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The Cape Breton Experiment on Legal Minimum Lobster Size Increase: An Intermediate Report.

by
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Abstract

In 1987 a minimum legal carapace size increase program for lobster was implemented on the west coast of Cape Breton Island. The carapace size was increased from 2 1/2" (63.5mm) to 2 3/4" (70.0mm) over four years in 1/16" increments. Biological parameters were monitored in the experimental Area and in an adjacent reference Area during the carapace size increase program. Landing trends were variable but increasing over the last ten years in the reference Areas (Areas 26A and 27) and also to a lesser extent in the experimental Area (Area 26A). In the last two years, the reference Areas have experienced a down turn in landings while the experimental Area has experienced an increase in landings coinciding with the completion of the carapace size increase program. Size frequency data standardized by fishing effort has shown a shift of the modes to the right in the experimental Area over the carapace size increase period. An increase in the standardized catch per unit effort for the lobsters with sizes ranging from 70.0 to 80.9 mm was noted in the experimental Area in 1991. Abundance of egg bearing females have increased in the experimental Area while the reference Areas have shown variation over the last four years. Observations to date have not shown any changes in movement patterns in and adjacent to the experimental Area and further studies on movement and growth are in progress.

Resumé

En 1987, un programme d'augmentation de la taille minimum de carapace du homard débuta sur la côte ouest du Cape-Breton. La taille de carapace fut augmentée de 2.5" (63.5mm) à 2.75" (70.0mm) pendant une période de quatre ans soit 1/16" par an. Les paramètres biologiques furent suivis dans la zone d'augmentation expérimentale ainsi que dans les zones de référence adjacentes.

La tendance des débarquements était variable mais augmenté pendant les 10 dernières années dans les zones de référence (région 26A et 27) ainsi que dans la zone experimentale (26B). Durant les deux dernières années, la zone de référence a fait l'expérience d'une chute dans les débarquements tandis que la zone expérimentale connu une hausse qui coincide avec les 2 dernières années du programme d'augmentation de la taille de carapace.

Les données de fréquence de taille standardisées selon l' effort de pêche démontre un changement vers la droite des modes dans la zone expérimentale durant les quatres années du programme. Une augmentation de la prise par unité d' effort standardiseé chez le homard de taille se situant entre 70.0 à 80.9 mm a été noté en 1991 dans la zone expérimentale. L'abondance des homards femelles portant des oeufs a augmenté dans la zoneexperimentale mais a démontré des variations dans la zone de référence pendant les quatres derniéres années. Les observations à date ne démontrent aucun changement dans le mouvement dedans et à proximité de la zone expérimentale. D' autres études de mouvement et de croissance sont en cours.

Introduction

Increasing minimum legal sizes was identified as a stock management priority at a Canada-United States lobster workshop in 1978 (Anthony and Caddy, 1980). The first officially recorded legal minimum carapace size increase (LMCSI) program for lobsters, for the southern Gulf of St. Lawrence, was a 1978 CAFSAC Steering Committee proposal " Real gains in Y/R would result from an increase in size limit" (CAFSAC 1977-1978). It was suggested that a carapace size increase program in the fall fishery of Area 25 would benefit the lobster population by 1) increasing the yield in weight of lobsters by leaving smaller lobsters to grow over one more molt and 2) increasing the size of first capture in heavily exploited fisheries to a point above the size at first maturity for female, in order to increase egg production. Statement #2 assumed that the population was recruitment limited, so that an increase in egg production would, over the long term, increase or stabilize the population biomass. To date, there has been no documented observations showing that egg production was related to larval density and further to recruitment to the fishery. In theoretical scientific discussions (Caddy 1986), concerns were raised of an increased number of lobsters producing recruits in excess of the system's carrying capacity and causing an over saturation of smaller lobsters. In the context of these theoretical discussions, it had also been suggested that an increased number of larger lobsters on the grounds may have the density dependent effect of increasing natural mortality, decreasing the growth or causing emigration out of the area.

In 1985, the prospect of a carapace size increase program in the southern Gulf of St. Lawrence was debated at Lobster Advisory Committees and fishermen meetings. Fishermen from the west coast of Cape Breton Island and the mainland coast of Nova Scotia proposed to undergo a carapace size increase program. Since there were diverging opinions between the Nova Scotia and Prince Edward Island fishermen within the same lobster fishing Area 26, an alternative solution was proposed by creating an experimental management zone splitting Area 26 into two separate zones (Figure 1). Tagging studies had shown (Maynard and Chiasson, 1986; Maynard et al. 1988) that there was limited (1.0 %) movement of lobsters between these Areas. The western coast of Cape Breton Island was designated Area 26B and slated for an experimental carapace size increase of 1/4" to be carried out in 1/16" increases over a four year period (Table 1). Area 26A remained at one minimum legal size (63.5 mm) throughout the carapace size increase program in 26B and in 1991 the legal carapace size increased 1/16" (65.1mm). As a comparison to an Area adjacent to Area 26B but not in the Gulf of St. Lawrence, we examined the landing trends of Area 27. This Area experienced a carapace size increase in 1957 and has been at 2.75" (70.0mm) since then.

To monitor the biological aspects of the LMCSI in and adjacent to Area 26B, a series of sampling and research programs were conducted before, during and remain ongoing after the LMCSI. Commercial landing statistics were documented for Areas 26A, 26B and 27. As part of an ongoing sea sampling program of lobsters caught in the commercial fishery, data were collected at six ports in and adjacent to Area 26B, (Figure 1). This program provided lobster size frequency distributions, catch per unit of effort (CPUE) and relative abundance index of egg bearing (berried) females from several years before the LMCSI (Maynard and Chiasson, 1986; Maynard et al. 1988) up to present. Lobster tagging programs were conducted in and adjacent to Area 26B before the LMCSI and during the LMCSI program (Currie et al. 1989). These programs were designed to monitor any possible large scale density dependent effects of a LMCSI on lobster emigration and growth patterns. A program of sampling berried female lobsters in order to estimate the total egg production was also conducted before and during the LMCSI to determine the fecundity in Area 26B (Conan et al. 1989).

The objective of this report was to descriptively identify what, if any, population variations have occurred in the experimental Area that can be attributed to the carapace size increase program. The following parameters were analyzed and discussed: 1) commercial landing trends, 2) the predicted versus observed results of a simple size increase model for canner sized (63.5 to 80.9 mm) lobsters derived from data collected before the carapace size increase program, and an application of the Ennis and Akenhead (1978) lobster yield per recruit model to LMCSI, 3) catch per unit of effort (CPUE), number per mm per 100 traps, of lobsters observed from samples at sea prior and after the experiment in experimental and reference Areas, 4) CPUE, weight per mm per 100 traps of lobsters observed from samples at sea prior, during and after the LMCSI in experimental and reference Areas, 5) proportion and trap observed abundance of spawning biomass (weight per 100 traps) in the commercial fishery prior, during and after the experiment in experimental and reference Areas, 6) movement and growth from tagging surveys pertinent to LMCSI program in and adjacent to the experimental Area.

Materials and Methods

Landings:

Definitions of commercial size categories of canners (minimum legal size below 80.9mm) and markets (81.0mm and greater) are set by the industry. The minimum legal size is regulated by the Department of Fisheries and Oceans (DFO) and varies as per Area and year in the experimental and adjacent Areas (Table 1).

For the purpose of comparisons, the index ports of Souris and Beach Point in P.E.I. and Ballantynes Cove in N.S. were chosen as references in the area adjacent to Area 26B (experimental Area). Port Hood, Margaree and Pleasant Bay N.S. were the ports chosen in the experimental Area (26B), (Figure 1). These index ports coincide with Campbell and Mohn's (1983) clusterings of lobster stocks defined by fishery landing trends as shown in Figure 2. Area 27 (within Scotia Fundy Region) which has a 70.0mm minimum legal size, was used as a reference Area.

Models:

Before the LMCSI program began a simple carapace size increase model was calculate[1] for the commercial canner lobster category was used as a basis for discussions with industry to explore the different scenarios that could result from a LMCSI. The simple linear methods of calculations lent to ease of understanding for non-scientific personnel. The calculation methods and data from of port samples of landed catches before 1986 are summarized in Appendix I. The projected canner landings from these calculations were plotted against the observed landing levels, at each port within the experimental Area.

A yield per recruit model (Ennis and Akenhead, 1978) was applied to parameters observed or estimated for the population before the LMCSI in Area 26B and used to project the theoretical yield resulting from changes in carapace size. Parameters for the model were derived from growth and size frequency data collected before the LMCSI (Maynard and Chiasson, 1986; Maynard et al. 1988). As per Campbell 1985, a range of exploitation rates were calculated from data collected before, during and after the LMCSI.

A summary of calculation techniques and parameters from the Port Hood area are found in Appendix II. As an extension of these calculations, an estimated pre-recruit cohort, for each sex was projected through the minimum legal size (70.0mm) and subjected to estimated and observed natural and fishing mortality. The resulting theoretical size frequency distribution is superimposed on a size frequency distribution observed after the LMCSI was completed. This representation allows a visual comparison of theoretical projections versus empirical observations.

Size Frequency Distributions and CPUE:

The catch on board commercial fishing vessels was sampled a minimum of three times during the fishing season (beginning, middle and end) at the index ports from 1983 to 1991. During sea sampling, all lobsters in each trap were measured and sexed and the data recorded (including sublegal sizes and berried females). Size frequency distributions and total weight (conversion made by a length weight relationship) of lobsters caught per standardized 100 trap hauls were calculated for various size categories. The size categories used were 1) a legal size (fixed at 70.0mm, the legal minimum carapace size in Area 26B at the end of the LMCSI) to commercial market (80.9mm) category catch, 2) a commercial category of markets (size of 81.0mm and greater), 3) legal retainable catch for each Area as per each years regulation in effect for each Area. In the first size category two temporal

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[1]Orginal calculations made by Greg Roach at the Nova Scotia Department of Fisheries.

categories of calculations were made using 1) samples taken at the beginning of the of the season, 2) samples collected over the entire season. The samples taken during the first week of the season are assumed to be representative of the harvestable population before it is affected by selective fishing effort (cropping). The samples taken throughout the season will have a greater number of lobsters sampled but legal size classes of lobsters were removed by fishing (cropping effect). To eliminate the cropping effect and focus on the recently recruited class, the first week of the season sample was used in further comparisons.

Berried Females:

The proportion of berried females observed from 1985 to 1986 (before LMCSI), 1987 to 1990 (during LMCSI) and 1991 (after LMCSI) in the Port Hood samples were fitted with a simple logistic equation with an asymptotic value (Maynard et al. 1987). This provides an indication of the annual variation and, by comparing the changes in carapace sizes on the X axis to the proportion of berried females on the Y axis, the extent of the projected changes in the abundance of berried female lobsters that might be expected from a LMCSI can be derived. The weight of berried lobsters observed from standardized CPUE samples at sea were calculated for the total season samples.

Growth and Movement:

Lobster tagging programs have been conducted before, during and will be conducted after the carapace size increase program. The long term objective of these programs is two fold, 1) to determine if patterns of movement have changed and 2) to determine if growth rates have changed in reference to concerns of density dependent variations.

To date, tagging programs were conducted in Margaree (August 1984) and in Ballantynes Cove (July 1986), a port adjacent to the carapace size increase Area. These two programs represent the monitoring before a carapace size increase. In 1988 tagging was conducted in the experimental Area at Port Hood, Margaree and Pleasant Bay.

Results

Landings:

Landings between 1893 and 1990 for the southern Gulf of St. Lawrence are plotted in Figure 3, showing the dramatic increase in landings over the last 15 years. Figures 4 and 5 illustrate Area 27, 26A and B landings for total, canner and market categories, respectively. Areas 27 and 26A have a similar trend in dramatic increases in landings in the last ten years with the last two years experiencing a decline. Area 26B has shown a steady increase (but of less magnitude than the other areas) but has not experienced a decline in the last two years.

The commercial landings for reference and experimental index ports, further broken down by the commercial categories of canners and markets, are shown in Figures 6A and B. The landings of canners and markets in the experimental ports follow the same patterns and have consistent ranges of variation. The reference ports show a degree of variation especially in Beach Point. Figure 7A shows the degree of differences in landings in Beach Point and Souris as compared to the other reference port (Ballantynes Cove) and the experimental ports.

Figure 7B shows the landings of the combined experimental and reference ports for the commercial size category in 1985, the proportion of canners in the reference Area increased while the experimental Area showed a steady state. Over the last two years there has been a 30% increase in canner landings in the experimental Area index ports. In 1991, a 23% decrease in canner landings was experienced in the reference ports after relative stability for three previous years. The first year of a LMCSI in this Area was 1991 and this event should factor in the observed decline.

Models:

The calculations of the carapace size increase model projected a level of canner weight for the years during the carapace size increase program and one year after (Appendix I). This projection model did not attempt to project the magnitude, if any of the increase in the weight of market size lobsters. The comparisons are shown in Figures 8A to C.

The yield per recruit model as per calculations in Appendix II, produced a recruitment curve for exploitation rates of 30, 48 and 58% for males, females and total combined (Figure 9A to C). The total yield curve shows a maximum recruitment at 90mm. It should be kept in context that the growth data provided information only up to 85mm and any results beyond this point are extrapolations.

The simulation of growth and mortality on the cohorts produced a size frequency distribution for each sex with a minimum legal carapace size of 70.0mm and this is superimposed on an observed size frequency distribution in Figures 10A and B. The comparisons of the simulations show they are compatible with the observed data and this is consistent for simulations of both males and females.

Size Frequency Distributions:

Size frequency distributions for each reference port for the year before the Area 26B LMCSI and 1991 are plotted in Figures 11A to F. Catch effort in the experimental Area, has shifted to the right as shown by the size frequency modes over the carapace size increase period. The extent of the shift appears relative to the change in legal size.

CPUE:

Figure 12B shows a summary of the first sample average CPUE of legal sized lobsters in the reference and experimental Areas. In 1991, the CPUE in the experimental Area exceeded the range of CPUE in the reference Areas over the last seven years. The weight of lobsters for the category of Area 26B canners (70.0 to 80.9mm) observed in standardized CPUE was calculated and plotted for reference and experimental ports for total and first sample of the season (Figures 12A and B, respectively). The CPUE's of the market category (greater than 80.9mm) for first samples are in Figure 13. Standardized CPUE by weight of lobsters in samples at sea was plotted for lobsters of actual legal carapace sizes and summarized by Area in Figure 14. The average CPUE showed a slightly increasing trend in the experimental Area but was within the variation observed in the reference Area. This shows an increasing trend in the experimental Areas but these trends are well within the range of variations observed from year to year in the reference Areas.

Berried Females:

The proportion of berried female lobsters observed in Port Hood between 1985 to 1991 was fitted with a simple logistic equation with an asymptotic value (Figure 15). Annual variation of the proportions over this time period is evident. The CPUE's in weight of berried females observed in total samples are shown in Figure 16. An upward trend was seen in the experimental Area but all results fall within the range observed in the reference Area.

Growth and Movement:

The movement of lobsters tagged in projects before and during the LMCSI are shown in Figures 17 and 18, respectively. From the studies to date, the movement of lobsters in Area 26B appears limited. The scope of movement (mean distance moved) of lobsters in the Margaree area before (1984) and during the LMCSI (1988) has not increased (Table 3).

Figures 19 and 20 show the superimposed male and female growth equations of lobsters recaptured during the 1986 Ballantynes Cove and Port Hood projects. The compiled data comes from different ports but they are in or adjacent to St. Georges Bay (Figure 17) where environmental and recruitment trends are probably similar. Table 4 is the growth increments observed during the tagging programs during the carapace size increase programs.

Discussion

Landings:

The global landings for the southern Gulf of St. Lawrence have shown a dramatic increase, steadily increasing from the mid 1970's to present day. It is during this period that the legal minimum carapace size increase (LMCSI) took place. If a change in landings was observed in experimental Areas these changes must be put in perspective of the variation observed in reference Areas.

The heterogeneous nature of the landing trends in Area 26A was also noted by Campbell and Mohn (1983). They also identified the areas encompassing Souris and Beach Point as having some of the same landing characteristics as western Cape Breton but Ballantynes Cove was the most similar to the whole coastal area of Cape Breton Island. It follows to group Souris, Beach Point and Ballantynes Cove as reference ports and Port Hood, Margaree and Pleasant Bay as the experimental ports.

A separation of the landings into canner and market size lobsters for each experimental index ports (Figure 6A) shows that the trends in both commercial categories are similar. It is worthy of mention that landing statistics of individual ports can vary from year to year for reasons other than catch. For example, lobster sales from vessels based in outside ports may change from one year to the next. The increased landing trends (dramatic increases in volume of canners landed, Figure 6B) of the reference ports especially Beach Point, show that inherent variations may be high. In this respect it would appear that the close geographic proximity of Ballantynes Cove to Port Hood would lend to the comparison of experimental and reference landings. Ballantynes Cove also shows an increase in landings of canners similar to other harbours of the experimental Area. Because of the proximity of Ballantynes Cove to the experimental area, it is possible that this port may have benefited from either a small distance (15 km) movement of lobsters between Areas 26A and B not detected in tagging studies or an effect of fishermen fishing near the boundary at mid bay.

The landings fluctuated at both the grouped reference and the grouped experimental ports (Figure 7 A and B). This was particulary apparent for the reference ports while there was an increasing upward trend for the experimental ports. It should be noted that the downturn in canner landings in 1991 in the reference Area, to some extent (approximately 10 to 15%), related to the first year losses due to the carapace size increase program. The commercial size lobster landings in Area 26B increased over their historical landings by the end of the period of LMCSI. Yet in the reference area of 26A, the landings also increased until 1988. The landing trends of Area 27, where the legal size has remained the same, were very similar to Area 26A (Figure 5). Comparison of the last two or three year landing trends in Areas 27, 26A and 26B showed that Area 26B has been steady while the Areas on either side had slight decreases in the catch of smaller lobster (canner).

The geographic location and proximity of the ports to one another may be an important factor in understanding the variations in the landing patterns among ports. Landing data of the reference Areas may not provide clear comparisons. The observed large scale variations in the landing patterns have not been attributed to any specific environmental or fishery related factor. These discrepancies complicate the assessment and evaluation of the direct of the impact of a LMCSI on the landings.

Models:

The canner landings predicted by the simple linear model are similar to the actual observations (Figures 8A to C), especially over the last two years of the experiment. The model is based on the simple assumptions of 10% natural mortality and 50% growth and these appear to be valid over the period of the LMCSI.

The yield per recruit model produced a yield curve (Figure 9A to C) that exhibited a maximum return if recruitment to the fishery was 90mm. This predicted size is a four fold increase over the present size increase being implemented. It is, however, an extrapolated figure for the smaller size length data base that was used for the analysis. Interestingly, the simulation of growth and mortality on the cohorts produced a size frequency distribution for males and females that matched the observed distribution.

The yield per recruit model used the best available parameter estimate from the published literature and our own research. The results could be further validated by using a wider variation of natural and fishing mortality to produce a variety of isopleths.

Size Frequency Distributions:

Since the size of escape mechanisms used in lobster traps did not change over the LMCSI program, the changes of modes of the size frequency distributions of males and females appear to follow the increase projected by the LMCSI. There appears to be an increase in the number of lobsters of the size range of lobsters from 63.5 and 70.0 mm in ports that experienced the LMCSI. Reference Area size frequency distributions did not show a consistent trend of changes in modes or frequency characteristics.

CPUE:

The standardized CPUE provides a descriptive index that can be used within the context of this LMCSI study to show the positive impact of the program. The cumulated samples over the season show some variability when compared to the uncropped first sample. Trends were generally similar among the summarized data sets. The most specific indicator of an increase due to LMCSI is the canner size category of 70.0 to 80.9mm which showed about a 15% increase of size specific CPUE. This is probably the results of it being the first size class to molt into the fishery. This trend has only recently been evident from the range of variation of the reference ports over the last year. It would therefore be prudent to continue monitoring the CPUE and ascertain its validity as an indicator of the LMCSI program. The total legal sizes, at each years specific legal size, shows that while the CPUE in the experimental Area increases it does not exceed the range of the reference Area. These indicators (Figure 14) best describes the observations of the fishermen and landing trends in the reference and experimental Areas. While these trends may have resulted from the carapace size increase program, there may also be a dimension of natural variation within the total population.

Berried Females:

The proportions of berried female lobsters observed in the commercial trap catches vary annually. A LMCSI of 63.5 to 70.0mm theoretically would increase the proportion of berried females observed in sea samples from approximately 0.027 to 0.105 before they could be subjected to fishing in a non-berried state. Abundance of egg bearing females have increased in the experimental Area while the reference Areas have shown variation over the last four years. Since our indexes are based on trap caught lobsters, we may be looking at catchability of females rather than actual variations of female abundance in the population because Miller (1990) suggests that they were less trappable due to a decrease in feeding activity.

Growth and Movement:

The pre- LMCSI movement patterns and the movement during the increase program (Figures 17 and 18) were similar. The upcoming 1992 tagging program in the experimental Area will produce a database of parameters for growth and movement to further investigate what, if any, density dependent effects a LMCSI might have on large scale lobster populations.

General:

The following are but a few of the techniques that would assist in monitoring the biological characteristics of a LMCSI given that sufficient resources are available to complete the study:

1. Have two (reference and experimental) areas where parallelism in recruitment is apparent .
2. Migration between each area should be minimal or well documented.
3. If possible, monitoring should be carried out over a period of 15 years with a minimum of 5 years pre-increase, 5 years of monitoring during the size increase in the experimental Area followed by 5 years of post-increase monitoring. The basic assumptions must be fulfilled that there is no further size increase or change in fishing effort in either area.

Conclusions

Landings:

1. Areas adjacent to the Area 26B have experienced a decrease in landings over the last two years but Area 26B has remained stable. Because of the generally increasing trends in landings over the southern Gulf at this point in time, we are unable to differentiate whether the increase in landings are durable and a consequence of the minimum legal carapace size increase(LMCSI) in Area 26B. Large ranges and fluctuations of the landings also make it difficult to evaluate other LMCSI programs.

Models:
2. Predictive yield modelling, using data from before the LMCSI, show similar trends observed recently in the population. Simple linear projections gave predictions similar to the more complicated yield per recruit models. Yield per recruit models predicted a maximum yield at a 90mm legal carapace size.

Size Frequency Distributions:
3. After the carapace size increase, with constant escape mechanisms, there appears to be a large proportion of lobsters between the old and new carapace size. This effect was not observed in reference Areas.

CPUE:
4. The CPUE in weight of the new canner size lobster in the experimental area, 70 to 80.9mm (approximately the first molt class into the fishery) increased from 1990 to 1991 in experimental Areas in comparison to the reference Area. Further monitoring should be conducted to ensure these observations are durable and not due to overriding natural variations. If these observations are observed over the long term, this would be a size specific indicator linking changes in CPUE to the LMCSI. The CPUE of the catch legally retainable by fishermen in the experimental and the reference Area shows a steady increase and wide annual variation for each respective Area over the LMCSI period.

Berried Females:
5. Abundance of egg bearing females have increased in the experimental Area while the reference Areas have shown variation over the last four years. Trap caught indexes may be biased due to physiological condition of the lobsters.

Movement and Growth:
6. Increased emigration has not been observed in the areas of Port Hood and Margaree during the LMCSI. Further studies of growth and movement in and adjacent to Area 26B are being conducted with the objective of examining the density dependent effects of LMCSI.

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Table 1. Lobster minimum legal carapace size for each year of the size increase program in Cape Breton 26(B) and Prince Edward Island 26(A) including the year prior to the increase.

Area 26(B)

YEAR	MINIMUM LEGAL CARAPACE LENGTH	
1985	63.50 mm	(2-1/2 inches)
1986	63.50 mm	(2-1/2 inches)
1987	65.09 mm	(2-9/16 inches)
1988	66.68 mm	(2-5/8 inches)
1989	68.27 mm	(2-11/16 inches)
1990	70.00 mm	(2-3/4 inches)
1991	70.00 mm	(2-3/4 inches)

Area 26(A)

YEAR	MINIMUM LEGAL CARAPACE LENGTH	
1985	63.50 mm	(2-1/2 inches)
1986	63.50 mm	(2-1/2 inches)
1987	63.50 mm	(2-1/2 inches)
1988	63.50 mm	(2-1/2 inches)
1989	63.50 mm	(2-1/2 inches)
1990	63.50 mm	(2-1/2 inches)
1991	65.09 mm	(2-9/16 inches)

Area 27

YEAR	MINIMUM LEGAL CARAPACE LENGTH	
1955	63.50 mm	(2-1/2 inches)
1957	70.00 mm	(2-3/4 inches)
1991	70.00 mm	(2-3/4 inches)

Table 2. Predicted percentage weight losses of commerical canner size lobsters for Port Hood, Margaree and Pleasant Bay over the period of the minimum legal carapace size increase program of 1/16" each year for four years commencing in 1987. All calculations as per N.S. Dept. of Fisheries size increase model shown in Appendix I.

PORT	1987	1988	1989	1990	1990
Port Hood	-7.6	-7.8	-2.5	-1.3	+15.3
Margaree	-11.3	-8.0	-3.4	+1.6	+20.0
Pleasant Bay	-11.3	-5.8	-3.2	+3.2	+20.7

Table 3. Average distances (km) moved for males, females and both sexes combined, over one year at liberty, for lobsters tagged and released at the Margaree study site in 1984 and 1988.

Margaree 1984					
Total	5.4	Males	6.2	Females	4.2
Margaree 1988					
Total	2.8	Males	2.4	Females	3.1

Table 4. Summary of lobster growth data collected from Cape Breton tagging programs conducted in Port Hood, Margaree, Pleasant Bay and Ballantyne's Cove. Tables show the size class, number tagged per size class(No.), average size at tagging(Cl. Tag), average size at recapture(Cl. Rec.) and growth increment(Inc.).

Port Hood, N.S. Tagged 1988 and Recapture 1989

	Males				Females			
Size Class (mm)	No.	Cl. Tag	Cl.Rec.	Inc.	No.	Cl. Tag	Cl. Rec.	Inc.
51-55	2	53.0	63.5	10.5				
56-60	25	58.3	68.8	10.5	27	58.7	66.8	8.1
61-65	70	63.1	72.0	8.9	77	63.1	71.3	8.2
66-70	20	67.5	76.4	8.9	23	67.1	74.7	7.6
71-75	8	72.2	81.8	9.6	4	71.8	81.8	10.0
76-80	2	78.0	87.5	9.5	2	78.0	90.0	12.0
81-85	1	81.0	90.0	9.0				

Margaree, N.S. Tagged 1988 and Recapture 1989

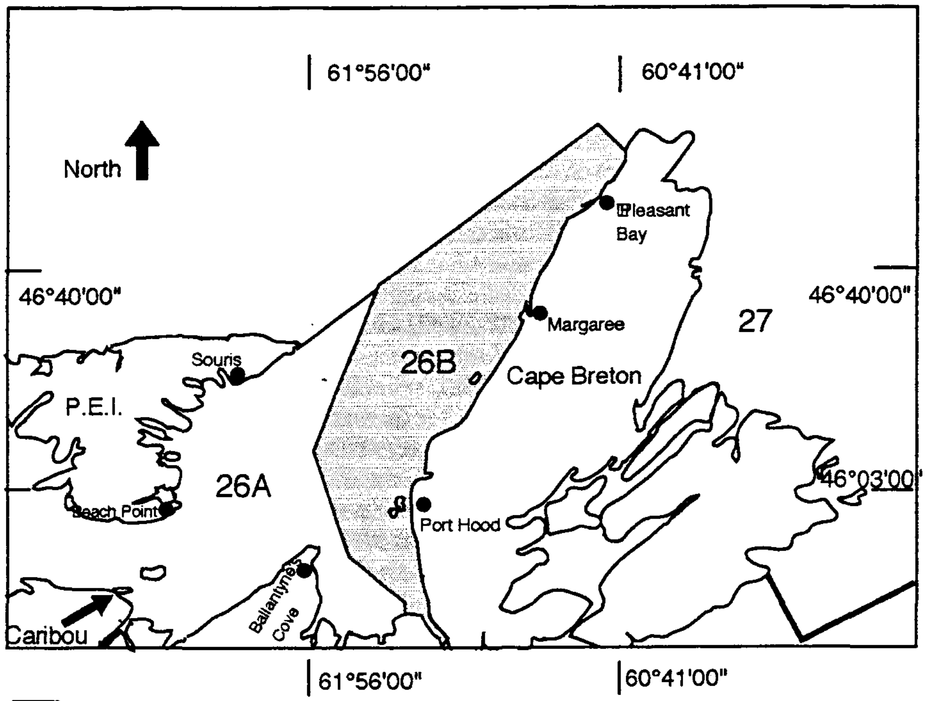
	Males				Females			
Size Class (mm)	No.	Cl. Tag	Cl.Rec.	Inc.	No.	Cl. Tag	Cl. Rec.	Inc.
51-55								
56-60	15	58.6	69.1	10.5	10	58.6	67.0	8.4
61-65	54	63.2	71.7	8.5	82	63.2	71.2	8.0
66-70	27	67.6	76.0	8.4	31	67.3	75.0	7.7
71-75	8	72.8	79.6	6.8	15	72.4	80.5	8.1
76-80	1	80.0	91.0	11.0	4	77.7	85.3	7.9
81-85					1	83.0	94.0	11.0

Pleasant Bay, N.S. Tagged 1988 and Recapture 1989

	Males				Females			
Size Class (mm)	No.	Cl. Tag	Cl.Rec.	Inc.	No.	Cl. Tag	Cl. Rec.	Inc.
51-55								
56-60	3	57.6	66.6	9.0	9	59.3	66.6	7.3
61-65	25	63.8	72.6	8.9	54	63.3	71.8	8.5
66-70	13	67.6	77.0	9.4	32	67.4	75.8	8.4
71-75	2	72.0	82.0	10.0	30	73.0	82.3	9.3
76-80					7	76.7	84.0	7.3
81-85	1	83.0	88.0	5.0	2	83.5	91.0	7.5

Ballantyne's Cove, N.S. Tagged 1986 and Recapture 1987

	Males				Females			
Size Class (mm)	No.	Cl. Tag	Cl.Rec.	Inc.	No.	Cl. Tag	Cl. Rec.	Inc.
51-55	1	55.0	63.0	8.0	2	54.5	63.5	8.5
56-60	6	59.3	70.3	11.0	8	58.6	67.4	8.8
61-65	18	63.0	74.6	11.6	28	60.8	71.9	11.1
66-70	16	68.2	79.3	11.1	21	68.2	78.2	10.0
71-75	15	72.5	82.7	10.2	34	72.8	82.0	9.2
76-80	8	77.4	88.0	10.6	22	78.2	83.5	5.3
81-85	3	82.7	88.7	6.3	17	82.4	87.7	5.3
86-90	4	87.3	91.3	4.0	7	88.4	97.3	8.9
91-95	2	94.0	94.0	0.0	4	91.8	94.4	2.6



Area 26B: Cape Breton experimental minimum carapace size increase zone.

Figure 1. Southern Gulf of St. Lawrence indicating lobster Areas 26A, 26B and 27.

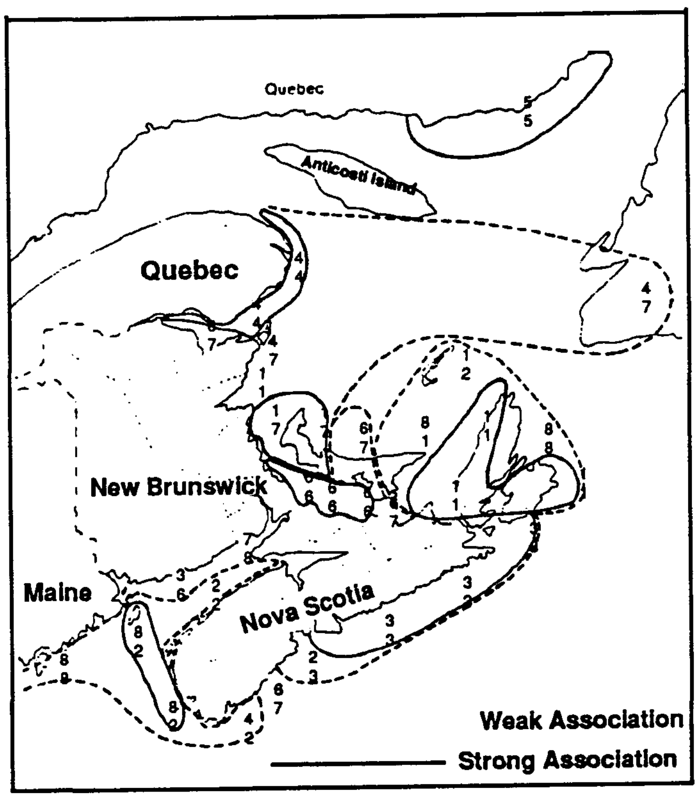


Figure 2. Associations of statistical areas for American lobster landings in the Canadian Maritimes and Maine, based on clusters derived from 6-year means and Chebysher functions of normalized landings. Associations are only considered for contiguous areas. "Strong Associations" occur when both the 6-year mean and Chebysher clusters have the same cluster number.

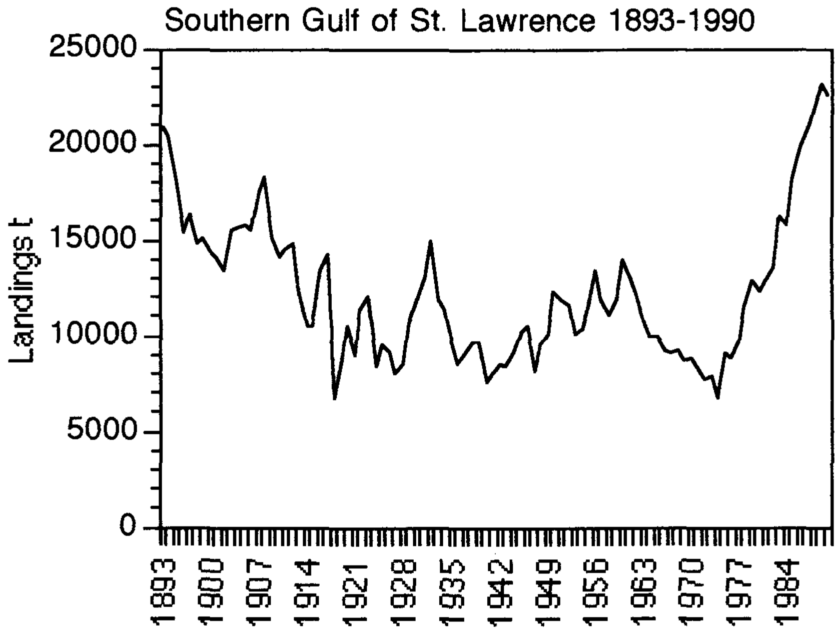


Figure 3. Historical landings (t) of lobsters in the Southern Gulf of St. Lawrence.

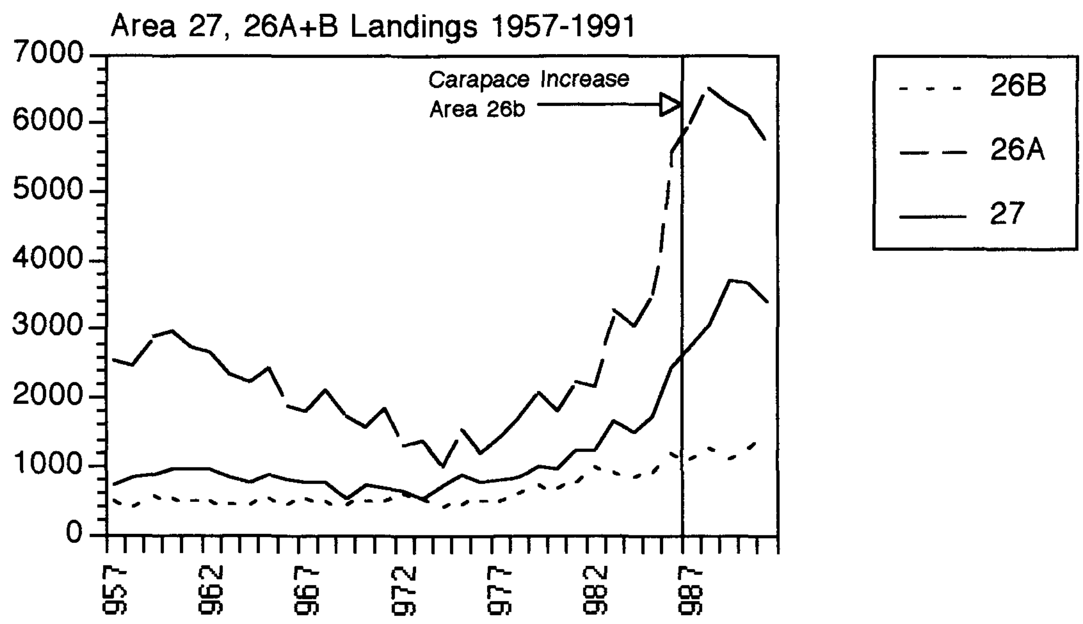


Figure 4. Total lobster landings for Areas 26A, 26B and 27, 1957 to 1991.

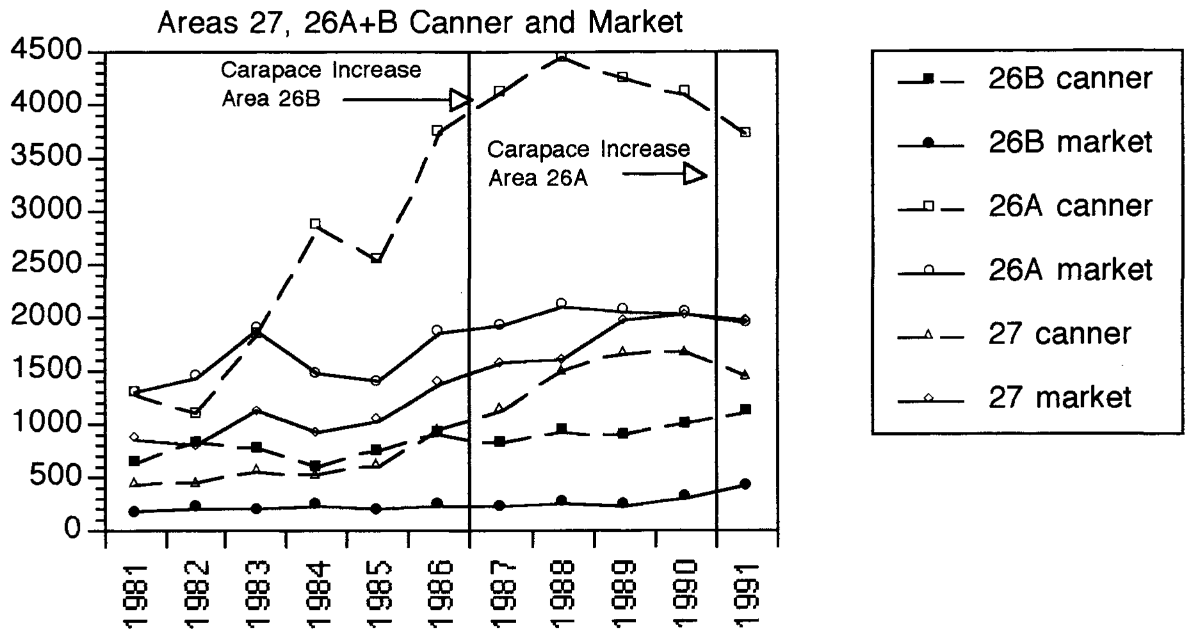


Figure 5. Landings of canner and market size lobsters in Areas 26A, 26B and 27 from 1981 to 1991.

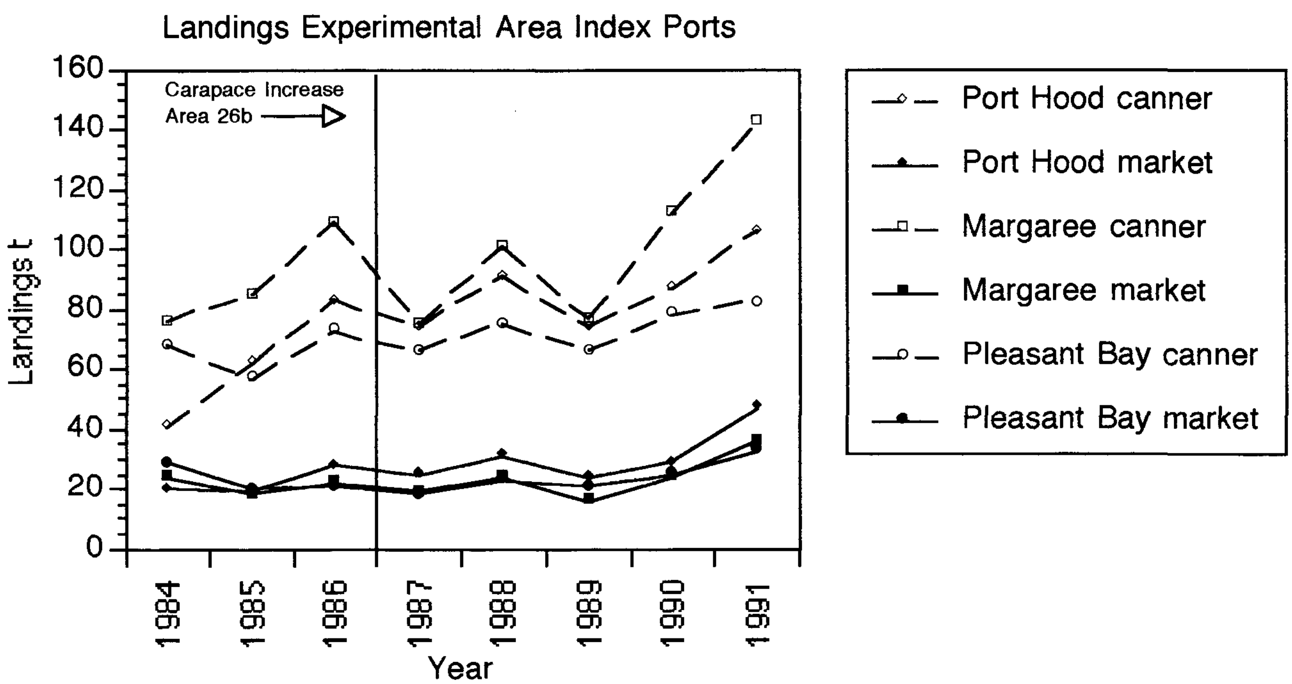


Figure 6.A. Landings of canner and market size lobsters in Area 26B experimental ports from 1984 to 1991.

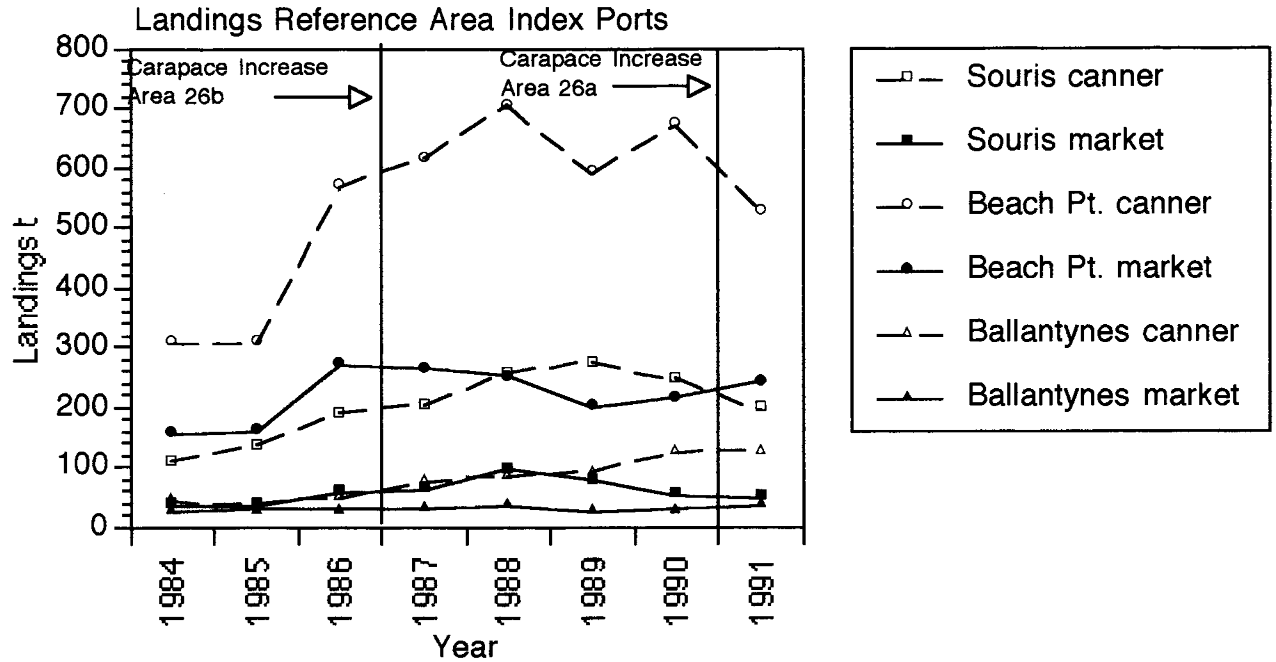


Figure 6. B. Landing of canner and market size lobsters in Area 26A reference ports from 1984 to1991.

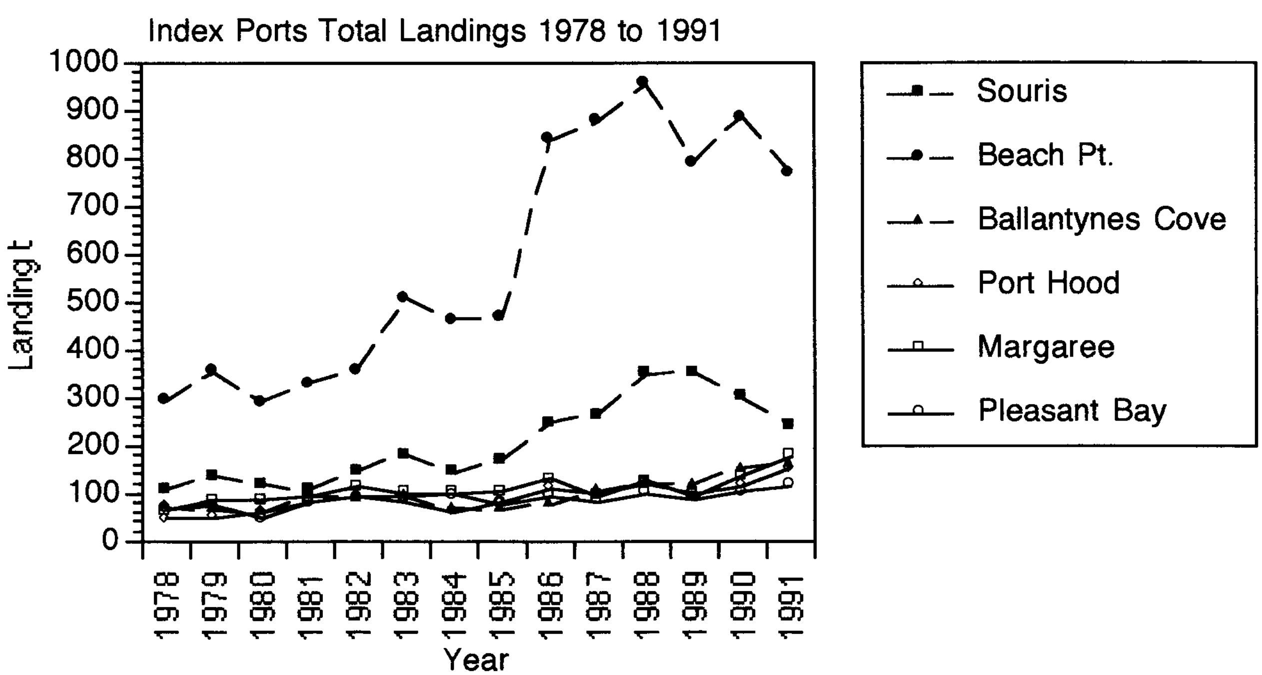


Figure 7.A. Total lobster landings in Area 26A by port, from 1978 to 1991.

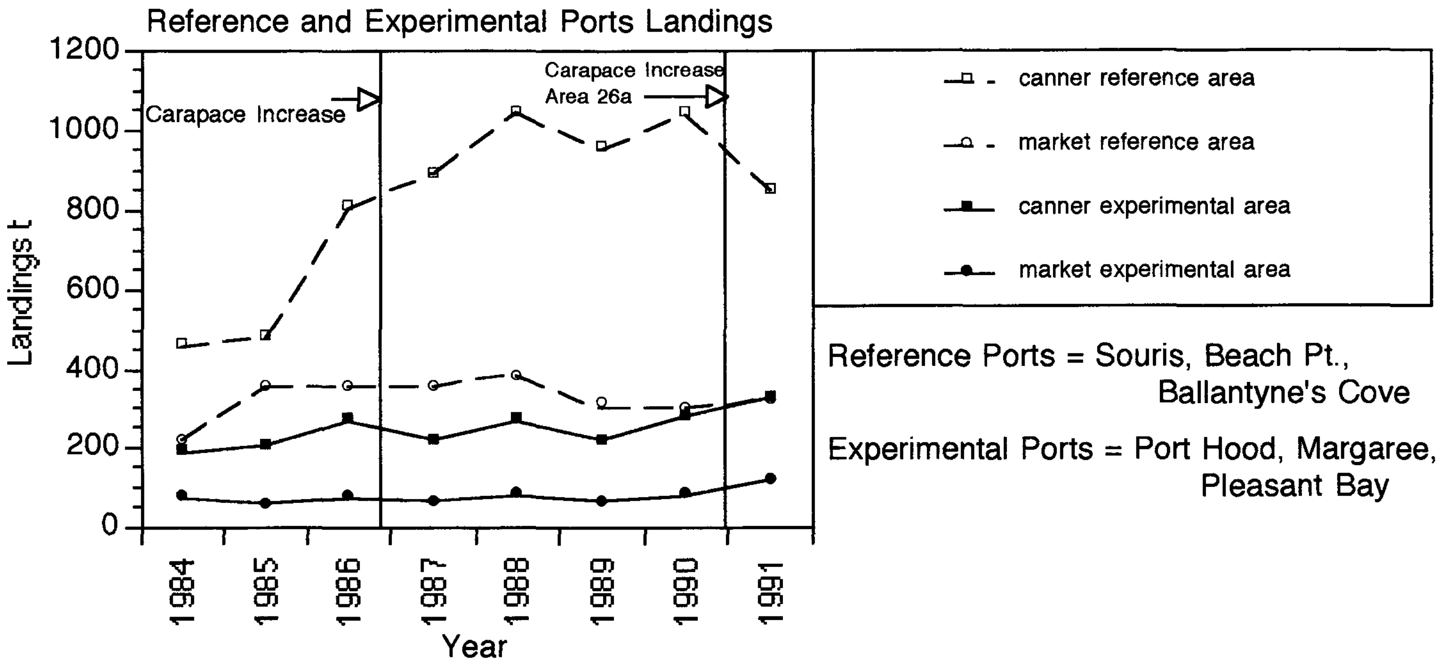


Figure 7.B. Landings for canner and market size lobsters for reference and experimental ports from 1984 to 1991.

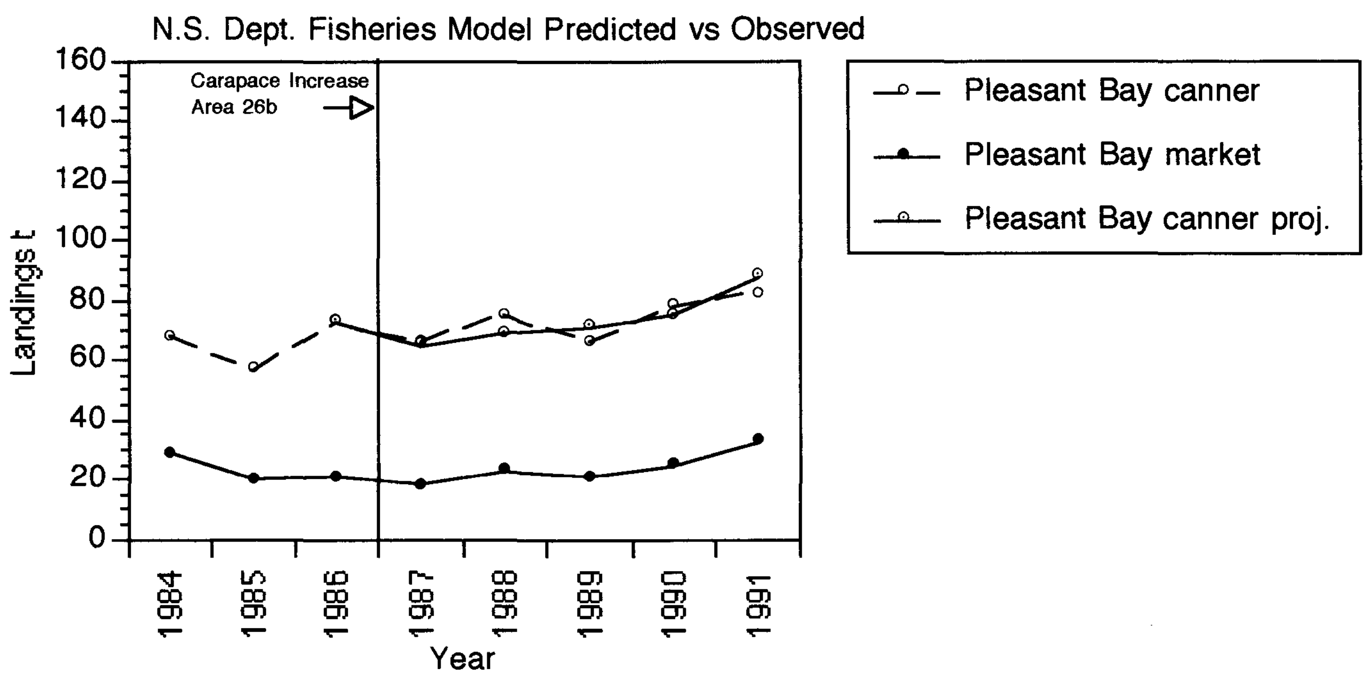


Figure 8.A. Predicted and observed lobster landings for Pleasant Bay, N.S..

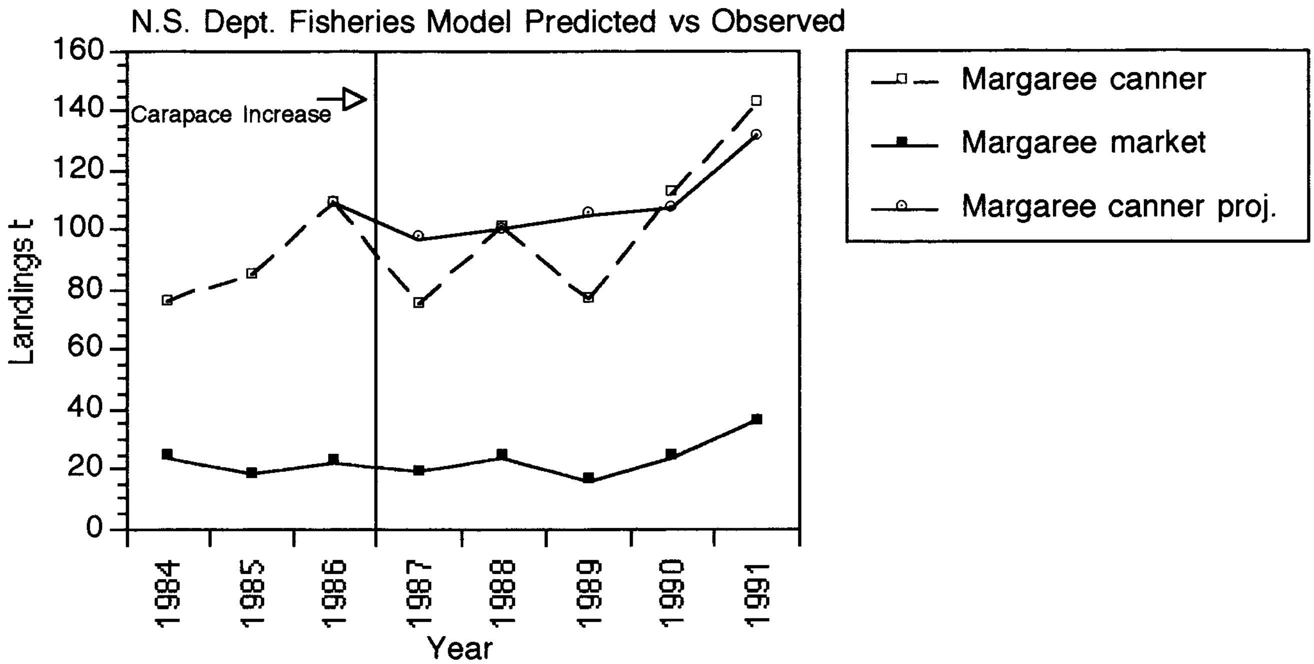


Figure 8.B. Predicted and observed lobster landings for Margaree, N.S.

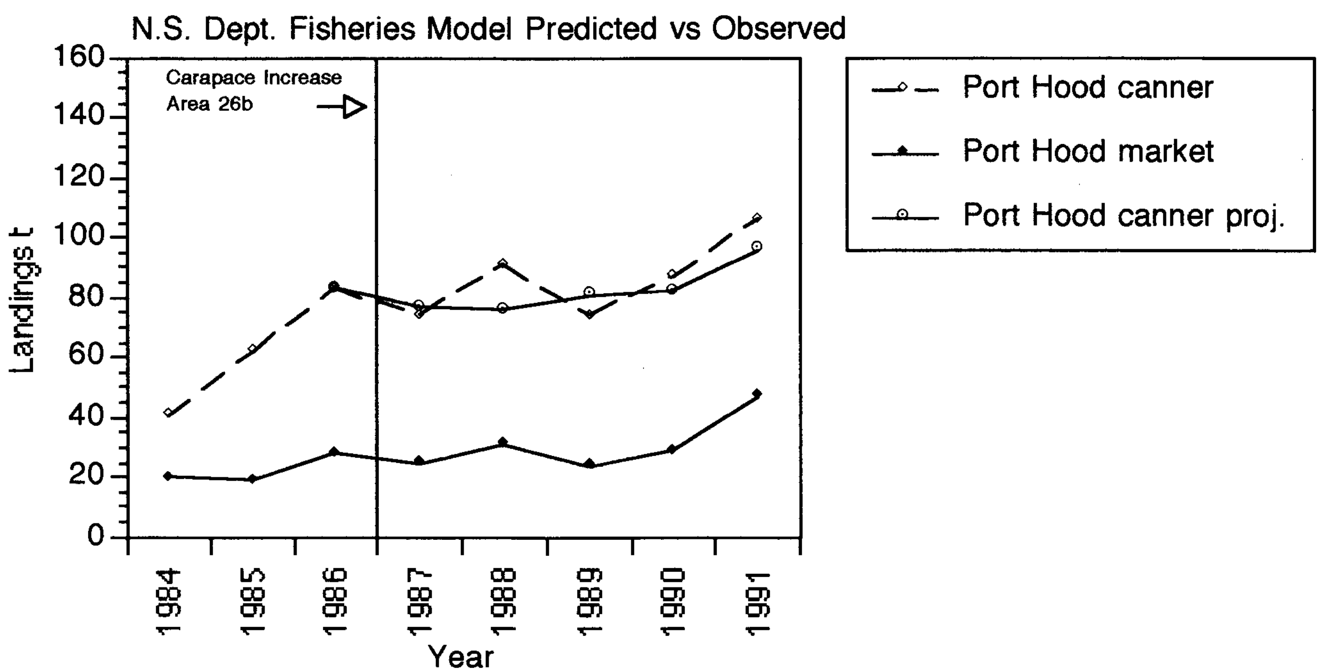


Figure 8.C. Predicted and observed lobster landings for Port Hood, N.S..

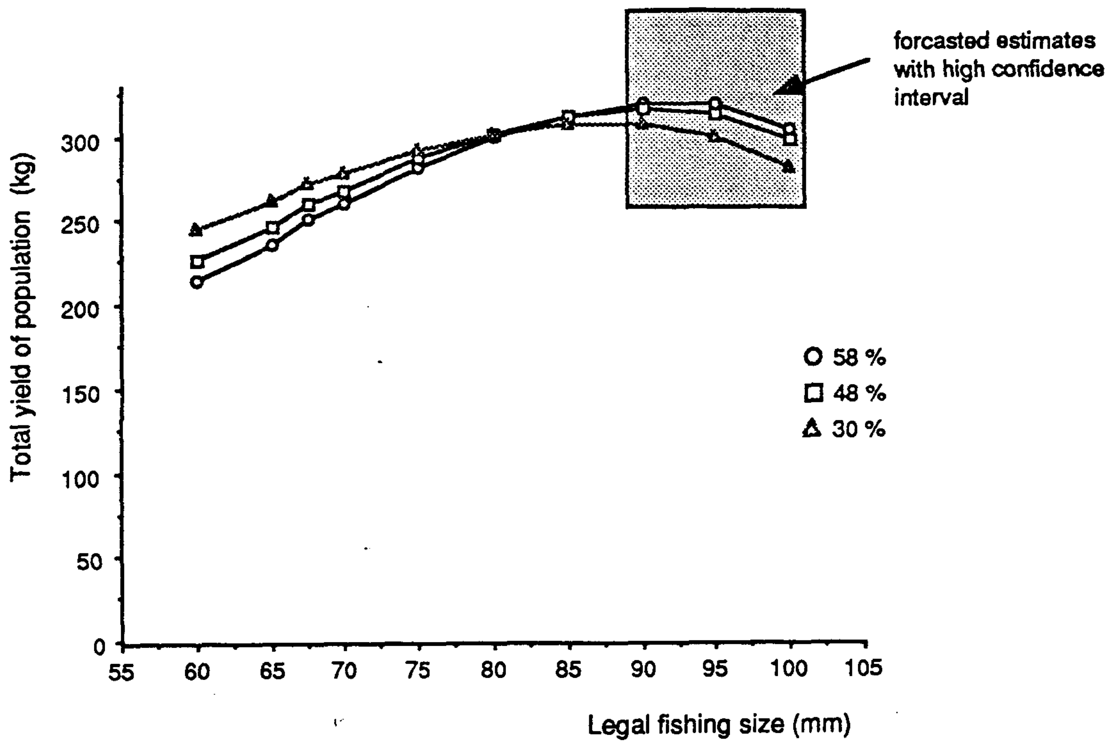


Figure 9A. Total fishable yield (kg) versus size at recruitment of male lobsters at three levels of fishing exploitaion. Stippled area represents data extrapolated for larger lobsters. Inital population of 1000 lobsters.

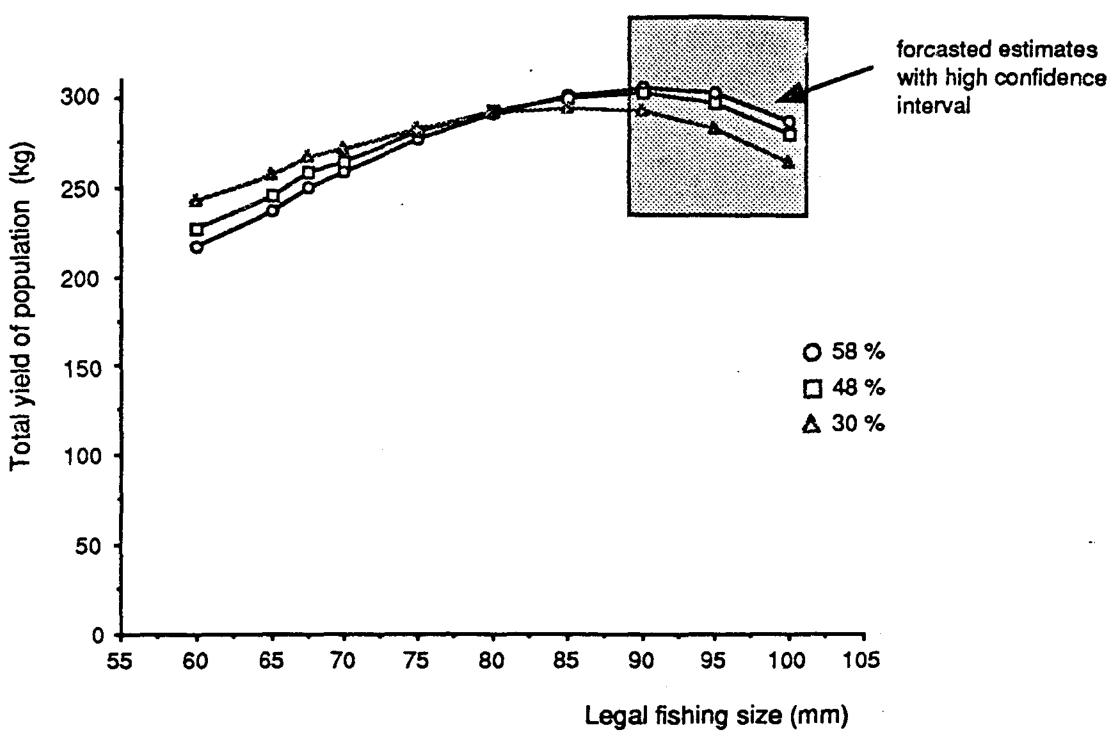


Figure 9B. Total fishable yield (kg) versus size at recruitment of female lobsters at three levels of fishing exploitaion. Stippled area represents data extrapolated for larger lobsters. Inital population of 1000 lobsters.

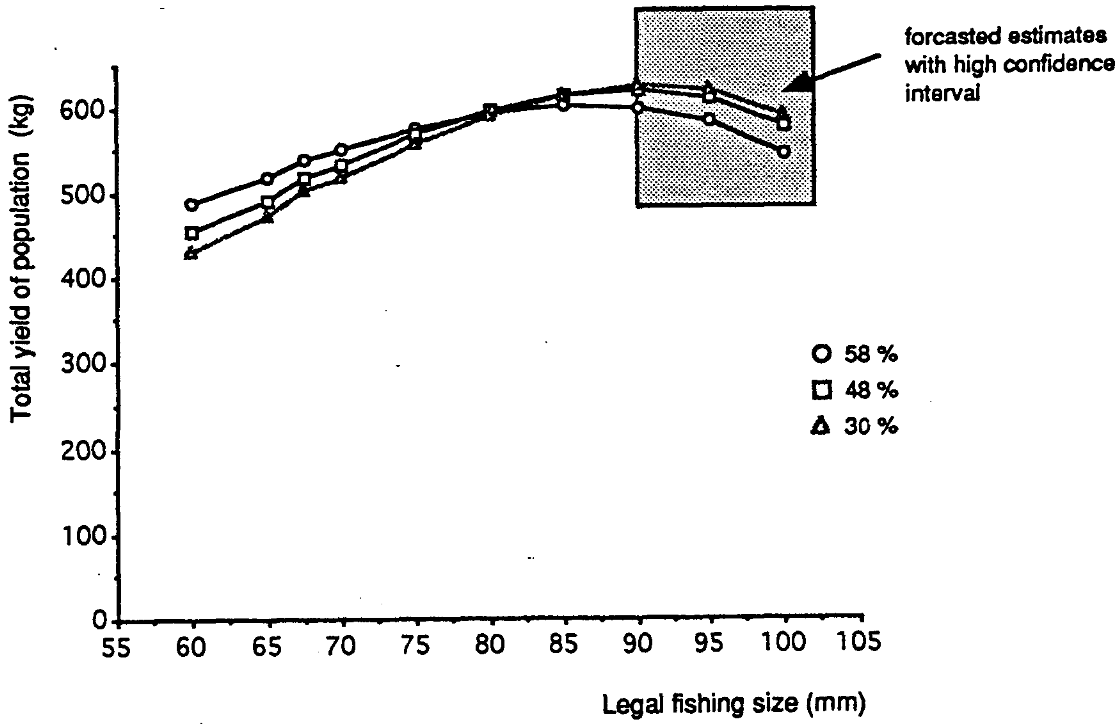


Figure 9C. Total fishable yield (kg) versus size at recruitment of male and female lobsters at three levels of fishing exploitaion. Stippled area represents data extrapolated for larger lobsters. Inital population of 1000 male and 1000 female lobsters.

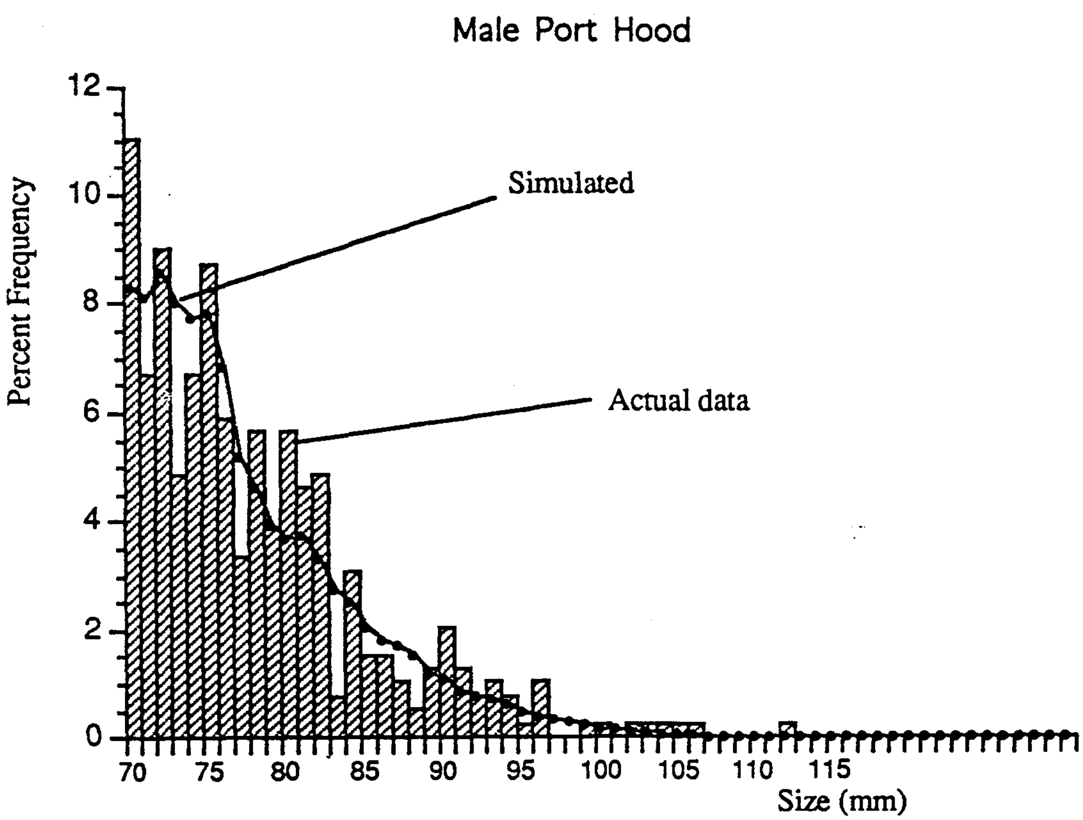


Figure 10A. Comparisons of observed male size frequencies (n=826) after minimum legal carapace size increase program and a simulation based on yield per recruit model using pre-carapace increase parameters.

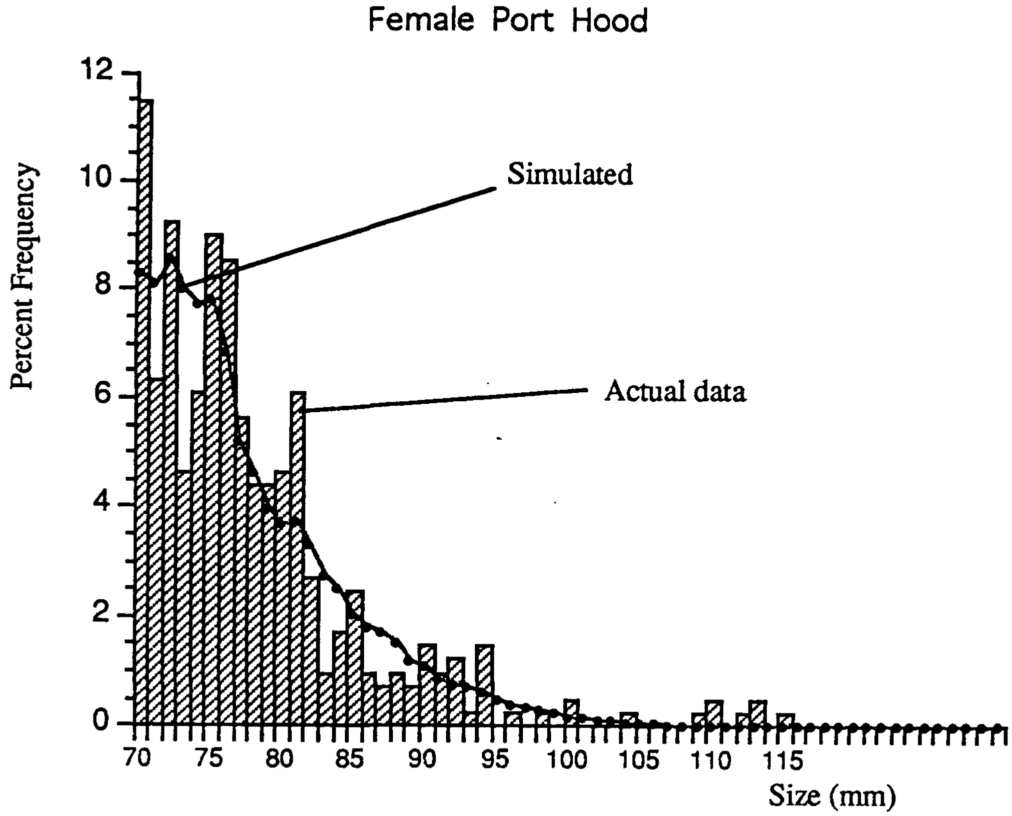


Figure 10B. Comparisons of observed female size frequencies (n=915) after minimum legal carapace size increase program and a simulation based on yield per recruit model using pre-carapace increase parameters.

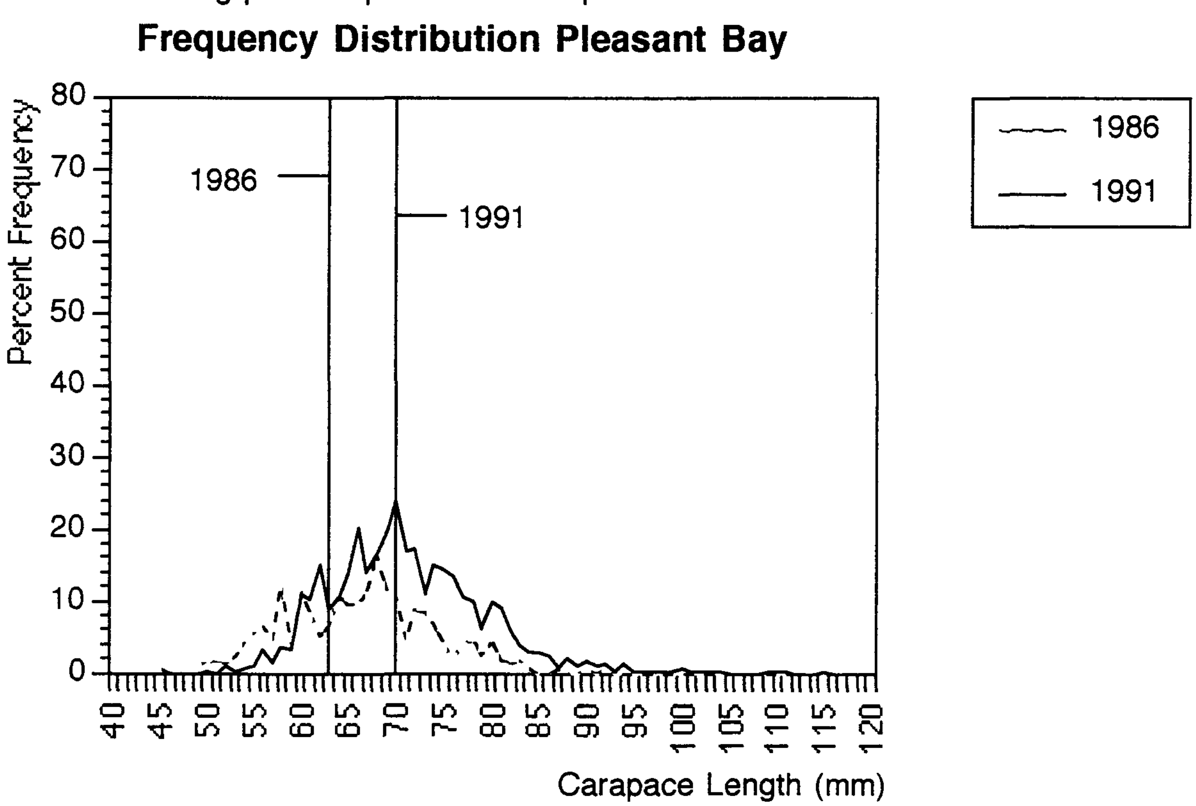


Figure 11.A. Size frequency distributions of the number of lobsters per 100 trap hauls per millimeter for Pleasant Bay. The two distributions represent observations before and after the carapace size increase (1986 and 1991) in Area 26B. Minimum legal size for the 1986 and 1991 are shown on graph.

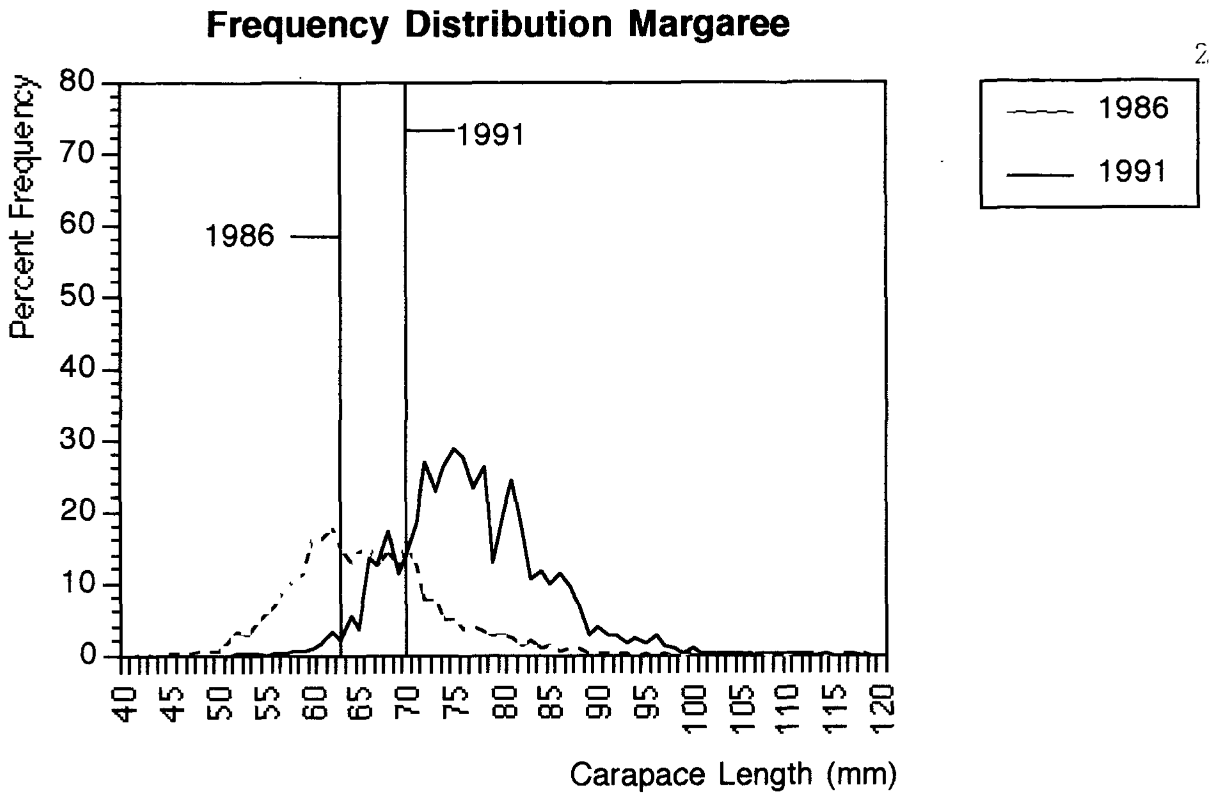


Figure 11.B. Size frequency distributions of the number of lobsters per 100 trap hauls per millimeter for Margaree. The two distributions represent observations before and after the carapace size increase (1986 and 1991) in Area 26B. Minimum legal size for the 1986 and 1991 are shown on graph.

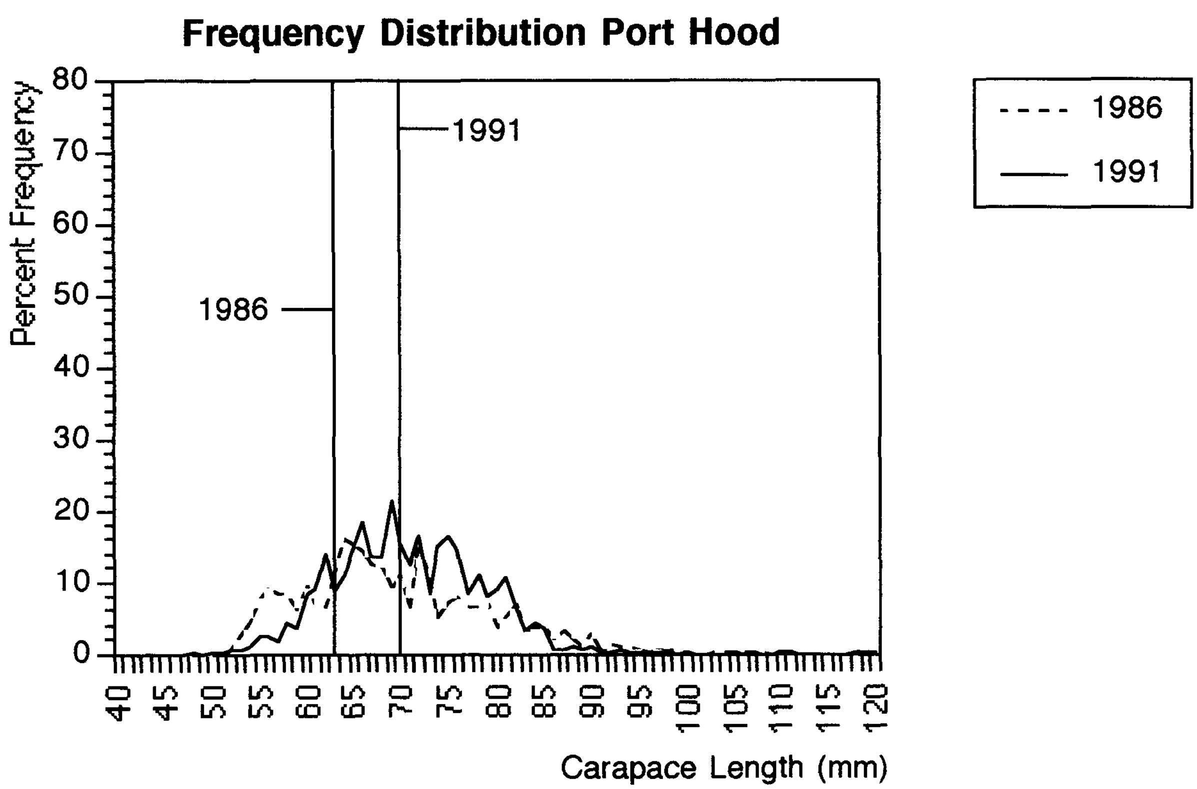


Figure 11.C. Size frequency distributions of the number of lobsters per 100 trap hauls per millimeter for Port Hood. The two distributions represent observations before and after the carapace size increase (1986 and 1991) in Area 26B. Minimum legal size for the 1986 and 1991 are shown on graph.

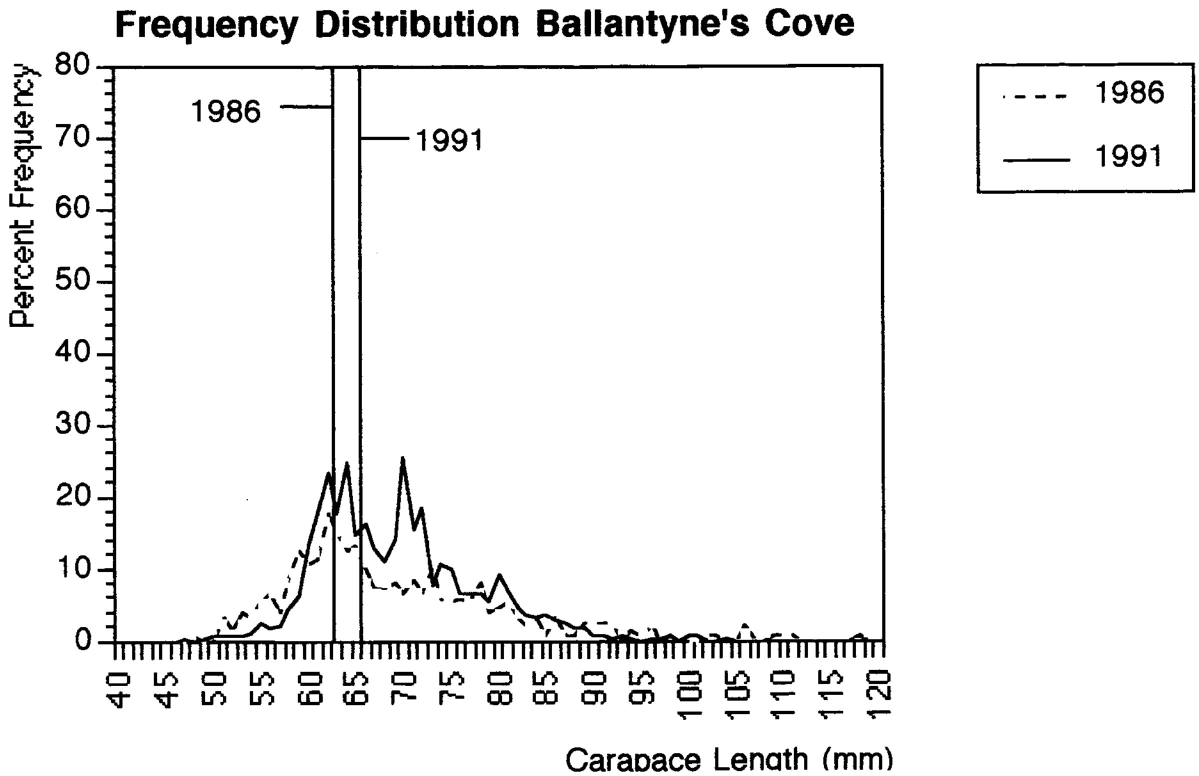


Figure 11.D. Size frequency distributions of the number of lobsters per 100 trap hauls per millimeter for Ballantyne's Cove. The two distributions represent observations before and after the carapace size increase (1986 and 1991) in Area 26B. Minimum legal size for 1986 and 1991 are shown on the graph.

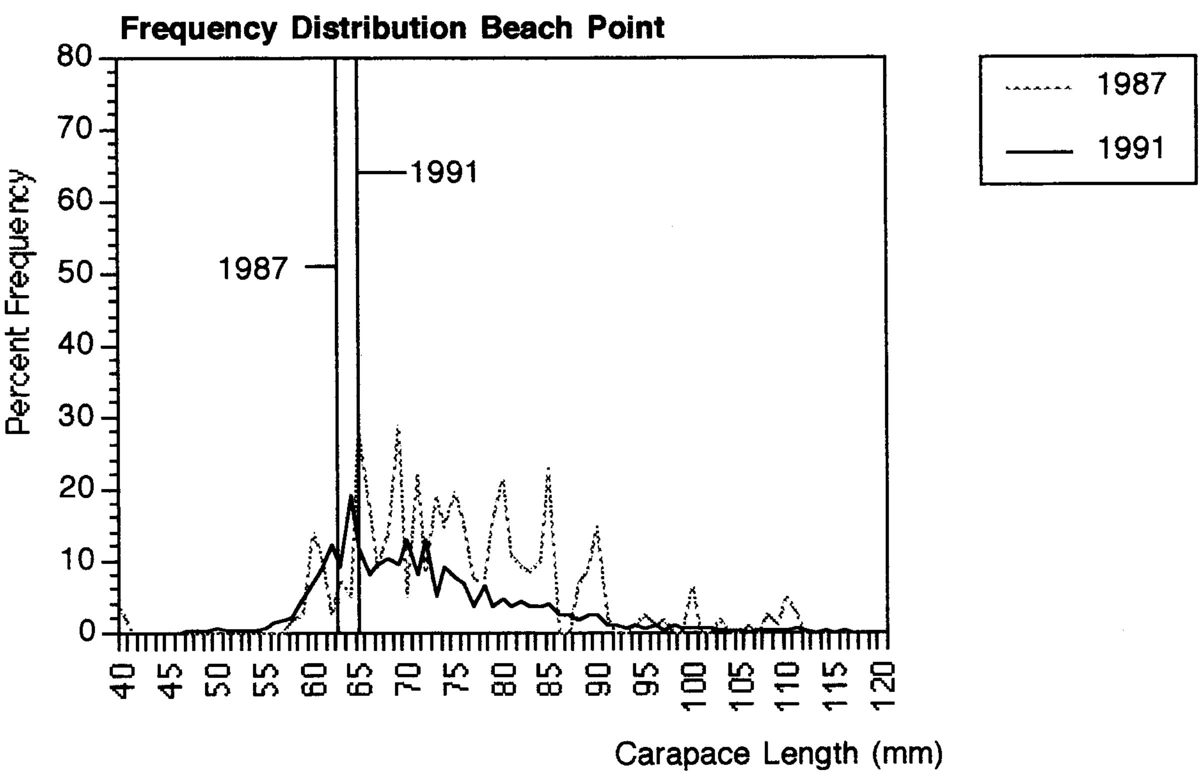


Figure 11.E. Size frequency distributions of the number of lobsters per 100 trap hauls per millimeter for Beach Point. The two distributions represent observations before and after the carapace size increase (1986 and 1991) in Area 26B. Minimum legal size for the 1986 and 1991 are shown on graph.

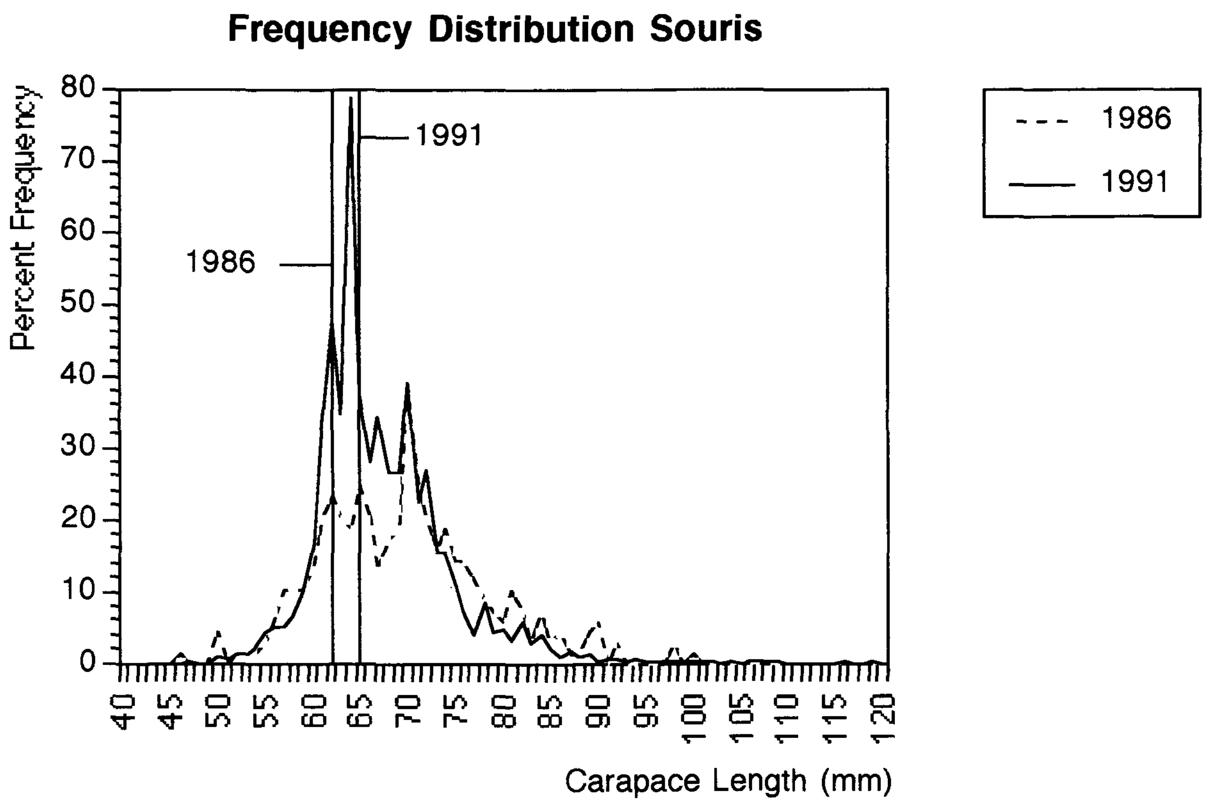
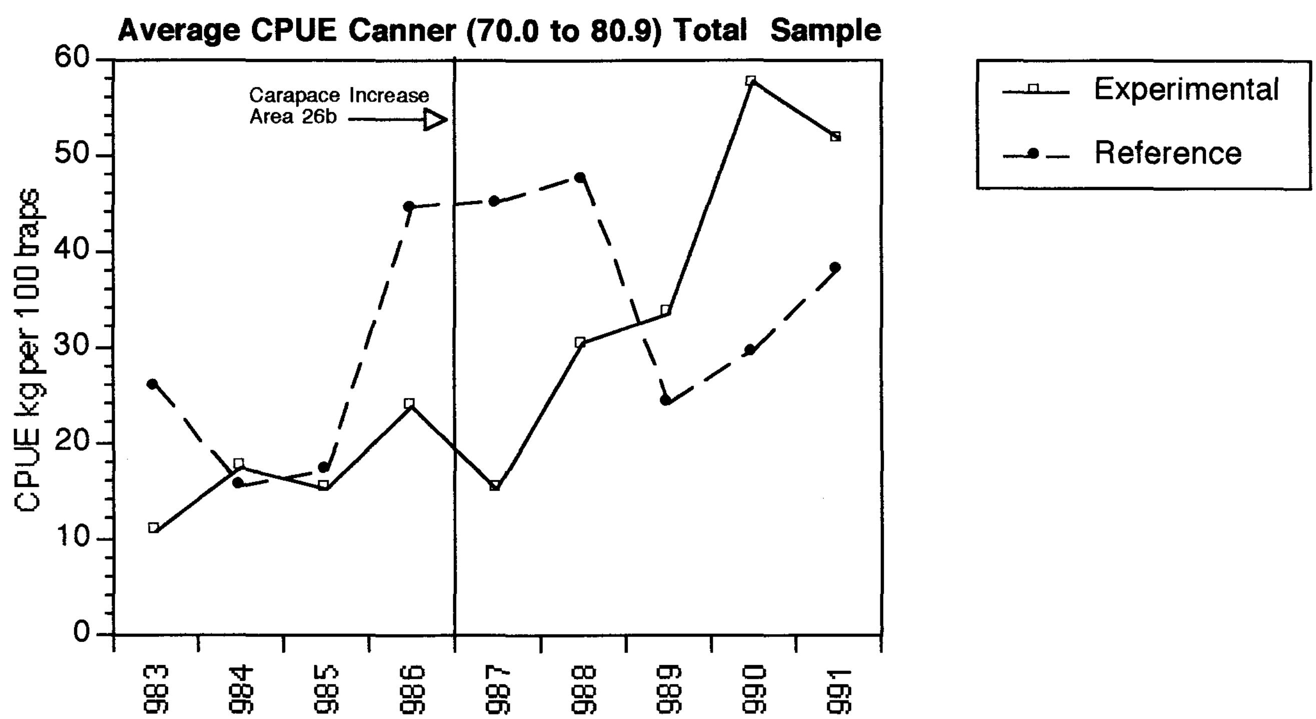
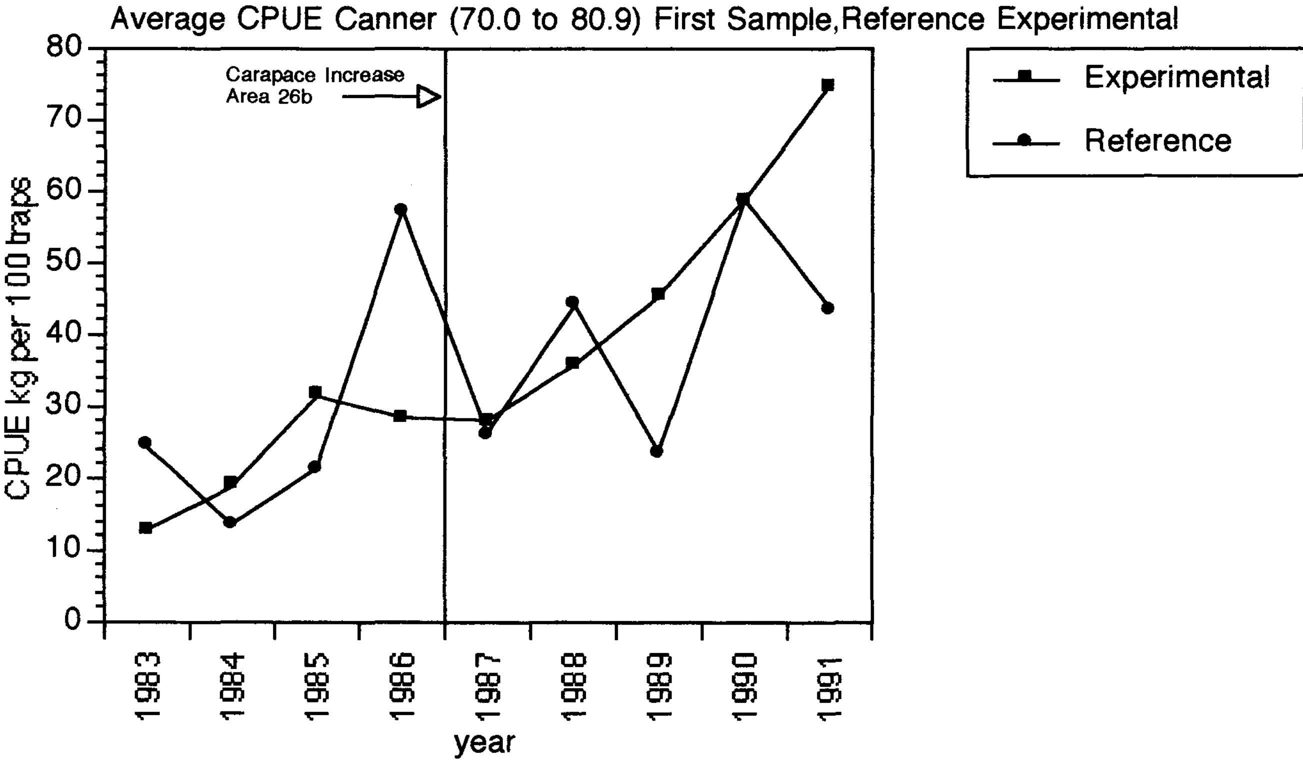


Figure 11.F. Size frequency distributions of the number of lobsters per 100 trap hauls per millimeter for Souris. The two distributions represent observations before and after the carapace size increase (1986 and 1991) in Area 26B. Minimum legal size for the 1986 and 1991 are shown on graph.



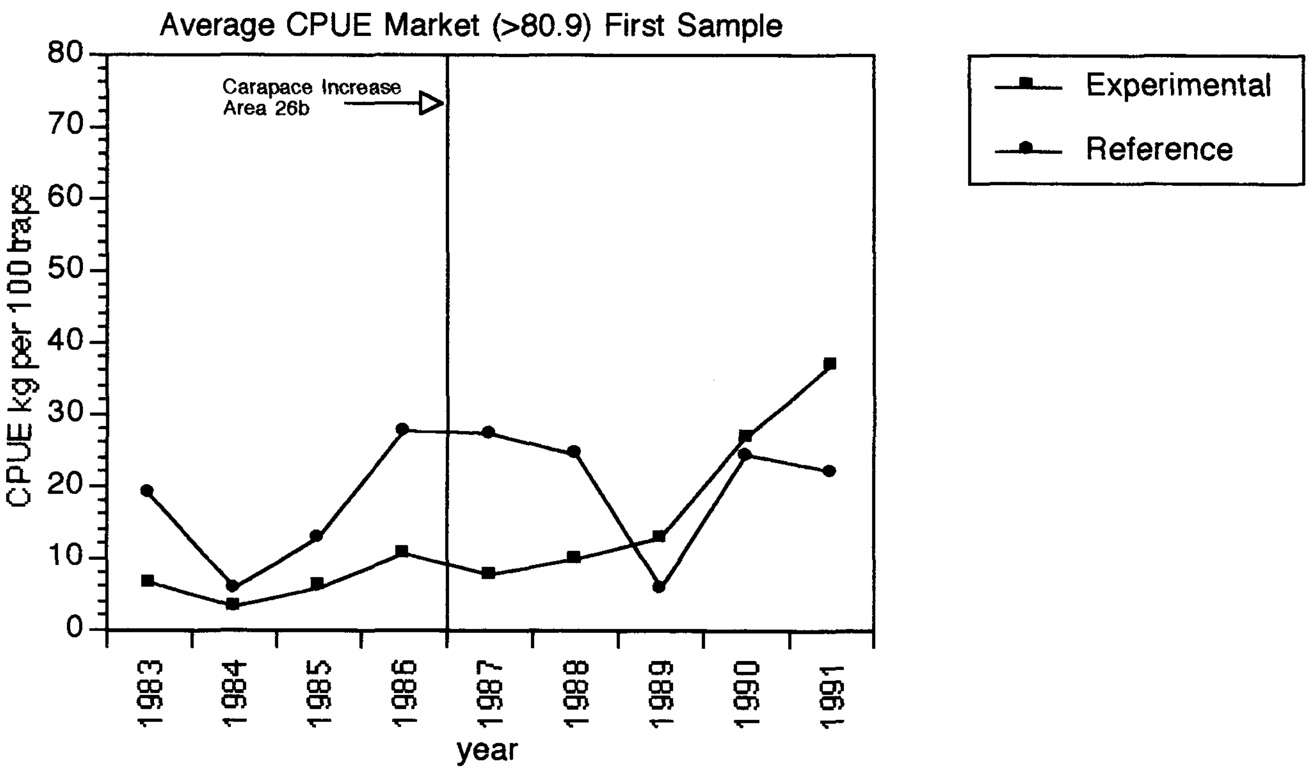
Reference Ports = Souris, Beach Pt., Ballantynes Cove
Experimental Ports = Port Hood, Margaree, Pleasant Bay

Figure 12.A. Average C.P.U.E. for lobsters 70.0 to 80.9 mm carapace size for all samples from the reference and experimental ports from 1983 to 1991.



Reference Ports = Souris, Beach Pt., Ballantynes Cove
Experimental Ports = Port Hood, Margaree, Pleasant Bay

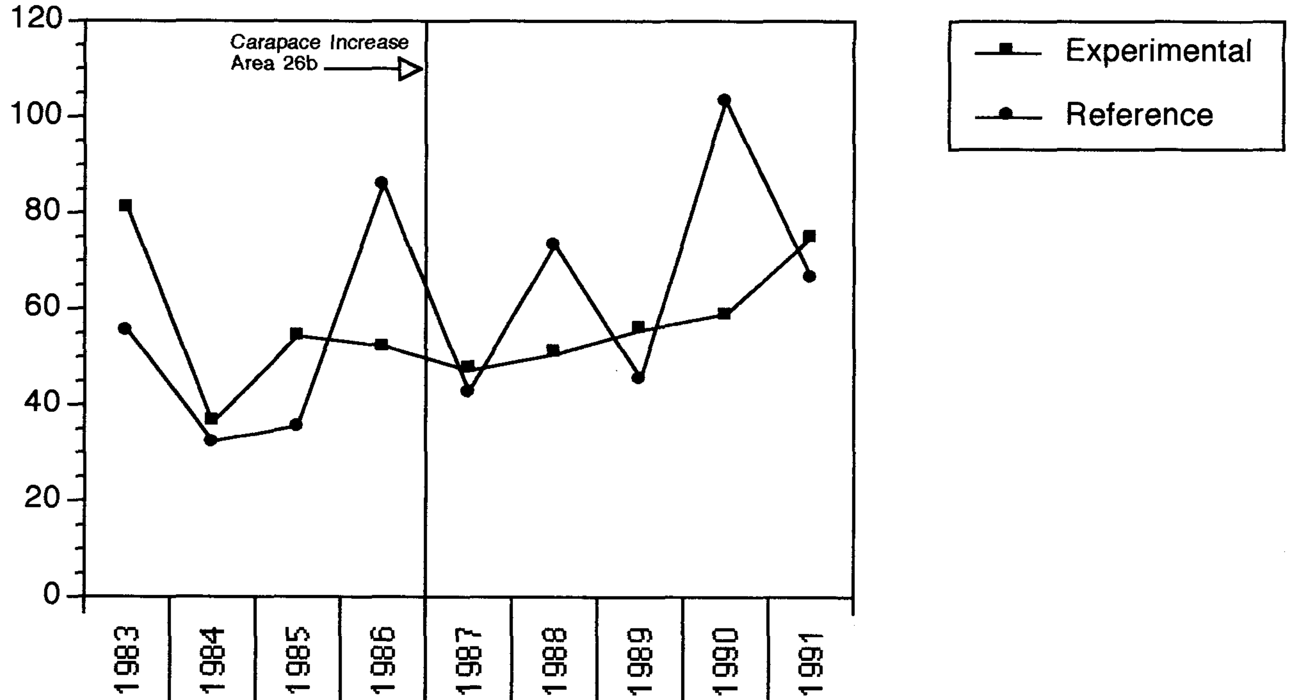
Figure 12.B. C.P.U.E. for canner lobster (70 to 80.9mm) for experimental and reference Areas (first sample) from 1983 to 1991.



Reference Ports = Souris, Beach Pt., Ballantynes Cove
Experimental Ports = Port Hood, Margaree, Pleasant Bay

Figure 13. C.P.U.E. for market lobsters in experimental and reference Areas (first sample) from 1983 to 1991.

Average CPUE (legal size as per year and Area) First Sample



	1983	1984	1985	1986	1987	1988	1989	1990	1991
Experimental	63.5	63.5	63.5	63.5	65.1	66.7	68.3	70.0	70.0
Reference	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	65.1

Reference Ports = Souris, Beach Pt., Ballantynes Cove
Experimental Ports = Port Hood, Margaree, Pleasant Bay

Figure 14. Average CPUE of legal size lobster for reference and experimental ports from 1983 to 1991. The legal sizes for each year of the study in each Area is shown below the figure.

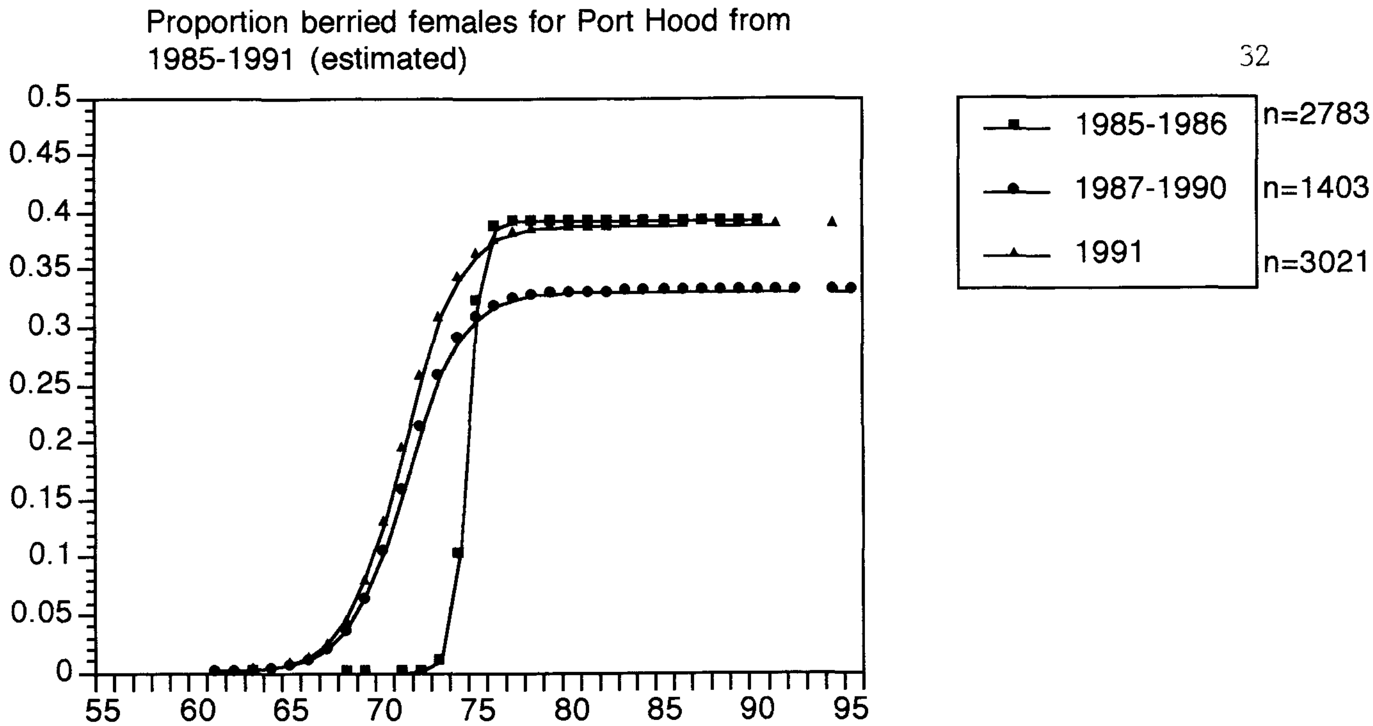
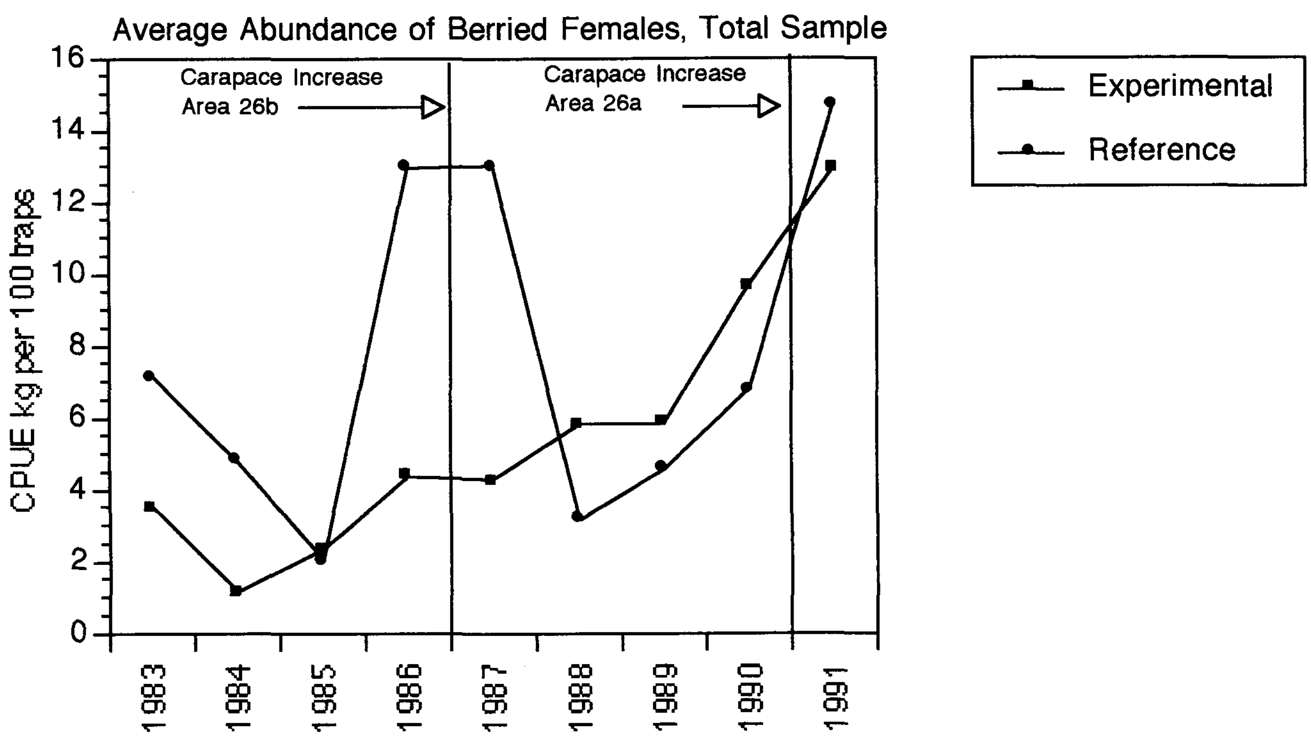


Figure 15. Berried female data fitted to a logistic curve to show the estimated proportion of berried females for Port Hood, N.S. from 1985 to 1991 year groupings. The numbers (n) of lobsters used in the equation are shown.



Reference Ports = Souris, Beach Pt., Ballantynes Cove
Experimental Ports = Port Hood, Margaree, Pleasant Bay

Figure 16. Abundance of berried females in the reference and experimental areas from 1983 to 1991. The date of the carapace increase in Areas 26B and 26A are also shown.

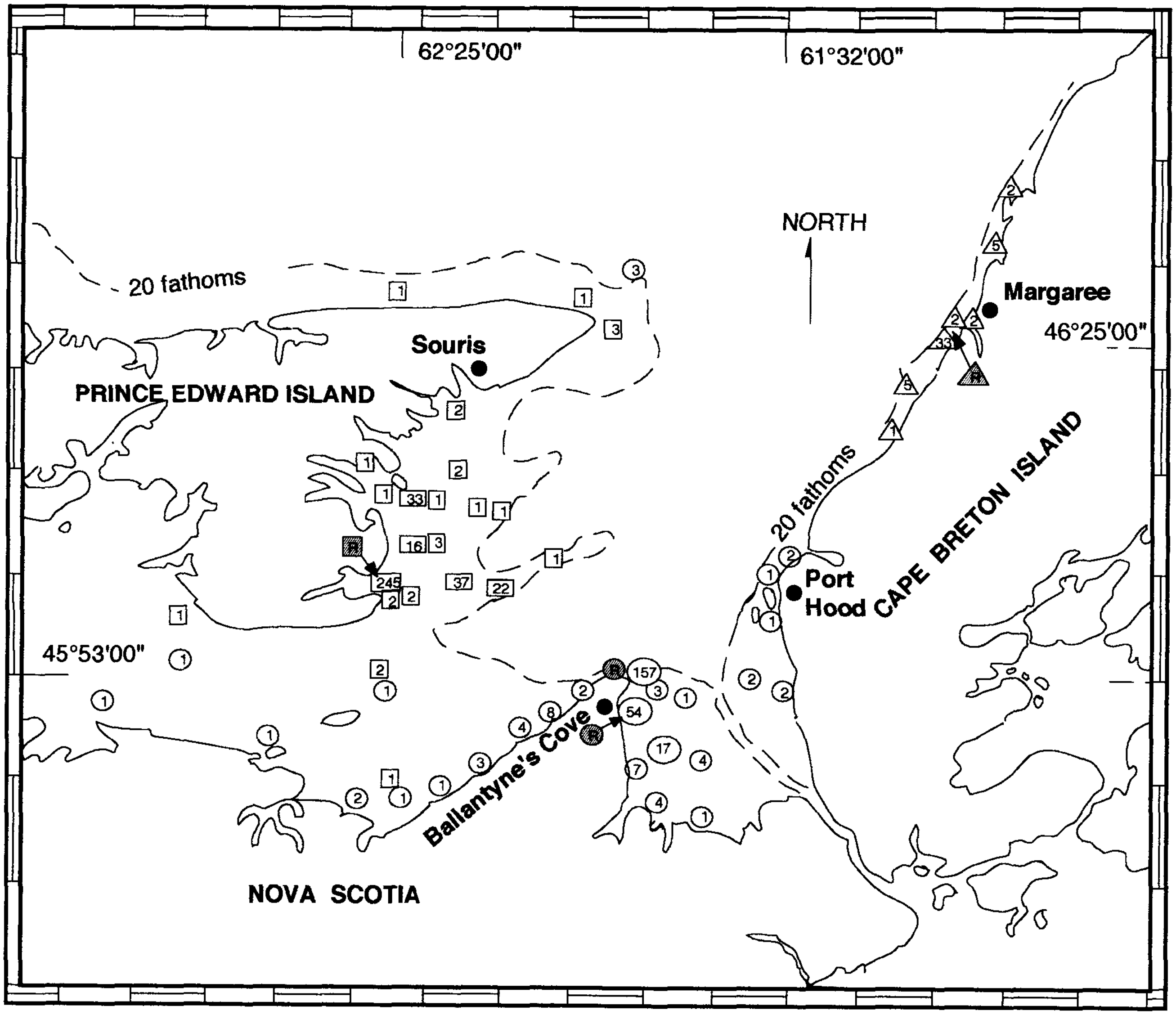


Figure 17 Geographic distribution of recapture sites of tagged lobster released at three different locations in the southern Gulf of St. Lawrence.

- **- Release site at Beach Point, P.E.I.(1982)**
- **- Release sites at St. George's Bay, N.S.(1986)**
- **- Release site at Margaree, Nova Scotia (1984)**

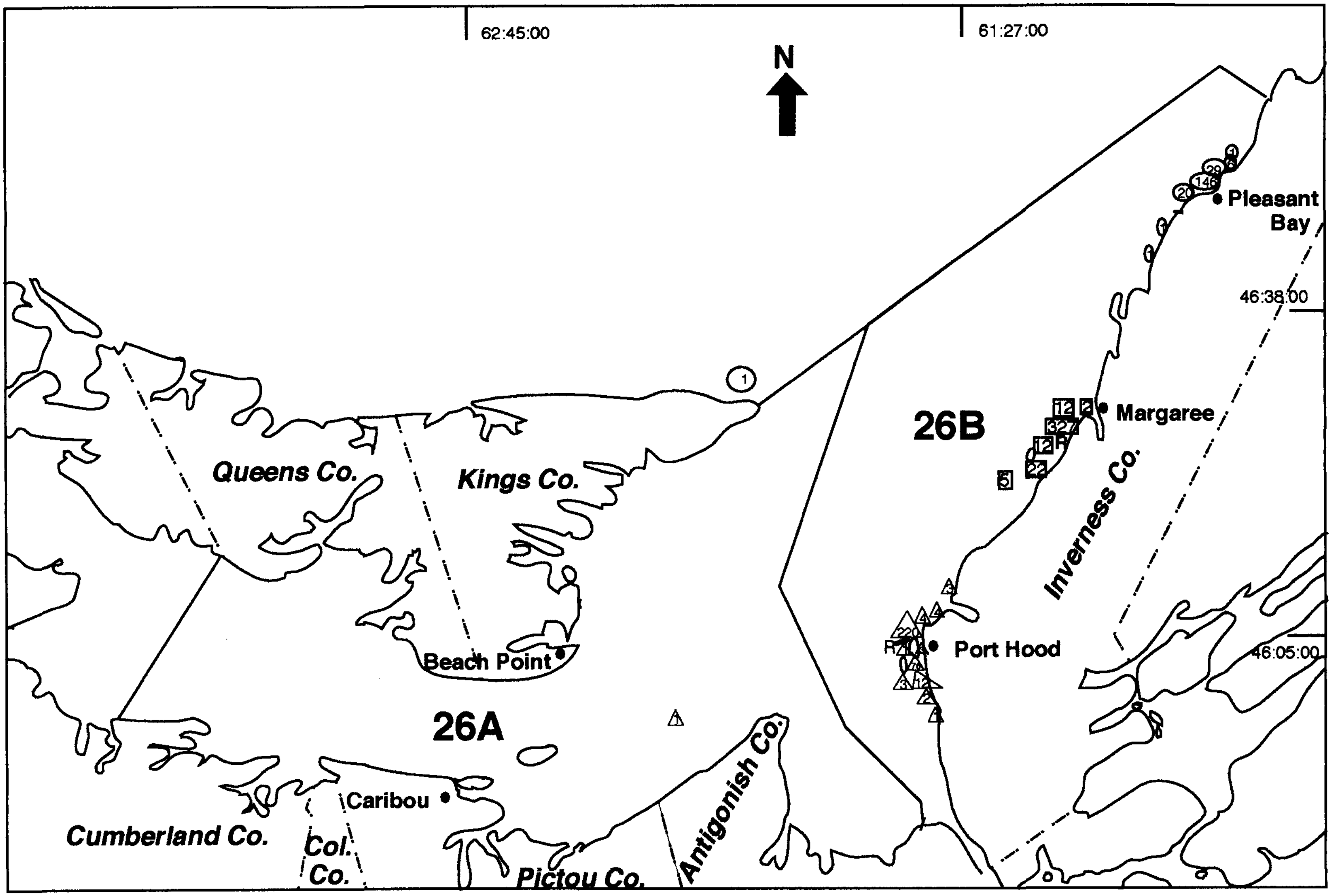


Figure 18 **Distribution of lobsters tagged(1988) and recaptured(1989).**

R=release site □ =number of lobsters recaptured at that site, released in Margaree

○ =number of lobsters recaptured at that site, released in Pleasant Bay

△ =number of lobsters recapatured at that site, released in Port Hood

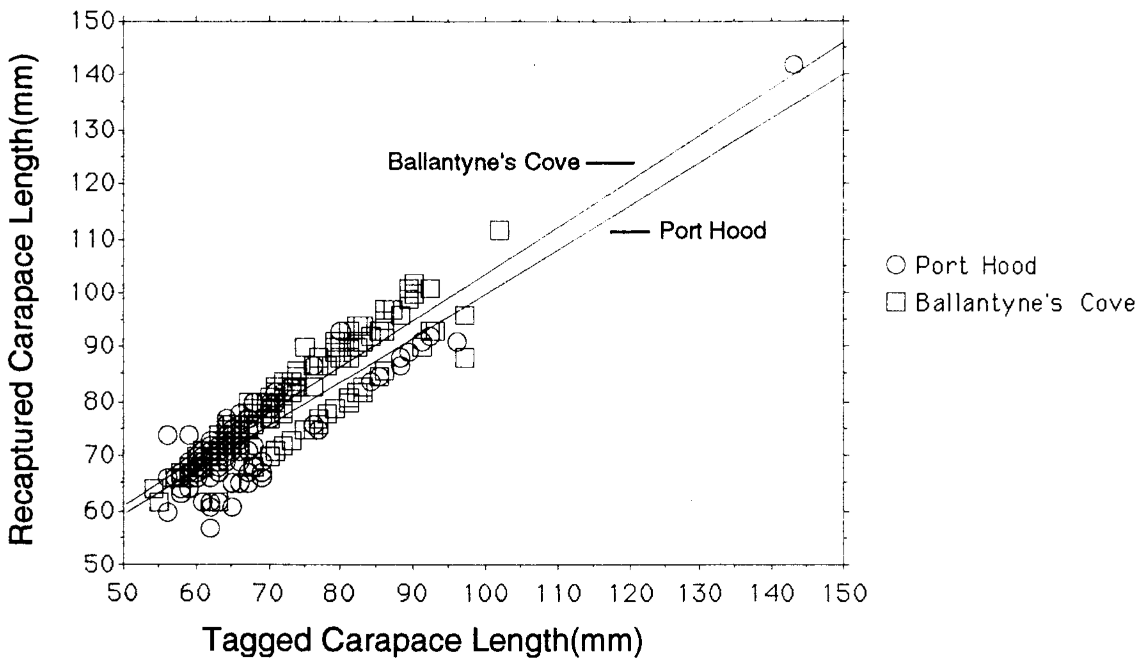


Figure 19 Regression of tagged versus recaptured carapace length of female lobster. Data from tagging programs Ballantyne's Cove(1986) and Port Hood(1988).

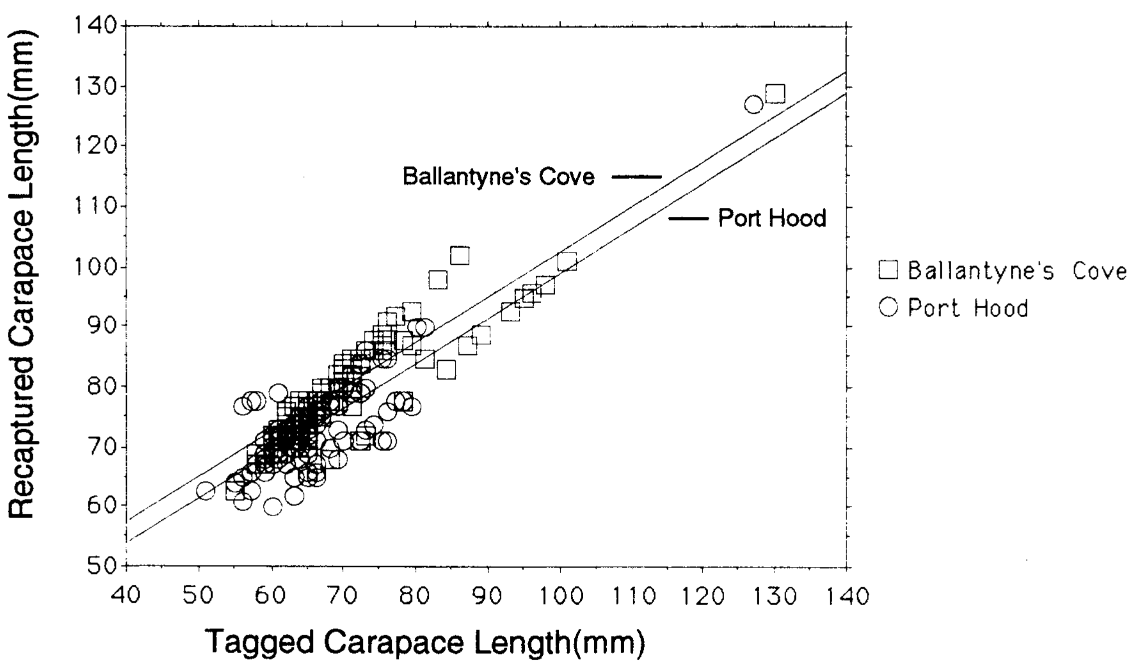


Figure 20 Regression of tagged versus recaptured carapace length of male lobster. Data from tagging program's Ballantyne's Cove(1986) and Port Hood(1988).

APPENDIX I

SIZE INCREASE MODEL

The following is an estimation of the impact $^{1}/_{16}$ inch size increases would have on a sample port. Data used were collected by summer students in Bayfield in St. Georges Bay during 7 port sampling visits between May 5 and June 30 of 1982. A constant canner price based on 1982 levels was used for all calculations. All estimated variables were given conservative values. One molt per year and constant fishing effort were anticipated. All increases and decreases in catch and value have been related to 1982 base year.

Group Weight Factor:

Canners of different sizes have different weights, therefore one size group such as the 2 $^{1}/_{2}$ - 2 $^{5}/_{8}$ inch lobsters will not make as significant a contribution to the overall canner weight as would a larger size group. The group weight factor is a value which represents the combined effect of number of animals in a particular size group and the average weight of those animals. The percentage of canners by weight in any size group is derived by dividing that group's weight factor into the sum of all group weight factors.

Growth Paragraph:

The growth paragraph in the calculations estimates the relative weight contribution a group of lobsters thrown back one year and caught the next. It is derived by first removing 10% (estimated annual mortality) from the % by number of the group thrown back. The initial weight of those surviving is then derived by multiplying the survivorship percentage by the average weight of that group. The final weight value of the group is attained by adding 50% (annual growth rate) to obtain a weight factor which will be added to the expected canner catch of that year.

Canner Size Frequency:

wt. Inches lbs.	Group mm Weight Factor		Estimated % % by Number by Wt.	per Animal	
2 1/2-2 5/8	64-67	17.1	.5	8.55	12.0
2 5/8-2 3/4	67-70	19.9	.6	11.94	16.8
2 3/4-2 7/8	70-73	21.9	.7	15.33	21.5
2 7/8-3	73-76	21.7	.8	17.52	24.6
3-3 3/16	76-81	19.8	.9	17.82	25.0
				71.16	

% canners to total catch (weight) = 54%

Average price canners = \$1.50
Average price markets = \$2.00

$$\frac{\$1.50 \times .54}{\$2.00 \times .46} = \frac{.81}{.92}$$

% canner value to value of total catch = 46.82%

1983

2 1/2 - 2 5/8 inches removed
12% of canner weight removed
5.6% of total value removed

1984

No additional change in size limit.

Growth: 17.1 - (10% mortality) 1.7 = 15.4 (lobster thrown back during previous year)
15.4 x (est. wt. per animal) .5 = 7.7
7.7 + (50% growth rate) 3.85 = 11.55

Group weight factors:

removed since '83 = 8.55
added in '84 = 11.55

gain 3.0

4.2% increase in canner weight
1.97% increase in total value

1985

2 $^{5}/_{8}$ - 2 $^{3}/_{4}$ inches removed

Group weight factors:

removed since '83 = 8.55
added since '84 = 11.55
removed in '85 = 11.94

decrease 8.94

12.56% decrease in canner weight
5.88% decrease in landed value

1986

No additional change

Growth: 19.9 - (10% mortality) 1.99 =17.91 (lobsters thrown back during previous year)
17.91 x (est. wt. per animal) .6=10.746
10.746 + (50% growth rate) 5.373 = 16.12

Group weight factors:

removed since '83	= 8.55
added since '84	=11.55
removed since '85	=11.94
added in '86	=16.12
gain	7.18

10.09% increase in canner wt.
4.72% increase in landed value.

Assumptions:

- Estimates are based on constant recruitment.
- Value estimates assume that canner prices remain the same.
- No increased recruitment or other beneficial long term effects are addressed.
- Two molts per year are possible for small canner lobsters.
- It is assumed that all returned losters will be caught the following year. It is likely that this will not occur; therefore, benefits observed during and immediately following the increases will be somewhat lower than estimated. Additional growth of these non-captured animals has also not been considered, so this factor should make up for any shortfalls that occurred because of the previous concern.

The following examples are based upon a $\frac{1}{16}$" size increase. Weight gains and losses are for canners only with the above assumptions.

Port Hood/Murphy's Pond 1986 Data

Size	Number	% by Number	Est. Wt/ea.	Group Wt.	% by wt.
$2\frac{1}{2}$-$2\frac{9}{16}$	583.2	10.5	0.5	5.25	7.6
$2\frac{9}{16}$-$2\frac{10}{16}$	758.44	13.7	0.55	7.53	10.8
$2\frac{10}{16}$-$2\frac{11}{16}$	631.16	11.4	0.6	6.84	9.9
$2\frac{11}{16}$-$2\frac{3}{4}$	590.6	10.7	0.65	6.95	10.0
$2\frac{3}{4}$-$2\frac{7}{8}$	1357.6	24.5	0.72	17.64	25.4
$2\frac{7}{8}$-3	901.4	16.5	0.82	13.53	19.5
3-$3\frac{3}{16}$	704.6	12.7	0.92	11.68	16.8
	5,527.0	100.0%		69.42	100.0%

based on 73.6% canners by weight x $2.00/lb = 1.472
26.4% markets by weight x $2.94/lb = <u>0.776</u>
2.248

canners = $\frac{1.472}{2.248}$ = 65.5% of total value of catch

markets - $\frac{0.776}{2.248}$ = 34.5% of total value

YEAR 1: legal size raised to 2 9/16
7.6% of canner weight lost
5.0% of <u>total</u> value lost

YEAR 2: Growth 5.2 - (10%) + (50%)
4.725 + 2.625 = 7.35

removed since YR 1 -5.25
added in YR 2 +7.35
removed in YR 2 <u>-7.53</u>
-5.43

$\frac{-5.43}{0.6942}$ = 7.8% wt loss

7.8 x 65.5% = 5.1% value loss

YEAR 3: Growth 7.53 - (10%) + (50%)
6.777 + 3.765 = 10.54

previous year total-5.43
added in YR 3 +10.54
removed in YR 3 <u>-6.84</u>
-1.73

$\frac{-1.73}{0.6942}$ = 2.5% wt loss

2.5 x 65.5% = 1.6% value loss

YEAR 4: Growth 6.84 - (10%) + (50%)
6.156 + 3.42 = 9.58

previous year total-1.73
added in Yr 4 +9.58
removed in Yr 4 <u>-6.95</u>
+0.90

$\frac{0.90}{0.6942}$ = 1.3% wt increase

1.3 x 65.5% = 0.8% value increase

YEAR 5: Growth 6.95 - (10%) + (50%)
6.2555 + 3.475 = 9.73

previous year total+0.90
added in YR 5 +9.73
+10.63

10.63 / 0.6942 = 15.3% wt increase
15.3 x 65.5% = 10.0% value increase

Margaree Harbour 1986 Data

Size	Number	% by Number	Est. Wt/ea.	Group Wt.	% by wt.
$2^1/_2$-$2^9/_{16}$	779.45	15.0	0.5	7.50	11.3
$2^9/_{16}$-$2^5/_8$	784.59	15.1	0.55	8.31	12.6
$2^5/_8$-$2^{11}/_{16}$	740.18	14.3	0.6	8.58	13.0
$2^{11}/_{16}$-$2^3/_4$	695.88	13.4	0.65	8.71	13.2
$2^3/_4$-$2^7/_8$	1214.90	23.5	0.72	16.92	25.6
$2^7/_8$-3	581.20	11.2	0.82	9.18	13.9
3-$3^3/_{16}$	387.80	7.5	0.92	6.90	10.4
	5,184.0	100.0%		66.10	100.0%

based on 83.7% canners by weight x $2.02/lb = 1.691
16.3% markets by weight x $2.94/lb = 0.479
2.170

canners = 1.691 / 2.170 = 77.9% of total value

markets = 0.479 / 2.170 = 22.1% of total value

YEAR 1: legal size raised to $2^9/_{16}$

11.3% of canner weight lost
8.8% of total value lost

YEAR 2: Growth = 7.5 - (10%) + (50%)
6.75 + 3.75 = 10.50

removed since YR 1	-7.50	-5.31 / 0.661	= 8.0% weight loss
added in YR 2	+10.50		
removed in YR 2	-8.31		
	-5.31	8.0% x 77.9% = 6.2% value loss	

YEAR 3: Growth = 8.31 - (10%) + (50%)
7.48 + 4.15 = 11.63

previous year total	-5.31	-2.26 / 0.661	= 3.4% weight loss
added in YR 3	+11.63		
removed in YR 3	-8.58		
	-2.26	3.4 x 77.9% = 2.6% value loss	

YEAR 4: Growth = 8.58 - (10%) + (50%)
7.72 - 4.29 = 12.01

previous year total	-2.26	1.04 / 0.661	= 1.6% weight increase
added in YR 4	+12.01		
removed in YR 4	-8.71		
	+1.04	1.6 x 77.9% = 1.2% value	

increase

YEAR 5: Growth = 8.71 - (10%) + (50%)
7.84 + 4.35 = 12.19

previous year total	+1.04	13.23 / 0.661	= 20.0% weight increase
added in YR 5	+12.19		
	+13.23	20.0 x 77.9 = 15.6% value increase	

Pleasant Bay 1986 Data

Size	Number	% by Number	Est. Wt/ea.	Group Wt.	% by wt.
$2^{1}/_{2}$-$2^{9}/_{16}$	250.98	18.7	0.5	9.35	14.3
$2^{9}/_{16}$-$2^{5}/_{8}$	183.78	13.7	0.55	7.53	11.5
$2^{5}/_{8}$-$2^{11}/_{16}$	199.34	14.8	0.6	8.88	13.5
$2^{11}/_{16}$-$2^{3}/_{4}$	169.60	12.6	0.65	8.19	12.5
$2^{3}/_{4}$-$2^{7}/_{8}$	283.30	21.1	0.72	15.19	23.2
$2^{7}/_{8}$-3	156.0	11.6	0.82	9.51	14.5
3-$3^{3}/_{16}$	101.0	7.5	0.92	6.90	10.5
	1,344.0	100.0%		65.55	100.0%

based on 79% canners by weight x $2.02/lb = 1.596
21% markets by weight x $2.94/lb = 0.617
2.213

canners = $\frac{1.596}{2.213}$ = 72.1% of total value

markets = $\frac{0.617}{2.213}$ = 27.9% of total value

YEAR 1: legal size raised to $2^{9}/_{16}$

11.3% of canner weight lost
8.1% of total value lost

YEAR 2: Growth = 9.35 - (10%) + (50%)
8.415 + 4.675 = 13.09

removed since YR 1 -9.35
added in YR 2 +13.09
removed in YR 2 -7.53
-3.79

$\frac{-3.79}{0.6555}$ = 5.8% weight loss

5.8 x 72.1% = 4.2% value loss

YEAR 3: Growth = 8.88 - (10%) + (50%)
6.777 + 3.765 = 10.54

previous year total	-3.79	$\frac{-2.13}{0.6555}$ = 3.2% weight loss
added in YR 3	+10.54	
removed in YR 3	-8.88	
	-2.13	3.2 x 72.1% = 2.3% value loss

YEAR 4 Growth = 8.88 - (10%) + (50%)
7.99 + 4.44 = 12.43

previous year total	-2.13	$\frac{2.11}{0.6555}$ = 3.2% weight increase
added in YR 4	+12.43	
removed in YR 4	-8.19	
	+2.11	3.2 x 72.1% = 2.3% value increase

YEAR 5: Growth = 8.19 - (10%) + (50%)
7.371 + 4.095 = 11.47

previous year total	+2.11	$\frac{13.58}{0.6555}$ = 20.7% weight loss
added in YR 5	+11.47	
	+13.58	20.7 x 72.1% = 14.9% value increase

APPENDIX II

Input Parameters for Yield per Recruit Model

A model used to assess yield per recruit, developed by G. Ennis and S. Akenhead (CAFSAC Res. Doc. 78/30) was applied using observed data from the Port Hood lobster fishery. The computer model was used to compute the total yield of a known population of undersized or sublegal lobsters (1000 individuals), and charts their progress in time given certain fixed parameters. The parameters input in the model were:

Starting length: This is the size of the smallest lobster considered for the analysis (49.5 mm was used).

Last length: The maximum size that the group of lobsters will attain (149 mm).

Hard shelled survival rate: Proportion of individuals that are expected to survive if the lobster does not molt (95%).

Soft shelled survival rate: Proportion of individuals which are expected to survive if the lobster molts (90%).

Length-weight regression: The constants in the following equation that describes the expected weight of an individual lobster according to its length in millimetres. Data derived from southern Gulf of St. Lawrence lobster sampling program.

Weight = A x $(\text{length})^B$

A = 0.00140744 for males
A = 0.0031 for females
B = 2.8675 for males
B = 2.6838 for females

Pre-post molt growth regression: The constants in the following equation that best describes the size (in mm) of an individual lobster after it has molted. Data derived from 1986 Ballantynes Cove tagging program.

Final size = A + B* starting size where A = 18.29 for females
A = 18.156 for males
B = 0.853 for females
B = 0.853 for males

Fishing mortality: Exploitation rates (A) were calculated as:

$$A = 1 - (M_2/M_1)$$

where $M_1 = M_1'/t_{m1}$, M_1' is the number oflobsters in the catch in the first molt class of legal size (approximately 62-70mm before and during the carapace increases, and 71-80mm after the carapace size increases) and T_{m1} is the average time in years spent in that molt class (Campbell 1985). Fishing mortality range was calculated as 30%, 48%, 58% for before during and after the carapace size increase.

Recruitment length: Size of legal sized lobster. This parameter was varied from 60 mm to 105 mm to study its effects on the total yield.

Proportion molting: Proportion of lobsters molting each year. This data was derived from the 1986 Ballantynes Cove tagging program (80% - males, 82% - females).

Residual growth variation: The proportion of the population falling into +/- 5 mm of mean postmolt length. This vector is calculated from SD of the growth regression.

Input parameters were:

Size (mm)	Proportion (%)
-5 to -4 mm	1.7
-4 to -3 mm	0.8
-3 to -2 mm	3.6
-2 to -1 mm	4.4
-1 to 0 mm	13.2
0 to 1 mm	14.1
1 to 2 mm	21.1
2 to 3 mm	17.5
3 to 4 mm	14.0
4 to 5 mm	9.6

Initial population: A known population of 1000 individuals distributed along a normal curve was defined as shown below. It was the progression of this cohort through the fishery that was observed. Distribution observed during sea sampling at Ballantynes Cove in 1986.

Size (mm)	Number of lobster
49.5	22
50.5	34
51.5	53
52.5	72
53.5	94
54.5	107
55.5	118
56.5	118
57.5	107
58.5	94
59.5	72
60.5	53
61.5	34
62.5	22