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An examination of growth and condition of Div. 3NO cod at different environmental temperatures

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Abstract

The effect of temperature on growth and condition of cod in Div. 3NO was examined. Both the average temperature occupied and the area weighted temperature (available temperature) increased in the spring starting in about 1990. Trends are less clear in the autumn data which only begins in 1990. There was no significant effect of temperature on the residuals from a model of weight increment vs. age applying time-invariant parameters. When temperature was included as a factor in a modified Von Bertalanffy growth model there was a significant effect of temperature on growth in length, but the effect was negative, with fish growing less when temperatures were higher. There was also a significant effect of temperature on relative body and relative liver condition. Except for the analyses of condition in autumn with autumn temperatures, the condition was higher at low and high temperatures than at intermediate temperatures.

Key words: growth, length, weight, condition temperature, cod

Introduction

Fishes, for the most part, are ectotherms, their body temperature being very similar to that of their environment. As a result, environmental temperature has a significant impact on physiological processes such as metabolism (Bond, 1979). The potential for growth in fishes is affected by this impact of temperature as well as by the availability of food. For each species there is an optimum temperature and ration level that results in maximum growth. As ration level (food availability) declines, the most efficient growth occurs at lower temperatures where requirements for maintenance are lower because of lower metabolic rate (Brett, 1979). If the temperature is above optimum, then growth will also be lower. Concave biological responses of this kind are common and reduce the usefulness of analyses based on assuming linear relationships with environmental variables. Use of categorical variables rather than continuous variables in environmental response models eats up more of the degrees of freedom but allows the data to determine the functional shape.

Temperature has been found to have a positive effect growth in cod, both in comparisons between and within populations (Brander, 1995; Campana et al. 1995; Fleming, 1960; Shelton et al, 1999; Jorgensen, 1992). For cod, growth rate has been found to increase to a maximum temperature of about 14^{o}C, above which it declines (Jobling, 1988). However, growth has occasionally been found to be unrelated to temperature (Swain et al. 2003).

Spring bottom temperature on the Grand Bank shows large inter-annual variations and a downward trend starting around 1983 that lasted until the early-1990s. In recent years, the thermal habitat in the 3NO region has shifted from cold conditions of the early 1990s to a relatively warm environment from 1998 onwards, with the exception of 2003 when spring temperatures were colder than normal. During 1998 and 1999 and during the past 4 years the area of the bottom on the Grand Bank with water depths <100 m covered by water <0^{O}C was <20% of the total area compared to over 50% in the early 1990s (Colbourne et al. 2005).

The purpose of this paper was to examine growth and condition for Div. 3NO cod from the late 1970's up to and including the recent warm period. It was hypothesized that there would be a significant effect of temperature on growth expressed in terms of annual length and weight increments, with growth increasing with temperature at the low end of the temperature range, but perhaps decreasing at the warmest temperatures.

Materials and Methods

Data were available from Canadian spring (1978-2005) and autumn (1990-2005) surveys, although there were no weight data available for 1988 from the spring survey and no spring survey in 1983.

Near-bottom temperature grids for NAFO Divisions 3NO were produced from all available data from the spring and fall surveys by interpolating the values onto a regular grid and contoured using a geostatistical (2-dimensional Kriging) procedure. Bottom temperatures for each grid element were computed and the grid area integrated to produce a yearly estimate of the mean near-bottom temperature and the percentage of the total area of the cod habitat within temperature ranges defined by ≤0^{o}C, 0^{o}-1^{o}C, 1^{o}-2^{o}C, 2^{o}-3^{o}C and ≥3^{o}C.

The total weight of cod of all ages per fishing set are displayed over the temperature contours as expanding solid circles. The size of the circle is proportional to the magnitude of the catch in each set, with white crosses representing 0 catch rates.

Average length at age and average weight at age were calculated, correcting for the bias introduced by length-stratified sampling (Morgan, 1999). Preliminary analyses showed that there were significant seasonal effects but little effect of sex on growth and condition. Therefore, average length at age and average weight at age were calculated separately for each season but sexes were combined.

Average temperature occupied by cod and average temperature of Div. 3NO were both calculated from each survey in each year.

The average temperature occupied by cod in year *y* TO_y was calculated as:

$$TO_y = \sum_{i=1}^{S} \sum_{i=1}^{n_i} \frac{W_i}{n_i} \frac{Y_{ij}}{\overline{\overline{Y}}} X_{ij}$$

where S is the number of strata, W_i is the proportion of the survey area in stratum *i*, n_i is the number of tows in stratum *i*, Y_{ij} is the number of cod caught in tow *j* in stratum *i*, X_{ij} is the bottom temperature in tow *i* in stratum *j*.

The area-weighted temperature for the survey in year y was calculated as:

$$TA_y = \frac{\sum_{i=1}^{s} \sum_{j=1}^{n} W_i T_j}{\sum_{i=1}^{s} \sum_{j=1}^{n} W_i}$$

Where *s* is the number of strata, W_i is the proportion of the survey area in stratum *i*, *n* is the number of tows in stratum *i* and T_j is the bottom temperature in tow *j*.

Growth was examined as growth in weight (weight increments) and growth in length (length increments).

To examine the effect of temperature on weight increments the weight increments were first modeled as a function of age

$$Ln(\Delta W_{a,y}) = \tau + \beta_a + \varepsilon$$

where $\Delta W_{a,y}$ is the weight increment for a cohort at age a in year y, τ is the intercept, β_a is the age effect and ε is normally distributed errors. The residuals from this fitted model were then tested for a significant effect of temperature where

$$residual = \tau + T_y + \varepsilon$$

The effect of temperature on growth in length was examined using the modification to the 3-parameter von Bertalanffy model proposed by Millar and Myers (1990).

$$L_{yt} = L_{\infty y}\left(1 - a e^{-k}\right) + \sum_{i=4}^{t}\left(L_{\infty yi} - L_{y,i-1}\right)\left(1 - e^{-k}\right)$$

where

$$L_{\infty yi} = L_{\infty 0} + tT_{yi}$$

L_{yt} is the expected length at age t for year class y. T_{yi} is the temperature for the year class at age i. The first time in the equation defining $L_{yt,}$ gives the length at the first age (in this case 3) and the second term sums the length increments at each subsequent age up to age t.

Hierarchical models were fit, beginning with the conventional von Bertalanffy. As in Millar and Myers (1990) hypotheses were tested using *F*-statistics where the numerator was the difference in the residual sum of squares between hierarchical models.

The effects of temperature on body condition and liver condition was examined using relative K (K_r) and relative liver condition (LK_r) as measures of condition. These were calculated as:

$$K_r = W / \hat{W}$$

$$LK_r = LW / \hat{LW}$$

where W is gutted body weight, LW is liver weight and $\hat{W}$ and $\hat{LW}$ are the predicted body weight and liver weight, respectively, from the following length/weight relationships:

Log W=intercept + log(L)

Log LW=intercept + log(L)

Generalized linear models with a gamma error structure and identity link were used to determine if temperature significantly influenced K_r or LK_r. Temperature was modeled as a class (i.e. categorical) variable with the temperature values categorized as low, medium and high by assigning 1/3 of the data to each category.

The effect of temperature in the current season was analysed with respect to growth in the same season (ie spring temperature with spring growth and condition data and autumn temperature with autumn growth and condition data) as well as the effect of temperature in the previous season (ie. spring growth and condition data with temperatures from the previous autumn and autumn growth and condition data with temperatures from the spring of the same year).

Results and Discussion

The areal extent of the bottom covered by water in various temperature ranges on the Grand Bank for the spring and fall is displayed in Fig. 1. From 1984 to 1997 there was a large increase in the area of <0°C water reaching near 60% in some years. Since 1997, with the exception of 2003, there was a significant decrease in the percentage area of the bottom covered by <0°C water reaching minimum values in 1999, 2004 and 2006. The spring of 2004 had the lowest area of <0°C water on the Grand Bank since the surveys began in the 1970s followed by 2006 and 1999. To contrast the differences in the temperature conditions on the Grand Banks from the early 1990s to that of recent years we present the bottom temperature and temperature anomaly map for the fall of 1993 and the spring of 2005. Temperature anomalies during the fall of 1993 ranged from 0.5–1.5°C below normal whereas spring in 2005 they ranged from 0.5-1.5°C above normal in most areas of the Grand Bank (Fig. 2 and 3).

The total weight of cod of all ages caught per set during the spring (1975-2006) and fall (1990-2006) surveys are displayed over the temperature fields in Appendix 1. In the northern most areas of Div. 3NO near-bottom temperatures during both spring and fall are usually <0°C. During the cold years of the mid-1980s and early 1990s, the area of cold water extended further south to cover near 50% of the total survey area. Conversely during warm years such as 1998 and 1999 <0°C water is restricted to a small area in northern 3N and during the warmest years such as 2004 and 2006 <0°C water was completely absent the 3NO region. In the southern half of the area bottom temperatures are much warmer, due to the influence of warmer slope water from the south and in the fall months the shallow areas of the Southeast Grand Bank are generally warmer than spring values by 2-3°C as a result of summer surface heating. In recent years, particularly since 1998 spring and fall temperatures have been above normal with the exception of the spring of 2003.

In general, it appears that higher biomass of cod in Divs. 3NO are found in the warmer portion of the available habitat, predominately in the 0°-3°C temperature range. There are exceptions however, the most notable, in the years 1985-1990 during the spring when the catch rates from the surveys appeared to peak. During these years the distribution of cod extended into northern areas of 3NO where bottom temperatures were generally <0°C.

Since the mid-1990s, survey catch rates in Division 3N have been extremely low, with a few larger catches on the slopes of the Grand Bank. In Div. 3O catch rates have also been low but generally higher than in 3N with fewer zero catches overall. Colbourne and Murphy (2000) reported a slight increase in catch rates in these areas during the spring of 1998 and fall of 1999, noting that the observed increase in catch numbers was almost entirely ages 3 and less. They suggested that the recent increase in water temperature in the area may have made the southern Grand Bank a more suitable environment for cod spawning and possibly improved survival rates. In addition, during 1998, a significant increase in the abundance of O-group Atlantic cod was sampled in the region (Anderson et al. 1999) and a further increase in both abundance and distribution during 1999 in a follow up pelagic O-group survey was noted. However, data since then do not show any increase in year-class abundance even as water temperatures in the region continued above normal values.

Both the average temperature occupied and the area weighted temperature (available temperature) increased in the spring starting in about 1990. The average temperature occupied since 1990 has been 2.2°C vs. 1.2°C from 1978 to 1989. The average temperature available increased from 0.8 to 1.2°C. Trends are less clear in the autumn data which only begins in 1990 (Fig. 4).

Average temperature occupied by cod in Div. 3NO was highly correlated with that available to the fish (Fig. 5). However, temperature occupied tended to be higher than the average available. All tests of the effect of growth were done using both measures of temperature but since the two are highly correlated and results were generally the same, only those for temperature occupied are presented.

There was no significant effect of temperature on the residuals from a model of weight increment vs. age. This is true regardless of the age range analyzed (1-10, 3-10, 4-6) and regardless of whether temperature was treated as a continuous or class variable. Shelton et al (1999) found that increased temperature (as measured by the area of the CIL) resulted in increased growth in weight in cod in 2J3KL and when populations are compared those inhabiting warmer waters have higher weight-at-age (Brander, 1995). It is possible that the range of variation in temperature in the present study was not sufficient to result in and increase in weight increment. 3NO has less variable temperatures than the area further north (2J3KL).

Applying the modified Von Bertalanffy model of Miller and Myers (1990) there was a significant effect of temperature on growth in length, but the effect was negative, with fish growing less when temperatures were higher ($F_{1,275}$= (136233-133405)/(133405/275)= 5.83 p= 0.0164). The time series was too short to make comparisons using fall growth data or comparing spring growth data with temperatures from the previous fall. Figure 6 shows the von Bertalanffy growth curve for the 1980 cohort (cold temperature) and the 1991 cohort (warm temperature). It is clear for these two cohorts that growth in length was greater at the colder temperature. Although in some cases temperature has been found not to have an effect on growth in length, generally warmer temperatures result in greater growth (Jorgensen, 1992; Campana et al., 1995; Swain et al., 2003). Such a decrease in growth could be expected if the warmer temperatures experienced by cod in Div. 3NO were above their optimum for growth. Although there have been no studies of optimum growth temperatures for this population, studies with fish from other populations indicate that the optimum is actually much higher than those temperatures in Div. 3NO (Jobling, 1988).

There was also a significant effect of temperature on relative body and relative liver condition. Examination of the data indicated that the effect was not continuous so temperature was analyzed as a class effect. Except for the analyses of condition in autumn with autumn temperatures, the condition was higher at low and high temperatures than at intermediate temperatures (Fig. 7 and 8). Dutil et al (1999) suggest that poor condition in Div. 3Pn4RS cod was associated with colder temperatures with the effect being either directly on cod or through an effect on cod prey.

Results are very different for the analyses of the effect of temperature on growth in length and on condition. It is difficult to compare the results for the growth in length analyses and the condition analyses. This was because the modified von Bertalanffy model requires that temperature be a continuous effect, while the effect of temperature on condition was modeled as a class effect. Further analyses could explore class effects of temperature on growth in length.

The effect of temperature on growth is not independent of food availability. As ration level (food availability) declines, the most efficient growth occurs at lower temperatures where requirements for maintenance are lower because of lower metabolic rate (Brett, 1979). Food availability is not taken into account in this study. There is little information on capelin, one of the major prey species for cod. However, for the period since the early 1990's capelin in Div. 3NO is thought to be at a very low population size (Gorchinsky and Golovanov, MS 2005). During this time the cod population has also been at low abundance and the food availability for individual cod is unclear (Power et al., MS 2005)

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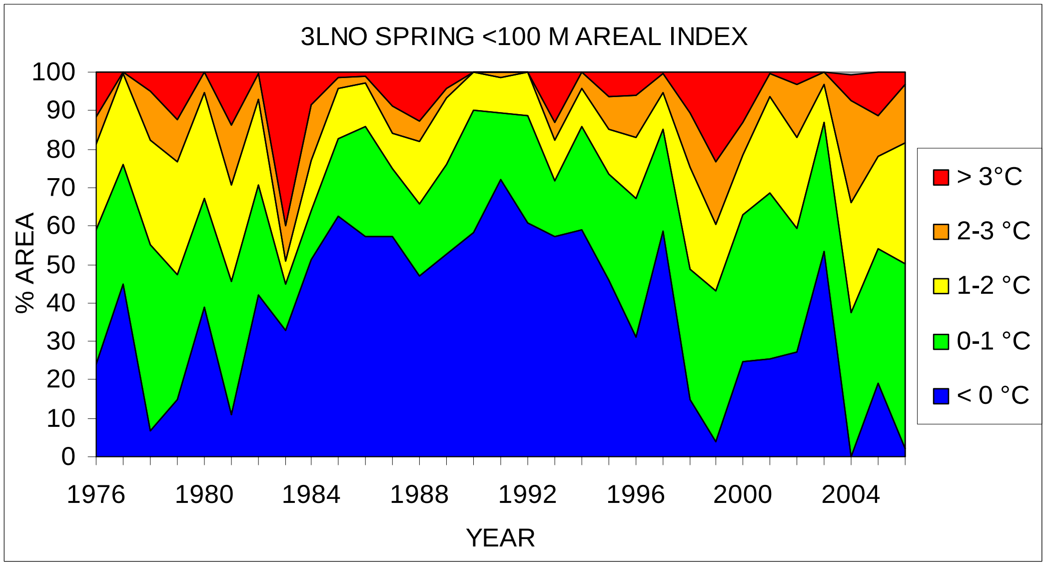


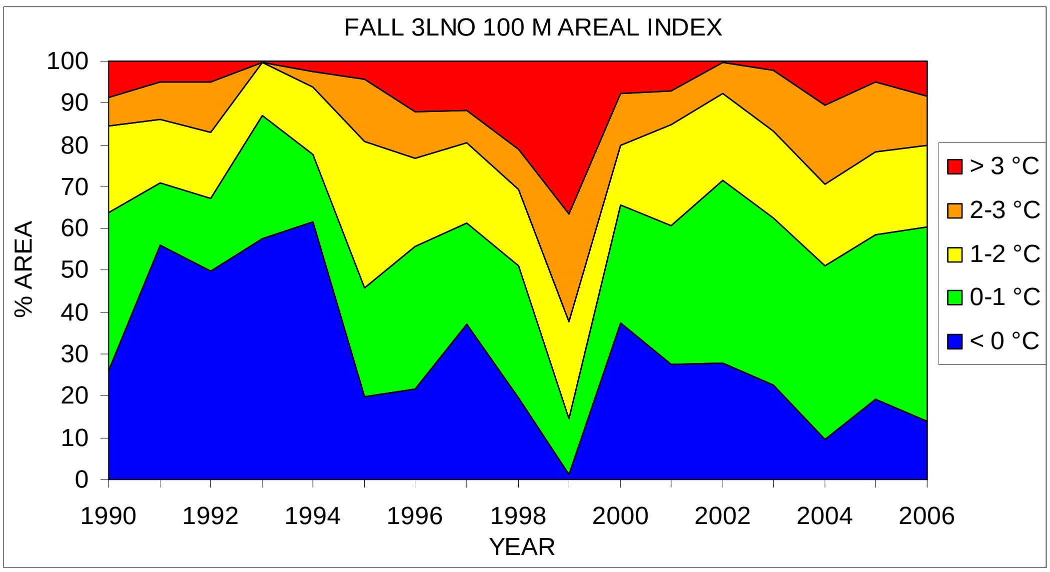


Fig. 1. Time series of the percentage area of the bottom covered by water with temperatures ≤ 0°C, 0-1°C, 1-2°C, 2-3°C and ≥3°C during the spring and fall on the Grand Bank in water depths < 100 m.

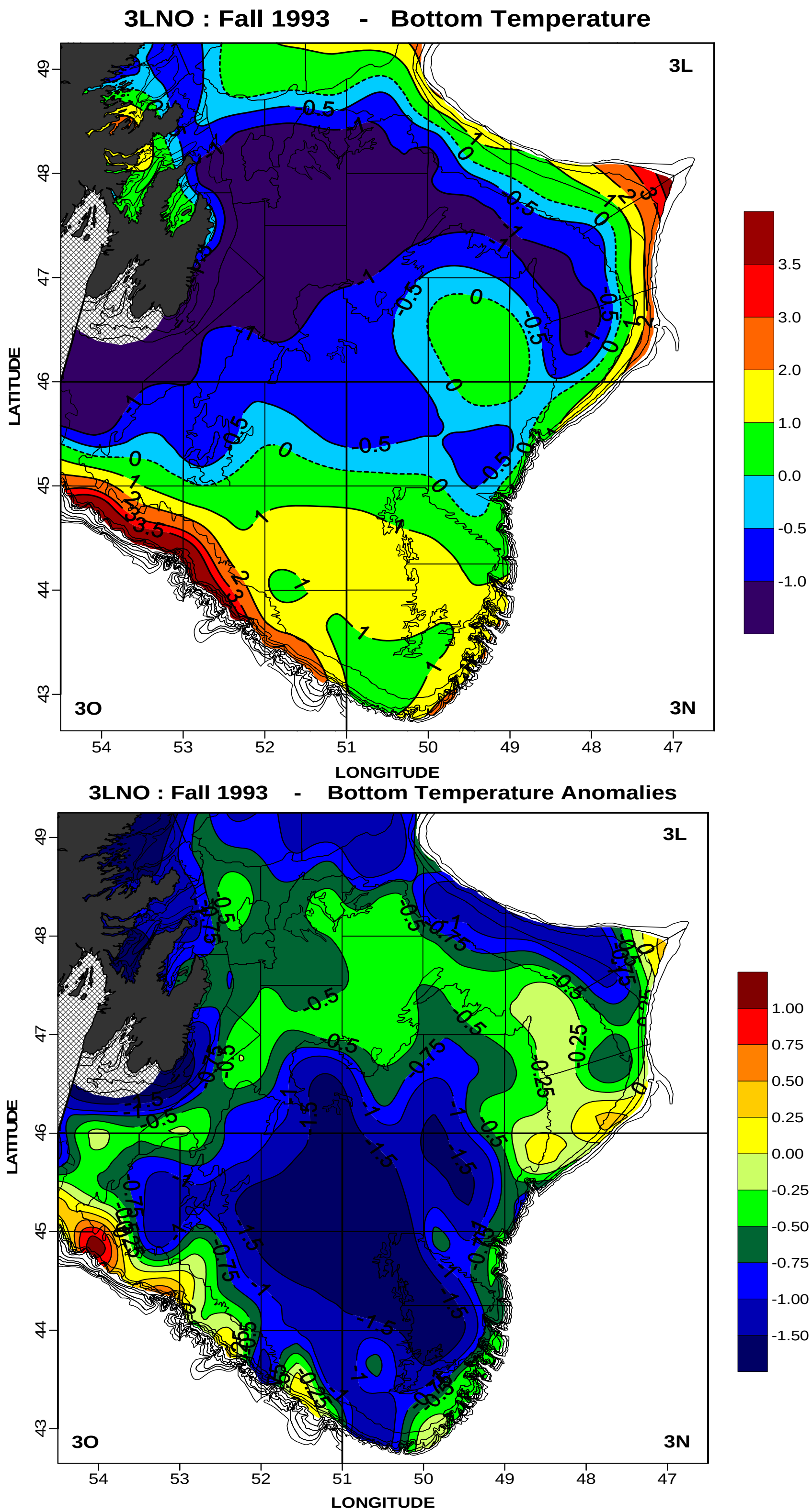


Fig. 2. Bottom temperature and temperature anomaly (in ^{O}C) maps for the Grand Banks during the fall of 1993.

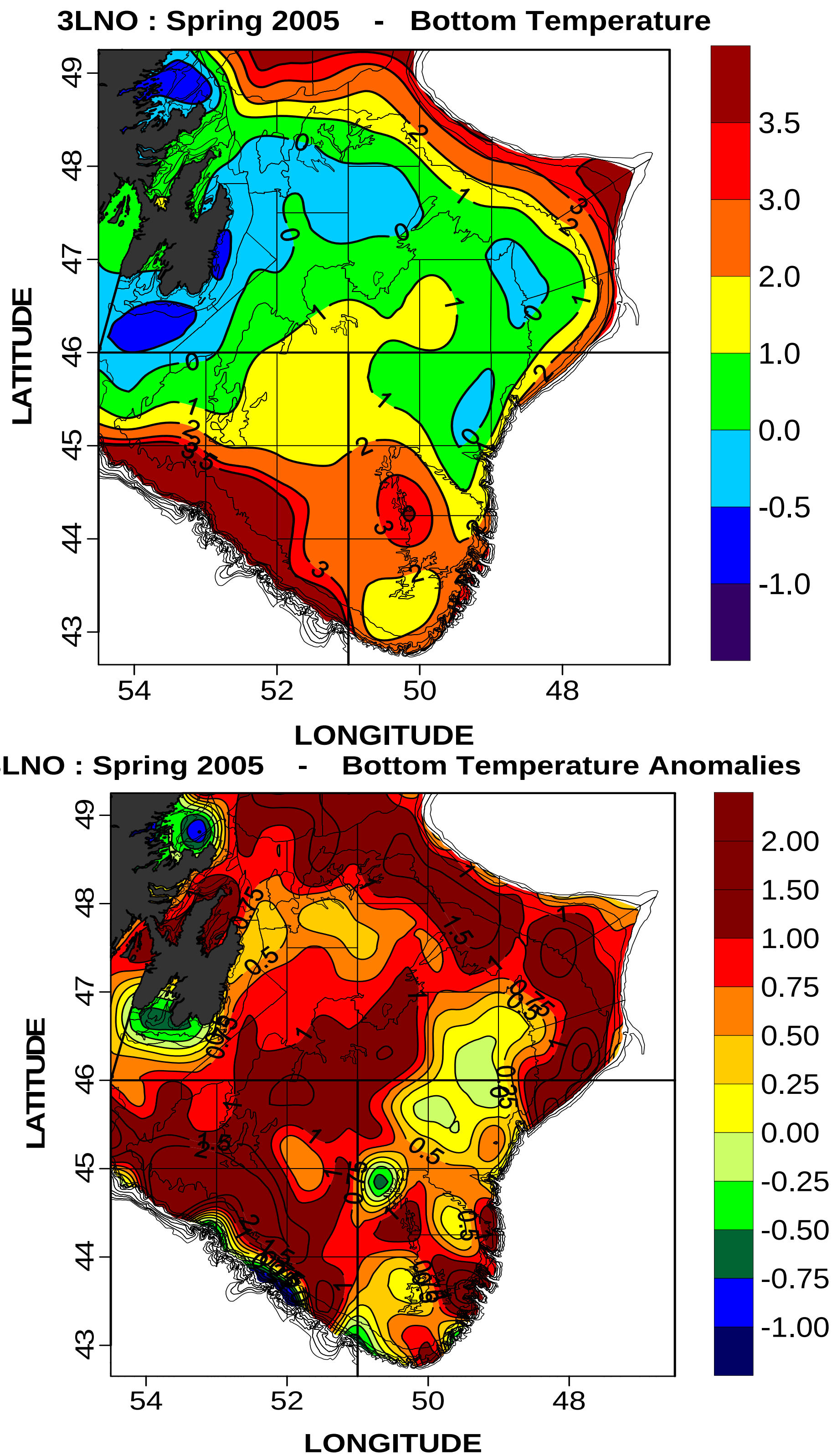


Fig. 3. Bottom temperature and temperature anomaly (in ^{O}C) maps for the Grand Banks during the spring of 2005.

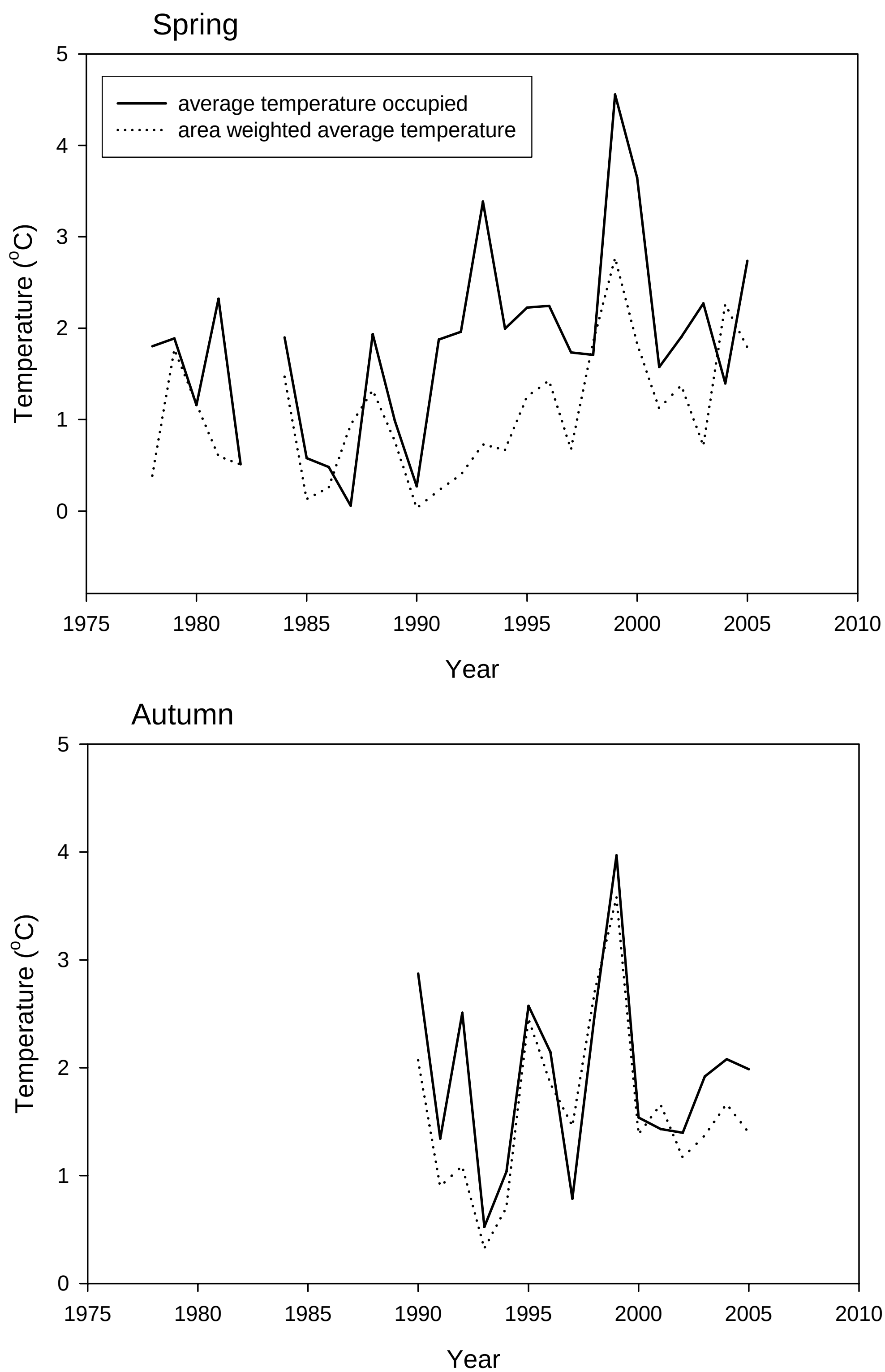


Figure 4. Average temperature occupied and average temperature available in the area for Div. 3NO cod.

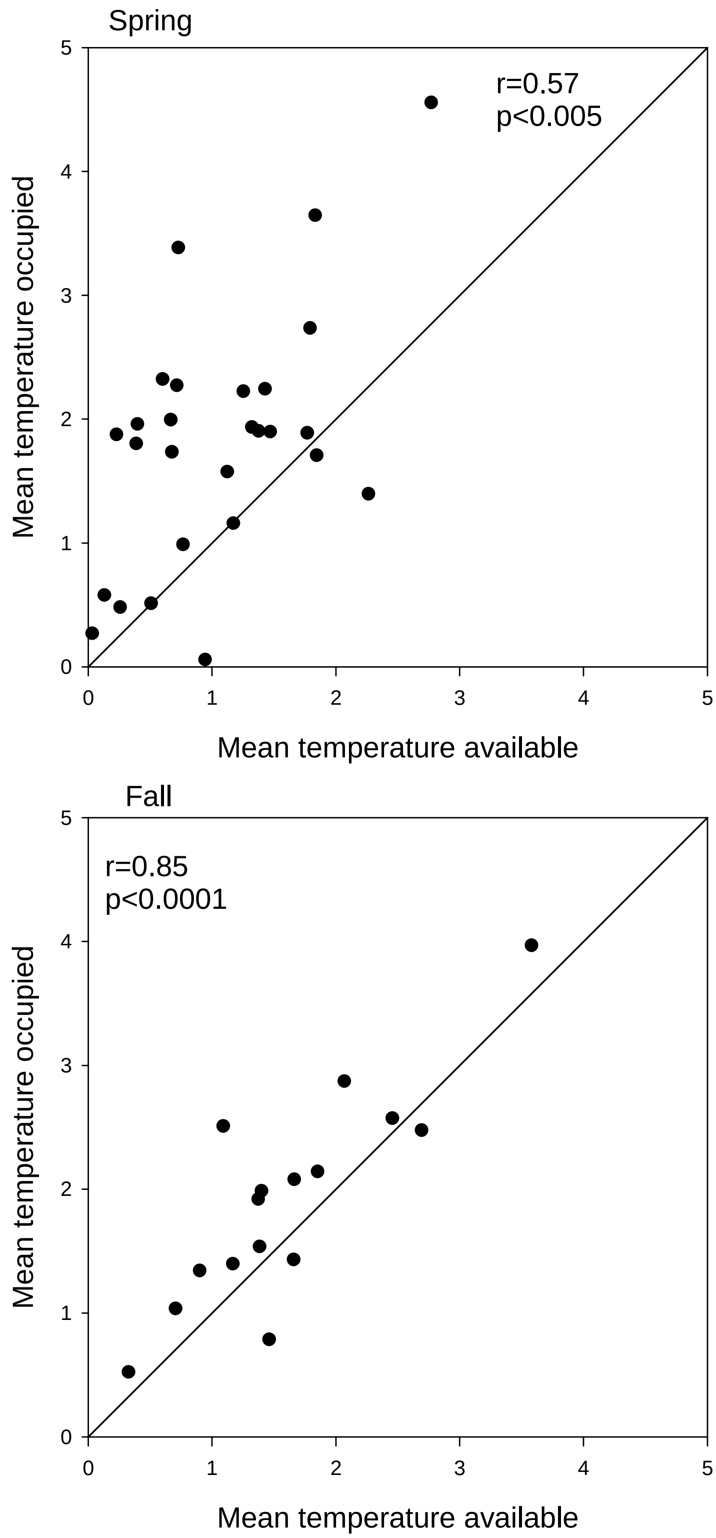


Figure 5. Average temperature occupied by cod in Div. 3NO plotted against the average temperature available (area weighted average). The Pearson correlation coefficient and probability level are given. The line is the 1:1 line.

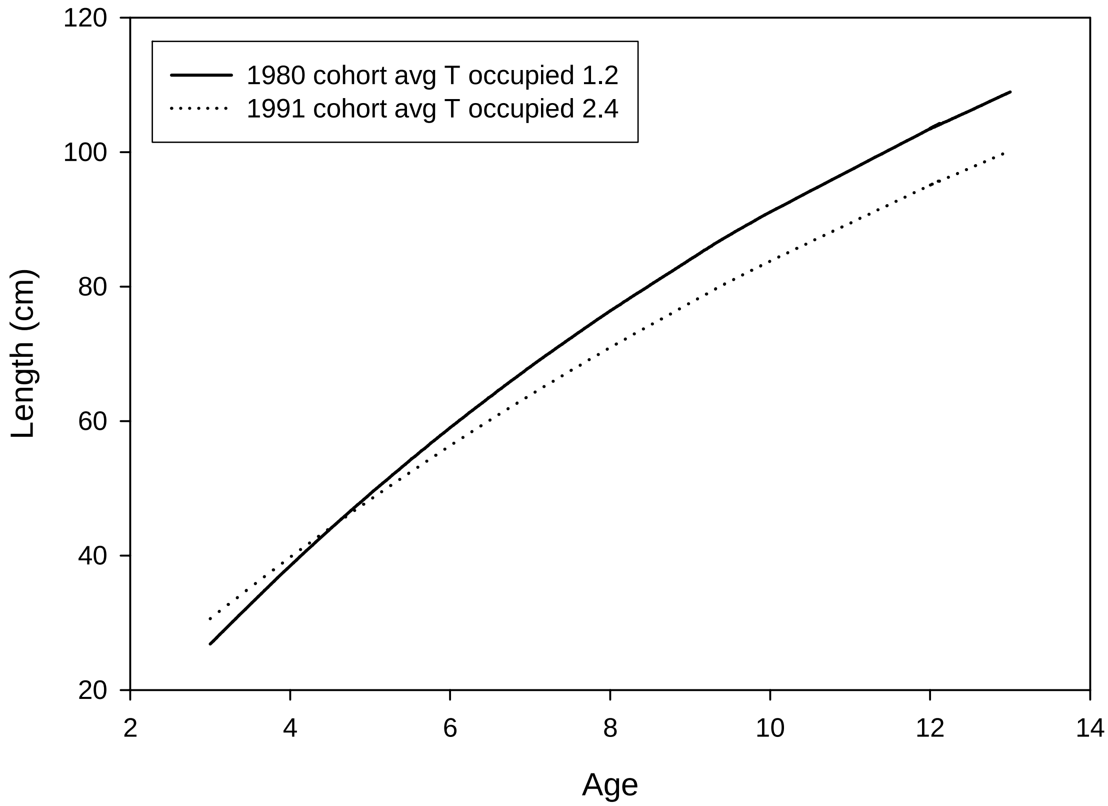


Figure 6. Estimated length at age from von Bertalanffy growth model for the 1980 and 1991 cohorts of cod in Div. 3NO.

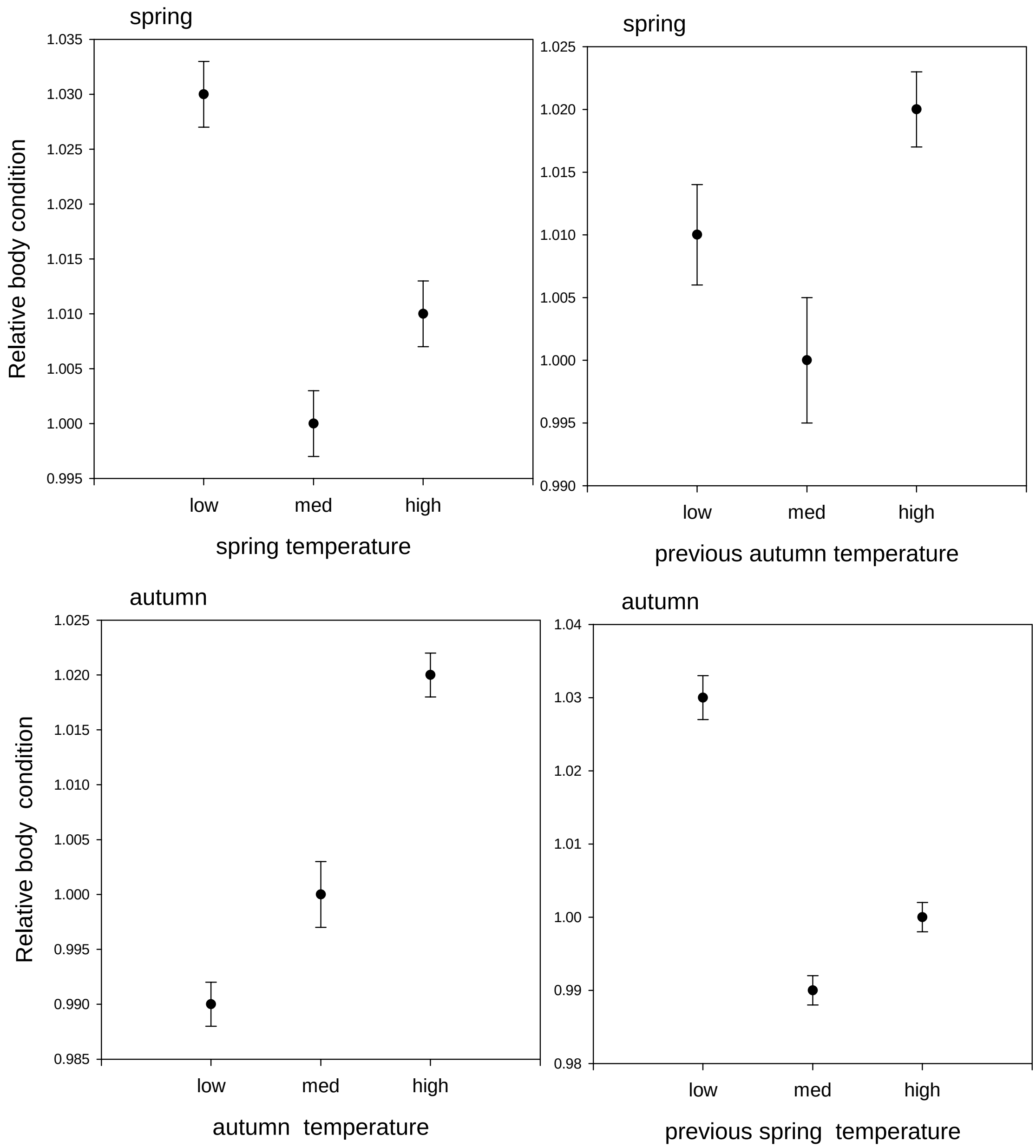


Figure 7. Average relative body condition (± S.E.) for Div. 3NO cod at low, medium and high temperatures. Spring condition was averaged for spring temperatures and for temperatures from the previous fall. Autumn condition was averaged for autumn temperatures and for temperatures from the spring of the same year.

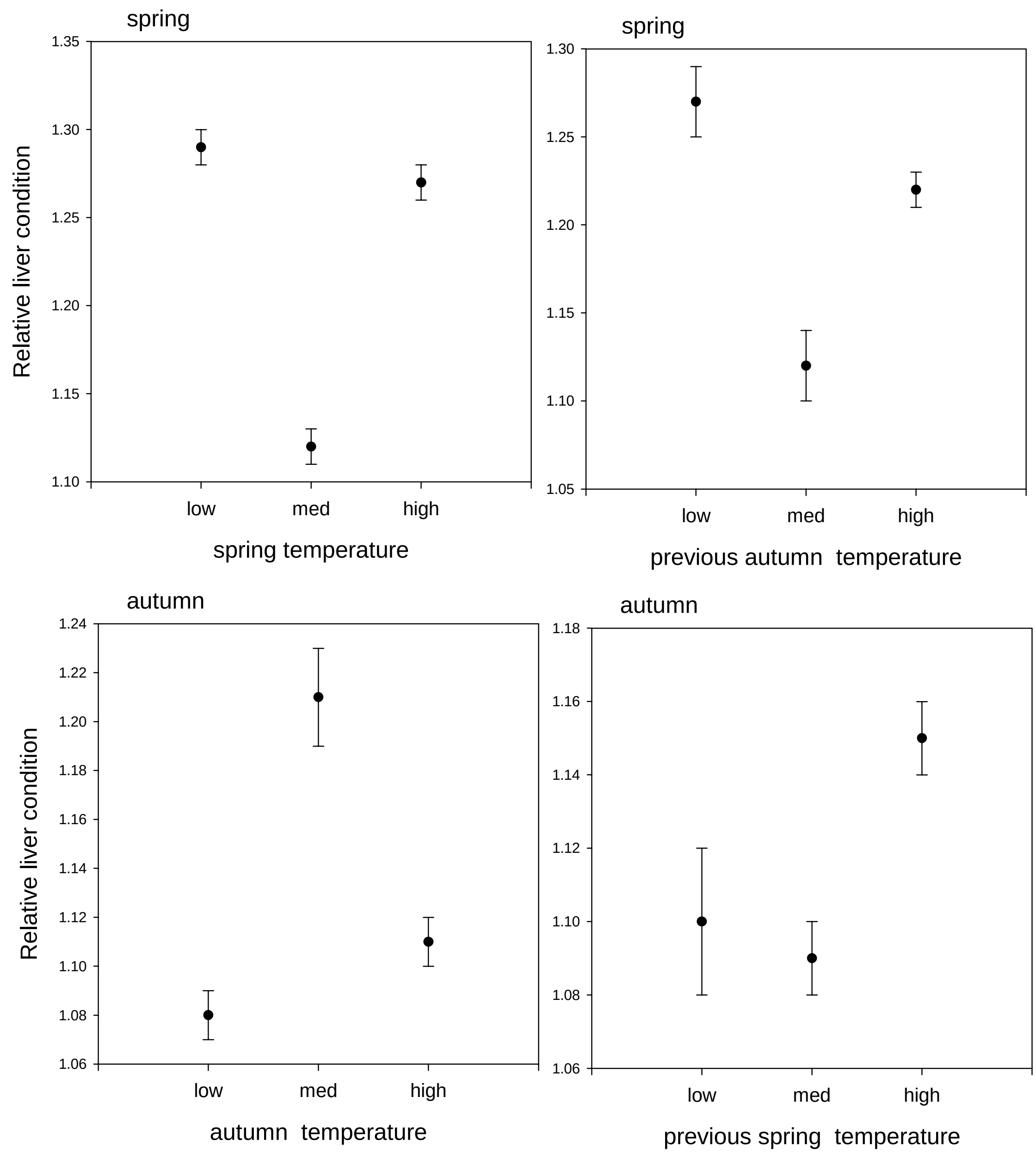
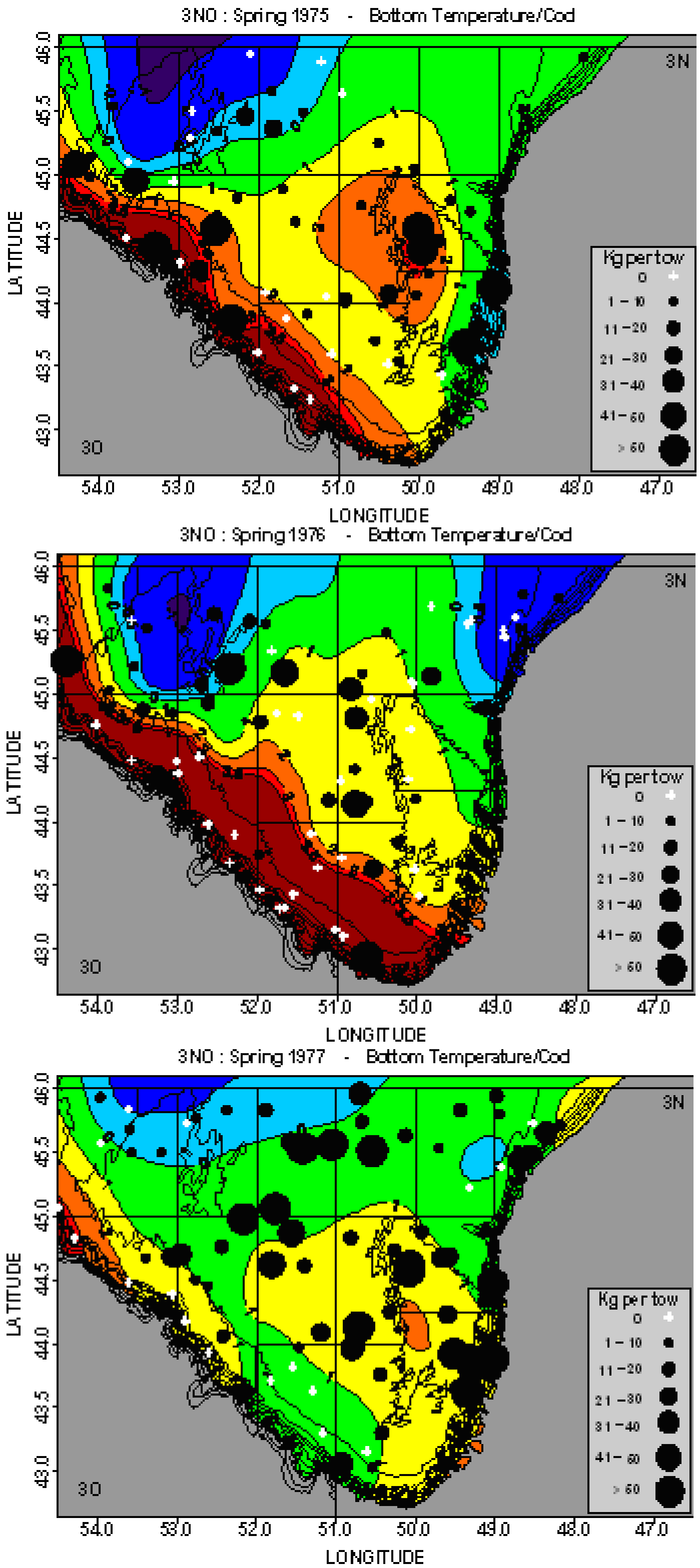
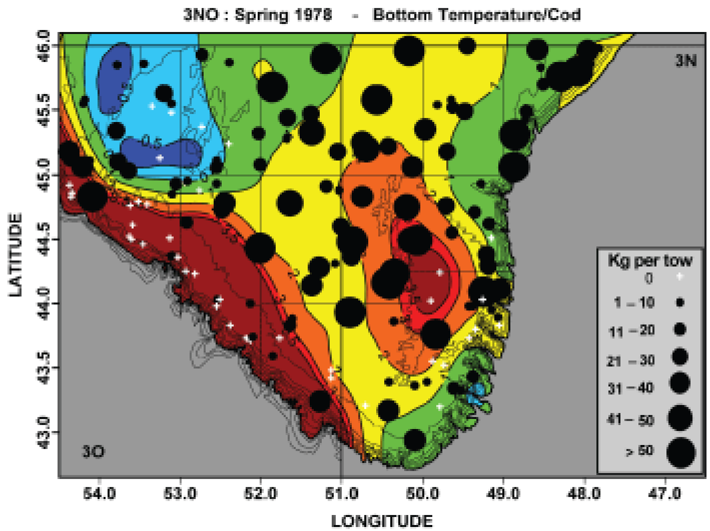
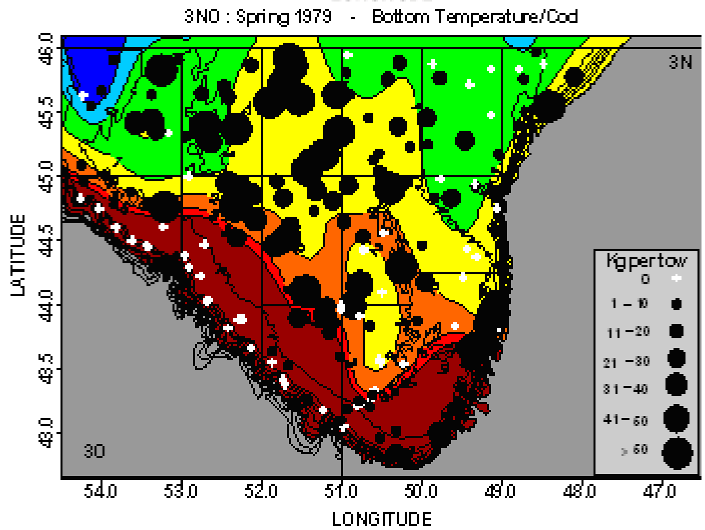


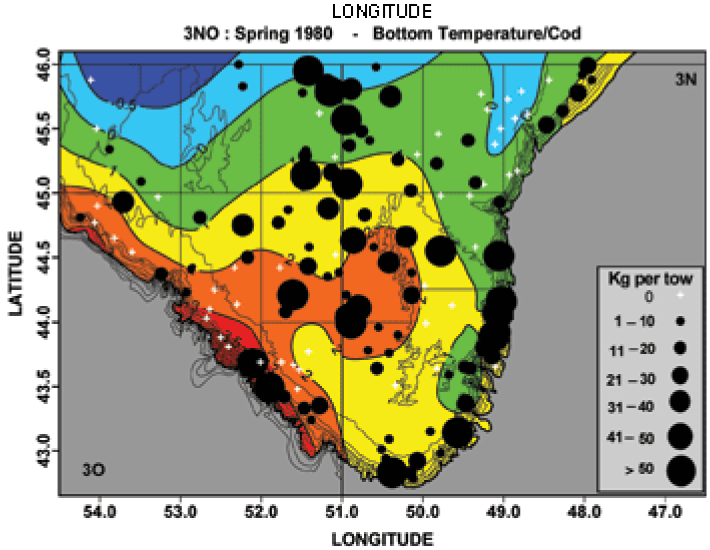
Figure 8. Average relative liver condition (+ S.E.) for Div. 3NO cod at low, medium and high temperatures. Spring condition was averaged for spring temperatures and for temperatures from the previous fall. Autumn condition was averaged for autumn temperatures and for temperatures from the spring of the same year.

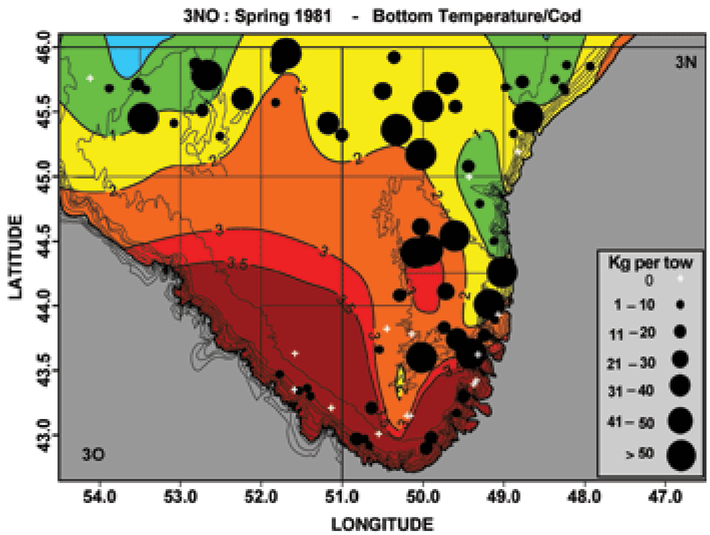
Appendix 1. 3NO Cod weights/set and Temperature Distribution Maps for the Spring Surveys from 1975-2006 and for the Autumn Surveys from 1990-2006.

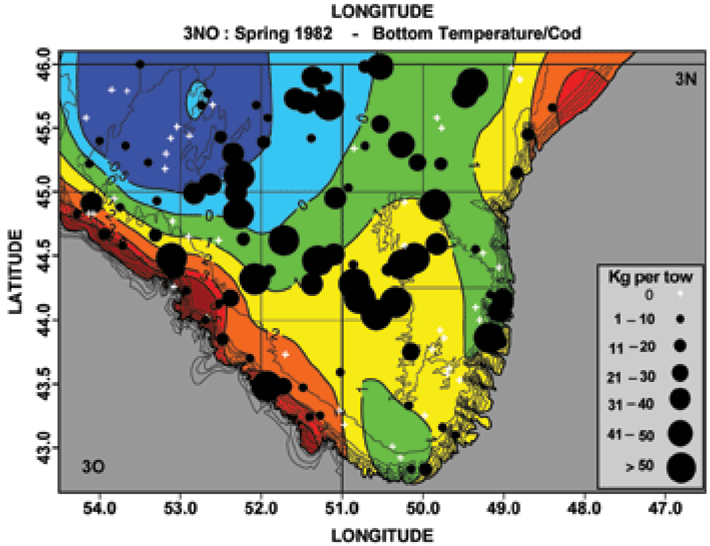

3NO : Spring 1975 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 - 10
11 - 20
21 - 30
31 - 40
41 - 60
> 60
3NO : Spring 1976 - Bottom Temperature/Cod
3NO : Spring 1977 - Bottom Temperature/Cod

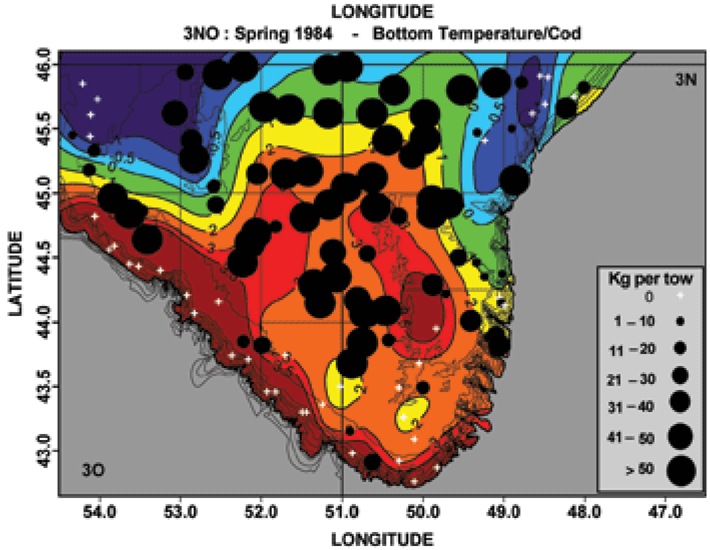

3NO : Spring 1978 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

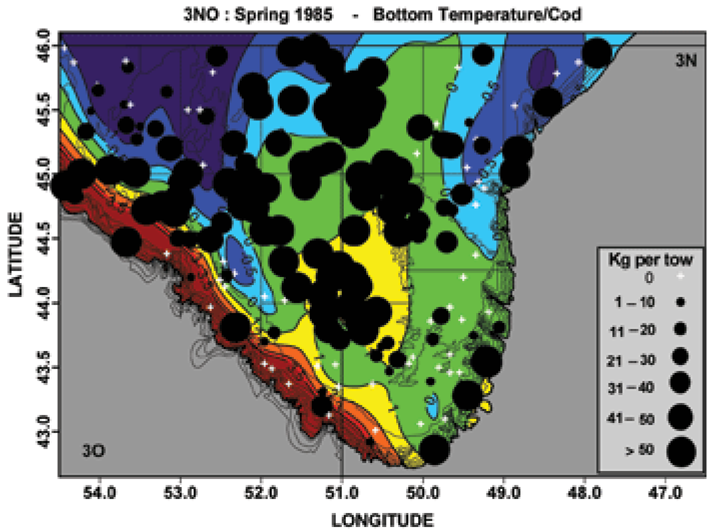

3NO : Spring 1979 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

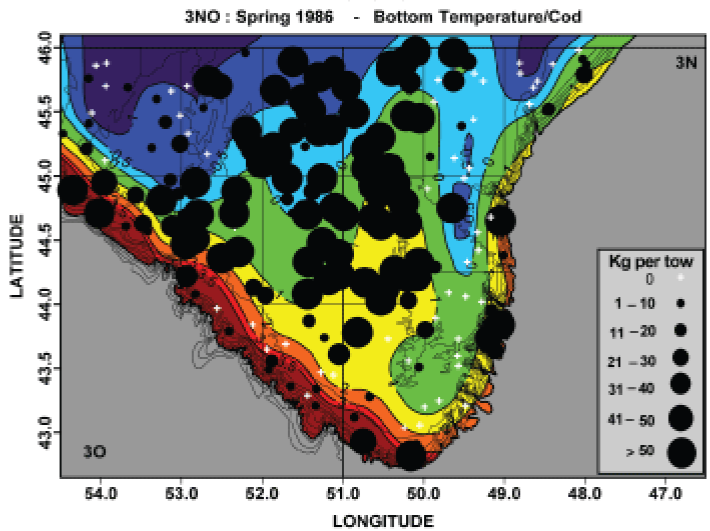

3NO : Spring 1980 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

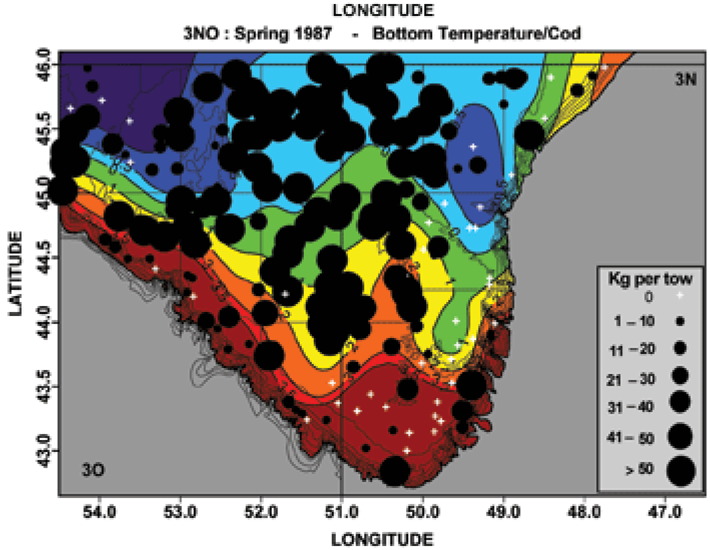

3NO : Spring 1981 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

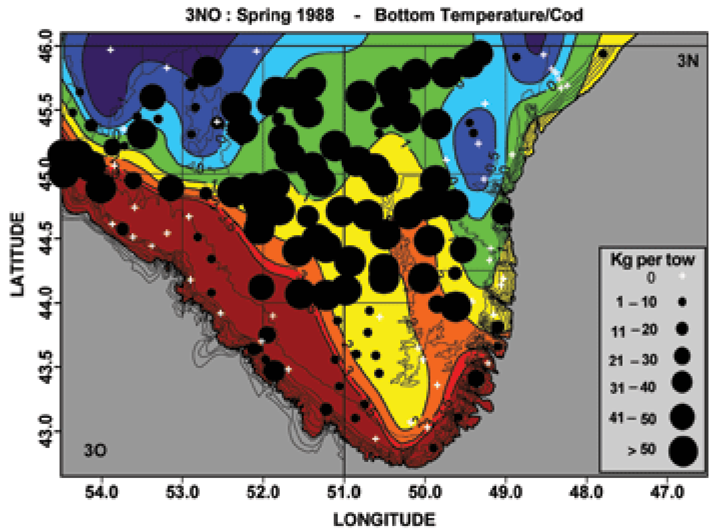

3NO : Spring 1982 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

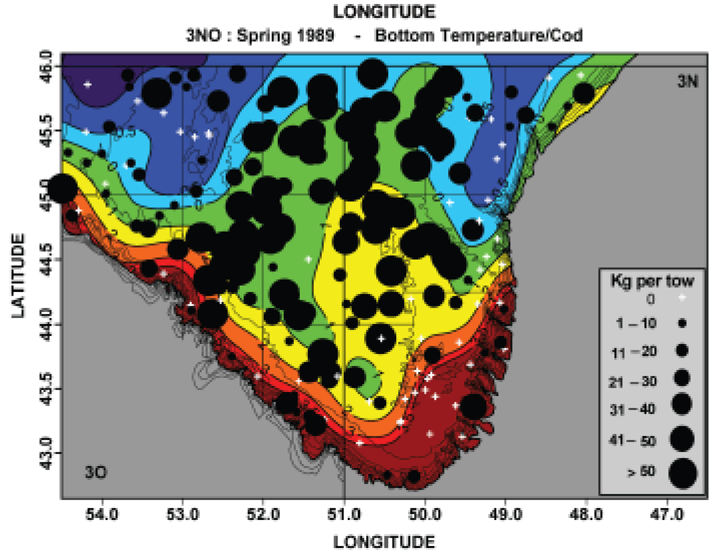

3NO : Spring 1984 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

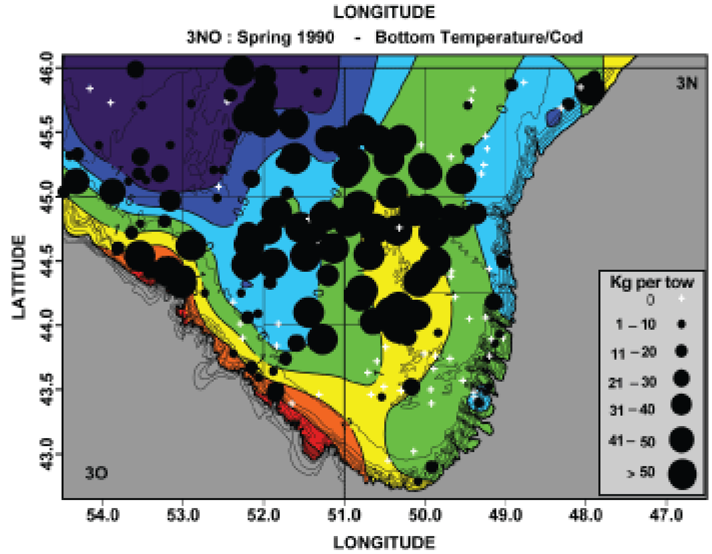

3NO : Spring 1985 - Bottom Temperature/Cod
LATITUDE
46.0
45.5
45.0
44.5
44.0
43.5
43.0
LONGITUDE
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

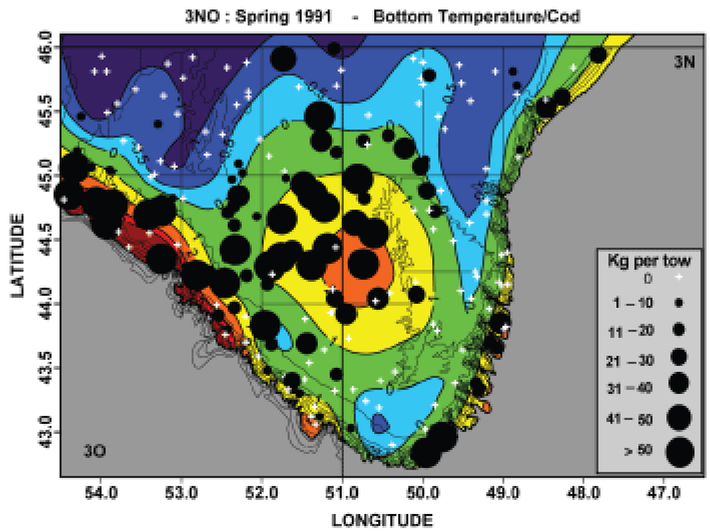

3NO : Spring 1986 - Bottom Temperature/Cod
LATITUDE
46.0
45.5
45.0
44.5
44.0
43.5
43.0
LONGITUDE
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

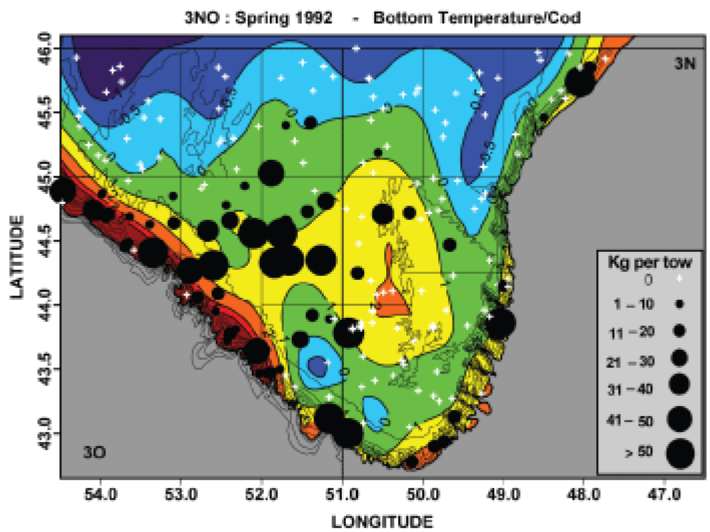

3NO : Spring 1987 - Bottom Temperature/Cod
LATITUDE
46.0
45.5
45.0
44.5
44.0
43.5
43.0
LONGITUDE
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50


3NO : Spring 1988 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
46.0
45.5
45.0
44.5
44.0
43.5
43.0
LONGITUDE
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0


3NO : Spring 1989 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
46.0
45.5
45.0
44.5
44.0
43.5
43.0
LONGITUDE
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0


3NO : Spring 1990 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
46.0
45.5
45.0
44.5
44.0
43.5
43.0
LONGITUDE
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0


3NO : Spring 1991 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
46.0
45.5
45.0
44.5
44.0
43.5
43.0
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0
LONGITUDE


3NO : Spring 1992 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
46.0
45.5
45.0
44.5
44.0
43.5
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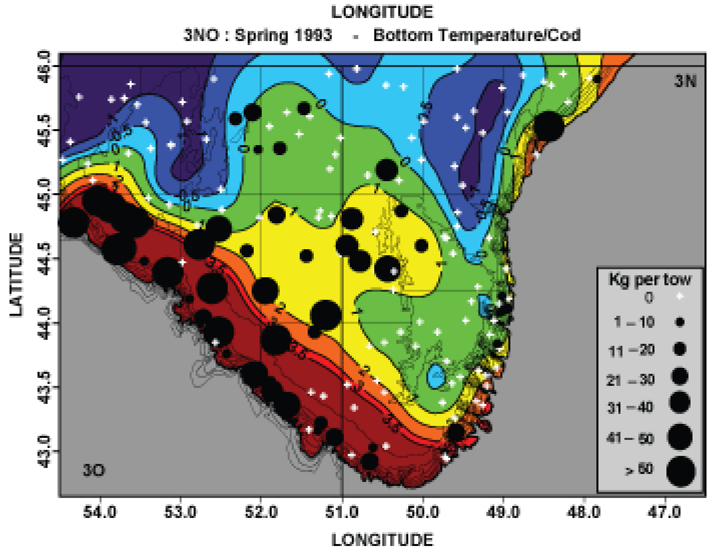
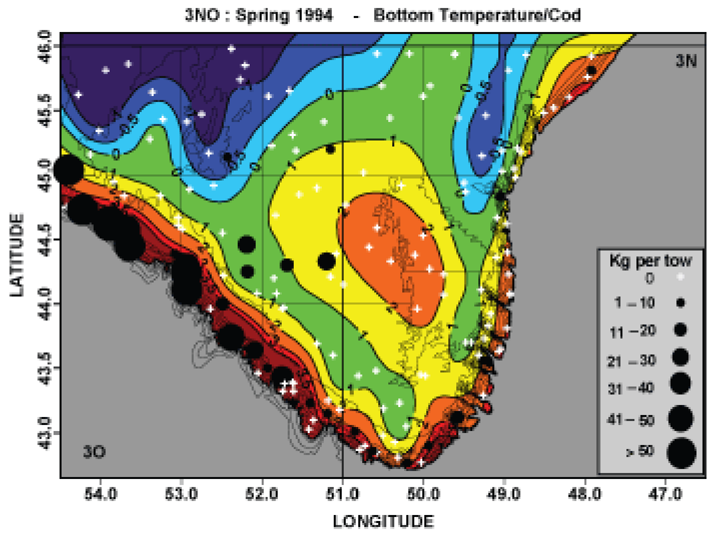
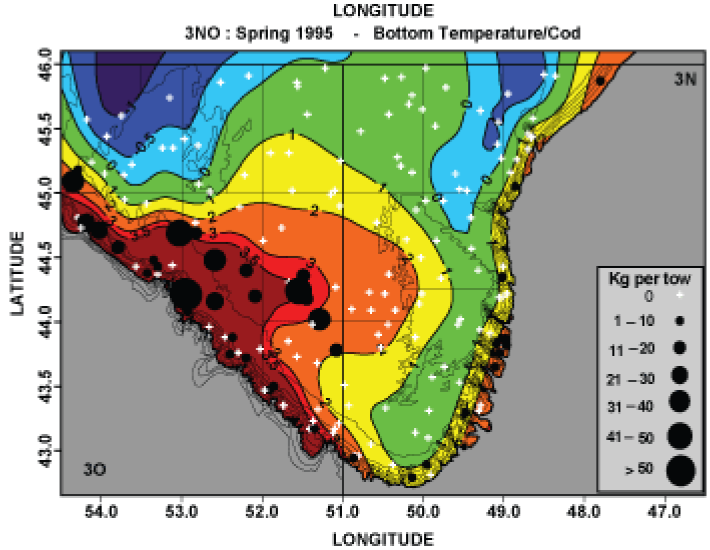
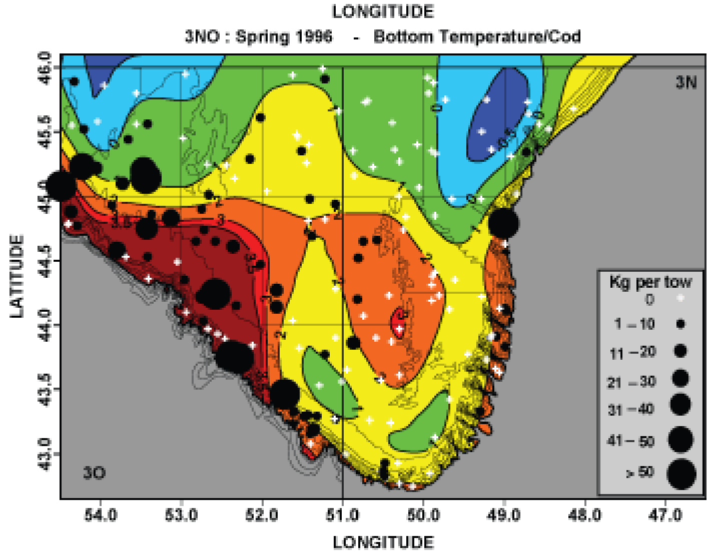
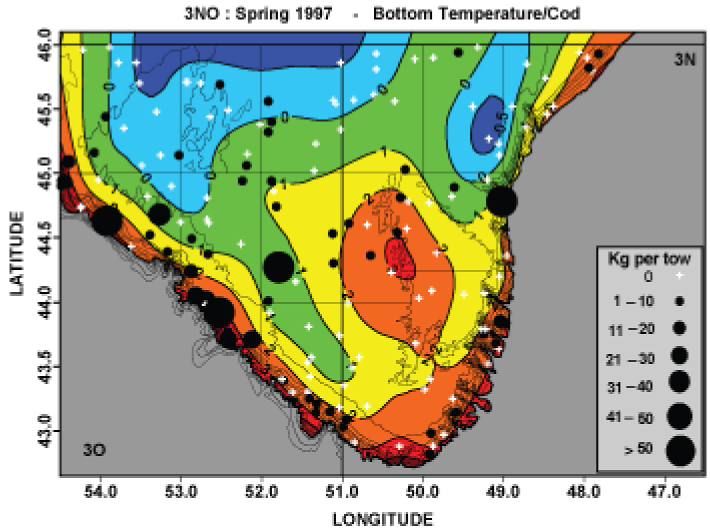
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0
LONGITUDE

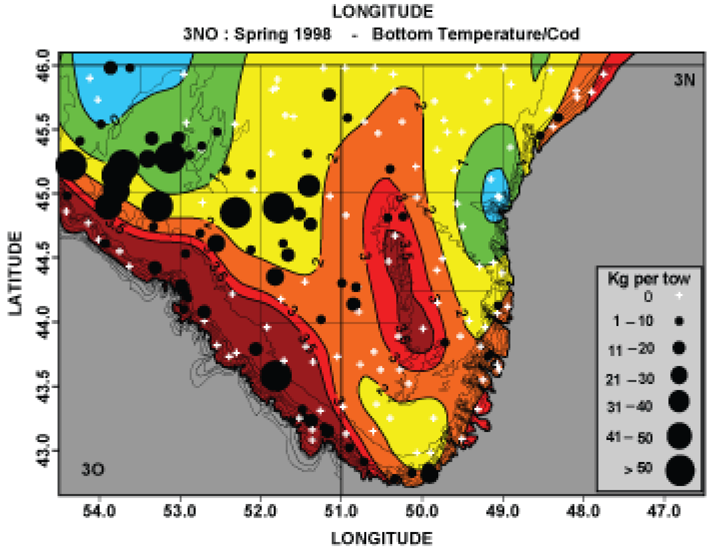

3NO : Spring 1993 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
46.0
45.5
45.0
44.5
44.0
43.5
43.0
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0
LONGITUDE

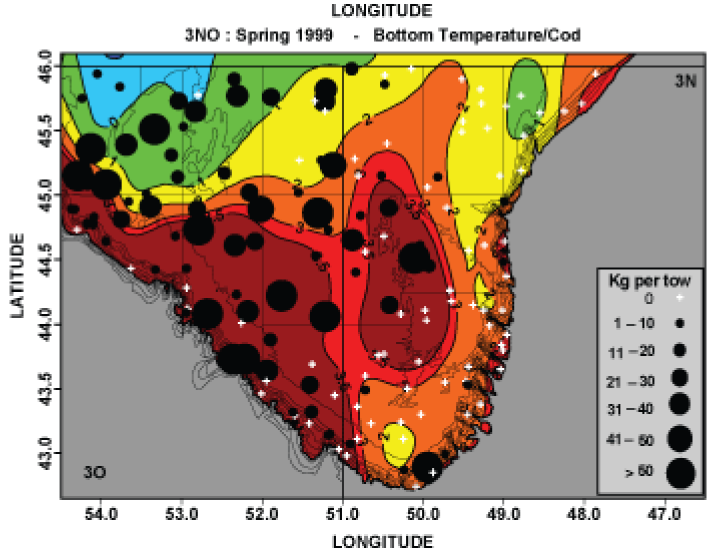

3NO : Spring 1994 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50


3NO : Spring 1995 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

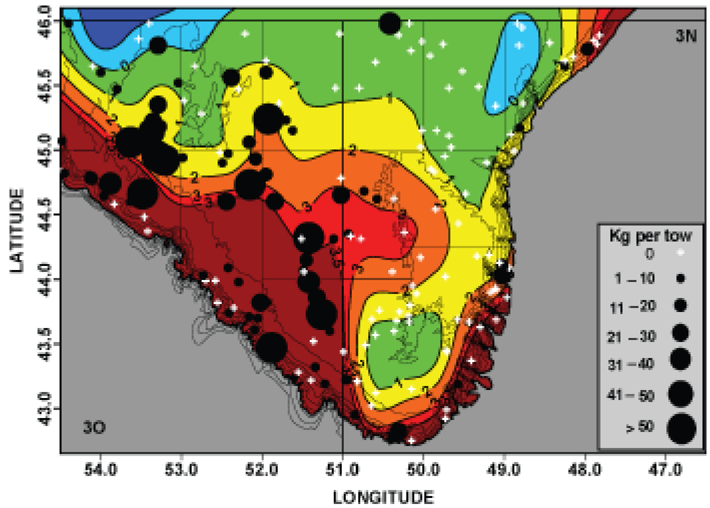

3NO : Spring 1996 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50


3NO : Spring 1997 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

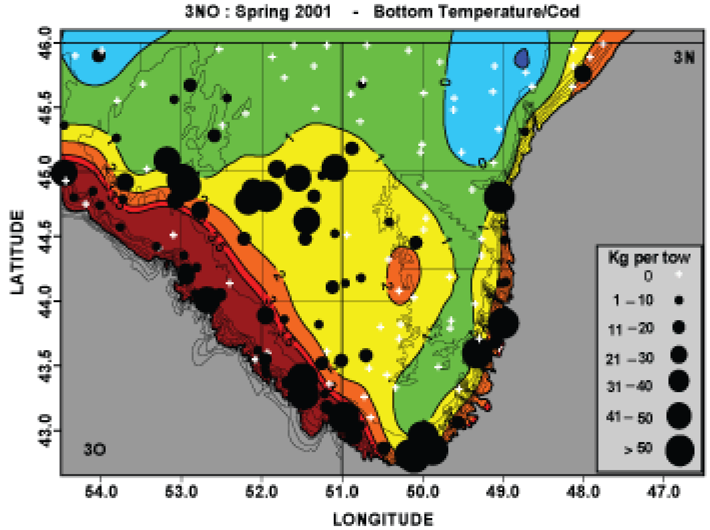

3NO : Spring 1998 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50


3NO : Spring 1999 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

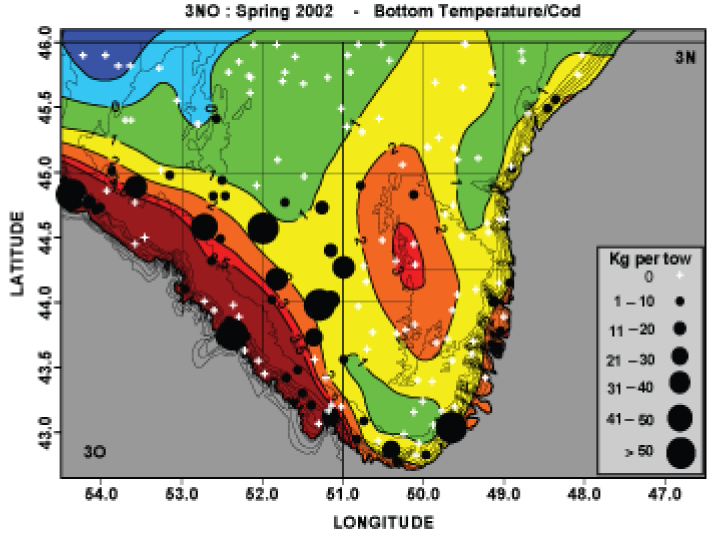
3NO : Spring 2000 - Bottom Temperature/Cod

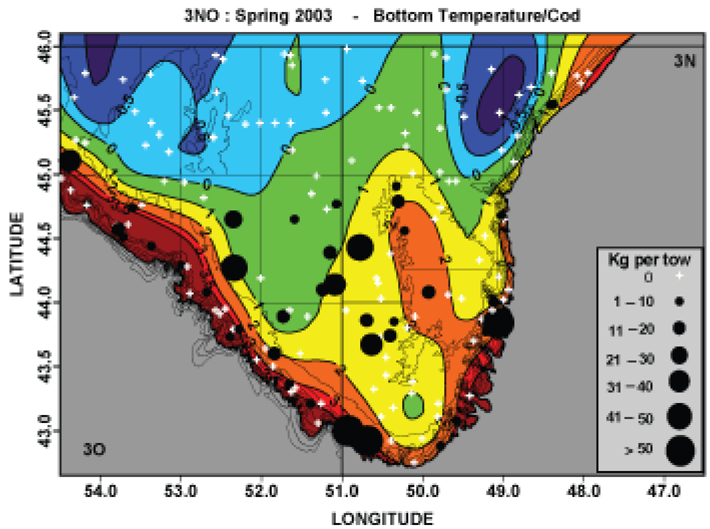


3NO : Spring 2001 - Bottom Temperature/Cod

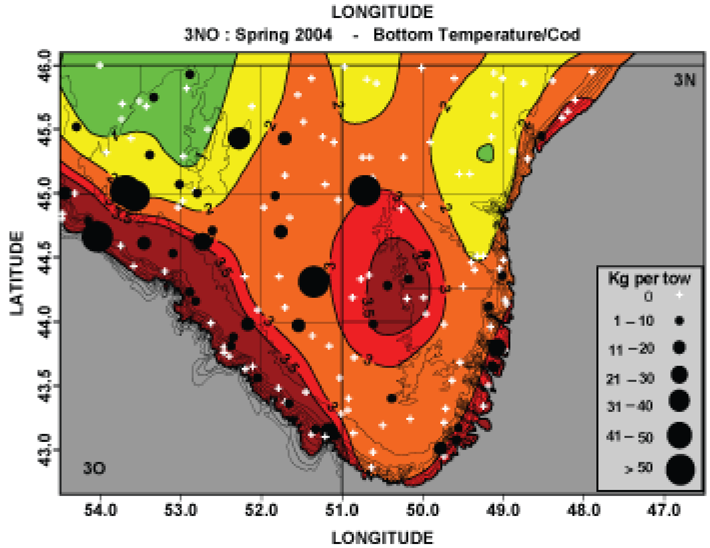


3NO : Spring 2002 - Bottom Temperature/Cod

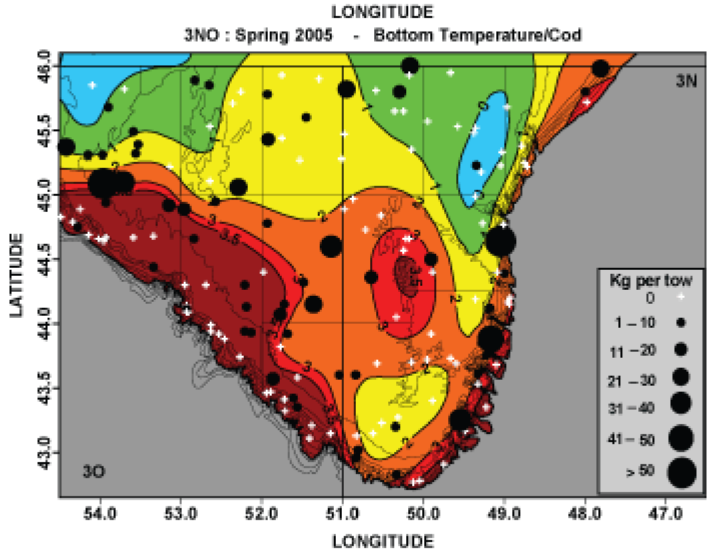




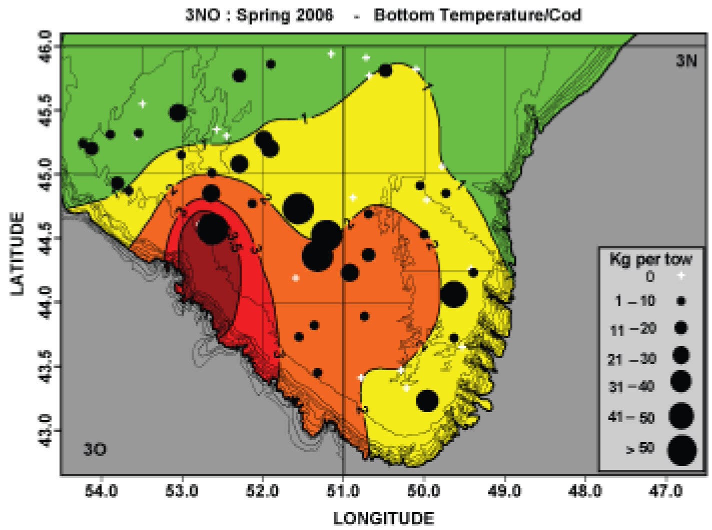
3NO : Spring 2003 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

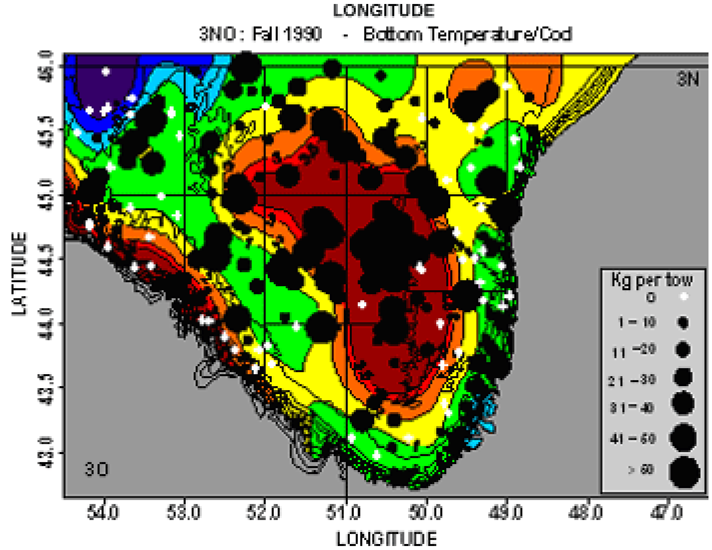


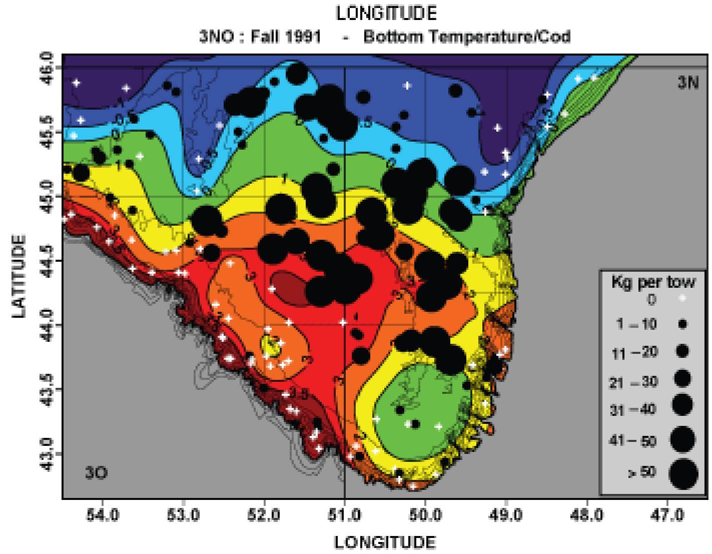
3NO : Spring 2004 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

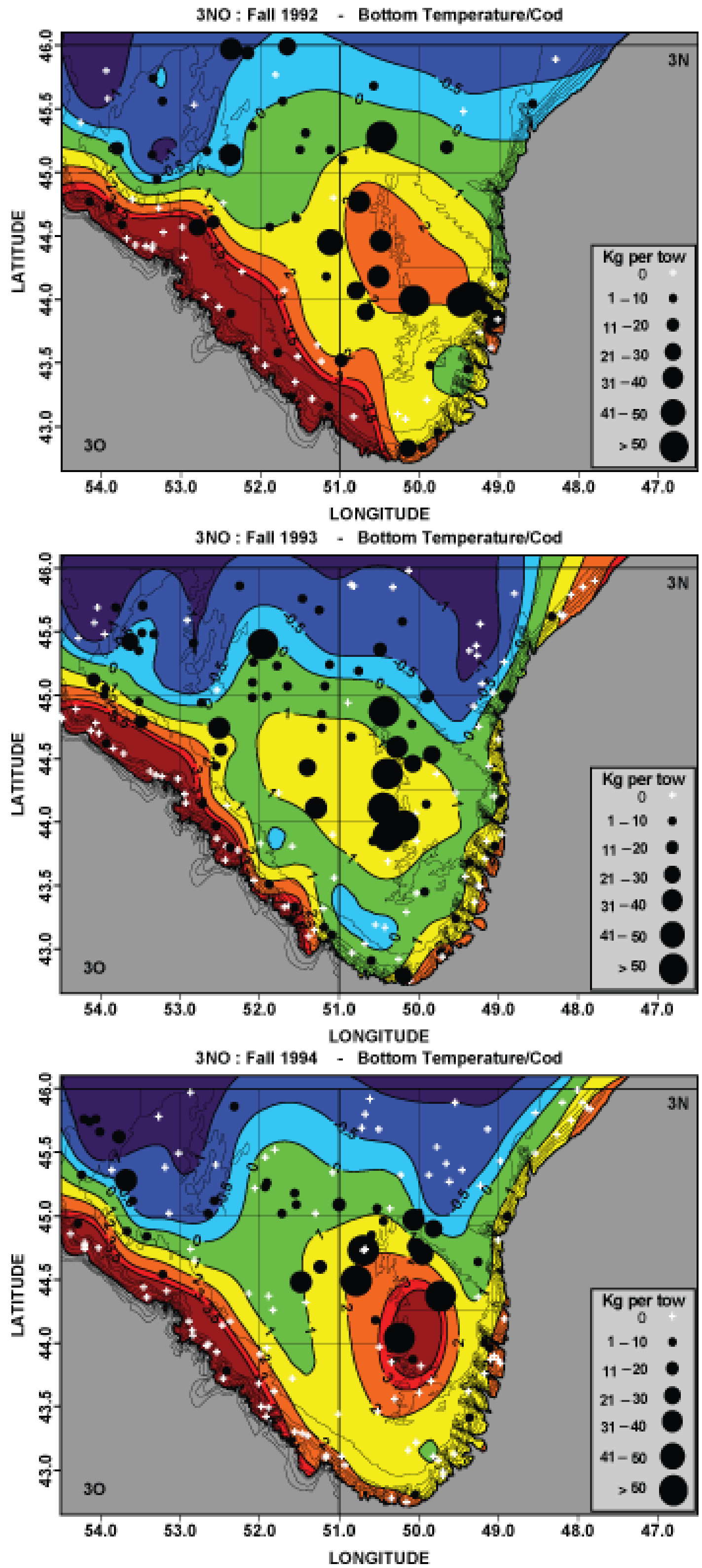


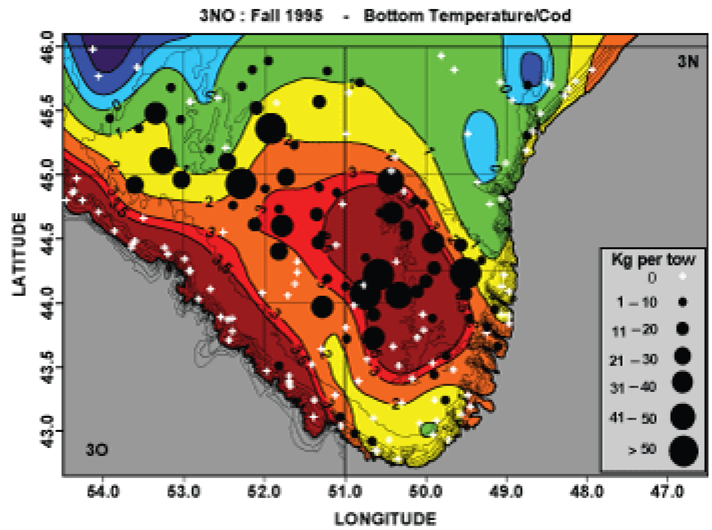
3NO : Spring 2005 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

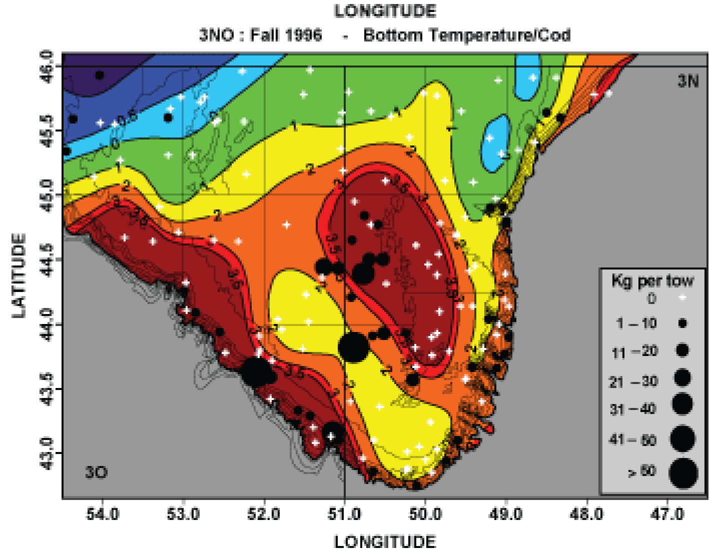

3NO : Spring 2006 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
3N
3O

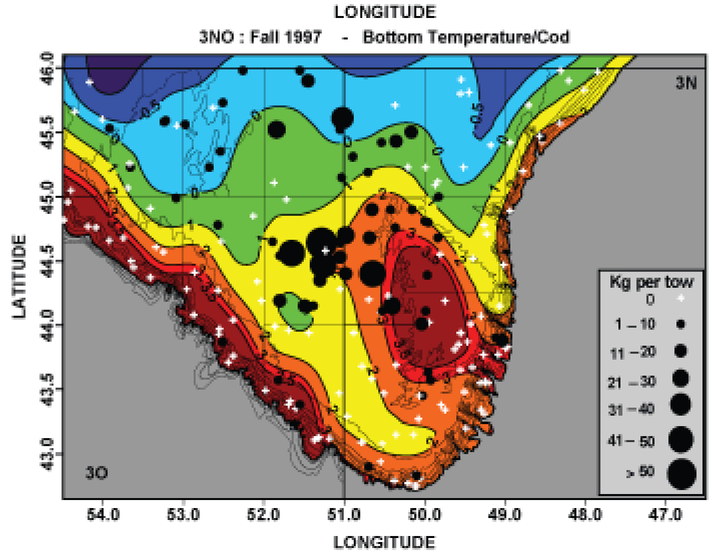

3NO : Fall 1990 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
3N
3O

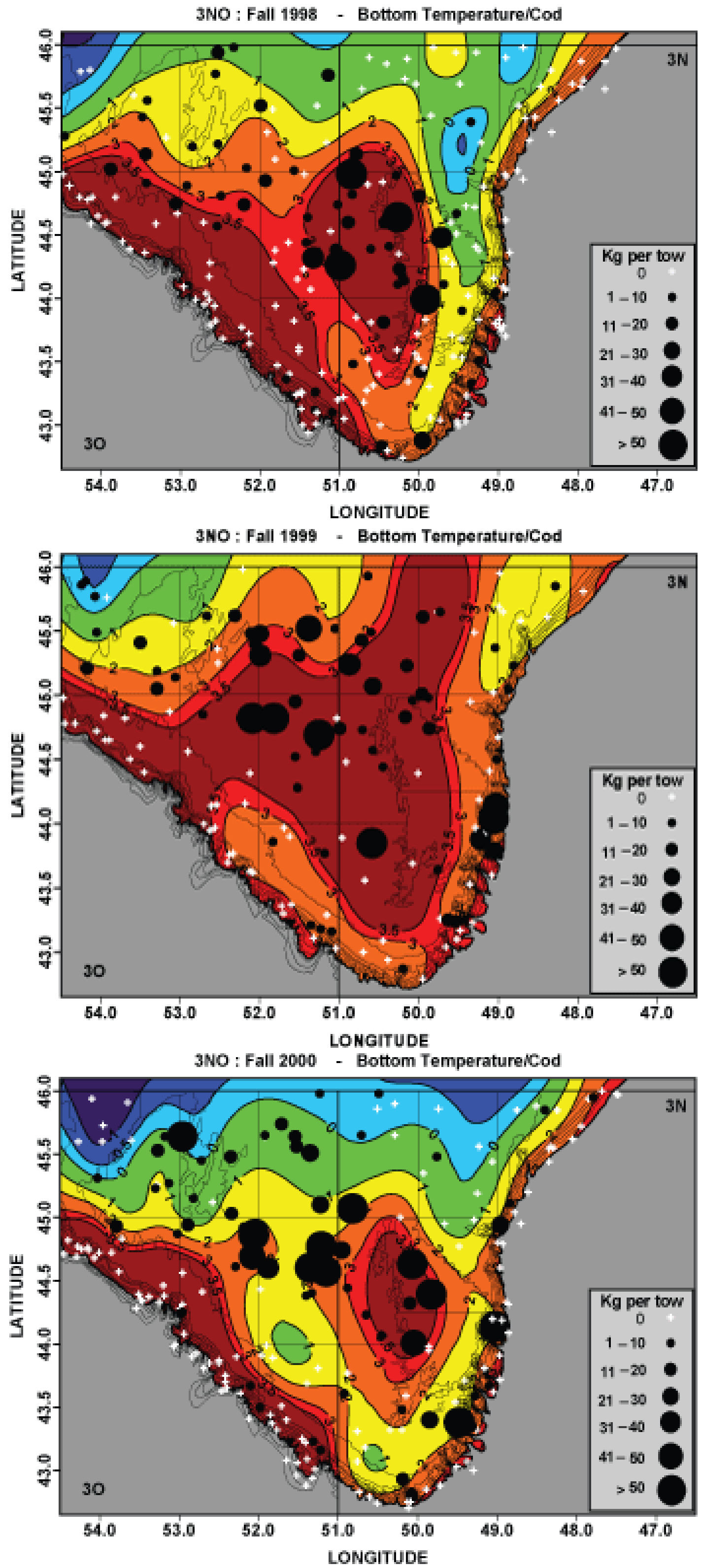

3NO : Fall 1991 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
3N
3O

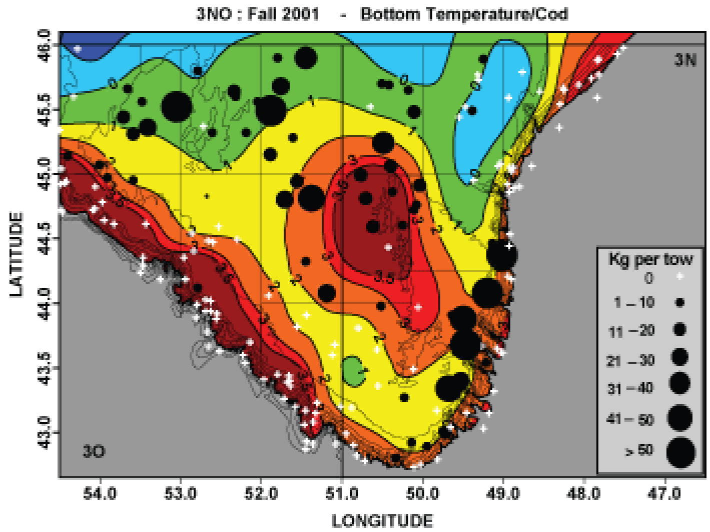

3NO : Fall 1992 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
3NO : Fall 1993 - Bottom Temperature/Cod
3NO : Fall 1994 - Bottom Temperature/Cod

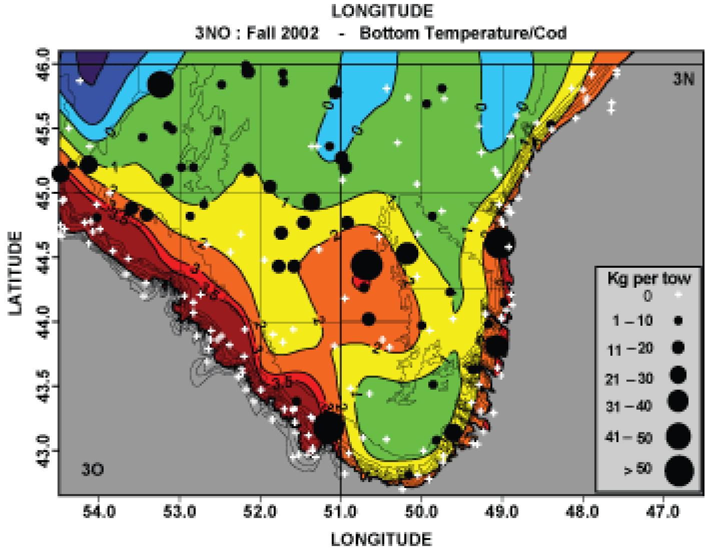

3NO : Fall 1995 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

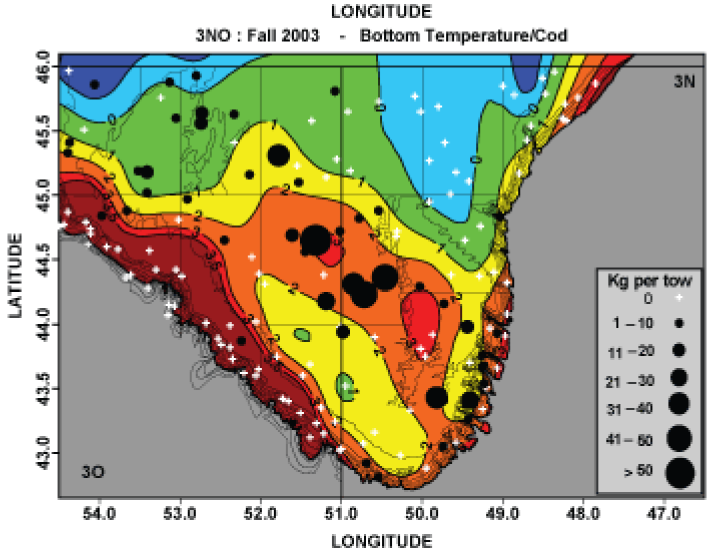

3NO : Fall 1996 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

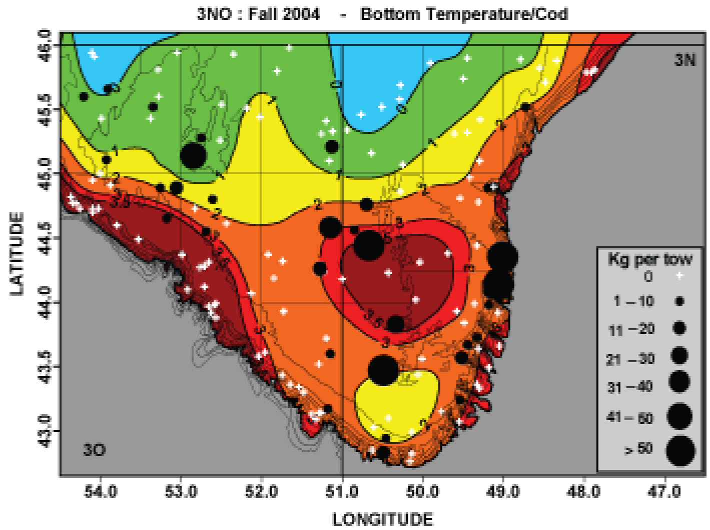

3NO : Fall 1997 - Bottom Temperature/Cod
3N
3O
LATITUDE
LONGITUDE
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50

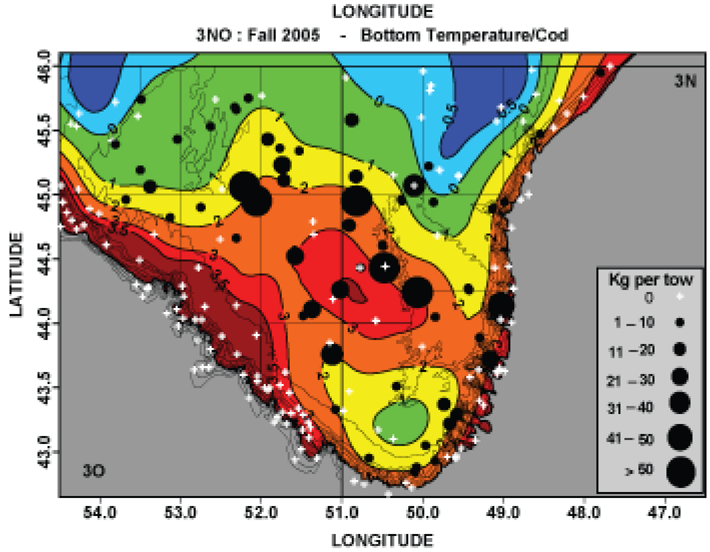

3NO : Fall 1998 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
LONGITUDE
3NO : Fall 1999 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
LONGITUDE
3NO : Fall 2000 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
LONGITUDE

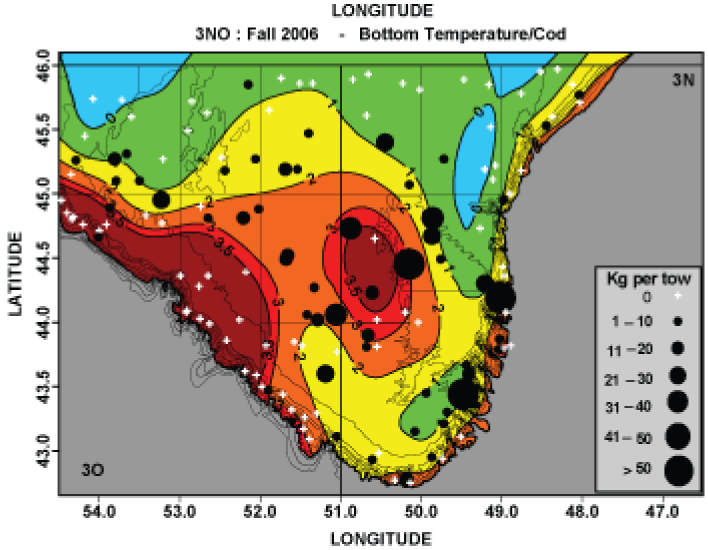

3NO : Fall 2001 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
43.0
43.5
44.0
44.5
45.0
45.5
46.0
LONGITUDE
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0


3NO : Fall 2002 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
43.0
43.5
44.0
44.5
45.0
45.5
46.0
LONGITUDE
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0


3NO : Fall 2003 - Bottom Temperature/Cod
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50
LATITUDE
43.0
43.5
44.0
44.5
45.0
45.5
46.0
LONGITUDE
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0


3NO : Fall 2004 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50


3NO : Fall 2005 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50


3NO : Fall 2006 - Bottom Temperature/Cod
LATITUDE
LONGITUDE
3N
3O
Kg per tow
0
1 – 10
11 – 20
21 – 30
31 – 40
41 – 50
> 50