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Herring spawn volume and progenitor biomass at Fisherman's Bank, Prince Edward Island, in 1995

by

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ABSTRACT

Thicknesses of herring egg beds deposited at Fisherman's Bank in eastern Northumberland Strait were measured by underwater video and egg volumes were estimated by geostatistic analysis. In 1995, herring deposited an estimated 1262 m^3 of spawn on Fisherman's Bank, the smallest deposition in the time series (1985-1987, 1989-1995). Progenitor biomass responsible for this spawning was estimated as 7514 tons. The decreased egg deposition does not necessarily mean a population crash because fish may have shifted spawning to the nearby Ridge or elsewhere.

RESUMÉ

On a mesuré les épaisseurs des tapis d'oeufs d'hareng déposés au Fisherman's Bank dans l'est du Détroit de Northumberland à l'aide d'un appareil vidéo à distance. L'analyse géostatistique indique que les harengs ont déposé 1262 m^3 d'oeufs sur Fisherman's Bank en 1995, la plus petite déposition de la série historique (1985-1987, 1989-1995). La biomasse des progéniteurs responsables pour ce frai étaient estimée comme 7514 tonnes. Le declin dans la déposition des oeufs n'indique pas nécessairement une chute dans la population car les poissons auraient pu changer leur site de frai au Ridge avoisinant, ou ailleurs.

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 (Claytor et al. 1995). 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; Cairns 1995). 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 and progenitor biomass at Fisherman's Bank for 1995.

STUDY AREA AND METHODS

STUDY AREA

Fisherman's Bank (46°01'N, 62°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

Field surveys were conducted on 28 August - 1 September and 5-8, 11-12, and 19 September 1995. The survey platform was the MV Opilio, a 20 m fiberglass research vessel, on all days except 19 September, when a commercial lobster boat was used. The Ridge was not surveyed in 1995.

Volume estimates 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 (to the nearest mm) of the ruler into the eggs. Mounting systems and camera operation are described by Cairns et al. (1993). The camera and its mount were lowered and raised by a power winch. At each camera station the vessel stopped at a pre-determined Loran TD where the camera was lowered to the bottom. The camera was hauled clear of the bottom for a few seconds and then dropped until five clear measurements were obtained.

Spawning bed surveys proceeded in three stages: exploratory surveys (Phase I), bed delineation (Phase II), and supplemental sampling (Phase III). Surveys were based on a 200 m grid with 46°00'N, 62°18'W as its base point. Twin arrays of Phase I stations were established, each of which used every second point of the 200 m grid. These arrays were diagonally offset from each other by 283 m. 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 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. Stations immediately northeast, southeast, southwest, and northwest of stations 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 220 m margin around all stations known to have eggs. The survey then proceeded to Phase III, where further sample points were then visited, usually in regular rows between the points already visited. Phase III stations were chosen from a 40 m grid.

Egg volume analysis

Volume of eggs deposited at each bed was estimated through geostatistical analysis of mean thickness measurements at stations within the bed's sampling zone. Data from all survey phases were used in estimates of mean and standard deviation of egg thickness.

Geostatistical analysis began by calculating variograms using the program GEOEAS (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 sampling zone of each spawning bed. Because sampling zones were complex polygons, egg volume was estimated by dividing them into contiguous rectangles which were then block kriged. The search radius for block kriging was 6 km and the total data set was used.

Progenitor biomass estimates

Biomass of the progenitor stock was estimated from egg volume estimates by a conversion factor based on roe percent calculations (Table 1) and specific gravity measurements (Table 2). The ratio of roe produced:population biomass was calculated by summing the weights of full Stage 6 ovaries from females in a sampled population, and dividing this sum by the sample's biomass (Table 1; data from F. Mowbray, unpubl.). This calculation was based on weights of full ovaries only, and assumes that all females will reach Stage 6 and that all Stage 6 eggs will be deposited.

Specific gravities of spawn were measured in intact spawn samples collected on Fisherman's Bank on 6 September 1995. On the basis of egg staging, these eggs were deposited on the previous night. Rectangular cubes were cut from the egg mat and their lengths, widths, and

mean thicknesses measured. Wet weights were measured after excess moisture was drained onto paper towel, and dry weights were measured after desiccation in a drying oven at 50° for 24 h. Dry specific gravity was calculated as the ratio of dry egg mass in g:volume in cm^3 occupied by these eggs.

The derivation of the progenitor biomass conversion is detailed in Table 3.

RESULTS

Two spawning beds were discovered on Fisherman's Bank in 1995 (Fig. 2). The first, deposited on the Western Shoal on 31 August, contained an estimated 323 m^3 of spawn (Table 4). The second was deposited on the Eastern Shoal on 5 September and contained an estimated 939 m^3 of spawn. Total estimated spawn deposition was 1262 m^3.

The ratio of progenitor biomass (tons):spawn deposition (m^3) was calculated as 5.954:1 (Table 3). This conversion factor yields an estimate of 7514 progenitor tons on Fisherman's Bank in 1995 (Table 5, Fig. 3).

DISCUSSION

Field surveys were not conducted on 2-4 and 13-18 September. However, it is unlikely that any significant egg depositions on Fisherman's Bank were missed because egg mats are visible on the bottom for at least 7 days (usually much longer), and because gaps in field work were immediately followed by full surveys of the Bank.

The estimated volume of herring spawn deposited on Fisherman's Bank in 1995 is the lowest in the 10 years for which data are available (Table 5, Fig. 3). In one previous year (1991), deposition was also markedly below the mean. Thus deposition estimates appear to fall in two categories: eight "normal" years, in which estimates ranged from 8241 to 17189 m^3, and two "low" years, with estimates of 1262 and 1661 m^3.

The previous "low" year (1991) was followed by a "normal" year. Thus a sharp decline in egg deposition does not necessarily mean a population crash. In 1991, some fish which normally spawned on Fisherman's Bank appear to have spawned on the Ridge, where egg deposition was the highest of the four years of that site's time series (Fig. 3). It is not known if a similar shift might have occurred in 1995 because the Ridge was not surveyed in that year. It is also possible that Fisherman's Bank herring might spawn in some years at alternate sites, notably the Pictou grounds, some 30 km distant from the Bank.

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Table 1
Length-frequencies, body weights, ovary weights, and sex ratios of herring samples from the commercial fishery at Fisherman's Bank, 1991. Ovary weights are derived from Stage 6 fish with full ovaries. Data from F. Mowbray (unpubl.).

Length (cm)	Number measured	Mean body weight (g)	Mean ovary weight (g)	Percent females	Total weight at length (g)	Ovary weight at length (g)
28	46	171.6	32.2	25	7894	370
29	462	206.6	37.0	39	95449	6726
30	1669	224.7	36.9	41	375024	24979
31	1812	245.0	47.5	50	443940	43035
32	836	265.6	58.1	40	222042	19540
33	715	292.5	69.0	44	209138	21707
34	1274	336.6	82.7	31	428828	32370
35	1911	364.6	96.2	38	696751	70471
36	1300	390.0	99.3	51	507000	65429
37	613	423.7	107.1	59	259728	38735
38	162	445.5	111.9	47	72171	8439
39	26	472.4	132.0	75	12282	2574
N	10826	2531	484	1158		
Mean		319.9	75.8	45.0		
Sum					3330247	334375
Roe percent						10.04

Table 2
Specific gravity of herring spawn deposited on Fisherman's Bank on the night of 5-6 September 1995, and collected on 6 September.

Sample number	Mean thickness of sample (cm)	Volume of sample (cm^3)	Mass (g)		Dry weight as a % of wet weight	Specific gravity (mass (g) per cm^3 of spawn)	
			Wet	Dry		Wet	Dry
1	1.0	13.7	9.8	1.3	12.9	0.720	0.093
2	1.4	21.9	14.7	1.9	12.7	0.668	0.085
3	1.7	16.4	10.7	1.4	13.1	0.653	0.086
4	1.2	19.6	13.1	1.6	12.6	0.667	0.084
5	1.7	14.3	7.6	1.0	12.8	0.530	0.068
6	0.8	6.3	3.6	0.5	12.9	0.579	0.075
7	0.8	8.7	5.7	0.7	12.8	0.657	0.084
8	0.6	9.2	6.6	0.9	13.1	0.719	0.094
9	0.7	9.5	6.1	0.8	13.2	0.641	0.085
10	1.8	65.7	38.7	5.0	13.0	0.589	0.077
11	0.5	4.2	3.3	0.4	12.8	0.799	0.102
12	0.4	4.5	4.5	0.6	12.3	0.995	0.122
13	0.8	9.6	6.2	0.8	12.8	0.649	0.083
14	0.7	9.1	5.8	0.7	12.9	0.634	0.082
15	0.3	4.0	3.6	0.5	13.1	0.910	0.119
16	1.2	12.1	8.6	1.1	12.7	0.714	0.091
17	1.1	12.7	7.1	0.9	12.6	0.561	0.071
18	0.4	4.5	3.5	0.5	13.1	0.779	0.102
Mean	0.9	13.7	8.8	1.1	12.9	0.692	0.089
SD	0.5	14.0	8.1	1.1	0.2	0.118	0.015

Table 3
Derivation of the relation between progenitor biomass and volume of deposited herring spawn, based on an initial progenitor biomass of 1 metric ton (1,000,000 g).

Assumed progenitor biomass (wet weight)		1,000,000	g
Mass of full Stage 6 ovaries as a proportion of total biomass (Table 1)		0.1003	
Wet weight of roe produced by progenitor biomass, assuming all females reach Stage 6 and all eggs are deposited	1,000,000 x 0.1003	100,300	g
Egg dry weight as a proportion of wet ovary weight (Messieh 1976)		0.1605	
Egg dry weight produced by progenitor biomass	100,300 x 0.1605	16,098	g
Age of eggs sampled for specific gravity measurements		1	day
Incubation period at Fisherman's Bank		7	days
Egg dry weight at hatching as a proportion of egg dry weight at beginning of incubation (Hay 1984)		0.50	
Dry weight of eggs on sampling date. Decrease in dry weight is linear (Hay 1984)	16,098-(16,098 x (1/7 x 0.5))	14,948	
Dry specific gravity of deposited spawn (Table 2)		0.089	g dry weight per cm^3 spawn volume
Volume of deposited spawn	14,948/0.089	167,958	cm^3
Metric tons of progenitor biomass required to produce 1 m^3 of spawn	1,000,000/167,958	5.954	metric tons
Cubic metres of spawn produced by 1 metric ton of progenitors	167,958/1,000,000	0.168	m^3

Table 4
Estimates of herring spawn volume at Fisherman's Bank and the Ridge, 1985-1995. Means and standard deviations are arithmetic for 1985-1987 and kriged for 1988-1995.

Year	Bed	Location (Bank or Ridge)	Estimated spawn date	Number of stations	Egg thickness (mm)			Survey area (km^2)	Egg volume (m^3)
					Mean	SD	CV		
1985	1	B	31 Aug	7	6.710			0.2860	1,920
	2	B	31 Aug	13	0.620			0.4888	304
	3	B	4 Sep	6	0.010			0.2390	3
	4	B	16 Sep	26	20.590			0.2470	5,085
	5	B	16 Sep	6	7.340			0.5595	4,105
	Total	B		58				1.8203	11,417
1986	1	B	3 Sep	29	9.850			1.1000	10,837
1987	1	B	23 Aug	5	6.170			0.1864	1,150
	2	B	26 Aug	22	5.130			0.7955	4,083
	3	B	1 Sep	14	5.960			0.4827	2,878
	4	B	9 Sep	16	6.010			0.6155	3,702
	Total	B		57				2.0800	11,814
1988	1	B	5 Sep	86	1.130	0.550	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	4.370	0.940	0.220	1.2778	5,589
	3	B	3 Sep	96	6.630	1.380	0.210	1.2231	8,103
	4	B	9 Sep	45	9.110	1.560	0.170	0.2583	2,352
	5	B	12 Sep	75	2.290	0.520	0.230	0.5002	1,145
	Total	B		322				3.2594	17,189
1990	1	B	20 Aug						
	2	B	28 Aug	74	2.510	0.730	0.290	1.0816	2,711
	3	B	2 Sep						
	4	B	3 Sep	50	0.880	0.350	0.400	0.4096	360
	5	B	11 Sep	60	4.190	1.150	0.280	0.5376	2,251
	6	B	13 Sep	106	6.080	0.740	0.120	1.2896	7,839
	7	B	16 Sep	20	1.780	0.460	0.260	0.1936	344
	Total	B		310				3.512	13,504
1991	1	B	21 Aug	38	0.301	0.102	0.339	0.4576	138
	2A				0.470	0.246	0.524	0.8520	400
	2B				2.778	0.308	0.111	0.2480	689
	2C				0.429	0.443	1.032	0.0968	42
	2D				0.108	0.581	5.360	0.0924	10
	2E				1.328	0.433	0.326	0.0924	123
	2F				0.209	0.441	2.109	0.1408	29
	2G				0.029	0.674	22.973	0.0968	3
	2	B	25 Aug	110				1.6192	1,296
	3A				0.136	0.033	0.244	0.5084	69

Year	Bed	Location (Bank or Ridge)	Estimated spawn date	Number of stations	Egg thickness (mm)			Survey area (km^2)	Egg volume (m^3)
					Mean	SD	CV		
	3B				0.024	0.059	2.491	0.0968	2
	3C				0.067	0.056	0.836	0.0968	6
	3	B	2 Sep	41				0.7020	78
	4A				0.313	0.074	0.237	0.2400	75
	4B				0.124	0.089	0.719	0.1408	17
	4C				0.240	0.089	0.372	0.1408	34
	4D				0.000			0.0484	0
	4E				0.471	0.138	0.293	0.0484	23
	4	B	5 Sep	24				0.6184	149
	5A				2.612	0.561	0.215	1.4640	3,824
	5B				0.442	1.156	2.613	0.1848	82
	5C				0.774	1.575	2.034	0.1408	109
	5D				1.821	0.715	0.393	0.2288	417
	5	R	13 Sep	126				2.0184	4,431
	Total	B		213				3.3972	1,661
	Total	R		126				2.0184	4,431
	Total	B&R		339				5.4156	6,092
1992	1A				0.695	0.100	0.144	1.4400	1,000
	1B				0.442	0.219	0.496	0.1848	82
	1C				0.168	0.284	1.689	0.0968	16
	1D				0.160	0.227	1.421	0.1848	30
	1	B	25 Aug	71				1.9064	1,128
	2A				4.565	0.478	0.105	1.2400	5,660
	2B				1.526	1.572	1.030	0.0968	148
	2C				1.089	0.799	0.734	0.2688	293
	2	B	29 Aug	71				1.6056	6,101
	3	B	6 Sep	35	6.433	1.545	0.240	0.8736	5,620
	4A				0.726	0.207	0.285	1.2648	918
	4B				0.428	0.391	0.914	0.0968	41
	4	R	10 Sep	38				1.3616	959
	Total	B		177				4.3856	12,849
	Total	R		38				1.3616	959
	Total	B&R		215				5.7472	13,808
1993	1A				0.322	0.103	0.321	0.3360	108
	1B				0.281	0.117	0.415	0.1848	52
	1	B	22 Aug	27				0.5208	160
	2A				0.467	0.257	0.550	0.0968	45
	2B				0.536	0.145	0.270	0.6200	332
	2C				0.384	0.221	0.575	0.1364	52
	2	B	25 Aug	43				0.8532	430
	3A				2.137	0.455	0.213	1.1984	2,559
	3B				0.555	1.220	2.198	0.0736	41
	3	B	4 Sep	60				1.2720	2,601
	4A				1.429	0.761	0.532	0.0968	138
	4B				3.638	0.270	0.074	1.1480	4,176
	4C				1.017	0.609	0.599	0.1600	163
	4D				0.806	0.380	0.472	0.5084	410

Year	Bed	Location (Bank or Ridge)	Estimated spawn date	Number of stations	Egg thickness (mm)			Survey area (km^2)	Egg volume (m^3)
					Mean	SD	CV		
	4E				0.769	0.665	0.864	0.1364	105
	4F				0.600	0.778	1.298	0.0968	58
	4	B	5 Sep	121				2.1464	5,051
	5A				0.693	0.222	0.321	0.1848	128
	5B				1.152	0.126	0.109	0.8400	968
	5C				0.681	0.379	0.556	0.0484	33
	5D				0.535	0.298	0.557	0.0968	52
	5E				0.806	0.254	0.315	0.1410	114
	5	R	20 Sep	77				1.3110	1,294
	Total	B		251				4.7924	8,241
	Total	R		77				1.3110	1,294
	Total	B&R		328				6.1034	9,535
1994	1A				0.170	0.221	1.296	0.0968	16
	1B				0.337	0.077	0.228	0.2688	91
	1	B	21 Aug	23				0.3656	107
	2A				0.464	0.654	1.407	0.1764	82
	2B				0.246	0.947	3.852	0.0968	24
	2C				1.913	0.302	0.158	0.9600	1,836
	2D				1.612	0.782	0.485	0.1408	227
	2E				0.284	0.578	2.033	0.2520	72
	2F				0.239	0.677	2.835	0.1364	33
	2G				2.213	0.345	0.156	1.0400	2,301
	2H				0.139	0.593	4.274	0.1848	26
	2	B	28 Aug	83				2.9872	4,600
	3	B	5 Sep	21	1.887	0.738	0.391	0.1936	365
	4A				0.638	0.617	0.966	0.0968	62
	4B				1.707	0.293	0.172	0.6120	1,045
	4C				1.000	0.283	0.282	1.2896	1,290
	4D				0.589	0.620	1.053	0.0968	57
	4	B	8 Sep	54				2.0952	2,454
	5A				3.352	0.461	0.138	0.6560	2,199
	5B				1.134	1.040	0.917	0.0968	110
	5C				0.576	1.020	1.771	0.1364	79
	5D				1.173	0.755	0.643	0.2480	291
	5E				0.406	0.796	1.959	0.1848	75
	5F				0.759	1.062	1.400	0.0924	70
	5	B	11 Sep	75				1.4144	2,823
	6A				2.109	0.638	0.302	0.3444	726
	6B				2.099	1.910	0.910	0.0484	102
	6C				3.140	0.878	0.280	0.1408	442
	6	B	11 Sep	31				0.5336	1,270
	Total	B		287				7.5896	11,619
	Total	R		0				0.0000	0
	Total	B&R		287				7.5896	11,619
1995	1A				0.391	0.081	0.285	0.1764	69
	1B				0.468	0.104	0.322	0.0924	43
	1C				0.556	0.062	0.249	0.3444	192

Year	Bed	Location (Bank or Ridge)	Estimated spawn date	Number of stations	Egg thickness (mm)			Survey area (km^2)	Egg volume (m^3)
					Mean	SD	CV		
	1D				0.388	0.139	0.373	0.0484	19
	1	B	31 Aug	40				0.6616	323
	2A				1.748	0.311	0.558	0.0968	169
	2B				1.497	0.156	0.394	0.0968	623
	2C				1.048	0.281	0.530	0.416	148
	2	B	5 Sep	48				0.6096	939
	Total	B		88				1.2712	1,262

Table 5
Egg volume and progenitor biomass estimates for herring spawning on Fisherman's Bank and the Ridge, 1985-1995.

Year	Fisherman's Bank			The Ridge			Both areas		
	Volume (m^3)	Weighted mean of CVs*	Progen. mass** (tons)	Volume (m^3)	Weighted mean of CVs	Progen. mass (tons)	Volume (m^3)	Weighted mean of CVs	Progen. mass (tons)
1985	11,417		67,977	No data					
1986	10,837		64,523	No data					
1987	11,814		70,341	No data					
1988	No data			No data					
1989	17,189	0.21	102,343	No data					
1990	13,504	0.19	80,403	No data					
1991	1,661	0.41	9,887	4,431	0.32	26,383	6,092	0.34	36,270
1992	12,849	0.20	76,500	959 ***	0.31	5,710	13,808	0.21	82,210
1993	8,241	0.20	49,069	1,294	0.18	7,705	9,535	0.20	56,773
1994	11,619	0.31	69,180	0		0	11,619		69,180
1995	1,262	0.40	7,514	No data					
Mean	9,127		59,774			9,949	10,263		61,108

* $\frac{\Sigma(\text{CV of block estimate} \times \text{block estimate})}{\text{Total estimate}}$

** Based on 5.954 tons of progenitor biomass required to produce 1 m^3 of spawn (Table 3)

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

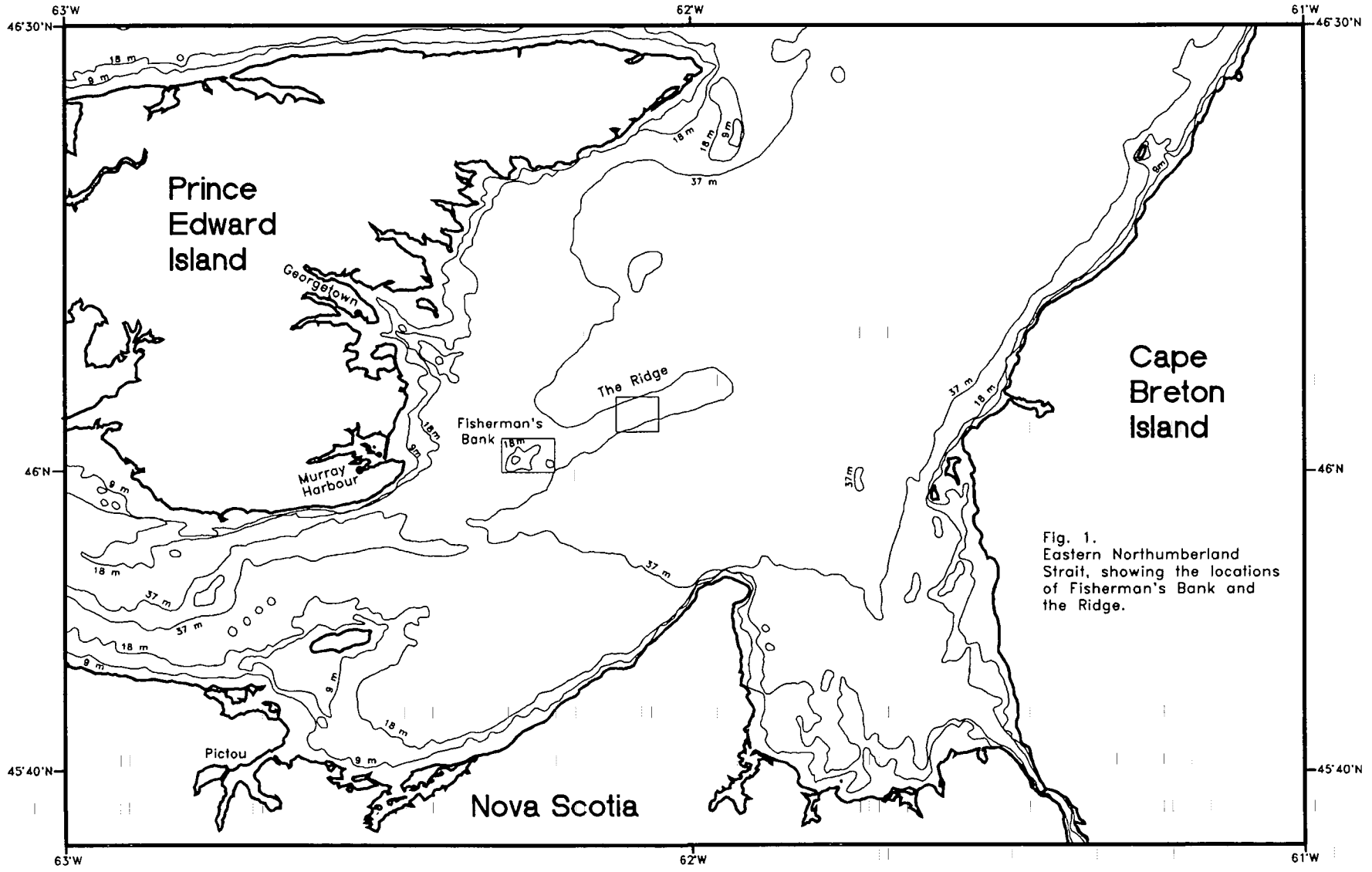
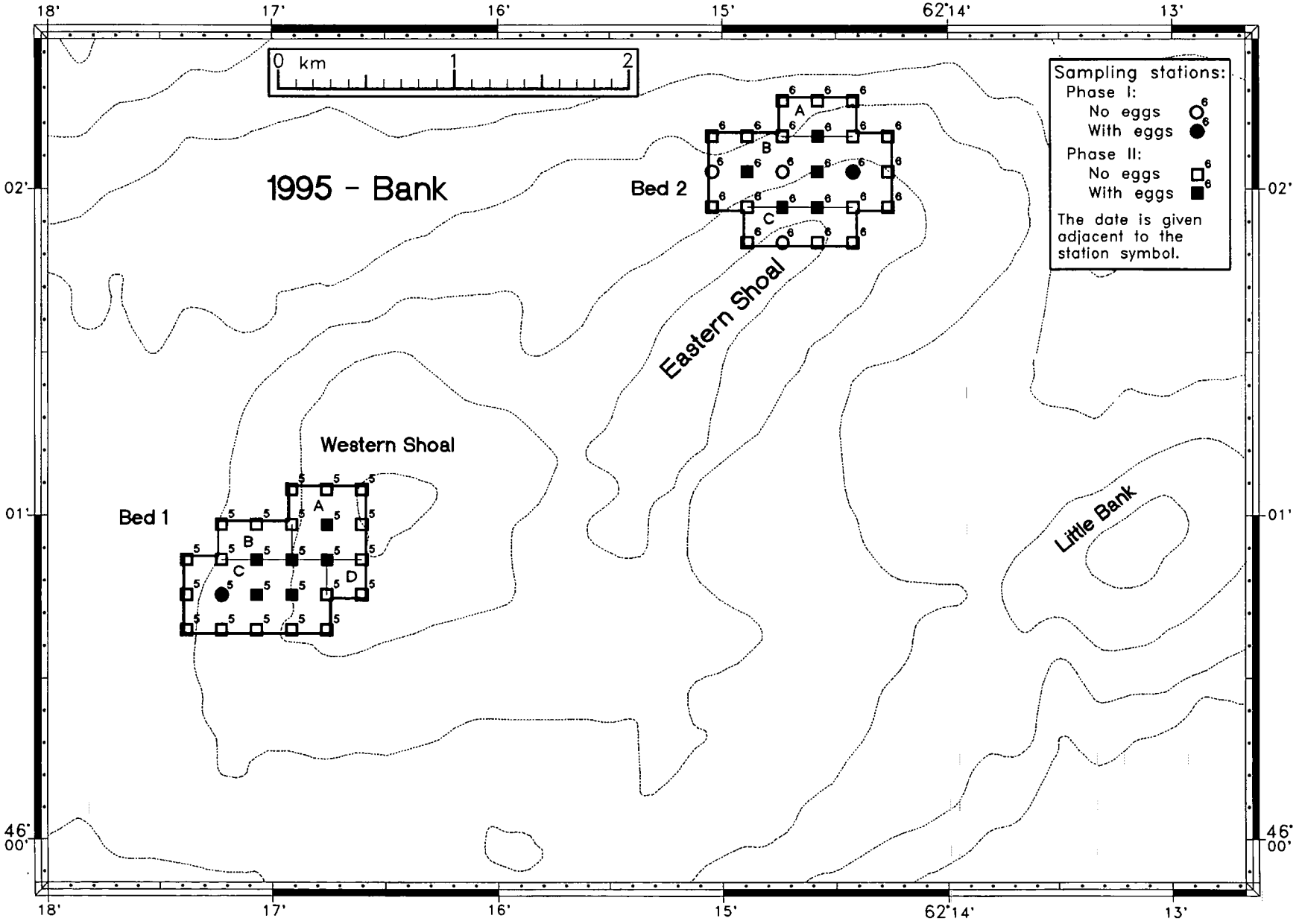


Fig. 1.
Eastern Northumberland Strait, showing the locations of Fisherman's Bank and the Ridge.

Fig. 2
Phase I and II surveys of herring spawning beds at Fisherman's Bank, 5-6 September 1995.



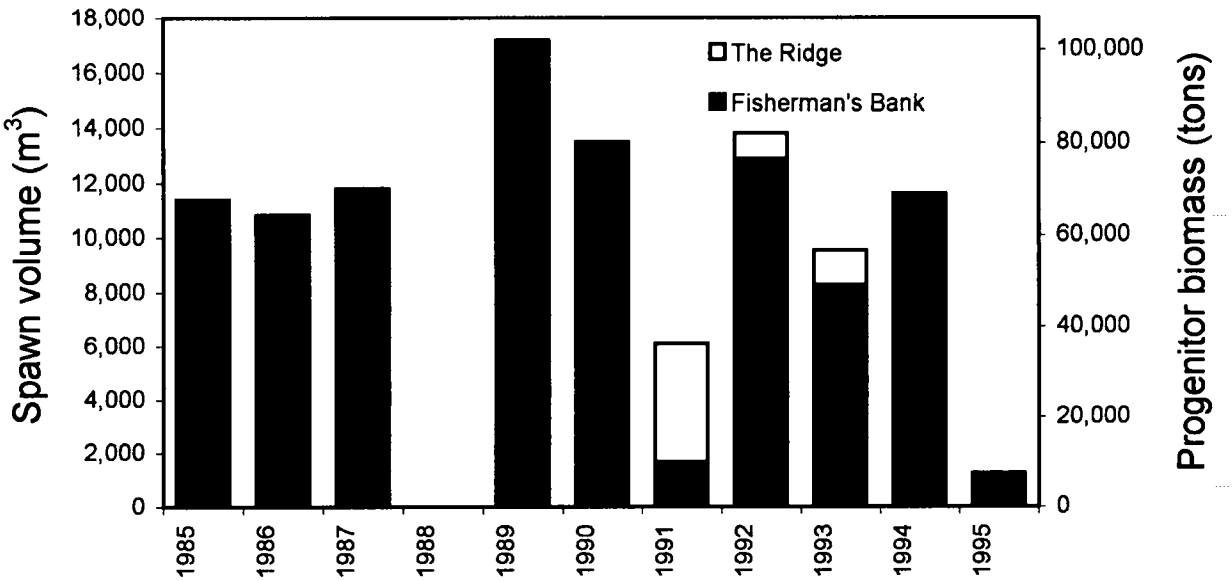


Fig. 3
Volume of deposited herring spawn and progenitor biomass at Fisherman's Bank, 1985-1987 and 1989-1995, and the Ridge, 1991-1994.