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Recent trends in the lobster fishery off eastern Cape Breton (LFA's 27-30): catch rate and exploitation

by

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ABSTRACT

The status of the lobster fishery off eastern Cape Breton (Lobster Fishing Areas 27-30) is evaluated from voluntary fishing logs, samples of the commercial catch, and recent tagging studies. Since 1990 landings and catch rates have declined in each Area. In the largest Area (27), 1995 landings were 43% lower than 1990. These declines are most likely due a decline in lobster abundance, rather than any declines in fishing effort or lobster catchability. Exploitation rate is estimated using Leslie analysis and mark-recapture studies; total mortality is estimated from the numbers of lobsters in successive molt classes. The best current estimates of exploitation are 65-80% for the northern two-thirds of LFA 27. For the southern part of LFA 27, and for LFA 29 and 30, exploitation estimates are lower (generally 35-70%) but more variable. Given the steep decline in lobster abundance, steps to increase the egg production of the average lobster are recommended. The most effective method to increase egg production and to increase yield-per-recruit in LFA 27 is through an increase in the minimum legal carapace size.

RÉSUMÉ

On évalue la situation de la pêche du homard au large de l'est du Cap-Breton (zones de pêche du homard 27 à 30) à partir des journaux de pêche remplis volontairement, des échantillons de prises commerciales et de récentes études de marquage. Depuis 1990, les débarquements et les taux de prises ont décliné dans chaque zone. Dans la plus grande (zone 27), les débarquements de 1995 étaient inférieurs de 43 % à ceux de 1990. Ces reculs sont dus vraisemblablement à une baisse de l'abondance du homard, plutôt qu'à une diminution de l'effort de pêche ou du potentiel de capture du homard. On estime le taux d'exploitation au moyen de l'analyse de Leslie et d'études de marquage-recapture, et la mortalité totale d'après le nombre de homards dans les classes de mue successives. Les meilleures estimations actuelles de l'exploitation se chiffrent à 65-80 % en ce qui concerne les deux tiers de la ZPH 27 situés le plus au nord. Pour ce qui est de la partie sud de la ZPH 27, ainsi que des ZPH 29 et 30, les estimations du taux d'exploitation sont plus basses (généralement de 35 à 70 %), mais plus variables. Étant donné l'important déclin dans l'abondance du homard, on recommande de prendre des mesures pour accroître la production d'oeufs du homard moyen. La méthode la plus efficace pour augmenter à la fois la ponte et le rendement par recrue dans la ZPH 27 consiste à accroître la taille minimale réglementaire de la carapace.

INTRODUCTION

The fishery for lobster off the east coast of Cape Breton Island (Lobster Fishing Areas 27 to 30 on Fig. 1) has been underway for well over 100 years. Management of these fisheries is based primarily on effort controls (seasons, limited entry and trap limits) minimum sizes, and protection of ovigerous females (Tables 1, 2). The recent FRCC report[1] 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. The FRCC report provides stock evaluations for large areas; more detailed evaluations are needed for individual Lobster Fishing Areeas (LFAs) or groups of LFAs. Here we evaluate the status of the lobster fishery in LFAs 27-30 using voluntary fishing logs, samples of the commercial catch, and recent tagging studies.

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. The effect on the 1996 landings figures has not been evaluated.

For LFA 27, landings for sub-areas (Fig. 1b) are also provided. These sub-areas (for assessment purposes only) exhibit a gradient in size structure, with the Northern sub-area having the highest percentage of 70-80 mm CL ("canner") lobsters (70% and higher) and the Southern area having the lowest percentage (less than 30%). The sub-areas are as follows: 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 sub-areas also correspond to S.D. 1, 4, 6 and 7, with the exception that Glace Bay (in S.D. 7) is included in the Central sub-area (Fig. 1b).

Catch rate (CPUE) and effort data - Voluntary fishing logs were completed in LFAs 27, 29 and 30 in 1996. The number of voluntary fishing logs in 1996 as a percentage of all licenses ranged from 9% to 36% (LFA 30) (Tables 1,3). No logs were available from LFA 28. Because the logs are kept voluntarily they do not represent a random selection of all available fishers, but it is assumed that annual fluctuations in the catch rate of logbook keepers reflects the fishery as a whole. To overcome inherent differences in catch rate among fishers, statistical comparisons of annual mean catch rate were restricted to groups of logs kept by the same fishers over the years of interest. In this approach the individual logs are blocks in a randomized block analysis of variance (Tremblay et al. 1992). If the overall anova was significant, post-hoc comparisons were made using the Bonferonni method in SYSTAT (Wilkinson et al. 1992). All catch rate and length composition data (see below) are maintained in a structured database described in Hunter and Tremblay (1992).

Samples of the commercial catch - Samples of the commercial catch at sea and at dockside for the period 1993 to 1996 were used for estimates of total mortality using catch composition analysis, and to provide a 1996 snapshot of size composition throughout eastern Cape Breton. At-sea samples provided additional information on the catch-rate of sublegal animals, and ovigerous females. The number of lobsters measured per sample ranged from 200-800. For estimates of total mortality samples were grouped into 2-3 periods. The samples were then weighted based on the percentage of the catch landed during each period, as estimated from voluntary logs.

[1] A Conservation Framework for Atlantic Lobster. A report to the Minister of Fisheries and Oceans by the Fisheries Resource Conservation Council (FRCC). FRCC95.R.1, Nov. 1995.

Estimates of exploitation rate

<u>Exploitation rate from fishing logs (Leslie method)</u> - The first method for estimating exploitation, the Leslie method, utilizes the relationship between fishing success (kg per trap haul) and cumulative catch (Ricker 1975). For this method the catch and effort data from voluntary fishing logs for a given area were aggregated by week. Leslie analysis is based on the relationship:

$$C_t/f_t = qB_0 - qK_t$$

where C_t is the catch at time t, f_t is the unit of effort (trap hauls), q is the catchability (fraction of the population taken by one unit of effort), B_0 is the biomass or number at the beginning of the interval, and K_t is the biomass or number of lobsters taken by time=t.

The assumptions of Leslie are listed in Miller and Mohn (1993) as: (i) catchability is constant over the fishing season; (ii) fishing effort is distributed uniformly over the area occupied by the stock; (iii) quality of fishing effort is constant; (iv) the fished population is closed; and (v) landings and catch rate are correctly reported. Violations of any of these assumptions can result in inaccurate estimates of initial biomass. With the exception of (i) and (iv), these assumptions would appear to be reasonably met for the inshore lobster fishery, particularly in areas where the lobster grounds are limited, such as in northern Cape Breton. Catchability during the lobster season will be a function of temperature, weather, sex, size and molt stage. With some knowledge of how catchability changes, it should be possible to determine whether the Leslie estimates of exploitation are under- or overestimates.

The assumption that the fished population is closed, is met for some groups of lobster, since tag returns in northern Cape Breton indicate limited, undirected movement (less than 5 km in one year on average, Tremblay unpublished data). For other areas there is evidence that larger females do not appear in the catch until the latter part of the season, either because they were not catchable earlier, or because they were not present on the grounds.

Given that fishing intensity is sufficient to deplete the stock, and the assumptions are reasonably met, a plot of CPUE against cumulative catch should yield a straight line with slope equal to the catchability q. N_o can then be estimated as the Y-axis intercept, and the rate of exploitation (u) can be estimated as

$$u = C/B_0$$

where C is the total catch for the season.

<u>Exploitation rate from mark-recapture (Petersen method)</u> - For a few areas, lobsters were tagged in one year and tag returns collected during the following season. The tag used was the polyethylene streamer type (Moriyasu et al. 1995). For these areas, exploitation rate can be estimated with the simple Petersen estimate (Ricker 1975):

$$u = R/M$$

where R is the number of recaptures, and M is the number of marked individuals. Assumptions of this method include: (i) tagged lobsters have the same natural mortality as untagged; (ii) tagged lobsters are not more trappable than untagged; (iii) lobsters retain tags; (iv) tagged lobsters become randomly mixed with untagged; and (v) upon recapture, all tagged lobsters are recognized and reported.

<u>Total mortality from catch composition analysis</u> - Catch composition analysis involves following the numbers of lobster in a given "cohort" over successive years. It is not a true cohort since it is length based, and above 70 mm CL, any given size interval may include lobsters differing in age by 2 years. Total mortality (Z) was estimated as:

$$Z_{m1} = (\log_e N_{m1} - \log_e N_{m2})/Dt_{m1}$$

Where Z_{m1} is the total mortality rate of molt group 1, N_{m1} is the number of animals in molt group 1, N_{m2} is the number in molt group 2 one year later, and Dt_{m1} is the mean intermolt period (years) for the first molt group (Cobb and Caddy, 1989). The molt groups (70-80 mm; 81-93 mm, and 94-107 mm) are based on an increase in length per molt of 14-16% (Miller et al. 1989; Tremblay unpublished data), and a legal size of 70 mm in LFA 27, and 81 mm in LFA's 28-30. Catch composition analysis assumes that the fished population is closed, and that catchability and natural mortality are constant across sizes. These assumptions will be met to varying degrees. The method requires representative samples of the commercial catch, and good estimates of molt probability.

Numbers per molt group were derived from annual length measurements of the commercial catch. Where more than one sample was available, length frequencies were weighted by the portion of the annual catch they represented.

The duration of the intermolt period was taken as the inverse of the probability of molting. For males probability of molting was estimated as (from Miller et al. 1987):

$$P_{ml} = 3.77 * e^{-0.019(CL)}$$

where P_{ml} is the probability of molting, and CL is the carapace length. The median carapace length of the molt group was used to represent the molt group as a whole.

For females, reproduction must be considered, since upon reaching maturity, most females molt every other year (i.e. would have a P_{ml} of 0.5). The probability of maturity (P_{mat}) for several areas of eastern Cape Breton (Watson 1988) is described by:

$P_{mat} = 1.0/1 + e^{16.117 - 0.2204(CL)}$ (Ingonish - Northern LFA 27)
$P_{mat} = 1.0/1 + e^{14.266 - 0.1959(CL)}$ (Glace Bay- Central LFA 27)
$P_{mat} = 1.0/1 + e^{16.508 - 0.2132(CL)}$ (Gabarus - Fourchu - Southern LFA 27/LFA 30)
$P_{mat} = 1.0/1 + e^{14.595 - 0.1727(CL)}$ (Petit de Grat- LFA 29)

A weighted probability of molting for females was estimated for the median size within a molt group as:

$$P_{ml} = (P_{mat})*.5 + (1 - P_{mat})* 3.77* e^{-0.019(CL)}$$

RESULTS

Landings

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. 2). The lowest recorded landings (540 mt) were in the late 1960s and early 1970s. Beginning in 1985 landings increased sharply to an all-time high of 3790 mt in 1990. Since then landings have declined. From 1990-1995, landings in LFA 27 declined by about 43% (Table 4); the decline was lower in the Northern sub-area (Table 5).

Compared to LFA 27, the historical landings pattern in LFAs 28-30 is substantially different. All-time high landings 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. In LFA 29 landings declined by about 56% from 1989-1995, while in LFA 30 landings were more stable in the first half of the 1990s. The low landings in LFA 28 are difficult to track accurately, but in 1995 landings were 29% lower than the peak in 1989.

Size distribution

Size frequencies of the 1996 landed lobster catch in LFA 27 demonstrate the gradient in size composition from north to south (Fig. 3). In Northern sub-area ports (Dingwall, Neils Harbour), mean CL was 76-77 mm, while in Southern sub-area ports (Port Morien, Main a Dieu, Louisbourg) mean CL was 80-84 mm. In LFAs 29 and 30, where the minimum legal CL is 81 mm, mean CL was 90-99 mm (Fig. 4).

Catch rate

LFA 27 - Average catch rate for all logs declined in each sub-area of LFA 27 (Table 6). To determine if the declines were significant, analyses of variance were restricted to those fishing logs kept by the same fishers in each year of the comparison. This limits either the number of logs or the number of years to be compared. Given these constraints, the best option was comparison of 1992 vs. 1993, 1993 vs. 1994 vs. 1995, and 1995 vs. 1996. Within at least one of these periods, catch rates declined significantly in the Northern, Central, and Southern sub-areas (Table 7). Total catch rate declines for the period 1992-96 were on the order of 30-50%. The North-central sub-area showed no significant decline, but insufficient data were available for the 1992 vs. 1993 comparison.

LFAs 29 and 30 - Average catch rate for all logs declined within each LFA (Table 8). As for LFA 27, inter-year comparisons for LFAs 29 and 30 indicate that the catch rate declines were significant within 2-3 of the periods (Table 9). Catch rate declines were approximately 50% over the 1992-96 period.

Exploitation rate (*u*)

Leslie analysis - Plots of catch rate versus cumulative catch for 1996 indicate that Leslie analysis is a useful approach for Northern, North-central and Central sub-areas of LFA 27 (Fig. 5). For the southern portion of LFA 27, the catch rate decline is less uniform. In LFAs 30 and 29, since catch rate at times increases in mid-season. Estimates of u for the Northern, North-central and Central sub-areas were 70-84% with high r^2 values (> 0.9) and narrow confidence intervals (Table 10). Estimated u for the Southern sub-area was lower with a wide confidence interval. For LFAs 29 and 30 the estimate was either not possible (LFA 29) or of no value because of wide confidence intervals (Table 10).

Leslie analysis was also used for selected ports with good log records over the last 4-5 years to assess whether any temporal trend was evident (Table 11). Estimates of u for northerly and Central LFA 27 ports (Neil's Harbour, Little River, Glace Bay) were 66-80%, with high r^2 values. There was no indication of a temporal trend. For ports in the Southern sub-area of LFA 27 (Gabarus, Louisbourg) estimates of u were lower (35-55%) with wide confidence intervals. For LFAs 29 and 30 the estimates of u were variable (40-68%), with wide confidence intervals, or not possible because of within-season increases in catch rate.

Mark-recapture - The return rates of lobsters tagged in LFA 27 indicate exploitation rates from 40-66%. The highest estimates were for Little River, in the North-central sub-area; the lowest values were for the Southern sub-area (Port Morien) (Table 12).

Catch composition analysis - Estimates of the total number of lobsters landed at Little River (Table 13) provided the basis for estimates of total mortality (A). Mortality estimates were 50-69% depending upon the size and sex (Table 14). Estimates of the total number of lobsters landed at Fourchu (LFA 30) and Petit de Grat (LFA 29) were based on fewer samples (Table 15), but landings for these ports were less than 20% of the landings at Little River. Estimates of total mortality for Petit de Grat, and Fourchu ranged from 3-55% (Table 16). The lowest estimates for LFAs 29 and LFA 30 were for cohorts of large females, which in some years showed little reduction from one year to the next.

DISCUSSION

The most reasonable explanation for lower lobster landings and catch rates in LFAs 27-30 is lower lobster abundance. Catch rate is affected by lobster catchability, which is influenced by temperature or food, but it is doubtful that these factors have acted in one direction over the last 5-7 years. There are no data on annual changes in lobster food availability, but there are temperature data. Average temperature at 16-20 m during the fishing season at one port in the North-central subarea (Little River) was lower in 1996 than 1994, but average temperature at about 8 m was higher than in 1994 (Table 17, Fig. 6,7). Temperatures in deeper waters off northeastern Nova Scotia in 1996 were colder than normal, but these cold conditions have persisted since the mid-1980s (Drinkwater et al. 1996). Therefore the decline in lobster catches in LFAs 27-30 is likely due to lower lobster abundance.

A variety of assumptions were made to estimate exploitation rates. Assumptions of limited immigration and emigration are reasonable given the results of tagging studies. Studies off Dingwall, Ingonish, Little River, Englishtown, Big Bras d'Or, Glace Bay and Port Morien have all indicated that most lobsters move less than about 5 km from one year to the next (unpublished data). The assumption of constant catchability over the season (Leslie method) is more debatable. There are at least three factors that might cause catchability to change over the season; if catchability changes, then the Leslie estimates are biased. Increased temperature over the season probably causes increased catchability, perhaps inflating catch rates at the end of the season. This would result in lower estimates of exploitation rate using Leslie analysis.

Increased catchability at the end of the season due to higher temperature may be counterbalanced to some extent if lobsters begin to prepare for molting near the end of the season, since lobsters in pre-molt are generally less catchable. Catchability may also be lowered when natural food sources, such as capelin, are available. Fishermen in some areas are of the opinion that when capelin arrive, lobsters do not trap as well because they have an alternative food source to the bait in traps. However there is no scientific information on lobster-capelin interactions. If catchability is actually lower at the end of the season, then the Leslie estimates of exploitation rate would be biased upwards.

The assumption that tagged lobsters are no more catchable than other lobsters is critical to the Petersen estimates of exploitation. This assumption is reasonable but should be addressed through field studies. In addition the Petersen method assumes no tag loss or mortality between the time of tagging and recovery; these two factors alone could reduce the numbers of tagged lobster by 5-40% depending upon when in the molt stage the lobster is tagged, and the type of tag used (Moriyasu et al. 1995). Given these factors, the Petersen estimates should be regarded as minimum exploitation rates. The catch composition analysis method is dependent on representative samples of the commercial catch. More samples are needed for some Areas (LFAs 29 and 30) to increase confidence in these estimates (see below).

Comparison of the different estimates of exploitation can be done in only a limited fashion because of the different periods and locations. The most comprehensive data set is for Little River, in the North-central sub-area of LFA 27. Leslie estimates of u for this port were 70-75% (Table 11). Estimated u from tag returns ranged from 53-66% (Table 12). For catch composition analysis, total annual mortality estimates ranged from 50-69% (Table 14). Given the different approaches of these methods, these estimates are in good agreement, and the true exploitation rate between 1993 and 1995 was probably between 65 and 75%.

Given that the Leslie estimates of exploitation are reasonable where there is a strong decline in catch rate over the season, exploitation rates of 65-80% are typical for the Central, North-central and Northern sub-areas of LFA 27. In the southern portion of LFA 27 estimates of exploitation were lower (35-55%), but also fewer and more variable. Many fishers in the southern portion of LFA 27 feel exploitation has actually increased in the last 5-10 years because of movement of licenses from north to south. The lower estimates for the Southern sub-area of LFA 27 are not easily reconcilable with this contention.

Exploitation estimates for LFAs 29 and 30 (34-68% from Leslie analysis) were also lower than those for northern LFA 27. Given the variability in the estimates for LFAs 29 and 30, we have less confidence in them. We expect exploitation in LFA 30 to be lower than LFA 27 because of the low number of licenses for the Area (20). In LFA 29 on the other hand, an Area with less lobster bottom per license compared to others, removal rate is expected to be higher than the 40-60% estimated by Leslie analysis for some years. The Leslie method is not appropriate for some years because of increased lobster availability in mid-season. This same increase may make the catch composition method problematical because the size frequency generated from commercial samples might be sensitive to the timing of any increase in the availability of large lobsters. The 2-3 samples obtained per season may not be sufficient to obtain a length frequency that is representative of the entire season.

Previous estimates of total mortality for LFAs 27-30 using catch composition analysis were for the mid-1980s (Miller et al. 1987). For LFA 27, estimates for Glace Bay and Ingonish were 82% for lobsters 81-93 mm. The correction for intermolt period used by Miller et al. (1987) was somewhat different than that used here; our estimates would be slightly higher if we used the same method. For LFAs 29-30, Miller et al. (1987) estimated total mortality to be 42-45% (sexes combined). This agrees with the current paper in that they are lower than LFA 27, but the Miller et al. (1987) estimates were based on similar sampling frequencies.

The exploitation estimates presented here are the best that are currently available for LFAs 27-30. The uncertainty in the estimates for the southern part of LFA 27, and for LFAs 29 and 30 will add to uncertainty in any egg-per-recruit estimates for these Areas. Sensitivity analyses over the possible range of exploitation are advisable. For the southern part of LFA 27, and for LFA 29, exploitation estimates as high as 70% should be used. The sensitivity of egg-per-recruit estimates to other input parameters (e.g. growth of larger animals) will need to be treated similarly. These analyses will be particularly important if a specific egg-per-recruit target is adopted (e.g. 5% of virgin egg production).

Given the recent declines in lobster abundance off eastern Cape Breton, there is reason for concern. Although this area experienced low lobster abundance in the past, many fishers feel the quality of effort is different now than in the 1970s when lobster abundance was low. High fishing effort in combination with declining abundance could prevent the stocks from returning to high levels in the near future. The fact that the grounds have supported high landings in recent years (LFA 27) or in the last century (LFAs 29-30) suggests higher stock levels are possible given sufficient recruitment. Given there are fewer lobsters, steps to increase the egg production of the average lobster are recommended. Increased egg production will not guarantee higher recruitment, but below some unknown level of egg production, improved recruitment is at risk. There are a variety of approaches for increasing egg production, including maximum size limits, reduced exploitation rates, closed areas, and increasing the minimum legal size. Probably the most effective way to increase both egg production and yield is through an increase in the minimum legal carapace size. This recommendation is long standing for all fishing areas along coastal Nova Scotia (Miller et al. 1987), and is particularly appropriate for LFA 27.

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Table 1. License numbers by Lobster Fishing Area in 1996. 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	495	32	4*	535
LFA 28	16	2	0	18
LFA 29	59	15	0	74
LFA 30	20	0	0	20

* 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
LFA 27	7	26	42	46	50	48
LFA 28	1	1	2	2	1	0
LFA 29	5	8	8	10	7	7
LFA 30	2	7	6	6	6	7

Table 4. Landings (mt) by LFA. 1996 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	61-70	71-80	81-90
27	3714	3790	3526	2778	2458	2190	2142	*1563*	802	787	2244
28	21	8	9	9	12	13	15	*13*			
29	236	164	159	141	92	91	90	*60*	97	39	133
30	132	119	151	167	132	130	126	*90*	94	31	77
Total	4103	4081	3845	3095	2694	2424	2373	*1726*	993	77	2010

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

	1990	1991	1992	1993	1994	1995	% decline,
Northern	700	683	5869	578	541	565	-19
N-Central	533	468	388	336	295	285	-47
Central	1310	1144	851	785	677	693	-47
Southern	1247	1221	947	755	670	599	-52
Total LFA 27	3790	3516	2772	2454	2183	2142	-43

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

	1992	1993	1994	1995	1996
Northern	0.45	0.46	0.40	0.38	0.31
	.40, .50;	.39, .52;	.33, .47;	.34, .43;	.27, .34;
	n=9	n=12	n=14	n=16	n=18
North Central	0.53	0.51	0.45	0.49	0.43
	.33, .54;	.44, .55;	.40, .50;	.44, .53;	.38, .48;
	n=2	n=14	n=12	n=11	n=10
Central	0.47	0.47	0.36	0.40	0.32
	.40, .54;	.41, .53;	.32, .40;	.34, .46;	.26, .37;
	n=6	n=8	n=9	n=10	n=8
Southern	0.63	0.54	0.48	0.42	0.30
	.56, .69;	.49, .59;	.44, .52;	.38, .46;	.28, .32;
	n=9	n=8	n=11	n=13	n=10

Table 7. Statistical comparison of annual mean catch rate (kg/trap haul) from voluntary fishing logs in sub-areas of LFA 27. Only logs available for each year of comparison were used. Means with same superscript were not significantly different (analysis of variance, block design followed by Bonferonni post-hoc comparisons, 5% significance level). TH = trap haul

	N logs	Mean kg/TH		N logs	Mean kg/TH			N logs	Mean kg/TH	
	'92-'93	1992	1993	'93-'95	1993	1994	1995	'95-'96	1995	1996
Northern	9	0.45^{1}	0.41^{2}	12	0.45^{1}	$0.42^{1,2}$	0.39^{2}	12	0.40^{1}	0.34^{2}
North-central	NA			11	0.51^{1}	0.46^{1}	0.48^{1}	9	0.47^{1}	0.43^{1}
Central	6	0.47^{1}	0.41^{1}	8	0.47^{1}	0.37^{2}	$0.43^{1,2}$	8	0.38^{1}	0.32^{2}
Southern	7	0.61^{1}	0.53^{2}	6	0.55^{1}	$0.49^{1,2}$	0.39^{2}	9	0.40^{1}	0.30^{2}

Table 8. 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
LFA 29	0.27	0.20	0.21	0.20	0.14
	.22, .33; n=7	.16, .24; n=8	.17, .25; n=10	.16, .24; n=7	.09, .18; n=7
LFA 30	0.81	0.70	0.63	0.57	0.46
	.72, .88; n=8	.62, .78; n=6	.52, .73; n=6	.46, .67; n=6	.39, .53; n=7

Table 9. Statistical comparison of annual mean catch rate (kg/trap haul) from voluntary fishing logs in LFA 29 and LFA 30. Only logs available for each year of comparison used. Means with same superscript were not significantly different (analysis of variance, block design followed by Bonferonni post-hoc comparisons, 5% significance level). TH = trap haul.

	N logs	Mean kg/TH		N logs	Mean kg/TH			N logs	Mean kg/TH	
	'92-'93	1992	1993	'93-'95	1993	1994	1995	'95-'96	1995	1996
LFA 29	6	0.27^{1}	0.19^{2}	6	0.20^{1}	0.18^{1}	0.20^{1}	6	0.21^{1}	0.15^{2}
LFA 30	6	0.84^{1}	0.70^{2}	5	0.72^{1}	$0.66^{1,2}$	0.60^{2}	6	0.57^{1}	0.48^{2}

Table 10. Estimates of exploitation (μ) for 1996 based on Leslie analysis of voluntary fishing logs. All logs within sub-areas utilized. C.I. is 95% confidence interval for μ. TH = trap haul.

Area	Yr	N logs	No. TH	avg kg/TH	r^2	μ (%)	C.I.
Northern LFA27 -	1996	18	191467	0.31	0.97	76	69, 82
North-central LFA 27. -	1996	10	108892	0.43	0.99	70	66, 74
Central LFA 27- Alder	1996	8	95307	0.32	0.99	84	81, 87
Southern LFA 27. - Port	1996	10	105928	0.30	0.67	49	22, 67
LFA 29	1996	6	59688	0.14	0.00	NA	NA
LFA 30	1996	7	76738	0.46	0.25	34	26, 68

Table 11. Multiple-year estimates of exploitation (μ) based on Leslie analysis of voluntary fishing logs. C.I. is 95% confidence interval for μ. TH = trap haul. NA is not applicable.

LFA	Port	Yr	N logs	No. TH	avg kg/TH	r^2	μ (%)	C.I.
27 (Northern)	New Haven/	1992	5	55732	0.40	0.93	80	69,90
	Neil's Harbour	1993	5	57821	0.37	0.75	77	50,95
		1994	5	58696	0.31	0.86	66	49,80
		1995	5	61061	0.32	0.95	80	71,87
		1996	5	53110	0.28	0.87	70	54,83
27 (North-central)	Little River	1993	7	86526	0.59	0.91	70	57,81
		1994	6	77284	0.51	0.96	74	66,81
		1995	6	75215	0.53	0.81	75	53,90
		1996	4	42109	0.47	0.95	72	63,80
27 (Central)	Glace Bay	1993	4	50591	0.48	0.85	66	48,79
		1994	4	64206	0.37	0.97	76	69,83
		1995	5	62704	0.40	0.94	74	64,82
		1996	3	38044	0.30	0.95	75	65,83
27 (Southern)	Gabarus/	1992	8	88915	0.61	0.84	55	39,68
	Louisbourg	1993	7	77691	0.53	0.50	44	6,68
		1994	7	79674	0.49	0.33	35	12,64
		1995	6	69850	0.40	0.18	NA	NA
		1996	6	35041	0.31	0.24	47	51,89
30	Fourchu	1992	4	51446	0.89	0.91	68	54,79
		1993	4	46803	0.75	0.56	59	16,85
		1994	4	48209	0.71	0.06	NA	NA
		1995	4	47777	0.64	0.04	NA	NA
		1996	4	43828	0.54	0.22	NA	NA
29	Petit de Grat	1992	3	39820	0.24	0.68	54	26,74
		1993	4	46620	0.17	0.76	60	36,77
		1994	4	47530	0.16	0.39	51	10,84
		1995	3	34775	0.18	0.73	40	21,55
		1996	3	36035	0.11	0.01	NA	NA

Table 12. Estimated exploitation (μ) based on single census returns of tagged lobster (Petersen method). Lobsters were tagged in year prior to fishing season. Data include only lobsters above the minimum legal size (70 mm CL).

LFA	Port	Tagging period	N tagged	N returned in following season	μ (%)
27 (Northern)	Ingonish	Sep '94	200	110	55
27 (North-central)	Little River/Englishtown	Sep '93	1077	615	57
27 (North-central)	Wreck Cove	Sep '94	200	125	63
27 (North-central)	Little River	Sep '94	198	129	65
27 (North-central)	Bras d'Or	Oct '94	544	296	54
27 (Southern)	Port Morien	Oct '95	253	104	41

Table 13. Estimated number of lobsters landed at Little River by year, size and sex. Samples were done at sea; only legal portion of catch was included in analysis. Samples were aggregated into 2-3 periods and weighted based on the portion of landings during each period reported in voluntary fishing logs. For example in 1993, 52% of the total landings at Little River (179 mt) were landed in weeks 1-3. Tot n measured includes only legal portion of catch.

Year	N of samples	Tot n measured	Year	Males			Females		
				70-80	81-93	94-107	70-80	81-93	94-107
1993	7	1444	1993	167902	46949	6544	187200	49402	2343
1994	9	3151	1994	130879	49680	11899	132032	41543	6934
1995	4	1022	1995	114620	57958	10999	127708	45048	4298

Table 14. Estimated total annual mortality for Little River from numbers at size in Table 14. D is estimated duration of first molt group. Corr = corrected for intermolt period of first molt group; Uncorr is uncorrected.

Group	Period	D (yr)	Estimated A (%) Uncorr	Estimated A (%) Corr
Males 70-80	93-94	1.11	70	67
	94-95	1.11	56	52
Females 70-80	93-94	1.56	78	62
	94-95	1.56	66	50
Males 81-94	93-94	1.39	75	63
	94-95	1.39	78	66
Females 81-94	93-94	1.96	86	63
	94-95	1.96	90	69

Table 15. Estimated number of lobsters landed by logbook keepers in LFA 30 (Fourchu) and LFA 29 (Petit de Grat). Samples were obtained at dockside and were aggregated into 2-3 periods and weighted based on the portion of landings during each period reported in voluntary fishing logs. For example in 1993, 55% of the total landings at Fourchu (35 mt), the representative port for LFA 30, were landed in weeks 1-4. P. de. G. is Petit de Grat.

Port	Year	N samples	N measured	Males			Females		
				81-94	94-107	107-123	81-94	94-107	107-123
Fourchu (LFA 30)	1993	2	716	10966	5809	2674	15823	12394	10024
Fourchu (LFA 30)	1994	2	636	7423	5015	3201	13595	8908	11728
Fourchu (LFA 30)	1995	2	594	8099	6275	2761	9125	6433	5930
Fourchu (LFA 30)	1996	2	445	6911	3576	1784	7723	5496	2937
P. de G. (LFA 29)	1993	3	692	2581	925	588	3946	1469	1997
P. de G. (LFA 29)	1994	2	621	2891	909	346	3552	1139	1467

Table 16. Estimated total annual mortality for LFA 30 (Fourchu) and LFA 29 (Petit de Grat) from numbers at size in Table 16. D is estimated duration of first molt group. Corrected= corrected for intermolt period of first molt group.

	Group	Period	Estimated duration	Estimated A (%) Uncorrected	Corrected
LFA 30	Males 81-93	93-94	1.30	54	45
		94-95	1.30	15	12
		95-96	1.30	56	47
	Females 81-93	93-94	1.65	44	29
		94-95	1.65	53	36
		95-96	1.65	40	26
	Males 94-107	93-94	1.56	45	32
		94-95	1.56	45	32
		95-96	1.56	72	55
	Females 94-107	93-94	1.96	5	3
		94-95	1.96	33	19
		95-96	1.96	54	33
LFA 29	Males 81-93	93-94	1.30	63	53
	Females 81-93	93-94	1.65	71	53
	Males 94-107	93-94	1.56	63	47
	Females 94-107	93-94	1.96	17	9

Table 17. Average temperature (°C) at Little River from May 26-July 8 from 1993-96. Temperature recorders were placed in the traps of a local lobster fisherman; dates represent latest start date and earliest finish date over the period.

Depth	1993	1994	1995	1996
16-20 m	6.2	6.3	7.1	6.0
6-10 m		6.8	8.9	7.7

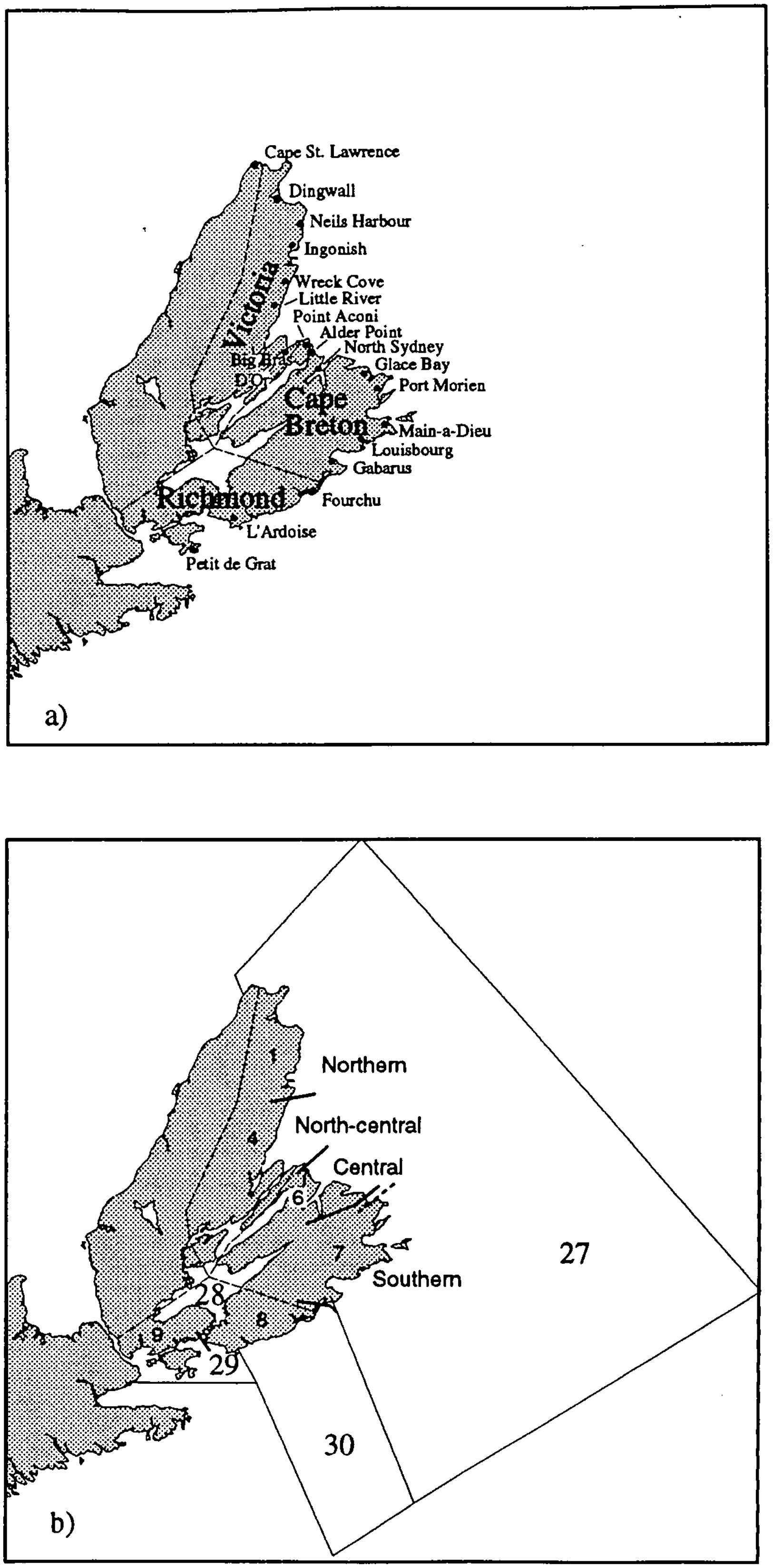

Figure 1. Eastern Cape Breton: (a) counties and selected fishing ports; (b) Lobster Fishing Areas (LFAs), Statistical Districts (S.D. - numbers on land) and sub-areas of LFA 27. Sub-areas correspond to S.D. except for Central/Southern boundary (shown as dashed line). Sub-areas are for purposes of assessment only.

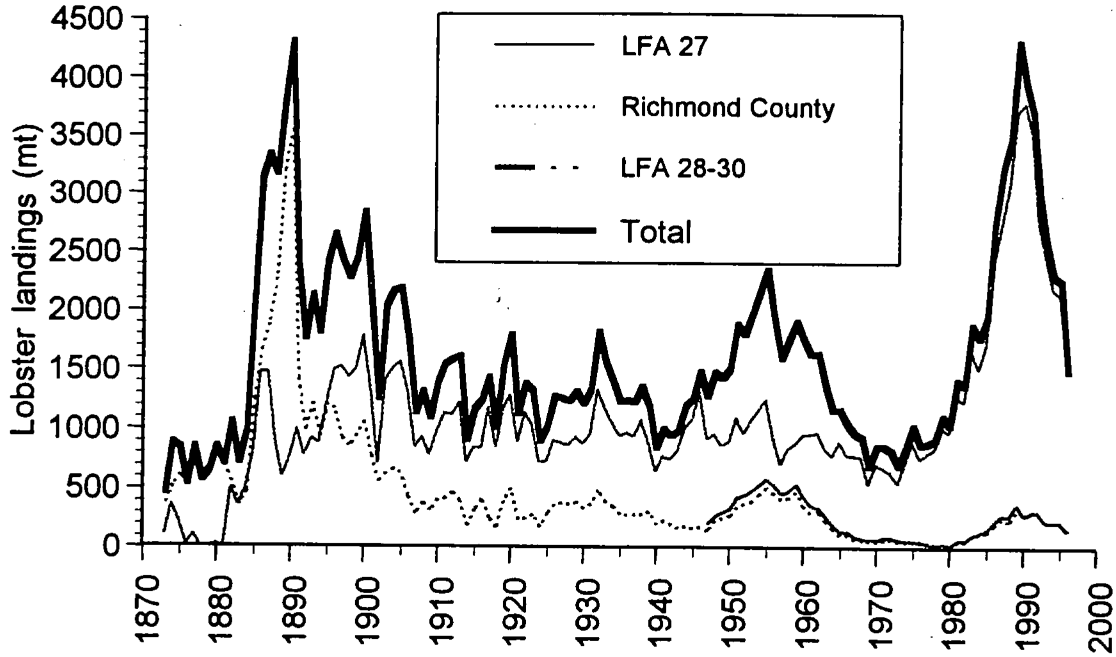

Figure 2. Historical lobster landings off eastern Cape Breton from Williamson (1992) and Commercial Data Division, DFO. Prior to 1947, landings were compiled by county. Since LFA 27 is comprised of Victoria and Cape Breton Counties, landings for this LFA are continuous back to the 1870s. LFAs 28-30 are 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.

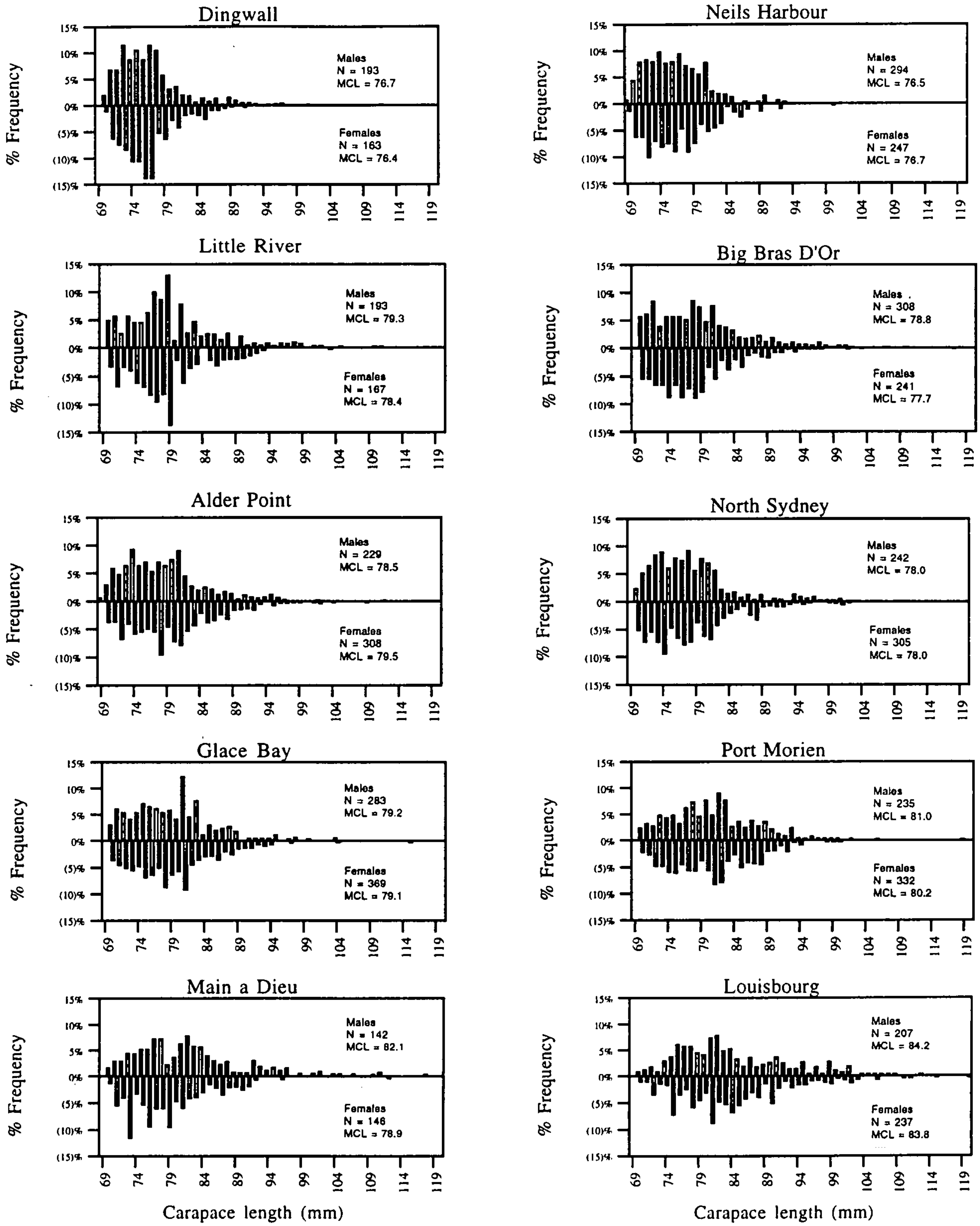

Figure 3. Length frequency at LFA 27 ports from May 16-29, 1996. For each sample 2 size categories ("canner" lobsters, <81 mm CL, and market lobsters, >80 mm CL) were measured separately. Numbers within each size category were then adjusted by the size category weight percentage in voluntary logs from May 16 - June 5. MCL = mean carapace length.

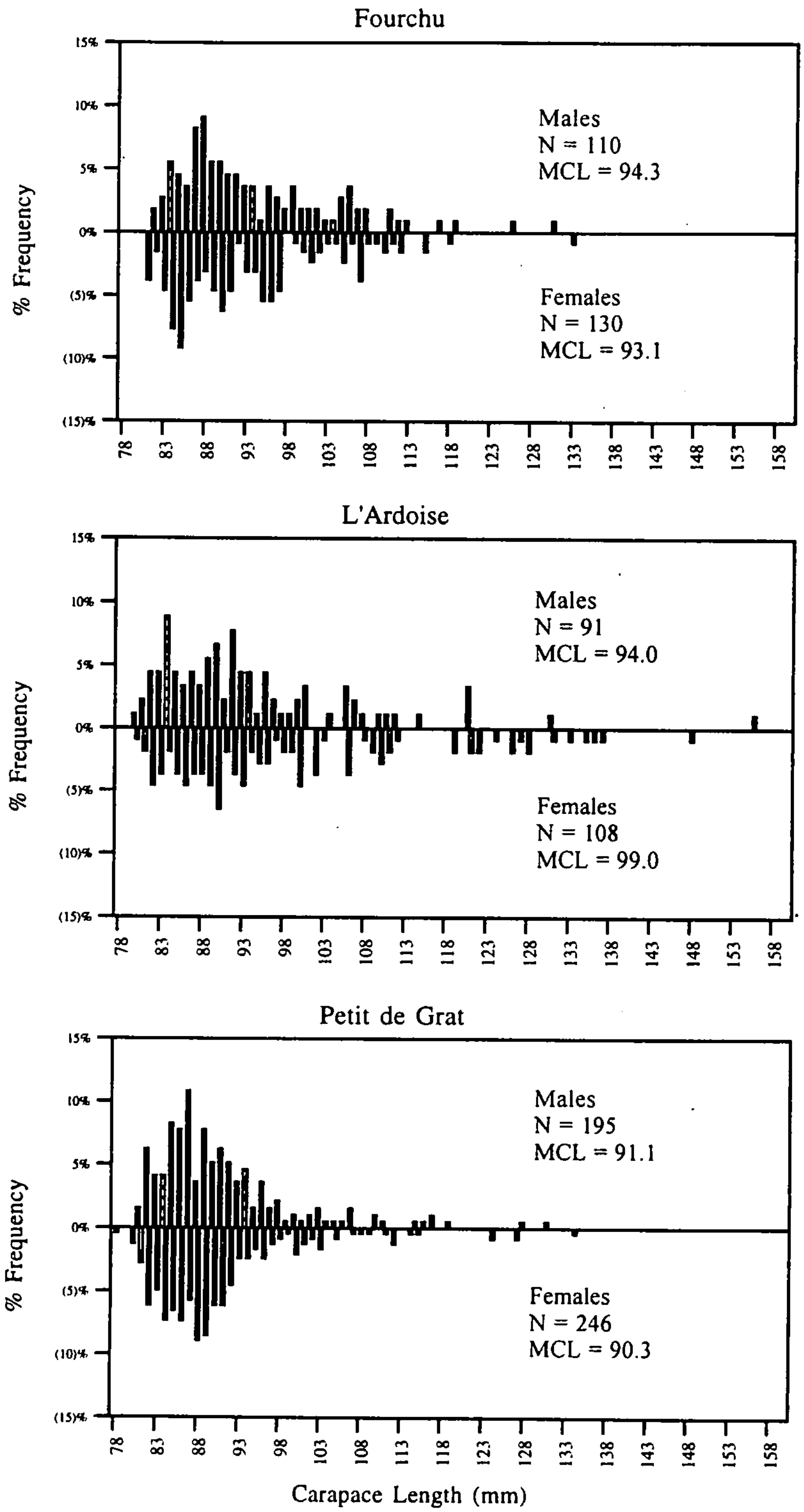

Figure 4. Length frequency at LFA 29-30 ports from May 15-31, 1996. MCL = mean carapace length.

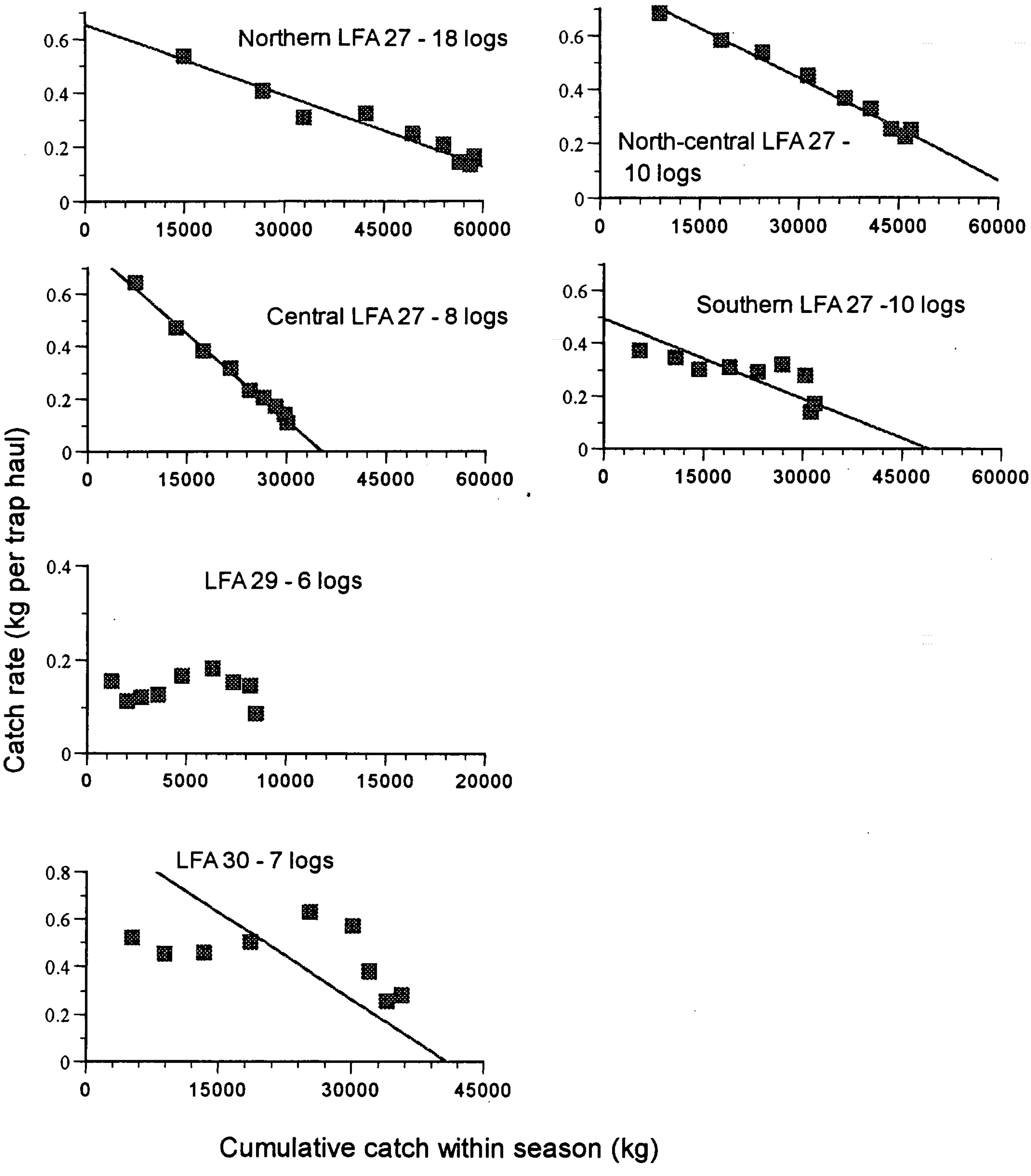

Figure 5. Catch rate versus cumulative catch for 1996 logbook keepers. For each of the 9 weeks of the season the total weight landed was divided by the total number of trap hauls for all logs. Table 10 give s the correlation coefficients for the linear regression lines.

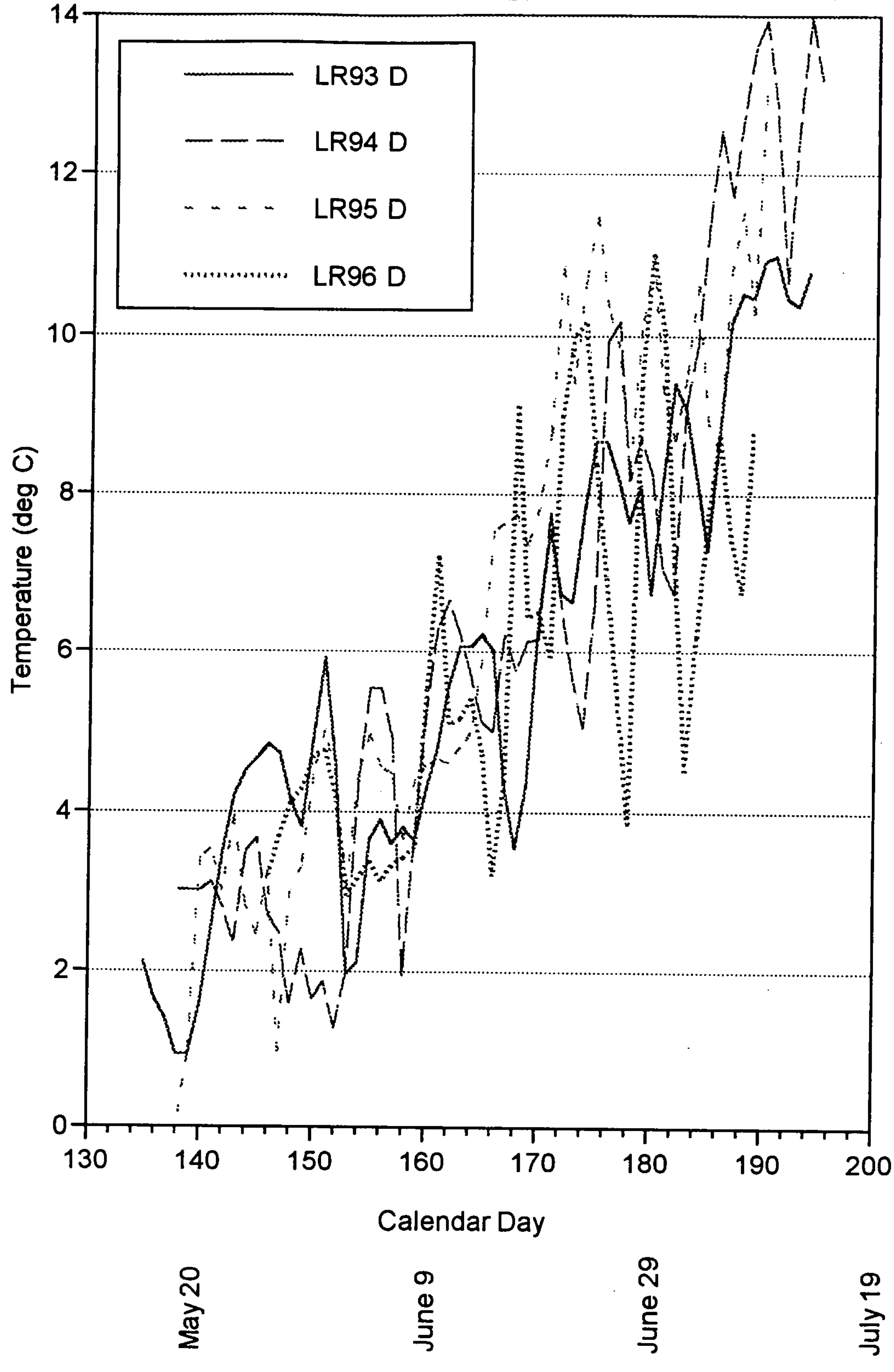

Figure 6. Bottom temperature during fishing season at Little River from 1993-96. Depth of 16-20 m. LR = Little River, D = Deep.

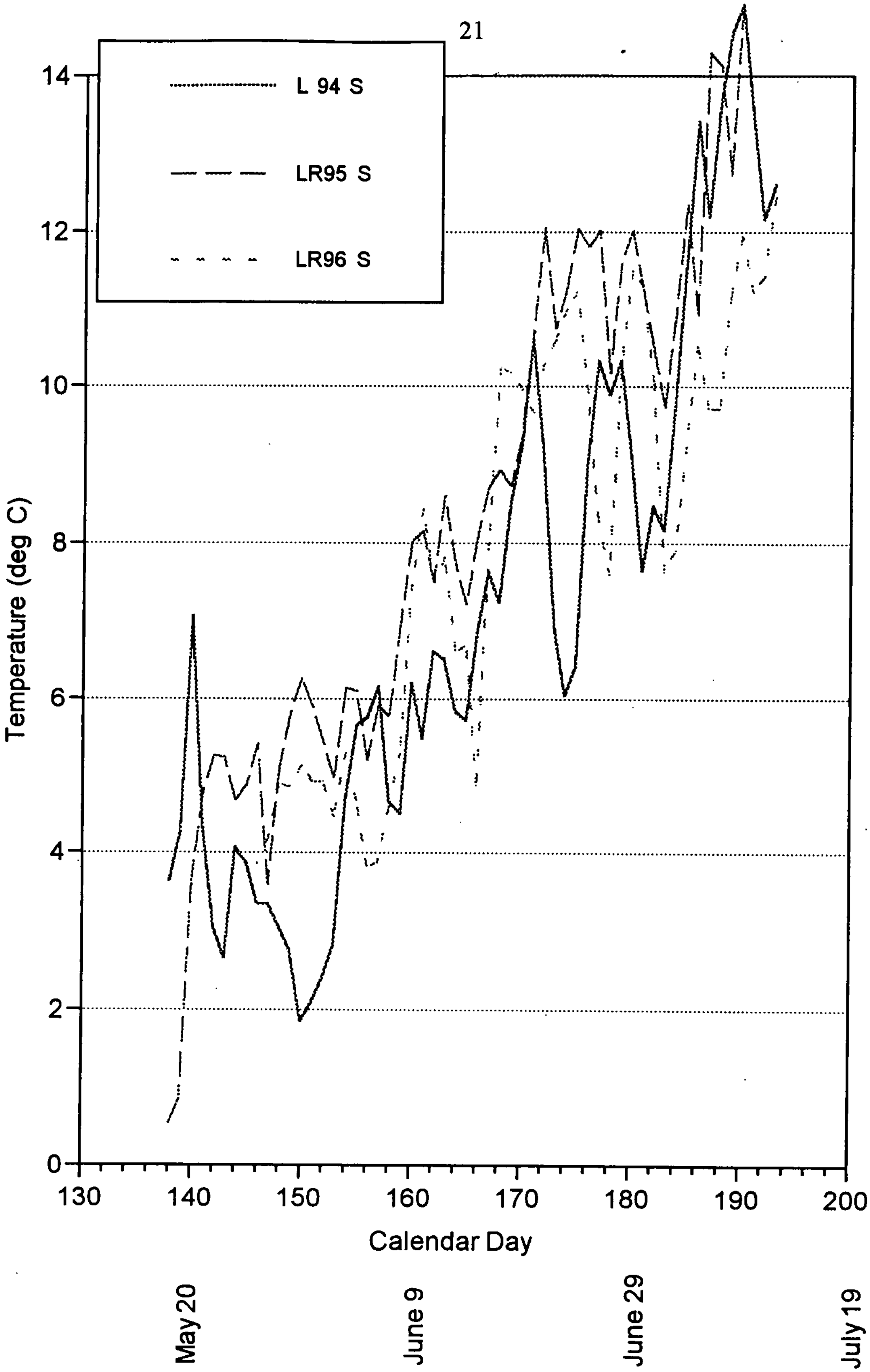

Figure 7 Bottom temperature during fishing season at Little River from 1994-96. Depth of 6-8 m. LR = Little River, S=shallow.