays contained about 65 stations in 1988-1989, and about 90-100 stations in 1990-1994. The increase in 1990 was due to the extension of the grid into deeper water. Each array could be completed within a day, given good weather and no equipment problems.

Phase I surveys alternated between the two offset arrays. When spawn was discovered in Phase I surveying, the boundaries of the bed were delineated in a Phase II survey which examined nearby stations on the 193 or 200 m grid. The survey proceeded by examining all stations that were immediate neighbours of a station where eggs were found. If any of these stations had eggs, additional stations were examined until all known egg sites were bounded by stations without eggs. In 1988 and 1989 immediate neighbours were considered those in cardinal compass directions from the station with eggs. Starting in 1990, stations immediately northeast, southeast, southwest, and northwest of the station with eggs were also examined.

After completion of Phase II sampling, a sampling zone was established around the spawning bed. This sampling zone included a 193 or 200 m margin around all stations known to have eggs. In 1988-1990 sampling zones were rectangular, but in 1991-1994 the boundary of the zone was placed 200 m outside known egg sites. In 1988-1991 Phase III sampling points were randomly chosen within the sampling zone. In 1988 sample points were chosen by randomly selecting points along the northern and western margins of the sample zone. Any point falling within 25 m of a previously existing point was rejected. Lines were projected perpendicularly from these points, and sampling stations were designated as the intersections of the north-south and east-west lines. In 1989 lines were set up 24 m apart on north-south and east-west axes. Lines were randomly chosen from these sets, and the intersections of selected lines were sampling stations. In 1990-1991 Phase III sampling stations were selected by establishing cells at the intersections of a 40 m grid within the sampling zone. Sampling stations were randomly selected from these cells, with each cell having an equal probability of being chosen.

The area of the sampling zone was the sum of the sampling areas around each potential sample point. Thus total sampling area consisted of the area inside the rectangle within which stations were randomly selected, plus the area of a strip around the edge of this box whose width was half the distance between potential sampling points. This peripheral strip was 12.5 m wide in 1988, 12 m wide in 1989, and 20 m wide in 1990-1994.

Phase IV sampling, used in 1990-1991, took advantage of the lack of requirement in geostatistics for randomness in sample selection. Phase IV points were chosen arbitrarily after the completion of Phase III sampling. Locations were selected to increase sample intensity in dense parts of the bed or to improve delineation of bed boundaries.

In 1992 random sampling was discontinued. Phase III sample points were arbitrarily chosen in like manner to

Phase IV points in 1990-1991. In 1993-1994 Phase III sample points were chosen along regular grids between rows of points that had already been sampled.

Egg volume analysis

Geostatistical analysis of spawn measurements was based on mean values of thickness measurements at each station. Because geostatistics does not require random selection of sample points, data from all survey phases were used in estimates of mean and standard deviation of egg thickness.

Geostatistical analysis began by creating variograms, which plot the association among sample values at various inter-point (lag) distances. Variograms were calculated by GEOEAS, developed by the U.S. Environmental Protection Agency (Englund and Sparks 1990). Nugget, sill, and range values were determined by applying a spherical model to these variograms (see Englund and Sparks 1990 for definitions and Armstrong et al. 1992 for discussion of models).

Block kriging was performed by COKRI, a program written in the Matlab language by Denis Marcotte of the École Polytechnique, Université de Montréal (Marcotte 1991). Block kriging was performed by COKRI on the sample zone of each spawning bed. In 1989-1990 sampling zones were simple rectangles and block kriging estimated their mean egg thickness directly. In 1991-1994 sample zones were complex polygons. Egg volume was estimated for these by dividing them into contiguous rectangles and block kriging each rectangle. Because Bed 3 of 1993 was long, narrow, and oriented on a Northeast-Southwest axis, numerous rectangles would have been required to cover it. A special grid on a Northeast-Southwest baseline was therefore devised, which reduced the required number of rectangles to two. The search radius for block kriging was 6 km and the total data set was used.

RESULTS

Surveys were conducted on Fisherman's Bank from 20 August to 20 September 1994. Most of the Bank was surveyed in Phase I passes every 3-4 days, except between 3 and 7 September, when the survey was grounded by bad weather and engine problems. The day after this interruption (8 September) two vessels and crews were used in the survey. The Ridge was surveyed on 9 and 18 September.

Six spawning beds were discovered on Fisherman's Bank (Fig. 2). Because of the frequency of Phase I coverage, it is unlikely that any spawning bed of significant size was missed. The longest gap in survey coverage (3-7 September) was immediately followed by a complete Phase I survey of the Bank on 8 September. Given an incubation period of 7 days, it is not possible that a spawning bed could have been laid down and hatched within this period.

No spawning beds were discovered on the Ridge. Because the Ridge was only surveyed twice, it is possible that herring spawned at that site without detection by the survey.

Estimated egg volumes of the six beds on Fisherman's Bank ranged from 107 to 4600 m^3 (Table 1). The first spawning was estimated to have occurred on 21 August and the last two on 11 September. A dense milt patch was observed on 8 September as Bed 4 was being deposited. Total estimated egg deposition was 11,619 m^3 (Table 1, Fig. 3).

DISCUSSION

The basic assumption of this survey is that there is a sub-stock of herring which spawns on Fisherman's Bank and the Ridge. This sub-stock may be called the Fisherman's Bank sub-stock.

Of the eight previous spawning bed surveys, four produced egg deposition estimates greater than that of 1994, and four produced lower estimates (Table 2). This suggests that the size of the Fisherman's Bank sub-stock is relatively stable.

However, such a conclusion must be tempered by the following considerations. First, surveys from 1985 to 1987 were conducted by a semi-quantitative procedure whose reliability is uncertain. Second, some fish of the Fishermans's Bank sub-stock spawn on the Ridge, at least in some years. Estimates for 1991-1994 include deposition estimates for the Ridge, which was not surveyed earlier. However, these estimates may not be complete in all cases because the Ridge was not visited as frequently as Fisherman's Bank and it is possible that some small beds on the Ridge could have been missed. Given the absence of a complete time series for the Ridge, egg deposition estimates for the Fisherman's Bank sub-stock cannot be considered full and complete.

Third, estimates for 1991 and 1992 suggest that not all herring of the Fisherman's Bank sub-stock spawn on Fisherman's Bank and the Ridge in all years. From 1990 to 1992, spawn deposition estimates decreased by half and then doubled back to typical levels (Fig. 3). Herring is a long-lived species, and its populations cannot halve in one year and double in the next. The most likely explanation for the drop in 1991 is that not all of the Fisherman's Bank sub-stock spawned in the survey area in that year. These fish may have spawned on the Pictou grounds on the Nova Scotia side of Northumberland Strait, or they may not have spawned at all.

These considerations notwithstanding, herring eggs offer a fundamental advantage as survey subjects: they do not move. Despite their limitations, herring spawning bed surveys can provide a valuable indicator of the size of the stock spawning in a particular area.

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Table 1
Estimates of herring spawn volume at Fisherman's Bank and the Ridge, 1985-1994.
Means and standard deviations are arithmetic for 1985-1987 and kriged for 1988-1994.

Year	Bed	Location (Bank or Ridge)	Estimated spawn date	Number of stations	Egg thickness (cm)			Survey area (km2)	Egg volume (m3)
					Mean	SD	CV		
1985	1	B	31 Aug	7	0.671			0.2860	1920
	2	B	31 Aug	13	0.062			0.4888	304
	3	B	4 Sep	6	0.001			0.2390	3
	4	B	16 Sep	26	2.059			0.2470	5085
	5	B	16 Sep	6	0.734			0.5595	4105
	Total	B		58				1.8203	11417
1986	1	B	3 Sep	29	0.985			1.1000	10837
1987	1	B	23 Aug	5	0.617			0.1864	1150
	2	B	26 Aug	22	0.513			0.7955	4083
	3	B	1 Sep	14	0.596			0.4827	2878
	4	B	9 Sep	16	0.601			0.6155	3702
	Total	B		57				2.0800	11814
1988	1	B	5 Sep	86	0.113	0.055	0.490	0.8447	950
	2	B	6 Sep	N/A					
	3	B	8 Sep	N/A					
	4	B	12 Sep	N/A					
1989	1	B	28 Aug						
	2	B	29 Aug	106	0.437	0.094	0.220	1.2778	5589
	3	B	3 Sep	96	0.663	0.138	0.210	1.2231	8103
	4	B	9 Sep	45	0.911	0.156	0.170	0.2583	2352
	5	B	12 Sep	75	0.229	0.052	0.230	0.5002	1145
	Total	B		322				3.2594	17189
1990	1	B	20 Aug						
	2	B	28 Aug	74	0.251	0.073	0.290	1.0816	2711
	3	B	2 Sep						
	4	B	3 Sep	50	0.088	0.035	0.400	0.4096	360
	5	B	11 Sep	60	0.419	0.115	0.280	0.5376	2251
	6	B	13 Sep	106	0.608	0.074	0.120	1.2896	7839
	7	B	16 Sep	20	0.178	0.046	0.260	0.1936	344
	Total	B		310				3.512	13504
1991	1	B	21 Aug	38	0.030	0.010	0.339	0.4576	138
	2A				0.047	0.025	0.524	0.8520	400
	2B				0.278	0.031	0.111	0.2480	689
	2C				0.043	0.044	1.032	0.0968	42
	2D				0.011	0.058	5.360	0.0924	10
	2E				0.133	0.043	0.326	0.0924	123
	2F				0.021	0.044	2.109	0.1408	29
	2G				0.003	0.067	22.973	0.0968	3
	2	B	25 Aug	110				1.6192	1296
	3A				0.014	0.003	0.244	0.5084	69
	3B				0.002	0.006	2.491	0.0968	2
	3C				0.007	0.006	0.836	0.0968	6
	3	B	2 Sep	41				0.7020	78
	4A				0.031	0.007	0.237	0.2400	75
	4B				0.012	0.009	0.719	0.1408	17
	4C				0.024	0.009	0.372	0.1408	34
	4D				0.000			0.0484	0
	4E				0.047	0.014	0.293	0.0484	23
	4	B	5 Sep	24				0.6184	149

	5A				0.261	0.056	0.215	1.4640	3824
	5B				0.044	0.116	2.613	0.1848	82
	5C				0.077	0.158	2.034	0.1408	109
	5D				0.182	0.071	0.393	0.2288	417
	5	R	13 Sep	126				2.0184	4431
	Total	B		213				3.3972	1661
	Total	R		126				2.0184	4431
	Total	B&R		339				5.4156	6092
1992	1A				0.069	0.010	0.144	1.4400	1000
	1B				0.044	0.022	0.496	0.1848	82
	1C				0.017	0.028	1.689	0.0968	16
	1D				0.016	0.023	1.421	0.1848	30
	1	B	25 Aug	71				1.9064	1128
	2A				0.456	0.048	0.105	1.2400	5660
	2B				0.153	0.157	1.030	0.0968	148
	2C				0.109	0.080	0.734	0.2688	293
	2	B	29 Aug	71				1.6056	6101
	3	B	6 Sep	35	0.643	0.155	0.240	0.8736	5620
	4A				0.073	0.021	0.285	1.2648	918
	4B				0.043	0.039	0.914	0.0968	41
	4	R	10 Sep	38				1.3616	959
	Total	B		177				4.3856	12849
	Total	R		38				1.3616	959
	Total	B&R		215				5.7472	13808
1993	1A				0.032	0.010	0.321	0.3360	108
	1B				0.028	0.012	0.415	0.1848	52
	1	B	22 Aug	27				0.5208	160
	2A				0.047	0.026	0.550	0.0968	45
	2B				0.054	0.014	0.270	0.6200	332
	2C				0.038	0.022	0.575	0.1364	52
	2	B	25 Aug	43				0.8532	430
	3A				0.214	0.046	0.213	1.1984	2559
	3B				0.056	0.122	2.198	0.0736	41
	3	B	4 Sep	60				1.2720	2601
	4A				0.143	0.076	0.532	0.0968	138
	4B				0.364	0.027	0.074	1.1480	4176
	4C				0.102	0.061	0.599	0.1600	163
	4D				0.081	0.038	0.472	0.5084	410
	4E				0.077	0.067	0.864	0.1364	105
	4F				0.060	0.078	1.298	0.0968	58
	4	B	5 Sep	121				2.1464	5051
	5A				0.069	0.022	0.321	0.1848	128
	5B				0.115	0.013	0.109	0.8400	968
	5C				0.068	0.038	0.556	0.0484	33
	5D				0.054	0.030	0.557	0.0968	52
	5E				0.081	0.025	0.315	0.1410	114
	5	R	20 Sep	77				1.3110	1294
	Total	B		251				4.7924	8241
	Total	R		77				1.3110	1294
	Total	B&R		328				6.1034	9535

1994	1A				0.017	0.022	1.296	0.0968	16
	1B				0.034	0.008	0.228	0.2688	91
	1	B	21 Aug	23				0.3656	107
	2A				0.046	0.065	1.407	0.1764	82
	2B				0.025	0.095	3.852	0.0968	24
	2C				0.191	0.030	0.158	0.9600	1836
	2D				0.161	0.078	0.485	0.1408	227
	2E				0.028	0.058	2.033	0.2520	72
	2F				0.024	0.068	2.835	0.1364	33
	2G				0.221	0.034	0.156	1.0400	2301
	2H				0.014	0.059	4.274	0.1848	26
	2	B	28 Aug	83				2.9872	4600
	3	B	5 Sep	21	0.189	0.074	0.391	0.1936	365
	4A				0.064	0.062	0.966	0.0968	62
	4B				0.171	0.029	0.172	0.6120	1045
	4C				0.100	0.028	0.282	1.2896	1290
	4D				0.059	0.062	1.053	0.0968	57
	4	B	8 Sep	54				2.0952	2454
	5A				0.335	0.046	0.138	0.6560	2199
	5B				0.113	0.104	0.917	0.0968	110
	5C				0.058	0.102	1.771	0.1364	79
	5D				0.117	0.075	0.643	0.2480	291
	5E				0.041	0.080	1.959	0.1848	75
	5F				0.076	0.106	1.400	0.0924	70
	5	B	11 Sep	75				1.4144	2823
	6A				0.211	0.064	0.302	0.3444	726
	6B				0.210	0.191	0.910	0.0484	102
	6C				0.314	0.088	0.280	0.1408	442
	6	B	11 Sep	31				0.5336	1270
	Total	B		287				7.5896	11619
	Total	R		0				0.0000	0
	Total	B&R		287				7.5896	11619

*Sum $\frac{\text{(CV of block estimate x block estimate)}}{\text{Total estimate}}$

Table 2
Egg volume and progenitor biomass estimates for herring spawning on Fisherman's Bank and the Ridge, 1985-1994.

Year	Fisherman's Bank		The Ridge			Both areas	
	Volume (m3)	Weighted mean of CVs*	Volume (m3)		Weighted mean of CVs	Volume (m3)	Weighted mean of CVs
1985	11,417		No data				
1986	10,837		No data				
1987	11,814		No data				
1988	No data		No data				
1989	17,189	0.21	No data				
1990	13,504	0.19	No data				
1991	1,661	0.41	4,431		0.32	6,092	0.34
1992	12,849	0.20	959	**	0.31	13,808	0.21
1993	8,241	0.20	1,294		0.18	9,535	0.20
1994	11619	0.31	0			11,619	0.31

*Sum $\frac{\text{(CV of block estimate x block estimate)}}{\text{Total estimate}}$

** Minimum estimate; some eggs had hatched by sampling time

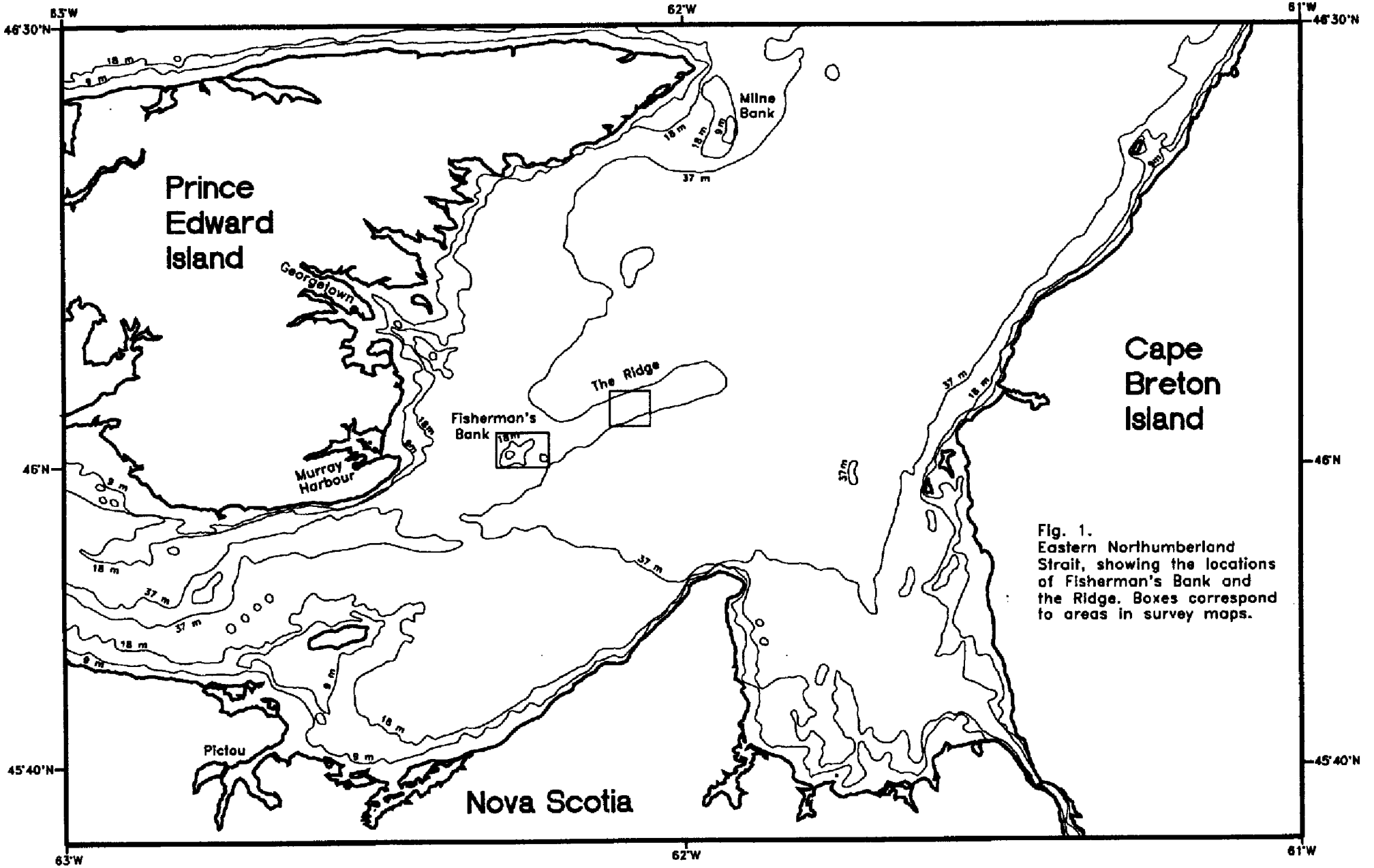


Fig. 1.
Eastern Northumberland Strait, showing the locations of Fisherman's Bank and the Ridge. Boxes correspond to areas in survey maps.

Fig. 2
Phase II surveys of herring spawning beds at Fisherman's Bank, 24 August - 15 September 1994.

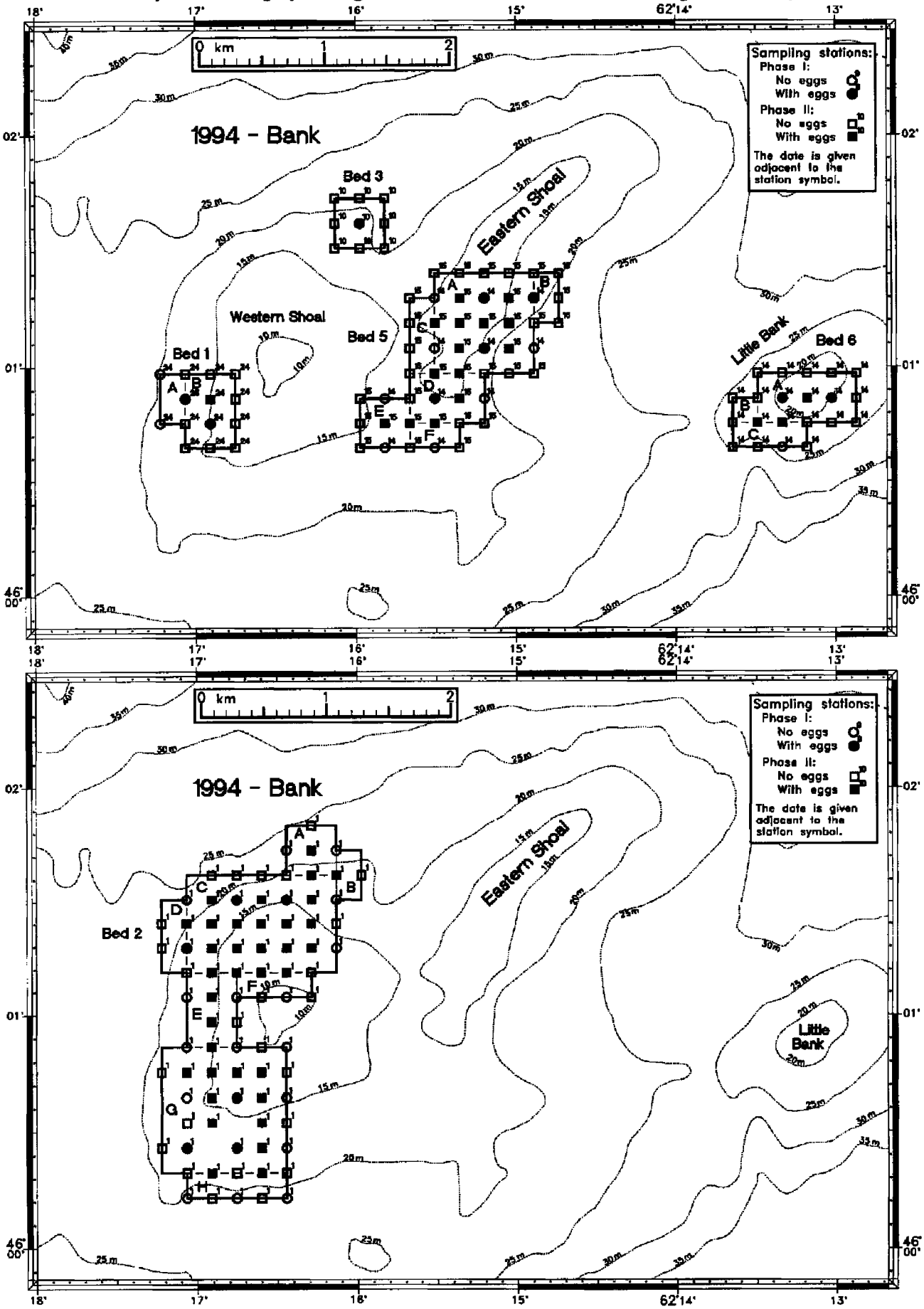
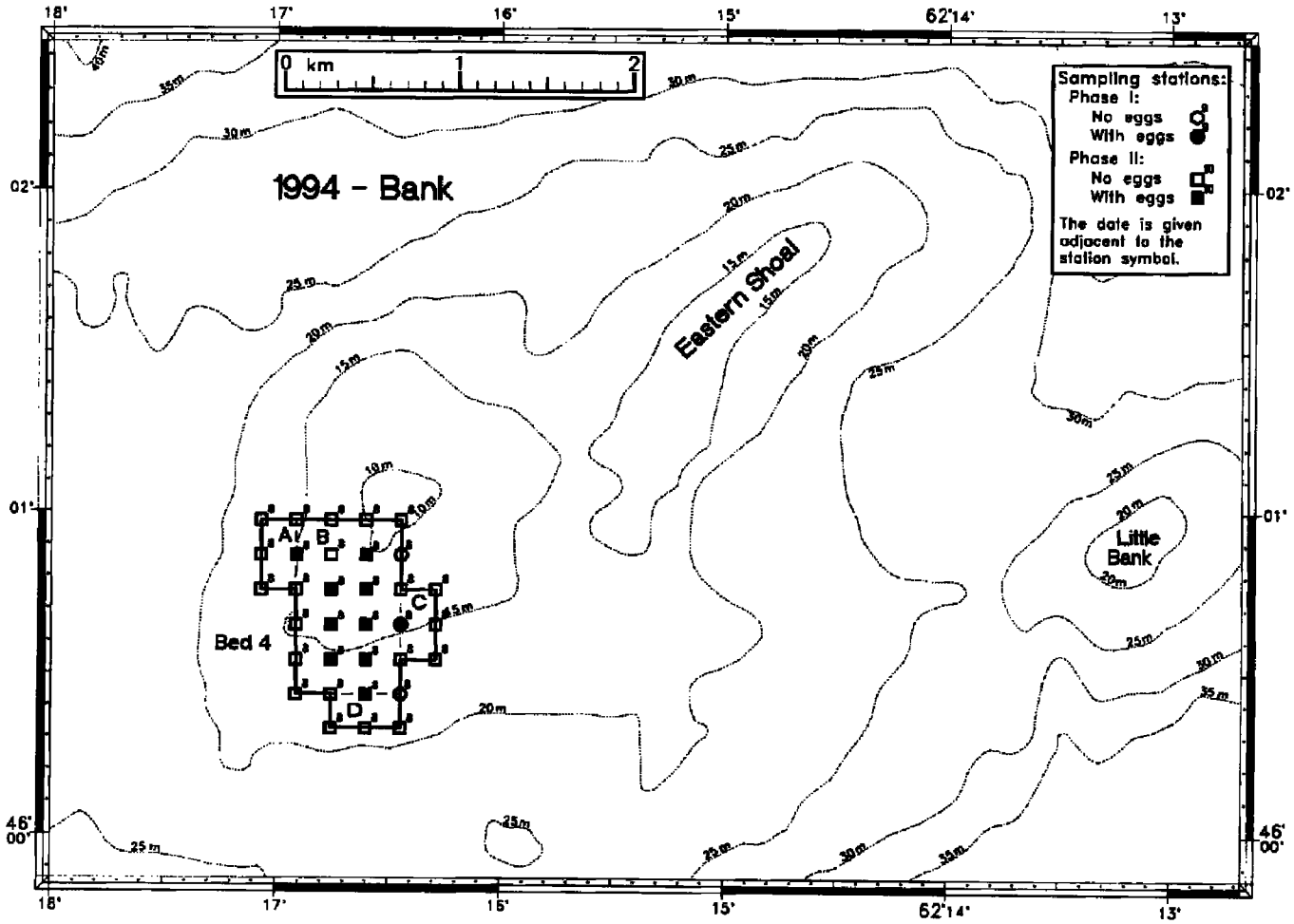


Fig. 2 (continued)



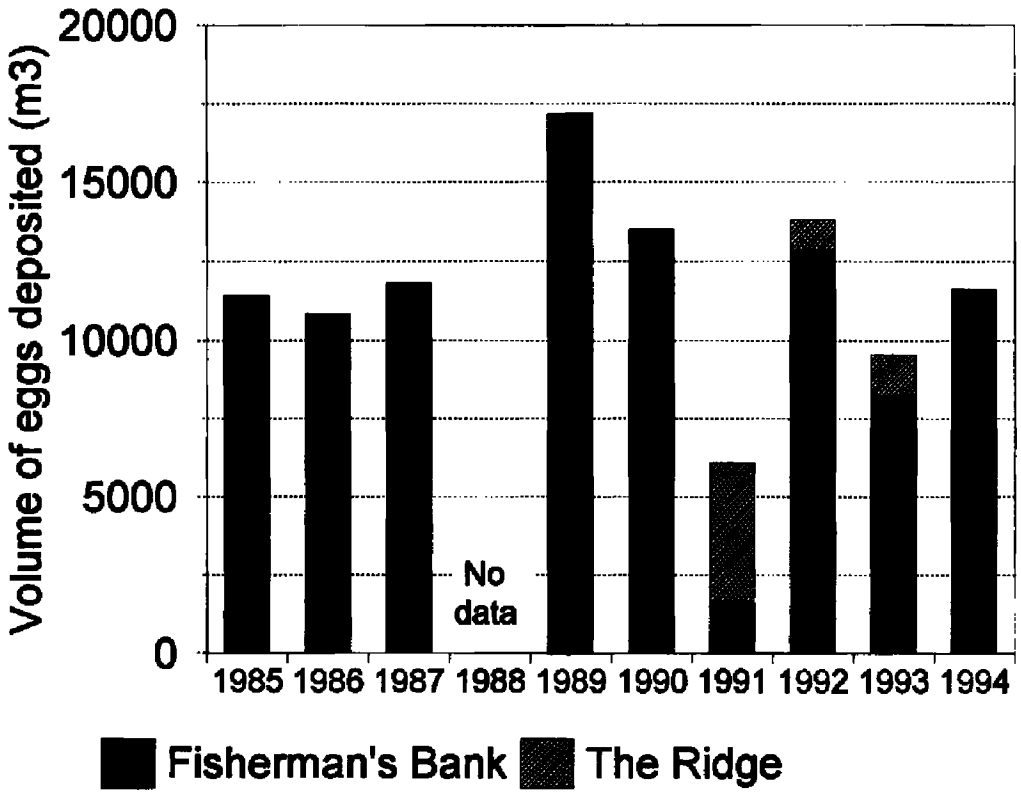


Fig. 3
Volume of herring spawn deposited at Fisherman's Bank and the Ridge. Data for Fisherman's Bank are from 1985-1987 and 1989-1994. Data for the Ridge are from 1991-1994.