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Year-Class Strength of Northern Cod (2J3KL) Estimated from Pelagic Juvenile Fish Surveys in the Newfoundland Region, 1994-1997.

by

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Abstract

Pelagic juvenile fish surveys were carried out in August-September 1994-1997 to index the year-class strength of Atlantic cod (*Gadus morhua*) in the NAFO Divisions 2J3KL. There were substantial differences in abundance, distributions, spawning times, growth rates, condition and size at settlement of pelagic juvenile cod among years. The abundance index was highest in 1994, at 81.6, declining to 40.6 in 1995 and to a low of 10.8 in 1996. In 1997, abundance increased to 21.8. In all years except 1994, abundance's were much higher inshore than offshore. In 1994, abundance offshore was approximately equal to that estimated inshore. The occurrence of pelagic juvenile cod offshore is indicative of the degree of successful offshore spawning which occurred each year. Hatching times for cod larvae were primarily unimodal and were derived from spawning times that spanned approximately 6-8 weeks each year. Peak hatching times varied by as much as 25 days among these four years, 1994-1997, where hatching was much later in 1995 compared to the other years. We estimate spawning occurred primarily in May 1994, 1996, 1997 and in June 1995, based on estimated egg development times of 25-30 days. Examination of plankton samples collected throughout the survey area indicated that no spawning occurred in July-August each year. Among years, daily growth rates averaged 0.49-0.62 mm d^{-1}. Projected size at time of settlement in mid-October ranged from 65.3-68.5 mm. Relative condition varied from 1.23-1.35 mg mm^{-3} (Fulton's K), 1995-1997. Consideration of abundance's, distributions and biological measures of growth rates, size at settlement and relative condition were combined into a predictive measure of year-class strength where we estimate year-class rank as: 1994>>1995>1997>1996.

Résumé

Des relevés des poissons pélagiques juvéniles ont été réalisés en août et septembre de 1994 à 1997 afin d'indexer l'importance des classes d'âge de la morue de l'Atlantique (*Gadus morhua*) dans les divisions 2J3KL de l'OPANO. On a noté des écarts annuels appréciables pour l'abondance, la répartition, le moment du frai, le taux de croissance, la condition et la taille au moment où les juvéniles cessent d'être pélagiques et se fixent en un lieu. L'indice d'abondance était le plus élevé en 1994, à 81,6, après quoi il a diminué à 40,6 en 1995 et à 10,8 en 1996. En 1997, il était remonté à 21,8. À l'exception de 1994, l'abondance a été de beaucoup plus importante dans les eaux côtières que hauturières à toutes les années. En 1994, le niveau d'abondance noté au large était presque le même que celui estimé pour les eaux côtières. La présence de morues juvéniles pélagiques au large constitue un indice du succès du frai en eaux hauturières qui se produit à chaque année. Les dates de l'éclosion présentent une allure surtout unimodale et ont été obtenues à partir du moment du frai qui s'étend sur de 6 à 8 semaines à chaque année. Au cours des quatre années, le pic de l'éclosion peut être décalé d'une période pouvant atteindre 25 jours et l'éclosion de 1995 a été la plus tardive. Nous estimons, en nous fondant sur un temps de développement des oeufs de 25 à 30 jours, que le frai a surtout eu lieu en mai en 1994, 1996 et 1997 et en juin en 1995. L'examen des échantillons de plancton prélevés dans l'ensemble de l'aire du relevé indique qu'il n'y a pas eu de frai en juillet et août de chaque année. Le taux de croissance quotidien moyen a oscillé entre 0,49 et 0,62 mm pendant cette période. L'indice de condition relative (K de Fulton) s'est situé entre 1,23 et 1,35 mg mm^{-3} de 1995 à 1997. L'examen combiné de l'abondance, de la répartition, du taux de croissance, de la taille à laquelle les poissons cessent d'être pélagiques et de la condition relative a permis d'établir une mesure prédictive de l'importance des classes annuelles et de les placer dans l'ordre suivant : 1994>>1995>1997>1996.

Introduction

Pelagic juvenile fish surveys have been carried out in the eastern north Atlantic ocean by ICES countries for many years. These surveys have spanned approximately 30 years for the Northeast Arctic cod stock (also known as the Arcto-Norwegian and Barents Sea cod stock), 25 years for the Icelandic cod stock and 15 years for the Faroe Plateau cod stock. In each case, year-class strength estimates from these surveys have predicted subsequent recruitment to the fisheries, in most years (Sundby et al. 1989, Assthorsson et al. 1994, Jakupsstovu and Reinert 1994). Failures to predict recruitment have resulted from over estimates. For the NE Arctic cod stock, failure to predict three year-classes in the mid-1980's was related to increased cannibalism on one and two year old cod following the collapse of the Barents sea capelin stock (Anon. 1995). Now, in the 1990's, low survival of demersal juvenile cod resulting from increased cannibalism is again resulting in an over-estimate of subsequent recruitment based on pelagic 0-group surveys (Anon. 1997). The importance of cannibalism as a regulator of juvenile cod survival and prediction of year-class strength is now explicitly modelled in the stock assessment process for this stock (op. cit.). For the Icelandic cod stock, failure to predict two large year-classes in 1973 and 1984 resulted from a large scale advection of eggs and larvae to West Greenland (Anon. 1996). However, these year-classes subsequently returned to spawn in Iceland; thereby, showing up as spawners but not as recruits.

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 survey has been carried out in August and September, timed to sample pelagic juvenile cod, before they settle to the bottom and to catch larval capelin following their release from beach and bottom sediments.

The purpose of this paper is to estimate year-class strength of northern cod (NAFO Divisions 2J3KL). We report on abundance, distributions, size (length, weight), ages, growth rates and hatching dates of pelagic juvenile (0-group) Atlantic cod (*Gadus morhua*) from the 1997 survey. We compare the 1997 survey results to those of the 1994–1996 surveys. The long-term goal of this work is to develop a multi-factored predictor of recruitment to the northern cod population (Anderson and Dalley 1997). Based on our observations, we rank the relative strength of each year-class. Capelin year-class strength estimates were presented during the Newfoundland Region Capelin Assessment meeting, March 1998. Multi-species ecosystem results from the surveys were presented during the Atlantic Zone Fisheries Oceanography assessment meeting, 24-26 February 1998.

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, with the mid-date of the 1997 survey occurring 8 days earlier than 1994 and 1996 and 24 days earlier than 1995 (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.

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.

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 $10^4\mathrm{m}^{-3}$) 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,

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

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

The abundance of pelagic juvenile cod increased in 1997 relative to 1996, although values remained much lower than those measured in 1994 and 1995 (Table 2, Figure 2). Inshore, abundance was 42.4, 34.5, 9.4 and 17.8 for the years 1994-1997, respectively. Offshore, abundance was 39.2, 6.1, 1.4, and 4.0, respectively. Overall, abundance declined during the period 1994-1996 and then recovered marginally in 1997. These values represent very small abundances compared to catches of Arctic cod (*Boreogadus saida*) caught during the surveys (Dalley and Anderson 1997). They also represent very small values compared to similar surveys conducted off Norway, comparing numbers of Atlantic cod caught per tow (K. Korsbrekke, Institute of Marine Science, Bergen, Norway, Per. Comm.). Overall, the abundance of pelagic juvenile cod throughout 2J3KL ranked as: 1994>>1995>>1997>1996.

Distributions

Pelagic juvenile cod occurred throughout most of the inshore area in 1997, although cod were noticeably absent from the outer part of Trinity Bay and the inner most station in Conception Bay (Figure 3). Peak abundance occurred in Bonavista Bay and in Notre Dame Bay, south of Fogo Island. Offshore, juvenile cod were distributed broadly at low abundance over the inner Northeast Newfoundland Shelf, indicating that some spawning had occurred offshore in 1997. The broadest distribution occurred in 1994 while in 1996 juvenile cod were almost non-existent in the survey area. Very few cod have been observed on the Grand Bank during these four years, 1994–1997.

Length, Age and Growth

In 1997, lengths of specimens ranged from 23.5–51.5 mmTL, and averaged 38.5 mm. These values compare with larger means of 45.4 (31.5–86.0mm), 45.8 (30.0–69.5mm), and 39.5 (23.5–59.5mm)in 1994, 1995 and 1996, respectively. Given the differences in survey dates, these average sizes can be projected to a common date based on measured growth rates (see below). For example, for a common date in mid-September (Day 258), cod would have averaged 52.9 mm in 1994, 46.8 mm in 1995, 48.3 mm in 1996 and 52.1 mm in 1997. Settlement to a demersal habitat is thought to occur sometime in October through to early November (Anderson et al. 1995, Anderson and Dalley 1997). Projecting lengths to mid-October (Day 288), cod would have averaged 68.5 mm, 65.3 mm, 63.9 mm and 68.3 mm each year, respectively. Therefore, length differences observed each year were reduced when projected to a common date in October, due to differences in growth rates. The rank of mean length at a common date in mid-October is: 1994>1997>1995>1996.

In 1997, pelagic juvenile cod averaged 65 days of age (Table 3). This was similar to 1995 and 1996 but 16 days younger than 1994 (Table 3). The 1997 survey was approximately eight days earlier than 1994 and 1996 but 24 days earlier than 1995 (Table 1).

There was a linear relationship between total length and age (Figure 4). The mean growth rate of cod in 1997 was 0.540 mm d^{-1} (Table 3). Growth rate in 1997 was similar to that measured in 1994 (0.520 mm d^{-1}) and 1996 (0.492 mm d^{-1}) but significantly lower than in 1995 (0.618 mm d^{-1}).

Hatching and Spawning Times

Pelagic cod sampled in 1997 hatched from the middle of May to the middle of July (Figure 5). The data indicate a unimodal distribution in hatching dates, with peak hatching occurring around the middle of June (mean hatch date was Day 168, June 17). These cod were spawned primarily in mid-May with earliest spawning occurring around mid to late April; based on egg development times of approximately 25-30 days for June and July water temperatures (Anderson and deYoung 1995). Spawning spanned periods of approximately 6-8 weeks each year.

Hatching times in 1997 were, on average, five days later than in 1994 but 20 days earlier than in 1995 and four days earlier than in 1996 (Figure 5). Examination of bongo samples (0.505 mm mesh) for the presence of cod eggs and larvae indicated that there was no spawning which occurred during the period June–August of 1994–1997. Therefore, spawning occurred much later in 1995 compared to the other three years when spawning did not vary significantly.

Length, Weight and Relative Condition

Pelagic juvenile cod increased in weight exponentially with increasing length (Figure 6). An exponential regression fit to the data each year explained 91-92% of the variation in weight as a function of length. In 1997, the rate of increase in weight was notably greater than either 1995 or 1996 (Figure 6). At smaller sizes, cod in 1997 weighed less than cod in 1995 and 1996. However, because of the greater rate of increase in weight with length in 1997, these cod weighed more than cod in 1995 and 1996 at lengths $\geq$ 40 mm.

Relative condition was estimated using Fulton's condition index (K = weight/(total length)^3). Cod were in better condition in 1995 (K=1.35 mg mm^{-3}, n=64) than in either 1996 (K=1.23 mg mm^{-3}, n=58) or 1997 (K=1.25 mg mm^{-3}, n=110).

Discussion

There has been a significant decline in the abundance of pelagic juvenile cod in 1996 and 1997 compared to 1994 and 1995. Estimated abundance in 1997 was greater than the 1996 year-class by a factor of 2.1, but it was only one half of that estimated for the 1995 year-class and one third of the 1994 year-class estimate. The only positive sign in 1997, compared to 1996, was the presence of juvenile cod in offshore waters over the Northeast Newfoundland Shelf. The occurrence of pelagic juvenile cod offshore indicates that some degree of successful spawning occurred in 1997, and this was similar to 1995. However, these offshore abundance are much less than in 1994, indicating that the degree of offshore spawning has remained very low since 1994. We note that there were essentially no cod present on the northern Grand Bank (3L) and only small numbers observed on the southern Grand Bank (3NO), as in the previous three years.

Inshore, the abundance of pelagic juvenile cod in 1997 was almost two times greater than in 1996 but it was about one half of that estimated in 1994 and 1995. Cod were most abundant in Notre Dame Bay and Bonavista Bay, followed by White Bay. The abundance of juvenile cod in both Trinity Bay and Conception Bay were low. The distributions of pelagic juvenile cod indicates that the primary spawning locations in 1997 were the inshore areas along the northeast coast of Newfoundland, and not offshore on the shelf or off southern Labrador.

Previously, we hypothesized that predicting recruitment in northern cod would be a function of three factors: abundance, size at settlement and distribution (Anderson and Dalley 1997). Initial high abundance at the pelagic juvenile stage is necessary to ensure eventual high abundance several years latter when cod are recruited to the fishery. Large sizes in the autumn are necessary to ensure higher survival during settlement and their first winter. While larger sizes may be effected by growth rates, we predict that earlier spawning times will result in larger fish in the autumn. A broad distribution over the shelf is necessary to ensure maximum utilization of productive habitats within the population area. In addition, it has been hypothesized that spawning off southern Labrador is necessary for the well being of this stock (deYoung and Rose 1993).

There were substantial differences among years in abundance, distributions, spawning times, growth rates, condition and size at settlement of pelagic juvenile cod. We rank year-class abundance as 1994>>1995>1997>1996. As a predictor of recruitment at age three, we estimate that the 1994 year-class will be the highest based on: relatively high abundance; a broad distribution offshore; an early spawning; and, a relatively large size at settlement. The 1995 year-class ranks next highest, although we regard the low abundance measured offshore as a poor sign. However, fish in 1995 grew at the fastest rate and condition was higher than either 1996 or 1997. The 1996 year-class ranks the lowest in all categories: low abundance, both inshore and offshore; later spawning; low growth rates; smallest size prior to settlement; poor condition. The 1997 year-class, while better than 1996, still ranks relatively low compared to 1994 and 1995. We base this prediction primarily on low abundance, particularly offshore.

How good are these predictions? Recruitment in northern cod was measured as the population abundance of three year old cod, 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.). However, the differences among values each year in divisions 3K and 3L are small. Finally, the bottom trawl survey indices are based exclusively on offshore data that do not account for abundance of juvenile cod inshore, where the majority of juvenile cod are known to exist (Dalley and Anderson 1997). Therefore, assessing the predictive power of this pelagic juvenile cod recruitment index is problematic, awaiting the development of a comprehensive and robust measure of recruitment for the northern cod stock.

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Table 1. Summary of Pelagic Juvenile Fish Surveys conducted, 1994-1996. Bongo–bongo plankton sampler; IYGPT–International Young Gadoids Pelagic Trawl. The numbers below each gear type list the number of stations sampled each year by each gear type. 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.

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

Table 2. Abundance indices estimated for pelagic juvenile cod (*Gadus morhua*) for the different Index Areas sampled each year, 1994-1996. 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.

Area	1994	1995	1996	1997
Inshore				
CB *	0.83	3.52	0.00	0.59
TB *	2.98	1.44	0.00	0.42
BB *	10.29	2.31	1.11	8.32
NDB *	11.45	24.78	0.00	5.47
WB *	16.80	2.45	8.28	2.97
SUM IN	42.35	34.50	9.39	17.77
Offshore				
HB		0.22		0.00
ISN *	0.90	1.21	0.00	0.00
ISS *	16.55	3.25	0.23	1.86
BIBI *	14.33	0.22	0.00	0.22
BIBO				
FIBI *	3.95	0.43	0.00	0.89
FIBO	0.31			
NGB *	0.37	0.59	0.00	0.36
SA	0.33		0.00	
SGB *	3.10	0.38	1.13	0.68
NOSE			0.00	
SGBO				
WD				
SUM OFF	39.20	6.08	1.36	4.01
TOTAL	81.55	40.58	10.75	21.78

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, 1994-1997.

		Age			Length		
Year	n	Mean	Min	Max	Mean	Min	Max
1994	104	80.7	58	121	45.4	31.5	86.0
1995	100	68.5	48	96	45.8	30.0	69.5
1996	61	63.7	42	104	35.2	18.0	59.5
1997	84	65.1	41	84	38.5	23.5	51.5

Growth Rates

Year	n	Mean	Min	Max	Std Dev	CV
1994	104	0.520	0.391	0.682	0.0554	10.6
1995	100	0.618	0.465	0.789	0.0691	11.2
1996	61	0.492	0.345	0.674	0.0732	14.9
1997	84	0.540	0.404	0.690	0.0652	12.1

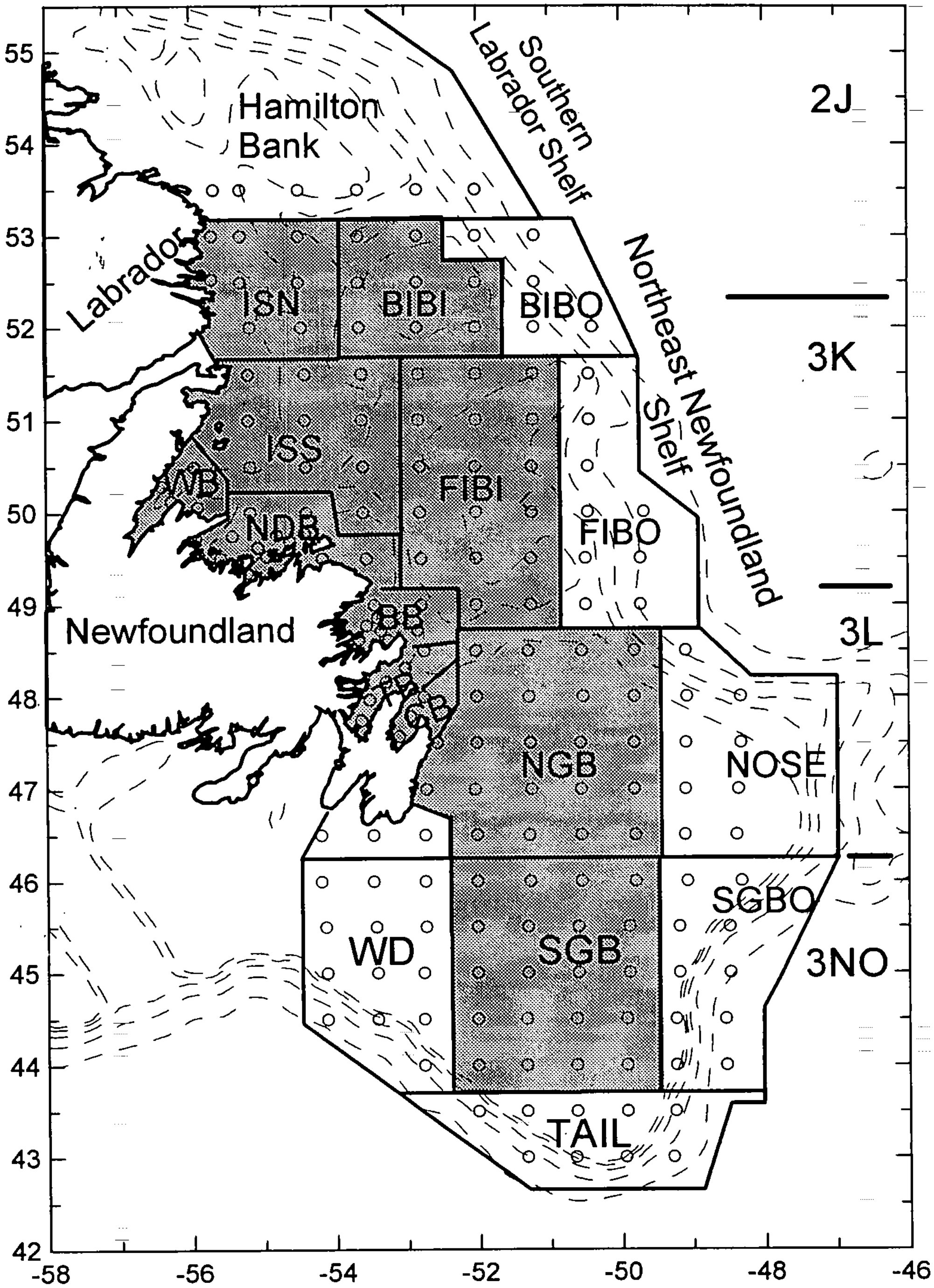

Figure 1. Pelagic Juvenile Fish Survey area, showing sampling locations (indicated by 'o') and Index Areas. See text for explanation of areas.

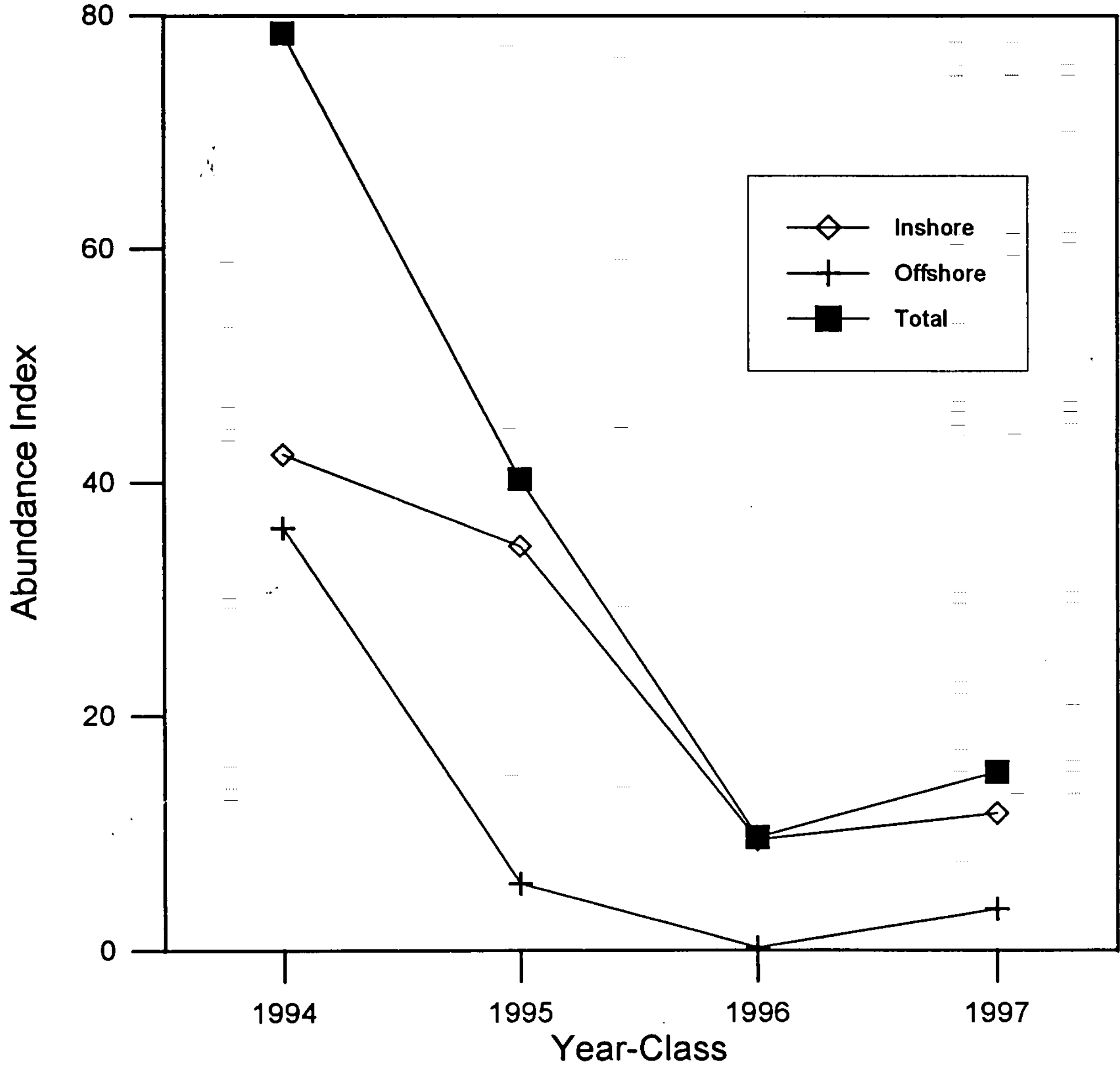

Figure 2. Pelagic juvenile cod (Gadus morhua) abundance indices for inshore, offshore and athe total for commonly sampled Weighted Index Areas for northern cod (2J3KL), 1994-1997.

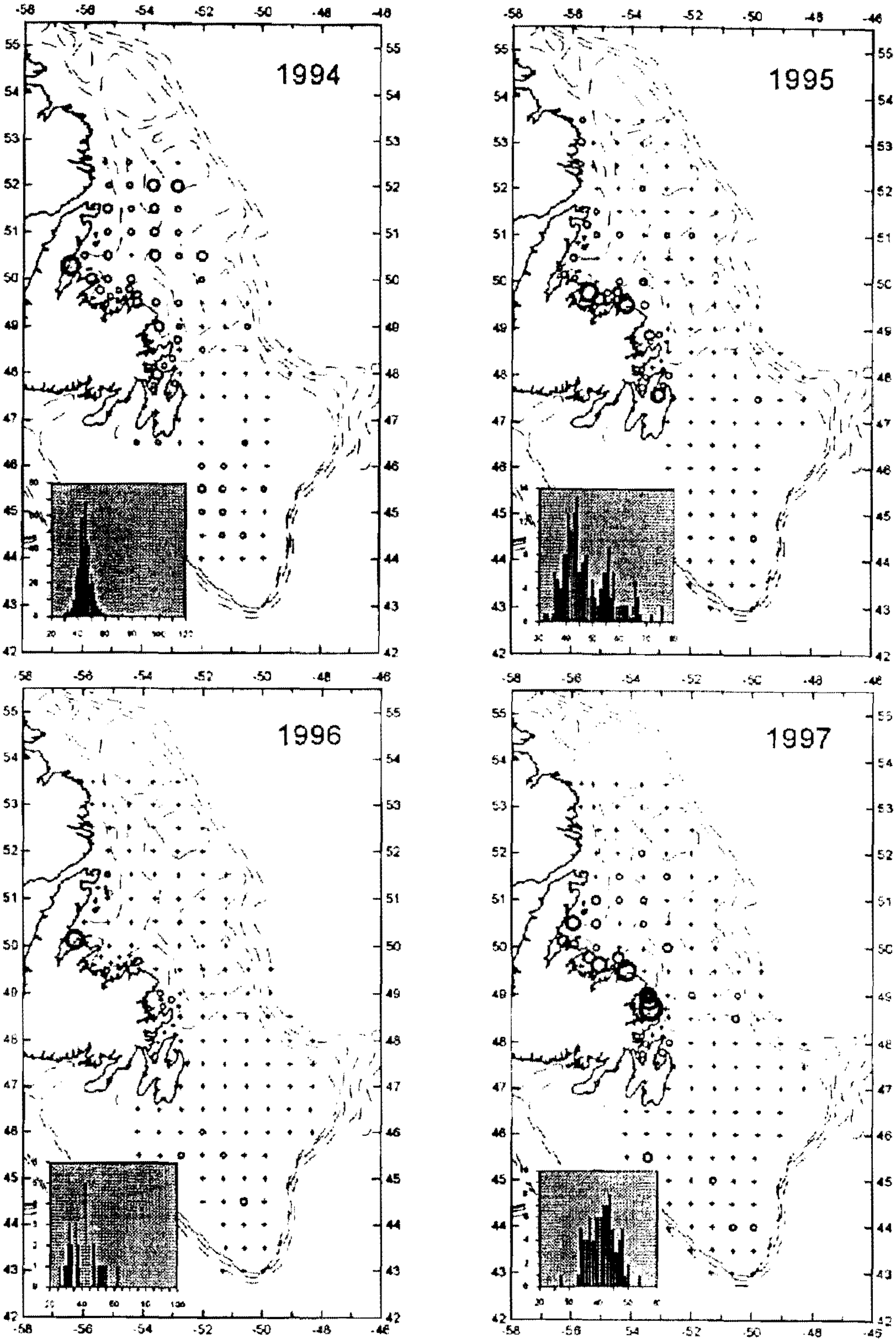

Figure 3. Distributions of pelagic juvenile cod (Gadus morhua) for 1994-1997. The expanding symbols represent abundances (log number/10000m^3), scaled witin each eyar. The plus symbols represent stations where cod were not caught.

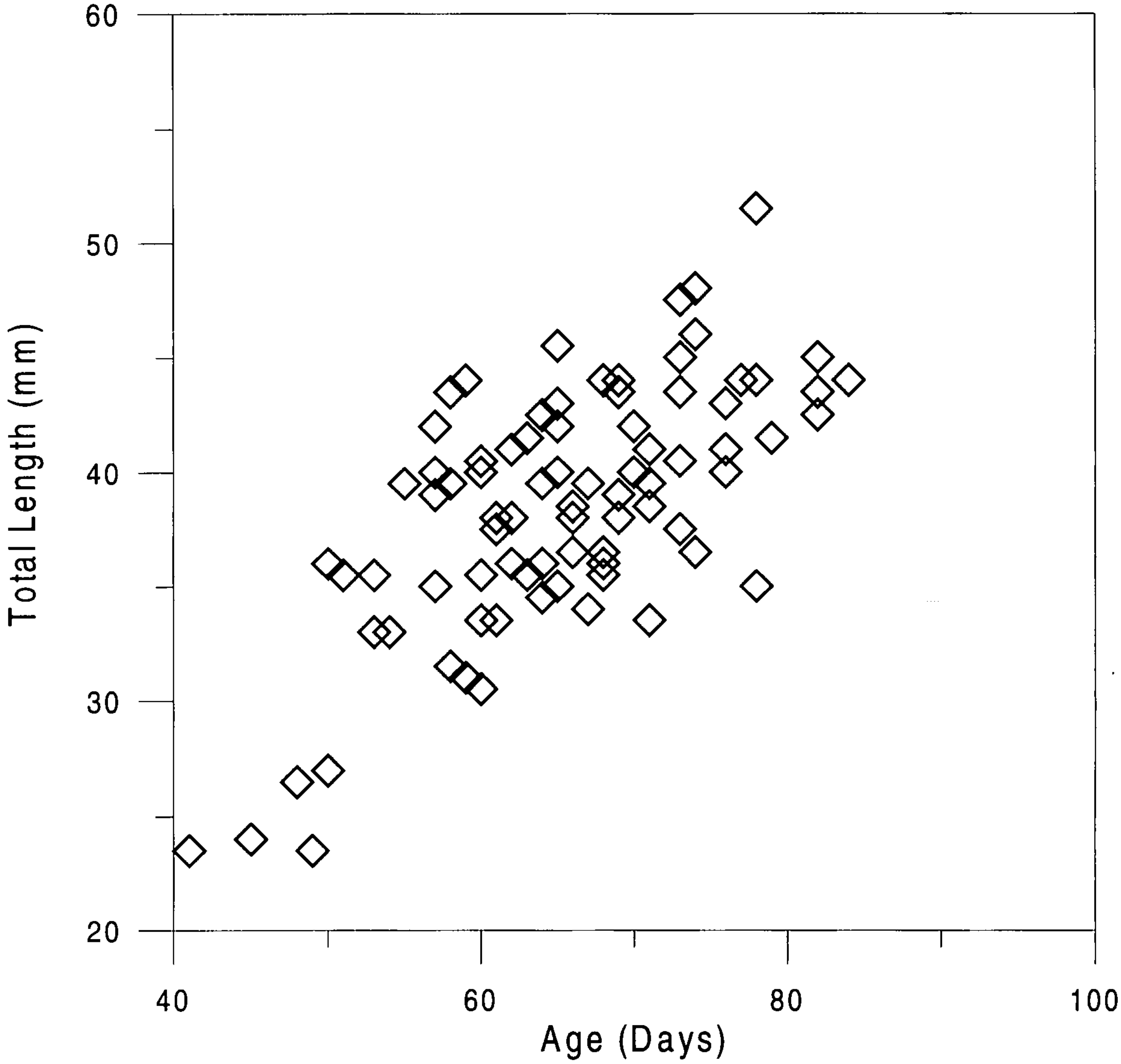

Figure 4. Length at age (growth) relationship for pelagic juvenile cod (Gadus morhua) sampled in 1997, based on micro-otoliths.

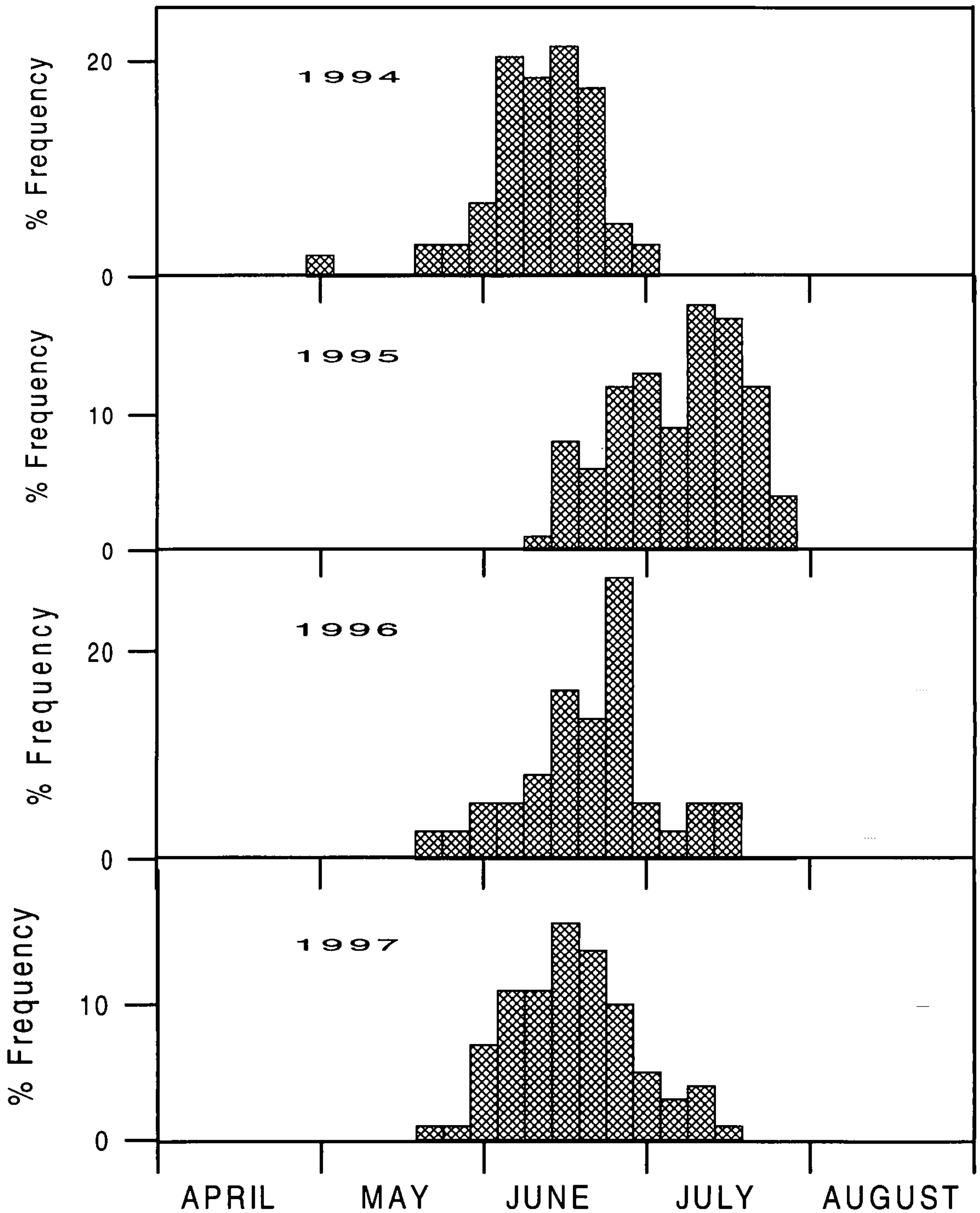

Figure 5. Larval hatch rates estimated from the ages of pelagic juvenile cod sampled each year 1994-1997, summarized into five day periods.

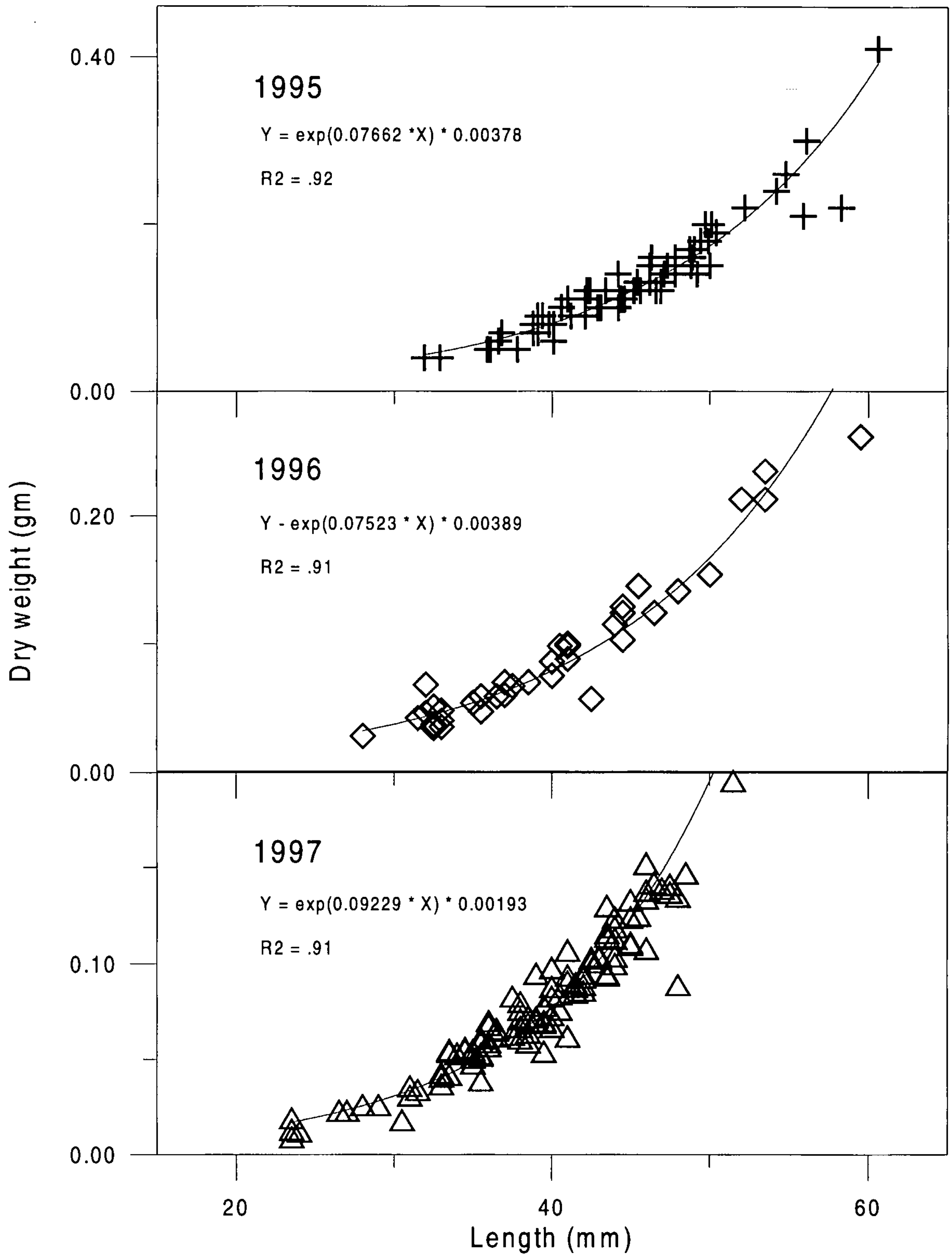

Figure 6. Length/dry weight relationships for pelagic 0-group cod sampled during pelagic surveys, 1995 - 1997. The lines are exponential fits drawn through the data points each year.