MASSACHUSETTS COASTAL COMMERCIAL LOBSTER TRAP SAMPLING PROGRAM MAY-NOVEMBER, 1982

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Division of Marine Fisheries
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ABSTRACT

The second consecutive American lobster (Homarus americanus) catch/effort and biological monitoring program was completed in Massachusetts coastal waters in 1982. With the aid of cooperating commercial lobstermen, a total of 12,760 lobster were sampled from 6,150 trap hauls. Five sampling regions were chosen for coverage of major lobstering regions of the state. Statewide catch per trap haul per set-over-day in number of lobster for all sizes was 0.650, slightly lower than the 1981 index of 0.689. The sublegal catch rate, 0.400, was lower than that of the previous year, 0.462; however, the legal lobster catch rate, 0.232, was elevated from the 1981 rate of 0.215. Mean length, 81.6 mm, was significantly larger than the 1981 mean, 80.4 mm. Sex ratio, 40/60 (M/F); percent of females ovigerous, 6.9%; cull rate, 10.5%; molt frequency, 1.3%; shell disease < 1%; and trap mortality, < 1%, were not significantly different from 1981 calculations. Total instantaneous mortality rates were highest in Buzzards Bay and lowest in the outer Cape Cod region. Size at first maturity and 100% maturity were found to occur at 70-74 mm and 95-99 mm, respectively, in Gulf of Maine regions; 80-84 mm and 100-104 mm, respectively, in the outer Cape Cod region; and 60-64 mm and 75-79 mm, respectively, in Buzzards Bay. Cape Cod Bay and Buzzards Bay female lobster exhibited significantly wider carapace widths than males, while no difference between sexes was found for outer Cape Cod lobster. Sex ratios from dimorphic regions exhibited fewer males. Analyses of sex ratios by set-over-day and from concurrent otter trawl catches support the existence of an escapement differential for sublegal males from populations exhibiting a sexually dimorphic carapace width.

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INTRODUCTION

The commercial lobster fishery is the most economically important single-species fishery in Massachusetts coastal waters. For many years this fishery has been monitored by the Massachusetts Division of Marine Fisheries (DMF) Commercial Fisheries Statistics Project. Selected lobster fishery statistics are compiled from catch reports filed annually by lobster license holders. However, coincident with the inception of the State-Federal Lobster Management Program, and ultimately the American Lobster Fishery Management Plan (FMP)[1], the need for a comprehensive, coastwide, organized American lobster management effort was recognized. According to the precepts of the FMP, a long-term state-wide monitoring program which would yield biological as well as catch per unit effort data was devised and initiated in Massachusetts in May, 1981. The FMP left the specifics of the data reporting system to the various licensing agencies, consequently we adopted a sea sampling survey design by which both catch per unit effort and biological data could be collected temporally and areally with sufficient precision for stock assessments. The objective was to assess variations in population parameters due to environmental and/or fishing pressure, or the effects of regulatory changes.

The following report summarizes the data collected during the 1982 state-wide commercial lobster trap sampling program in Massachusetts coastal waters.

STUDY AREA

The study area is primarily defined by the Massachusetts territorial sea, except where lobstering activities of cooperating commercial lobstermen exceeded territorial boundaries (Figure 1). Territorial waters total 5322 sq. km. (2055 sq n mi), of which an estimated 60% is considered major lobster habitat. Five sampling regions, Cape Ann, Beverly-Salem, Cape Cod Bay, outer Cape Cod, and Buzzards Bay, were chosen for coverage of the major lobstering regions of the state within resources available. For convenience, these regions are depicted as generalized hatchmarked areas wherein lobster gear sampled may be discontinuously distributed.

Three major lobster population groups are defined within Massachusetts coastal waters: Gulf of Maine (including Cape Ann, Beverly-Salem, and Cape Cod Bay regions), outer Cape Cod, and Buzzards Bay.

SAMPLING PROCEDURE

Coverage of coastal waters was accomplished by monitoring catches during the normal lobstering operations of volunteer commercial lobstermen in each designated region. Four lobstermen were monitored in Gulf of Maine regions,

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[1] Draft American Lobster Fishery Management Plan, New England Fishery Management Council, Saugus, Massachusetts, August 16, 1982.

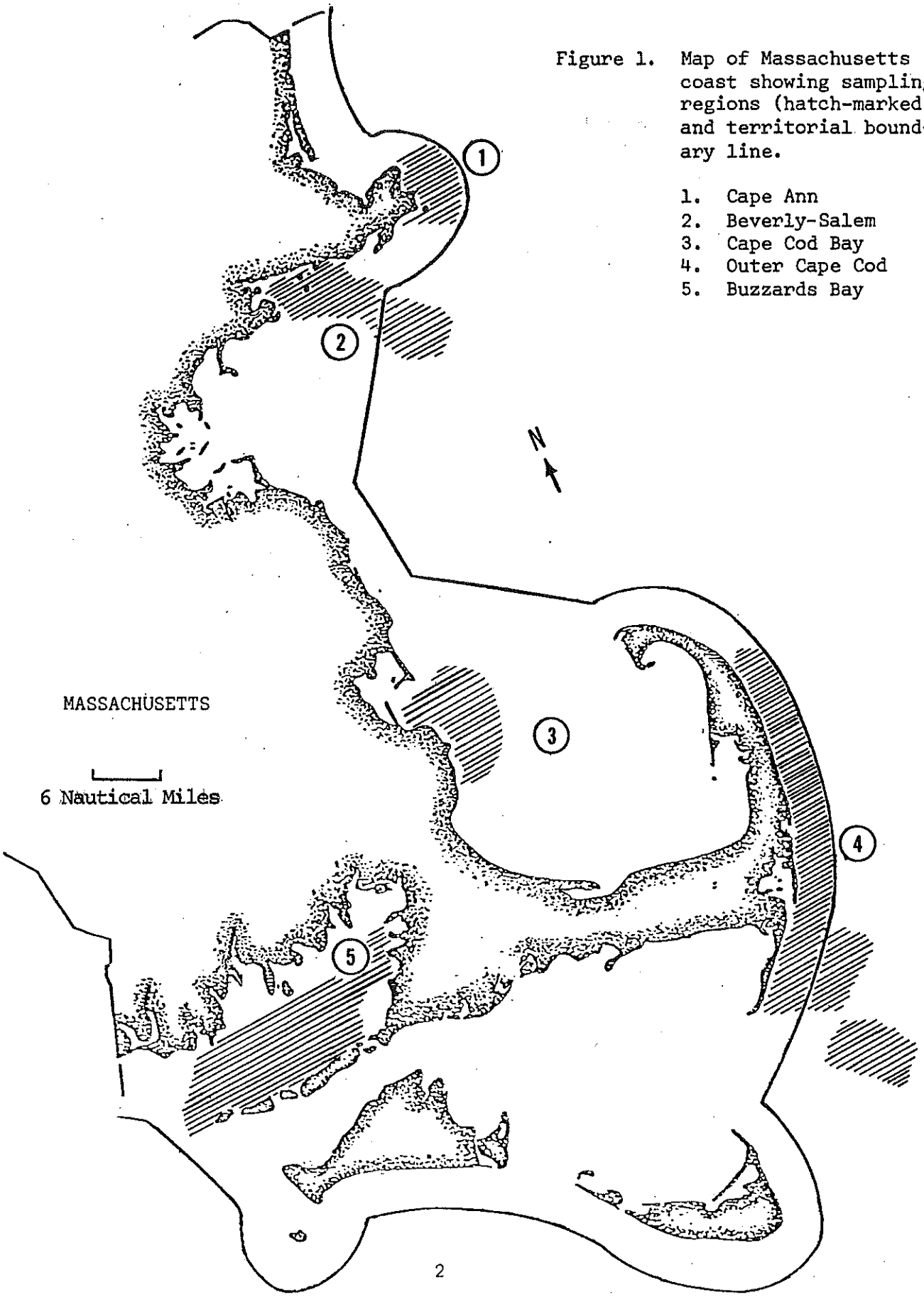

Figure 1. Map of Massachusetts coast showing sampling regions (hatch-marked) and territorial boundary line.

1. Cape Ann
2. Beverly-Salem
3. Cape Cod Bay
4. Outer Cape Cod
5. Buzzards Bay

two in the outer Cape Cod region and two in Buzzards Bay. Pot-sampling trips were day trips, conducted a minimum of once per month per region (except where manpower limitations precluded effort) during the major lobstering season, May through November.

Sampling units (lobster traps) were apportioned according to the relative area of the inshore region inhabited by each of the major lobster groups:

	Area (sq n mi)	Sampling Unit Allocation	Percent Units Sampled 1981	Percent Units Sampled 1982
Gulf of Maine	869	72%	78.6%	71.6%
Outer Cape Cod	155	13%	9.9%	18.0%
Buzzards Bay	183	15%	11.5%	10.4%

The development of software which will randomly select the exact theoretical apportionment of sampling units is planned. This will insure accurate and reliable annual comparability of statewide indices (pooled regional data).

Utilizing portable cassette tape recorders, sea samplers recorded carapace length to the nearest mm and to the nearest 0.1 mm between 80.5 and 81.0 mm; sex; and condition, including the degree of shell hardness, culls and other shell damage, external gross pathology, mortality, and presence of extruded ova on females (ovigerous). Catch in number of lobster, number of trap hauls, set-over-days, trap and bait type were also recorded.

ANALYTICAL PROCEDURE

Data were computer coded and keypunched for analysis on the Woods Hole Oceanographic Institution's Digital Equipment Corporation VAX-11/780 computer system. A computer auditing process was used to uncover keypunch and recording errors and statistical analyses were performed with SPSS (Nie et al. 1975) and BMDP (Brown et al. 1979) statistical subprograms.

Tests for normality of variables were conducted using normal probability plots. The expected normal values for relative ranks of observations were estimated by:

$$\Phi^{-1}[3j-1)/3N+1)]$$

where,

Φ = normal probability function
j = rank order of observation
N = total frequency.

Cross-tabulations of variables were tested for homogeneity of distribution using the Kolmogorov-Smirnov two-sample test which is sensitive to differences in median, dispersion, and skewness. Kruskal-Wallis one-way analysis of variance and Duncan's multiple range test were used in trend analyses to determine whether sample sets tested were from the same population.

In order to reduce variability zero frequencies were not plotted in graphical presentations.

Unless specified otherwise, the terms "legal" or "legal sized" lobster include all lobster in the carapace length category $\geq$ 81 mm. The marketable segment of this category, which excludes ovigerous females, is analyzed separately. The sublegal length category includes all lobster < 81 mm.

Since current management strategy stresses uniform coastwide regulations, all data are grouped for a statewide analysis. However, the uniqueness of the Massachusetts coastline, its role in providing a temperature barrier which profoundly affects many marine species (Colton 1964), and the influence of offshore lobster stocks on the inshore population mandate a regional data treatment as well. Comparability of reported regional differences may be slightly influenced by irregular monthly sampling.

RESULTS AND DISCUSSION

During the period of May through November, 1982, thirty-nine trips were made aboard commercial lobster vessels in Massachusetts coastal waters. A total of 12,760 lobster were sampled from 6,150 trap hauls.

Catch Per Unit Effort

Catch per unit effort (CPUE) in the lobster fishery has been traditionally measured by catch per trap haul (CTHAUL). However, this index of abundance was reported as unreliable due to its insensitivity to seasonal changes in catchability (Thomas 1973). The weighting of CTHAUL with trap immersion time (soak time), which is gauged by set-over-days, is currently regarded as the preferred technique for measuring stock density.

The relationship between CTHAUL of legal-sized lobster and soak time was shown to be asymptotic while catch per trap haul per set-over-day (CTHSOD) decreased with increasing soak time (Fogarty and Borden 1980). The relationship for sublegal lobster was an immediate decline followed by a slight increase with time. These relationships are depicted in Figure 2 with pooled data from the 1981 and 1982 surveys. Curve fluctuations are evident because of the pooling of discontinuous soak time data exhibiting regional and seasonal catch rate variation. Nevertheless, the relationships are similar to those previously described, except that sublegal trends indicate a fairly steady decline. The sublegal peak at four set-over-days in 1982 represents a comparatively small sample size of only 21 traps and consequently may not be representative of that soak time. Because of the decline in CTHSOD with increasing soak time, most

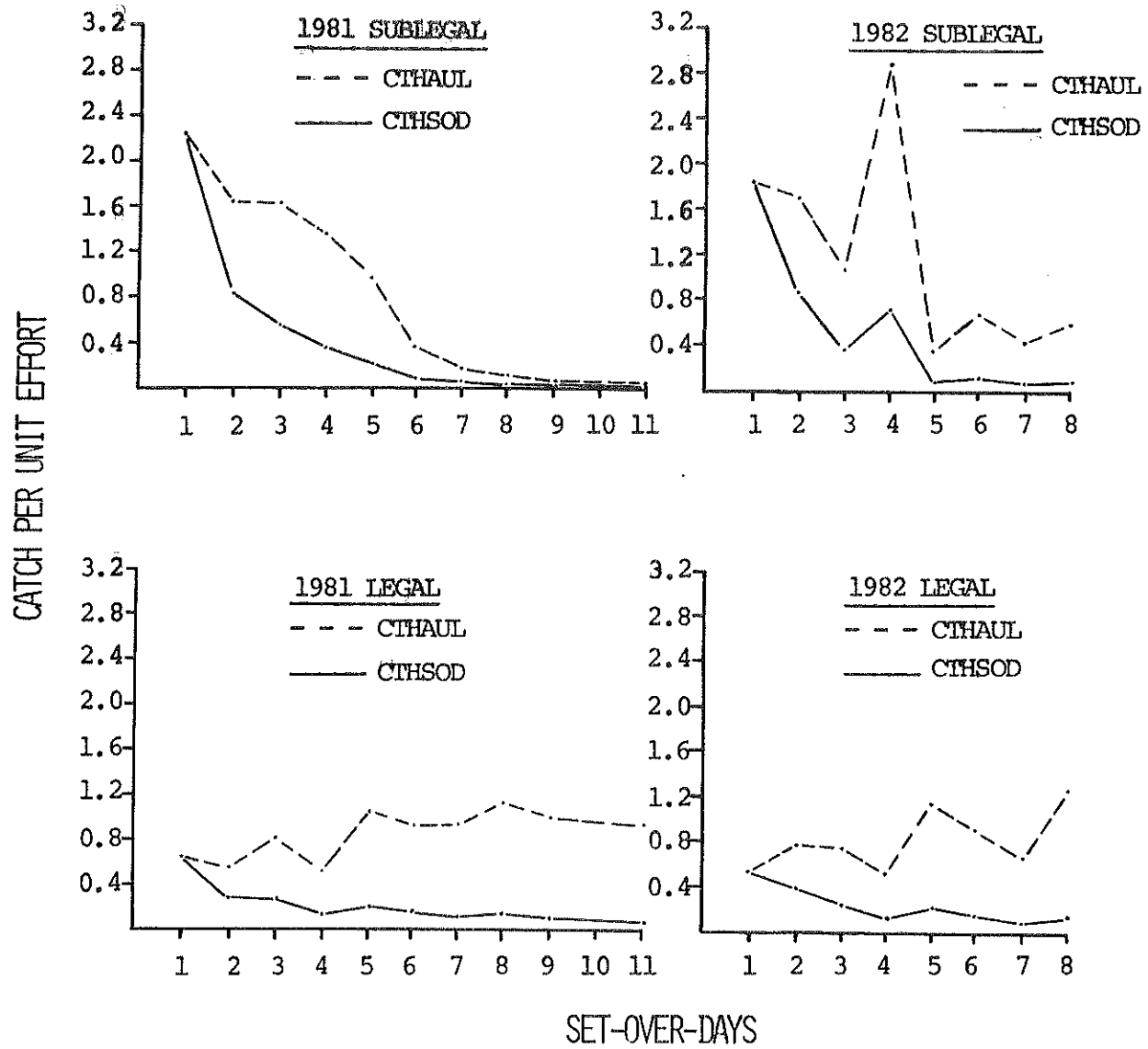

Figure 2. Relationship between catch per unit effort and set-over-days for sublegal and legal-sized lobster, Massachusetts coastal waters, 1981 and 1982.

recent efforts have been directed at modelling this relationship in order to standardize effort to a common soak time and thereby improve the precision of CPUE calculations (Fogarty and Borden 1980).

The statewide average CTHSOD in number of lobster for all sizes was 0.650. For lobster ≥ 81 mm CTHSOD was 0.250 and for those < 81 mm CTHSOD was 0.400. Excluding berried females, the legal CTHSOD was 0.232 (Table 1).

By region, for combined length categories, CTHSOD was greatest in Cape Cod Bay at 1.054 followed by Buzzards Bay, 0.712; Beverly-Salem, 0.738; Cape Ann, 0.437; and outer Cape Cod, 0.193. Regional indices for legal sized lobster indicated Cape Ann was highest at 0.348, followed by Cape Cod Bay, 0.328; Beverly-Salem, 0.249; Buzzards Bay, 0.206; and outer Cape Cod, 0.169. The legal index trend, less berried females, was similar. For sublegals, CTHSOD was greatest in Cape Cod Bay at 0.726, followed by Buzzards Bay, 0.504; Beverly-Salem, 0.489; Cape Ann, 0.089; and outer Cape Cod, 0.023 (Table 1).

By month, the statewide CTHSOD averages for all lobster, legals and sublegals, are listed in Table 2. The general trend is marked by a decline in catch in June-July followed by elevated catches through November. The same pattern has been exhibited in Maine's trap fishery (Thomas 1973). Indications are that the Buzzards Bay trend may occur one month earlier than other regions (Tables 3 and 4) and is probably due to warmer water temperatures (Phillips et al. 1980). The early season decrease is characteristic of the onset of the molt period and a concomitant unavailability of legal sized lobster. Subsequent catch elevations may be due to the recruit molt class or the influence of seasonal offshore stock mixing (Morrissey 1971). Reduced availability in the fall may again be subject to the influence of several variables among which are fishing effort, effect of temperature on seasonal activity (McLeese and Wilder 1958), diminished offshore stock influence, or the onset of the autumn molt period.

Spring, 1982, catch rates tended to be lower than those of the previous year. The much publicized adverse weather conditions during spring, 1982 (Weiner and Quayle 1982) may have been responsible. Autumn catches, however, were higher than in 1981. Despite minimal change in mean survey soak time between years, the annual statewide CTHSOD for all sizes was lower than the 1981 index. This was primarily due to a lower sublegal catch rate; however, indices for lobster categories ≥ 81 mm were higher than the 1981 rates:

	1981	1982
All lobster	0.689	0.650
All ≥ 81 mm	0.227	0.250
≥ 81 mm (less berried females)	0.215	0.232
Sublegal lobster	0.462	0.400
Mean set-over-days	3.1356	3.1920

CTHSOD of sublegals must be interpreted cautiously not only because of variable soak time influence but due to differences in application of the escape vent regulation. Some lobstermen utilize standard commercially produced escape vents, and others separate trap lathes. Fogarty and Borden (1980) found the former method was more efficient in allowing escapement. A plausible explanation may be that if lathe spacing is accomplished during haul-out when traps are dry, subsequent immersion and wood swelling will constrict the vent opening. The relative thickness of the two vent types may be another factor for consideration. Krouse (1978) found no significant difference in catch with vent orientation; however, several studies demonstrated that escape vents enhanced legal lobster catch (Fair and Estrella 1976; Fogarty and Borden 1980; Krouse 1978; Weber and Briggs 1983).

Nevertheless, sublegal to legal ratios in 1982 were lower than those of 1981 for every region sampled:

	1981	1982
State	2.03	1.60
Cape Ann	0.33	0.26
Beverly-Salem	2.24	1.96
Cape Cod Bay	2.25	2.21
Outer Cape Cod	0.22	0.14
Buzzards Bay	3.50	2.45

A statewide mean of 0.7 legal lobster per trap (excluding berried females) was calculated for an average of approximately three set-over-days in both 1981 and 1982; the mean catch rate of sublegals was 1.3.

The legal CTHSOD index (less berried females) converted to pounds (1.17 lbs/ lobster derived from experimental lobster pound sampling data weighted by regional area) is listed below along with total Massachusetts inshore landings tallied from catch reports by the DMF Commercial Fisheries Statistics Project:

	1981	1982	Factor Increase
Legal CTHSOD (lbs.)	0.252	0.271	1.08
Landings (lbs.)	9,186,219	9,638,188	1.05

Catch rates of American lobster in Massachusetts waters were shown to be higher with traps constructed of wire than with wood for a given bait type, region, and month (Estrella 1983). However, there are numerous variables

affecting catch rate which must be considered. Acheson (1980) conducted the most comprehensive study undertaken on the subject. Multiple regression analyses indicated season was the most important factor influencing legal lobster catch, followed by trap size, fishing skill, then bait, and trap construction material. The least important factors influencing catch rate were bottom type, depth, and head type. His indication of the minimal significance of bottom type did not diminish the importance of trap placement. He emphasized that no particular bottom type will produce year round - traps must be moved to maintain efficiency. Results revealed that traps constructed of aluminized wire outfished vinyl-coated wire traps which in turn outfished wood traps.

The percentage of wood traps sampled remained nearly equal in 1981 and 1982, 96.7% and 96.8%, respectively. Consequently the influence of trap construction material did not affect the comparability of survey results.

Carapace Length

The statewide average carapace length for all lobster was 81.6 mm ranging from 38 to 178 mm (Table 5, Figure 3). Legal sized lobster averaged 89.8 mm and sublegals averaged 76.5 mm. The average male, at 82.3 mm, was significantly larger than the average female, 81.1 mm ($P < 0.001$, Table 6).

By region, outer Cape Cod averaged largest at 96.4 mm followed by Cape Ann, 86.0 mm; Beverly-Salem, 80.1 mm; Cape Cod Bay, 79.8 mm; and Buzzards Bay, 78.4 mm. Cape Ann and outer Cape Cod means were not significantly different nor were those of Beverly-Salem and Cape Cod Bay; however, the Buzzards Bay mean was significantly different from all other means ($P = 0.05$, Table 5, Figures 4-8). For all regions except outer Cape Cod, males averaged larger than females (Table 6). The average legal length was greatest in outer Cape Cod at 99.2 mm followed by Cape Ann, 88.2 mm; Beverly-Salem, 87.2 mm; Cape Cod Bay, 86.9 mm; and Buzzards Bay, 85.3 mm. Average sublegal length was 77.5 mm for Cape Ann, followed by Cape Cod Bay, 76.7 mm; Beverly-Salem, 76.6 mm; outer Cape Cod, 76.0 mm; and Buzzards Bay, 75.6 mm (Table 5).

Histogram production indicates that there is a strong similarity between Cape Ann and outer Cape Cod length frequencies in the comparatively high number of lobster between 81 and 100 mm carapace length. A greater offshore population influence may be responsible here. Both Cape Ann and outer Cape Cod are adjacent to steeply sloping gradients which yield to a much greater depth range than is available to other, more "sheltered" inshore regions. This may be a factor in concentrating migrants.

In order to substantiate an inshore-offshore resource relationship, length frequency data from offshore commercial lobster traps was obtained from the National Marine Fisheries Service (NMFS), Woods Hole (Michael J. Fogarty, pers. comm.) for comparison to our inshore data. Percent length frequency from the NMFS southern New England statistical area was found to be nearly identical to outer Cape Cod data. However, no affinity with Georges Bank area size structure was evident. The lack of offshore commercial trap data from the NMFS Gulf of Maine strata grouping precluded a similar analysis for the Cape Ann region.

Average legal sizes calculated for Beverly-Salem, Cape Cod Bay, and Buzzards Bay regions in 1981 and 1982 are similar to those calculated by Fair and Estrella (1976) from vented traps five years earlier:

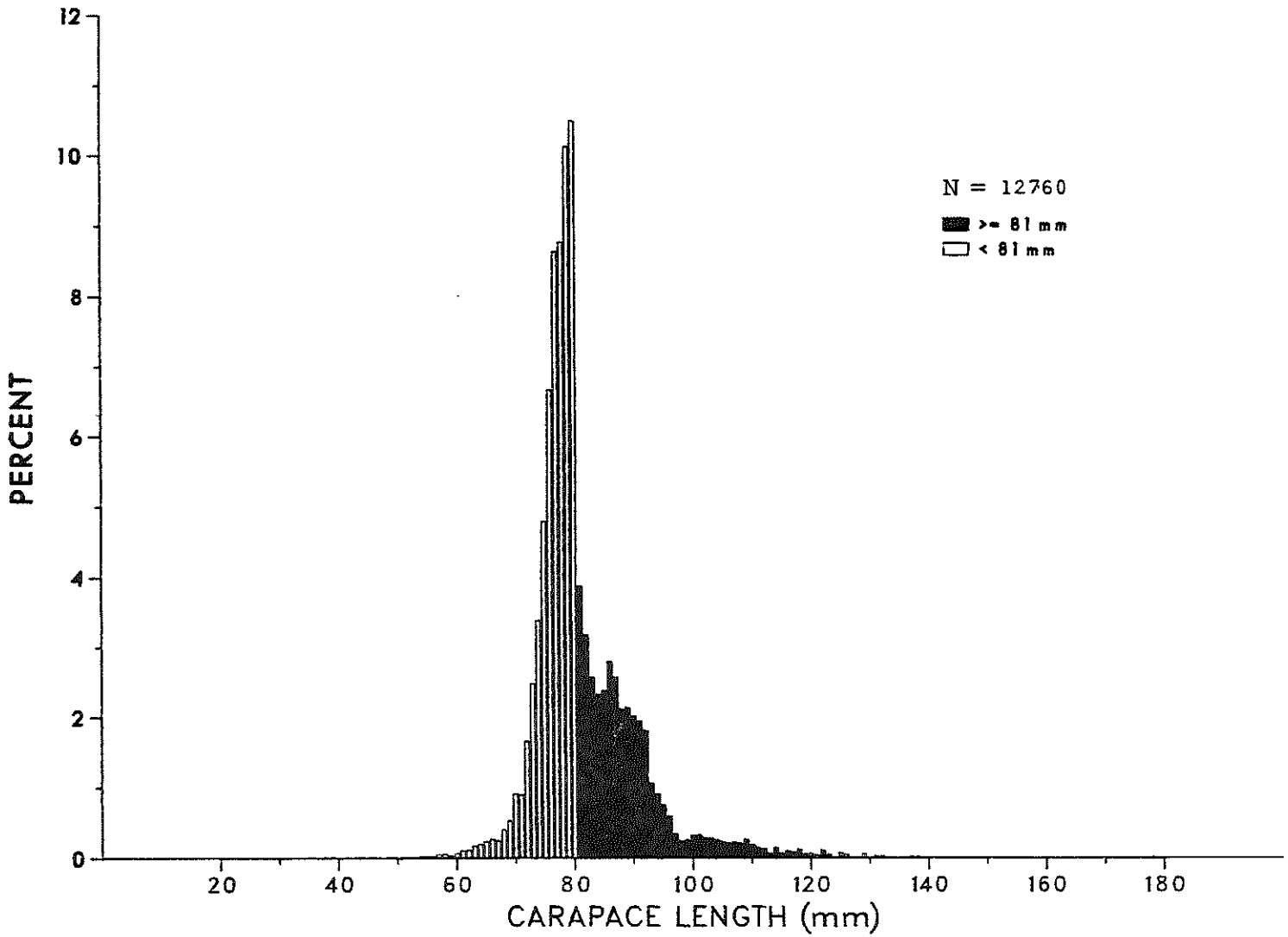

Figure 3. Percent size frequency histogram of American lobster sampled from Massachusetts in 1982.

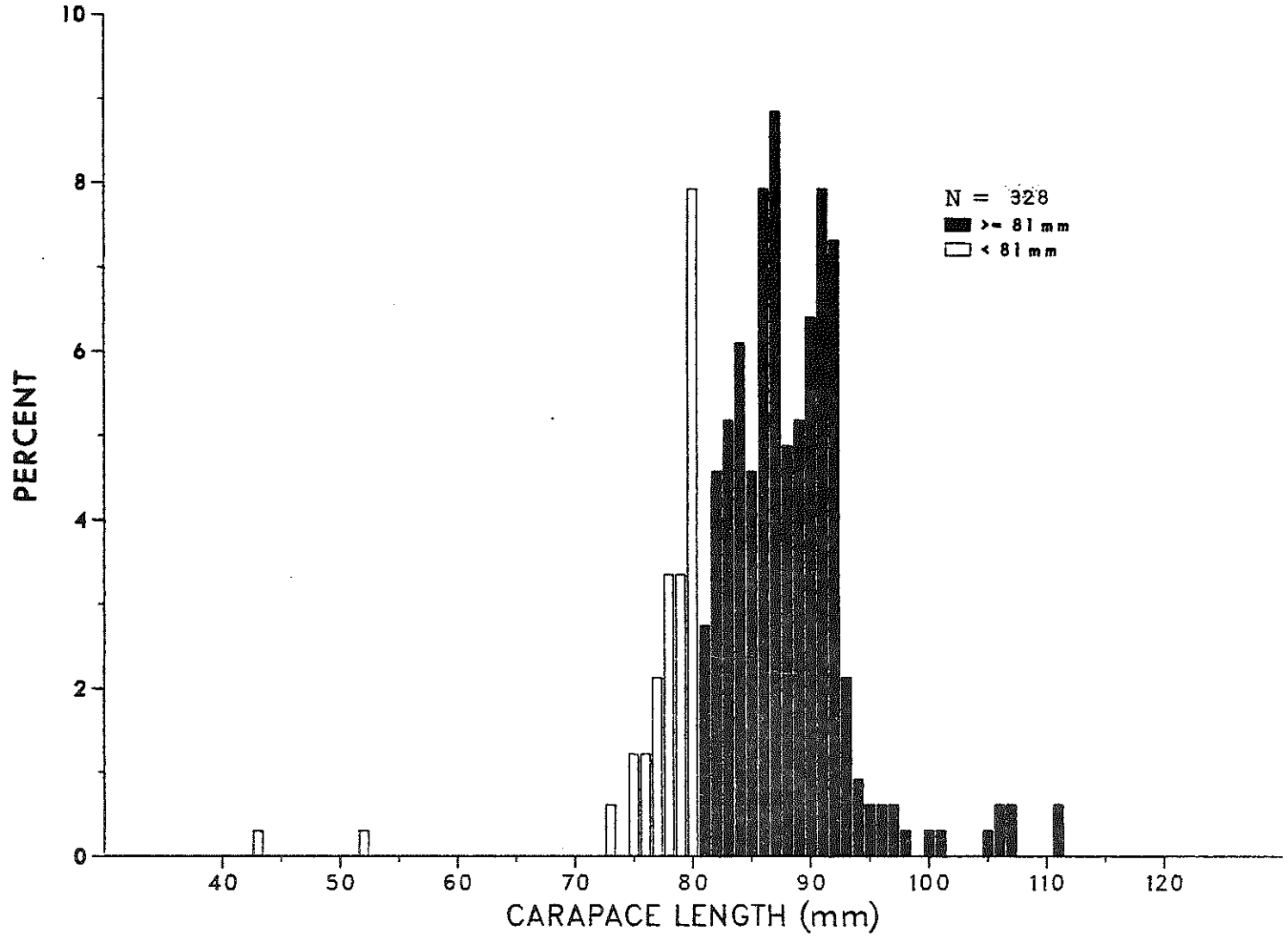

Figure 4. Percent size frequency histogram of American lobster sampled from Cape Ann region in 1982.

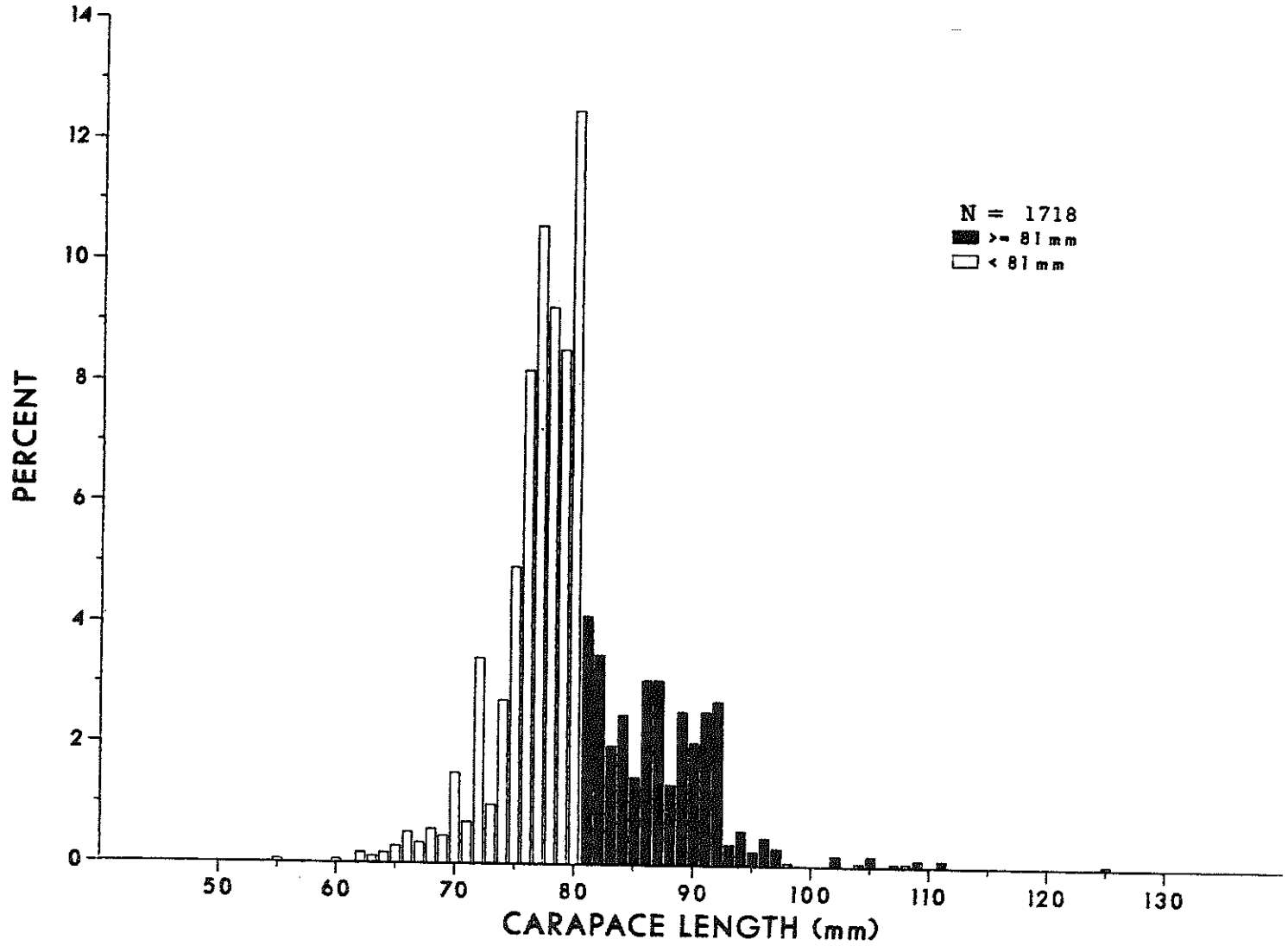

Figure 5. Percent size frequency histogram of American lobster sampled from Beverly – Salem region in 1982.

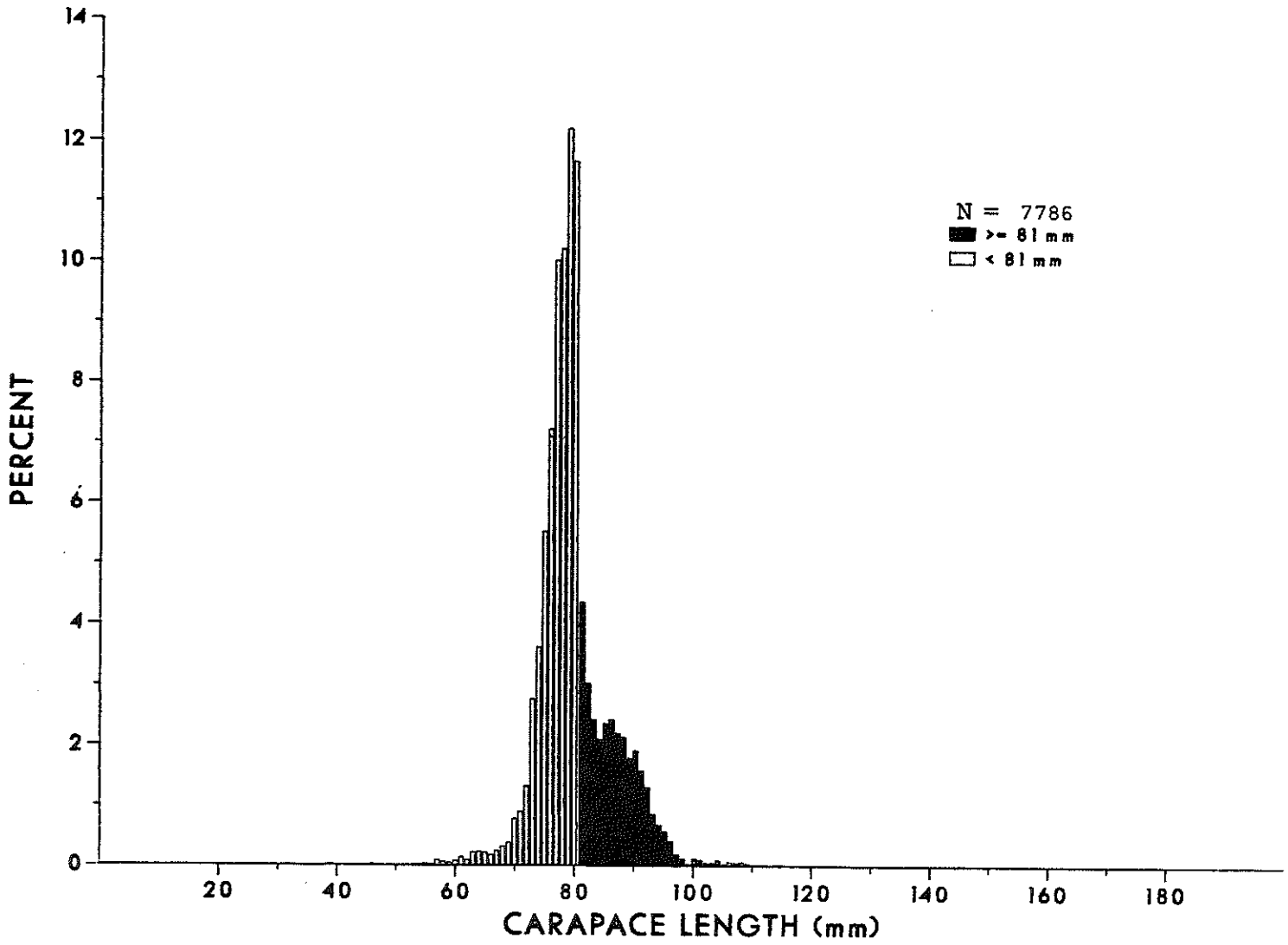

Figure 6. Percent size frequency histogram of American lobster sampled from Cape Cod Bay region in 1982.

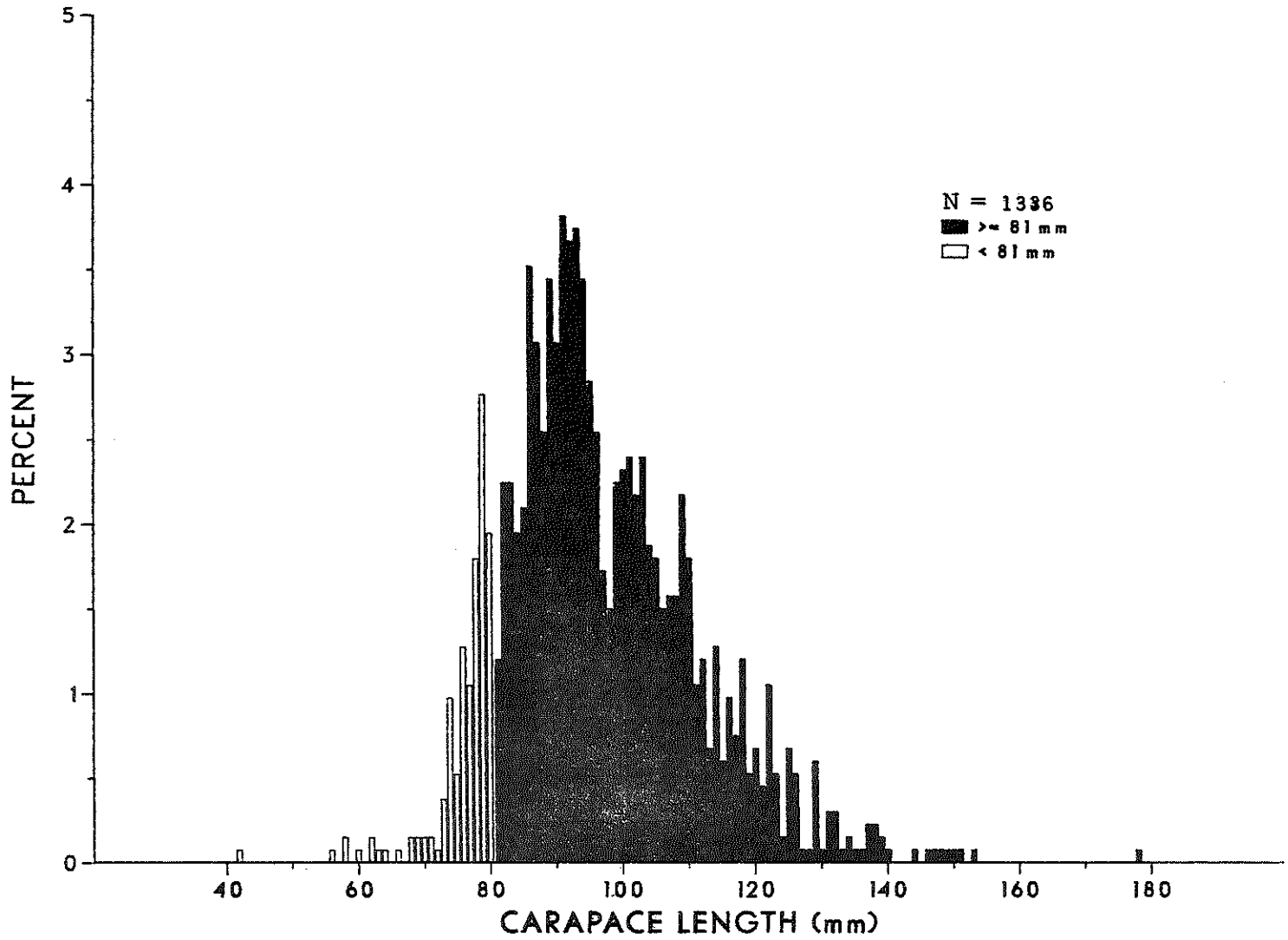

Figure 7. Percent size frequency histogram of American lobster sampled from outer Cape Cod region in 1982.

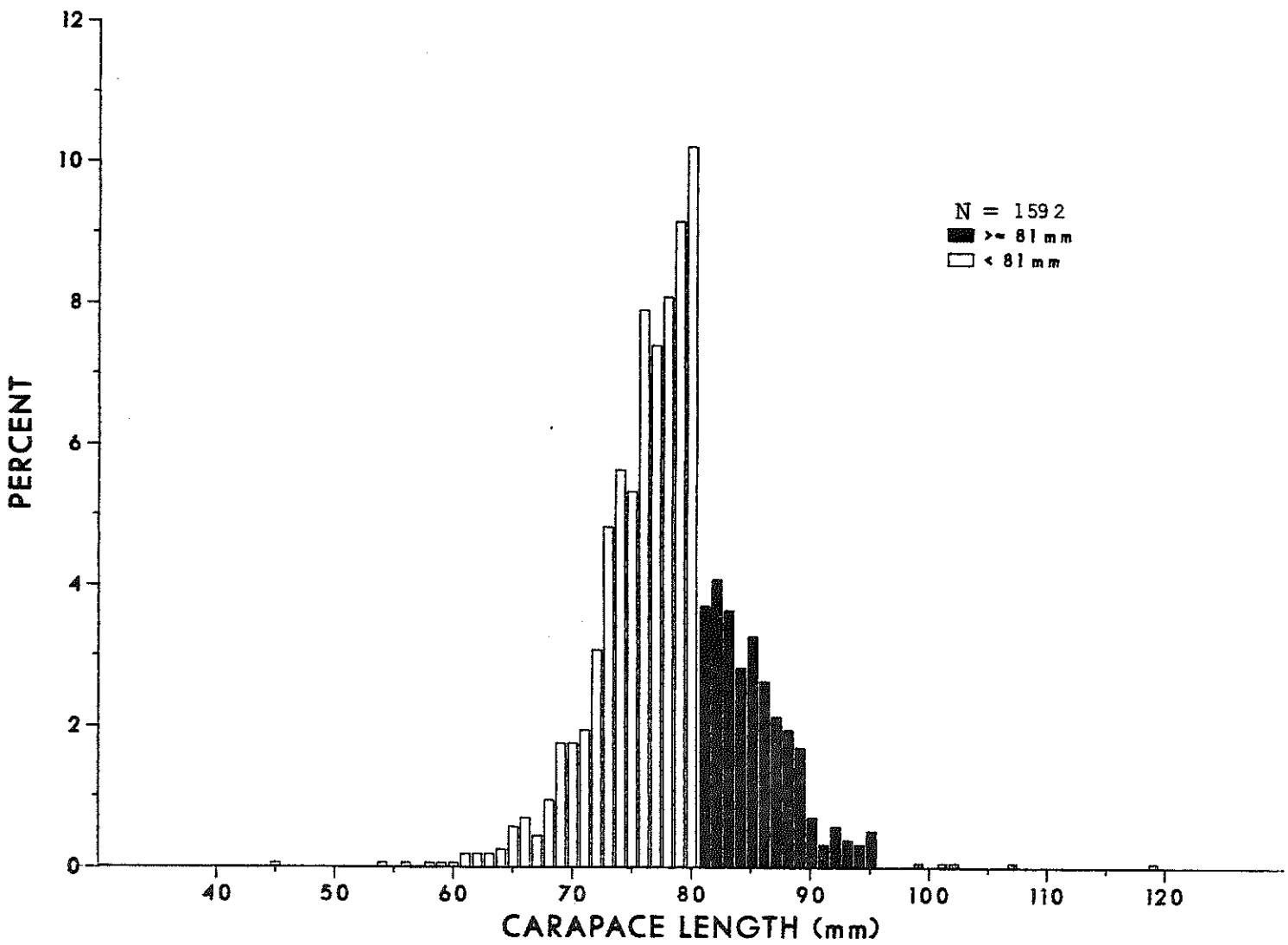

Figure 8. Percent size frequency histogram of American lobster sampled from Buzzards Bay region in 1982.

	1976	1981	1982
Beverly-Salem	86.9	87.5	87.2
Cape Cod Bay	87.3	87.7	86.9
Buzzards Bay	85.1	84.8	85.3

These minimal changes in average length indicate relatively static exploitation rates.

As an estimate of fishing pressure, the proportion of legal sized lobster within the recruit molt size group, 81-92 mm (81-91 mm in Buzzards Bay), was calculated. Except for the outer Cape Cod region, where fishing pressure is lower and a larger offshore migrant population is seasonally available, over 88% of the lobster landed in the 1981-1982 period had recently molted into legal size:

	1981	1982
Cape Ann	89%	91%
Beverly-Salem	91%	92%
Cape Cod Bay	88%	89%
Outer Cape Cod	45%	42%
Buzzards Bay	97%	93%

The Buzzards Bay lobster fishery is almost entirely recruitment dependent with recruits from the late spring-early summer molt period being generally depleted by August. At this time, alternative fisheries are undertaken by most lobstermen until the autumn molt period produces another limited crop of legal-sized lobster. Fair (1979) calculated an exploitation rate of 0.93 for lobster north of Cape Cod and the 1982 NOAA American lobster population assessment[2] indicates that the lobster fishery is fully exploited.

It is noteworthy that Buzzards Bay, exhibited the highest fishing pressure estimate and was also characterized by the smallest mean size (77.6 mm). Few lobster larger than 90 mm were found in this embayment (Figures 4-8). Fogarty and Borden (1980) and Krouse (1973) observed the same relationship between fishing pressure and small mean size.

By month, the statewide trend in average length for all lobster indicated a decline in average length in June, followed by a rise to a peak in September, then a downward trend through November ($P < 0.001$, Tables 7-9, Figures 9-15). The June decrease may be due to fishing mortality and unavailability during ecdysis, while July through October increases may be related to recruitment from

[2] Status of the Fishery Resources of the Northeastern United States for 1982, NOAA Technical Memorandum NMFS-F/NEC-22, June 1983.

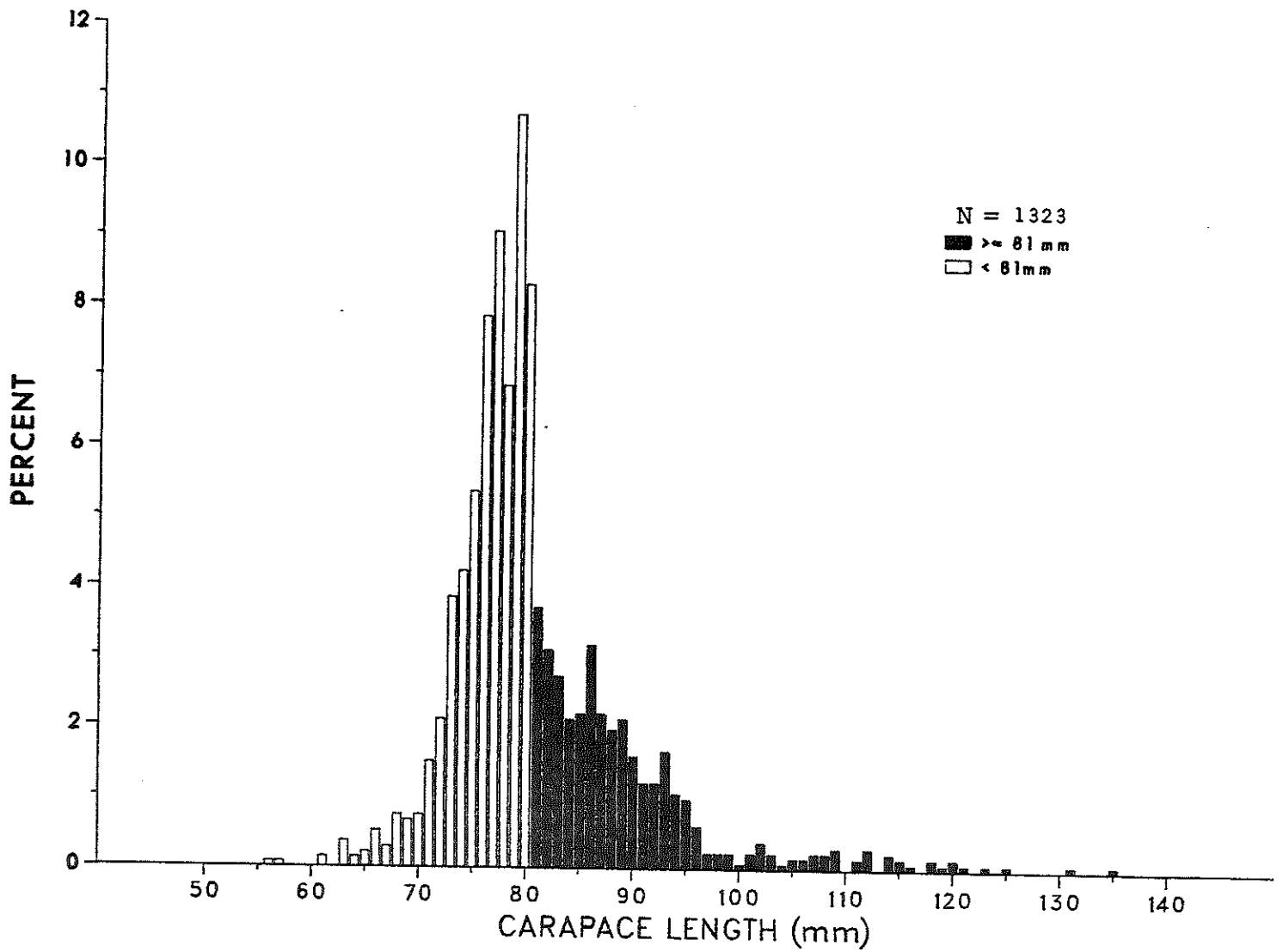

Figure 9. Percent size frequency histogram of all American lobster sampled during May, 1982.

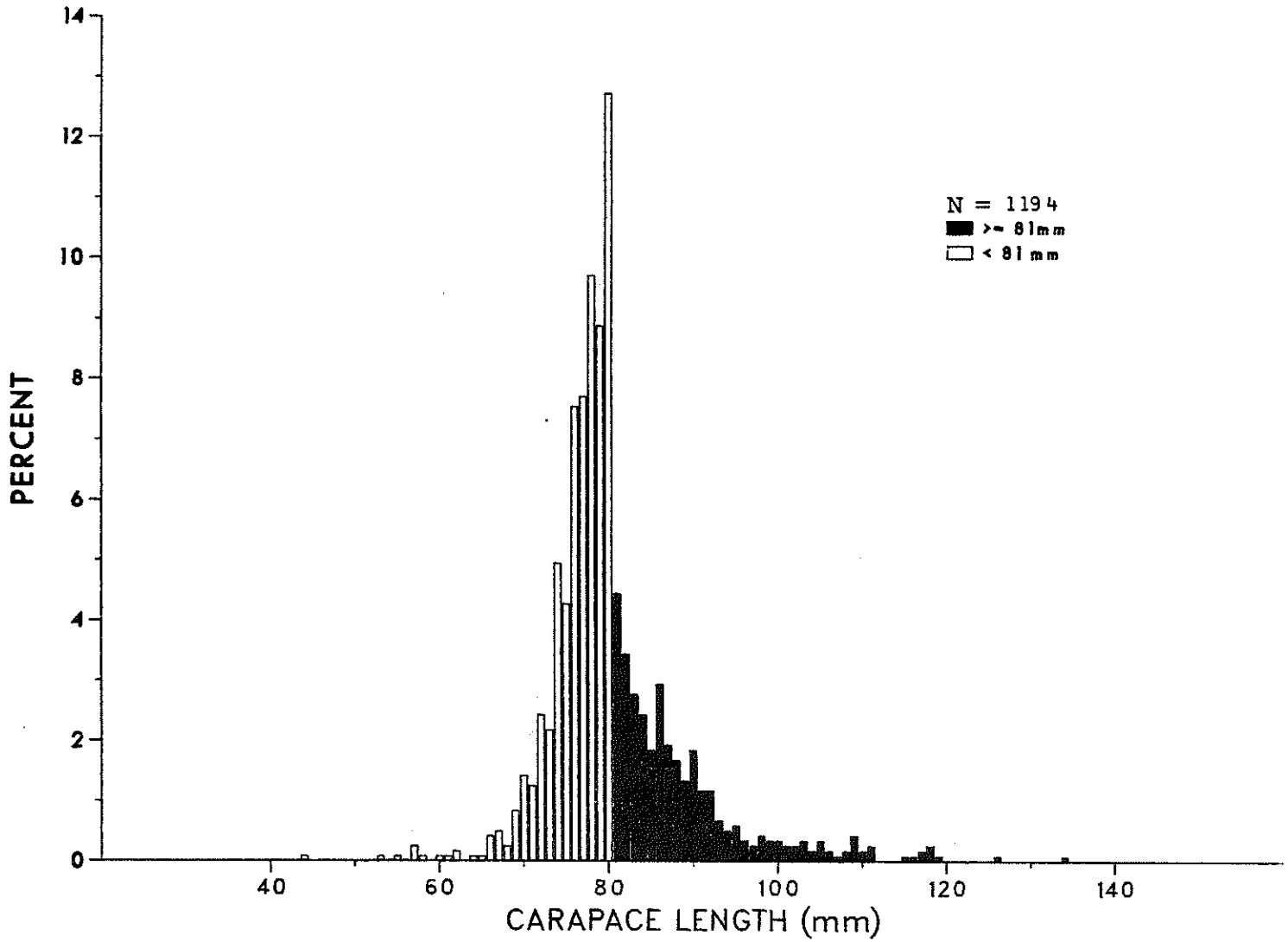

Figure 10. Percent size frequency histogram of all American lobster sampled during June, 1982.

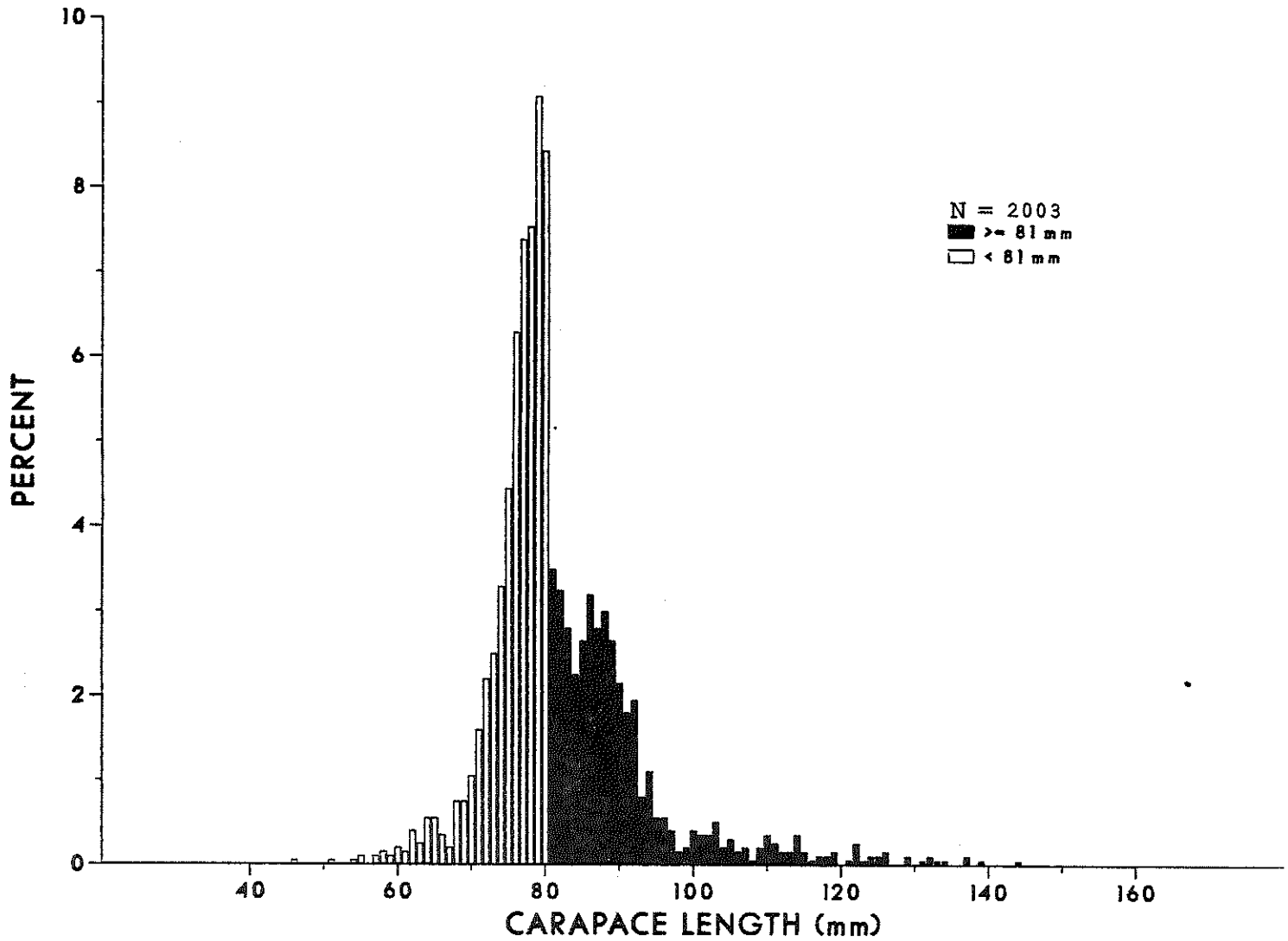

Figure 11. Percent size frequency histogram of all American lobster sampled during July, 1982.

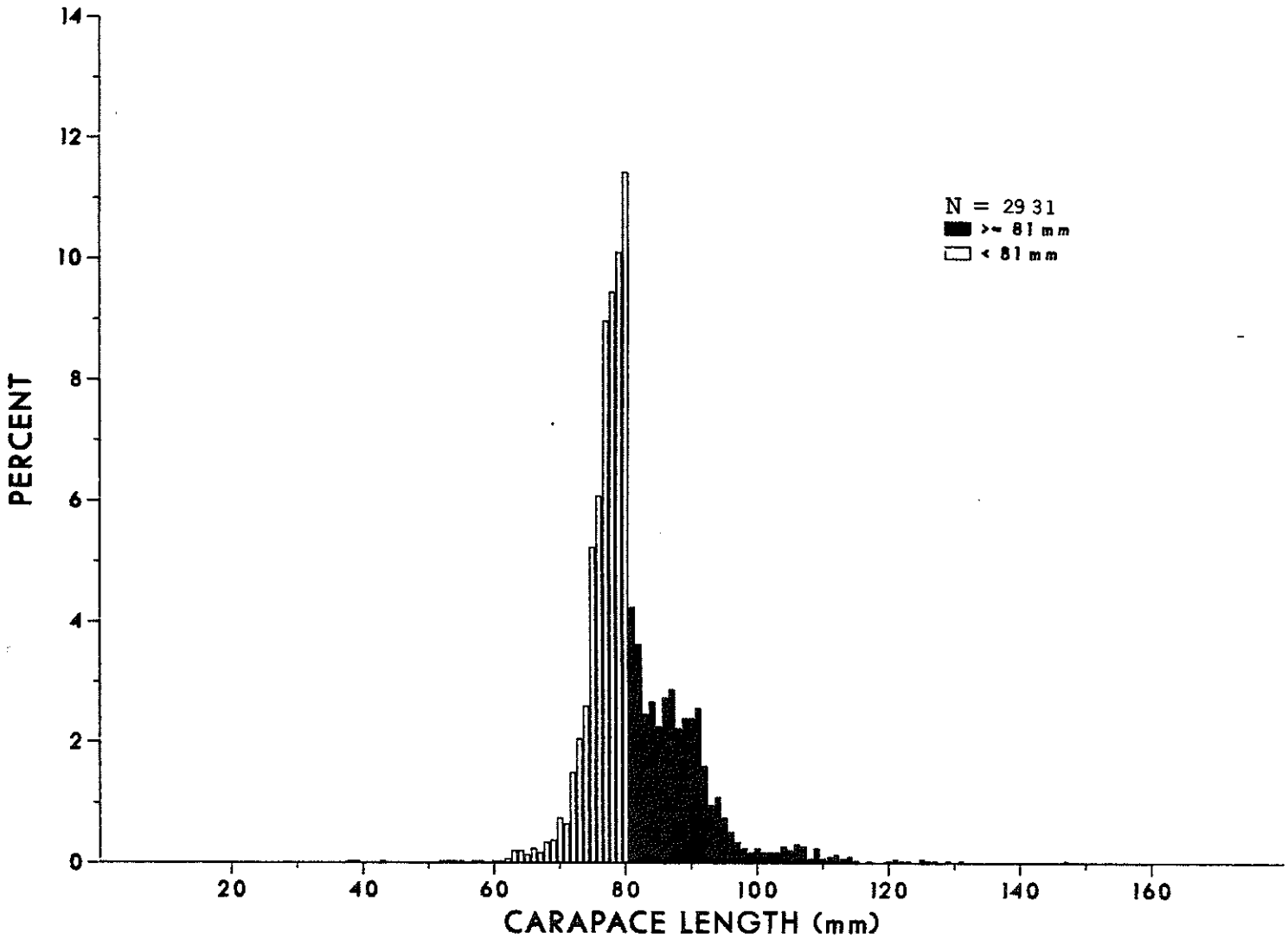

Figure 12. Percent size frequency histogram of all American lobster sampled during August, 1982.

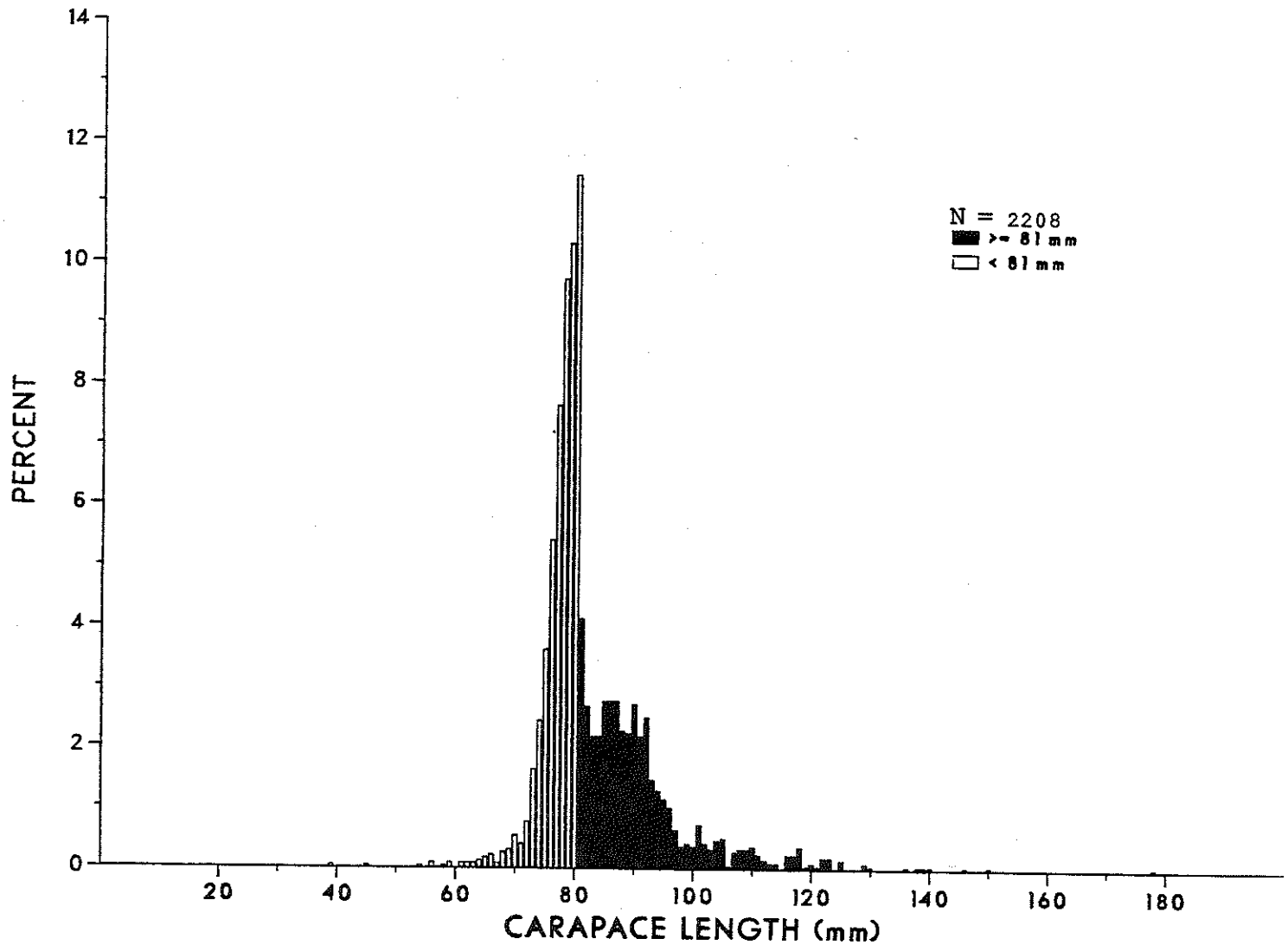

Figure 13. Percent size frequency histogram of all American lobster sampled during September, 1982.

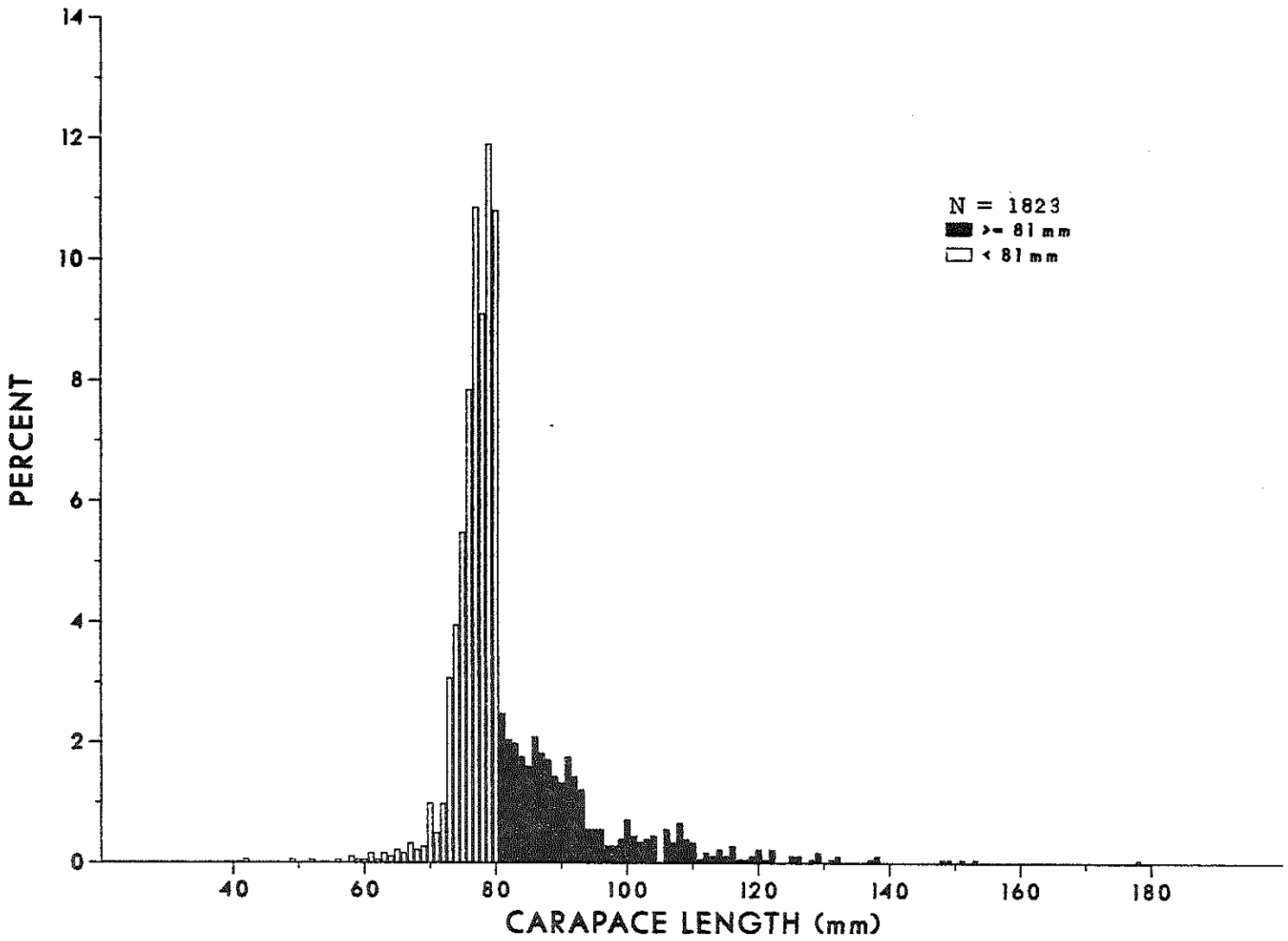

Figure 14. Percent size frequency histogram of all American lobster sampled during October, 1982.

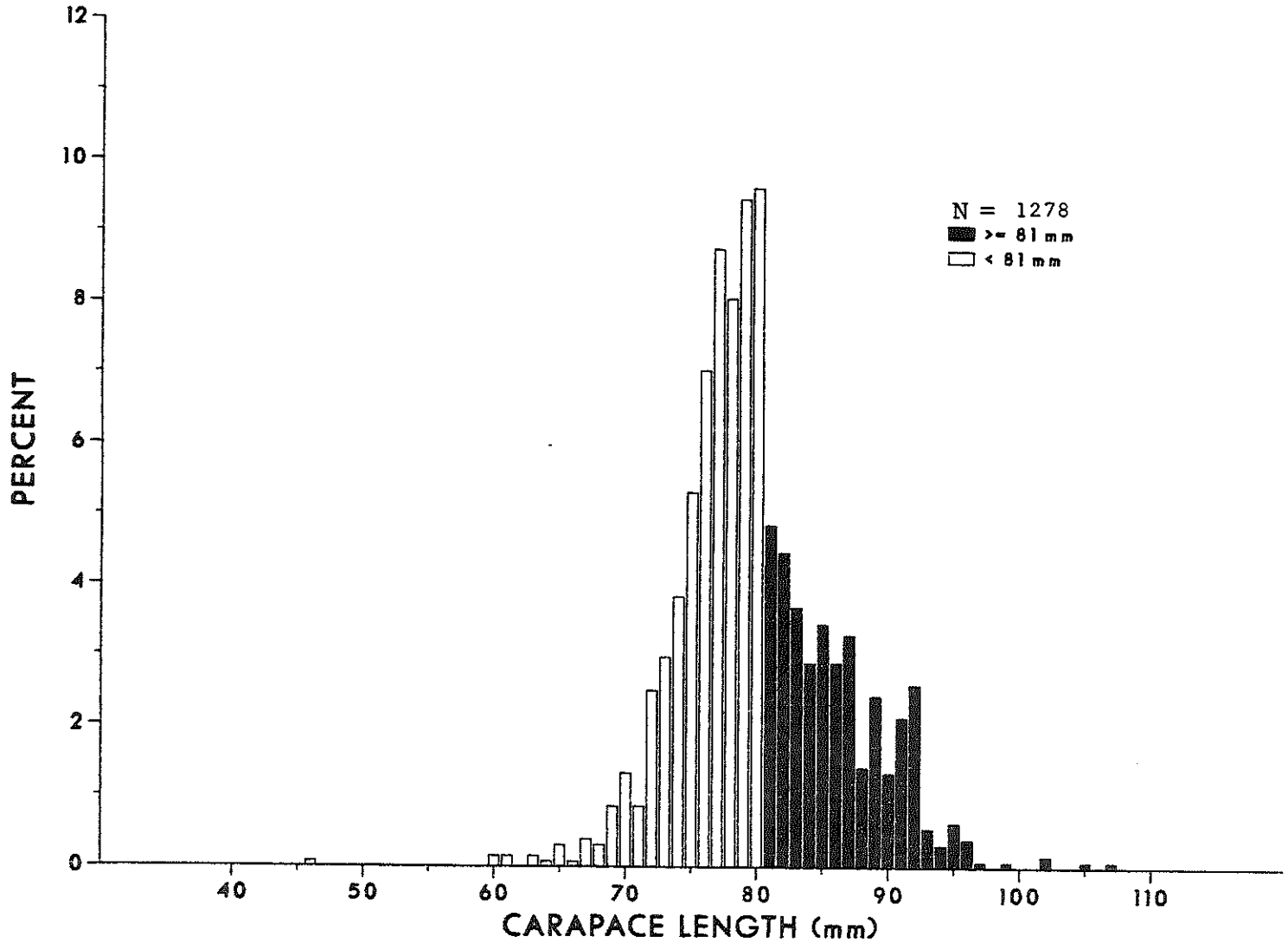

Figure 15. Percent size frequency histogram of all American lobster sampled during November, 1982.

the summer and fall molts. The August peak is significantly different from all other months and may be due to the combined effects of recruitment and seasonal inshore migration of large offshore lobster. Briggs and Mushacke (1980) encountered the greatest number and widest size range of all lobster in July and August off the south shore of Long Island and classified this as an offshore size distribution. The 1981 and 1982 trends are the same except for higher 1982 September and October means which are attributed to enhanced sampling of larger outer Cape Cod region lobster.

Excluding berried females, the average statewide legal carapace length was 89.1 mm. Males averaged 89.6 mm and females 88.5 mm. By region, Cape Ann, Beverly-Salem, and Cape Cod Bay exhibited similar average lengths of 88.0 mm, 87.0 mm, and 86.7 mm, respectively. Outer Cape Cod averaged largest at 97.7 mm and Buzzards Bay smallest at 85.3 mm (Table 5).

Mean statewide carapace lengths for all lobster length categories were significantly different between 1981 and 1982:

	1981	1982	Significance
All lobster	80.4	81.6	$P < 0.001$
All $\geq$ 81 mm	88.9	89.8	$P < 0.001$
$\geq$ 81 mm (less berried females)	88.6	89.1	$P = 0.007$
Sublegal lobster	76.2	76.5	$P < 0.001$

The 1981 and 1982 length frequencies by state and region are presented in Figures 16-21. A greater number of larger lobster were evident in 1982 accounting for the significantly higher mean lengths in that year. This may be the result of the previously discussed harvest reduction in spring 1982 which enhanced the molting stock size. This is indicative of the benefits which could be achieved by an increase in the minimum legal size.

Mortality Estimates

Estimates of total instantaneous mortality (Z) and total annual mortality ($1-e^{Z}$) were computed by each of two methods (Table 10). The method of Gulland (1969) requires computing the slope of the regression line of numbers at estimated age plotted in the natural log. Beverton and Holt's (1957) process employs Von Bertalanffy Growth Equation parameters and mean and minimum length of exploitable sizes:

$$Z - \frac{K(L_\infty - \bar{\ell})}{\bar{\ell} - \ell_c}$$

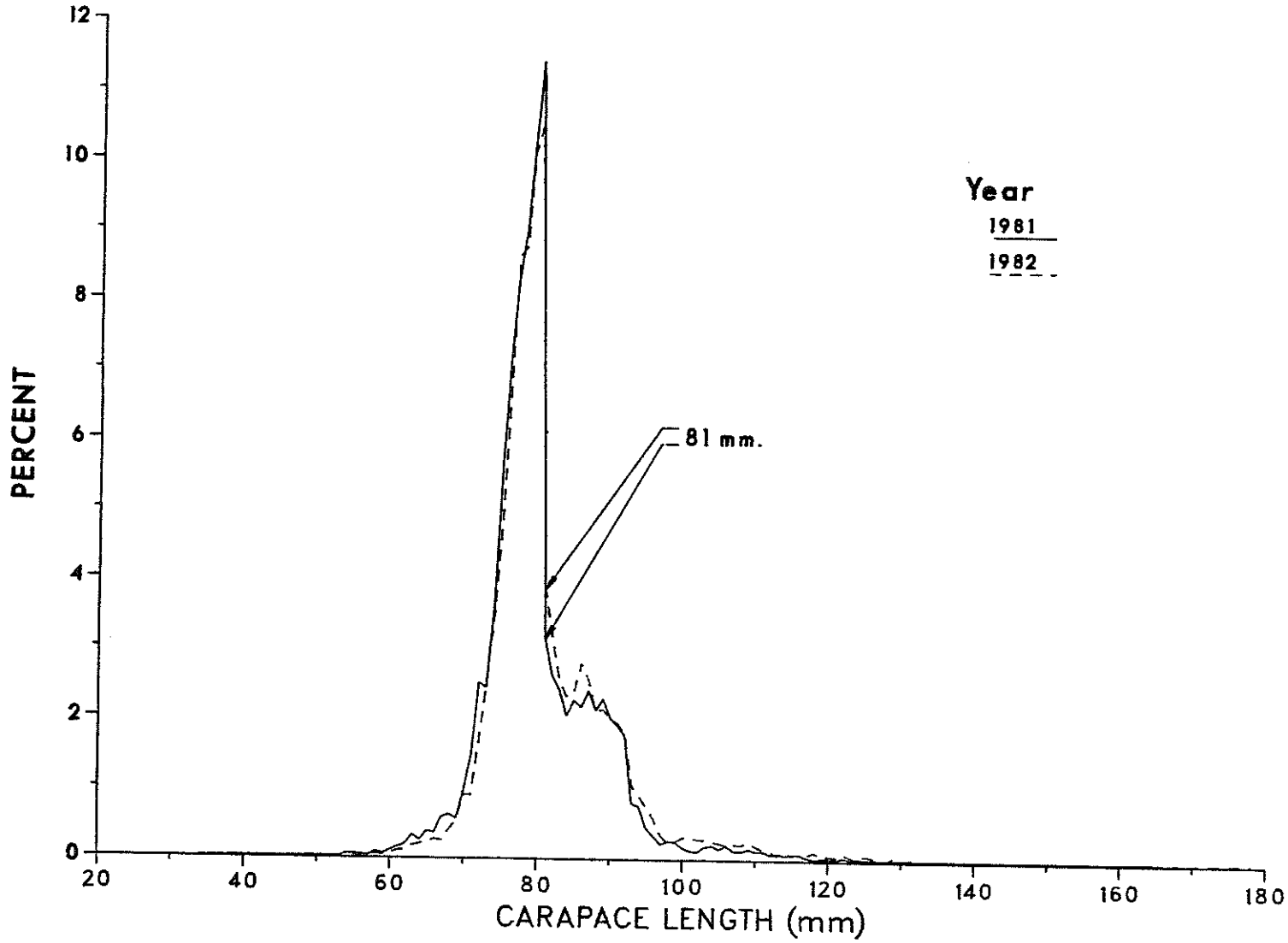

Figure 16. Percent size frequency of American lobster sampled from Massachusetts during 1981 and 1982.

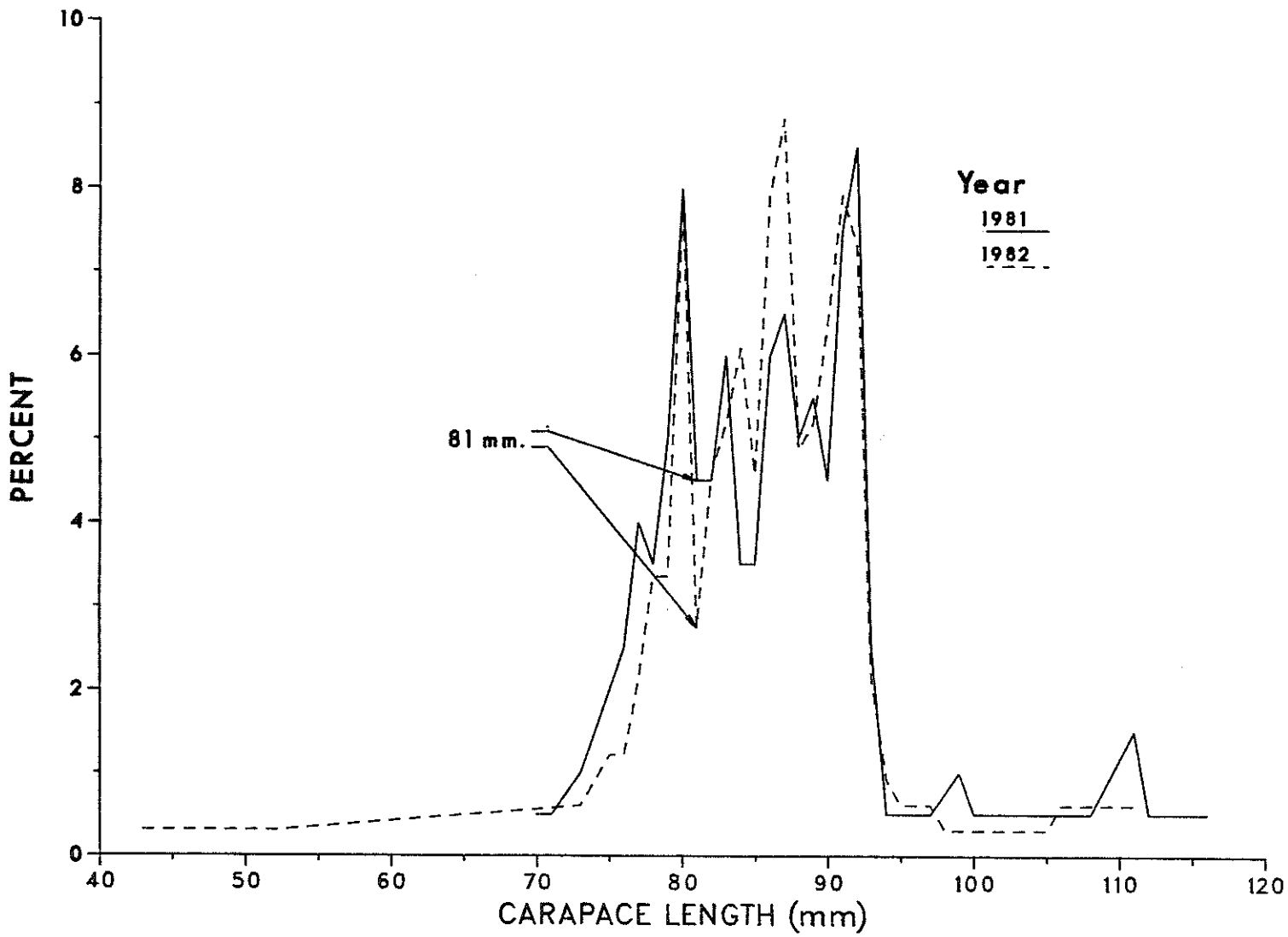

Figure 17. Percent size frequency of American lobster sampled from Cape Ann region during 1981 and 1982.

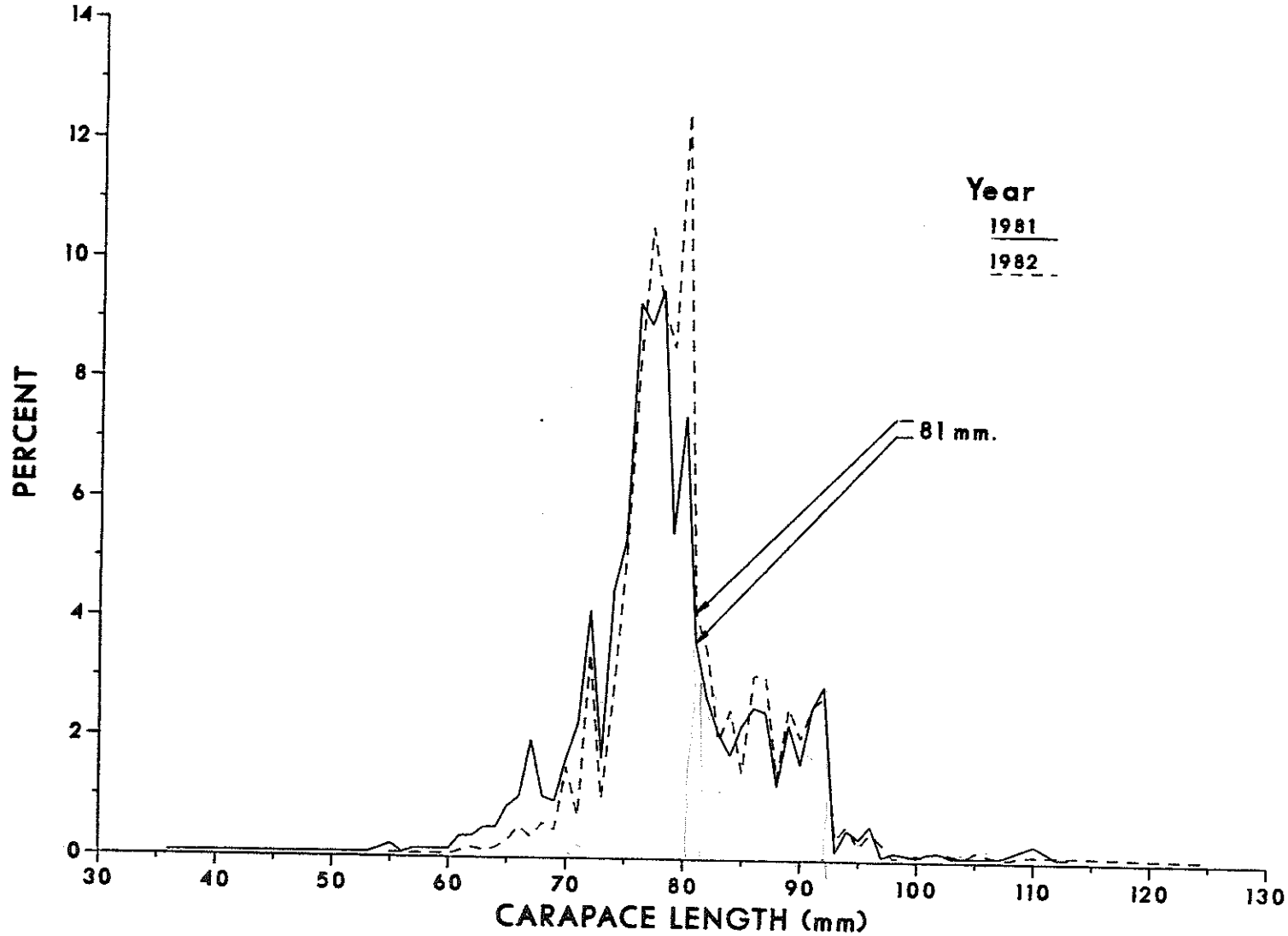

Figure 18. Percent size frequency of American lobster sampled from Beverly – Salem region during 1981 and 1982.

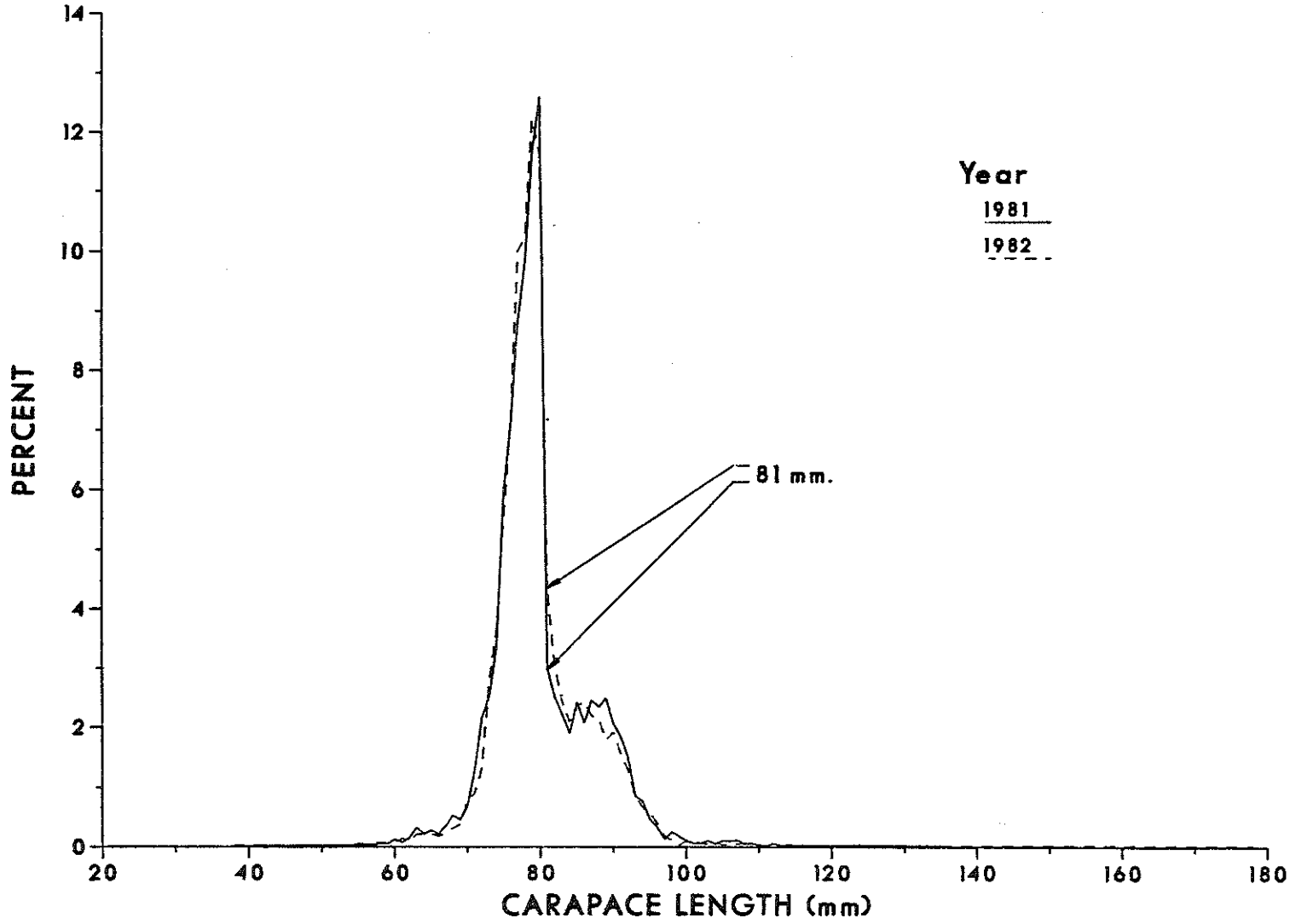

Figure 19. Percent size frequency of American lobster sampled from Cape Cod Bay region during 1981 and 1982.

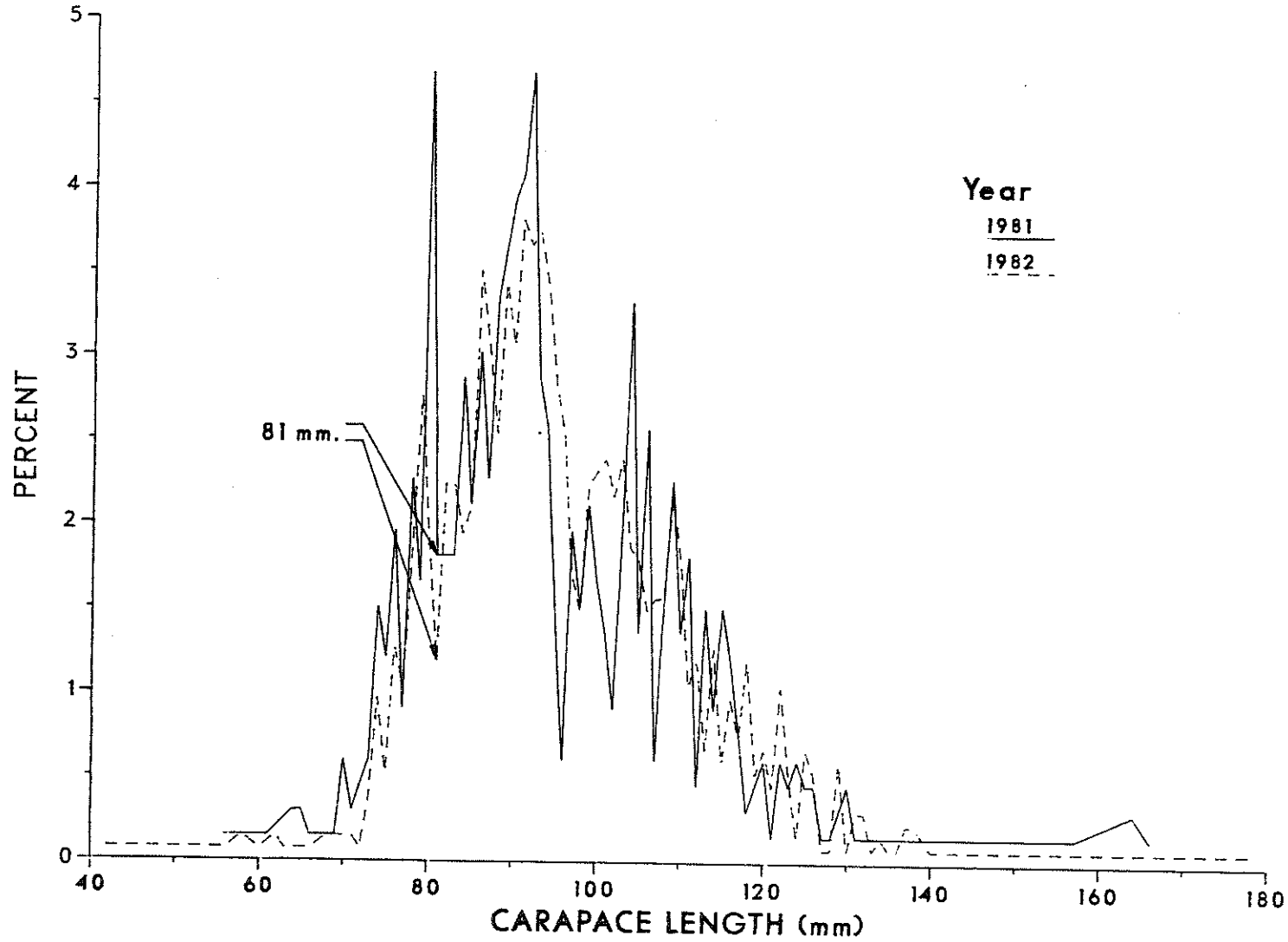

Figure 20. Percent size frequency of American lobster sampled from outer Cape Cod region during 1981 and 1982.

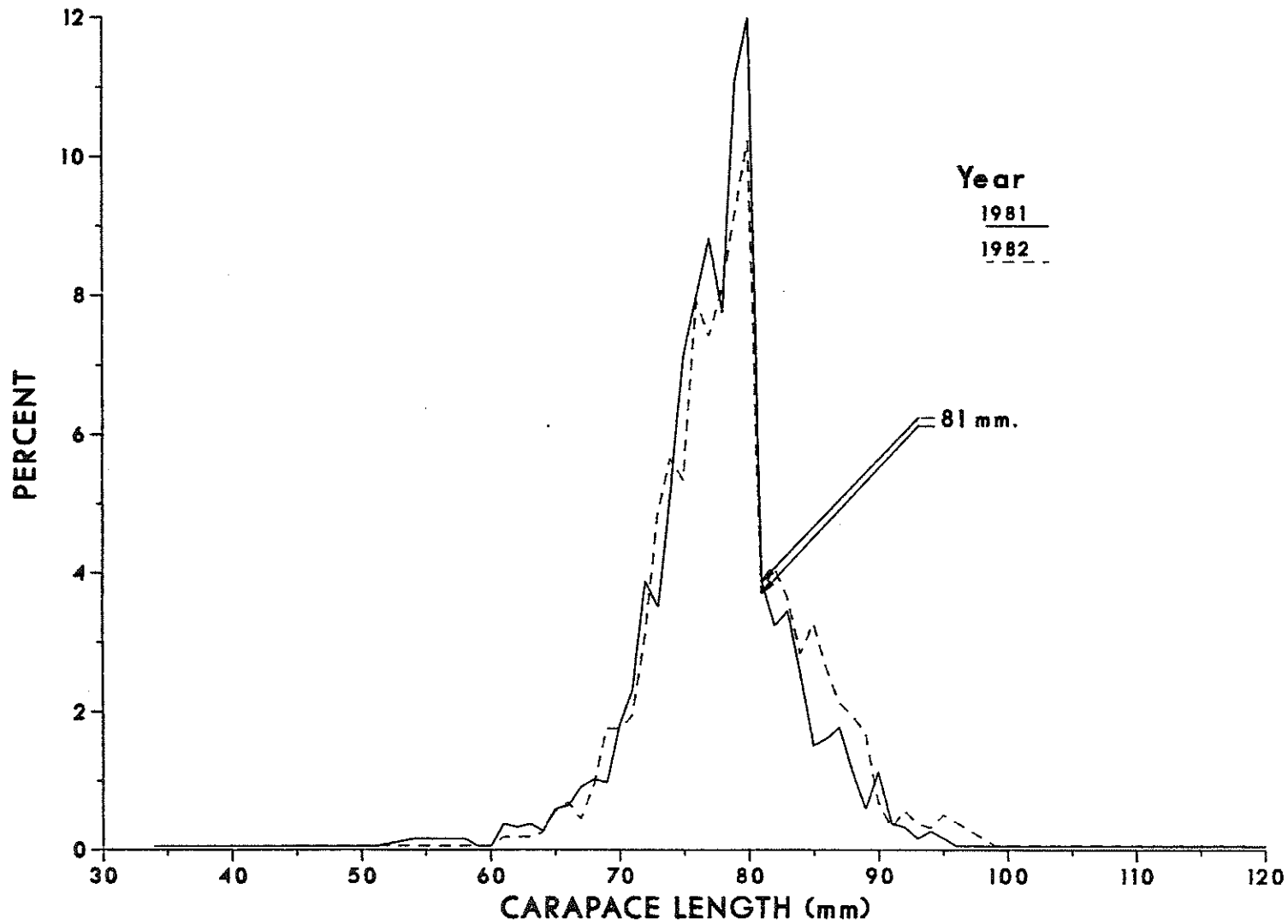

Figure 21. Percent size frequency of American lobster sampled from Buzzards Bay region during 1981 and 1982.

where

K = growth rate constant
L_∞ = asymptotic length
$\bar{\ell}$ = mean length of exploitable sizes
ℓ_c = minimum exploitable size

Fourteen percent molt groups derived from 1982-83 Buzzards Bay tagging results were used to represent annual growth increments in that embayment and fifteen percent molt groups and Von Bertalanffy Growth Equation parameters derived from Cape Cod Bay tagging results ($K = 0.0634$, $L_\infty = 253$ mm, Fair 1977) were used in other regional and statewide estimates.

Results of Gulland's method tend to be slightly higher than those of Beverton and Holt's for all regions except outer Cape Cod. Considering the high level of effort in most of the inshore area, the higher estimates seem more realistic. Nevertheless, results of the two methods were averaged for regional and yearly comparisons.

Mean total annual mortality rates for Beverly-Salem and Cape Cod Bay regions were almost identical within 1981 and 1982. Cape Ann rates were lower than these regions, which may be due to the availability of only postmolt sampling data for Cape Ann and/or greater offshore population influence than in the other, more inshore, Gulf of Maine regions. Mean total annual mortality estimates for all Gulf of Maine regions increased from 1981 (80%) to 1982 (85%); however, outer Cape Cod and Buzzards Bay regional mean rates decreased slightly over the same time period (38% to 34% and 94% to 92%, respectively). It is not possible to assess the significance of this mortality rate variation with only two sample years; however, regional mean lengths were significantly different for the two years. Preliminary 1983 catch rate calculations for these regions have to date exhibited an inverse relationship to the 1981-82 mortality trend, while the size of the prerecruit molt groups (67-80 mm) in 1981 and 1982 indicated relatively stable recruitment for the study period.

	1981	1982
State	64.8%	60.0%
Cape Ann	25.0%	19.8%
Beverly-Salem	64.1%	64.8%
Cape Cod Bay	67.5%	67.3%
Outer Cape Cod	16.5%	11.4%
Buzzards Bay	74.5%	68.6%

The Cape Cod Bay estimates of total instantaneous mortality, $Z = 2.05$, and total annual mortality, 87%, in 1981, and 2.36 and 91%, respectively in

1982, as calculated by Gulland's procedure approximate 7-year means calculated from length frequency data by Fair (1977) for the same region and by the same method, 2.1496 and 88.35%.

The statewide estimate of Z was 1.42 (76%) in 1981 and 1.26 (72%) in 1982. These were considerably lower than that recommended for the Massachusetts inshore lobster population, southern Gulf of Maine region, (Z = 2.3, 90%) by Fair (1977) because of the inclusion in the present study of length frequency data from the less exploited outer Cape Cod population.

Maturity

Percent Ovigerous

Of all females captured statewide, 6.9% were ovigerous (berried). Among legal and sublegal female size groups, 13.4% and 3.4%, respectively, were berried ($P < 0.001$, Table 11).

By region, the largest percentage of females ovigerous, 26.2%, was encountered in the outer Cape Cod region, followed by Buzzards Bay, 17.9%; Cape Ann, 3.5%; Cape Cod Bay, 3.1%; and Beverly-Salem, 2.4%. The percentages of legal and sublegal females ovigerous were also typically low in Gulf of Maine regions (Cape Ann, Beverly-Salem, and Cape Cod Bay) and highest in the southernmost regions off outer Cape Cod and Buzzards Bay.

The statewide percentage of all females ovigerous peaked in May, declined during summer months as a result of the hatching process, and increased again during autumn months, attributable to newly extruded egg masses ($P < 0.001$, Table 12). Sublegal and legal trends were similar. Both 1981 and 1982 seasonal trends were parallel, except that September and October, 1982 values were slightly higher due to enhanced sampling off outer Cape Cod.

Regional indices by month for combined length categories (Table 13) indicate that peaks occurred in May and September in Buzzards Bay, and in June and October in Cape Cod Bay. Results of larval lobster sampling from 1976-1978 indicated that hatching commenced in late May and larval densities peaked in late June in Buzzards Bay and southern Cape Cod Bay (Collings 1981). Outer Cape Cod "eggers" peaked in May, declined in June and then increased steadily from July through October. Index peaks were probably delayed as a result of the inshore migration of offshore berried females (Briggs and Mushacke 1980; Morrissey 1971).

Buzzards Bay exhibited a large percentage of sublegal females ovigerous in May, 19.0%, and September, 22.7%, while 19.2% and 45.9% of legal sized females were ovigerous in May and September, respectively (Table 14).

Table 15 indicates that of all ovigerous females captured statewide (N = 525), 67.2% were legal sized and 32.8% were sublegal sized. By region, Buzzards Bay exhibited the greatest percentage of sublegal berried females, 59.1%, followed by Cape Cod Bay, 46.8%; Beverly-Salem, 37.5%; Cape Ann, 16.7%; and outer Cape Cod, 1.0%. Figure 22 emphasizes the similarity between Cape Ann and

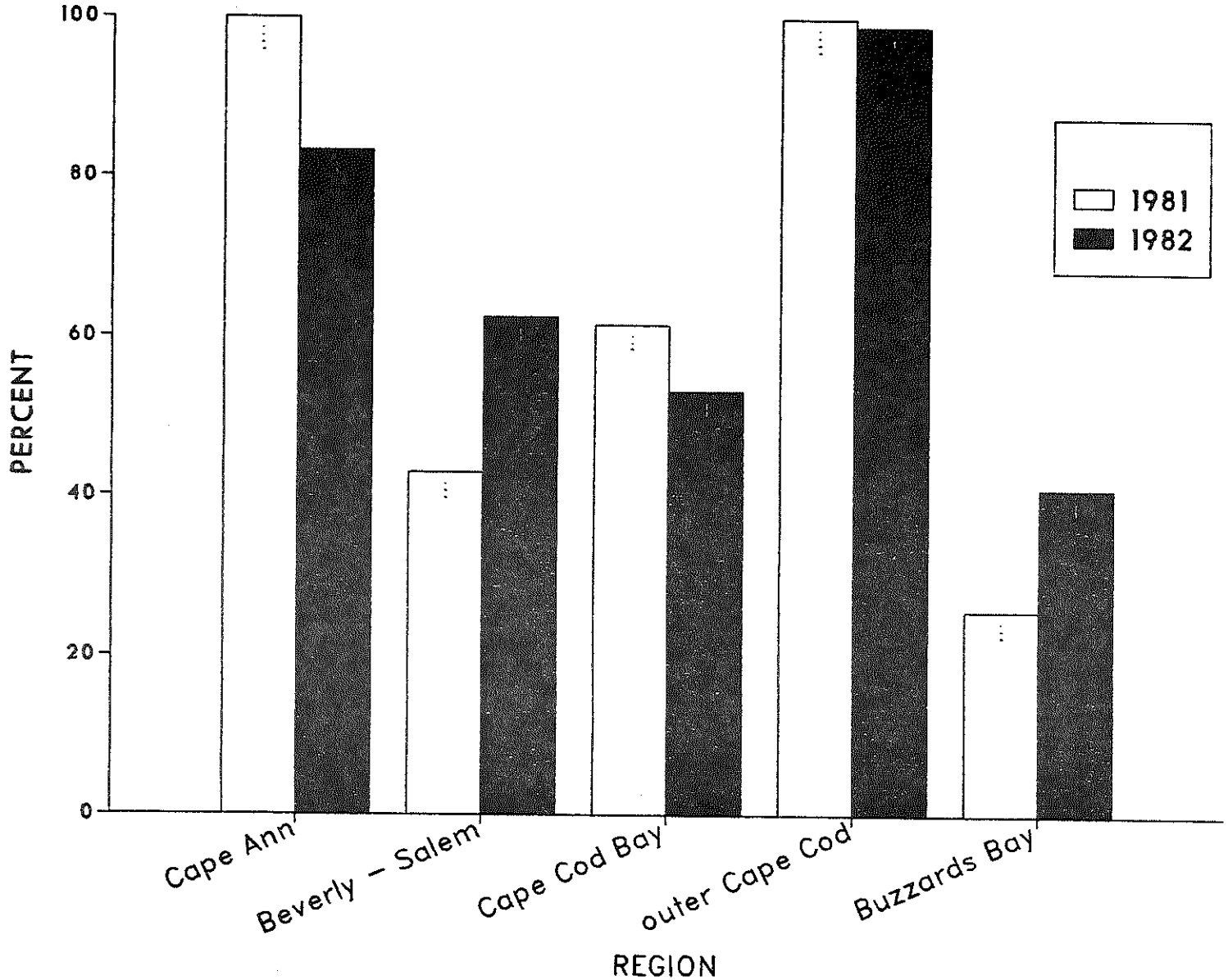

Figure 22. Percent of ovigerous female American lobster greater than or equal to 81 mm by region and year, Massachusetts coastal waters, 1981–1982.

outer Cape Cod regions in the percent of ovigerous females which were ≥ 81 mm. Beverly-Salem and Cape Cod Bay values also appear similar.

There is no statistically significant difference in the percent of females ovigerous between 1981 and 1982 surveys (P = 0.818):

	1981	1982
State	5.8%	6.9%
Cape Ann	1.7%	3.5%
Beverly-Salem	1.8%	2.4%
Cape Cod Bay	3.8%	3.1%
Outer Cape Cod	12.4%	26.2%
Buzzards Bay	16.6%	17.9%

Carapace Length of Ovigerous Females

The statewide average carapace length of egg-bearing females was 92.0 mm and ranged from 66 to 153 mm. Those in the legal size category (≥ 81 mm) averaged 99.0 mm while sublegals (< 81 mm) averaged 77.6 mm (Table 16, Figure 23).

By region, outer Cape Cod exhibited the largest average berried female length of 107.0 mm, followed by Cape Ann, 95.8 mm; Beverly-Salem, 86.2 mm; Cape Cod Bay, 85.2 mm; and Buzzards Bay, 80.4 mm. Sublegal berried females averaged 80.0 mm off Cape Ann (one specimen), 78.2 mm in Cape Cod Bay, 78.1 mm in Beverly-Salem, and 77.0 mm in both outer Cape Cod and Buzzards Bay regions. Cape Ann and outer Cape Cod regions exhibited the largest average legal lengths of 99.0 mm and 107.4 mm, respectively, followed by Cape Cod Bay, 91.3 mm; Beverly-Salem, 91.1 mm, and Buzzards Bay, 85.4 mm (Table 16). Regional and statewide length frequency histograms of berried females are presented in Figures 24-28. Size frequency distributions of ovigerous females sampled in both 1981 and 1982 were similar (Figure 29). The greater frequency of ovigerous females larger than 98 mm carapace length in 1982 was due to enhanced sampling effort during September and October when newly extruded egg masses were prevalent.

In western Long Island Sound, an area comparable to Buzzards Bay in depth, similarly warm average water temperature, and restricted access, Briggs and Mushacke (1979) computed a similar average berried female length of 80 mm (range 64-120 mm). While investigating the pot fishery on the south shore of Long Island, Briggs and Mushacke (1980) calculated an average berried female length of 99 mm (range 78-135 mm) and found only nine sublegal "eggers". Size distribution in this area was thought to reflect mixing of large offshore migrants. This relatively open area with a greater depth range is comparable to outer Cape Cod and Cape Ann regions which exhibited similarly large average egg-bearing female lengths with only three ovigerous females < 81 mm captured

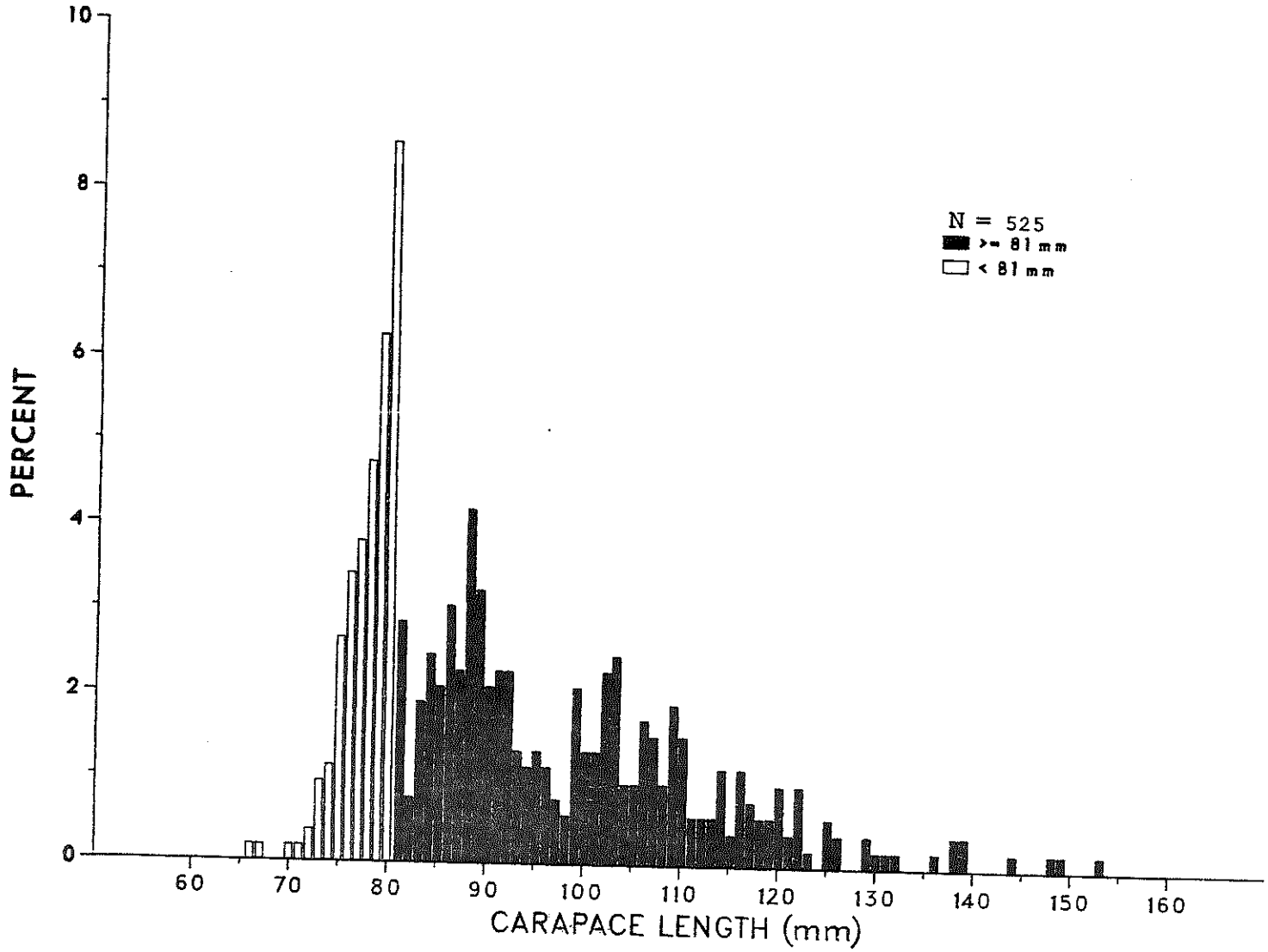

Figure23. Percent size frequency histogram of ovigerous female American lobster sampled from Massachusetts in 1982.

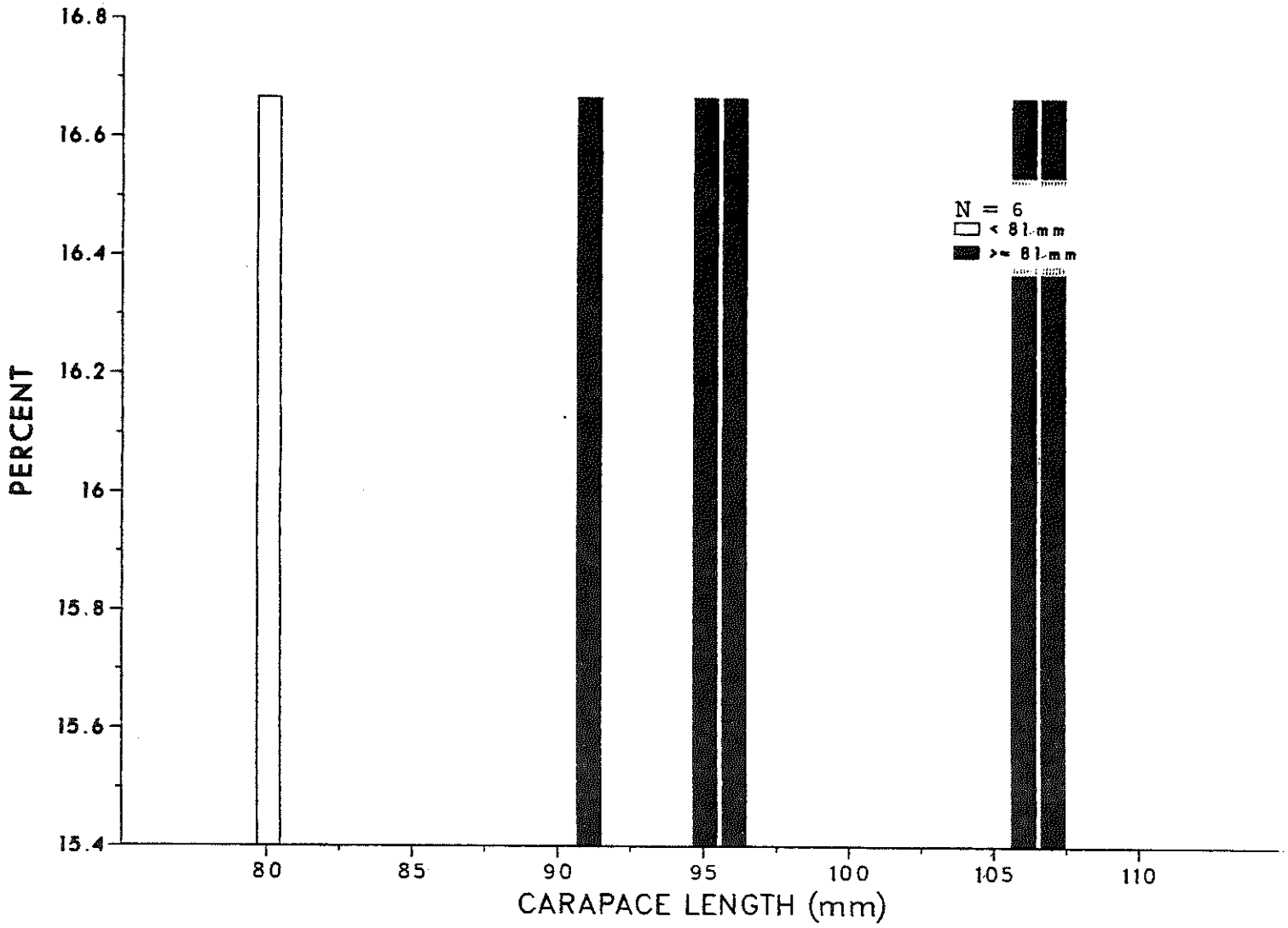

Figure 24. Percent size frequency histogram of ovigerous female American lobster sampled from Cape Ann region in 1982.

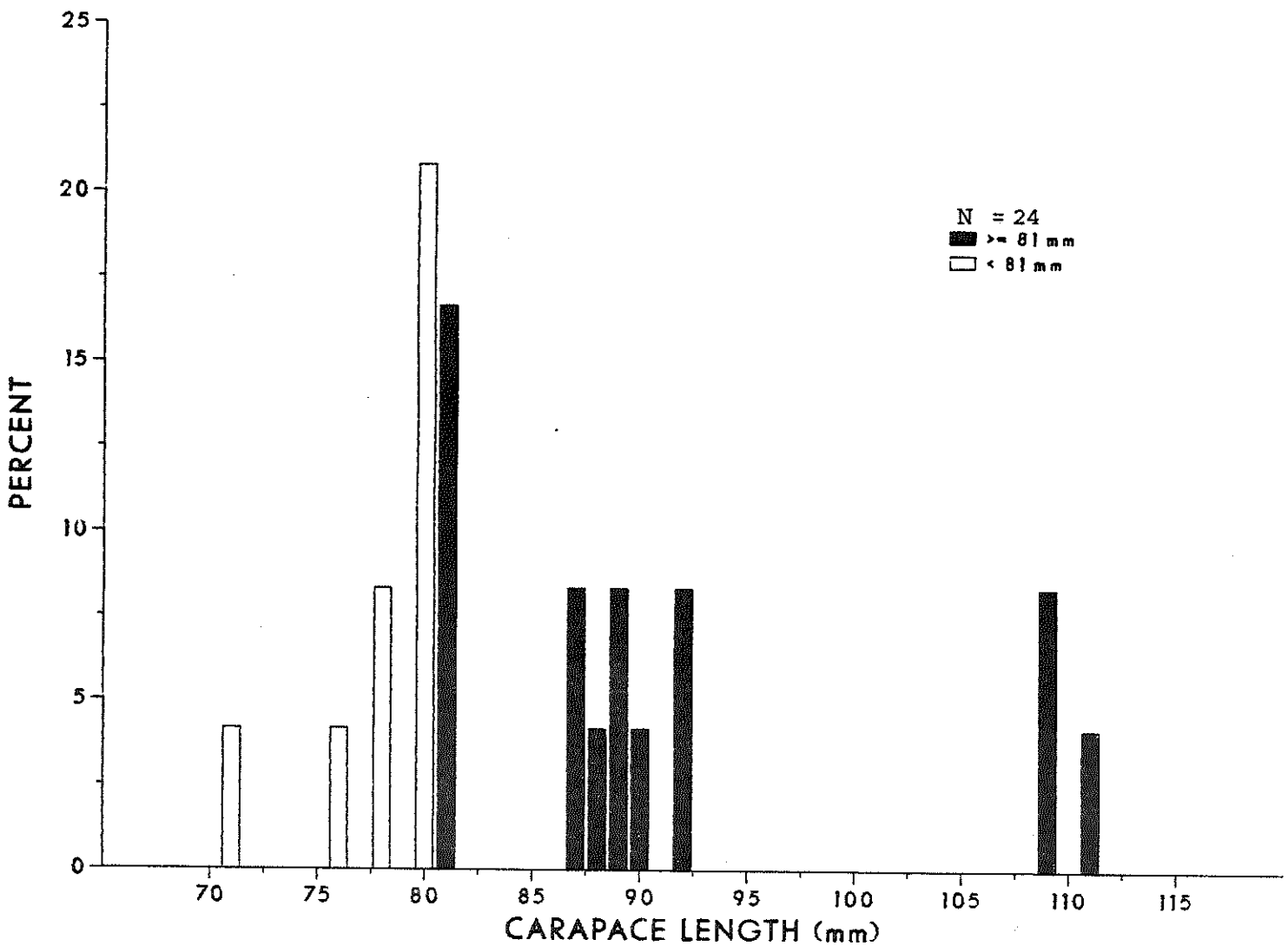

Figure 25. Percent size frequency histogram of ovigerous female American lobster sampled from Beverly – Salem region in 1982.

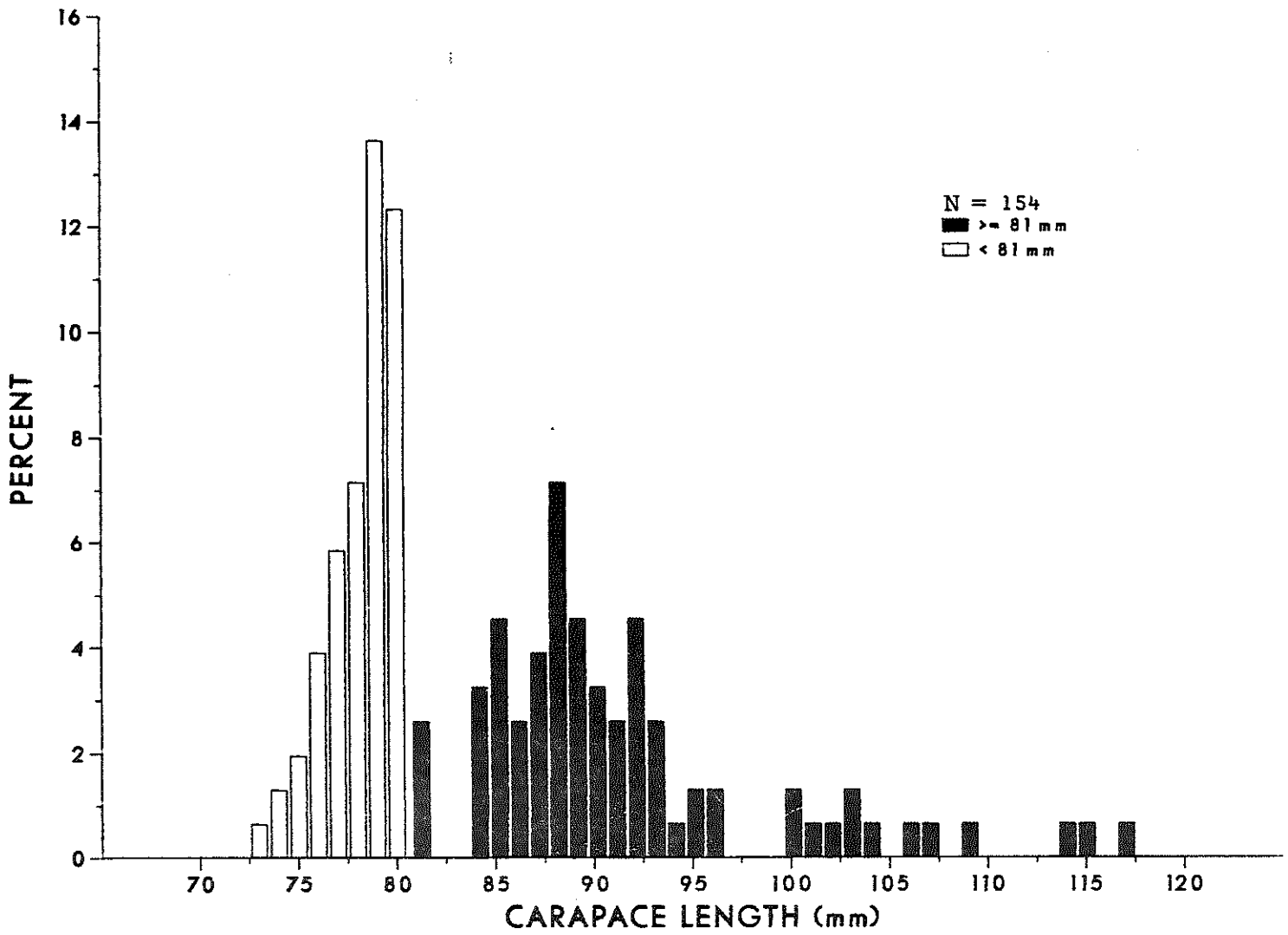

Figure 26. Percent size frequency histogram of ovigerous female American lobster sampled from Cape Cod Bay region in 1982.

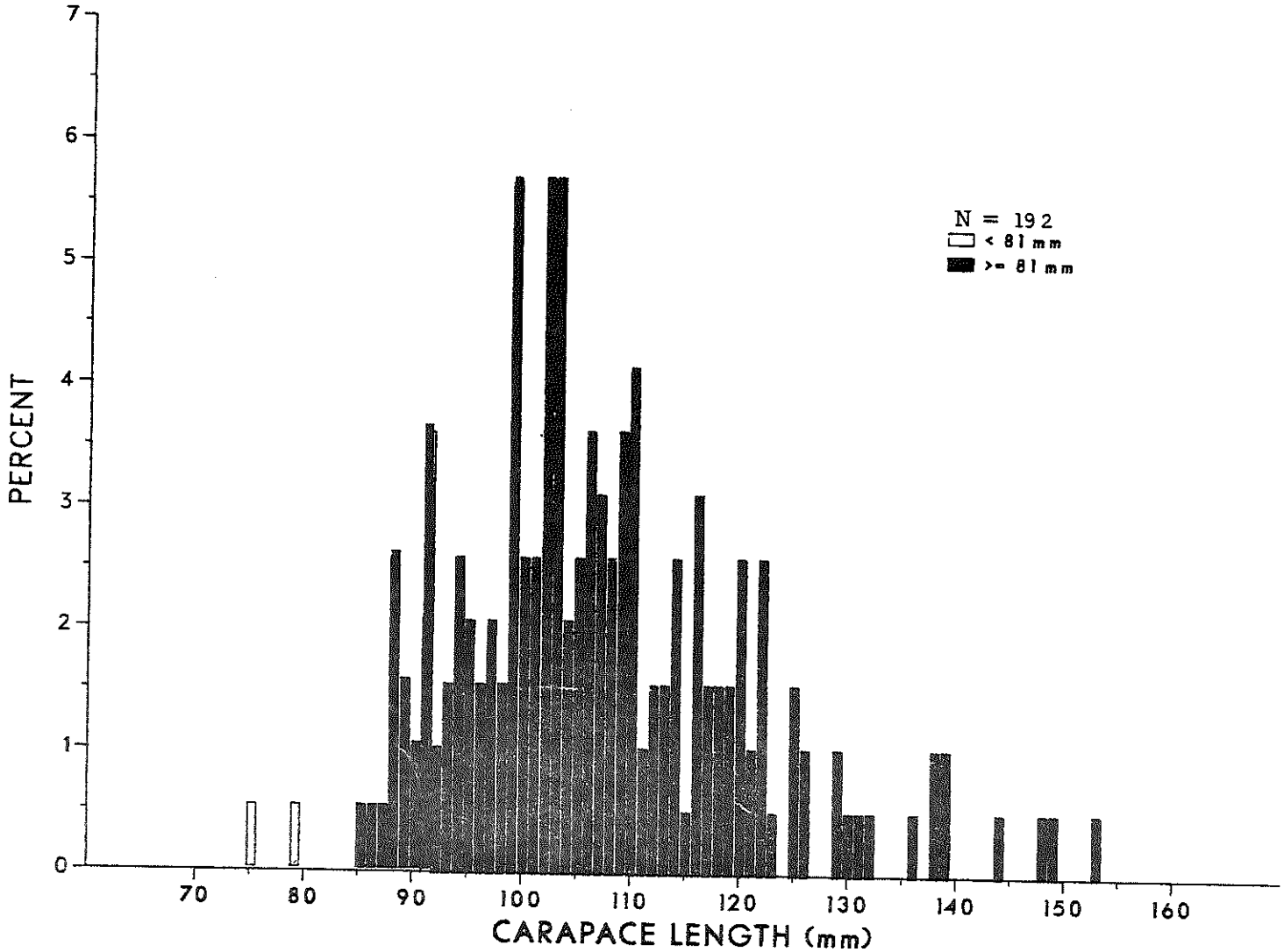

Figure 27. Percent size frequency histogram of ovigerous female American lobster sampled from outer Cape Cod region in 1982.

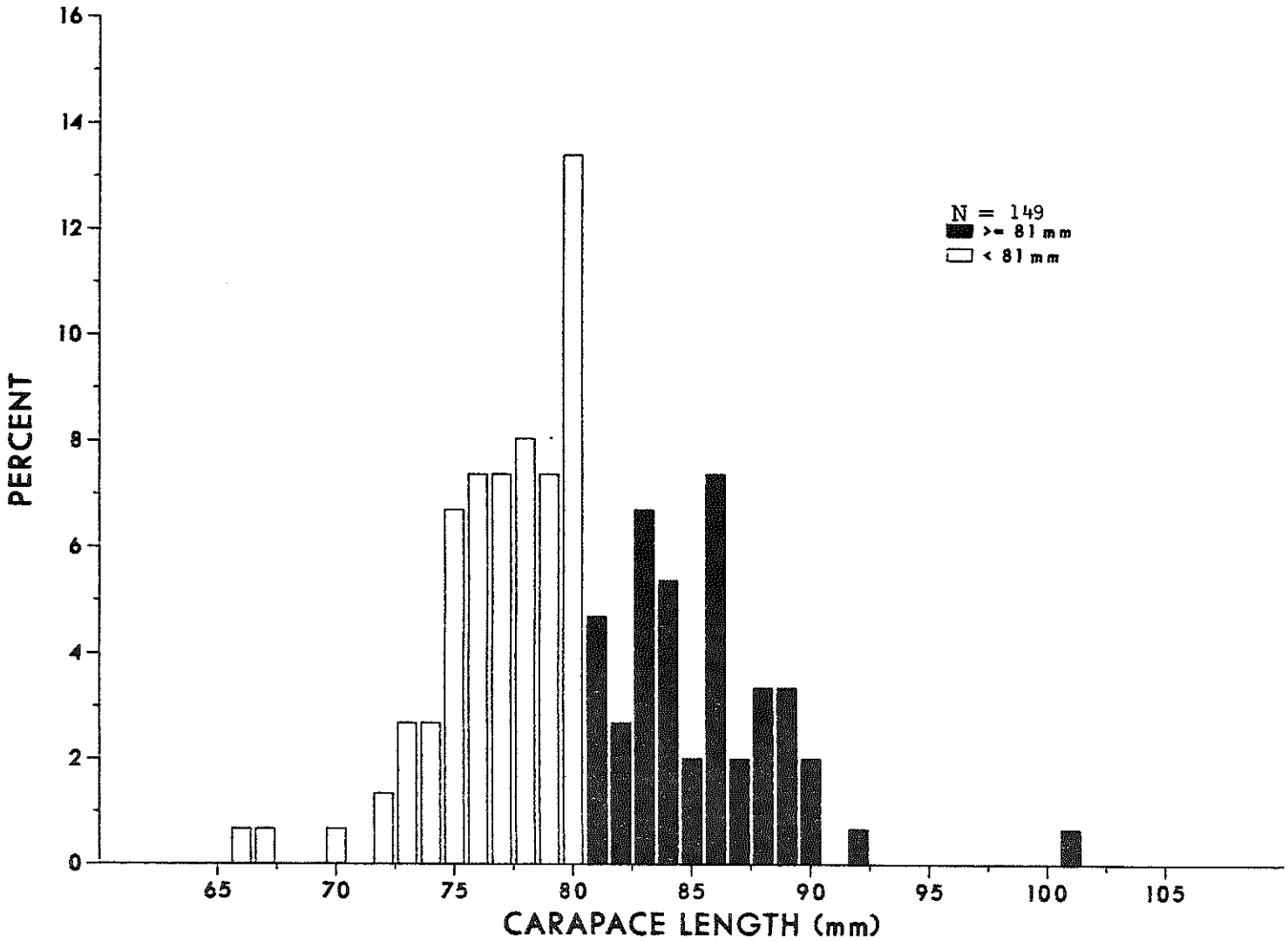

Figure 28. Percent size frequency histogram of ovigerous female American lobster sampled from Buzzards Bay region in 1982.

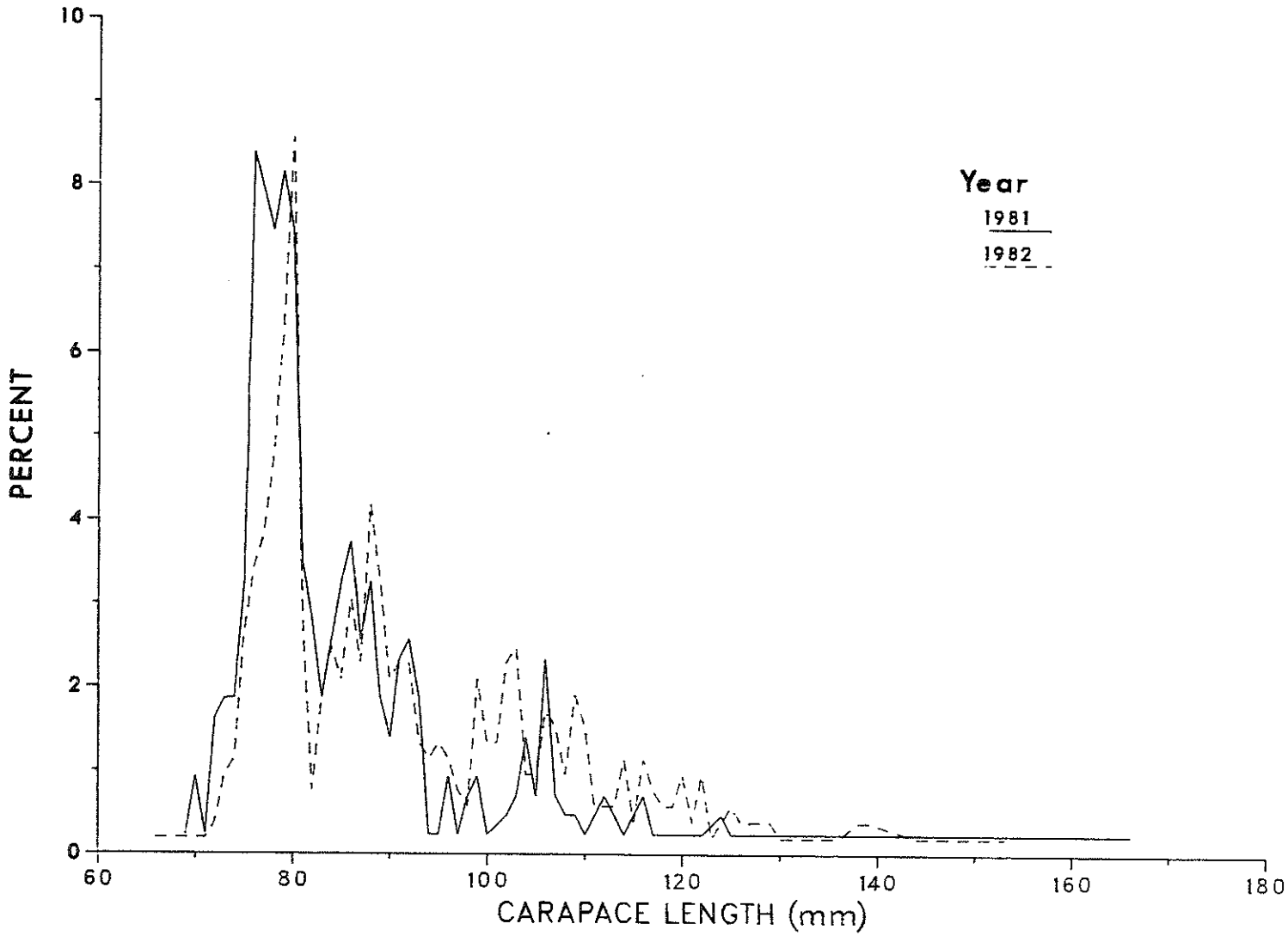

Figure 29. Percent size frequency of ovigerous female American lobster sampled from Massachusetts during 1981 and 1982.

during both 1981 and 1982 surveys. The seasonal influence of an offshore migrant population in the outer Cape Cod region has been documented (Morrissey 1971) and Dow (1974) described the movement of large lobster, tagged off the Maine coast, into Massachusetts waters. In addition, tagged lobster which were released off the New Brunswick coast have been recaptured by Massachusetts inshore lobstermen; data collected prior to 1981 were reported by Campbell (1982).

Size at Maturity

Analysis of ovigerous female length frequency has been used to provide a relative index of sizes at first maturity and 100% maturity (Briggs and Mushacke 1979, Briggs and Mushacke 1980, Krouse 1973, Marcello et al. 1979, Russell et al. 1978, Thomas 1973, Skud and Perkins 1969). Aiken and Waddy 1980a, and Van Engel 1980 discuss its relative merits. However, when employing this technique, one must distinguish between the definitions of size at 50% maturity (the management objective when considering size limits) and size at 50% ovigerous. Size at which 50% of females are ovigerous is theoretically equal to size at 100% maturity. It is apparent from a review of the literature that not all females are mature after reaching the size at first maturity, nor are all females ovigerous when mature. Depending upon the region, the proportion of females ovigerous may be affected by fishing pressure. Some female lobster may be removed from the population before they have the opportunity to reach maturity or extrude eggs, thereby depressing the proportion ovigerous at a given size and escalating the estimated size at 50% maturity. Also, resorption of lipovittelin occurs commonly with varying intensity and may be related to unfavorable conditions encountered near the expected time of oviposition or the dominance of ecdysis over oviposition when the cycles coincide (Aiken and Waddy 1980b). Unlike spent ovaries, however, resorption requires only a one-year recovery period compared to two years before complete ovarian maturation is again possible. A further complication affecting maturity estimates lies in the fact that size classes may contain more than one age class. Consequently, accuracy of maturity estimates may be improved through combining several annual survey data sets.

Both 1981 and 1982 survey data sets were merged and the percentage of females ovigerous was calculated by 5 mm intervals to reduce variability. These data were plotted by region with Gulf of Maine regions (Cape Ann, Beverly-Salem, and Cape Cod Bay) combined due to data similarities (Figures 30-32). The relationship of the ratio of second somite width to carapace length with carapace length was superimposed on these graphs in order to substantiate maturity estimates previously made from length frequency analyses (Estrella 1983). Inflection points, designated by arrows on graphs of the second somite width to carapace length relationship indicate sizes at onset of maturity and 100% maturity (Templeman 1935). These points correspond closely with size at first ovigerous observation and size following which most females were ovigerous.

It is evident that the conditions of high fishing mortality in the Massachusetts inshore area indeed depressed the graphs of the percentage of females ovigerous at length; however, the size at 100% maturity may still be discerned by the initial "plateau" depicted in the plots.

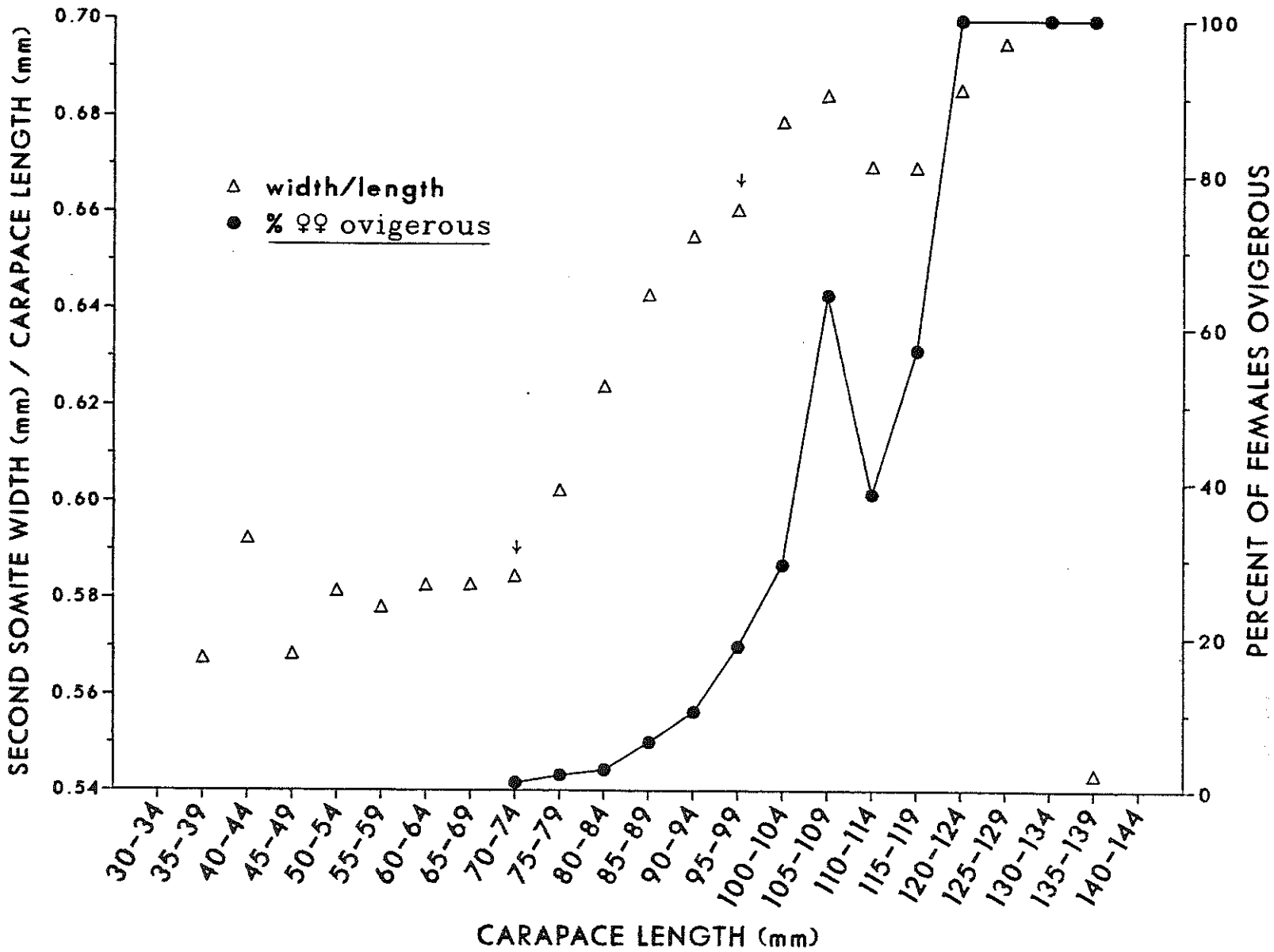

Figure 30. Percent of American lobster females ovigerous, 1981-1982, and relationship of the ratio of second somite width and carapace length to carapace length, 1980-1983, Gulf of Maine regions.

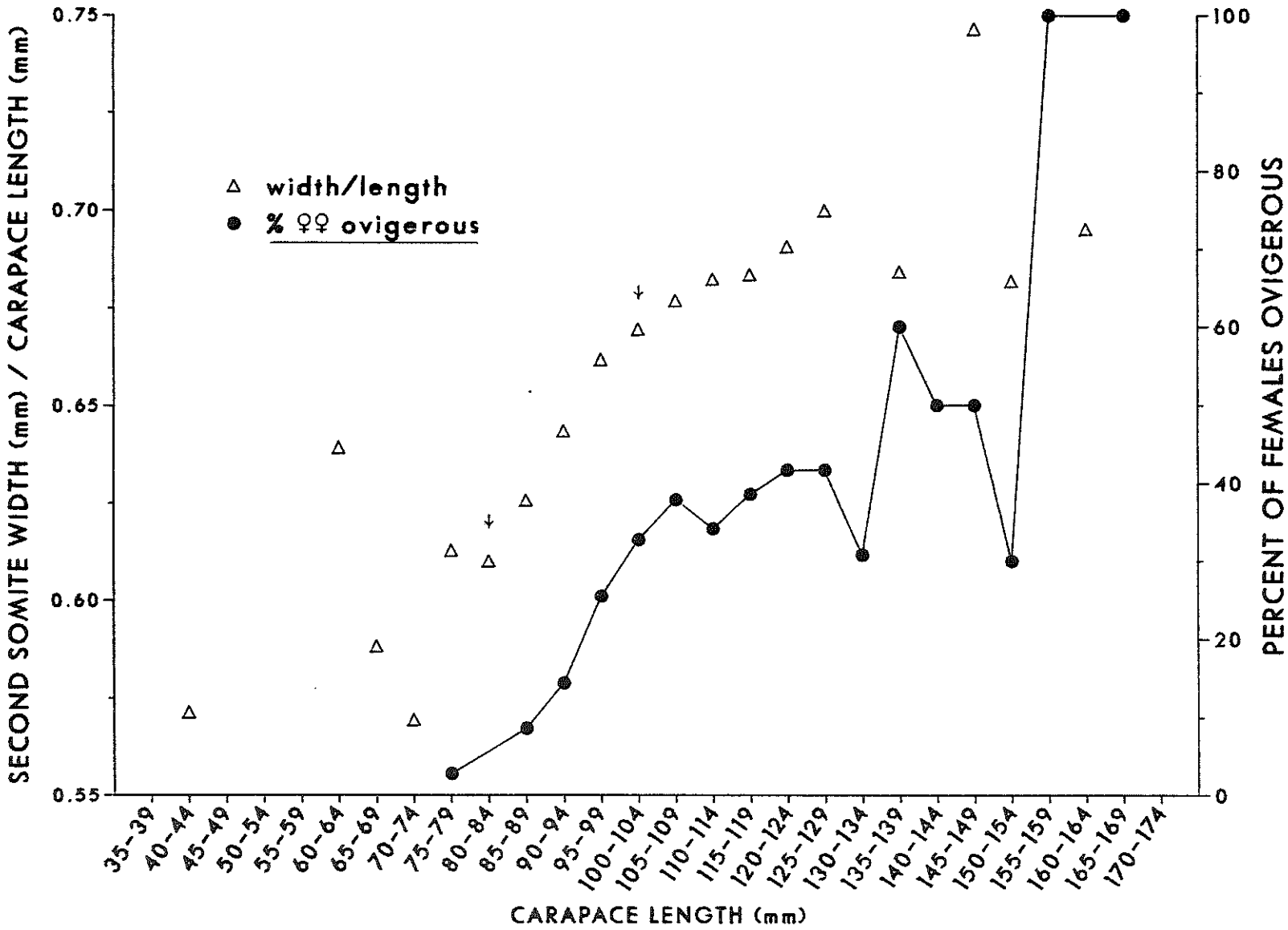

Figure 31. Percent of American lobster females ovigerous, 1981-1982, and relationship of the ratio of second somite width and carapace length to carapace length, 1980-1983, outer Cape Cod region.

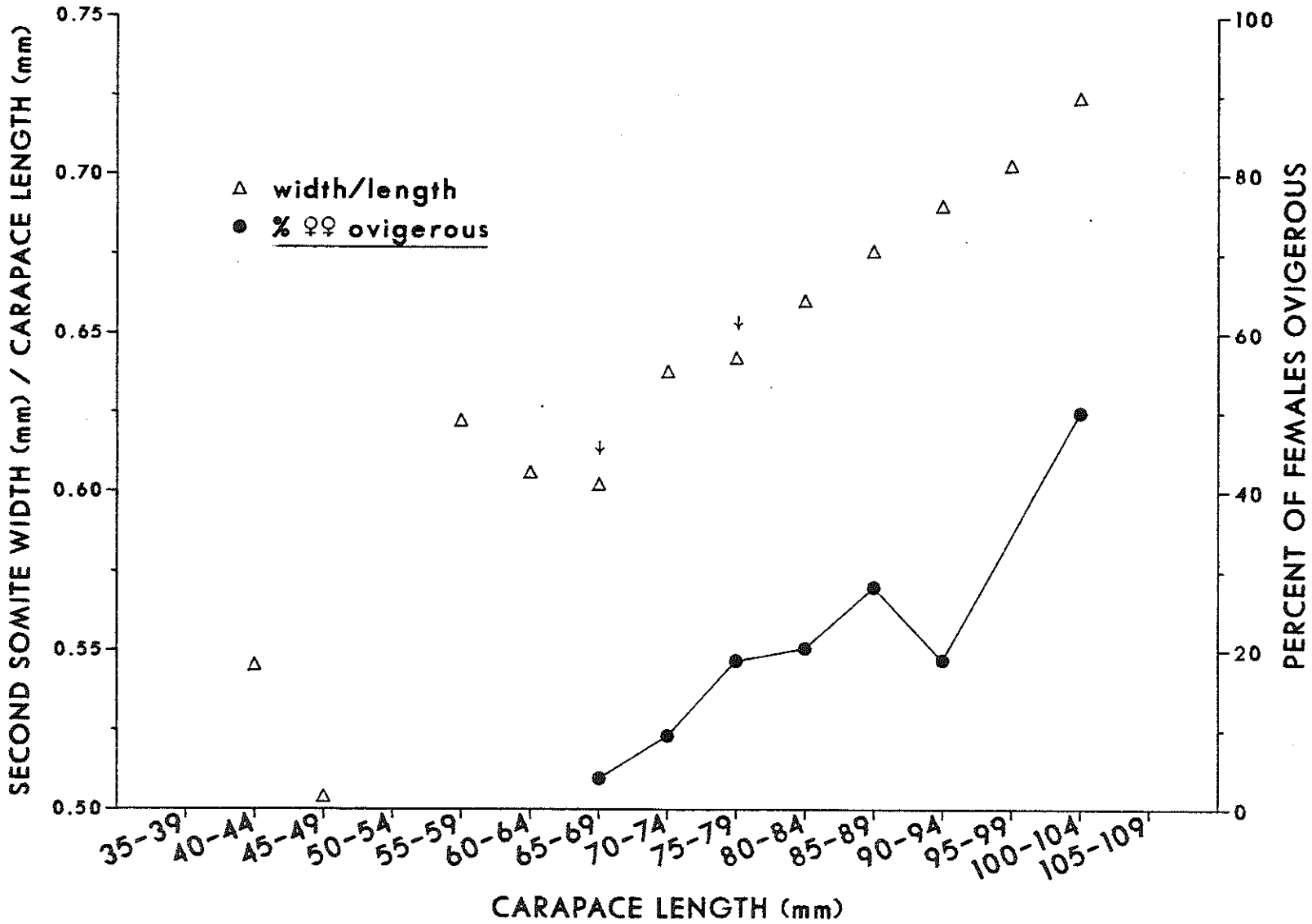

Figure 32. Percent of American lobster females ovigerous, 1981-1982, and relationship of the ratio of second somite width and carapace length to carapace length, 1980-1983, Buzzards Bay region.

Based on second somite width analysis, size at first maturity in Gulf of Maine regions occurred at 70-74 mm. Even though the smallest berried female captured off Cape Ann was 80 mm, 71 and 70 mm berried females were captured in Beverly-Salem and Cape Cod Bay, respectively. It is possible that more intensive sampling in the Cape Ann region may lower the minimum observed size there. Size at 100% maturity was 95-99 mm.

Size at first maturity from the outer Cape Cod region was between 80-84 mm, however, the smallest berried specimen observed was 75 mm. Size at 100% maturity was 100-104 mm.

In Buzzards Bay, size at first maturity, estimated from second somite analysis was 60-64 mm. Even though the smallest berried female captured in 1981 and 1982 was 66 mm, one 59 mm berried female was measured during experimental commercial lobster trap sampling in that bay during 1980. Size at 100% maturity was determined at 75-79 mm. Consequently, by the time the current legal size (81 mm) is reached, most Buzzards Bay females are mature.

These data compare favorably with results reported elsewhere. For example, size at 100% maturity from the Gulf of Maine regions of Cape Ann, Beverly-Salem and Cape Cod Bay resemble findings from Maine waters reported by Thomas (1973) which indicated that most females extrude their eggs between 90-100 mm. Krouse (1973) reported that nearly all females were mature by 100 mm carapace length and size at onset of maturity approximated 80 mm.

Size at first maturity from the outer Cape Cod region resembles that from offshore canyons. Skud and Perkins (1969) found that the size at first maturity in lobster sampled from five offshore canyons was 8 cm carapace length. Most were berried from 10 cm and larger, though only 21.9% (16.8-67.0%) of all females above 8 cm were ovigerous. An analysis of ovarian development and second segment width indicated that all females $\geq$ 10 cm were actually mature.

Maturity estimates for Buzzards Bay resemble those found in western Long Island Sound where Briggs and Mushacke (1979) found females reached first maturity at 60-64 mm with most mature by 80 mm. However, in the neighboring inshore area of Rhode Island Sound, Russell et al. (1978) determined the onset of maturity at 70-73 mm with 50% maturity (ovigerous) at 92-93 mm.

Morrissey (1975) noted a relationship between environment and size at maturity. Areas where maturity is reached at less than 70 mm are characterized by higher summer temperatures (about 20°C), limited water circulation and exchange, and high population density. However, areas where maturity was not reached until after 85 mm were generally in or adjacent to oceanic waters with relatively low summer temperatures (10°C).

When all data are pooled to yield a statewide average maturity index, it is suggested from Figure 33 that most lobster are mature by 100-104 mm carapace length.

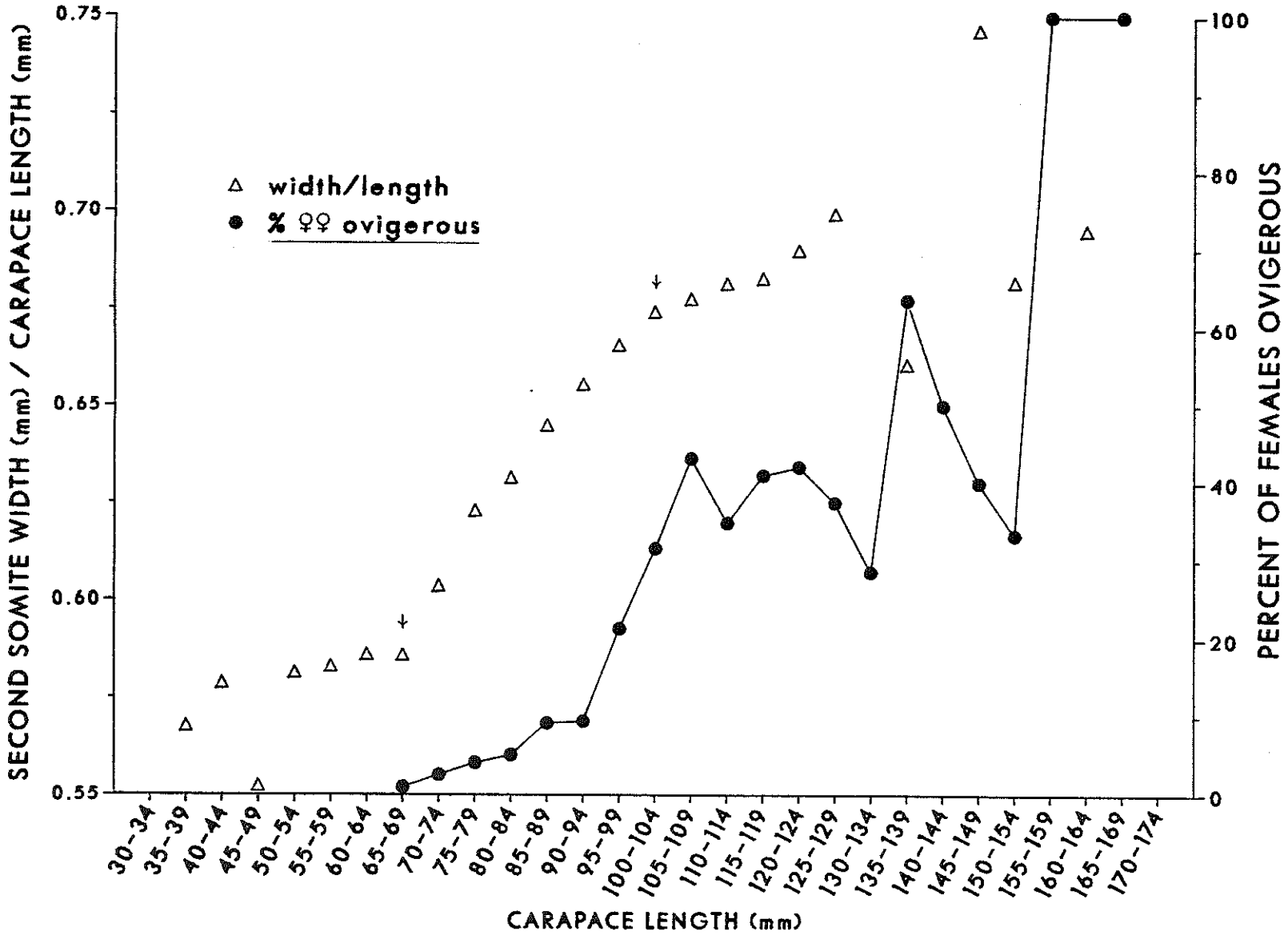

Figure 33. Percent of American lobster females ovigerous, 1981-1982, and relationship of the ratio of second somite width and carapace length to carapace length, 1980-1983, Massachusetts coastal waters.

Sex Ratio

The statewide male to female ratio, expressed in percent, was 40/60. The ratio for legal-sized lobster was 46/54 and for sublegals, 36/64 ($P < 0.001$, Table 17).

Regional sex ratios did not vary much from the statewide proportion, ranging from 37/63 to 48/52, yet differences were statistically significant ($P < 0.001$). By length category, legal ratios approached 50/50, ranging from 44/56 to 52/48, while sublegal ratios ranged from 33/67 to 55/45 with Gulf of Maine regions exhibiting a predominance of sublegal females (Table 17).

By month, the statewide average sex ratio ranged from 37/63 to 47/53. Differences were statistically significant ($P < 0.001$) with the November index exhibiting a significantly higher percentage of males than all other months. Legal ratios ranged from 39/61 to 51/49 while sublegal ratios exhibited fewer males and ranged from 34/66 to 44/56 (Table 18).

Regional ratios by month for combined length categories (Table 19) and legals and sublegals (Table 20) demonstrated no clear trend other than a predominance of females in most cross-tabulations.

Regional and seasonal sex ratio trends were similar in 1981 and 1982 surveys. No significant difference was found between the statewide indices of either year:

	1981	1982	Significance
Sex Ratio	41/59	40/60	$P = 0.987$

In order to examine the existence of sexual dimorphic characteristics which may effect differential escapement by sex, an ancillary study was undertaken to assess the carapace width to length relationship (since carapace width is the critical dimension in escapement through vents). For logistical reasons only lobster from Buzzards Bay, Cape Cod Bay, and outer Cape Cod were measured. Regression equations were:

Region	Sex	Regression Equation	Correlation Coefficient (r)	N	Range Tested (mm)
Cape Cod Bay	M	CW = 0.76095 + 0.58578 CL	0.87072	80	65-92
	F	CW = -3.77171 + 0.65930 CL	0.91600	130	65-92
Buzzards Bay	M	CW = -1.00401 + 0.62441 CL	0.95966	72	68-97
	F	CW = 1.88130 + 0.60304 CL	0.90818	76	68-97
Outer Cape Cod	M	CW = -4.94521 + 0.68447 CL	0.94659	92	75-107
	F	CW = -4.51702 + 0.68153 CL	0.92632	293	75-107

Regression lines are graphed in Figures 34-36.

Analyses of covariance of regression coefficients indicated that Buzzards Bay and Cape Cod Bay female lobster exhibited significantly wider carapace widths than males of a given carapace length, while no difference between sexes was found for outer Cape Cod lobster:

	Range Tested	N	F-value	Significance
Cape Cod Bay	65-92	210	32.657	$P < 0.001$
Buzzards Bay	68-97	148	15.754	$P < 0.001$
Outer Cape Cod	75-107	385	0.483	$P = 0.488$

In Narragansett Bay and Rhode Island Sound, Fogarty and Borden (1980) suspected differential escapement by males and females biased the sex ratio in vented traps toward females. A subsequent investigation revealed a broader female carapace width. However, no significant difference was found in the carapace width-length relationship in Maine (Krouse and Thomas 1975). Unlike the Massachusetts sublegal sex ratio (39/61 and 36/64 in 1981 and 1982, respectively), sublegal lobster near Boothbay Harbor, Maine approximated a 50/50 sex ratio (Krouse 1973, Cooper et al. 1975) while females predominated in deeper 30-60 m Maine waters (24/76,Cooper et al. 1975).

It is not known whether a sexual dimorphic relationship also exists in Cape Ann and Beverly-Salem regions; however, their sex ratio trends are similar to those of Cape Cod Bay. This dimorphism would allow sublegal males to escape at a greater frequency than females while most legal sized lobster are retained.

Although sex ratios in both 1981 and 1982 surveys were biased toward females in most regional cross-tabulations, the trend was very pronounced for sublegals from Gulf of Maine regions, but less so for Buzzards Bay. The proportion of males was generally higher for legal sized lobster than for sublegals in these regions.

Outer Cape Cod sublegal ratios were slightly biased toward males in both years while legal ratios exhibited more females. Since no dimorphic relationship exists with outer Cape lobster, one would expect that each sex would have an equal probability of escaping. Offshore population influence may explain the predominance of females in the legal size category; however, except for natural variation about a 50/50 ratio it is otherwise difficult to explain the male bias among sublegals without considering behavioral differences.

Variation within these trends may be related to potential trap selectivity differences in each region. Since the size of the vulnerable segment of the sublegal length frequency is limited due to behavioral and/or trap selectivity factors, the use of undersized escape vents in a dimorphic region would retain more males from the prerecruit molt group. Also, a region which is densely

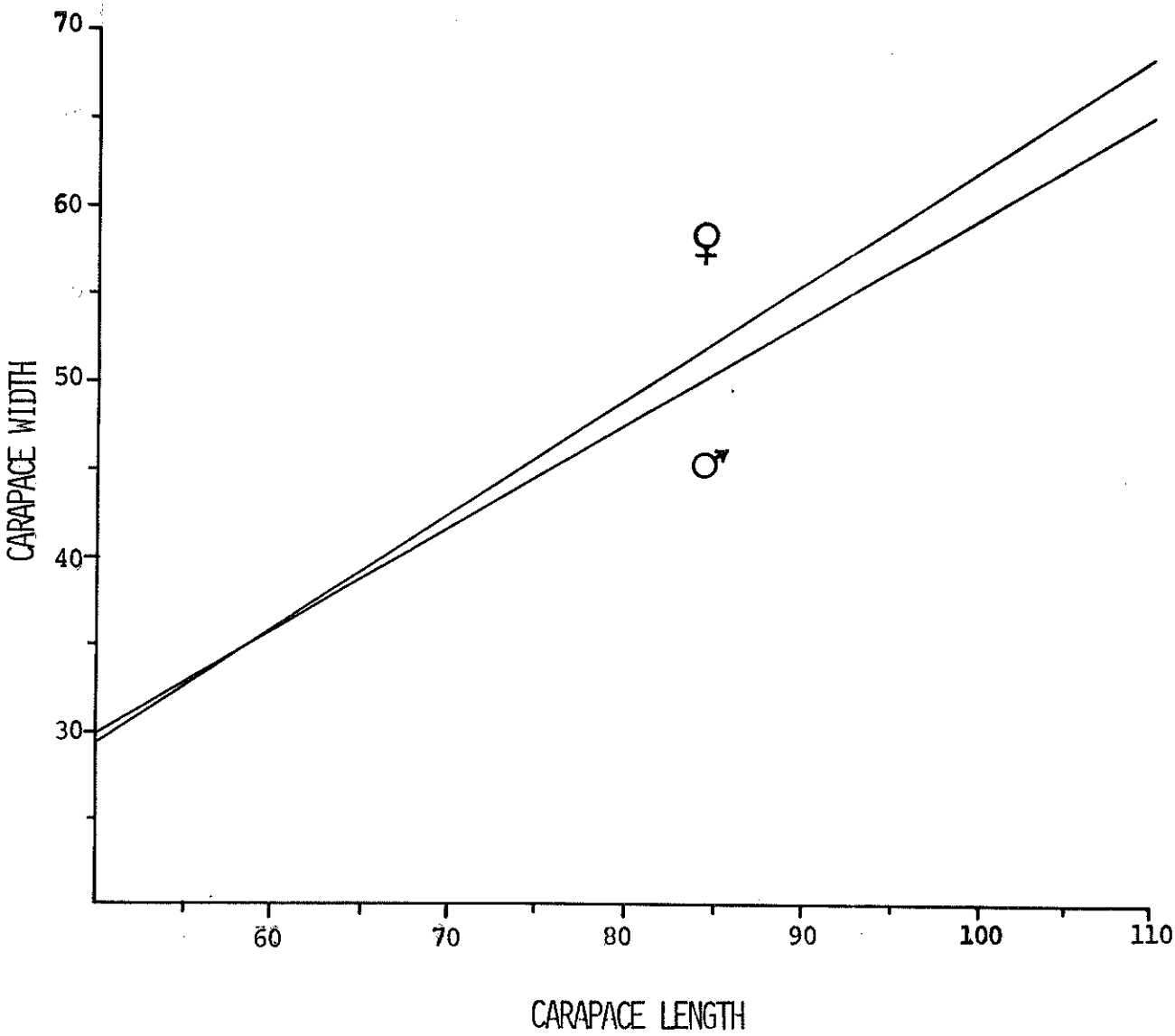

Figure 34. Regression lines of the carapace width to length relationship for male and female American lobster from Cape Cod Bay, 1983.

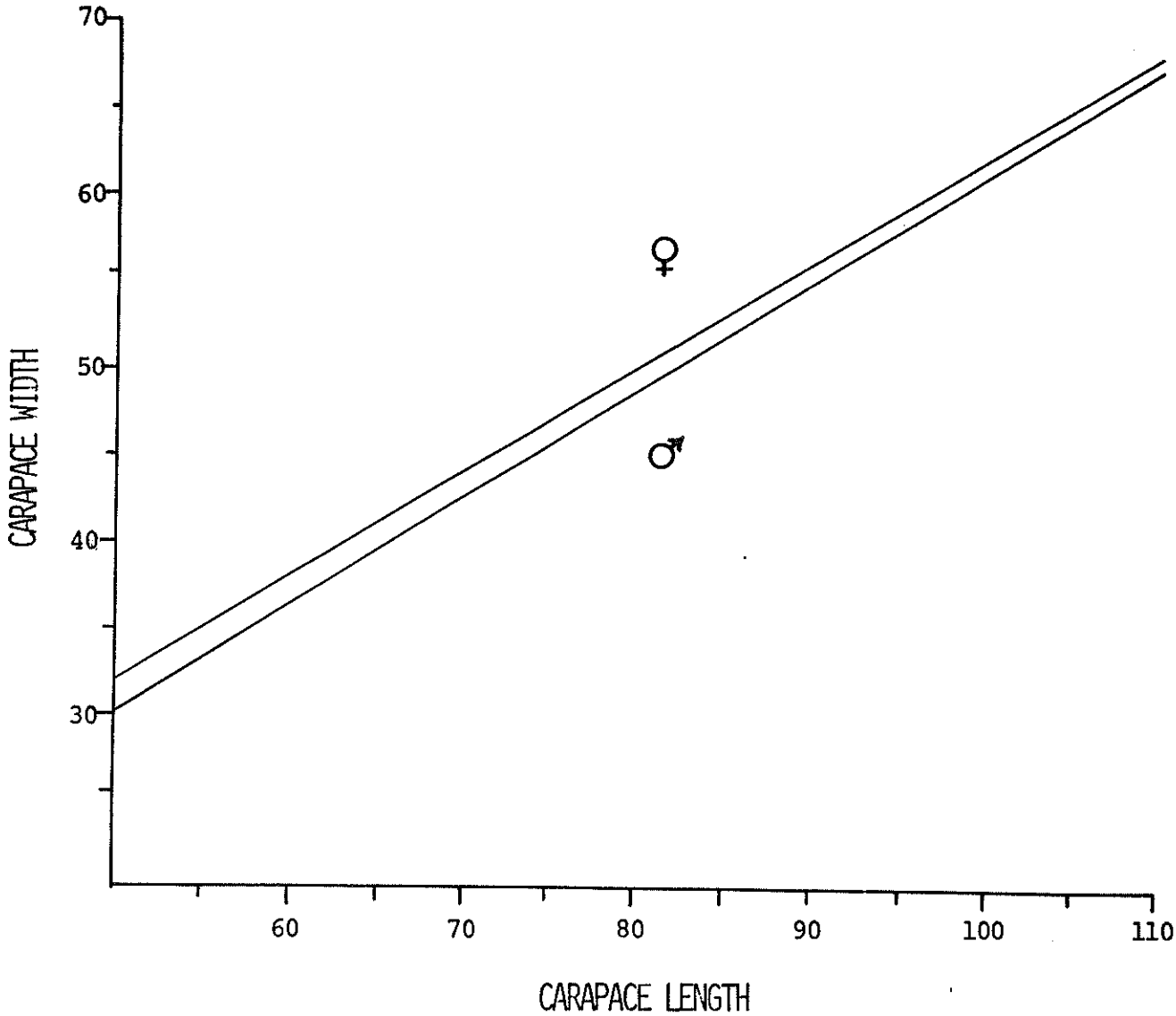

Figure 35. Regression lines of the carapace width to length relationship for male and female American lobster from Buzzards Bay, 1983.

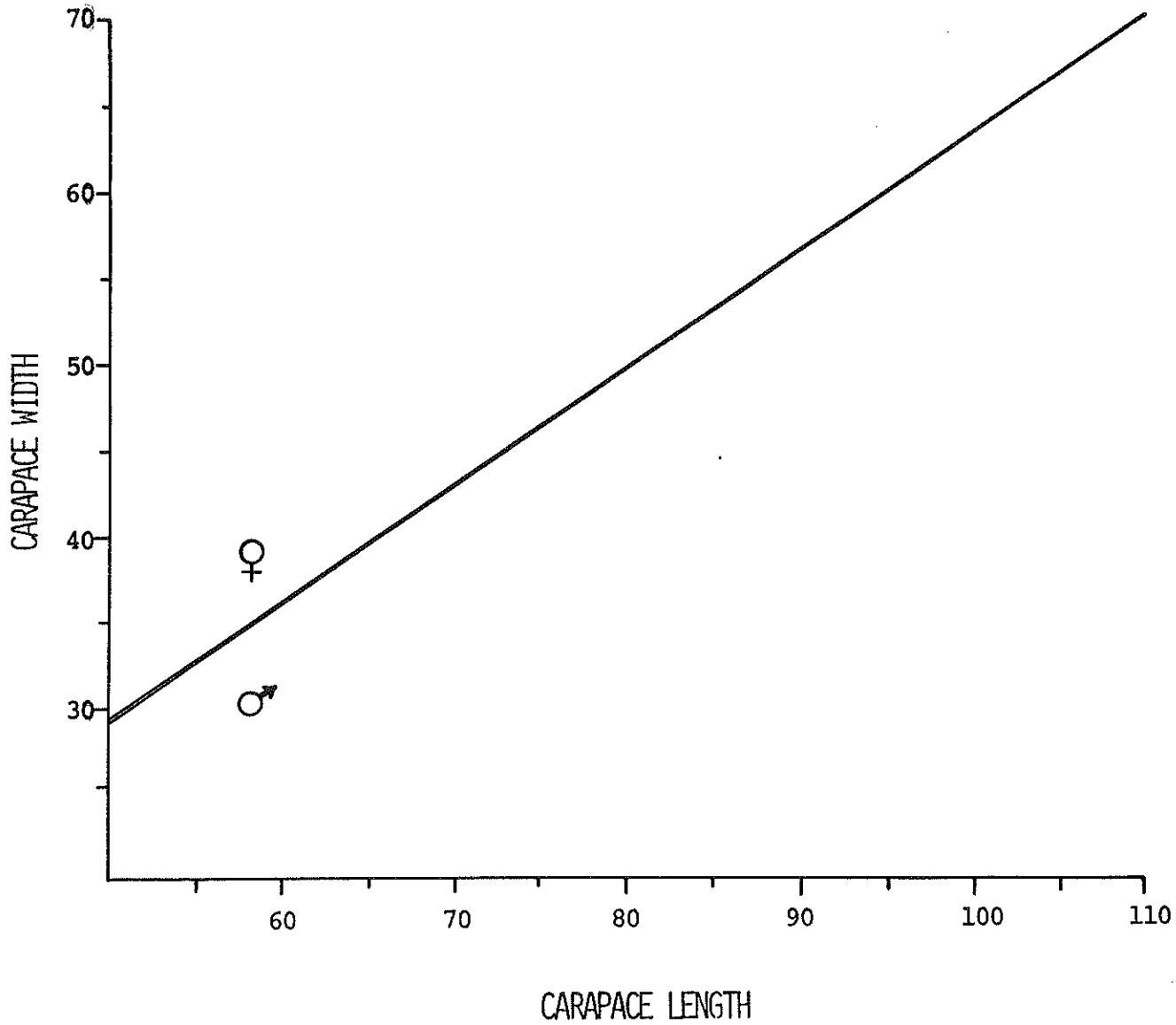

Figure 36. Regression lines of the carapace width to length relationship for male and female American lobster from the outer Cape Cod region, 1983.

populated with juvenile lobster, as in Buzzards Bay, would enhance availability of sublegal males for entrapment.

Behavioral segregation by sex should be considered as a potential variable affecting sex ratio. Indications are that sex ratio may vary with depth with females prefering deeper water than males (Briggs and Mushacke 1979, Briggs and Zawacki 1974, Skud and Perkins 1969).

A predominantly male population was observed in shallow waters of Western Long Island Sound while females predominated at deeper 30-60 foot depths (Briggs and Mushacke 1979). Karnofsky et al. (in prep.) noted a similar bias toward males in a mainly sublegal population in a shallow cove in Buzzards Bay. They hypothesized that it may have been due to mature male competition in deeper water for territory and mating burrows, thereby concentrating sublegal males in shoal areas.

Analysis of sex ratios of lobster captured by otter trawl from the same Massachusetts regions and during the same time period as that of the lobster trap sampling program is enlightening. Lobster sex ratios were calculated from inshore trawl survey data collected by the DMF Coastwide Resource Assessment Project and listed along with trap survey data by year, region, and length category in Tables 21 and 22. It is obvious that in most cases the proportion of males in the trawl survey data is higher than in trap survey data for both legal and sublegal sized lobster and approach fifty percent.

An analysis of trawl survey data by depth (Table 23) yielded no consistent trends. The small sample sizes for many depth categories contributed to excessive variability and were inadequate for drawing conclusions.

Nevertheless, the disparity in sex ratios between the surveys may be explained by escapement from traps. An analysis of trap survey data by set-over-days was conducted with the hypothesis that through escapement, the male proportion, at least for sublegals, should decrease over time. Table 24 indicates that a tendency toward a smaller percentage of males over time is evident. The only exceptions are the Beverly-Salem data in 1981 and Buzzards Bay data in 1982; the latter data set, however, exhibits a higher mean for the first four set-over-days (53%) than for the last four set-over-days (43%). Male proportions from the non-dimorphic outer Cape Cod region remained elevated as expected. This analysis is complicated, however, by the efficiency of the escape vent in allowing escapement soon after entrapment and also by the longevity of the bait's attracting force (Fogarty and Borden 1980). Consequently elevated male proportions may not be readily evident during short soak times.

Molting

The molt cycle of a lobster population can be defined by temporally noting the percentage of lobster with incompletely hardened shells. The hardening process may vary with diet, water temperature, and age (Cobb 1976) but is estimated to take an average of 10 days. All lobster sampled were subjectively assessed as to their degree of shell hardness, categorizing them as "soft" (when carapace does not spring back after exerting lateral pressure with fingertips), "papershell" (when carapace does spring back), or "hardshell" (no resilience). Lobster with other than hard shells were considered to have recently molted. It should be noted that this index is designed to determine the molt period and is only a relative index of the total number of lobster which actually do molt at a given time.

The statewide percentage of recently molted lobster was 1.3%. Among legal sized lobster, 2.4% had recently molted while only 0.6% of sublegals had soft or papershells(Table 25). Indices were 1.7% for males and 1.0% for females. The lower female index may have been influenced by the egg-bearing females in the catch which molt on a two year schedule due to the ovarian cycle. Pooled data below indicate male indices are higher than female indices through August with reversal occurring in September.

	Males		Females	
	Legal	Sublegal	Legal	Sublegal
May	.44	.00	.00	.37
June	1.83	3.87	2.08	1.98
July	2.31	.69	2.27	.54
August	4.80	.16	.71	.17
September	2.99	.24	4.82	.00
October	2.61	.46	1.11	.75
November	2.83	.57	.43	.23

This trend occurred approximately one month later than that of the previous year but in either case may be related to delayed female molting until after egg hatching. Briggs and Mushacke (1979) found similar results indicating that females peak later than males as a possible aid in mating.

By region, for combined length categories, outer Cape Cod ranked highest in recently molted lobster with 6.4%. Buzzards Bay ranked second with 2.1% followed by Beverly-Salem, 0.5%; Cape Cod Bay, 0.4%; and Cape Ann, 0.3%. The percentage of recently molted legal sized lobster was 7.1% in outer Cape Cod; 3.0% in Buzzards Bay; 1.0% off Beverly-Salem; 0.5% in Cape Cod Bay; and 0.4% off Cape Ann. Sublegal molt incidence ranged from zero off Cape Ann to 1.8% in the southernmost region of Buzzards Bay.

As in 1981, newly molted lobster were encountered in all months sampled, however, statewide peaks occurred in June, 2.4%, and September, 1.8%. Both

legals and sublegals exhibited similar trends (Table 26).

Regional indices by month (combined length categories) indicate that Beverly-Salem and outer Cape Cod lobster peaked in July and August, respectively, while Cape Cod Bay peaked in June and November and Buzzards Bay in June and October (Table 27). Sublegal and legal trends were similar (Table 28).

The Buzzards Bay sublegal length category exhibited the highest frequency of "shedders" in both 1981 and 1982 (9.7% and 1.8%, respectively, Table 25). The higher average water temperature in Buzzards Bay probably enhances molt frequency and under unusually high temperatures may overcome the normal fall-winter molt refractory period (Aiken and Waddy 1976). Such an event was documented in Buzzards Bay during winter 1980-81 when high incidences of soft-shelled lobster were encountered by local lobstermen (Estrella 1981). Briggs and Mushacke (1979) found soft-shelled lobster in January 1976 in western Long Island Sound and speculated whether this was due to a winter molt or delayed shell hardening from the fall molt as a result of low water temperature.

There was no significant difference between 1981 and 1982 indices:

	1981	1982	Significance
Percent Recently Molted	2.5%	1.3%	P = 0.318

Culls

Of all lobster sampled, 10.5% had one or both major claws (chelae) missing or regenerating. For males, this cull rate was 9.9% and for females, 10.9%, but the difference was not significant. Legal sized lobster had a cull rate of 9.5% while that of sublegals was 11.1% (Table 24).

By region, Buzzards Bay ranked significantly higher than all other regions with a 12.9% cull rate, followed by outer Cape Cod, 11.3%; Cape Cod Bay, 10.4%; Cape Ann, 9.1%; and Beverly-Salem, 8.2% ($P < 0.001$, Table 29). It is difficult to explain the approximate doubling of the outer Cape Cod cull rate from that of 1981 (5.6%) without considering adverse weather conditions during spring, 1982 which may have contributed to the enhanced shell damage.

The Buzzards Bay cull rate was the highest in the state in both 1981 and 1982. It is not clear without additional data if this is due to the high fishing pressure and high "throw back" rate characteristic of that fishery. Krouse (1976) noted a direct relationship between fishing intensity and cull rate off the coast of Maine. Russell et al. (1978) found a higher incidence of culls on mud bottom near a trawlable area of Rhode Island Sound than on ledges elsewhere (12.4% vs. 10.3%) inferring trawl induced damaged. Ganz (1980) reported that otter trawl activity contributed a 3.54% cull rate and a 10.58% incidence of all damage types compared to that produced by other causes; however,

Massachusetts regulation prohibits trawling in Buzzards Bay throughout the year and other trawlable Massachusetts inshore regions do not exhibit excessive cull rates.

By month, the general statewide trend for all lobster was lowest in May and November and high through the summer months, with a peak in June (P = 0.001). Seasonal trends by length category were similar (Table 30). The June peak may be due in part to escalated effort during fair weather and susceptibility to damage as a result of the molt. Similar seasonal and sublegal trends have been reported by Briggs and Mushacke (1979) and Briggs and Mushacke (1980), respectively. Monthly trends for both 1981 and 1982 data were nearly identical.

Regional indices by month for all lobster length categories (Tables 31 and 32), substantiate the statewide seasonal trend exhibited by Table 30 with few exceptions. The comparatively higher cull rate exhibited by Buzzards Bay legal sized lobster in May, 1981 (21.4%) was unusual for spring catches. This may have been correlated with the previous anomalous molt period and subsequent high incidence of soft-shelled lobster reported throughout the winter months in Buzzards Bay (Estrella 1981). The May, 1982 legal rate was considerably lower (2.0%).

The cull rates for legal lobster (excluding berried females) by state and region are listed in Table 29, but vary little from previously described patterns. The incidence of lobster body damage or damage to appendages other than major chelae was comparatively low at 0.35% reported statewide for all lobster sampled.

No significant difference in cull rate was found between 1981 and 1982 data:

	1981	1982	Significance
Percent Culls	11.3%	10.5%	P = 0.839

Pathology

Susceptibility of lobster to disease may be directly influenced by environmental stress which generally surfaces in visual pathological symptoms. Consequently, regular monitoring of these symptoms was incorporated into the study. However, because of the nature of the survey and the limitations experienced in sea sampling on a commercial lobster vessel, it was deemed impractical to search for anything but gross visual symptoms of shell disease. The most important symptoms are shell discoloration, erosion and ulceration.

In addition, a search for nemertean parasites on lobster egg masses was undertaken.

Shell Disease

The etiology of shell disease has been described in detail (Sinderman 1970, Rosen 1970, Stewart 1980). The shell is enveloped by a thin outer layer of proteolipid material, the epicuticle, which is inert to biochemical attack but, subject to mechanical abrasion. Beneath this layer are three chitinous layers: an exocuticle (calcified pigmented layer), a calcified endocuticle, and a non-calcified endocuticle. Shell disease generally results from an initial external injury, followed by an invasion of chitin consuming (chitinoclastic) microorganisms which expose the calcium carbonate. Subsequent gradual erosion through tunneling and pitting uncovers the epithelium and creates a necrotic lesion (Dow et al. 1975, Stewart 1980).

It is unknown whether the causative agent is fungal or bacterial or the synergistic result of both; however, chitinoclastic bacteria have been isolated from lesions and subsequent laboratory inducement of the disease accomplished.

Fisher et al. (1976) showed diet was more important than mechanical damage in establishing this syndrome in juvenile American lobster, indicating deficiencies in epicuticular repair following ecdysis. More cases were found in postmolt lobster than in those approaching ecdysis due to nutritional deficiencies affecting new shell formation (Malloy 1978).

Nevertheless, extremely high incidences of shell disease have been reported in the wild from areas of environmental degradation. Lobster and crabs collected near dumping grounds receiving large quantities of sewage sludge and dredge spoils were found to commonly exhibit appendage and gill erosion (Young and Pearce 1975). Gapolin and Young (1975) discovered a high prevalence of 15% shell disease in Crangon septemspinosa samples from New York Bight while it was only rarely observed at control sights of Beaufort, NC and Woods Hole, MA.

In the present study, the reported incidence of shell disease was the percentage of lobster exhibiting evidence of shell discoloration, erosion, or ulceration. The statewide incidence of shell disease was 0.16%. Males averaged 0.06% and females 0.22%. The legal size group displayed 0.06% incidence while 0.22% of sublegal sized lobster exhibited symptoms. Differences between sex and length category were not statistically significant (Table 33).

Although shell disease was found to occur in all regions in 1981, incidence was reported from all regions except Cape Ann during 1982. Even though indices were extremely low, indications were that the Beverly-Salem region exhibited a significantly higher index than other regions (Table 33). By month, tests revealed no statistically significant trends (Tables 34-36).

Shell disease incidence was very low, in most cases less than 1.0% indicating concentrations of pollution-associated microorganisms are well within normal limits in our coastal waters. This conclusion is corroborated by a rock crab analysis conducted by the National Marine Fisheries Service Pathobiology Division. As a result of a cooperative effort with the Massachusetts

Division of Marine Fisheries, 107 rock crabs were collected from Cape Cod Bay on 12 May, 1980. Specimens yielded a low incidence of gill discoloration (fouling and necrosis associated with ocean disposal) and supported earlier observations that rock crabs with completely blackened gills are rarely found in areas which are not in proximity to ocean disposal sites.[3]

Shell disease incidence did not differ significantly between 1981 and 1982:

	1981	1982	Significance
Shell Disease Incidence	0.15%	0.16%	P = 1.000

Parasites

A recently discovered nemertean species, tentatively assigned to the genus Carcinonemertes by Fleming (1979), has initiated concern due to its habit of actively ingesting lobster eggs (Aiken et al. 1980). Its known distribution extends from the Bay of Fundy and outer Nova Scotia south to Boothbay Harbor, Maine. Whether low water temperature is a factor governing its range is not known; however, for the second consecutive year, no nemertean parasites were reported from lobster sampled in Massachusetts coastal waters.

Trap Mortality

Only 0.04% of all lobster sampled were found dead in traps. Incidence was 0.04% for males and 0.04% for females. Legal and sublegal size groups exhibited 0.04% and 0.04% mortality, respectively. Differences between sex and length category were not significant. Dead lobster were reported only from Cape Cod Bay and outer Cape Cod (Table 37) and only during May and October (Tables 38-40). Though the October index was significantly higher, no clear seasonal trend was discernible in 1981 or 1982.

Lobster mortality in the wild may be attributed to a number of causes (Sinderman 1979). Gaffkemia, a naturally occurring disease of the blood, has received the greatest notoriety as a potential lobster killer. It has claimed many crustaceans in lobster impoundments in Maine, however, no one has been able to assess its contribution to natural mortality. Young (1973) related documented lobster mortality off the New Jersey coast to a possible synergistic effect of low dissolved oxygen, high temperatures and gill fouling due to copious suspended flocculated material. McLeese and Wilder (1964) found death ensued when the chitinous covering of the gills was attacked by shell disease, subsequently interfering with respiration.

Temperature, salinity, pollution, predation and aggression, may be particularly detrimental during stressful periods such as ecdysis. It is at this

[3]NEFC (Northeast Fisheries Center) News, May 1980.

time that lobster are most vulnerable, particularly to predation.

The crowded conditions that potentially can occur in a lobster trap enhance aggressive behavior which is less frequently displayed in the wild (Atema and Cobb 1980). Such behavior may be particularly lethal to relatively defenseless, recently molted lobster.

No significant difference in trap mortality was discernible between 1981 and 1982:

	1981	1982	Significance
Percent Mortality	0.09%	0.04%	P = 1.000

SUMMARY

The value of this long-term American lobster monitoring program, lies in the potential it provides to delineate trends in population parameters, forecast conditions in the fishery, and improve management decisions. The results of the 1982 commercial lobster trap sampling program are reported and compared to 1981 survey data.

In both 1981 and 1982, catch rates were highest in Gulf of Maine regions (Cape Ann, Beverly-Salem, and Cape Cod Bay), followed by Buzzards Bay, then outer Cape Cod. However, variation in catch rates between years was not uniformly paralleled regionally for all size categories. This may be due to local variation in density of prerecruits and ultimately recruits due to the non-selective pattern of larval settlement (i.e. subject to wind and water currents) and/or regional differences in recruitment source. Reported decreased premolt cropping as a result of adverse weather conditions during spring, 1982, apparently enhanced post-molt stock size. A monthly analysis indicated spring catch rates were indeed lower than the previous year, whereas late summer and autumn catches were higher. Accordingly mean length was significantly larger in 1982. The 1982 legal catch rate increased over the 1981 rate in the same proportion as the reported increase in total pounds landed from the Massachusetts inshore region during the same period.

Only catch rate and mean length differed between years. Sex ratio, percent of females ovigerous, cull rate, molt frequency, shell disease, and trap mortality remained statistically equal.

Findings support previous studies which suggested that Gulf of Maine, outer Cape Cod, and Buzzards Bay lobster groups differ in length-frequency, growth rate, size at maturity, and migratory habits. The underlying factors maintaining the integrity of these groups are the unique shape of the Massachusetts coastline and its role as an effective temperature barrier. The relatively warmer summer water temperatures experienced by Buzzards Bay lobster produce an accelerated growth rate evidenced by the highest frequency of sublegal new-shelled lobster (9.7% and 1.8% in 1981 and 1982, respectively) and the smallest size at first maturity (60-64 mm) and 100% maturity (75-79 mm) in the state. This environment is also responsible for producing the largest percentage of

sublegal-sized ovigerous females (15.3% and 14.8% in 1981 and 1982, respectively) contributing to record high larval densities in that embayment (Lux et al. 1980) and the highest sublegal to legal ratio in the state. Buzzards Bay exhibited the smallest average size for all length categories which was inversely correlated with the highest estimates of fishing pressure and mean total annual mortality rates in the state.

The outer Cape Cod segment of the Massachusetts population is seasonally augmented by shoalward migration of offshore stocks. This region's lobster exhibited the largest average size due to their comparatively lower exploitation and greater migratory behavior. Mean total annual mortality rates and sublegal to legal ratio were the lowest in the state. Large egg-bearing females comprised a significant percentage of this group (12.4% and 26.2% in 1981 and 1982, respectively). Size at first maturity and size at 100% maturity were 80-84 mm and 100-104 mm, respectively.

Gulf of Maine lobster are intermediate in average size, size at first maturity (70-74 mm), size at 100% maturity (95-99 mm), sublegal to legal ratio and percent of sublegal females ovigerous. This group exhibited the lowest overall percent of ovigerous females and percent new-shelled lobster. Mean total annual mortality rates were also intermediate and only slightly lower than those of Buzzards Bay.

Unlike outer Cape Cod lobster, Buzzards Bay and Cape Cod Bay populations exhibited a sexually dimorphic carapace width to length relationship. This allowed differential escapement of males and substantially biased sublegal sex ratios toward females. Sublegal sex ratios (M/F) were 39/61 and 36/64 in 1981 and 1982, respectively while ratios for the legal size category were 44/56 and 46/54 for 1981 and 1982, respectively.

In both years the molt peak of legal sized females occurred approximately one month later than males, and cull rate approximated 11.0%. Statewide shell disease incidence was less than 1.0% indicating concentrations of pollution associated organisms are well within normal limits in our coastal waters. Trap mortality incidence was also less than 1.0% and no nemertean parasites were reported from lobster egg masses.

Cape Ann lobster appear similar to those sampled in the outer Cape Cod region in that they also exhibit a low sublegal to legal ratio, a high percentage of ovigerous females $\geq$ 81 mm carapace length, and high frequencies of lobster in general between 81 and 100 mm carapace length. These characteristics suggest a greater offshore population influence in these exposed regions than is apparent in the other more inshore and shallower regions.

Outer Cape Cod's ovigerous females essentially represent an offshore recruitment source. The extent of offshore recruitment elsewhere along the Massachusetts coast, whether by larval drift or direct deposition is yet to be determined. Nevertheless, the relatively small percentage of ovigerous females in the Gulf of Maine regions (< 4.0% in both 1981 and 1982) strongly suggest the importance of both Buzzards Bay and outer Cape Cod lobster groups to

sustenance of the Massachusetts inshore lobster fishery. Larval lobster abundance studies conducted from 1976-1978 led to the conclusion that Buzzards Bay and Cape Cod Canal larvae represent a major recruitment influence on the Cape Cod Bay population (Collings et al. 1981). This may be a factor in maintaining the sexually dimorphic characteristics exhibited by both Buzzards Bay and Cape Cod Bay lobster when no difference between sexes was found in lobster from outer Cape Cod or Maine waters.

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Table 1. Catch per trap-haul per set-over-day by state and region for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

		≥ 81 mm		< 81 mm
	All lobster	All	Less berried females	
State	0.650	0.250	0.232	0.400
Cape Ann	0.432	0.348	0.341	0.089
Beverly-Salem	0.738	0.249	0.243	0.489
Cape Cod Bay	1.054	0.328	0.317	0.726
Outer Cape Cod	0.193	0.169	0.142	0.023
Buzzards Bay	0.712	0.206	0.178	0.504

Table 2. Catch per trap-haul per set-over-day by month, regions combined, for all American lobster, and legal (≥ 81 mm) and sub-legal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Month	All lobster	≥ 81 mm	< 81 mm
May	0.431	0.155	0.276
June	0.349	0.118	0.231
July	0.575	0.238	0.337
August	0.792	0.310	0.482
September	0.771	0.340	0.431
October	0.844	0.273	0.571
November	1.377	0.517	0.855

Table 3. Catch per trap-haul per set-over-day by region and month for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Region	May	June	July	August	September	October	November
Cape Ann				0.600	0.275		
Beverly-Salem		0.249	0.689	1.497			1.903
Cape Cod Bay	0.706	0.821	0.684	1.037	1.311	1.945	2.692
Outer Cape Cod	0.184	0.103	0.262	0.177	0.275	0.814	
Buzzards Bay	0.385	0.901	0.912		1.296	0.673	0.809

Table 4. Catch per trap-haul per set-over-day by region and month for legal (≥ 81 mm) and sublegal (< 81 mm) length categories of American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

≥ 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				0.491	0.205		
Beverly-Salem		0.070	0.242	0.363			0.819
Cape Cod Bay	0.186	0.268	0.242	0.345	0.476	0.461	0.589
Outer Cape Cod	0.153	0.085	0.234	0.158	0.243	0.170	
Buzzards Bay	0.117	0.171	0.216		0.340	0.136	0.331

< 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				0.109	0.069		
Beverly-Salem		0.179	0.447	1.133			1.084
Cape Cod Bay	0.520	0.554	0.443	0.692	0.835	1.484	2.103
Outer Cape Cod	0.032	0.018	0.028	0.020	0.032	0.014	
Buzzards Bay	0.269	0.730	0.696		0.956	0.536	0.468

Table 5. Carapace length (mm) by state and region for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

		≥ 81 mm		< 81 mm
	All lobster	All	Less berried females	
State	81.6	89.8	89.1	76.5
Cape Ann	86.0	88.2	88.0	77.5
Beverly-Salem	80.1	87.2	87.0	76.6
Cape Cod Bay	79.8	86.9	86.7	76.7
Outer Cape Cod	96.4	99.2	97.7	76.0
Buzzards Bay	78.4	85.3	85.3	75.6

Table 6. Carapace length (mm) by state and region of all male and female American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

	Males	Females
State	82.3	81.1
Cape Ann	86.9	85.3
Beverly-Salem	81.1	79.5
Cape Cod Bay	80.9	79.2
Outer Cape Cod	93.9	98.5
Buzzards Bay	78.5	78.3

Table 7. Carapace length (mm) by month, regions combined, for all American lobster, and legal (≥ 81 mm) and sublegal (< 81mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Month	All Lobster	> 81 mm	< 81 mm
May	80.9	89.4	76.1
June	80.5	88.7	76.4
July	81.8	90.4	75.8
August	81.4	88.6	76.8
September	83.3	91.2	77.1
October	81.9	92.9	76.7
November	80.0	86.2	76.3

Table 8. Carapace length (mm) by region and month for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Region	May	June	July	August	September	October	November
Cape Ann				85.8	86.6		
Beverly-Salem		79.9	79.6	79.2			81.4
Cape Cod Bay	78.7	79.3	79.6	80.1	81.3	79.4	77.8
Outer Cape Cod	92.8	92.0	97.2	97.0	97.1	100.0	
Buzzards Bay	78.8	77.6	78.1		77.6	76.6	79.7

Table 9. Carapace length (mm) by region and month for legal (≥ 81 mm) and sublegal (< 81 mm) length categories of American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

≥ 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				87.8	89.4		
Beverly-Salem		87.9	87.3	86.7			87.0
Cape Cod Bay	85.9	85.5	86.4	86.6	87.8	87.7	85.6
Outer Cape Cod	96.0	95.3	99.9	99.4	99.9	102.3	
Buzzards Bay	85.3	84.8	86.4		86.0	82.9	85.1

< 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				77.0	78.3		
Beverly-Salem		76.8	75.4	76.8			77.1
Cape Cod Bay	76.1	76.4	76.0	76.8	77.5	76.8	75.6
Outer Cape Cod	77.5	76.4	74.7	77.0	76.2	73.2	
Buzzards Bay	75.9	76.0	75.6		74.6	75.0	75.9

Table 10. American lobster total instantaneous (Z) and total annual ($1-e^{-Z}$) mortality estimates calculated by two methodologies for Massachusetts inshore regions and regions combined, 1981 and 1982.

		1981		1982	
		Gulland (1969)	Beverton and Holt (1957)	Gulland (1969)	Beverton and Holt (1957)
Cape Ann	Z	1.46	1.32	2.04	1.45
	$1-e^{-Z}$	77%	73%	87%	77%
Beverly-Salem	Z	2.00	1.61	2.24	1.70
	$1-e^{-Z}$	87%	80%	89%	82%
Cape Cod Bay	Z	2.05	1.56	2.36	1.78
	$1-e^{-Z}$	87%	79%	91%	83%
Outer Cape Cod	Z	0.40	0.55	0.31	0.54
	$1-e^{-Z}$	33%	42%	27%	42%
Buzzards Bay	Z	2.99	2.81	2.68	2.47
	$1-e^{-Z}$	95%	94%	93%	92%
Regions combined	Z	1.53	1.32	1.33	1.18
	$1-e^{-Z}$	78%	73%	74%	69%

Table 11. Percent of females ovigerous by state and region for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

	All lobster	≥ 81 mm	< 81 mm
State	6.9	13.4	3.4
Cape Ann	3.5	4.0	2.2
Beverly-Salem	2.4	5.2	1.3
Cape Cod Bay	3.1	6.2	2.0
Outer Cape Cod	26.2	28.8	2.7
Buzzards Bay	17.9	25.6	14.8

Table 12. Percent of females ovigerous by month, regions combined, for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Month	All lobster	> 81 mm	< 81 mm
May	8.2	11.6	6.6
June	5.9	8.3	4.7
July	4.8	10.4	1.5
August	2.0	5.0	0.5
September	9.1	17.1	3.8
October	13.9	33.1	5.3
November	6.0	8.1	5.0

Table 13. Percent of females ovigerous by region and month for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Region	May	June	July	August	September	October	November
Cape Ann				4.5	1.7		
Beverly-Salem		7.4	2.2	0.4			1.3
Cape Cod Bay	4.0	4.6	3.5	1.1	0.6	7.5	0.6
Outer Cape Cod	10.9	3.6	15.8	16.5	37.9	53.4	
Buzzards Bay	19.1	7.6	1.4		30.6	23.8	19.1

Table 14. Percent of females ovigerous by region and month for legal (≥ 81 mm) and sublegal (< 81 mm) length categories of American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

≥ 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				4.6	2.6		
Beverly-Salem		17.6	6.0	1.7			1.5
Cape Cod Bay	7.5	5.6	7.8	2.6	0.7	18.6	0.0
Outer Cape Cod	13.0	4.3	16.9	18.4	42.1	55.1	
Buzzards Bay	19.2	10.0	0.0		45.9	42.9	24.3

< 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				4.0	0.0		
Beverly-Salem		3.6	1.1	0.0			1.1
Cape Cod Bay	6.6	4.2	1.6	0.5	0.6	4.4	0.7
Outer Cape Cod	0.0	0.0	0.0	0.0	0.0	25.0	
Buzzards Bay	10.0	7.1	1.8		22.7	20.0	16.1

Table 15. Percent of ovigerous female American lobster within legal (≥ 81 mm) and sublegal (< 81 mm) length categories, by state and region, commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

	≥ 81 mm	< 81 mm
State	67.2	32.8
Cape Ann	83.3	16.7
Beverly-Salem	62.5	37.5
Cape Cod Bay	53.2	46.8
Outer Cape Cod	99.0	1.0
Buzzards Bay	40.9	59.1

Table 16. Carapace length (mm) of ovigerous female American lobster by state and region for all lobster, and legal (≥ 81 mm) and sub-legal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

	All lobster	≥ 81 mm	< 81 mm
State	92.0 (525)*	99.0 (353)	77.6 (172)
Cape Ann	95.8 (6)	99.0 (5)	80.0 (1)
Beverly-Salem	86.2 (24)	91.1 (15)	78.1 (9)
Cape Cod Bay	85.2 (154)	91.3 (82)	78.2 (72)
Outer Cape Cod	107.0 (192)	107.4 (190)	77.0 (2)
Buzzards Bay	80.4 (149)	85.4 (61)	77.0 (88)

* (N)

Table 17. Sex ratios (males to females, expressed in percent) by state and region for all American lobster, and legal (≥ 81 mm) and sub-legal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

	All lobster	≥ 81 mm	< 81 mm
State	40/60	46/54	36/64
Cape Ann	48/52	52/48	33/67
Beverly-Salem	42/58	50/50	38/62
Cape Cod Bay	37/63	46/54	33/67
Outer Cape Cod	45/55	44/56	55/45
Buzzards Bay	48/52	48/52	47/53

Table 18. Sex ratios (males to females, expressed in percent) by month, regions combined, for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Month	All Lobster	> 81 mm	< 81 mm
May	40/60	47/53	35/65
June	38/62	41/59	36/64
July	41/59	47/53	37/63
August	41/59	51/49	35/65
September	39/61	45/55	34/66
October	37/63	39/61	35/65
November	47/53	51/49	44/56

Table 19. Sex ratios (males to females, expressed in percent) by region and month for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Region	May	June	July	August	September	October	November
Cape Ann				50/50	43/57		
Beverly-Salem		32/68	47/53	41/59			45/55
Cape Cod Bay	34/66	32/68	37/63	39/61	38/62	36/64	39/61
Outer Cape Cod	55/45	42/58	38/62	53/47	48/52	38/62	
Buzzards Bay	45/55	48/52	58/42		33/67	43/57	56/44

Table 20. Sex ratios (males to females, expressed in percent) by region and month for legal (≥ 81 mm) and sublegal (< 81 mm) length categories of American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

≥ 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				53/47	49/51		
Beverly-Salem		35/65	66/34	46/54			46/54
Cape Cod Bay	43/57	38/62	45/55	51/49	47/53	40/60	46/54
Outer Cape Cod	54/46	42/58	35/65	53/47	46/54	36/64	
Buzzards Bay	47/53	52/48	57/43		13/87	53/47	60/40

< 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				39/61	23/77		
Beverly-Salem		30/70	36/64	39/61			44/56
Cape Cod Bay	31/69	29/71	32/68	33/67	32/68	35/65	36/64
Outer Cape Cod	57/43	44/56	61/39	55/45	56/44	56/44	
Buzzards Bay	44/56	47/53	59/41		40/60	41/59	52/48

Table 21. Percent of sublegal American lobster males sampled during concurrent trap and otter trawl surveys, Massachusetts coastal waters, 1981 and 1982.

	1981				1982			
	Trap Survey		Trawl Survey		Trap Survey		Trawl Survey	
State	39	(8307)*	53	(1166)	36	(7858)	52	(573)
Cape Ann	24	(50)	50	(107)	33	(67)	54	(92)
Beverly-Salem	43	(950)	54	(488)	38	(1138)	53	(236)
Cape Cod Bay	37	(5745)	53	(506)	33	(5361)	52	(221)
Outer Cape Cod	52	(117)	67	(6)	55	(162)	67	(3)
Buzzards Bay	41	(1445)	49	(59)	47	(1130)	24	(21)

	May 1981				May 1982			
	Trap Survey		Trawl Survey		Trap Survey		Trawl Survey	
State	38	(1069)	55	(694)	31	(1197)	56	(211)
Cape Ann	24**	(50)	58	(50)	47**	(150)	68	(41)
Beverly-Salem	34	(295)	56	(423)	30***	(200)	56	(123)
Cape Cod Bay	36	(327)	53	(161)	31	(586)	59	(32)
Outer Cape Cod	53	(17)	100	(2)	57	(35)	50	(2)
Buzzards Bay	44	(380)	50	(58)	44	(226)	8	(13)

	September 1981				September 1982			
	Trap Survey		Trawl Survey		Trap Survey		Trawl Survey	
State	40	(2266)	50	(472)	35	(1574)	49	(362)
Cape Ann	24**	(50)	44	(57)	23	(26)	43	(51)
Beverly-Salem	45****	(373)	38	(65)	39**	(340)	49	(113)
Cape Cod Bay	38	(1688)	53	(345)	32	(975)	51	(189)
Outer Cape Cod	50**	(30)	50	(4)	56	(36)	100	(1)
Buzzards Bay	47**	(125)	0	(1)	40	(197)	50	(8)

* (N)
** August data substituted
*** June data substituted
**** November data substituted

Table 22. Percent of legal American lobster males sampled during concurrent trap and otter trawl surveys, Massachusetts coastal waters, 1981 and 1982.

	1981				1982			
	Trap Survey		Trawl Survey		Trap Survey		Trawl Survey	
State	44	(4085)*	56	(172)	46	(4902)	47	(145)
Cape Ann	47	(150)	64	(36)	52	(261)	41	(63)
Beverly-Salem	47	(425)	52	(65)	50	(580)	53	(49)
Cape Cod Bay	44	(2554)	56	(59)	46	(2425)	47	(30)
Outer Cape Cod	42	(543)	55	(11)	44	(1174)	67	(3)
Buzzards Bay	50	(413)	0	(1)	48	(462)		

	May 1981				May 1982			
	Trap Survey		Trawl Survey		Trap Survey		Trawl Survey	
State	43	(650)	58	(99)	48**	(738)	58	(24)
Cape Ann	47**	(150)	81	(16)	53***	(184)	86	(7)
Beverly-Salem	26	(95)	52	(52)	35	(78)	46	(13)
Cape Cod Bay	39	(191)	62	(21)	43	(210)	33	(3)
Outer Cape Cod	42	(130)	44	(9)	54	(168)	100	(1)
Buzzards Bay	67	(84)	0	(1)	47	(98)		

	September 1981				September 1982			
	Trap Survey		Trawl Survey		Trap Survey		Trawl Survey	
State	42	(1266)	53	(73)	45	(1083)	45	(129)
Cape Ann	47**	(150)	50	(20)	49	(77)	36	(56)
Beverly-Salem	44****	(239)	54	(13)	46**	(109)	56	(36)
Cape Cod Bay	44	(699)	53	(38)	47	(556)	48	(27)
Outer Cape Cod	32**	(129)	100	(2)	46	(271)	50	(2)
Buzzards Bay	17**	(48)			13	(70)		

* (N)
** August data substituted
*** June data substituted
**** November data substituted

Table 23. Percent of sublegal and legal American lobster males from regions and depth categories (ft.) sampled during otter trawl surveys, Massachusetts coastal waters, 1981 and 1982.

	0-30	31-60	61-90	91-120	121-180	> 180
1981 Sublegals						
Cape Ann	67 (6)*	48 (62)	82 (11)	33 (15)	42 (12)	100 (1)
Beverly-Salem	60 (25)	54 (345)	50 (113)	50 (4)	100 (1)	
Cape Cod Bay	51 (245)	50 (50)	56 (96)	54 (101)	71 (14)	
Outer Cape Cod	100 (1)	60 (5)				
Buzzards Bay	50 (2)	49 (57)				
1982 Sublegals						
Cape Ann	58 (62)	41 (22)	0 (1)	100 (1)	80 (5)	0 (1)
Beverly-Salem	45 (38)	57 (104)	48 (66)	52 (23)	80 (5)	
Cape Cod Bay	51 (75)	51 (86)	45 (20)	63 (27)	54 (13)	
Outer Cape Cod		100 (2)		0 (1)		
Buzzards Bay		27 (15)		17 (6)		
1981 Legals						
Cape Ann	0 (1)	78 (9)	67 (12)	57 (7)	57 (7)	
Beverly-Salem		60 (30)	52 (29)	33 (3)	0 (3)	
Cape Cod Bay	58 (12)	56 (9)	57 (14)	56 (16)	50 (8)	
Outer Cape Cod	33 (3)	60 (5)	100 (2)		0 (1)	
Buzzards Bay		0 (1)				
1982 Legals						
Cape Ann	44 (32)	42 (19)	0 (2)		50 (8)	0 (2)
Beverly-Salem	75 (4)	50 (4)	38 (21)	62 (13)	60 (5)	100 (2)
Cape Cod Bay		43 (7)	50 (6)	45 (11)	50 (6)	
Outer Cape Cod	0 (1)	100 (1)	100 (1)			
Buzzards Bay						

* (N)

Table 24. Percent of sublegal American lobster males by set-over-days and region, Massachusetts coastal waters, 1981 and 1982.

1981

	1	2	3	4	5	6	7	8	9	10	11
Cape Ann		30	0		23						
Beverly-Salem	25	42	37	46	51						
Cape Cod Bay	38	41	32	37							
Outer Cape Cod			50			53	52	40			50
Buzzards Bay			43		31						

1982

	1	2	3	4	5	6	7	8
Cape Ann	61	11	23					
Beverly-Salem		41	36			30		
Cape Cod Bay	38	34	27					
Outer Cape Cod					56	58	44	56
Buzzards Bay	40	46	57	70	45	42	39	46

Table 25. Percent recently molted by state and region for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

	All lobster	≥ 81 mm	< 81 mm
State	1.3	2.4	0.6
Cape Ann	0.3	0.4	0.0
Beverly-Salem	0.5	1.0	0.3
Cape Cod Bay	0.4	0.5	0.4
Outer Cape Cod	6.4	7.1	1.2
Buzzards Bay	2.1	3.0	1.8

Table 26. Percent recently molted by month, regions combined, for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Month	All lobster	> 81 mm	< 81 mm
May	0.2	0.2	0.2
June	2.4	2.0	2.7
July	1.3	2.3	0.6
August	1.2	2.8	0.2
September	1.8	4.0	0.1
October	1.0	1.7	0.6
November	0.9	1.7	0.4

Table 27. Percent recently molted by region and month for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Region	May	June	July	August	September	October	November
Cape Ann				0.0	1.0		
Beverly-Salem		0.7	1.2	0.4			0.0
Cape Cod Bay	0.3	2.0	0.8	0.2	0.2	0.2	1.0
Outer Cape Cod	0.0	0.0	4.5	15.9	11.7	3.4	
Buzzards Bay	0.3	5.5	0.0		0.0	9.5	1.9

Table 28. Percent recently molted by region and month for legal (≥ 81 mm) and sublegal (< 81 mm) length categories of American lobster sampled during commercial lobster trap survey, Massachusetts coastal waters, 1982.

≥ 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				0.0	1.3		
Beverly-Salem		0.0	2.7	1.8			1.7
Cape Cod Bay	0.0	2.1	1.0	0.3	0.4	0.3	1.6
Outer Cape Cod	0.0	0.0	4.6	17.3	13.3	3.7	
Buzzards Bay	1.0	8.1	0.0		0.0	6.7	4.0

< 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				0.0	0.1		
Beverly-Salem		1.0	0.4	0.0			0.0
Cape Cod Bay	0.3	2.0	0.7	0.1	0.1	0.2	0.9
Outer Cape Cod	0.0	0.0	3.6	5.0	0.0	0.0	
Buzzards Bay	0.0	4.9	0.0		0.0	10.2	0.4

Table 29. Cull rate by state and region for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

		≥ 81 mm		< 81 mm
	All lobster	All	Less berried females	
State	10.5	9.5	10.5	11.1
Cape Ann	9.1	8.4	9.3	11.9
Beverly-Salem	8.2	6.9	8.2	8.9
Cape Cod Bay	10.4	9.3	10.4	10.9
Outer Cape Cod	11.3	10.4	11.7	17.9
Buzzards Bay	12.9	12.1	12.8	13.3

Table 30. Cull rate by month, regions combined, for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Month	All lobster	> 81 mm	< 81 mm
May	10.1	9.0	10.6
June	13.7	10.9	15.1
July	9.5	8.8	10.1
August	10.1	8.3	11.3
September	11.0	10.8	11.2
October	11.4	12.0	11.0
November	8.5	7.3	9.2

Table 31. Cull rate by region and month for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Region	May	June	July	August	September	October	November
Cape Ann				8.0	11.7		
Beverly-Salem		9.7	11.3	8.0			5.3
Cape Cod Bay	11.4	16.8	7.8	10.1	10.4	10.3	7.6
Outer Cape Cod	10.3	10.4	11.3	11.5	10.4	13.7	
Buzzards Bay	6.5	14.1	13.6		15.0	25.7	13.2

Table 32. Cull rate by region and month for legal (≥ 81 mm) and sublegal (< 81 mm) length categories of American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

≥ 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				6.5	13.0		
Beverly-Salem		11.5	9.4	10.1			2.5
Cape Cod Bay	13.3	11.7	7.2	7.8	10.3	10.9	3.2
Outer Cape Cod	7.7	9.2	10.9	11.1	9.6	13.0	
Buzzards Bay	2.0	11.3	9.5		17.1	26.7	15.4

< 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				14.6	7.7		
Beverly-Salem		9.0	12.4	7.4			7.4
Cape Cod Bay	10.8	19.3	8.2	12.1	10.5	10.1	8.9
Outer Cape Cod	22.9	16.0	14.3	15.0	16.7	22.2	
Buzzards Bay	8.4	14.7	14.8		14.2	25.4	11.7

Table 33. Percent shell disease incidence by state and region for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

	All lobster	≥ 81 mm	< 81 mm
State	0.16	0.06	0.22
Cape Ann	0.00	0.00	0.00
Beverly-Salem	0.52	0.17	0.70
Cape Cod Bay	0.10	0.04	0.13
Outer Cape Cod	0.15	0.09	0.62
Buzzards Bay	0.06	0.00	0.09

Table 34. Percent shell disease incidence by month, region combined, for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Month	All lobster	> 81 mm	< 81 mm
May	0.23	0.00	0.35
June	0.34	0.25	0.38
July	0.30	0.12	0.43
August	0.03	0.00	0.06
September	0.05	0.00	0.08
October	0.16	0.17	0.16
November	0.16	0.00	0.25

Table 35. Percent shell disease incidence by region and month for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Region	May	June	July	August	September	October	November
Cape Ann				0.00	0.00		
Beverly-Salem		1.08	1.42	0.00			0.00
Cape Cod Bay	0.38	0.22	0.00	0.05	0.00	0.13	0.35
Outer Cape Cod	0.00	0.00	0.00	0.00	0.33	0.43	
Buzzards Bay	0.00	0.00	0.00		0.00	0.00	0.24

Table 36. Percent shell disease incidence by region and month for legal (≥ 81 mm) and sublegal (< 81 mm) length categories of American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

≥ 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				0.00	0.00		
Beverly-Salem		0.00	0.67	0.00			0.00
Cape Cod Bay	0.00	0.69	0.00	0.00	0.00	0.00	0.00
Outer Cape Cod	0.00	0.00	0.00	0.00	0.00	0.46	
Buzzards Bay	0.00	0.00	0.00		0.00	0.00	0.00

< 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				0.00	0.00		
Beverly-Salem		1.50	1.82	0.00			0.00
Cape Cod Bay	0.51	0.00	0.00	0.07	0.00	0.17	0.44
Outer Cape Cod	0.00	0.00	0.00	0.00	2.78	0.00	
Buzzards Bay	0.00	0.00	0.00		0.00	0.00	0.40

Table 37. Percent trap mortality by state and region for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

	All lobster	≥ 81 mm	< 81 mm
State	0.04	0.04	0.04
Cape Ann	0.00	0.00	0.00
Beverly-Salem	0.00	0.00	0.00
Cape Cod Bay	0.03	0.00	0.04
Outer Cape Cod	0.22	0.17	0.62
Buzzards Bay	0.00	0.00	0.00

Table 38. Percent trap mortality by month, regions combined, for all American lobster, and legal (≥ 81 mm) and sublegal (< 81 mm) length categories sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Month	All Lobster	> 81 mm	< 81 mm
May	0.08	0.00	0.12
June	0.00	0.00	0.00
July	0.00	0.00	0.00
August	0.00	0.00	0.00
September	0.00	0.00	0.00
October	0.22	0.34	0.16
November	0.00	0.00	0.00

Table 39. Percent trap mortality by region and month for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

Region	May	June	July	August	September	October	November
Cape Ann				0.00	0.00		
Beverly-Salem		0.00	0.00	0.00			0.00
Cape Cod Bay	0.00	0.00	0.00	0.00	0.00	0.13	0.00
Outer Cape Cod	0.49	0.00	0.00	0.00	0.00	0.85	
Buzzards Bay	0.00	0.00	0.00		0.00	0.00	0.00

Table 40. Percent trap mortality by region and month for legal (≥ 81 mm) and sublegal (< 81 mm) length categories of American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1982.

≥ 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				0.00	0.00		
Beverly-Salem		0.00	0.00	0.00			0.00
Cape Cod Bay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Outer Cape Cod	0.00	0.00	0.00	0.00	0.00	0.93	
Buzzards Bay	0.00	0.00	0.00		0.00	0.00	0.00

< 81 mm

Region	May	June	July	August	September	October	November
Cape Ann				0.00	0.00		
Beverly-Salem		0.00	0.00	0.00			0.00
Cape Cod Bay	0.00	0.00	0.00	0.00	0.00	0.17	0.00
Outer Cape Cod	2.86	0.00	0.00	0.00	0.00	0.00	
Buzzards Bay	0.00	0.00	0.00		0.00	0.00	0.00