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Fleming Survey of Demersal Juvenile Cod in Coastal Areas of Eastern Newfoundland

David C. Schneider, Peter Hennebury, David Methven, Danny Ings, and David Pinsent
Ocean Sciences Centre, Memorial University of Newfoundland
St. John's Newfoundland, Canada A1B 3X7

Abstract

The primary objective during the 1995 study of Fleming survey area was to test for any possible enhanced density of first year demersal juvenile cod resulting from a well documented spawning aggregation in Smith Sound area in April and May of 1995. Enhanced density of juveniles settling to the bottom in suitable coastal habitat was expected about 3–4 months later, in August and September. The second objective was to compare the abundance of identifiable length groups corresponding to ages 0+ 1+ and 2+ cod to the abundance of the same length groups in previous years. The survey revisited sites sampled in 1959–64 and 1992–94. The density of first year (0+) demersal juvenile cod (length group 0) did not exceed the average for 1992–94 for the entire survey area (St. Mary's Bay north to Notre Dame Bay). Within this area the density of length group 0 in Trinity and Conception Bay did not exceed that in previous years. The density of second year (1+) juveniles was expected to be higher in 1995 than 1994, based on higher density of the 0-group in 1994 than in 1993. Instead, the numbers of length group 1 fish were the lowest in the 10 year record of comparable counts. Third year (2+) juveniles were expected to be more abundant in 1995 than 1994, again based on strength of that cohort in previous years. Contrary to expectation the density of length group 2 fish was lower in 1995 than 1994. The expected density calculated from cohort strength the prior year assumed no change in performance of gear, and no greater shift of juvenile length group 1 cod into deep water than in previous years. Potential sources of mortality include incidental catch, predation by seals or large cod moving into shallow water.

Key words: cod, cohort strength, demersal, *Gadus morhua*, inshore, juvenile abundance, juveniles, surveys

Introduction

Research carried out under the Northern Cod Science Program has shown that juvenile cod of age groups 0 and 1, since 1992 tend to concentrate in coastal areas, with highest densities at depths of 4– 7 m. 0-group cod are also known to concentrate in time, arriving in coastal nursery areas as distinct and predictable pulses in April–June, mid-August, mid-October, and possibly late December–January.

In 1959 Allister Fleming, Tom Collier, and others from the Government of Canada Departments (which represented the present day Department of Fisheries and Oceans) began a series of annual surveys along the coast of eastern Newfoundland to assess the abundance of small juvenile cod (Fig. 1). The objective of the "Fleming survey" was to determine if catches could be used as an index to assess year-class strength (Lear *et al.*, MS 1980). Surveys continued each year until 1964. After a lapse, the surveys were repeated in 1992 to 1994 making every effort to duplicate the methodology. The survey was continued in 1995 with special objectives.

The first objective of the 1995 Fleming survey was to test for any enhanced abundance of first year demersal juveniles in coastal habitats, subsequent to spawning by a well documented aggregation of cod in Smith Sound (Trinity Bay) several months earlier, in April and May. Spawning aggregations of such magnitude in deep sounds of coastal Newfoundland had not been reported previously in the scientific literature, although personal records kept by Eric Bailey (town of Petley, Newfoundland, pers. comm.) and Jack Marsh (Lance Cove, Newfoundland, pers. comm.) indicated that spawning aggregations do occur in Smith Sound in most years. The Smith Sound aggregation was the only one of its size reported in 1995, and hence it was of interest to test whether this spawning aggregation, estimated at 10 000 tons or more (G. Rose, Northwest Atlantic Fisheries Centre, St. John's, Newfoundland, pers. comm.) would have enhanced the abundance of juvenile fish settling into suitable coastal habitats 3–4 months later.

The second objective of the 1995 survey was to compare the abundance of fish in size-classes identifiable as age 0+, 1+ and 2+ fish to abundance

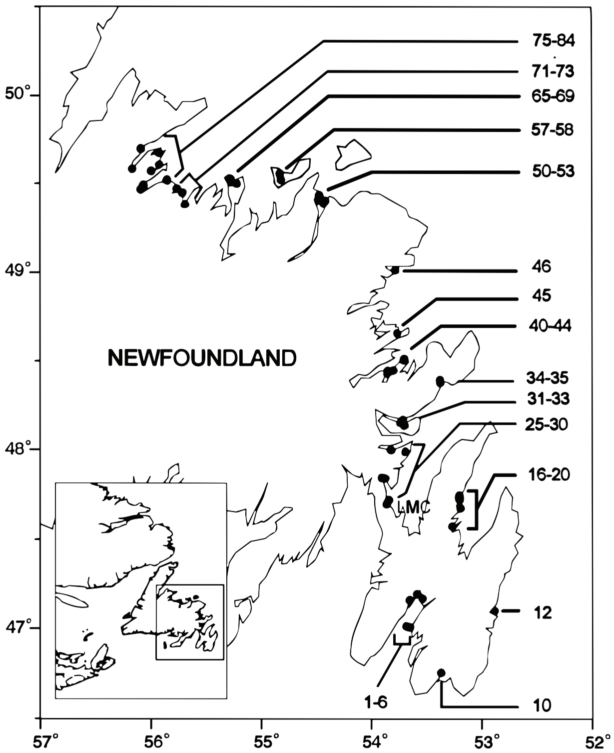

Fig. 1. Map of eastern Newfoundland showing Fleming survey sites sampled during 1959–64 and 1992–95.

of the same size-classes (*LG*0, *LG*1 and *LG*2) of previous years. The abundance of *LG*1 fish in 1995 was expected to be 1.5 times that of 1994 (Schneider *et al.*, MS 1995), based on detection of a recruitment signal in the 1959–64 and 1992–94 surveys (Ings *et al.*, 1997). The abundance of *LG*2 fish in 1995 was expected to be 1.6 times that in 1994, based on *LG*1 abundances in 1993 (Schneider *et al.*, MS 1995).

Methods

During the Fleming surveys of 1959 to 1964, approximately 40–60 sites were sampled each year, except in the two start-up years 1959 and 1960. These surveys were repeated in 1992–94 (Table 1). To ensure that past and present surveys were as similar in execution as possible, special attention was given to each of the following.

i. locating sampling sites
ii. gear specifications, construction and deployment
iii. sampling design
iv. time of sampling

For the 1995 study, the Fleming sites were identified from charts and station records used during the 1959–64 and 1992–94 surveys. Black and white photographs taken in 1962 and colour photographs from 1992–94 surveys were examined for characteristic features to ensure that the same site was resampled in 1995. Present day shoreline features, underwater algae and substrate were similar to the 1959–64 period as determined by photographs and station records taken at that time. The survey party leader in 1995 was Peter Hennebury, who participated in the 1994 survey and thus was able to relocate sites quickly and accurately. He was assisted by Jason Howell and Stephen White, both student interns under the Environmental Technology program within the Marine Institute of Memorial University. A fourth member of the survey party, Wade Bailey, conducted a habitat survey at each beach site, for the Environmental Innovation Program collaboration between Department of Fisheries and Oceans, Canada, and Memorial University of Newfoundland.

The fishing gear deployed in 1959–64 and 1992–95 was a 25 m bottom seine hauled by two people towards shore after being deployed from a small boat. Net deployment in 1992–95 (Schneider *et al.*, 1997) was as similar as possible to that used in 1959–64 (Lear *et al.*, MS 1980). During 1992, Tom Collier, who participated in the 1959–64 surveys, made a trip into the field to compare execution with the earlier survey. After viewing the sampling procedure, he suggested several changes, to arrive at a protocol as similar as possible to that used in the 1960s (Schneider *et al.*, 1997).

Three tows were conducted at each site in 1992–95. Two consecutive sets were made at exactly the same location, with an additional set being conducted immediately adjacent to the first two sets. All sets were conducted during daylight with the first two consecutive sets being conducted usually within one hour of each other. Sampling was not confined to any particular time of the day or to a particular tide level. Present day sampling was very similar to the historical sampling in that the same beaches were sampled at the same time each year (Table 2).

Cod catches were measured for standard length (mm) in the field. Standard length was used to divide the catch into three length groups defined by clear modes in the catch from several types of gear. The length groups, which corresponded to age groups 0+, 1+ and 2+ (*LG*0, *LG*1 and *LG*2, respectively) (Methven, MS 1995), were:

*LG*0 = 96 mm or less
*LG*1 = 97–192 mm
*LG*2 = 193 mm or greater

Birth dates of *LG*0 fish during the 1995 survey were back calculated using daily otolith increments (Pinsent and Methven, 1997).

TABLE 1. Sites sampled in Fleming survey with at least two successive sets of a bottom seine.

Site	1959	1960	1961	1962	1963	1964	1992	1993	1994	1995	
From St. Mary's Bay to Cape Bonavista											
01			X	X	X	X	X	X	X	X	Harricot Beach
02				X	X		X	X	X	X	Half Island
03							X	X		X	Mother Hicks Cove
04		X	X	X							Admirals Beach
05		X	X		X	X	X	X			Mosquito Cove
06			X	X		X	X	X	X	X	North Harbour (bottom)
10				X	X	X	X	X	X	X	Trepassey
12		X		X	X	X					Cape Broyle
16	X	X	X		X		X	X	X	X	Davies Head (N)
17	X	X	X	X			X	X	X	X	Davies Head (S)
18	X	X	X	X			X	X	X		Crockers Cove
19	X	X	X	X	X	X	X	X	X		Bryants Cove
20	X	X	X	X	X	X	X	X	X		Bristols Hope Cove
25			X	X	X	X					Rantem Cove
26							X	X	X	X	Masters Head
27			X	X	X		X	X	X	X	Little Mosquito Cove
28			X	X			X	X	X	X	Bald Point Beach
29		X				X	X	X	X	X	Long Beach (E)
30				X		X	X	X	X	X	Long Beach (W)
31			X	X	X	X					Lower Lance Cove
32				X		X	X	X	X	X	Middle Lance Cove
33					X	X	X	X	X	X	Burgoynes Cove
34	X	X	X	X	X	X	X	X	X	X	Lockston's Arm
35					X	X	X	X	X	X	Cap Cove
40		X	X	X	X	X	X	X	X	X	Cannings Cove
41		X		X		X	X	X	X	X	Man Point
42				X							Jamestown
From Cape Bonavista to western Notre Dame Bay											
43				X	X						Great Chance Harbour (bottom)
44				X	X	X					Great Chance Harbour (right)
45			X	X		X					Eastport
46		X	X	X	X		X	X	X	X	Indian Bay
50				X	X	X	X	X	X		Rubens Cove
51			X		X		X	X	X	X	Grassy Island
52					X		X	X	X	X	Seal Island
53				X		X	X	X	X	X	Fox Island
57		X		X	X	X	X	X		X	Bridgeport
58		X	X	X	X		X	X		X	Luke's Arm
65		X			X		X	X	X	X	Fortune Harbour (NW, bottom)
66							X	X			Fortune Harbour (Fox Cove 1)
67			X		X		X	X	X	X	Fortune Harbour (Fox Cove 2)
68			X	X	X		X	X	X	X	Fortune Harbour (SW bottom)
69				X	X		X	X		X	Fortune Harbour (SE bottom)
70			X	X	X		X	X	X	X	Wild Bight
71				X	X	X	X	X	X	X	Julies Harbour
72			X	X	X	X	X	X	X	X	Tommy's Arm
75			X	X	X	X	X	X	X		Woodfords Arm (outcrops)
76			X		X	X	X	X	X		Woodfords Arm (mid)
77			X		X		X	X	X		Woodfords Arm (bottom)
78			X	X	X	X	X	X	X	X	Lower Wolfe Cove
79						X		X	X	X	Green Island
80			X	X	X	X	X	X	X	X	Halls Bay, Beachy Cove
81			X	X	X	X	X		X		Shimmey Cove
82				X	X	X					Little Bay Arm
83					X						Middle Arm (bottom)
84		X			X		X	X	X	X	Middle Arm (Green Bay)
85			X	X	X	X	X	X	X	X	King's Point (Green Bay)

TABLE 2. Duration of sampling for juvenile cod by year and bay in eastern Newfoundland, 1959–64 and 1992–95. SMB = Saint Mary's Bay, SS = Southern Shore, CB = Conception Bay, TB = Trinity Bay, BB = Bonavista Bay, NDB = Notre Dame Bay (locations given in Fig. 1).

Location	1959	1960	1961	1962	1963	1964	1992	1993	1994	1995
SMB	---	12 Sep–20 Sep	08 Sep–14 Sep	17 Sep–21 Sep	19 Sep–25 Sep	19 Sep–25 Sep	22 Sep–23 Sep	22 Sep–23 Sep	23 Sep	21 Sep–27 Sep
SS	23 Sep–24 Sep	---	15 Sep	22 Sep	26 Sep	18 Sep	21 Sep	21 Sep	21 Sep	20 Sep
CB	02 Oct–08 Oct	28 Sep–29 Sep	21 Sep–23 Sep	26 Sep–27 Sep	05 Oct–07 Oct	24 Sep–25 Sep	28 Sep–29 Sep	28 Sep–29 Sep	29 Sep, 04 Oct	28 Sep
TB	10 Oct–12 Oct	03 Oct–04 Oct	25 Sep–30 Sep	01 Oct–14 Oct	10 Oct–12 Oct	29 Sep–03 Oct	20 Sep–06 Oct	30 Sep–06 Oct	30 Sep–06 Oct	30 Sep–07 Oct
BB	16 Oct	06 Oct–10 Oct	03 Oct–07 Oct	11 Oct–16 Oct	17 Oct–19 Oct	06 Oct–08 Oct	08 Oct–09 Oct	08 Oct–09 Oct	07 Oct–08 Oct	08 Oct–09 Oct
NDB	23 Oct, 26 Oct	17 Oct–27 Oct	09 Oct–24 Oct	17 Oct–26 Oct	21 Oct–31 Oct	12 Oct–22 Oct	14 Oct–21 Oct	14 Oct–21 Oct	14 Oct–22 Oct	14 Oct–20 Oct

Analysis of the 1959–64 together with 1992–94 data showed that the abundance of *LG*1 fish in any one year was related to *LG*0 abundance the previous year. Similarly *LG*2 fish were related to *LG*1 abundance the year before (Schneider *et al.*, MS 1995). The equations for these relationships were:

$$LG1 = \beta_{0\rightarrow1} LG0$$

$$LG2 = \beta_{1\rightarrow2} LG1$$

An iterative weighting algorithm was used to estimate parameters, which were as follows:

$\beta_{0\rightarrow1} = 0.7984$ standard error = 0.1112

$\beta_{1\rightarrow2} = 0.02019$ standard error = 0.00061

Based on these estimates and the observed mean catches of *LG*0 and *LG*1 fish in 1994, the predicted catch of *LG*1 for 1995 was 16 fish/haul.

Results

Age of *LG*0 Fish

The age of *LG*0 fish caught on 4 October 1995 at Little Mosquito Cove ranged from 93 to 123 days, depending on standard length (Table 3). The corresponding dates of hatching ranged from 3 June to 3 July. The spawning dates will be one to two weeks earlier, given the water temperatures near zero at this time of year. For *LG*0 fish greater than 70 mm in standard length, spawning would have occurred in mid-May or earlier, matching the time of spawning by fish in Smith Sound (G. Rose, Northwest Atlantic Fisheries Centre, St. John's, Newfoundland, unpublished observation).

Abundance and Distribution of *LG*0 Fish

Enhancement of *LG*0 fish density was tested at 3 different spatial scales. At the scale of the entire survey, from St. Mary's Bay to western Notre Dame, a slight increase was expected, because the only reported spawning activity by any sizable aggregation was in Smith Sound. Contrary to expectation, no increase was observed. The average catch of *LG*0 fish in 1995 was 13.3 fish/haul, a value that did not exceed that of 1994 and was nearly the same as 1993 (Table 4). The 1995 catch of *LG*0 fish was similar to the average catch from 1992 to 1994 combined.

The abundance enhancement was expected to be more evident at the scale of individual bays, with greater abundance in Trinity (and perhaps Conception) Bays in 1995 than in preceding years. Conception Bay was included in the prediction because the prevailing water flow is with the coast to the right, and hence Conception Bay lies "downstream" of Trinity Bay. Contrary to expectation, no increase in *LG*0 fish was observed in Trinity Bay, relative to preceding years (Fig. 2, Table 5). During 1995 the fish density at sites in Trinity Bay was 15.96/21 = 76% of the mean density of the period 1992–94 (Table 5). Outside Trinity Bay, the density in 1995 was 11.53/14.5 = 80% of the density of 1992–94. The hypothesis of an increase in density at Fleming sites in Trinity Bay in 1995 was thus rejected. Catches of *LG*0 cod in Trinity Bay were low, relative to the early-

TABLE 3. Ages (days) of *LG*0 cod caught at Little Mosquito Cove on 4 October 1995. Standard length (SL in mm). Estimated hatching date = 277 – mean age.

Specimen	SL	Count 1	Count 2	Count 3	Age	Hatch Date
1 left	56	97	93	90	93	3 July
right		95	91			
2	53	89	95	96	93	3 July
3	57	101	96	100	99	27 June
4	59	103	99	93	98	28 June
5	71	115	124	130	123	3 June

TABLE 4. Summary of the number of hauls (NHAUL) and mean catch (fish/haul) by year for *LG*0 *LG*1 and *LG*2 juvenile cod collected at Fleming sites along the northeast coast of Newfoundland, where two consecutive sets were conducted at each beach. N = Number of sites.

Year	NHAUL	N	*LG*0	*LG*1	*LG*2
1959	12	6	177.833	5.167	1.500
1960	34	17	31.353	133.941	0.588
1961	60	30	10.967	27.683	2.067
1962	80	40	29.513	6.963	0.813
1963	82	41	17.841	30.732	0.439
1964	64	32	9.531	50.797	2.063
1992	92	46	9.598	3.946	0.391
1993	88	45	13.250	10.216	0.233
1994	80	40	19.775	16.450	0.937
1995	72	36	13.264	1.194	0.264

1960s (Fig. 2). This difference was statistically significant, as indicated by 95% confidence limits that did not overlap (Fig. 3).

Abundance enhancement at the scale of sections of Trinity Bay was also expected, with greater catches in the inner part of Trinity Bay due to lower exchange rates and greater retention in the inner bay. Also, the prevailing currents on the western side of Trinity Bay run toward the inner bay from the spawning site at Smith Sound. No enhancement within inner Trinity Bay was observed in 1995, relative to earlier years (Fig. 4). Catches near Smith Sound (Random Island sites) were low in all years. During 1995 catches to the north and to the south were low, relative to previous years (Fig. 4). The pattern of higher catches north and south of Smith Sound in recent years matched that observed in the 1960s (Fig. 4). This pattern may have been due to the presence of sites with good habitat to the north (Trinity) and south (Bull Arm), rather than any drift related patterns in transport of eggs and newly hatched fish.

Abundance and Distribution of *LG*1 and *LG*2 Fish

The expected catch of *LG*1 fish in 1995 was 16 fish/haul (1.5 times the 1994 catch), as computed from regression equations that project relative abundance at time scales of 1 year (Schneider *et al.*, MS 1995). Contrary to expectation, the observed catch of *LG*1 fish in 1995 was less than 1994 (Table 4). The observed catch was the lowest on record in the ten year series (Table 4). The decrease in 1995 was statistically significant at α = 5%, as indicated by non-overlapping 95% confidence limits around the 1994 and 1995 estimates of *LG*1 density (Fig. 5). This shortfall in catch was not evenly distributed along the coast. It occurred primarily in Conception and Trinity Bay (Fig. 2).

The expected catch of *LG*2 fish in 1995 was 0.33 fish/haul (1.6 times the 1994 catch) again based on regression equations that predict relative year-class strength. Contrary to expectation, the observed catch in 1995 was less than 1994 (Table 4). This decrease was statistically significant (α = 5%) based on non-overlapping 95% confidence limits (Fig. 5). This shortfall was due to Notre Dame and Bonavista Bays (Fig. 2), which account for more than half of the survey sites.

Discussion

Neither of the two results were expected. Possible explanations are therefore listed and briefly discussed. Possible explanations for the failure of

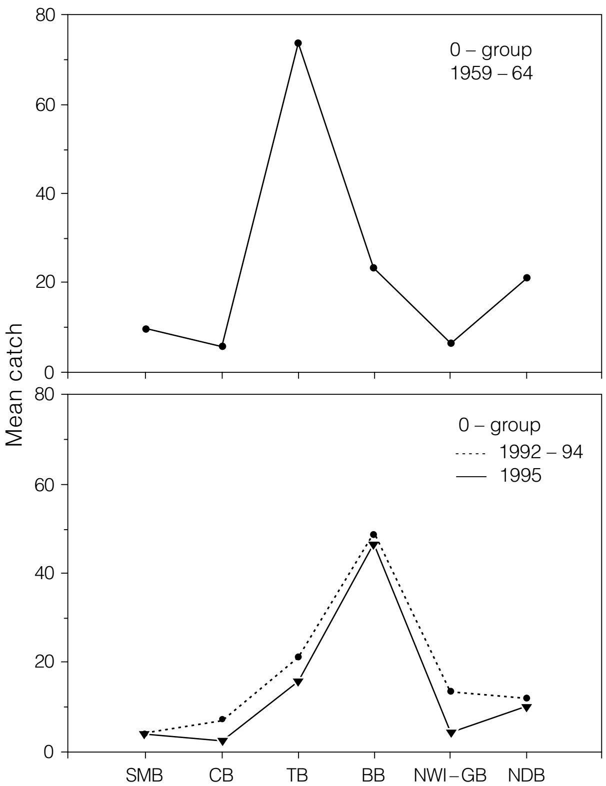

Fig. 2. Mean catch of *LG*0 fish from St. Mary's Bay to Notre Dame Bay in 1995, compared to three previous years (1992–94) and to historical catches (1959–64). SMB = St. Mary's Bay and Southern Shore, CB = Conception Bay, TB = Trinity Bay, BB = Bonavista Bay, GB = Gander Bay, NWI = New World Island, NDB = Notre Dame Bay.

more than 10 000 tons of spawning fish to produce detectable increases in the density of *LG*0 fish are:

1. Survey sites were too widely spaced to detect local abundance enhancement.
2. The error rate of the survey was too high to detect an effect.
3. Spawning biomass in Trinity Bay or along entire coast was no higher than in previous years.
4. The number of eggs produced by cod at Smith Sound was too small to bring about detectable increase.
5. The eggs were washed out to sea and never contributed to recruitment to demersal populations along the coast.
6. During 1995 juvenile cod settled at greater distances from the coast than in previous years.

The analysis was carried out at three scales of spatial resolution: the coast of eastern Newfoundland, individual bays, and sections of Trinity Bay. A finer scale of resolution was not possible because of the lack of prior measurements at more sites in Trinity Bay. Consequently, a more localized enhancement within Trinity Bay would have gone undetected. However, typical values of horizontal eddy diffusivity (κ = 500 m^2 s^{-1}) acting over a period of T = 90 days will diffuse particles over an area of κT = 3 900 km^2, for which the diameter is 70 km. This is of the same order of magnitude as Trinity Bay. The sample spacing of this survey was sufficient to detect a density increase, unless eggs and larvae drifted in a more cohesive pattern than the surrounding water, leading to settlement in one highly restricted area.

The error rate as measured by a bootstrapping method for the Fleming survey, estimates of 95% confidence limits (Fig. 3, Fig. 5), and compares favourably with other fisheries surveys but is still substantial. The true value of *LG*0 abundance in 1995 lies between 7.1 and 19.4 fish/haul, 95% of the time. Given the uncertainly in the estimate, what change in density could have been detected? The observed density of *LG*0 cod in Trinity Bay in 1995 relative to previous years was 15.96/21 = 76%, compared to 11.53/14.5 = 80% outside the Bay (Table 5). The

TABLE 5. Mean catch of age 0+ cod (fish/haul) in 1995 in Trinity Bay, compared to recent (1992–94) catches outside Trinity Bay. **Note**: means are based on differing sample sizes, and hence cannot be added together directly.

	1992–94			1995		
	Mean	Standard deviation	N	Mean	Standard deviation	N
Inside	21.00	3.964	81	15.96	6.865	27
Outside	14.53	2.004	317	11.53	3.964	81
Both	17.76	2.221	398	13.75	3.964	108

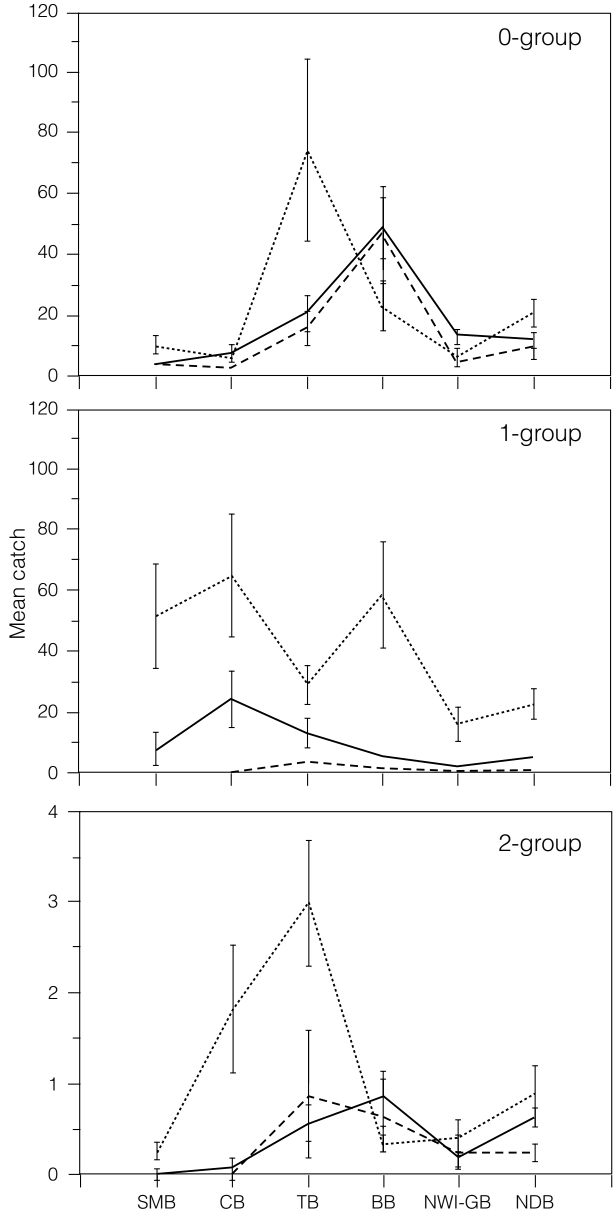

Fig. 3. Mean catch by bay of *LG*0, *LG*1, and *LG*2 cod, with bootstrap 95% confidence limits of juvenile cod. Abbreviations as in Fig. 2.

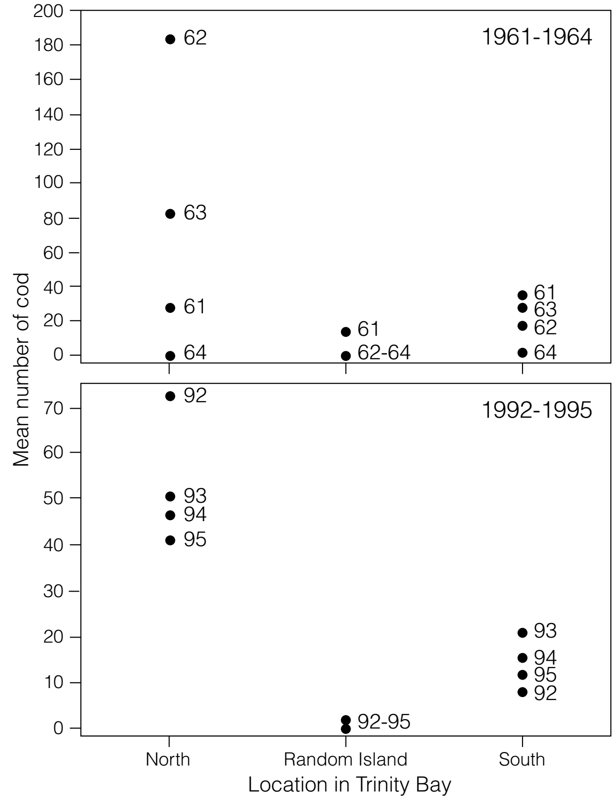

Fig. 4. Mean catch of *LG*0 cod within Trinity Bay, comparing to recent catches (1992–94) and catches during the early-1960s (note change in scale).

minimum detectable increase inside Trinity Bay, at the 5% significance level, was 35.96/21 = 171%, based on analysis of the means in Table 5 (minimum increase to obtain significant interaction term in a two-way ANOVA). The survey could have detected, with a high degree of confidence, an increase of 171 – 100 = 71% in density in 1995, relative to previous years.

The third possibility was that the spawning biomass in Trinity Bay in 1995 was no greater than in previous years, and hence the increase predicted in 1995 was based on greater information about coastal spawning, rather than any increase in the size of the spawning aggregation in the bay. Estimates of spawning biomass in Trinity Bay were not made prior to 1995, and so no direct evaluation was possible. However, egg densities in 1995 in the vicinity of Random Island were higher than in previous years (K. Smedbol, Memorial University of Newfoundland, unpublished observations).

The number of eggs produced by the Smith Sound aggregation may have been too few to bring about detectable abundance enhancement, even though egg densities in 1995 exceeded those in previous years. In this respect, we plan to estimate the expected degree of enhancement by comparing the enhancement of egg density in Smith Sound relative to previous years. An effort will also be made to compute the number of eggs released by the spawning aggregation, and the subsequent dispersion of those eggs.

The fifth possibility was that the eggs were washed out of Trinity Bay by sustained southwesterly winds in June. This can be tested with

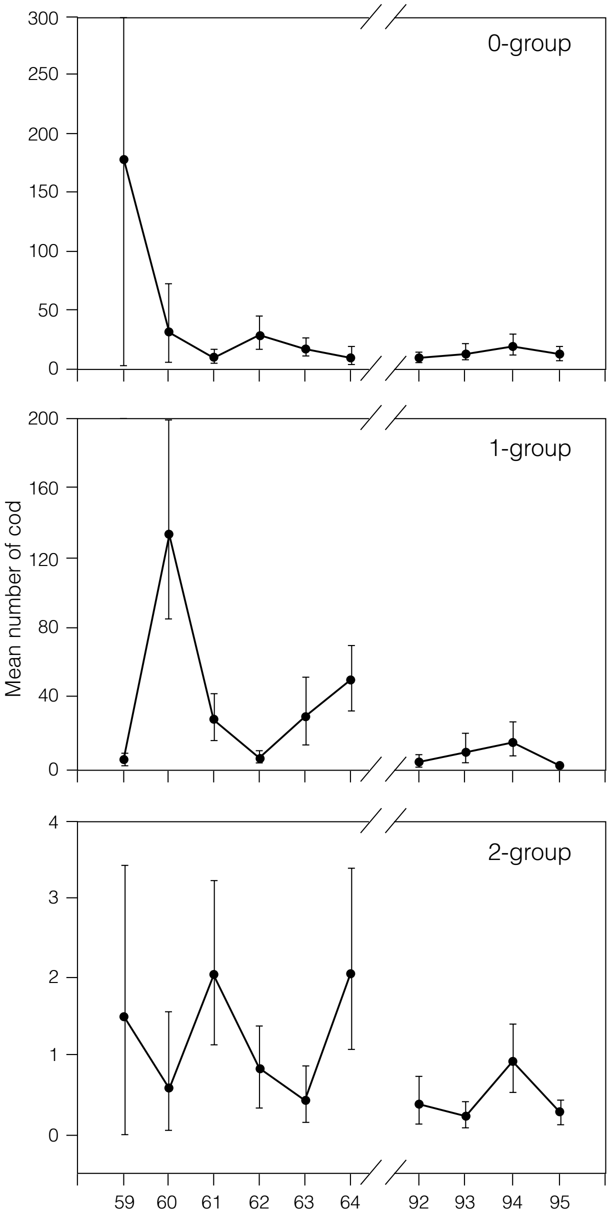

Fig. 5. Mean catch of *LG*0, *LG*1, and *LG*2 cod in 1992–95, compared to 1959–64. 95% confidence limits were computed by repeated resampling (bootstrap) methods.

computations of wind-driven drift of the surface water layer, which will be undertaken as part of a recently funded GLOBEC initiative. There was no evidence that settlement of 0+ juveniles occurred at greater distances from the coast in 1995 than in previous years (Schneider *et al.*, 1996).

Low numbers of *LG*1 and *LG*2 fish were even more unexpected than low numbers of *LG*0 fish. These low numbers were not due to a change in survey design. The execution and design were exactly the same as previous years, when regression equations for the survey successfully predicted increased *LG*1 and *LG*2 cod. High error rate was not a problem because a statistically significant decrease was observed. Several biological explanations for the decrease are possible.

1. High rates of incidental catch of juvenile fish.
2. Shift of *LG*1 and *LG*2 away from coastal nursery areas in 1995 relative to earlier years.
3. High rates of loss of *LG*1 and *LG*2 fish to predators in 1994–95.

With respect to the first explanation, most sources of incidental catch were reduced or ended in 1992, due to the moratorium on groundfishing. The capelin fishery in 1994 and 1995 was reduced because of late arrival of small fish. There was no evidence of increase in incidental catch of cod by this fishery in 1994–95, relative to previous years.

A shift away from coastal nursery areas will normally occur in *LG*1 and *LG*2 relative to *LG*0 fish, based on winter surveys in 1992–94 (Dalley and Anderson, 1996). Results of the 1995 winter survey (Dalley and Anderson, 1996) showed that density of *LG*1 fish declined substantially in 1995 within 30 naut. miles of the coast. Decline in density of *LG*1 fish in 1995 relative to previous years was less evident away from the coast. This indicates that the decline observed in the Fleming survey was not confined to the coast, but rather was an indicator of a larger scale decline in density.

The third possibility, high rates of loss to predators, was consistent with observed patterns of size selectivity by seals (*LG*1 and *LG*2 cod) and with anecdotal observations of small cod found in stomachs of larger cod taken by the sentinel fishery. The estimate of increased mortality (M) of *LG*1 in 1995, relative to previous years, was $\Delta M = -258\%$ per year. This was estimated from the ratio of *LG*1 in 1995 to *LG*0 in 1994 (0.06038) compared to the average ratio in the past ($\beta_{0 \rightarrow 1} = 0.7984$) estimated by regression (Schneider *et al.*, MS 1995). That is, $\Delta M = ln(0.06038/.7984) = -258\%$/year. This computation assumes that the performance of the Fleming seine did not change in 1995 (no change in catchability); it also assumes that shift offshore in 1995 was similar to previous years.

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