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# Overview of 1997 Hydrographic Sampling Effort and Near-50 meter 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

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

and

M. Ringuette
Department of Fisheries and Oceans
Biological Station, St. Andrews, New Brunswick, Canada E0G 2X0



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## ABSTRACT

Hydrographic sampling effort and near-50 meter water temperatures and salinities from the 1970-97 Canadian research vessel summer groundfish, stratified random, bottom-trawl surveys are summarised. The surveys cover NAFO divisions 4VWX. Time series of stratified mean temperatures show distinct trends that are similar for 4X , 4W and 4VW. The mean temperatures decrease from west to east (Bay of Fundy to eastern Scotian Shelf) and the amplitude of the trend increases from west to east. In 1997, sampling dates were typical of those seen in the past. The temperatures sampled in 1997 near 50 meters were found to be below normal off central Nova Scotia and near normal on the eastern and western Scotian shelf. The salinities were near normal throughout much of the 4VWX area. They were below normal in several of the Scotian Shelf strata within 4X. Some historically low temperatures and salinities were observed in specific strata.



## RÉSUMÉ

L'effort de l'échantillonnage hydrographique et les valeurs de température et de salinité de l'eau à 50 m environ notées au cours des relevés stratifiés aléatoires canadiens du poisson de fond au chalut de fond réalisés par navires de recherche pendant les étés de 1970 à 1997 sont résumés. Les relevés ont été effectués dans les divisions 4VWX de l'OPANO. Les séries chronologiques des températures moyennes stratifiées présentent des allures semblables pour 4X, 4W et 4VW. La température moyenne décroît d'ouest en est (baie de Fundy à est du plateau néo-écossais) et l'amplitude de la tendance s'accroît d'ouest en est. Les dates d'échantillonnage de 1997 à 50 mètres environ étaient typiques de celles des années antérieures. Les températures notées en 1997 à 50 mètres environ étaient inférieures à la normale au large du centre de la Nouvelle-Écosse et près de la normale sur les parties est et ouest du plateau néo-écossais. Les salinités se rapprochaient de la normale dans la plus grande partie de 4VWX. Elles étaient inférieures à la normale dans plusieurs strates du plateau néo-écossais en 4X. Des températures et salinités de valeurs historiquement faibles ont été décelées dans certaines strates.

## 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 the near-bottom conditions are summarised on an annual basis (e.g. Page, Losier and McRuer 1994, 1995, 1996).

The intent of this summary is to briefly describe the extent and nature of the hydrographic sampling effort and conditions at or near 50 meters 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. These conditions may be more appropriate to fish, such as pollock, living and being fished in the mid-depth ranges of the water column.

In this overview, we present a summary of sampling effort and the resulting estimates of water temperatures and salinities during the 1970-97 summer surveys conducted within 4VWX. The focus is on the near-50 meter conditions in 1997 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 1970-97 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 1997. Survey N97026 covered the western Scotian Shelf (4X) and N97034 covered the eastern Scotian Shelf (4VW).

From 1970 to 1989, depth profiles of temperature and salinity were taken at approximately 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 1990-96 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. 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 expendable bathythermoraph (XBT) profile was taken.

In 1997, 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, de-spiking 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 report, mean temperatures and salinities were calculated using database values >= 44 and <=54 meters. These means were designated as "near 50 meter" conditions. The range was selected in an attempt to extract as much of the historical (pre-1989) reversing bottle data as possible. Sampling methodology could not guarantee a sample at the target depth of 50 meters due to water current and wind conditions. Data were edited and wire angles were used to calculate the actual depth

of the reversing bottles. These were the depths recorded on the database. CTD database values are entered at 2 meter intervals beginning at 1 meter. There are no 50 meter values. CTD near 50 meter values will include mean values calculated using 45, 47, 49, 51 and 53 meters.

# RESULTS

## Sampling

In 1997, sampling was conducted from 2 July (consecutive day 183) to 31 July (consecutive day 212). 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, 482 and 485) not being widely distributed throughout the strata.

The maximum CTD profile depths ranged from <50m to >300m. The distribution of near-50 meter depths were sampled in all strata (Fig. 1 & 2). In 1997, the depths sampled were, consistent with previous years.

### *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 to 20 days later than in the more recent years.

With the exception of strata 453 and 455, the sampling dates in 1997 were generally typical of those in recent years. Sets in strata 453 and 455 respectively, were approximately 2 weeks later than the average dates for these strata.

## Near-50m Temperatures

### *Means and 1997*

The overall range of near-50 meter temperatures within the survey domain, and during the complete survey time period (1970-97), 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-50m temperatures in 1997 ranged from 0.63 to 11.04°C which was within the previously observed limits (Fig. 4,8). In 4VW, temperatures from many stations were either above or below the 1970-96 75th and 25th percentiles respectively (eg. 442, 461 and 465). In many of the central shelf strata, the temperatures tended to be below the median. In 4X strata 471/478, historic lows were recorded. However, in strata 480 and 482 near historic highs were observed. Temperatures for strata 483 / 495 fell within the 50th percentile.

The geographic distribution of the 1997 temperatures (Fig. 5) is similar to that of the long-term (1980-90) strata mean temperatures (Fig. 6) except for warmer waters observed on the Sable Island banks. The lowest temperatures (<2°C) occurred on the eastern Scotian Shelf and over the shelf to the west of Halifax. The highest temperatures occurred in the upper Bay of Fundy, and the deep waters between Georges and Browns Banks (>8°C). Temperatures throughout the remainder of the survey domain were between 2° and 8°C.

These patterns are also evident in the distribution of 1997 strata mean temperatures (Fig. 7). With the exception of 4 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 1997 were near or below normal in 4VW, although they were not the lowest in the history of the survey series. The cumulative frequency for 4X overall fell within expected ranges with the exception of some low temperature values which were at historic lows.

### *Historical Context: Temporal Patterns*

The time series of area unweighted temperature percentiles is shown in Fig. 9. In 4VW, the median temperatures decreased from 1970-75, tended to increase from 1975 to 1980, decreased to 1982 and increased again to 1984. With the exception of 1988, the temperatures decreased from 1984 to 1992 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 1996, the distribution of temperatures was still centred below those in the

late 1970's and early 1980's. For 1997, temperatures were about the same as values recorded for the previous three years.

In 4X the temperatures have been variable with no trend from 1970 to 1989. In 1990, with the introduction of the use of a CTD at each station, the temperatures began to drop to a minimum in 1992. Median temperatures have been variable since, with temperatures in 1997 being similar to the 1970's.

In 4X the minimum and 25th percentile temperatures are generally about 2 degrees higher than those in 4VW. For 4X, the 25th percentile of the temperatures range between 2 and 6°C with the exception of 1973 which was above 7°C. In 4VW they range from <1 to ~4°C.

Unlike the temperature unweighted time series, the time series of stratified mean temperatures (Fig. 10) show distinct trends that are similar for 4X , 4W and 4VW. The mean temperatures decrease from west to east (Bay of Fundy to eastern Scotian Shelf) and the amplitude of the trend increases from west to east. The strata specific time series of temperatures are shown in Fig. 11.

## Salinities

### *Means and 1997*

The near-50 meter salinities sampled within the survey domain have ranged from about 30.5 to 35 psu (Fig. 12, 14) during the 1970-97 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 plateau of the Scotian Shelf and in the upper Bay of Fundy (490, 494-95) tend to be relatively fresh (75th percentile <33 psu), whereas those in the shelf edge or deep Gulf of Maine strata (451, 453, 462-466, 478, 482-485) can have relatively high salinities. 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 1997 (Fig. 13).

Near-50 meter salinities in 1997 ranged from 30.6 to 33.9 psu (Fig. 5,12,14). In most strata, the 1997 observations were distributed throughout the previous range of values. In strata 465, 470 and 473 some salinities were series lows (Fig.12). Most strata mean salinities were within 0.5psu of baseline means (Fig. 14). Salinities were >0.5psu below the 1980-90 baseline means in only eight strata (441, 460, 470, 471, 473, 477, 481, and 494). The cumulative frequency distributions of the area unweighted salinities (Fig. 14) indicate that in 1997 some relatively low salinities were observed in 4VW, although they were not the lowest in the history of the survey series. In 4X, the salinities fell

within the expected range, although in specific strata some salinities were historic lows (Fig. 12).

***Historical Context: Temporal Patterns***

Like temperatures, the near-50 meter salinities have varied inter-annually. The trends in the distribution of unweighted salinities for 4VW are weak (Fig. 15). In 4VW, the median salinities were generally around 32 psu. The median salinities reached a historical high in 1984 in 4VW, and in 1980 in 4X. The strata specific time series of temperatures are shown in Fig. 16.

The stratified mean salinities for the Scotian Shelf portion of 4X (4X SS) increased during the 1970's and early 1980's, and decreased throughout the 1980's and early 1990's (Fig.10). The trends in 4W and 4Vs are unclear.

# 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 monthly 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 substantial a problem for the summer surveys as it is for the spring surveys. This is discussed more fully in Page et al. 1994.

Whether or not the temperature and salinity changes are climatic in nature 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). Therefore, the suggested trends in temperatures may 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 fat content was explored by Stephenson et al. 1995.

## Acknowledgements

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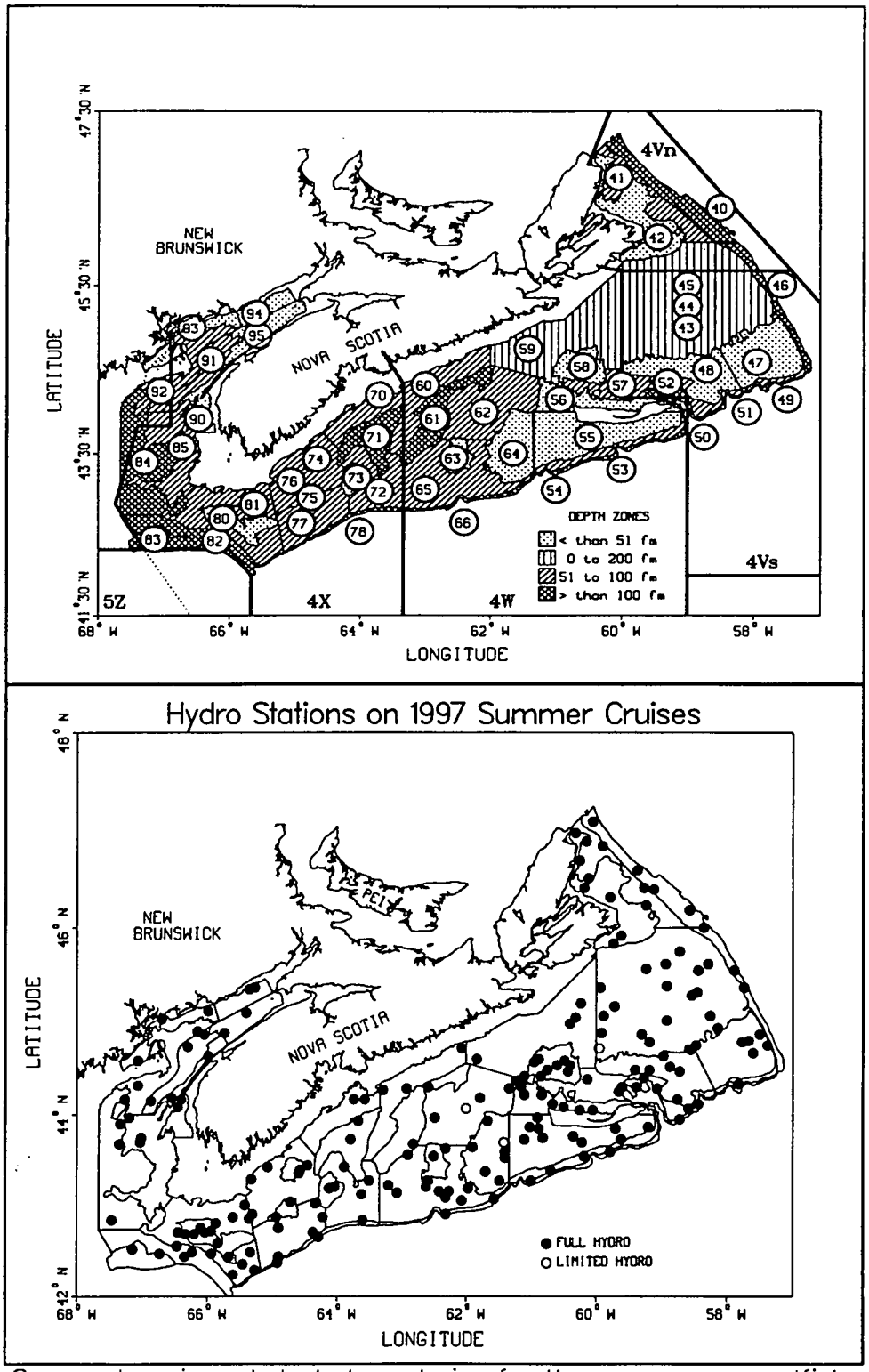



Figure 1: Survey domain and strata boundaries for the summer groundfish research vessel surveys conducted within NAFO area 4VWX from 1970–1997 (top panel) and the location of hydrographic sampling stations taken during the 1997 survey (bottom panel). In the bottom panel solid circles indicate a CTD cast 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. Only the last two digits of the summer strata designations are shown.

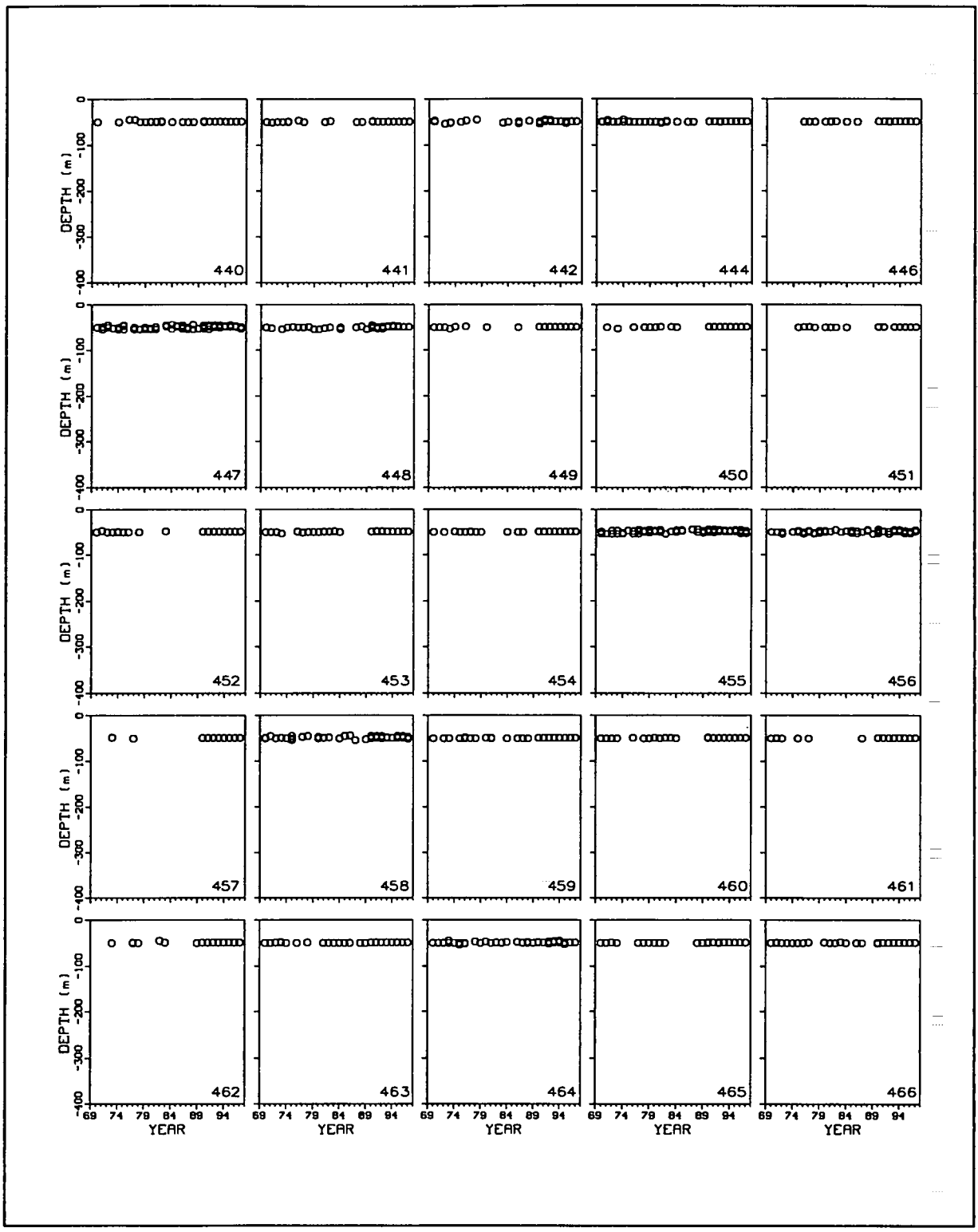
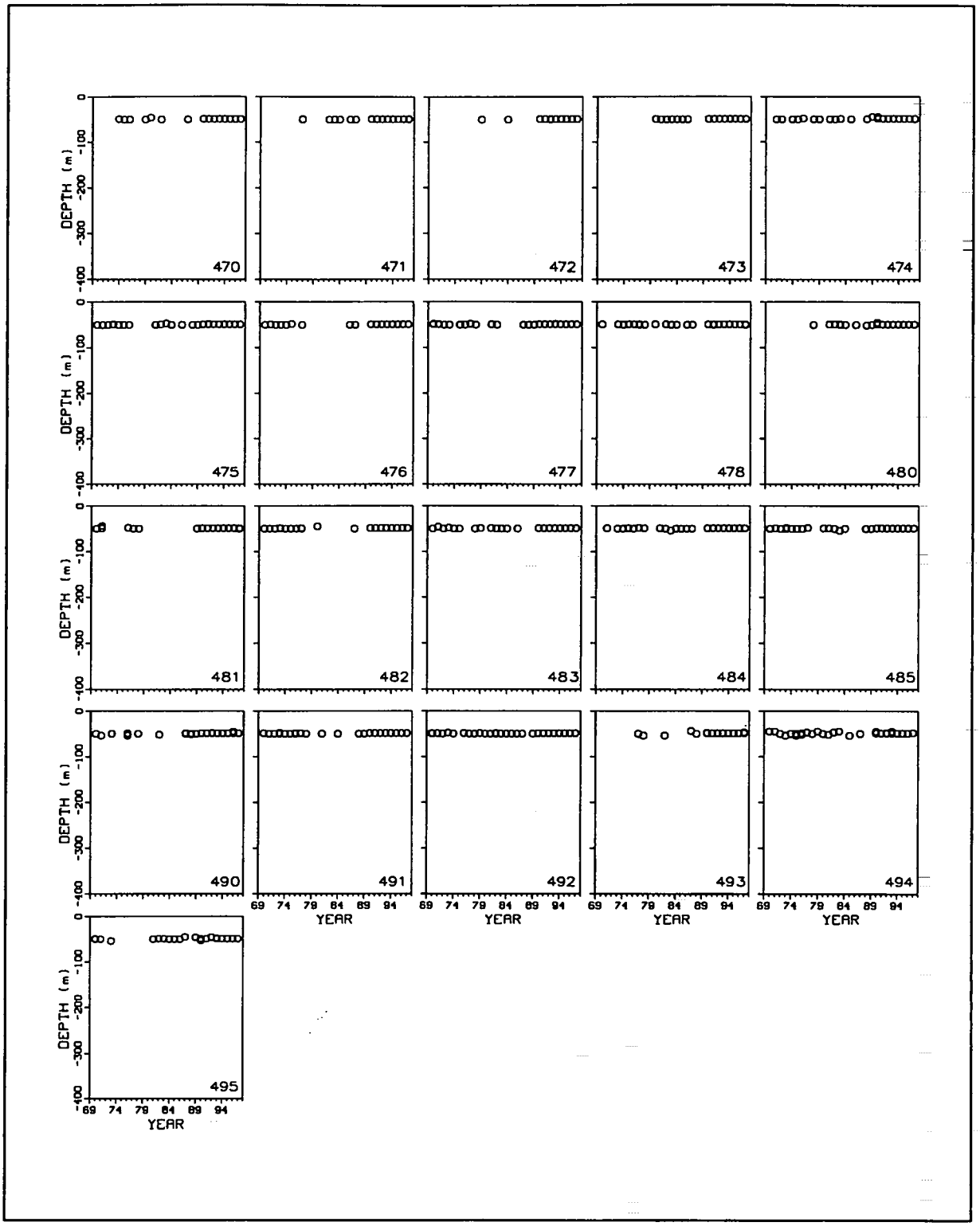



Figure 2: Time series of the 50 meter hydrographic sampling depth for each station within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the 50 meter sampling depth of one hydrographic station.

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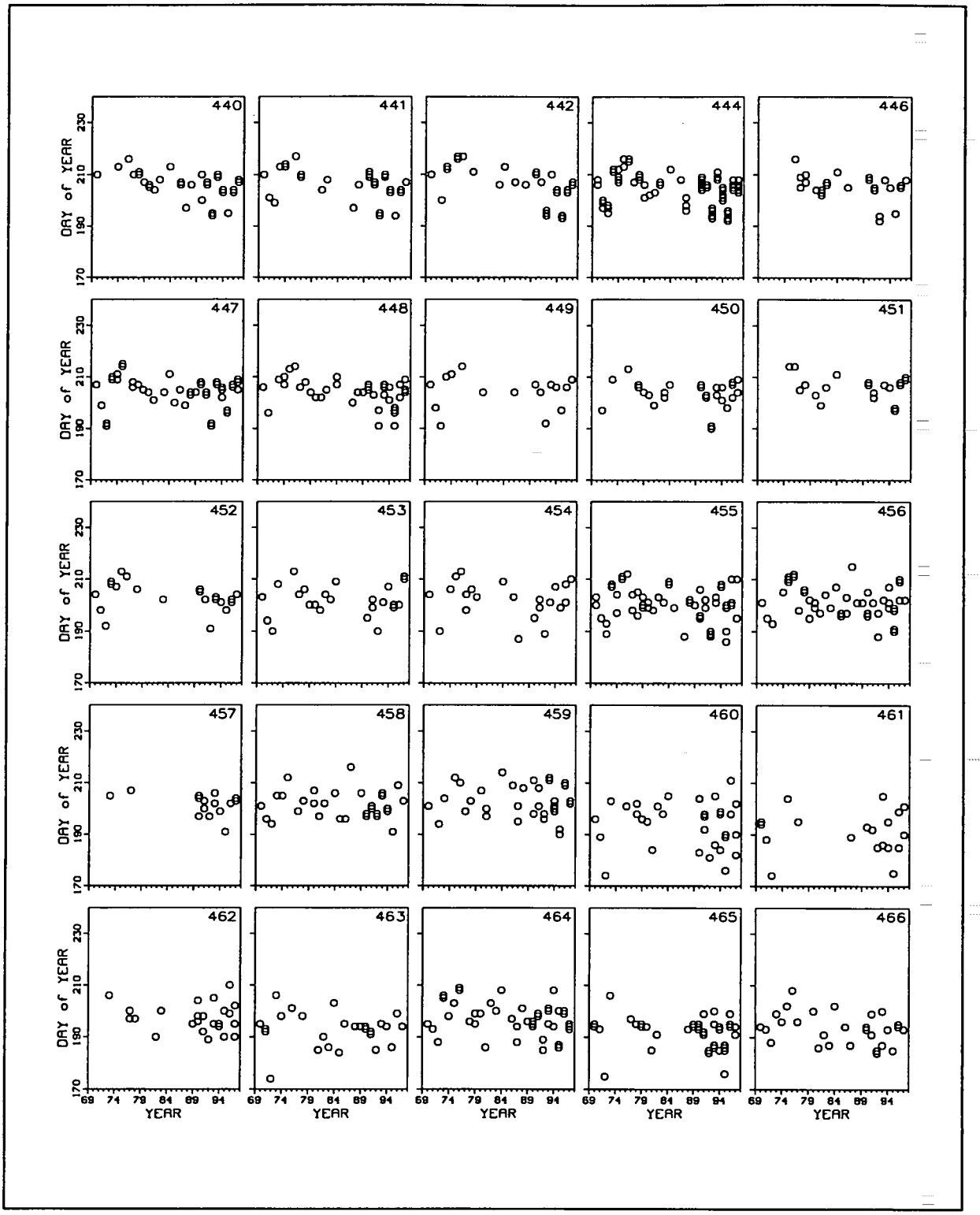
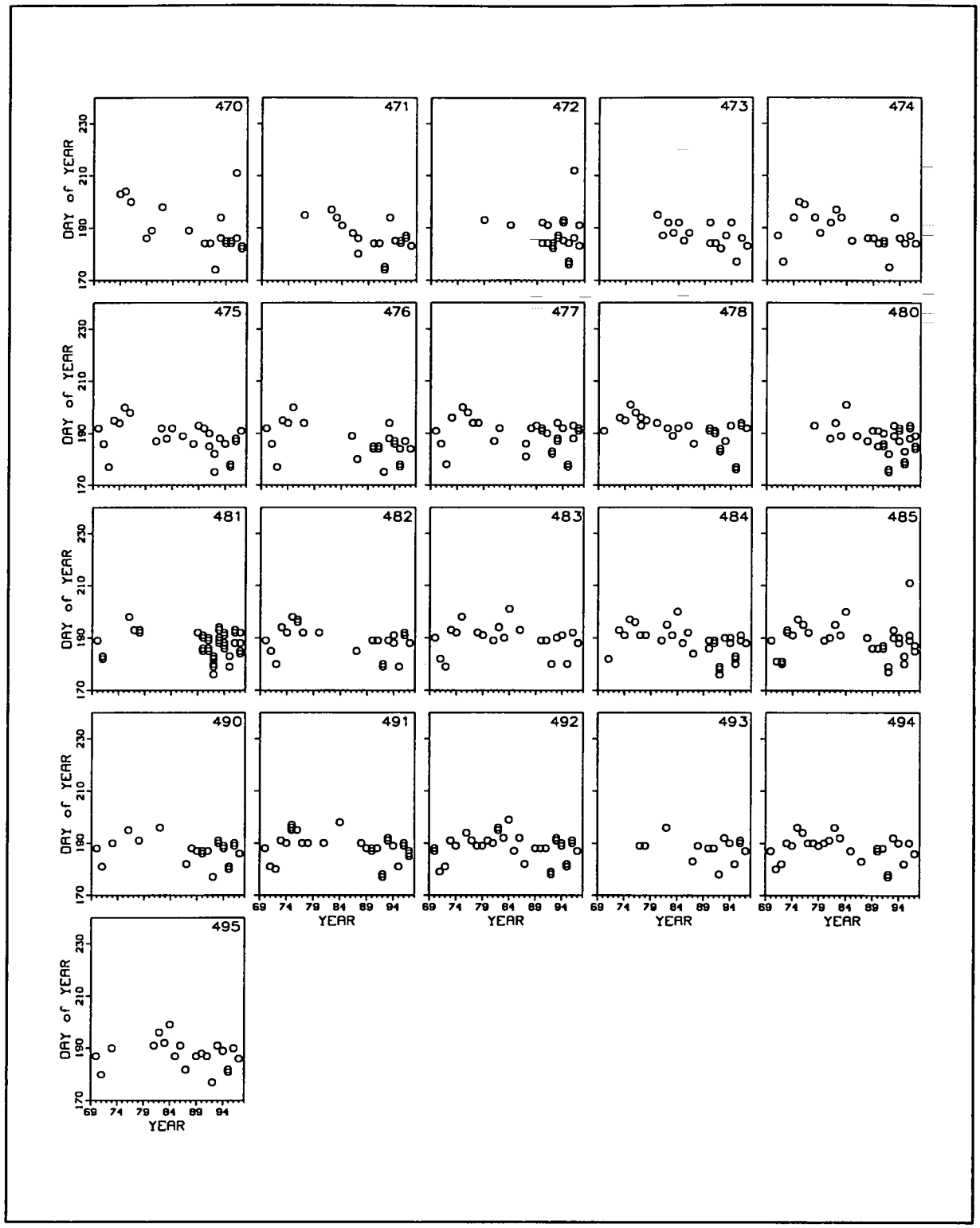



Figure 3: Time series of the consecutive day of sampling within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.

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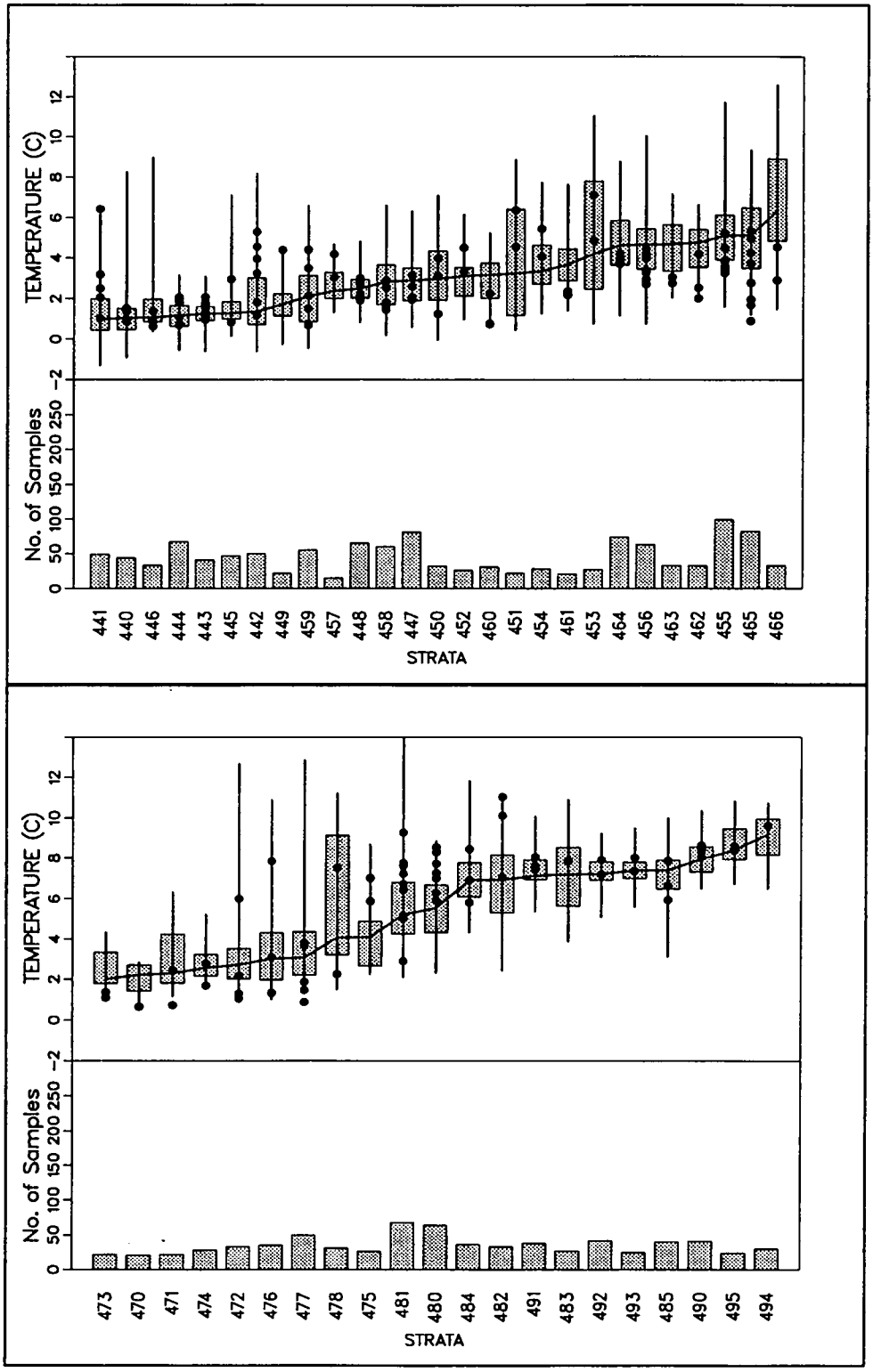


Figure 4: Box and whisker plots of strata specific, 1970–96, 50 meter water temperatures for strata within 4VW (top panel) and 4X (lower panel) ordered by temperature medians. The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each strata over the entire 1970–96 period. Solid circles are 1997 observed temperature data.

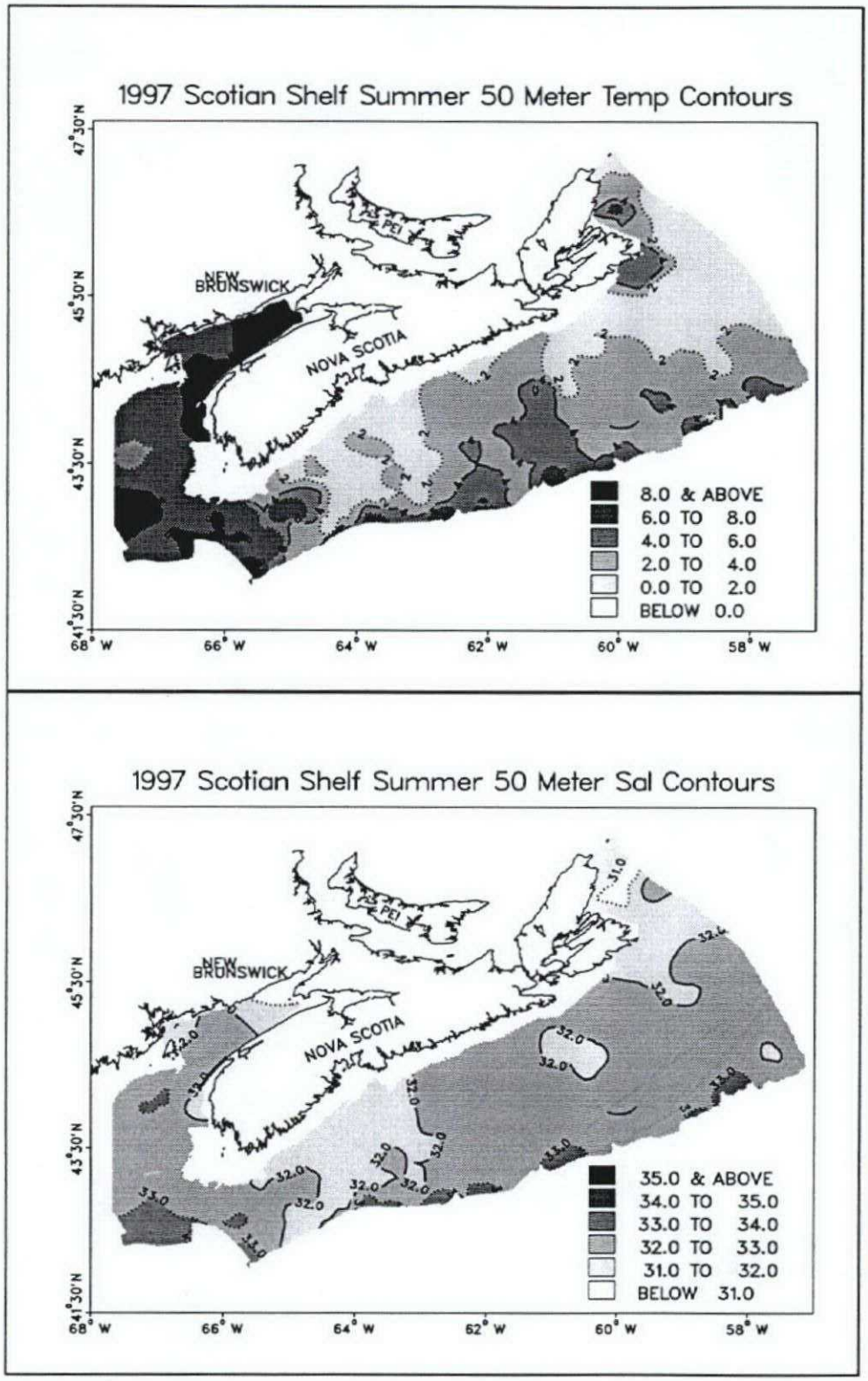


Figure 5: Contour maps of 50 meter temperature and salinities within the 4VWX Canadian research vessel bottom–trawl surveys conducted during the summer of 1997.

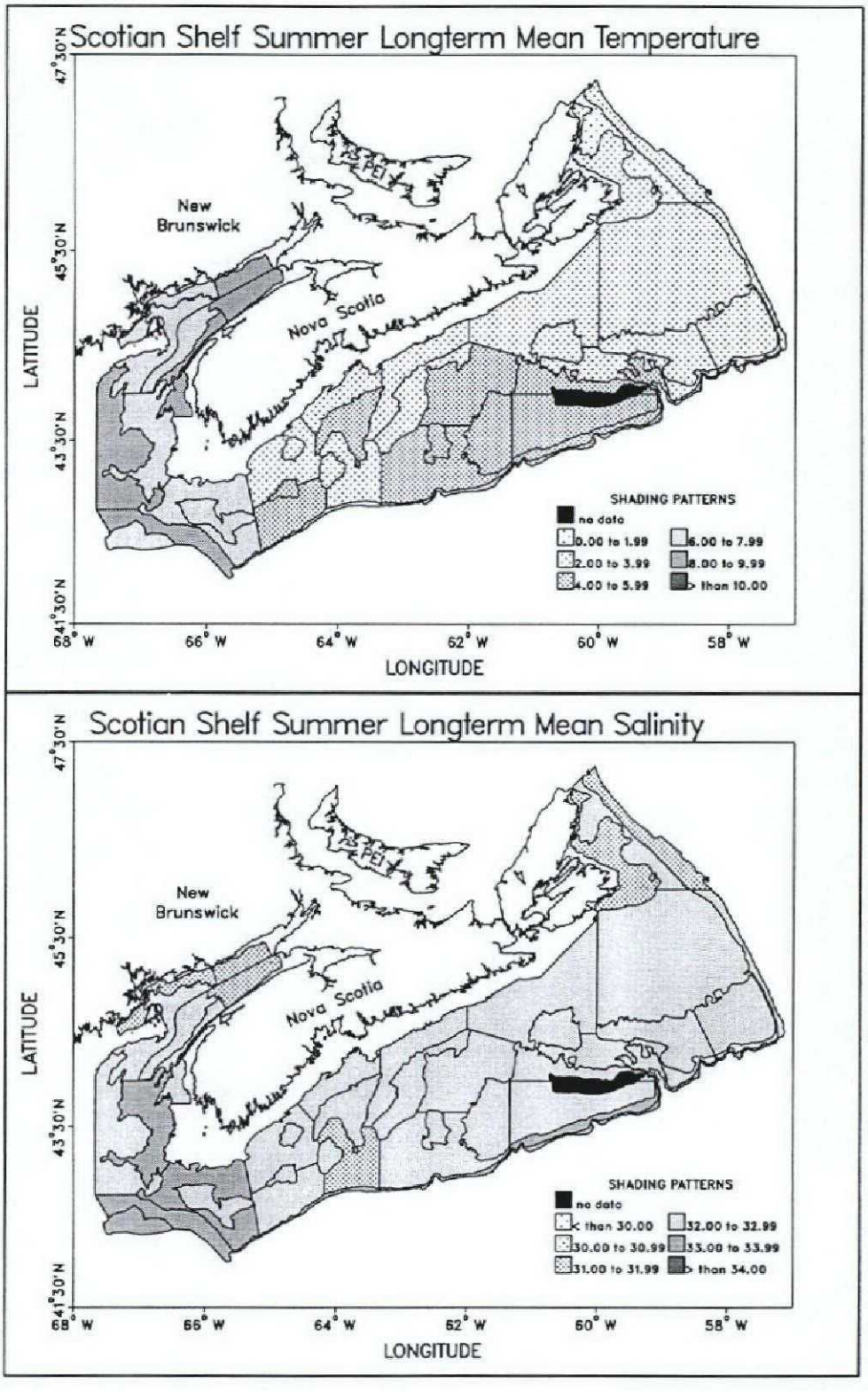


Figure 6: Map of 50 meter strata long term mean temperatures (top panel) and salinities (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom–trawl survey conducted during the summer of 1980–1990.

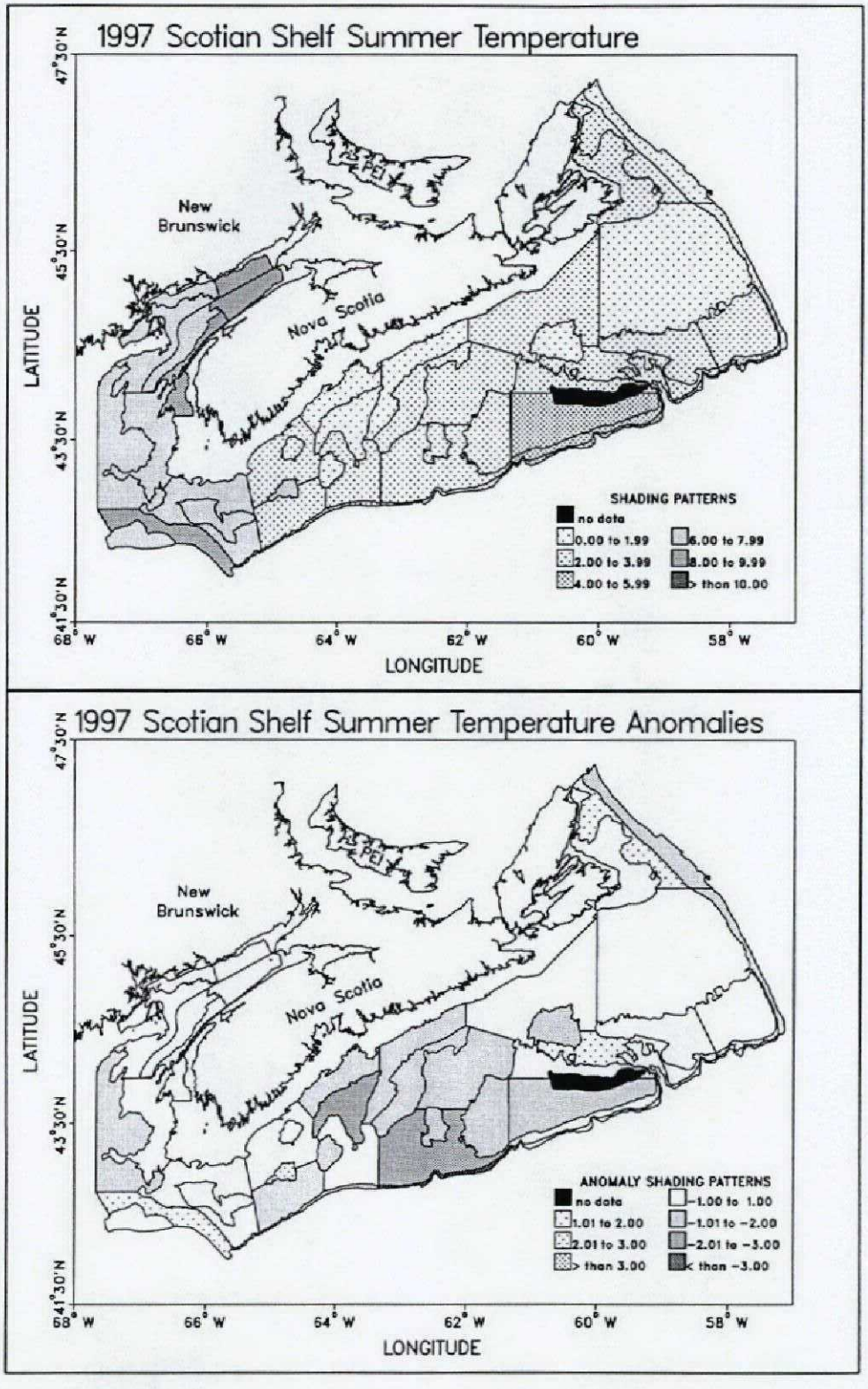


Figure 7: Map of 50 meter strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom–trawl survey conducted during the summer of 1997.

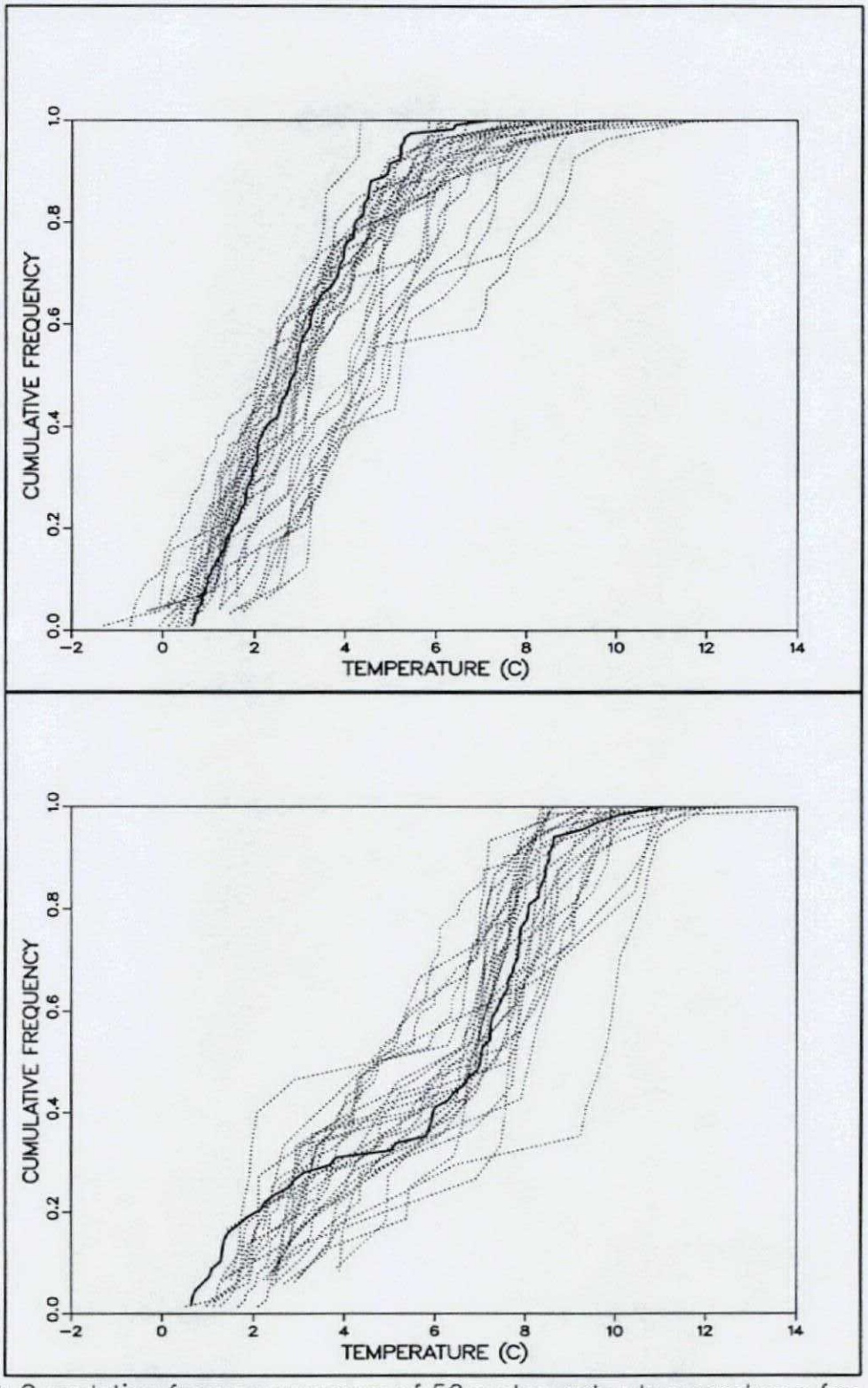


Figure 8: Cumulative frequency curves of 50 meter water temperatures for the 1970–97 Canadian research vessel bottom–trawl summer 4VW (top panel) and 4X (lower panel) surveys. Each line represents the cumulative frequency for a single year. The dotted lines are for the years 1970–96 and the heavy solid line is for 1997.

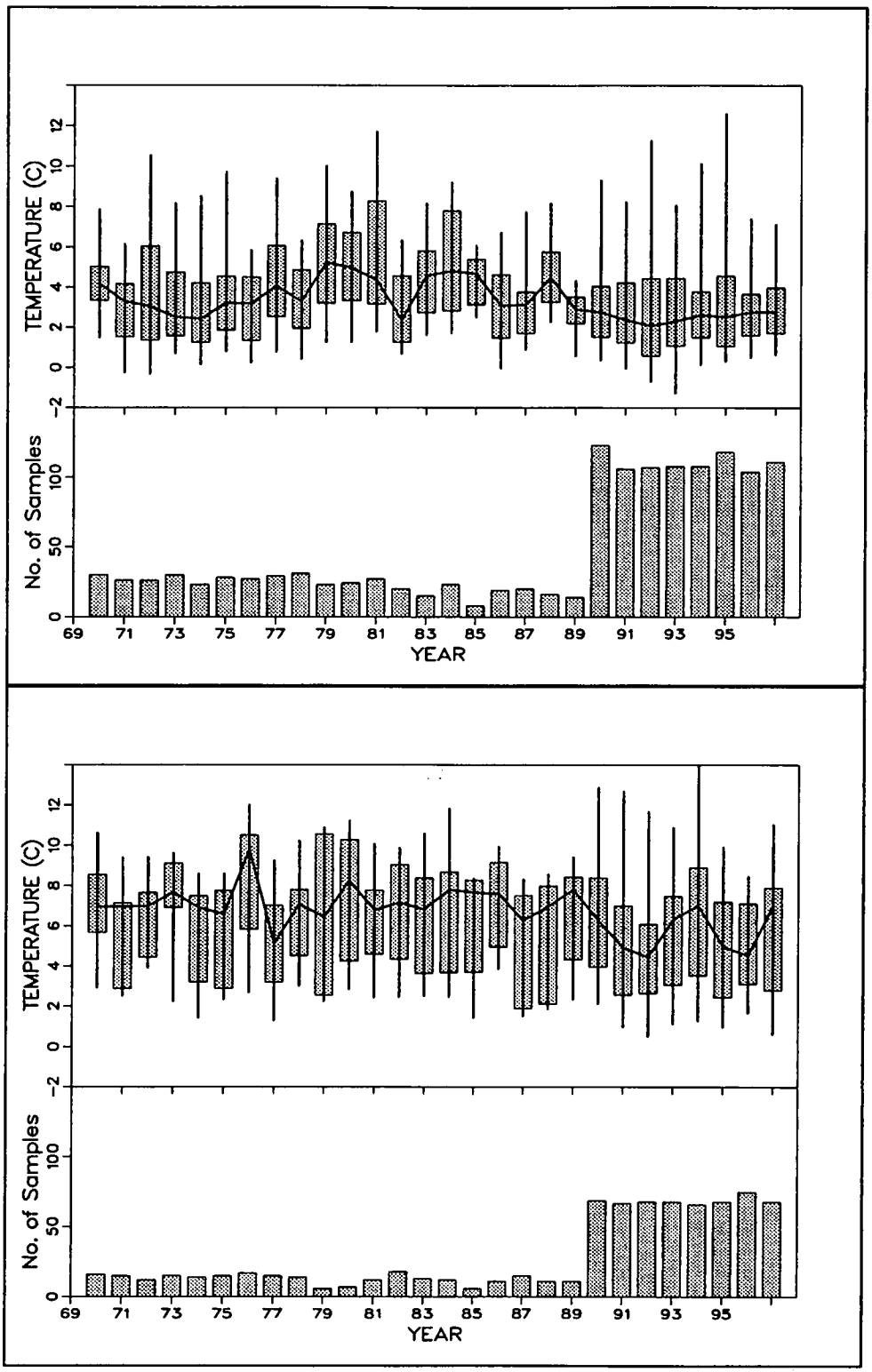


Figure 9: Box and whisker time series plots of 50 meter water temperatures for each year within 4VW (top panel) and 4X (lower panel). The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each year over the entire 1970–97 period.

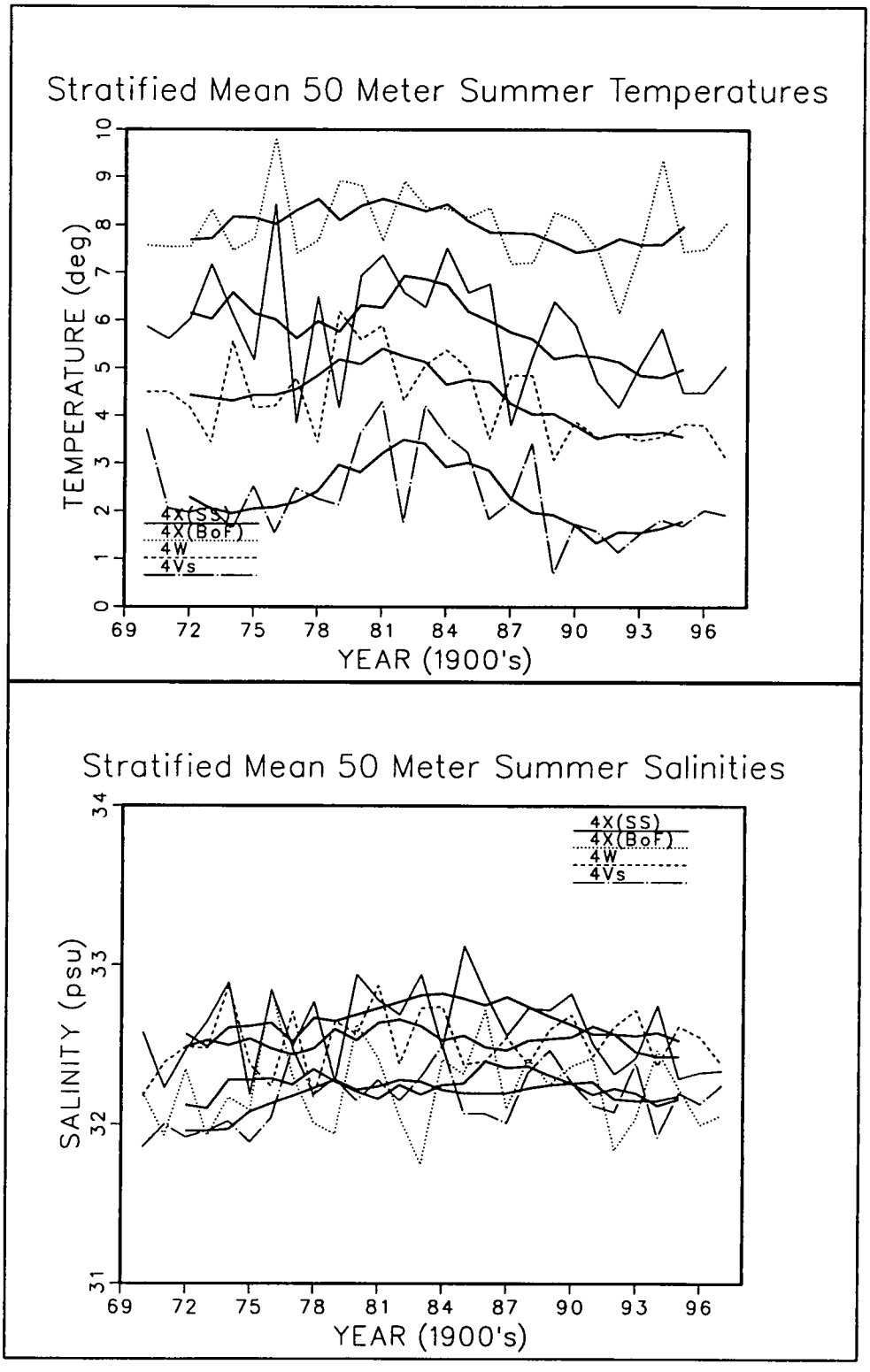


Figure 10: Time series of stratified mean 50 meter temperatures(upper panel) and salinities (lower panel)for Canadian summer research vessel groundfish surveys. The smooth curves running through each series is a five year running mean.

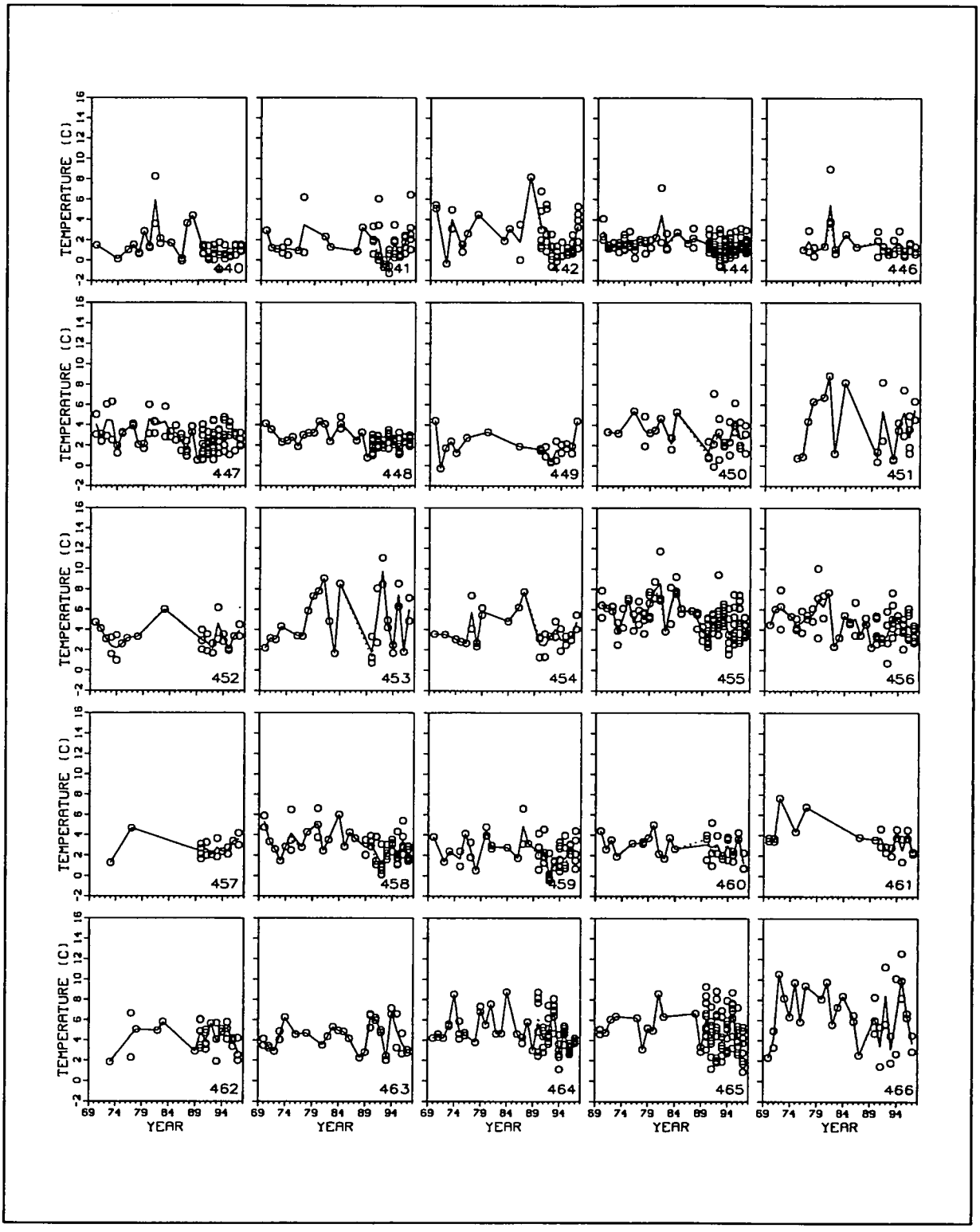


Figure 11: Time series of 50 meter temperatures within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

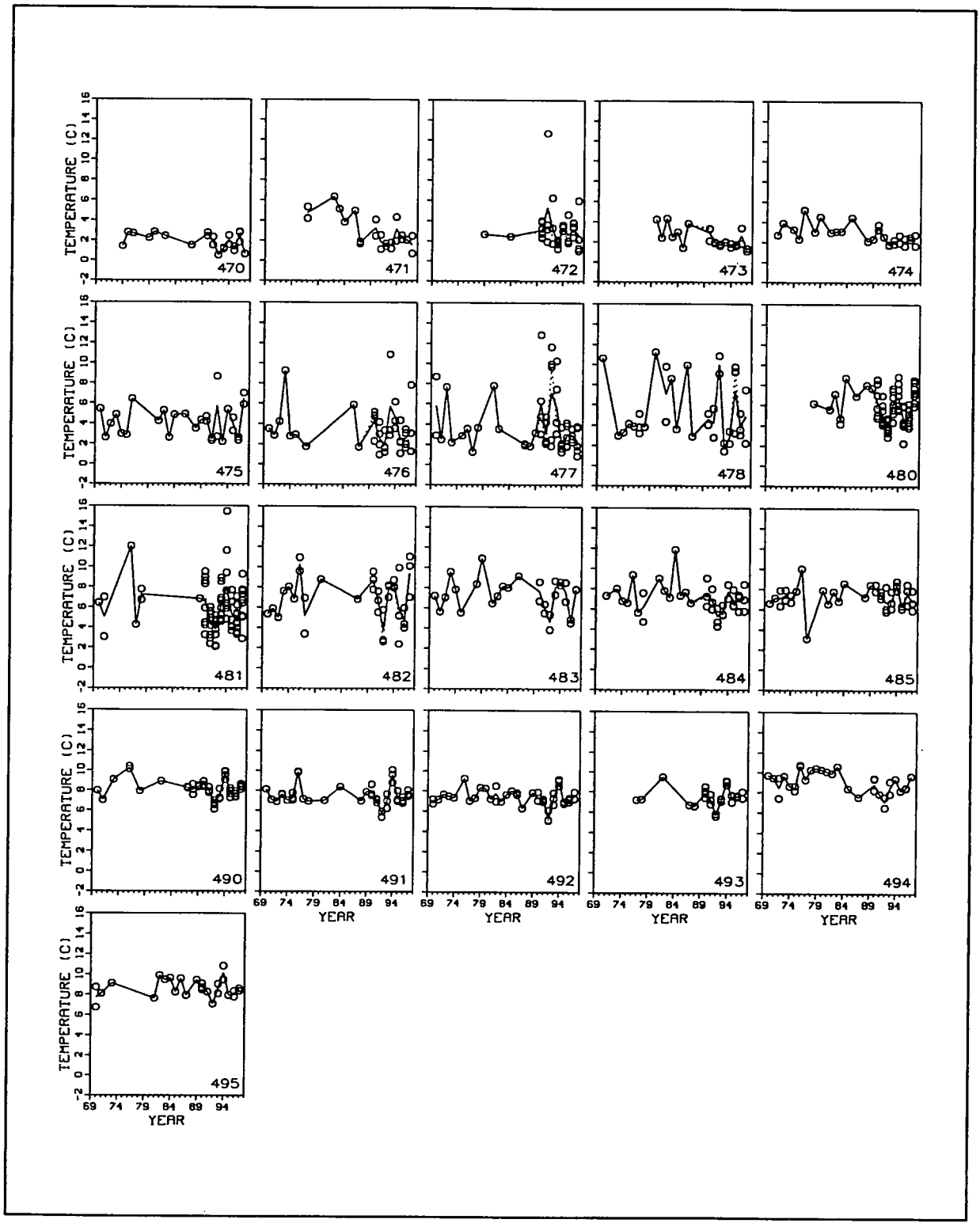


Figure 11: continued

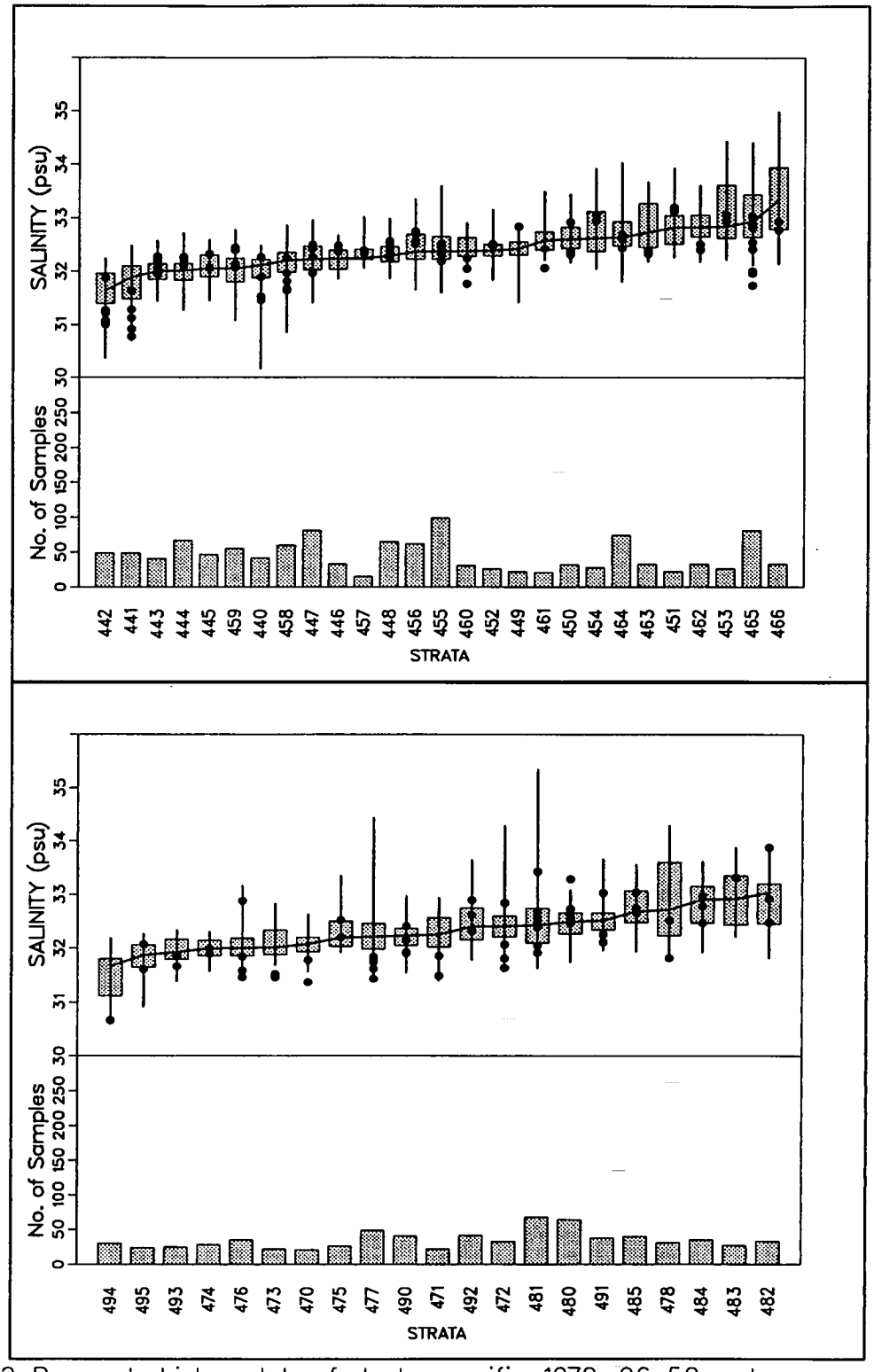


Figure 12: Box and whisker plots of strata specific, 1970–96, 50 meter water salinities for strata within 4VW (top panel) and 4X (lower panel) ordered by salinity medians. The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each strata over the entire 1970–96 period. Solid circles are 1997 observed temperature data.

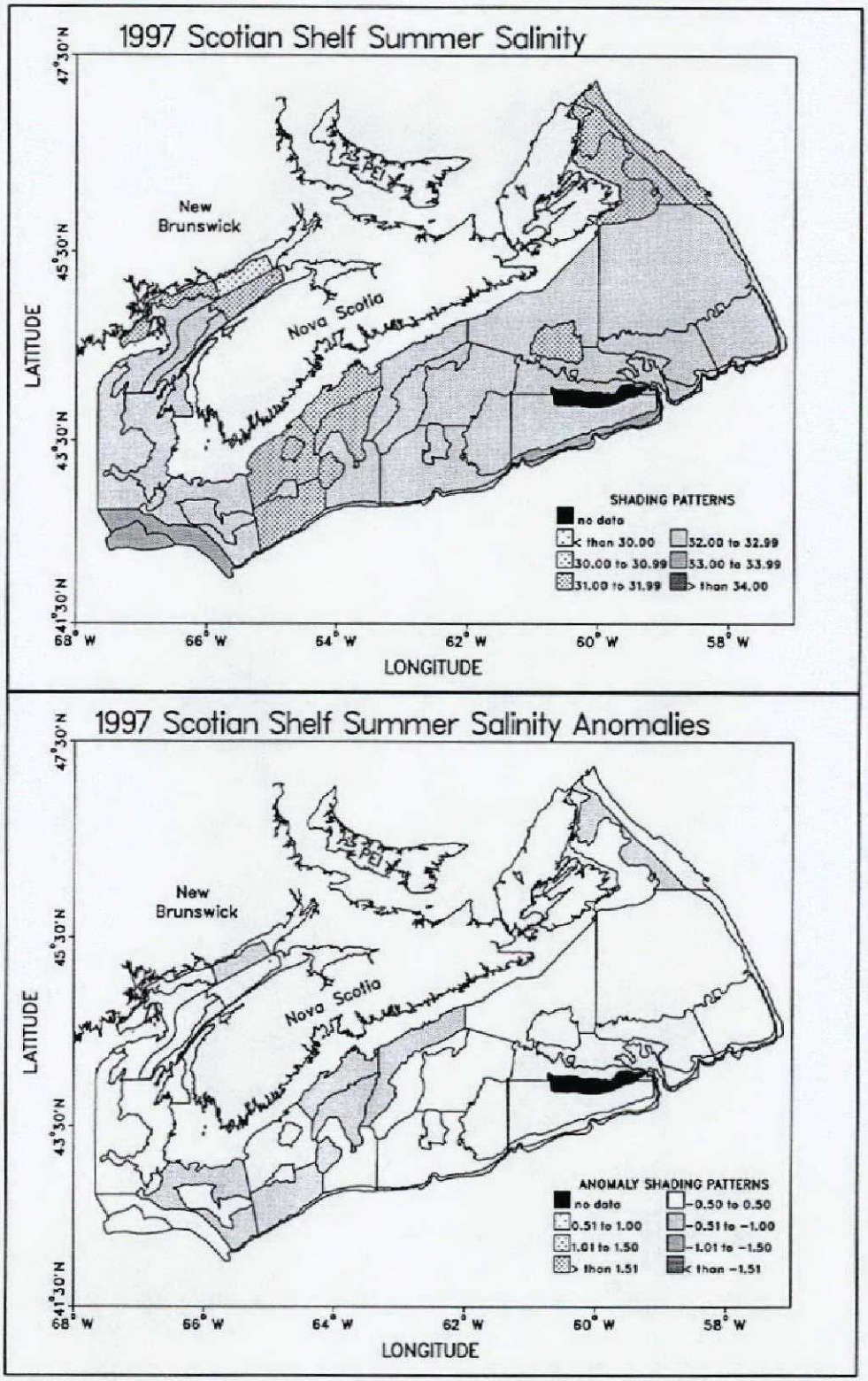


Figure 13: Map of 50 meter strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1997.

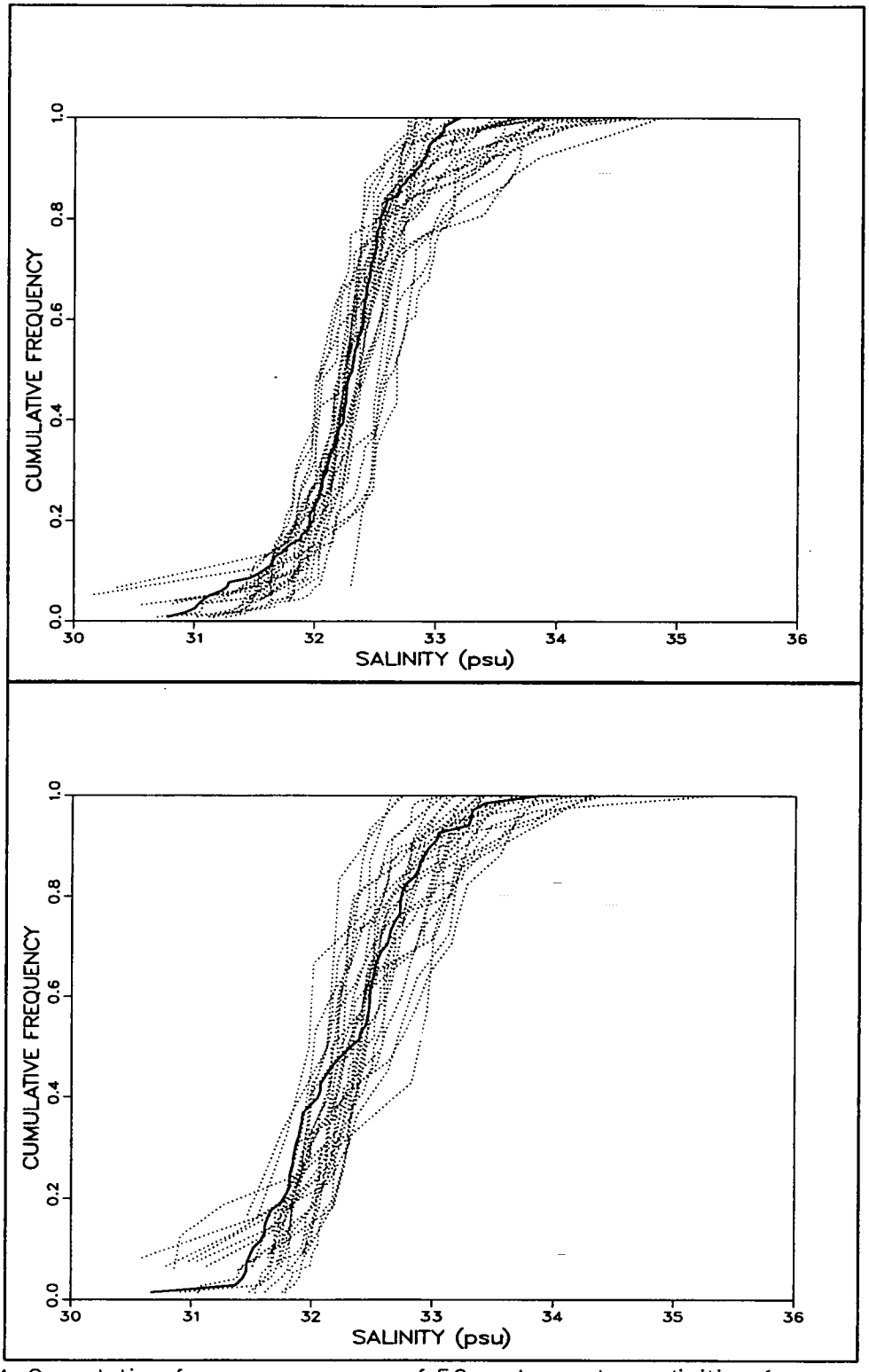


Figure 14: Cumulative frequency curves of 50 meter water salinities for the 1970–97 Canadian research vessel bottom–trawl summer 4VW (top panel) and 4X (lower panel) surveys. Each line represents the cumulative frequency for a single year. The dotted lines are for the years 1970–96 and the heavy solid line is for 1997.

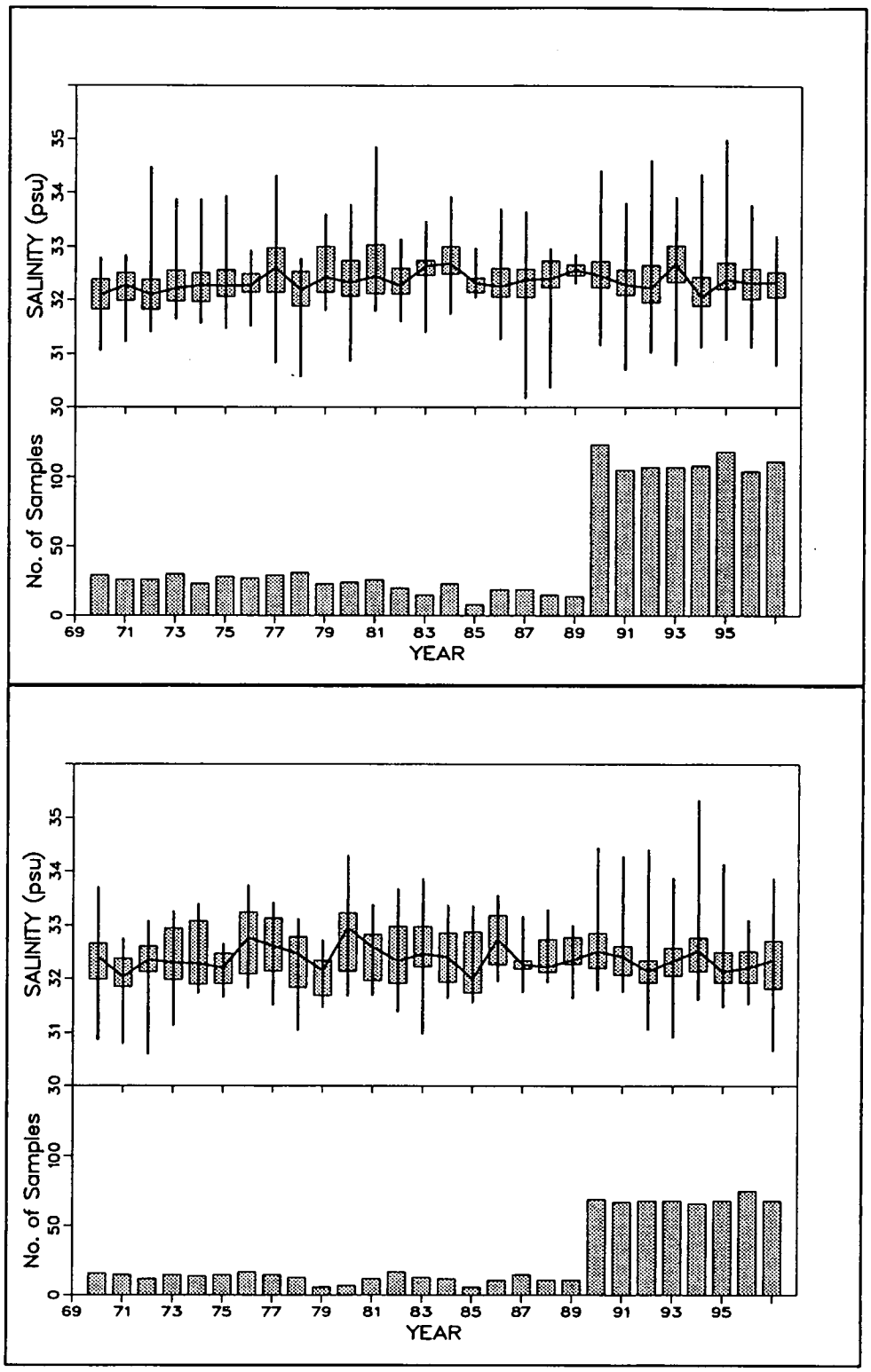


Figure 15: Box and whisker time series plots of 50 meter water salinities for each year within 4VW (top panel) and 4X (lower panel). The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each year over the entire 1970–97 period.

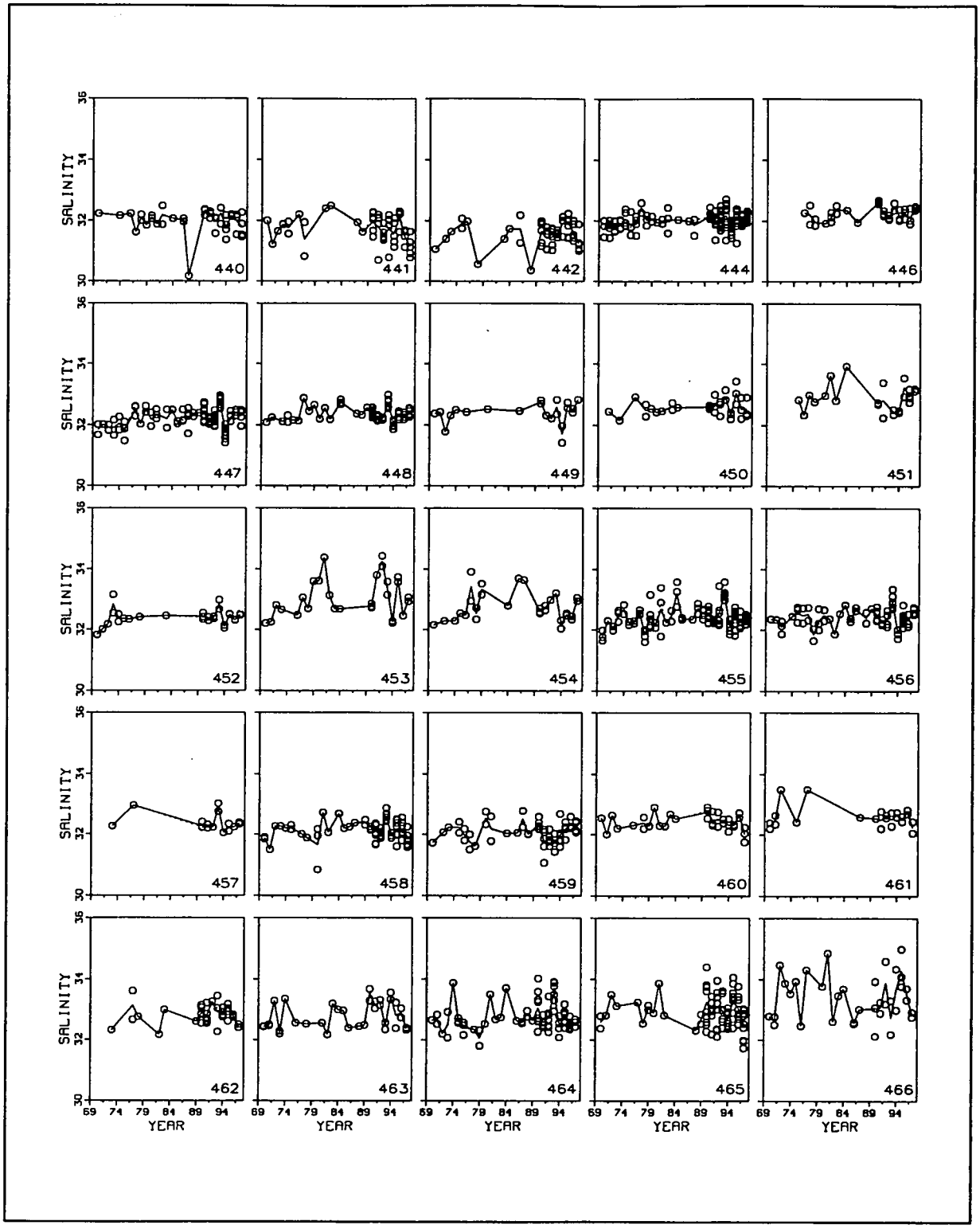


Figure 16: Time series of 50 meter salinities within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

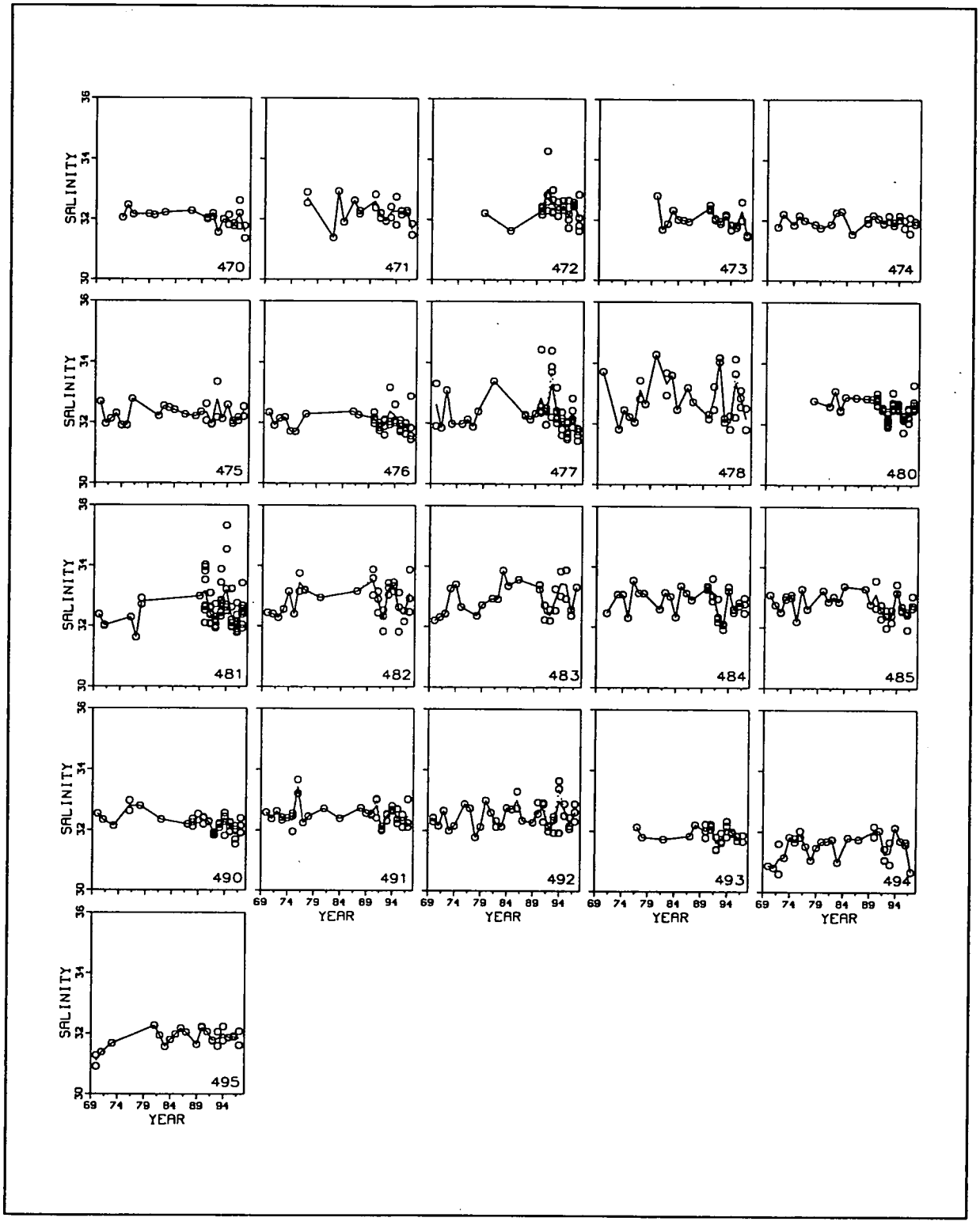


Figure 16: continued