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Effects of Recent Management Changes and Stock Status in Lobster Fishing Areas 31 and 32.

Effets de récents changements en gestion et état des stocks de homard dans les zones de pêche du homard 31 et 32

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ABSTRACT

The purposes of this paper are 1) to investigate changes in LFAs 31 and 32 lobster stocks resulting from recent regulation changes, 2) consider the utility of our stock monitoring metrics, and 3) review the recent stock status. Regulation changes contributed about 35% and 20% of the 2001-2003 total egg production in LFAs 32 and 31B respectively. LFA 31A size frequencies showed benefits from minimum size increase and protection of large females. More eggs were produced by small females, but less than expected from protection of large females. In-port and at-sea samples were of limited use for tracking year-to-year changes and were best suited for location specific static measurements, such as exploitation rate or portion of the catch affected by a change in size regulation. Fishermen's records of daily catches were especially useful, and volunteer records were more reliable than mandatory ones. Measuring absolute abundance of ovigerous females from fishermen-directed tag-recapture studies and relative abundance of larvae and pre-recruits from out-of-season surveys show promise for stock monitoring. Stock indicators of landings and catch per trap haul of legals and pre-recruits were higher. Median lobster size, catch rate of ovigerous females, and exploitation rate showed little or no change.

RÉSUMÉ

Les objectifs du présent document sont 1) d'examiner les changements dans l'état des stocks de homard des ZPH 31 et 32 résultant des récentes modifications réglementaires, 2) de considérer l'utilité de nos paramètres de surveillance des stocks et 3) de passer en revue l'état récent de ces stocks. Les modifications réglementaires ont permis d'assurer environ 35 % et 20 % de la production totale en oeufs pour 2001-2003 dans les ZPH 32 et 31B respectivement. D'après les fréquences des longueurs dans la ZPH 31A, l'augmentation de la taille réglementaire minimale et la protection des grosses femelles ont porté fruit. Un plus grand nombre d'œufs ont ainsi été produit par les petites femelles, mais les grosses en ont produits moins que prévus même si elles étaient protégées. Les échantillons prélevés en mer et à quai se sont révélés peu utiles pour ce qui est de suivre les changements d'une année à l'autre, se prêtant mieux à des mesures statiques strictement localisées, comme le taux d'exploitation ou le pourcentage des prises touché par un changement dans la taille réglementaire. Les données des pêcheurs sur les prises quotidiennes se sont révélées particulièrement utiles, les données consignées volontairement étant plus fiables que celles exigées. La mesure de l'abondance absolue des femelles ovigères par le biais d'études d'étiquetage et de recapture dirigées par des pêcheurs et de l'abondance relative des larves et des prérecrues par le biais de relevés hors-saison se révèlent prometteurs pour ce qui est de la surveillance des stocks. Les indicateurs des stocks que sont les débarquements et les prises par casier relevé de homards de taille réglementaire et de prérecrues étaient plus élevés. La taille médiane des homards, le taux de capture de femelles ovigères et le taux d'exploitation ont peu ou pas changé.

INTRODUCTION

Since the early 1970s DFO lobster biologists made repeated requests for regulation changes to increase egg production of the stocks (Miller et al. 1987). However, until 1998 there were only modest improvements in the Maritimes. In 1978-81 a buyback of inactive licenses, mostly from the Eastern Shore and southern Cape Breton, caused moderate reductions in fishing effort. Minimum legal size was increased by 6 mm carapace length (CL) in Inverness County, western Cape Breton (Maynard et al. 1992). Since 1993 escape gaps to release undersized lobsters from traps and timed release panels to reduce ghost fishing by lost traps were required. The former is better observed than the latter (pers. obs.).

In 1995 the Fisheries Resource Conservation Council recommended that all lobster fishing areas (LFAs) in the fishery increase average female lifetime egg production (eggs/recruit) to 5% of the unfished level (FRCC 1995). This report had been requested by DFO minister Tobin, but no action was taken until December 1997 when DFO minister Anderson announced that over the next 2-3 years (later increased to 4-years) measures would be put into place to double female lobster's average lifetime egg production in each LFA unless fishers demonstrated to DFO that the change was not required. Lobster biologists advocated the doubling rather than the 5% recommended by the FRCC because in several areas such large changes were not attainable in a short time. The doubling was intended as a modest, but meaningful beginning to precautionary management of lobster stocks, but not a final target. The Minister asked LFA advisory committees, with the help of DFO, to choose measures to achieve doubling. Lobster biologists were asked to present default measures to be applied if industry did not choose. These options were included in 1998 RAP documents and summarized in DFO (1998a). Unfortunately, few LFA committees proposed measures to reach the doubling target. Also, the minister's directive lacked support from some DFO managers (pers. obs.). In December 2001 DFO minister Daliwhal reaffirmed DFO's commitment to doubling eggs/recruit. A 2001 task force of DFO Scientists and Fisheries Managers (Anon. 2001) reviewed progress toward doubling and recommended continuing effort, but without a timetable.

The purpose of this document is to collate recent fishery based data, look for empirical results of fishery management changes implemented in LFAs 31A, 31B, and 32 (Fig. 1) since 1997, consider the present stock status, and consider the utility of our lobster stock-monitoring metrics. Previous assessments of the fishery in these LFAs can be found in Robinson (1979), Miller et al. (1987), Pringle et al. (1993), DFO (1996), Miller et al. (1997), DFO (1998b), and Koeller (1999).

METHODS

Landings were recorded by county until 1947, and by lobster fishing area (LFA) since. LFA 31 A and 31B together includes all but a very small part of Guysborough county. LFA 31 was divided into A and B sections in 1993 to allow for a later season because of Spring ice in 31A. About 55 % of the landings of Halifax County are in LFA 32. In 1996, the method of data collection changed from buyers submitting purchase slips to DFO to fishermen mailing monthly reports to DFO.

Catch per unit effort is given in units of catch per trap haul (CPTH) obtained from daily logs kept by volunteer fishermen.

At-sea sampling during commercial fishing provided catch rates and sizes for ovigerous, tail notched, and window (114-123 mm carapace length) female components of the lobster population that fishers were required to return to the water on the fishing ground. Carapace length measurements were rounded down to the nearest whole mm, e.g. measurements from 123 to 123.9 mm were reported as 123 mm.

The percentage of legal catch in the first molt class above legal minimum size was an index of exploitation rate. This length interval was 13 mm carapace length (CL) and represented a weight range of about 220 g.

Percent of catch in first molt as well as the ratio of frequencies in the first two recruited molt classes (Cobb and Caddy 1989), and length cohort analysis (Cadrin and Estrella 1996) can be biased by changes in annual recruitment and by change in catchability with size. The change in ratio of legal to undersized lobsters within a season (Claytor and Allard 2004) and the Leslie analysis (Miller and Mohn 1989) avoids the problem of changing recruitment, but Leslie can be biased by changes in catchability within a season and between sizes. The change in ratio method is affected by catchability changes within a season. The percentage of catch in the first molt class was chosen to represent exploitation because of its simplicity.

The authors have a limited repertoire of time series analyses, therefore most conclusions are drawn from inspection of the data.

RESULTS

LFAs 32 and 31B

LFA 32 and 31B advisory committees and DFO Fisheries Management developed a plan in which minimum legal size was increased by a small amount (Table 1). Also, each season each fisherman saves from his catch or purchases a prescribed weight of non-ovigerous but mature females and returns them to the fishing ground (put-backs). These lobsters' tails (first endopodite to right of telson) are v-notched so they can not be immediately recaptured. The v-notching, weighing, and returning of lobsters are carried out by a third party. A minimum put-back size of 109 mm was chosen to increase the abundance of repeat spawners. Eggs of repeat spawners tend to hatch earlier than first time spawners (Attard and Hudon 1987). Cumulative benefits of changes are greater than the sum of benefits applied independently, e.g. a 3 mm size increase giving 27% is more than double a 1.5 mm size increase giving 12%.

Table 1. Regulation changes and the resulting increase in eggs/recruit, assuming the regulation is maintained until the population reaches equilibrium (based on the Idoine-Rago model, Anon 1996). The percentage increase was compared to 1997 with 81 mm minimum CL and no put-back.

Year	Regulation	LFA	% increase
1998	82.5 mm min. CL	32	12
		31B	7
1999	84 mm min. CL	32	27
		31B	17
2000	82.5 mm min. CL, & put-back 100 kg mature females	32	37 + v-notch protection
		31B	<37 + v-notch protection
2001-2003	82.5 mm min. CL, put-back 50 kg mature females	32	23 + v-notch protection
		31B	<23 + v-notch protection

Eggs

The benefit to eggs/recruit from the size increase could be calculated from the Idoine-Rago model (Anon. 1996). Also, the benefit of the female put-back was roughly estimated from this model. A size interval of large females which included the same percentage of catch weight as was put back by all fishers in an LFA was set in the model as illegal to retain. Lobster mortality and egg resorption due to storing, handling, and releasing lobsters in unfavorable habitats will reduce the egg contribution of the returned females. Fishermen chose not to support a study to measure these effects and in the absence of data this loss was set at 50% based on experience of the authors and S. Waddy (DFO, St. Andrews, N.B., pers. comm.) with egg absorption after stress. The eggs contributed by the put-back lobsters after a subsequent molt (the "+ v-notching" designation in Table 1) was not included because we could devise no method for entering into the model a weight of v-notched females. Because LFA 31B began the program with a higher density of mature females than LFA 32, the same weight of put-back (50 kg per fisherman) gave a smaller percentage increase.

We have a measure of rate of extrusion of put-backs from the first 3-years (Table 2). Of the females put-back in 2000 and recovered in 2001, 52% were ovigerous in LFA 31B and 64% were ovigerous in LFA 32. If we assume the ovigerous 2002 recaptures from the 2000 put-backs are females that didn't extrude in 2001, then we can add the percents from 2001 and 2002. This gives total extrusion from 2000 releases of 87% for LFA 31B and 88% for LFA 32. The 2001 releases gave similar extrusion rates from both LFAs of 75% and 72% in 2002. We do not have data on 2003 recaptures of 2001 releases. Also we don't have a measure of mortality of put-backs, but likely the assumption of 50% loss from mortality plus absorption was too high.

Table 2. Percentage of put-backs in 2000 and 2001 that are ovigerous in 2001 and 2002. Releases 2000 were untagged and in 2001 were tagged with yellow streamers. (Carl MacDonald, Fisheries and Scientist Research Society, unpub. rep.)

LFA	Date of release	Date of recapture	Number of fishermen	Total recaptures	Percent ovigerous
31B	2000	2001	6	268	52
	2000	2002	7	393	35
	2001	2002	7	101	75
32	2000	2001	9	496	64
	2000	2002	9	541	24
	2001	2002	9	238	72

We now have a more direct method than the egg/recruit model of measuring the egg increase from the put-back of mature females. This is the fraction of the ovigerous females in the population that are tail-notched (Table 3). All tail-notched lobsters were caught and would have been removed from the stock if not for the put-back program. Because tail-notched ovigerous lobsters are on average larger than un-notched (naturally occurring) ovigerous lobsters, the percentage increase in ovigerous females must be increased to account for the higher fecundity of the larger lobsters. Fecundity vs. carapace length regressions are similar for the Canadian Maritimes and New England (Estrella and Cadrin 1995). Therefore, we used the combined regression for the Maritimes (Campbell and Robinson 1983). After converting carapace length to weight (Campbell 1985) it became apparent that the fecundity-weight relationship was linear.

$$\text{Eggs/gram} = 11 + 0.1\ \text{CL}$$

In fact, there is little change in eggs per gram lobster size, and 22,000/kg or 10,000/pound is a good approximation. The above regression was used in calculating the egg addition from the put-back. Sources for catches of notched and un-notched ovigerous females were daily log records fishermen provide to the Eastern Shore Fishermans Protective Association (ESFPA), Guysborough County Inshore Fishemen's Association (GCIFA), Fishermen and Scientists Research Society (FSRS), volunteer records to DFO, and at-sea samples collected for DFO. The at-sea samples and reports from the ESFPA[2] and FSRS[1,3,4] provided the sizes of ovigerous females with and without tail notches.

The most consistent of these data sources may be the at-sea samples because these are collected by a small group of trained samplers. All other sources are

[1] MacDonald, C., and Scott, S. 2000. Lobster v-notch conservation program for LFA 32 and 31B, Fishermen and Scientists Research Society, 19p.
[2] Crandelmere, T. 2001. Lobster v-notch and tagging program for LFA 32 and 31B, Eastern Shore Fishermans Protective Association, 25p.
[3] MacDonald, C., and Scott, S. 2002. Lobster v-notch conservation program for LFA 32 and 31B. Fishermen and Scientist Research Society, 30p.
[4] MacDonald, C. and Scott-Tibbetts, S. 2003. 2003 lobster v-notch conservation program for LFA 32 and 31B. Fishermen and Scientists Research Society. 19p.

fishermen's' records, some of which are more carefully compiled than others. Tail-notched lobsters which are caught and sold[4] would cause the benefit to be overestimated and lobsters that continue to spawn after absorbing the notch would result in an underestimate.

The many observations in Table 3 present a similar picture of egg addition from large females put back. In LFA 32 the put-back added about 22% to egg production and in LFA 31B the addition was about 14%. Whereas the Idoine-Rago model compares the contribution of the put-back to eggs/recruit relative to 1997, this method gives the percentage increase in stock egg production in the year data are collected.

Adding egg benefits from the 1.5 mm size increase of 12% and 7% as predicted by the egg/recruit model, we get a total of 34% and 21% for LFAs 32 and 31B respectively.

Table 3. Percentage increase in ovigerous females and eggs due to female put-back; based on counts of ovigerous lobsters with and without tail notches.

			Number of ovigerous		Percentage increase		Mean size of ovigerous	
Year	LFA	Source	with notch	without notch	ovigerous	eggs	w/o notch	with notch
2001	32	ESFPA	312	1434	22	31	101	114
		FSRS	317	1981	16	23		
		DFO logs	44	647	7[1]	10		
		DFO samples	6	39	15	19		
	31B	GCIFA	123	1091	11	15	101	111
		FSRS	140	2049	7	10		
2002	32	ESFPA	412	2308	18	24	101	112
		FSRS	302	2051	15	21		
		DFO logs	140	836	17	23		
		DFO samples	5	34	15	20		
	31B	GCIFA	366	4638	8	11	103	114
		ESFPA	115	1422	8	11		
		FSRS	214	2776	8	11		
2003	32	FSRS	438	3529	12	20	103	118
		DFO logs	162	847	19	30		
		DFO samples	18	132	14	22		
	31B	GCIFA	432	6217	7	12	100	118
		FSRS	391	3879	10	18		
		DFO samples	12	116	10	17		

[1]Logs from only eastern part of district with high abundance of ovigerous females.

The predictions of increased eggs from put-backs can also be compared using the egg/recruit model and the ratio for notched/un-notched ovigerous from the 2003 data for LFA 32.

$$\% \text{ increase}_{\text{ratio}} = 22/(100-12) = 25\%$$

In the above equation the 22% is from Table 3. The 12% must be subtracted from 100% in the ratio because this resulted from the size increase and was not naturally occurring ovigerous. If we add back the 12% for minimum size increase, the benefit of both measures is 37%. The same calculations for 31B results in a benefit of about 20% from both measures.

With potentially large errors, we can calculate the egg production from 1-year's put-backs. If 83% spawned during the two summers following the put-back (Table 2), female mortality was 20%, and we used the approximation of 22,000 eggs per kg female, then the 7819 kg[4] in LFA 32 would yield 121 million eggs (7819 x 22,000 x 0.88 x 0.80) and the 3705 kg[4] in LFA 31 B would yield 57 million eggs. Lobsters that retained the v-notch, were returned to the water, and survived 2 years to spawn again would add to this number.

Final measures of the benefit of regulation changes could be the number of ovigerous females and pre-recruits reported by fishermen in their volunteer log books provided to DFO. Only log books continuing to the present time were included. The first benefit of regulation change in ovigerous females should appear in 2001 because the first put-back of non-ovigerous females was in 2000. From inspection of Table 4 we can see no increase in 2001-2003 for either Torbay or Halifax County East. An increase for Clam Bay is indicated, although it appears to have started before 2001 and became larger during 2001-03. Assuming the smallest pre-recruits in catches are about 4-years old, we would not yet expect to see benefits of put-backs or window female restrictions in new recruits.

Table 4. Catch of ovigerous females and pre-recruits (shorts) per 1000 trap hauls for full seasons, based on voluntary log books.

Ovigerous

LFA/Port	Fisher	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
LFA 31A														
Canso	4	a	a	58	54	a	46	36	72	72	50	44	52	74
Whitehead	3	a	a	37	b	a	23	24	123	56	75	47	47	b
LFA 31B														
Torbay	1	61	61	a	20	a	18	9	33	29	37	30	20	27
	6								43	28	39	28	40	30
LFA 32														
Halifax Co. E.	3	42	26	25	12	16	14	12	17	37	40	37	65	39
	5			23	16	b	16	25	24	b	49	27	35	28
	6			58	46	34	39	36	64	44	86	52	46	54
	7			42	36	27	27	23	34	32	60	38	b	56
Clam Bay	4			6	3	3	5	4	7	7	11	10	10	15
	10				9	5	7	6	12	17	15	19	21	37
	16										15	19	24	27
	17											13	21	23

Table 4 (Continued)

Pre-recruits

LFA/Port	Fisher	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
LFA 31A														
Canso	4	91	72	45	35	38	45	33	54	82	125	110	88	907
LFA 31B														
Torbay	1	292	168	102	90	65	61	71	113	230	264	183	183	341
	6								145	238	224	172	152	448
LFA 32														
Halifax Co. E.	3	206	145	98	84	115	146	205	266	223	264	159	157	257
	5			41	37	132	72	147	129	142	114	136	128	164
	6			118	75	110	151	209	265	266	249	181	196	312
	7			62	66	61	99	108	153	161	156	123	147	239
Clam Bay	4			81	96	76	102	122	212	262	286	241	229	228
	10				97	81	86	89	108	140	127	97	107	108
	17											96	109	135

[a] Season began and finished late because of ice cover.
[b] Fisher stopped fishing or stopped recording before end of season.

Landings and CPUE

Landings over the past 50 years for Halifax and Guysborough Counties are far below the highs of the late 1800s (Fig. 2). Recent Halifax County landings compare favorably with landings since 1910, and those in Guysborough County have been at the present low levels since the 1960s. In the short term, landings from 32 and 31B increased over 70% from 1997 through 2001 (Fig. 3). However, this could not be attributed to the conservation measures. Any benefit of increased eggs to landings will not be seen until at least 2008, and the benefit to yield per recruit from the 1.5 mm size increase is only about 2% (based on the Idoine-Rago model).

Catch per trap haul for Port Bickerton (LFA 31B), Clam Bay, and Halifax Co. East (LFA 32) all increased since 1996 (Fig. 4), but for the reasons mentioned above, these cannot be attributed to regulation changes.

Size Frequency

Comparing the size frequencies in figures 5, 6, and 7 we see that Eastern Halifax County has a higher portion of large lobsters than the other areas, but there are no clear temporal trends for any area.

Size frequencies of ovigerous lobsters from at-sea samples should first show increases in large sizes in the 2001 season because the first put-back was in 2000. This put-back was double the size of subsequent ones (100 vs. 50 kg per fisherman). We have sea samples for only 2001, 2002, and 2003 in LFA 32 and only 2002-2003 for 31B (Fig. 8). A chi-square test shows no difference in frequency of ovigerous females among the 3-years for LFA 32 (X^2=8.0, 8 d.f.).

If tail-notched females are not retained by fishermen, if tail notches remain visible through two molts, and if spawning occurs on a 2-year cycle, then the number of ovigerous should peak in the 2005 fishery. Lobsters put-back in 2000 would molt twice and be carrying their third batch of eggs in the 2005 fishing season. These would be joined by the 2002 releases with their second batch of eggs and 2004 releases with their first batch. After 2005, ovigerous females from three releases would continue to be in the fishery.

To date the recapture rate has kept pace with releases of tail-notched females in LFA 31B, but not in LFA 32 (Table 5). If the above sequence of molting is correct, none of 2000, 2001, or 2002 releases should have molted more than once by 2003.

Table 5. Release and recapture rates of tail-notched females (C. MacDonald, Fishermen and Scientist Research Society, pers. comm.).

Year	Cumulative release per fisherman (no.)	Recaptures per fisherman (no.)	
		LFA 31B	LFA 32
2000	85		
2001	127	45	55
2002	165	71	87
2003		99	72

Exploitation

The relationship between the percentage of catch in first molt and the exploitation rate (the percentage of legal stock, in numbers, taken by the fishery in 1-year) is graphed in figure 9 and is represented by the quadratic equation

$$Y = -0.70\ X^2 + 16.62 – 14.62$$

Table 6 is an example calculation of catch at 50% exploitation assuming 15% natural mortality at each molt. The population was taken through a series of molts until all were caught or lost to natural mortality. In the example, an exploitation of 50% results in a percentage catch in the first molt of 57.9% (50/86.4). Percentage in the first molt is larger than exploitation rate because of molt-to-molt losses to natural mortality.

Table 6. Example calculation of the relationship between 50% exploitation and 57.9% of the catch in the first molt.

	Molt 1	2	3	4	5	6	Total catch
Population	100	42.5	18.1	7.7	3.2	1.4	
Catch	50	21.2	9.0	3.8	1.6	0.7	86.4
Survivors	50	21.3	9.1	3.8	1.6		
Natural mortality	7.5	3.2	1.4	0.6	0.2		

To obtain the percentage at first molt from size frequencies requires a size interval of the first molt. Unpublished growth increments for females 61-119 mm CL based on spherion tagging in Jeddore (n=57) and streamer tagging in Shad Bay (n=88) showed no correlation with size and a median at 13 mm (Fig. 10). Growth increments at 86 mm CL (sexes combined) were 12.1 mm at New Harbour and 12.5 mm at Port Mouton (Miller et al. 1989). A 13 mm interval was used here.

Although the time trends based on port samples are somewhat erratic, there have been no shifts in percentage in the first molt for either sex in Clam Bay or Port Bickerton (Table 7). An increase in 2001 appears in the shorter time series from Halifax County East.

The median size of lobsters in the port samples is another expression of exploitation. Again, there is no temporal trend for either sex in Clam Bay or Port Bickerton, but perhaps there is in Halifax county East (Table 7). As expected, median size and percentage in the first molt are negatively correlated. For Clam Bay r-values are near –0.7 for both sexes and for Port Bickerton r-values are near –0.5 for both sexes. The years 1999 and 2000 were omitted from the correlations because by 1999 the minimum size had increased by 3 mm and these animals would recruit to the fishery in 2000. The 1.5 mm increment in 1998 and 2001-03 had a negligible impact on sizes in the catch.

Table 7. Number of males and females in port samples and percentages in the first molt class .

Sampling location	Year	First molt (%) Male	First molt (%) Female	Median size (mm CL) Male	Median size (mm CL) Female
Clam Bay	89	70	75	89	89
	90.	67	72	90	90
	91.	50	55	94	92
	92.	62	68	90	90
	93.	63	68	92	91
	94.	72	74	89	89
	95.	No data			
	96.	66	67	90	90
	97.	No data			
	98.	68	73	91	91
	99.	63	72	93	92
	00.	73	65	92	92
	01.	71	77	91	90
	02.	64	64	93	92
	03.	65	69	93	92
Halifax County E.	99	52	56	96	95
	00	53	53	95	95
	01	67	73	92	91
	02	58	63	93	93
	03	56	63	94	92
Port Bickerton	89	61	73	91	89
	90	60	67	91	89
	91		Only 1 sample		
	92	57	62	92	91
	93	63	56	91	92
	94	56	67	92	91
	95	No data			
	96	68	56	89	91
	97	No data			
	98	63	67	93	92
	99	70	73	92	92
	00	78	66	90	91
	01	75	80	90	90
	02	65	64	93	93
	03	63	62	92	93

The median size of lobsters in their second molt and larger (>96 mm CL) shows no temporal trend for Clam Bay (Fig. 11), but a decrease in 2000-2003 in Port Bickerton (Fig. 12). This suggests an increased exploitation rate on larger animals. The median size is a more stable indicator than the percentage of catch (Figs. 11 and 12).

LFA 31 A

This LFA includes the south shore of Chedabucto Bay and 20 km of the outer coast west of Chedabucto Bay.

Three increases, from 81 to 86 mm CL, were adopted (Table 8) leading to the largest minimum legal size of any Homarus fishery. To protect large females this area also has a “closed window” regulation requiring that all non-ovigerous females 114-123 mm CL be returned to the water on the fishing ground. Tail-notched lobsters that cross into 31A from 31B must be returned to the fishing ground. Although an annoyance to fishermen fishing near the line, this has negligible impact on 31A egg production. These measures were selected from the default toolbox offered by DFO Science Branch. Although this is the first place the window has been applied, it was first described by Campbell (1985) and was suggested to him by fishermen from Grand Manan Island, New Brunswick (A. Campbell, pers. comm.). Although the increase in eggs/recruit was only a little over 50%, numerically it was from 5400 to 8200 eggs, probably the largest increase for any LFA. Note that the benefits are cumulative. The increase from minimum size alone is 34% and window alone is 15%, but together are 54%.

Table 8. Regulation changes and the percentage increase in eggs/recruit if the regulation is maintained until the population reaches equilibrium. Percentage change is compared to 1997. The window regulation requires returning to the fishing ground all non-ovigerous females 114-123 mm CL.

Year	Regulation	% increase
1998	82.5 mm min. CL	8
1999	84 mm min. CL	19
2000	86 mm min. CL	34
2001	86 mm min. CL, window	54

Exploitation

Before 1998 there is no trend over time, for either sex, in the percentage of catch in the first molt in Canso (Table 9). The abrupt changes of >10% between successive years in a few cases is unlikely to represent actual changes in exploitation because the number of licenses, traps per license, and length of season were unchanged. These year-to-year changes could be caused by any of unrepresentative samples, changes in recruitment, or changes in catchability. The years 1998-2001 were transition years when a significant increase in minimum size occurred. As in LFAs 31B and 32, the percentage of catch in the first molt class and median lobster size are correlated, r is near -0.9 for both sexes. The 1998-2001 transition years were excluded from the correlation.

<u>Size Frequency</u>

The effect of the change in minimum legal size can be seen by comparing the percentage size frequency of lobsters in the catches before and after implementation. The first molt class would increase from about 81-93 mm to about 86-98 mm. Therefore, the size interval 94-98 mm would be in the first molt class only after the size increase and should include a larger fraction of the catch because it is in the first rather than second season of fishing. The full 5 mm size increase would be recruited to the fishery by 2001 and transition years would be 1999-2000. Percentage of the catch 94-98 mm CL was 19-23% from 2001-03 and 11-15% from 1992-98 (Table 9).

Table 9. For the port of Canso, percentage of catch represented by the first molt into legal size, percentage of females >124 mm CL, percentage of both sexes 84-98 mm CL, and median size of males and females. Data from port samples.

Year	First molt (%) Male	First molt (%) Female	Female (%) >124 mm	Male & Female (%) 94-98 mm	Median size (mm CL) Male	Median size (mm CL) Female
1988	48	57	6.5	15	94	91
1989	59	68	1.8	16	92	90
1990	56	59	1.9	17	92	92
1991	52	56	2.9	16	93	92
1992	52	56	3.8	14	93	92
1993	54	54	1.9	15	92	92
1994	57	57	4.6	13	92	92
1995	no data					
1996	56	52	4.1	15	92	93
1997	no data					
1998	45	54	6.9	11	99	94
1999	49	43	11.8	14	98	100
2000	68	67	3.3	25	94	94
2001	59	65	5.3	19	96	95
2002	50	53	5.4	23	97	100
2003	65	58	10.1	19	95	95

Effects of the closed window for females should first be evident in the catch size frequency in 2003. Most females in the 114-123 mm window size, first returned in 2001, would be ovigerous in the 2002 season and molt before the 2003 season. There was an abrupt increase to 10% of the females >124 mm CL in 2003 from about 5% the previous several years (Table 9). The one anomalous value of 11.8% in 1999 is unexplained.

Size frequency plots (Fig. 13) show the years with high (2000, 2001, 2003) and low (1999) percentage of catch in the first molt, and the absence or near absence of window females in 2001-2003. The higher percentage of the catch in 93-98 mm in

2001-2003 compared to 1990-1998 reflects molt of the newly protected 81-85 mm sizes. Except for the increase in females in 2003, the fraction of large animals in the catches are variable and temporal patterns are not clear.

We looked at the median size of males and females >100 mm CL, as this size would have included lobsters in their second molt and higher both before and after the increase in minimum size. This statistic is more stable than the percentage of catch >100 CL (Fig. 14). We expected increases by the end of the series because of changes to the minimum size and the addition of the window. From 1998-2003 male median size decreased a little and there was no pattern for females. This result suggests higher exploitation on larger lobsters. Fishermen have reported increasing the entrance sizes in some of their traps to target larger lobsters.

At-sea samples give equivocal evidence of benefits from the window size (Table 10). These samples are available for only 2001, 2002, and 2003, the years the window regulation was in effect. Only samples from ports sampled all three years were included. The increase in total catch in the window size may indicate better compliance with the regulation. The low number of ovigerous in the window size in 2001 is expected because they were removed by the fishery the previous year before becoming ovigerous. However, assuming most window lobsters become ovigerous by the next fishing season, and assuming recruitment to window size is about the same in two successive years, the difference between number of ovigerous and non-ovigerous should only reflect natural mortality. Thus, the proportion of windows which were ovigerous in 2002 and 2003 seems low. The increase in window lobsters was not related to the catch rate of all lobsters >86 mm, which was similar all three years, but was related to the catch of total ovigerous. The correlation of window ovigerous with total ovigerous and the unexpected scarcity of window ovigerous are grounds for suspicion that either the window regulation may not be completely adhered to or ovigerous catchability is much reduced. The large change in total ovigerous is greater than we would expect from ovigerous window (Table 10) plus increased minimum size.

Table 10. Catch per 1000 trap hauls for window lobsters, all sizes of ovigerous and legal lobsters, based on at-sea samples in 2001, 2002, and 2003 from Canso, Dover and Whitehead.

			Number of lobsters per 1000 trap hauls			
Year	Samples	Trap hauls	Total window	Ovigerous window	Total legals	Total ovigerous
2001	6	1400	13.6	2.1	394	29
2002	7	1459	20.5	4.8	371	41
2003	5	1161	43.9	5.2	397	56

Catch rates of ovigerous are very sensitive to sampling time and location, as discussed in the next section.

A shift to larger ovigerous in 2002 and 2003 was not seen. (Fig. 15). A chi-square test shows no difference in size frequency distribution of ovigerous females among the 3-years for LFA 31A (X^2=6.6, 8 d.f.).

Landings and catch per trap haul

The benefit from increasing the minimum size would first be realized in the weight of landings in 2001, the year after the three successive increases. However, in 2001 the added measure of putting back window sized lobsters would have reduced the catch, and in 2002 a second lot of windows were returned while the 2001 group were ovigerous and not yet regained fishable size. Thus, not until 2003 should the full benefit of the increased minimum size appear in landings. Catch per trap haul was higher in both Canso and Whitehead in 2002 and 2003 (Fig. 4) and could reflect this growth benefit. If higher recruitment to the fishery results from the additional eggs produced by the window females and females protected by the larger minimum size, that will not be realized for a few years, assuming the time from hatching to recruitment is 8 years (Wilder 1953). LFA 31A landing doubled from 1997-2001 (Fig. 3), but most of the growth benefit from regulation changes will have occurred subsequently. The long term landings in Guysborough County are still quite low by historical standards (Fig. 2).

Eggs

The increase in eggs within the newly protected 81 to 85 mm CL was small. In seven at-sea samples from 2003, 36 of 190 females 81-85 mm CL were ovigerous. Under the 81 mm CL minimum size about half of these would have been removed in the year before they became ovigerous. Egg production from these 18 ovigerous would have added only 9% to that from the 104 ovigerous females in the sea samples >86 mm. However, the egg/recruit model predicts a greater benefit from the minimum size increase because more 81-85 mm females survive to molt into legal size and more survive the fishery to spawn.

The absolute number of eggs produced by the size increase and window size cannot be calculated, as we did for the put-backs in LFAs 32-31B, because there was no record of the number of window lobsters returned.

Sensitivity of Port and At-Sea Samples

Are the port samples representative of the season's catch? In 1998 four samples were distributed through the season in Canso (Table 11). The frequencies were significantly different in five of the six possible paired comparisons ($P<0.05$, chi-square contingency tables). Only the 5 May-10 June comparison was not different. The proportion of lobsters >124 mm CL increased throughout the season as expected, but the low frequency in the smallest size class in 22 May was unexpected.

Table 11. Size frequency of four port samples taken in Canso in 1998.

CL (mm)	Sample date 5 May	22 May	10 June	23 June
83-88	95	51	68	47
89-94	104	82	61	31
95-100	47	46	33	31
101-106	36	44	31	26
107-112	25	26	22	23
113-118	15	20	14	23
119-124	10	16	11	18
>124	17	14	29	34
Totals	349	299	269	233

Sex ratios in port samples (Tables 6 and 8) were inconsistent from year to year. Out of 44 port-years, ratios were not significantly different in 25, males were greater in 14, and females were greater in 5 (Table 12). The variation was greatest in Canso. At least two port samples were taken in each port each year.

Table. 12. Chi-square tests of sex ratios in port samples from Clam Bay, Halifax County East, Port Bickerton, and Canso. At least two samples were taken each year.

Port	No. port-years P>0.05	No. port-years P<0.05 Males greater	Females greater
Clam Bay	9	4	0
Hfx. Co. E.	3	2	0
P. Bickerton	7	4	1
Canso	6	4	4
Totals	25	14	5

The port samples didn't represent the increase in density of large females from the put-backs in LFAs 32 and 31B. Annual changes in percentage in the first molt are somewhat erratic, often more than 10% between successive years. For LFA 31A, the change in minimum size was reflected in median size of the catch and in the 94-98 mm size class.

At-sea samples were very sensitive to date of collection. The means of ovigerous per 100 trap hauls were compared for individual fisherman for the first and last 10 days of the season for 2-years in each of three ports (Table 13). All six comparisons were significantly different at P<0.05 (t tests, unequal variance). For undersized catches two of the six mean comparisons were significant (Table 13). The standard deviations for the full season for both treatments shows large variation as do the plots of daily values for 2002 (Table 13 (Fig. 16).

Table 13. Means and standard deviations for catch of ovigerous and undersize lobsters per 100 trap hauls for one fisherman in each of LFA's 31A,31B, and 32.

		LFA 31A		LFA 31 B		LFA 32	
		Canso		Tor Bay		Clam Bay	
Ovigerous		**2002**	**2003**	**2002**	**2003**	**2002**	**2003**
first 10 days	mean	1.77	2.4	1.94	1.26	0.37	0.36
last 10 days	mean	8.30	14.5	7.28	5.53	2.29	5.40
full season	mean	5.46	7.4	3.88	3.12	1.07	1.80
	S	3.27	5.3	2.60	2.60	0.93	2.73
Undersize							
first 10 days	mean	5.51	79.4	14.69	30.18	22.98	14.32
last 10 days	mean	11.91	94.0	21.29	64.35	26.65	38.70
full season	mean	8.91	90.2	15.80	46.60	23.30	24.05
	S	4.81	21.2	6.97	19.96	6.42	13.76

DISCUSSION / SUMMARY

Benefits from regulation changes

The only measure of the benefit of 1.5 mm minimum size increase in LFAs 32 and 31B is from the egg/recruit model, 12% and 7% respectively (Table 14). The model prediction for put-backs in LFA 32 is 11%, assuming 50% loss of benefits from egg resorption and mortality. Because the quality of lobster selected for put-back has increased (Nellie Baker-Stevens, pers. comm.), and the evidence that lobsters which don't spawn in the summer following put-back will spawn the next summer, this assumption is now probably too high. There is an additional benefit afforded by v-notch protection that was not quantified using the model.

Fishermen's records, from several sources, of ovigerous females with and without v-notches indicate put-backs are contributing 22% and 14% of total egg production in 32 and 31B respectively. A second method of calculation using the same data gave 25% and 13% respectively. If tail notches are visible through two molts and tail-notched females are not landed these percents should increase through 2005.

Records of ovigerous females in volunteer logs showed an increase in Clam Bay but not in Halifax County E. or Torbay. It is too soon to see increases in large females in catch sampling.

In LFA 31A the egg/recruit model predicted 34% more eggs from the 5mm size increase and 20% more from the window measure (Table 15).

Catch sampling in port showed expected increases in 94-98 mm and >124 mm from the minimum size increase and from protection of window size, but not from overall median size.

At-sea samples showed that the fraction of window lobsters that are ovigerous is much lower than expected; the number of ovigerous females in the newly protected 81-85 mm size added 9% to egg production; and there was no increase in total ovigerous. Tag-recapture studies provided total egg production from window size (Miller and Boudreau 2004).

Table 14. For LFAs 32 and 31B, summary of observed benefits to egg production from regulation changes and uncertainties in results.

Method	Measurements	Results: LFA 32	Results: LFA 31B	Uncertainties
Idoine-Rago model, assuming 50% egg resorption	predicted percent change in egg/recruit compared to 1997	12% for 1.5 mm size increase, 11% for put-backs + v-notch protection	7% for 1.5 mm, <11% for put-back + v-notch protection	model inputs (F, M, growth), year-to-year change in F, egg resorption and mortality of put- backs, eggs resulting from v-notch protection
portion of ovigerous females v-notched, fishermen's records	percent increase in egg production in current year compared to no put-back	22%	14%	correct reporting of number ovigerous and number notched
2nd method of calculating above ratio	same as above	25%	13%	same as above
median size, port samples	expected to increase with size increase	no change for Clam Bay or Halifax Co. E.	no change for Port Bickerton	catch sampling in ports is representative of stock size distribution
time series of ovigerous females in volunteer logs	expected to increase with put-backs	Clam Bay - benefit Halifax Co. E. - no change	Torbay - no change	catchability of ovigerous females same year-to year, ovigerous females reported correctly, enough fishermen's records
landings, legal & pre-recruit catch per trap haul	higher recruitment from higher egg per recruit	too soon	too soon	landings are at least an index of actual landings, CPUE sample size adequate

Table 15. For LFA 31A, summary of benefits from regulation changes and uncertainties in results.

Method	Measurements	Results	Uncertainties
Idoine-Rago model	predicted percent change in egg/recruit compared to 1997	34% more eggs/recruit from 5 mm size increase, 20% from window	model inputs (F, M, growth), change in F year-to-year, regulations are observed
time series of percent catch 94-98 mm, port samples	more 94-98 mm lobsters from 5 mm size increase	benefit shown	port samples represent stock size distribution
time series of percent female >124 mm CL, port samples	increased number of females having passed through window size	benefit shown	port samples represent stock size distribution
time series of number of all window & ovigerous window lobsters, at-sea samples	increased numbers from window protection	equivocal	year-to-year consistency in time and location of at-sea samples, fishermen are returning window lobsters
ovigerous females 81-85 mm, at-sea samples	increased egg production in 5 mm size range	9% more eggs	at-sea samples are representative of stock
time series of all ovigerous, sea samples	increased number due to size increase and window	no changes	year-to-year consistency in time and at-location of at-sea samples, fishermen are returning window and short lobsters
median size, port samples	from size increase and window protection	probable benefit size distribution	catch sampling representative of stock
landings, legal, and pre-recruit catch per trap haul	from higher yield per recruit and recruitment	possible benefit from yield per recruit	landings are correct sample size of catch per trap haul adequate

To summarize, regulation changes appear to be contributing about 35% and 20% to the existing total egg production in LFAs 32 and 31B respectively. Calculation of the benefit of put-backs was based on fraction of the ovigerous that were tail-notched. In 31A the egg/recruit model predicted, at population equilibrium, eggs/recruit will be 54% higher than before 1998. Note that neither method measures year-to-year changes in total egg production. Changes in fishing effort or recruitment to legal size can affect total egg production independent of regulation changes. Tagging studies, as described in Miller and Boudreau (2004), have the potential of measuring total population egg production and documenting net year-to-year changes arising from any source.

Many fishermen expect to see increases in fishery recruits and landings one lobster life cycle (6-9 years) after regulation changes were introduced. This is unlikely. A common method of identifying stock-recruitment relations in finfish fisheries is to regress fishery recruits on spawning stock biomass using many annual measurements of both variables, with the appropriate time lag. The best data sets show, on average, lower recruitment at low spawning stock biomass. However, their remains a very large scatter of points around the regression line such that any particular spawning stock size is a poor predictor of fishery recruitment (Payne and Bannister 2003). In a similar treatment Fogarty and Idoine (1986) regressed a 14-year series of lobster stage IV larval production against legal stock size and Ennis and Fogarty (1997) regressed and 12-year series of lobster egg production against fishery recruits. Significant regressions were produced by forcing the line through the origin, however of only the data points were used neither regression was near statistical significance. Minimum size was increased 6.5 mm in western Cape Breton (LFA 26B) from 1987-1990. From 1990 to 1997 landings decreased by 16%. However, they declined by 45% and 60% in the adjoining areas of LFAs 26A and 27.

Stock Indicators

We sampled lobster stocks three ways. Size frequencies of catch landed in port was usually sampled twice per season, early and late. Select fishermen provided volunteer logs of their daily catch, number of trap hauls, and in some cases, number of ovigerous females and pre-recruits caught. When we could afford it, we sampled at-sea by accompanying fishermen during their fishing operations.

Recently we have initiated tag-recapture studies to estimate the number of windows and ovigerous females, juvenile surveys, and larval surveys (Miller and Boudreau 2004). Finally, annual landings are the measure of most interest to the fishing industry. These data sources are discussed.

Port samples provided exploitation rate and weight of catch affected by regulations that change minimum, maximum, and window sizes. In this report we have looked for year-to–year changes in size frequency. From Table 7 and Figures 5, 6, 7, 11, and 12 we could see few if any annual trends in size frequency for LFAs 32 and 31B. We were a little more successful for LFA 31A, but only because of the recent large changes affecting minimum size and the window exclusion. The large year-to-year variation in percentage in the first molt, median size, sex ratios, and percentage of large sizes, suggest our frequencies are too imprecise or inaccurate for these purposes. Possible causes are size sorting of the catch before we measure it, variation in size-specific catchability, and segregation of sizes on the fishing ground.

An alternate approach for these data is to sample each port only every several years, sample more than twice in a season, and use the data for the more static measures mentioned above rather than for temporal trends.

Logs provided DFO by fishermen are an inexpensive source of total catch per trap haul, ovigerous and pre-recruit catch per trap haul, and catch rate throughout a season. The total catch per trap haul reflects landings trends and spatial trends appear consistent among fishermen. The variation among fishermen in one year can be considerable, however (Table 4). Tremblay et. al (1992) and Koeller (1999) provide information of the number of logs needed to resolve temporal and spatial trends.

From at-sea samples we measure stock components that must be returned to the water on the fishing grounds, ovigerous and window females, pre-recruits (shorts), and tail notched. These are expensive samples requiring a dedicated person on board for a full day plus travel costs. At-sea samples share with port samples the problem of spatial and temporal variation in catches. The large within season variation seen in daily records of volunteer logs (Table 13, Fig. 16) show that one-day, one-fisherman at-sea samples may not be representative of annual trends in catch rates of any catch component. Pringle et al. (1993) has also presented seasonal variation from volunteer logs. At-sea samples may be best suited for specific questions such as sizes of ovigerous females (Figs. 8 and 15) used for calculating egg contribution from put-backs (Table 3), egg production from 81-85 mm ovigerous in LFA 31A, or location of ovigerous females (Miller and Boudreau 2004).

Annual landings are a convenient report card for the success of management, however, we have reasons to doubt their accuracy. In a 1994 survey Stephen Nolan (DFO lobster technician) found that catch was under-reported by 15% and 18% in LFAs 31 and 32 respectively (DFO 1998). During a few years in the late 1990s Alan Reeves (DFO lobster technician) found that 20-25% of license holders in LFA 27 reported no landings, whereas following a threat of withholding fishing privileges the non-reporting dropped to 6% and 5% in 2001 and 2002. Regardless of the reporting method, fishermen will choose whether or not to report accurately. Unless verified by independent checks, landings should not be used as a sensitive stock indicator.

Logs fishermen provide to their representative organizations (GCIFA, ESFPA, and FSRS) have also proven valuable. In 32 and 31B the percent of ovigerous that are tail-notched is a conservative measure of the percentage of total ovigerous resulting from put-backs (Table 3). Recapture rate and spawning frequency (Table 2) of tail-notched lobsters are also available. Although not presented here, catch rates of pre-recruits are collected by FSRS. The quality of data reporting in mandatory logs is inconsistent and separating the correct from incorrect records can be difficult. Data quality could be improved if only motivated volunteers kept records and received training.

Tag-recapture studies can estimate actual abundance, rather than relative abundance or percent change, of any stock component fishermen return to the fishing ground. Some of the many inputs to the egg/recruit model are based on poor data and the prediction of eggs/recruit cannot be verified. Annual changes in recruitment and exploitation are not included in egg/recruit predictions or in the percent addition of ovigerous from tail notching. Annual changes in catch rates of ovigerous would be an index of absolute abundance, but this measure is very sensitive to catchability. Tag-recapture studies have a set of assumptions that must be dealt with, however. Actual numbers of window, ovigerous, or tail-notched lobsters and their egg production should be meaningful to fishermen, fishery managers, and scientists alike. Fishermen's involvement is positive in that they assume a large role in the assessment process, but problematic in that at least several participants are required per port and they must accept the discipline of complete and accurate data collection.

Larval and juvenile surveys provide indices rather than absolute abundance, but if consistently done, may fore-warn stakeholders of changes to fishery recruits resulting from changes in the environment or fishing effort. These surveys may also measure stock response to changes in fishery management. Fewer fishermen are required for these studies than for tagging, but data collection is more expensive because surveys described here are carried out outside the fishing season, and training and specialized equipment are required. However, the Fishery and Scientist Research Society conducts juvenile trapping in-season at lower cost (Claytor and Allard 2004)

We have used several indicators of stock health here and previously: catch per trap haul, eggs per recruit as a percentage of unfished level, exploitation rate, minimum legal size versus size at maturity, ovigerous or pre-recruits per trap haul, and landings. Caddy (2001) recommended indicators based on comparing number of fishery recruits to a long-term average, sex ratio of large lobsters, percent of total egg production produced by first-time spawners, and change to the area of fishing grounds.

In summary, port samples and at-sea samples may not be useful for tracking year-to-year changes, and are best used for occasional location–specific static measurements. Any number of fishermen's log books are useful, but to track annual changes in catch per trap haul or catch rates of ovigerous females variance among fishermen's records and sample size should be taken into consideration. DFO landings are known to be inaccurate, inconsistently inaccurate, and one or more years behind in reporting. Because all put-backs in 31B and 32 are notched, the percentage increase in eggs from put-backs can be calculated. The tag-recapture method of measuring absolute abundance of stock components returned on the fishing grounds is a potentially powerful tool for measuring stock status. However, we need more experience to decide whether the assumptions of tag-recapture studies are met. The off-season larval and juvenile surveys are also potentially useful for discovering impacts of environmental, fishing effort, and regulation changes years before year classes recruit to the fishery. A few years of data will be required to decide whether they fulfill expectations. Fishermen are involved in all of the above data collection except port samples.

Stock Status

Recent increases in catches looks favorable for the near future. Catch per trap haul of legal sizes was up at least 70% in all five sampling ports since 1997. Catch per trap haul of pre-recruits was up more than 50% from 2002 to 2003 in Canso, eastern LFA 31B and eastern LFA 32, and were unchanged in western LFA 32. Pre-recruits are higher in all ports compared to the mid-1990s. From 1997 to 2001 landings doubled in LFAs 31 A and B and rose 70% in LFA 32.

Although these and other stock indicators discussed in this report are measurable, the more difficult problems of choosing a fishery performance target and the level of indicator(s) that will achieve that target remains. Recently, Miller (2003) argued for a be-all-you-can-be performance target. Under this approach stakeholders continually adjust, on a trial and error basis, the management regime. Next, the impacts of adjustments are measured as early as practical as change in ovigerous females, egg production, larval production, or juveniles. This approach requires uncharacteristic flexibility from fishermen and DFO. It also requires aggressively confronting the complaint, Why do we have to change if another LFA doesn't change? Changes are for the benefit of those who make them; what others do to help themselves, or not, is irrelevant!

Potential for improving Halifax and Guysborough County catches can be taken from long term landings (Fig. 2). Lobster sizes in catches indicated that fishing up of the virgin stock was largely complete by mid 1890s while landings were still several times higher than now (Robinson 1979). If the habitat has not been degraded since that time the stock is now far under carrying capacity.

The same level of a stock indicator will probably not provide the same stock performance on different fishing grounds, e.g. 5% of the unfished egg/recruit in Canada (FRCC 1995), or 10% in the U.S. (NEFMC 1991). In 13 fishing areas of the Canadian Maritimes eggs/recruit and landings (in tons/km of shore and tons/km^2 of fishing ground) were negatively correlated (Fig. 17) (Miller et al. submitted). In this case, a uniform value of eggs/recruit is inappropriate.

To summarize, fishery performance in LFAs 31 and 32 can be better. It is recommended that stakeholders experiment with changes to make it better and measure affected life history stages to see if the changes are working.

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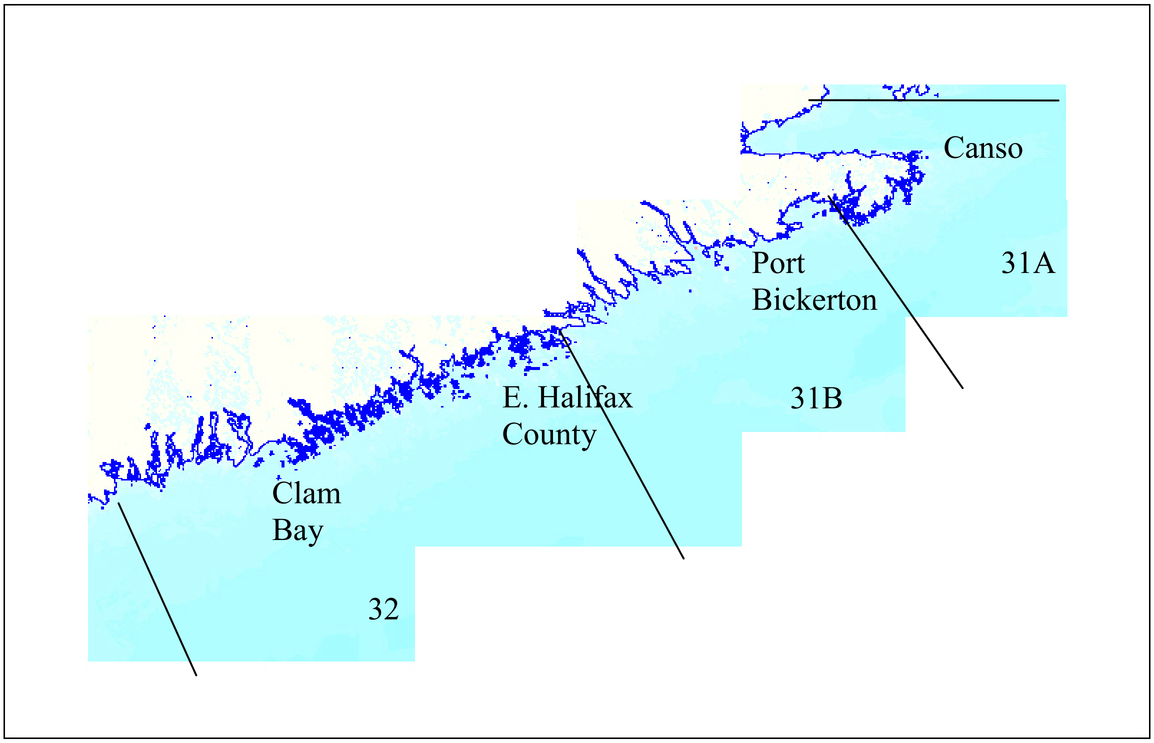


Fig. 1. Lobster fishing areas and principal sampling ports.

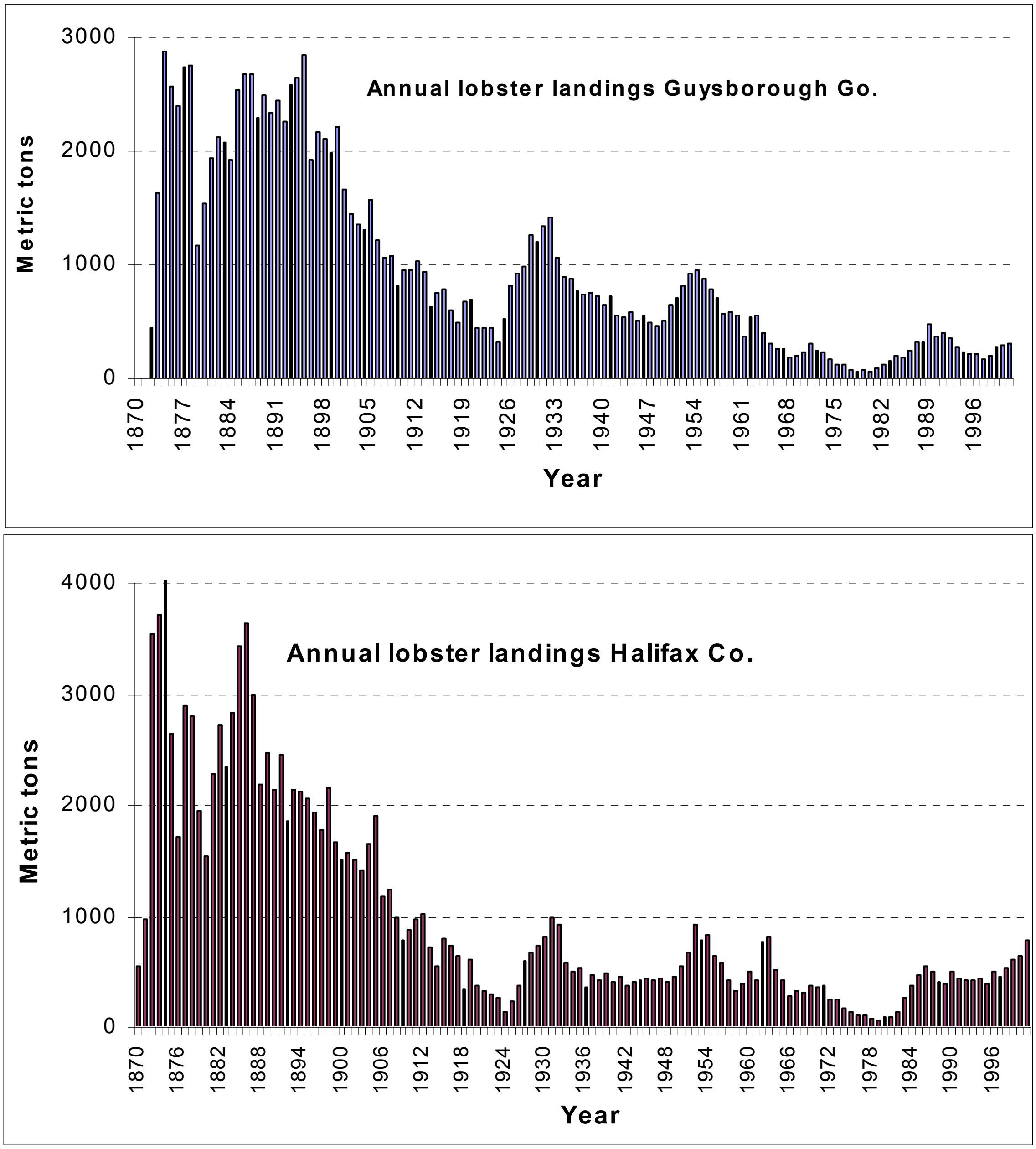


Fig. 2. Annual lobster landings from Guysborough and Halifax Counties, 1870-2001.

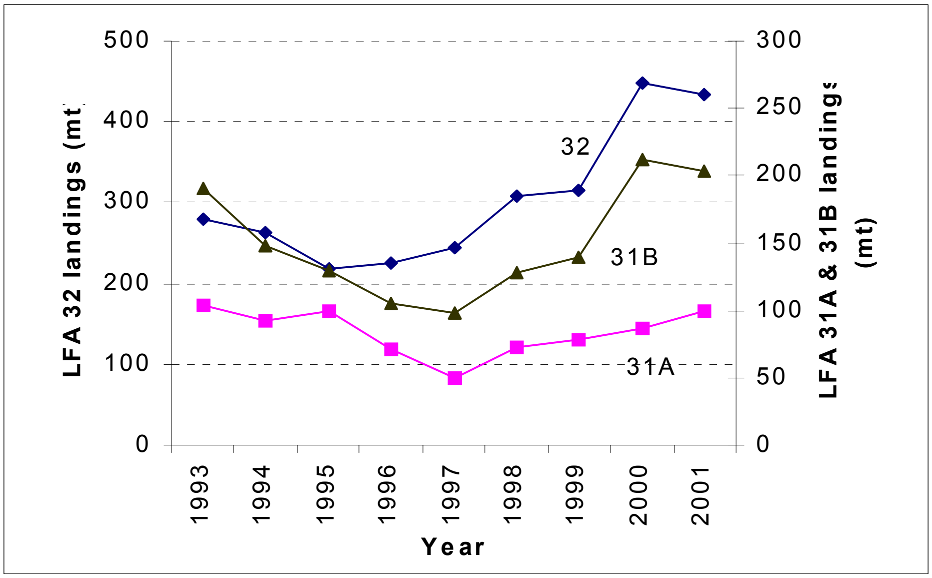


Fig. 3 Recent lobster landings in LFAs 32, 31B and 31A.

Fig. 4. Mean annual catch per trap haul (kg) from volunteer logs.

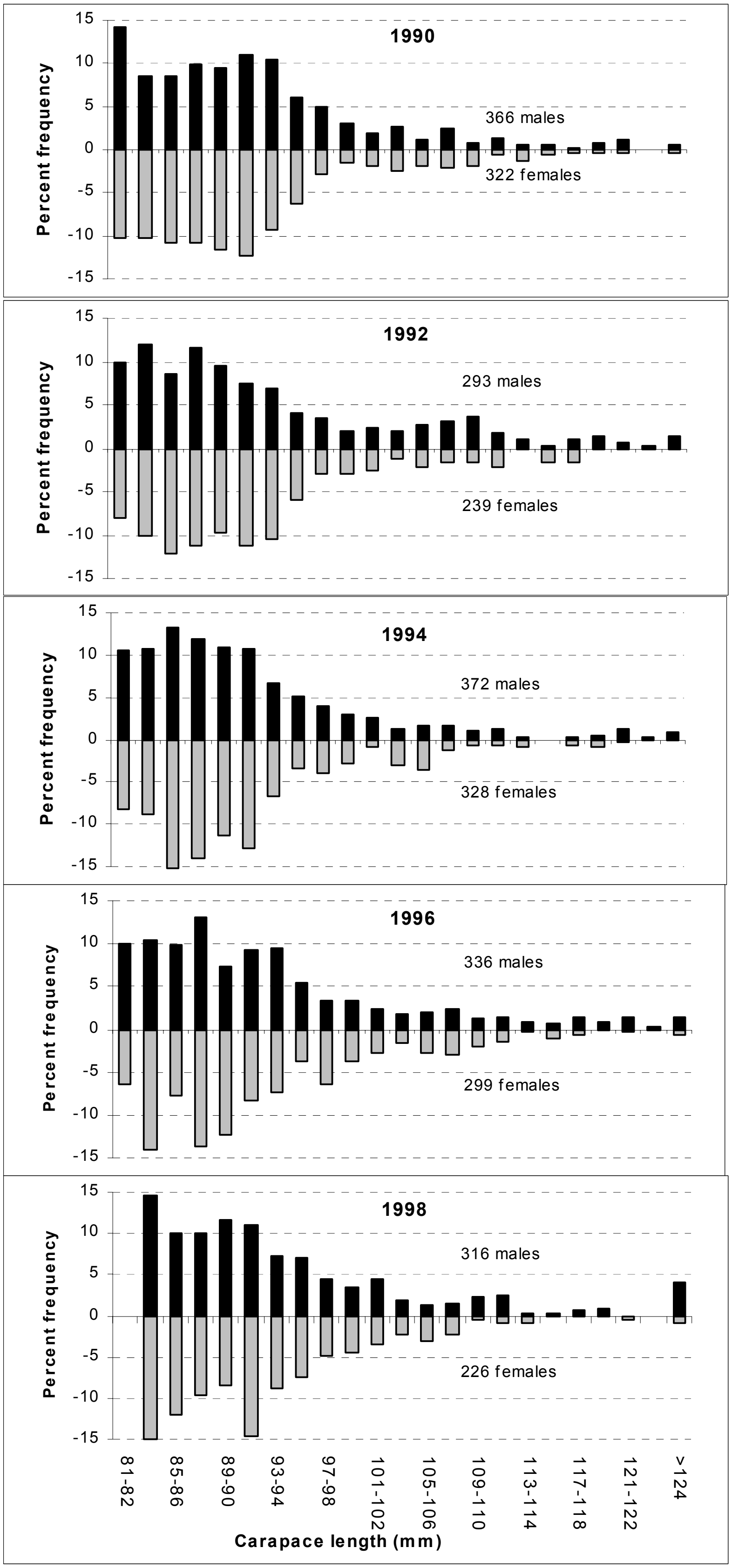


Fig. 5 a. Size frequencies from port samples in Clam Bay, LFA 32.

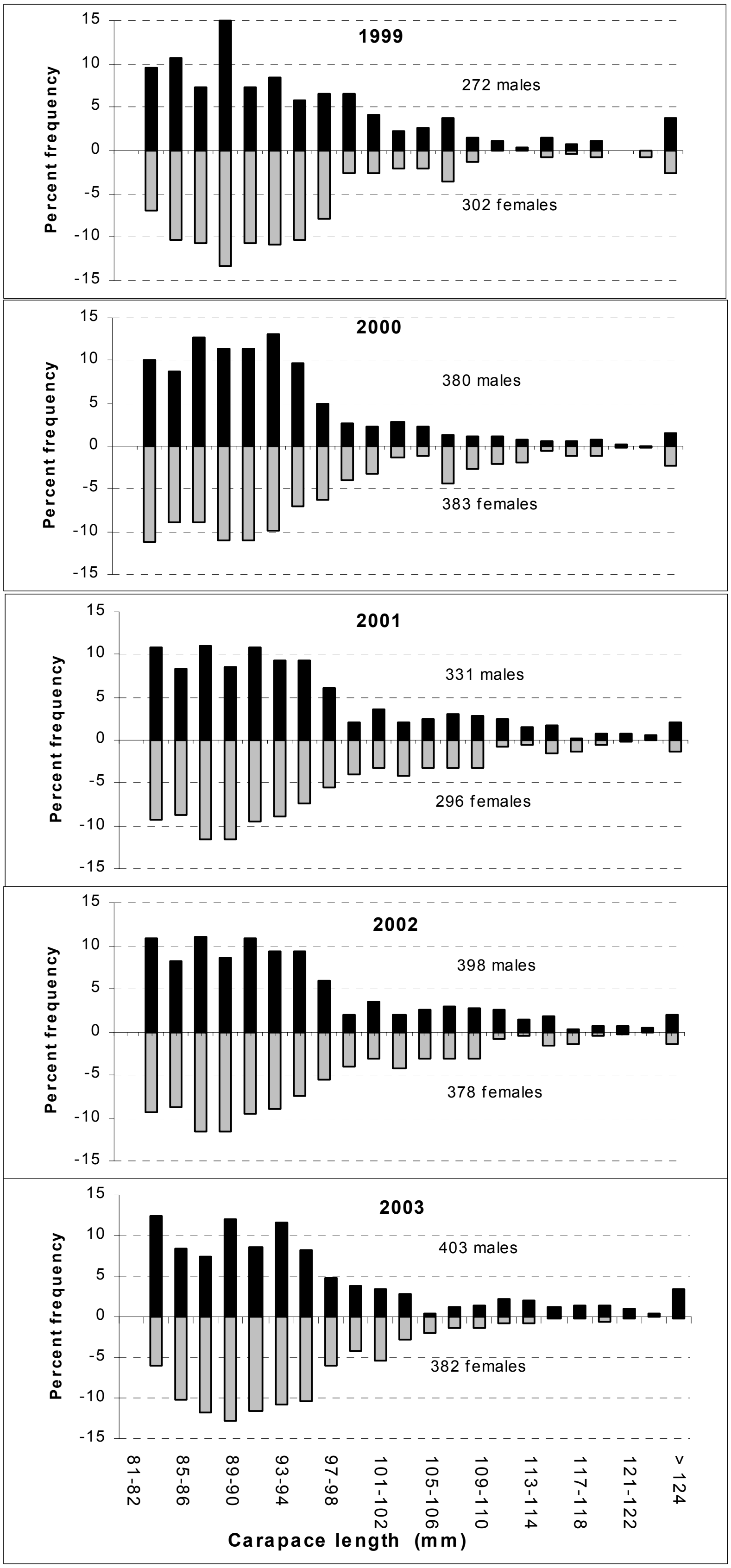


Fig. 5b. Size frequencies from port samples in Clam Bay, LFA 32.

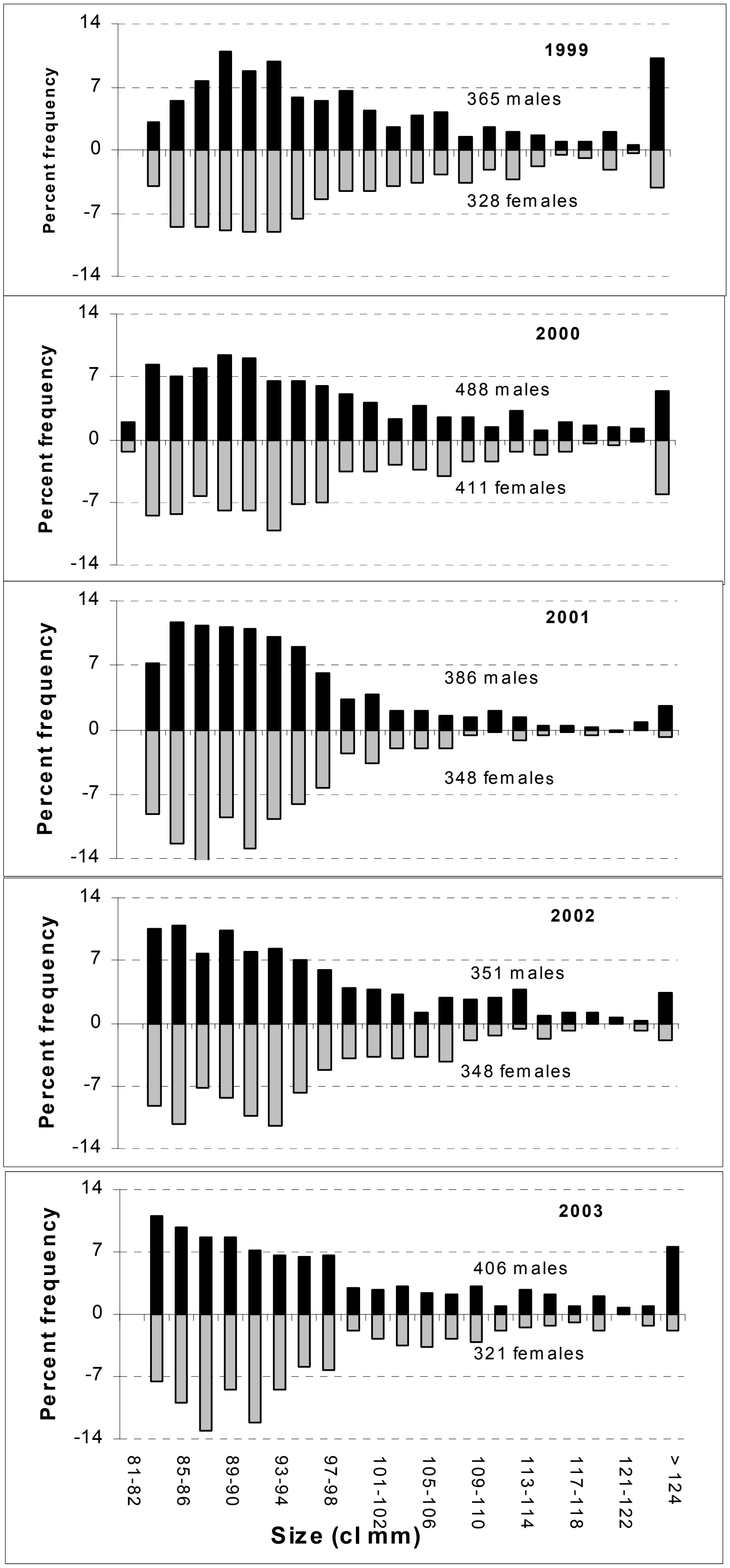


Fig. 6. Size frequencies from port samples in E. Halifax Co., LFA 32.

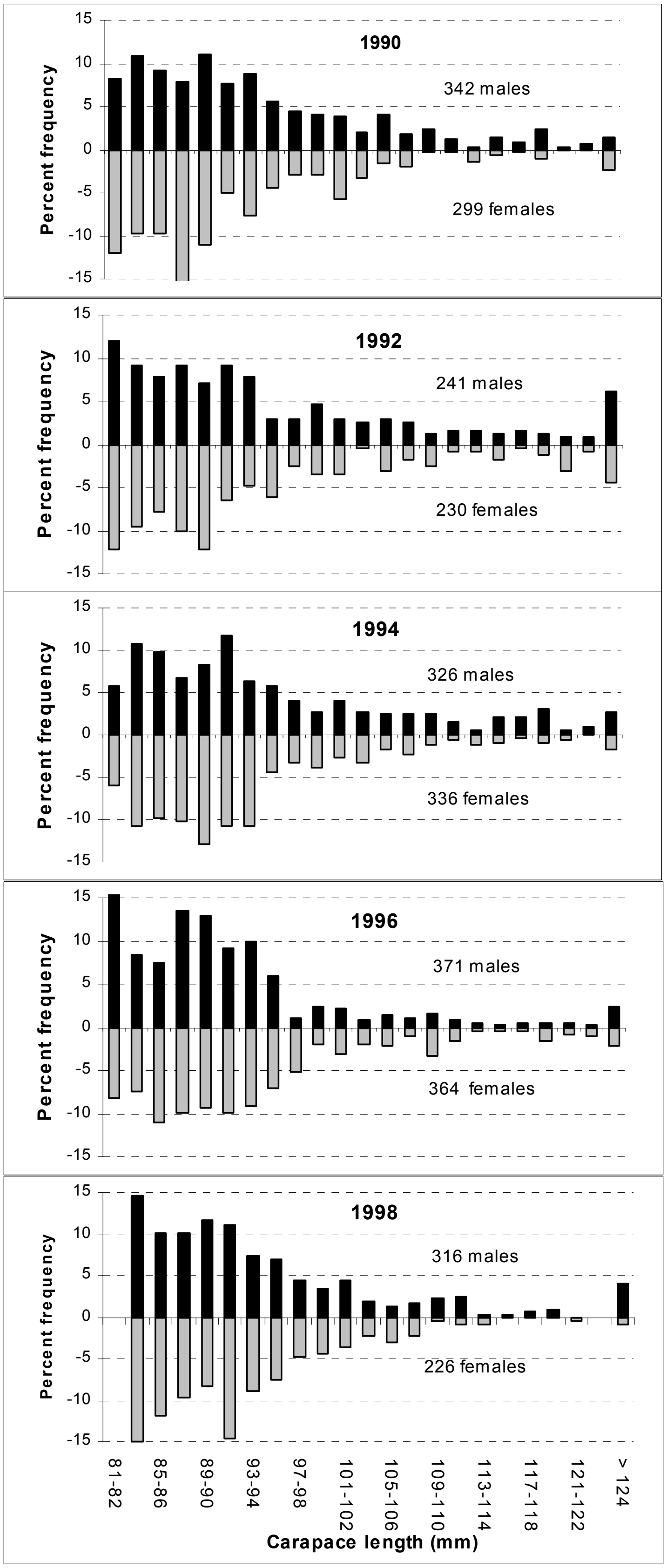
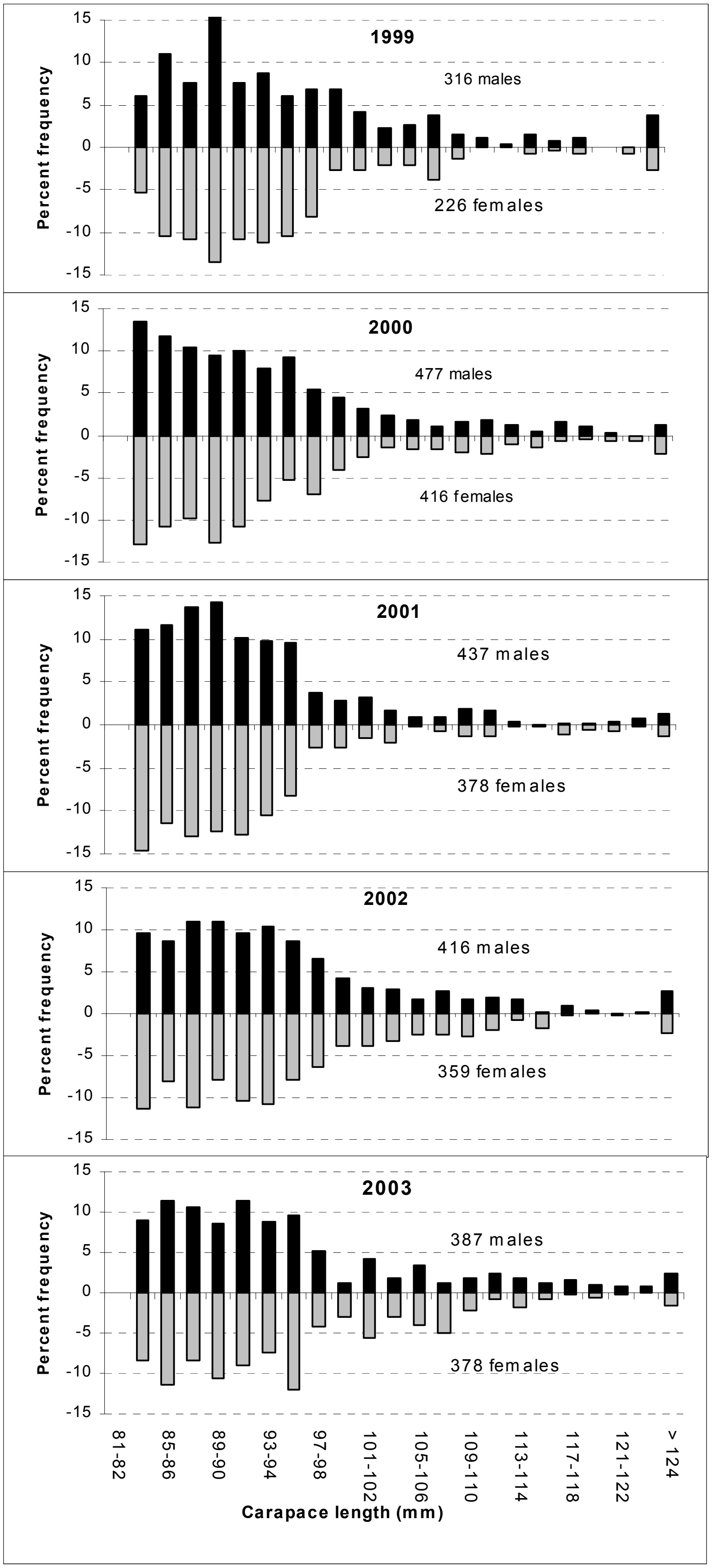


Fig. 7 a. Size frequencies from port samples in Port Bickerton, LFA 31B.



7 b. Size frequencies from port samples in Port Bickerton, LFA 31B.

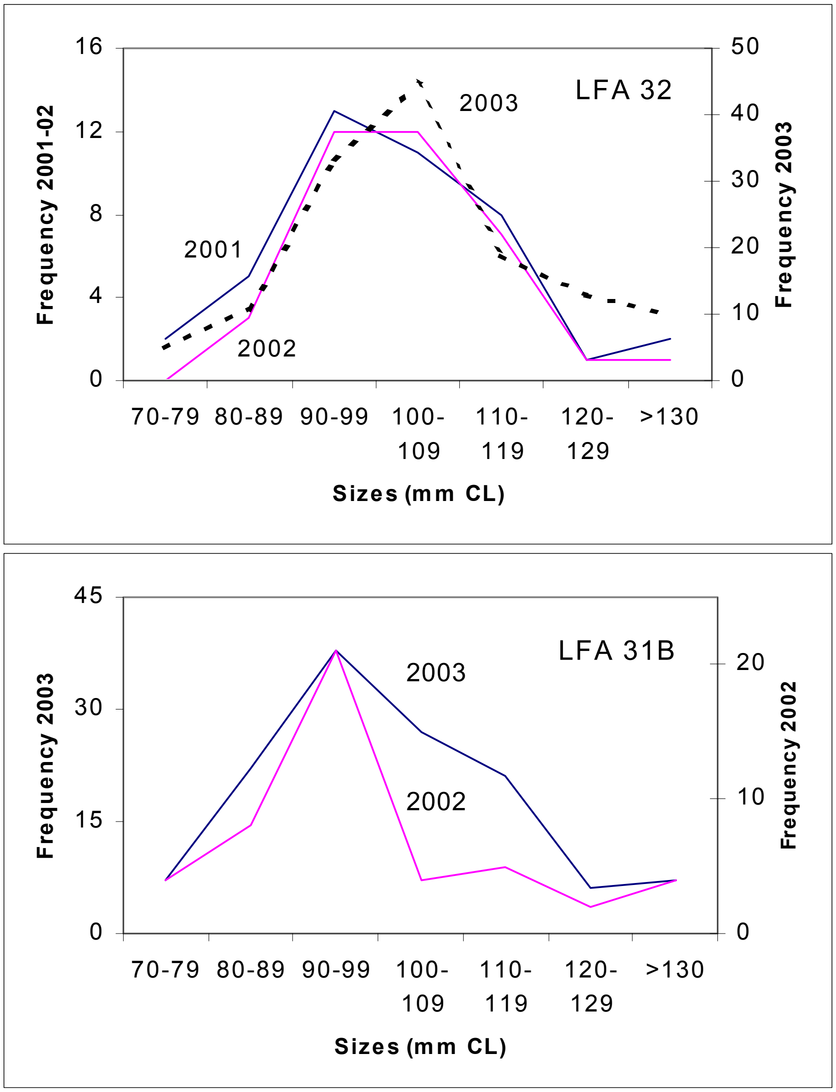


Fig. 8. Size distribution of ovigerous females from at-sea samples, LFAs 32 and 31B.

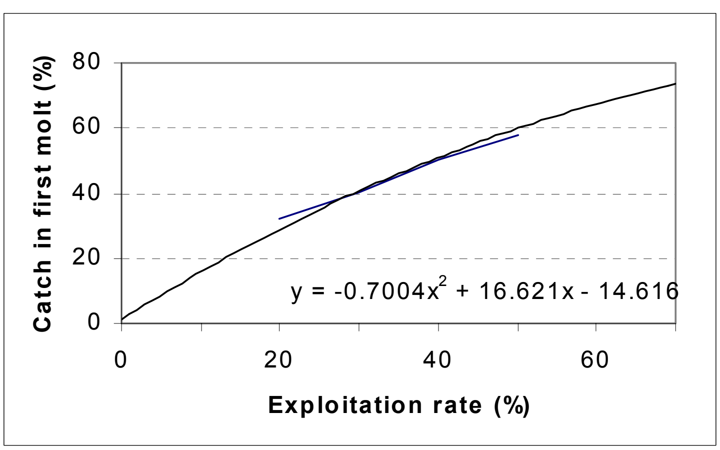


Fig. 9. Relationship between catch a first molt and exploitation rate.

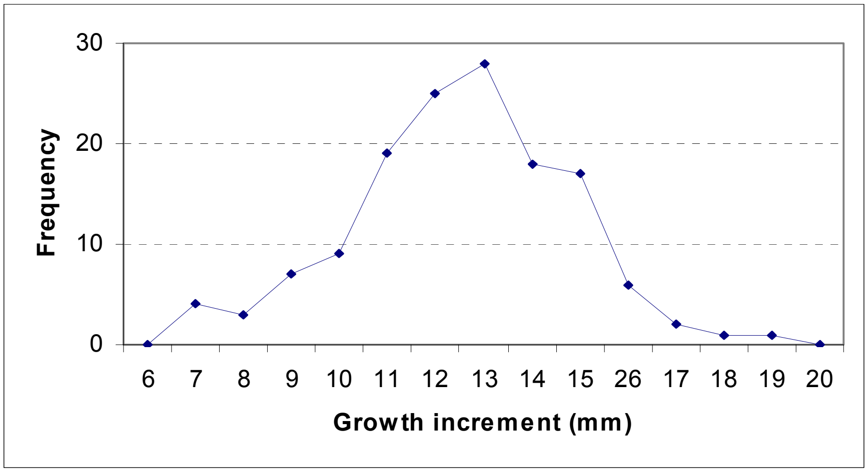


Fig. 10. Growth increments for female lobsters from
Shad Bay and Jeddore.

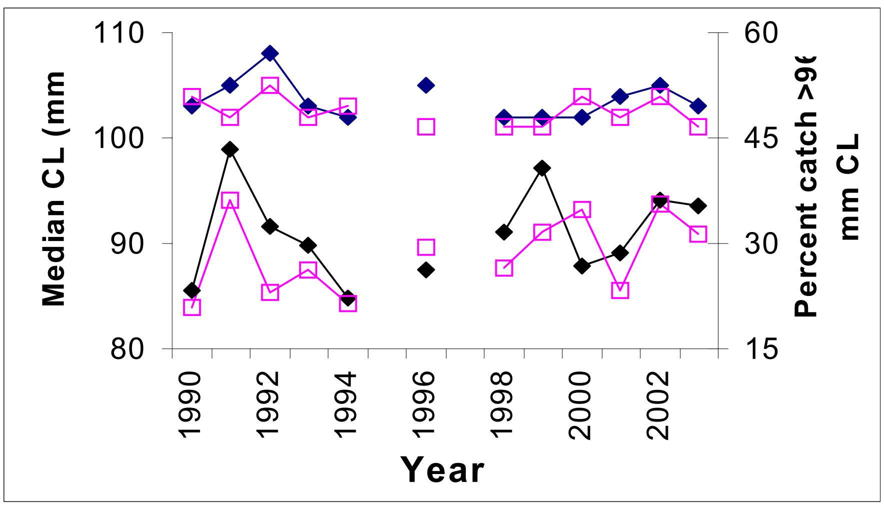


Fig. 11. Clam Bay: median carapace length among lobsters >96 mm CL (top lines). Percent of catch >96 mm CL (bottom lines). Diamond symbols males, square symbols females.

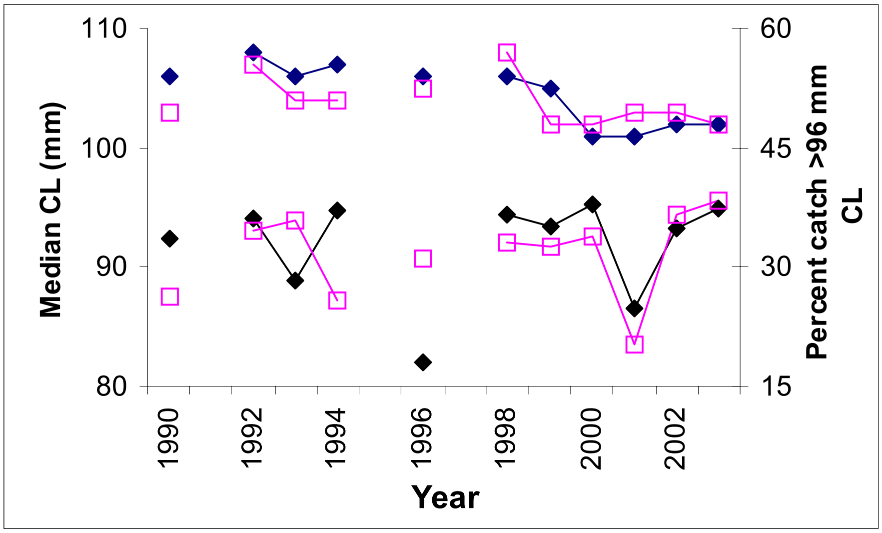


Fig. 12. Port Bickerton: median carapace length among lobsters >96 mm CL (top lines). Percent of catch >96 mm CL (bottom lines). Diamond symblols males, square symbols females.

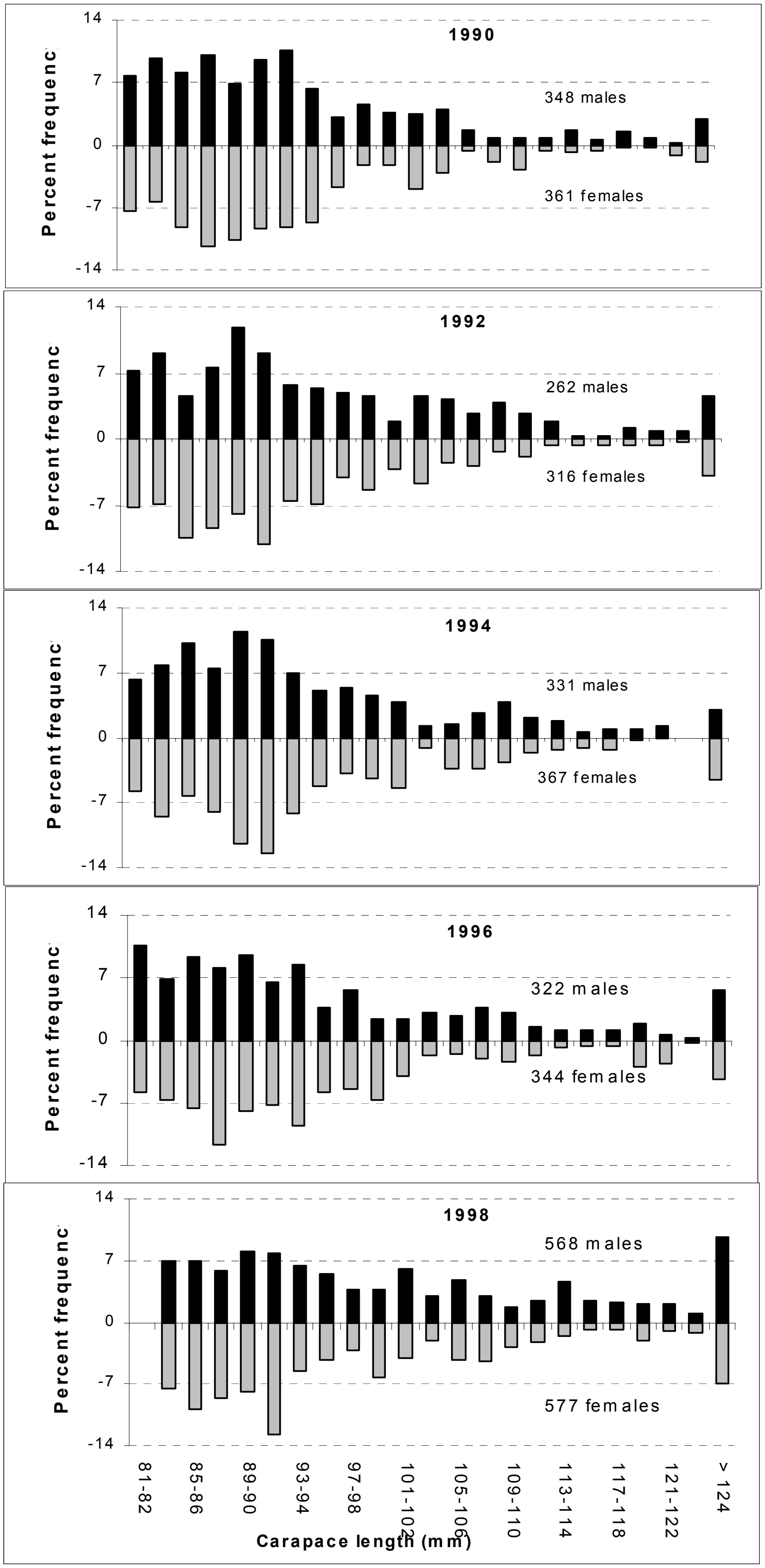


Fig. 13 a. Size frequencies from port samples in Canso, LFA 31A.

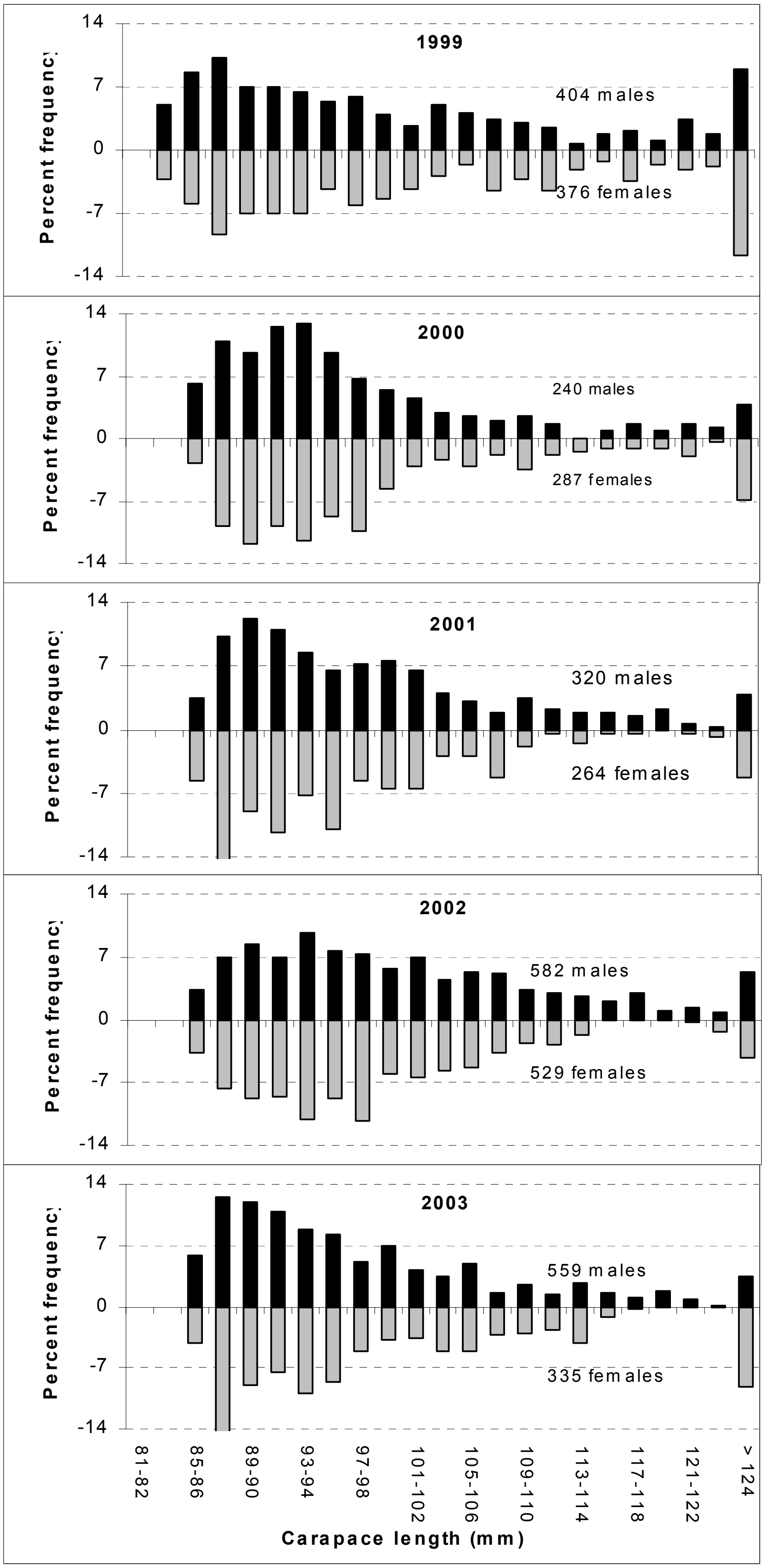


Fig. 13 b. Size frequencies from port samples in Canso, LFA 31A.

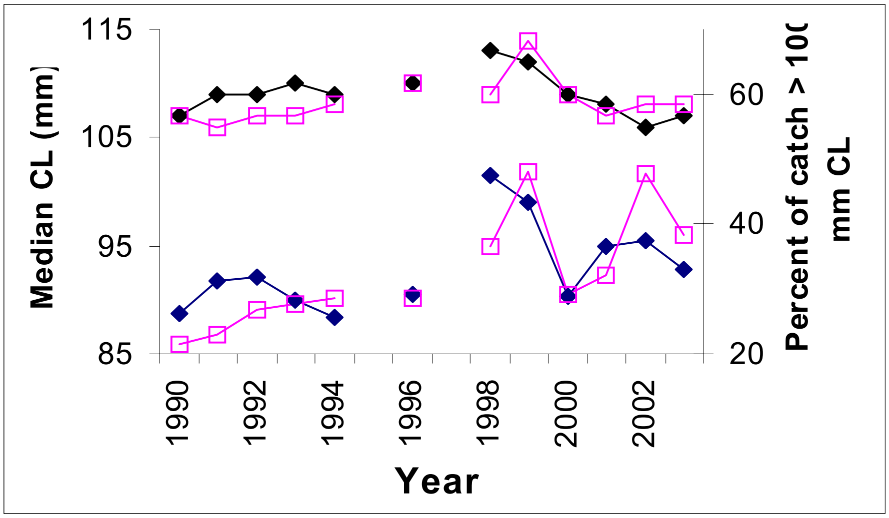


Fig. 14. Canso: median carapace length among lobsters >100 mm CL (top lines). Percentage of catch >100 mm CL (bottom lines). Daimond symbols males, square symbols females. Data from port samples.

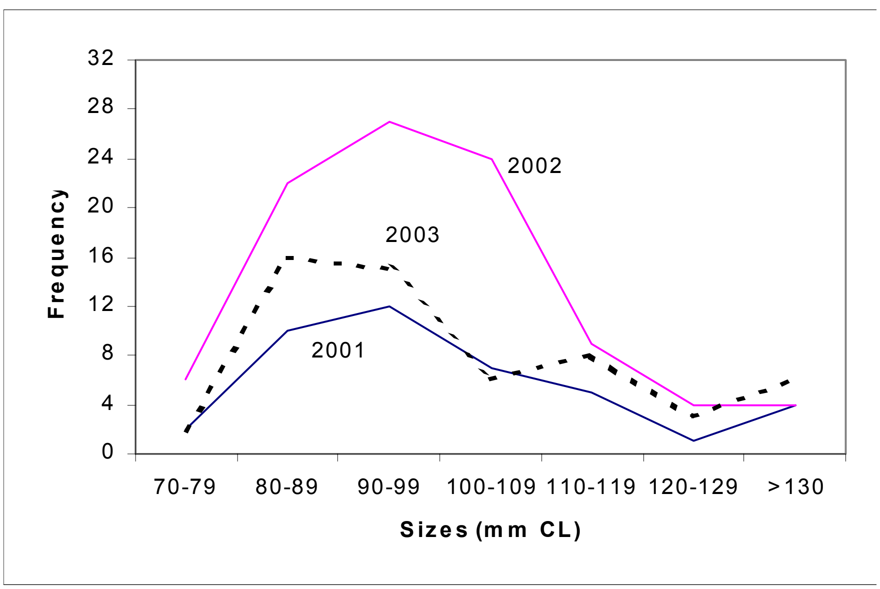
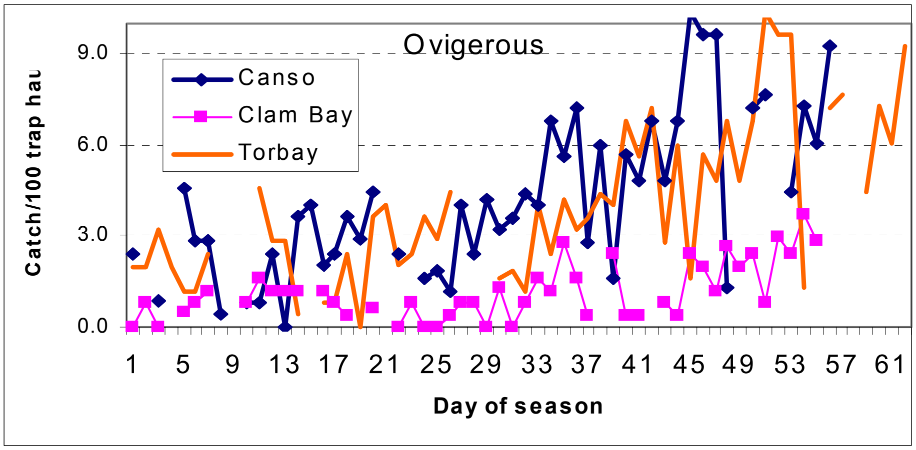


Fig. 15. Size distribution of ovigerous females from at-sea samples, LFA 31A.



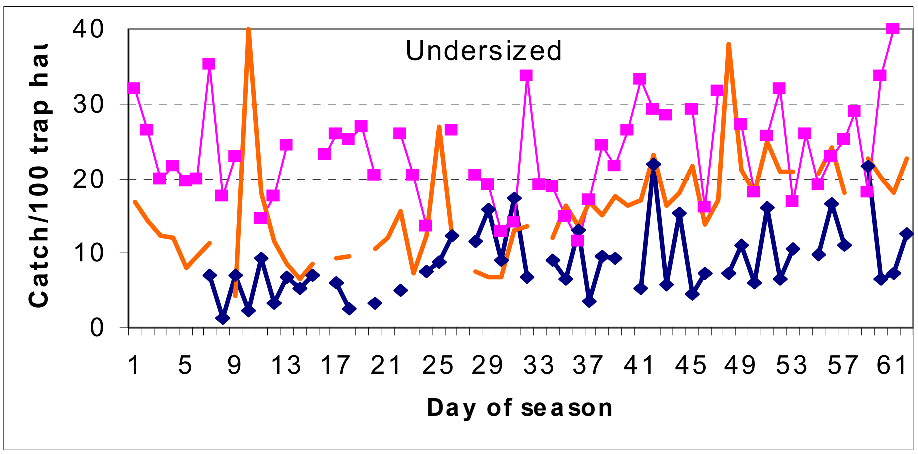


Fig. 16. Catch of ovigerous and undersized lobsters per 100 trap hauls each day of the season by three fishermen in 2002

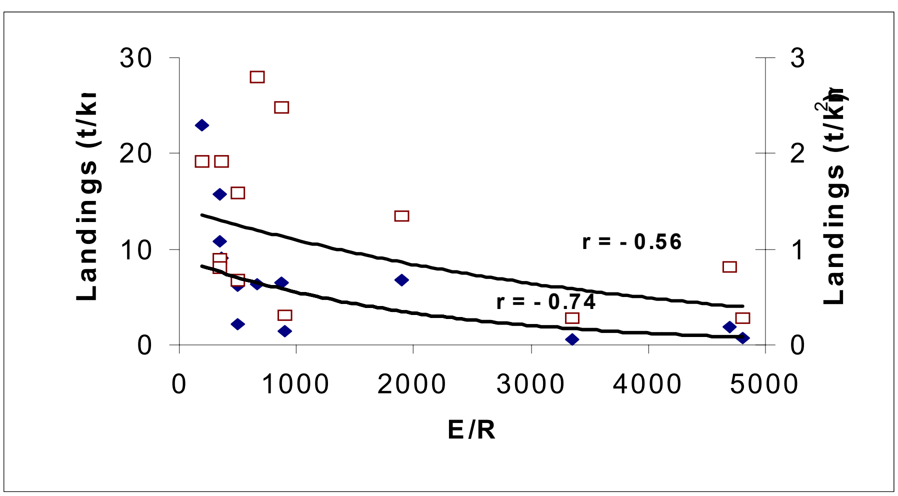


Fig. 17. 4. Landings (open squares for t/km^2 of fishing ground and solid diamonds for t/km of shore), averaged over the years 1994-97, versus eggs per recruit for 13 fishing areas in the Canadian Maritimes.