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Overview of 1997 Hydrographic Sampling Effort and Near-Bottom Water Temperature and Salinity Conditions During the Canadian Research Vessel Groundfish Surveys Conducted during the Spring on the Eastern Scotian Shelf (4VsW) and Georges Bank (5Z).

by

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ABSTRACT

Hydrographic sampling effort and near-bottom water temperatures and salinities from the 1987-97 Canadian research vessel spring groundfish, stratified random, bottom-trawl surveys are summarised. The surveys cover NAFO divisions 4VsW and 5Z. The timing of the surveys continues to be variable between years. Therefore, caution must be exercised in interpreting the hydrographic trends as climatic variability in the hydrography. Never-theless, the conditions are representative of the conditions in which the fish were caught. In both, the 4VsW and 5Z surveys the temperatures have increased marginally over the past few years. In 1997, the surveys were conducted near the mid-date of the previous surveys in the series and samples were obtained from all strata. The temperatures and salinities sampled in 1997 were near or above those observed in previous surveys. In 4VsW sampling effort was extended further north in strata 401, 402 and 406 than in most previous surveys. This resulted, in part, in the temperatures in several strata being near or above historical maxima. In 5Z the amount of relatively low salinity water was the greatest in the survey series.

RÉSUMÉ

L'effort de l'échantillonnage hydrographique et les valeurs de température et de salinité de l'eau à proximité du fond notées au cours des relevés stratifiés aléatoires canadiens du poisson de fond au chalut de fond réalisés par navires de recherche aux printemps de 1987 à 1997 sont résumés. Les relevés ont été effectués dans les divisions 4VsW et 5Z de l'OPANO. Le moment des relevés varie selon l'année et il faut donc faire preuve de prudence lors de l'interprétation des tendances hydrographiques dans le contexte de la variabilité climatique. Il n'en demeure pas moins que les conditions sont représentatives de celles qui existaient au moment de la capture du poisson. Les températures notées au cours des relevés en 4VsW et en 5Z étaient légèrement supérieures à celles des dernières années. En 1997, les relevés ont été effectués aux environs des dates moyennes des relevés antérieurs de la série et des échantillons ont été obtenus pour toutes les strates. Les températures et salinités notées pour 1997 approchaient ou dépassaient celles notées au cours des relevés antérieurs. En 4VsW, l'échantillonnage dans les strates 401, 402 et 406 a été poussé plus au nord qu'au cours de la plupart des relevés antérieurs. Cela s'est notamment traduit par des températures de plusieurs strates approchant ou dépassant les maximums historiques. En 5Z, la quantité d'eau de salinité relativement faible était la plus importante de toute la série des relevés.

INTRODUCTION

The Canadian Department of Fisheries and Oceans conducts bottom-trawl surveys on an annual basis within NAFO unit areas 4VsW and 5Z as part of its approach for developing scientific advice on the status of groundfish resources. Water temperatures and salinities are measured during these surveys and summaries of the near-bottom conditions have been produced on an annual basis (e.g. Page, Losier and McRuer 1994, 1995, 1996).

The intent of the summaries has been to briefly describe the extent and nature of the hydrographic sampling effort and the temperature and salinity conditions sampled within the resource assessment surveys. In so doing, it is hoped that trends and anomalies in conditions and sampling procedures may be identified and that the impact of these conditions, on estimates of the status of fisheries resources, will be explored on a stock by stock basis within the stock specific assessments and Regional Assessment Process (RAP) Reviews.

In this overview, we present a summary of sampling effort and the resulting estimates of near-bottom water temperatures and salinities during the 1986-97 spring surveys conducted within 4VsW and 5Z. The focus is on the near-bottom conditions in 1997 and how these compare to conditions encountered throughout the history of the survey series.

MATERIALS and METHODS

Data Sources

The hydrographic data summarised in this report were collected during the 1986-97 research vessel, groundfish bottom-trawl surveys conducted during the spring on the eastern Scotian Shelf (NAFO unit area 4VsW, Fig. 1), and on Georges Bank (NAFO unit area 5Z, Fig. 2). The surveys were conducted by the Canadian Department of Fisheries and Oceans using a stratified random design. The 4VsW and 5Z survey domains are divided into 11 and 8 strata, respectively. The strata boundaries are defined on the basis of bottom depth and the distribution of groundfish, mainly cod and haddock (Doubleday 1981).

From 1986 to 1989, depth profiles of temperature and salinity were taken at standard hydrographic sampling depths (0,10,20,30,50,75,100,150 and 200 meters) using reversing thermometers and water samples taken with hydrographic water sampling bottles. Profiles were taken at less than 25% of the sampling stations (Page, Losier and McRuer 1995). Surface temperatures were recorded at all stations with bucket thermometers. Salinities of water samples, taken from the surface bucket or subsurface water bottles, were measured with a laboratory salinometer.

From 1990-97, depth profiles of water temperatures and salinities were measured with a Seabird Model (SBE) 19 or 25 internally recording conductivity, temperature and depth (CTD) profiler (Page et al. 1995). In recent years, use of this equipment has resulted in profiles being taken at about 90% of the trawl stations (Page, Losier and McRuer 1996). A SeaBird Electronics (SBE) model 25 was used in 1997.

The CTD deployment protocol was as follows. The CTD was attached to a hydrographic wire spooled on a variable speed hydraulic winch. Each CTD profile was taken by lowering the instrument to approximately 10m below the sea surface and allowing it to equilibrate with ambient conditions for about 5 minutes. At some stations a water bottle equipped with a reversing thermometer was triggered at the end of this period to obtain water samples and temperatures for later calibration of the CTD temperature and salinity sensors. After the equilibration period the instrument was raised to just below the sea surface and then lowered to within a few meters of the bottom at a drop rate of approximately 20-40 $m \cdot min^{-1}$. If calibration samples were not taken at the initial equilibration depth the instrument was raised approximately 5-10m off the bottom, and a water bottle equipped with a reversing thermometer was triggered at the end of a 5 minute waiting period. The CTD was then recovered and stored on deck. Sea surface temperatures were also measured at each station with an electronic thermometer. Subsequent to the survey a laboratory salinometer was used to obtain salinities from the water samples.

Data Analyses

All CTD temperature and salinity profiles have been edited using a combination of quantitative and visual techniques, including range checks, despiking routines and density inversion algorithms. In most cases, only the down profiles are used. An up profile may be used in rare occasions if the editing indicates it is more reliable than the down profile.

The edited data is compared ("calibrated") with the reversing thermometer temperatures and salinities from water bottle samples to determine whether the instrument was giving reasonable data. In 1997, water bottle salinity values were available from the 4VsW survey in time for this overview. The final edited and "calibrated" data is stored in GSHYD, the hydrographic component of the Maritimes Region Scotian Shelf-Gulf of Maine-Bay of Fundy groundfish ORACLE database. In this database, all measurements made within 20 meters of the bottom are designated as bottom samples. These are referred to as "near-bottom" conditions in this report.

RESULTS

4VsW Sampling Effort

In 1997, sampling was conducted from 8-23 March (consecutive days 67-82) during survey N255. CTD profiles were obtained from all strata (Fig. 1). As in previous years, sampling stations within some strata (e.g. 401, 403) were not widely distributed throughout the strata. Unlike many previous years sampling was conducted in the northern regions of strata 401 and 402.

The maximum CTD profile depths in the survey series ranged from <50m to >300m with the range varying between strata (Fig. 1 & 3). With the exception of one set in strata 407, the depths sampled in 1997, were within previous limits. In strata 407 one sample was deeper than previous extremes. In strata 411 one of the sample depths was near the shallow extreme.

Historically, the surveys have been conducted between 27 February (consecutive day 58) and 29 March (consecutive day 88; Fig. 4). A distinct time trend exists in the dates. The dates became earlier during the 1987 to 1995 period with sampling in 1995 being 26 days earlier than in 1987. In 1996 the time trend was reversed with the dates in 1997 being near the mid-date of the survey series.

4VsW Near-Bottom Temperatures: Means and 1997

The overall range of near-bottom temperatures within the survey domain, and during the complete historical period of the survey (1986-96), is approximately -1°C to 12°C (Fig. 5). The range of temperatures differs considerably between strata. In some strata the range is only a few degrees, whereas in others, it is >10°C. The near-bottom temperatures in 1997 ranged from 0.1 to 10.4°C. In several strata, these were above the 1986-95 strata medians but within previously observed limits (Fig. 5). In strata 402 two temperatures exceeded the previous maximum and in strata 404 several temperatures were near the historical maximum.

The geographic distribution of the 1997 temperatures indicates the warmest water (>4°C) along the shelf edge, in the Gully and in the Central Scotian Shelf area (Fig. 7). The coldest water (<2°C) was in the eastern area of the survey domain, in the Misaine and Banquereau Banks area. Temperatures throughout the remainder of the survey domain were between 2° and 4°C. Although less distinct, the 1997 and long-term (1987-90) strata mean temperatures (Fig. 8 and 9) show similar patterns.

The strata mean temperatures were near or above the 1987-90 means (Fig.9). This is also indicated by the cumulative frequency distributions of the area unweighted temperatures (Fig. 13).

4VsW Near-Bottom Temperatures: Temporal Patterns

The time series of area unweighted temperature percentiles is shown in Fig. 15. With the exception of 1994, the temperatures have remained relatively stable over the 1987-96 period. From 1995 to 1997 the distribution of temperatures has progressively shifted toward higher temperatures, so that in 1997 there was a higher proportion of warmer (4-7°C) water than in most previous years.

The time series of stratified mean temperatures (Fig. 17) suggests that the survey has sampled progressively warmer water since about 1990-91.

The strata specific time series of temperatures are shown in Fig. 18. The pattern of increasing temperatures indicated by the stratified means is evident in some of the strata (eg. 402, 408-9) whereas, there is little trend in the temperatures from several of the other strata. The bi-modal temperatures in strata 406 are due to some stations being within the relatively cold and fresh Cold Intermediate Layer (CIL) and some being in the warmer and saltier deep layer below the CIL.

4VsW Near-Bottom Salinities: Means and 1997

The overall range of near-bottom salinities within the survey domain, and during the complete historical period of the survey series (1986-96), is approximately 31.5 to 35psu (Fig 6). With the exception of strata 401 and 411, where the ranges are reduced, the range is similar between strata. In 1997 the salinities at a few stations within strata 401-2, 409 and 411 were near historical lows and those in strata 402 and 406 were near historical highs. This was due, in part, to the more northerly distribution of sampling effort.

The geographic distribution of the 1997 salinities is shown in (Fig. 7). The lowest salinities occurred on the eastern Scotian Shelf in the Misaine and Banquereau areas and the highest occurred on the central shelf , Gully and shelf edge regions. Although less distinct this general pattern is reflected in the long-term (1987-90) strata mean salinities (Fig. 8). The 1997 strata mean salinities were near or above the 1987-90 means (Fig.10). The cumulative frequency distributions of the area unweighted salinities (Fig.14) indicate a similar general pattern. However, they also suggest the occurrence of 33-34 psu water was relatively low in 1997.

4VsW Near-Bottom Salinities: Temporal Patterns

The time series of area unweighted salinity percentiles is shown in Fig.16. The salinities have remained relatively stable over the 1987-97 period. The time trend in the time series of stratified mean salinities (Fig. 17) indicates relatively constant conditions in 4W, a slight decrease in sampled salinities during the early 1990's and an increase since 1993 in 4Vs. These trends are not clearly evident in most of the strata specific time series (Fig. 19).

5Z Sampling Effort

In 1997, sampling was conducted from 25 February to 5 March (consecutive days 56-64) during survey N254. CTD profiles were obtained from all strata (Fig. 2). In 1997 it was decided to take CTD profiles at only about one half of the trawl sampling stations. As in previous years, sampling stations within some strata (e.g. 5Z7-8) were not widely distributed throughout the strata.

As in previous years, the near-bottom CTD sample depths in the survey ranged from <50m to >200m. The range within each stratum varied between strata (Fig. 3). The depths sampled in 1997 were, for the most part, consistent with previous years.

The surveys have been conducted between 13 February and 18 March (consecutive days 44-77, Fig. 4). As in 4VsW, the timing of the surveys has varied considerably between years. In 1991, sampling began on 13 Feb, whereas in 1987 it began on 10 March, 25 days earlier than in 1987. The sampling dates in 1997, 25 Feb. to 5 Mar., were near the middle of the previous dates and continues the recent trend toward earlier sampling dates.

5Z Near-Bottom Temperatures: Means and 1997

The overall range of near-bottom temperatures within the survey domain, and during the historical survey time period (1987-96), is approximately 3°C to 14°C (Fig. 5). The range of temperatures differs considerably between strata. In some strata the range is only a few degrees, whereas in others, it is >10°C. The near-bottom temperatures in 1997 ranged from 4.6 to 13.4°C. With the exception of some samples in 5Z3 and 5Z5, these were within the previously observed limits (Fig. 5). In 5Z3 one near-bottom temperature was above the previous maximum and in 5Z5 several temperatures were near the previous maximum.

The geographic distribution of the 1997 temperatures (Fig. 7,11) is similar to that of the long-term (1987-90) strata mean temperatures (Fig.8). The lowest temperatures (<6°C) occurred on top of Georges Bank and the highest temperatures occurred along the bank edge in the deeper water and in the Great South Channel. The strata mean temperatures were near (±1°C) and above (>1°C) the 1987-90 means for all strata (Fig. 11). The temperatures over the Northeast peak and southern flank tended to be near normal and those over the Northwest portion of the bank were above normal. The cumulative frequency distributions of the area unweighted temperatures (Fig. 13) also indicate that the temperatures sampled in 1997 were above or near normal.

5Z Near-Bottom Temperatures: Temporal Patterns

The time series of area unweighted temperature percentiles is shown in Fig. 15. The temperatures rose from 1987-91, decreased until 1993, increased in 1994 and have remained relatively constant since then. In 1997, the median temperature is near the long-term normal. The time series of stratified mean temperatures (Fig. 17) shows interannual variability, and perhaps a weak trend toward increasing temperatures. This trend is driven mainly by the temperatures in the western strata 5Z5-7. Each of the strata specific time series (Fig. 18) show aspects of the trends shown in both the area unweighted and area weighted composite time series.

5Z Near-Bottom Salinities: Means and 1997

The overall range of near-bottom salinities within the survey domain, and during the complete survey time period (1986-96), is approximately 31.0 to 35.5psu (Fig. 6). The range is smaller in the strata on top of the bank (5Z2-7). The bank edge strata have the largest ranges (5Z1, 5Z8).

The geographic distribution of the 1997 salinities (Fig. 7,12) is similar to that of the long-term (1987-90) strata mean salinities (Fig. 8). That is, the lowest salinities occurred on top of Georges Bank and the highest occurred along the bank edges and in the Great South Channel. The 1997 strata mean salinities were near or below the 1987-90 means (Fig.12). This is also indicated by the cumulative frequency distributions of the area unweighted salinities (Fig. 14). This figure also indicates that in 1997, the proportion of low salinity water was the greatest in the series.

5Z Near-Bottom Salinities: Temporal Patterns

The time series of area unweighted salinity percentiles is shown in Fig. 16. The median salinities have undulated over the 1987-96 period, with maxima in 1990 and 1995 and minima in 1988 and 1993. The trend in the time series of stratified mean salinities (Fig. 17) indicates similar fluctuations, although the minima and maxima occur in 1988, 1992 and 1990, 1995 respectively. In both series the 1997 median and stratified mean values were the lowest in the survey series. The composite trends are also evident in several of the strata specific time series of salinities (Fig. 19).

DISCUSSION

The Canadian bottom-trawl research vessel spring survey program began in 1986. Unfortunately, the timing of the surveys has been very variable. The start date of the surveys has differed by approximately 3 weeks. Because of this and the stratified random allocation of set locations, the patterns and trends in temperatures and salinities observed during the surveys cannot be considered as reliable indicators of

climate change. However, they are indicators of the trends in the hydrographic conditions that were sampled.

The possibility that the hydrographic conditions may influence perceptions of fish distribution and abundance has been suggested by several authors (e.g. Pinhorn and Halliday 1985). Some recent examinations of relationships between research vessel fish catch and sampling depth, water temperature and salinity, include Mountain and Murawski (1992), Page et al. (1994), Smith et al. (1994) and Swain and Kramer (1995). These authors have examined the associations between cod and haddock abundance and sampling depth, water temperature and salinity in survey data from the Georges Bank, Bay of Fundy, Scotian Shelf and southern Gulf of St. Lawrence. Smith, Perry and Fanning (1991) have shown that during the 1979 to 1988 period inter-annual changes in the proportion of 4VW bottom waters identified as Cold Intermediate Layer (CIL) water coincide with changes in the estimated abundance of 4VsW cod. When the proportion of the CIL is large (small), and hence, the temperatures are relatively cool (warm), the estimate of cod abundance is relatively low (high). This connection has been explored more fully by Smith and Page (1996) and the connection with haddock has been explored by Smith and Page (1994). Swain and Kramer (1995) examine the changes in cod-temperature associations in relation to stock abundance in the southern Gulf of St. Lawrence.

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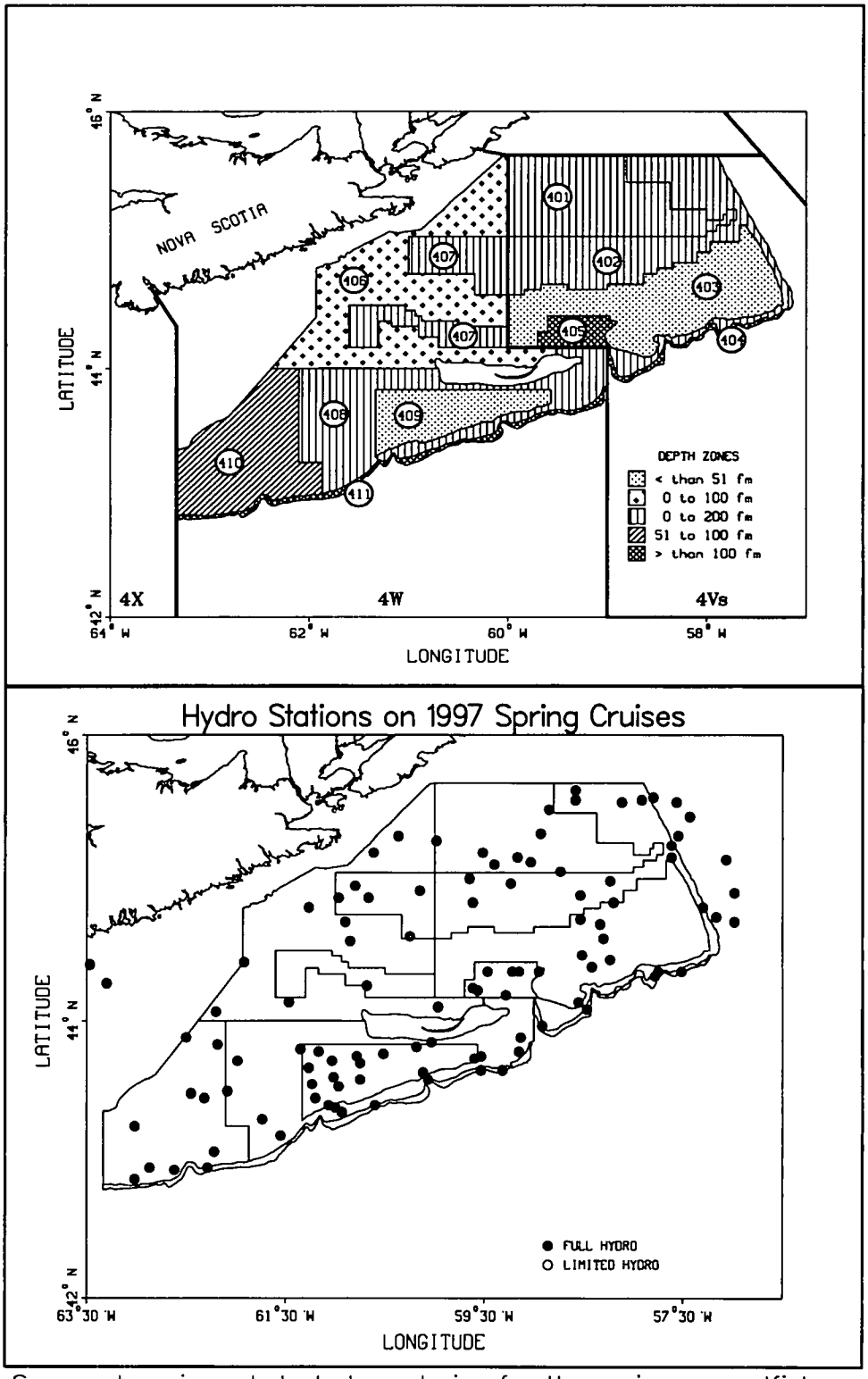

Figure 1: Survey domain and strata boundaries for the spring groundfish research vessel surveys conducted within NAFO area 4VsW from 1987–1997 (top panel) and the location of hydrographic sampling stations taken during the 1997 survey (bottom panel). In the bottom panel solid circles indicate a CTD cast and open circles indicate where only bottom temperatures and salinities were measured. (In the top panel the numbers enclosed within circles are the strata designations.)

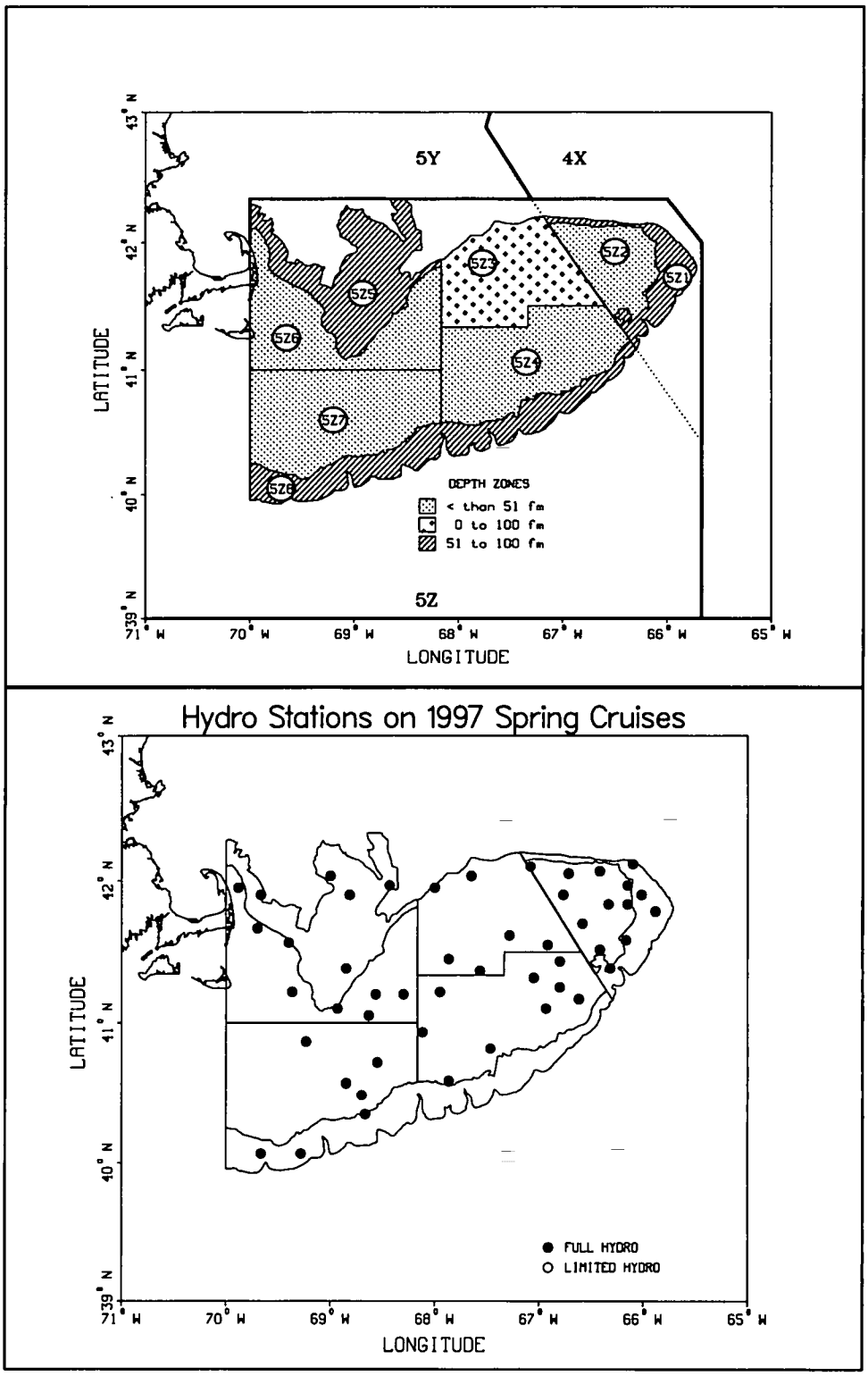

Figure 2: Survey domain and strata boundaries for the spring groundfish research vessel surveys conducted within NAFO area 4VWX from 1987–1997 (top panel) and the location of hydrographic sampling stations taken during the 1997 survey (bottom panel). In the bottom panel solid circles indicate a CTD cast and open circles indicate where only bottom temperatures and salinities were measured. (In the top panel the numbers enclosed within circles are the strata designations.)

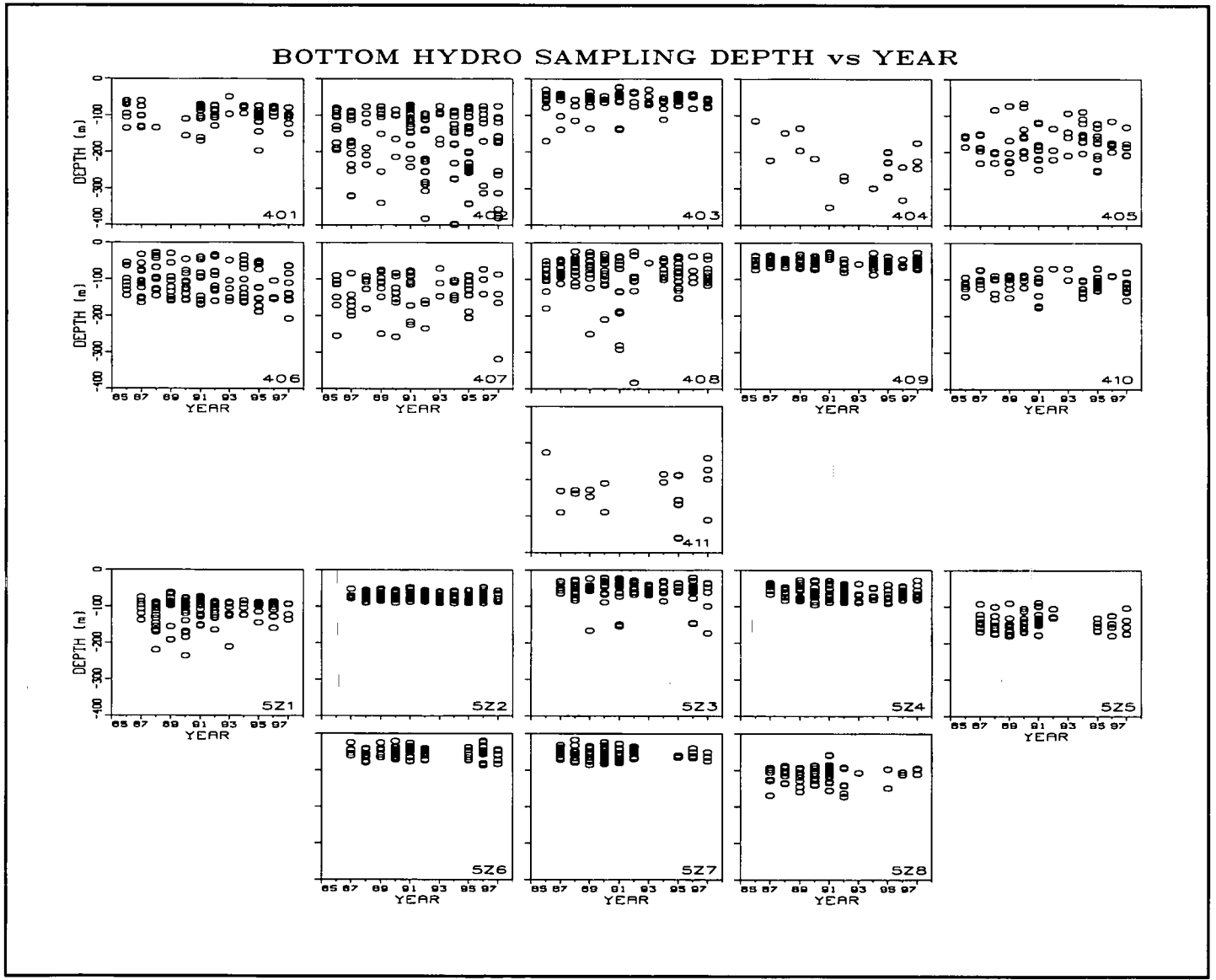

Figure 3: Time series of the near–bottom hydrographic sampling depth for each station within the spring 4VsW and 5Z surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the near–bottom sampling depth of one hydrographic station.

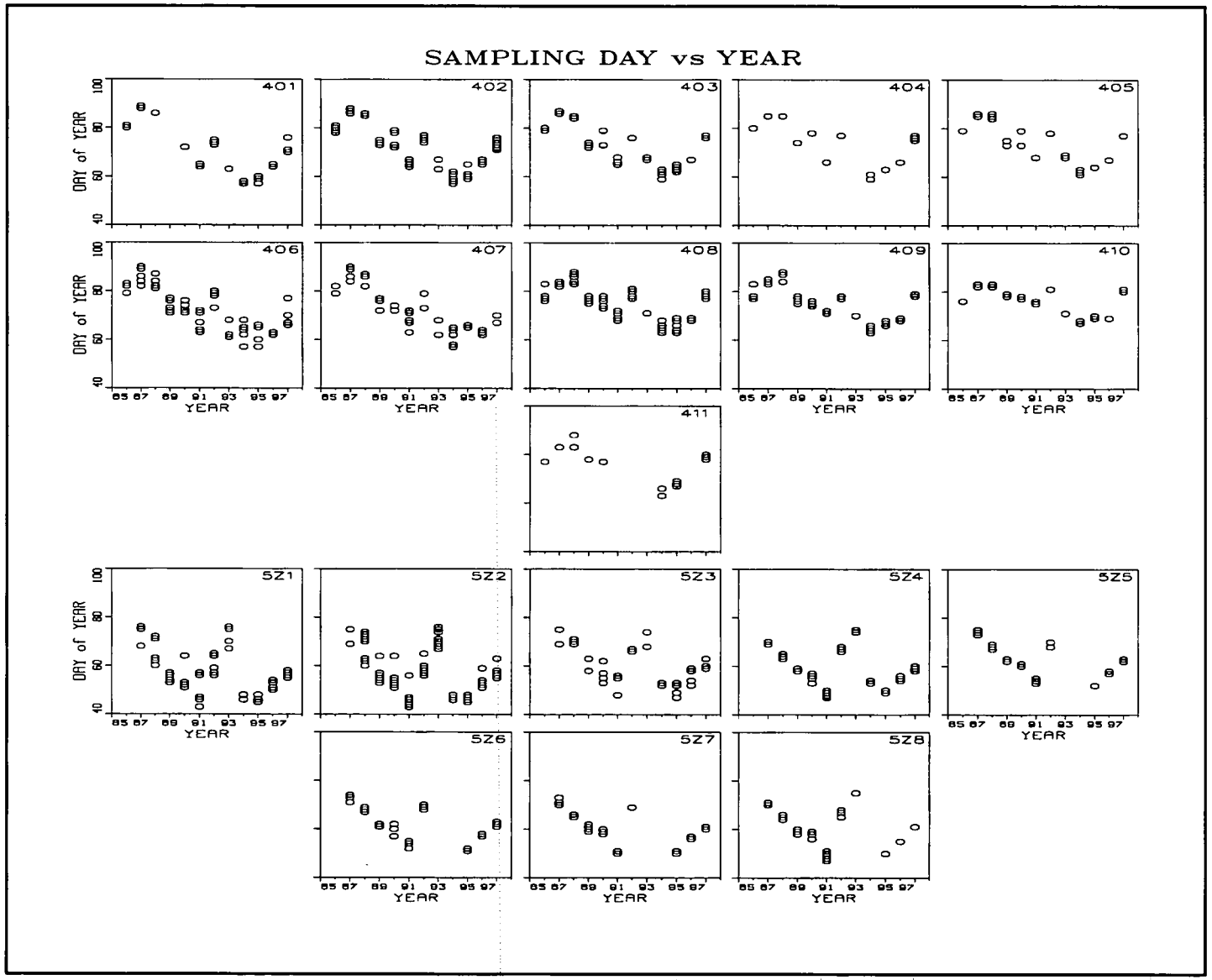

Figure 4: Time series of the consecutive day of sampling within the spring 4VsW and 5Z surveys. The numbers and letters in the upper right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.

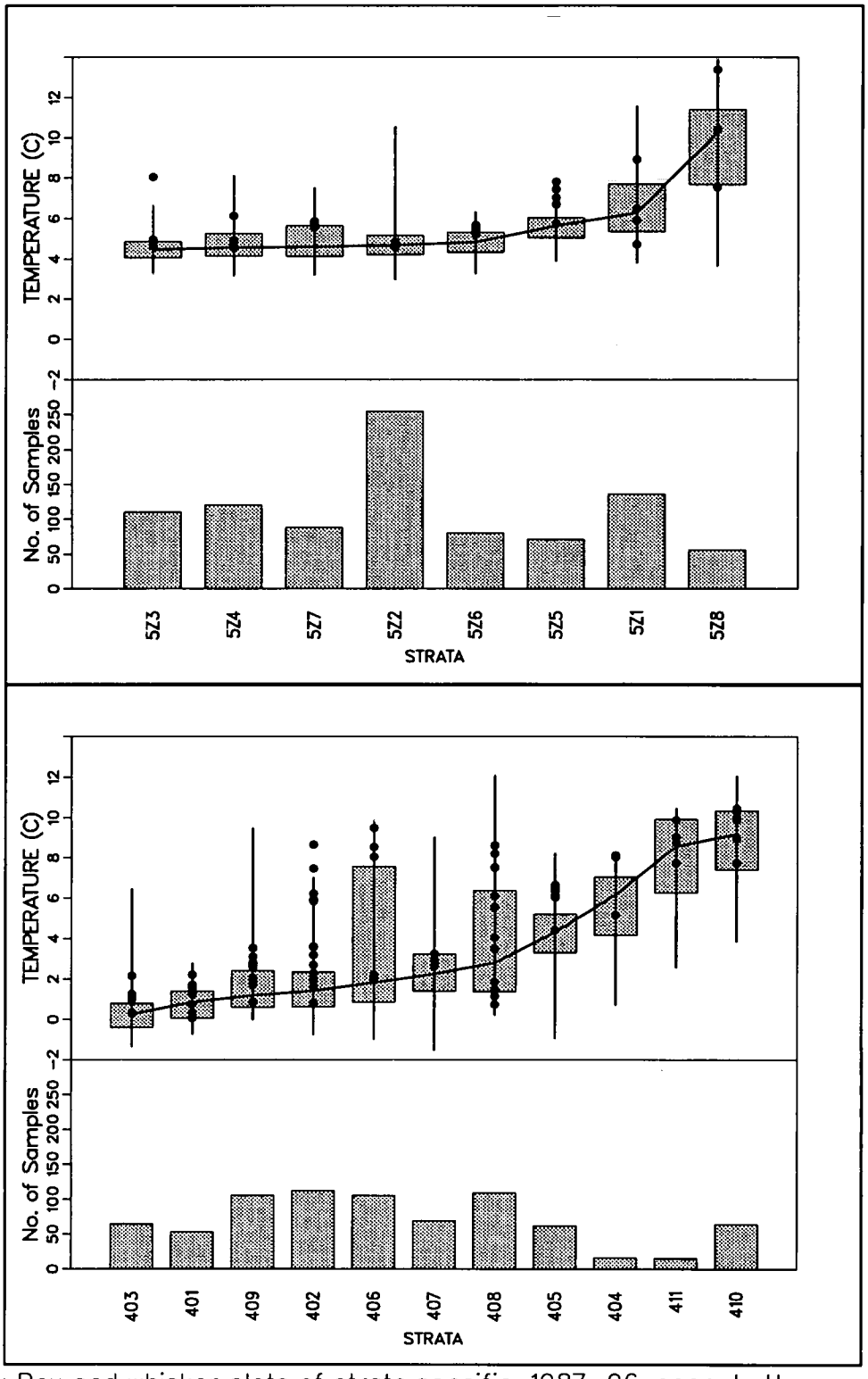

Figure 5: Box and whisker plots of strata specific, 1987–96, near–bottom water temperatures for strata within 5Z (top panel) and 4VsW (lower panel) ordered by temperature medians. The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each strata over the entire 1987–96 period. Solid circles are 1997 observed temperature data.

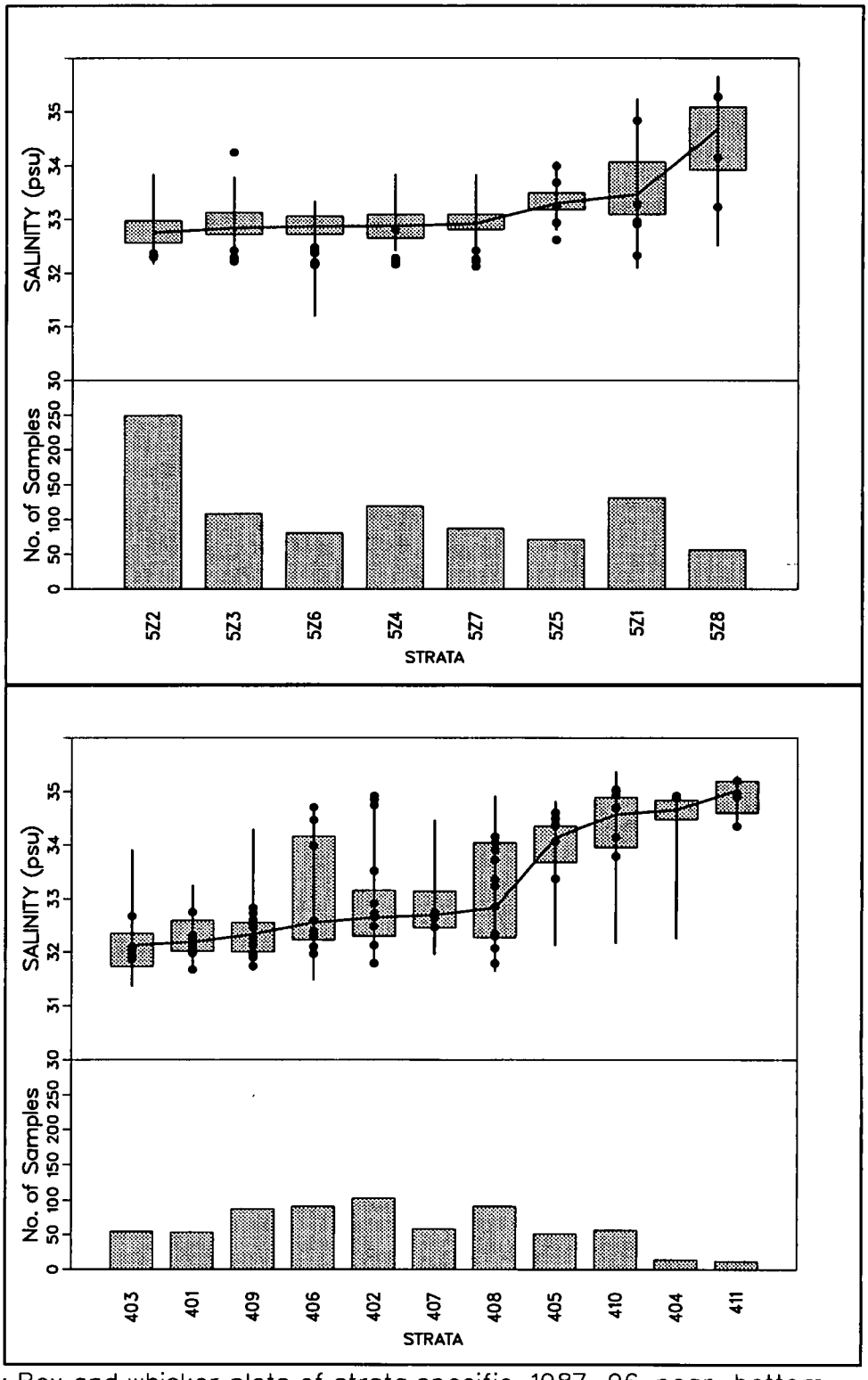

Figure 6: Box and whisker plots of strata specific, 1987–96, near–bottom water salinities for strata within 5Z (top panel) and 4VsW (lower panel) ordered by salinity medians. The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each strata over the entire 1987–96 period. Solid circles are 1997 observed salinity data.

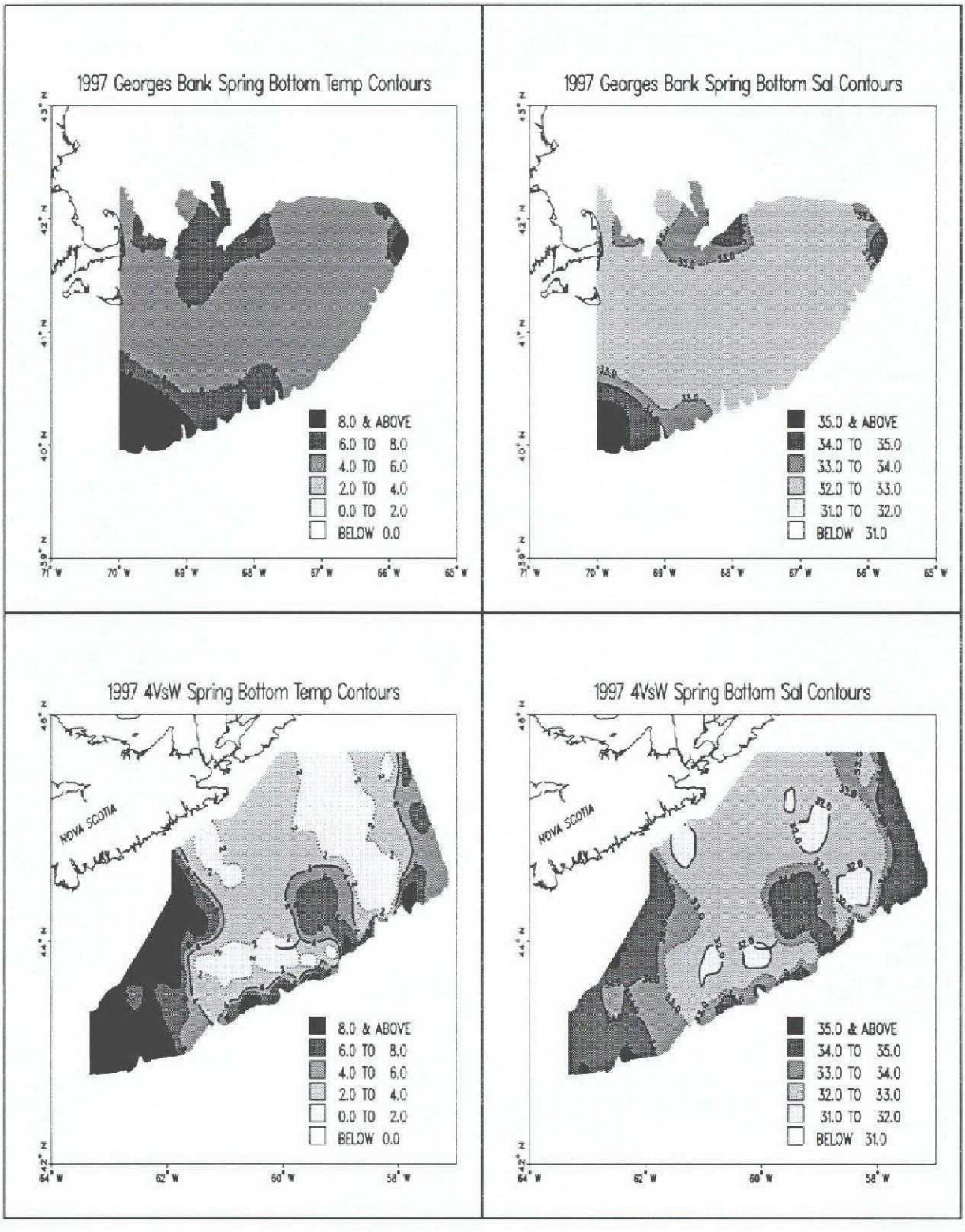

Figure 7: Contour maps of near-bottom temperature and salinities within the 5Z and 4VsW Canadian research vessel bottom-trawl surveys conducted during the spring of 1997.

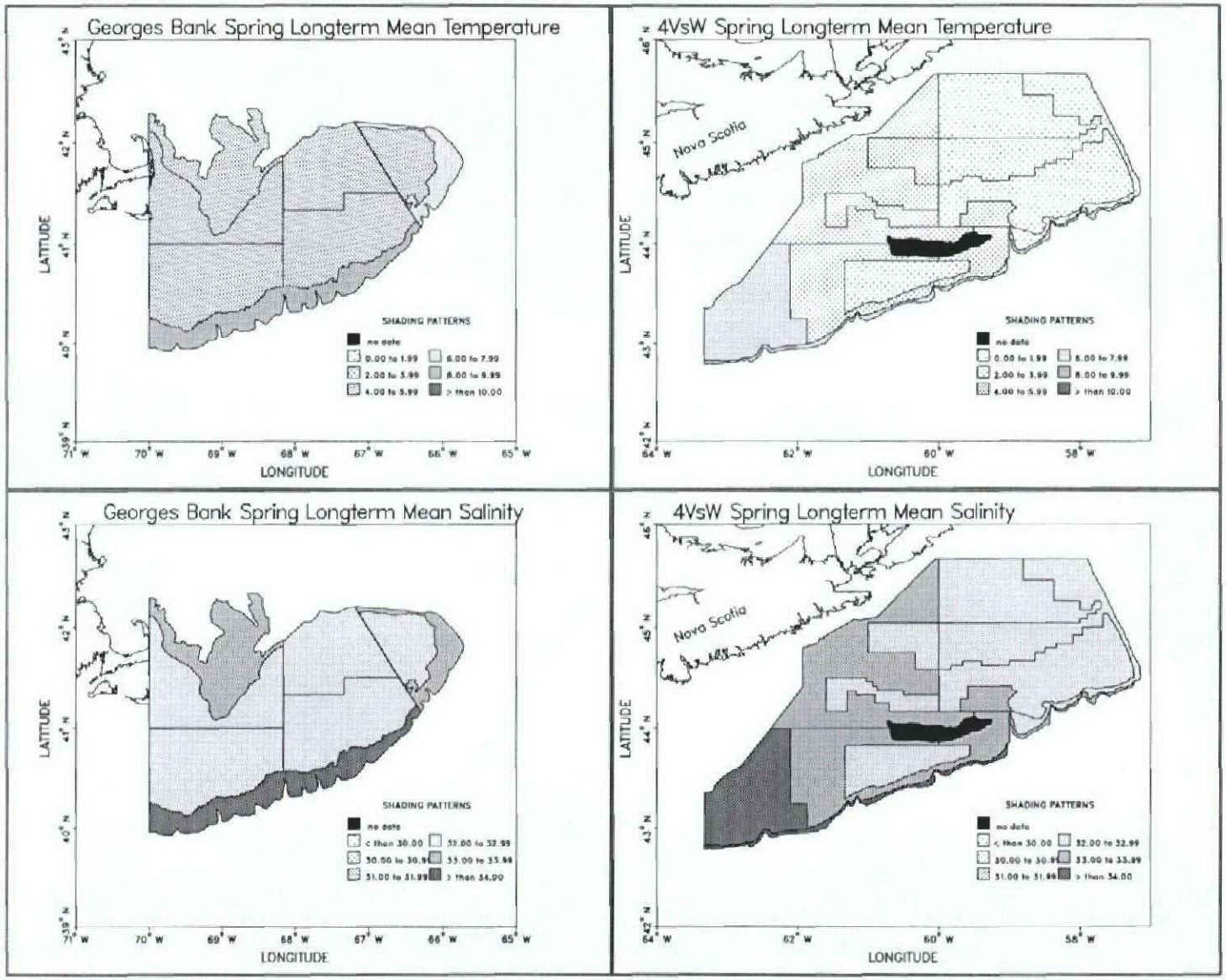

Figure 8: Map of near-bottom strata long term mean temperatures (top panel) and salinities (bottom panel) within NAFO statistical areas 5Z and 4VsW during the Canadian research vessel bottom-trawl survey conducted during the spring of 1987-1990.

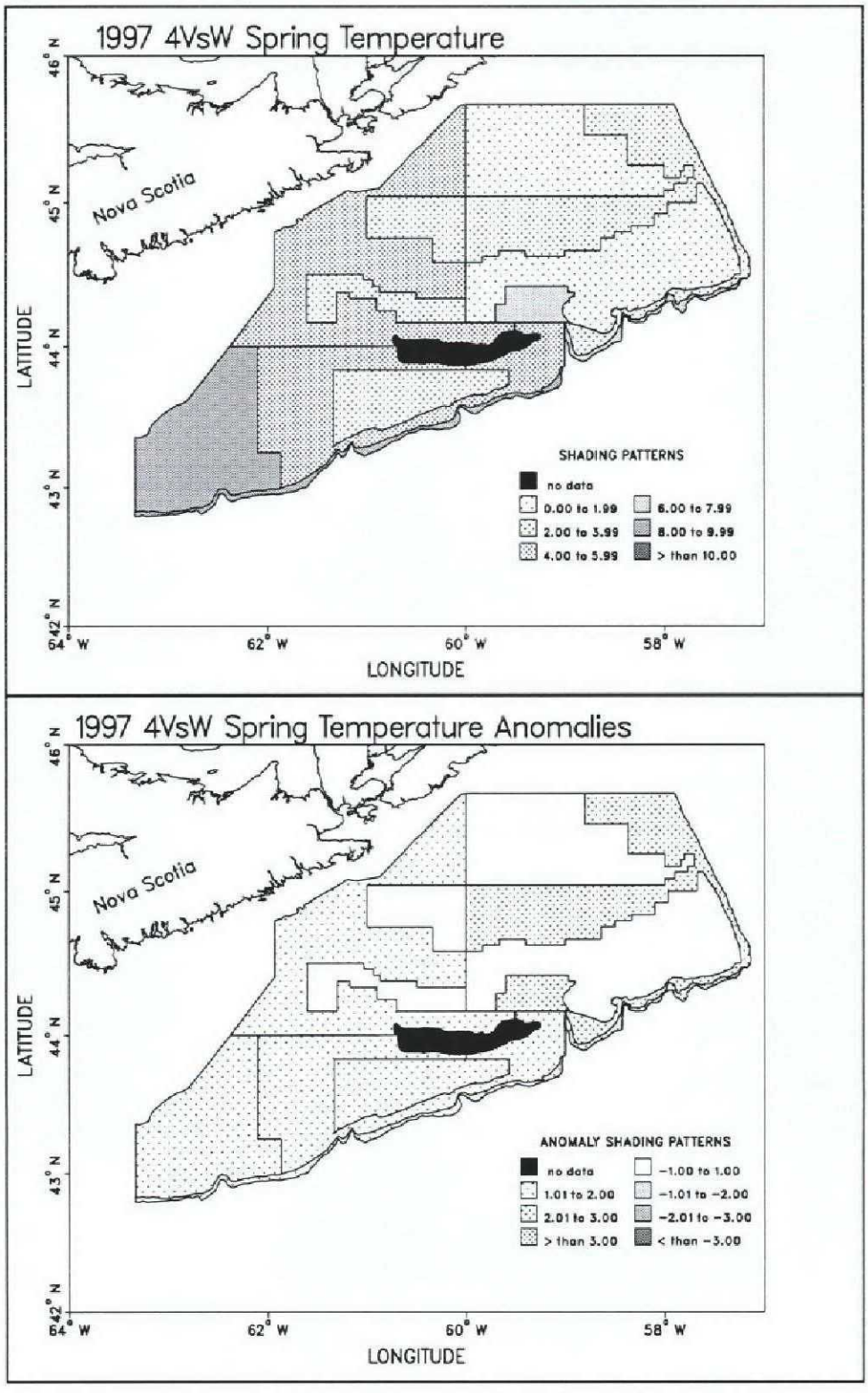

Figure 9: Map of near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VsW during the Canadian research vessel bottom-trawl survey conducted during the spring of 1997.

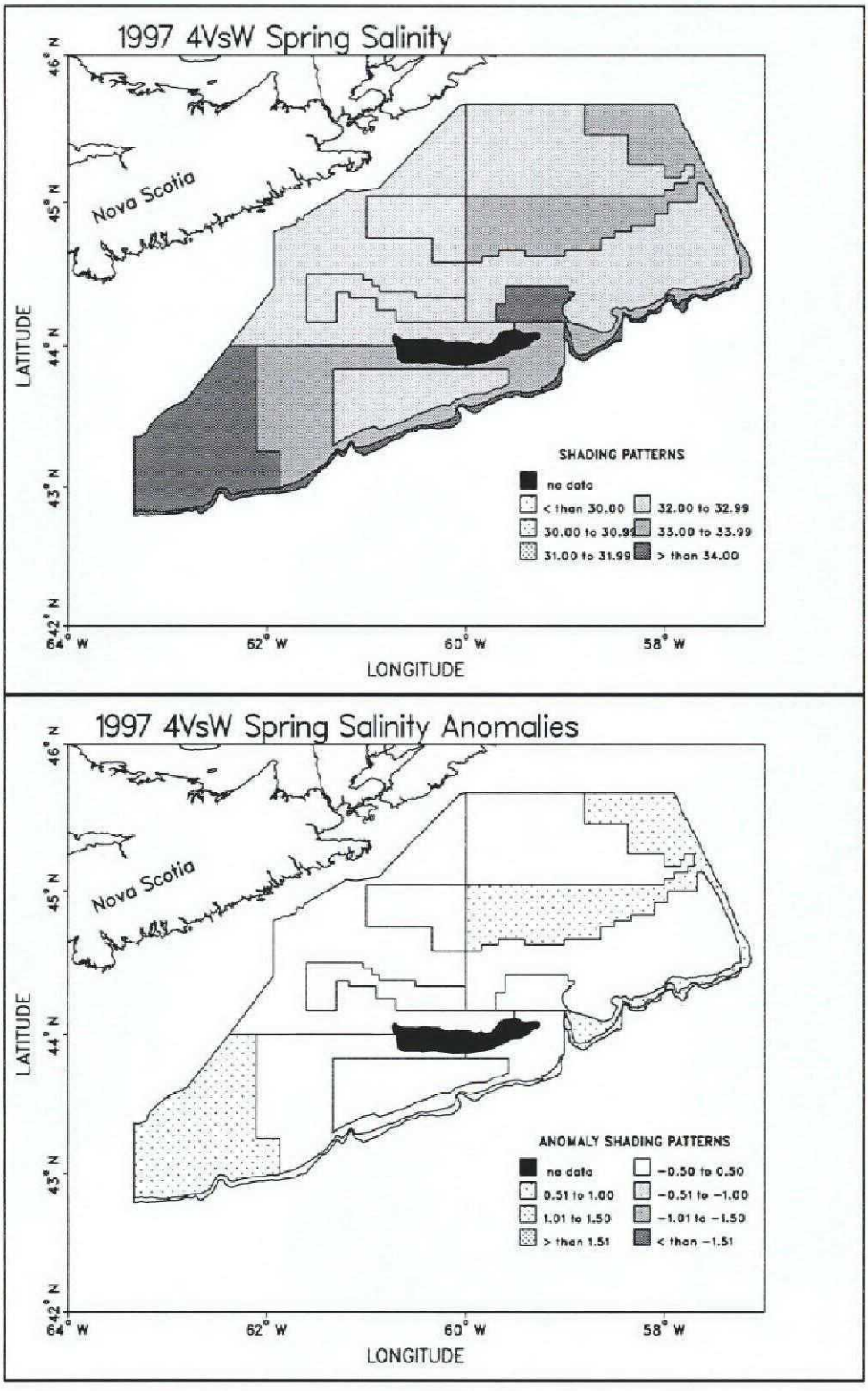

Figure 10: Map of near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VsW during the Canadian research vessel bottom-trawl survey conducted during the spring of 1997.

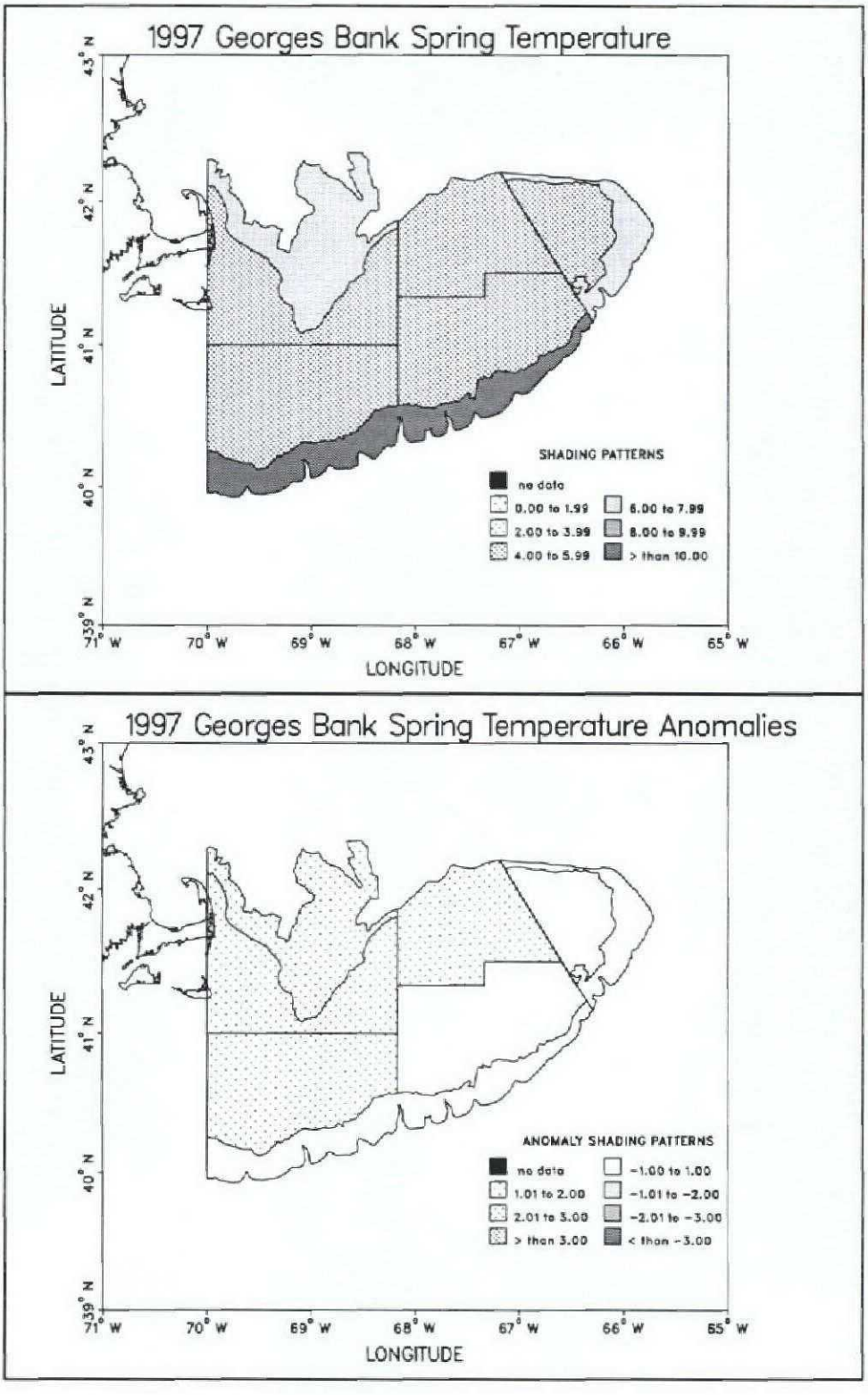

Figure 11: Map of near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 5Z during the Canadian research vessel bottom-trawl survey conducted during the spring of 1997.

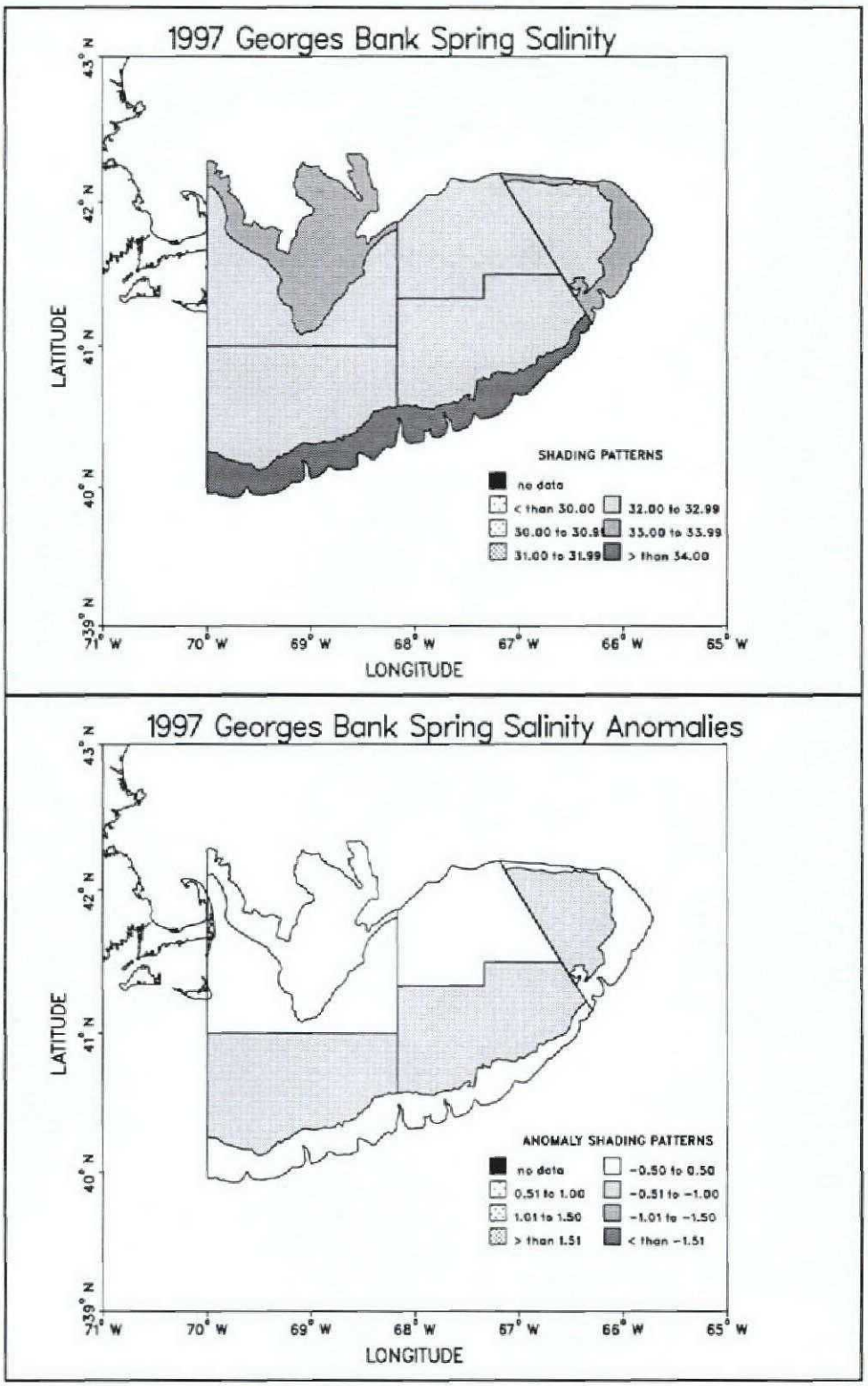

Figure 12: Map of near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 5Z during the Canadian research vessel bottom-trawl survey conducted during the spring of 1997.

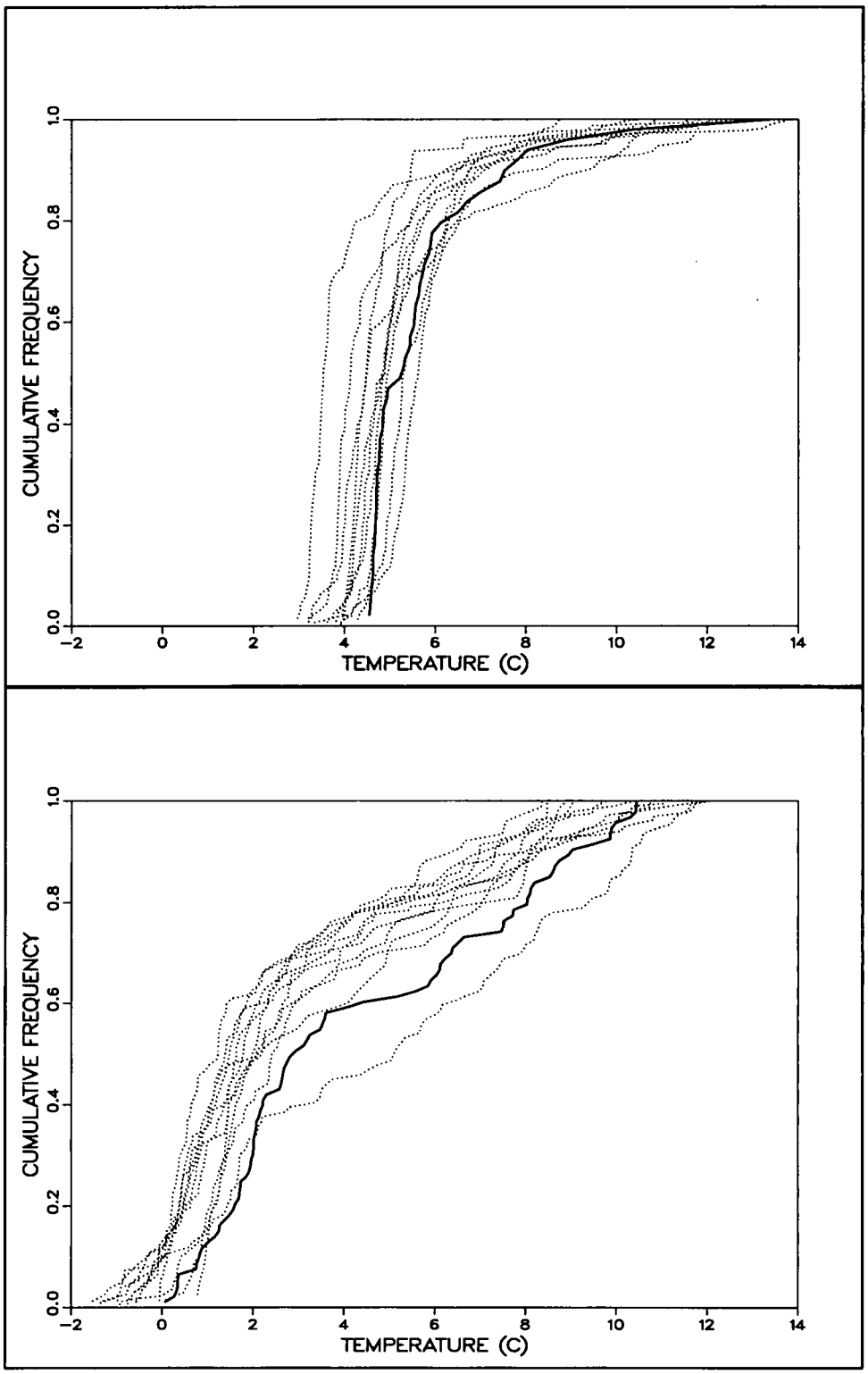

Figure 13: Cumulative frequency curves of near–bottom water temperatures for the 1987–97 Canadian research vessel bottom–trawl spring 5Z (top panel) and 4VsW (lower panel) surveys. Each line represents the cumulative frequency for a single year. The dotted lines are for the years 1987–96 and the heavy solid line is for 1997.

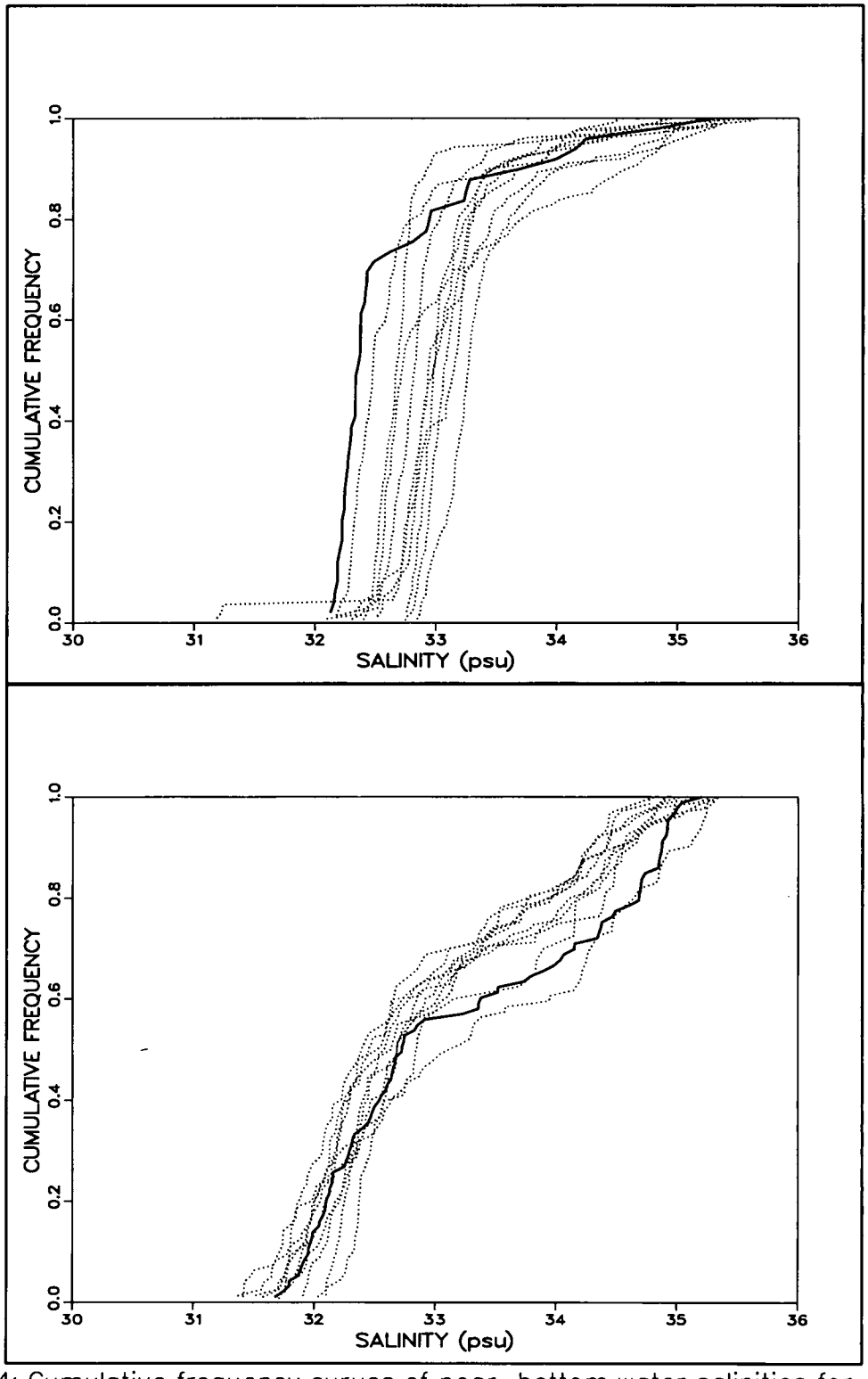

Figure 14: Cumulative frequency curves of near–bottom water salinities for the 1987–97 Canadian research vessel bottom–trawl spring 5Z (top panel) and 4VsW (lower panel) surveys. Each line represents the cumulative frequency for a single year. The dotted lines are for the years 1987–96 and the heavy solid line is for 1997.

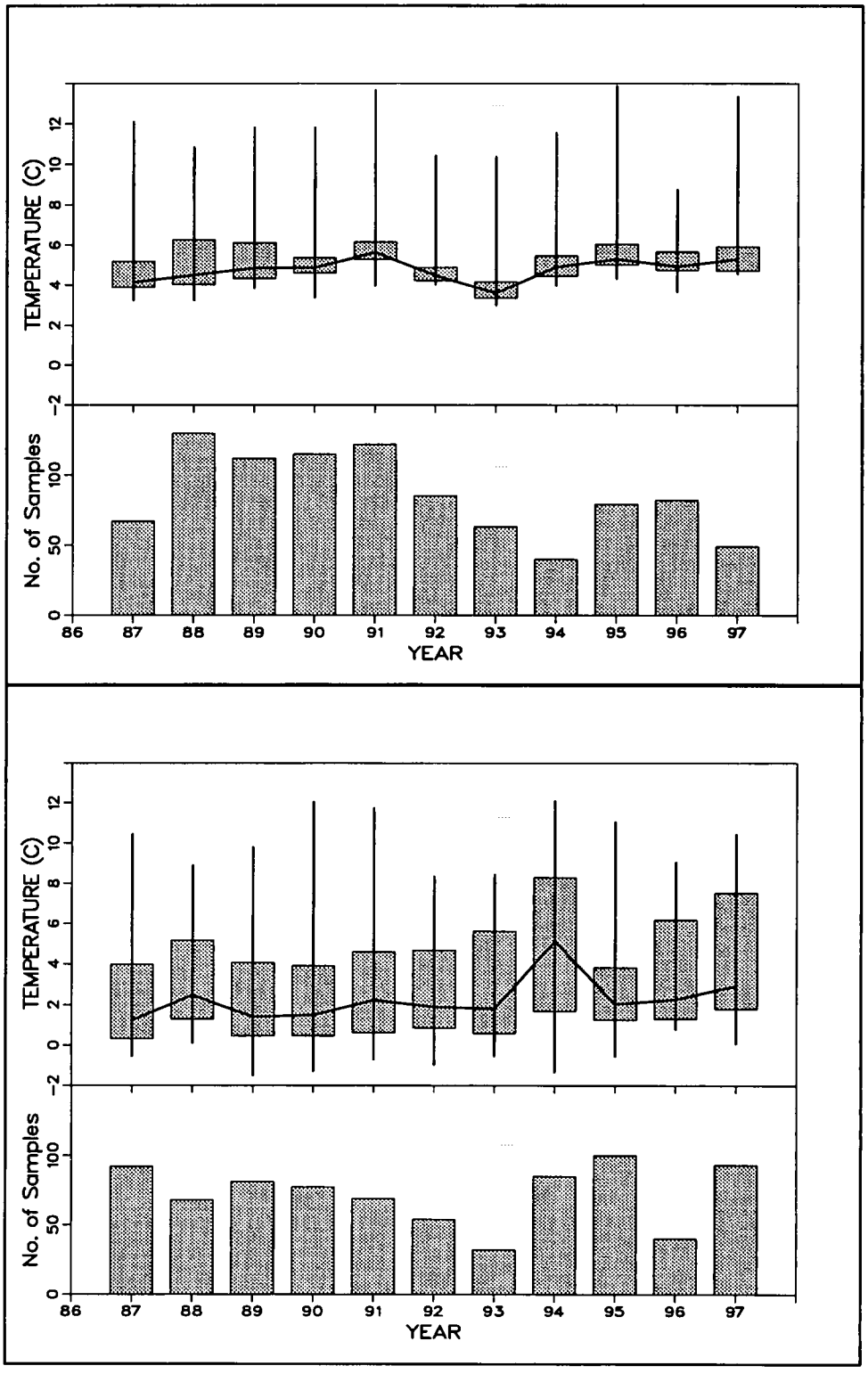

Figure 15: Box and whisker time series plots of near–bottom water temperatures for each year within 5Z (top panel) and 4VsW (lower panel). The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each year over the entire 1987–97 period.

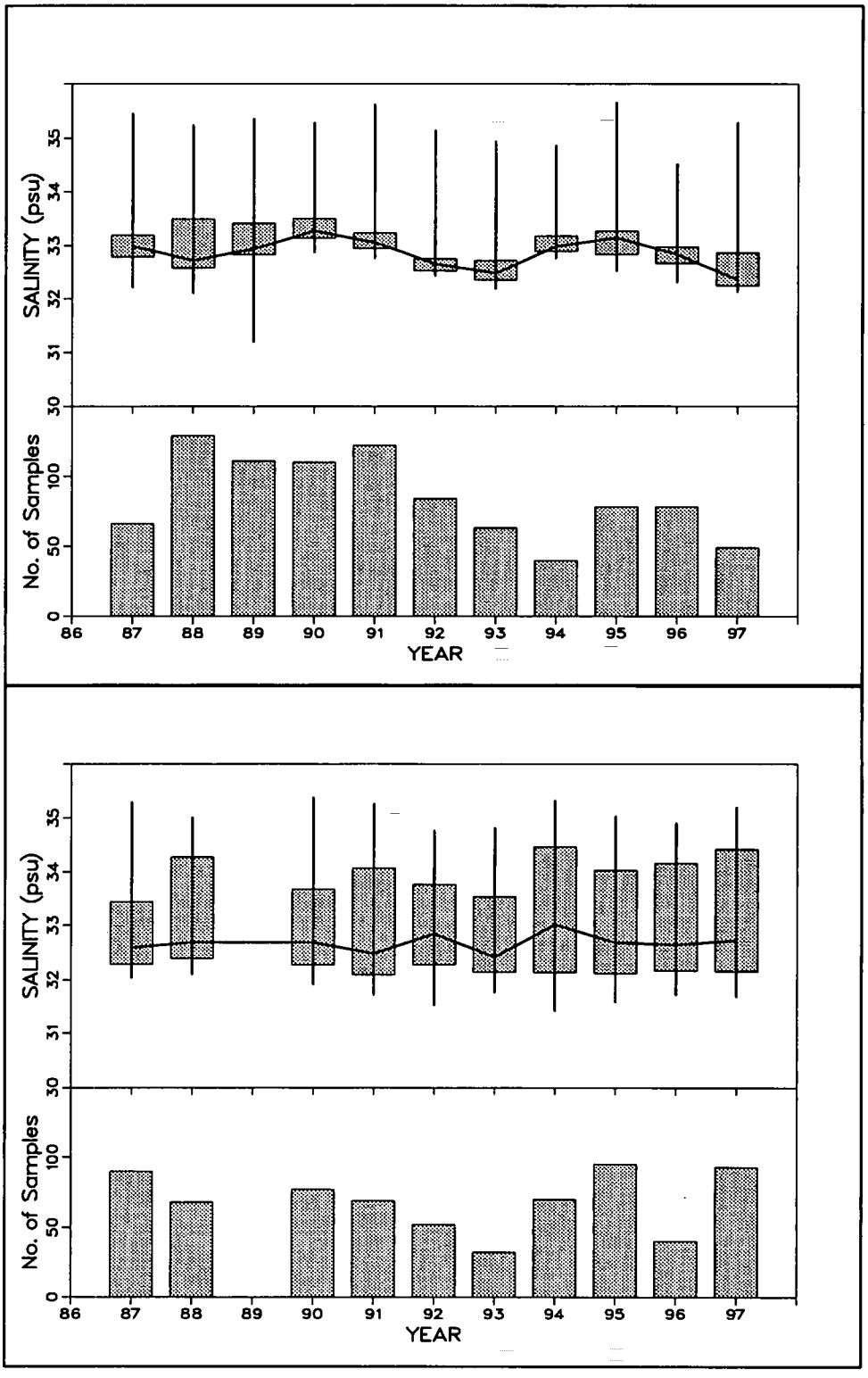

Figure 16: Box and whisker time series plots of near-bottom water salinities for each year within 5Z (top panel) and 4VsW (lower panel). The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each year over the entire 1987-97 period.

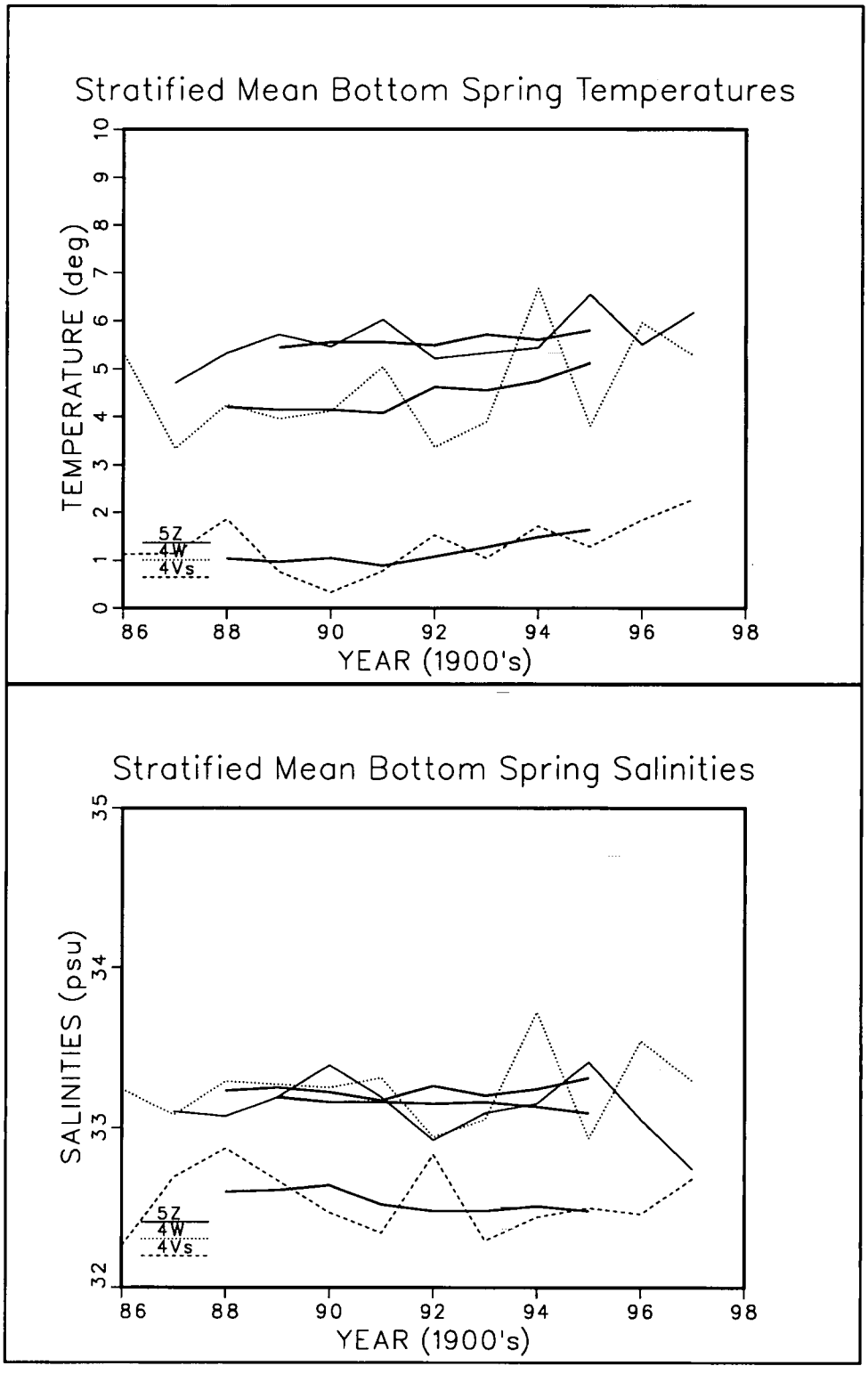

Figure 17: Time series of stratified mean near-bottom temperatures(upper panel) and salinities (lower panel)for Canadian spring research vessel groundfish surveys conducted within 4VsW and 5Z. The smooth curves running through each series is a five year running mean.

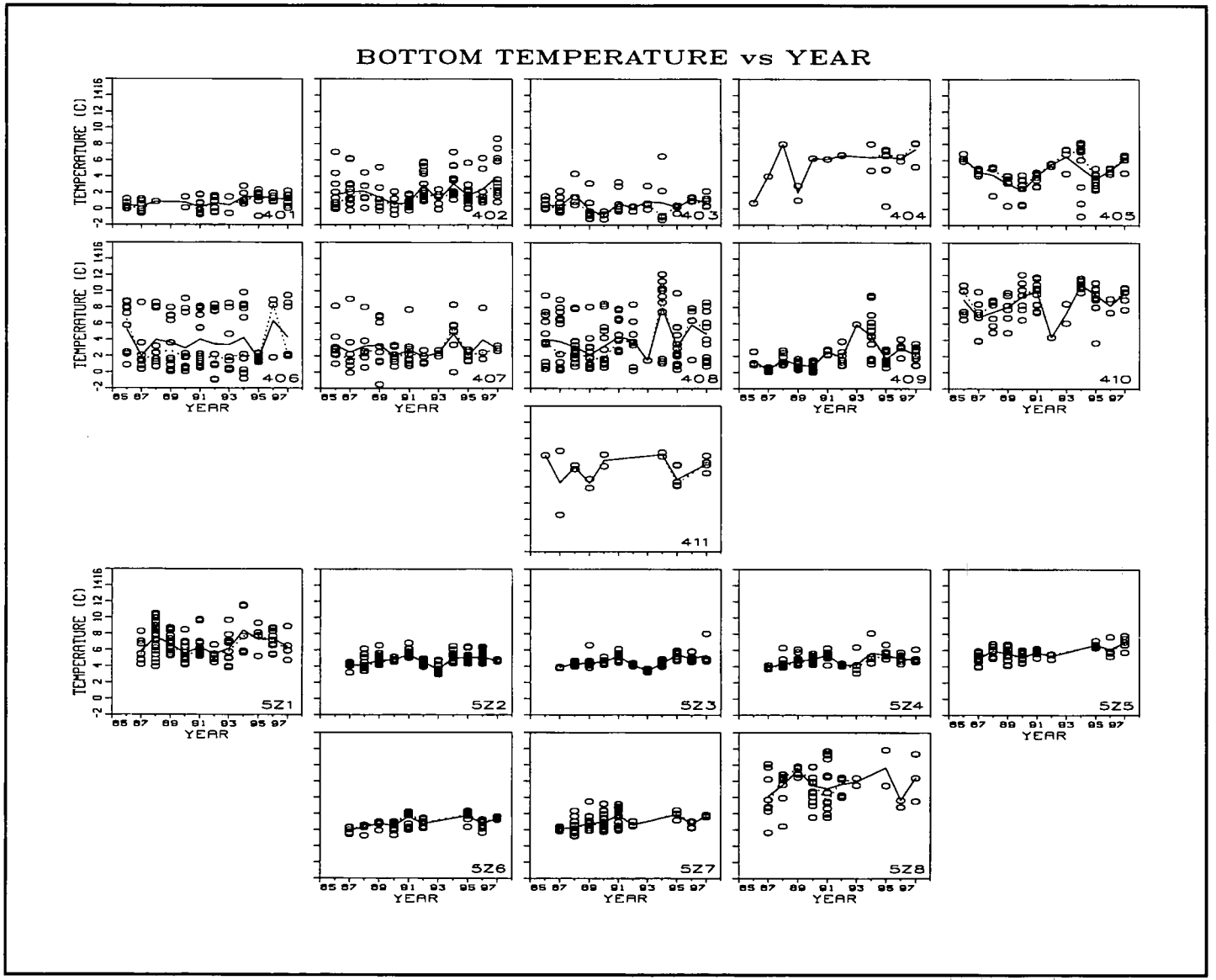

Figure 18: Time series of near-bottom temperatures within the spring 4VsW and 5Z surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

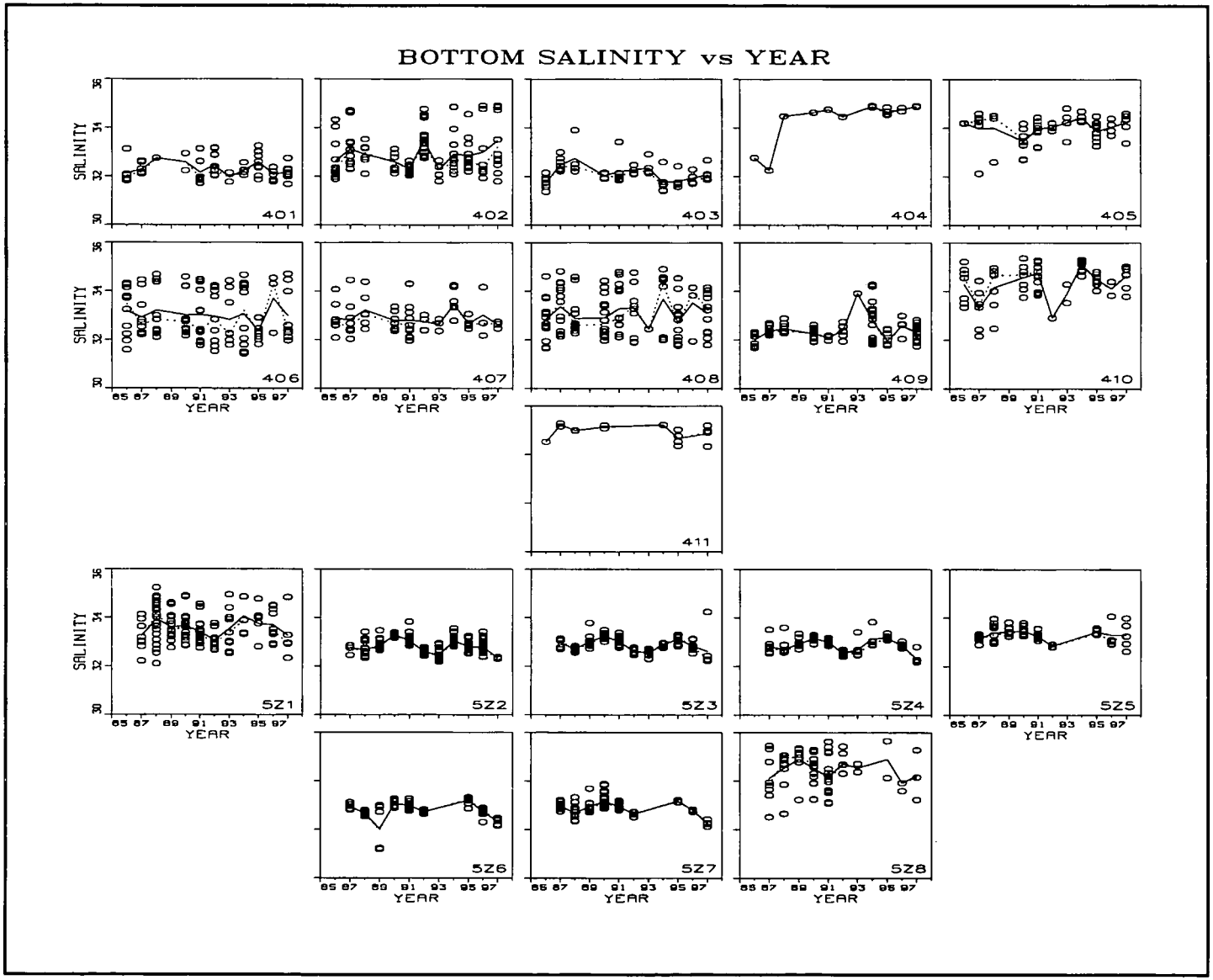

Figure 19: Time series of near-bottom salinities within the spring 4VsW and 5Z surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.