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DISTRIBUTION AND ABUNDANCE OF DEMERSAL JUVENILE COD (*GADUS MORHUA*) IN INSHORE AND OFFSHORE AREAS OF NORTHEAST NEWFOUNDLAND (NAFO DIVISIONS 3KL) IN THE EARLY 1990'S.

by

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Abstract

Demersal juvenile cod were widely distributed in inshore and offshore areas of NAFO Div. 3KL during surveys carried out in early winter, 1992 to 1994. Catch rate of age 0 and 1 cod was inversely related to depth and catch rate of age 3 was positively related to temperature during all three surveys. There was an ontogenetic pattern in distribution whereby age 0 fish were restricted to the inshore, age 1 fish extended further onto shelf areas, and larger juveniles were widely distributed on the shelf. Relatively high catch rates of age 1, 2, and 3 were maintained in the inshore, particularly Trinity and Conception Bays, even though distribution extended further onto the shelf. Distribution of age 0 appears more restricted than historic distributions when low numbers were also found in offshore portions of the survey area. Distribution of older juveniles was similar to that observed historically. Ranking of mean catch rates of each age group over the three years indicates that 1991 has been the weakest year-class since 1989. Mean catch rates of age 0-3 juveniles indicate an increase in spawning success each year since 1991. The 1994 year class has been measured only as age 0's and although increased catch rates were not pervasive throughout the survey area overall catch rate of 0's increased nearly 7x and was statistically higher (P=0.02) than that of 1992.

Résumé

Selon des relevés effectués au début de l'hiver, de 1992 à 1994, les morues juvéniles de fond étaient présentes dans l'ensemble des aires côtières et hauturières de la division 3KL de l'OPANO. Dans les trois relevés, le taux de capture des poissons d'âge 0 et 1 présentait une corrélation inverse à la profondeur et celui des poissons d'âge 3 une corrélation positive avec la température. La répartition semblait être de type ontogénétique, c'est-à-dire que les poissons d'âge 0 se trouvaient uniquement près des côtes, les poissons d'âge 1 occupaient une zone plus étendue atteignant certaines aires de la plate-forme. Quant aux juvéniles plus gros, ils étaient répartis sur toute la surface de la plate-forme. Le taux de capture de poissons d'âge 1, 2 et 3 près des côtes est demeuré assez élevé, particulièrement dans les baies Trinity et Conception, bien qu'il se trouvait des poissons plus loin sur la plate-forme. La répartition des poissons d'âge 0 semble plus limitée que les répartitions historiques qui indiquaient la présence d'un nombre peu élevé de poissons dans les aires hauturières de la zone des relevés. La répartition des juvéniles plus âgés était semblable à celle observée historiquement. Un classement des taux de capture moyens de chaque groupe d'âge au cours des trois années indique que la classe d'âge de 1991 a été la plus faible depuis 1989. Les taux de capture moyens des juvéniles d'âge 0 à 3 révèlent une augmentation de la ponte tous les ans depuis 1991. La détermination de l'effectif de la classe d'âge de 1994 a été limitée aux poissons d'âge 0. Même si des taux de capture plus élevés n'étaient pas la norme dans toute la zone des relevés, le taux de capture global de poissons de la classe d'âge 0 a augmenté presque de 7 fois et était statistiquement plus élevé (P = 0,02) que celui de 1992.

INTRODUCTION

The Northern cod (*Gadus morhua*) stock (NAFO Divisions 2J3KL) is the largest in the Northwest Atlantic and has provided the economic basis for the settlement of eastern Newfoundland and Labrador (Lear and Parsons 1993). Landings peaked in the late 1960's at more than 1,000,000 tons, but since then fell to record low levels (Taggart et al. 1994). In 1992 a commercial fishing moratorium was declared for cod off Labrador and Newfoundland (NAFO Divisions 2J3KL) and subsequently included the cod stock on the southern Grand Bank (NAFO Divisons 3NO). Rebuilding of these stocks will depend on significant recruitment over a number of years. A number of studies have demonstrated that recruitment in cod is often established by the pelagic 0-group stage (Campana et al. 1989, Sundby et al. 1989, Assthorsson et al. 1994, Jakupsstovu and Reinert 1994). However, density dependent predation on demersal juveniles (ages 0-2 years) can significantly reduce recruitment in some cases (Mehl 1989, Bogstad et al. 1994). Sissenwine (1984) hypothesized that effects of natural mortality throughout the demersal pre-recruit stage is an important regulating mechanism of recruitment to the fishery. Estimating the abundance of pre-recruit cod at multiple ages, particularly during the period of population recovery, will provide important measures of population growth. Estimating fluctuations in natural mortality among these pre-recruit ages could provide valuable information on major factors effecting survival at specific early life history stages.

Historically demersal juvenile cod (< 35-40 cm.) were caught from directed sampling by the former USSR during the 1950's, 60's and 70's (Bulatova 1962, 1963, 1970, 1971), and more recently in the 1980's through trawl acoustic surveys (Bulatova 1990, Kuzmin and Tevs 1991). In winter (December-March) juveniles were caught throughout the shelf areas of Labrador (Divisions 2GHJ), on the Northeast Newfoundland Shelf (Divison 3K) and on the Grand Banks (Divisions 3LNO) (Bulatova 1971). Low numbers of age 0 demersal cod occurred on the shelf and abundance increased from north to south (2J to 3L) in the December-January period (Bulatova 1963). Bogstad et al. (1994), from a cod cannibalism study, also demonstrated qualitatively that age 0 demersal cod occurred in offshore areas of the Labrador and Northeast Newfoundland shelfs. Young cod (1-2 years old) were also caught throughout Divisions 3KL in the spring (Bulatova 1970, 1980, Kuzmin and Tevs 1991). Analysis of 12 years of Canadian autumn research vessel survey data demonstrated that one year old cod were most abundant on the inner NE Newfoundland Shelf and along the edge of the northern Grand Bank, and that these distributions were separate from cod aged three and four years that were more widely distributed (Anderson 1993). Due to very low catchability 0-group cod were not considered in the analysis. In all cases (Russian and Canadian) the data are limited by sampling trawls that had low catchabilities for young cod, particularly those younger than two years old (eg. Bulatova 1962, Godo and Walsh 1992). Also these surveys typically undersampled the inner shelves and did not sample within the inshore bays.

Juvenile cod occur abundantly in the shallow nearshore areas along the northeast coast of Newfoundland (Lear et al. 1980, Keats et al. 1987, Clark and Green 1990, Keats 1990, Methven and Schneider, submitted). Recent studies have demonstrated 0-group and 1-group cod are seasonally abundant in the very nearshore (Methven and Bajdik 1994). However, these studies have seldom extended beyond 10-20 m depth. Recently Anderson et al. (1995) demonstrated that the abundance of age 0 and 1 cod extended away from shore at selected sites to approximately 40-60 m depth. However, all of these studies have been carried out with different sampling techniques and have been spatially restricted, disallowing any comparison with trawl measurements made in the offshore.

As part of a research effort on juvenile cod (Anon. 1994), we undertook a three year study to determine the relative abundance of demersal juvenile cod, age 0 to 3 years old, in inshore and offshore locations along the northeast coast of Newfoundland. The surveys were done to measure overwintering distributions of juvenile cod and also to examine settlement patterns of settled 0-group cod. We also wanted to examine abundance of recent year classes of juvenile cod considering the stock collapse.

METHODS AND MATERIALS

Sampling locations were distributed within each of the 5 major bays along the northeast coast of Newfoundland and along six transects that extended from inshore areas, across the shelf to the shelf break (Figure 1). Surveys were carried out in December 1992, December 1993-January 1994, and December 1994-January 1995 and will be referred to as the 1992, 1993, and 1994 surveys respectively (Table 1). In considering a design for the survey, a trade-off was made between intensive spatial coverage to examine variability within any given area and the necessity to cover a large geographic area synoptically in a relatively short period of time. An effort was made to sample all available depths along a transect and within the bays (minimum depth ~ 60m.). However, it was not always possible to sample all available depths due to rough bottom, rendering some areas 'untrawlable' using the methods applied here. Generally, distance between stations did not exceed 30 nautical miles.

The sampling trawl was a three-bridle Campelen 1800 mesh shrimp trawl with 80 mm. stretched meshes in the front which decrease to 40 mm. in the codend (Engas and Godo, 1989). The Campelen was outfitted with 14 inch rubber disc rockhopper groundgear and 1400 kg. polyvalent doors. Trawl depth, headline height, wing spread and door spread were monitored using Scanmar. On average the vertical height was 4.5 m., wing spread was 15-16 m. and door spread was 35-40m. Effort was standardized by fishing for 30 minutes along bottom once the trawl had settled, as observed from the Scanmar readings. Temperature and depth along the tow path were monitored using a trawl mounted CTD. All cod were sorted from the catch prior to onboard sampling for length and weight measurements, sex determination and otolith removal.

The length groups (LG's) approximating the age groups of juvenile cod are as follows: age 0 (LG0) < 116 mm; age 1 (LG1) 116-195 mm; age 2 (LG2) 196-290 mm; age 3 (LG3) 291-390 mm. Although convention is that all cod increment 1 year on January 1 here the age of the fish in December is maintained until the end of the survey. For example the year-class that was age 0 during the first leg of the survey was also age 0 during the second leg. The length ranges were determined from overall length frequency distributions and subsequently substantiated using mean length at age data from the 1992 and 1993 aged samples. An upper limit of 390mm was chosen to include all age 3's but due to overlap in sizes of age groups some older fish may be included in LG3. Length ranges for LG1, LG2, and LG3 differ slightly from those presented following the first demersal cod survey in December 1992 (Dalley and Anderson 1994) as a result of further refinement using additional data. Correlation analysis was carried out using Pearson's correlation coefficient between catch rates and environmental variables (depth and temperature). T-Tests were carried out to test for differences in mean (log10 catch rate + 1) during daylight and darkness, and also for differences in catch rates between years. Correlations and T-Tests were carried out using SAS (1990).

RESULTS

Catch Rates in relation to Environmental Factors

Mean, minimum, and maximum depth, temperature, and catch rate (including zero catches) of each of the age (length) groups at stations fished during the demersal juvenile cod surveys is summarized in Table 2. In all years there was an inverse relationship between catch rate of the two youngest age groups and water depth (Table 3). In 1993 and 1994 there was a relationship between catch rate at age 3 and depth which in contrast to that for age 0 and age 1 was positive (Table 3).

There were no relationships between catch rate of the 3 youngest age groups and temperature. However, during all three surveys there was a significant positive relationship between catch rate at age 3 and temperature.

Comparison of mean catch rates between daylight and darkness here indicated no significant differences between the two, in either the inshore or the offshore catches (t-test, $P<0.05$).

Distributions

Juvenile cod (all sizes combined) were distributed throughout the survey area, inshore and offshore, during each of the surveys (Figure 2). Five zero catches were recorded during each of 1992 and 1993 and seven during 1994.

Distribution of male and female juvenile cod did not differ noticeably throughout the survey area for any of the surveys (Figure 3). Minor disparities in distribution between the sexes occur in the offshore, where catches were generally smaller than in the inshore.

The distribution of age 0 cod was restricted to the inshore areas during all three surveys (Figure 4). Only in 1992 was a single individual found further than ~30nm. from the coast, that on the most southern line (47.5 degrees N). Highest catch rates occurred in Conception and Trinity Bays in all three years and Notre Dame Bay in 1993 and 1994 (Figure 4). Age 0 cod were found in all five Northeast coast bays, but not in all years.

The highest catch rates of age 1 cod also occurred in the inshore, particularly Trinity and Conception Bays (Figure 5). In contrast to the LG0's, however, there is a greater utilization of the shelf area, with the possible exception of the most southern line. Only low numbers of age 1 cod occurred near the shelf edge.

Two and three year old cod were widely distributed, both inshore and offshore, and in the case of these larger length groups (particularly age 3) relatively high catch rates were taken near the shelf edge (Figures 6 and 7).

Differences in Bays and Lines

Variability in mean catch rates among the 5 bays for the three years is illustrated in Figure 8. Catch rates of all length groups of juvenile cod were low in White Bay and Bonavista Bay relative to the other 3 bays.

Overall the highest catch rates of age 0, age 1, and age 2 occurred in Trinity Bay in 1994 (Figures 4,5,6, and 8) which contributed to the overall higher mean catch rates in 1994 (Table 2). High catch rates of age 0 also occurred in Notre Dame Bay in 1993 and 1994, and in Conception Bay all three years (Figure 8). Age 1 catch rate was relatively high in Trinity and Conception Bays all three years and in Notre Dame Bay in 1993 (Figure 8). Catch rate of age 2 (the 1991 year class) was low in all bays in 1993. Age 2's were relatively abundant in Trinity Bay in 1992 and 1994. Catch rates of age 3 were low in the bays relative to other length groups but high in Trinity Bay in 1993 and 1994 and Conception Bay in 1992.

Relative to the bays mean catch rates on the transect lines were relatively low, particularly for age 0 and age 1, and generally quite variable (Figure 9). There was high variability from line to line and year to year with little indication of a latitudinal cline (Figure 9).

Length Frequency Distributions

Length frequency distributions of juvenile cod, for all sets combined (weighted by CPUE), for each of the surveys are shown in Figure 10. Modes in the frequency distributions allow identification of the age 0 and age 1 cohorts in all three years, and the age 2's in 1994 (Figure 10). Notable is the low frequency of age 2 fish (196-290mm.) in 1993.

Using length frequency distributions weighted by catch rate relative abundances in 3K and 3L may be examined (Figure 11). In 2 of 3 years 0's were more abundant in 3L than 3K (Figure 11). In all 3 years age 1's were more abundant in 3L than 3K. In 1994 age 1's produced a very weak mode in 3K, but a strong one in 3L.

Length frequency distributions of juvenile cod caught inshore and offshore (Figure 12) corroborate expanding symbol plots (Figures 4,5,6, and 7) in terms of relative abundance of the age groups in inshore and offshore areas. A numerical comparison of catch rates inshore and offshore (Table 4) corroborates that all of age 0 and nearly all the 1's are inshore. The most distinct mode of age 2's in the distributions was also taken inshore, in 1994 (Table 4, Figure 12). Age 3's are opposite with relatively higher catches offshore than inshore.

Year-Class Strength

Considering the mean catch rates of juvenile cod ages 0-3 over the three survey years, relative year-class strength can be evaluated both among years for a given age and for successive years for a given year-class. At each age sampled the 1991 year-class ranked lowest compared to abundance measured for the 1989, 1990, 1992 and 1993 year-classes at different ages (Table 5). Table 6 shows the results of T-tests between mean log10 catch rate of each of the age groups for the three surveys. Mean catch rate of the 1994 year class (measured as age 0's) increased nearly 7x (Table 2) and was statistically higher (P=0.02) than that of 1992 (Table 6) in the inshore to which they were limited. The 1994 year class was ~3x that of 1993 measured as age 0's (but not statistically higher), (Tables 2,6). Other statistical differences corroborate the ranking and include: the 89 YC > 90YC (P=0.05) and 89 > 91YC (P=0.0002) measured as age 3's. Measured as age 2's in the inshore 90YC > 91YC (P=0.006) and 92YC > 91YC (P=0.04). The 90YC > 91YC (P=0.003) measured as age 3's in the offshore (Table 6).

DISCUSSION

Demersal juvenile cod were distributed throughout the area surveyed during 1992-1994, both inshore and offshore. A significant factor in the catch rate of age 0 and 1 fish was depth, the abundance of these younger juveniles increasing in shallower depths. This is largely due to the fact that, on average, stations fished in the inshore, where most smaller juveniles were captured, were shallower (161-169m.) than those in the offshore (273-284m.). It should be noted however that the minimum depth fished here was 58-59m., significantly deeper than the nearshore (4-7m.) where high numbers of age 0-1 cod are known to occur annually (Lear et al. 1980, Keats et al. 1987, Clark and Green 1990, Keats 1990, Methven and Schneider submitted, Ings et al. submitted).

The positive relationship between catch rate of age 3 fish and temperature is consistent with observations of Kao and Fletcher (1988) and Goddard et al. (1992) in that larger cod, having lower antifreeze protein levels, are not as tolerant of colder temperatures prevalent in the inshore (mean = -0.12 to -0.32 degrees C.) as smaller juvenile cod. Larger juvenile cod, being less freeze resistant, would therefore select warmer water in the offshore (mean = 0.84 - 1.01 degrees C.).

Differences in catch rate between daylight and dark observed in the nearshore were not observed in any survey here, neither in the inshore nor the offshore. A nocturnal inshore migration of 0+

and 1+ juvenile cod has been reported in the nearshore (Keats 1990) and a flexible diel cycle of feeding activity and habitat utilization has been suggested (Keats and Steele 1992). Methven and Badjik (1994) reported significantly higher catch rates of younger juveniles (O's and 1's) in the nearshore that moved into the area at night. The lack of day-night differences in catch rate may also be attributable to the relatively deep water fished here (> 58-59m.) compared to that in the nearshore (<10m.).

There was a clear ontogenetic pattern of distribution observed for juvenile cod. The youngest (age 0) cod that had settled to the bottom by early winter occurred exclusively within the inshore areas. By the following year, at age 1, they were dispersed widely onto shelf areas at depths up to 400 m; although they still existed at higher densities within the inshore. Mean catch rates of age 2 fish were higher inshore during 2 of 3 surveys while catch rates of age 3 were higher offshore in 2 of 3 surveys. This age dependent distribution was also demonstrated for cod, ages one to four years old, from the Canadian fall surveys, where age one cod were predominantly distributed on the shoreward side of the shelves (Anderson 1993). It is not possible to compare historical inshore distributions since no systematic sampling had occurred in the inshore areas.

The coastal distribution of age 0 cod appears more restricted than that recorded historically when the spawning population was larger and more widely dispersed. Qualitatively, Russian data (Bulatova 1962,1963,1971) demonstrates that age 0 cod occurred in the offshore areas off southern Labrador and the northeast coast of Newfoundland. In all cases however, low numbers of settled 0+ cod were taken relative to older age groups. Also, Bogstad et al. (1994), based on fall surveys 1978-1992, showed that larger cod preyed upon low numbers of age 0 cod in the offshore areas of Labrador and the Northeast Newfoundland Shelf (2J3K). The degree of cannibalism was relatively low compared to the phenomenon in cod in Iceland and Norway. This may result from a predominantly coastal distribution of demersal age 0 cod in Newfoundland and Labrador (op. cit.). Alternatively, these surveys (November-December) may occur prior to full settlement of juveniles destined to settle in the deeper waters in offshore areas. Methven and Bajdik (1994), in a review of timing of settlement, concluded that settlement generally occurs earlier in shallower as opposed to deeper water, and earlier at southerly as opposed to more northerly locations. Considering the relatively deep water and high latitude of offshore areas surveyed here, particularly 3K, it is reasonable to assume that any settlement on the shelf areas would occur somewhat later than in the inshore.

The historical Russian information indicates that demersal 1+ (the most recent year-class) cod were found in the offshore in the spring (Bulatova 1963) and as recently as 1989 in 3L (Bulatova 1990). The fact that only low numbers were taken by the Russians on the Flemish Cap supports low catchability of their trawl since this is a relatively isolated stock (Templeman 1979), and larvae and juveniles would be expected to be retained in the area. Despite this low catchability for age 0 cod low numbers were taken.

Catch rates of age 0 cod also appear low here considering they averaged ~30% of mean catch rate at age 1 (Table 2). The Campelen trawl catches age 0 cod abundantly, relative to ages 1 and 2 when available to the trawl (Figure 13) and we therefore consider that gear selectivity is not a problem. The distribution of demersal age 0 cod therefore appears restricted in offshore areas compared to historical distributions when low numbers were taken in a trawl that had low catchability of age 0 fish relative to older juveniles (Bulatova 1962).

It suggests, however, that the age 0 may not be available to the trawl. One explanation is that most 0-group cod occur primarily at depths shallower, and closer to the coast, then we surveyed. Demersal age 0 and 1 year old cod have historically been sampled in the very nearshore region (see above). Anderson and Dalley (1995) reported that their abundance at two inshore study sites remained high until approximately 40-60 m depth, after which it declined. Alternatively, experimental studies have demonstrated that age 0 cod readily seek shelter among cobble (70-200 mm) when threatened (Gotceitas and Brown 1993, Gotceitas et al. submitted). The age 0 cod may have the ability to seek refuge within bottom habitat that affords sufficient cover for them to evade capture by the Campelen bottom trawl.

This may also relate to untrawlable areas. A large proportion of Bonavista Bay in particular is untrawlable. The proportion of trawlable to untrawlable areas, and its relative utilization by juvenile cod, should be determined to avoid a potential source of bias in calculating abundance indices. Habitat selection studies indicate that juvenile cod survival may be affected by substrate types available to newly demersal juveniles, rougher bottom types offering reduced predation risk (Lough et al. 1989; Gotceitus and Brown 1993; Gotceitus et al. in press).

The observation that age 0's were more abundant in 3L than 3K 2 of 3 years and age 1's in all 3 years is consistent with historical data from the offshore (Bulatova 1962,1963,1971,1980) that abundance of youngest juveniles increased from north to south.

The results indicate that relative strength of particular pre-recruit year classes may differ between statistical areas (Figure 12). This dictates the need to consider variation in age structure between areas, in calculating pre-recruit indices of year class strength for the whole stock complex. These differences in year class strength between areas occupied by the stock are important in understanding the spatial dynamics of stock structure as it relates to recruitment. Harris (1990) considered this essential to improved management of the stock.

If Bulatova's (1971) assumption that the age 0 fish collected historically in 3KL were those of 'Labrador Cod', which spawn on offshore banks off southern Labrador and northern Newfoundland, it can be concluded that any recent spawning in these areas has led to little success as measured by settling in the area. An improvement of the success of offshore spawning may be signaled by the re-occurrence of age 0's on the shelf.

Models of egg and larval drift demonstrate that cod eggs spawned on the shelf will largely remain on the shelf, although some portion may drift to the inshore (Helbig et al. 1992, Davidson and deYoung 1994, Pepin and Helbig, submitted). Helbig et al. (1992) concluded that favourable storm tracts were required for significant numbers of eggs and larvae to reach the bays of Northeast Newfoundland. Both historic (Anderson et al. 1995) and recent (Anderson and Dalley, submitted) studies confirm that pelagic juvenile cod do occur extensively offshore several months after spawning, in support of the modelling studies. However, it is unknown what proportion of these fish may have settled in the bays. Also, Hutchings et al. (1993) concluded that inshore spawning populations may provide a considerably larger contribution to cod recruitment in coastal Newfoundland than previously believed. Conversely, Anderson et al. (1995) concluded that the inshore may only account for ten percent of pelagic juvenile cod sampled during the fall.

The most recent demersal survey (1994) indicates that pelagic 0-group cod caught offshore in 3K in 1994 (Anderson and Dalley, submitted) had not settled in the area at the time of the demersal survey, and that a corresponding increase in demersal 0-group juveniles was detected only at the head of Trinity Bay. If the younger juveniles collected in the inshore are derived from inshore spawning only the relative proportion of overall spawning occurring in the offshore has been very small indeed the past three years.

Simple ranking and statistical comparisons of catch rates of recent year classes indicate that the 1991 year-class has made a relatively small contribution to recruitment at age three. Catch rates of the 1994 year class measured as age 0's are ranked higher than the previous two year classes (1993 and 1992) and is statistically higher than 1992 even though increased catch rates were not pervasive throughout the survey area in 1994. The observation agrees with estimates from pelagic juvenile cod surveys carried out 1991-94, where the 1994 year-class was significantly greater than the other years (Anderson and Dalley, submitted). Ings et al. (submitted) also found higher catch rates of age 0's in 1994 compared to 1992 and 1993 such that three independent indices find that 1994 is higher than the previous two years. The 1993 year-class ranked higher than the 1992 year-class at ages 0 and 1 year but no statistical differences were found. Caution should be used in predicting prerecruit year class strength based on mean catch rates of younger age groups. Since high mortality is characteristic of earlier life history stages differences in year class strength based on older age groups take on more biological significance, in terms of eventual recruitment to the fishery, than differences at age 0 and 1.

Previously, the 1989 year-class has been estimated as relatively low compared to recruitment throughout the 1970's and 1980's (Bishop et al. 1994). Therefore, the 1990 and 1991 year-classes can be considered to be near the minimum level of recruitment ever recorded for the Northern cod stock. The higher ranking of year-class strength at two years of age for the 1992 and 1993, year-classes, compared to the 1990 and 1991 year-classes indicates that recruitment to these ages has improved in recent years.

Since relative strength of year classes can be examined in successive years the demersal surveys are a useful tool to monitor prerecruit age groups of Northern cod as the stock rebuilds. It is necessary however to cover inshore areas not presently surveyed during annual groundfish resource surveys (Bishop et al. 1994) considering that such a high proportion, of particularly ages 0-2, juvenile cod occupy the inshore. Considering that large numbers of cod (particularly age 0-1) occur shoreward of inshore areas surveyed here, indices of abundance from the nearshore could be integrated to refine the index. Potential biases in the index could be minimized by determining extent and relative utilization of untrawlable areas by juvenile cod.

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Table 1 : List of research vessel trips comprising the 1992, 1993 and 1994 demersal juvenile cod surveys.

Survey Year	Vessel	Trip Number	Trip Dates	Number of Successful Sets
1992	Wilfred Templeman	131	Dec. 2 - 15/92	64
1993	Wilfred Templeman	147	Dec. 7 - 16/93	41
	Wilfred Templeman	148	Jan. 4 - 13/94	22
1994	Wilfred Templeman	163	Dec. 10 - 20/94	27
	Wilfred Templeman	164	Jan. 4 - 13/95	39

Table 2 : **Summary of mean, minimum, and maximum depth and temperature along each tow path, and CPUE (numbers/30min tow) for each length group, for each of three surveys.**

Length Group	Mean	Min	Max
	1992 (N=64)		
All LG's	52.45	0	548
LG0	3.39	0	76
LG1	27.16	0	425
LG2	16.42	0	226
LG3	5.48	0	47
DEPTH	237.25	59	603
TEMPERATURE	0.46	-1.3	3.8
	1993 (N=63)		
All LG's	52.24	0	820
LG0	8.21	0	218
LG1	34.06	0	591
LG2	5.60	0	48
LG3	4.35	0	100
DEPTH	237.00	59	615
TEMPERATURE	0.42	-1.5	3.9
	1994 (N=66)		
All LG's	99.65	0	2910
LG0	22.17	0	862
LG1	51.86	0	1765
LG2	22.97	0	1000
LG3	2.65	0	45
DEPTH	232.17	58	582
TEMPERATURE	0.53	-1.3	3.7

Table 3. Summary of Pearson's correlation coefficients (and associated probabilities) between log 10 abundance of the various length groups and mean temperature and mean depth along the tow path.

1992

	ALL LG'S	LG0	LG1	LG2	LG3
DEPTH	-0.253*	-0.444**	-0.425**	-0.192	0.115
	0.0440	0.0002	0.0005	0.1274	0.3641
TEMP	0.129	0.055	-0.110	0.129	0.354**
	0.3100	0.6657	0.3848	0.3106	0.0041

1993

	ALL LG'S	LG0	LG1	LG2	LG3
DEPTH	-0.226	-0.532**	-0.557**	0.175	0.538**
	0.0754	0.0001	0.0001	0.1698	0.0001
TEMP	0.047	-0.115	-0.234	0.118	0.4332**
	0.7155	0.3703	0.0652	0.3557	0.0004

1994

	ALL LG'S	LG0	LG1	LG2	LG3
DEPTH	-0.194	-0.535**	-0.435**	0.029	0.376**
	0.1186	0.0001	0.0003	0.8167	0.0019
TEMP	0.022	-0.187	-0.209	0.183	0.437**
	0.8606	0.1338	0.0917	0.1403	0.0002

Table 4. Comparison of mean inshore and offshore catch rates for 0 - 3 age group juvenile cod during demersal juvenile cod surveys carried out in 1992 - 1994. (Catch rate = mean no. fish / 30 min. tow).

Year	Age Group	INSHORE	OFFSHORE
1992	0	8.64	0.03
	1	64.40	3.28
	2	32.28	6.26
	3	5.40	5.54
1993	0	20.64	0.03
	1	83.64	1.45
	2	4.68	6.21
	3	0.88	6.63
1994	0	60.92	0.02
	1	137.92	2.69
	2	52.54	6.07
	3	3.08	2.41

Table 5. Ranking of year-class strength based on the mean catch rate sampled during demersal juvenile surveys 1992-1994.

Ranking	Age 0	Age 1	Age 2	Age 3
High	1994	1993	1992	1989
	1993	1992	1990	1990
Low	1992	1991	1991	1991

Table 6. Comparison of Year Class Strengths based on T-Tests of mean catch rate of each age (length) group during demersal juvenile cod surveys carried out 1992 - 1994.

AGE	1992/1993	1992/1994	1993/1994
		INSHORE + OFFSHORE	
0	93>92 .26	94>92 .08	94>93 .47
1	91>92 .57	93>91 .97	93>92 .54
2	90>91 .06	90>92 .33	92>91 .43
3	89>90 .05*	89>91 .0002*	90>91 .08
		INSHORE	
0	93>92 .21	94>92 .02*	94>93 .24
1	91>92 .99	93>91 .61	93>92 .60
2	90>91 .006*	90>92 .55	92>91 .04*
3	89>90 .01*	89>91 .17	91>90 .26
		OFFSHORE	
0	N\A	N\A	N\A
1	91>92 .14	91>93 .83	93>92 .18
2	91>90 .98	90>92 .49	91>92 .47
3	89>90 .53	89>91 .0002*	90>91 .003*

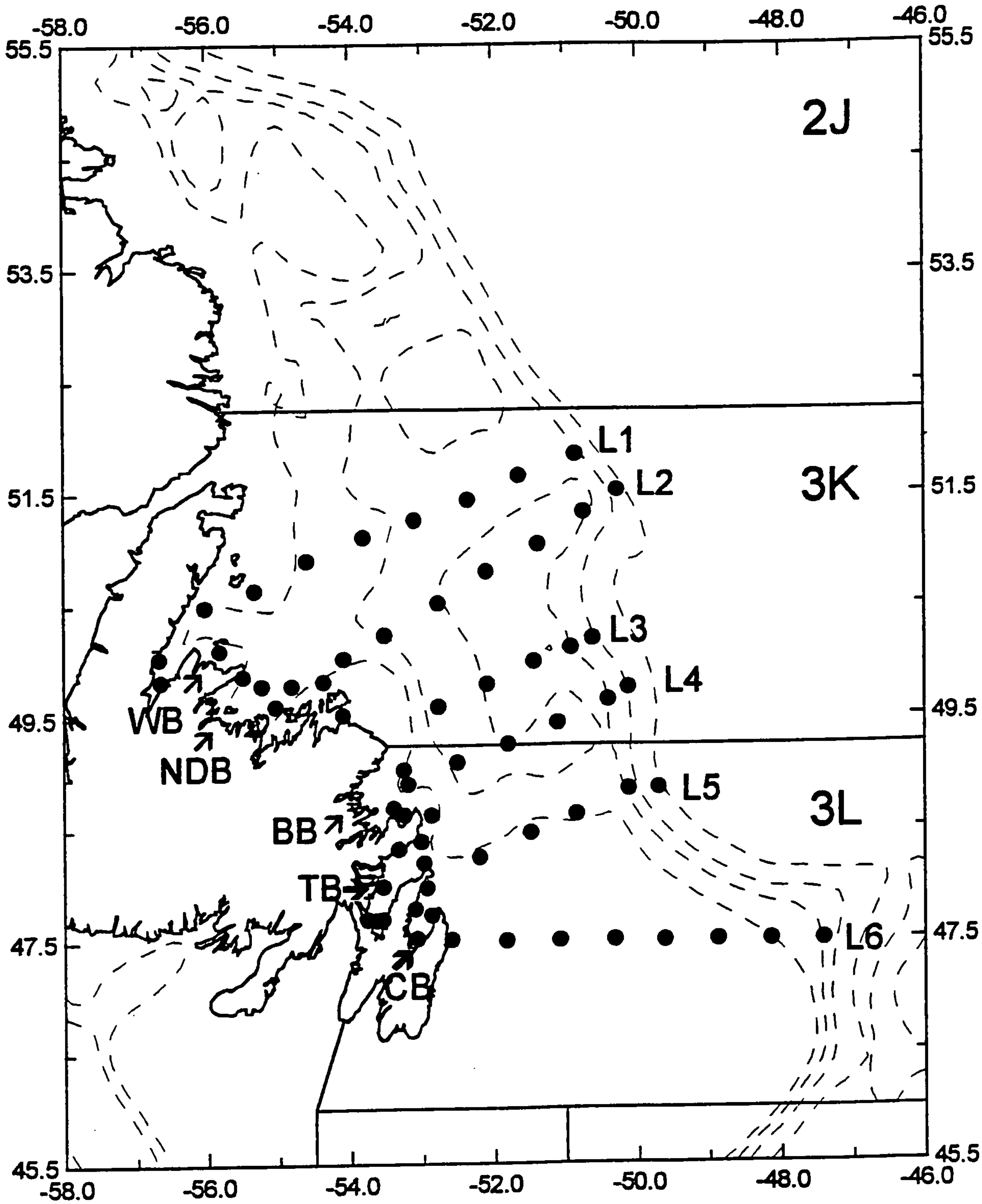


Figure 1. Map of the northeast Newfoundland shelf area showing the positions of stations sampled during demersal juvenile cod surveys on R. V. Wilfred Templeman, 1992-1994. (WB, NDB, BB, TB, CB = White, Notre Dame, Bonavista, Trinity and Conception Bays, respectively, L1 - L6 = transect lines 1 to 6)

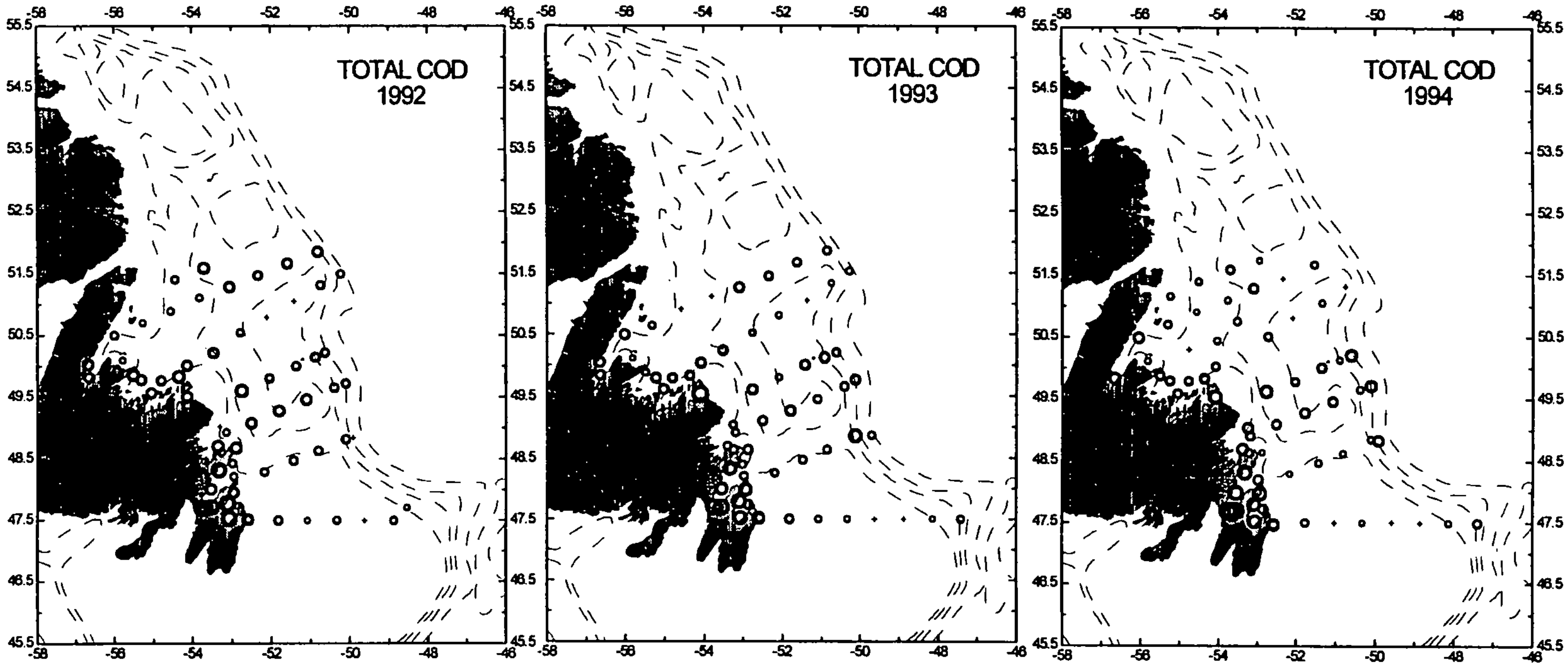


Figure 2. Catch rates of juvenile cod (all size groups combined, <391mm.) sampled during Campelen 1800 trawl surveys carried out, 1992 - 1994. The expanding symbols represent a linear scale based on log10 catches per 30 minute tow. Largest expanding symbol = 2910 fish. Crosses represent zero catches.

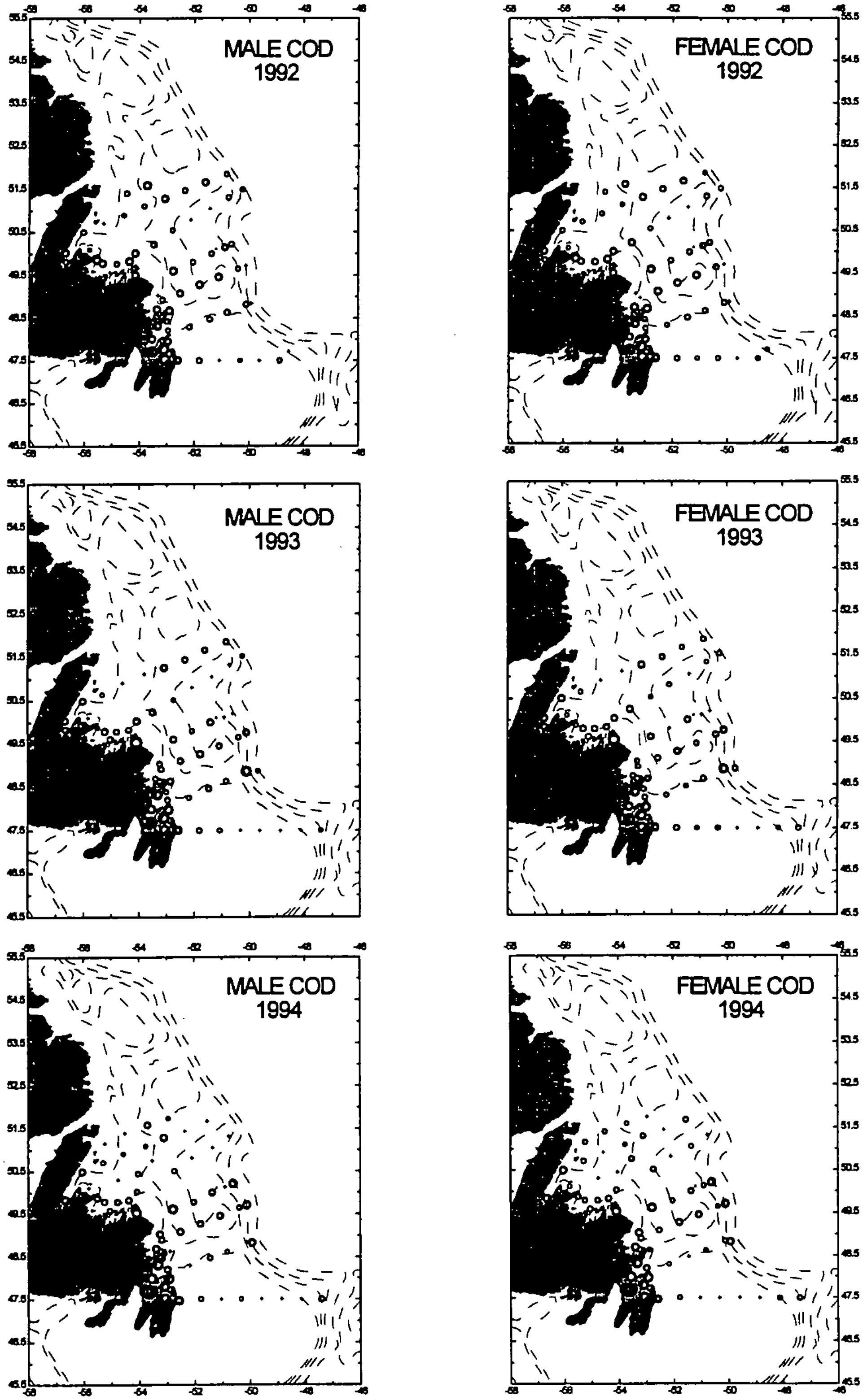


Figure 3. Catch rates of male (left panels) and female (right panels) juvenile cod sampled during Campelen 1800 trawl surveys carried out, 1992 - 1994. The expanding symbols represent a linear scale based on log10 catches per 30 minute tow. Largest expanding symbol = 1484 fish. Crosses represent zero catches.

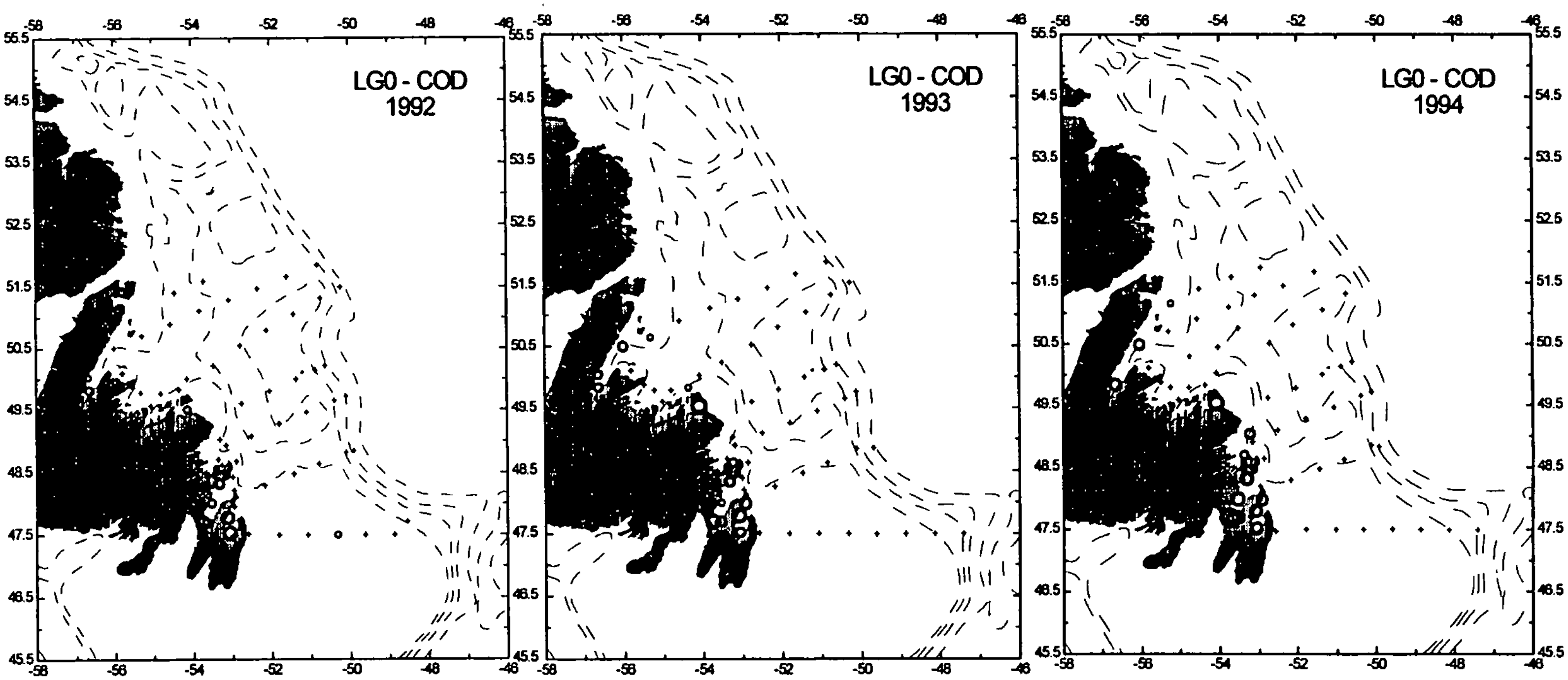


Figure 4. Catch rates of length (age) group 0 juvenile cod sampled during Campelen 1800 trawl surveys carried out, 1992 - 1994. The expanding symbols represent a linear scale based on log10 catches per 30 minute tow. Largest expanding symbol = 862 fish. Crosses represent zero catches.

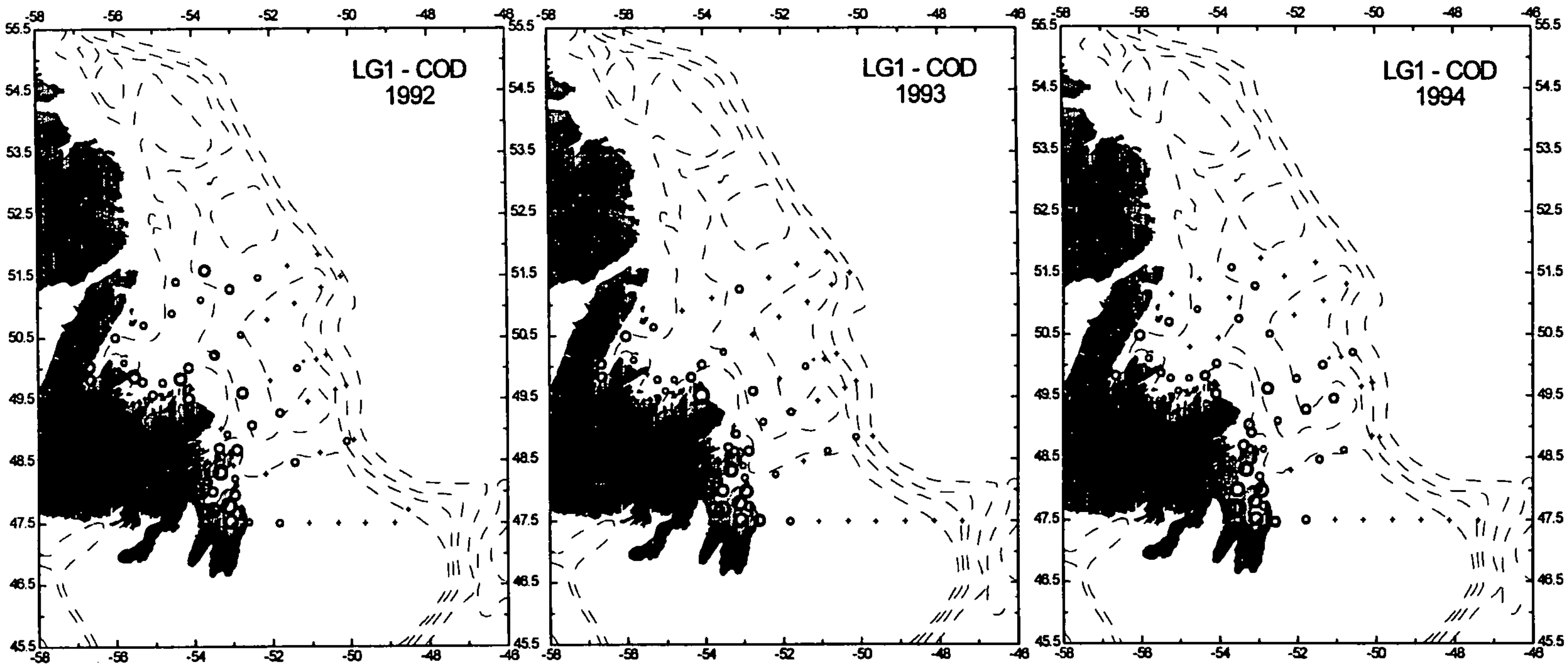


Figure 5. Catch rates of length (age) group 1 juvenile cod sampled during Campelen 1800 trawl surveys carried out, 1992 - 1994. The expanding symbols represent a linear scale based on log10 catches per 30 minute tow. Largest expanding symbol = 1765 fish. Crosses represent zero catches.

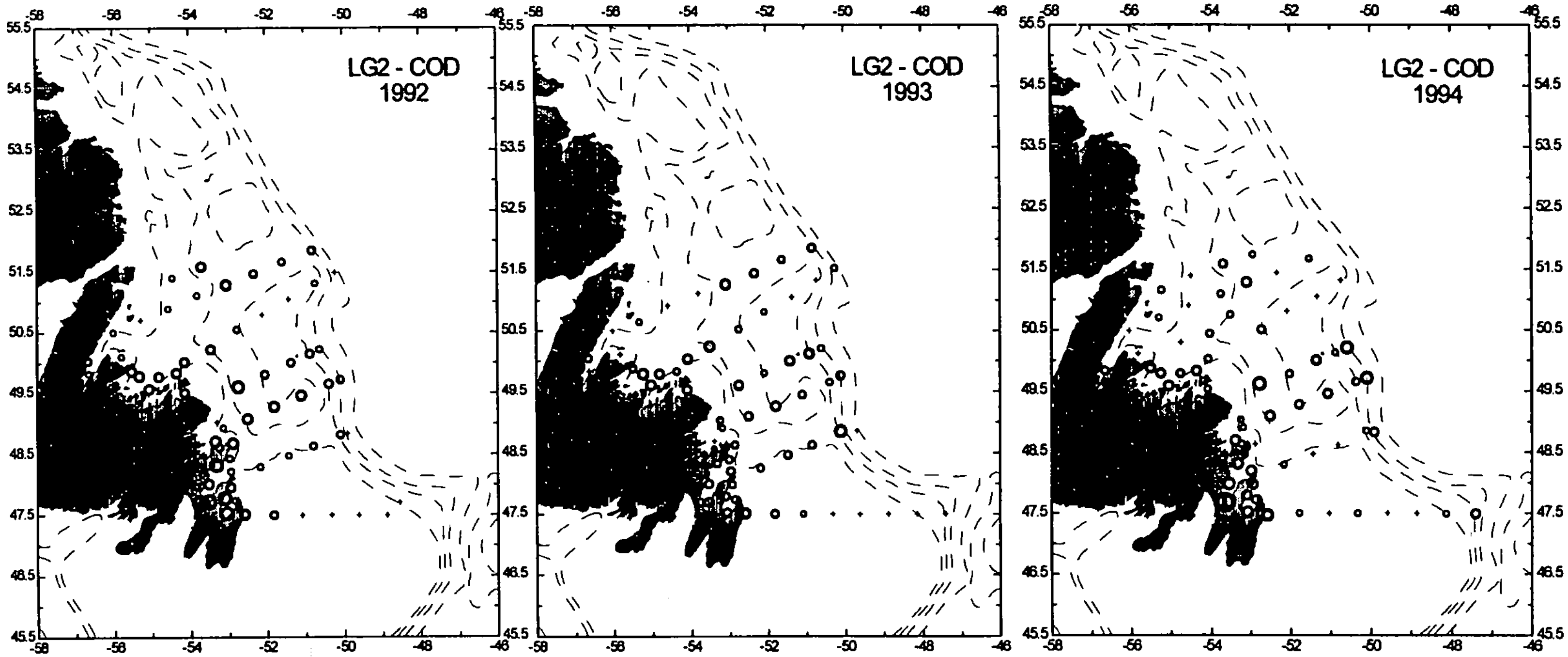


Figure 6. Catch rates of length (age) group 2 juvenile cod sampled during Campelen 1800 trawl surveys carried out, 1992 - 1994. The expanding symbols represent a linear scale based on log10 catches per 30 minute tow. Largest expanding symbol = 1000 fish. Crosses represent zero catches.

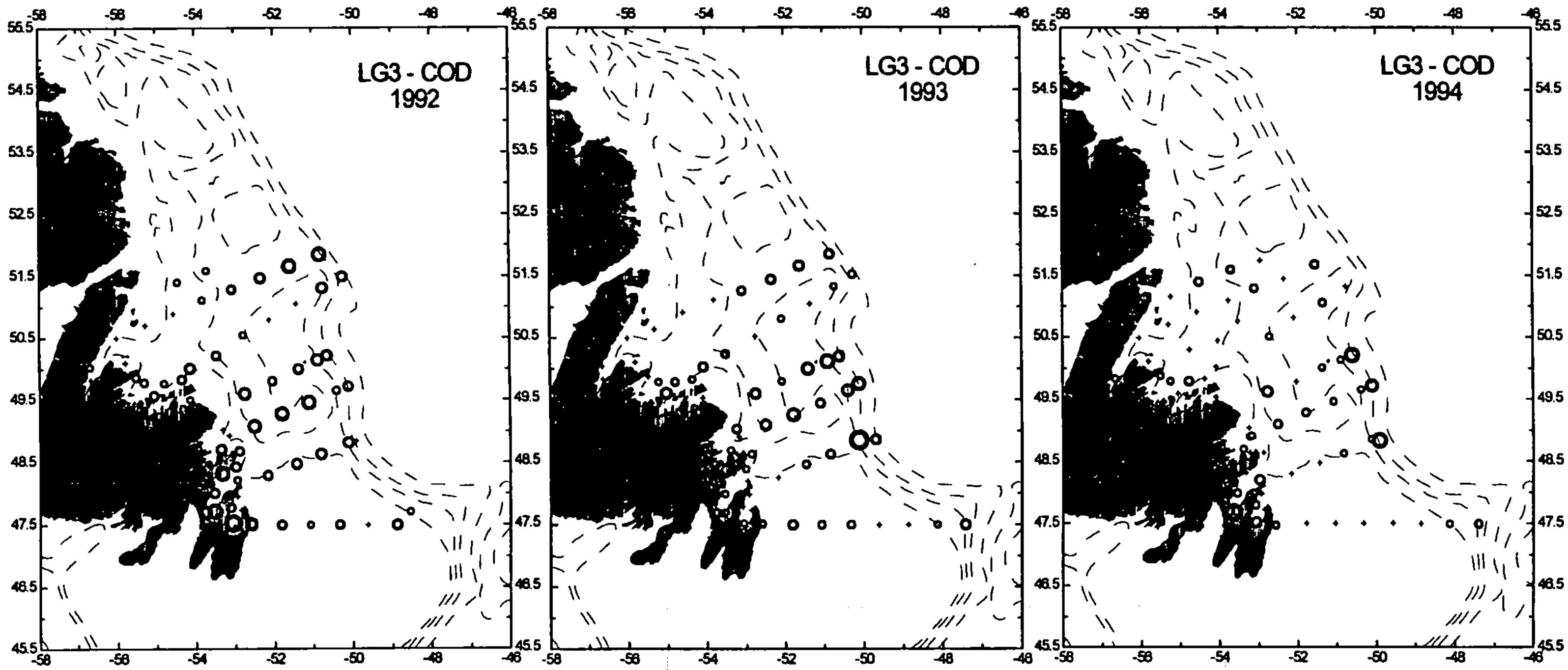


Figure 7. Catch rates of length (age) group 3 juvenile cod sampled during Campelen 1800 trawl surveys carried out, 1992 - 1994. The expanding symbols represent a linear scale based on log10 catches per 30 minute tow. Crosses represent zero catches.

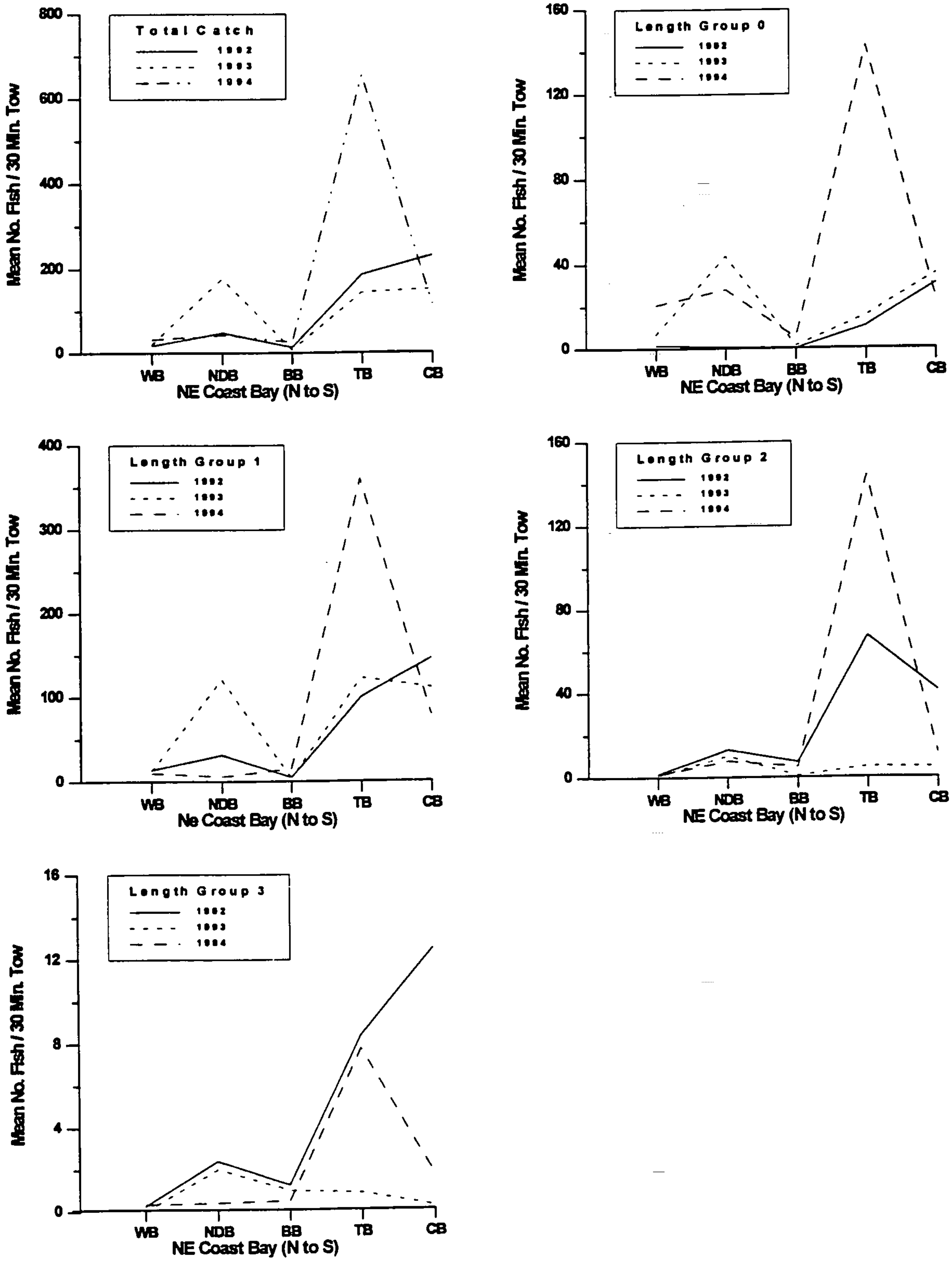


Figure 8. Mean catch rate of all juvenile cod combined, and for each of the length groups approximating age 0-3 in each of the large Northeast coast bays during demersal surveys carried out 1992-1994.

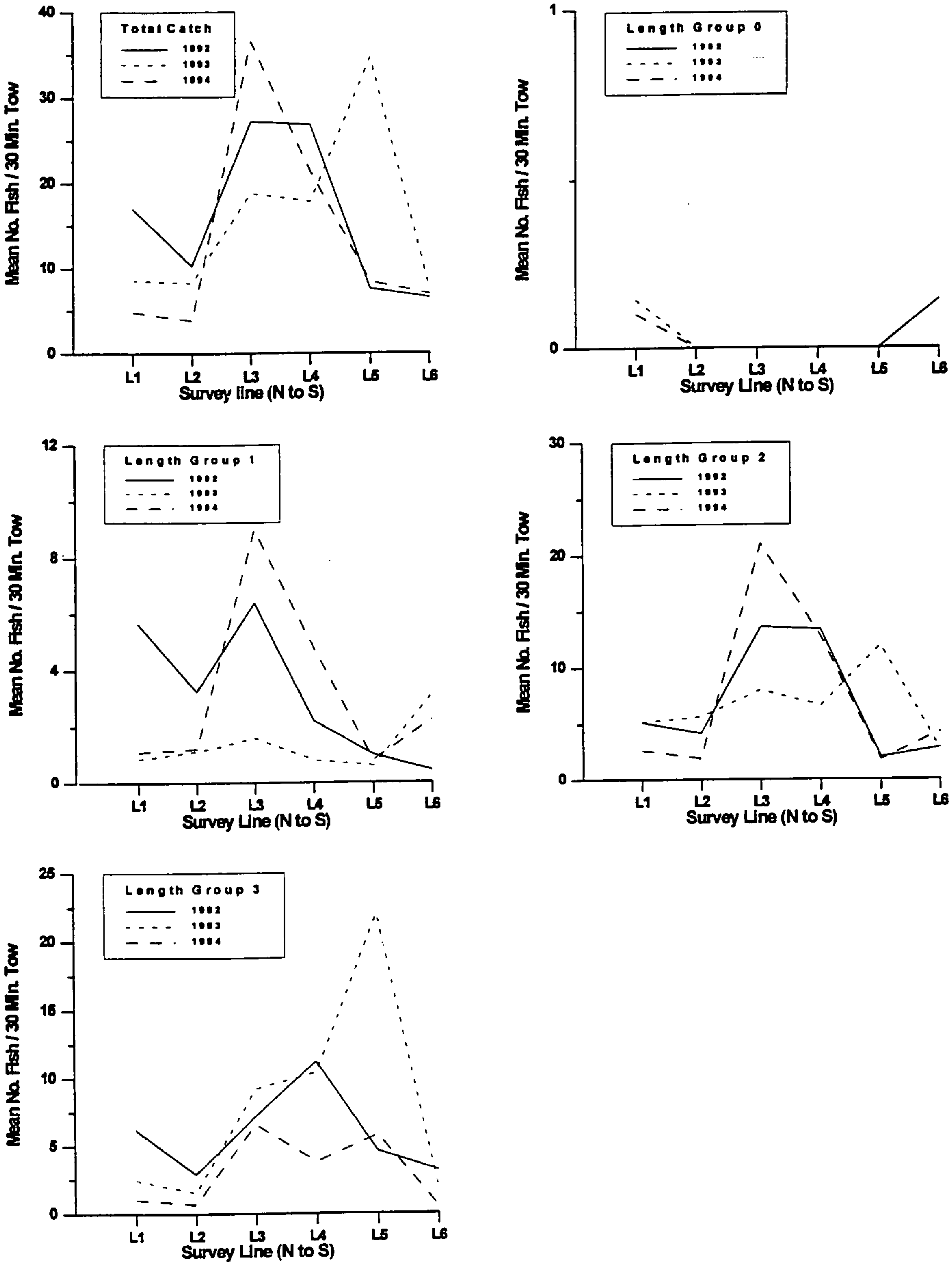


Figure 9. Mean catch rate of all juvenile cod combined, and for each of the length groups approximating age 0-3 in each survey line on the Northeast Newfoundland Shelf and Northern Grand Bank during 1992-1994 demersal surveys.

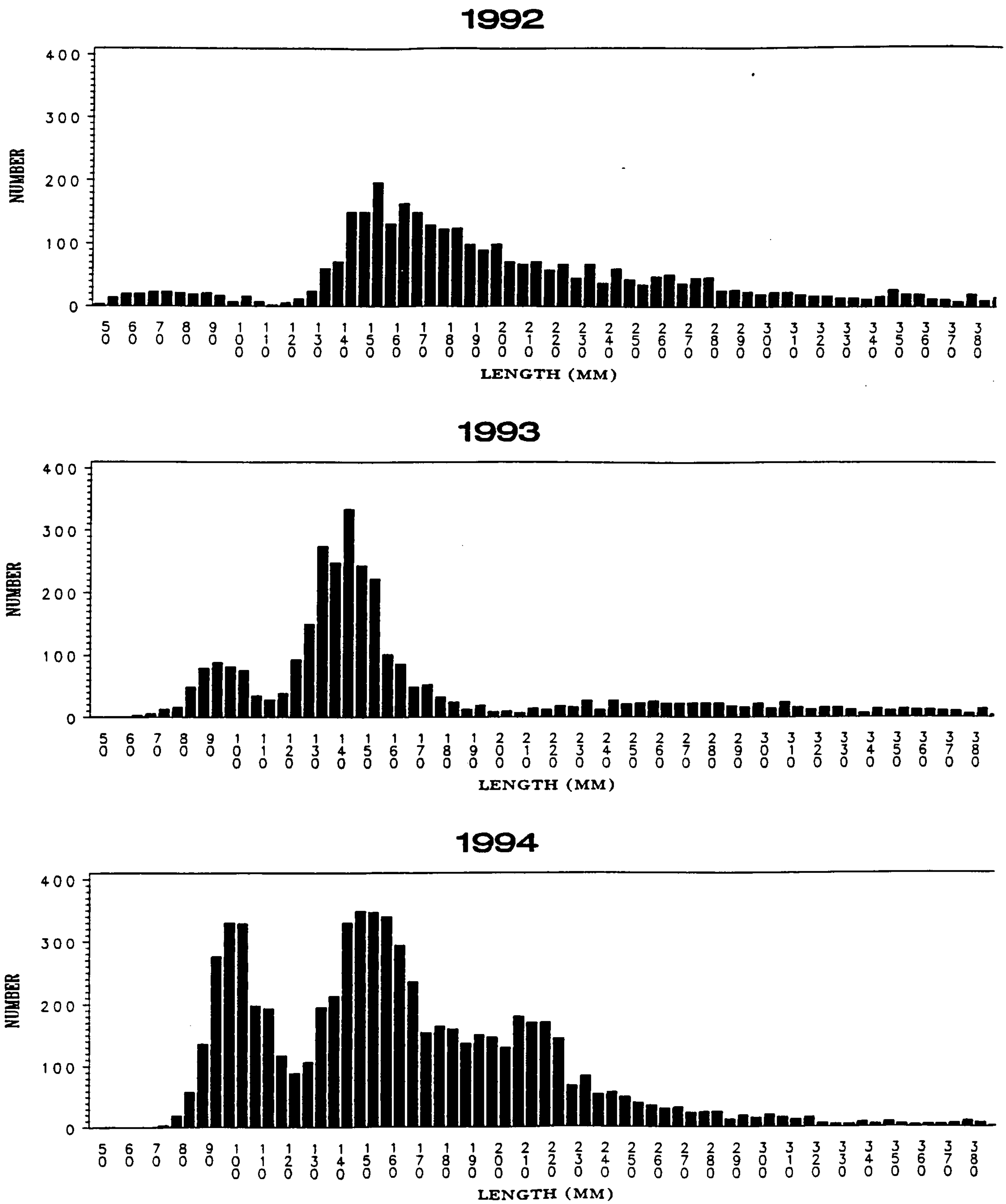


Figure 10. Juvenile cod (<391mm.) length frequency distributions (weighted by CPUE) for all sets combined, from each of three Campelen 1800 trawl surveys carried out 1992-1994.

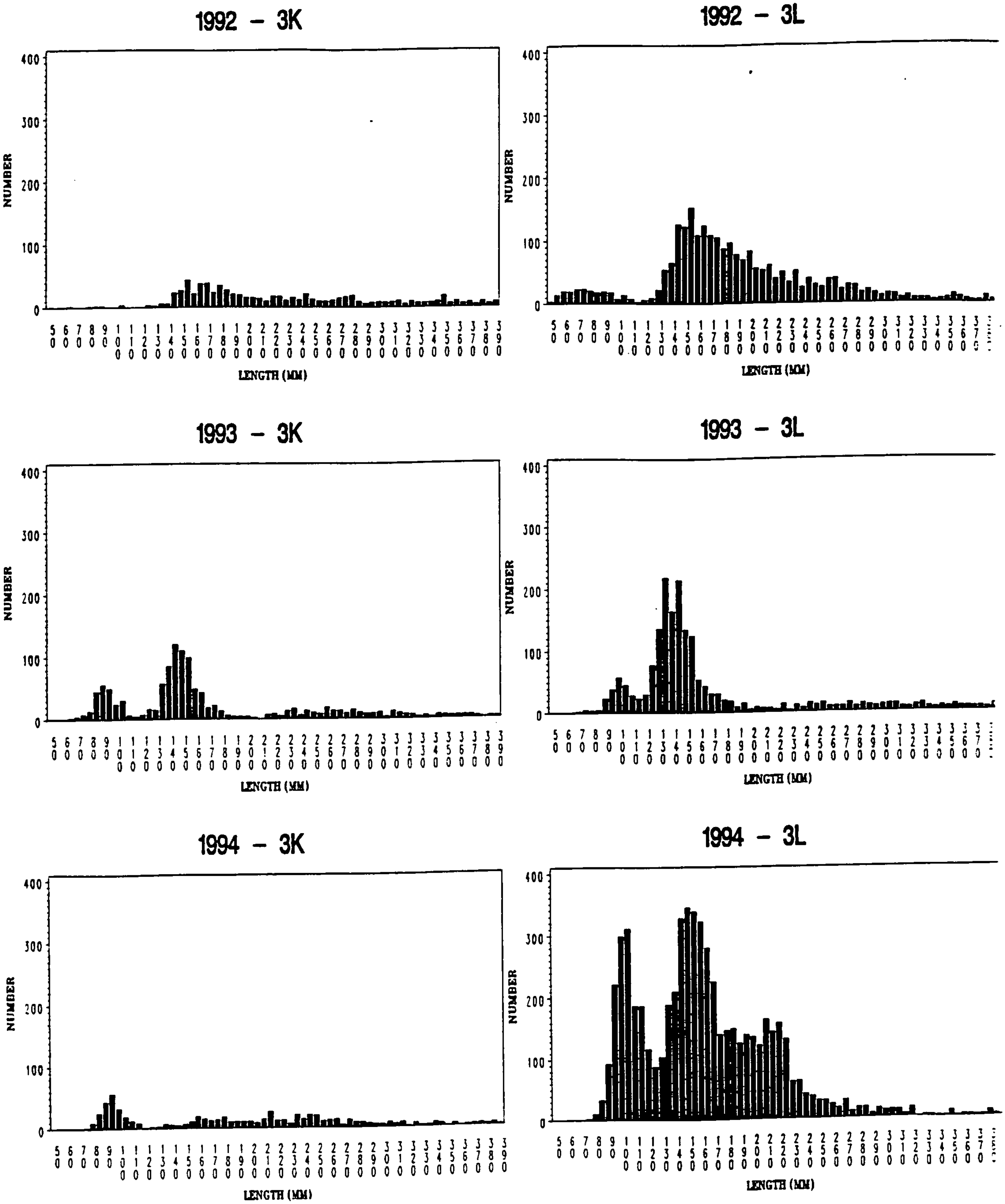


Figure 11. A comparison of weighted length frequency distributions of juvenile cod caught in NAFO Divisions 3K and 3L during Campelen 1800 trawl surveys carried out 1992-1994.

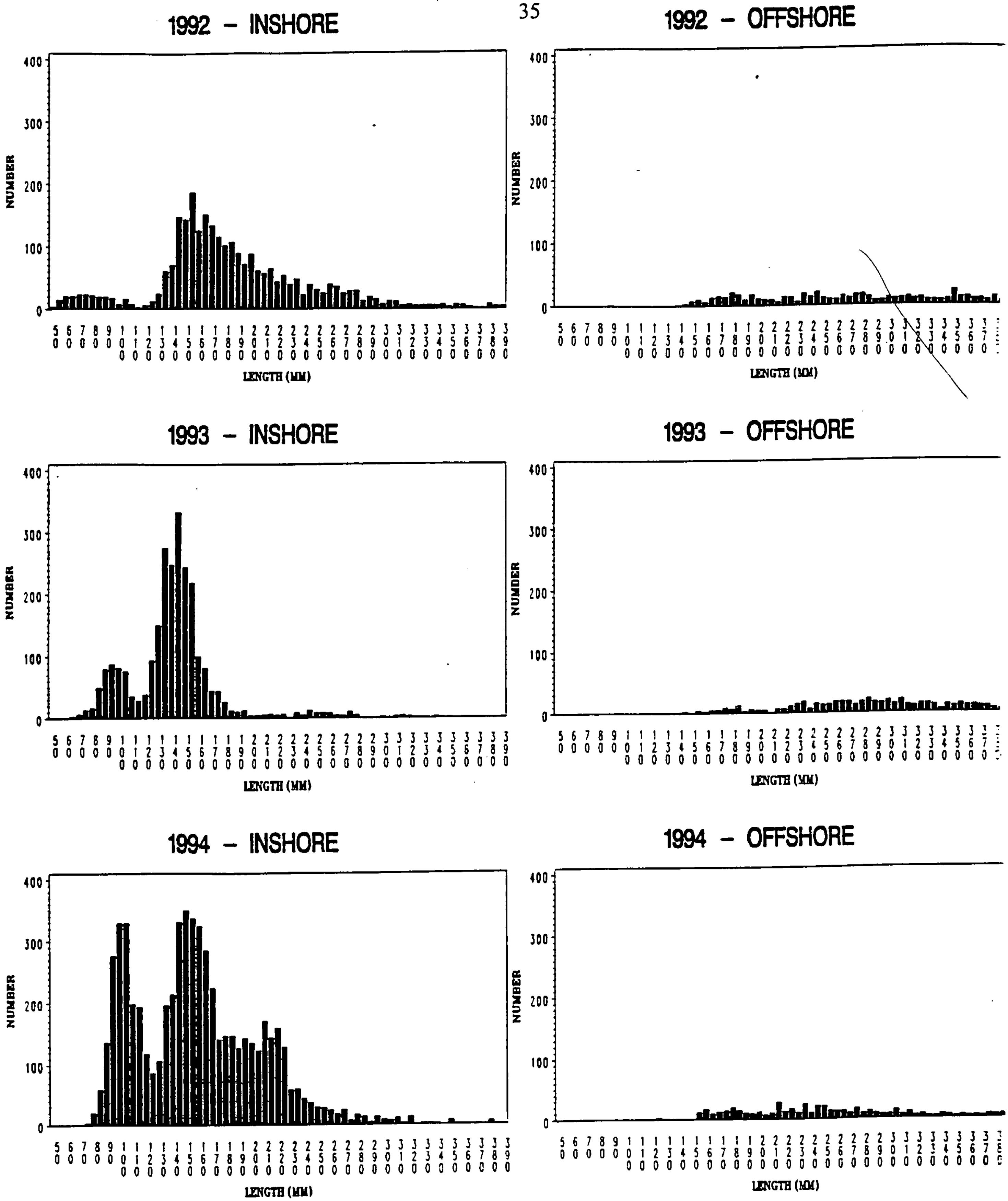
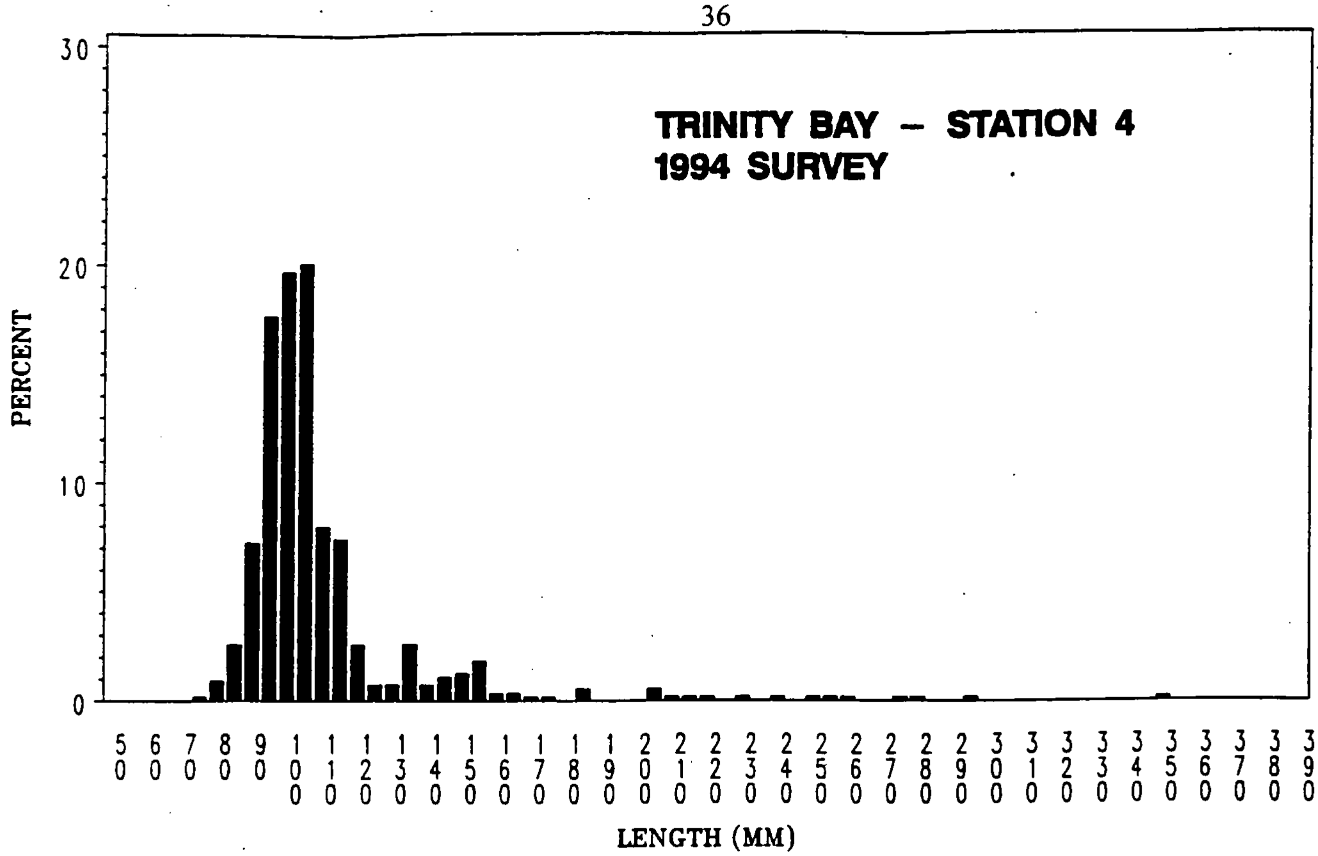


Figure 12. A comparison of weighted length frequency distributions of juvenile cod caught in inshore (large bays) and offshore (transect lines) areas of Northeast Newfoundland, the Northeast Newfoundland shelf and Northern Grand Bank, during Campelen 1800 trawl surveys carried out 1992-1994.



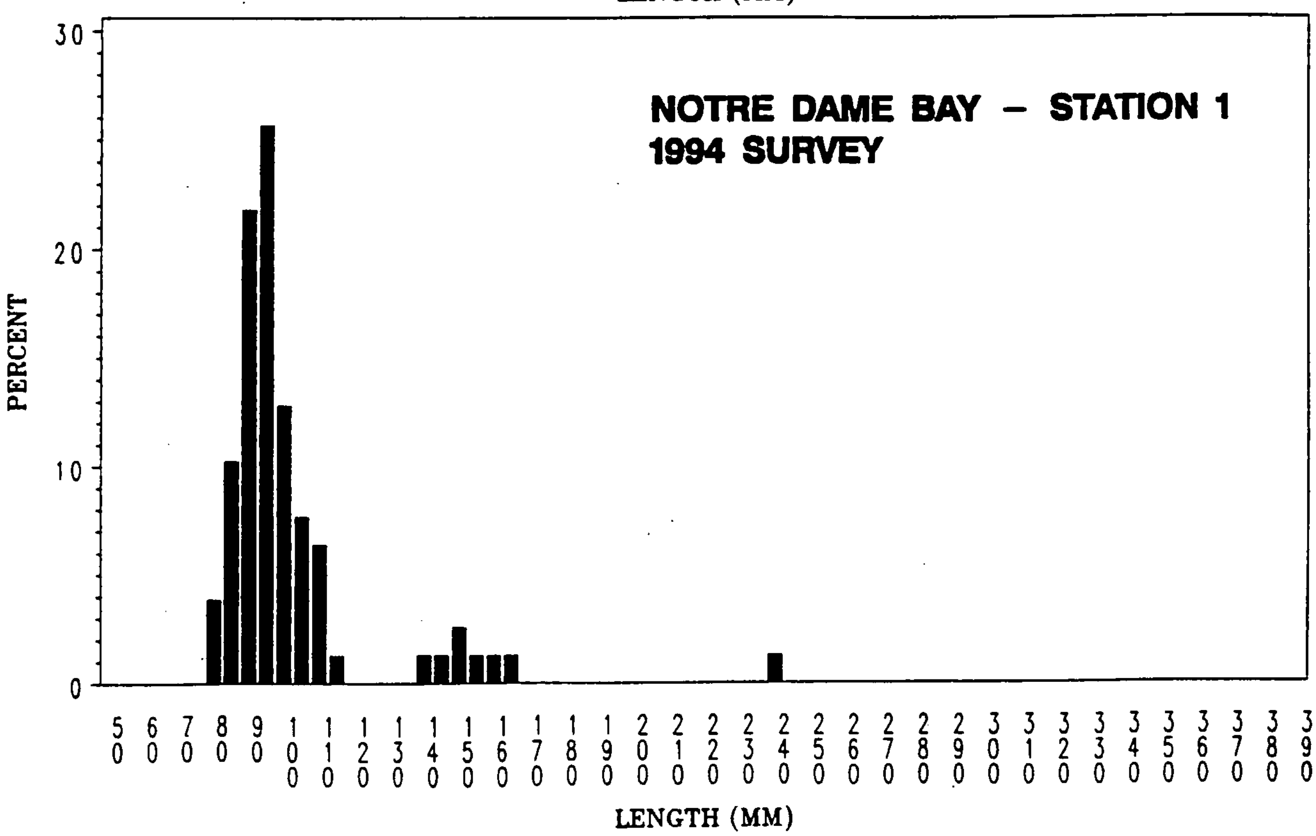


Figure 13. Length frequency distributions from two stations, one in Trinity Bay, the other in Notre Dame Bay indicating a predominance of age group 0 (<116mm.) juvenile cod in the catch.