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Fecundities of Atlantic Herring Spawning Populations from Coastal Maine and Jeffreys Ledge

by

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Abstract

Length-specific fecundities were estimated for mature female herring (*Clupea harengus harengus*) obtained from samples of commercial catches made on four presumed spawning grounds along the Maine coast during 1982. No significant differences in fecundity between groups were found, indicating that discrete spawning groups in the Gulf of Maine stock could not be differentiated on the basis of fecundity. The least significant differences existed between the two groups which were separated by the greatest distance. Similar results were obtained from an analysis of 1969 fecundity data from the same areas. Predicted fecundities-at-length for 1982 were higher than in 1969 and similar to published 1980 estimates whereas the 1969 data were similar to published 1963/64 estimates, supporting the hypothesis that fecundity increases as spawning stock size declines.

Introduction

This report presents the results of fecundity analyses carried out on female Atlantic herring collected from three locations along the coast of Maine and from Jeffreys Ledge during a three month period in the summer and fall of 1982. The major objective of this study was to determine if individual spawning groups of herring in the Gulf of Maine could be differentiated on the basis of fecundity. A secondary objective was to compare the 1982 results with fecundity estimates for the Gulf of Maine stock made in the 1960s when stock size was higher.

Methods

Samples of mature (ICNAF stages IV and V) female herring were obtained from commercial catches made from Hamilton Cove in eastern Maine, between Matinicus Rock and Isle au Haut, near Pumpkin Ledge (off Boothbay Harbor) and from the northern end of Jeffreys Ledge (Fig. 1). All four of these areas have been identified as spawning grounds based on the collection of stage VI adults (Boyar et al. 1973; Jean Chenoweth, Maine Department of Marine Resources, personal communication). In addition, Graham et al. (1973; 1982) have reported discrete aggregations of larvae in the vicinity of Jeffreys Ledge, Boothbay Harbor and the Cutler Harbor/Machias Bay area of eastern Maine (but not near Matinicus Rock). Samples were taken from weir catches made in eastern Maine and from purse-seine catches in the other three locations. Samples from eastern Maine were obtained on August 18 and September 8, from Matinicus/Isle au Haut between August 4-16, from Pumpkin Ledge August 24-September 6 and from Jeffreys Ledge September 9-October 25.

Length-specific fecundities were estimated by a gravimetric technique for 237 fish. Length was measured as total length to the nearest millimeter. Fecundity/length relationships were derived for each of the four areas as a power function ($F = aL^b$) and a linear regression function ($F = a + bL$). Straight lines were fit by the method of least squares to log transformed and untransformed data and analysis of variance techniques were used to test the goodness of fit of each model to data from individual spawning populations. Differences in fecundity between areas were tested using covariance analysis; in this procedure mean fecundities were compared after adjusting for differences in length between areas. Predicted fecundities at length for all areas combined were estimated from the linear regression of fecundity versus length (untransformed data).

In addition to the data collected during this study, unpublished length-specific fecundity estimates obtained by F.E. Perkins (U.S. Bureau of Commercial Fisheries, Boothbay Harbor) for 216 adult herring collected from Campobello Island (eastern Maine), Matinicus and Jeffreys Ledge in 1969 were analyzed using the same techniques that were employed with the 1982 data. Perkins' fecundity estimates were based on egg counts made using an automatic counting device.

Results

Both models fit the 1982 data well (Table 1), although the curvilinear model produced a slightly better fit than the linear model. Since the Matinicus/Isle au Haut and Pumpkin Ledge samples had very similar parameter estimates (Table 1) and could not be distinguised from each other (Table 2), they were combined into a single mid-coastal group for all subsequent analyses. There were no significant ($\alpha = 0.05$) differences in fecundity between areas, either in terms of slopes or intercepts (Table 3). Pairwise comparisons revealed that the two most distant spawning populations (eastern Maine and Jeffreys Ledge) were considerably more homogeneous than the adjacent populations. All site-specific 1982 data (Fig. 2) were therefore combined (Fig. 3). Predicted fecundities ranged from 36,850-185,170 eggs per 26-34 cm female (Table 4); confidence intervals ranged from ±4400-5970 eggs per female at large and small sizes to ±2500 eggs per female at intermediate sizes. A single large fish (38 cm) which was not included in the analyses contained an estimated 301,000 eggs.

Both the exponential and linear models provided acceptable fits to the 1969 data even though the correlation between fecundity and length for Jeffreys Ledge was low (Table 5), because of the smaller sample size, the narrow range of sizes which was examined and the greater variability in relative fecundities reported from this location (Fig. 4). There were significant differences between groups in terms of the intercepts of the log fecundity vs. log length model, but not for slope (Table 6).

Discussion

The results of this study did not support the hypothesis that separate spawning groups of herring exist within the Gulf of Maine stock. Clearly, if this were the case, a different management approach would be called for in order to avoid the depletion and possible elimination of individual spawning groups which could result from fishing on mixed aggregations of fish. More information is needed, however, before the hypothesis is completely rejected. Since there are no consistent genetic differences between fall-spawning populations in the northwest Atlantic (Kornfield et al. 1982), the problem of detecting differences in phenotypic characteristics on a small geographic scale is not trivial. If discrete spawning populations do exist in the Gulf of Maine, they could probably only be differentiated on the basis of a combination of characteristics. Clearly, fecundity is not one of them. The same conclusion was reached by Messieh (1976) who compared the fecundity of fall spawners off southwest Nova Scotia and by Nagasaki (1958) who compared adjacent populations of Pacific herring in British Columbia. Baxter (1959), however, did find differences between fall spawners in the northern and southern North Sea and between spawning populations in Norway and the Firth of Clyde (west coast of Scotland).

Fecundities of herring from adjacent locations in 1969 and 1982 were more distinct than fecundities from eastern Maine and Jeffreys Ledge, two spawning areas at opposite "ends" of the Maine coast located approximately 100 km from each other. Spawning in eastern Maine is earlier than on Jeffreys Ledge (ripe and spent fish were caught in Hamilton Cove on September 8 and on Jeffreys Ledge on September 23) and produces larvae which are dispersed westward along the coast, apparently at least as far as the Sheepscot estuary near Boothbay Harbor (Graham 1982; Graham et al. 1982). No ripe or spent fish were sampled in either of the two mid-coastal locations in 1982 during the period August 4-September 6. Fishing in mid-coastal Maine ceased after September 8 when the fleet moved westward to Jeffreys Ledge.

Length-specific fecundities have been reported for the Gulf of Maine stock in two previous studies: Perkins and Anthony (1969) reported fecundities for 25-33 cm females for 1963/64 as did Morse and Morris (1981) for 25-36 cm fish collected largely from the Isles of Shoals near Jeffreys Ledge in 1980. Predicted fecundities in the latter study were very similar to the 1982 results, but were a little lower for 29-33 cm females and higher for 26-27 cm females (Table 7). In the earlier study, fecundity estimates were considerably less than in 1982 and were more similar to the 1969 results.

The lower size-specific fecundities reported in 1969 prevailed during a time when estimated stock size in the Gulf of Maine was about twice that which has been estimated for the period 1974-1981 (Fogarty and Anthony 1982). Analysis of the 1969 and 1982 fecundity data therefore supports the contention that fecundity increases as spawning stock size declines, a relationship suggested by historical data from Georges Bank (Anthony 1981). Messieh and Sinclair (1981) were unable to demonstrate density-dependent changes in fecundity for Nova Scotian herring, but they were handicapped by insufficient observations for three of the four years examined and by a narrow range of estimated stock sizes.

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Table 1: Statistics of the fecundity vs. body length relations $F = aL^b$ and $F = a + bL$ of Gulf of Maine herring by area in 1982.

			$F = aL^b$		
Group	n	a	b	r	F
Eastern Maine	80	1.479×10^{-10}	5.983	0.914	395.8
Matinicus/ Isle au Haut	36	3.206×10^{-8}	5.054	0.925	200.1
Pumpkin Ledge	41	2.421×10^{-8}	5.101	0.851	102.7
Mid-coastal Maine	77	2.729×10^{-8}	5.081	0.888	280.1
Jeffreys Ledge	80	1.127×10^{-10}	6.032	0.934	531.6
			$F = a + bL$		
	n	a	b	r	F
Eastern Maine	80	-404206	1707.0	0.913	392.8
Mid-coastal Maine	77	-463632	1920.1	0.886	272.7
Jeffreys Ledge	80	-465273	1916.3	0.915	401.3

All P values <0.001

Table 2: Results of analysis of covariance for Matinicus/Isle au Haut and Pumpkin Ledge log fecundity vs. log length relations, 1982.

Comparison	source of variation	df	F	P
Matinicus vs. Pumpkin	between groups (intercepts)	1	0.04	0.840
	between slopes	1	0.01	0.939

Table 3: Results of analysis of covariance for log fecundity vs. log length relations of three areas in the Gulf of Maine, 1982.

Comparison	source of variation	df	F	P
All areas	between groups (intercepts)	2	1.28	0.281
	between slopes	2	2.74	0.067
E. Maine vs. mid-coastal	between groups (int.)	1	2.86	0.093
	between slopes	1	4.00	0.047
E. Maine vs. Jeffreys	between groups (int.)	1	0.06	0.811
	between slopes	1	0.01	0.905
Mid-coastal vs. Jeffreys	between groups (int.)	1	1.42	0.235
	between slopes	1	5.64	0.019

Table 4: Predicted length-specific fecundities of Gulf of Maine herring, 1982 (all areas combined).

Body length (mm)	Fecundity	95% Confidence limits
260	36854	31881-41827
270	55393	51255-59531
280	73933	70542-77324
290	92472	89669-95275
300	111011	108521-113501
310	129551	126995-132105
320	148089	145117-151062
330	166629	163006-170253
340	185168	180763-189574

Table 5: Statistics of the fecundity vs. body length relations $F = aL^b$ and $F = a + bL$ of Gulf of Maine herring by area in 1969.

			$F = aL^b$			
Group	n	a	b	r	F	P
Campobello	68	1.070×10^{-5}	4.000	0.755	87.8	<0.001
Matinicus	102	6.000×10^{-7}	4.530	0.812	193.1	<0.001
Jeffreys Ledge	46	5.675×10^{-4}	3.313	0.439	10.5	0.002

			$F = a + bL$			
	n	a	b	r	F	P
Campobello	68	-277919	1226.2	0.739	79.5	<0.001
Matinicus	102	-404340	1662.2	0.818	201.8	<0.001
Jeffreys Ledge	46	-243686	1122.5	0.428	9.8	0.003

Table 6: Results of analysis of covariance for log fecundity vs. log length relations of three areas in the Gulf of Maine, 1969.

Comparison	source of variation	df	F	P
All areas	between groups (intercepts)	2	10.10	<0.001
	between slopes	2	1.30	0.274
Campobello vs. Matinicus	between groups (int.)	1	15.91	<0.001
	between slopes		NS	
Campobello vs. Jeffreys	between groups (int.)	1	0.01	0.923
	between slopes		NS	
Matinicus vs. Jeffreys	between groups (int.)	1	12.89	0.001
	between slopes		NS	

Table 7: Predicted fecundities by length (x 10^3) for Gulf of Maine herring in 1963/64, 1969, 1980 and 1982.

Length (cm)	1963-64[1]	1969[3]	1980[2]	1982[3]
25	18	21	44	
26	33	35	52	37
27	49	49	63	55
28	64	64	75	74
29	79	78	88	92
30	95	92	104	111
31	110	106	121	130
32	126	120	141	148
33	141	135	163	167
34		149	188	185
35		163	216	
36		177	246	

Sources: [1]Perkins and Anthony (1969)

[2]Morse and Morris (1981)

[3]This study

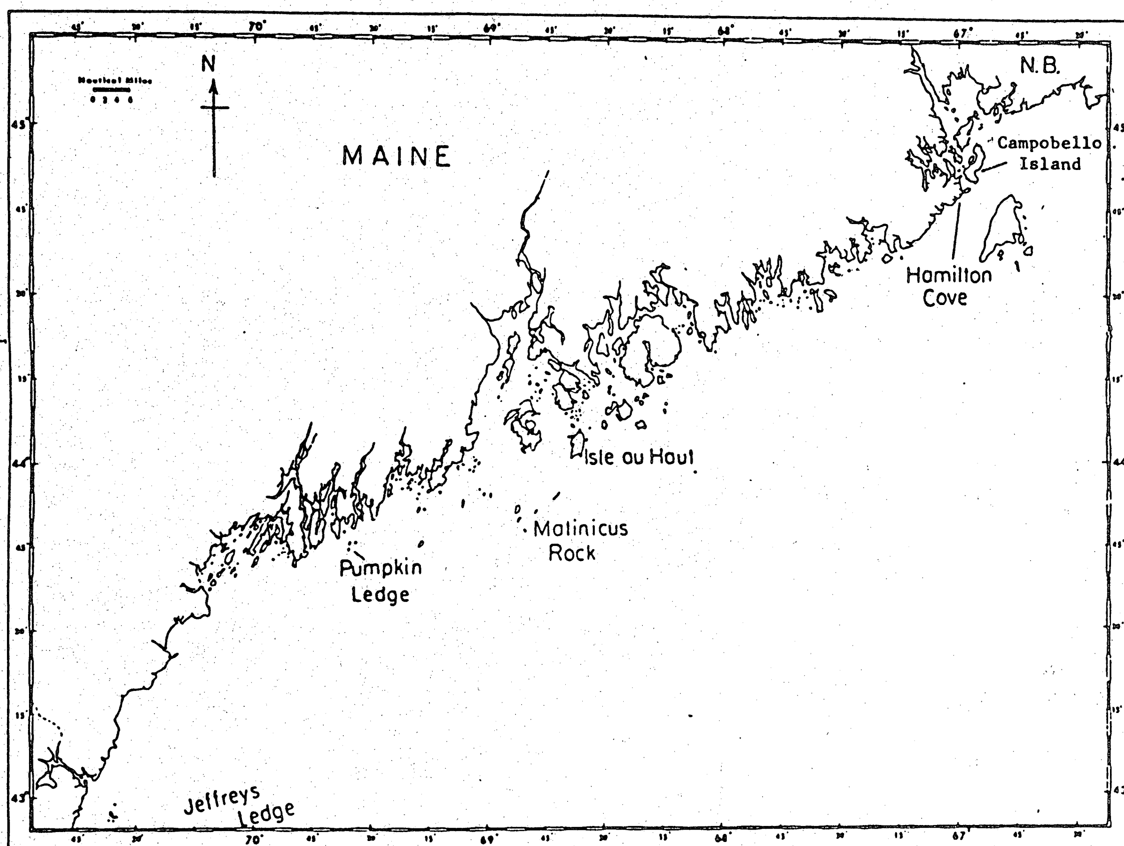

Figure 1: Sampling locations on the Maine coast, 1969 and 1982.

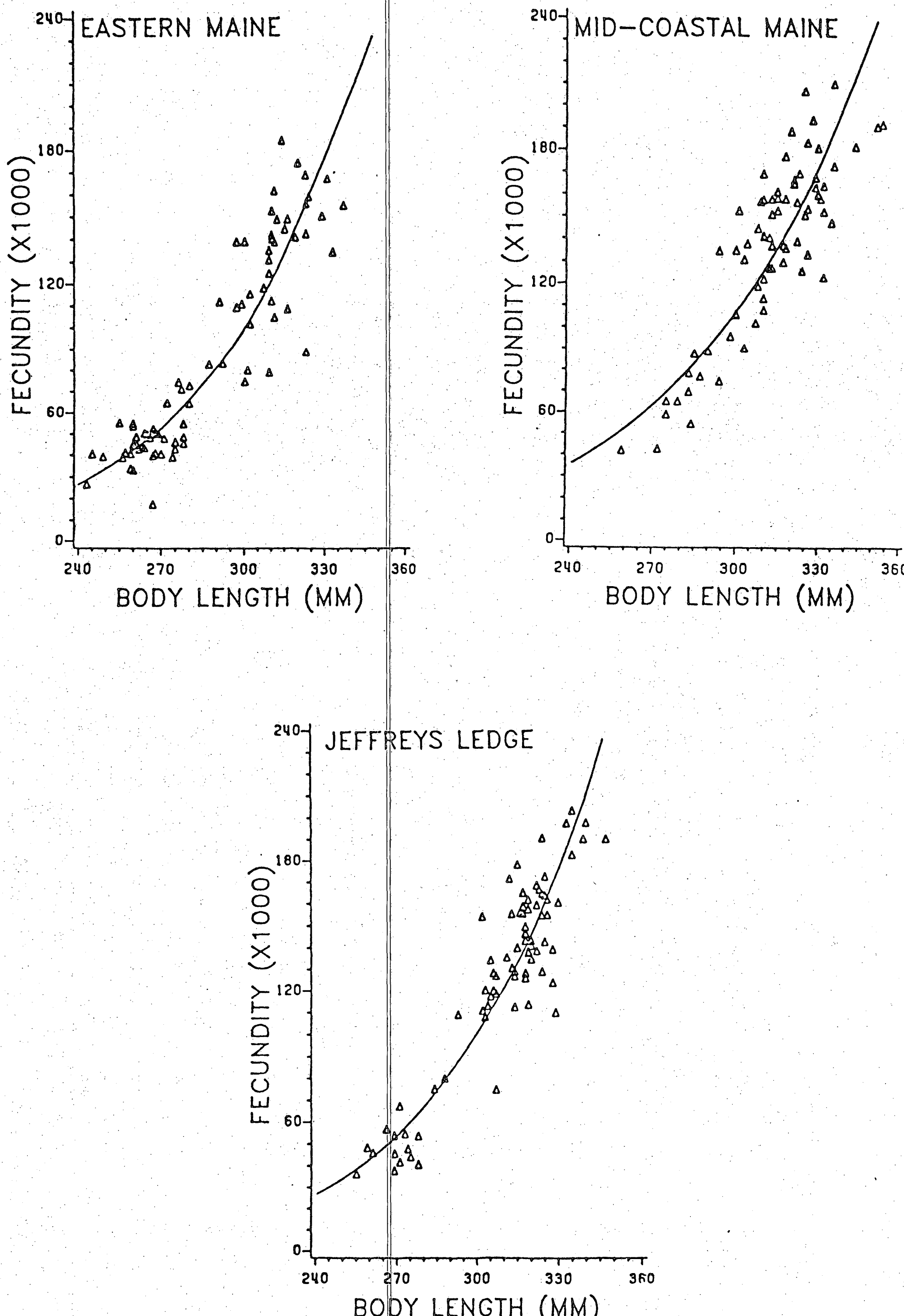

Figure 2: Fecundity versus length relationships for three spawning groups sampled in the Gulf of Maine in 1982.

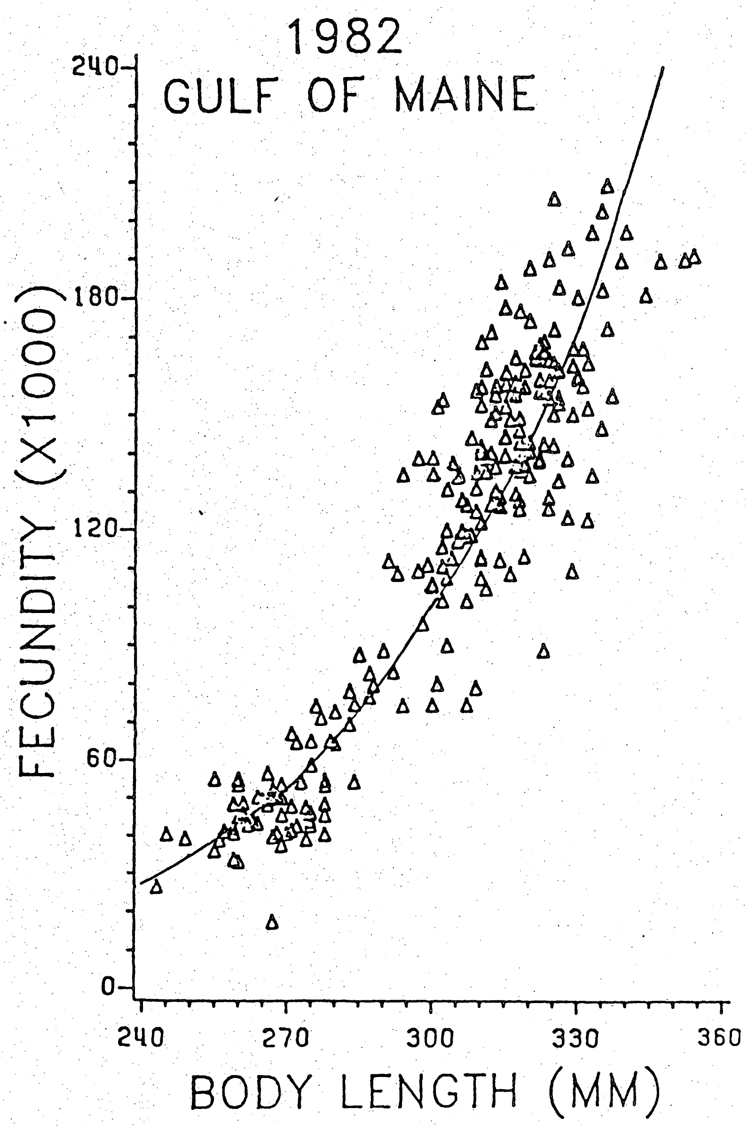

Figure 3: Fecundity versus length relationship for all areas in the Gulf of Maine, 1982.

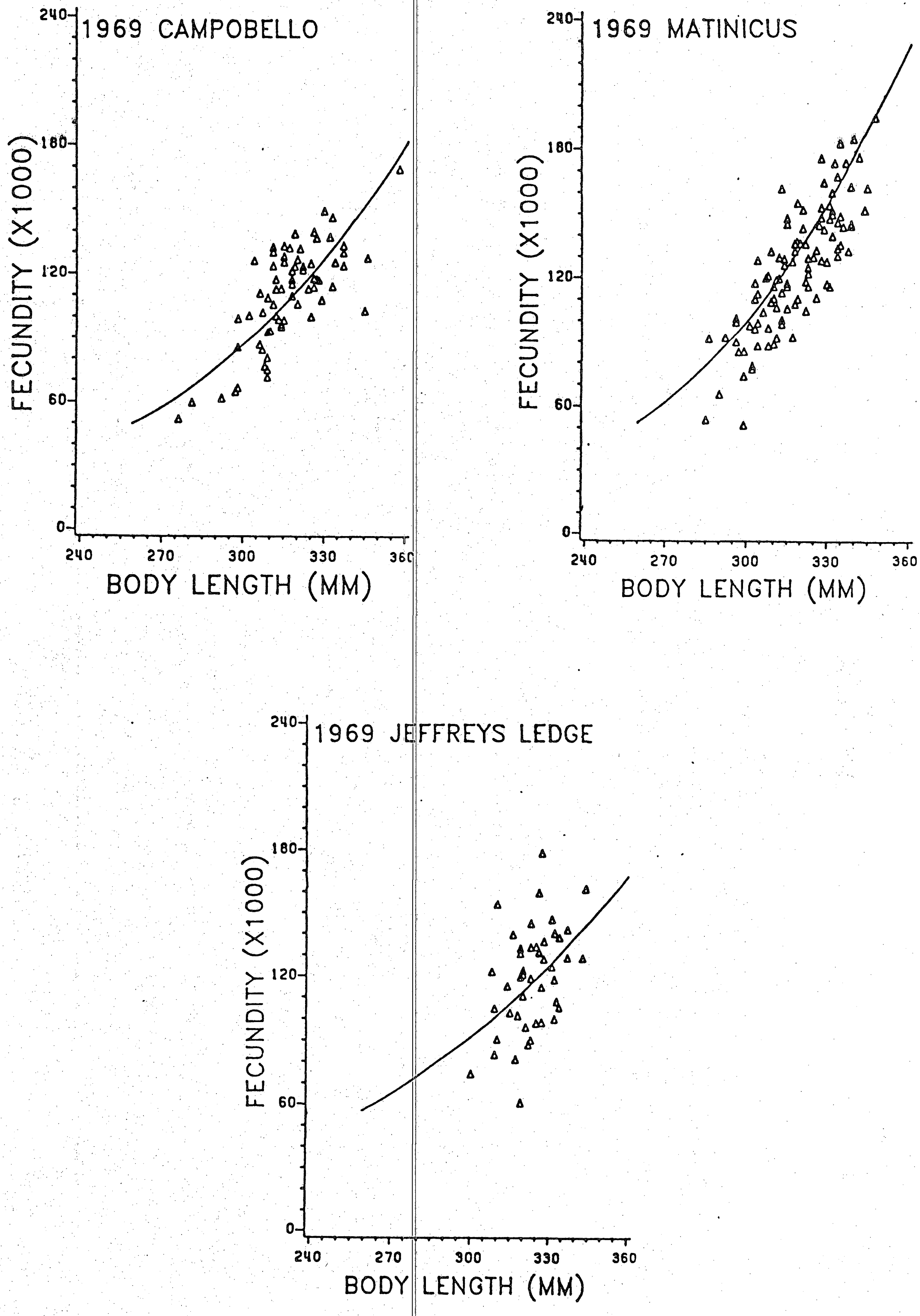

Figure 4: Fecundity versus length relationships for three spawning groups sampled in the Gulf of Maine in 1969.