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Overview of 1996 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)

by

F. Page and R. Losier
Department of Fisheries and Oceans
Biological Station
St. Andrews, New Brunswick
Canada E0G 2X0

and

J. McRuer
Department of Fisheries and Oceans
Bedford Institute of Oceanography
Dartmouth, Nova Scotia
Canada B2Y 4A2

ABSTRACT

Hydrographic sampling effort and near-bottom water temperatures and salinities from the 1970-96 Canadian research vessel summer groundfish, stratified random, bottom-trawl surveys are summarised. The surveys cover NAFO divisions 4VWX. In 1996, samples within several strata were restricted to narrower depth ranges than in the past and, in three strata, samples were taken 2-3 weeks later than in the past. The temperatures and salinities sampled in 1996 continued to be below normal, but not at historical lows. The largest deviations continue to be on the eastern Scotian Shelf.

RÉSUMÉ

Ce rapport résume les résultats des échantillonnages hydrographiques et des mesures de la température et de la salinité près du fond effectués dans le cadre de relevés stratifiés aléatoires au chalut de fond de poissons de fond menés au printemps par des navires de recherche canadiens de 1970 à 1996. Les relevés couvraient la division 4VWX de l'OPANO. En 1996, les échantillonnages couvrant plusieurs strates ont été limités à des profondeurs moindres que dans le passé et, dans ces strates, les échantillons ont été prélevés de 2 à 3 semaines plus tard. Les valeurs de température et de salinité mesurées en 1996 étaient encore inférieures aux normales, mais n'atteignaient pas les minimums historiques. C'est encore au-dessus de la partie est du plateau néo-écossais qu'on enregistre les plus grands écarts.

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 1994, 1995, 1996).

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 1970-96 summer surveys conducted within 4VWX. The focus is on the near-bottom conditions in 1996 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 1970-96 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 1996. Survey N246 covered the western Scotian Shelf (4X) and N247 covered the eastern Scotian Shelf (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 1990-95 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 using the procedures described below for 1996. 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 1996, standard survey hydrographic procedures were used for obtaining vertical profiles of water temperature and salinity at each valid (type 1) bottom trawl sampling station. Water temperatures and salinities were measured using an 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, 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 $m \cdot min^{-1}$. 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 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 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. 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

Mean and 1996

In 1996, sampling was conducted from 4 July (consecutive day 186) to 31 July (consecutive day 213). 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. 459, 462 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 1996, the depths sampled were, for the most part, consistent with previous years. In a few strata (e.g. 440, 446, 452) the sampling tended to be restricted to a narrower and shallower depth range than in previous years, whereas, in other strata (e.g. 491, 492, 494), sampling tended to be restricted to a narrower and deeper depth range than in the past.

Historical Context: Temporal Trends

The 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.

With the exception of 4 sets, the sampling dates in 1996 were generally typical of those in recent years. Set numbers N247-123 and N247-126, in strata 470 and 472 respectively, were approximately 2-3 weeks later than any previous sets in these strata. In strata 485, two sets (N247 set numbers 124 and 125) were approximately 2-3 weeks later than previous sets. The reason for these anomalies was that, due to operational constraints, the stations could not be occupied, as initially scheduled, during the first leg (N246) of the back-to-back surveys. They were, therefore, picked up at the end of the second leg (N247).

Near-Bottom Temperatures

Means and 1996

The overall range of near-bottom temperatures within the survey domain, and during the complete survey time period (1970-96), is approximately -1°C to 14°C (Fig. 4,8). The range of temperatures within a strata 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 1996 ranged from 0.53 to 11.67°C which was within the previously observed limits (Fig. 4,8). In 4VW, temperatures from many stations were either above or below the 1970-95 75th and 25th percentiles respectively (eg. 447, 456, 441, 450). In 4X, many of the 1996 temperatures were below the 1970-95 medians.

The geographic distribution of the 1996 temperatures (Fig. 5) is similar to that of the long-term (1980-90) strata mean temperatures (Fig. 6). The lowest temperatures (<2°C) occurred on the eastern Scotian Shelf. The highest temperatures occurred on the central shelf, upper Bay of Fundy, and the deep waters along the shelf edge west of the Sable Island relatively warm (>8°C). Temperatures throughout the remainder of the survey domain were between 2° and 8°C. Localised pockets of relatively cold water (<4°C) occurred in the central offshore and off south-western Nova Scotia.

These patterns are also evident in the distribution of 1996 strata mean temperatures (Fig. 7). With the exception of only 2 strata, the strata mean temperatures were near or below the 1970-90 means (Fig. 7). The cumulative frequency distributions of the area unweighted temperatures (Fig. 8) indicates that the temperatures sampled in 1996 were lower than in most previous years, although they were not the lowest 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 occurred 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. However, in 1996 the distribution of temperatures was still centred below those in the late 1970's and early 1980's.

In 4X, the minimum and 25th percentile temperatures are generally higher than those in 4VW. With the exception of only a few years (1970-71, 1990-91, 1995-96), the 25th percentile of the temperatures was above 6°C. In contrast to 4VW, the time trends in unweighted median temperatures are relatively weak (Fig. 9).

These general patterns are also reflected in the time series of stratified mean temperatures (Fig. 10) and in the distribution and frequency of stations with temperatures below 0.0°C (Fig. 11). In the later figure, the location of eastern Scotian Shelf sampling stations in which temperatures below 0°C were observed somewhere within the water column are plotted for each of the 1970-1996 surveys. With the exception of 1987 and perhaps 1974, temperatures below 0°C were generally not observed prior to 1990. However, from 1990 to 1994, subzero temperatures were routinely recorded in the north-eastern portion of the survey area with the greatest occurrence being in 1992. The conditions in 1995 and 1996 are similar to those in 1974 and 1987 with only 3 and 2 stations, respectively, in the north-eastern corner of the survey domain having temperatures less than 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°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 1996.

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. The general pattern for 4X as a whole is representative of the pattern in each of the 4X strata.

Salinities

Means and 1996

The near-bottom salinities sampled within the survey domain have ranged from about 31 to 35 psu (Fig. 13, 15) during the 1970-96 time period of the surveys. As with temperature, the salinity range within strata differs between strata. The range in some strata is only a few tenths of a psu, whereas it is >2 psu in others. 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 between about 33 and 34 psu. In the eastern, central and south-western 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. 6) and strata mean salinities for 1996 (Fig. 14).

Near-bottom salinities in 1996 ranged from 31.4 to 35.1psu (Fig. 5,13,15). In most strata, the 1996 observations were distributed throughout the previous range of values with a tendency to be below strata medians (Fig.13). Most strata mean salinities were within 0.5psu of baseline means (Fig. 14). In only three strata (454, 480 & 490) were salinities >0.5psu below the 1980-90 baselines. The cumulative frequency distributions of the area unweighted temperatures (Fig. 15) indicates that the 1996 salinities were lower than in most previous years, although they were not the lowest in the history of the survey series.

Historical Context: Temporal Patterns

Like temperatures, the near-bottom salinities have varied with 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 33 psu since 1990. In 4X, the trends in unweighted median salinities are relatively weak and with the exceptions of a few years (1991 & 1995), the median salinity has been above 33 psu.

The stratified mean salinities for 4W and 4Vs show trends similar to that of the above and correspond with that of the temperatures (Fig.10). The salinities increased during the 1970's and early 1980's, decreased in 4Vs throughout the 1980's and from about 1986 to 1990 in 4VW, and increased since the early 1990's in both areas. As with temperature, the pattern is much weaker in 4X.

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.

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 (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. This possibility has been suggested by several authors (e.g. Pinhorn and Halliday 1985). 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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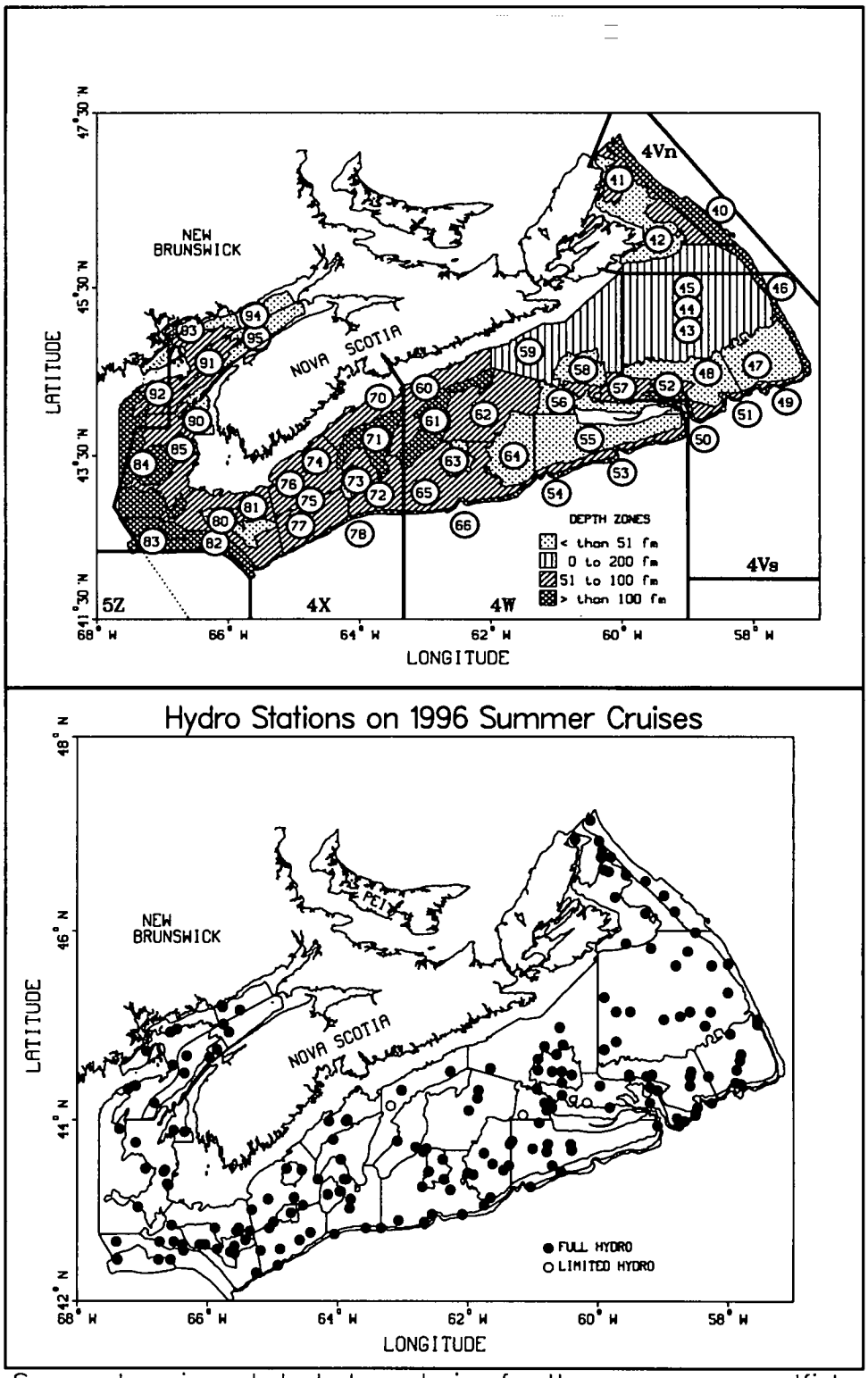


Figure 1: Survey domain and strata boundaries for the summer groundfish research vessel surveys conducted within NAFO area 4VWX from 1970–1996 (top panel) and the location of hydrographic sampling stations taken during the 1996 survey (bottom panel). In the bottom panel solid circles indicate a CTD cast 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 last two digits of the summer strata designations are shown.

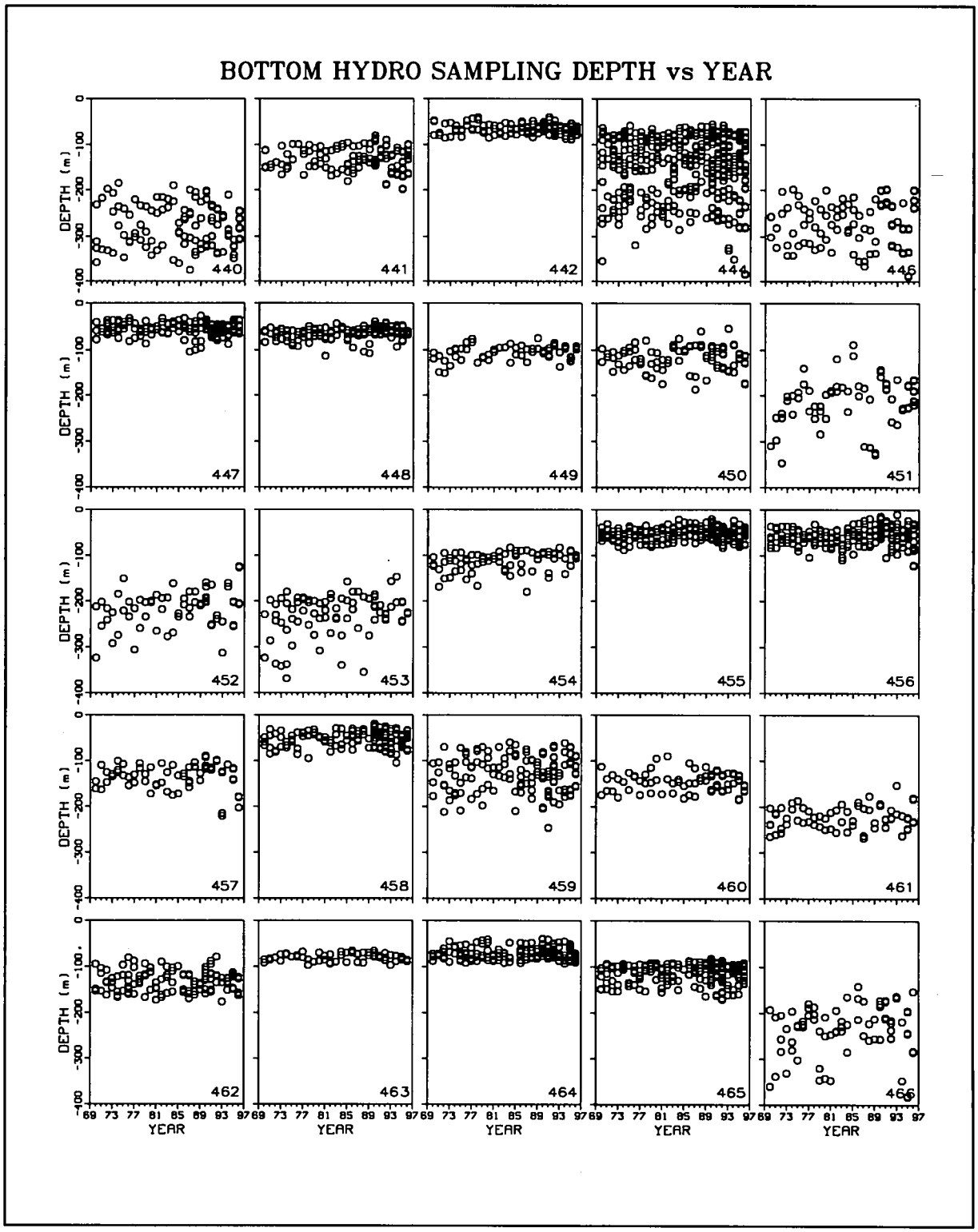
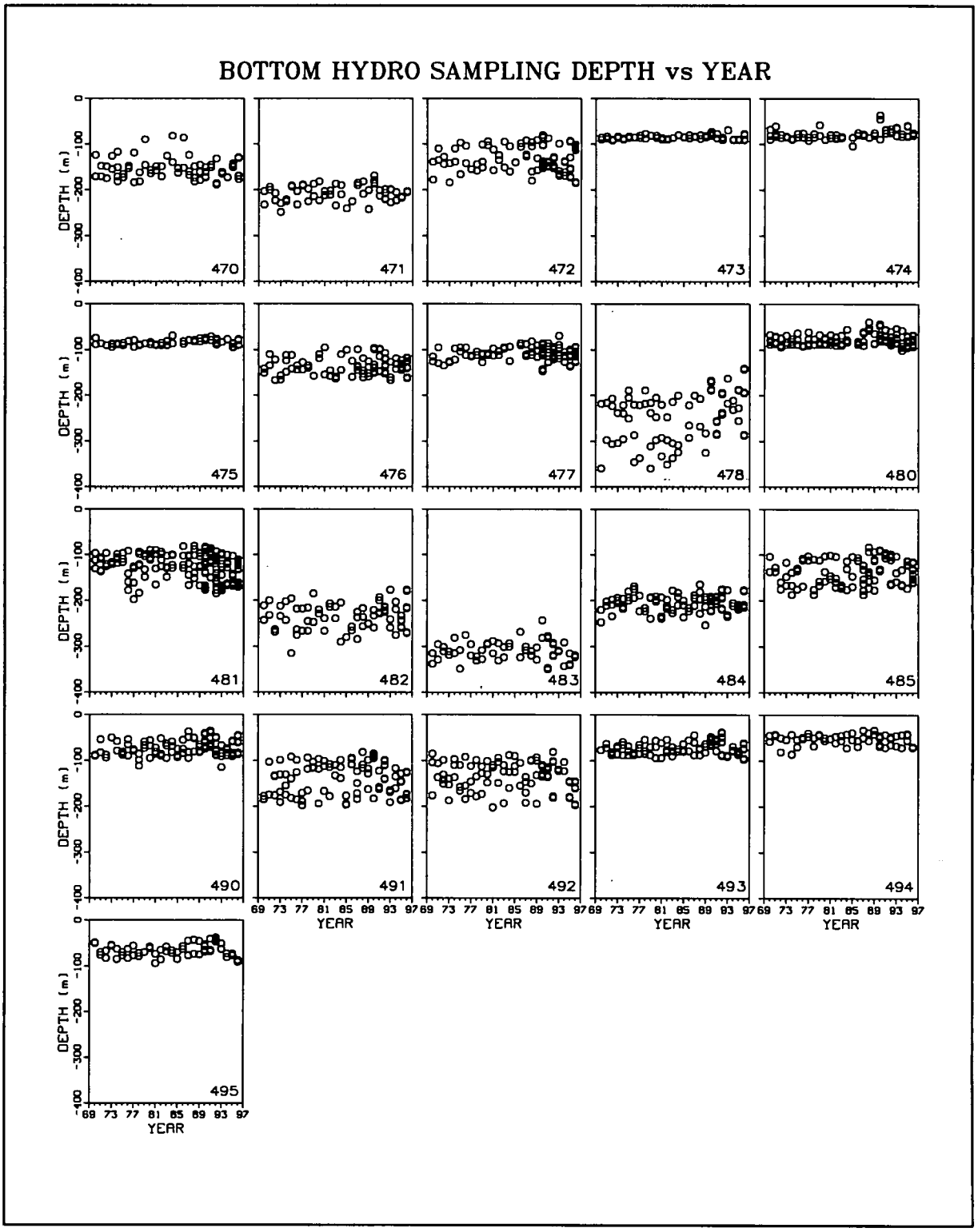


Figure 2: Time series of the near–bottom hydrographic sampling depth for each station within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the near–bottom sampling depth of one hydrographic station.



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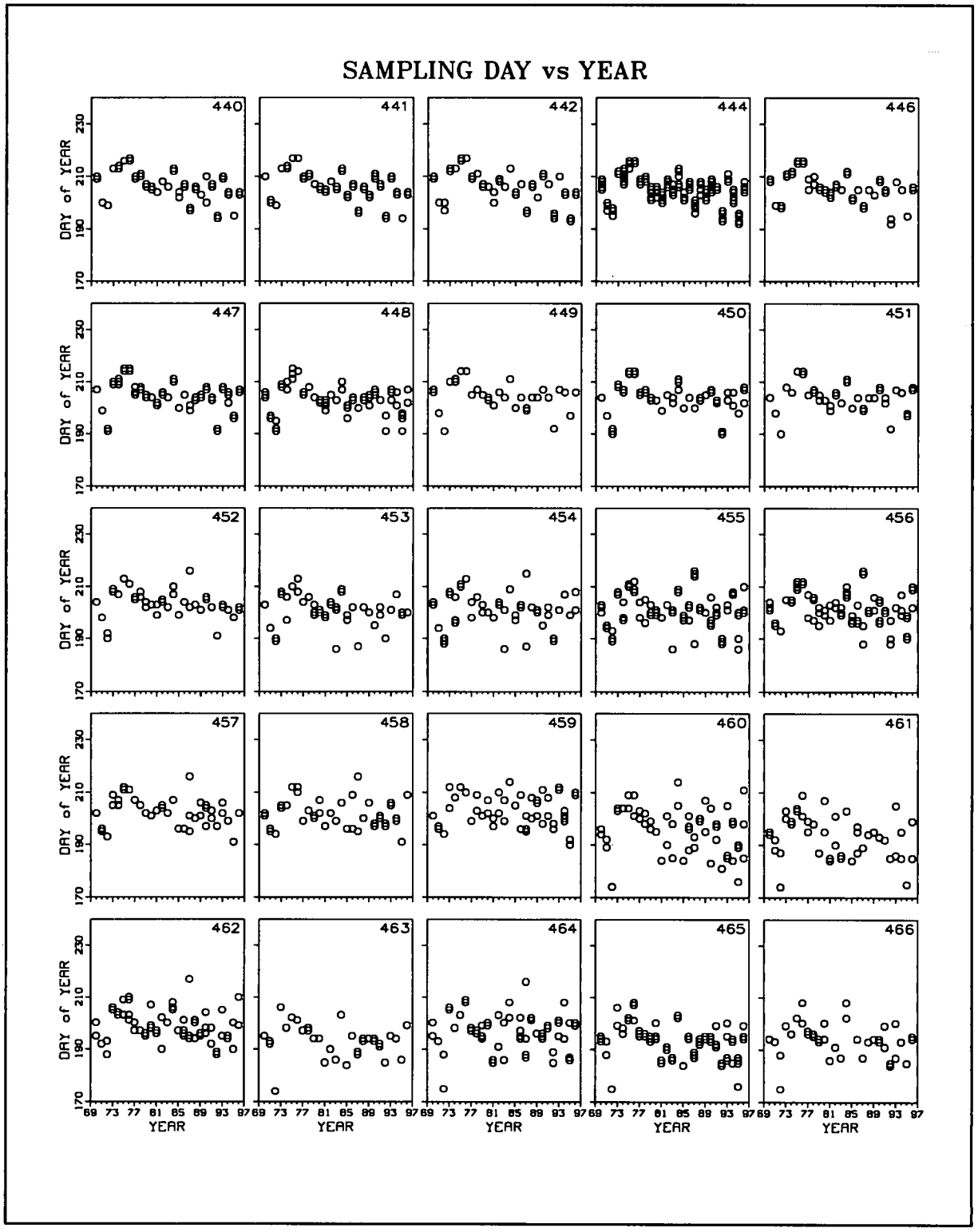
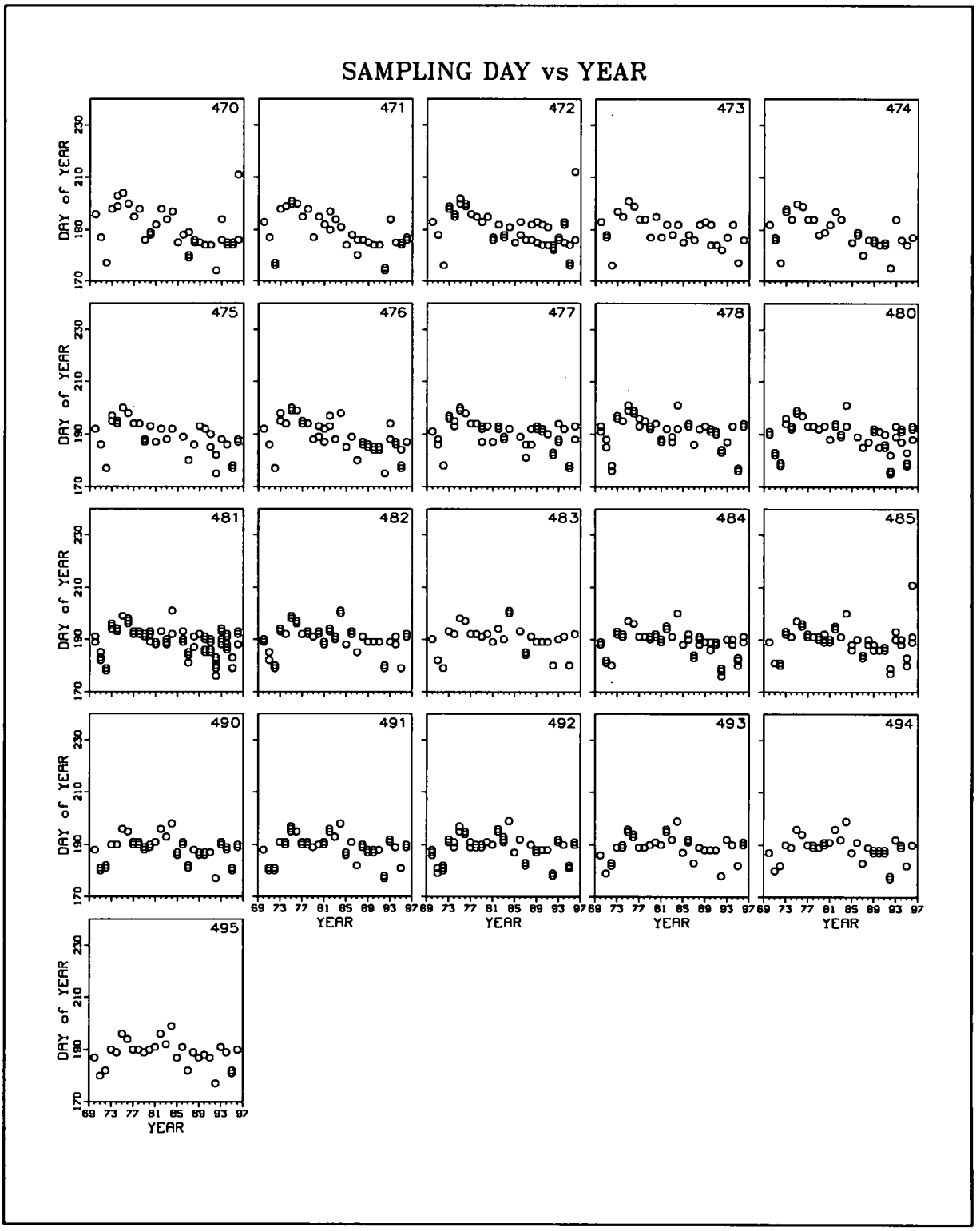


Figure 3: Time series of the consecutive day of sampling within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.



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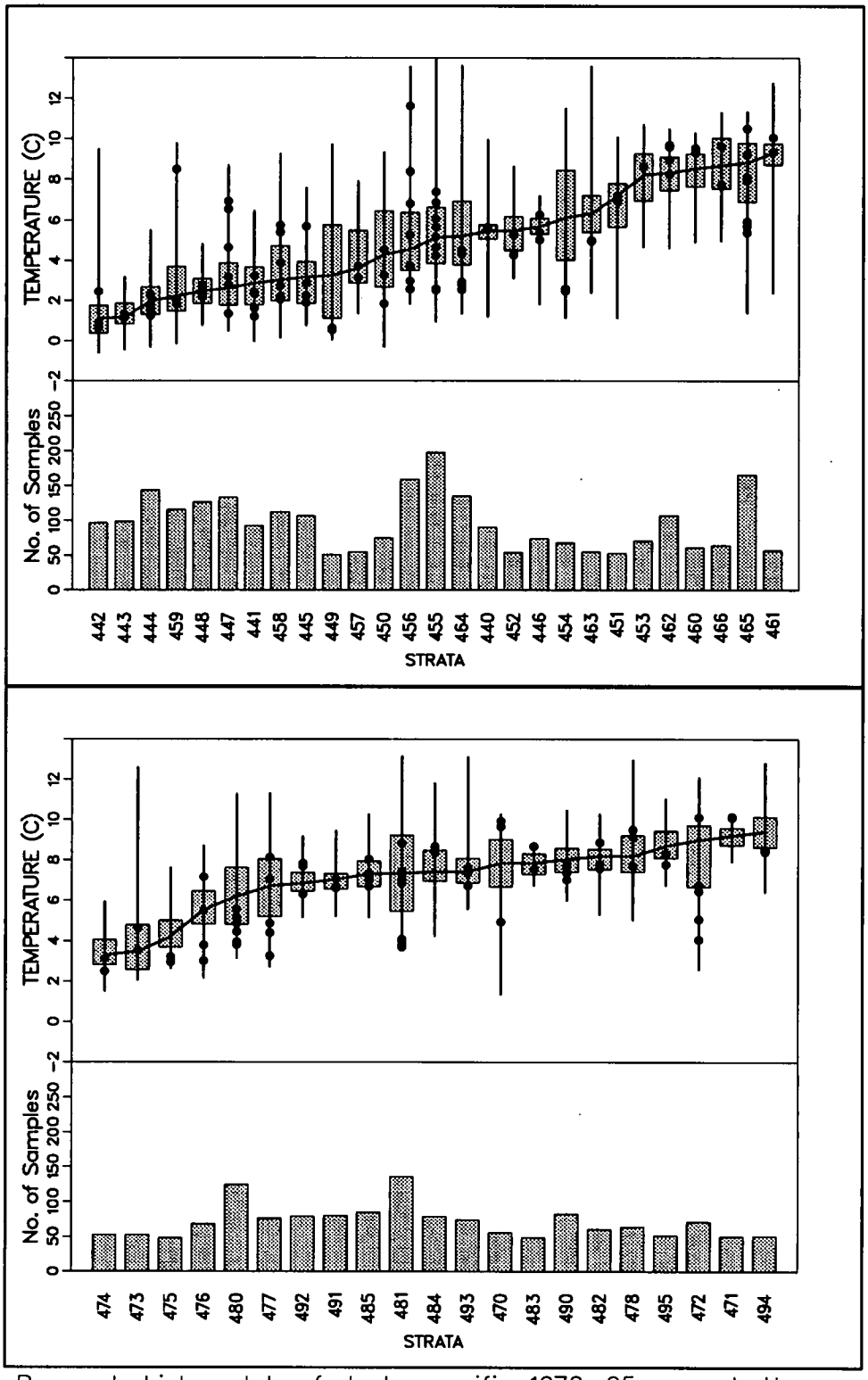

Figure 4: Box and whisker plots of strata specific, 1970–95, near–bottom water temperatures for strata within 4VW (top panel) and 4X (lower panel) ordered by temperature medians. The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each strata over the entire 1970–95 period. Solid circles are 1996 observed temperature data.

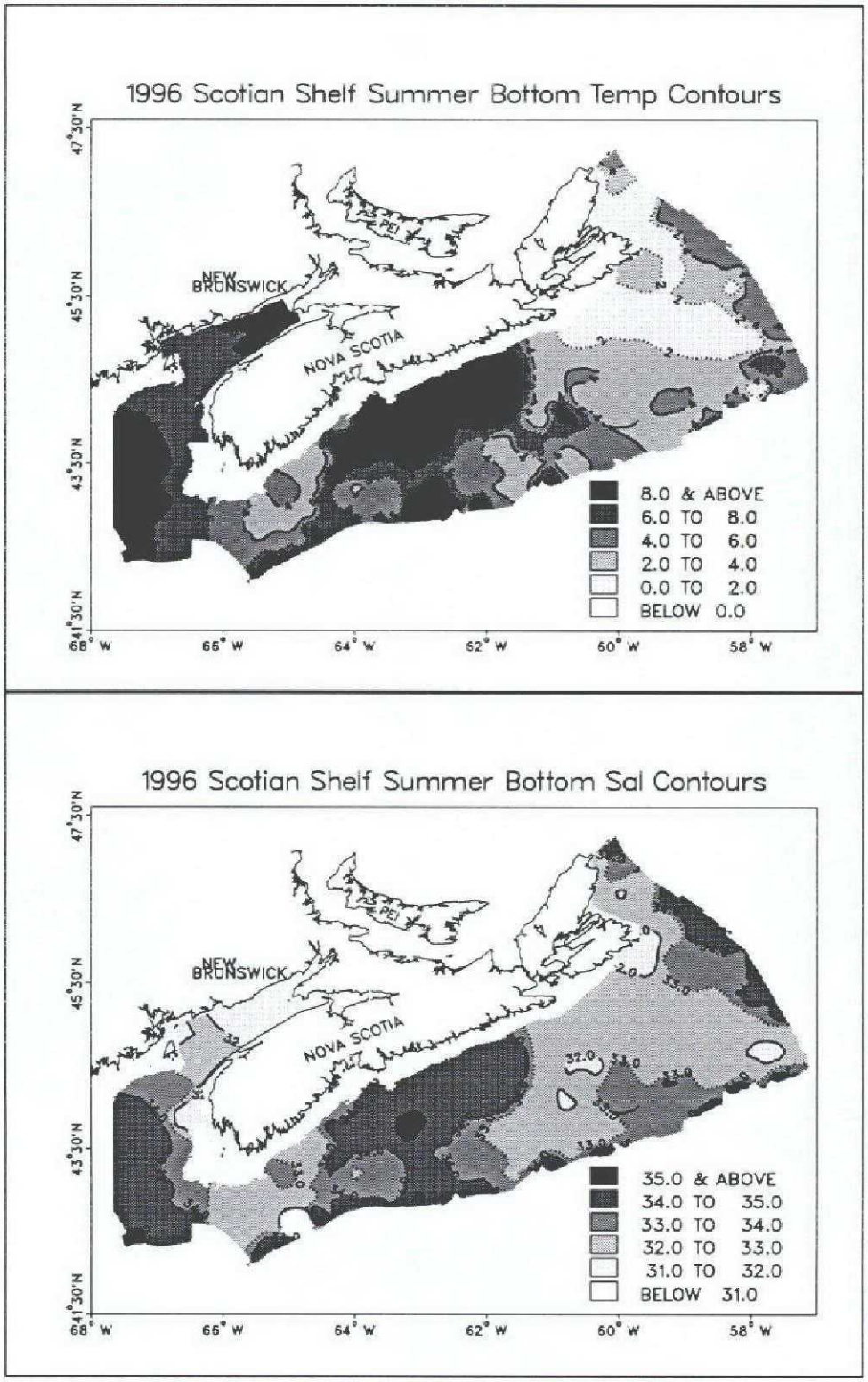

Figure 5: Contour maps of near-bottom temperature and salinities within the 4VWX Canadian research vessel bottom-trawl surveys conducted during the summer of 1996.

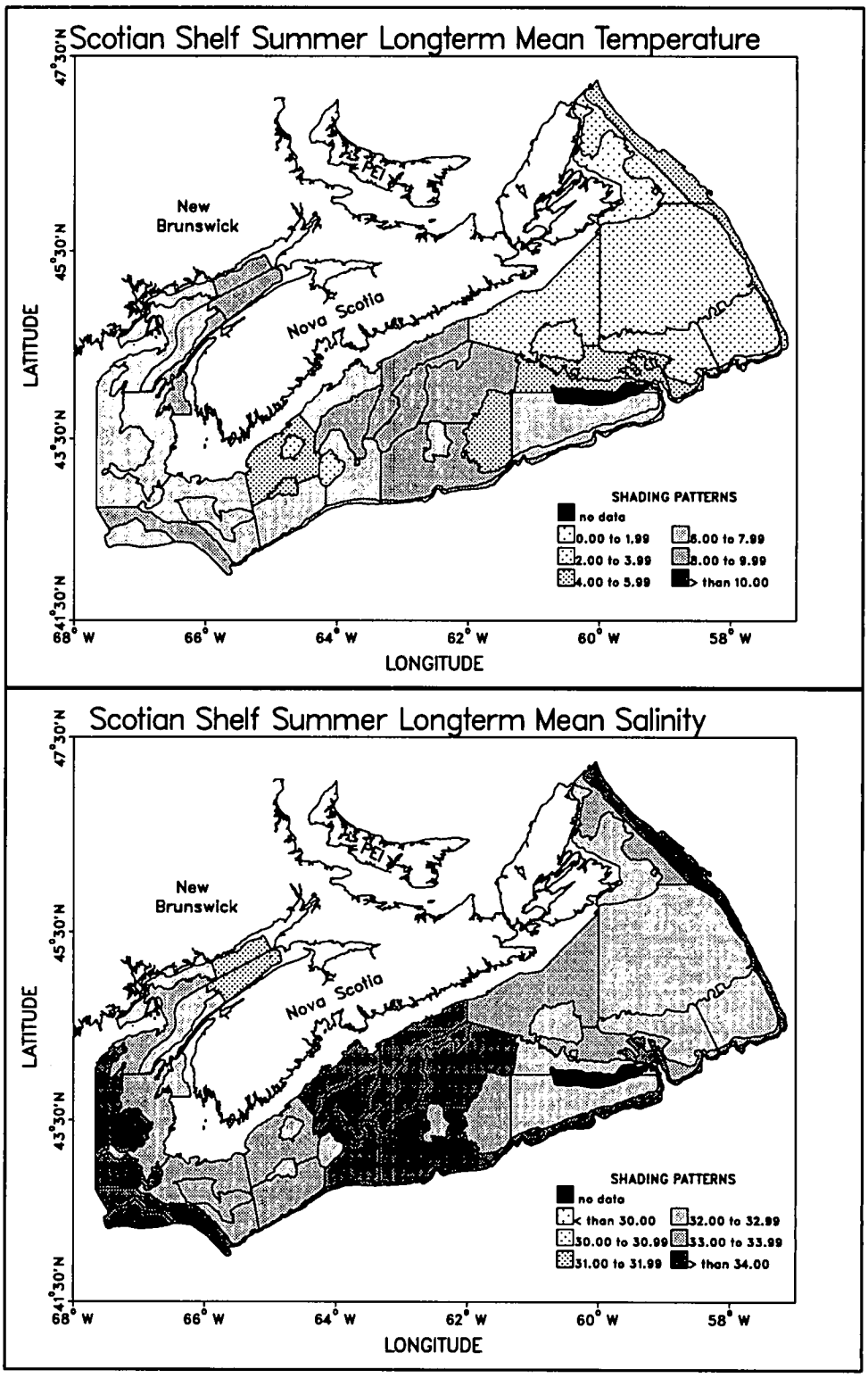

Figure 6: Map of near–bottom strata long term mean temperatures (top panel) and salinities (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom–trawl survey conducted during the summer of 1980–1990.

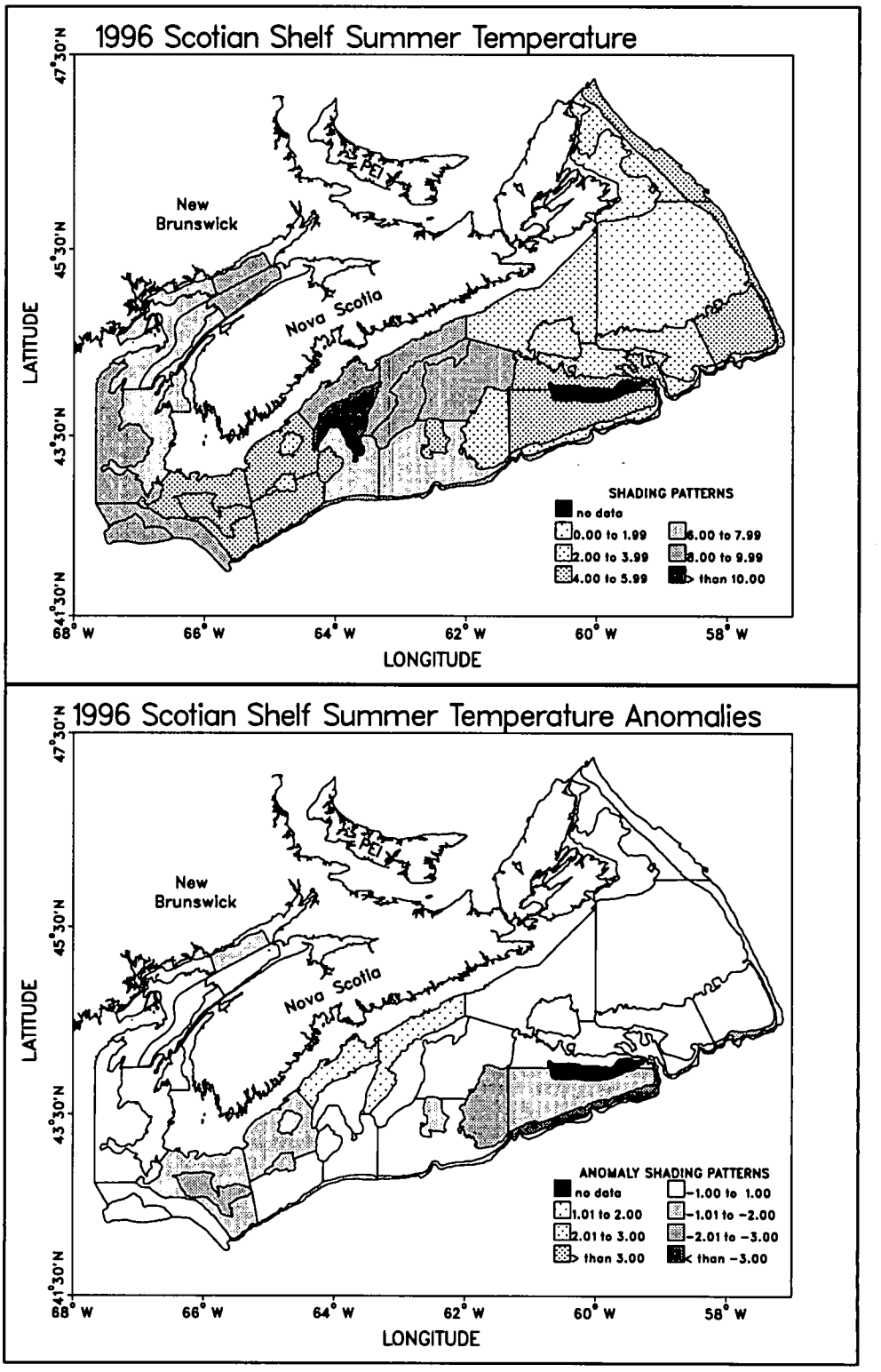

Figure 7: Map of near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1996.

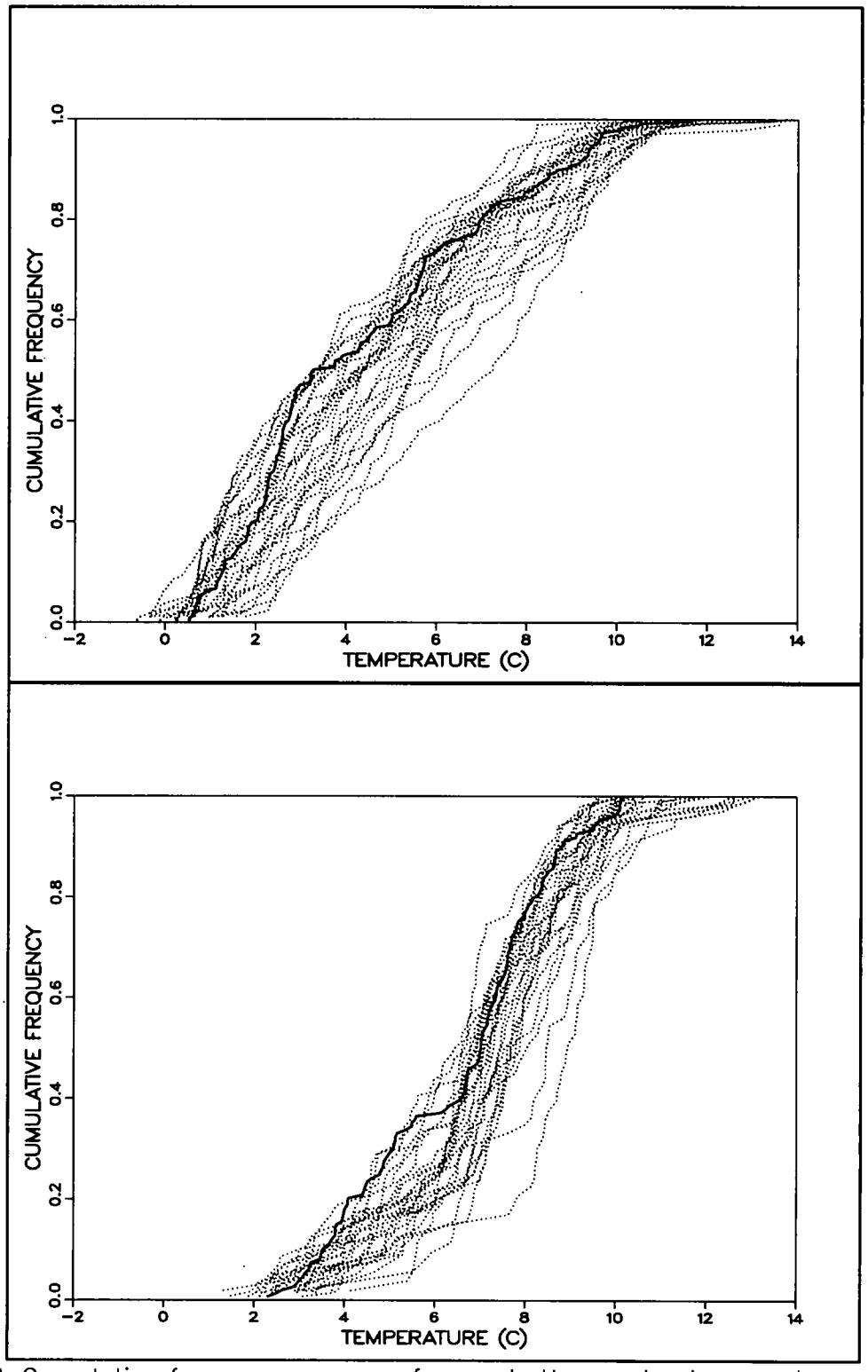

Figure 8: Cumulative frequency curves of near–bottom water temperatures for the 1970–96 Canadian research vessel bottom–trawl summer 4VW (top panel) and 4X (lower panel) surveys. Each line represents the cumulative frequency for a single year. The dotted lines are for the years 1970–95 and the heavy solid line is for 1996.

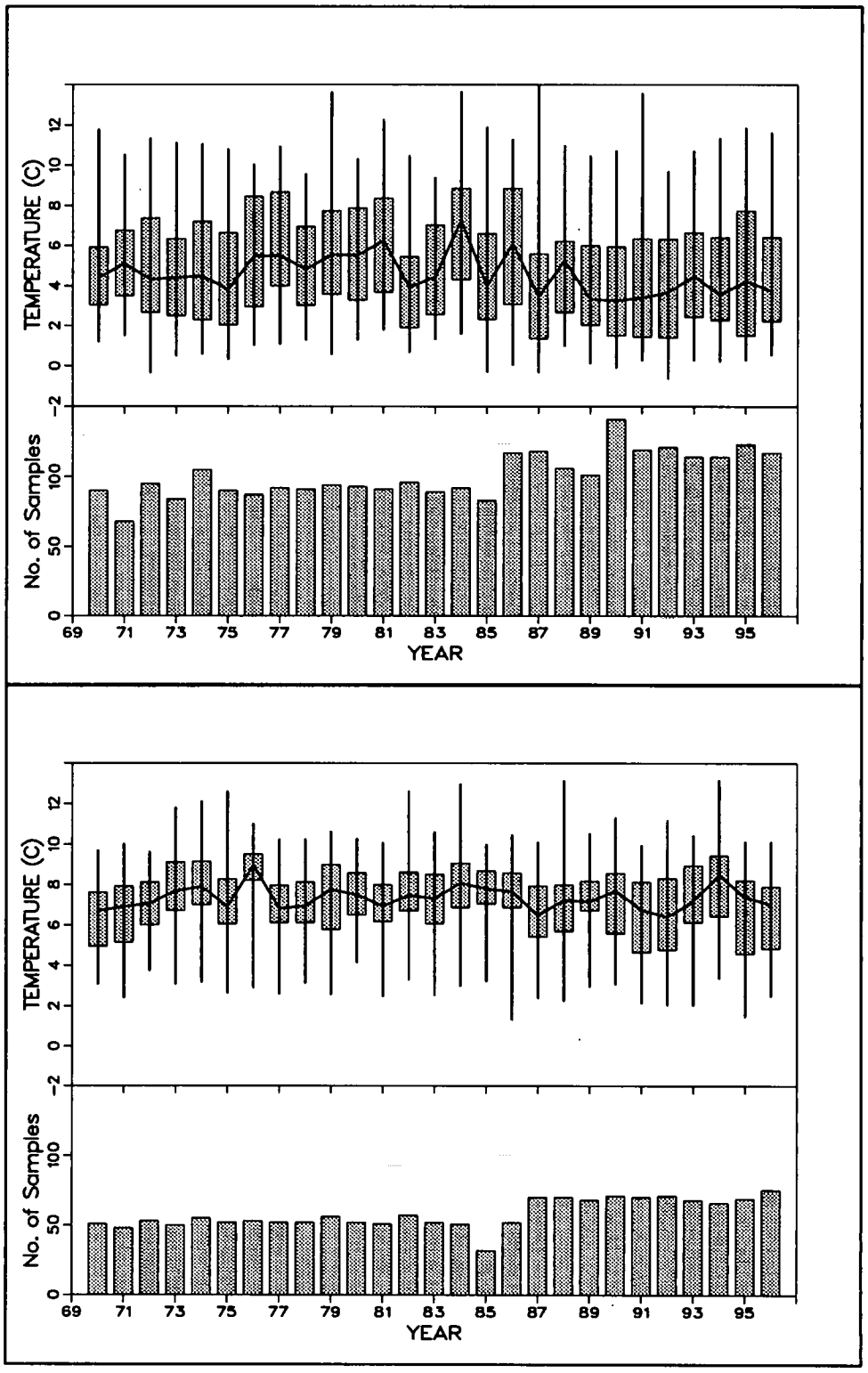

Figure 9: Box and whisker time series plots of near–bottom water temperatures for each year within 4VW (top panel) and 4X (lower panel). The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each year over the entire 1970–96 period.

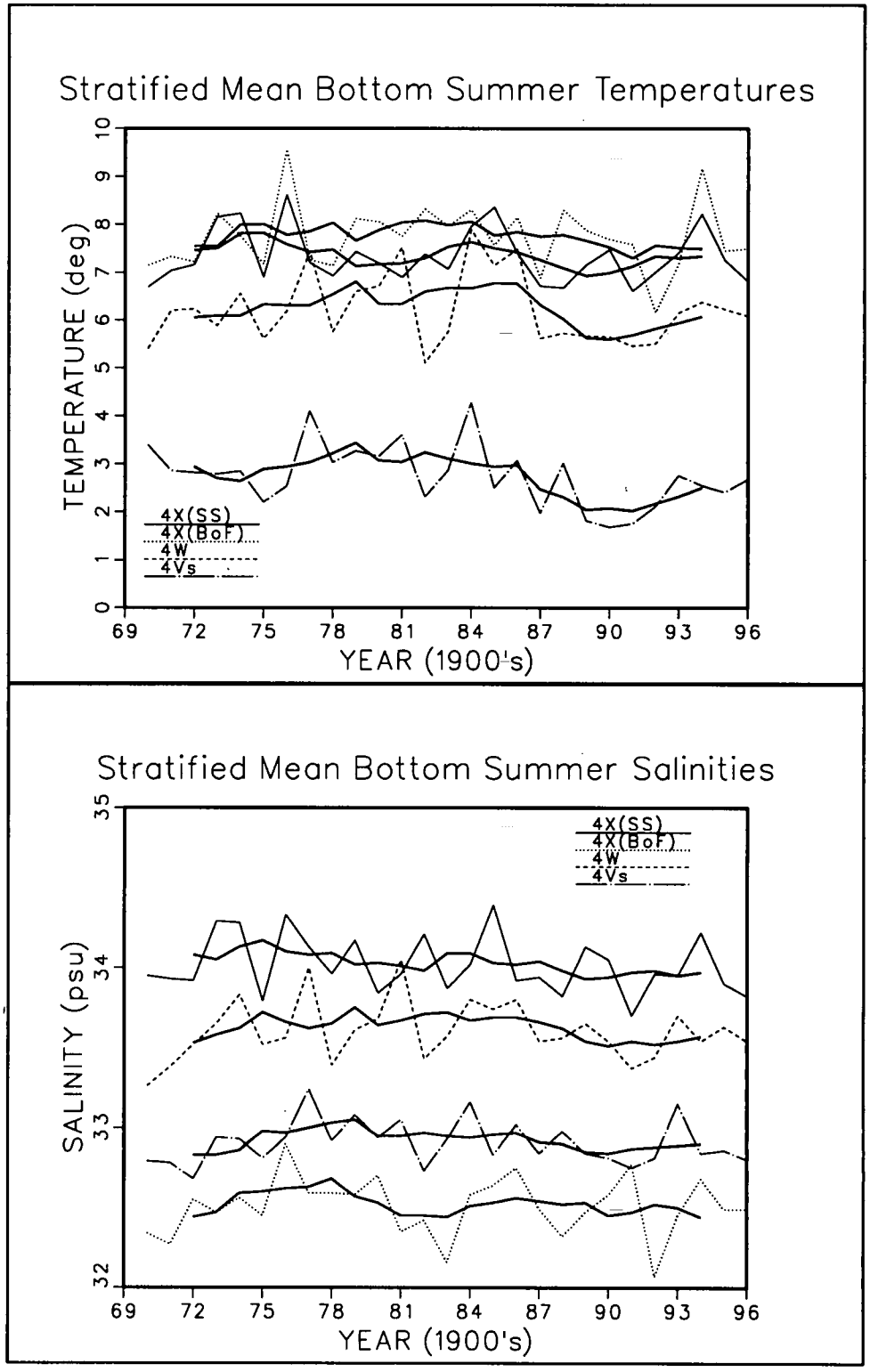

Figure 10: Time series of stratified mean near–bottom temperatures(upper panel) and salinities (lower panel)for Canadian summer research vessel groundfish surveys. The smooth curves running through each series is a five year running mean.

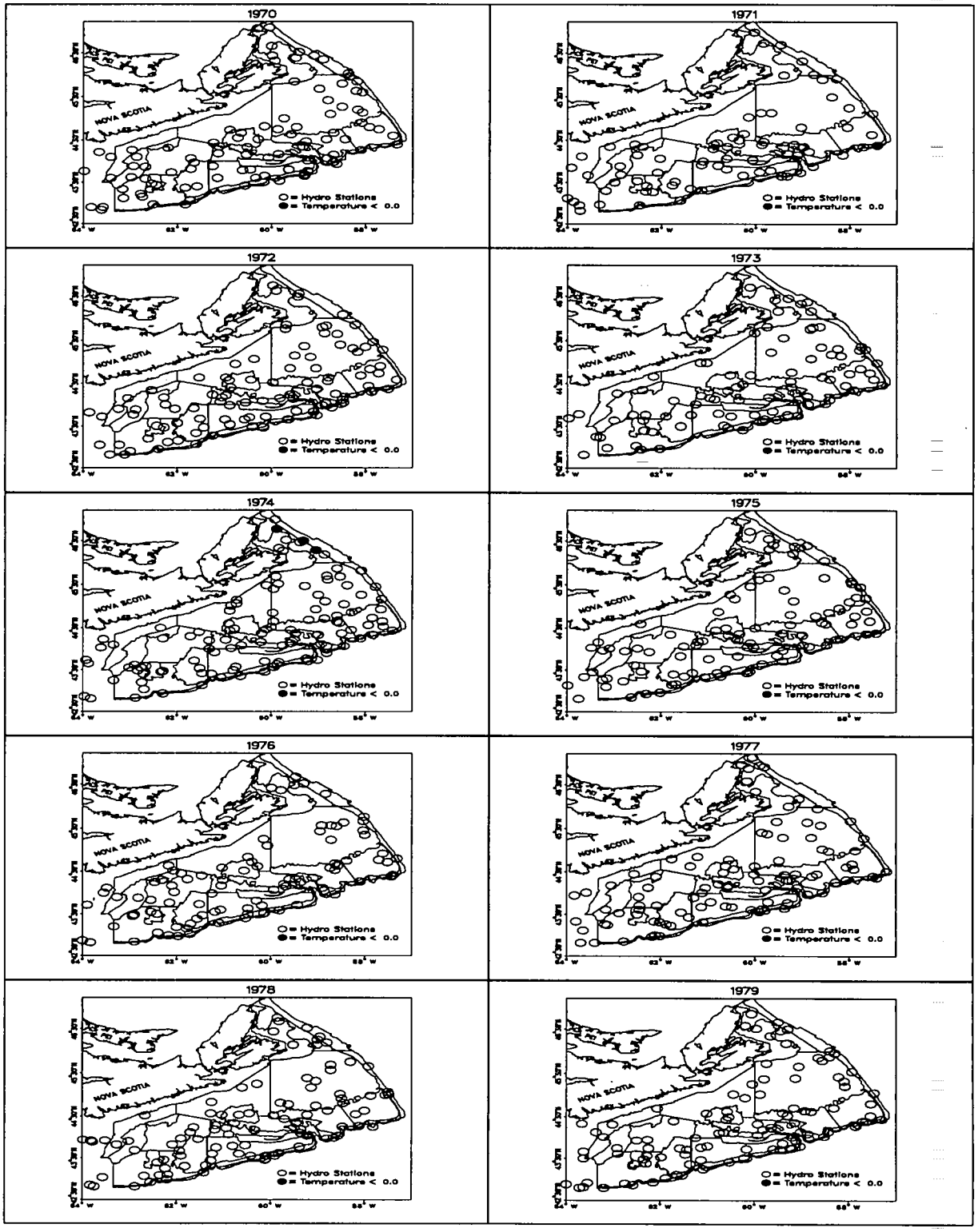

Figure 11: Time series of maps showing the location of hydrographic stations in which water temperatures less than 0.0 C were recorded somewhere in the water column for summer groundfish surveys.

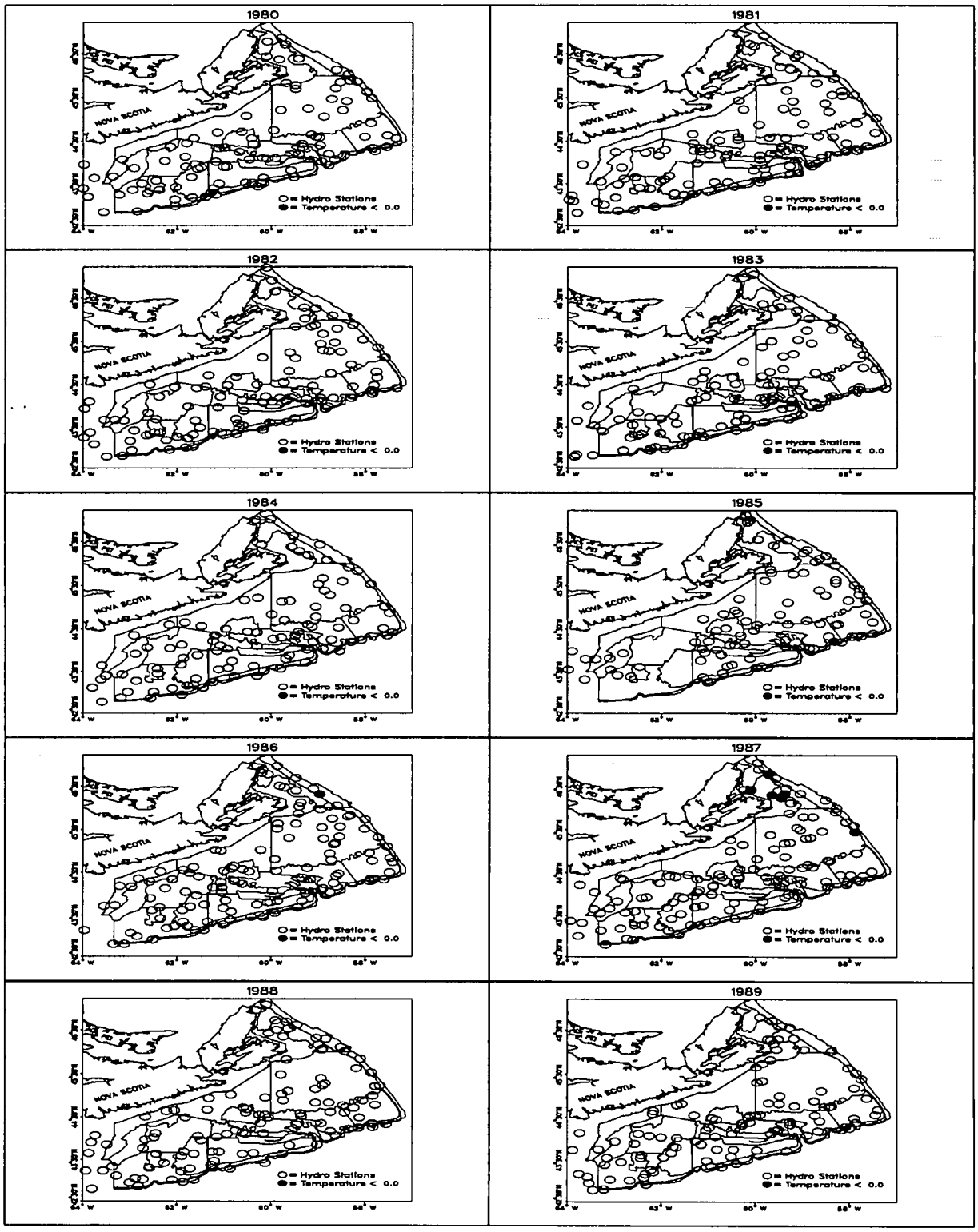

Figure 11: continued

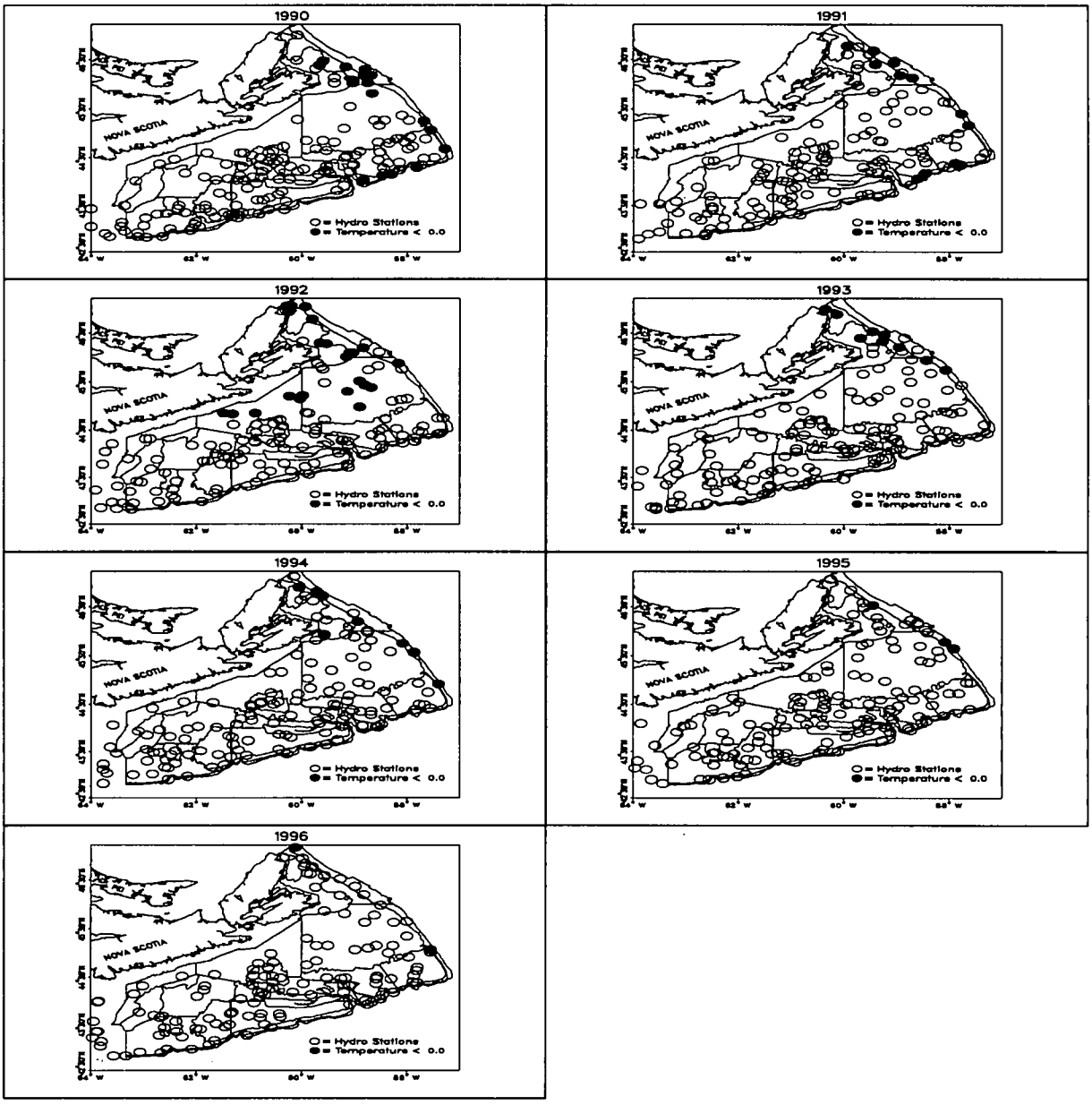

Figure 11: continued

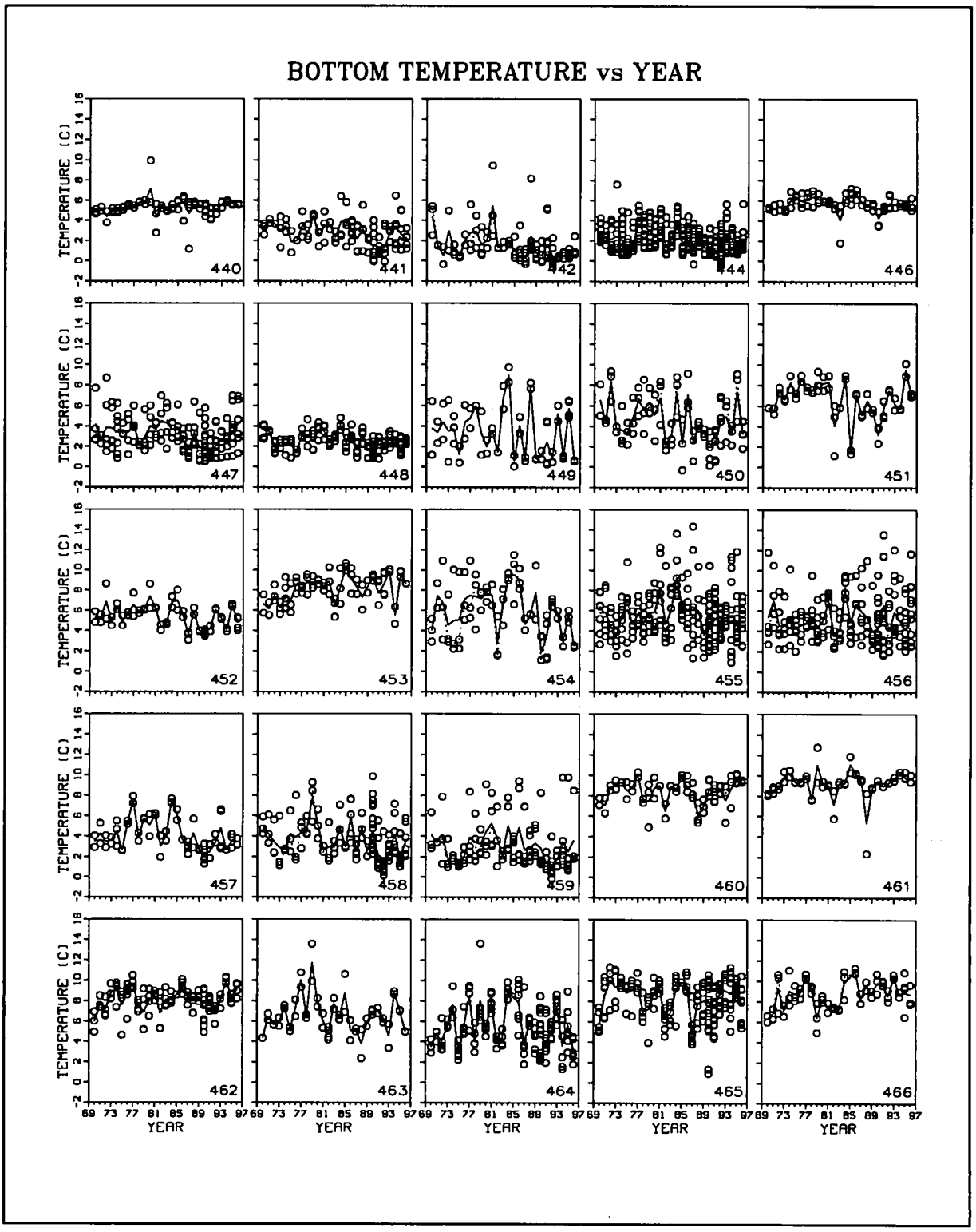

Figure 12: Time series of near-bottom temperatures within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

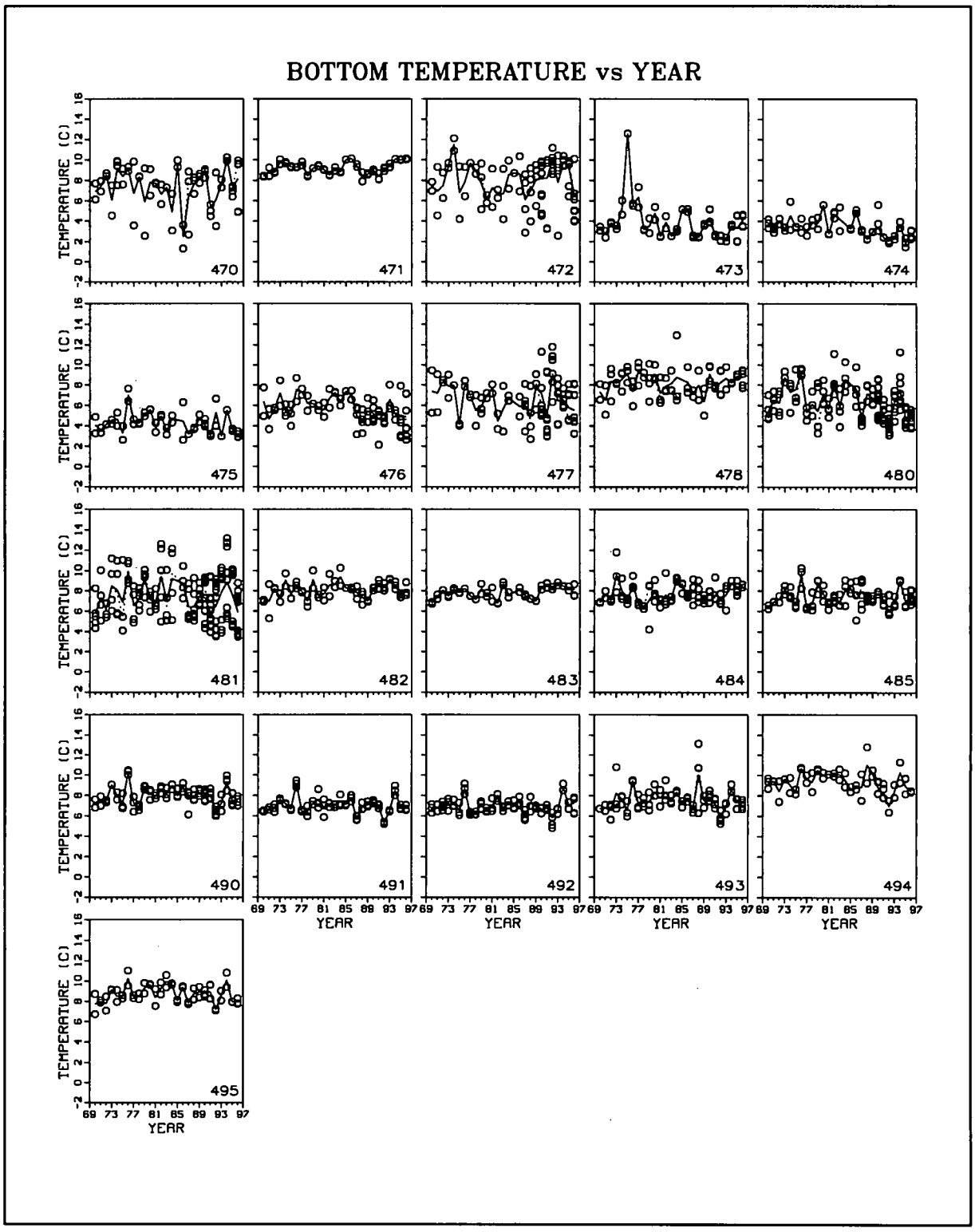

Figure 12: continued

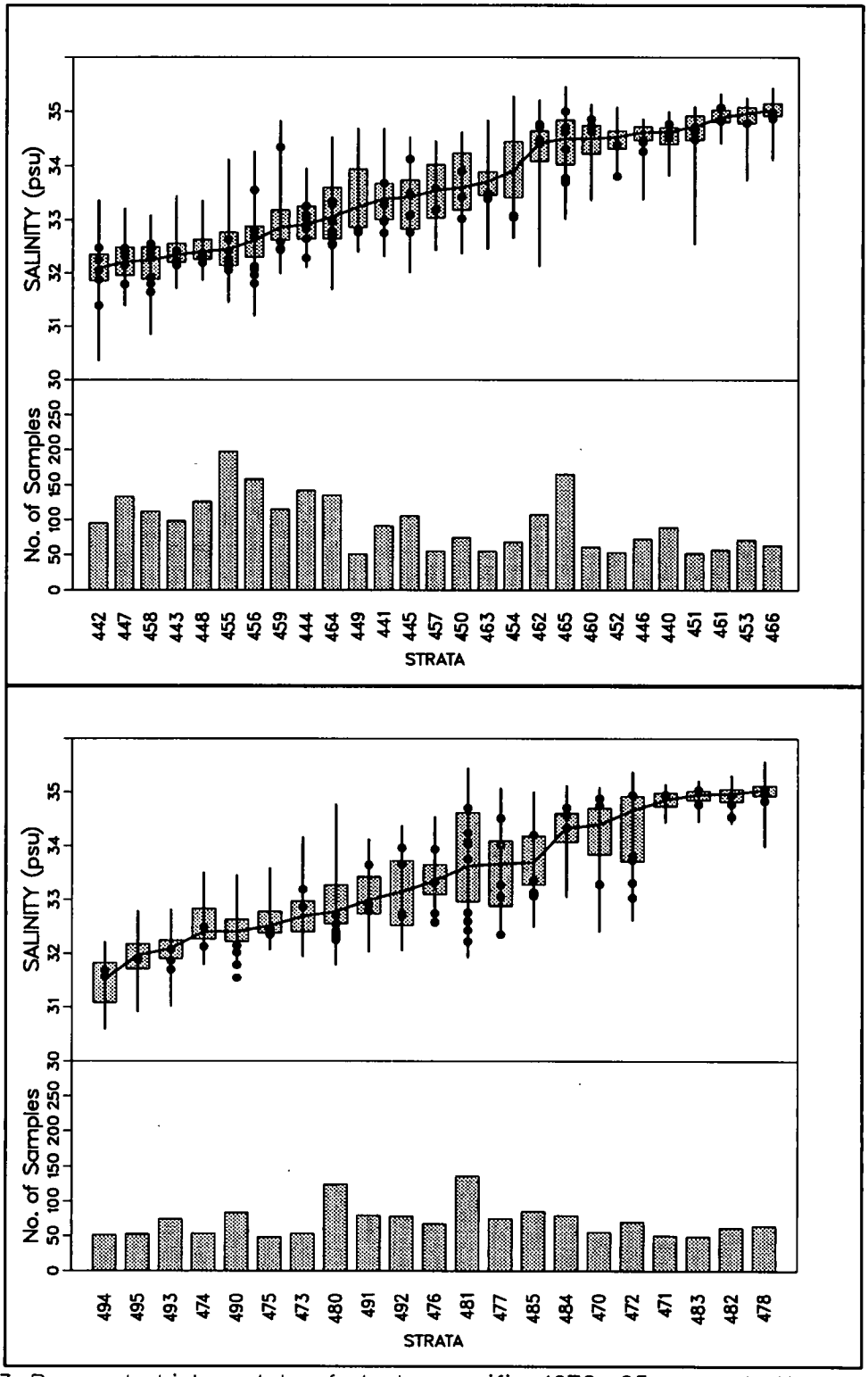

Figure 13: Box and whisker plots of strata specific, 1970–95, near–bottom water salinities for strata within 4VW (top panel) and 4X (lower panel) ordered by salinity medians. The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each strata over the entire 1970–95 period. Solid circles are 1996 observed temperature data.

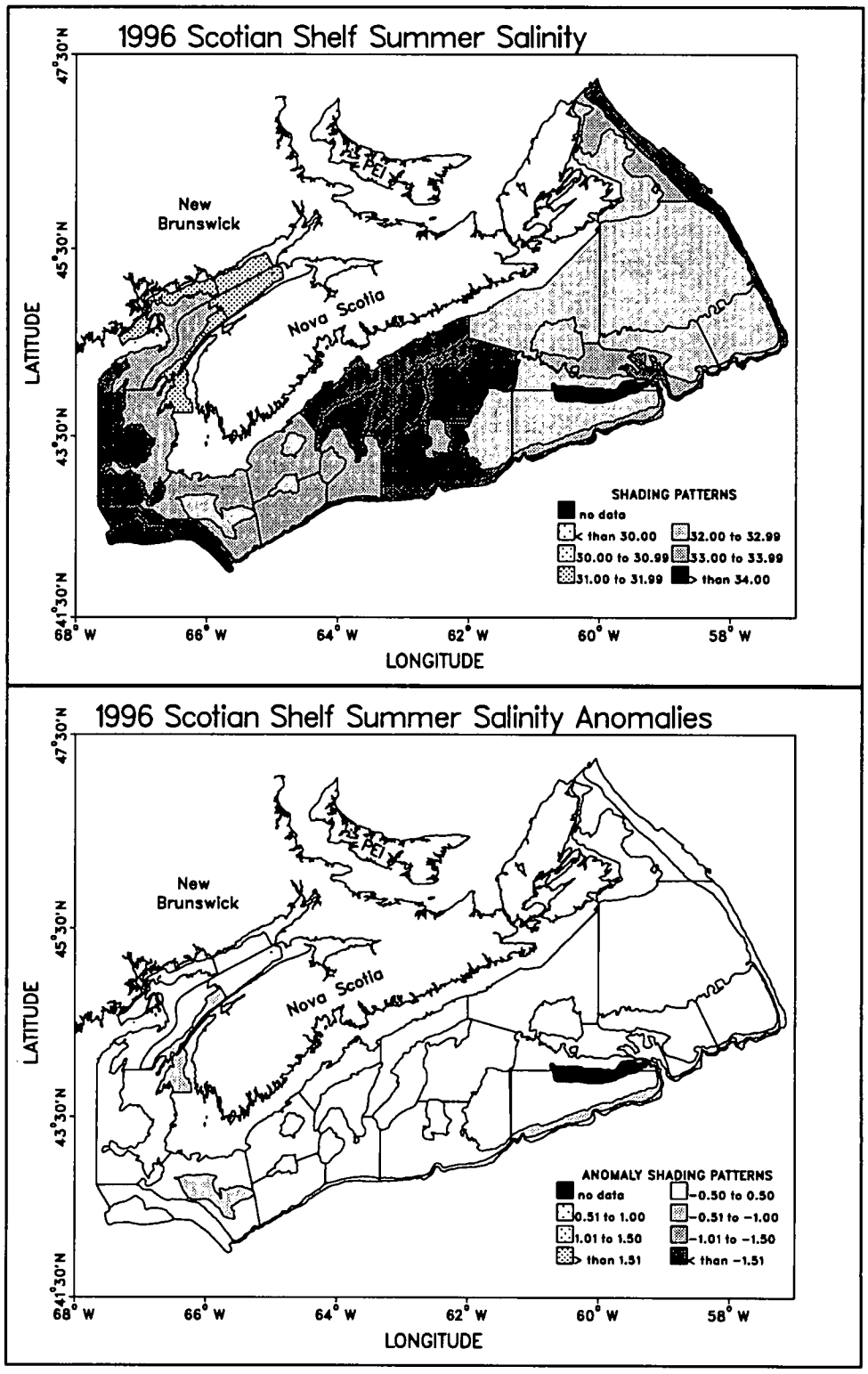

Figure 14: Map of near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1996.

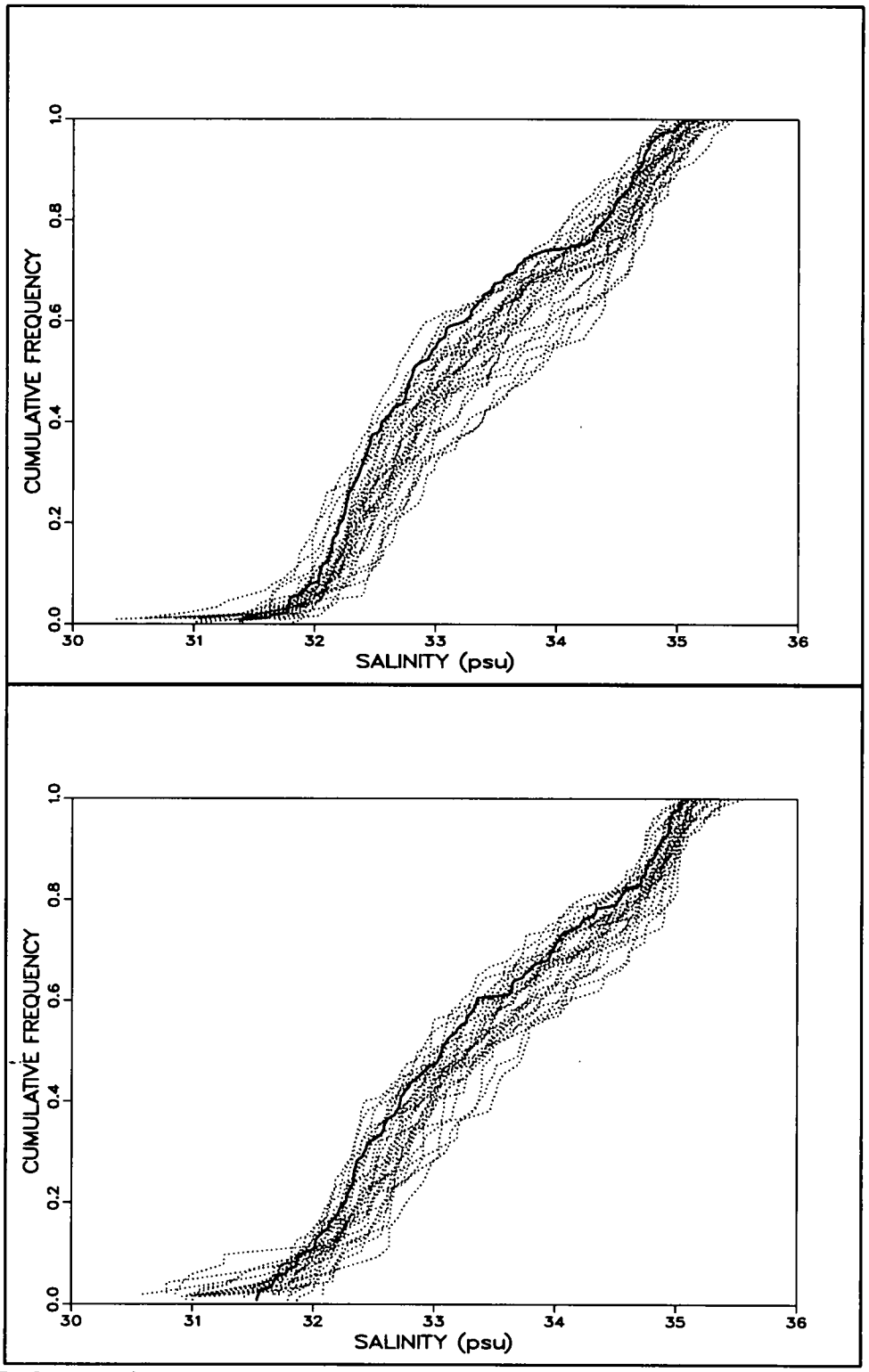

Figure 15: Cumulative frequency curves of near–bottom water salinities for the 1970–96 Canadian research vessel bottom–trawl summer 4VW (top panel) and 4X (lower panel) surveys. Each line represents the cumulative frequency for a single year. The dotted lines are for the years 1970–95 and the heavy solid line is for 1996.

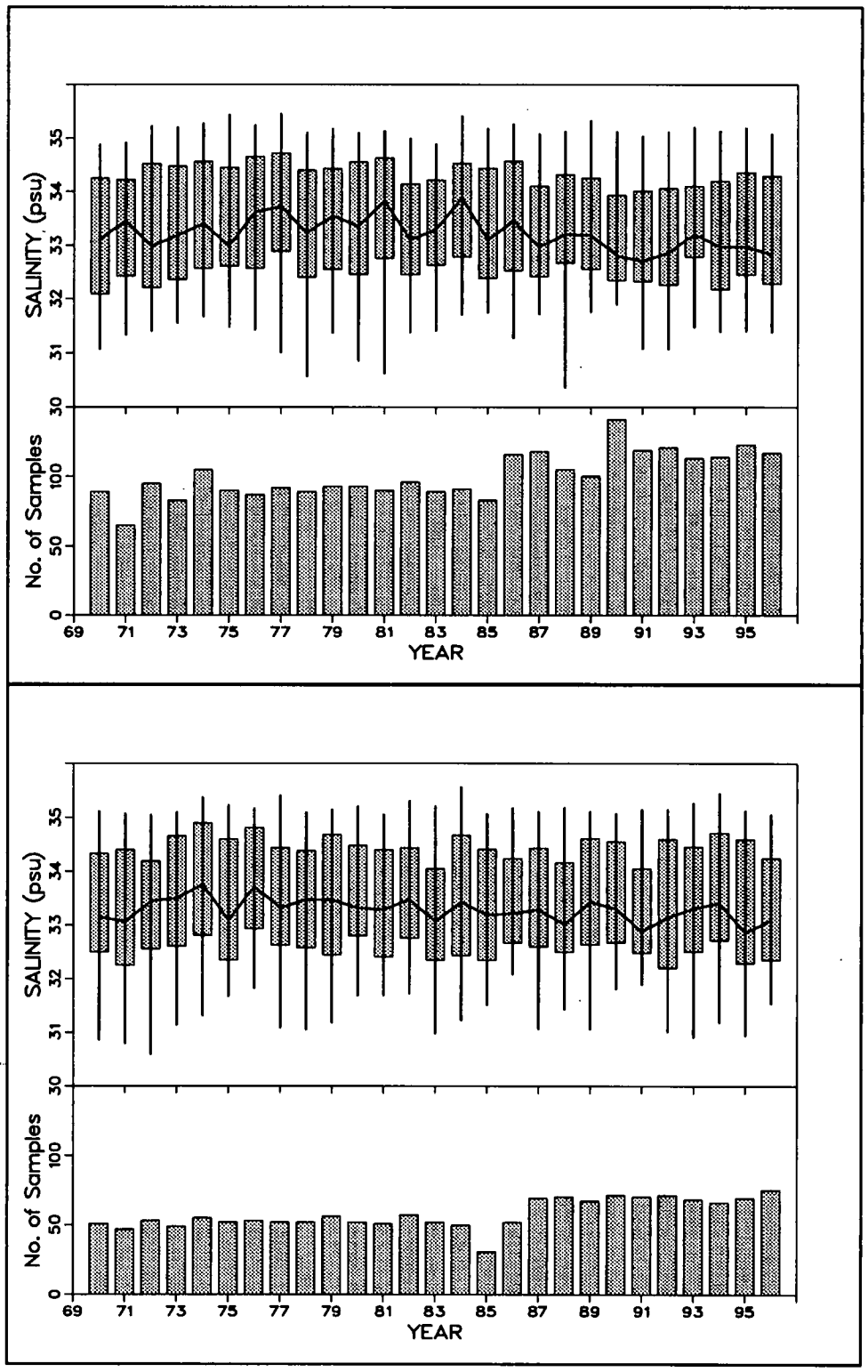

Figure 16: Box and whisker time series plots of near–bottom water salinities for each year within 4VW (top panel) and 4X (lower panel). The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each year over the entire 1970–96 period.

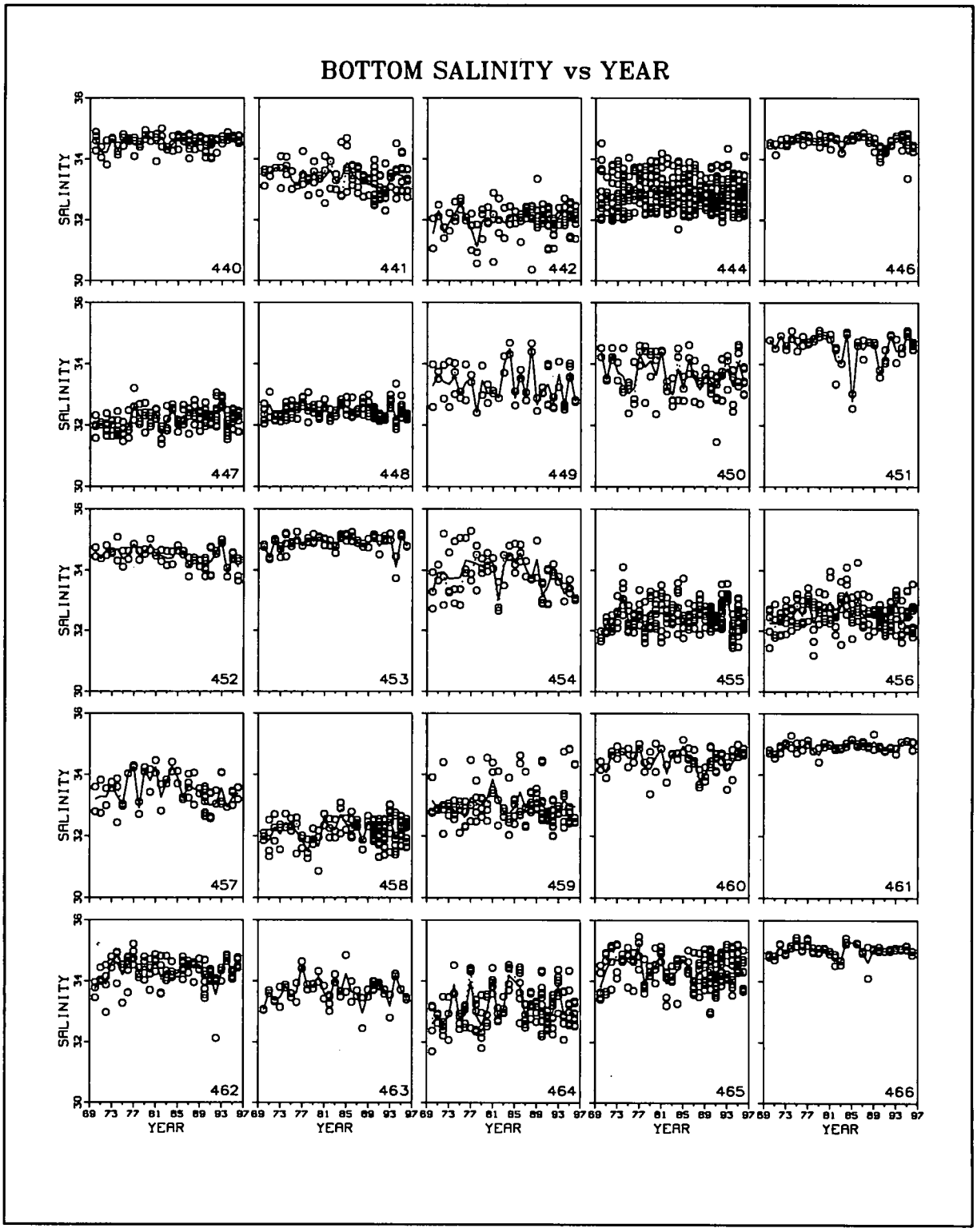

Figure 17: Time series of near-bottom salinities within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

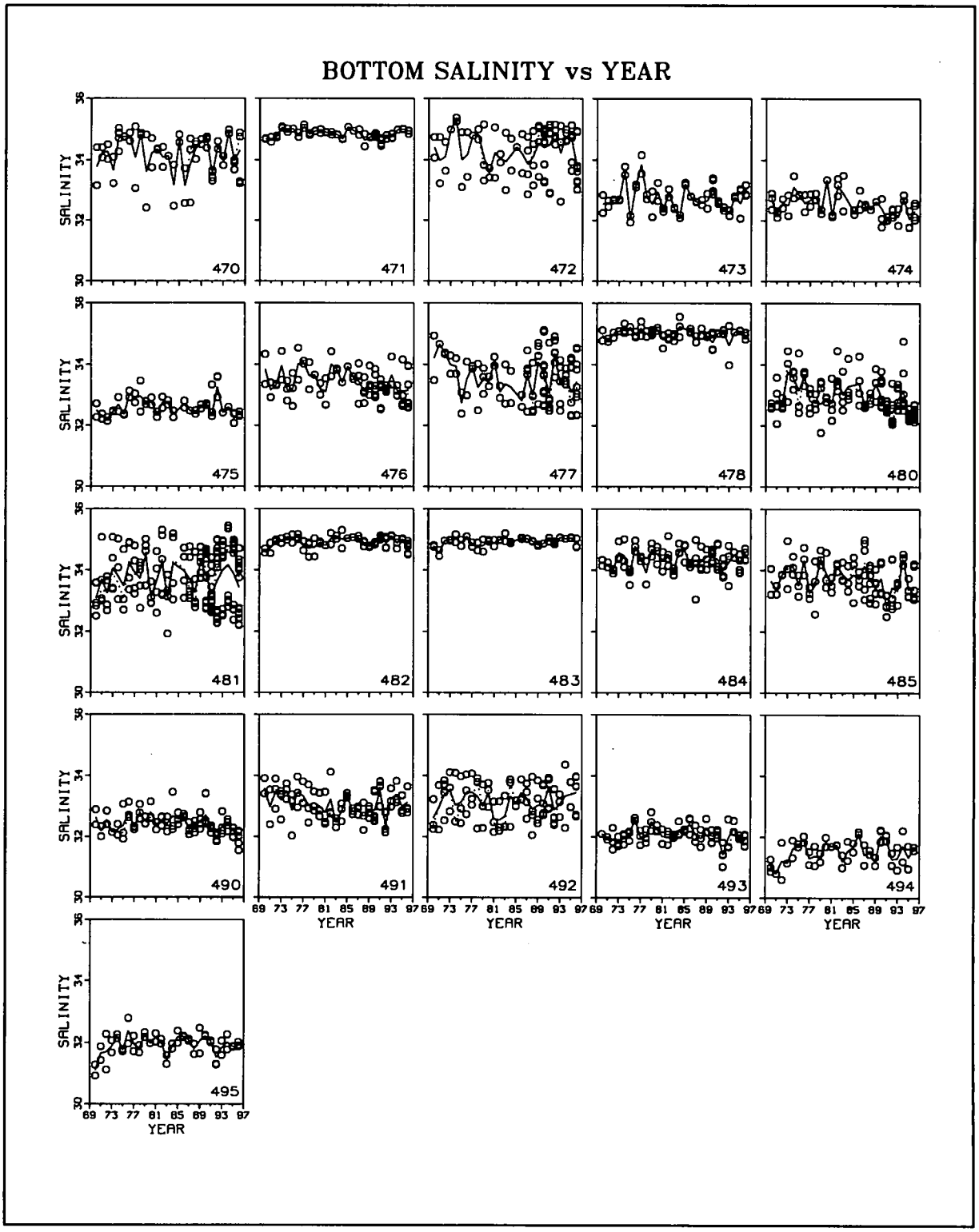

Figure 17: continued