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Overview of 1998 Hydrographic Sampling Effort and Near-Bottom Water Temperature and Salinity Conditions During the Canadian Research Vessel Groundfish Summer Surveys Conducted on the Scotian Shelf and in the Bay of Fundy (4VWX)

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ABSTRACT

Hydrographic sampling effort and near-bottom water temperatures and salinities from the 1970-98 Canadian research vessel summer groundfish, stratified random, bottom-trawl surveys are summarised. The surveys cover NAFO divisions 4VWX. Temperatures in area 4V and Bay of Fundy were about average in 1998, while lower than average temperatures were recorded in areas 4W and the Scotian shelf portion of 4X, with a new record low mean temperature established for 4X this year. Salinities in area 4V tended to be slightly above normal, but all other areas recorded lower than average values. The 4X recorded historic low salinities for 1998. The largest deviations of temperatures and salinities continue to be on the eastern Scotian Shelf.

RÉSUMÉ

Les travaux d'échantillonnage hydrographique et les mesures de la température et de la salinité à proximité du fond réalisés à partir de navires de recherche canadiens au cours des relevés aléatoires stratifiés d'été du poisson de fond, par chalutage de fond, sont résumés pour la période de 1970 à 1998. Ces relevés couvrent les divisions 4VWX de l'OPANO. En 1998, les températures ont été près de la moyenne dans la division 4V et la baie de Fundy, mais des températures inférieures à la moyenne ont été enregistrées dans 4W et dans la partie du plateau néo-écossais se trouvant dans 4X, avec un nouveau record de faible température moyenne noté cette année en 4X. La salinité dans 4V était légèrement supérieure à la normale mais inférieure à la moyenne dans toutes les autres zones. La salinité dans 4X en 1998 est la plus faible jamais enregistrée. Les plus grands écarts de température et de salinité ont continué d'êtres notés dans la partie est du plateau néo-écossais.

INTRODUCTION

The Canadian Department of Fisheries and Oceans conducts bottom-trawl surveys on an annual basis within NAFO unit areas 4VWX 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 are summarised on an annual basis (e.g. Page, Losier and McRuer 1995, 1996; and Page, Losier, McRuer and Ringuette, 1997).

The intent of each summary has been to briefly describe the extent and nature of the hydrographic sampling effort and conditions within recent resource assessment surveys and to place these within a historical context. In so doing, it is hoped that trends and anomalies in conditions and sampling procedures may be identified.

In this overview, we present a summary of sampling effort and the resulting estimates of water temperatures and salinities during the 1970-98 summer surveys conducted within 4VWX. The focus is on the near-bottom conditions in 1998 and how these compare to conditions encountered throughout the history of the survey series. The impact of these conditions on estimates of the status of fisheries resources is not explored.

MATERIALS and METHODS

Data Sources

The hydrographic data summarised in this report were collected during the 1970-98 research vessel, summer groundfish bottom-trawl surveys conducted in NAFO unit area 4VWX. The surveys were conducted by the Canadian Department of Fisheries and Oceans and they cover the Scotian Shelf, eastern Gulf of Maine and the Bay of Fundy (Fig. 1). A standard stratified random design was used each year. The survey domain is divided into 48 strata. The strata boundaries were defined, primarily, on the basis of bottom depth and, secondarily, on the distribution of groundfish, mainly haddock (Doubleday 1981). As in the past, two standard summer surveys were conducted in 1998. Survey N98027 covered the western Scotian Shelf (4X) and N98032 covered the eastern Scotian Shelf and outer Bay of Fundy (4VW).

From 1970 to 1989, depth profiles of temperature and salinity were taken at about 30% of the sampling stations. Measurements were taken at standard hydrographic sampling depths (0,10,20,30,50,75,100,150, 200, 250 etc. meters). Surface temperatures were recorded with bucket thermometers and sub-surface temperatures with reversing thermometers. Salinities of water samples, taken from the surface bucket or subsurface water bottles, were measured with a laboratory salinometer.

From 1990-98, depth profiles of water temperatures and salinities were measured with a Seabird (SBE) Model 19 or 25 CTD profiler, internally recording conductivity, temperature and depth using the procedures described below. CTD profiles were

consistently taken at more than 90% of the trawl stations. When a CTD was not available for use, due to malfunction or extreme weather, standard hydrographic profiles (described above) were taken with reversing thermometers attached to water bottles and/or an XBT profile was taken.

In 1998, standard survey hydrographic procedures were used for obtaining vertical profiles of water temperature and salinity at each valid (type 1) bottom trawl sampling station. Type 1 stations are those trawled for at least 20 minutes with minimal damage to the trawl. Water temperatures and salinities were measured using a SBE 25. The instrument 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 of 3 minutes, 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 30-40 m per minute. 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 to obtain water samples and temperatures for later calibration of the CTD. 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 is 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. The CTD data have been compared with the reversing thermometer derived measurements of temperature and the salinometer derived measurements of water sample salinities. Corrections have been applied where necessary.

The edited CTD and bottle 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

Sampling

In 1998, sampling was conducted from 6 July (consecutive day 187) to 30 July (consecutive day 211). CTD profiles were obtained from every strata (Fig. 1). As in previous years, the random allocation of the sampling stations resulted in the stations within some strata (e.g. 476, 482 and 484) not being widely distributed throughout the strata.

The maximum CTD profile depths ranged from <50m to >300m. The distribution of near-bottom depths varied between strata (Fig. 1 & 2). In 1998, the depths sampled were consistent with previous years.

Historical Context: Temporal Trends

Previous summer surveys have been conducted between 23 June (consecutive day 175) and 6 August (consecutive day 219; Fig. 3). The first survey samples the 4X area (median date: 9 July; range: 23 June to 31 July) and the second survey samples the 4VW area (median date: 22 July; range: 23 June to 6 August). Hence, the sampling dates are approximately 2 weeks earlier in the 4X area. The dates have been relatively consistent over the years. However, in a few strata (e.g. 440-450 and 470-78) the sampling dates during the first few years of the survey series (~1970-80) were 5-20 days later than in the more recent years.

Sampling dates in 1998 were generally typical of those in recent years. One set in strata 464 was sampled approximately 2 weeks later than the average sets in this stratum.

Near-Bottom Temperatures

Means and 1998

The overall range of near-bottom temperatures within the survey domain, and during the complete survey time period (1970-98), is approximately -1°C to 14°C (Fig. 4,8). The range of temperatures within a stratum differs considerably between strata. In some strata (strata 482,490), the range is only a few degrees, whereas in others (strata 472), it is >10°C. The near-bottom temperatures in 1998 for areas 4VWX ranged from 0.34 to 9.69°C, which was within the previously observed limits (Fig. 4,8). In 4VW, temperatures in the traditionally warm strata (463 $\rightarrow$ 461 in Fig.4) were all well below the long-term strata medians and 25th percentiles. In 4X, most of the 1998

temperatures fell below the 75th percentiles. Temperatures were close to or below the minimum recorded value in 11 strata, with new minimum temperatures recorded in strata 471, 472, 481 and 483. Only in stratum 493 in the 4X area were temperatures recorded above the historic 75th percentile.

The geographic distribution of the 1998 temperatures (Fig. 5) is similar to that of the long-term (1980-90) strata mean temperatures (Fig. 6). The lowest temperatures (<1°C) occurred on the eastern Scotian Shelf. The highest temperatures occurred in the central shelf and upper Bay of Fundy. Temperatures throughout the remainder of the survey domain were between 2° and 8°C. Localised pockets of relatively cold water (<4°C) occurred in stratum 472,473 and the Sable Island Banks.

Strata mean temperature for 1998 (Fig.7) shows a similar pattern to that of the long-term (1980-90) strata mean temperatures (Fig 6). All strata mean temperatures were near or below the 1970-90 means (Fig. 7). Bay of Fundy and 4V areas showed about average temperatures while below average temperatures were recorded in other areas of 4X and southern 4W. The cumulative frequency distributions of the area unweighted temperatures (Fig. 8) indicate that the temperatures sampled in 1998 in 4VW fell within the expected range but with fewer high temperature values. However, the cumulative frequency for 4X fell well below the normal values resulting in the lowest curve in the history of the survey series.

Historical Context: Temporal Patterns

The time series of area unweighted temperature percentiles is shown in Fig. 9. In 4VW, the temperatures remained relatively stable from 1970-75, tended to increase from 1975 to 1981, decreased in 1982 and increased to a historical high for the survey series in 1984. From 1984 to 1989, the temperatures trended downward and remained relatively low throughout the 1990's. From 1990 to 1992, the median temperatures remained below 4°C and the 25th percentile remained below 2°C. Since 1992 the temperatures have warmed slightly. In 1997, the distribution of temperatures was still centred below those in the late 1970's and early 1980's. For 1998, the mean temperature for 4VW was slightly higher than 1997, with 75th and 25th percentile ranges similar through the past 3 years, although a record low maxima (9.69°C) was recorded for 1998. In area 4X, the temperatures increased yearly (except for 1975) from 1969 to a record high median temperature in 1977. A sharp decrease followed for 1976, and then a gradual increase until 1984. Mean temperatures fluctuated throughout the mid 80's and early 90's showing a general decrease until 1992, followed by a sharp rise in 1993 and 1994, then a general decrease to the current year. For 1998 in 4X, mean temperature was much lower than 1997, setting a record low for the history of the survey series. In addition, record lows were set for the maximum, 75th percentile and 25th percentile. The minimum temperature for 1998 was very close to the record low set in 1986.

Minimum and 25th percentile temperatures are generally higher in 4X than in 4VW. With the exception of only a few years (1970-71), the 25th percentile of mean temperature was above 6°C up until 1991, with large year to year fluctuations from 1992 to present. Minimum temperatures rarely fell below 2°C. In contrast, 4VW minimum temperatures were always below 2°C, with several values below 0°C. Also, 25th percentile temperatures were generally below 2°C, with some exceptions (1970-1971, 1976-1981,1984, 1986) (Fig. 9).

These general patterns are also reflected in the time series of stratified mean temperatures (Fig. 10). The five-year running mean shows temperature trends for each area. Presently in 4Vs, temperatures are gradually increasing following a period of decline from 1979-1991. Water temperatures are much warmer in 4W than 4Vs but for 1998 4W temperatures are lower and the trend beginning to decrease. Area 4X temperatures show similar patterns, but while Bay of Fundy temperatures seem to be increasing, Scotian Shelf temperatures have decreased. Figure 11 shows the location of eastern Scotian Shelf sampling stations (4VW) in which temperatures below 0^{o}C were observed somewhere within the water column, plotted for each of the 1970-1998 surveys. With the exception of 1987 and perhaps 1974, temperatures below 0^{o}C were generally not observed prior to 1990. However, from 1990 to 1994, subzero temperatures were routinely recorded in the northeastern portion of the survey area with the greatest occurrence being in 1992. From 1995 to 1997, only a few stations recorded temperatures less than 0^{o}C, while data for 1998 shows a pattern similar to pre-1990 plots, with no stations recording temperatures below 0°C. It should be noted that the implied increase in cold water during the early 1990s corresponds with the implementation of the routine use of a CTD on the surveys. Hydrographic profiles were obtained prior to 1990 by taking water bottle and reversing thermometer samples at standard hydrographic depths. These depths encompassed the cold intermediate layer, although they probably did not routinely sample the temperature minimum within this layer. The distribution of water temperatures below 2^{o}C (not shown) also suggests the volume of cold water increased in the early 1990's and indicates that relatively cold water still persists in 1998.

The strata specific time series of temperatures are shown in Fig. 12. The general pattern indicated above for 4VW is generated by the temperatures within the relatively cold strata (441-445, 447-48, 457-59). There is little trend in the temperatures from the other 4VW strata. Some strata show large variability in temperatures both within a year and from year to year (eg 455,456) while others show little range within the year but vary year to year (464,465). Still others show little year to year or within year variability (446,448). The general pattern for 4X as a whole is representative of the pattern in most of the 4X strata. The Scotian Shelf strata seem generally more variable in temperature ranges, while the outer Bay of Fundy strata show less temperature variability both year to year and within years. As expected, warmer temperatures are recorded from near shore and inner Bay of Fundy stations.

Salinities

Means and 1998

The near-bottom salinities sampled within the survey domain have ranged from about 30.5 to 35 psu (Fig. 13, 15) during the 1970-98 time period of the surveys. As with temperature, the salinity range within strata differs between strata. The range in some strata (strata 482,483) is only a few tenths of a psu, whereas it is >2 psu in others (strata 472,481). The salinities on the eastern Scotian Shelf, (strata 441-45, 447-48, 455-56, 458-59) tend to be relatively fresh (75th percentile <33 psu), whereas, those in the central shelf area (strata 460-62, 465-72), the shelf edge (451-52, 453-54, 466, 478) and deep Gulf of Maine (482-84) tend to be relatively salty (25th percentile >34 psu). The waters of the upper Bay of Fundy (490, 494-95) tend to have relatively low salinities. Salinities within the remaining strata range from 33 to 34 psu. In the eastern, central and southwestern Scotian Shelf areas the relatively low and high salinities correspond with the relatively low and high temperatures. In the Bay of Fundy, the low salinities correspond with high temperatures. This general pattern is also reflected in the contoured (Fig. 5) and strata mean salinities for 1998 (Fig. 14).

Near-bottom salinities in 1998 ranged from 31.3 to 34.9 psu (Fig. 5,13,15). In most strata, the 1998 salinity values were distributed throughout the previous observed ranges of values. Within areas 4VW, salinities tended to be lower than average in samples from area 4W, and higher than average in area 4V. Salinites from all stations in stratum 461 were lower than previously recorded values. In 4X, 1998 salinities were generally lower than average values for each stratum, with 18 strata recording salinities below the 25th percentile compared with 6 strata recording salinities above the median values for the 1990-1997 period and only 1 stratum recording a salinity value above the 75th percentile. New minima were established in strata 471 and 472. Most strata mean salinities were within 0.5psu of baseline means (Fig. 14). Salinities >0.5psu below the 1980-90 baselines were recorded in area 4W in strata 460-462, and in area 4X in strata 470-473, 476,480,484,485 and 490, resulting in slightly fresher water in the central Scotian Shelf and Gulf of Maine. The cumulative frequency distributions of the area unweighted saqlinities (Fig. 15) indicates that the 1998 salinities were lower in 4X than in most previous years, although they were not the lowest in the history of the survey series. In area 4VW, the salinities fell within the expected range.

Historical Context: Temporal Patterns

Like temperatures, the near-bottom salinities have varied inter-annually. The trends in the distribution of unweighted salinities for 4VW and 4X show similar patterns (Fig. 16). In 4VW, the median salinities from 1970 to 1987 were generally above 33 psu. From 1975 to 1981, the salinities tended to increase to a historical high in 1984. The salinities trended downward from about 1984 to 1990 and have exhibited a weak upward trend throughout the early 1990's. With the exception of 1993, the 25th percentile has

remained below 32.5 psu since 1990. For 1998, the mean salinity in 4VW showed a slight increase from 1997, with the 25th and 75th percentiles within historic ranges. In 4X, the trends in unweighted median salinities are relatively weak and with the exception of a few years (1991 & 1995), the median salinity has been above 33 psu. For 1998, the mean salinity in 4X sharply decreased to approach the 1995 record low, with the 25th and 75th percentile values being the lowest of the history of the survey series.

The stratified mean salinities for 4W and 4Vs (Fig. 10) show similar trends. The five-year running mean shows smoothed salinity trends for each area. In area 4VW, the salinities increased during the 1970's and early 1980's, decreased in 4V throughout the 1980's and from about 1986 to 1990 in both 4V and 4W, and increased since the early 1990's in both areas. Presently, salinities in both 4V and 4W appear to be decreasing. Area 4X shows a similar pattern, with salinities in both Scotian Shelf and Bay of Fundy presently decreasing. As with temperature, the trend is much weaker in 4X compared with 4VW.

The strata specific time series of individual station salinities are shown in Figure 17. The trend in 4VW salinities is seen most clearly within the intermediate salinity strata (441, 454, 457). The general lack of a trend in the 4X strata (470-495) is reflected in the individual 4X series. The pattern of stratum-specific salinity variability from year to year and within each year is similar to that shown by temperature.

DISCUSSION

The oceanographic climate has been consistently monitored within the Scotia-Fundy region at only one offshore station. This is the Prince 5 station located in 90-100 m of water on the northern side of the tidally energetic mouth of the Bay of Fundy. Full hydrographic profiles have been recorded at this station on a once a month basis since 1924 and twice monthly since October 1997 (Trites and Drinkwater 1983). A second indicator of offshore conditions has been constructed from hydrographic profiles taken within Emerald Basin on an opportunistic basis (Petrie et al. 1991). Both of these time series contain a low frequency (decadal time period) trend in temperature that is horizontally and vertically coherent throughout the Scotia-Fundy region (Petrie et al. 1991). The trend indicates that the late 1930's to early 1940's and the early 1960's were relatively cold, whereas, the late 1940's to early 1950's and the 1970's and 1980's were relatively warm. The trend during the later 1980's has been toward decreasing temperatures such that the early 1990's are below the long-term mean. The research vessel surveys have been conducted within this framework of climate change.

The Canadian bottom-trawl research vessel summer survey program began in 1970. Because of the stratified random allocation of set locations, the potential exists for the patterns and trends in temperatures and salinities observed during the surveys to be confounded by variation in the location and timing of the sampling. Hence, the trends in

temperatures and salinities observed during the surveys are only indicators of trends in the hydrographic conditions that were sampled and are not always good indicators of actual changes in the hydrographic climate. Fortunately, this is not as large of a problem for the summer surveys as it is for the spring surveys. This is discussed more fully in Page et al. 1994.

Whether the changes are climatic in nature or not does not alter the fact that the changes are indicative of inter-annual differences in the type of hydrographic habitat sampled. As such, they may be related to inter-annual variations in estimates of fish distribution and abundance. Several authors (e.g. Pinhorn and Halliday 1985) have suggested this possibility. Page et al. (1994) and Smith et al. (1994) have examined the associations between cod and haddock abundance and sampling depth, water temperature and salinity. 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 (Smith, et al. 1991). 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). The suggested trends in temperatures may, therefore, be associated with changes in the distribution and abundance of cod within at least the 4VW area. This connection has been explored more fully by Smith and Page (1996). The connection with haddock has been explored by Smith and Page (1994). The possibility of a relationship between temperature and herring was explored by Stephenson et al. 1995.

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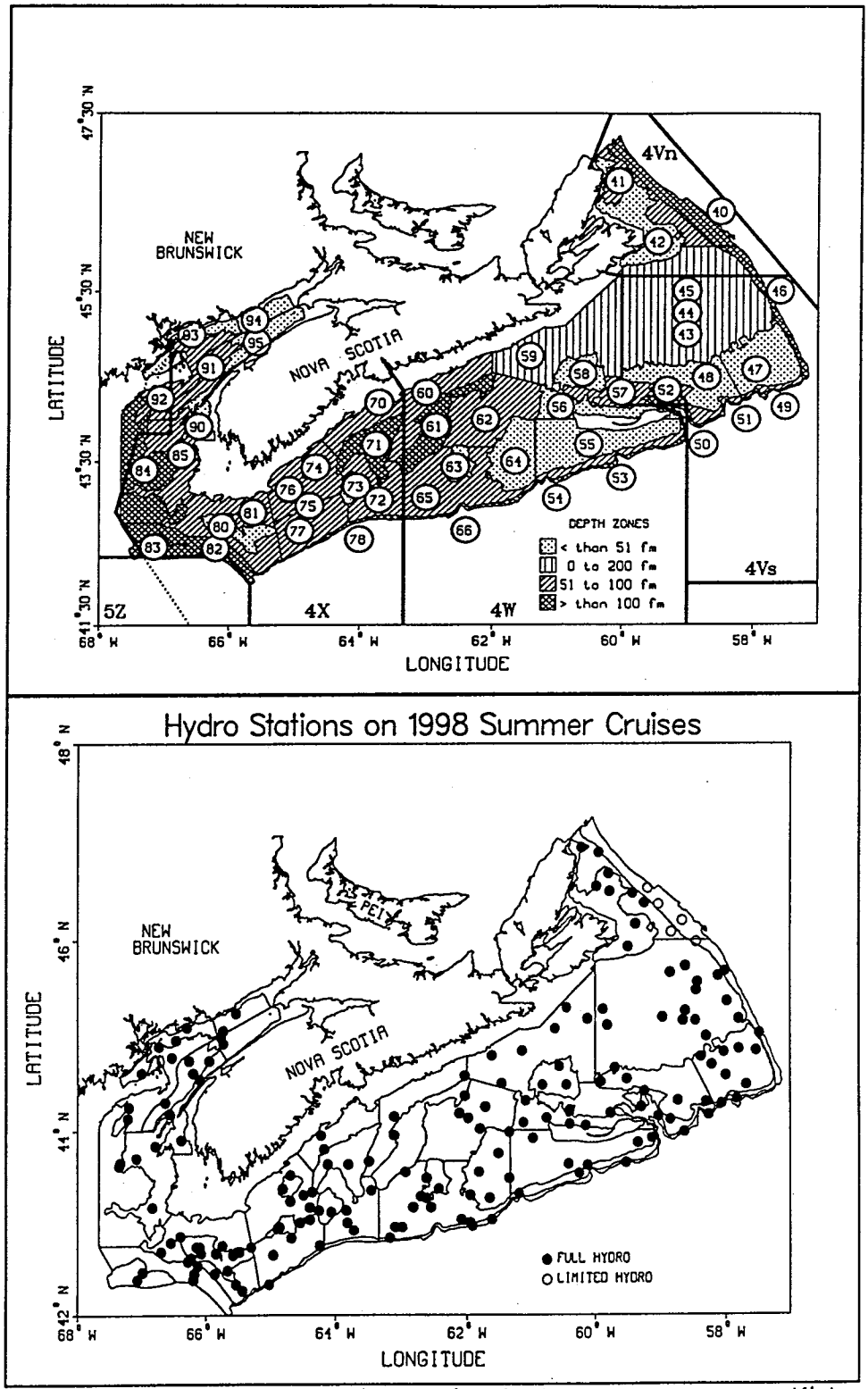


Figure 1: Survey domain and strata boundaries for the summer groundfish research vessel surveys conducted within NAFO area 4VWX from 1970–1998 (top panel) and the location of hydrographic sampling stations taken during the 1998 survey (bottom panel). In the bottom panel solid circles indicate a CTD cast 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. Only the last two digits of the summer strata designations are shown.

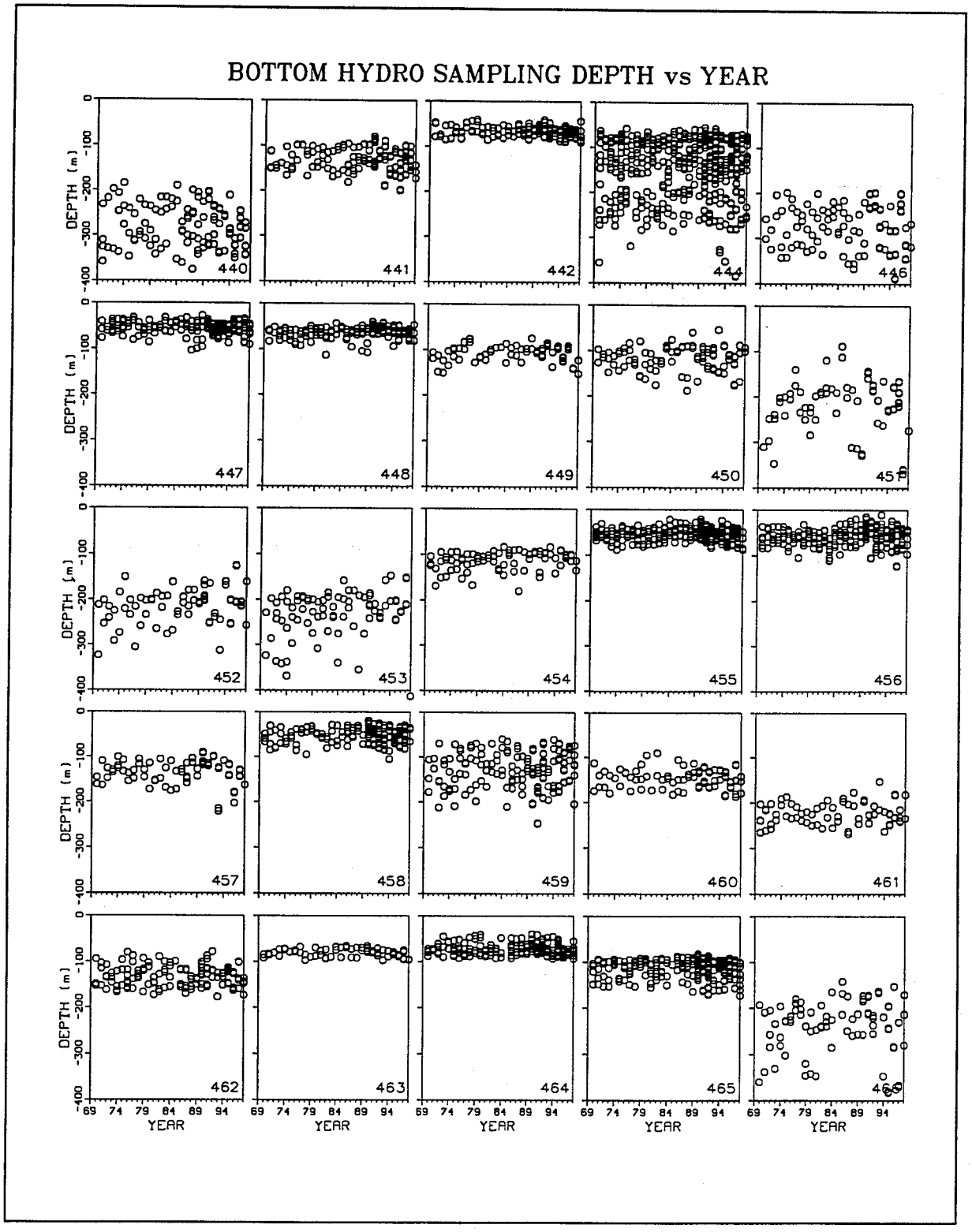
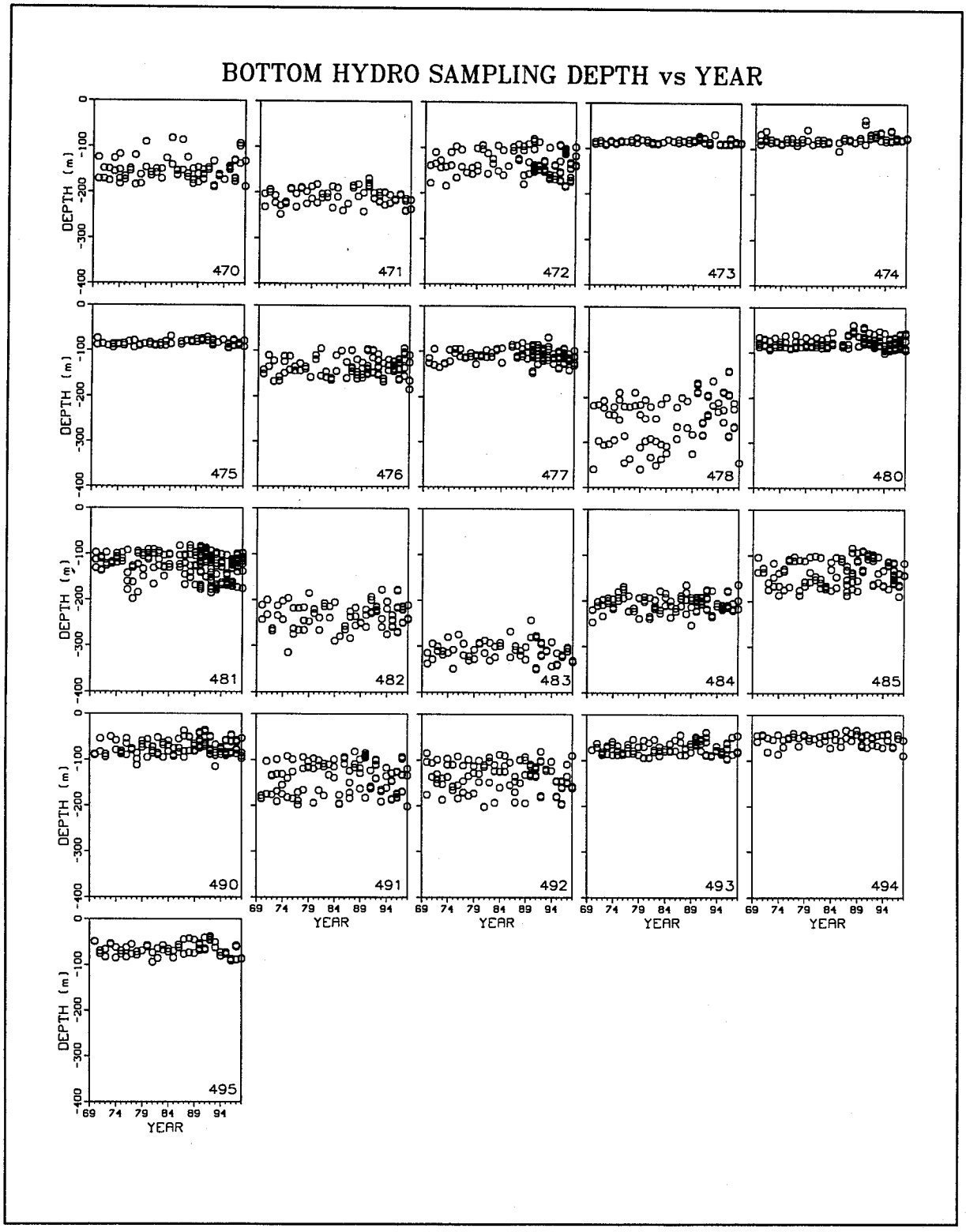


Figure 2: Time series of the consecutive day of sampling within the summer 4VWX surveys. The numbers in the upper right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.



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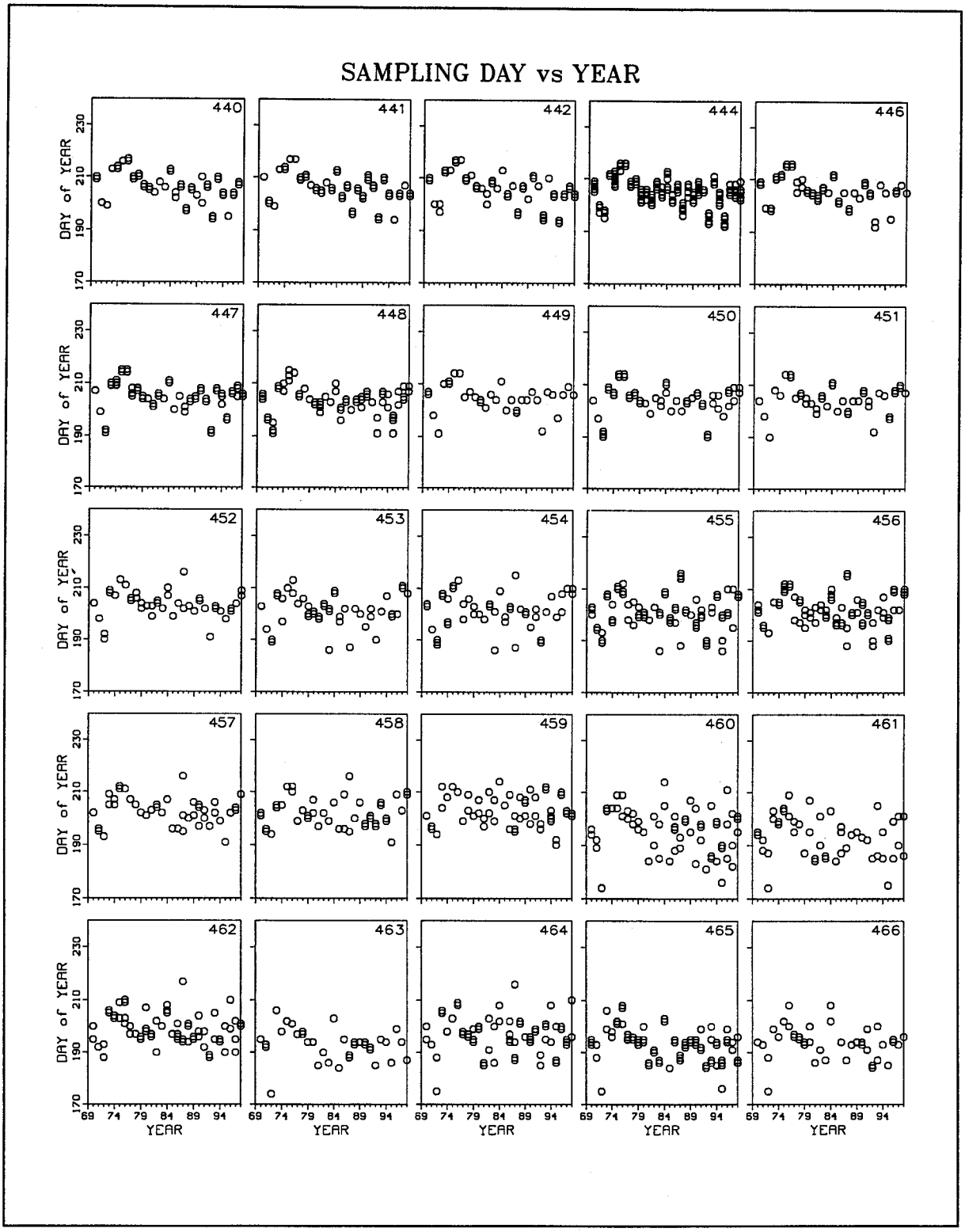
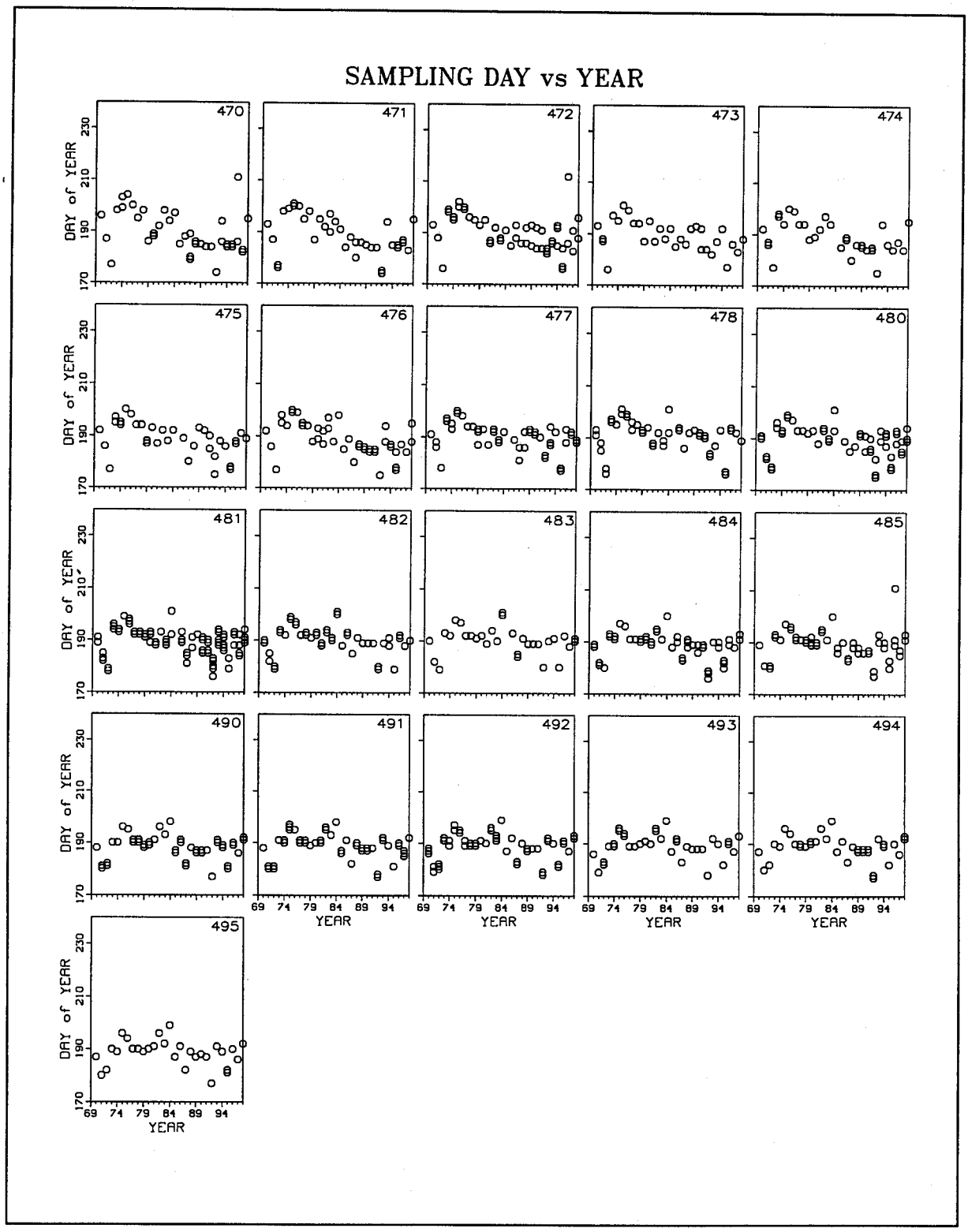


Figure 3: Time series of the consecutive day of sampling within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.



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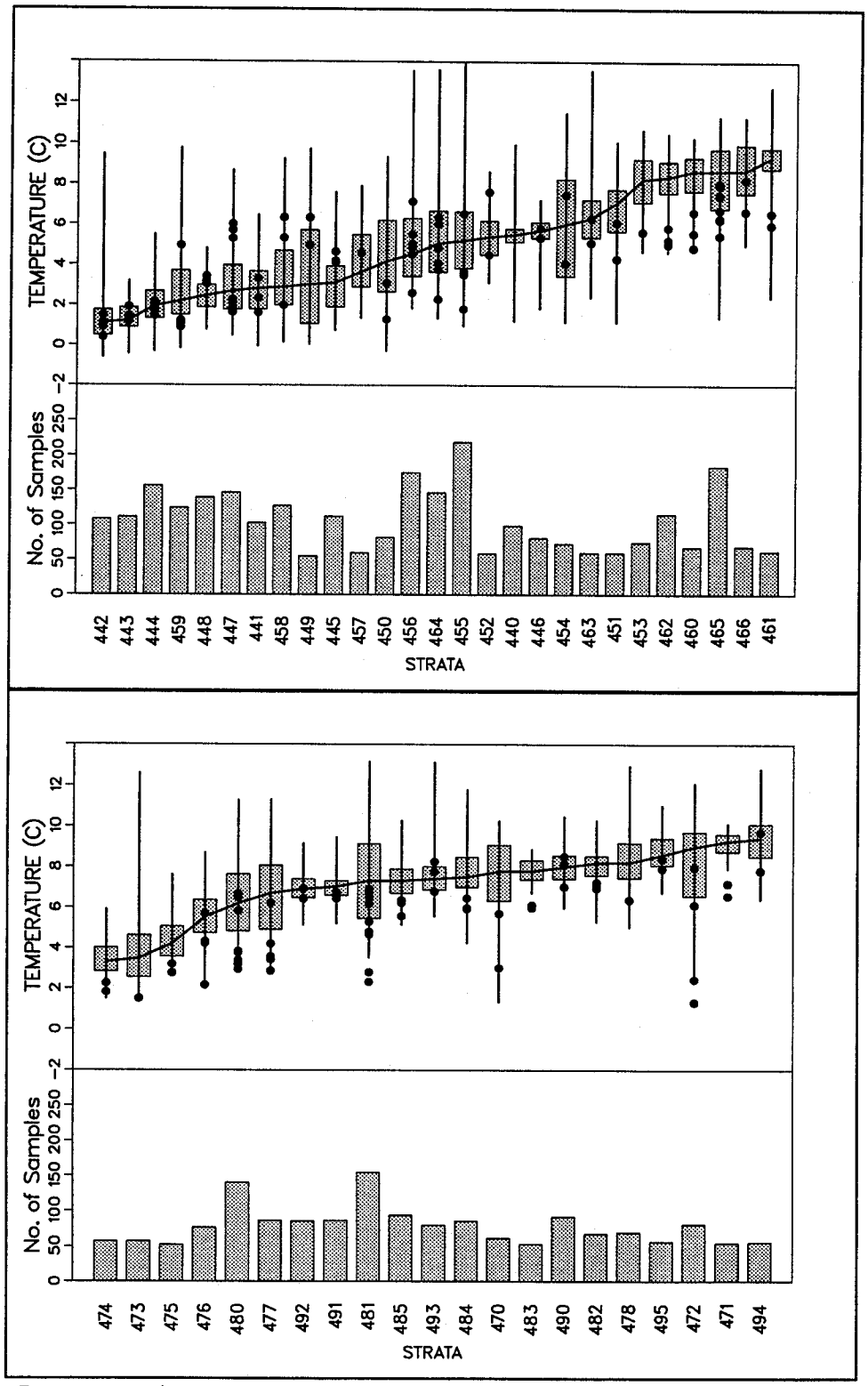

Figure 4: Box and whisker plots of strata specific, 1970–97, near–bottom water temperatures for strata within 4VW (top panel) and 4X (lower panel) ordered by temperature medians. The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each strata over the entire 1970–97 period. Solid circles are 1998 observed temperature data.

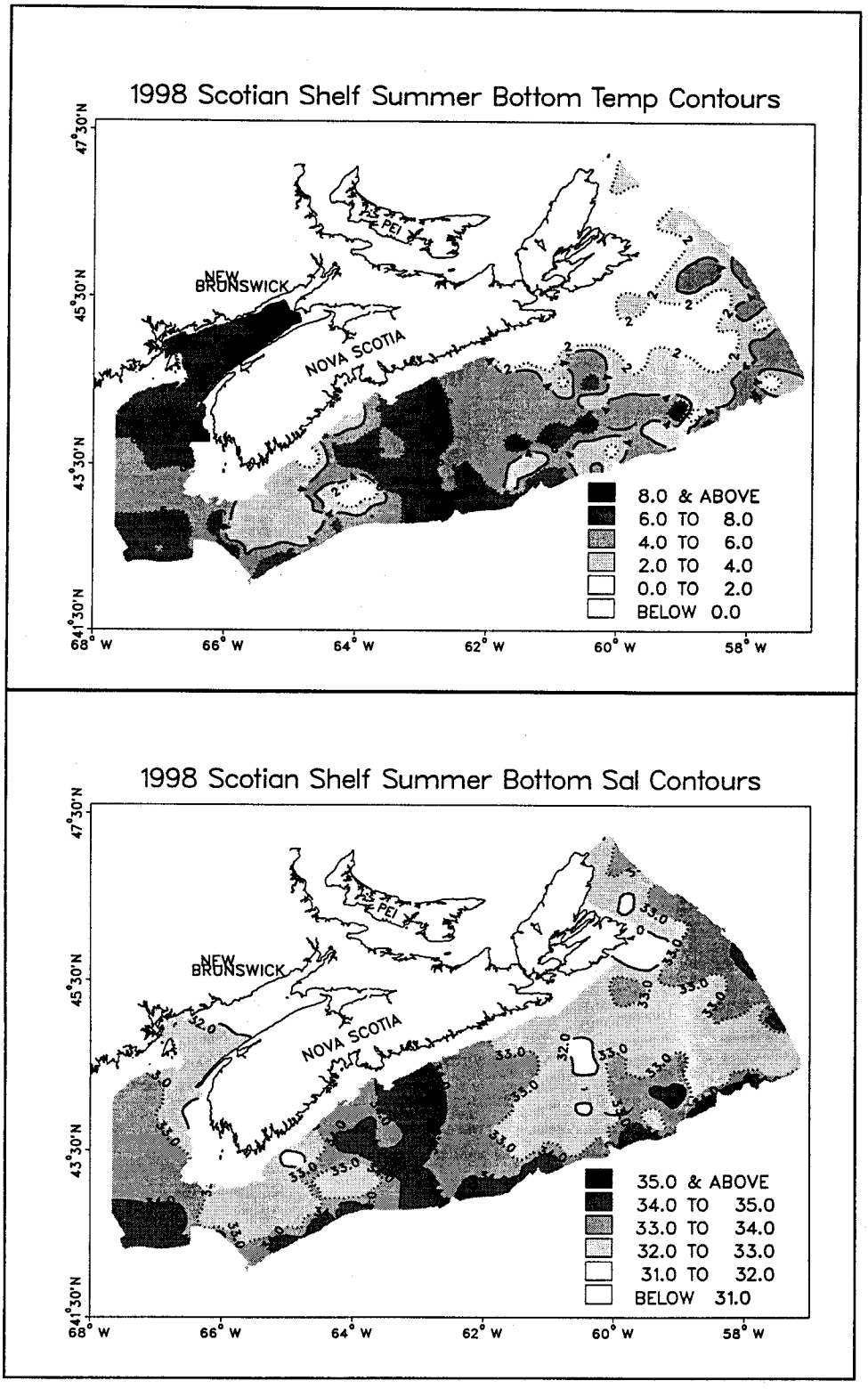

Figure 5: Contour maps of near-bottom temperature and salinities within the 4VWX Canadian research vessel bottom-trawl surveys conducted during the summer of 1998.

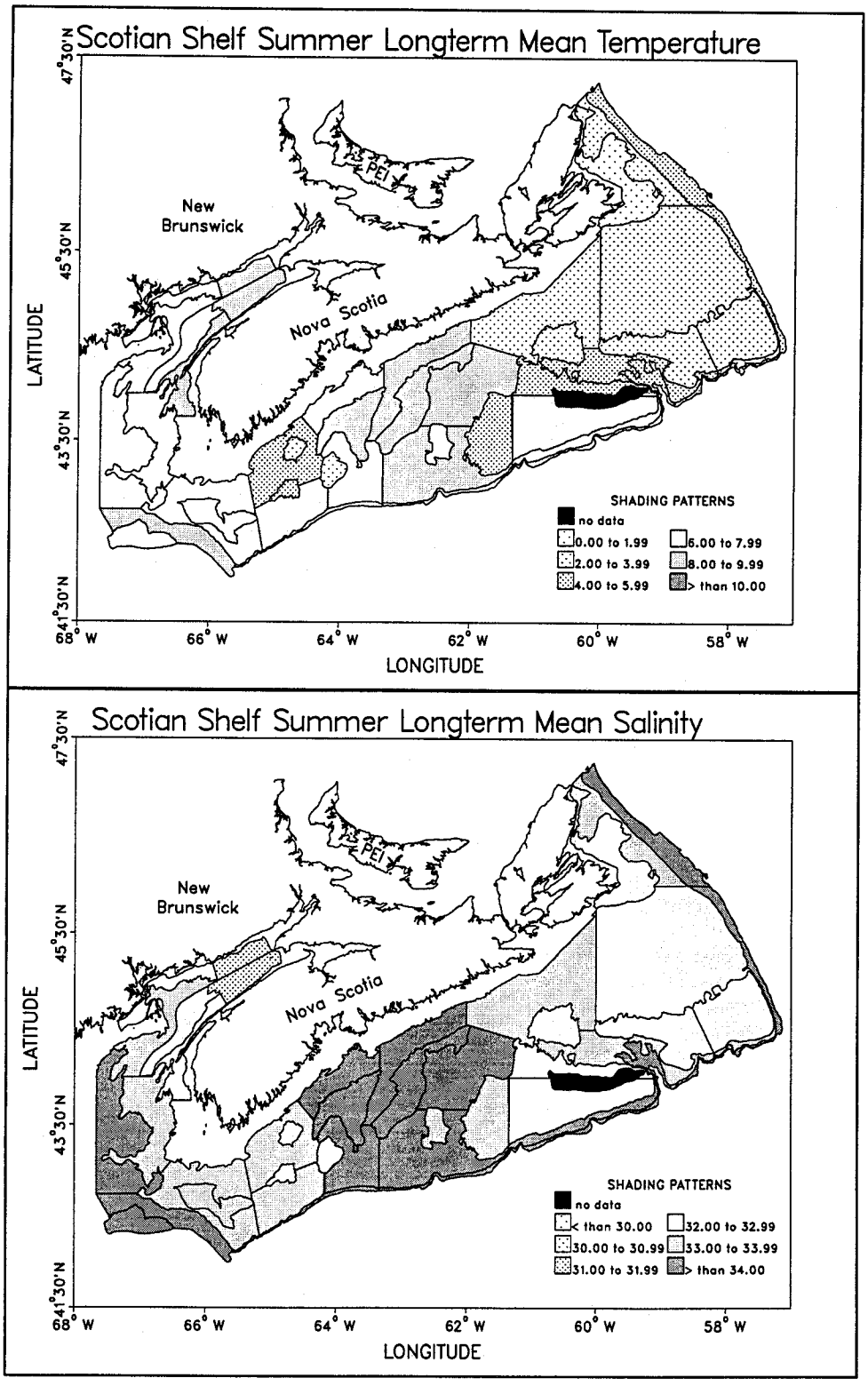

Figure 6: Map of near-bottom strata long term mean temperatures (top panel) and salinities (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1980-1990.

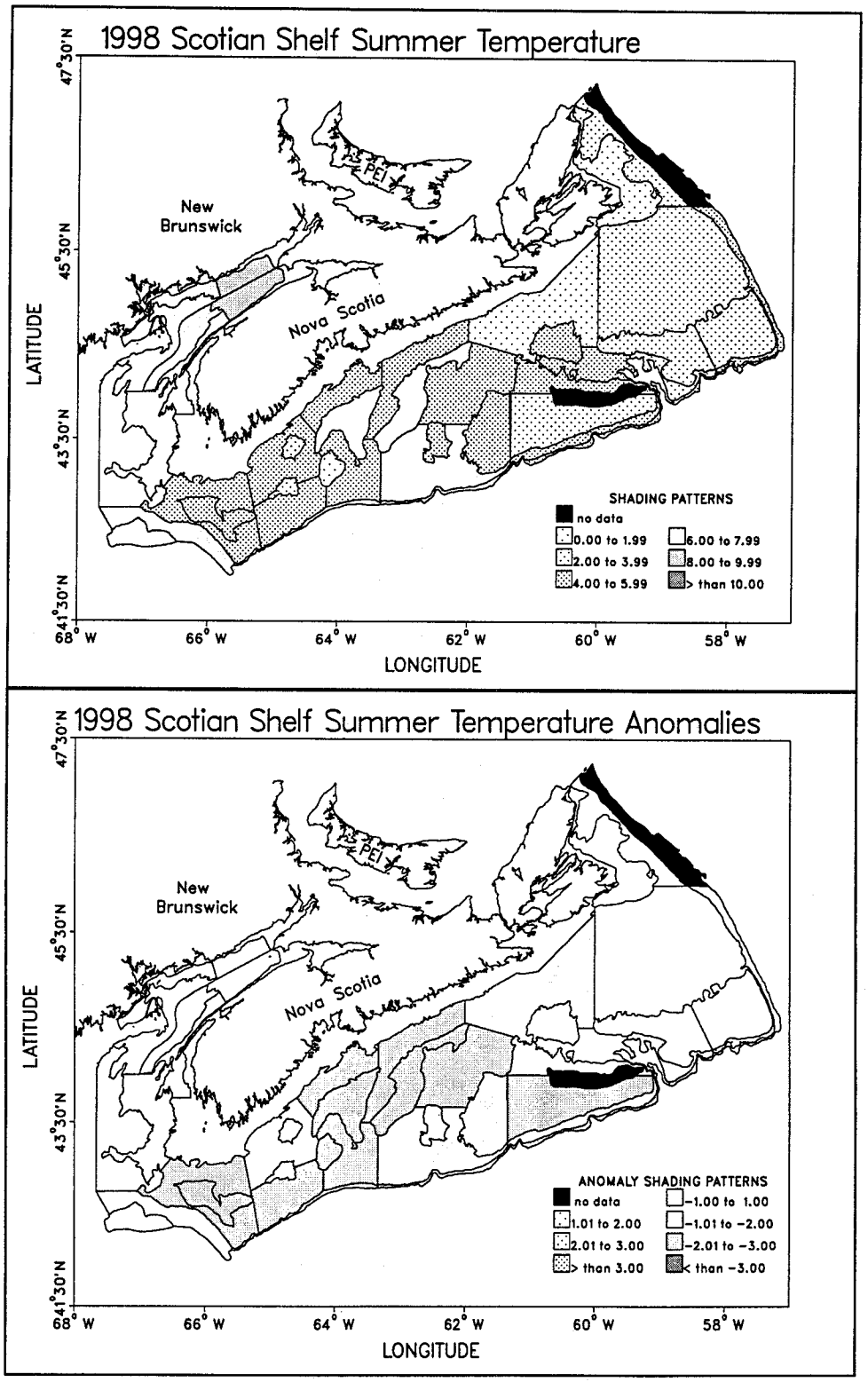

Figure 7: Map of near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1998.

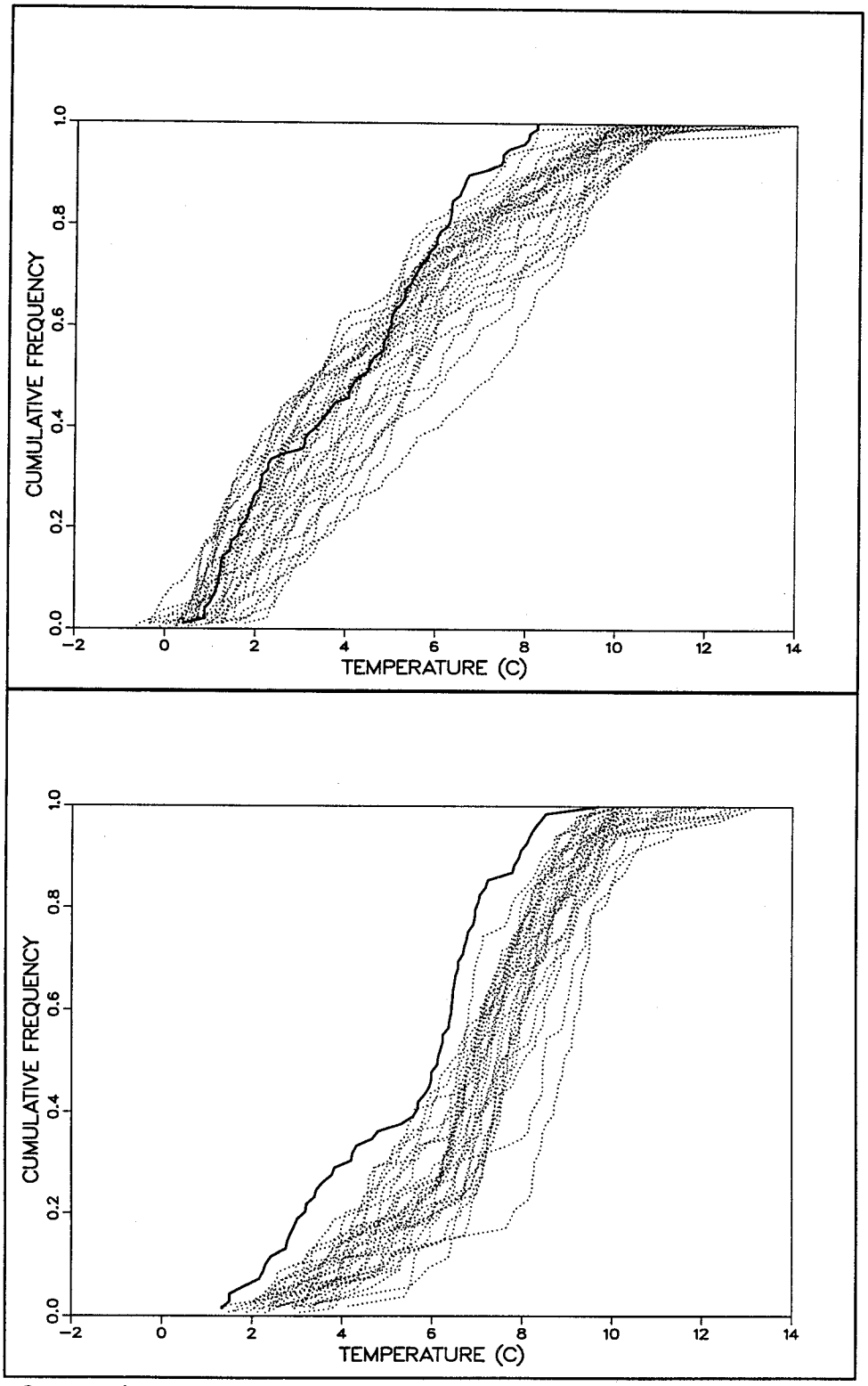

Figure 8: Cumulative frequency curves of near−bottom water temperatures for the 1970−98 Canadian research vessel bottom−trawl summer 4VW (top panel) and 4X (lower panel) surveys. Each line represents the cumulative frequency for a single year. The dotted lines are for the years 1970−97 and the heavy solid line is for 1998.

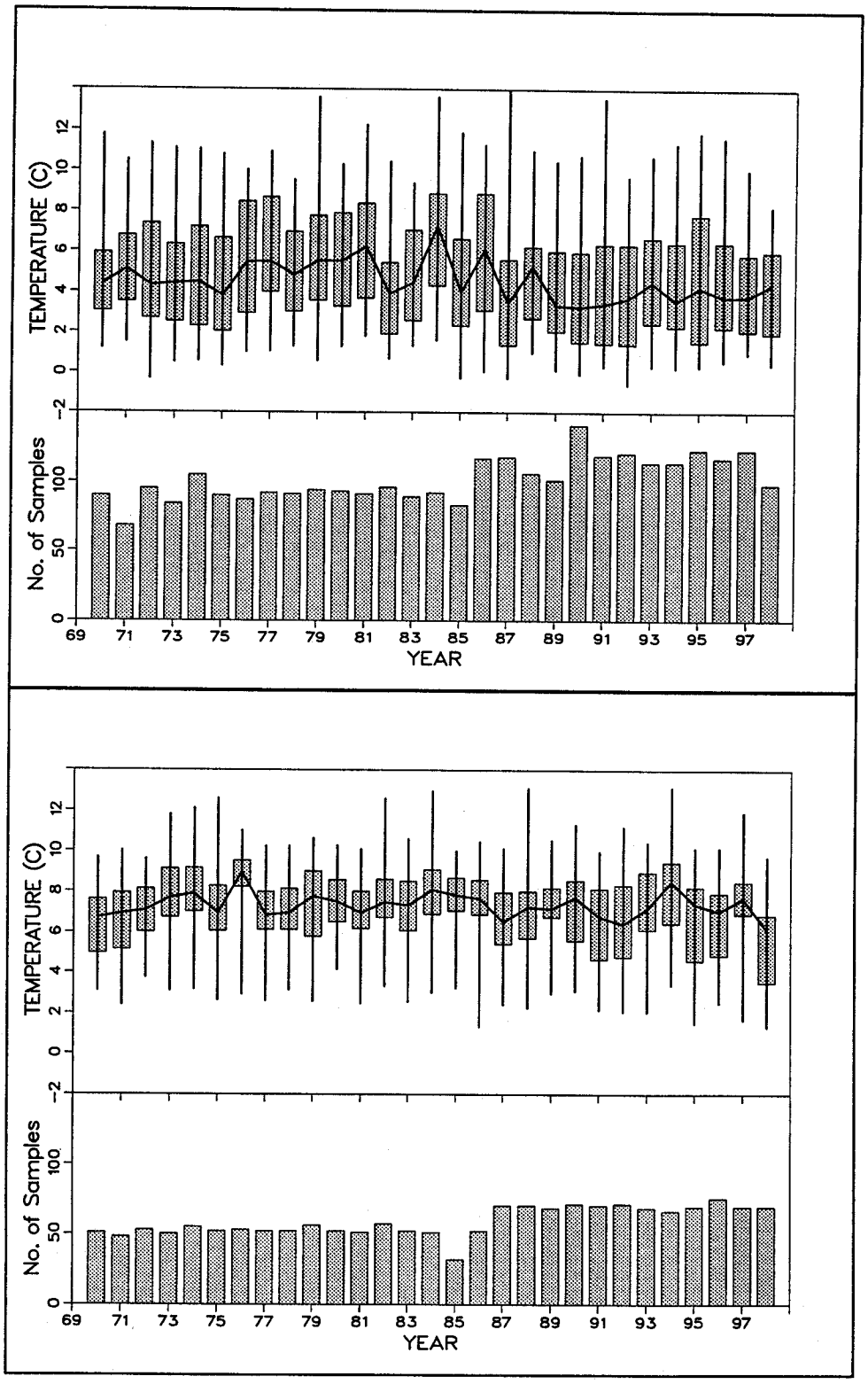

Figure 9: Box and whisker time series plots of near–bottom water temperatures for each year within 4VW (top panel) and 4X (lower panel). The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each year over the entire 1970–98 period.

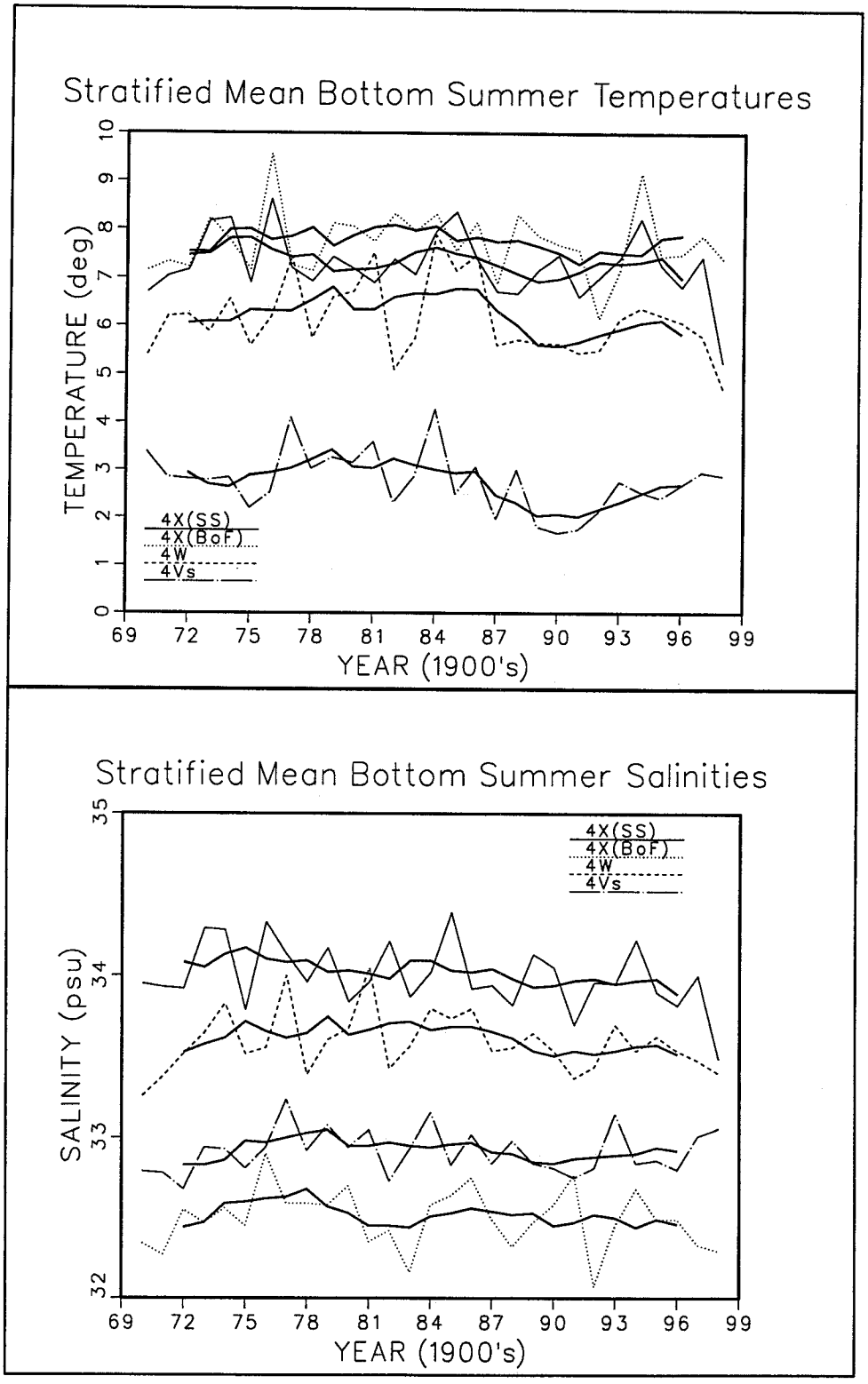

Figure 10: Time series of stratified mean near-bottom temperatures(upper panel) and salinities (lower panel)for Canadian summer research vessel groundfish surveys. The smooth curves running through each series is a five year running mean.

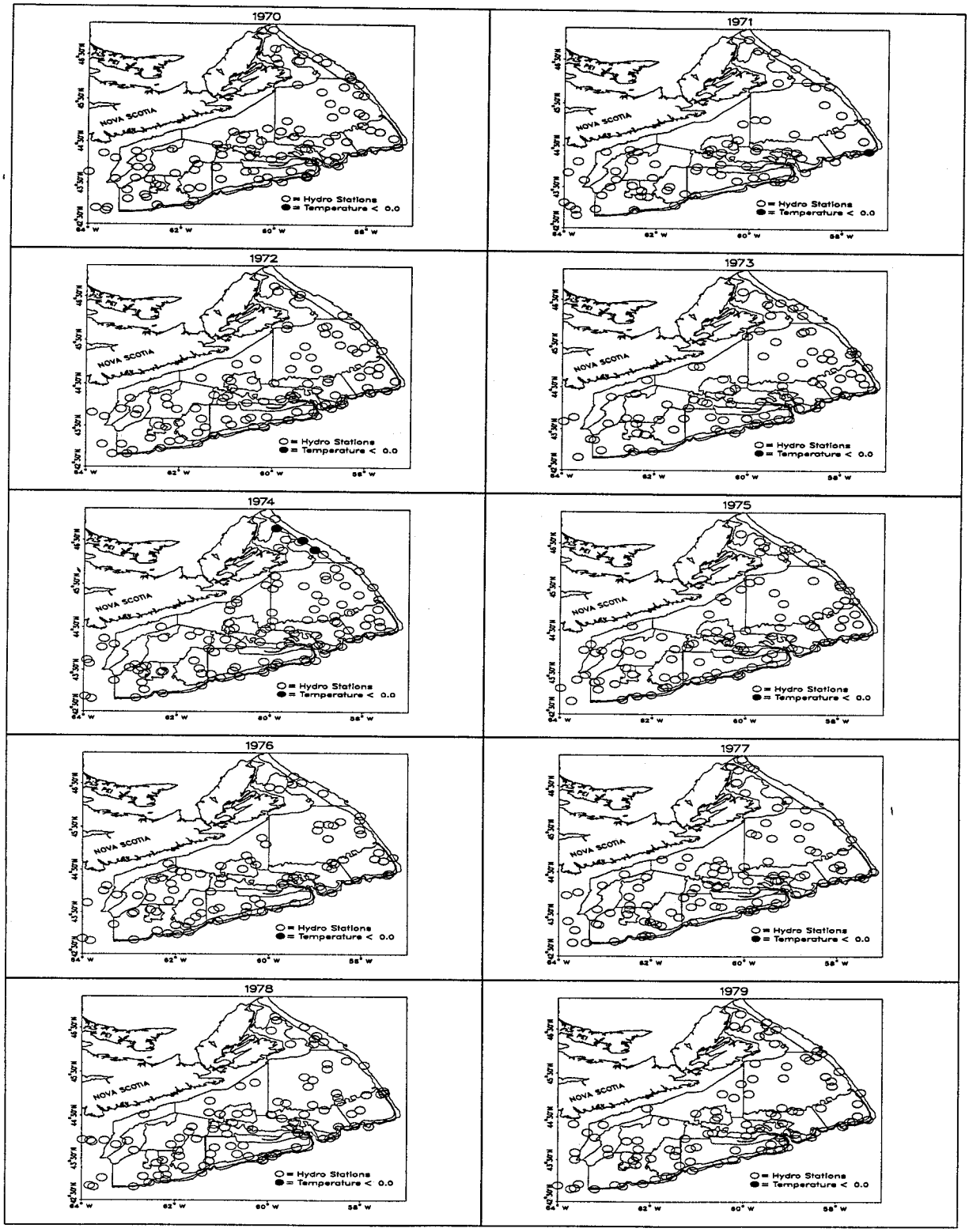

Figure 11: Time series of maps showing the location of hydrographic stations in which water temperatures less than 0.0 C were recorded somewhere in the water column for summer groundfish surveys.

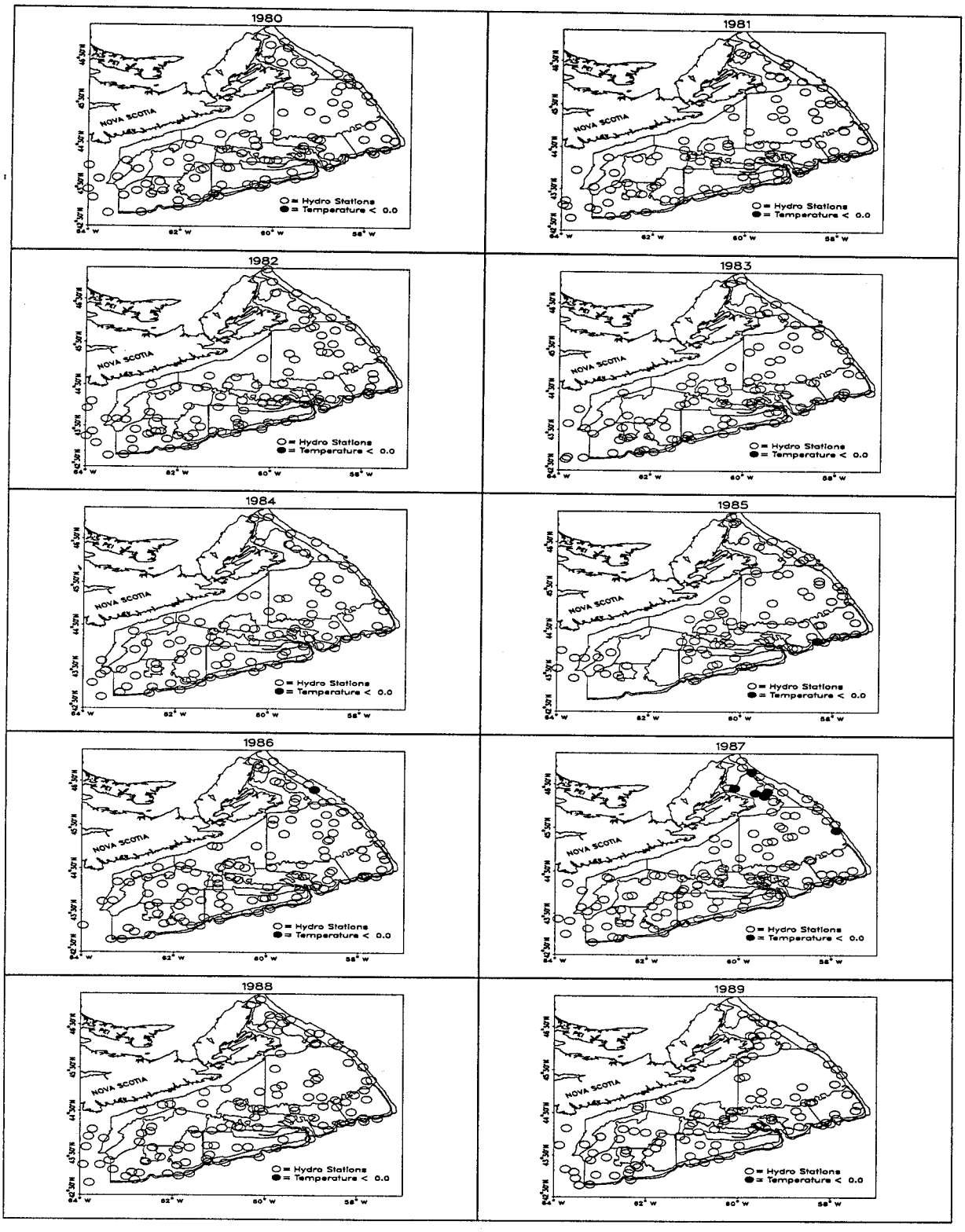

Figure 11: continued

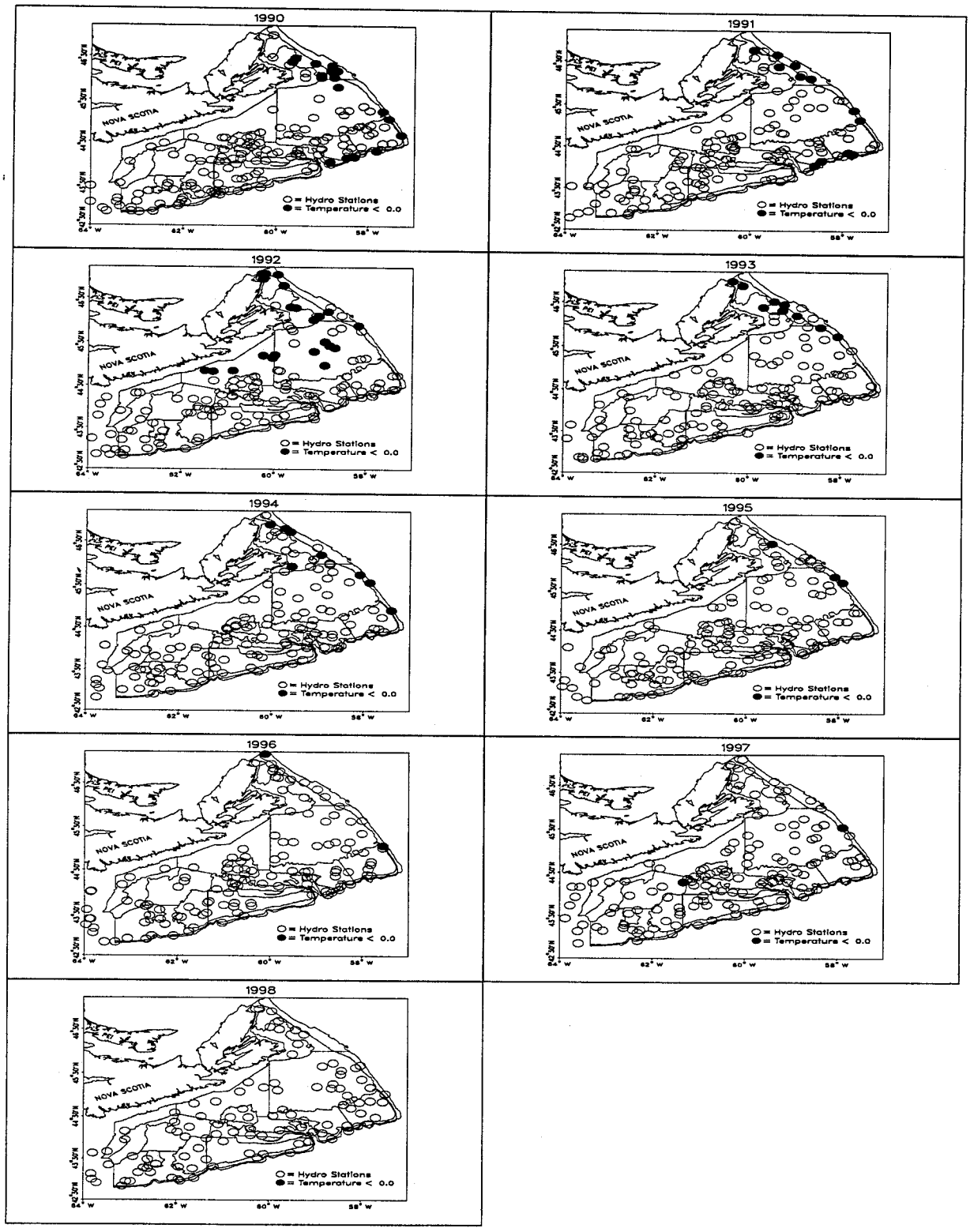

Figure 11: continued

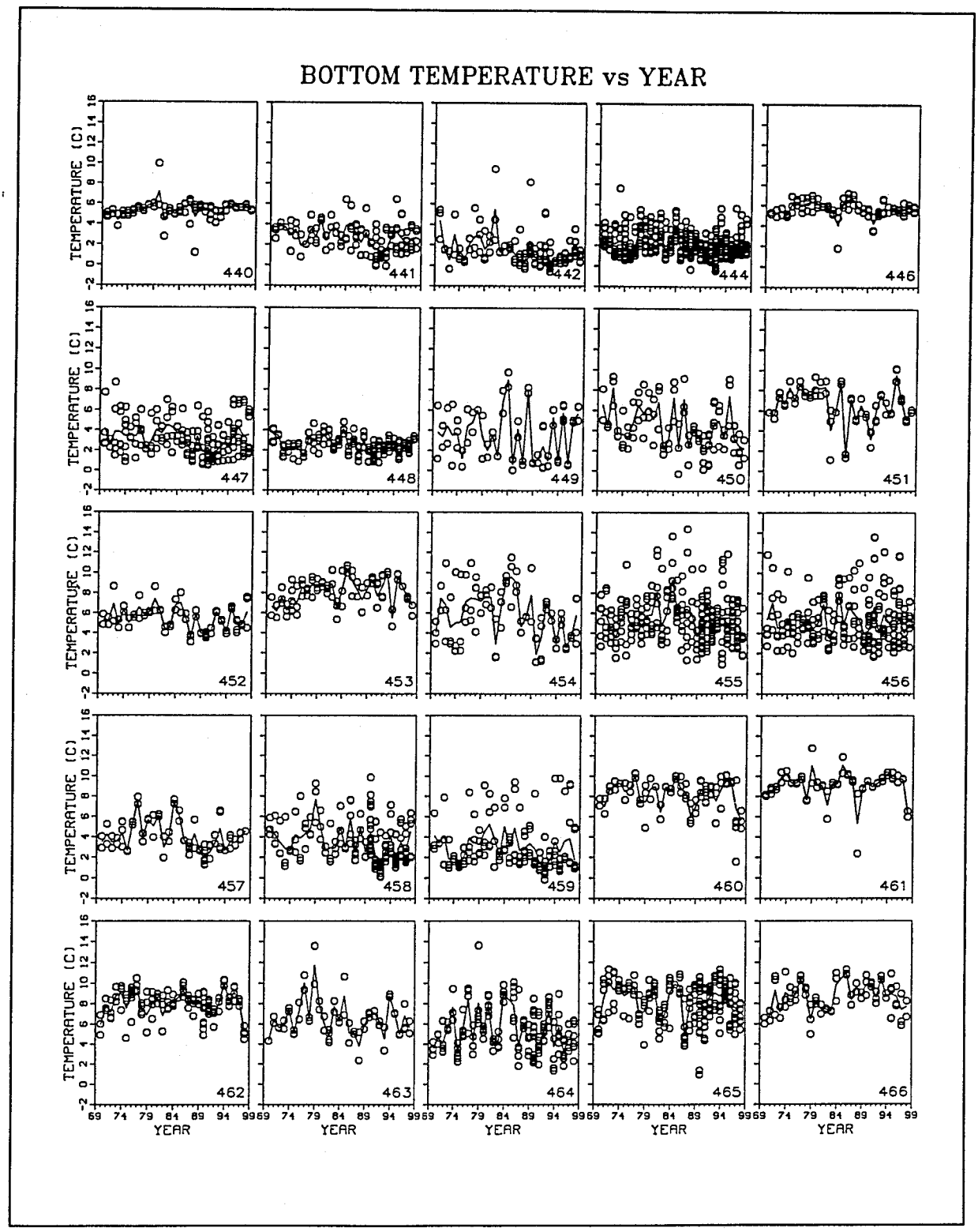

Figure 12: Time series of near-bottom temperatures within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

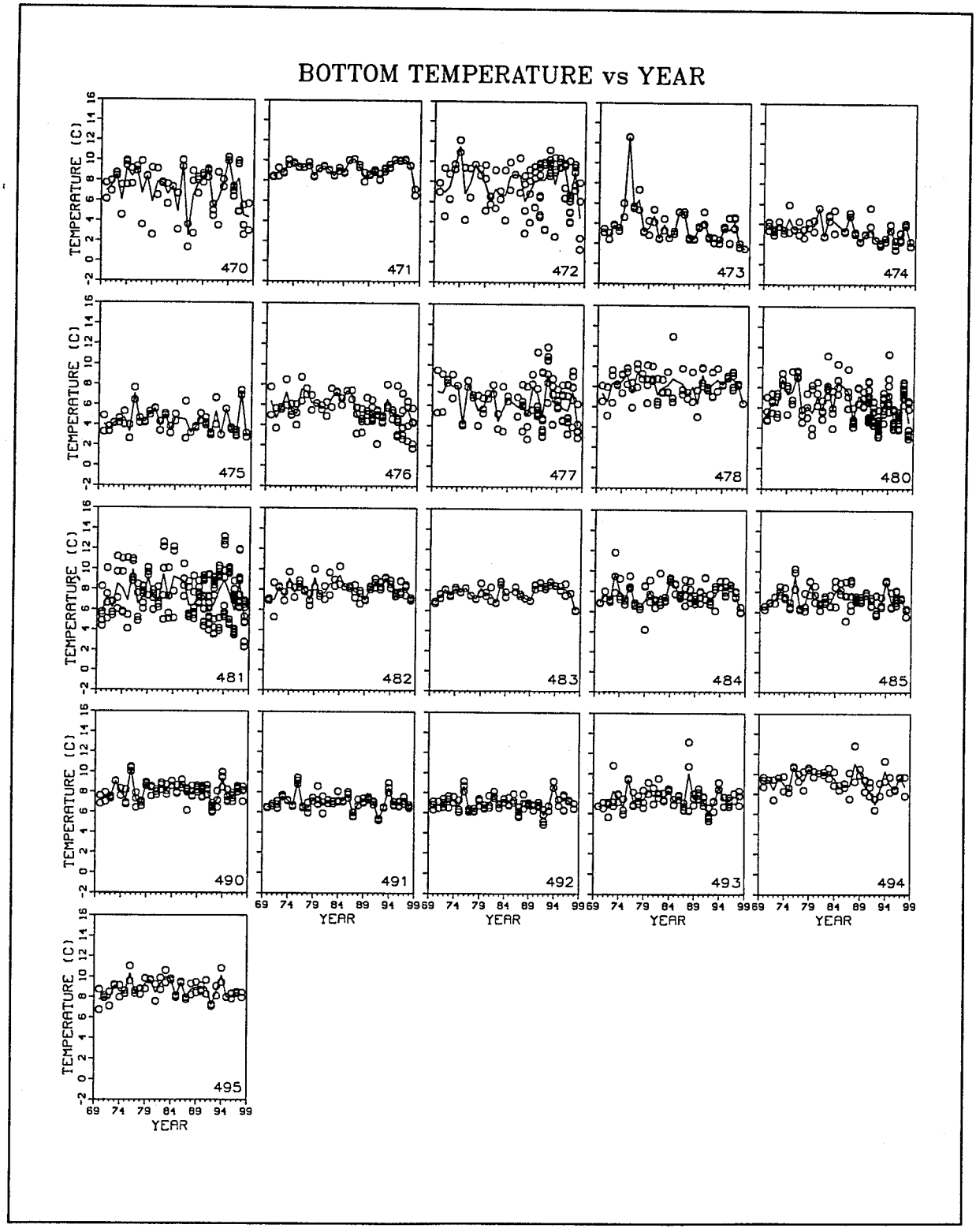

Figure 12: continued

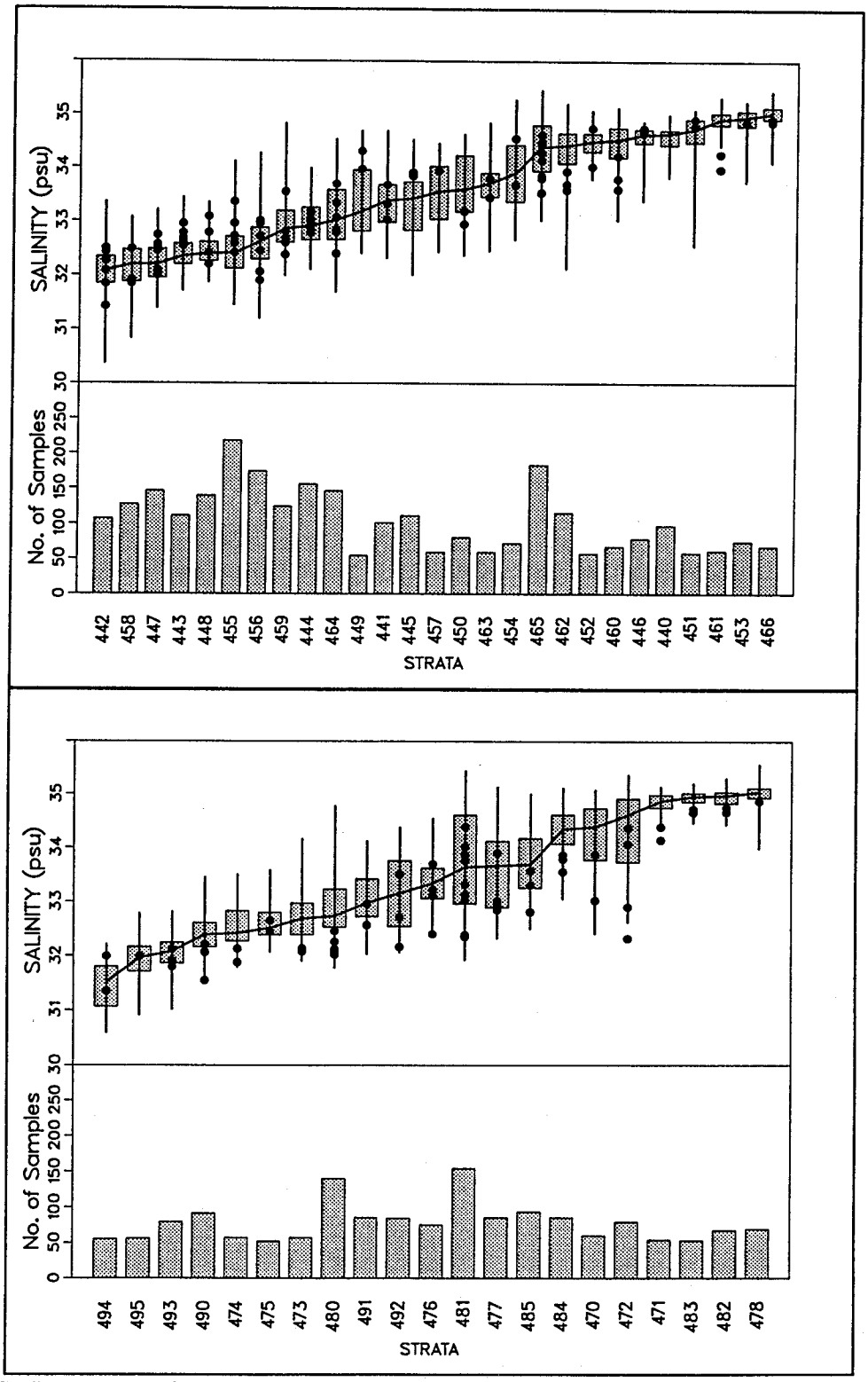

Figure 13: Box and whisker plots of strata specific, 1970–97, near–bottom water salinities for strata within 4VW (top panel) and 4X (lower panel) ordered by salinity medians. The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each strata over the entire 1970–97 period. Solid circles are 1998 observed salinity data.

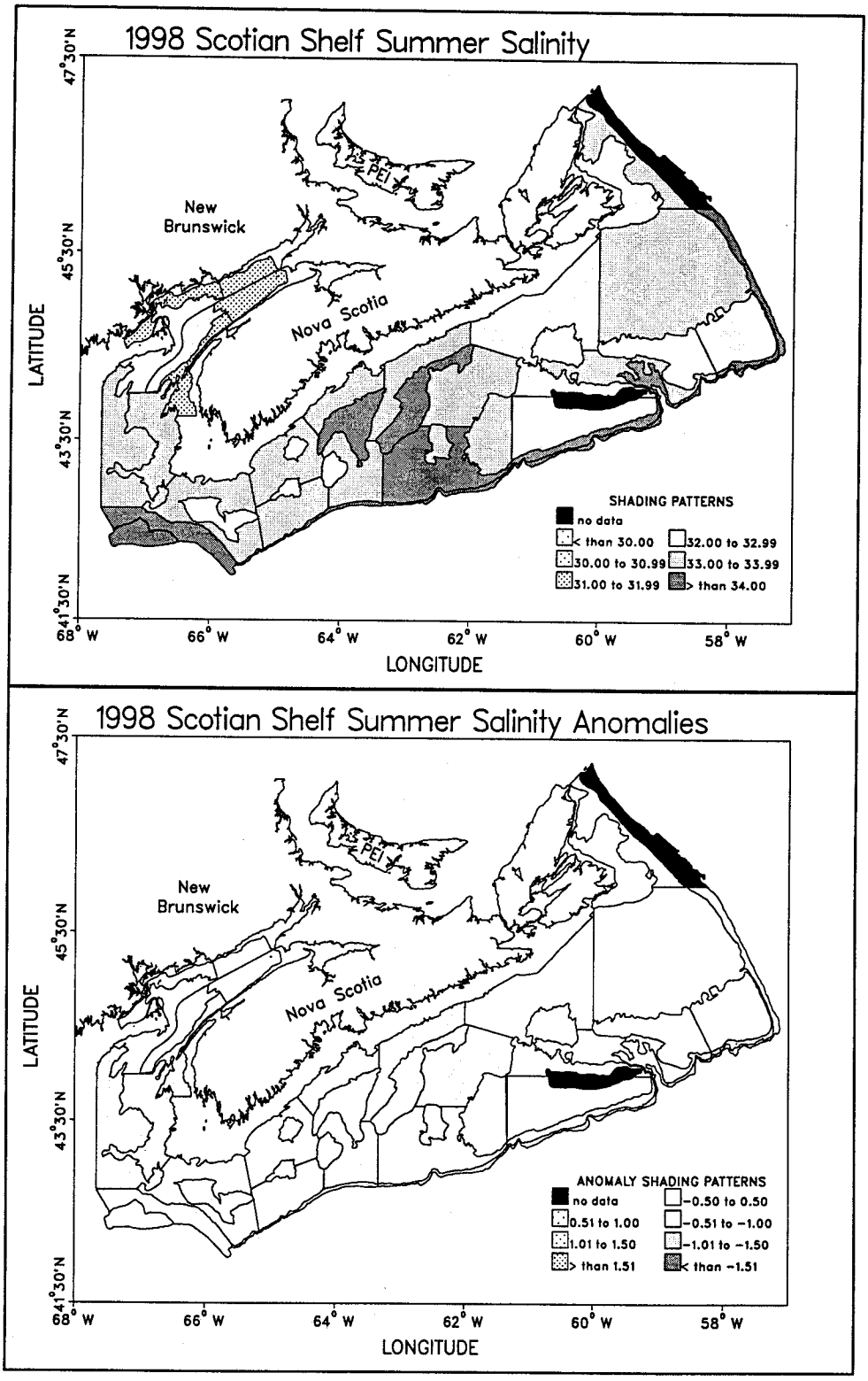

Figure 14: Map of near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1998.

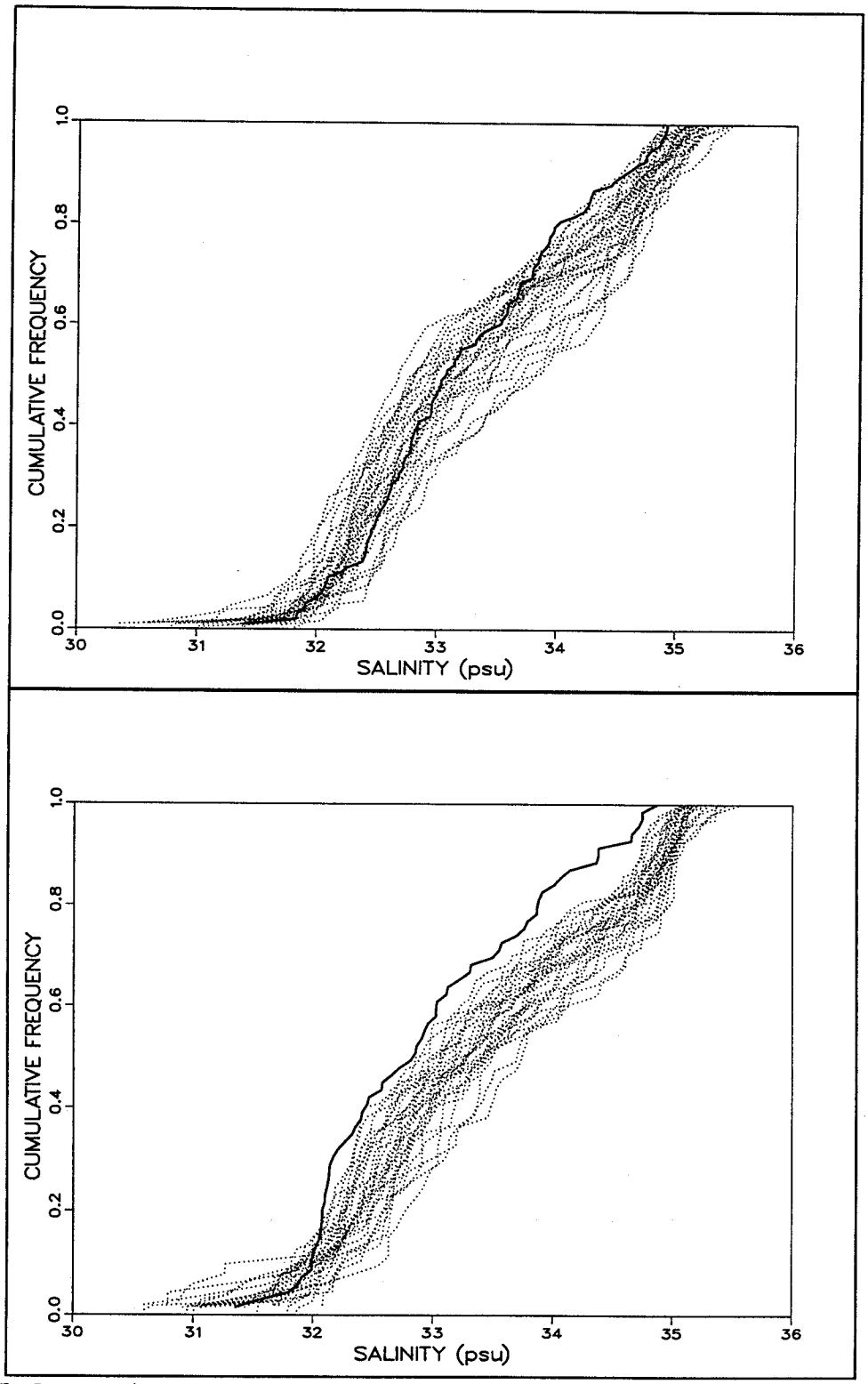

Figure 15: Cumulative frequency curves of near–bottom water salinities for the 1970–98 Canadian research vessel bottom–trawl summer 4VW (top panel) and 4X (lower panel) surveys. Each line represents the cumulative frequency for a single year. The dotted lines are for the years 1970–97 and the heavy solid line is for 1998.

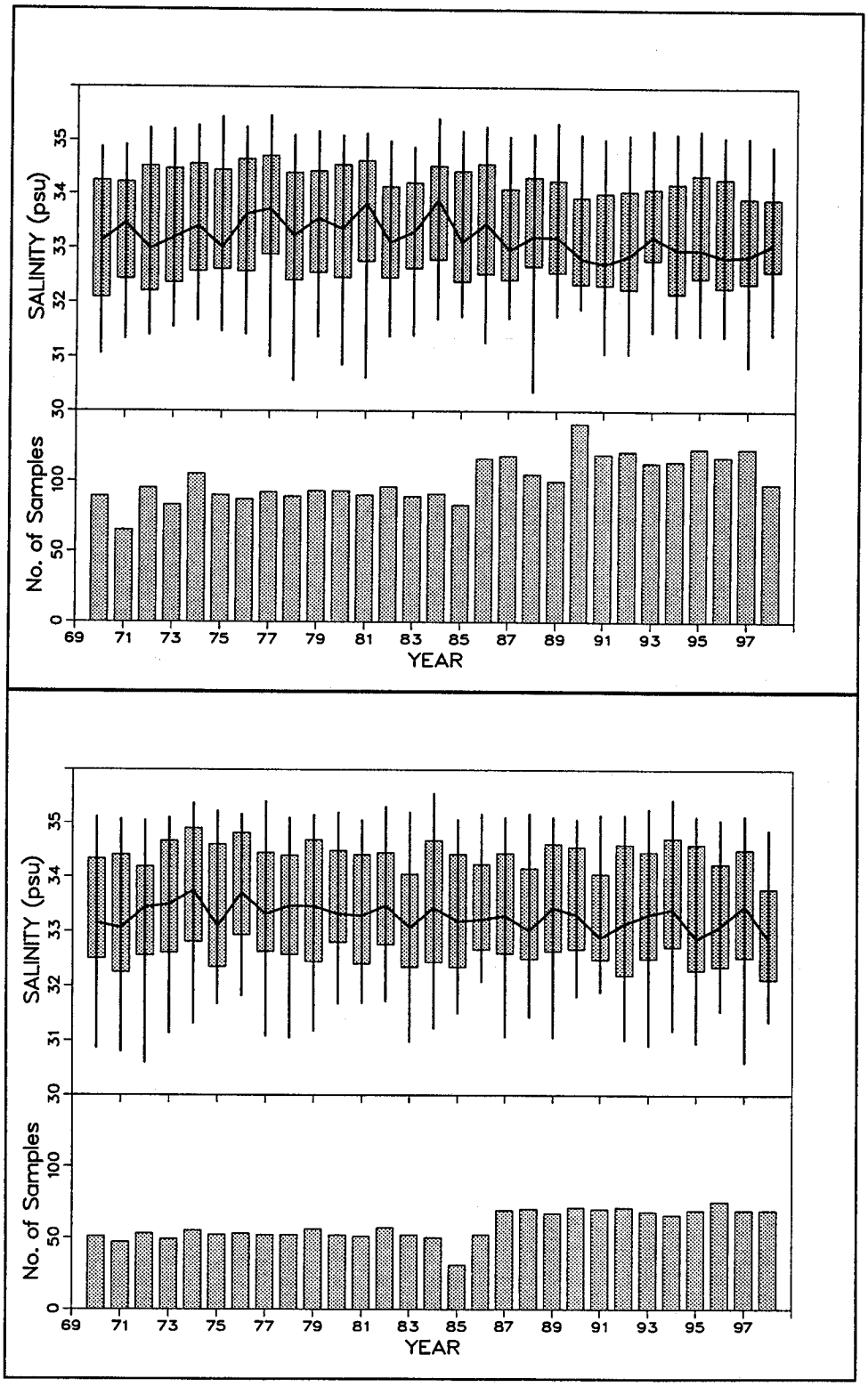

Figure 16: Box and whisker time series plots of near-bottom water salinities for each year within 4VW (top panel) and 4X (lower panel). The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each year over the entire 1970-98 period.

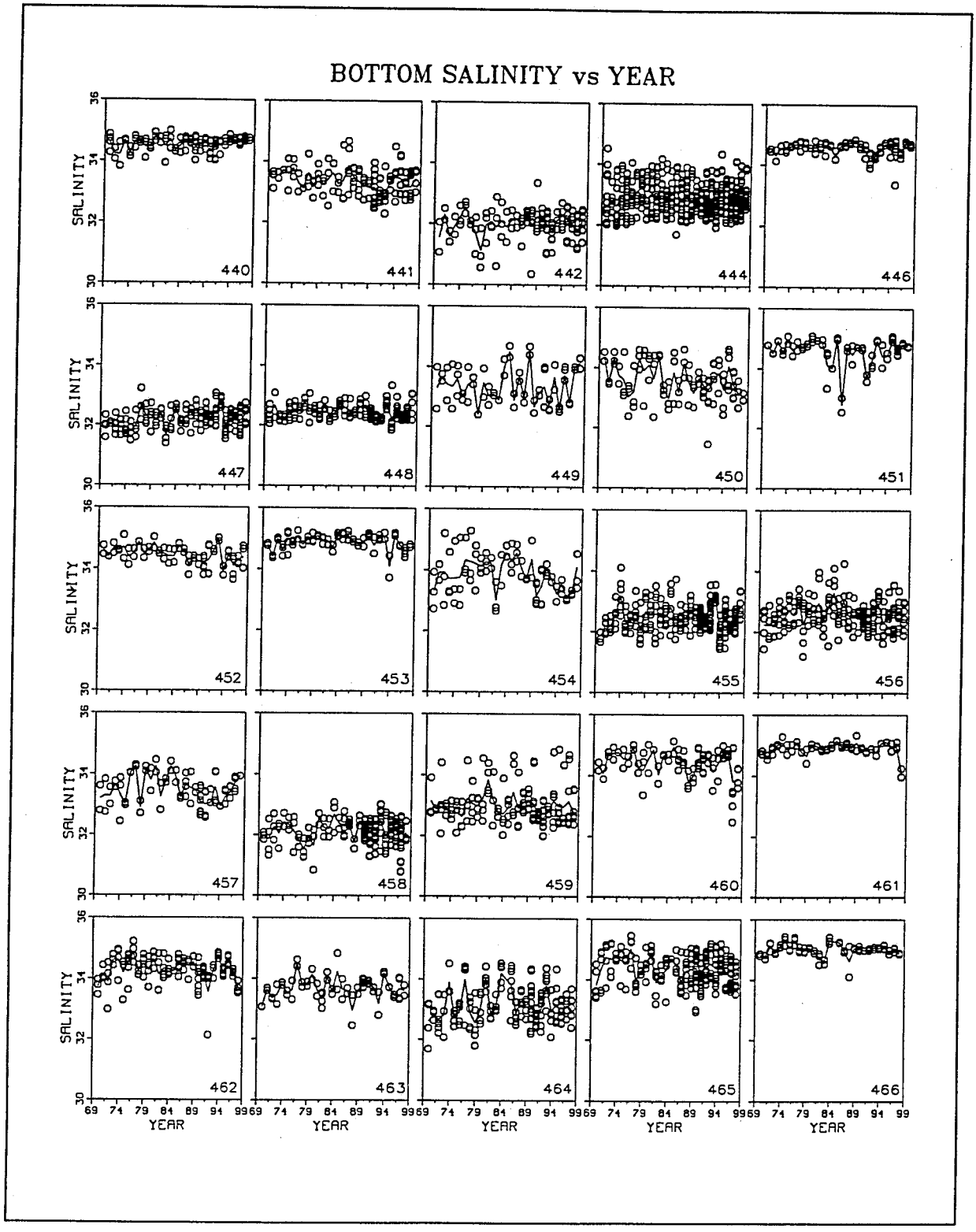

Figure 17: Time series of near-bottom salinities within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

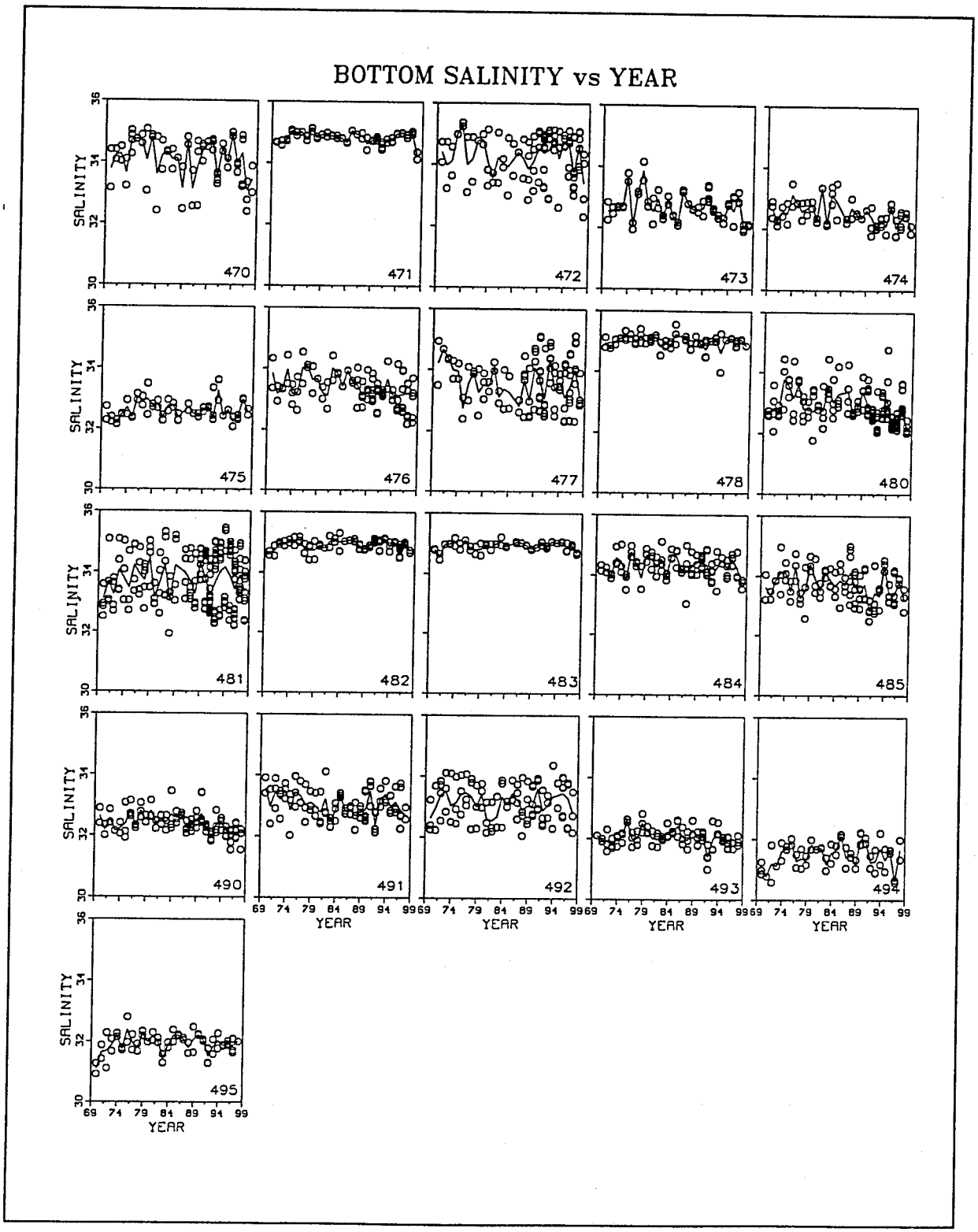

Figure 17: continued