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Northwest Atlantic Fisheries Organization

Serial No. N4782 **NAFO SCR Doc. 02/153**

SCIENTIFIC COUNCIL MEETING – NOVEMBER 2002

The Distribution and Abundance of Northern Shrimp (*Pandalus borealis*) in Relation to Bottom Temperatures in NAFO Divisions 3LNO Based on Multi-Species Surveys from 1995-2002.

by

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ABSTRACT

The spatial distributions and abundance of northern shrimp are presented in relation to their thermal habitat for NAFO Divisions 3LNO during spring surveys from 1998-2002 and for fall surveys from 1995-2001. The highest numbers of shrimp were caught in the 2°-4°C-temperature range during the spring surveys with lower numbers in the 1°-2°C and 4°-5°C temperature ranges. During the fall surveys most shrimp were caught in the 1°-3°C temperature range. Cumulative frequency distribution of the number of shrimp caught and temperature indicates that only about 5% of the catches are associated with temperatures <1°C in the spring and about 30% are associated with temperatures <1°C in the fall. About 80-90% of the shrimp were caught in the 2°-4°C temperature range during the spring, while only about 50% of the catch appeared in this temperature range during the fall. In terms of available thermal habitat, about 30% of the surveyed region was covered with water in the 2°-4°C-temperature range during the spring, while about 40% was covered by water in this temperature range in the fall. An apparent shift in the shrimp distribution towards colder temperatures, further upon the Grand Bank and towards the inshore regions occurred during the fall and as a result, a greater proportion (30%) of the catch shifted into the 0°-1°C-temperature range. Very low numbers of shrimp were found in temperatures <0°C and >4°C during both spring and fall. Shrimp catches were mostly zero in all surveys in the swallow waters (<100 m) of the southeast Grand Bank, where temperatures generally range from 2°-7°C. In general, during the spring most of the large catches were found in the warmer water along the slopes of Div. 3LN, while in the fall, larger catches were found in most areas of Div. 3L including the inshore areas of the bays along the east coast of Newfoundland.

Introduction

Canada has been conducting stratified random groundfish trawl surveys in NAFO Div. 3LNO since 1971. Each division was stratified based on the depth contours from available standard navigation charts (Fig. 1). Areas within each division, within a selected depth range, were divided into strata and the number of fishing stations in each stratum was allocated based on an area weighted proportional allocation (Doubleday 1981). The stratification scheme is constantly being revised as more accurate navigation charts become available and efforts are being made to extend the stratification scheme shoreward and into deeper water along the shelf edge (Bishop, 1994; Murphy, 1996; Brodie, 1996).

Since the fall of 1995 the Canadian research vessel surveys in the Newfoundland Region made use of a Campelen 1800 shrimp trawl (Mccallum and Walsh, 1996). As a result the annual spring and fall stratified random surveys now provides abundance and distribution data on northern shrimp (*Pandalus borealis*). The purpose of this analysis is to present the distribution and abundance of northern shrimp in relation to their thermal habitat in NAFO

Div. 3LNO based solely on these surveys. We begin by examining the mean catch rates and the cumulative distributions of available temperature to the survey and catch numbers for the complete range of temperatures encountered in the region. We then present the spatial distribution of northern shrimp in relation to the near-bottom temperature fields for both the spring and fall surveys.

Data and Methods

The historical oceanographic data set for the Newfoundland Shelf is available from archives at the Marine Environmental Data Service (MEDS) in Ottawa and from databases maintained at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia and at the Northwest Atlantic Fisheries Centre (NAFC) in St. John's Newfoundland. Since 1989, net-mounted conductivity-temperature-depth (Seabird model SBE-19 CTD systems) recorders have replaced XBTs on the annual assessment surveys as the primary oceanographic instrument. This system records temperature and salinity data during trawl deployment and recovery and for the duration of the fishing tow. Data from the net-mounted CTDs are not field calibrated, but are checked and factory calibrated periodically maintaining an accuracy of 0.005^{o}C in temperature and 0.005 in salinity. Expendable bathythermographs (XBTs) are only used when the net-mounted CTD fails during the tow, these are accurate to within 0.1^{o}C.

Data on shrimp abundance and distribution were available for the years 1995-2001 for the fall and from 1998-2002 for the spring surveys. Fishing sets of 15-minute duration at a towing speed of 3 knots were randomly allocated to strata covering the Grand Bank and slope waters to a depth of 1500 m (Fig. 1) (Brodie, 1996; McCallum and Walsh, 1996). The mean numbers and weight of northern shrimp for all sets within 1^{o}C-temperature bins for each year were computed. Cumulative frequency distributions of catch numbers for each temperature bin are compared to the available temperature distribution within the Div. 3LNO region for all surveys. For the purpose of this preliminary analysis, these distributions were not weighted by sampling intensity or stratum area. Near-bottom temperature grids for NAFO Div. 3LNO were then produced from all available data for spring for the years 1998-2001 and for the fall surveys for the years 1995 to 2001. All near-bottom temperature values for the time period of each survey were interpolated onto a regular grid and contoured using a geostatistical (2-dimensional Kriging) procedure. The numbers and total weight of northern shrimp per fishing set are displayed over the temperature contours as expanding solid circles.

Results

The average number of northern shrimp caught per fishing set in 1^{o}C-temperature bins are displayed in Fig. 2 and 3 for the spring and fall surveys, respectively. Significantly higher numbers and weight of shrimp were caught in the 2^{o}-4^{o}C-temperature range during the spring surveys, with much lower numbers in the 1^{o}-2^{o}C and 4^{o}-5^{o}C temperature ranges. Shrimp were also found in the –1.5^{o}-1^{o}C and 5-7^{o}C temperature ranges but in very low numbers. During the fall surveys most shrimp were caught in the 0^{o}-3^{o}C-temperature range. Larger catches were observed in the 2^{o}-4^{o}C-temperature range during the spring compared to the fall, while smaller catches were observed in 0-1^{o}C temperature range during the spring compared to the fall (Fig. 2 and 3). This was the result of an apparent shift in shrimp distribution further south and west in over the Grand Bank in colder water during the fall. The observed seasonal change in distribution as determined by the surveys was most evident in the northern regions of NAFO Div. 3L. The largest observed catches of shrimp occurred in the fall of 2001 and spring of 2002 in the 2^{o}-3^{o}C-temperature range. In general, catch rates and the estimated biomass of northern shrimp has increased substantially during the past three years, compared to earlier years of the surveys (Orr *et al*., 2000; 2001).

To further partition the thermal habitat of northern shrimp in Div. 3LNO we computed cumulative distributions of available temperature and catch number temperature distributions based on all data from the surveys for the time period 1998-2002 for the spring and 1995-2001 for the fall (Fig. 4). The cumulative frequency distribution of the number of sets for each temperature bin shows the temperature available to the survey and the cumulative distributions of catch numbers show the distribution of catches in relation to the available temperature. These preliminary results indicate that about 5% of the catches are associated with temperatures <1^{o}C in the spring while about 30% are associated with temperatures <1^{o}C in the fall. In the 1^{o}-2^{o}C range, 10% were caught in the spring and 20% in the fall surveys. About 80-90% of the shrimp were caught in the 2^{o}-4^{o}C temperature range during the spring, while about 50% of the catch appeared in this temperature range during the fall. In temperatures >4^{o}C, less than 5% of the shrimp were caught in spring and <1% in the fall (Fig. 4).

In terms of available near-bottom thermal habitat, in the spring about 25% of the surveyed region was covered with <0^{o}C water, about 45% was in the 1^{o}-3^{o}C temperature range and about 30% of the bottom was covered by water with temperature >3^{o}C. In the fall, about 30% of the surveyed region was covered with <0^{o}C water, about 30% was in the 1^{o}-3^{o}C temperature range and about 40% of the bottom was covered by water with temperature >3^{o}C. These results indicate a similar thermal habitat in the surveyed area of Div. 3LNO during both spring and fall with differences in the % area of the bottom in the same temperature range generally between 5-15%. It should be noted that these percentages are based on the relatively warm years of 1995-2002. The shift in the shrimp distribution towards colder temperature bins during the fall is clearly evident by comparing the cumulative distributions displayed in Fig. 4.

The spring and fall bottom temperature maps together with the number and weight of shrimp caught per set for NAFO Div. 3LNO are shown in Fig. 5 and 6. In general, spring bottom temperatures in the northern areas ranged from <0^{o}C in the inshore regions of the Avalon Channel to >3^{o}C at the shelf edge. Over the central and southern areas bottom temperatures ranged from 1^{o}C to >3.5^{o}C on the Southeast Shoal and >3^{o}C along the edge of the Grand Bank. During the cold years from 1990-1995 virtually the entire Div. 3L area (except the deeper slope regions) and a significant portion of 3NO was covered by <0^{o}C water (Colbourne, 2000). Beginning around 1996 the area of <0^{o}C water began to retract and by 1999 it was restricted to a small area in the Avalon Channel. During 2001 and 2002 the area of <0^{o}C water began to increase again covering most of the plateau of the Grand Bank in Div. 3L. During the fall, temperatures in Div. 3L were very similar to spring values with <0^{o}C water covering most of the area during cold years. During the warm years of 1998 and 1999 again most of the coldest water was restricted to the deeper portions of the Avalon Channel. In the shallower regions of Div. 3NO however, fall bottom temperatures are generally warmer than spring values (by 2^{o}-3^{o}C) as a result of summer surface heating (Colbourne, 2000; Colbourne and Murphy, 2000).

The numbers and weight of northern shrimp caught per set during each survey are displayed with the temperature fields in Fig. 5 for the spring surveys and in Fig. 6 for the fall surveys as expanding symbols. The size of the circle is proportional to the magnitude of the catch or weight in each set. The majority of fishing sets in the shallow regions (water depths <100-m) of southern 3L and most of Div. 3NO show either zero catches or very low numbers. During the spring surveys most of the large catches were found in the warmer water along the slopes of Div. 3LN with very low catches in Div. 3O (Fig. 5). During the fall surveys, again large catches occurred along the outer areas and slopes of the Grand Bank, however as described above, larger catches were more widely distributed in Div. 3L, including the inshore areas of the bays along the east coast of Newfoundland (Fig. 6). It appears that during the fall, shrimp were caught in all available temperatures in Div. 3L, although in much lower numbers in the cold-intermediate-layer (CIL <0^{o}C) water of Div. 3L. Shrimp catches were mostly zero in all surveys both spring and fall in the swallow waters (<100 m) of the southeast Grand Bank where temperatures generally range from 2^{o}-7^{o}C. There were also many zero catches observed in the deepest sets (>1000 m) along the edges of the Grand Bank during the fall surveys in temperatures usually >3.5^{o}C. In general, as catch rates and the total biomass of shrimp increased during the most recent years of the surveys there were more non-zero catches occurring in all areas of the region, particularly in Div. 3L.

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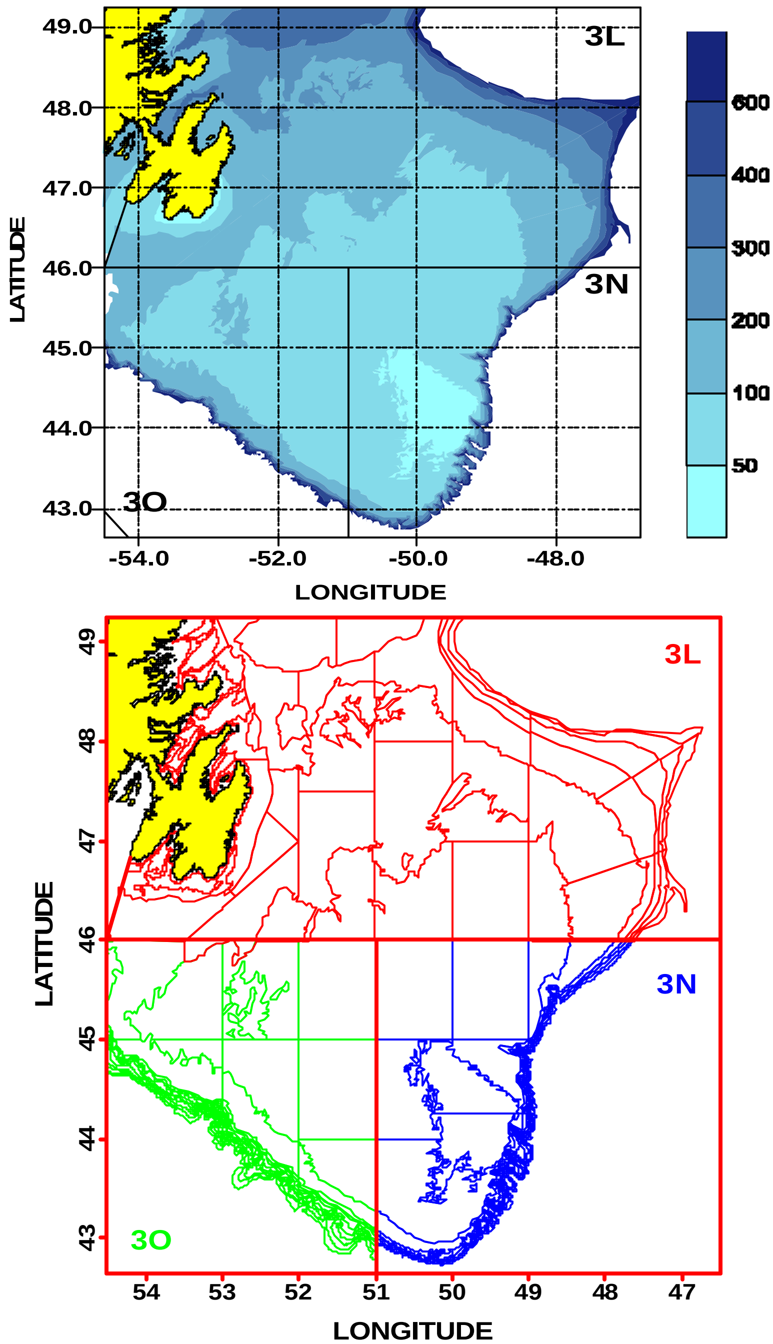

Fig. 1. Bathymetry (m) and stratified area for the Canadian research trawl surveys in NAFO Div. 3LNO.

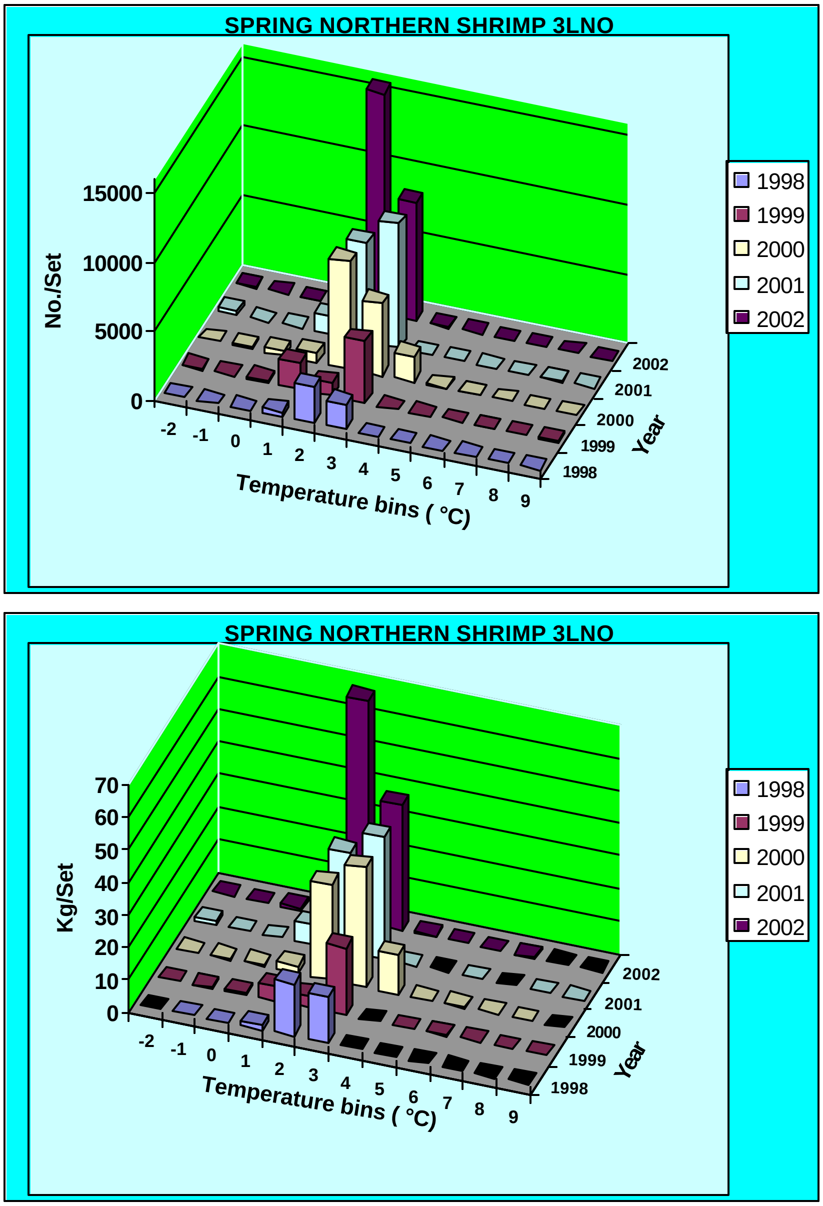

Fig. 2. The average number (top panel) and weight (bottom panel) of northern shrimp per fishing set in 1°C temperature bins for the **spring** surveys in NAFO Div. 3LNO for the years 1998-2002.

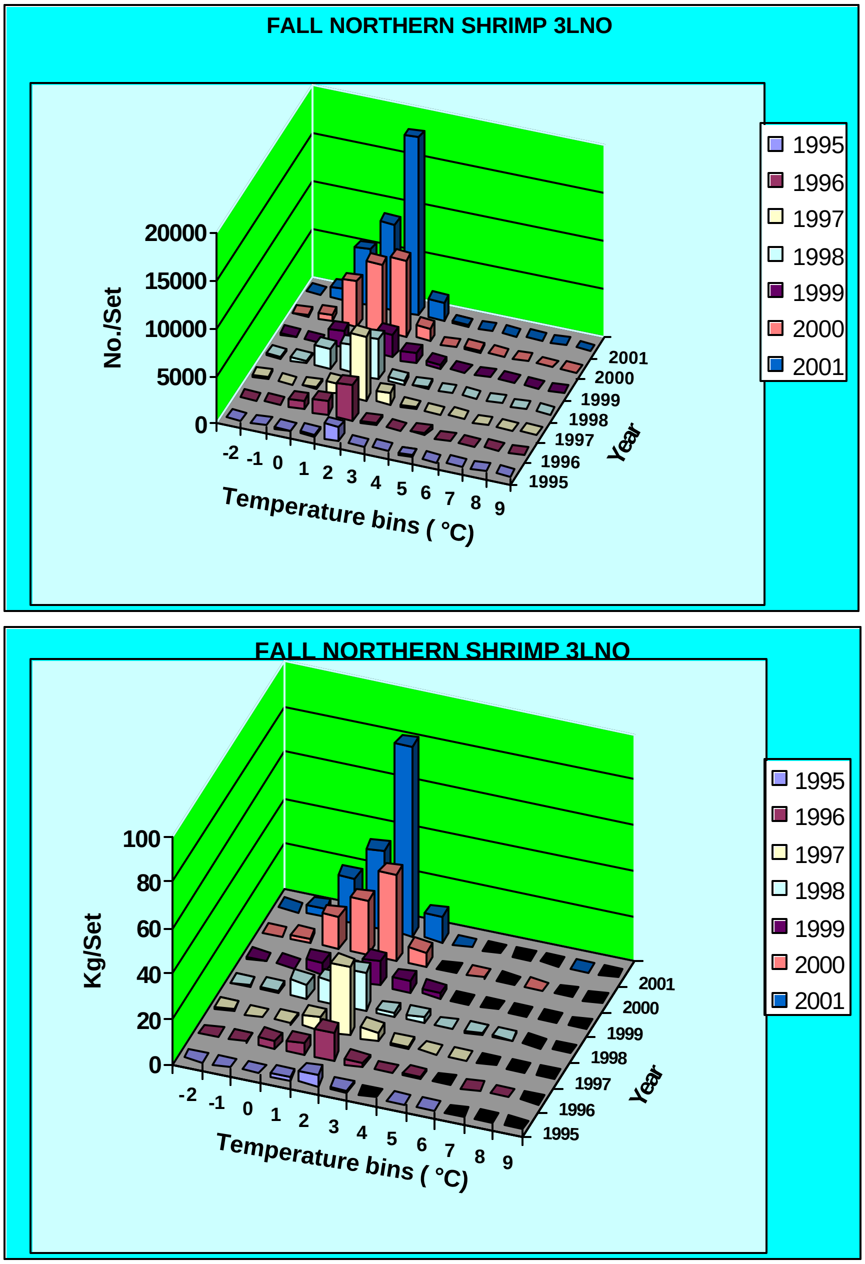

Fig. 3. The average number (top panel) and weight (bottom panel) of northern shrimp per fishing set in 1°C temperature bins for the **fall** surveys in NAFO Div. 3LNO for the years 1995-2001.

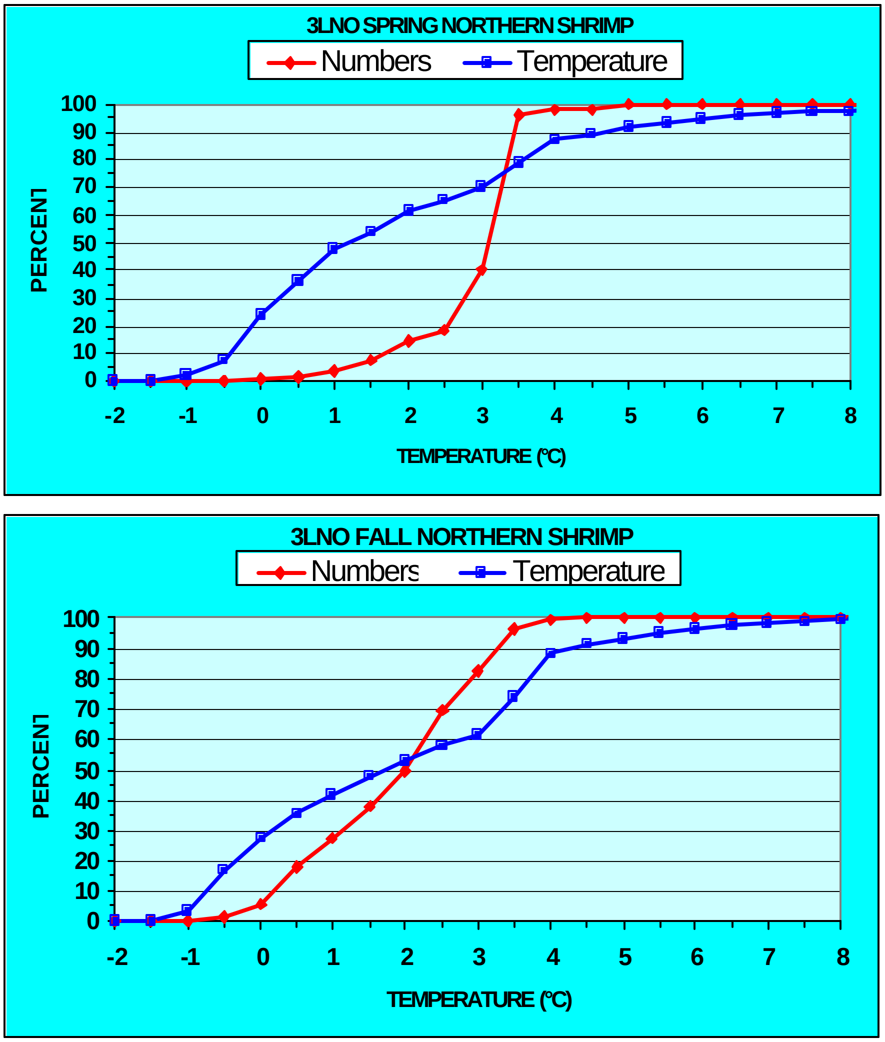

Fig. 4. Cumulative frequency distributions of the number of sets in the Div. 3LNO survey in 1°C temperature bins and the cumulative frequency distribution of the number of shrimp caught in 1°C temperature bins for the **spring** (top panel) and **fall** (bottom panel) surveys.

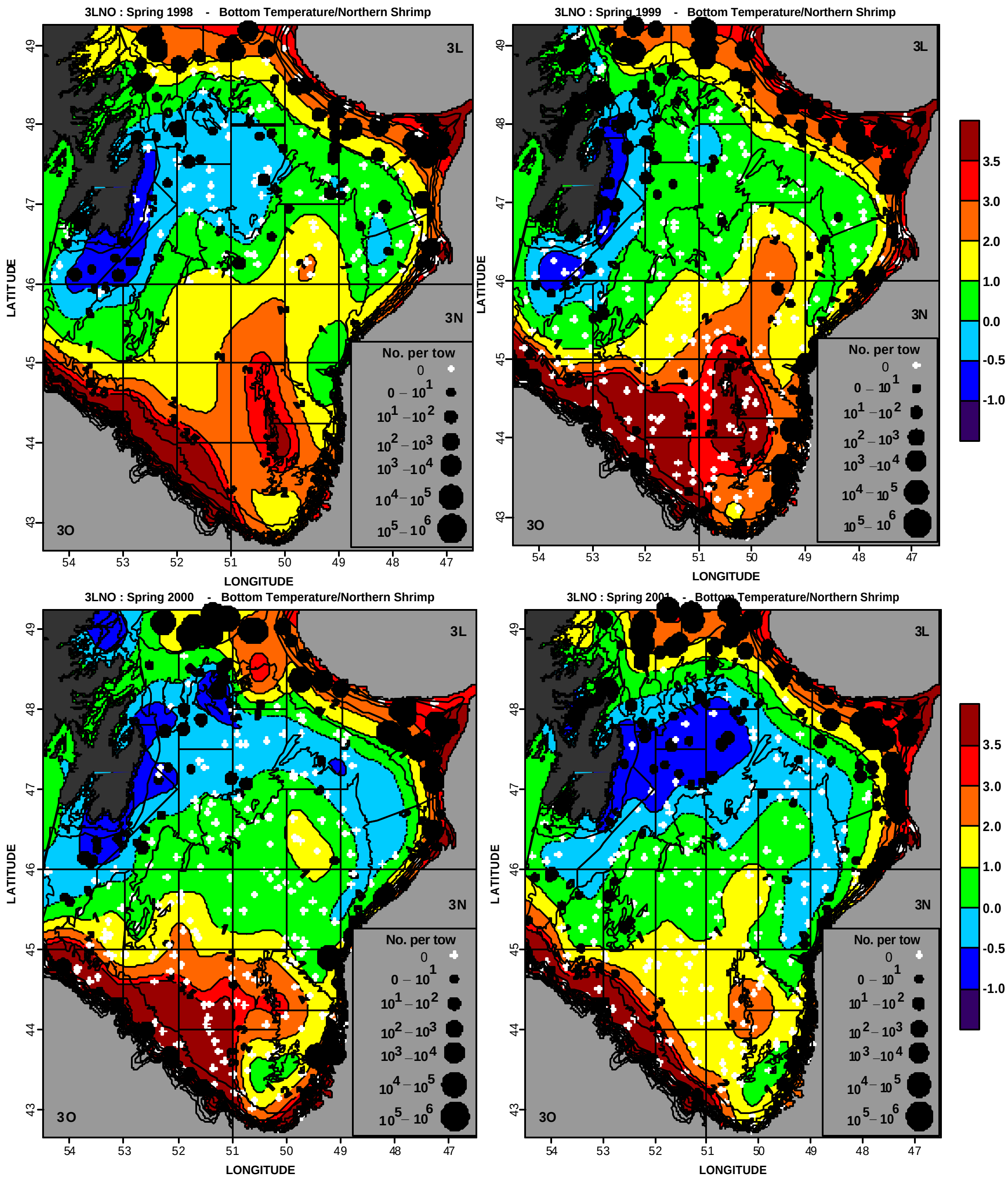

Fig. 5a. Bottom temperature contour maps (in °C) for the **spring** of 1998-2001 from the annual Div. 3LNO survey. The numbers of shrimp in each fishing set are shown as solid circles. The white crosses represent zero catches.

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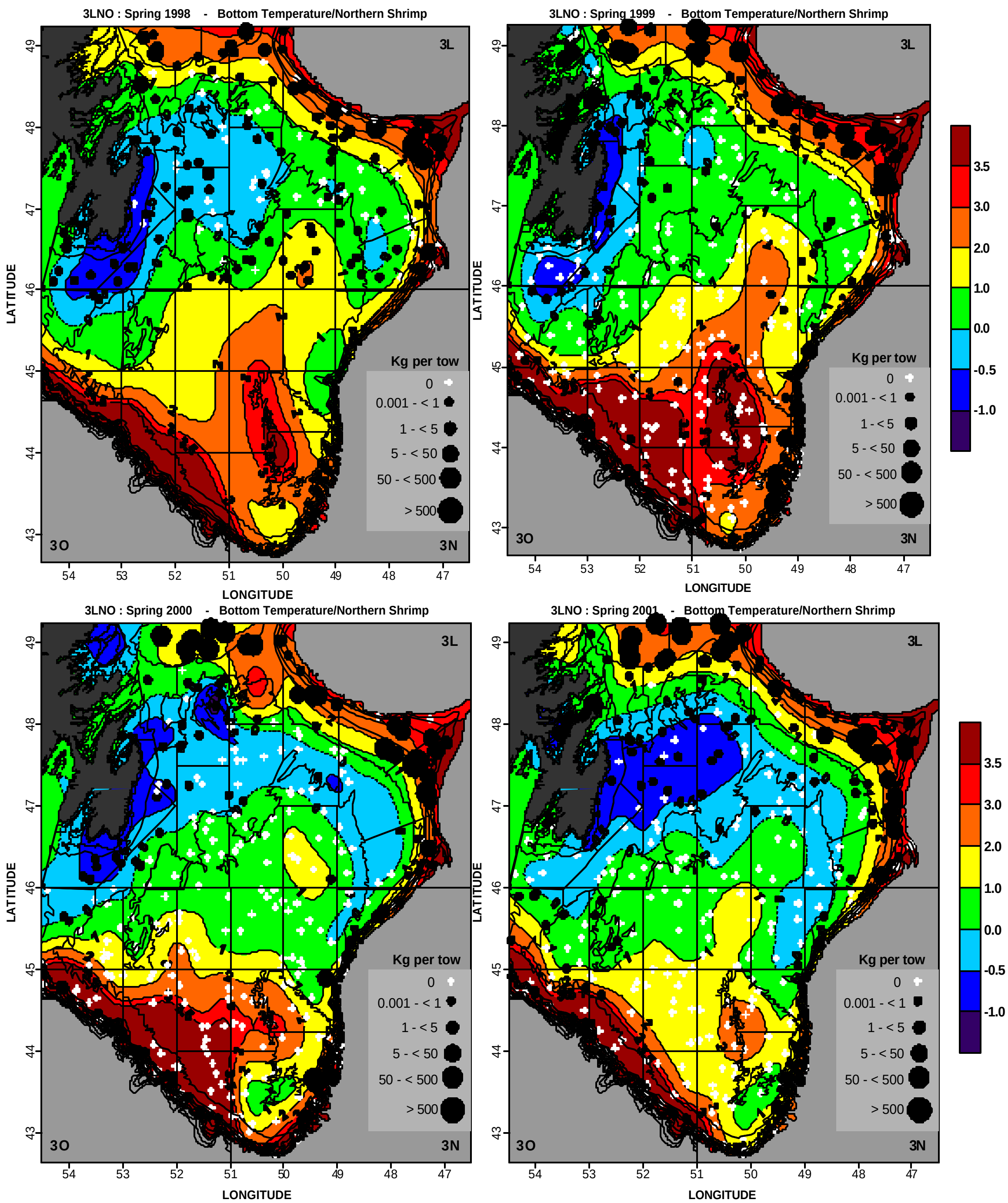

Fig. 5b. Bottom temperature contour maps (in °C) for the **spring** of 1998-2001 from the annual Div. 3LNO survey. The total weight of shrimp in each fishing set is shown as solid circles. The white crosses represent zero catches.

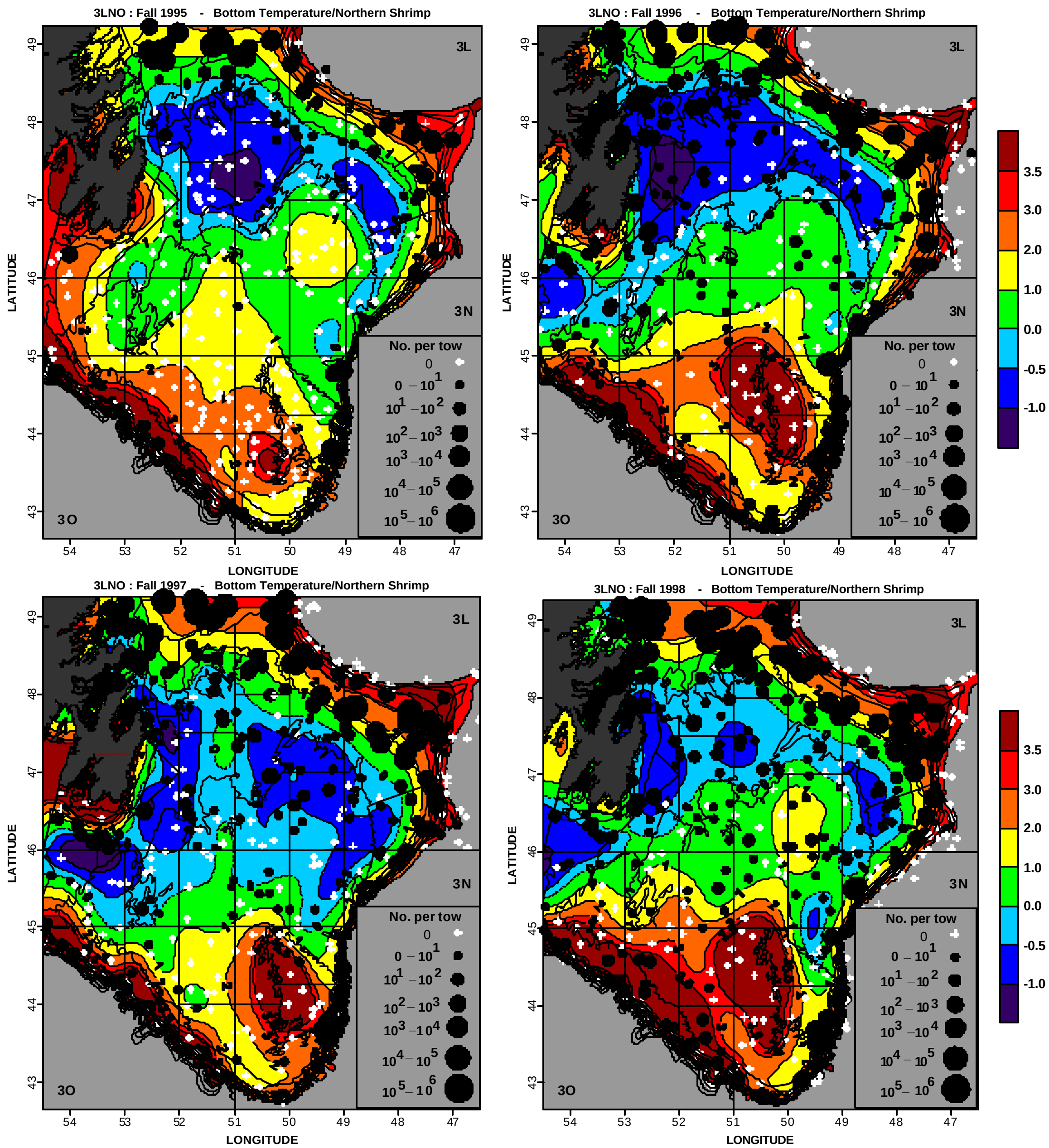

Fig. 6a. Bottom temperature contour maps (in °C) for the **fall** of 1995-1998 from the annual Div. 3LNO survey. The numbers of shrimp in each fishing set are shown as solid circles. The white crosses represent zero catches.

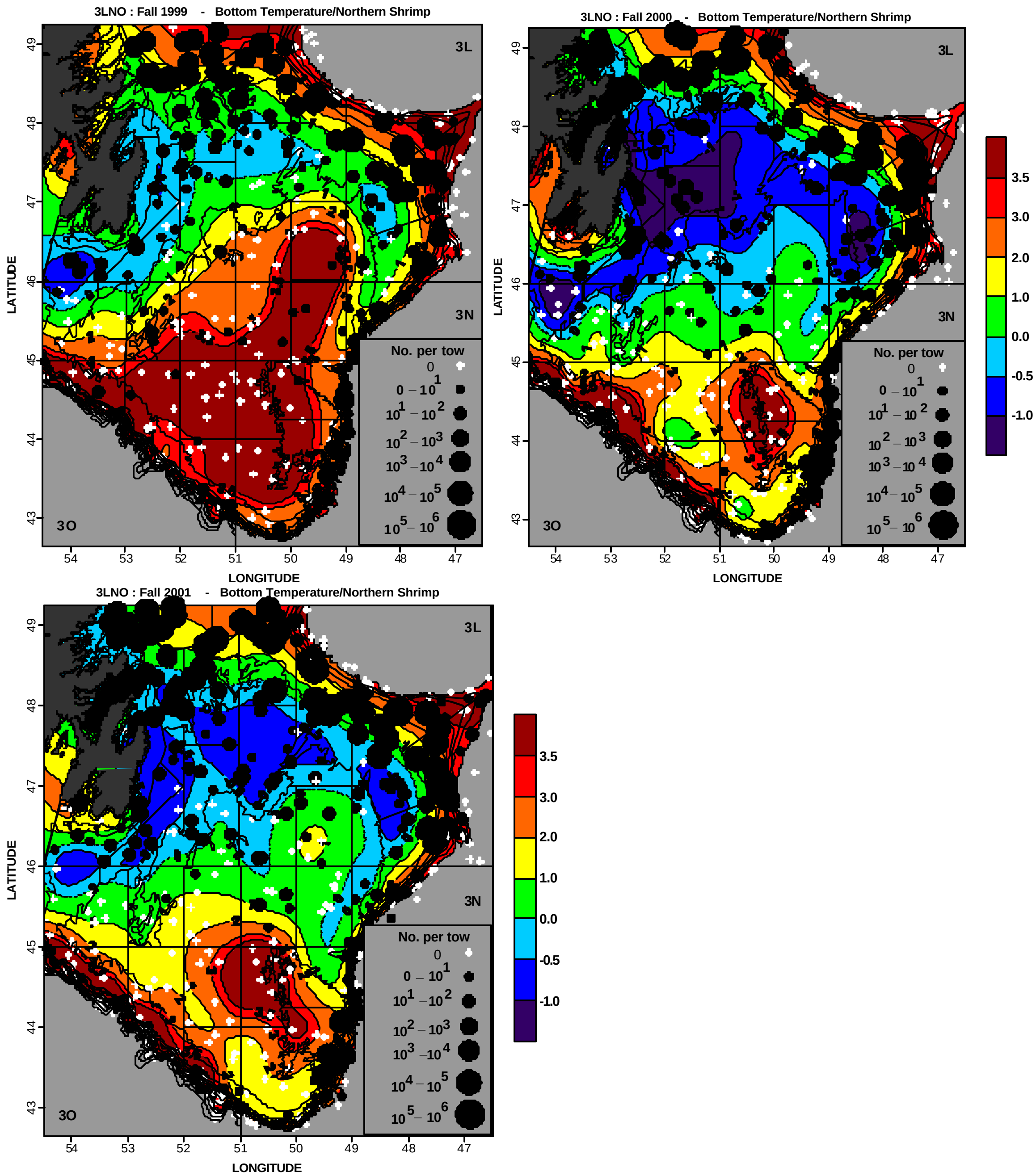

Fig. 6b. Bottom temperature contour maps (in °C) for the **fall** of 1999-2001 from the annual Div. 3LNO survey. The numbers of shrimp in each fishing set are shown as solid circles. The white crosses represent zero catches

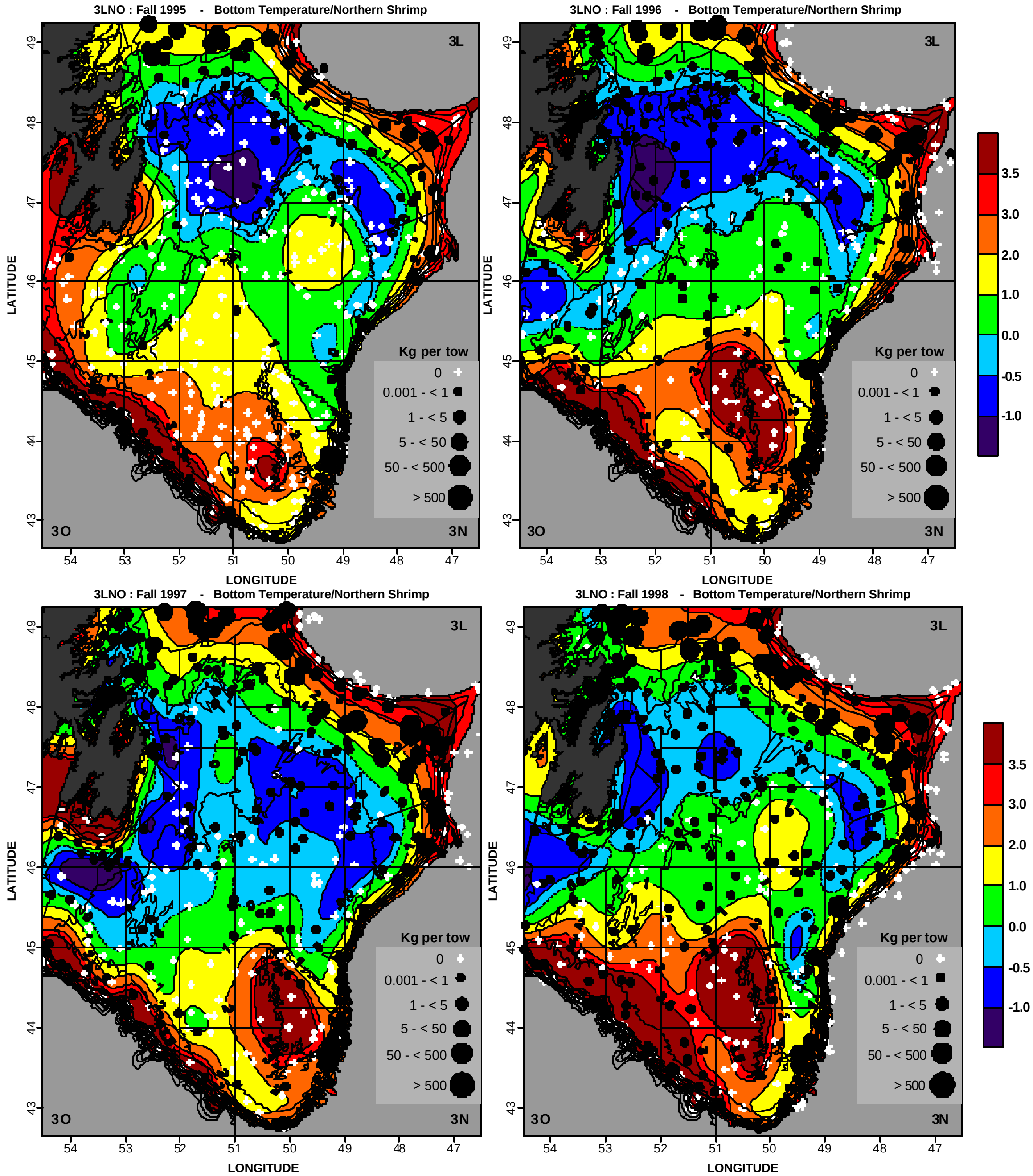

Fig. 6c. Bottom temperature contour maps (in °C) for the **fall** of 1995-1998 from the annual Div. 3LNO survey. The weight of shrimp in each fishing set is shown as solid circles. The white crosses represent zero catches.

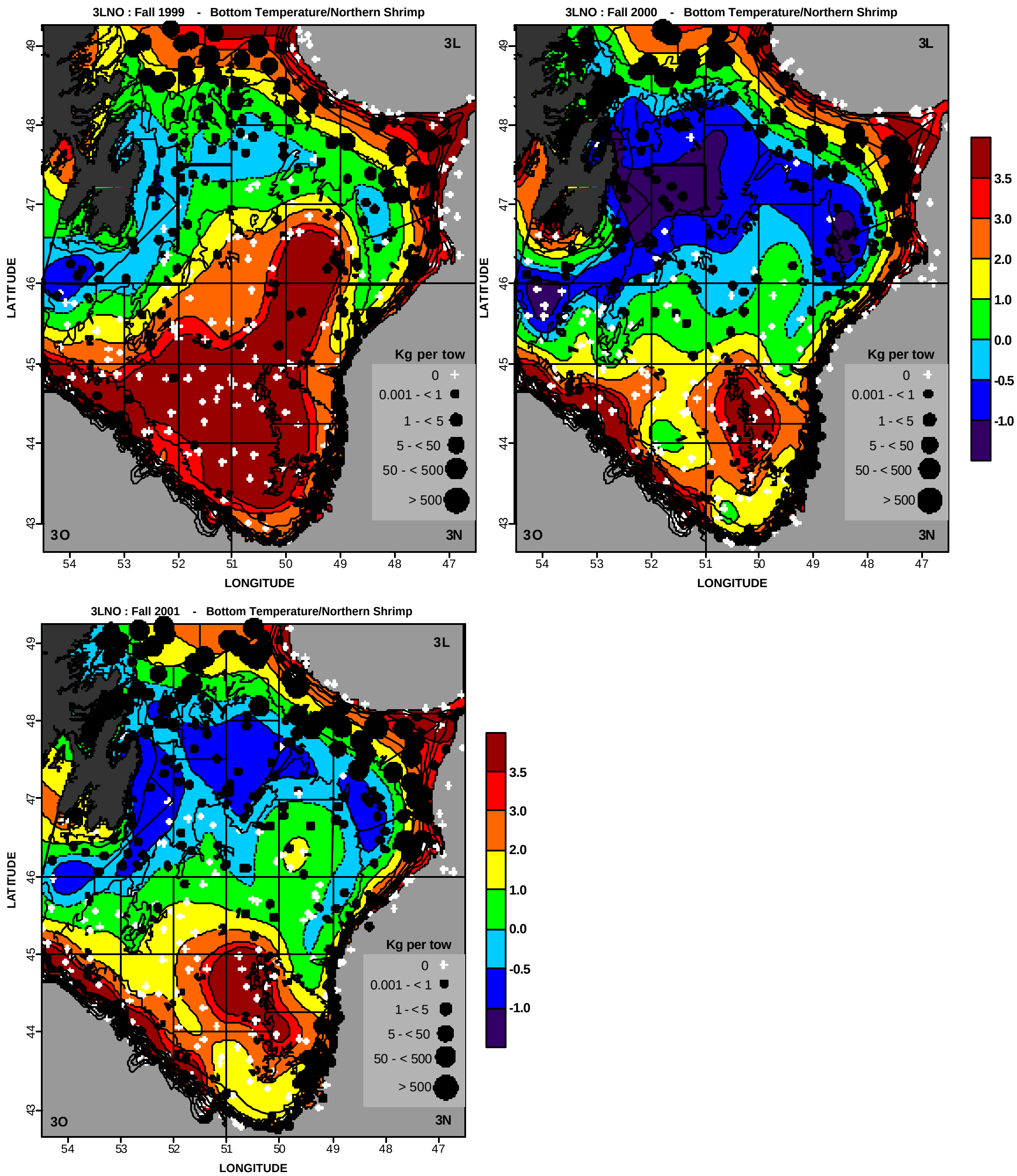

Fig. 6d. Bottom temperature contour maps (in °C) for the **fall** of 1999-2001 from the annual Div. 3LNO survey. The weight of shrimp in each fishing set is shown as solid circles. The white crosses represent zero catches.