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Eastern Cape Breton Lobster (LFA 27-30): Stock Status and Eggs-Per-Recruit Estimates

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ABSTRACT

The status of lobster stocks off eastern Cape Breton (Lobster Fishing Areas 27-30) was evaluated using voluntary fishing logs and samples of the commercial catch up to the end of the 1997 fishing season. We also estimated eggs-per-recruit (E/R) using the Idoine-Rago model with current regulations and with potential regulations that would increase E/R. The steady decline in lobster landings over most of eastern Cape Breton is coincident with decreased catch rates, most likely due to decreased lobster abundance. While there were uncertainties in some of the inputs to the E/R model (e.g. fishing mortality), the model indicated that for LFA 27, E/R would double with a minimum legal size of 75 mm CL (increase of 5 mm) and a maximum legal size of 127 mm CL (females only). Since LFA 27 comprises more than 90% of the lobster landings in eastern Cape Breton, E/R in eastern Cape Breton as whole would double. Within the relatively small LFAs of 29 and 30, current E/R levels were estimated to be higher than most LFAs and doubling E/R would require relatively larger increases in the minimum legal size.

RÉSUMÉ

On a évalué l'état des stocks de homard des eaux situées à l'est du Cap-Breton (zones de pêche du homard 27-30) d'après les journaux de pêche tenus volontairement et des échantillons des prises commerciales recueillis jusqu'à la fin de la saison de pêche de 1997. On a également estimé la production d'oeufs par recrue (O/R) en appliquant le modèle Idoine-Rago à la réglementation actuelle et à la réglementation éventuelle destinée à accroître les O/R. Le déclin constant des débarquements de homard dans la majeure partie de l'est du Cap-Breton coïncide avec une baisse des taux de prises, due vraisemblablement à une diminution de l'abondance du homard. Bien que comportant des incertitudes dans certains de ses intrants (p. ex. la mortalité par pêche), le modèle révèle que la production O/R dans la ZPH 27 doublerait si on adoptait une taille minimale réglementaire (LC) de 75 mm (augmentation de 5 mm) et, pour les femelles exclusivement, une taille maximale réglementaire de 127 (LC). Comme la ZPH 27 produit plus de 90 % des débarquements de homard dans l'est du Cap-Breton, la production O/R dans l'est du Cap-Breton doublerait par le fait même. Dans les ZPH 29 et 30, qui sont relativement petites, les estimations des niveaux O/R actuels se sont avérées supérieures à celles de la plupart des ZPH et il faudrait y accroître notablement la taille minimale réglementaire pour doubler la production O/R.

INTRODUCTION

The lobster fishery off the east coast of Cape Breton Island occurs in Lobster Fishing Areas (LFA) 27 to 30 (Figs. 1,2). Most landings are in LFA 27 (about 91%), with LFA 30 and 29 comprising about 8.5% and LFA 28 less than 1%. These LFAs all experienced large increases in landings in the late 1980s and early 1990s and have been declining since (Tremblay and Eagles 1996). Historical landings in LFA 27 (Victoria and Cape Breton counties) reached 1775 mt in 1900 and then trended downward, fluctuating mainly in the range of 700-1200 mt between 1900 and the 1960s (Fig. 3). The lowest recorded landings (540 mt) were in the late 1960s and early 1970s. Beginning in 1985 landings increased to an all-time high of 3790 mt in 1990. The historical landings pattern in LFAs 28-30 is different than LFA 27. All-time high landings for LFA 27 were recorded between 1886 and 1891 (> 1400 mt). Landings declined thereafter, and short-term increases in landings in the mid-1950s and late 1980s did not approach historic highs. Reported landings peaked in 1989 in LFA's 28 and 29 and in 1992 in LFA 30.

Management of Canadian lobster fisheries is based primarily on effort controls (seasons, limited entry and trap limits) minimum sizes, and protection of ovigerous females (Tables 1, 2). The FRCC report (FRCC 1995) argues that while these effort controls should be maintained, steps are needed to increase egg production and the number of year classes comprising the biomass, and to decrease fishing mortality. In December 1997 the Minister of Fisheries and Oceans set conservation targets for the lobster industry: "Prior to the 1998 fishery, lobster fishermen are being asked to prepare conservation harvesting plans to include multi-year conservation measures that will lead to doubling of lobster egg production in the next two to three years. Fishermen are encouraged to apply the principles and approaches recommended by the Fisheries Resource Conservation Council in its recent report, A Conservation Framework for Atlantic Lobster. The report contains a 'tool box' of measures to increase egg production and reduce fishing effort and exploitation rates." Following discussions with industry, Minister Anderson announced a set of conservation measures for the spring lobster fisheries in the Maritimes Region in April 1998. For LFA 27-30, these measures consisted of a 5 mm increase in the minimum legal size, and a maximum size of 127 mm CL, to be phased in over 4 years.

Here we evaluate stock status in LFAs 27-30 using voluntary fishing logs and samples of the commercial catch up to the end of the 1997 fishing season. We also estimate eggs-per-recruit for the different LFAs under current regulations and under different conservation measures (primarily those announced in April 1998).

MATERIALS AND METHODS

Landings, catch rate and effort

Landings - Up until 1947, landings were recorded by county; from 1947 onwards landings were recorded by Statistical District, which are smaller units than LFAs (Williamson 1992). Landings data were tabulated from sales slips collected by DFO until 1995; in 1996 mandatory self-reporting logs were initiated.

For LFA 27, more detailed subarea (Figs. 1,2) landings and catch rates are available: Northern - Cape St. Lawrence to Ingonish; North-central - Wreck Cove to Pt. Aconi; Central - Alder Pt. to Glace Bay, and Southern - Port Morien to Gabarus. The subareas correspond to statistical districts (S.D.) 1, 4, 6 and 7, with the exception that Glace Bay (in S.D. 7) is included in the Central subarea (Fig. 1).

Catch rate (catch per unit effort or C/E) and effort data - Voluntary fishing logs reporting daily catch and effort (number of trap hauls per day) data were completed in LFAs 27 (N=48), 29 (N=6) and 30 (N=7) in 1997. The number of voluntary fishing logs as a percentage of all licenses was 9% in LFA 27, 35% in LFA 30, and 8% in LFA 29 (Table 3). No logs were available from LFA 28. The logs are not assigned randomly to fishermen (since they are kept voluntarily), but it is assumed that annual fluctuations in the catch rate of logbook keepers reflects the fishery as a whole. All catch rate and length composition data (see below) are maintained in a structured database described in Hunter and Tremblay (1992).

Temperature - Temperature during the fishing season was measured by Vemco minilogs secured to lobster traps of volunteer fishermen. Readings were taken every 1 to 1.5 hours. The traps were placed in shallow (9-12 m) and deep (18-22 m) locations and were not moved during the season other than for daily hauling.

Catch composition - A total of 27 samples of the commercial catch (primarily at dockside) were used here to generate carapace length (CL) frequencies of the lobster catch in different areas. These were used primarily for estimating fishing mortality using length-based cohort analysis (LCA, see below). CL was rounded down to the nearest mm. The number of lobsters measured per sample ranged from 200-800. When samples were combined they were weighted based on the percentage of the catch landed during each of 2-3 periods within the season, as estimated from voluntary logs.

In LFA 27, the catch is separated on board the fishing vessel into two size classes: "canners" (70-80 mm CL) and "markets" (> 81 mm CL). For obtaining information on size structure, this has advantages and disadvantages. An advantage is that a coarse measure of catch composition (% canners by weight) is readily obtainable from fishing logs. A disadvantage is that unless the entire catch of a fisherman (or group of fishermen) can be measured, dockside samples in LFA 27 consist of 2 separate samples for any given date and port. To combine these two samples into a single length frequency, the weight proportion of canners in the catch was obtained from logbooks for the period and port. The different size classes were then weighted so that their total weights were in proportion to the actual catch. For example if the canner portion from logs was 65%, then the canner length frequencies were transformed to weights and the number at size adjusted so the total weight was 650 kg. The market size frequencies were then adjusted so that the total market weight was 350 kg.

Estimates of fishing mortality (F and μ)

One of the key input parameters to eggs-per-recruit models is fishing mortality. This can be expressed as an instantaneous measure (F) or as a finite annual removal or exploitation rate (μ). Methods for estimating this parameter and applications to several areas in eastern Cape Breton are discussed in Tremblay and Eagles (1996). For the area with the most data (Little River, LFA 27, north-central subarea), estimates of annual removals by the fishery were in good agreement:

Leslie analysis 74 % (95% C.I. = 53-90%)
Mark-recapture 57-65%
Catch composition analysis 50-69 % (total mortality)

Leslie analysis tended to give the highest estimates; this may be because of a reduction in catchability near the end of the season (Tremblay and Drinkwater 1997). Mark-recapture estimates are limited in availability and are not discussed further here.

Here we present exploitation estimates for representative ports generated from length -based cohort analysis (LCA), an approach applied to U.S. lobster fisheries (Cadrin and Estrella 1996). LCA is analogous to the "catch composition analysis" method used in Tremblay and Eagles (1996), but LCA better accounts for fishing mortality, the timing of fishing and natural mortality, and growth rate.

Eggs-per-recruit model

Eggs-per-recruit (E/R) for the different LFAs and different management scenarios were estimated using the Idoine-Rago model (Anonymous, 1996). Inputs to the model were as in Appendix 1.

RESULTS

Landings

1997 landings in LFA 27 were 15% lower than those in 1996, and 64% lower than 1990 (Table 4). The size of the decline from 1990 was not uniform within LFA 27. The northern subarea declined 34%, while the southern subarea was 74% lower than 1990 (Table 5). In 1997 landings in the northern subarea actually increased by 7% over 1996. The percentage of the total 1997landings by subarea in LFA 27 was 33% (northern), 15% (north-central), 28% (central) and 23% (southern).

In LFA 29 1997 reported landings were 33% lower than 1996 and 76% lower than 1989. In LFA 30 landings were 13% lower than 1996 and 34% lower than 1990. The low landings in LFA 28 are difficult to track accurately, but the 1997 landings were 21% lower than 1996 and 64% lower than 1990.

Size distribution of catch

In the northern portion of LFA 27 canners comprised about 75% of the catch weight in 1996 and 1997, while in the southern portion canners made up about 20% of the total catch weight in both years (Fig. 4). In the large north-central and central subareas (Little River south to Glace Bay), canners made up 50-65% of the landed weight.

Size frequencies of the 1997 landed lobster catch for 11 ports in LFA 27 during the first 2 weeks of the season are shown in Fig. 5. Mean carapace length was fairly consistent from Dingwall to Port Morien. Mean CL increased about 5-10 mm south of Port Morien.

Outside of LFA 27, mean CL ranged from about 88 mm off Arichat, to greater than 97 mm CL off L'Ardoise and Fourchu (Fig. 6). Male and female lobsters greater than 125 mm CL were not uncommon in L'Ardoise and Fourchu.

As input to the LCA, female size frequencies for a series of years were produced for representative ports. In LFA 27 Little River was considered representative of the northern, north-central and central subareas. Louisbourg and Gabarus represented the southern subarea (Fig. 7). LFA 30 was represented by Fourchu and LFA 29 by L'Ardoise, Petit-de-Grat and Arichat (Fig. 8). Off Little River, canners comprised greater than 75% of the total number landed in each year from 1993-97. In southern LFA 27 the percentage of canners by number in the catch ranged from 20-40% from 1995-97 (Fig. 7). In LFAs 29 and 30 the first molt group (approximately 81-95 mm CL) comprised 46-62% of the number caught in LFA 30, and 58-71% in LFA 29 between 1993-97 (Fig. 8).

Catch rate

The decline in landings in LFAs 27-30 is explicable largely by lower catch rates. In LFA 27, average catch rate for all logs declined in each subarea of LFA 27 between 1992 and 1997(Table 6, Fig. 9). As with landings, the largest C/E decline from 1992-97 was in the southern subarea (62%), while the smallest C/E decline was in the northern subarea (20%). The northern subarea C/E in 1997 was higher than 1996, as were the landings.

In LFAs 29 and 30, average catch rate for all logs declined between 1992 and 1997 (Table 7). In both LFAs the decline has been close to 60%, even though the landings decline has been greater in LFA 29.

Temperature

Temperature during the 1997 fishing season in Cape Breton was lower than 1996 (Fig. 10), and for Little River at least, lower than the previous 4 years (Fig. 11). The decline from 1996 to 1997 was generally 1-2 °C. The only port that showed little change from 1996 to 1997 was Petit de Grat.

Temperature declines were not always associated with catch rate declines. Aspy Bay had one of the largest declines (2.1 °C), yet was in the northern subarea where landings and catch rate increased. Louisbourg on the other hand had a relatively small drop in temperature, yet was in the southern subarea where landings and catch rates declined sharply.

Fishing mortality estimates

Exploitation estimates from the length based cohort analysis are shown for LFA 27 (Fig. 12), LFA 30 and LFA 29 (Fig. 13). The instantaneous fishing mortality (F) estimates were stable over the years, not varying more than +/- 0.1 from the mean. Average F for the port representative of northern and central subareas of LFA 27 was 0.76 (annual removal = 53%); for the southern portion mean F was just 0.26 (annual removal = 23%). The mean F for LFA 30 was 0.34 (annual removal = 29%); for LFA 29 the mean F estimate was 0.26.

Eggs-per-recruit

The exploitation estimates using LCA for Little River were at the low end of the range of estimates using other methods in 1996 (Tremblay and Eagles 1996). Estimates for the southern part of LFA 27, and for LFAs 30 and 29 were also lower. Because of the uncertainty in the F estimates, and because the F estimates for the northern subarea of LFA 27 would be higher yet (larger proportion of small lobsters) we ran the E/R model at the F estimated from LCA and at a higher F. F's for each LFA were:

LFA	Low F	High F	Corresponding A
27 (N)	0.76	1.5	0.53, 0.78
27 (S)	0.26	0.6	0.23, 0.45
29	0.26	0.6	0.23, 0.45
30	0.34	0.6	0.29, 0.45

The E/R estimates under different scenarios are shown in Figs. 14 and 15. For the north and central portions of LFA 27, E/R is unaffected by the maximum size option, regardless of which F is used. V-notching has a modest effect. With a 5 mm increase in the minimum legal size E/R is more than doubled at the higher F. For the southern subarea, E/R is more sensitive to whether the higher or lower F is used. Under the lower F a maximum size of 127 mm CL increases E/R by 34%; at the higher F this option has little effect. A 5 mm increase in the minimum size results in only a 31% increase in E/R at the lower F; under the higher exploitation a 72% increase results. At the lower F the combination of a minimum size increase of 5 mm plus maximum size increases E/R by 75%; with the higher F, E/R is increased by 84%. To double E/R at the higher F an increase in the minimum size of 6 mm is required along with the maximum size. To double E/R at the lower F would require a smaller maximum size.

LFA 30 and LFA 29 are similar to the southern portion of LFA 27 with respect to the relative benefits of different conservation options under different F's. However these areas do not double with a 5 mm increase in minimum size and a maximum size of 127 mm CL. Eggs per recruit in LFA 30 would increase by about 63% with a 5 mm increase and a maximum size in place; LFA 29 E/R would increase by about 80% with these measures. To double egg production in these two areas would require a combination of a larger minimum size and a smaller maximum size.

It is important to note the relatively high E/R in LFA's 30 and 29 (8070-9326 at the lower F's) compared with LFA 27 (1795-6881 at the lower F's) under current conditions. The lower E/R is more representative of LFA 27 as a whole since it represents the northern to central subareas, which comprise greater than 3/4 of the total landings.

DISCUSSION

The steady decline in lobster landings over most of eastern Cape Breton is explicable in terms of decreased catch rates, which we believe reflect decreased abundance. Catch rate is influenced by lobster catchability, which can be affected by a variety of factors including temperature, wind, molting and bait, but it is doubtful that these factors have combined to produce steady declines in catchability since 1990. Average temperature declined in 1997 throughout much of eastern Cape Breton, and although catch rate declined in most areas, it actually increased in northern Cape Breton. Off Little River average temperature during the fishing season ranged from 6.0-6.6°C from 1993-1996 but catch rate declined by about 15%. Some fishermen suggest catchability is lower in areas where capelin spawn because the spent capelin provide food for lobster and reduce the motivation of lobster to trap. This may explain some catch rate reductions within a particular season in some areas, but capelin spawning does not appear to be as widespread in eastern Cape Breton as the catch rate declines. We believe the decline in lobster catch rate in LFAs 27-30 is due mainly to lower lobster abundance, but the role of annual differences in catchability needs study.

The relationship between the number of eggs produced and recruitment to the fishery 5-8 years later is not well understood for Eastern Cape Breton lobster nor for any lobster stock(s) (Fogarty, 1996). We also have only a limited understanding of the extent to which larvae are retained near their hatching location. While these are significant gaps in our understanding of lobster population dynamics, they should not prevent conservation steps such as increasing E/R. Increased E/R is an example of the precautionary apporach to managment, and can be thought of as insurance for those periods when the environment is poor for the survival of young lobsters. During these periods in particular, more eggs will provide benefits. As far as the source of eggs for any given area is concerned, if all lobster areas increase E/R, the source location is less important.

The estimates of exploitation are critical to the eggs-per-recruit model. Previous estimates for eastern Cape Breton using 3 methods (Leslie analysis, tagging, and length composition analysis) were mainly 55-80% for northern and central LFA 27, 35-50% for southern LFA 27, and 30-50% for LFA 29 and LFA 30. The estimates based on LCA are at the low end of the range. The approach taken here of using a low and high estimate for exploitation illustrates our uncertainty, but it is clear that northern to central portions of LFA 27 have higher exploitation than the southern end and LFAs 30 and 29.

The low estimates for F in the southern subarea of LFA 27 compared to the north and central subareas are in spite of a net flux of licenses from north to south from the mid 1980s to 1992 (Fig. 16). It may be that exploitation was even lower prior to this movement of licenses. This could be examined with the historical length frequency data for a few areas.

We expect exploitation in LFA 30 to be lower than LFA 27 because of the relatively low number of licenses for the Area (20). We would expect exploitation to be higher in LFA 29 than LFA 30, because there are more than 3 times as many licenses in LFA 29 than LFA 30, and the available lobster bottom is roughly similar.

The output of the E/R model indicates that the northern and central portions of LFA 27, which represent 77% of the landings, can achieve a doubling of the 1997 E/R by increasing the minimum legal size to 75 mm CL and putting a maximum size of 127 mm CL in place. The two approaches will have different effects within the northern and southern portions of LFA 27. The southern portion of LFA 27 would approach a doubling with the higher fishing mortality; LFA 27 as a whole would double if the exploitation in LFA 27 north and central areas is above about 70%.

In LFAs 29 and 30 more extensive measures would be required to achieve a doubling of egg production. These areas are starting out with higher levels of E/R than most LFAs because of the small gap between the minimum legal size and the 50% size of maturity. Given the low productivity of LFAs 29 and 30 (Hudon 1994), these LFAs probably need relatively more eggs than other LFAs.

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Table 1. License numbers by Lobster Fishing Area in 1977. Obtained from Scotia-Fundy DFO Licensing, and Gulf Region DFO Licensing (port of Bay St. Lawrence in LFA 27).

	Type of license			
	A	B	Partnership	Total Licenses
LFA 27	503	32	2*	539
LFA 28	16	2	0	18
LFA 29	64	13	1*	79
LFA 30	20	0	0	20

* each counted as 2 licenses because a partnership license can revert to 2 separate licenses.

Table 2. Seasons, trap limits, and minimum legal sizes by LFA. From Schedule XIV of the Atlantic Fishery Regulations.

Area	Season	Trap limit	Minimum legal size (mm)
LFA 27	May 15 - Jul 15	275	70
LFA 28	May 9 - Jul 9	275	81
LFA 29	May 10 - Jul 10	275	81
LFA 30	May 19 - Jul 20	250	81

Table 3 - Numbers of voluntary fishing logs by LFA and year.

Year	1991	1992	1993	1994	1995	1996	1997
LFA 27	7	26	42	46	50	50	48
LFA 28	1	1	2	2	1	0	0
LFA 29	5	8	8	10	7	7	6
LFA 30	2	7	6	6	6	7	7

Table 4. Landings (mt) by LFA. 1997 figures are not final but should not increase substantially. LFA 27 landings include figures for Bay St. Lawrence (the only port within LFA 27 tracked by DFO Gulf Region Statistics).

	Year									10 yr averages		
Area	89	90	91	92	93	94	95	96	97	61-70	71-80	81-90
27	3714	3790	3526	2778	2458	2190	2142	1616	*1379*	802	787	2313
28	21	8	9	9	12	13	15	14	*11*			
29	236	164	159	141	92	91	90	60	*40*	97	39	133
30	132	119	151	167	132	130	126	90	*78*	94	31	77
Total	4103	4081	3845	3095	2694	2424	2373	1780	*1508*	993	857	2523

Table 5. Landings (mt) by subarea within LFA 27. Percentage decline is between 1990 and 1995.

	1990	1991	1992	1993	1994	1995	1996	1997
Northern	700	683	586	578	541	565	433	463
N-Central	533	468	388	336	295	285	258	209
Central	1310	1144	851	785	677	693	501	393
Southern	1247	1221	947	755	670	599	426	324
Total LFA 27	3790	3516	2772	2454	2183	2142	1618	1389

Table 6. Catch rate (kg/trap haul) from voluntary fishing logs in subareas of LFA 27. Shown is mean, 95% confidence interval, and N. All logs included.

	1992	1993	1994	1995	1996	1997
Northern	0.45	0.46	0.40	0.38	0.31	0.36
	.40, .50;	.39, .52;	.33, .47;	.34, .43;	.27, .34;	.32, .40;
	n=9	n=12	n=14	n=16	n=18	n=18
North Central	0.53	0.51	0.45	0.49	0.43	0.39
	.33, .54;	.44, .55;	.40, .50;	.44, .53;	.38, .48;	.32, .46;
	n=2	n=14	n=12	n=11	n=10	n=8
Central	0.47	0.47	0.36	0.40	0.35	0.29
	.40, .54;	.41, .53;	.32, .40;	.34, .46;	.29, .41;	.25, .33;
	n=6	n=8	n=9	n=10	n=10	n=19
Southern	0.63	0.54	0.48	0.42	0.31	0.24
	.56, .69;	.49, .59;	.44, .52;	.38, .46;	.28, .34;	.21, .27;
	n=9	n=8	n=11	n=13	n=12	n=13

Table 7. Catch rate (kg/trap haul) from voluntary fishing logs in LFA 29 and LFA 30. Shown is mean, 95% confidence interval, and N. All logs included.

	1992	1993	1994	1995	1996	1997
LFA 29	0.27	0.20	0.21	0.20	0.14	0.11
	.22, .33; n=7	.16, .24;	.17, .25;	.16, .24;	.09, .18;	.06, .16;
		n=8	n=10	n=7	n=7	n=6
LFA 30	0.81	0.70	0.63	0.57	0.46	0.34
	.72, .88;	.62, .78;	.52, .73;	.46, .67;	.39, .53;	.31, .38;
	n=8	n=6	n=6	n=6	n=7	n=7

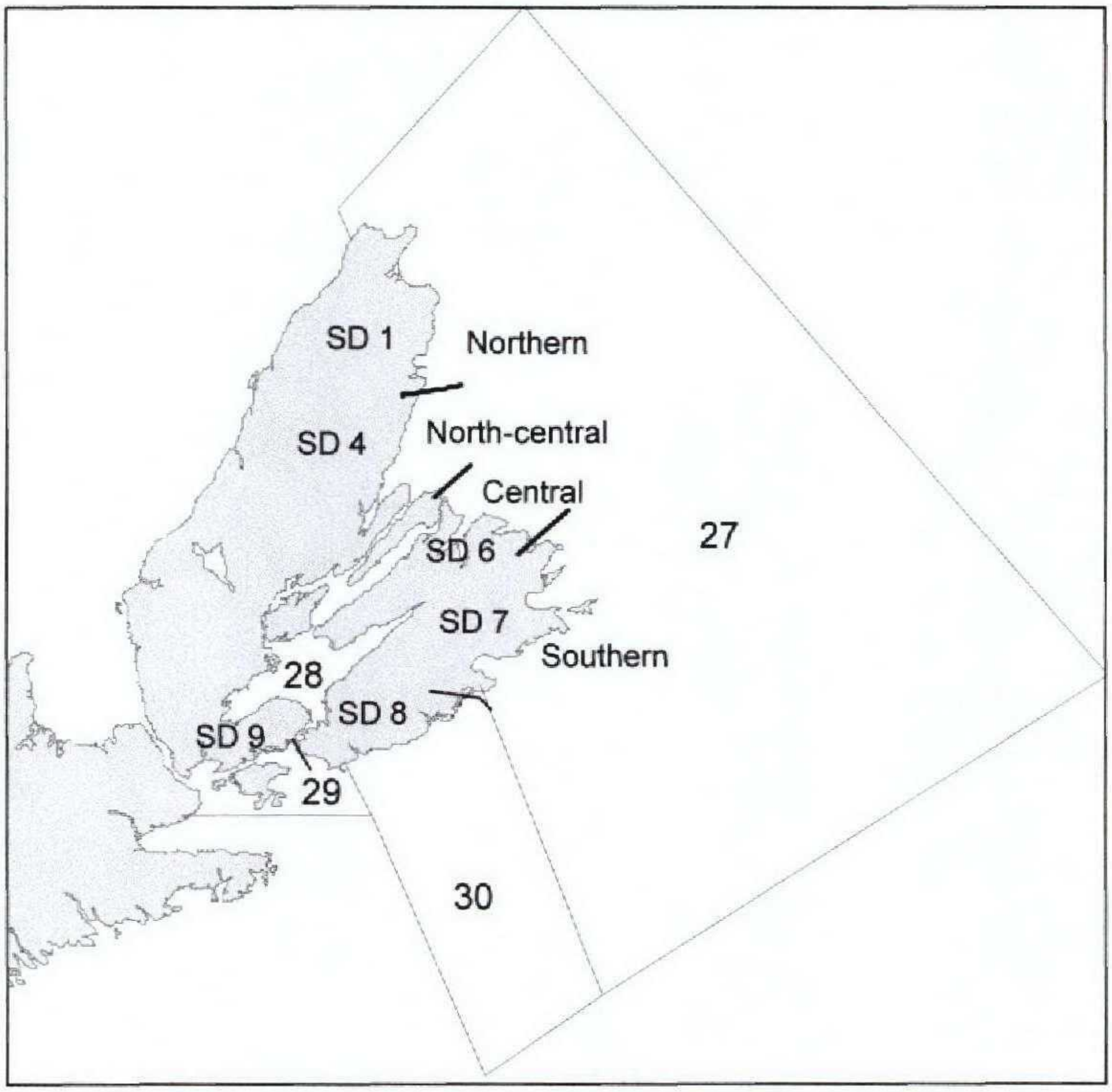


Figure 1. Eastern Cape Breton Lobster Fishing Areas (LFA's). SD is statisticial district. Subareas in LFA 27 (Northern, North-central, Central and Southern) are for assessment purposes only. They correspond to SD except for the Central/Southern dividing line.

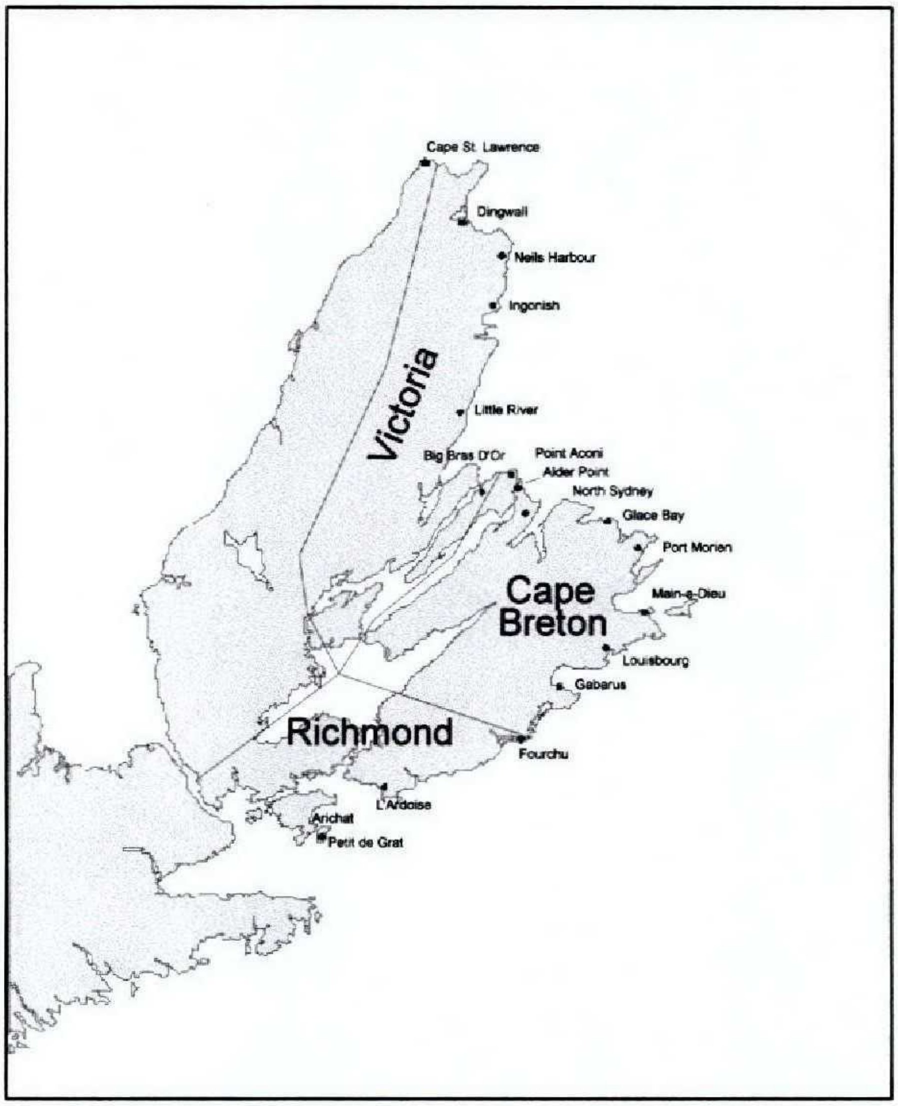


Figure 2. Eastern Cape Breton counties and selected fishing ports.

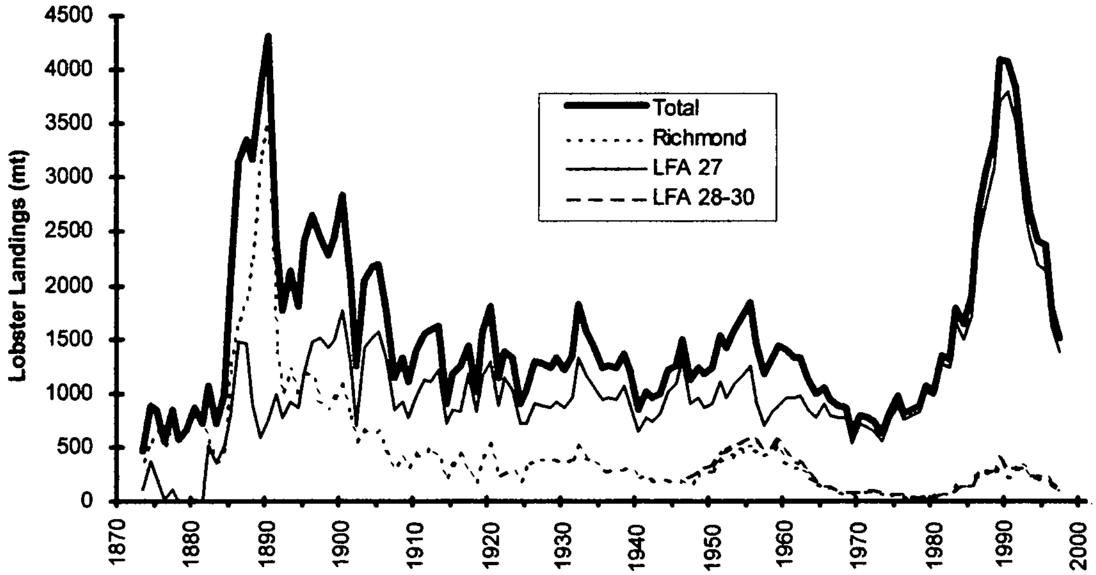


Figure 3. Historical lobster landings off eastern Cape Breton from Williamson (1992) and Commercial Data Division, DFO. Prior to 1947, landings were compiled by county. Since LFA 27 is comprised of Victoria and Cape Breton Counties, landings for this LFA are continuous back to the 1870s. LFAs 28-30 are nearly the same as Richmond County but include a slightly larger area. For comparison purposes, landings for LFAs 28-30 and for Richmond County are both shown for the period 1947-1989.

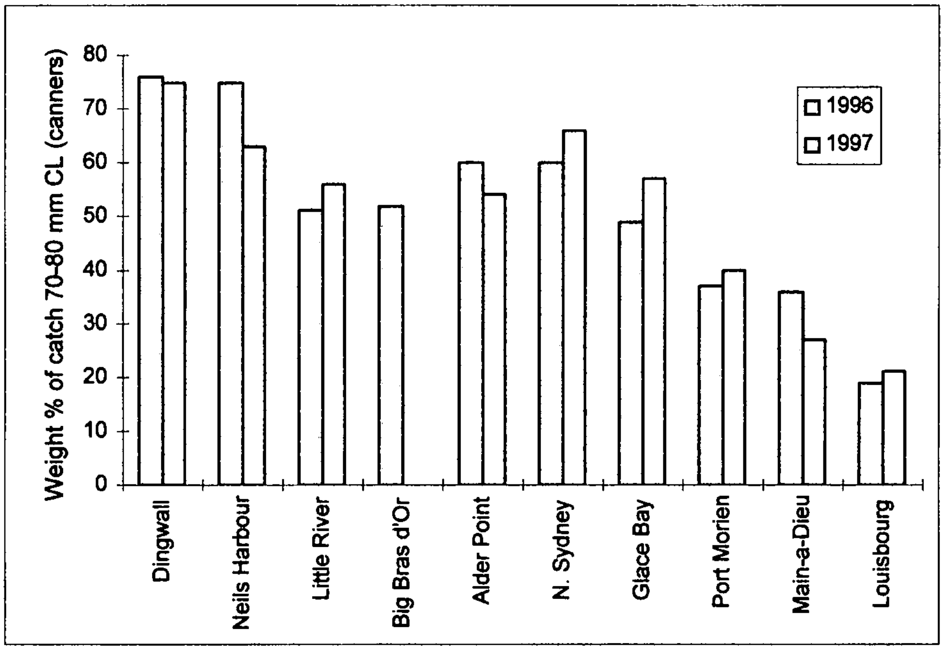


Figure 4. Weight percentage of canners in the catch in different ports of LFA 27, 1996 and 1997.

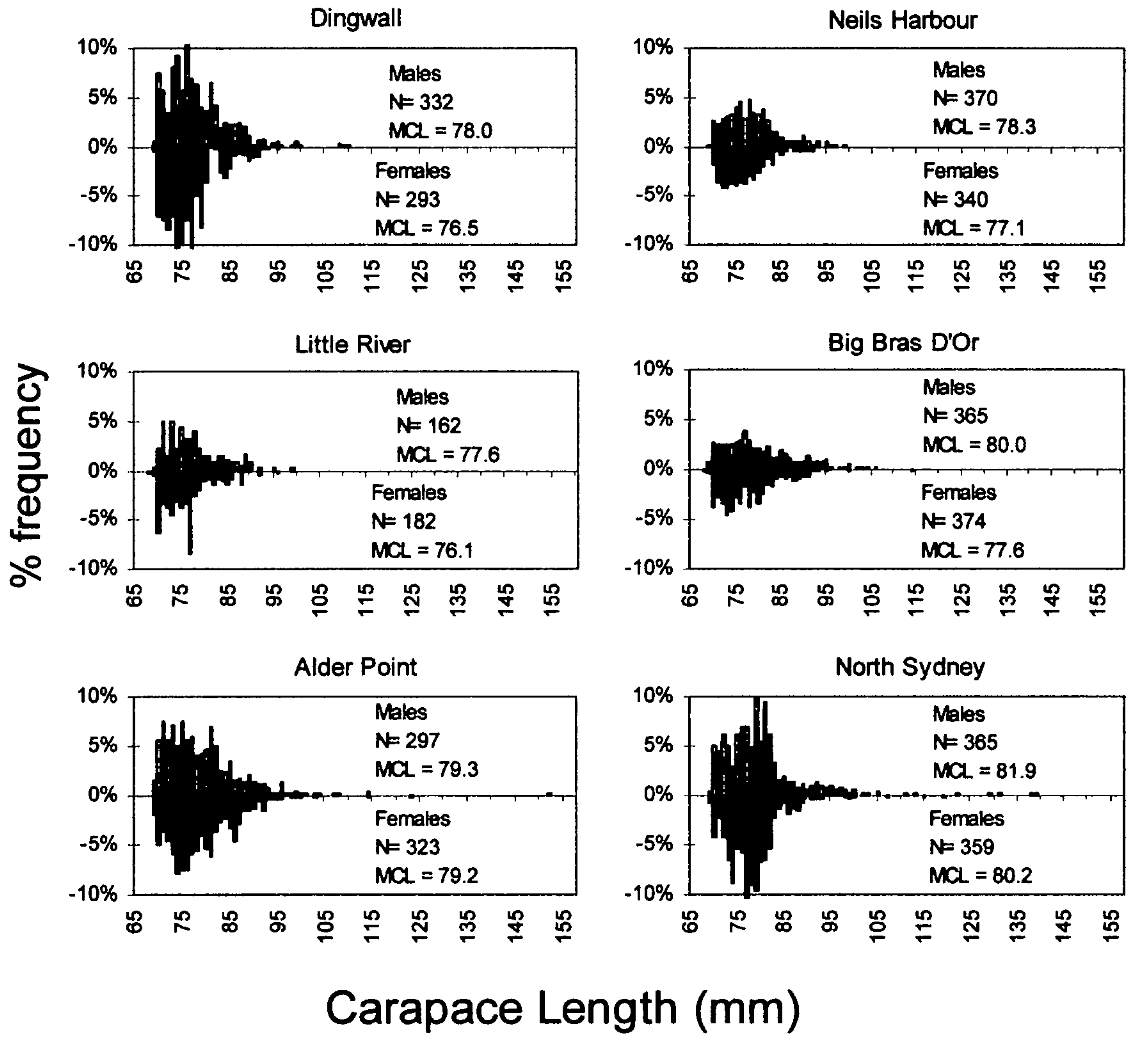


Figure 5. LFA 27 length frequencies measured at dockside in different ports between May 21-29 1997.

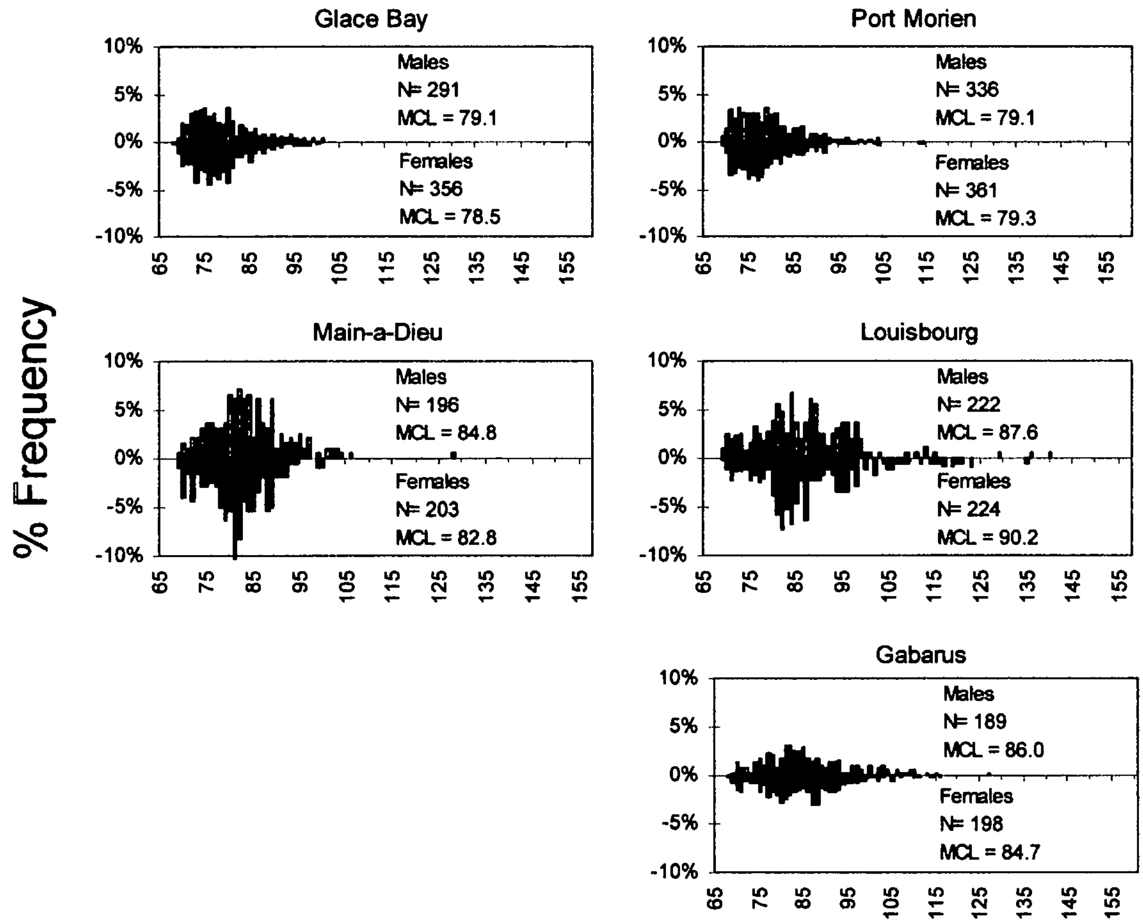


Figure 5 (cont'd). LFA 27 length frequencies measured at dockside in different ports between May 21-29 1997.

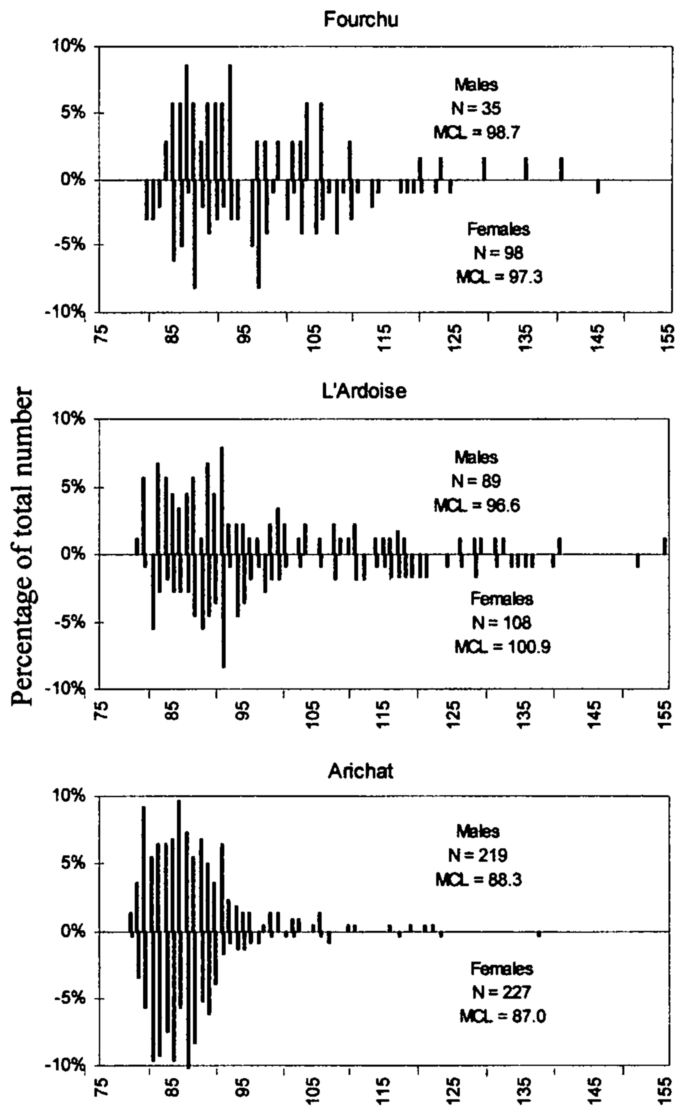


Figure 6. Percentage of male and female lobsters at size between May 12-27 in LFA 30 (Fourchu) and LFA 29. LFA 29 samples were dockside; LFA 30 was an at-sea sample but only legal sizes are shown here.

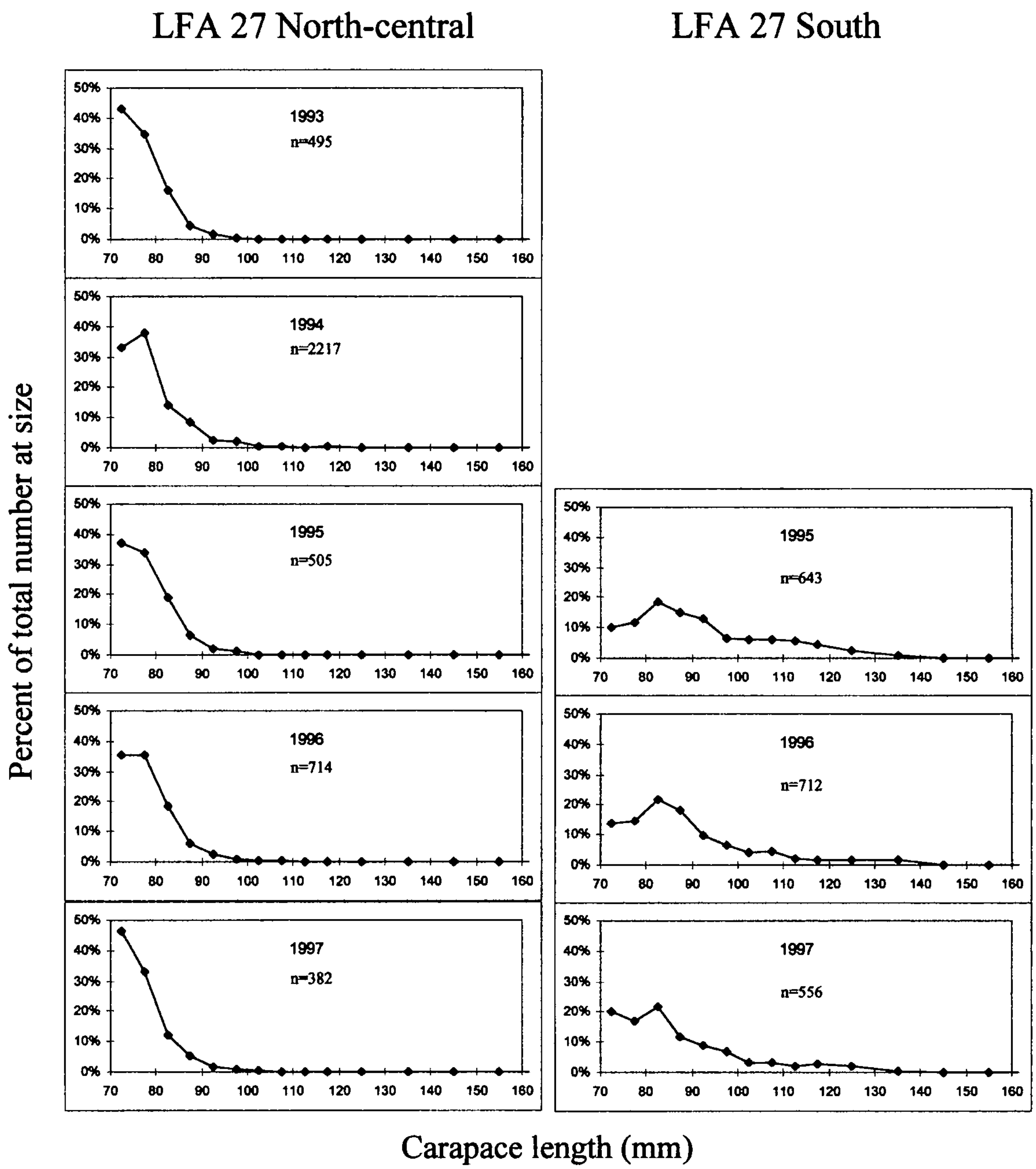


Figure 7. Data for input to length based cohort analysis. Shown is percentage of female lobsters at size for a port representative of northern and central subareas of LFA 27 (Little River) and southern LFA 27 (Louisbourg and Gabarus combined). Each graph represents at least 2 samples weighted by the proportion of the total seasonal catch they represent. Grouped by 5 mm intervals from 70-120 mm; 10 mm intervals for sizes 120-160 mm.

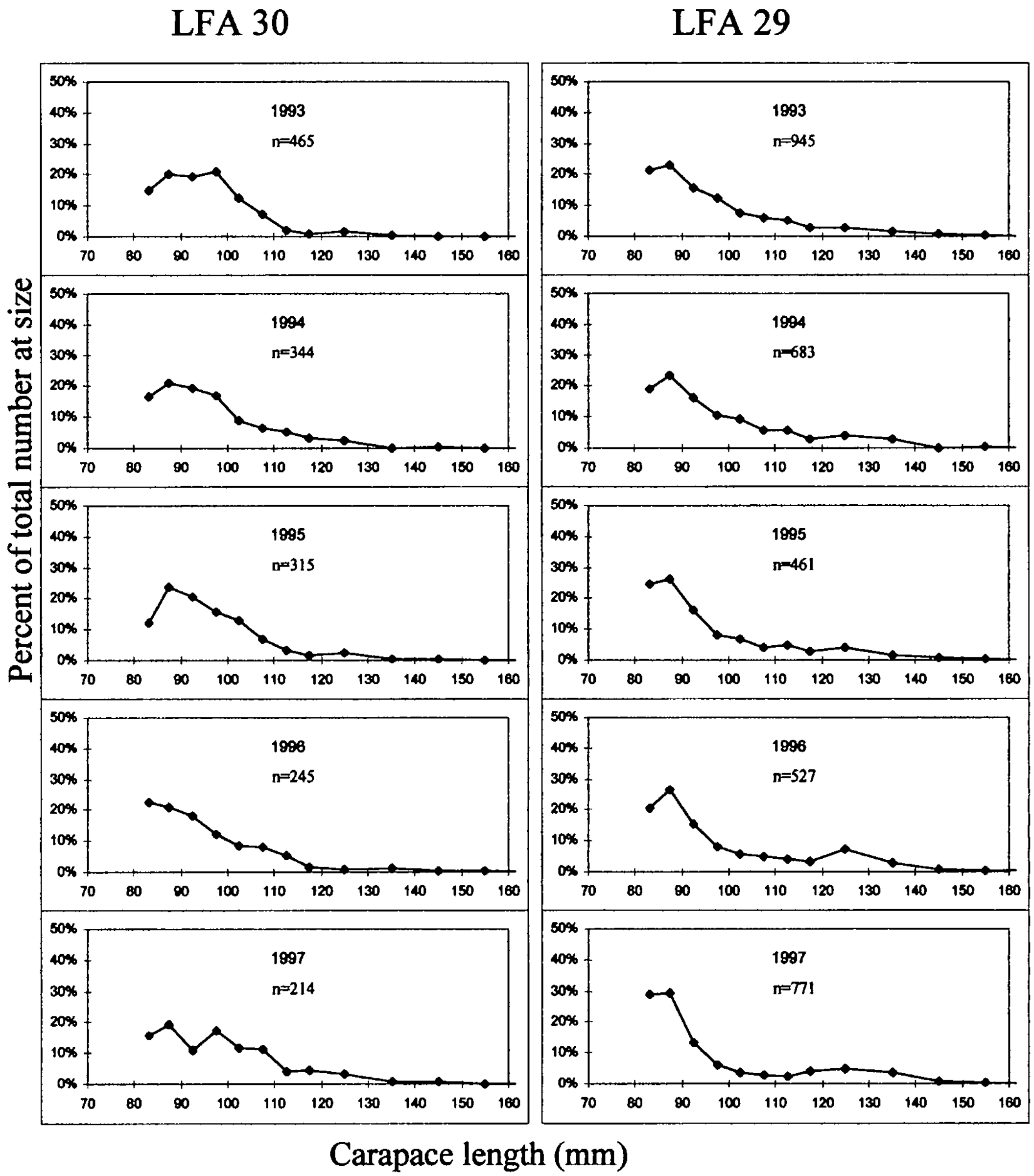


Figure 8. Data for input to length based cohort analysis. Shown is percentage of female lobsters at size for LFA 30 (Fourchu) and LFA 29 (Arichat, Petit de Grat and L'Ardoise). Each graph represents at least 2 samples weighted by the proportion of the total seasonal catch they represent. Grouped by 5 mm intervals from 80-120 mm; 10 mm intervals for sizes 120-160 mm.

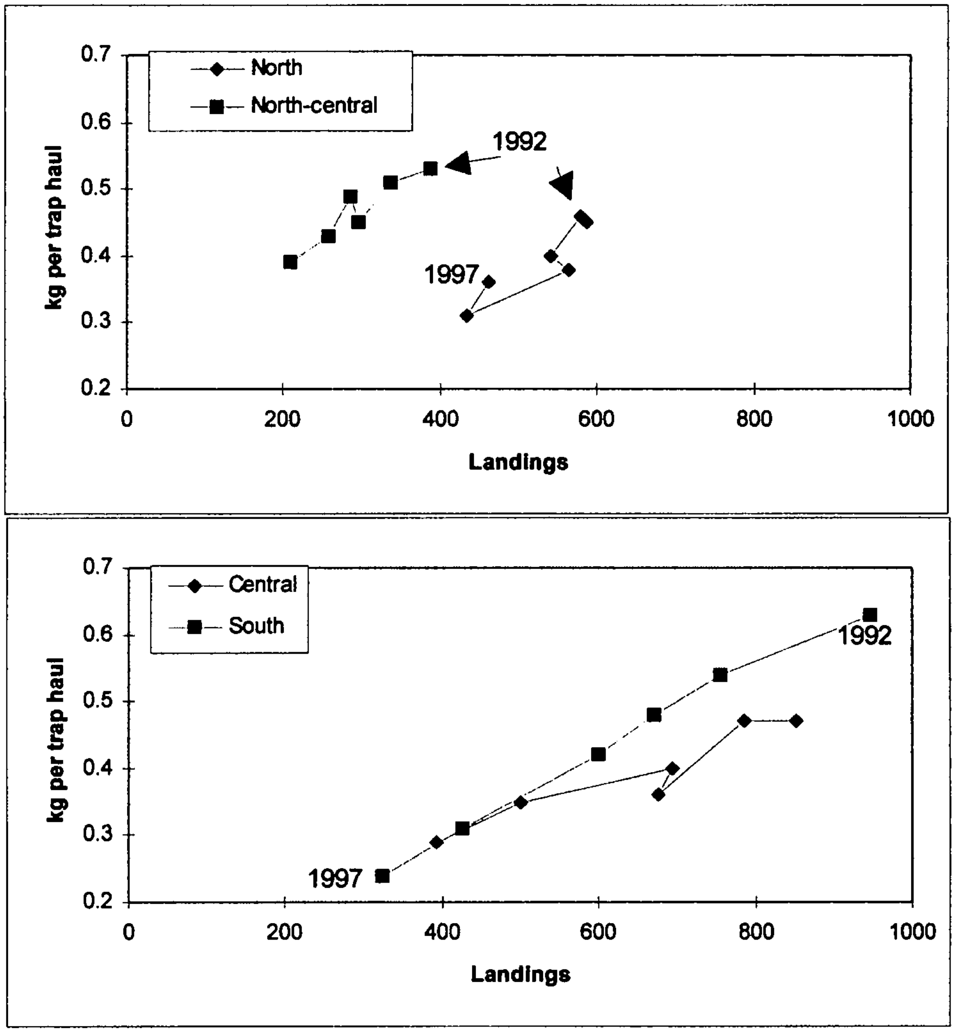


Figure 9. Lobster catch rate versus landings by LFA 27 subarea, 1992-97.

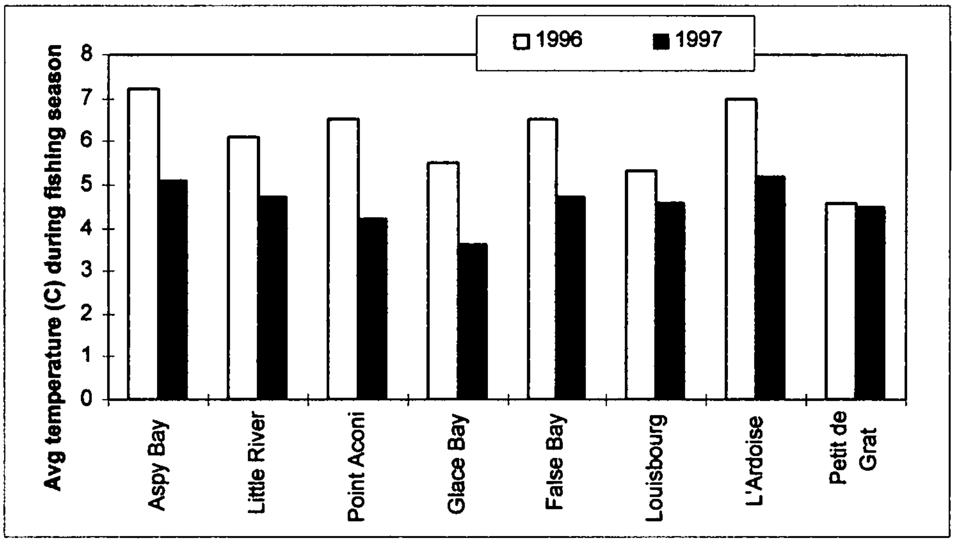


Figure 10. Average temperature during 1996 and 1997 fishing seasons in eastern Cape Breton. Measured using Vemco minilogs at 18-22 m depth from May 26-July 8.

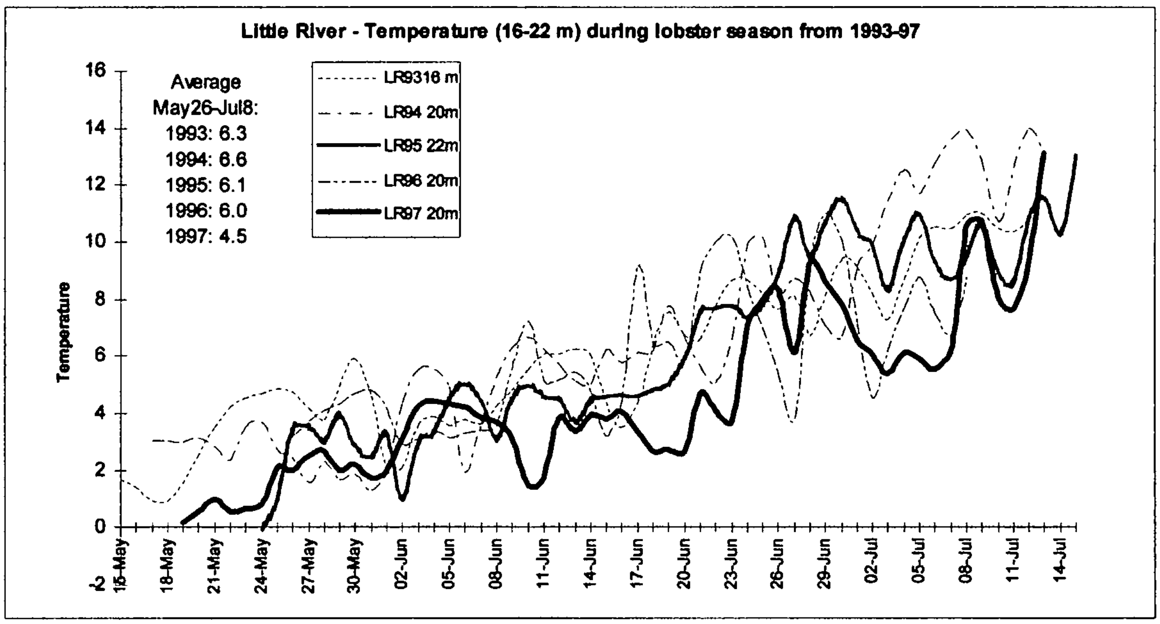


Figure 11. Little River average daily temperature (16-22 m) during fishing season 1993-1997.

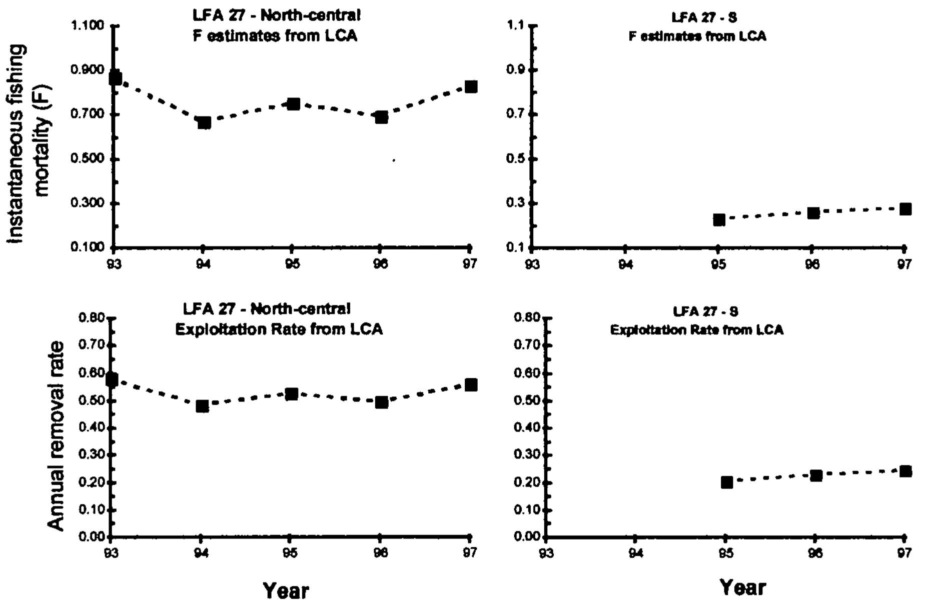


Figure 12. Exploitation estimates from length based cohort analysis (LCA) for representative ports in northern LFA 27 (Little River) and southern LFA 27 (Louisbourg-Gabarus).

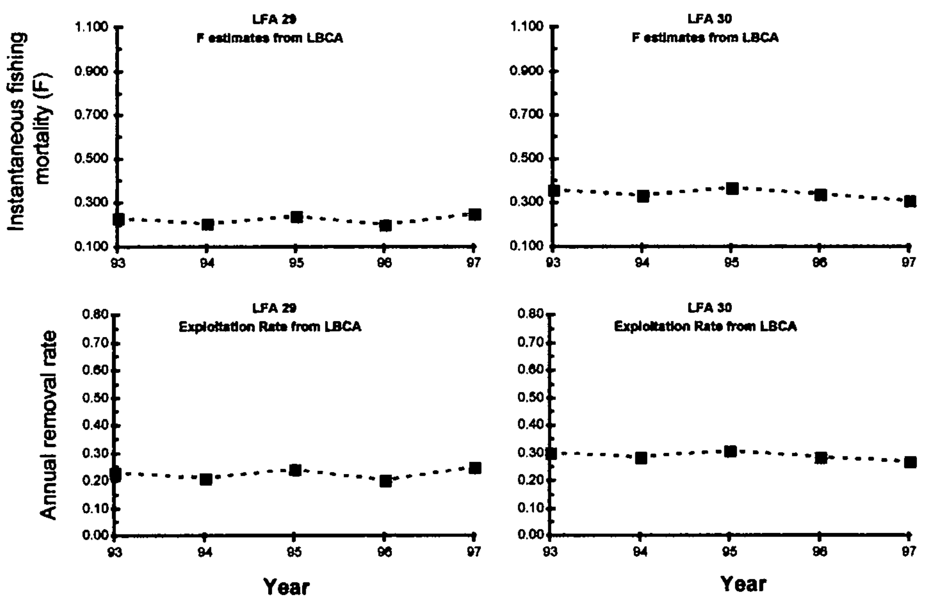
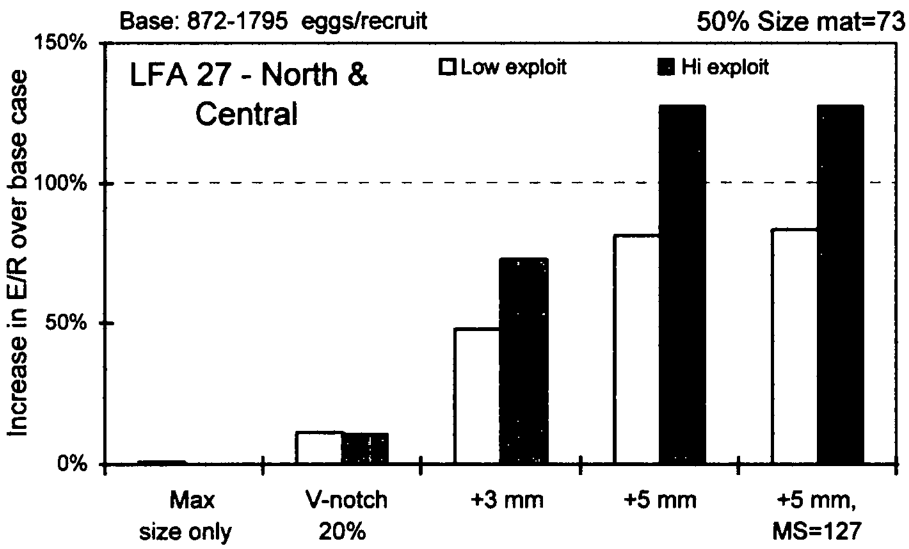


Figure 13. Exploitation estimates from length based cohort analysis (LCA) for representative ports in LFA 30 (Fourchu) and LFA 29 (L'Ardoise, Petit de Grat and Arichat).



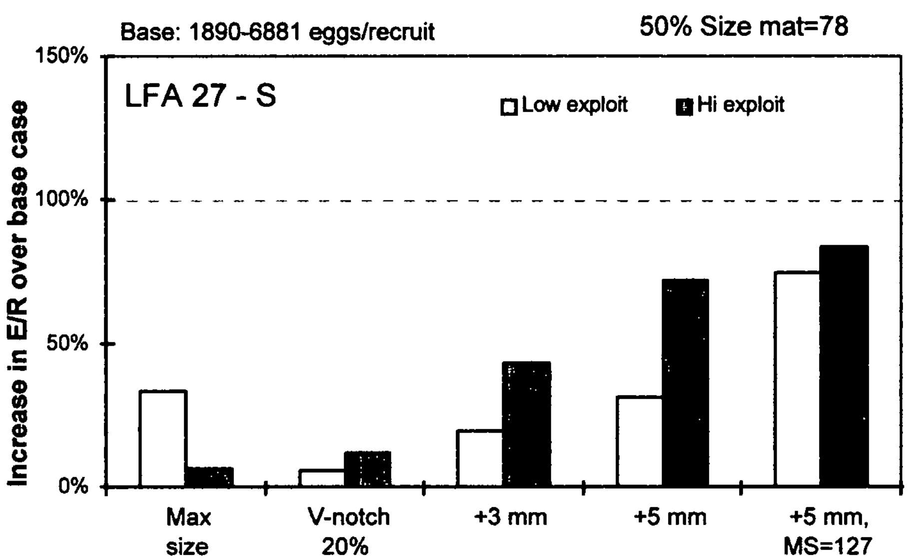


Figure 14. Increase in eggs/recruit over base (1997 regulations) under various conservation options for LFA 27, and under a low and high exploitation rate. Dashed line shows objective (a doubling of E/R).

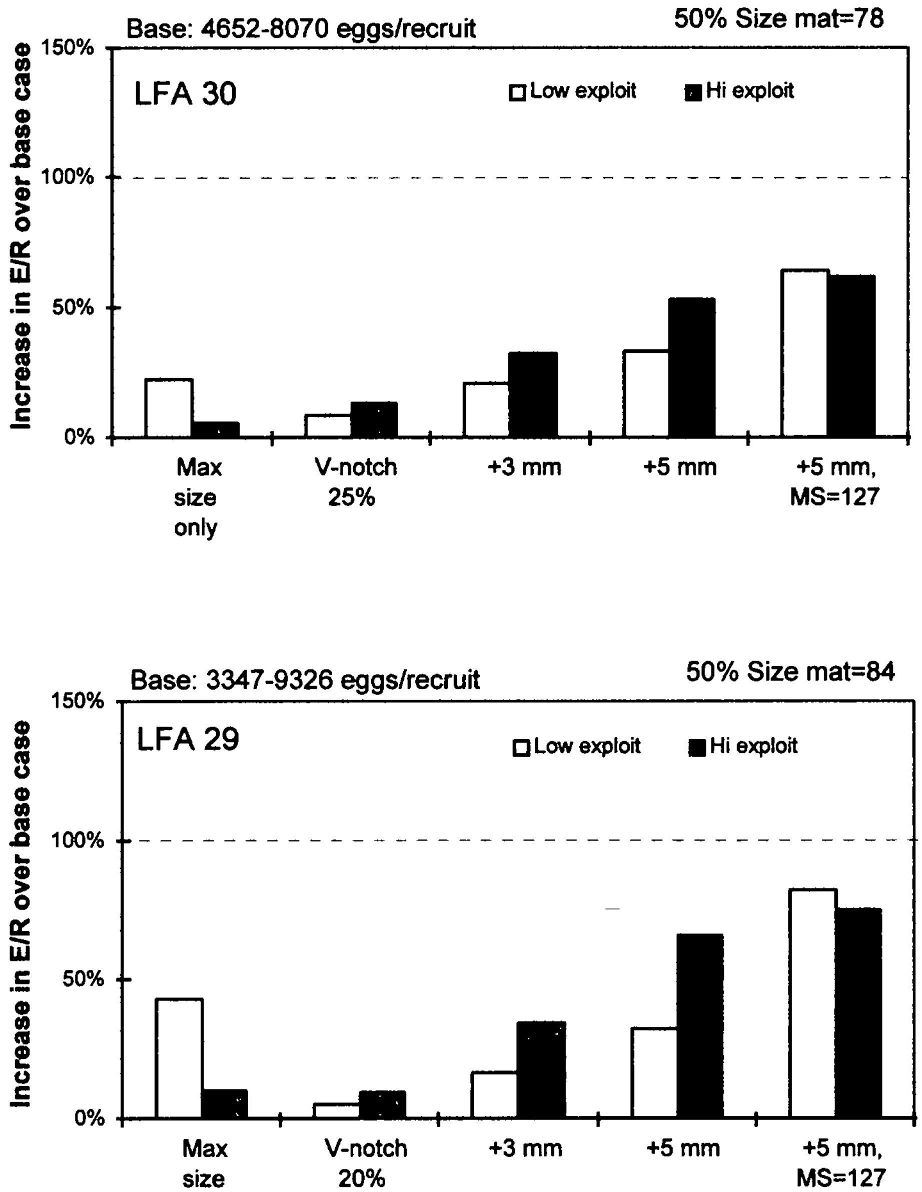


Figure 15. Increase in eggs/recruit over base (1997 regulations) under various conservation options for LFAs 29 and 30, and under a low and high exploitation rate. Dashed line shows objective (a doubling of E/R).

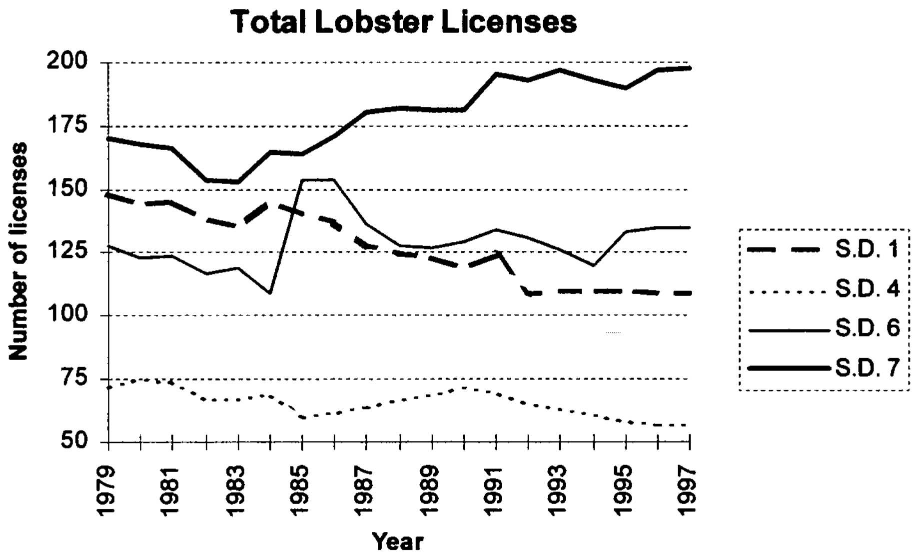
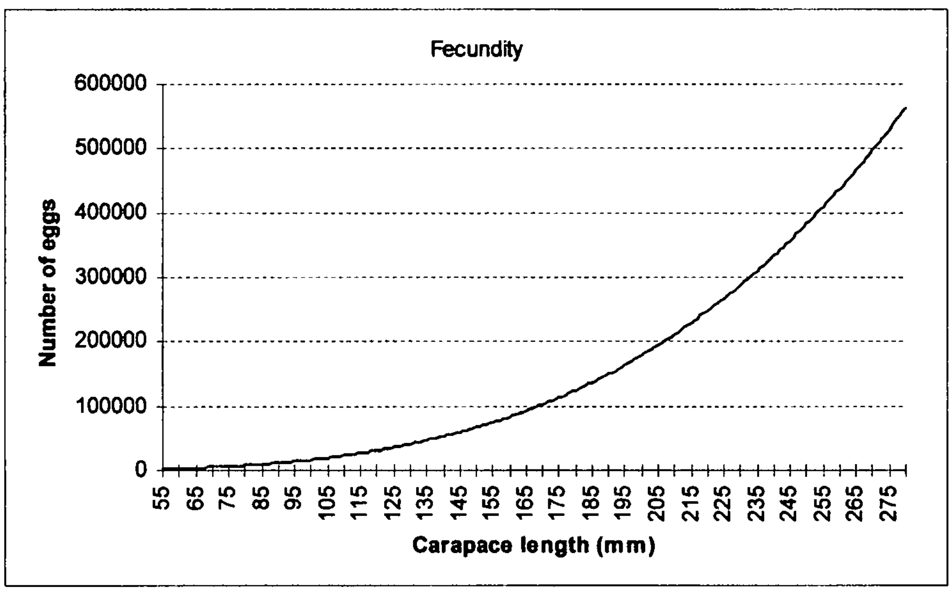


Figure 16. Number of lobster licenses in LFA 27 by Statistical District (SD) 1979-1997. SD 1 is in the north, SD 7 in the south (see Fig. 1).

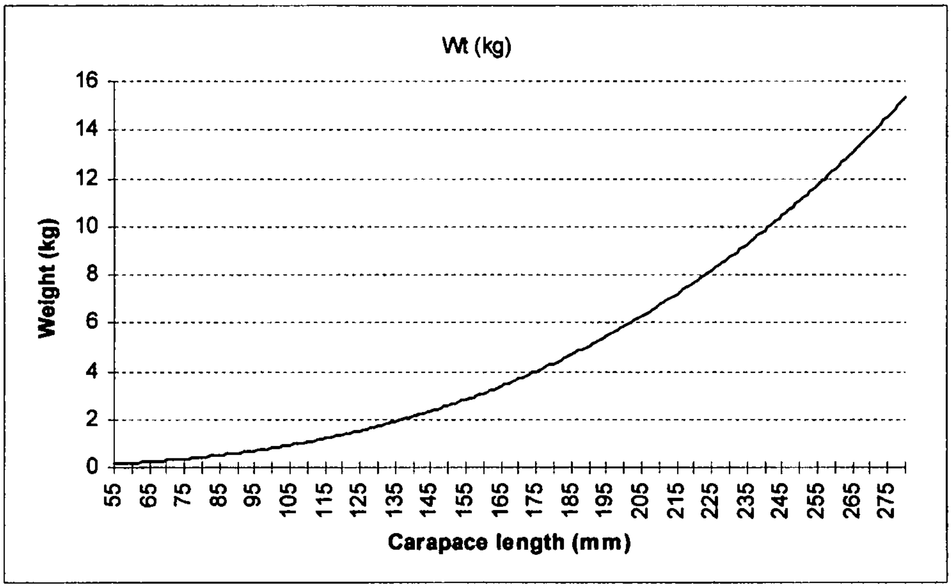
Appendix 1. Summary of data for input to Idoine-Rago Eggs per Recruit model.

Table of inputs to Idoine-Rago model - baseline run

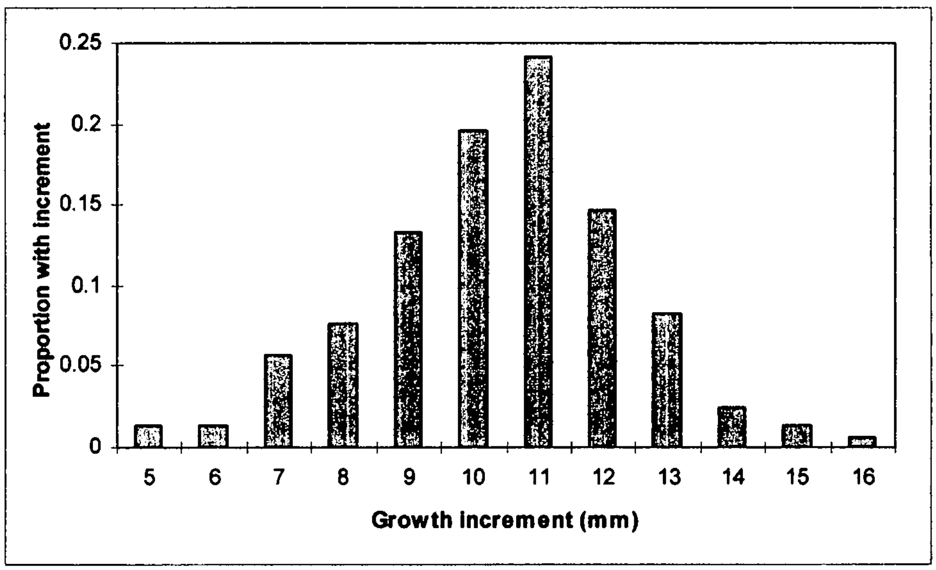
Fecundity	See Appendix Fig. 1	F = .00256(L^3.409) - Campbell & Robinson 1983. Can. J. Fish. Aquat. Sci. 40:1958-1967.
Weight at size	See Appendix Fig. 2	W = 0.001525(L^2.8612) - Campbell 1985. North Am. J. Fish. Management 5:91-104
Growth increments	See Appendix Fig. 3	From 158 females tagged in NE Cape Breton in Sept 93 & May 94
Prob double molting		LFA 27-30 - 0.05 (50-60 mm CL); 0.03 (60-69 mm CL)
Intermolt duration	See Appendix Fig. 4	
Reproduction	See Appendix Fig. 5	
Mortality		Hard shell = 0.1; soft shell = 0.05
Fishing effects		Prop of catch Q1 Oct-Dec = 0
		Prop of catch Q2 Jan-Mar = 0
		Prop of catch Q3 Apr-Jun = 90
		Prop of catch Q4 Jul-Sep = 10
		Min size in model = 55 mm CL
		Max size in model = 280 mm CL
Model specifications		N of years model runs = 100
		Number of 1 mm size classes = 12
		Distribution of animals within size classes - Normal



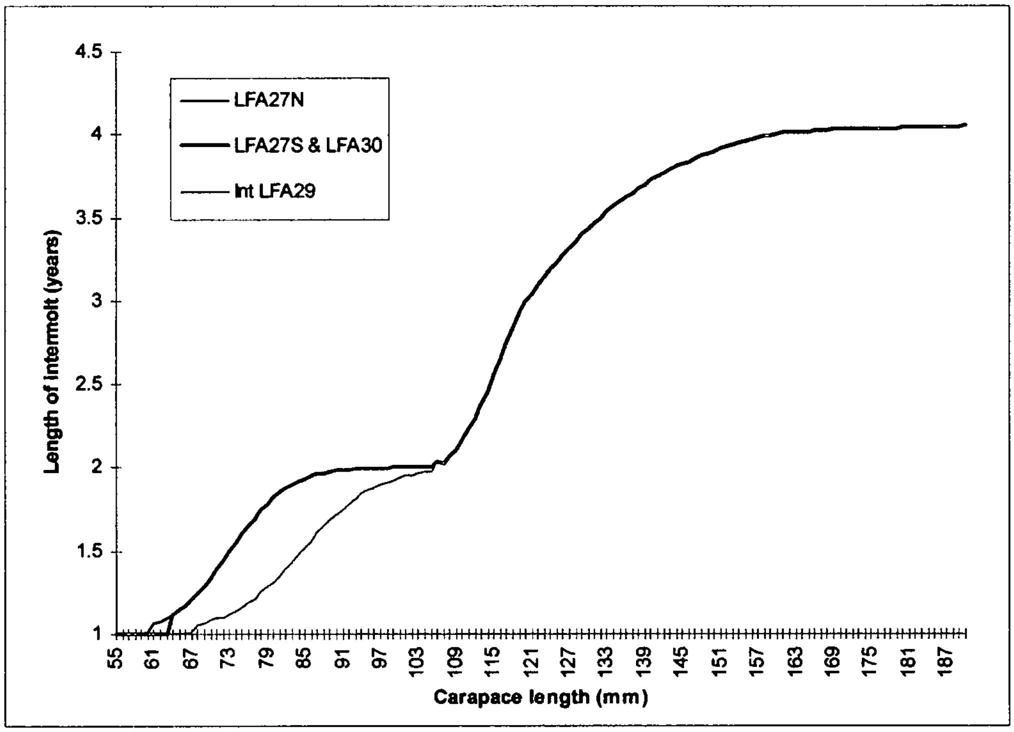
Appendix Fig. 1. Fecundity versus size for female lobsters.



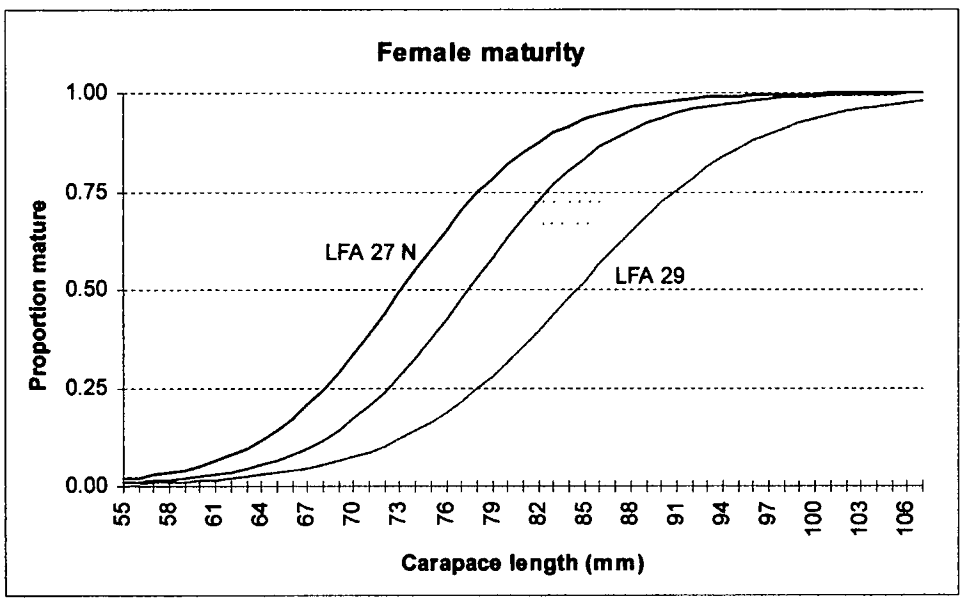
Appendix Fig. 2. Weight of female lobsters.



Appendix Fig. 3. Distribution of growth increments of female lobsters used as input to E/R model. From 158 tagged lobsters off northeastern Cape Breton.



Appendix Fig. 4. Female intermolt period versus size.



Appendix Fig. 5. Proportion of females mature versus size.