

dicted that molting would not occur that year), had molted when recaptured prior to the molting period the following year. For these animals premolt development must have occurred very rapidly during the 1981 molting period. This indicates that periodic sampling throughout the molting period along with a validation study are required in order to use these molt prediction techniques as a basis for estimating annual proportions molting in a lobster population.

The overall success rate with predicting egg extrusion was much greater than with molt prediction (94% cf. 78%). The small number of incorrect predictions may have resulted from loss of eggs rather than failure of the animals to extrude. One of 6 ovigerous females with newly laid eggs that were tagged during the 24 June-17 July sampling period had molted and was nonovigerous when recaptured. While egg extrusion prediction based upon the cement gland staging technique provides a reliable basis for estimating annual proportions laying eggs in a lobster population, it is clear that such estimates should be adjusted, using the kind of information that can be obtained from a validation study before being used in an assessment of reproductive potential in a population.

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G. P. ENNIS

Department of Fisheries and Oceans
Fisheries Research Branch
P.O. Box 5667
St. John's, Newfoundland, Canada A1C 5X1

COMPARISON OF PHYSIOLOGICAL AND FUNCTIONAL SIZE-MATURITY RELATIONSHIPS IN TWO NEWFOUNDLAND POPULATIONS OF LOBSTERS *HOMARUS AMERICANUS*

Lobster (genus *Homarus*) fisheries are characterized by excessive exploitation rates and small, minimum legal sizes in relation to sizes at maturity (Anonymous 1977, 1979). Under such conditions, widespread recruitment overfishing is a distinct possibility and in eastern Canada appears to be the cause of stock collapses in certain areas (Robinson 1979). Stock-recruitment relationships as such are poorly known for the genus *Homarus*; however, since current levels of landings are well below historical levels in most fisheries, it is reasonable to assume that, within the limits of habitat carrying capacity, increased egg production will result in increased recruitment. It is clear that increasing the minimum legal size and/or reducing exploitation rates will result in increased egg production within a lobster stock; however, detailed knowledge of size-fecundity and size-maturity relationships is required to properly assess the impact of changes in fishery regulatory measures on annual egg production within a given stock.

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Size-maturity relationships, based mainly on observations of ovary color and ova size in nonovigerous females for five Newfoundland lobster populations, indicate 100% maturity (physiological) for sizes at which tagging results show that substantially <100% of the nonovigerous females lay eggs in a given spawning season (Ennis 1980). Resorption of the mature ovary near the expected time of oviposition is a common phenomenon in *H. americanus* (Aiken and Waddy 1980a) and presumably is the main reason for failure on the part of physiologically mature females to express their maturity by extruding eggs. Clearly, it is an "expressed" or functional size-maturity relationship that is required to assess the impact of size limit and/or exploitation rate changes in a fishery on annual egg production. Using the pleopod cement gland staging technique described by Aiken and Waddy (1982) as a basis for predicting egg extrusion, such a relationship was derived for two Newfoundland populations. These are compared with physiological size-maturity relationships for the same populations.

Materials and Methods

Pleopods were obtained from 172 nonovigerous female lobsters caught between 24 June and 17 July 1981 and 77 caught between 14 and 18 June 1982 near Arnold's Cove, Placentia Bay, and 246 caught between 1 and 7 July 1982 at Comfort Cove, Notre Dame Bay, Newfoundland, (Fig. 1) using traps and by scuba diving. Sizes ranged from 40 to 111 mm CL (carapace length) at Arnold's Cove and from 58 to 113 mm at Comfort Cove. Pleopods were examined for molt stage according to the method of Aiken (1973) and for cement gland development according to the method of Aiken and Waddy (1982) to determine whether molting or egg extrusion would occur during the current molting/spawning period. In this study it was predicted that females with cement glands in stages 0 and 1 would not extrude eggs during the current spawning period whereas those with stage 2 or higher cement glands would (see Aiken and Waddy 1982 for descriptions of cement gland stages). A validation study (Ennis 1983) has demonstrated that egg extrusion prediction based on cement gland staging is quite reliable. Of the predictions that could be validated, 94% were correct. The only incorrect predictions were for females with stage 2 cement glands of which 2 out of 9 (22%) failed to extrude eggs. Accordingly, in the data analyzed here the number of animals with stage 2 cement glands in each size group was reduced by 22% to obtain a more accurate estimate of the number that would actually

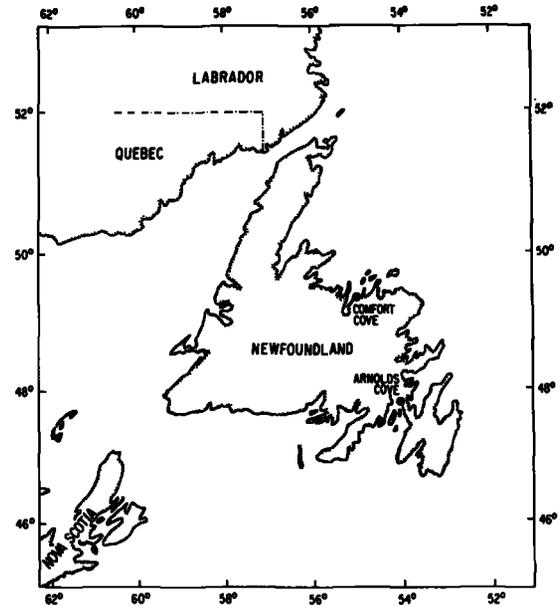


FIGURE 1.—Map of Newfoundland showing location of Arnold's Cove and Comfort Cove.

extrude eggs. Where 22% of the number was < 0.5, nothing was subtracted.

The two Arnold's Cove samples were combined. For each area the numbers examined and numbers functionally mature (i.e., going to extrude eggs during the current season) were grouped by 1 mm CL and subjected to probit analysis. Although good statistical fits were obtained (P values > 0.9), the fitted curves did not approximate the data very well at the upper and lower ends. Proportions from the same data were analyzed using the logistic equation

$$Y = \frac{a}{1 + e^{b+cX}} \quad (1)$$

An SAS¹ program, which performs this analysis by means of a nonlinear regression procedure using the Marquardt method, was used. Curves were obtained with substantially improved visual fits to the data.

Previously published size-maturity relationships for Arnold's Cove and Comfort Cove lobsters (Ennis 1980) were based mainly on detailed examination of the gonads of nonovigerous females, but ovigerous females in the samples were included as mature animals. For this paper the ovigerous specimens were excluded from these samples and the data

¹SAS User's Guide: Statistics, 1982 ed. SAS Institute Inc., Cary, N.C., 584 p.

reanalyzed using the above equation. The size maturity relationships thus derived are a more accurate reflection of the proportions of non-ovigerous females whose gonads are developing for extrusion during the upcoming spawning season (i.e., physiologically mature).

Results

The smallest female lobsters with cement glands in stage 2 (or higher), indicating that egg extrusion would occur during the current spawning period, were 73 mm CL at Arnold's Cove and 71 mm at Comfort Cove (Tables 1, 2). All smaller animals had stage 0 or 1 cement glands, indicating that egg extrusion would not occur. The largest female lobsters with cement glands in stage 0 or 1 were 96 mm CL at Arnold's Cove and 88 mm at Comfort Cove. All larger animals had stage 2 (or higher) cement glands.

Functional and physiological size-maturity relationships were derived for each area and plotted together (Figs. 2, 3). Sizes at 50% functionally mature female lobsters from the relationships were 81 mm CL at Arnold's Cove and 80 mm at Comfort Cove. These compare with sizes at 50% physiologically

mature female lobsters of 74 mm and 76 mm for Arnold's Cove and Comfort Cove, respectively.

Observations taken from the data indicate that at Arnold's Cove the shift in physiological maturity from none to all occurred over a 9 mm CL size range (71-80 mm) compared with a 25 mm size range (72-97 mm) for functional maturity. The equivalent size ranges for Comfort Cove lobsters were 22 mm CL (64-86 mm) for physiological maturity and 23 mm (70-93 mm) for functional maturity. Examination of the fitted curves shows considerable disparity between proportions of physiologically mature and functionally mature lobsters at given sizes over much of the size range in each area. In order to quantify this disparity, points on the curves were treated as numbers (out of 100) rather than percentages and the difference determined between the two curves at any given size. The greatest disparities were for 73 mm CL lobsters at Arnold's Cove (Fig. 2) and for 70 mm lobsters at Comfort Cove (Fig. 3) where this comparison of the curves indicates that 60% and 41%, respectively, of the physiologically mature animals fail to extrude eggs. This percentage decreases with increasing size in each area. To derive an estimate of this percentage for the population as a whole, the

TABLE 1.—Cement gland stages for female lobsters caught at Arnold's Cove, Newfoundland, 24 June - 17 July 1981 and 14-18 June 1982.

Carapace length (mm)	Cement gland stage					Total
	0	1	2	3	4	
40-69	31					31
70	2	1				3
72	1					1
73	3	1	1	1		6
74	2					2
75	2					2
76	2	3			2	7
77	5		3	3	4	15
78	3	4	3	3	2	15
79	3	6	7	8	9	31
80	3	3	8	4	6	24
81	2	6	9	4	1	22
82	1	1		1	1	4
83	4	2	5	1	1	13
84	1	1	1	1		3
85	2	2	3	4	1	12
86	2	1	3	1		7
87	1	1	1	1	3	6
88	1		9		1	11
89	1	1	3	1		6
90			2	1		3
91		1	3			4
92			1			1
93			1	1		2
94			1			1
95				2	1	3
96	1		1	2		4
97			1	1		2
98			2	2		4
100				1		1
102				2		2
107			1			1
109-111				1	1	2

TABLE 2.—Cement gland stages for female lobsters caught at Comfort Cove, Newfoundland, 1-7 July 1982.

Carapace length (mm)	Cement gland stage					Total
	0	1	2	3	4	
58-69	7	1				8
70	2	1				3
71	1	1	1			3
72	3	1				4
73	2		1			3
74	1	2	1			4
75			5			5
76	1	2				3
77			2	1		3
78	1	2	1			4
79	1	1	7			9
80		1	7			8
81		2	7			9
82	3	2	8			13
83	1	4	16	4		25
84		4	15			19
85	1	2	15	1		19
86		4	4	4		12
87	1	2	8	6		17
88		1	13	1		15
89			8	1		9
90			5	5		10
91			4	1		5
92			3	2		5
93			2	4		6
94			1	2	1	4
95			1	1		2
96				4		4
97				1		1
98			2			2
100			1	2		3
101-113				7	2	9

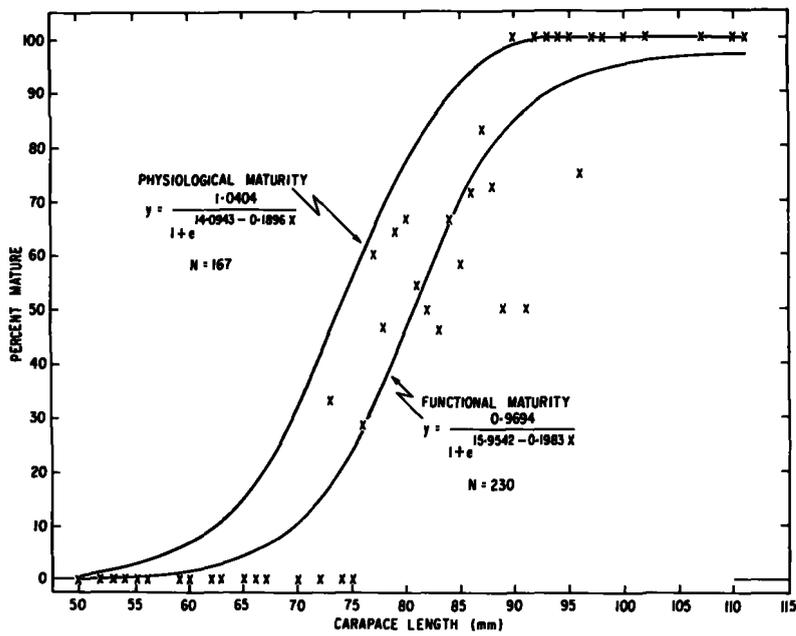


FIGURE 2.—Physiological and functional size-maturity relationships for female lobsters at Arnold's Cove, Newfoundland. Functional maturity data only are provided.

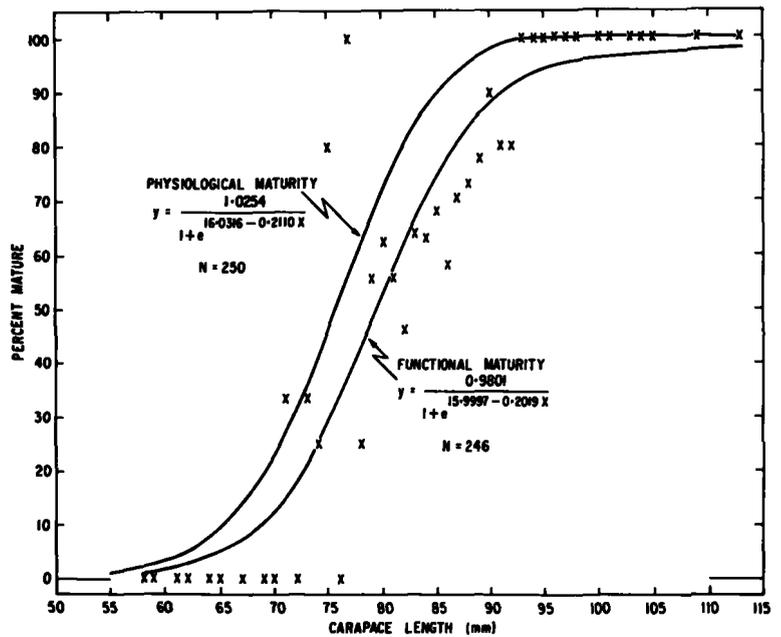


FIGURE 3.—Physiological and functional size-maturity relationships for female lobsters at Comfort Cove, Newfoundland. Functional maturity data only are provided.

above procedure was followed for those sizes between the largest with 100% functionally immature and the smallest with 100% functionally mature (from the data) and the numbers added. The resulting estimates were 25% at Arnold's Cove and 20% at Comfort Cove.

Discussion

This study has demonstrated that failure on the part of physiologically mature female lobsters to "express" their maturity by extruding eggs is quite common in the wild. Resorption of the mature ovary near the expected time of extrusion appears to be the main reason. Resorption occurs when the molting and reproductive cycles conflict (Aiken and Waddy 1976, 1980a, b). These cycles are normally synchronized by temperature and photoperiod regimes so that conflict between them is minimized. However, final ovary maturation is disrupted, if it coincides with middle to late premolt, and the ovary is resorbed prior to the impending molt. Not only would this ensure the conservation of energy, but it might also serve to resynchronize the molt and reproductive cycles (Aiken and Waddy 1980b).

Nonfertilization may also be a cause of resorption. In *Jasus lalandii*, for example, oviposition will not occur in unfertilized females (Heydorn 1969). While oviposition will occur in *H. americanus* even if the female has not successfully mated (Aiken and Waddy 1980a), it is not clear if this is the rule or the exception. Physiologically mature *H. americanus* females which are unfertilized (i.e., empty seminal receptacles) occur in the wild (Krouse 1973; Ennis 1980). In sampling from January to June 1973 at St. Chads, Bonavista Bay, on the northeast coast of Newfoundland, Ennis (1980) found 6 (11.5%) of 52 physiologically mature females to be unfertilized. At Arnold's Cove in August and September 1981, 98 of 100 females ≥ 79 mm CL were fertilized as determined by the presence of spermatophores in seminal receptacles. While nonfertilization may be a contributing factor in some areas, it does not appear to be a major cause of ovary resorption in wild *H. americanus*.

A validation study (Ennis 1983) has demonstrated that the cement gland staging technique enables a reliable prediction of whether a female lobster will extrude eggs during the upcoming spawning season. However, caution has to be exercised in applying a functional size-maturity relationship based on these predictions because there is substantial loss of eggs subsequent to spawning. For example, 2 of 15 females with well-developed (stages 3 and 4) cement

glands, indicating extrusion to be imminent, and 1 of 6 females with newly laid eggs (all tagged during the 24 June to 17 July 1981 sampling period at Arnold's Cove) had molted and were nonovigerous when recaptured prior to the 1982 molting/spawning period.

There is also substantial loss of eggs other than through molting. Some of this loss may be the result of eggs not being fertilized. Unfertilized eggs do not attach securely and may be lost soon after oviposition, but in some cases a fair number will remain attached for several months (Aiken and Waddy 1980a, b). However, it is common for fertilized eggs to be lost as well (Aiken and Waddy 1980a, b). Normal attrition of properly attached (fertilized) eggs over the 9-12 mo incubation period has been estimated at around 36% (Perkins 1971); however, some females lose up to 100% of their eggs. The six ovigerous females referred to above (i.e., tagged during 24 June to 17 July 1981 at Arnold's Cove) had apparently normal clutches of eggs when tagged, but, of the five that had eggs when recaptured, four had normal clutches and one had < 200 eggs remaining. A normal clutch for this particular animal, which was 79 mm CL, would have been about 10,000 eggs (Ennis 1981). Similar observations were made on animals tagged between 1 and 14 August 1981 at Arnold's Cove. Of six females with newly laid, normal-sized clutches of eggs, one had just a few hundred eggs remaining when recaptured. Another female, which had well-developed (stage 4) cement glands, had no eggs but had pleopods covered with cement when recaptured, indicating that eggs had been extruded and subsequently lost (Templeman 1940).

These observations demonstrate that there is substantial loss of eggs subsequent to extrusion over and above that attributed to normal attrition. This loss of eggs should be taken into account in any assessment of the impact of changes in fishery regulatory measures on reproductive potential (i.e., annual egg production) in a population.

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G. P. ENNIS

Fisheries Research Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland, Canada A1C 5X1

CONVERSIONS BETWEEN TOTAL, FORK, AND STANDARD LENGTHS IN 35 SPECIES OF *SEBASTES* FROM CALIFORNIA

In recent years, the rockfishes (Scorpaenidae: *Sebastes*) of the northeastern Pacific Ocean have been investigated extensively. With many institutions studying diverse aspects of their biology and fisheries, a lack of standardized methods has hampered attempts to synthesize the data. A particular problem has been the reporting of different length measurements. To provide the means to convert one of these length measurements to another, we report here the linear regression statistics necessary for conversions in 35 species of *Sebastes*.

Specimens were collected from fishery catches between Cape Blanco, Oreg., and San Diego, Calif., during 1977-82. The sample included five fish for each centimeter of body length throughout the size range of each species. Measurements were taken on a meter board in millimeters on frozen, then thawed, carcasses. Standard length was measured from the anterior tip of the upper jaw to the posterior end of the vertebral column (Hubbs and Lagler 1970:25); fork length was measured from the anterior tip of the longest jaw to the median point of the caudal fin; and the total length was measured from the most anterior tip of the longest jaw to the most posterior part of the tail when the caudal rays are squeezed together (Holt 1959:71). Linear regressions were run on all combinations of the measurements of length. Outliers (± 3.0 standard deviations) from the line were noted by the computer program, then checked for data entry error and corrected when possible. If a data entry error was not found, an outlier was assumed to result from measurement error and the observation was deleted.

Statistics reported for each species are y -intercept (α), slope (β), standard error of estimate ($S_{y,x}$), correlation coefficient (r), range in length, and the sample size used in the regression (n) (Tables 1-3). Estimates of α imply impossible values for the dependent variable when the independent variable is zero. The impossible results could be caused by random error in estimation of α or nonlinearity for values less than those observed. The high values of r and examination of scattergrams indicate that the length relationships are linear over the observed range of values. The standard precaution of limiting the application of these regressions to the ranges of observed values is advised. To calculate the total length (TL) of *S. alutus*, given a standard length (SL) of 250 mm, the regression values from Table 1, total length on standard length, are used so that