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Year-Class Strength of Northern Cod (2J3KL) and Southern Grand Bank Cod (3NO) Estimated from the Pelagic Juvenile Fish Survey in 1998

by

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Abstract

The pelagic juvenile fish survey was carried out from August 24 to September 10, 1998 from southern Labrador to the southern Grand Bank, including the inshore areas of the northeast coast of Newfoundland (NAFO 2J3KLNO). Abundance of pelagic juvenile Atlantic cod (*Gadus morhua*) was relatively high in 1998, compared to surveys carried out 1994-1997. The high abundance in 1998 resulted from high abundance on the Grand Bank (3LNO) compared to other years. Abundance on the Northeast Newfoundland Shelf (2J3K) was relatively low offshore while inshore it was mid-range compared to the previous four years. Over the five years during which the survey has been carried out, abundance in 2J3KL declined from 1994 to 1996 and has increased since then. However, abundance in 1997 and 1998 remained below that measured in 1994 and 1995.

Juvenile cod were most abundant in White Bay and Notre Dame Bay along the northeast coast of Newfoundland (3K). Bonavista Bay was not sampled in 1998 due to the early termination of the research trip. However, in previous years Bonavista Bay has ranked among the highest in terms of abundance. Abundance in Trinity and Conception Bays was relatively low and very few cod were found offshore in 2J3K. On the Grand Banks, juvenile cod were found throughout the surveyed area, with the distribution extending onto the northern Grand Bank.

Juvenile cod averaged 18 mm larger and 26 days older on the Grand Banks (3LNO) compared to the northern area (2J3K). Cod in 3NO averaged 62.7 mm and in 3L averaged 67.2 mm in length compared to the north within the inshore bays where cod averaged 43.0-50.3 mm in length.

Growth rates were not different between northern and southern areas in 1998, averaging 0.569 mm d^{-1}. These growth rates fell within the range observed in previous years, 1994-1997.

Larval hatching dates were earlier and spanned a longer period of time in 1998, compared to 1994-1997. On the Grand Banks (3LNO) larval hatching occurred from late April until late July, whereas to the north hatching did not begin until late June and continued into the middle of July. Peak spawning is predicted to have occurred in April on the Grand Banks and in May along the northeast Newfounland coast.

The relatively large year-class measured on the southern Grand Bank in 1998 appears to be a positive response by Atlantic cod to a warmer environment. Warm bottom water temperatures during spring (Colbourne 1999) appear to be related to a successful spawning by cod. To the north, in 2J3K, the production of young fish continues to be low with no sign of recovery six years after the introduction of the fishing moratorium on northern cod.

Résumé

Le relevé des poissons juvéniles pélagiques a été effectué du 24 août au 10 septembre 1998, du sud du Labrador au sud du Grand Banc, y compris les zones côtières du nord-est de Terre-Neuve (divisions 2J3KLNO de l'OPANO). L'abondance des morues de l'Atlantique (*Gadus morhua*) juvéniles pélagiques était relativement grande en 1998, comparativement aux valeurs obtenues suite aux relevés de 1994 à 1997. Cela s'explique par la grande abondance notée en 1998 sur le Grand Banc (3LNO) comparativement aux autres années. Sur le plateau nord-est de Terre-Neuve (2J3K), le niveau d'abondance était relativement faible au large et moyen en zone côtière, par rapport aux quatre années antérieures. Au cours des cinq années où le relevé a été réalisé, l'abondance en 2J3KL a diminué de 1994 à 1996 pour ensuite augmenter. Par ailleurs, le niveau d'abondance de 1997 et 1998 est demeuré inférieur à celui de 1994 et 1995.

Les morues juvéniles étaient les plus abondantes dans les baies White et Notre Dame, le long de la côte nord-est de Terre-Neuve (3K). La baie Bonavista n'a pas fait l'objet d'un relevé en 1998 à cause de la fin hâtive de la campagne de recherche. Mais, au cours des années précédentes, cette baie comptait parmi les endroits où l'abondance était la plus élevée. Le niveau d'abondance des baies Trinity et Conception était relativement faible et très peu de morues ont été décelées en zone hauturière, en 2J3K. Sur les Grands Bancs, les morues juvéniles étaient présentes dans toute la zone du relevé, leur aire s'étendant jusque dans la partie nord du Grand Banc.

En moyenne, les morues juvéniles étaient de 18 mm plus grandes et de 26 jours plus âgées sur les Grands Bancs (3LNO) que dans la partie nord (2J3K). La taille moyenne des morues était de 62,7 mm en 3NO, de 67,2 mm en 3L, comparativement à celle des baies côtières du nord qui était de 43,0 à 50,3 mm.

Les taux de croissance notés pour les parties nord et sud ne différaient pas en 1998 et leur moyenne était de 0,569 mm d^{-1}. Cette valeur se situe dans la gamme observée au cours des années antérieures, de 1994 à 1997.

Par rapport à de 1994 à 1997, les dates d'éclosion étaient plus hâtives et s'étalaient sur une plus longue période. Sur les Grands Bancs (3LNO), l'éclosion est survenue de la fin d'avril à la fin juillet tandis que, dans le nord, elle n'a pas débuté avant la fin de juin et s'est poursuivie jusqu'au milieu de juillet. Il semble que le pic de l'éclosion soit survenu en avril sur les Grands Bancs et en mai le long de la côte nord-est de Terre-Neuve.

La classe d'âge relativement importante notée dans la partie sud du Grand Banc en 1998 semble constituer une réaction favorable de la morue de l'Atlantique à un environnement plus chaud. Un lien semble exister entre les températures élevées au fond pendant le printemps (Colbourne, 1999) et la réussite du frai de la morue. Dans le nord, en 2J3K, la production de jeunes poissons continue d'être faible et il n'y a pas d'indice de rétablissement six ans après l'imposition du moratoire de la pêche de la morue du Nord.

Introduction

Recruitment in Atlantic cod (*Gadus morhua*) is established by the pelagic juvenile stage in most years (Sundby et al. 1989, Assthorsson et al. 1994, Jakupsstovu and Reinert 1994). Occasional failures to predict recruitment have resulted from over estimates, where relatively large year-classes of pelagic juveniles suffer high mortality during their demersal period of life prior to recruitment at age three (Anon. 1995). With sufficiently long time series of data, indices of pelagic juvenile cod abundance can improve analytical predictions of recruitment (Anon. 1997). When predictions fail, we stand to measure important dynamics within cod stocks where mortality during the demersal juvenile stage is known to be density dependent (Myers and Caddigan 1993, Anderson and Gregory 1999). Measures of population abundance before and after the period of demersal juvenile mortality which occurs on one and two year old cod will provide direct estimates of predation mortality.

A research program to develop a multi-species, pre-recruit fish survey in the Newfoundland region was carried out during 1991-1993, as part of the northern Cod Science Program (Anderson and Dalley 1997). Beginning in 1994, a two-ship survey was initiated to measure pre-recruit abundance of cod (*Gadus morhua*) and capelin (*Mallotus villosus*) from the southern Labrador Shelf to the southern Grand Bank (NAFO Divisions 2J3KLNO), including both inshore and offshore areas (Figure 1). A mid-water trawl (IYGPT) and plankton gear (bongo) are used to sample the upper water column for the abundance of pelagic juvenile fish. The surveys are carried out in August and September each year, timed to sample pelagic juvenile cod prior to settlement and to catch larval capelin following their release from beach and bottom sediments.

In this paper we report on the results of the 1998 survey for the northern (2J3KL) and southern Grand Banks cod stocks (3NO). We examine results of abundances, distributions, sizes (length, weight, condition), ages, growth rates and hatching dates of pelagic juvenile (0-group) Atlantic cod and compare these results to those of the 1994–1997 surveys. We discuss these results in terms of the production of cod from the existing populations and predictions of recruitment in these two stocks.

Materials and Methods

The surveys are designed to capture plankton (0.3–10 mm) and nekton (10–200 mm) across almost three orders of magnitude in size, as a broad-scale measure of these communities in late summer, following the spring and summer spawning periods. The surveys have been carried out in August and September each year (Table 1). The survey design is based on a systematic survey grid at 55 km (30 mm) station spacing. This design is equivalent to a systematic stratified sampling design, where the first station was selected randomly from one 55x55 km stratum (Snedcor and Cochrane 1967). Within the bays, stations were positioned approximately 55 km apart through the center of each bay.

The 1998 survey was carried out from August 24 until September 10, which was similar to the dates of the 1994 and 1996 surveys, earlier than the 1995 survey and later than the 1997 survey. A smaller number of stations were sampled in 1998, compared to previous surveys of comparable duration, due to the early termination of the north ship (Teleost Trip 69) and due to poor weather and ship maintenance problems with the south ship (Wilfred Templeman Trip 226). The unpredicted termination of the Teleost trip resulted in the loss of the Bonavista Bay area from the survey index in 1998. The reduced survey time of the Templeman trip resulted in the loss of the Southern Avalon area from the survey index in 1998.

At each station a SeaBird 25 CTD fitted with a fluorometer was lowered to a maximum depth of 500 m, followed by a plankton tow (0-100 m) and then a mid-water trawl (20-60 m). Plankton were sampled using a bongo sampler (61 cm, 0.232 mm mesh) towed at 1.25-1.5 m s^{-1} using a double oblique haul 0-100 m with payout and retrieval rates of approximately 0.8 and 0.4 m s^{-1}, respectively. Beginning in 1996, 0.232 mm and 0.505 mm mesh nets were used on each side of the bongo sampler to measure invertebrate zooplankton and ichthyoplankton, respectively. The bongo sampler was instrumented and transmitted data in real time to the ship, including sampler speed, volume filtered, distance towed, sampling time, salinity, temperature and depth. The IYGPT (International Young Gadoids Pelagic Trawl) is a pelagic mid-water trawl designed to catch pelagic juvenile gadoids with an effective opening of approximately 10 m by 10 m, (Anderson and Dalley 1997). The IYGPT trawl was towed at 1.25-1.5 m s^{-1} for 30 minutes, slowly oscillating the head rope between 20-50 m depth through two complete cycles, such that the trawl sampled the 20-60 m depth stratum. The trawl depth and configuration were monitored using acoustic net sensors (Scanmar) to measure net depth, net opening, wing and door widths. For both samplers, the net performance data were used to estimate the volume of water (m^3) filtered during the tow to standardize catch rates.

The IYGPT trawl catches were processed at sea, identifying all fish to species level, where possible, and recording total length for fish species. Total lengths of pelagic juvenile (0-group) Atlantic cod (*Gadus morhua*) were recorded at sea, prior to preservation in alcohol (1994) or frozen (1995). Total length was recorded again at the time of otolith extraction. Over the four years examined, changes in mean total length were not systematic. In fact, for two of the years mean length increased by ~1%, whereas in the other two years mean length decreased by ~2%. Since the change in length over the period of preservation was small and not systematic, preserved lengths were used in all analyses. All other species were preserved in 5% buffered formalin. Total trawl wet weight was also estimated (g). In 1994 this weight included jelly fish, whereas in subsequent years jelly fish were weighed separately. Wet weight was also determined for the dominant species sorted from the catch. Squid were counted and weighed but not speciated. Samples of squid were preserved in formalin and returned to the laboratory for taxonomic identification.

Samples from one side of the bongo were sub-sampled at sea for identification and measurement of capelin and herring larvae, without replacement. Sorted samples were preserved in alcohol. The remainder of the sample was processed in the laboratory, following standard procedures for fish eggs and larvae (Smith and Richardson 1997). From the other bongo sample, the plankton was split into two equal halves using a Motoda plankton splitter. One half of this sample was divided into three size categories (< 1 mm, 1-2 mm, > 2 mm), dried for 24 h at 55-60°C and weighed to the nearest milligram. Selected zooplankton samples from 1994 (n=29) and 1995 (n=29) were processed for full taxonomic classification following standard laboratory procedures.

Atlantic cod were measured for total length, preserved frozen and returned to the laboratory where the otoliths (sagittae and lapillae) were removed, measured and mounted on microscope slides using "crystal bond". Otoliths were polished to their central plane using different grades of lapping film. In most cases lapillae were aged under a light microscope at magnifications of 400 to 1000 times with the assistance of an Optimus Image Analysis System. Replicate readings of daily rings were made to ensure consistency of the age estimates. When age estimates of replicate readings differed by more than 10% then the otolith was discarded. Samples for otolith age analyses were stratified across all length groups and for different geographic areas, when possible. Hatch date was estimated as the difference between the age of the fish subtracted from the date of capture. The hatching date frequency distribution was estimated by adjusting the age frequency distribution for a fixed mortality rate of 0.04 d^{-1}, as $N_{0i} = N_{1i} \cdot e^{-zt}$ where N_0 is the number at the time of hatching, N_1 is the number at the date of capture, z is the daily instantaneous mortality rate, and t is the age and i is the age group.

Dry weight (g) of cod was estimated from those specimens used for otolith extraction and age estimation. Prior to weighing, each specimen was measured for standard length and total length to the nearest millimeter. Each fish was placed on a tared weighing disc, weighed to the nearest 0.001 gram (wet weight) and then placed in a drying oven at 75°C for 24 hours. Following drying, each fish was placed in a dessicator to cool and then re-weighed to the nearest 0.001 gram (dry weight).

An abundance index was developed based on a number of selected areas, following the method of Randa (1982). These Index Areas were chosen to represent different regions for inshore and offshore locations (Figure 1). The index is dependent on all stations being sampled within each area for a given year. When two or more areas have been sampled, an area weighted overall index of abundance can be derived. The basic index for a unit area is calculated as,

$$I_j = \overline{X}_j \cdot p_j$$

where, I_j is the index of abundance for area$_j$, $\overline{X}_j$ is the geometric mean abundance ($\log_e$ number $10^4 m^{-3}$) and p_j is the proportion of non-zero catches. The geometric mean abundance is calculated for each Index Area as,

$$\overline{X_j} = \frac{1}{N_{lj}} \cdot \sum_{i=1}^{N_{lj}} \cdot ln(X_{ij})$$

where N_{lj} is the number of non-zero catches and the variance of $\overline{X_j}$ is calculated as,

$$S_j^2 = \frac{1}{N_{lj} - 1} \cdot \sum_{i=1}^{N_{lj}} \cdot (ln(X_{ij}) - \overline{X}_j)$$

where a is the number of zero catches. Finally the Index Area is weighted by the size of each area as,

$$P_j = a_j \cdot I_j$$

where a_j is area of each Index Area (km^2).

An overall index for several commonly sampled areas can be estimated as the sum of the weighted Index Area values

$$SUM_{P_j} = \sum_{j=1}^{k} P_j$$

where k is the total number of commonly sampled Index Areas.

Results

Abundance

There has been a trend of decreasing abundance from 1994-1996, followed by an increase in abundance from 1996-1998 for northern cod (2J3KL) (Figure 2). Abundance in 1998 increase from 1996 and 1997 but remained lower than 1994 and 1995. However, the abundance in 2J3KL in 1998 was influenced by the relatively high abundance in 3L, which was a direct extension of the abundant fish distribution observed throughout the southern Grand Bank (3NO) in 1998 (see below). When we compared abundance of Atlantic cod in the northern part of the stock area (2J3K) to previous years, 1998 ranked in the middle, comparable to 1997, lower than 1994 and 1995 and higher than 1996 (Table 2).

Inshore in 2J3K, abundance in 1998 ranked third highest for the period 1994-1998; lower than 1994 and 1995 but higher than 1996 and 1997 (Table 2). However, we note that the inshore value in 1998 was estimated without an index area value from Bonavista Bay. Previously, Bonavista Bay has been an important area for Atlantic cod ranking either first or second in abundance compared to the other inshore areas. If we make the simple assumption that the abundance of Atlantic cod in Bonavista Bay in 1998 was comparable to the previous four years, the average abundance index is 2.32. Recalculating the inshore summed index using this historical average for Bonavista Bay gives a total of 11.60, which still ranks third in abundance. Similarly, if we use the maximum index value previously observed in Bonavista Bay, 3.86 in 1994, the summed total is 13.23, which still ranks third highest in abundance inshore. Therefore, we conclude that the inshore abundance in 1998 ranks third overall.

Offshore in 2J3K (Index Areas: ISN, ISS, BIBI, FIBI), the abundance of pelagic juvenile cod has varied logarithmically from a maximum in 1994 (16.6) to a minimum in 1996 (0.2). Abundances among the remaining three years were similar and lay between these extremes (2.0–3.8). Except for 1994, there has been almost no production of juvenile cod offshore in 2J3K.

On the southern Grand Bank (3NO), there was a significant increase in abundance in 1998 compared to the previous four years (Figure 2, Table 2). In 1994 we observed cod distributed over a small but continuous area of the southern Grand Bank (Anderson et al. 1998) but abundance was only 20% of that measured in 1998. In the intervening there was a sporadic distribution of cod, where index values ranged from 0.4–1.1 (Table 2).

Distributions

Inshore for the 2J3KL stock area, pelagic juvenile cod were distributed throughout White Bay and Notre Dame Bay but were less abundantly distributed in Trinity and Conception Bays, occurring primarily at the heads of the bays (Figure 3). Offshore, there were very few cod until reaching approximately 47 °N latitude on the northern Grand Bank. Notably, we observed a small number of cod at two stations near the coast of southern Labrador.

On the southern Grand Bank (3NO), cod were distributed throughout the surveyed area, although abundance declined to zero values at the south and eastern extent of the survey (Figure 3). Abundance was highest within the central portion of the southern Grand Banks. Cod were abundant at the western edge of the surveyed area and the extent to which these distributions continued into the adjacent St. Pierre stock area (3Ps) remains unknown.

Length, Weight and Relative Condition

Cod were longer in 1998 than any of the previous years, averaging 57.4 mm compared to 39.3–45.3 mm in 1994-1997. The length frequency distribution extended from 40–75 mm (Figure 3). The larger length of fish in 1998 was due entirely to fish caught on the Grand Banks. In 3NO (SGB), fish length averaged 62.7 mm and in 3L (NGB) 67.2 mm. To the north, within the inshore bays, cod averaged 43.0–50.3 mm in length. Overall, fish in the northern part of the surveyed area (2J3K) averaged 47 mm compared to 65 mm in the south (3NO), a difference of 18 mm.

Fish weight increased exponentially with length, as in previous years (Figure 4, Anderson et al. 1998). On average, fish in 3NO weighed less than fish in 2J3KL over all lengths. However, we note that the large fish measured on the northern Grand Bank (3L) were a direct extension of the fish distribution for the southern Grand Bank.

Relative fish condition, measured as Fulton's K, was 1.34 in 1998 (Table 4). This is the lowest measure of condition observed during the period 1995–1997 when condition ranged from 1.61–1.78.

Age and Growth

For the entire surveyed area, 2J3KLNO, cod were older in 1998 compared to the previous four years, averaging 93 days of age (Table 3). In 1994, cod averaged 80 days in age while in 1995–1997 cod averaged 65–69 days in age. Growth rate averaged 0.569 mm d^{-1} in 1998, which was similar to previous years (Table 3). In addition, there was no significant difference in growth rates for the smaller cod measured in Notre Dame Bay compared to the larger cod measured on the southern Grand Bank (Table 3). Given the similar growth rates among areas in 1998, the larger cod in the south were much older. On the southern Grand Bank, pelagic juvenile cod averaged 101 days old, compared to 75 days of age in White and Notre Dame Bays, a difference of approximately one month. In Trinity Bay, the fish averaged 94 days of age.

Hatching and Spawning Times

Larval hatching dates were earlier and spanned a longer period of time in 1998, compared to the previous four years (Figure 5). Peak hatching occurred in late May 1998, whereas peak hatching in the preceeding years occurred in June and July. The earlier hatching times in 1998 occurred entirely in the south on the Grand Banks, where larvae hatched from late April until late July (Figure 6). To the north, in White Bay and Notre Dame Bay, hatching did not begin until late June and continued into the middle of July (Figure 6). Assuming an approximate 30 day egg development time, spawning on the Grand Banks would have occurred primarily in April while to the north it occurred primarily in May.

Discussion

The most dramatic difference observed in the abundance of pelagic juvenile cod in 1998 was the broad distribution and relatively high abundance on the Grand Banks (3LNO). The large size and earlier spawning period of Grand Banks cod indicates a significant and successful spawning occurred on the southern Grand Banks in 1998 that was distinct from spawning to the north in 2J and 3K. This was the most significant successful spawning by cod on the southern Grand Banks since our surveys began in 1994. This occurred coincident with a large positive temperature signal in the bottom waters during the spring spawning period (Colbourne 1999). Unpublished reports of significant concentrations of large spawning cod and haddock in the western area of 3NO and the extreme eastern portion of 3Ps indicate that the warm water environment favoured the occurrence of spawning cod on the southern Grand Banks in 1998.

Several factors indicate that cod sampled on the northern Grand Bank (3L) originated from spawning on the southern Grand Bank (3NO). These factors include:

1. The continuous distribution of juvenile cod from the southern to northern Grand Banks.

2. The larger lengths, older ages and earlier hatching and spawning times of juvenile cod in 3L were comparable to those in 3NO, whereas cod to the north (2J3K) were smaller, younger and spawned almost one month later.
3. Cod in 3L were slightly longer and older than cod in 3NO which is consistent with spawning to the south and dispersal to the north.

Therefore, the significant production of juvenile cod in 1998 appeared to result from spawning of the southern Grand Banks cod stock.

The annual production of juvenile fish within the northern cod stock area (2J3KL) remained low in 1998. Although abundance increased in 1998 relative to that in 1996 and 1997, it remained significantly below that measured in 1994. The most significant concentration of cod occurred in White Bay and Notre Dame Bays, similar to previous years. While Bonavista Bay was not sampled in 1998, we assume that the production of fish in Bonavista Bay would have been comparable to that in White and Notre Dame Bays, as in previous years. The production of juvenile cod offshore remained extremely low, indicating that very little successful spawning occurred offshore in 1998. The production of juvenile cod appears to be confined to the inshore and primarily to the north of Trinity and Conception Bays. However, even within the inshore, the production of young fish in 1998 remained below that of 1994 and 1995. Based on our indices of year-class abundance, there has been no increase in the production of juvenile cod six years after the implementation of a fishing moratorium.

Ocean temperatures in the upper 170 m have been increasing since 1991 and recently temperatures have been at or above the historical mean (Colbourne 1998). Both capelin (*Mallotus villosus*) and Arctic cod (*Boreogadus saida*) have responded to these warmer temperatures by increasing and decreasing annual year-class abundance, respectively, during the 1990's (Dalley and Anderson 1998). We regard such changes as expected, where we consider Arctic cod as representative of cold water conditions and capelin to be representative of warmer water conditions. Together, these physical and biological changes indicate that the ocean environment is changing from the cold water regime of the early 1990's to a warmer water regime characteristic of previous years. In general, a warmer ocean climate should favour the survival of cod eggs and larvae (deYoung and Rose 1993). Therefore, we hypothesize that the low levels of young fish production by the northern cod stock results from a low level of spawner biomass and is not due to low egg and larval survival from a relatively large spawning stock.

Recruitment in northern cod was measured previously as the population abundance of three year old cod, as estimated using sequential population models. However, with the collapse of the commercial fishery the traditional assessment methods using analytical models (VPA) within a tuning framework (ADAPT) have failed. Most recently, abundance at age three has been approximated using the mean catch rate of three year old cod in the autumn research vessel survey (catch/tow) (Lilly et al. 1998). However, beginning with the 1995 survey, changes in the trawl have complicated a direct comparison to historical survey data. Presently, three years of survey data using the Campelen trawl, 1995–1997, give unadjusted abundance estimates of the 1992–1994 year-classes at age three. These data indicate that the 1994 year-class was highest in 2J and 3L but that the 1992 year-class was highest in 3K (op. cit.). The differences among values each year in divisions 3K and 3L are small. Compared to the historical times series, based on trawl catchability coefficients, the abundance of the 1994 year-class is amongst the lowest on record. However, the bottom trawl survey indices are based exclusively on offshore data that do not account for abundances of juvenile cod inshore, where the majority of juvenile cod are known to exist (Dalley and Anderson 1997). Therefore, assessing the predictive power of the pelagic juvenile cod recruitment index is problematic, awaiting the development of a comprehensive and robust measure of recruitment for the northern cod stock at ages three or four years.

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Table 1. Summary of Pelagic Juvenile Fish Surveys conducted, 1994-1998. Bongo–bongo plankton sampler; IYGPT–International Young Gadoids Pelagic Trawl. DoY–refers to the calendar day of the year; Start, End and Mid refer to the starting, ending and middle day of the year for each survey. The numbers below each gear type list the number of stations sampled each year by each gear type.

Year	Ship	Dates	DoY Start	DoY End	DoY Mid	Bongo	IYGPT
1994	TEM157/GAD247	22 Aug–3 Sep	234	246	241	99	99
1995	TEM175/TEL018	5 Sep–22 Sep	248	264	257	139	139
1996	TEM193/TEL034	19 Aug–6 Sep	231	249	241	147	147
1997	TEM210/TEL050	11 Aug–29 Aug	223	241	233	148	148
1998	TEM226/TEl069	24 Aug–10 Sep	236	253	244	132	132

Table 2. Abundance indices ($\log_e$ transformed) estimated for pelagic juvenile cod (*Gadus morhua*) for the different Index Areas sampled each year, 1994-1998. SUM IN–sum of all weighted Index Area values for the commonly sampled inshore areas (shaded); SUM OFF–sum of all weighted Index Area values for the commonly sampled offshore areas (shaded); TOTAL = the sum of SUM IN + SUM OFF. For individual area identifications refer to Figure 1.

Area	1994	1995	1996	1997	1998
Inshore					
CB *	0.29	1.22	0.00	0.20	0.45
TB *	0.87	0.43	0.00	0.12	0.39
BB *	3.86	1.52	0.42	3.12	
NDB *	5.86	12.69	0.00	2.80	7.02
WB *	7.09	1.03	3.49	1.25	1.51
SUM IN	17.97	16.89	3.91	7.49	9.37
Offshore					
HB		0.20	0.00	0.00	0.00
ISN *		0.98	0.00	0.00	0.34
ISS *	16.55	2.20	0.23	1.86	1.50
BIBI *		0.22	0.00	0.22	0.20
BIBO					
FIBI *		0.43	0.00	0.89	0.00
FIBO					
NGB *	0.34	0.55	0.00	0.34	4.33
SA	0.30		0.00		
SGB *	3.05	0.38	1.13	0.68	14.54
NOSE			0.00	0.00	1.20
SGBO					
WD					
SUM OFF	19.94	4.76	1.36	3.99	20.91
TOTAL	37.91	21.65	5.27	11.48	30.28
2J3KL	34.86	21.27	4.14	10.80	15.74

Table 3. Summary of daily ages, total lengths (mm) and growth rates (mm d^{-1}) measured for pelagic juvenile cod (*Gadus morhua*) sampled each year, 1994-1998.

		Age			Length		
Year	n	Mean	Min	Max	Mean	Min	Max
1994	103	80.4	58	121	45.4	31.5	86.0
1995	100	68.5	48	96	45.8	30.0	69.5
1996	37	69.4	48	104	39.5	23.5	59.5
1997	84	65.1	41	84	38.5	23.5	51.5
1998	97	92.5	47	131	56.2	29.0	81.0

		Growth Rate				
Year	n	Mean	Min	Max	Std. Dev.	CV
1994	103	0.520	0.391	0.682	0.055	10.6
1995	100	0.618	0.465	0.789	0.069	11.2
1996	37	0.521	0.389	0.674	0.064	2.3
1997	84	0.540	0.404	0.690	0.065	12.1
1998	97	0.569	0.422	0.732	0.065	11.5

		Growth Rate				
Area	n	Mean	Min	Max	Std. Dev.	CV
Trinity Bay	6	0.483	0.427	0.564	0.055	11.4
Grand Banks	60	0.583	0.467	0.732	0.055	9.5
White Bay & Notre Dame Bay	31	0.557	0.422	0.701	0.071	12.8

Table 4. Relative condition of cod, measured as Fulton's K, for the cod subsample selected for ageing and growth.

	Year 1995	1996	1997	1998
Average	1.78	1.63	1.61	1.34
n	63	59	120	109
Standard Deviation	0.230	0.223	0.215	0.124
Minimum	1.24	1.14	0.91	1.06
Maximum	2.39	2.17	2.12	1.67

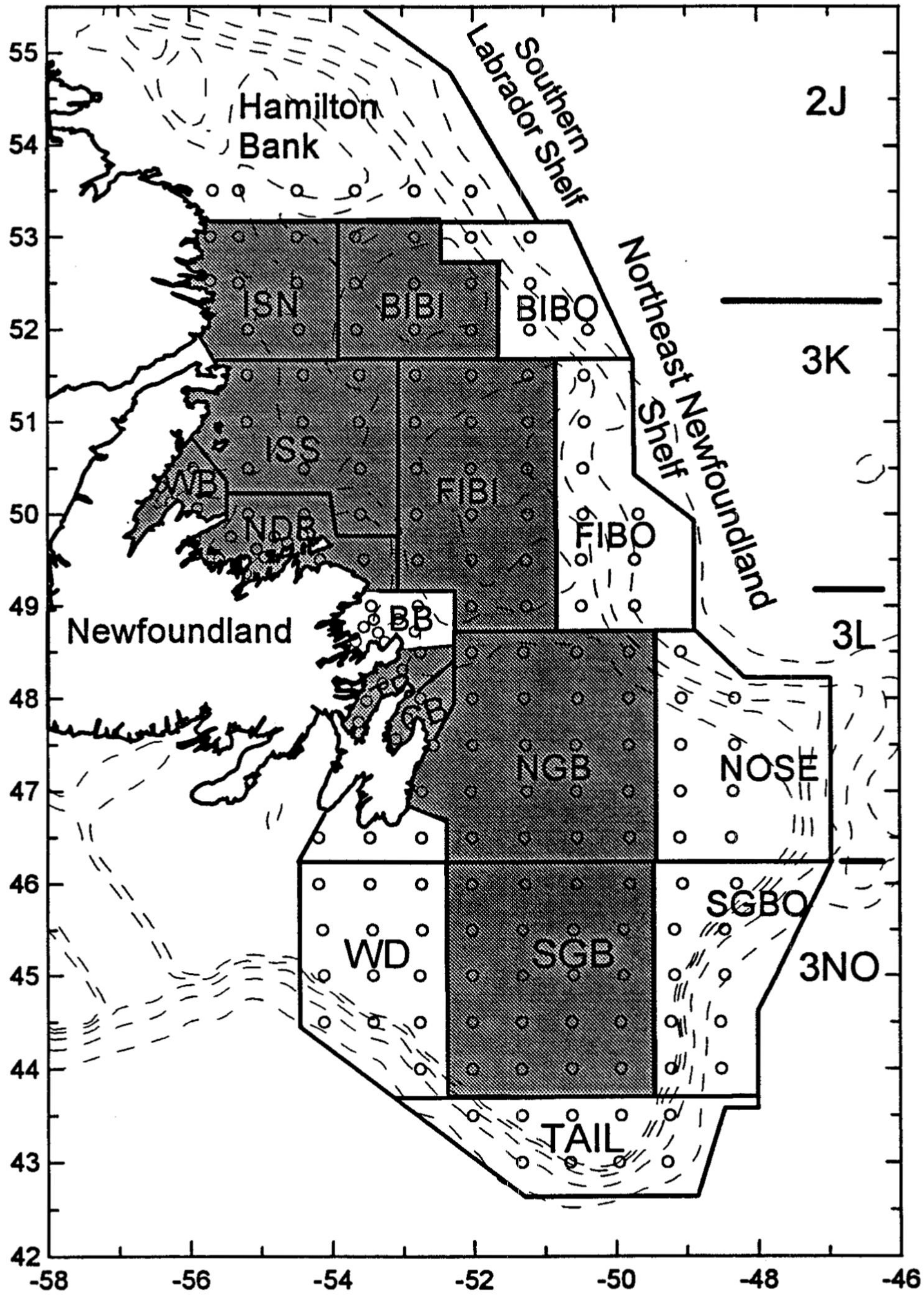

Figure 1. Pelagic Juvenile Fish Survey area, showing sampling locations (indicated by 'o') and Index Areas in 1998. The shaded areas represent the Index Areas used in the calculation of annual abundance indices. See text for explanation of areas.

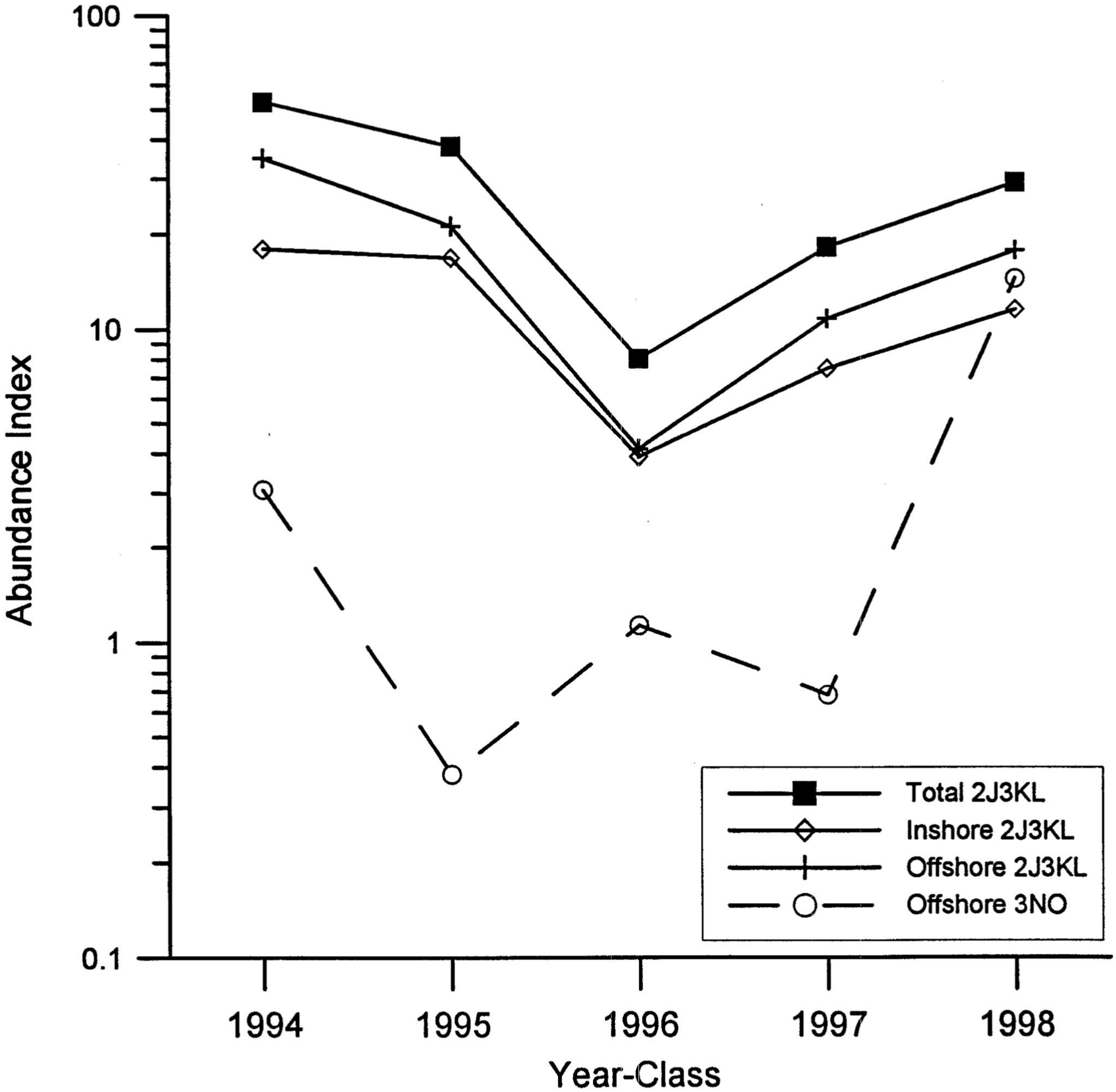

Figure 2. Pelagic juvenile cod (*Gadus morhua*) abundance indices for northern cod (2J3KL) inshore, offshore and total areas and southern Grand Banks cod (3NO), 1994-1998.

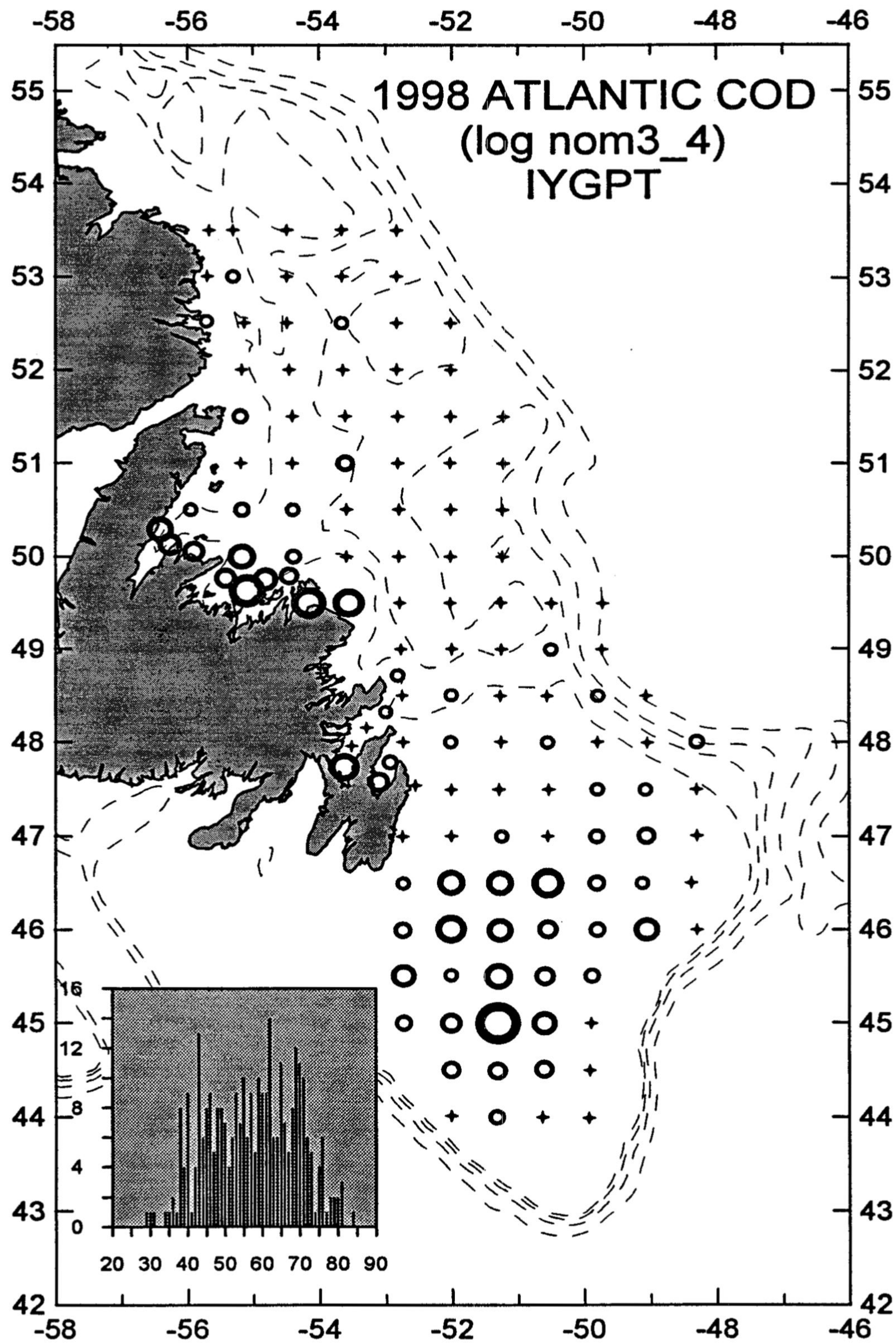

Figure 3. Distribution of pelagic juvenile Atlantic cod (Gadus morhua) in 1998. The expanding symbols represent abundance (log10 number/10,000m^3). The plus symbols represent stations where cod were not caught. The length frequency distribution is plotted in the embedded graph.

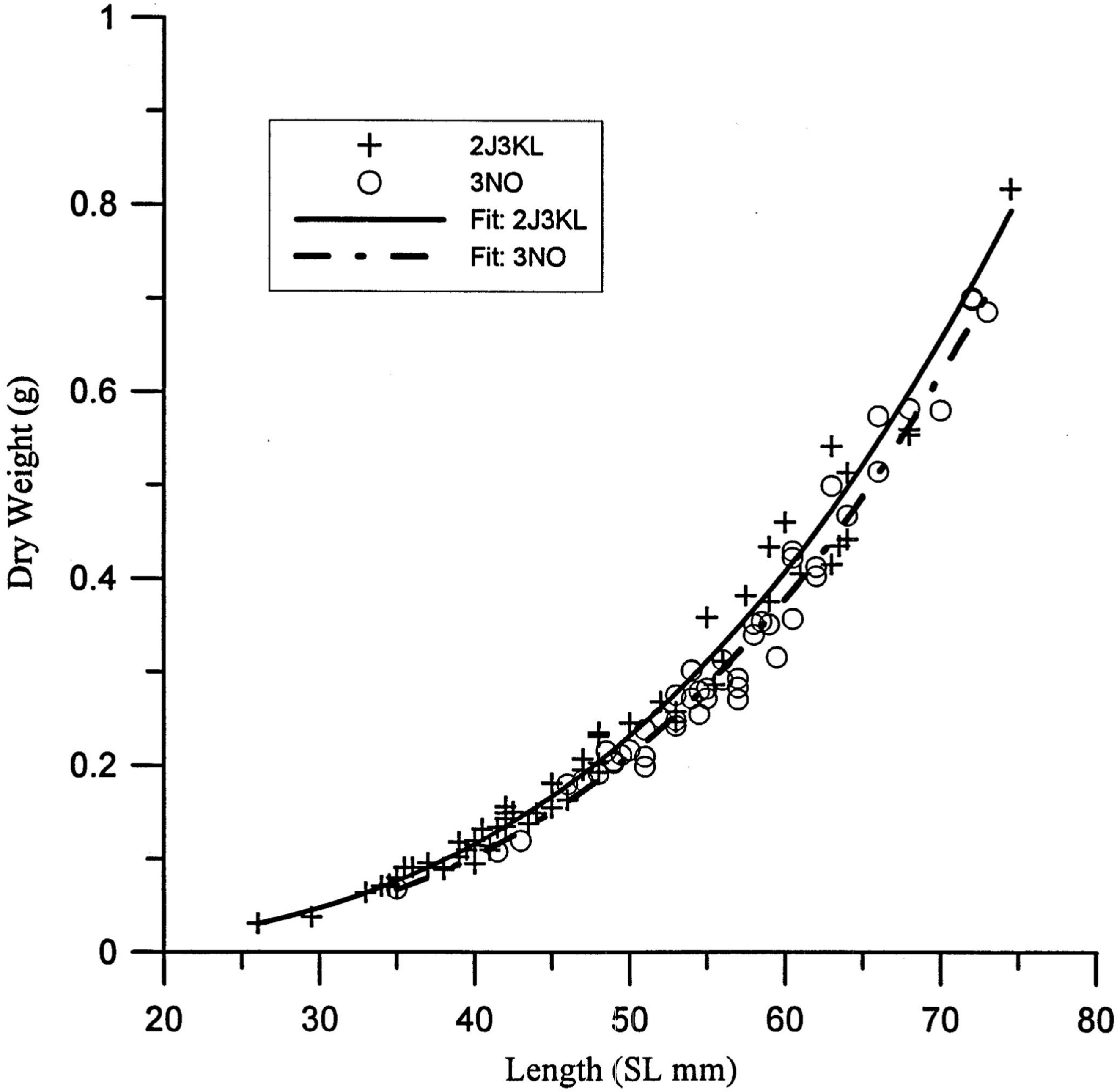

Figure 4. Length-dry weight relationship for northern cod (2J3KL) and southern Grand Bank cod (3NO) in 1998.

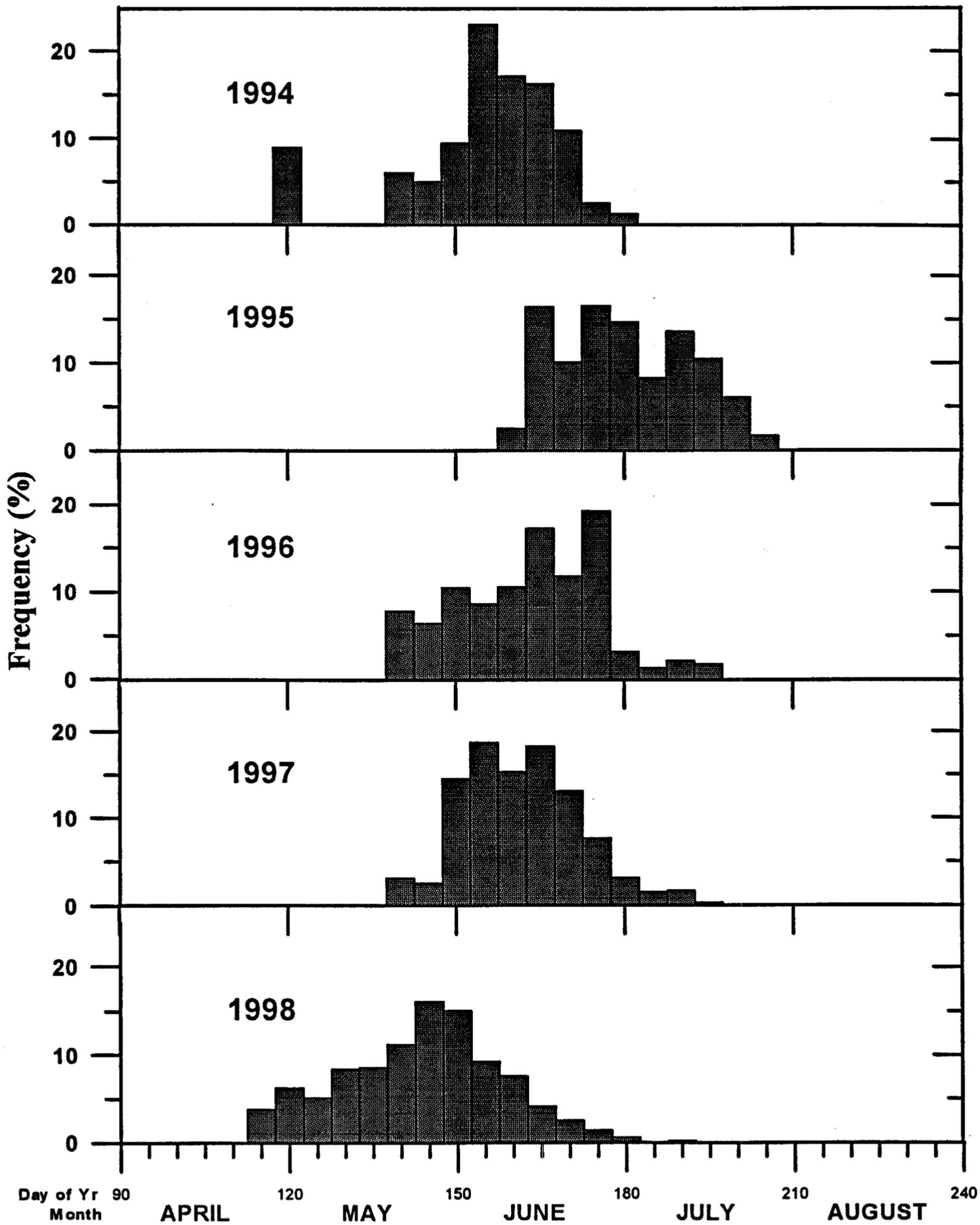

Figure 5. Larval hatch dates adjusted for 4% daily mortality and summarized in five day periods estimated from the ages of pelagic 0-group cod sampled each year, 1994-1998.

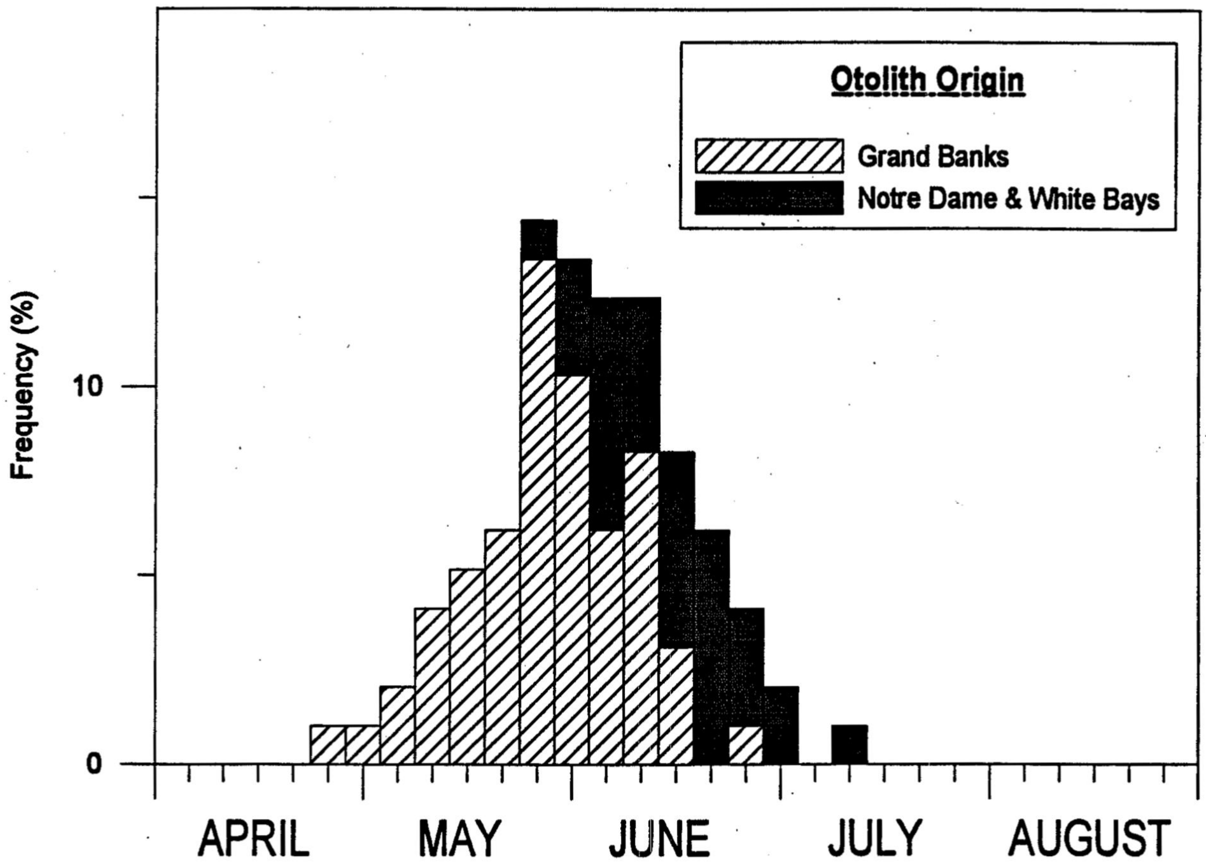

Figure 6. Larval hatch date distributions for cod spawned inshore along the northeast coast of Newfoundland (Notre Dame and White Bays) and on the southern Grand Banks.