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Overview of 2000 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)

Vue d'ensemble de l'effort d'échantillonnage hydrographique et des conditions de température et de salinité près du fond en 2000 pendant les relevés canadiens du poisson de fond effectués sur la plate-forme Scotian et dans la baie de Fundy (4VWX)

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Abstract

The Canadian Department of Fisheries and Oceans conducts bottom trawl surveys on an annual basis within NAFO subdivisions 4VWX as part of its approach for developing scientific advice on the status of groundfish resources. Vertical profiles of water temperatures and salinities are measured during these surveys. The sampling locations are randomly allocated as part of the stratified random design of the survey. Each year the most recent sampling effort and associated temperature and salinity data are summarised and compared to the historical data from the survey. The summary presents strata specific analyses of the data so fisheries assessment biologists can easily scan the overview for conditions of interest to their species areas. In the present overview, we present a summary of sampling effort and the resulting estimates of water temperatures and salinities during the 1970-2000 summer surveys conducted within NAFO subdivisions 4VWX. The focus is on the near-bottom conditions in the year 2000 and how these compare to conditions encountered throughout the history of the survey series. In 2000, sampling was conducted from 4 July (consecutive day 187) to 28 July (consecutive day 210). CTD profiles were obtained from all 48 strata. The analyses indicate that in the year 2000 near-bottom temperatures throughout NAFO subdivisions 4VWX area were greater than those in most of the previous years and above the 1980-90 baseline mean. This was due mainly to a relative lack of low temperature water. Salinities in the year 2000 within 4VW were lower than most previous years. However, relative to the 1980-90 strata means, the 2000 strata specific anomalies varied between positive and negative. In NAFO subdivision 4X, the salinities were greater than most previous years and the strata mean salinities for 2000 were generally above the 1980-90 means. This was mainly due to a relative lack of low salinity (<~32.5) water.

Résumé

Le ministère des Pêches et des Océans du Canada effectue chaque année des relevés au chalut de fond dans les divisions 4VWX de l'OPANO afin de pouvoir formuler des avis scientifiques sur l'état des ressources en poisson de fond. Des profils verticaux des températures et des salinités de l'eau, mesurés à des points d'échantillonnage répartis au hasard comme le prescrit l'échantillonnage aléatoire stratifié, sont établis lors de ces relevés. Chaque année, l'effort d'échantillonnage le plus récent et les données connexes sur les températures et les salinités sont résumés puis comparés aux données historiques. Ces résumés contiennent des analyses des données spécifiques à chaque strate de sorte à ce que les biologistes responsables de l'évaluation des pêches peuvent facilement parcourir la vue d'ensemble et y relever les conditions pertinentes à l'espèce concernée. Nous présentons dans ce document un résumé de l'effort d'échantillonnage et des estimations résultantes des températures et des salinités de l'eau issus des relevés d'été effectués entre 1970 et 2000 dans les divisions 4VWX. L'accent est mis sur les conditions près du fond en 2000 et sur leur comparaison aux conditions rencontrées tout au long de la série de relevés. En 2000, l'échantillonnage a eu lieu du 4 juillet (jour courant 187) au 28 juillet (jour courant 210). Des profils CTP ont été établis pour les 48 strates. Les analyses révèlent que les températures près du fond en 2000 dans l'ensemble des divisions 4VWX étaient supérieures à celles mesurées la plupart des années précédentes et à la moyenne de référence pour 1980-1990. Cela était principalement imputable à l'absence relative de faibles températures de l'eau. La salinité de l'eau dans 4VW en 2000 était plus faible que pendant la plupart des années précédentes. Par contre, les anomalies spécifiques à chaque strate en 2000 oscillaient entre positives et négatives par rapport aux moyennes des strates pour 1980-1990. Dans la division 4X, la salinité était supérieure à celle observée pendant la plupart des années précédentes, alors que la salinité moyenne des strates en 2000 était généralement supérieure à la moyenne pour 1980-1990. Cela était principalement imputable à l'absence relative d'eau de faible salinité (<~32,5).

INTRODUCTION

The Canadian Department of Fisheries and Oceans conducts bottom-trawl surveys in July on an annual basis within NAFO subdivisions 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 have been summarised on an annual basis by Page et al (1994,1995,1996,1997) and Losier et al (1998,1999).

The intent of each summary has been to briefly describe, on a strata specific basis, the extent and nature of the hydrographic sampling effort and the observed temperature and salinity conditions within the 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 1970-2000 summer surveys conducted within NAFO subdivisions 4VWX. The focus is on the near-bottom conditions in the year 2000 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 1970-2000 research vessel, summer groundfish bottom-trawl surveys conducted in NAFO subdivisions 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 has been 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). Relatively new deep strata (not shown), identified as 397, 398, 399, 496, 497, and 498 in the database are ignored in this report because of the lack of historical data for these areas. As in the past, two standard summer surveys (Fig. 1) were conducted in 2000. Survey NED2000426 covered the western Scotian Shelf (4X) and NED2000431 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 1990-99 depth profiles of water temperatures and salinities were measured with a Seabird Electronics Model (SBE) 19 or 25 internally recording conductivity, temperature and depth (CTD) profiler using the procedures described below for 2000. 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 2000, 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 a SBE 25 CTD profiler. 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 10 meters below the sea surface and allowing it to equilibrate with ambient conditions for about 5 minutes. At some stations a water bottle equipped with a reversing thermometer was triggered at the end of this period to obtain water samples and temperatures for later calibration of the CTD temperature and salinity sensors. After the equilibration period, the instrument was raised to just below the sea surface and then lowered to within a few meters of the bottom at a drop rate of approximately 20-40 $m \bullet min^{-1}$. 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 the Seasoft Software with a Standard processing deck provided by the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. A combination of quantitative and visual techniques, including range checks, despiking routines and density inversion algorithms were also applied to the data. The CTD were calibrated with reversing thermometer derived measurements of temperature and the salinometer derived measurements of water sample salinities. Corrections were applied where necessary.

The edited CTD and bottle data are 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. The data are also forwarded to the national Marine Environmental Databases (MEDS) and the Maritimes Regional working hydrographic database.

RESULTS

Sampling

The summer surveys have been conducted between 23 June (consecutive day 175) and 6 August (consecutive day 219 Fig. 2,3). The first survey traditionally samples the 4X area and the second survey samples the 4VW area with the sampling dates 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 some of the first few years of the survey series (~1970-80) were 5-20 days later than in the more recent years.

In 2000, sampling was conducted from 4 July (consecutive day 187) to 28 July (consecutive day 210) (Fig. 2,3). CTD profiles were obtained from all 48 strata (Fig. 1,2,3). Hence, sampling dates in 2000 were typical of those in recent years although 4V sets were generally a few days earlier than those sampled during the more recent years. As in previous years, the random allocation of the sampling stations resulted in the stations within some strata not being widely distributed throughout the strata (e.g., 472 and 482).

The maximum CTD profile depths ranged from <50m to >300m. The distribution of near-bottom depths varied between strata (Fig. 1,4,5). In 2000, the depths sampled were, for the most part, consistent with previous years with the exception of Strata 472 where no shallow depth stations were occupied. In the past the sampling depths were all < 170 m for this strata.

Near-Bottom Temperatures

The overall range of near-bottom temperatures within the survey domain and during the complete survey time period (1970-2000) is approximately -1°C to 15°C (Fig. 6,7). The range of temperatures within a stratum differs considerably between strata (Fig. 8). In some strata, the range is only a few degrees, whereas in others, it is >10°C. The near-bottom temperatures in 2000 ranged from 1.69 to 11.14°C, which was within the previously observed limits. In 4VW (strata 440-466) near-bottom temperatures from many stations were above the 1970-99 strata medians and many of these were above the 75^{th} percentiles. Although in strata 441,449,450,455,456 and 465 some temperatures were also below the median, temperatures in 50% of the strata were all above the median. An historical high temperature was recorded in strata 447. Only strata 455 recorded a value below the 1970-99 25^{th} percentiles. Most of the near-bottom temperatures in 4W (strata 452-466) were above the 75^{th} percentiles with values in strata 456, 458, 460, 462, 465 and 466 approaching historical highs. In 4X, as in 4VW, many of the 2000 temperatures were above the 1970-99 strata medians with many observations

above the 75th percentiles. Historical high values were recorded for strata 483. Only strata 478 had a recorded value below the 25th percentile.

The cumulative frequency curves of the area unweighted temperatures (Fig. 9, 10) indicate that the temperatures sampled in 2000 were near normal in 4VW in the mid and upper temperature range. In the lower temperature ranges there is a complete lack of cold water (<2°C) as had been recorded in previous years (Fig. 11). However, the cumulative frequency for 4X was well above normal for the entire temperature range, with temperatures not dropping below 5 °C.

The geographic distributions of the 2000 strata mean temperatures (Fig. 12) is similar to that of the long-term (1980-90) strata means (Fig. 13). The lower temperatures (<3°C) occurred on the eastern Scotian Shelf. Strata 442 was observed to have the lowest value. The higher temperatures occur on the central shelf, upper Bay of Fundy, and the deep waters between Georges and Browns Banks (>8°C). The highest near-bottom mean temperature occurred in strata 466. Mean temperatures throughout the remainder of the survey domain were between 2°C and 9°C.

These observed trends in strata means are seen more clearly by the anomalies (2000 temperatures – longterm means (1980-1990)) shown in Figures 14 and 15. Only strata 464 and 478 recorded negative strata mean temperature anomalies.

The time series of area unweighted temperature percentiles is shown in Figure 16. In 4VW, the median 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 early to mid 1990's. From 1990 to 1992, the median temperatures remained below 4°C and the 25th percentile remained below 2°C. In 1996, the distribution of temperatures was still centred below those in the late 1970's and early 1980's. For 2000, temperatures for 4VW were slightly higher than 1999 and fall within the same temperature ranges recorded in the late 1970's.

In 4X values are generally higher than those in 4VW (Fig. 16). With the exception of only a few years (1970-71, 1991-92, 1995-96 and 1998), the 25th percentile of the temperatures was above 6°C. In contrast to 4VW, the time trends in unweighted median temperatures are relatively weak. In 4X, the median temperature generally increased from 1970 to the recorded historical high in 1976. Values in 1977-78 and 81 were similar to those of the early 70s. The medians in the late 80s and early 90s were below those in the 1970s with another warming trend from 1992-94. Median temperatures were then stable for 1995-97 and historically low in 1998. In 1999 temperature medians increased by almost 2°C. The 75th percentile in 2000 is close to an historic high.

These general patterns are also reflected in the time series of stratified mean temperatures (Fig. 17). The 2000 median value for 4W is close to the historic highs. The strata specific time series of temperatures are shown in Figure (6,7). The temperatures within the relatively cold strata (441-445, 447-48, and 457-459) generate the general pattern indicated above for 4VW. There are no significant temperature trends for the other 4VW strata. The general pattern for 4X as a whole is representative of the pattern in each of the 4X strata.

In Figure 18, the location of eastern Scotian Shelf sampling stations in which temperatures below 0^{o}C were observed anywhere within the water column are plotted for each of the 1970-2000 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. The conditions in 1995, 1996 and 1997 are similar to those in 1974 and 1987 with only a few stations having temperatures less than 0^{o}C. Sampling in 1998-2000 indicates no 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 water intrusions on the surveys.

Hydrographic profiles prior to 1990 were obtained 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 (Fig. 11) also suggests the volume of cold water in the western portion of the 4VW area increased in the early 1990's and that relatively cold water persisted until 1998. In 1999 and 2000 few stations recorded values of less than 2^{o}C in the temperature profile.

Near-Bottom Salinities

The overall range of near-bottom salinities within the survey domain and during the complete survey time period (1970-2000) have ranged from about 30.5 to 35 psu (Fig. 1,19,20). As with temperature, the salinity range differs between strata. The range in some strata is only a few tenths of a psu, whereas it is >2 psu in others (Fig 21). 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). Typically the lower salinities are on the shallow banks and in the upper Bay of Fundy and the higher salinities are observed in the basins and along the shelf edge (deeper depths). Salinities within the remaining strata range between about 33 and 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 strata mean salinities for 2000 (Fig. 12).

The near-bottom salinities in 2000 ranged from 31.03 to 35.33 which was within the previously observed limits (Fig. 21). In most 4VW strata, the 2000 observations were distributed throughout the previous range of values with values below strata medians on the central part of 4VW (strata 452,455,456,459 and 464) and 4Vn (strata 440) and above the strata medians on the eastern and western part of 4VW. Only strata 464 had no recorded salinity values above both long-term (1980-90) and 1970-1999 medians. In 4X salinities in the eastern Scotian Shelf were mostly above the 75th percentiles whereas the western Scotian Shelf recorded salinity values around the baseline medians. Only 8 of the 22 stratas in 4X recorded salinities below the baseline medians. Bay of Fundy (Strata 490 to 495) recorded many values over the 75th percentiles.

Cumulative frequency distributions of the area unweighted salinities (Fig. 9, 10) indicates that the salinities for the year 2000 were slightly below normal in 4VW, but fell above the expected range in 4X.

The geographic distribution of the 2000 strata mean salinities (Fig. 12) is similar to that of the long-term (1980-90) strata mean salinities (Fig. 13). The spatial pattern in the 2000 anomalies is shown in Figure 14 and 15. Only strata 464 had a negative anomaly greater than 0.5 psu and strata 451 and 470 had positive anomalies approaching 0.5 psu and strata 471 exceeding 0.5 psu.

Like temperatures, the near-bottom salinities have varied inter-annually. In NAFO subdivisions 4VW, the median salinities from 1970 to 1987 were generally above 33 psu (Fig 22). From 1975 to 1981, the salinities tended to increase to a historical high in 1984. The salinities trended downward from about 1984 to 1991 and have exhibited a weak upward trend throughout the early 1990's. From 1993 to 1997 median values decreased. They increased during 1998, 1999 and decreased in 2000. The 2000 values were close to those recorded in the early 1970's and mid eighties. Since 1987 most of the median salinity values have remained below 33 psu. In 4X (Fig. 22), the trends in unweighted median salinities are relatively weak and with the exceptions of a few years (1991,1995 & 1998), the median salinity has been above 33 psu. In 2000, the median salinity was 33 psu.

The stratified mean salinities for 4W and 4Vs (Fig. 17) show trends similar to that described above and correspond with those of temperature. The salinities in 4X Scotian Shelf have been decreasing throughout the survey series but 1999 and 2000 stratified mean salinities have recovered to values observed during the late 1970s. In 4W, the salinities were variable until the early 1980's when a decreasing trend began. This trend continued into the late 1990's. In 4Vs, salinities increased during the early 1970's, decreased throughout the 1980's and increased during the 1990s. In 4X Bay of Fundy, the salinities increased during the 1970's, dipped in the

early 1980s and have been decreasing throughout the 1990s until 1999. These values have since recovered to those recorded values of the early eighties.

DISCUSSION

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

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.

In conclusion, the temperatures throughout the 4VWX area were above the baseline mean in the year 2000. Salinities decreased in 4VW relative to 1999 although they were still near the baseline mean. In 4X, the salinities remained relatively high.

Acknowledgements

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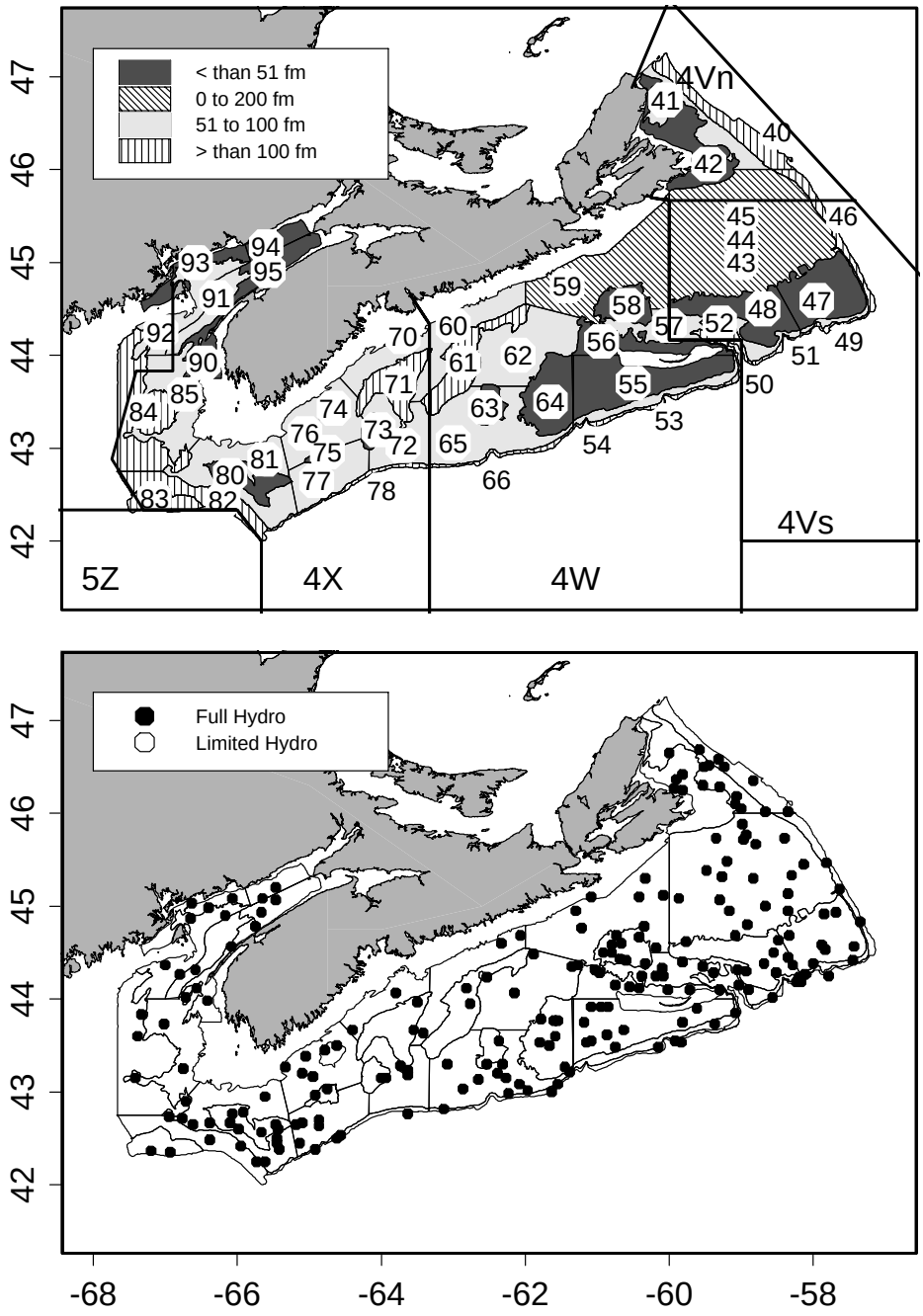

Figure 1: Domain and strata boundaries (last two digits shown) for summer Scotian Shelf surveys (top panel) and the locations of hydrographic stations (bottom panel) sampled during the 2000 summer 4VWX survey-missions NED2000426 and NED2000431.

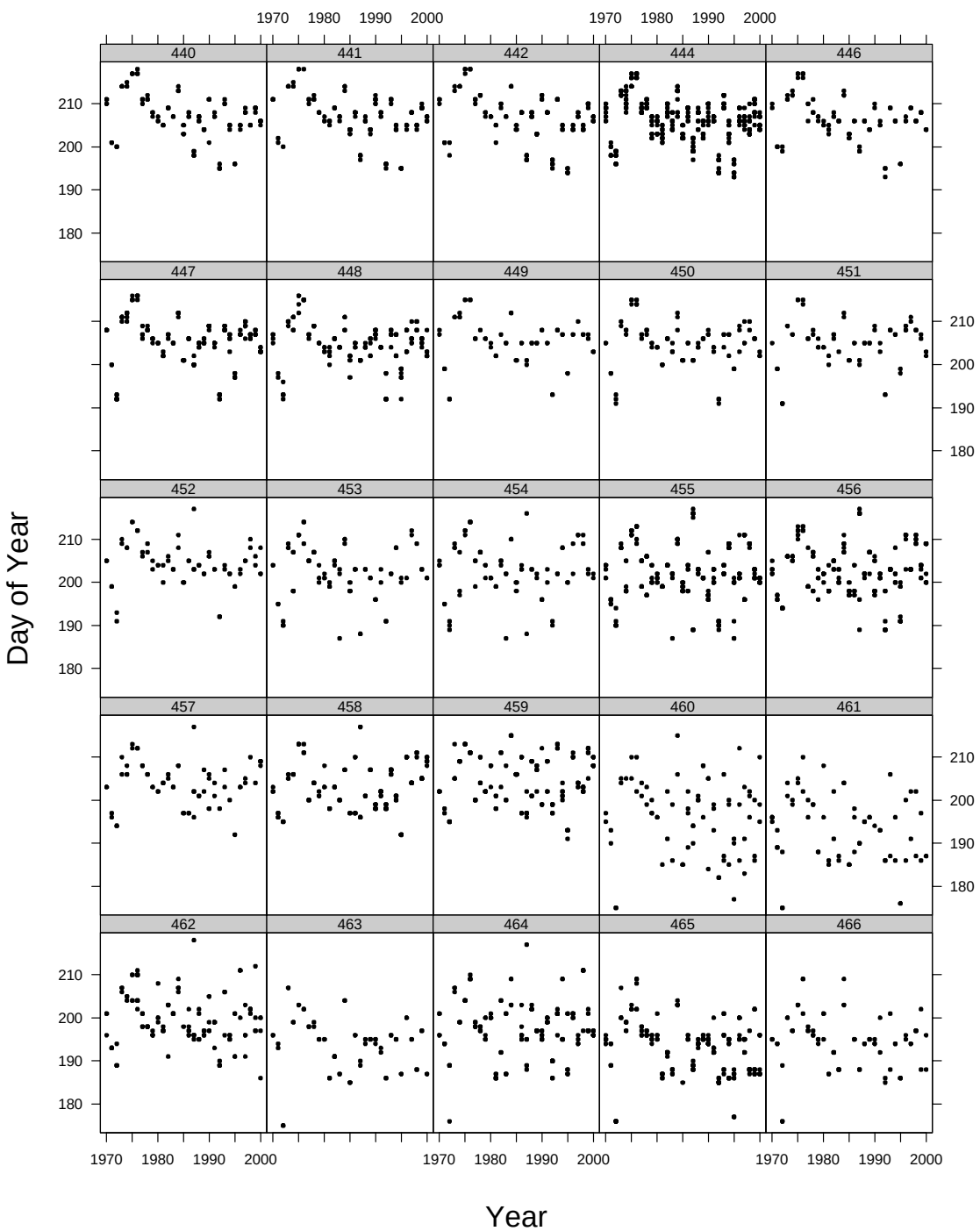

Figure 2: Time series of consecutive day of sampling for 4VW summer surveys. Numbers in strip panels indicate strata locations. Closed circles represent one sampled station.

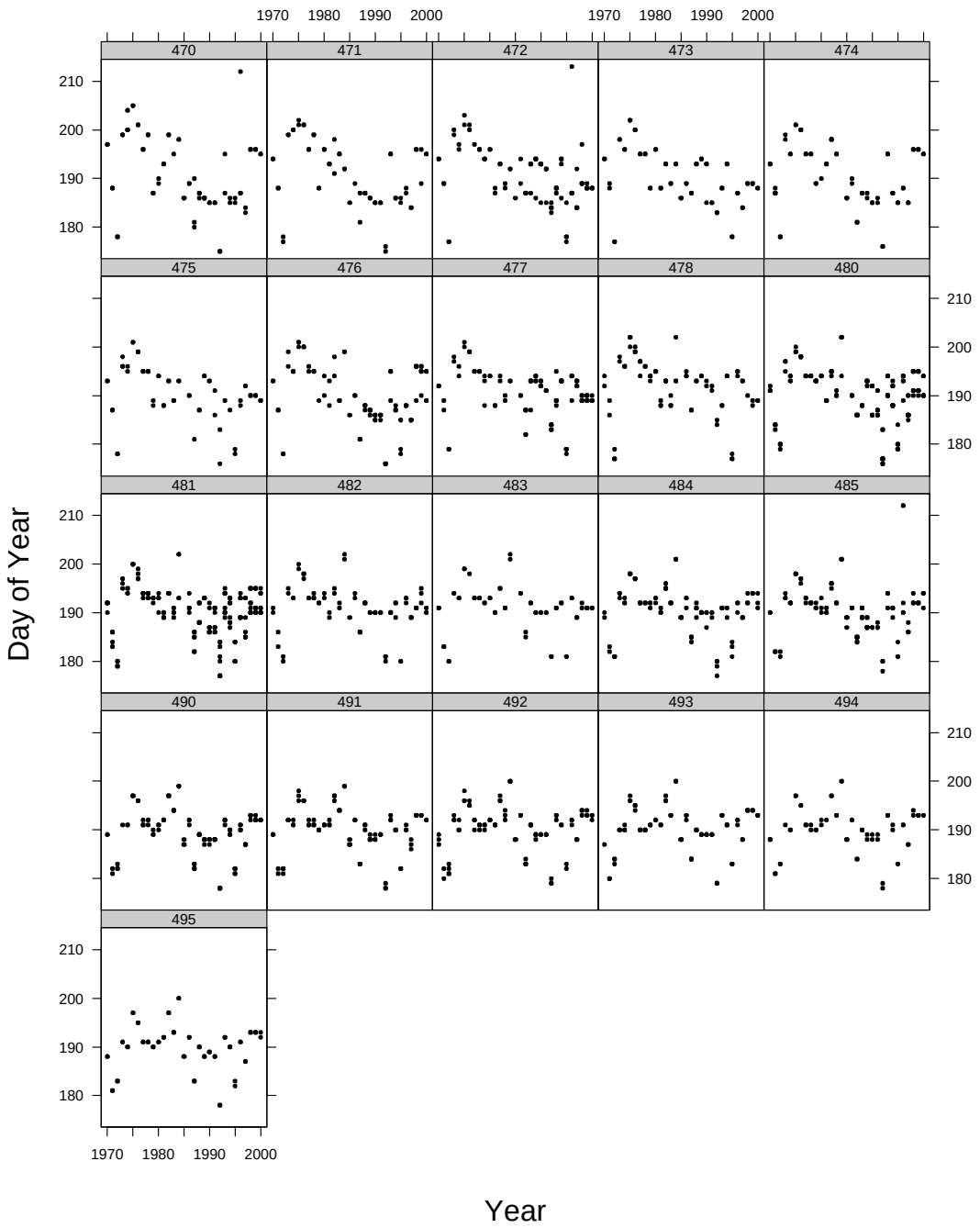

Figure 3: Time series of consecutive day of sampling for 4X summer surveys. Numbers in strip panels indicate strata locations. Closed circles represent one sampled station.

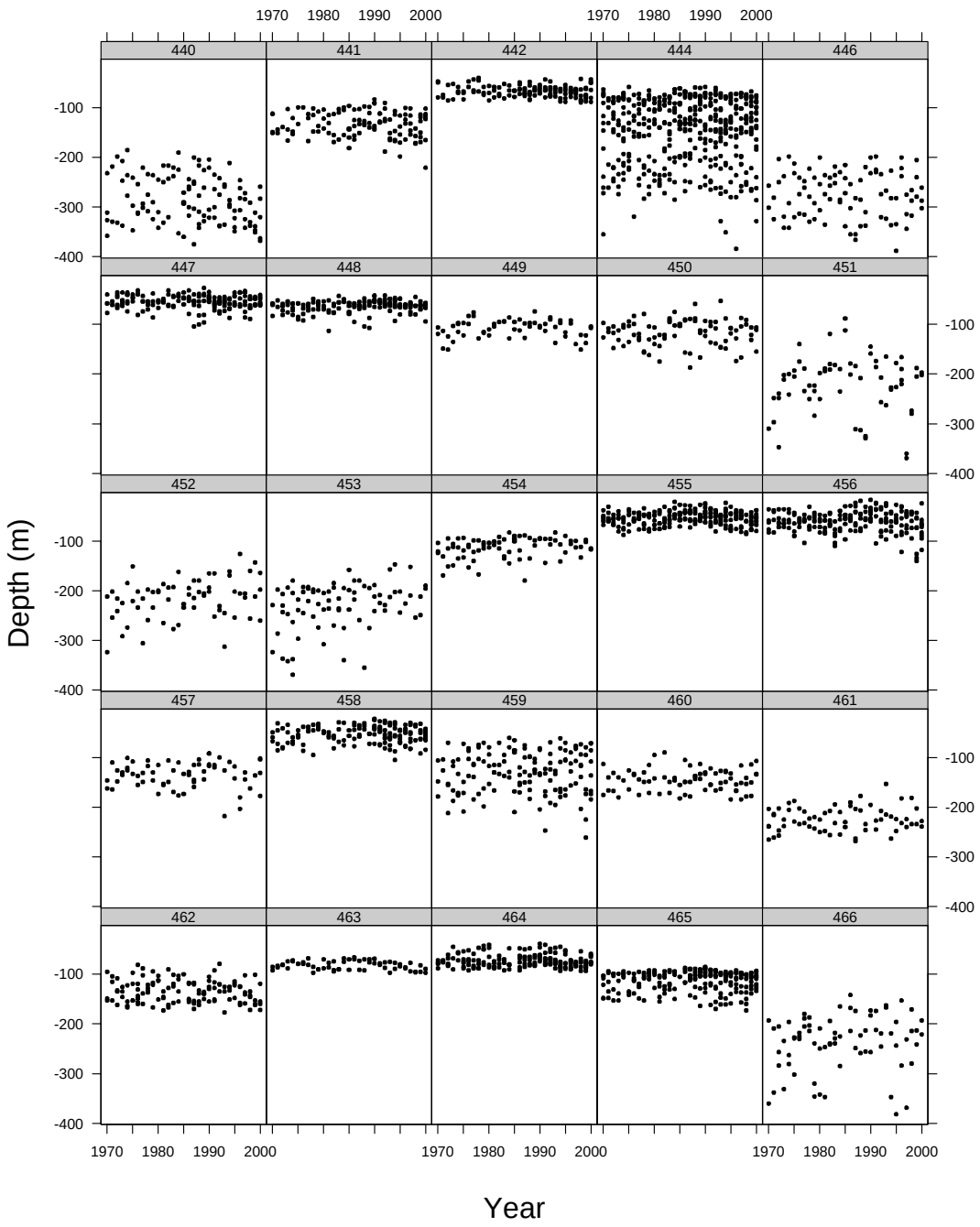

Figure 4: Time series of sampling depths for 4VW summer surveys. Numbers in strip panels indicate strata locations. Closed circles represent one sampled station.

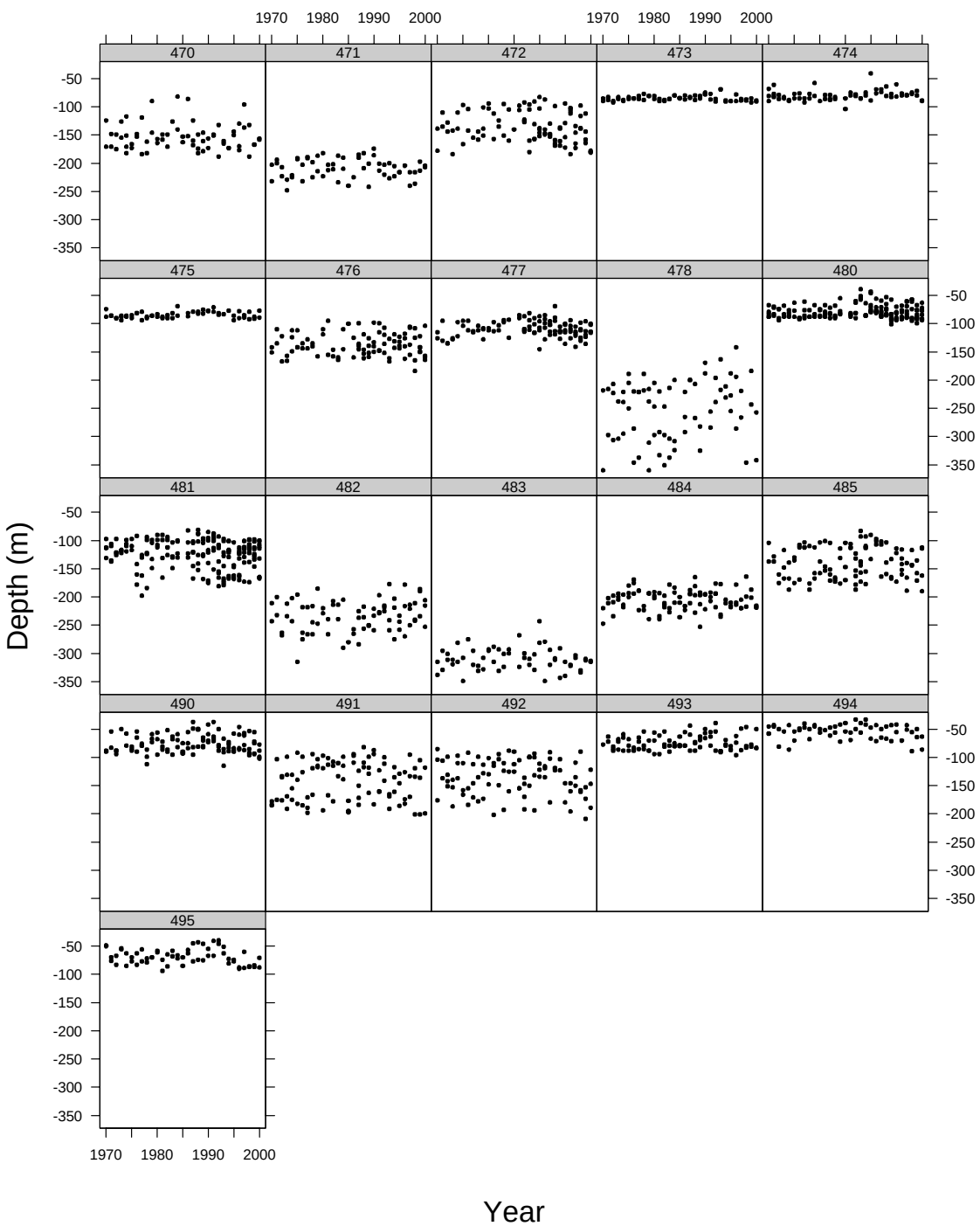

Figure 5: Time series of sampling depths for 4X summer surveys. Numbers in strip panels indicate strata locations. Closed circles represent one sampled station.

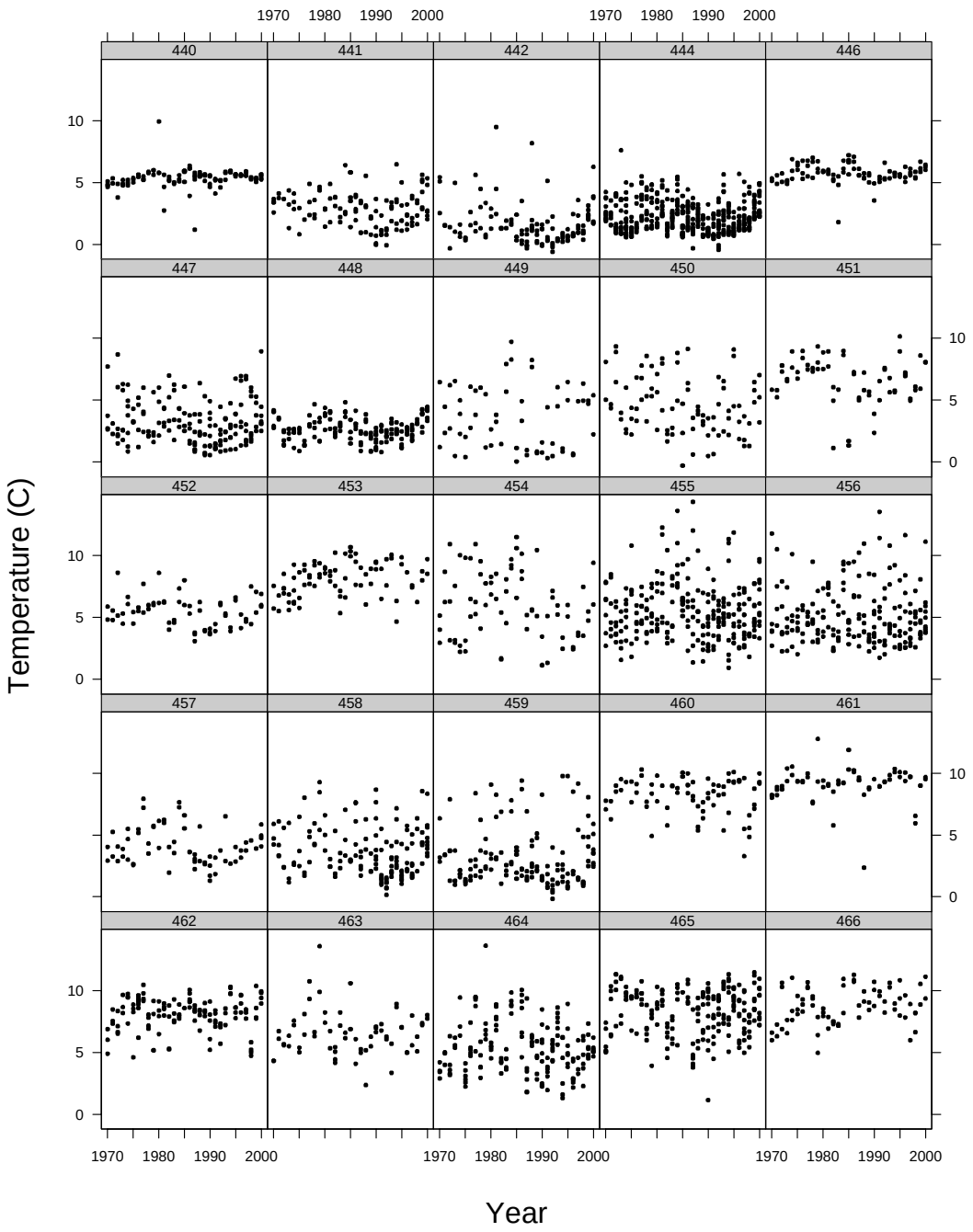

Figure 6: Time series of near-bottom temperatures for 4VW summer surveys. Numbers in strip panels indicate strata locations. Closed circles represent one sampled station.

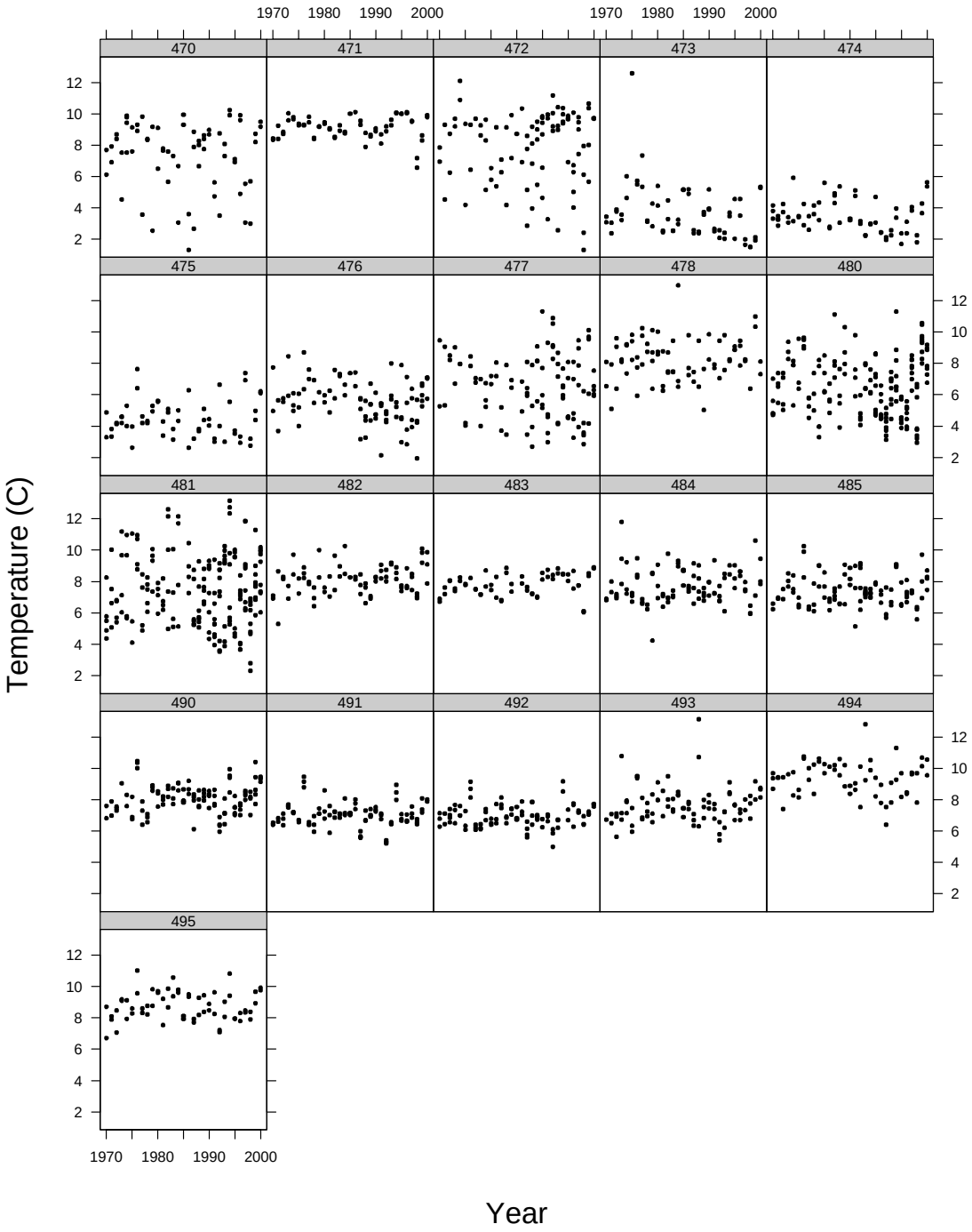

Figure 7: Time series of near-bottom temperatures for 4X summer surveys. Numbers in strip panels indicate strata locations. Closed circles represent one sampled station.

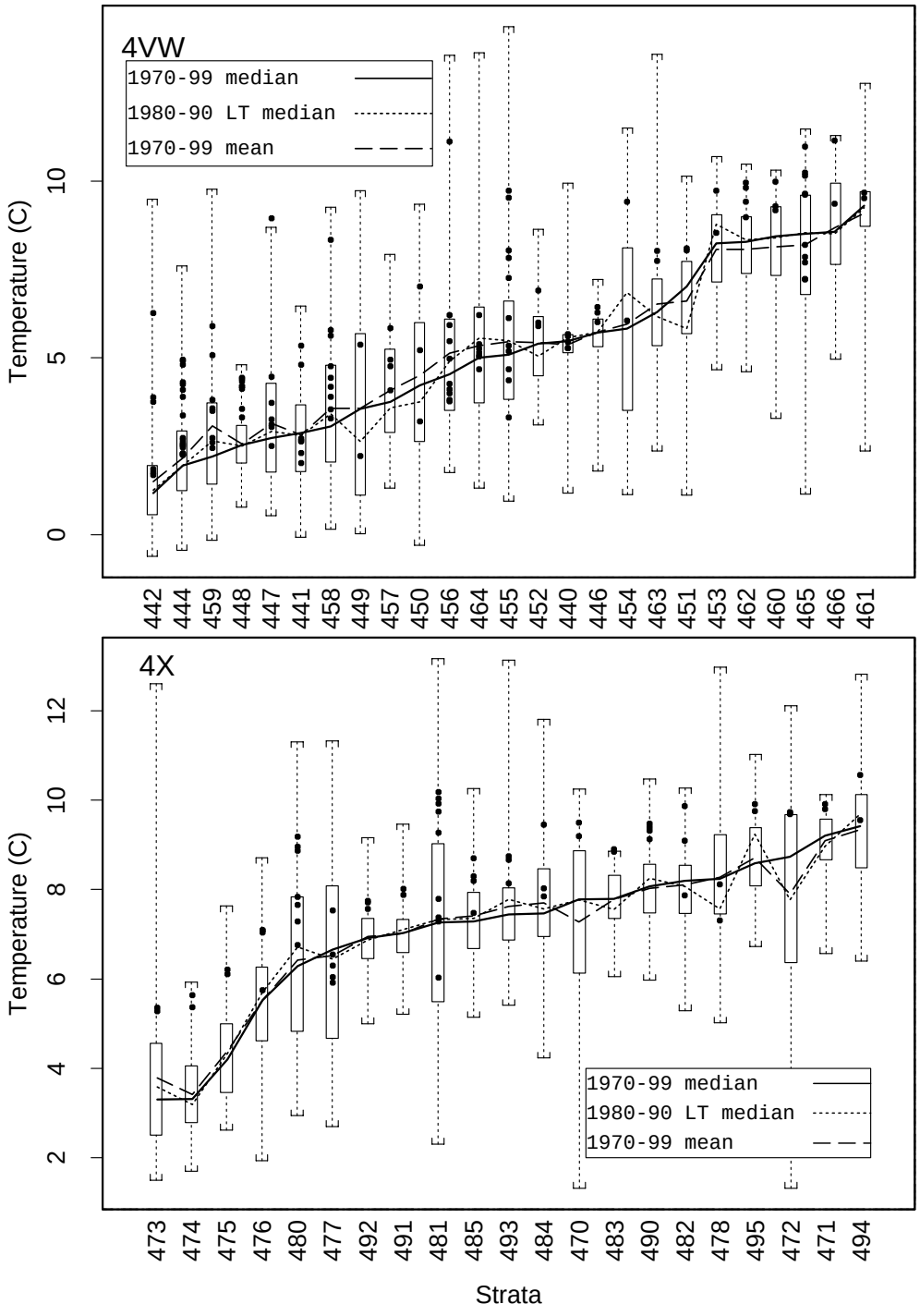

Figure 8: Box and Whisker plots of strata specific near-bottom water temperatures for summer 4VWX surveys. Solid circles are observed temperature data for 2000.

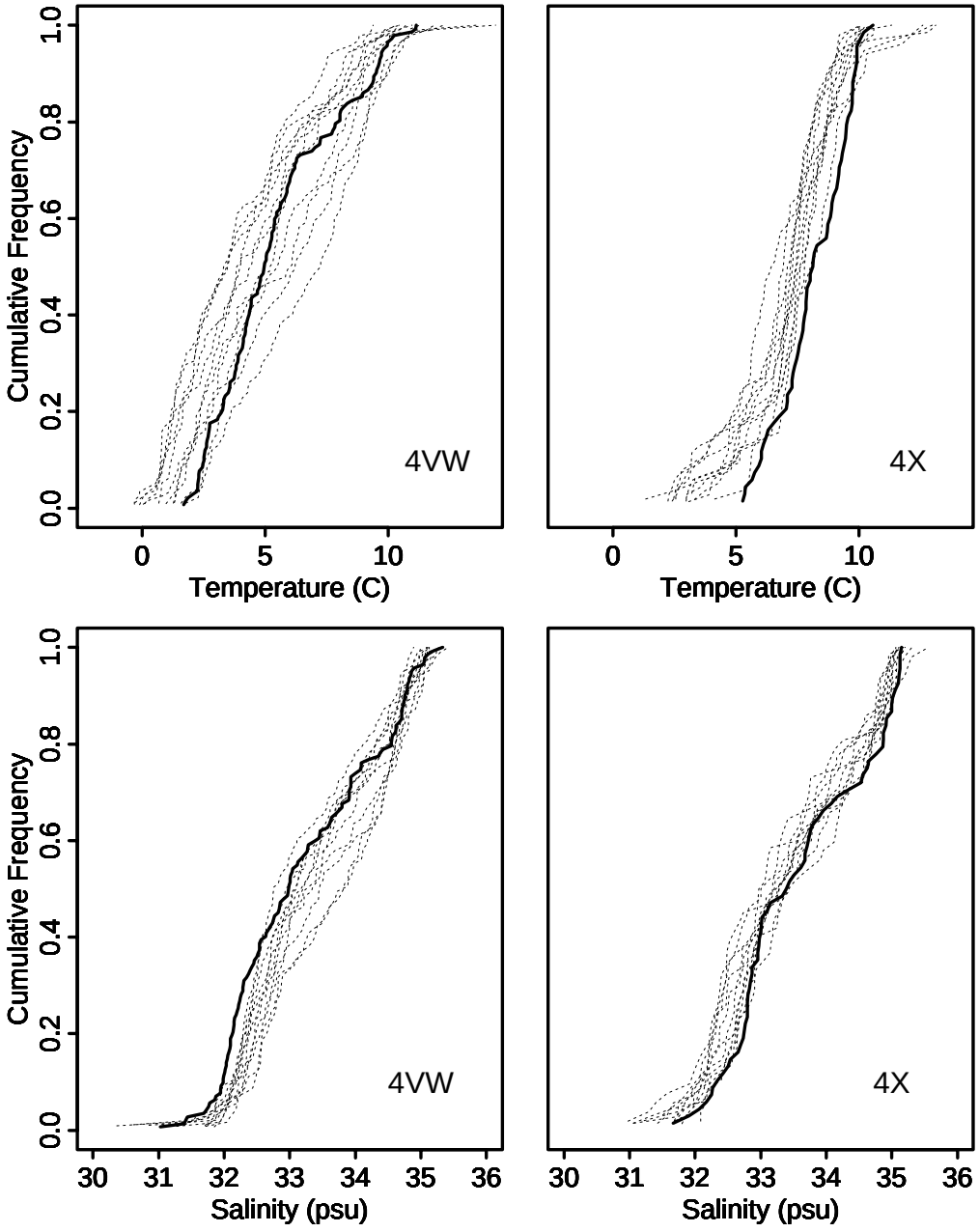

Figure 9: Cumulative Frequency curves of longterm near-bottom water temperatures and salinities for 4VWX 1980-1990 surveys. Bold line is for 2000 data.

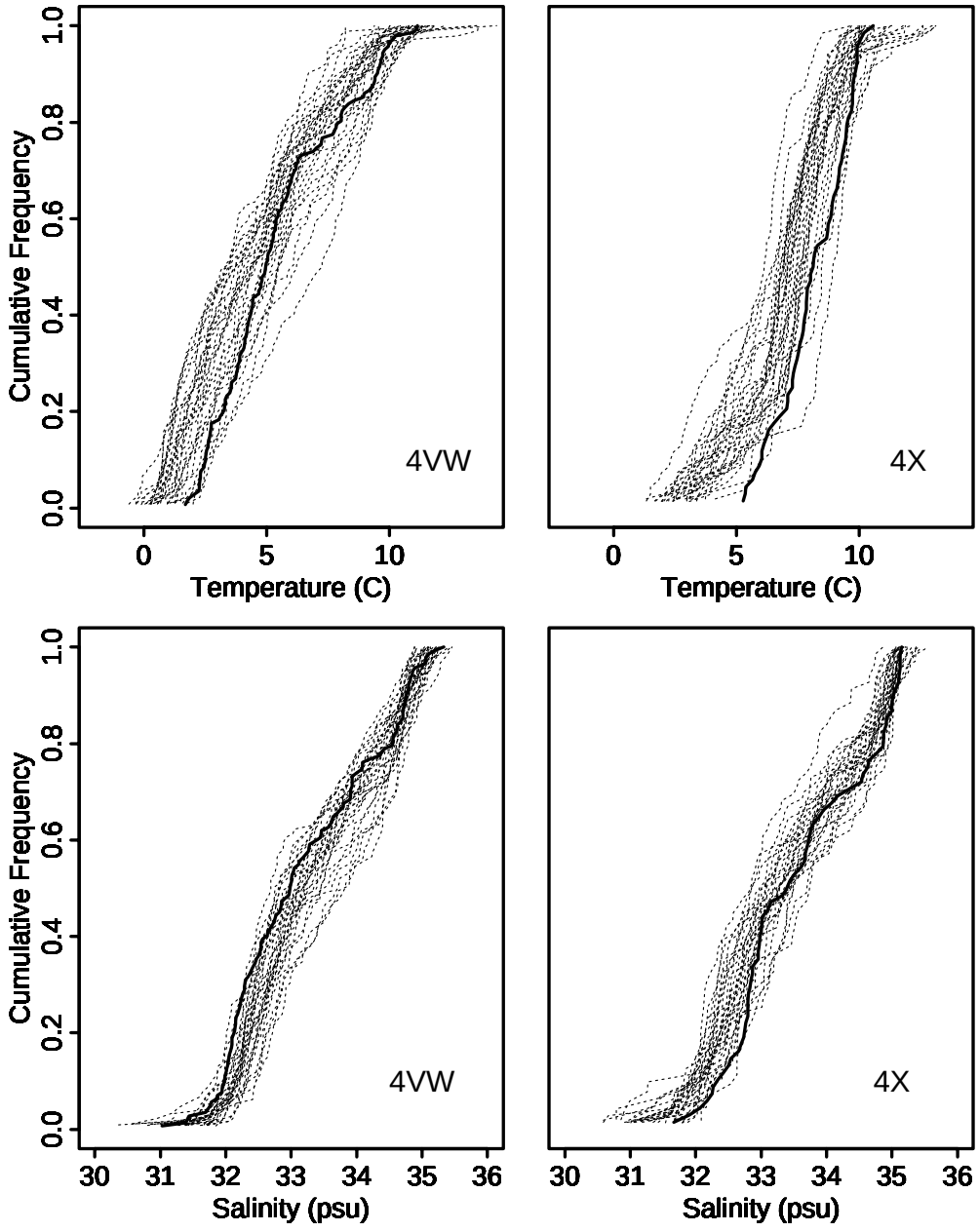

Figure 10: Cumulative Frequency curves of near-bottom water temperatures and salinities for 4VWX 1970-1999 surveys. Bold line is for 2000 data.