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FECUNDITY OF THE AMERICAN LOBSTER, *HOMARUS AMERICANUS*, IN NEWFOUNDLAND WATERS

In lobster (genus *Homarus*) fisheries generally, current minimum legal size limits are below the size at 50% female maturity and fishing mortality rates are very high (Anonymous 1979). Under such conditions, widespread recruitment overfishing appears to be a distinct possibility. Conventional yield per recruit assessment models are not totally adequate when dealing with lobsters and this has led to the development of models which are much more species oriented (Caddy 1977, 1979; Ennis and Akenhead 1978). A feature of these models which resulted from concern with recruitment overfishing is provision for assessing the effect on population fecundity of changes in size limit and fishing mortality. In addition to size-maturity information, such assessments require data on fecundity.

Unfortunately, the general applicability of size-fecundity relationships for the American lobster, *Homarus americanus*, which are available from the literature, is suspect. Saila et al. (1969) concluded that the methodology used by Herrick (1911) resulted in quite substantial overestimates of egg numbers. The size-fecundity relationship Saila et al. (1969) presented was based on samples obtained from three widely separated areas; however, Squires (1970) and Squires et al. (1974) suggested that size-fecundity relationships for American lobsters in different areas could be quite different. Squires' (1970) methodology was similar to that of Herrick but he found that his estimates varied from actual counts by <2%, an error factor comparable with that reported by Saila et al. (1969) and Perkins (1971) using electronic counters. Aiken and Waddy (1980) suggested that standardized egg counts from different areas would clarify the question of geographic variation in American lobster fecundity and concluded that Herrick's estimates should not be dismissed until the results of these or other, more explicit studies are available.

This paper presents new fecundity data for a Newfoundland area as a contribution to the literature on the subject and provides comparisons with published size-fecundity relationships.

Materials and Methods

Ovigerous females were included in samples ob-

tained during spring (near the end of the incubation period) trap fishing in the area of Arnold's Cove, Placentia Bay, on the southeast coast of Newfoundland in 1969, and in the areas of Ship Harbour and Paradise in Placentia Bay in 1970 (Figure 1). Portions of the samples (up to 50 American lobsters) were usually held in floating wooden boxes (about 100-lb capacity) for several days before being subjected to detailed biological examination. Carapace lengths (millimeters) were recorded and the abdomens of ovigerous specimens with attached egg masses were preserved individually in 10% Formalin.¹ Loss of eggs over the holding period cannot be discounted, but it is felt that such losses were minimal.

Eggs were removed from the pleopods, washed on a screen of fine-meshed plankton netting to remove the larger pieces of connective tissue and other material, and then left to soak in freshwater overnight. After soaking, the eggs were spread

¹Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

thinly over very shallow pans to dry at room temperature until they were quite hard (usually after about 24 h) and could withstand being rubbed over a fine-meshed screen to remove the remaining connective tissue. After drying and final cleaning, the weight of the egg sample was obtained (to the nearest 0.0001 g). A subsample, representing approximately 1/30 of the whole sample (as determined by weighing), was weighed and the eggs counted manually. The number of eggs in the whole sample was then calculated.

To determine the error associated with this method, total numbers for 11 samples were determined by actual counts for comparison with the estimated total numbers for the same samples. The error ranged from -3.6% to 0.04% and for the 11 sets of counts totaled the error was 0.54%.

Carapace length and fecundity data were log (base 10) transformed and the linearized version of the power curve was fitted to each set. The linear relationships thus derived were compared by analysis of covariance.

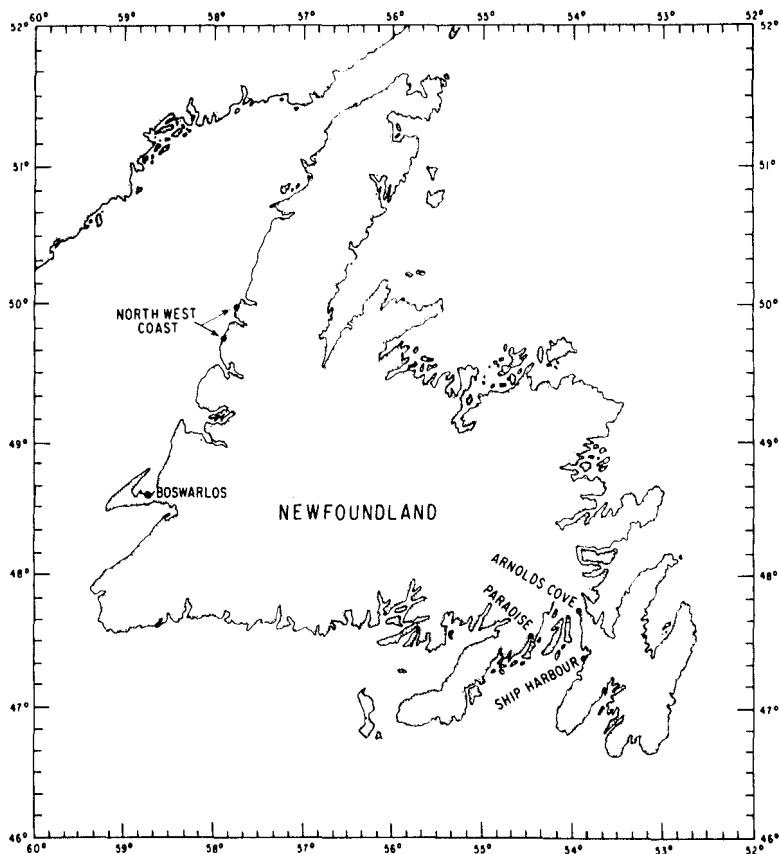


FIGURE 1.—Map of Newfoundland showing places mentioned in the text.

Results and Discussion

Curvilinear size-fecundity relationships derived from log-log (base 10) regression analysis for spring-caught (April-June) samples are presented for three areas in Placentia Bay, along with the same relationships obtained from reanalysis of the data presented by Squires (1970) and Squires et al. (1974) for two Newfoundland west coast areas (Figure 2, Table 1). The methodology of Squires (1970) and Squires et al. (1974) was similar to that used here except that the estimates were determined volumetrically instead of by weighing. These estimates varied from actual counts by <2% which is within the range of error determined in this study. For this reason the following statistical comparisons between the Placentia Bay and west coast samples are considered valid.

An F_{MAX} test on the log-transformed data demonstrated significantly different ($P < 0.01$) residual variances among the five samples. Various combinations of the log-log relationships were compared by analysis of covariance. In all comparisons between relationships for Placentia Bay and the comparison between the two relationships for the west coast, residual variances were similar. However, in all comparisons between one of the Placentia Bay and one of the west coast relationships, residual variances were significantly different (Table 2). Two of the four sets of relationships

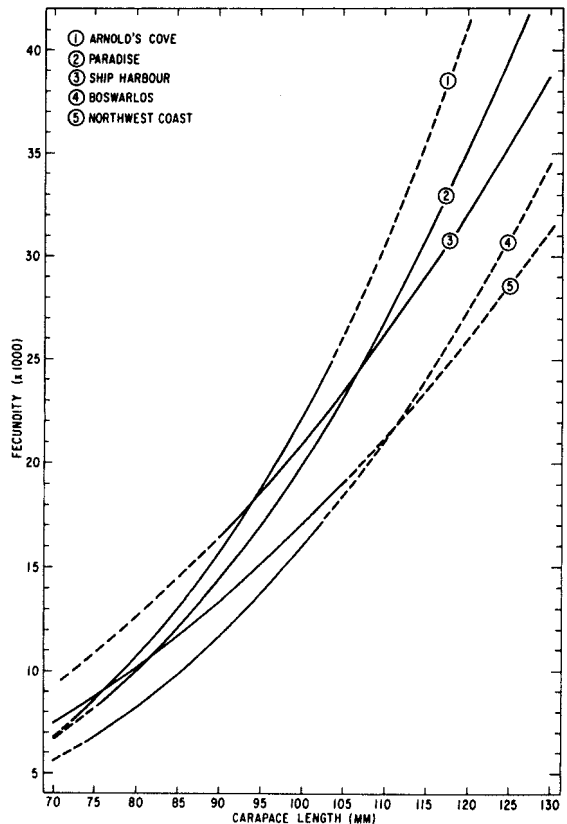


FIGURE 2.—Carapace length-fecundity relationships for American lobsters from three areas in Placentia Bay, Newfoundland and two areas on the west coast of Newfoundland. Dashed lines indicate extrapolations beyond the data.

TABLE 1.—Regression equations from which the curvilinear relationships shown in Figure 1 were derived.

Sample	N	Carapace length range (mm)	Regression equation	r
Arnold's Cove	43	72-104	$\log_{10} F = 3.3471 \log_{10} CL - 2.3437$	0.88
Paradise	72	75-139	$\log_{10} F = 3.0984 \log_{10} CL - 1.8963$.94
Ship Harbour	68	89-159	$\log_{10} F = 2.3188 \log_{10} CL - 0.3117$.89
Boswarlos	75	74-103	$\log_{10} F = 2.9387 \log_{10} CL - 1.6747$.58
Northwest coast	63	70-107	$\log_{10} F = 2.3161 \log_{10} CL - 0.3998$.60

TABLE 2.—Results of analyses of covariance of size-fecundity relationships presented in Figure 1.

Relationships compared	Mean squares		Slopes		Means	
	F	P	F	P	F	P
Arnold's Cove vs. Ship Hr.	1.29	>0.20	9.44	<0.01		
Arnold's Cove vs. Paradise	1.27	>.20	.57	.542	6.29	0.013
Paradise vs. Ship Hr.	1.02	>.50	15.86	<.001		
Arnold's Cove vs. Boswarlos	3.08	<.001				
Arnold's Cove vs. NW coast	3.48	<.001				
Boswarlos vs. NW coast	1.13	>.50	.98	.674	15.08	<.0001
Paradise vs. Boswarlos	2.42	<.001				
Paradise vs. NW coast	2.73	<.001				
Ship Hr. vs. NW coast	2.69	<.001				
Ship Hr. vs. Boswarlos	2.38	<.001				

with similar residual variances had significantly different slopes, the other two had similar slopes but significantly different means. There was wide variation in fecundity at size and the samples differed in size composition (Table 3). Significant differences in these relationships may result in large part from differences in sample size and size composition.

Samples with at least six specimens in the same 5 mm size group were compared by analysis of variance. There is some size-related variation in fecundity within each 5 mm size group. This could confound a comparison if, in the samples being compared, there is clustering of specimens at opposite ends of the size range. Upon examination it was found that for each sample compared in Table 4 the specimens were fairly well distributed throughout the 5 mm size range and it is assumed that size-related variation does not invalidate

TABLE 3.—Summary of fecundity data on which relationships shown in Figure 1 are based.

Carapace length	Arnold's Cove			Paradise			Ship Harbour			Boswarlos			Northwest coast		
	N	\bar{X}	Range	N	\bar{X}	Range	N	\bar{X}	Range	N	\bar{X}	Range	N	\bar{X}	Range
66-70													1	4,700	
71-75	3	9,096	8,293-10,115	1	6,756					4	8,000	7,000-9,300	4	10,075	9,100-11,500
76-80	4	9,375	7,299-11,423	12	9,716	7,727-12,535				37	8,178	4,600-11,800	14	10,236	6,800-15,100
81-85	12	11,821	9,894-13,479	16	11,391	7,112-15,704				21	8,414	3,500-12,800	21	11,214	6,700-16,100
86-90	11	14,393	9,836-19,909	9	13,156	10,245-16,992	1	13,773		8	10,850	7,800-15,300	8	13,887	9,400-18,800
91-95	8	18,085	15,833-20,858	8	16,445	11,248-20,767	6	17,348	12,703-22,555	3	13,667	13,000-14,000	7	13,500	6,900-22,100
96-100	3	21,432	16,414-29,888	8	19,697	14,304-24,421	4	20,291	12,926-24,875	1	19,200		5	20,240	16,700-23,900
101-105	2	23,379	22,535-24,223	4	26,213	24,477-27,530	4	22,544	21,351-25,216	1	22,800		2	12,500	10,700-14,300
106-110				3	24,920	20,477-30,099	5	26,266	22,548-28,878				1	26,000	
111-115				3	29,462	25,516-33,660	6	32,559	27,894-36,896						
116-120				2	38,536	34,621-42,450	12	32,247	24,135-43,116						
121-125				2	39,778	32,887-46,669	6	32,018	19,915-38,601						
126-130				1	36,337		4	40,794	34,078-45,443						
131-135				2	42,591	41,645-43,537	6	43,467	37,882-49,681						
136-140				1	42,837		5	46,038	40,638-55,937						
141-145							4	44,511	36,395-57,457						
146-150							2	47,904	47,716-48,092						
151-155							2	56,986	52,399-61,573						
156-160							1	56,995							

these comparisons. All comparisons between Placentia Bay samples showed no significant differences (Table 4). For the comparisons between the two west coast samples and between samples from each of the two areas, there were significant differences for some size groups but not for others. The relationships shown in Figure 2 indicate that American lobsters in Placentia Bay are more fecund than those on the west coast. This observation is supported by the analysis of covariance and to a lesser extent by the analysis of variance.

Data for the three Placentia Bay areas were combined as were data for the two west coast areas. The curvilinear relationships derived from log-log regression analysis were plotted with those available from the literature for other areas (Figure 3). Substantial differences in size-fecundity relationships between some of these areas are apparent.

Perkins (1971) reported substantial egg loss during incubation (36% between October and June) for American lobsters from the offshore canyon areas of the northeast United States. This should

not be a significant factor in the above comparisons, however, since in all cases samples were ob-

TABLE 4.—Results of analyses of variance of fecundity data for different size groups from the various samples.

Samples compared	Size groups (mm)			
	76-80	81-85	86-90	91-95
Arnold's Cove vs. Paradise	—	NSD	NSD	NSD
Arnold's Cove vs. Ship Hr.	—	—	—	NSD
Paradise vs. Ship Hr.	—	—	—	NSD
Arnold's Cove vs. Boswarlos	—	**	*	—
Arnold's Cove vs. NW coast	—	NSD	NSD	NSD
Paradise vs. Boswarlos	*	**	NSD	—
Paradise vs. NW coast	NSD	NSD	NSD	NSD
Ship Hr. vs. NW coast	—	—	—	NSD
Boswarlos vs. NW coast	**	**	NSD	—

NSD = no significant difference $P \geq 0.05$, * $0.01 < P < 0.05$, ** $P < 0.01$.

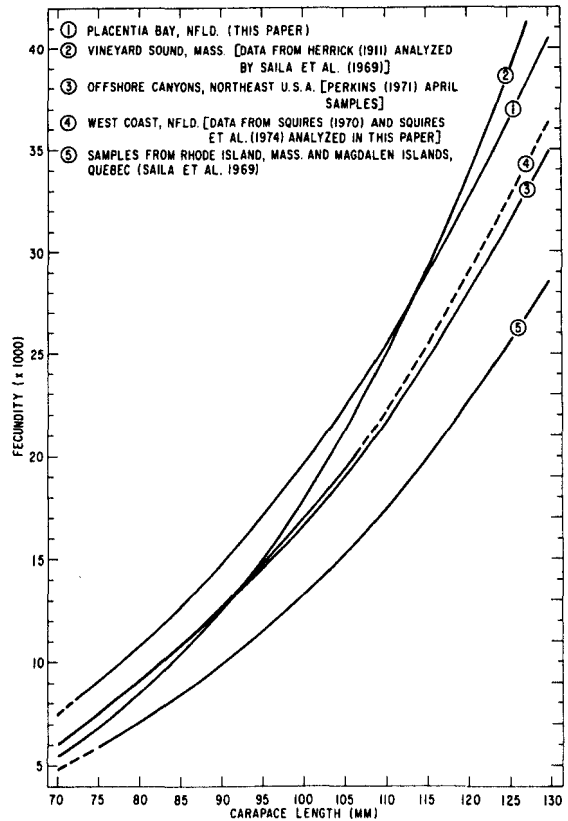


FIGURE 3.—Carapace length-fecundity relationships for American lobsters from two Newfoundland areas and those available for the literature for other areas. Dashed lines indicate extrapolations beyond the data.

tained during late spring-early summer towards the end of the incubation period.

Fecundity values calculated from the relationships in Figure 2 range from 4,800 to 7,450 at 70 mm carapace length and from 25,400 to 38,300 at 125 mm. The relationship of Saila et al. (1969) gives the lowest values over the entire range of sizes considered. This relationship is suspect, however, since it is based on samples obtained from three widely separated areas. Over most of the size range considered the relationship for Placentia Bay gives higher estimates than those from the relationship derived by Saila et al. (1969) from Herrick's (1911) data, indicating that Herrick's data should not be discounted as Saila et al. (1969) suggested.

Definitive statistical comparisons of size-fecundity relationships for American lobsters from different areas would require large samples which adequately cover a wide range of sizes. Even with such samples comparisons could be somewhat confounded by geographic variation in size at first maturity, which, for certain areas, would preclude direct comparison of fecundity at smaller sizes. In addition, samples would have to be taken at approximately the same stage in the incubation period by the same method of capture and be subjected to similar handling and procedures for determining egg numbers. These requirements are unlikely to be met in the foreseeable future. However, as tenuous as the comparisons presented here may be, they do suggest substantial geographic variation in size-fecundity relationships for American lobsters.

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MORTALITY OF SEABIRDS IN HIGH-SEAS SALMON GILL NETS¹

Since 1952, the Japanese have operated a large salmon driftnet fishery in the northern North Pacific Ocean and Bering Sea. This fishery is divided into two components: the high-seas mother-ship fleet, which consists of several processing ships and their numerous, smaller catcher boats that remain at sea during the entire fishing season, and the land-based fleet, which consists of independent fishing boats that catch and store their own fish and return to Japan at more fre-

¹Contribution No. 224 of the Point Reyes Bird Observatory.