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Overview of Near-Bottom Water Temperature and Salinity Conditions Observed During the Groundfish Research Vessel Surveys Conducted within the Scotia-Fundy Region, NAFO Areas 4VWX and 5Z in 1995

by

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ABSTRACT

Near-bottom water temperatures and salinities that were measured during the spring (5Z and 4VsW) and summer (4X and 4VW) 1995 Canadian research vessel bottom-trawl surveys are summarized. In 1995, the spring and summer temperatures and salinities in the 5Z and 4VsW surveys continue to be within the historical ranges observed during the surveys. The temperatures on the eastern Scotian Shelf are still below normal but are above the minimum observed in 1992. The temperatures on the western Scotian Shelf and on Georges Bank continue to be variable but several degrees warmer than those over the eastern Scotian Shelf. As in previous years, the conditions within many strata are confounded by changes in sampling date and location (horizontal and vertical) and, hence, the time trends in the survey series are not necessarily indicative of trends in hydrographic climate. The trends, however, are indicative of interannual variation in the conditions sampled for fish abundance.

RÉSUMÉ

Nous résumons les mesures de la température et de la salinité près du fond effectuées en 1995 pendant les campagnes canadiennes de chalutage scientifique menées au printemps (5Z et 4VsW) et à l'été (4X et 4VW). En 1995, les températures et les salinités mesurées pendant les relevés menés dans 5Z et 4VsW au printemps et en été restent dans les plages historiques observées jusque-là au cours des missions scientifiques. Sur la partie est du plateau néo-écossais, les températures sont encore inférieures à la normale, mais elles dépassent le minimum observé en 1992. Sur la partie ouest du plateau néo-écossais et sur le banc Georges, les températures continuent à être variables, mais se situent plusieurs degrés au-dessus de celles de la partie est du plateau. Comme les années précédentes, les conditions qui règnent dans de nombreuses strates sont perturbées par les changements dans les dates et le point d'échantillonnage (dans le sens vertical et horizontal), et les tendances temporelles des séries de données recueillies ne sont donc pas nécessairement indicatives des tendances du régime hydrographique. Ces tendances indiquent toutefois la variation interannuelle des conditions qui sont mesurées pour évaluer l'abondance du poisson.

INTRODUCTION

The Canadian Department of Fisheries and Oceans conducts bottom-trawl surveys on an annual basis within NAFO unit areas 4VWX and 5Z as part of its approach for developing scientific advice on the status of groundfish resources. Water temperatures and salinities are routinely measured during these surveys since it is recognized that changes in environmental conditions may influence the behaviour, distribution, physiology, growth and survival of the fish. These, inturn, may influence fish catchability and availability and hence estimates and indices of their abundance (Pinhorn and Halliday 1985, Smith et al. 1991, Smith and Page 1996).

The temperatures and salinities measured during these surveys are summarized on an annual basis (eg. Page, Losier and McRuer 1994, 1995). The intent of these overviews is to briefly describe the extent and nature of the hydrographic data, the hydrographic conditions within recent resource assessment surveys and to place these within an historical context. In so doing it is hoped that trends and anomalies in conditions and sampling procedures may be identified. These conditions can then be examined more fully to address their influence on estimates and interpretations of biological and fisheries data considered during the regional stock assessment process . These latter analyses are be species and stock specific since each species and stock may show unique associations with hydrographic conditions (eg.Page et al. 1994, Smith and Page 1994, Smith et al. 1994, Stephenson et al. 1995).

In this overview a summary of the hydrographic sampling effort and the resulting estimates of water temperatures and salinities during the 1995 Canadian research vessel bottom-trawl surveys conducted during the spring within NAFO statistical areas 4VsW and 5Z and during the summer within area 4VWX is presented. The focus is on the near-bottom conditions since these are considered the most relevant to groundfish. The conditions are discussed in the context of conditions encountered throughout the history of the survey series.

MATERIALS and METHODS

Data Sources

The hydrographic data summarized in this report were collected as part of the Canadian Department of Fisheries and Oceans, Maritimes Region, stratified random groundfish bottom-trawl research vessel surveys conducted in NAFO unit areas 4VWX and 5Z as part of the regional groundfish stock assessment process. Particular emphasis is placed on the 1995 surveys.

In 1995, four standard groundfish bottom-trawl surveys were conducted within the Scotia-Fundy region. These included two spring surveys (4VsW and 5Z) and two summer surveys, one mainly covering the western Scotian Shelf (4X) and the other, the eastern Scotian Shelf (4VW). All of the surveys utilized a stratified random design in which the strata are primarily defined on the basis of bottom depth and secondarily on the distribution of groundfish, mainly haddock (Doubleday 1981). Survey designations, sampling dates,

hydrographic sampling gear and the number of sampling stations are summarized in Table 1.

In order to place the environmental conditions observed during the 1995 surveys into an historical context, the hydrographic information from the full series of standard spring and summer surveys conducted in unit areas 4VWX and 5Z from 1970-94 are included in the time series presentations. A list of all surveys is given in Table 2a,b.

Temperature and Salinity Measurement Techniques

Within the 1995 bottom-trawl surveys, profiles of water temperature and salinity were primarily measured using an internally recording Seabird model 19 or 25 conductivity, temperature and depth (CTD) profiler. The instruments were attached to a hydrographic wire spooled on a variable speed hydraulic winch. A CTD profile was taken by lowering the instrument several meters below the sea surface and allowing it to equilibrate with ambient conditions for 5 minutes. The instrument was then raised to less than 1 meter below the sea surface and lowered to within 5-10 m of the bottom at a rate of approximately 30-40 $m \cdot min^{-1}$. After 5 minutes at the maximum depth or after the 10 m equilibration period, a water sample and water temperature recording were obtained by mechanically triggering a reversing thermometer and a Niskin water bottle. When a CTD was not available, efforts were made to take a surface water temperature with an electronic thermometer and a near-bottom temperature with a reversing thermometer. A laboratory salinometer was used to obtain salinities from the water samples. At some stations, XBT (expendable bathythermograph) temperature profiles were taken.

In the years, 1970 to 1989, profiles of temperature and salinity were taken at less than about one third of the sampling stations. Measurements were taken at standard hydrographic sampling depths (0,10,20,30,50,75,100,150 and 200 meters). Surface temperatures were sampled usinf a bucket and mercury thermometer, and sub-surface temperatures with reversing thermometers. Salinities of water samples from the surface bucket or water bottles were measured with a salinometer. Since 1990, temperatures and salinities have been measured using a Seabird Model 19 or 25 CTD and efforts have been made to obtain hydrographic profiles at all sampling stations. This has resulted in obtaining CTD profiles at more that 70% of the stations occupied during the spring surveys and at more than 90% of the stations during the summer surveys (Table 2a,b).

Data Analyses

All temperature and salinity values collected have been edited using a combination of quantitative and visual techniques, including despiking and density inversion algorithms and range checks. The CTD measurements were compared with the reversing thermometer estimates of temperature and the salinities estimated from the water bottle samples. The edited 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 and are referred to as "near-bottom" conditions in this report.

In order to place the 1995 survey results in the context of previous surveys, deviations of strata means from long-term or baseline strata mean conditions have been calculated. These deviations are referred to as anomalies. The baseline means were calculated as the average of the annual strata means obtained for each survey over the baseline time period. The baseline period differs between surveys. The baseline mean for the summer surveys was calculated over the 1980-90 period. The means for the 4VsW and 5Z spring bottom-trawl surveys were calculated over the period 1987-90. The present strata boundaries for these surveys were first implemented in 1986. These definitions are the same as those used for the overview of conditions in 1993 and 1994 (Page and Losier 1994, 1995). The baseline means are reported in Table 4.

RESULTS

Strata Specific Conditions

Spring Survey: 4VsW

The 4VsW spring survey has been conducted since 1979. The traditional strata definitions (Fig.1) have been used since 1986. In 1995, several new strata were added to the survey design. These strata (boundaries are not shown on Fig.1) include the deep water along the eastern edge of the Laurentian Channel and the area north of the traditional survey domain. Because of these new strata more sampling stations have been added to the survey, and hence, more hydrographic profiles, were taken in 1995 than in previous years (Table 2a). In 1995 type 1 bottom trawl sets were made at 127 locations (Fig.1, Table 2a). Temperature and salinity profiles were taken at 119 of these stations using a CTD. Reversing thermometer and water bottle samples were taken at 103 of the CTD stations for calibration purposes. The CTD sampling effort was reasonably well distributed throughout the survey domain with samples taken in all strata (Fig. 1). However, as in previous years, the sampling within some strata (eg. 406) was not evenly dispersed throughout the strata. The data from the new strata have been summarized in the tables but not in the figures.

The summary statistics of the near-bottom temperatures and salinities for each strata are given in Table 3a. In 1995, the near-bottom temperatures within the traditional strata varied between -0.59 and 11.06°C, a range of 11.65°C. This range is not increased by the new sampling stations. The near-bottom strata mean temperatures increased from the northeast to the southwestern portions of the survey domain (Fig.2, 3b). All of the near-bottom strata mean temperatures were near their 1987-90 baseline means except for strata 406 which was -0.6 to -2°C below normal and strata 410 which was 1 to 2°C above normal (Fig. 2, Table 4a). The near-bottom salinities within the traditional strata varied between 31.58 and 35.03psu, a range of 3.45psu. This range is increased by the higher salinities encountered in some of the new strata. The near-bottom strata mean salinities were highest in the west and along the shelf edge (Fig.3,4). With the exception of strata 403 and 406, which had below normal salinities, the strata mean salinities were near normal (+- 0.5psu).

The strata specific time series of the sampled near-bottom temperatures and salinities are shown in Figures 5 and 6. The temperature means increased relative to 1994 in one strata

(401), decreased in eight strata (402, 403, 405, 406, 407, 408, 409, 410 and 411) and remained nearly the same in one strata (404). The salinity means increased relative to 1994 in one strata (401), decreased in eight strata (404, 405, 406, 407, 408, 409, 410 and 411) and remained nearly the same in two strata (402, 403,). Obvious low frequency time trends are indicated in only two of the strata (405 and 409). In strata 405, the mean temperature decreased from 1986 to 1990, increased from 1990 to 1993 and decreased from 1993 to 1995. The salinities also decreased from 1986 to 1990, but increased for the longer 1990 to 1994 period and decreased in 1995. In strata 409, the mean temperatures remained relatively constant from 1986 to 1990, increased by several degrees from 1990 to 1993 (based on one data point in 1993) and have decreased since 1993. The mean salinities increased from 1986 to 1988, decreased from 1988 to 1991, increased from 1991 to 1993 (based on one data point in 1993) and have decreased since 1993. The remaining strata show little indication of time trends. In strata 404 and 411 the small sample sizes preclude detection of any potential trends and in strata 401, 403, 406, 407, 408 and 410 the large within year variation in temperature and salinity makes it difficult to detect trends. In strata 406, the temperatures and salinities are split into two ranges. In the upper range the temperatures are approximately 8°C and the salinities are approximately 34psu. In the lower range the temperatures are about 1°C and the salinities are approximately 33psu. The strata mean temperatures and salinities fall in between these two ranges and are, therefore, not a good indicator of conditions that actually exist within the strata.

The ability to detect and interpret the interannual variability in the near-bottom temperatures and salinities observed in this survey series is compromised by changes in the timing of the survey and the interannual changes in the station locations and depths resulting from the randomized selection of station locations. Perhaps the most serious of these variations is that of the trend in survey timing. The survey has been conducted progressively earlier since 1987 (Fig.7). In most strata, the temperatures and salinities do not vary systematically with the date of sampling (Fig.8 and 9). However, in strata 409 and 410 the temperatures decrease with the day of sampling and in strata 405, 409 and 410 the salinities decrease with the day of sampling. Therefore, the trends in temperatures and salinities noted for strata 409 may be due, at least in part, to changes in sampling time. With the exception of strata 404, in which a clear time trend in sampling depth exists, the range of sample depths has remained relatively constant in all strata (Fig.10). Therefore, even though near-bottom temperature and salinity increases with depth in most strata ((401, 402, 403, 404, 405, 406, 408, 409, 410, Fig. 11 and 12), the time trends in temperatures and salinities are unlikely to be due to changes in the sample depths.

Spring Survey: 5Z

The 5Z spring survey has been conducted since 1986. The present strata definitions (Fig.13) have been used since 1987. In 1995 the survey completed 85 type 1 bottom trawl sets (Table 2). Temperature and salinity profiles were taken at 76 of these stations. Temperature and salinity measurements were obtained for calibration purposes with reversing thermometers and water bottles at 5 of the CTD stations (Fig.13, Table 1). This low number of calibration samples is due to the loss of water bottle samples while in transit from the ship to the laboratory. Unlike the previous year, sampling effort was spread over the bank in all eight

survey strata $5Z_j$ to $5Z_8$ (Fig. 13). As in previous years, the sampling in strata $5Z_8$ was very limited.

The summary statistics of the near-bottom temperatures and salinities for each strata are given in Table 3b. In 1995, the near-bottom temperatures varied between 4.3 and 13.9°C, a range of 9.6°C. The near-bottom temperatures within the deep strata along the edges of Georges Bank (5Z1, 5Z5 and 5X8) and those within the Great South Channel continued to be warmer than those within the shallow strata on top of the bank (5Z2-4, Fig. 4, 14). The temperatures on top of the bank varied between 4 and 6°C (Fig.4). The means for all sampled strata were above or near their 1987-90 baseline normals (Tables 3b and 4a). The near-bottom salinities varied between 32.5 and 35.6psu, a range of 3.1psu (Table 3b). Salinities within strata $5Z_{1-4}$ varied between 32.18 and 34.94 psu, a range of 2.76 psu. The strata mean salinities were greatest within the deep strata along the southern edge of Georges Bank ($5Z_8$, Fig.4, 15). With the exception of a tongue of relatively low salinity water on the northeast portion of the bank, the salinities on top of the bank were generally between 33 and 34 psu. All of the strata means were above or within +/-0.50psu of their baseline means (Fig.15, Tables 3b and 4a).

The strata specific time series of near-bottom temperatures and salinities are shown in Figures 5 and 6. Small amplitude low frequency time trends are indicated in most of the strata. The 1995 temperatures were generally near or above those sampled in 1994. In the strata on top of the bank, in which the majority of the cod and haddock are caught (5Z2-4), the temperatures and salinities have been increasing since 1993. This trend appears in the data for most of the other strata as well.

As in the 4VsW spring survey, the ability to detect and interpret the interannual variability in the near-bottom temperatures is compromised by changes in the timing of the survey and the random changes in the station locations, and hence bottom depths sampled. The 5Z survey has a large interannual variation in its timing (Fig.7). From 1987 to 1991, the survey was conducted progressively earlier, whereas from 1991 to 1993, the survey was conducted progressively later. This resulted in the 1987 and 1993 surveys being conducted at similar times of the year. In 1994 and 1995, the surveys were once again conducted early in the year, approximately 20-30 days earlier than in 1987 or 1993. These changes in timing probably account for much of the interannual variation in temperatures and salinities since there is a distinct relationship between temperature and salinity and the day of sampling within most strata (Fig. 8 and 9). Although temperature and salinity varies with bottom depth in some strata (Fig. 11 and12), and may contribute to some of the interannual variation in sampled temperatures and salinities, the range of sample depths has remained relatively narrow and constant over the years (Fig.10), with the possible exception of strata $5Z_1$. Hence the time trend in the sampled temperatures and salinities is unlikely to be due to variation in sample depths.

Summer Surveys: 4VWX

The 4VWX summer surveys have been conducted since 1970. The strata boundaries shown in Figure 16 have been used throughout this period. In 1995, two new strata were added (496, 497). These are along the edge of the Scotian Shelf and are not shown in Figure 16. Five new survey stations and hence hydrographic profiles are associated with these

strata. In 1995, the survey completed 204 type 1 bottom trawl sets (Table 2). Temperataure and salinity profiles were completed at 200 of these sets using CTDs. Temperature and salinity measurements were taken with reversing thermometers and water bottles at 163 stations (Fig.16, Table 1).

The level of sampling effort is consistent with previous years (1991-1994) in which a CTD was used. The CTD sampling effort was reasonably well distributed throughout the survey domain with samples taken in all strata. However, as in previous years, the sampling within some strata was not dispersed throughout the strata (eg. 459, 484). The data from the new strata have been summarized in the tables but not in the figures.

Summer Survey: 4VW

The summary statistics of the near-bottom temperatures and salinities for each strata are given in Table 3c. In 1995, the near-bottom temperatures varied between 0.3 and 11.9°C, a range of 11.6°C (Table 3c). The near-bottom temperatures generally increase from east to west with those in the east being generally less than those on the western shelf and in the Bay of Fundy (Fig.17 and 19). The temperatures on the eastern shelf in the northeast portion of 4W and the central and northern region of 4V were less than 2°C (Fig.19). The temperatures within the western 4W area were generally greater than 8°C. The means for all sampled strata were above or near their 1987-90 baseline normals (Tables 3c and 4b). Most of the means for strata over the eastern Scotian Shelf were below or within -1.00°C of their baseline means, whereas, those for strata within the central shelf region tended to be above or within baseline means (Fig.17, Tables 3c and 4b). The near-bottom salinities varied between 31.4 and 35.2psu, a range of 3.8psu (Table 3c). The salinities are generally less than 32psu over the eastern portions of 4W and most of 4V and are greater than 33psu in the western 4W area (Fig. 18). Salinities along the edge of the shelf tended to be higher than those on the shelf. Most of the strata means were within +/-0.50psu of their baseline means (Fig.18, Tables 3c and 4b).

The strata specific time series of near-bottom temperatures and salinities are shown in Figures 20 and 21. Low frequency time trends in temperature are suggested in several of the strata. In eleven of the strata, the temperature decreased relative to 1994, whereas they increased in nine strata. Unlike the temperature time series only a few strata appear to have systematic trends in salinity (Fig. 21).

As in the spring surveys, the ability to detect and interpret the interannual variability in the near-bottom temperatures and salinities is compromised by changes in the timing of the survey and by the design based random changes in station locations, and hence, bottom depths sampled. Unlike the spring surveys, however, no strong trend in the timing of the eastern Scotian Shelf surveys (strata 440-466) is apparent since about 1980 (Fig. 22). During the 1970's a low amplitude trend in the timing of the surveys is apparent with sampling in 1975-76 being 10-20 days later than in the earlier or later 1970's. Relationships between near-bottom temperature or salinity and the day of sampling is only suggested for a few strata (Fig. 23 and 24). For most strata the range of depths sampled has been reasonably consistent over the survey period (Fig. 25). However, in strata 451, 452, 453 and 466 the range of sample depths has been quite variable and in strata 454 and 457 the sample depths have been shallower in recent years. In strata 453 samples have not been taken below 250m since

1990. Since temperature varies with depth in many of the strata, including 451, 452 and 466 (Fig.26), the trends in temperatures and salinities in strata with inconsistencies in the range of depths sampled will, to some extent, be artifacts of the depth temperature interaction. For example, the trend of decreasing salinities in strata 454 and 457 that began in the mid 1980's may be due in part to the trend toward shallower sample depths. In the remaining strata, the temperature and salinity interactions with depth (Fig. 26 and 27) and time do not produce a pronounced systematic effect in the time trends in temperature because the sampling dates and depths have been consistent throughout much of the survey series.

Summer Survey: 4X

The summary statistics of the near-bottom temperatures and salinities for each strata are given in Table 3d. In 1995 the near-bottom temperatures varied between 1.5 and 10.0°C, a range of 8.5°C (Table 3d). The temperatures were >6°C over much of 4X with the exception of a tongue of <6°C water extending across the shelf off Shelbourne to eastern Browns Bank (Fig. 19). Most of the stratified means for strata within 4X were within 1.00°C of baselines (Fig.17, Tables 3d and 4b). Browns and Roseway Banks (strata 480 and 474) were below normal and strata 472 was above normal. The near-bottom salinities varied between 30.9 and 35.2psu, a range of 4.3psu (Table 3d). The salinities in the deeper waters of the Gulf of Maine and the central Scotian Shelf are generally greater than 34psu whereas those in the Bay of Fundy and in the tongue of water extending off Shelbourne are less than 33psu (Fig. 19). As with temperatures, most of the stratified means for strata within 4X were within 0.5psu of baselines (Fig.18, Tables 3c and 4b). Browns and Roseway Banks (strata 480 and 474) were below normal and strata 472 was above normal.

The strata specific time series of near-bottom temperatures and salinities are shown in Figures 20 and 21. Low frequency time trends are indicated in several of the strata. As noted previously (Page and Losier 1994) the temperatures within the Bay of Fundy (strata 490, 491, 492, 493, 494, 495) vary coherently with the temperatures on the western Scotian Shelf (strata 471, 480, 481, 482, 483, 484, 485). That is, they declined during the late 1980's to 1992, increased from 1992 to 1994 and decreased in 1995. A similar trend has occurred in the salinities within these strata. In several of the Bay of Fundy strata (490, 491, 492, 495), temperatures as high as those in 1994 have not been observed since 1976 and in strata 471 the temperatures are near the highest observed.

As in the other surveys, interannual variation in the time and location of sampling has occurred (Fig. 22). In the central Scotian Shelf strata (470-74) a distinct trend in the timing of the survey has occurred with the sampling being conducted progressively earlier since 1975/6. The pattern is apparent but not as pronounced as in the other strata within 4X. This may contribute to some of the temperature trends, since, there is evidence of a relationship between the day of sampling and temperature in many of these strata during this time of year (Fig. 23). For example, the low temperatures and salinities observed in 1992 may be due, in part, to an early sampling date in this year. Unlike sampling date, the range of sampling depths has remained relatively constant (Fig. 25). Therefore, even though temperature and salinity varies with depth in many of the strata (Fig's. 26 and 27), this factor probably does not contribute strongly to the temperature and salinity trends.

Composite Conditions

The above sections present the near-bottom hydrographic conditions on a stratum by stratum basis within the major groundfish stock unit areas. In this section, an effort is made to give a more concise overview of the temperature and salinity conditions sampled during the surveys by presenting composite patterns for the major unit areas. Two types of composites are presented. The first (Fig. 28 and 29) are the time series of stratified mean near-bottom temperatures and salinities for the 4Vs, 4W and 5Z areas during the spring surveys and the 4Vs, 4W, 4X (Bay of Fundy) and 4X (Scotian Shelf) areas during the summer surveys. The second is a time series of maps showing the location of hydrographic stations in which water temperatures less than 0 or 2°C were recorded somewhere within the water column (Fig. 30 and 31).

Stratified Means

The time series of stratified mean near-bottom temperatures and salinities all show low amplitude low frequency trends (Fig. 28 and 29). The spring series for both temperature and salinity are short, highly variable, and are confounded with changes in sample time and depths. The 5 year running mean smoothed versions of these time series show relatively little variability. The summer time series are considerably longer and are not confounded as much by changes in sample times and depths. Although the raw series are quite variable, the five year running mean smoothed versions show definite trends. Although the 4X series tend to be distinct from the 4Vs and 4W series as noted by Page and Losier (1994), a low degree of coherency is suggested at the low frequency. The largest amplitude temperature trend is in 4Vs where it is of order 1°C. The amplitude decreases toward the west and is of order 0.25°C in the bay of Fundy. The trend indicates that the near-bottom temperatures sampled by the surveys declined throughout the 1980's until about 1989-91 and increased from 1991 to 1993-94. In 1995, the temperatures decreased again but not to the lows of 1990. The trends in the salinity series are harder to detect, but show similar trends with the salinities decreasing throughout the latter 1980's until about 1991 and, perhaps, increasing since then.

Occurrence of Cold Water

An additional indicator of changes in the hydrographic regime on the eastern Scotian Shelf is the location and number of sampling stations in which temperatures below 0°C were observed somewhere within the water column during the summer groundfish surveys. Figure 30 shows the distribution of these stations for the full 1970-1995 time period. 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 northeastern portion of the survey area with the greatest occurrence being in 1992. The conditions in 1995 are similar to those in 1974 and 1987 with only three stations in the northeastern corner of the survey domain having temperatures less than 0°C. Although the implied increase in cold water during the early 1990s corresponds with the implementation of the routine use of a CTD on the surveys (Table 2), 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 only suggests that the volume of cold water increased in the early 1990's but suggests that the cold water still persists in 1995 (Fig. 31).

DISCUSSION

The oceanographic climate has been consistently monitored within the Scotia-Fundy region at only one offshore station. This is the Prince 5 station which is 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 early 1990's are below the long-term mean. The research vessel surveys have been conducted within this framework of climatic change.

The Canadian bottom-trawl research vessel summer survey program began in 1970 and the present design of spring surveys began in 1986/7. Unfortunately, the patterns and trends in temperatures and salinities observed during the surveys are influenced by the location and timing of the sampling. This is discussed more fully in Page et al. 1994. The spring surveys are particularly affected by interannual changes in the timing of the surveys. The trends in temperatures and salinities observed during these surveys are indicators of trends in the hydrographic conditions that were sampled for fish but they are not good indicators of trends in the actual hydrographic climate. The changes in the summer strata are more indicative of actual changes in the hydrographic climate since the sampling is not as badly aliased by interannual variation in the timing of the surveys and in the depth of sampling.

In the summer surveys, many strata show a decreasing trend in near-bottom temperatures during the late 1980's and early 1990's and a reversal toward warming since 1992. The decrease began in the northeastern strata in the early 1980's and did not begin until later in the more easterly strata. In 1992, the near bottom temperatures dropped below zero within some strata and the frequency and horizontal extent of hydrographic stations in which below zero temperatures have been recorded within the water column reached historic highs. In 1992, the extent of the sub-zero temperature extended over much of the northeastern portion of the survey area. The extent of this area seems to have been reduced in recent years.

Although the changes may not indicate climatic variability, they are indicative of interannual differences in the type of hydrographic habitat sampled and may be indicative of interannual variations in fish distribution and abundance. This possibility has been suggested by several authors. Smith, Perry and Fanning (1991) have shown that, during the 1979 to 1988 period, inter-annual changes in the proportion of 4VW bottom waters identified as Cold

Intermediate Layer (CIL) water coincide with changes in the estimated abundance of 4VsW cod. When the proportion of the CIL is large (small), and hence, the temperatures are relatively cool (warm), the estimate of cod abundance is relatively low (high). 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).

Summary

Water temperatures on the eastern Scotian Shelf show signs of returning toward normal, although, the return is not yet complete. The stratified mean near-bottom temperatures continue to be warmer than those in the early 1990s and the extent of stations with temperatures less than 0ºC is once again relatively low. However, the distribution of water less than 2ºC remains similar to that of the cold years in the early 1990s suggesting that a full recovery has not yet occurred. The temperatures on the western Scotian Shelf and on Georges Bank continue to be variable and several degrees above those on the eastern shelf.

4VsW Spring

Temperatures

-large amplitude (~1-2°C) high frequency variation; low amplitude (~0.1°C) low frequency trend
-1995 range of -0.6 to 11.1°C; within historical range (1986-94)
-1995 near 1987-90 strata means; generally cooler than 1994
- < 2°C over much of eastern shelf in 1995

Salinities

-large amplitude (~0.2psu) high frequency variation; low amplitude (<0.1psu) low frequency trend
-1995 range of 31.6 to 35.0 psu; within historical range (1986-94)
-1995 near or below 1987-90 strata means; generally fresher than 1994
-generally < 31psu over much of eastern shelf with pockets of >33 psu along the edge of the SS and Emerald Basin in 1995

Sampling times

-trend toward earlier sampling dates continues
-range of day 58 to 71; within historical range (1986-94)
-1995 one of the earliest years

Hydro sampling depths

-no temporal trend
-range of ca. 50 to 300+m; within historical range
-near normal range for each strata

5Z Spring

Temperatures

-large amplitude (~1°C) high frequency variation; low amplitude (~0.1°C) low frequency trend
-1995 range of 4.3 to 13.9°C; within historical range (1987-94)
-near or above 1987-90 strata means
-1995 generally warmer than 1994
-4 - 6 °C over much of the bank in 1995

Salinities

-large amplitude (~0.2psu) high frequency variation; low amplitude (<0.1psu) low frequency trend
-1995 range of 32.5 to 35.6 psu; within historical range (1987-94)
-mainly near 1987-90 strata means
-1995 generally higher salinity than 1994
-33 - 34psu over much of the bank in 1995

Sampling times

-large interannual variation in sampling dates (range of 30 days)
-1995 range of day 46 to 54; within historical range (1987-94)
-1995 one of the earliest years

Hydro sampling depths

-no temporal trend
-range of ca. 30 to 250+m; within historical range
-near normal range for most strata

4VW Summer

Temperatures

-large amplitude (~1°C) high frequency variation; large (~0.5°C) amplitude low frequency trend
-range of 0.3 to 11.9°C; within historical range (1970-94) except high in strata 451, 459
-generally near 1987-90 strata means but below mean in eastern 4W and above mean in western 4W.
-generally marginally lower than 1994 but less 0°C water than in 1994
-< 2°C over much north and northeastern portions of 4VW, >8°C in western 4W

Salinities

-large amplitude (~0.3psu) high frequency variation; low amplitude (~0.1psu) low frequency trend
-range of 31.4 to 35.2 psu; within historical range (1970-94) but low in 446 and high in 459
-near or below 1970-90 strata means
-marginally higher than 1994
-generally < 32psu over eastern 4W and 4V, >33psu in western 4W

Sampling times

-little temporal trend

-range of day 176 to 201; within historical range (1970-94)
-1995 one of the earliest years

Hydro sampling depths
-no strong temporal trend; some notable deviations in early 1970's and in some strata
-range of ca. ~50 to 300+m; within historical range (1970-94)
-near normal range for each strata

4X Summer

Temperatures
-large amplitude (~1°C) high frequency variation; low (~0.2°C) amplitude low frequency trend
-range of 1.5 to 10.0°C; within historical range (1970-94)
-near 1970-90 strata means but below mean in Browns and Roseway
-overall area lower than 1994
->6°C over much of 4X; <6°C off Shelbourne

Salinities
-large amplitude (~0.3psu) high frequency variation; low amplitude (~0.1psu) low frequency trend
-range of 30.9 to 35.2 psu; within historical range (1970-94)
-near 1970-90 strata means but below mean in Browns and Roseway
-overall lower than in 1994
-generally < 34psu over much of 4X with >34 psu along the edge of the SS and Emerald Basin

Sampling times
-no distinct temporal trend except in 470-74
-range of day 176 to ~185; within historical range (1970-94)
-1995 one of the earliest years

Hydro sampling depths
-no temporal trend
-range of ca. 50 to 300+m; within historical range
-near normal range for each strata

Recommendations

1) As more information becomes available for the new strata added to the spring 4VsW and summer 4VWX surveys, it should be more fully incorporated into the overview.

2) Continue to investigate the influence of the cold water found over the eastern Scotian Shelf on the indices of fish abundance, particularly cod and haddock, and evaluate its influence on estimates of stock status.

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TABLE 1: Summary of 1995 Canadian groundfish bottom-trawl surveys conducted within the Scotia-Fundy region, NAFO areas 4VWX and 5Z. In the Cruise column N refers to the Canadian Research Vessel Alfred J. Needler. In the sampling date column, the numbers in brackets indicate the consecutive day within 1995.

SAMPLING AREA	STRATA	CRUISE (vessel-cruise no.)	SAMPLING DATES day/month	NO. of UNIQUE SAMPLING STATIONS
4VsW Spring	396-446 (several new strata for redfish) (only the old groundfish strata 401-411 summarized here)	N217	27/02 (58) 12/03 (71)	127 total 119 CTD 0 XBT 103 bottle
5Z Spring	$5Z_1$-$5Z_8$	N216	15/02 (46) 23/02 (54)	85 total 76 CTD 0 XBT 5 bottle
4VWX Summer	440-498 (several new strata for redfish) (only the old groundfish strata 440-495 summarized here)	N226/227	25/06 (176) 20/07 (201)	204 total 200 CTD 0 XBT 163 bottle

TABLE 2a: Listing of the intensity of hydrographic sampling during Canadian research vessel spring stratified random groundfish surveys conducted within NAFO Statistical Area 4VsW during 1986 to 1995 and 5Z during 1987 to 1995 inclusive. In the cruise column, N refers to the Alfred J. Needler and T refers to the Wilfred Templeman. (RT= reversing thermometer, B=water bottle, CTD=conductivity, temperature and depth profiler)

CRUISE(S)	YEAR	NUMBER of COMPLETED TYPE 1 SETS	NUMBER of T & S PROFILES	PROPORTION(%) of T & S PROFILES	GEAR USED
5Z					
N59	1986	77	14	18	RT/B
N77	1987	71	15	21	RT/B
N97	1988	132	19	14	RT/B
N116	1989	116	21	18	RT/B
N133	1990	123	29	24	RT/B/CTD
N148	1991	132	113	86	RT/B/CTD
N165	1992	91	78	86	RT/B/CTD
T134	1993	65	64	98	RT/B/CTD
N200	1994	45	41	91	RT/B/CTD
N216	1995	85	76	89	RT/B/CTD
4VsW					
N60	1986	77	15	19	RT/B
N78	1987	92	19	21	RT/B
N98	1988	68	16	24	RT/B
N117	1989	79	14	18	RT/B
N134	1990	77	0	0	RT/B/CTD
N149	1991	94	68	72	RT/B/CTD
N166	1992	75	24	32	RT/B/CTD
N182	1993	79	37	47	RT/B/CTD
N201	1994	95	87	92	RT/B/CTD
N217	1995	127	119	94	RT/B/CTD

TABLE 2b: Listing of the intensity of hydrographic sampling conducted during each Canadian research vessel summer stratified random groundfish survey conducted within NAFO Statistical Areas 4VWX during 1970 to 1995 inclusive. In the cruise column, A refers to the A. Cameron, N refers to the Alfred J. Needler and T refers to the Wilfred Templeman. (RT = reversing thermometer; B = water bottle; CTD = conductivity, temperature and depth profiler)

CRUISE(S)	YEAR	NUMBER of COMPLETED TYPE 1 SETS	NUMBER of T & S PROFILES	PROPORTION of T & S PROFILES	GEAR USED
A175/A176	1970	134	42	31	RT/B
A188/A189	1971	118	36	31	RT/B
A200/A201	1972	147	34	23	RT/B
A212/A213	1973	134	39	29	RT/B
A225/A226	1974	153	37	24	RT/B
A236/A237	1975	143	38	27	RT/B
A250/A251	1976	135	41	30	RT/B
A265/A266	1977	144	41	28	RT/B
A279/A280	1978	141	42	30	RT/B
A292/A293	1979	147	19	13	RT/B
A306/A307	1980	145	21	14	RT/B
A321/A322	1981	143	33	23	RT/B
H80/H81	1982	150	38	25	RT/B
N12/N13	1983	146	27	18	RT/B
N31/N32	1984	143	29	20	RT/B
N48/N49	1985	152	8	5	RT/B
N65/N66	1986	171	23	13	RT/B
N85/N86	1987	188	32	17	RT/B
N105/N106	1988	177	28	16	RT/B
N123/N124	1989	184	16	9	RT/B
N139/N140	1990	223	211	95	RT/B/CTD
N154/H231	1991	189	188	99	RT/B/CTD
N173/N174	1992	193	184	95	RT/B/CTD
N189/190	1993	190	183	96	RT/B/CTD
N221/N222	1994	195	182	93	RT/B/CTD
N226/N227	1995	204	200	98	RT/B/CTD

TABLE 3a: Summary of near-bottom temperature and salinity statistics for Canadian groundfish bottom-trawl surveys conducted within NAFO area 4VsW in the spring of 1995. (n is the sample number)

STRATA	TEMPERATURE(°C)					SALINITY (psu)				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
396	2	4.9	4.9	5.0	0.1	2	34.9	34.9	34.9	0.0
397	4	4.8	4.6	5.0	0.4	2	34.9	34.9	34.9	0.0
398	3	4.7	4.6	5.0	0.4	2	34.8	34.8	34.8	0.0
399	5	5.1	4.6	5.6	1.0	5	34.8	34.7	34.8	0.1
400	5	5.1	4.9	5.4	0.5	5	34.9	34.8	34.9	0.1
401	9	1.5	0.9	2.3	1.4	9	32.6	31.9	33.2	1.3
402	16	1.6	0.0	5.7	5.7	15	32.8	32.2	34.6	2.4
403	7	0.2	-0.6	0.4	1.0	6	31.8	31.6	32.4	0.8
404	4	6.5	4.8	7.3	2.5	4	34.7	34.5	34.8	0.3
405	9	3.7	2.5	5.0	2.5	9	33.9	33.3	34.5	1.2
406	9	1.6	1.2	2.4	1.2	8	32.3	31.8	32.9	1.1
407	8	2.0	1.3	2.8	1.5	7	32.7	32.4	33.1	0.7
408	12	3.2	0.8	9.8	9.0	12	32.7	31.8	34.5	2.7
409	13	1.6	0.6	2.9	2.3	12	32.0	31.8	32.5	0.7
410	9	9.6	8.1	11.1	3.0	9	34.5	34.0	34.8	0.8
411	4	6.9	6.1	8.7	2.6	4	34.7	34.4	35.0	0.6
440	1	5.5	5.5	5.5	0.0	1	34.7	34.7	34.7	0.0
441	1	1.9	1.9	1.9	0.0	1	33.2	33.2	33.2	0.0
444	4	2.1	1.0	3.4	2.4	4	33.4	33.1	33.7	0.6
446	2	5.6	5.5	5.7	0.2	2	34.7	34.6	34.8	0.2

Table 3b: Summary of near-bottom temperature and salinity statistics for Canadian groundfish bottom-trawl surveys conducted within NAFO area 5Z in the spring of 1995. (n is the sample number)

STRATA	TEMPERATURE (°C)					SALINITY (psu)				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
5Z1	7	7.3	5.2	9.3	4.1	7	33.7	32.8	34.8	2.0
5Z2	28	5.1	4.3	6.4	2.1	27	32.8	32.5	33.2	0.7
5Z3	11	5.4	4.7	6.0	1.3	11	33.1	32.8	33.3	0.5
5Z4	12	5.4	4.9	6.7	1.8	12	33.2	33.1	33.4	0.3
5Z5	5	6.7	6.3	7.2	0.9	5	33.4	33.3	33.6	0.3
5Z6	10	5.8	4.3	6.3	2.0	10	33.2	32.9	33.3	0.4
5Z7	4	5.9	5.2	6.4	1.2	4	33.2	33.1	33.2	0.1
5Z8	2	11.7	9.5	13.9	4.4	2	34.9	34.1	35.6	1.5

TABLE 3c: Summary of near-bottom temperature and salinity statistics for Canadian groundfish bottom-trawl surveys conducted within NAFO area 4VW in the summer of 1995. (n is the sample number)

STRATA	TEMPERATURE (°C)					SALINITY (psu)				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
440	4	5.6	5.5	5.7	0.2	4	33.9	31.6	34.8	3.2
441	5	2.6	1.1	5.0	3.9	5	33.5	32.9	34.2	1.3
442	6	0.6	0.3	1.2	0.9	6	32.2	31.4	32.6	1.2
444	15	1.3	0.7	2.6	1.9	15	32.8	32.2	33.5	1.3
446	3	5.6	5.4	5.7	0.3	3	34.2	33.4	34.7	1.3
447	6	3.4	1.0	6.5	5.5	6	32.2	31.8	32.5	0.7
448	7	1.8	1.1	3.0	1.9	7	32.5	32.2	33.0	0.8
449	2	5.8	5.1	6.4	1.3	2	33.7	33.6	33.9	0.3
450	3	7.4	4.5	9.1	4.6	3	34.1	33.3	34.6	1.3
451	2	9.5	8.9	10.1	1.2	2	35.0	34.9	35.0	0.1
452	2	6.5	6.4	6.6	0.2	2	34.4	34.4	34.6	0.2
453	2	9.5	9.3	9.8	0.5	2	35.1	35.1	35.1	0.0
454	2	5.7	5.4	6.0	0.6	2	33.5	33.4	33.7	0.3
455	9	5.0	2.9	11.9	9.0	9	32.5	31.5	33.1	1.6
456	8	4.2	2.6	7.8	5.2	8	32.6	32.0	33.3	1.3
457	2	3.5	2.8	4.2	1.4	2	33.2	33.0	33.5	0.5
458	8	1.9	1.0	4.2	3.2	8	32.2	31.7	32.6	0.9
459	6	2.5	0.7	9.8	9.1	6	33.0	32.4	34.8	2.4
460	3	9.5	9.2	10.1	0.9	3	34.8	34.6	35.0	0.4
461	2	9.8	9.7	9.8	0.1	2	35.1	35.1	35.1	0.0
462	4	8.3	7.8	8.6	0.8	4	34.2	34.1	34.3	0.2
463	2	7.1	7.0	7.1	0.1	2	33.7	33.7	33.7	0.0
464	7	5.7	4.1	8.9	4.8	7	33.1	32.6	34.3	1.7
465	10	9.5	8.4	10.3	1.9	10	34.6	34.3	35.2	0.9
466	3	8.9	6.5	10.8	4.3	3	35.1	35.0	35.2	0.2

TABLE 3d: Summary of near-bottom temperature and salinity statistics for Canadian groundfish bottom-trawl surveys conducted within NAFO area 4X in the summer of 1995. (n is the sample number)

STRATA	TEMPERATURE (°C)					SALINITY (psu)				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
470	2	7.3	7.2	7.4	0.2	2	34.0	34.0	34.0	0.0
471	1	10.0	10.0	10.0	0.0	2	35.0	35.0	35.0	0.0
472	4	9.2	7.4	9.9	2.5	4	34.7	33.9	35.1	1.2
473	2	3.3	2.1	4.6	2.5	2	32.6	32.1	33.1	1.0
474	2	1.9	1.5	2.4	0.9	2	32.1	31.8	32.3	0.5
475	2	3.6	3.5	3.7	0.2	2	32.2	32.1	32.4	0.3
476	4	5.0	3.1	7.9	4.8	4	33.1	32.6	34.2	1.6
477	5	5.8	4.5	8.1	3.6	5	33.1	32.3	34.1	1.8
478	3	8.9	8.8	9.1	0.3	3	35.1	35.1	35.1	0.0
480	8	4.8	3.9	5.9	2.0	8	32.3	32.2	32.6	0.4
481	7	7.6	4.5	10.1	5.6	7	33.9	32.4	35.0	2.6
482	3	7.6	7.4	7.7	0.3	3	35.0	35.0	35.0	0.0
483	2	8.2	8.0	8.4	0.4	2	35.0	35.0	35.1	0.1
484	3	8.4	7.6	9.0	1.4	3	34.2	33.9	34.5	0.6
485	3	7.0	6.5	8.0	1.5	3	33.4	33.1	33.7	0.6
490	5	7.5	7.0	8.2	1.2	5	32.2	32.0	32.3	0.3
491	3	6.8	6.7	7.1	0.4	3	33.0	32.8	33.3	0.5
492	2	7.0	6.7	7.4	0.7	2	33.4	33.0	33.8	0.8
493	3	7.3	6.7	7.7	1.0	3	32.0	31.9	32.1	0.2
494	2	8.9	8.2	9.7	1.5	2	31.3	30.9	31.7	0.8
495	2	7.9	7.9	8.0	0.1	2	31.9	31.8	31.9	0.1
496	3	4.8	4.4	5.0	0.6	3	34.9	34.9	34.9	0.0
497	2	4.8	4.8	4.9	0.1	2	34.9	34.9	34.9	0.0

TABLE 4a: Long-term (1987-90) averages of annual strata mean near-bottom temperatures and salinities for spring Canadian groundfish bottom-trawl surveys conducted within NAFO statistical areas 4VsW and 5Z. (Note: Due to updates and corrections to the hydrographic database during the past year some of the values in this table, those marked with an *, are marginly different than the values reported by Page et al. 1994.)

STRATA	MEAN TEMP. (°C)	MEAN SALINITY (psu)		STRATA	MEAN TEMP. (°C)	MEAN SALINITY (psu)
401	0.62	32.54		5Z1	6.42	33.61
402	1.54	32.87		5Z2	4.44*	32.89
403	0.29	32.41		5Z3	4.29*	32.98
404	5.04	33.79		5Z4	4.43	32.90
405	3.54*	33.81*		5Z5	5.42	33.36
406	3.11	33.04		5Z6	4.38	32.68
407	2.73	32.94		5Z7	4.53	32.94
408	3.06*	33.05*		5Z8	9.64	34.52
409	0.87	32.36				
410	7.90	34.01				
411	7.67	35.12				

TABLE 4b: Long-term (1980-90) averages of annual strata mean near-bottom temperatures and salinities for summer Canadian groundfish bottom-trawl surveys conducted within NAFO statistical areas 4VWX. (Note: Due to updates and corrections to the hydrographic database during the past year some of the values in this table, those marked with an *, are marginly different than the values reported by Page et al. 1994.)

STRATA	MEAN TEMP. (°C)	MEAN SALINITY (psu)		STRATA	MEAN TEMP. (°C)	MEAN SALINITY (psu)
440	5.40	34.55		470	7.08*	34.12
441	2.85	33.38		471	9.13	34.84
442	1.69	32.08		472	7.46*	34.14
444	2.15	32.91		473	3.63	32.70
446	5.59	34.58		474	3.72	32.64
447	3.25	32.24		475	4.28	32.59
448	2.73	32.50		476	6.00	33.48
449	3.46	33.39		477	6.31	33.45
450	4.16	33.57		478	7.99	34.97
451	5.83	34.36		480	6.85	33.08
452	5.39	34.43*		481	7.61	33.73
453	8.49	34.96		482	8.06	34.95
454	6.59	34.04		483	7.66	34.95
455	6.07*	32.53		484	7.76	34.38
456	5.34*	32.70		485	7.48	33.78
457	4.31	33.65		490	8.24	32.53
458	3.80	32.26		491	7.07	32.88
459	3.67	33.13		492	6.96	33.03
460	8.24*	34.46		493	7.95	32.14
461	8.92	34.97		494	9.64	31.63
462	8.13	34.35		495	8.97	32.00
463	6.21	33.69				
464	5.70	33.34				
465	8.08	34.36				
466	8.75*	34.96*				

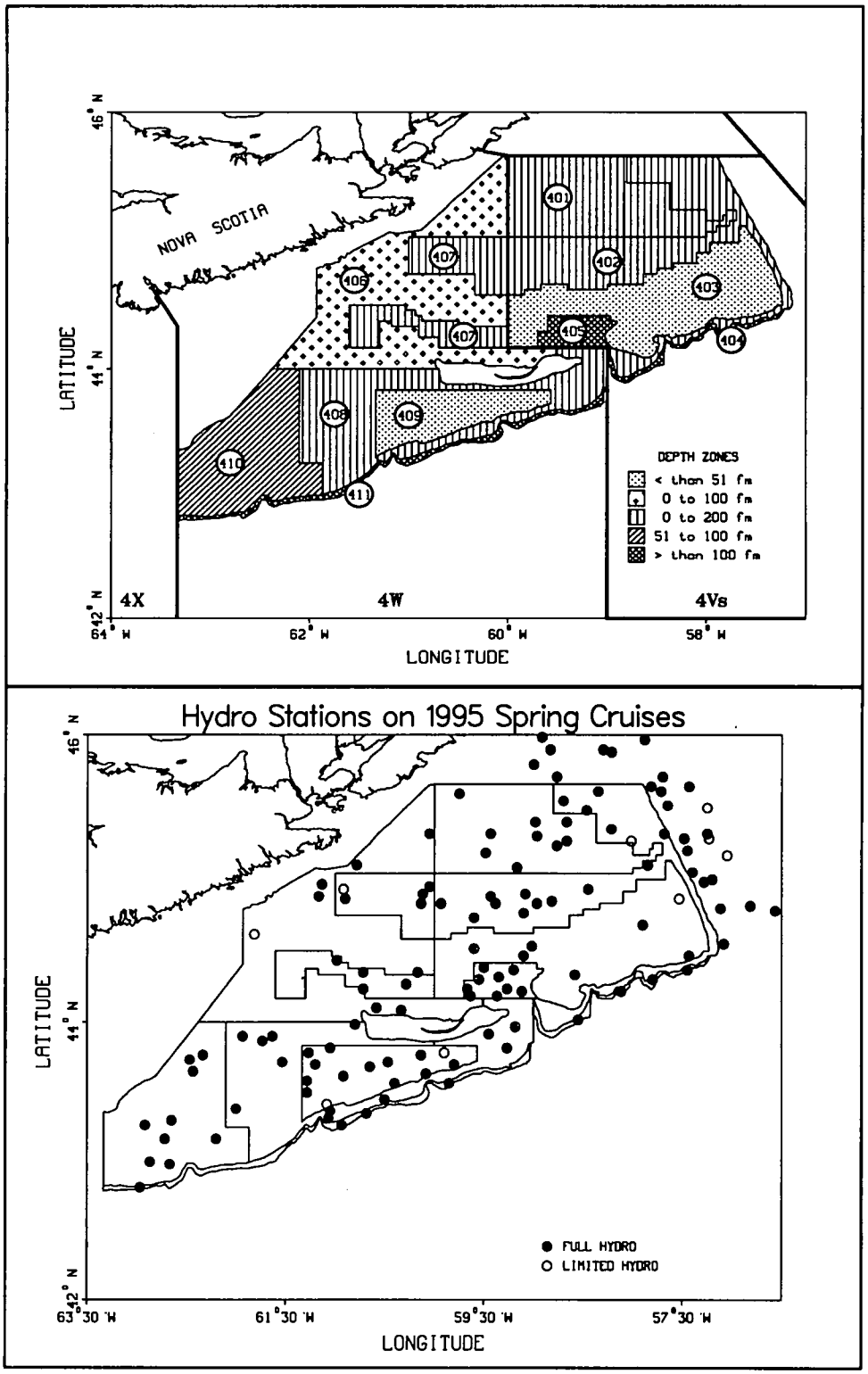

Figure 1: Survey domain and strata boundaries for the Canadian spring groundfish bottom–trawl research vessel surveys conducted within NAFO area 4VsW from 1986–1995 (top panel) and the location of hydrographic sampling stations taken during the 1995 spring survey (bottom panel). In the top panel the numbers enclosed within circles are the strata designations.

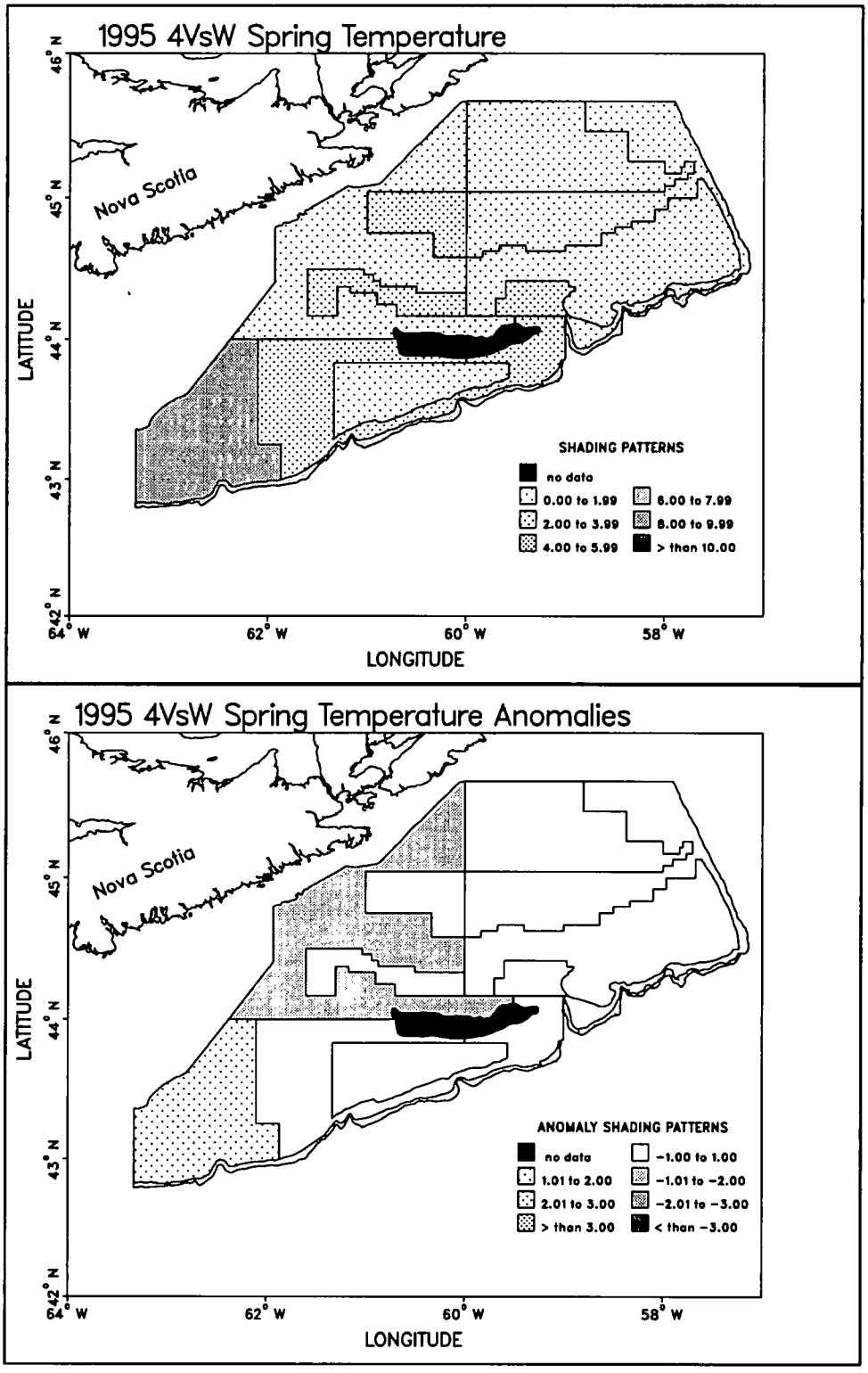

Figure 2: Map of near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VsW during the Canadian research vessel bottom-trawl survey conducted during the spring of 1995.

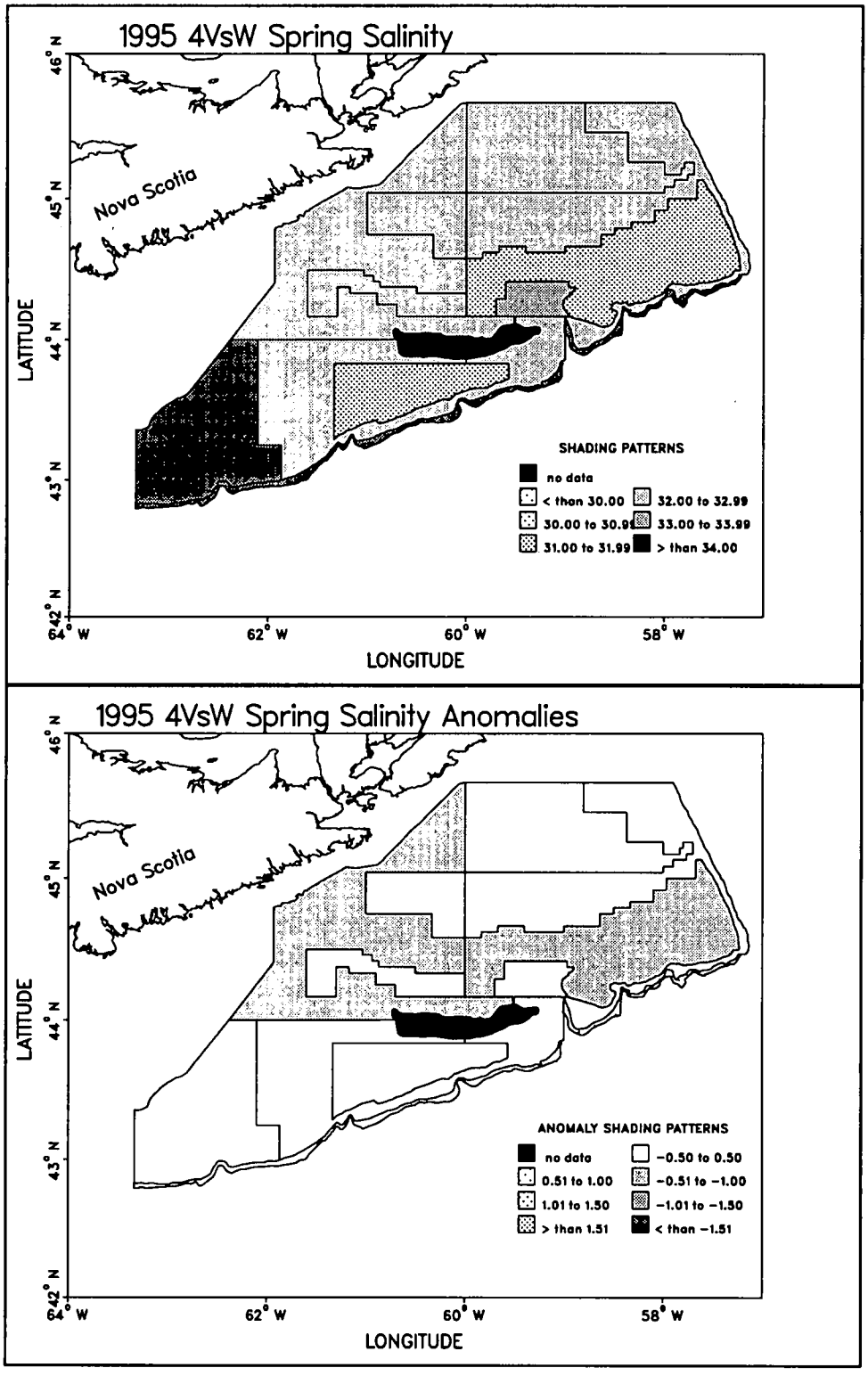

Figure 3: Map of near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VsW during the Canadian research vessel bottom-trawl survey conducted during the spring of 1995.

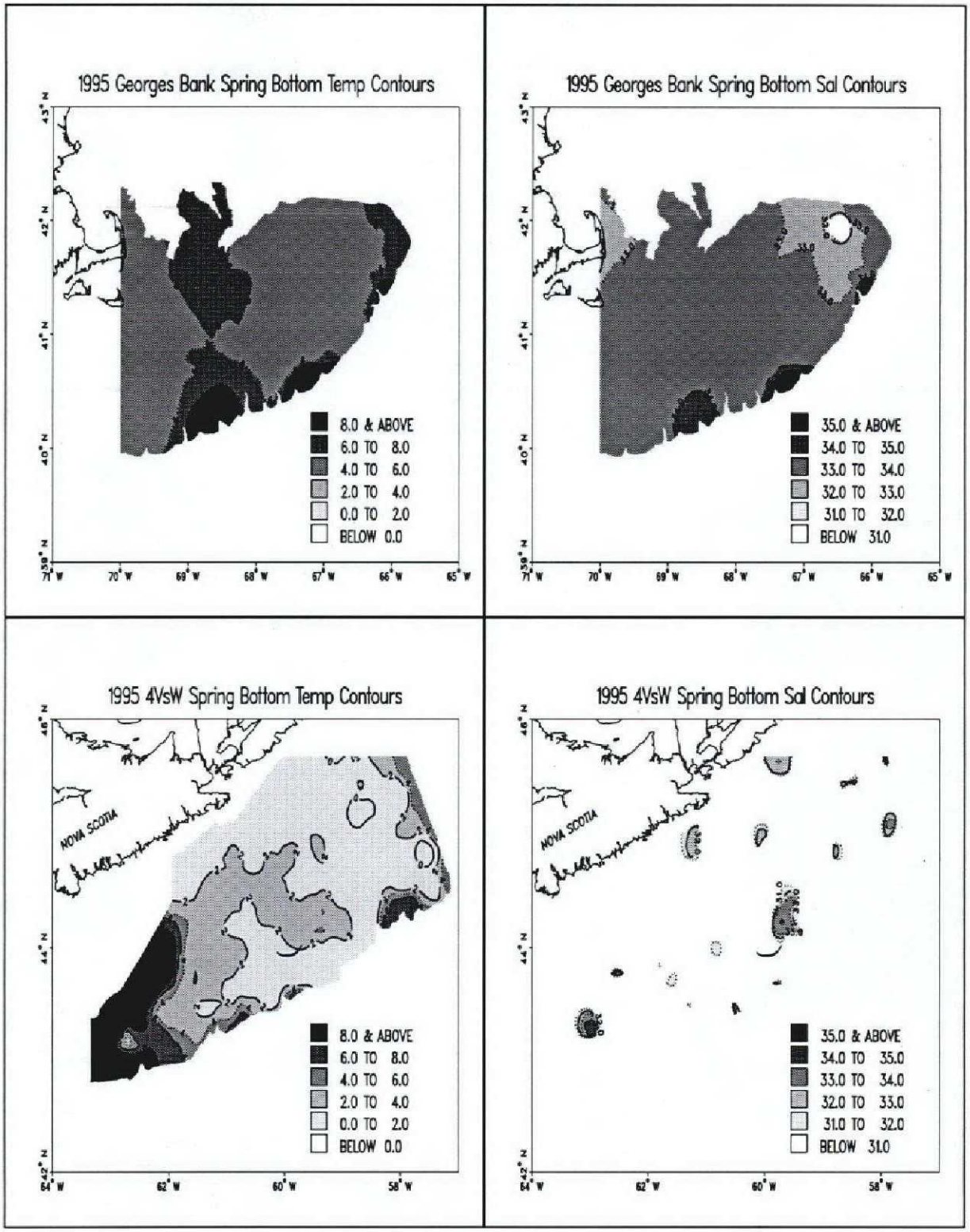

Figure 4: Contour maps of near-bottom temperature and salinities within the 5Z and 4VsW Canadian research vessel bottom-trawl surveys conducted during the spring of 1995.

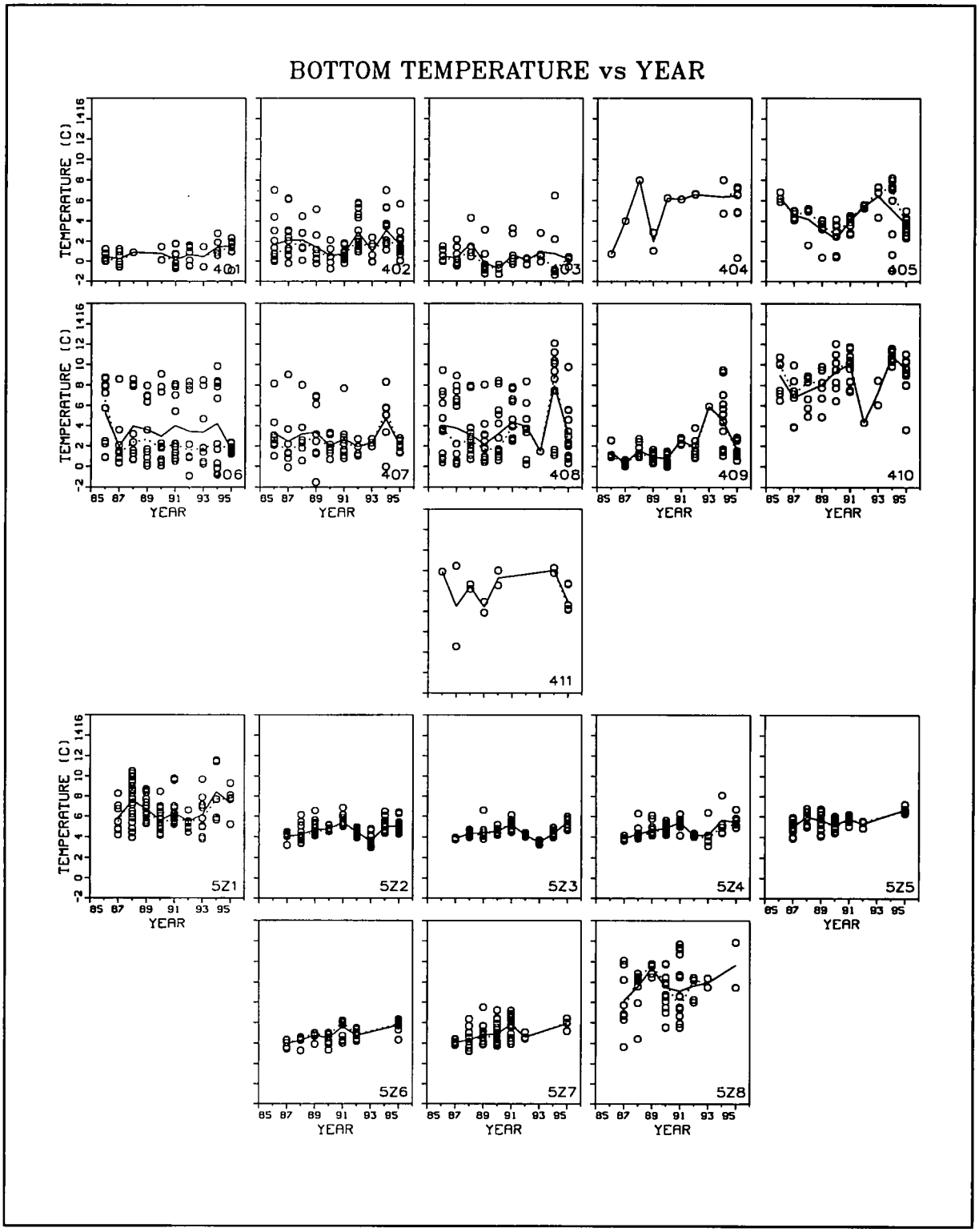

Figure 5: Time series of near–bottom temperatures within the spring 4VsW and 5Z surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

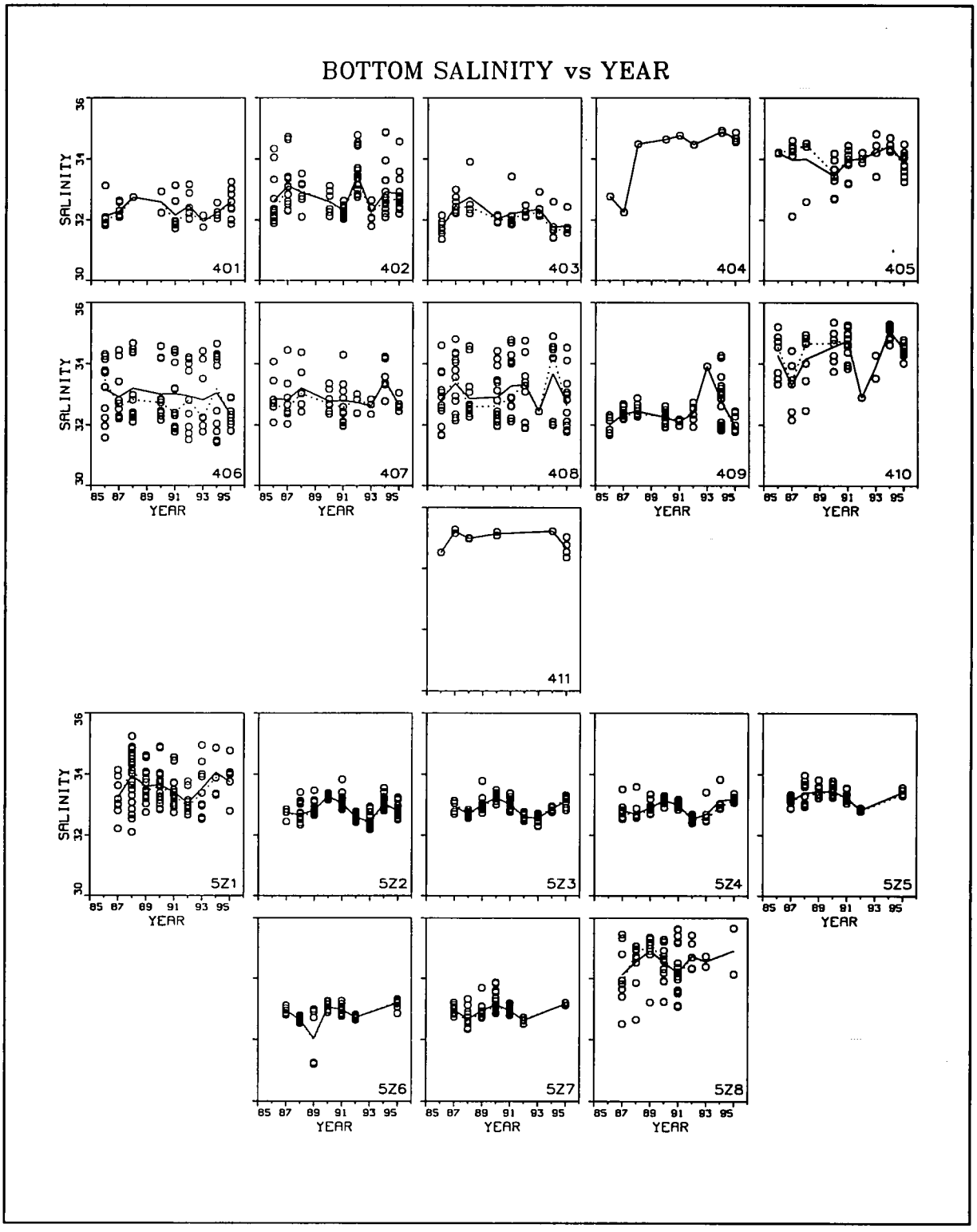

Figure 6: Time series of near-bottom salinities within the spring 4VsW and 5Z surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

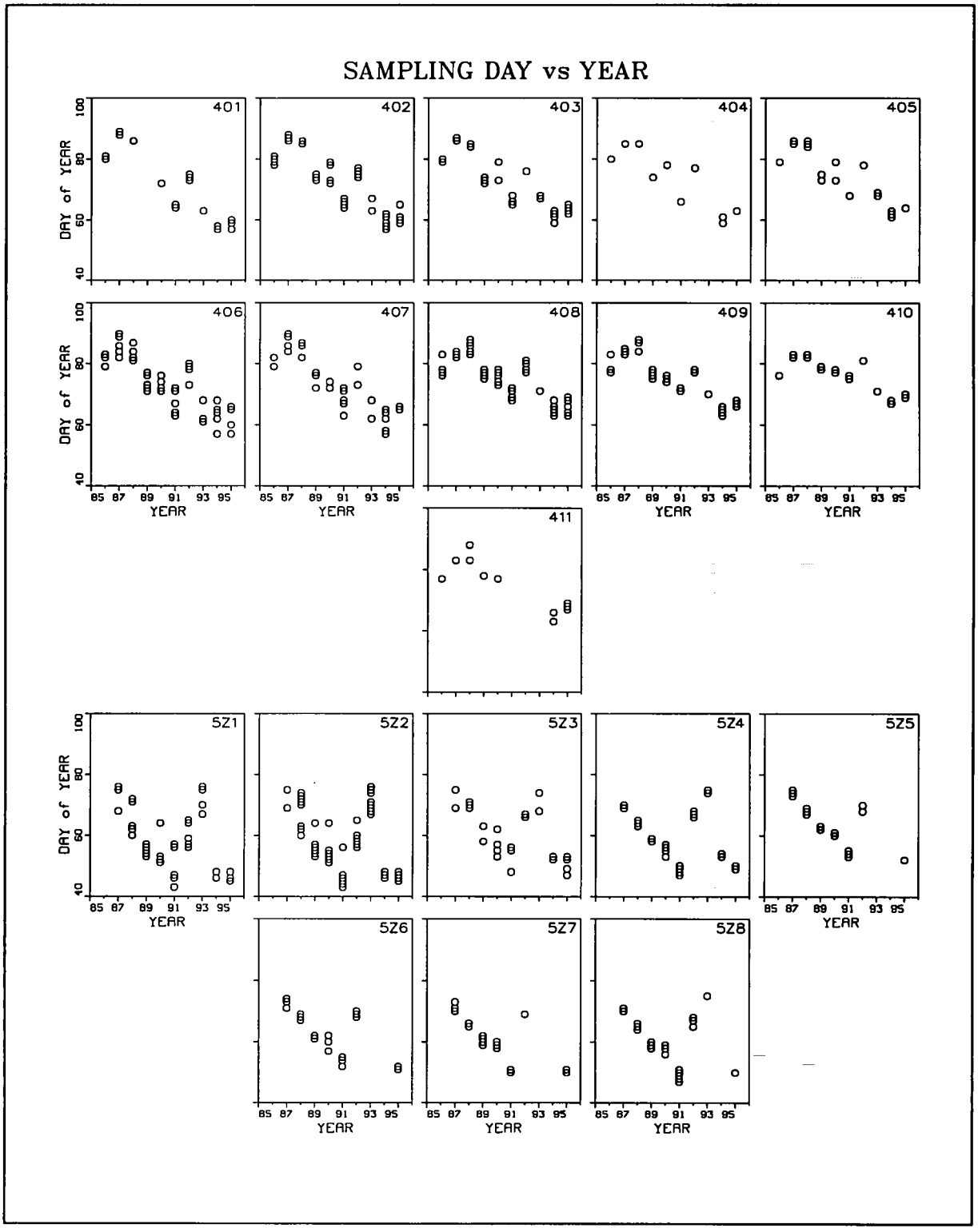

Figure 7: Time series of the consecutive day of sampling within the spring 4VsW and 5Z surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.

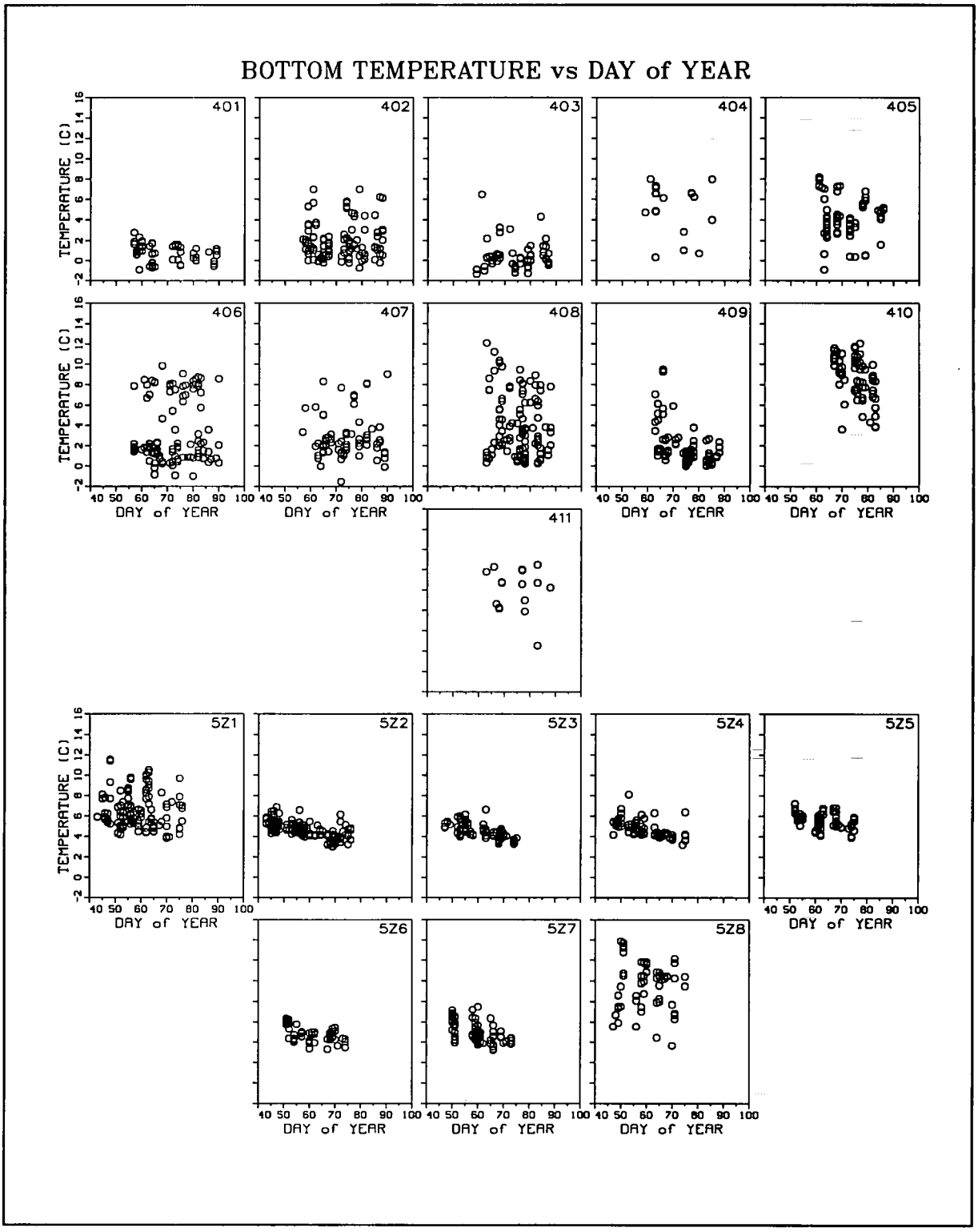

Figure 8: Near-bottom temperatures within the spring 4VsW and 5Z surveys in relation to the day of the year. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

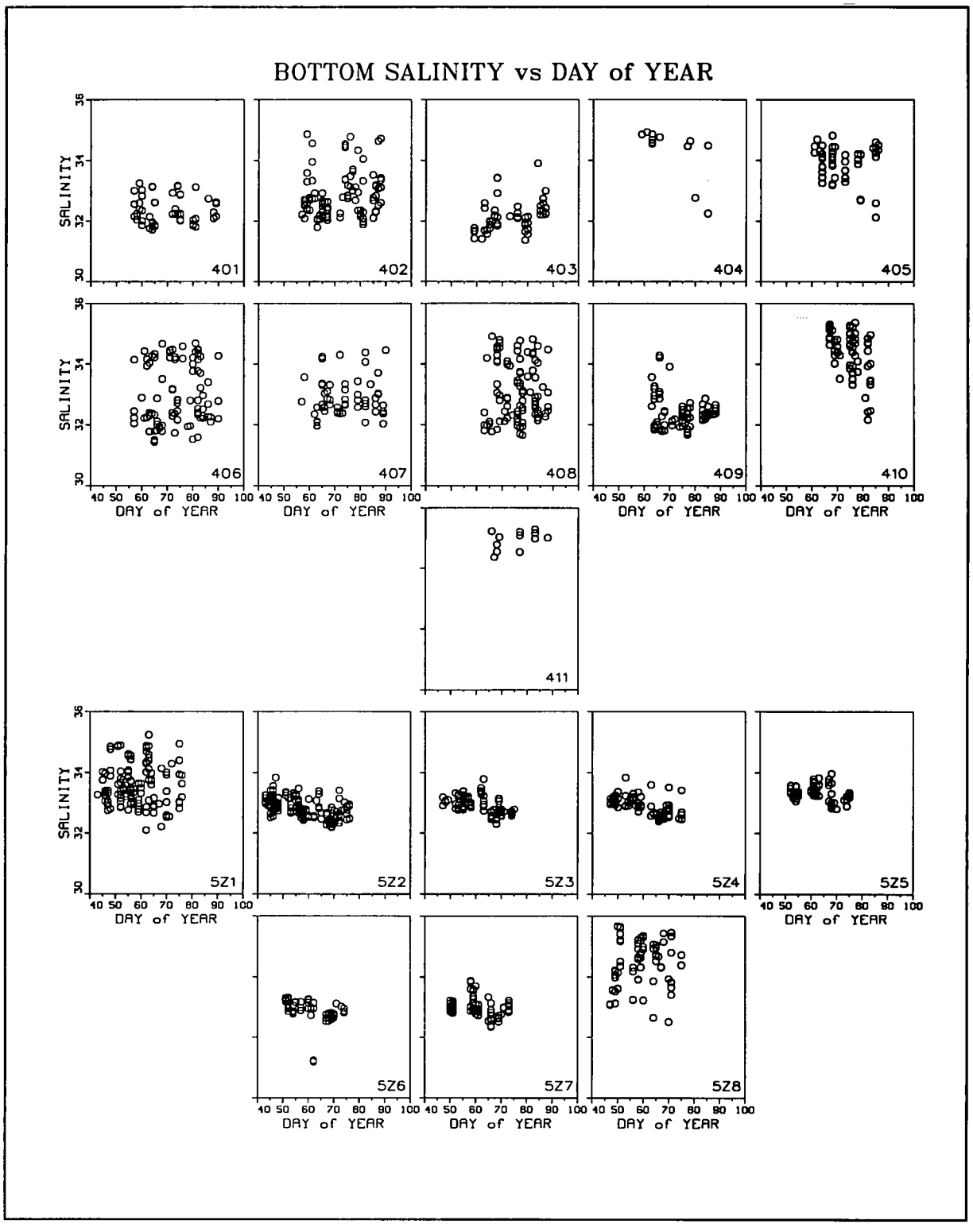

Figure 9: Near-bottom salinities within the spring 4VsW and 5Z surveys in relation to the day of the year. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

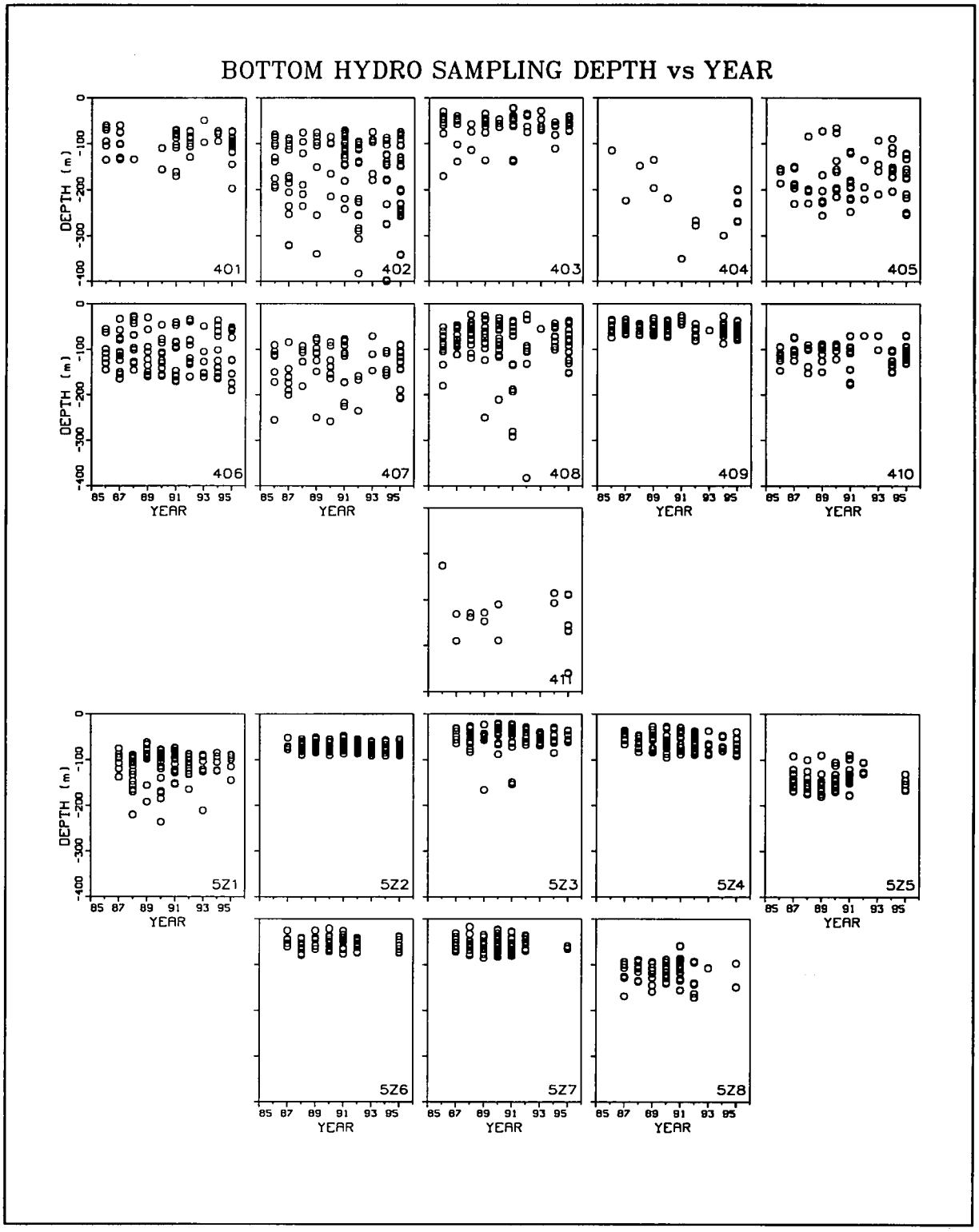

Figure 10: Time series of the near–bottom hydrographic sampling depth for each station within the spring 4VsW and 5Z surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the near–bottom sampling depth of one hydrographic station.

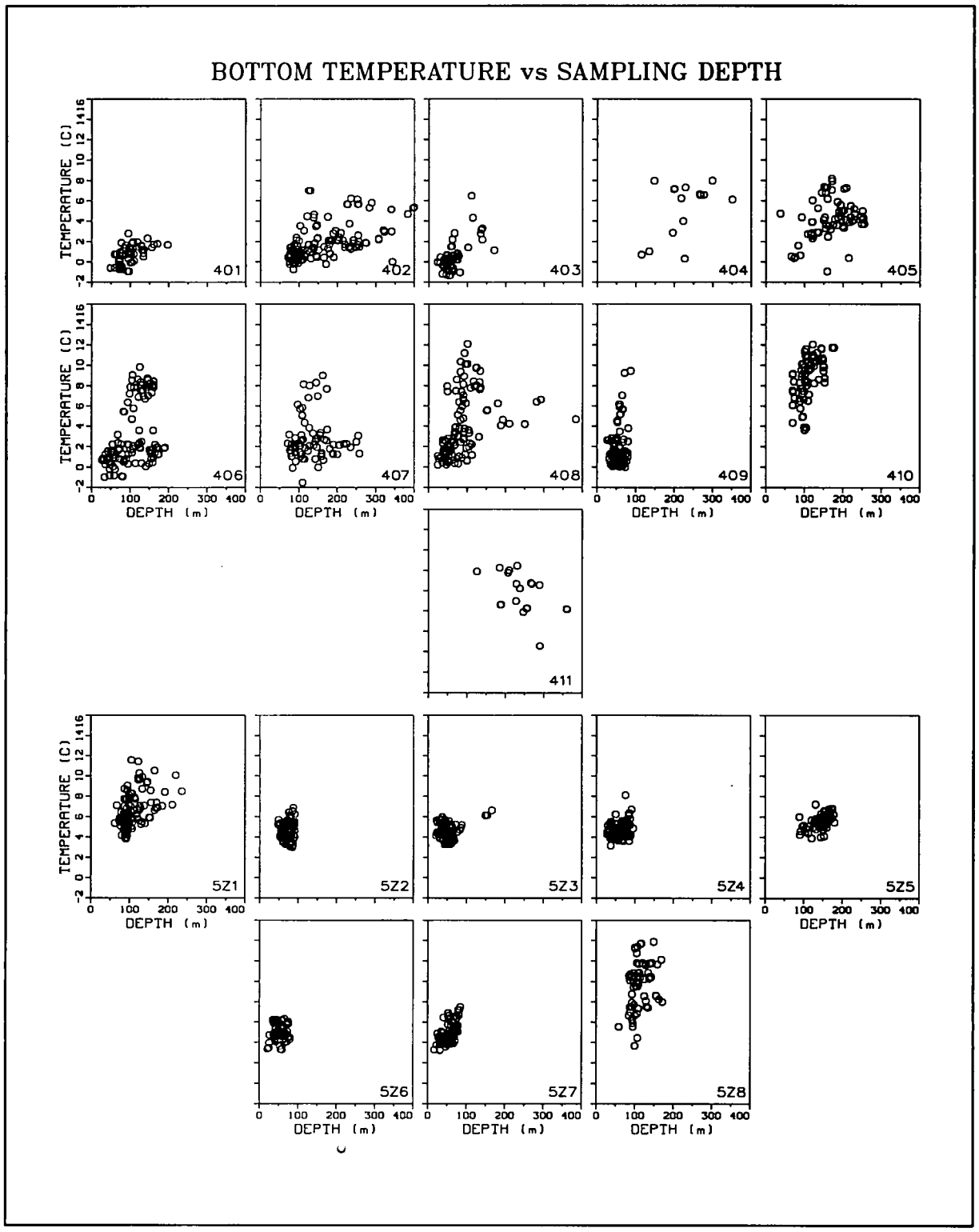

Figure 11: Near-bottom temperatures within the spring 4VsW and 5Z surveys in relation to sampling depth. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

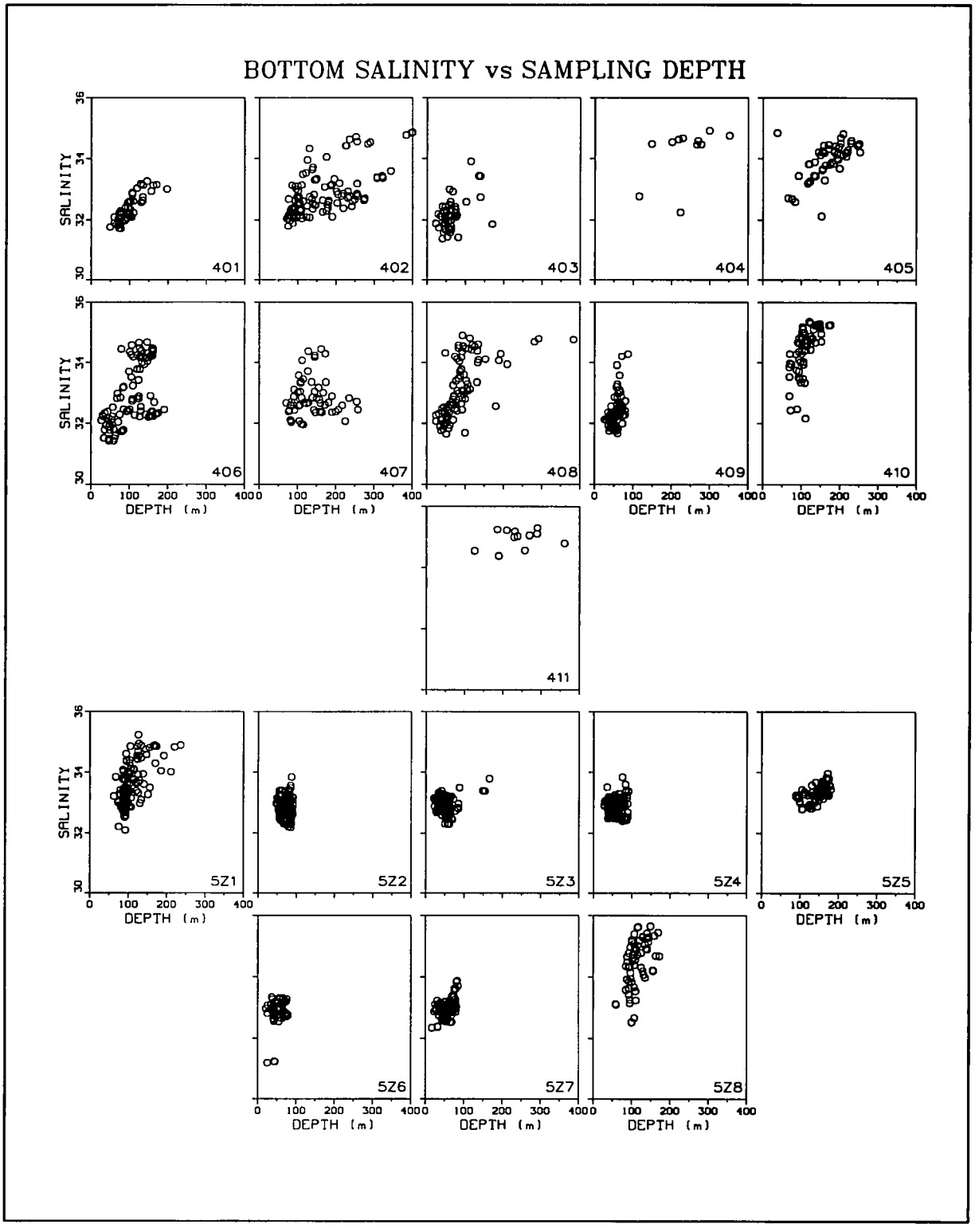

Figure 12: Near-bottom salinities within the spring 4VsW and 5Z surveys in relation to sampling depth. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

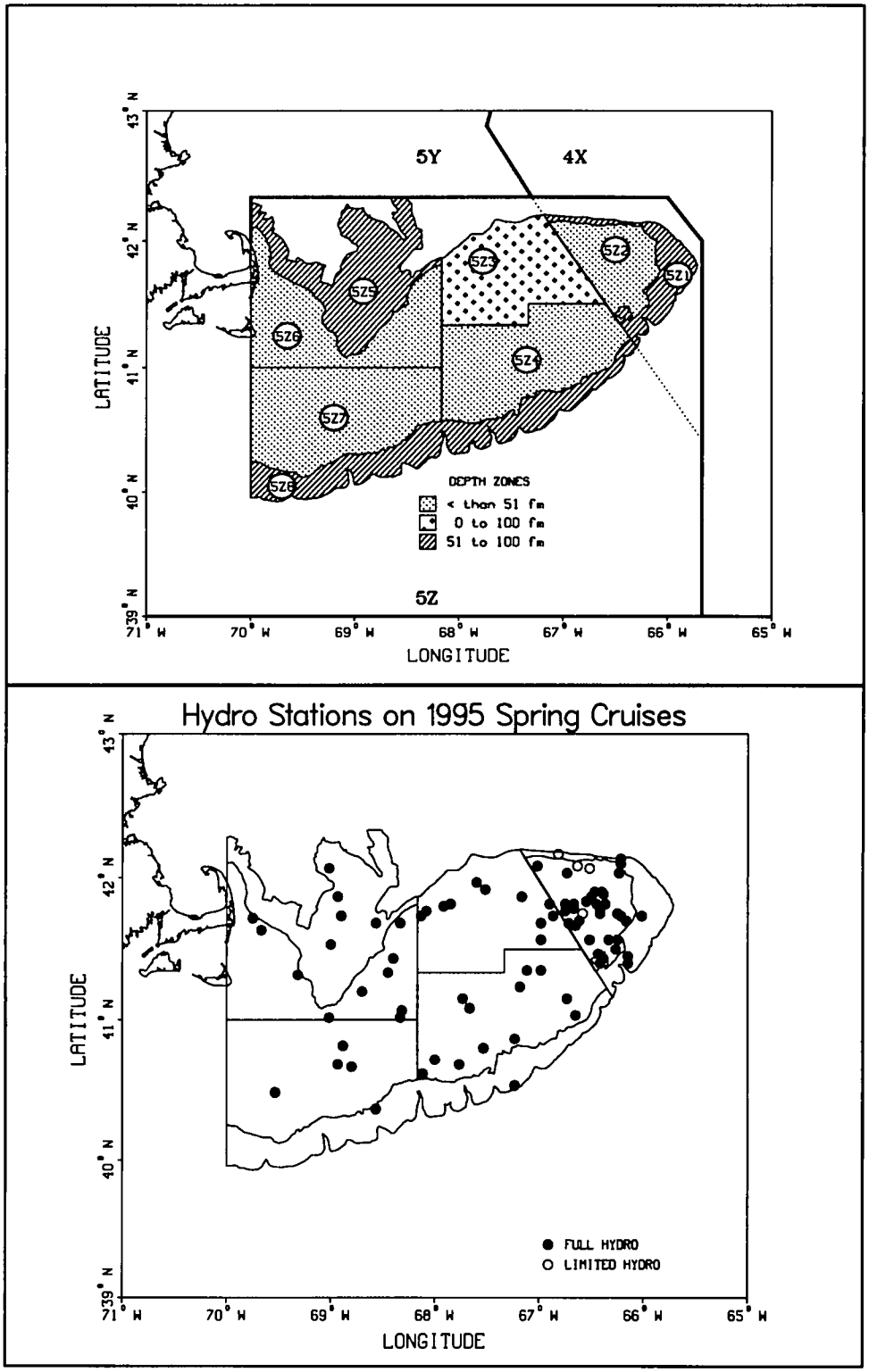

Figure 13: Survey domain and strata boundaries for the Canadian spring groundfish bottom–trawl research vessel surveys conducted within NAFO area 5Z from 1987–1995 (top panel) and the location of hydrographic sampling stations taken during the 1995 spring survey (bottom panel). In the top panel the numbers enclosed within circles are the strata designations.

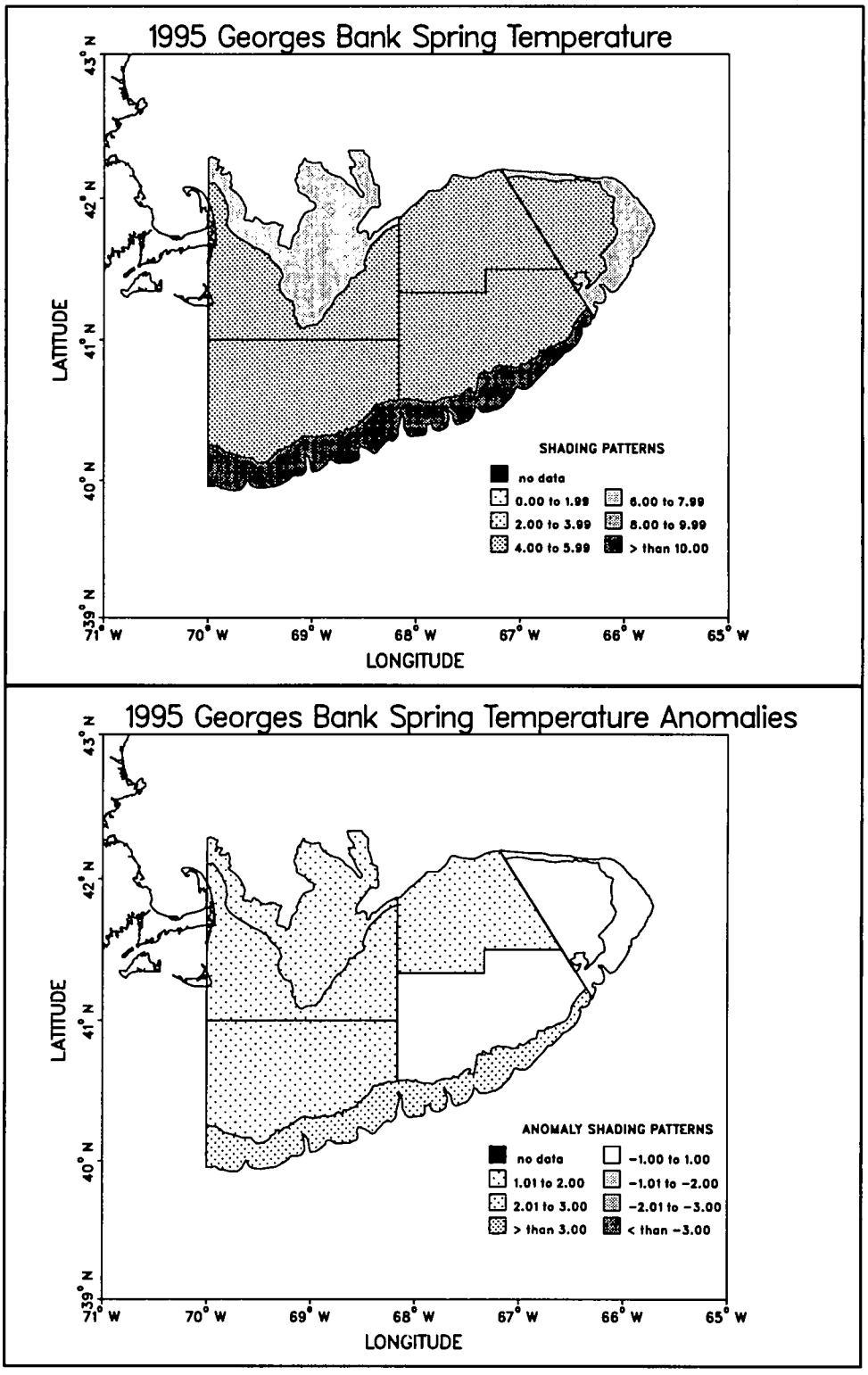

Figure 14: Map of near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 5Z during the Canadian research vessel bottom-trawl survey conducted during the spring of 1995.

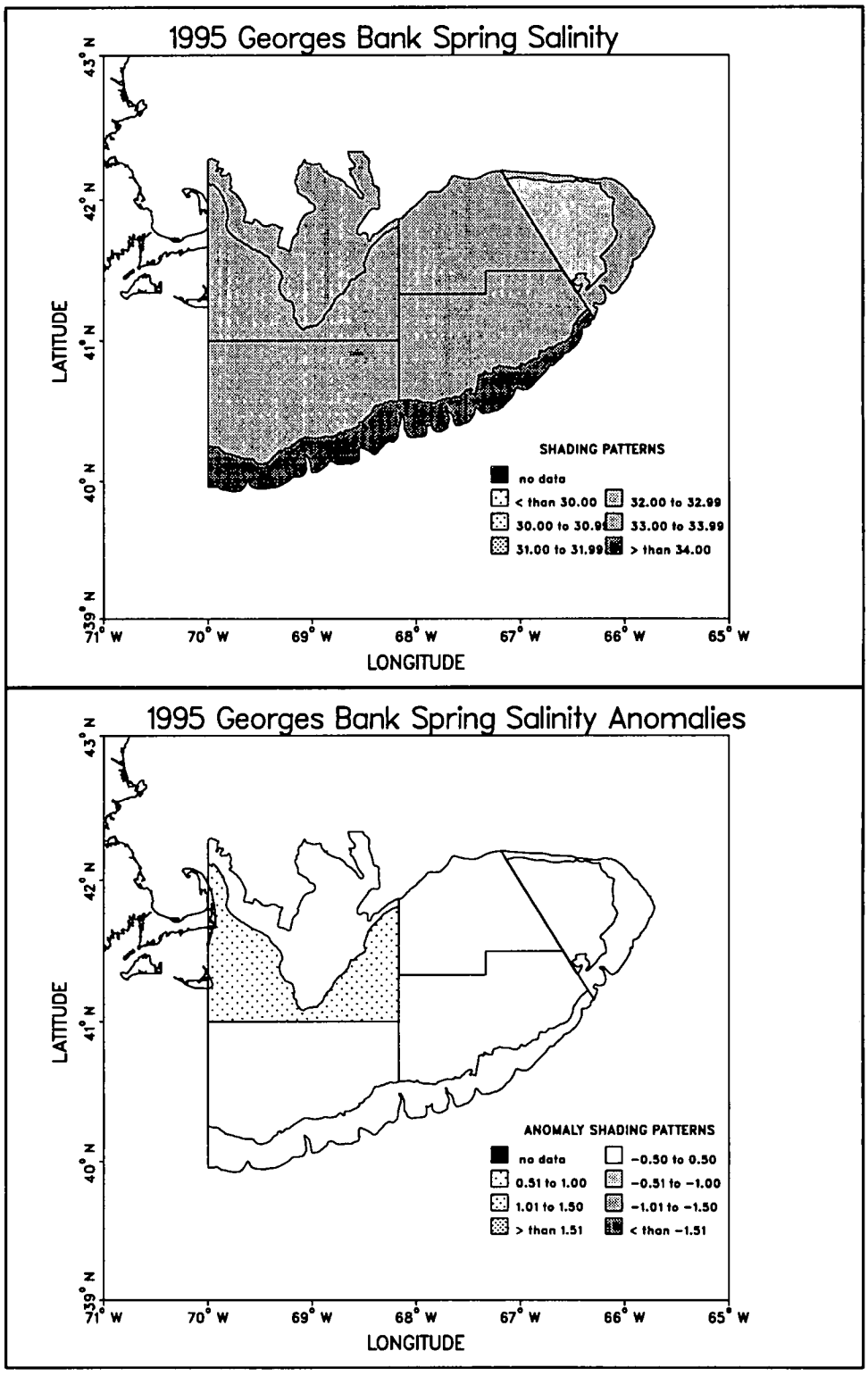

Figure 15: Map of near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 5Z during the Canadian research vessel bottom-trawl survey conducted during the spring of 1995.

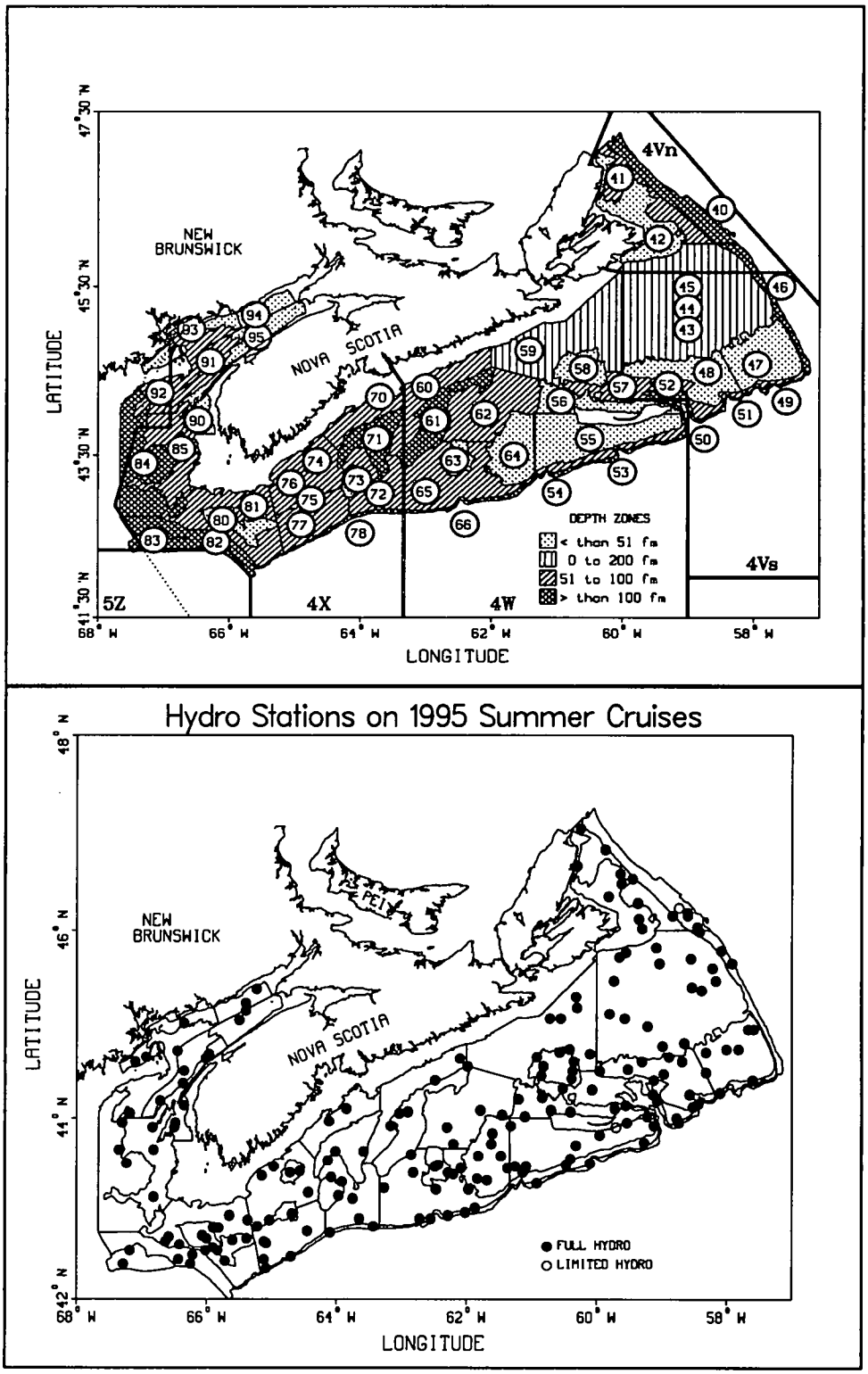

Figure 16: Survey domain and strata boundaries for the Canadian summer groundfish bottom–trawl research vessel surveys conducted within NAFO area 4VWX from 1970–1995 (top panel) and the location of hydrographic sampling stations taken during the 1995 summer survey (bottom panel). In the top panel the numbers enclosed within circle are the strata designations. Only the last two digits of the summer strata designations are shown.

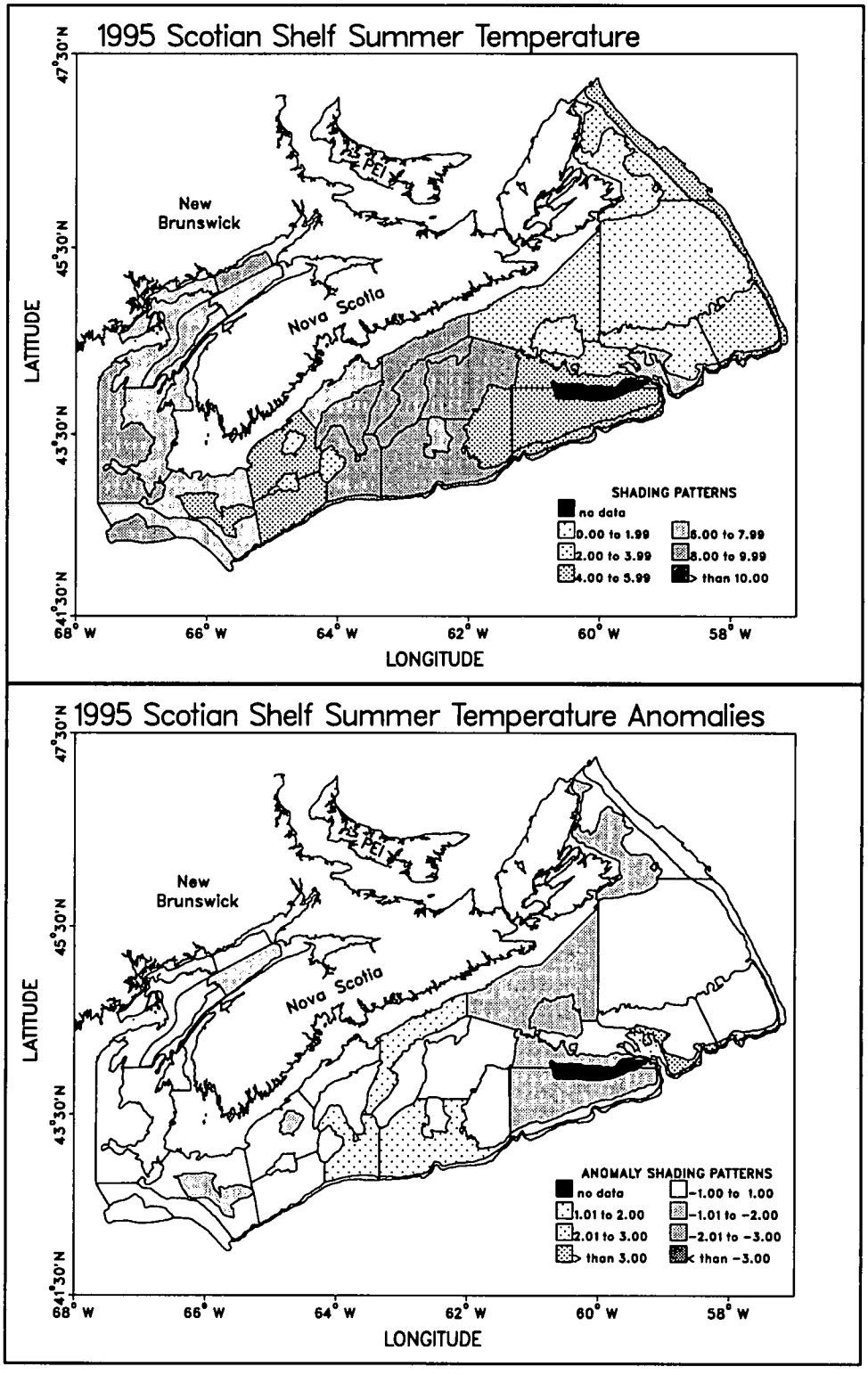

Figure 17: Map of near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1995.

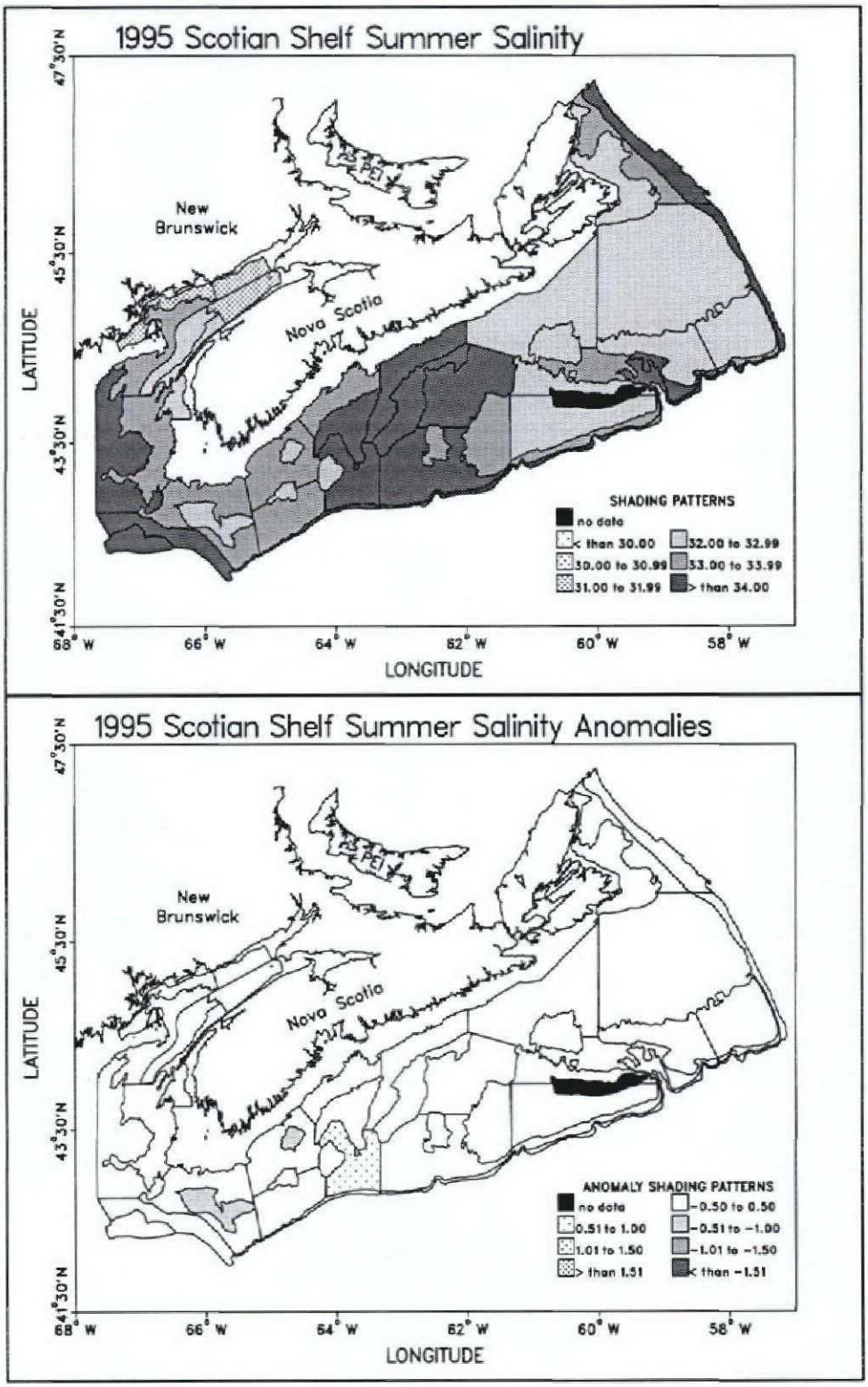

Figure 18: Map of near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1995.

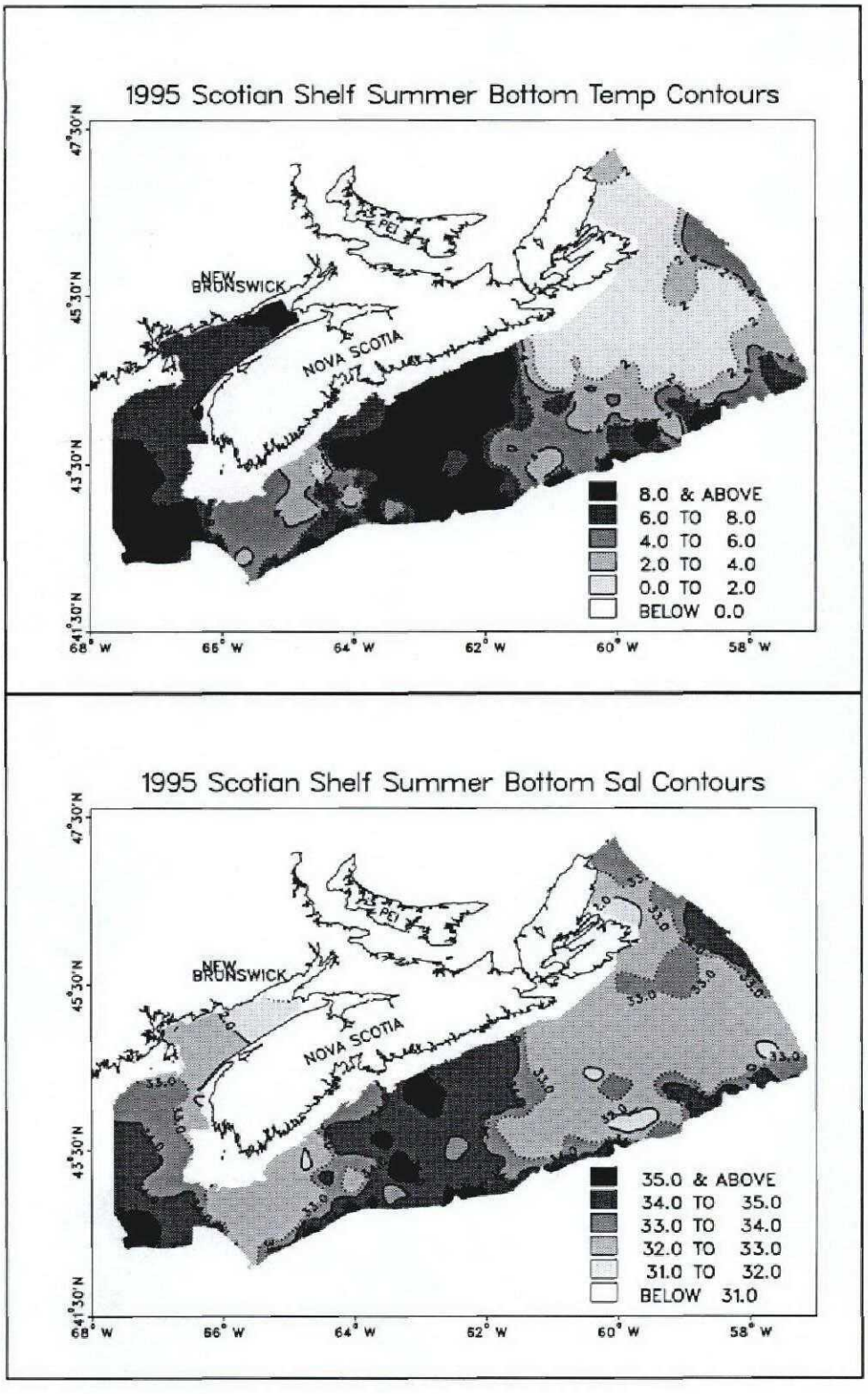

Figure 19: Contour maps of near-bottom temperature and salinities within the 4VWX Canadian research vessel bottom-trawl surveys conducted during the summer of 1995.

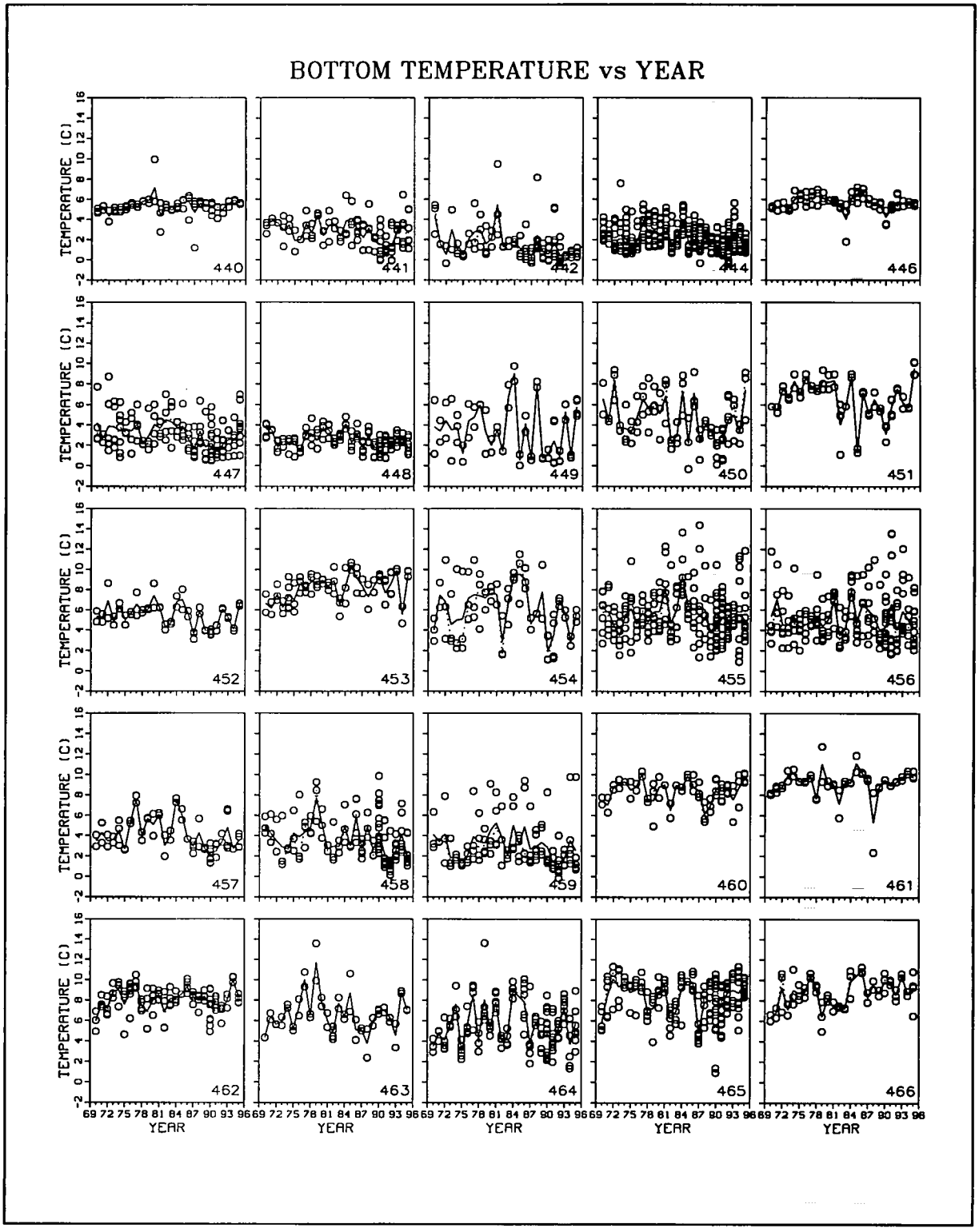

Figure 20: Time series of near–bottom temperatures within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

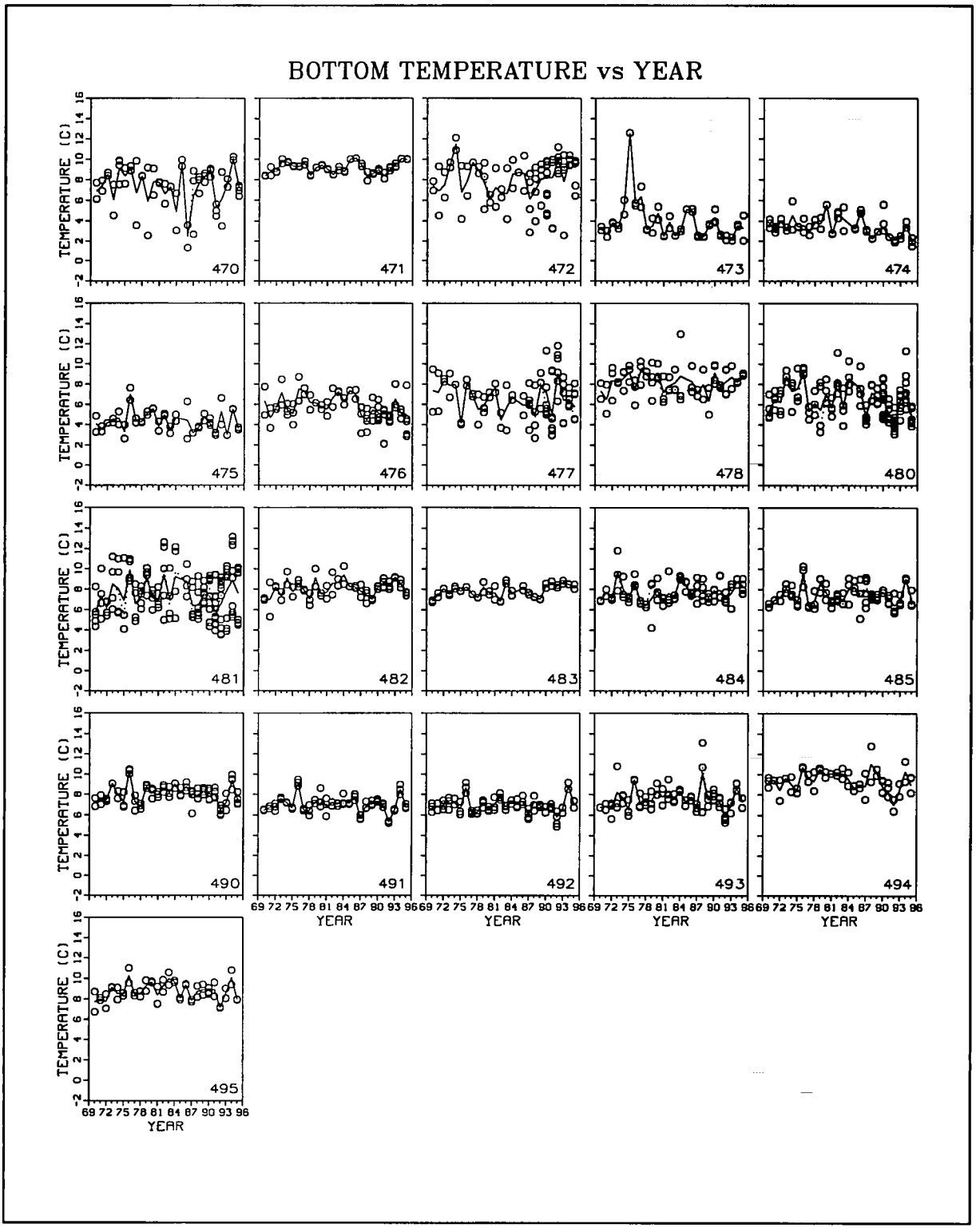

Figure 20: continued

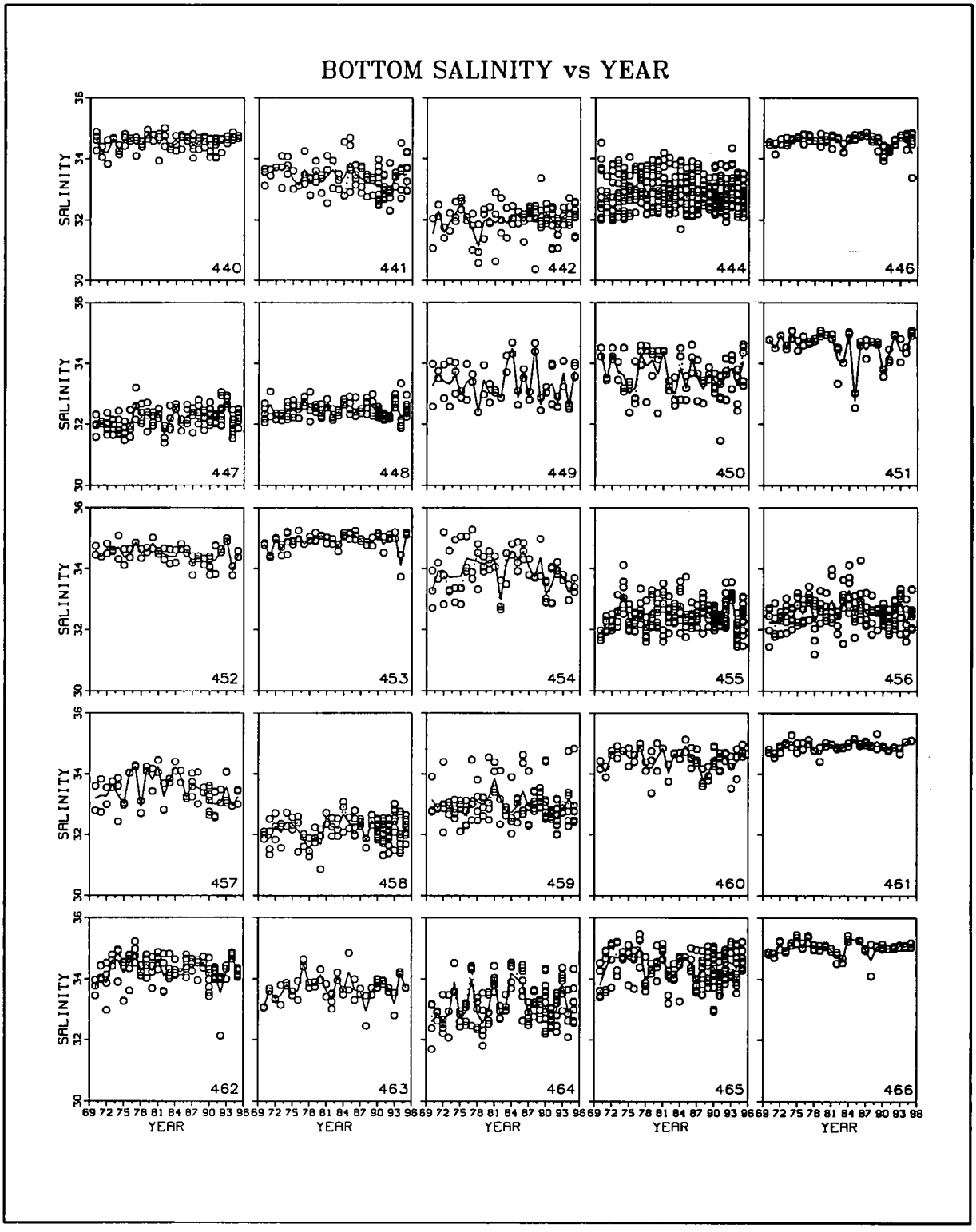

Figure 21: Time series of near-bottom salinities within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

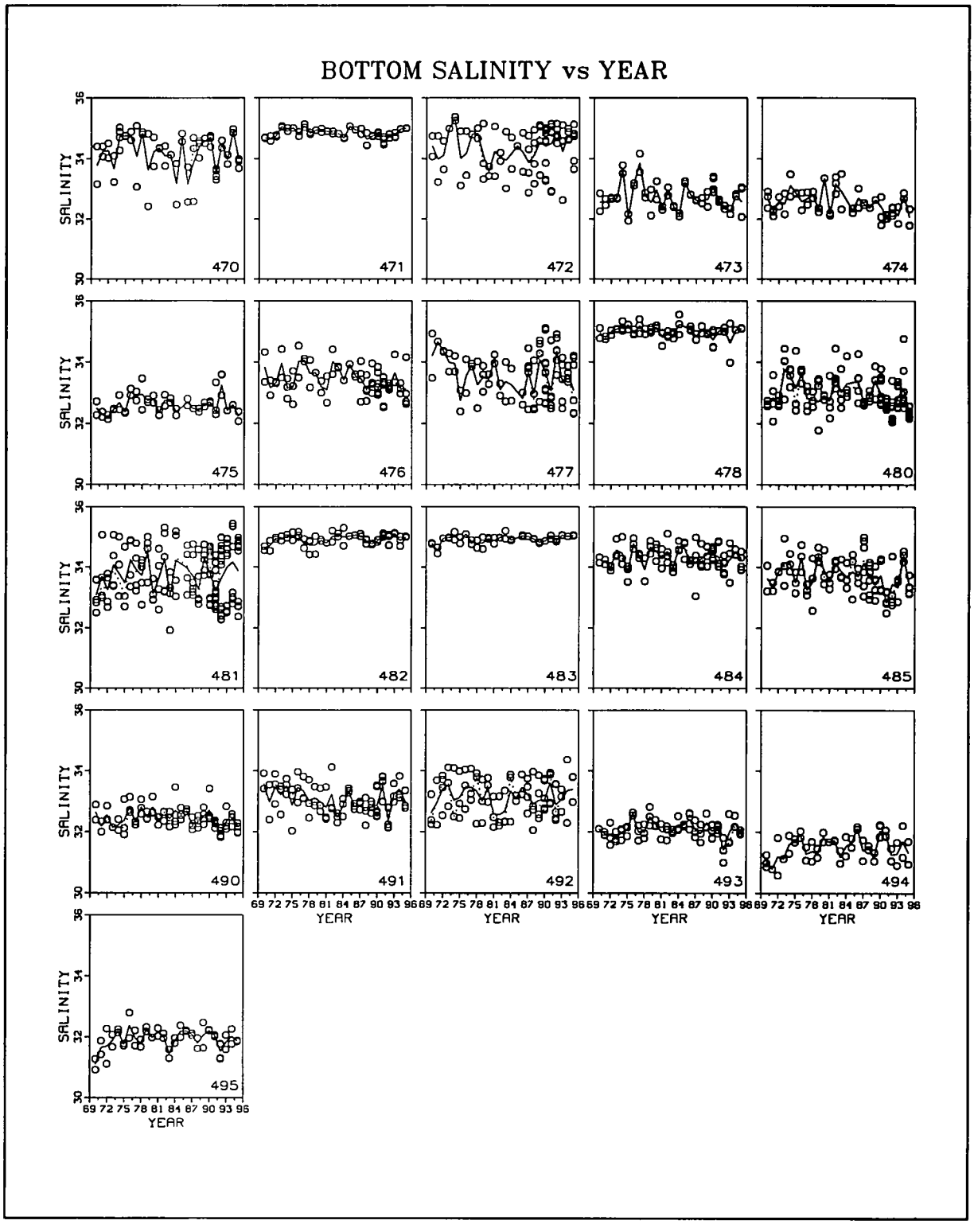

Figure 21: continued

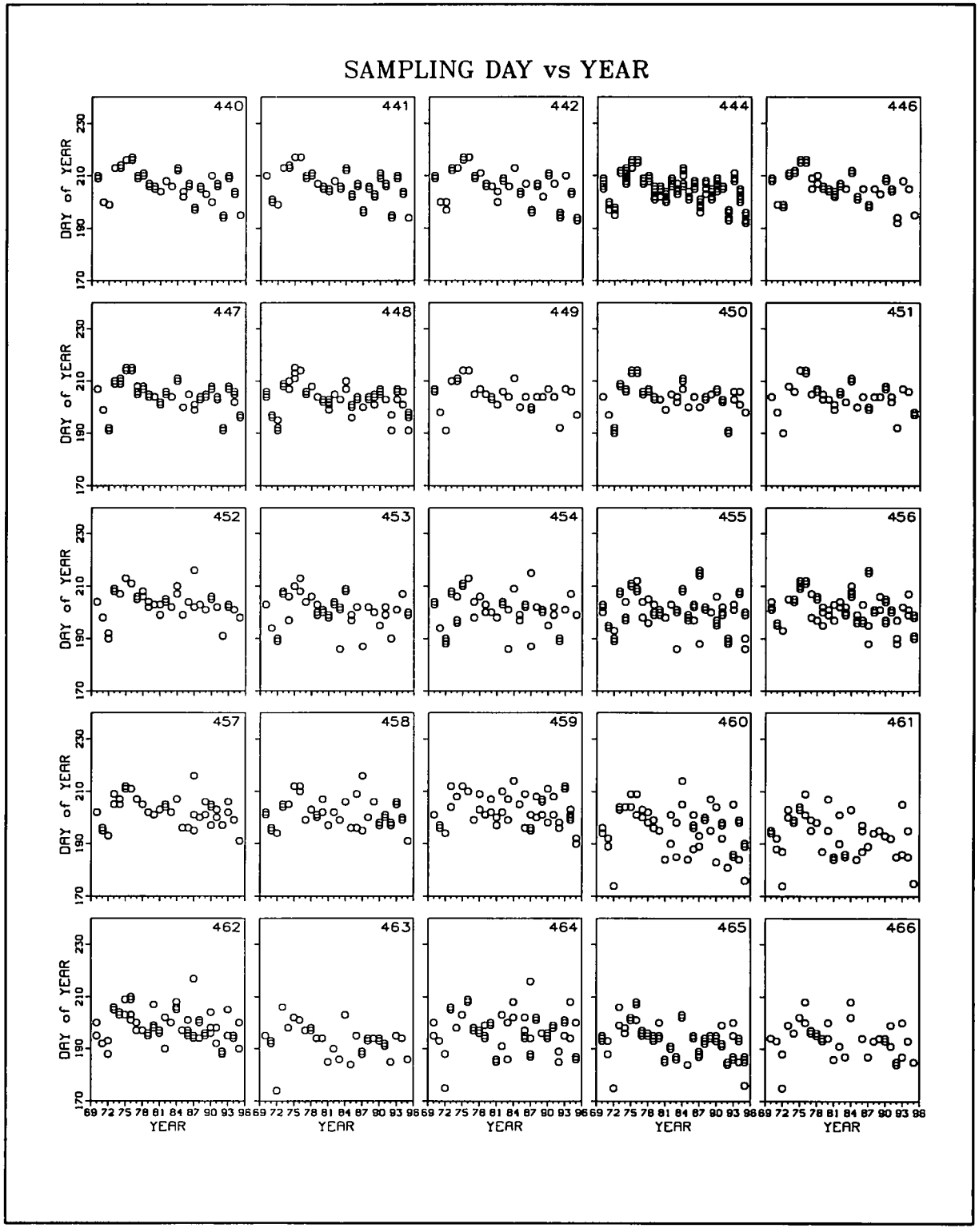

Figure 22: Time series of the consecutive day of sampling within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.

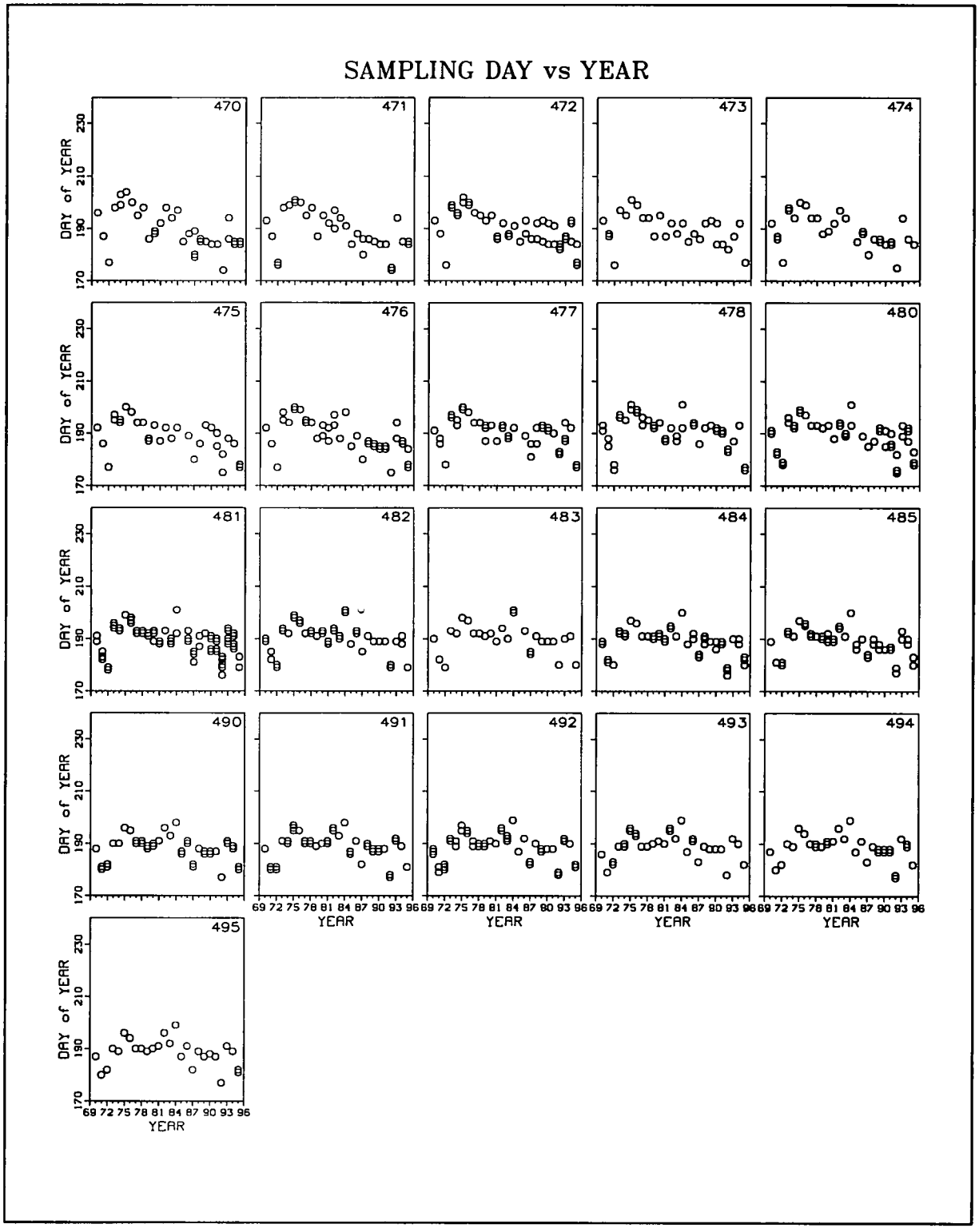

Figure 22: continued

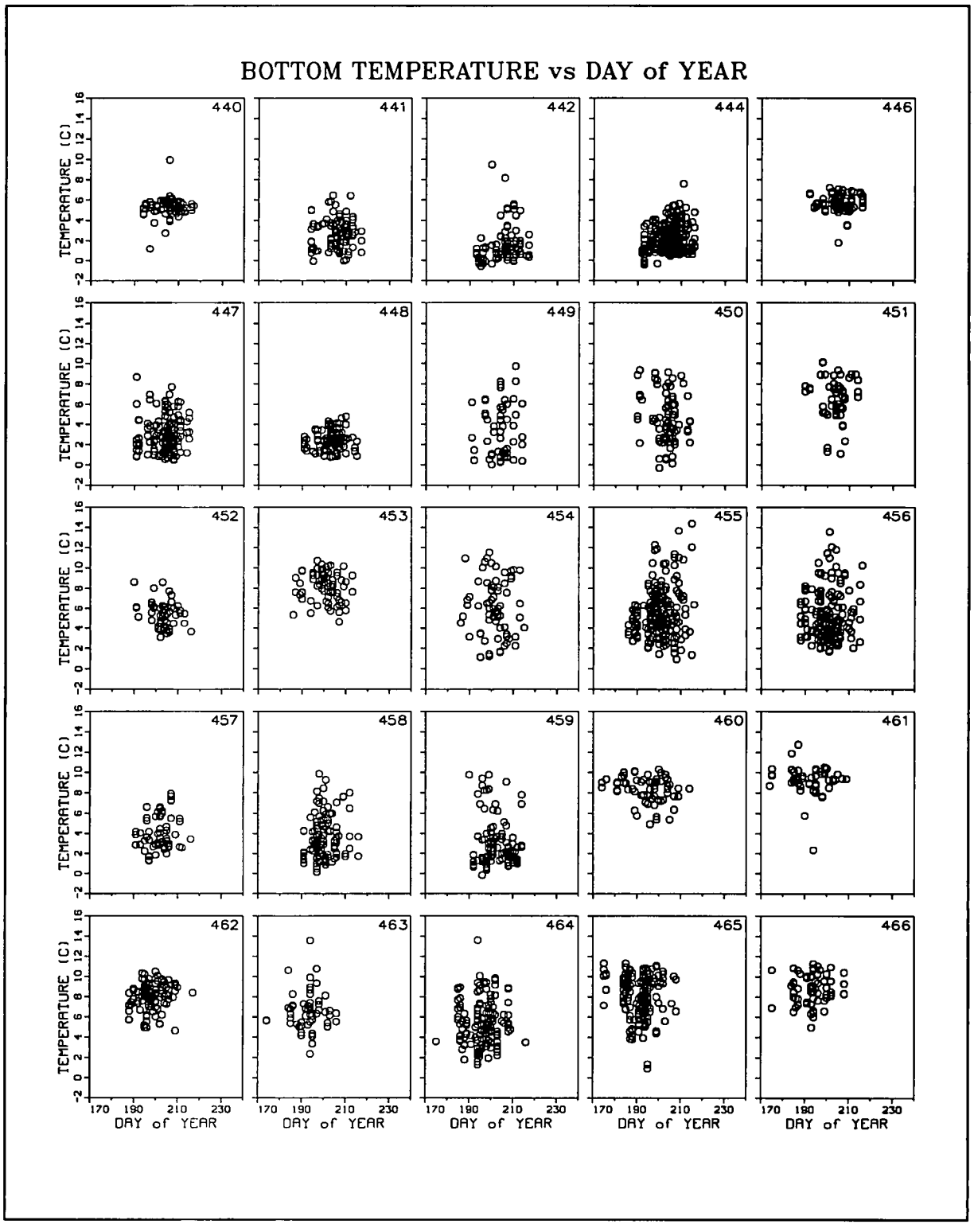

Figure 23: Near-bottom temperatures within the summer 4VWX surveys in relation to the day of the year. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

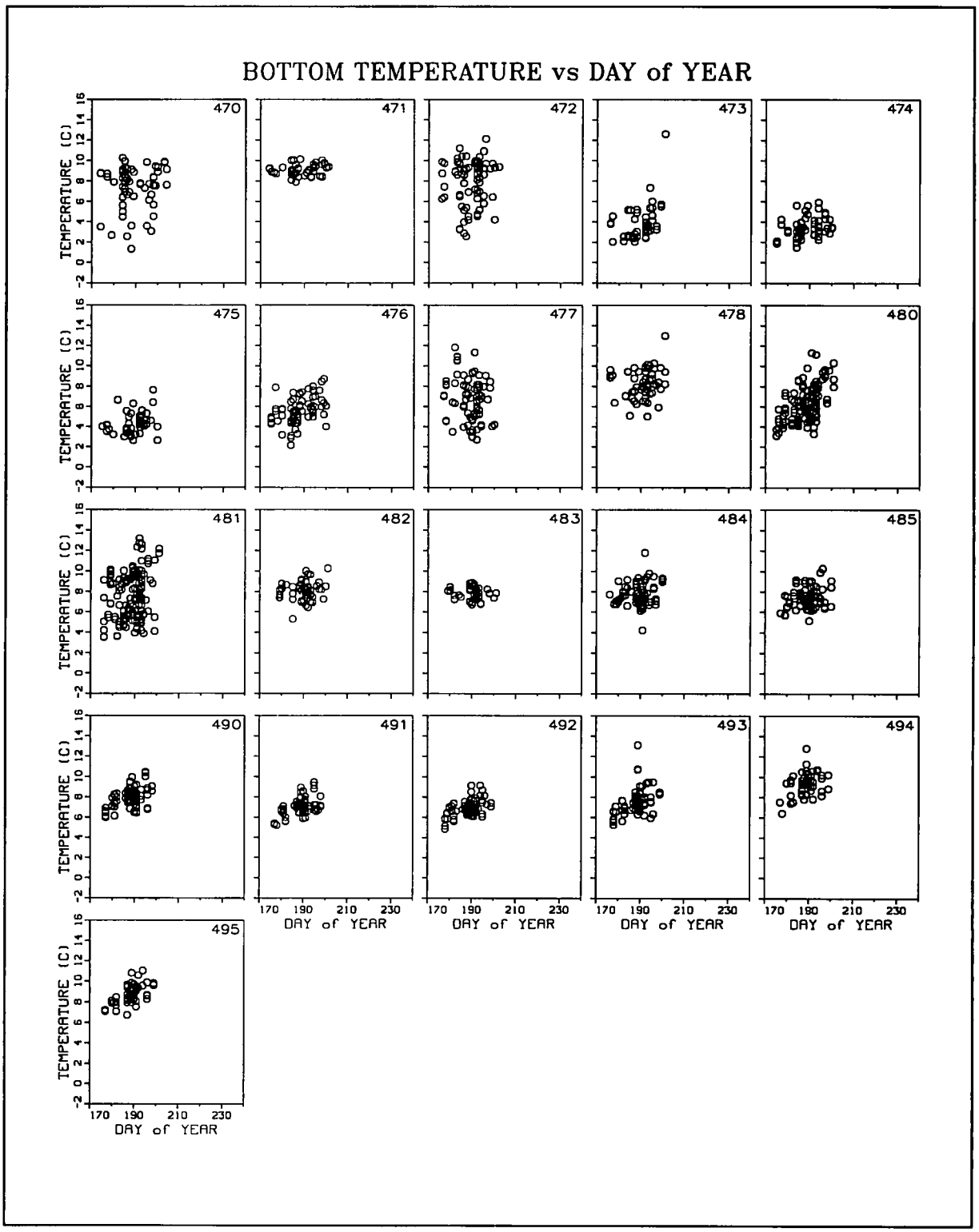

Figure 23: continued

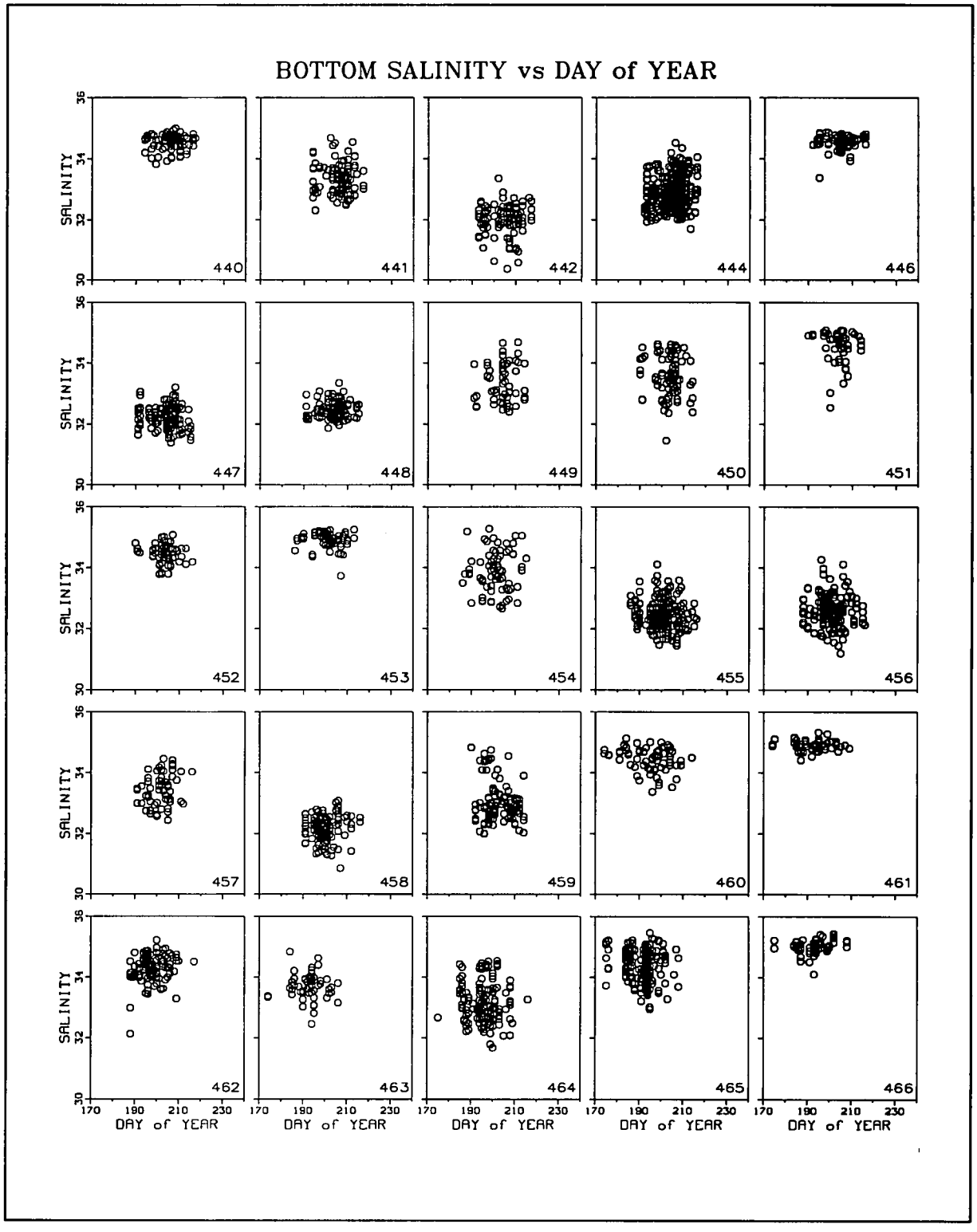

Figure 24: Near-bottom salinities within the summer 4VWX surveys in relation to the day of the year. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

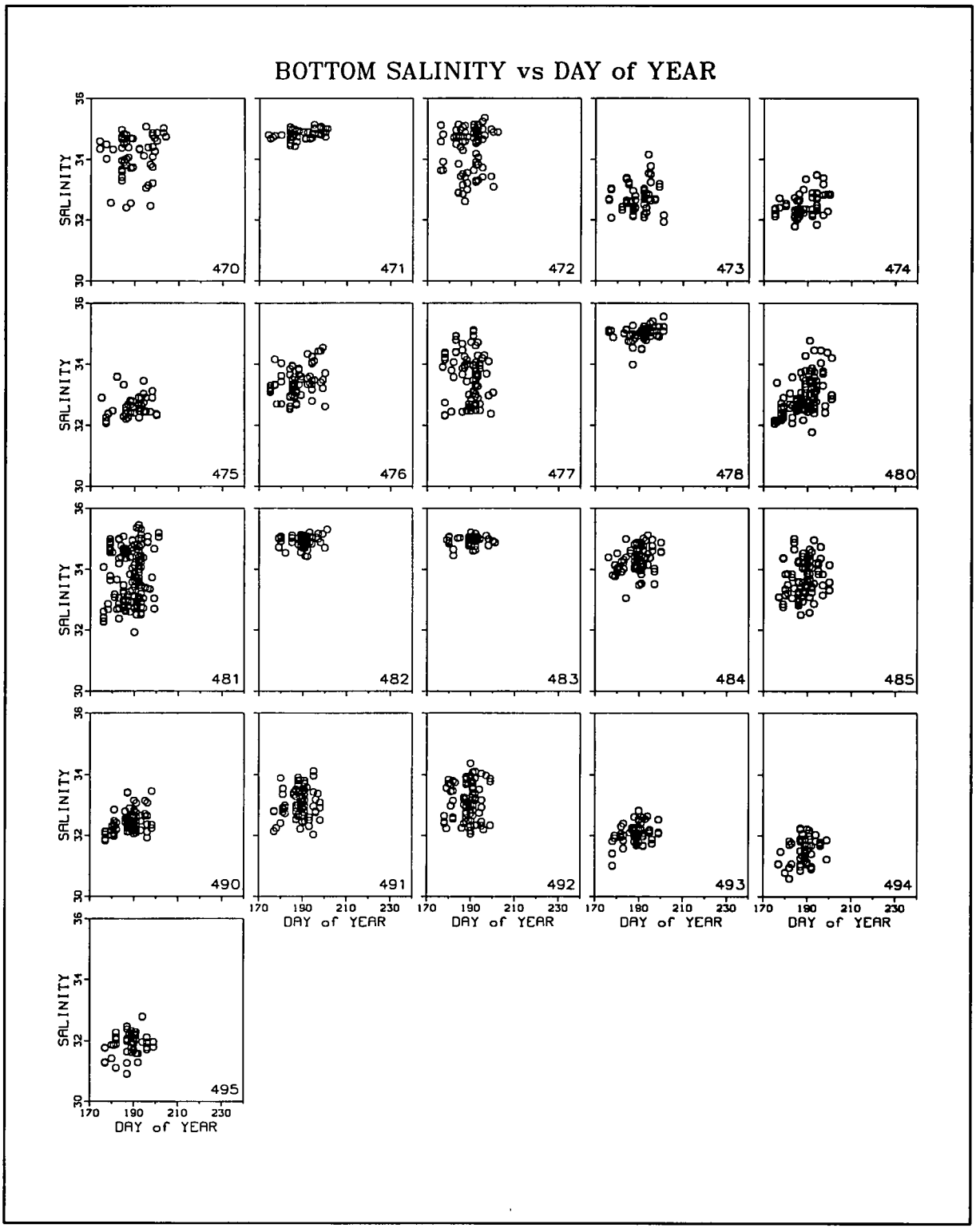

Figure 24: continued

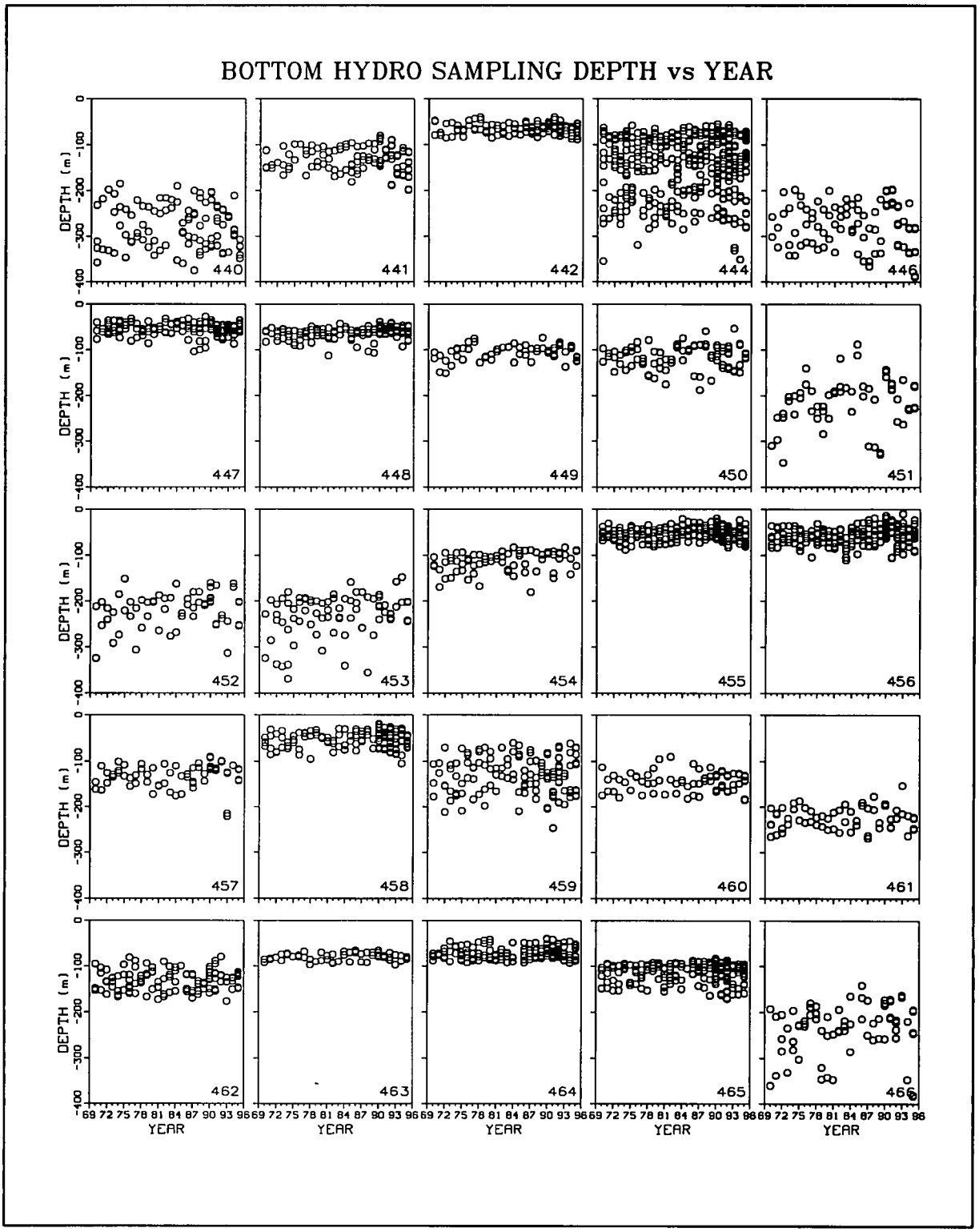

Figure 25: Time series of the near-bottom hydrographic sampling depth for each station within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the near-bottom sampling depth of one hydrographic station.

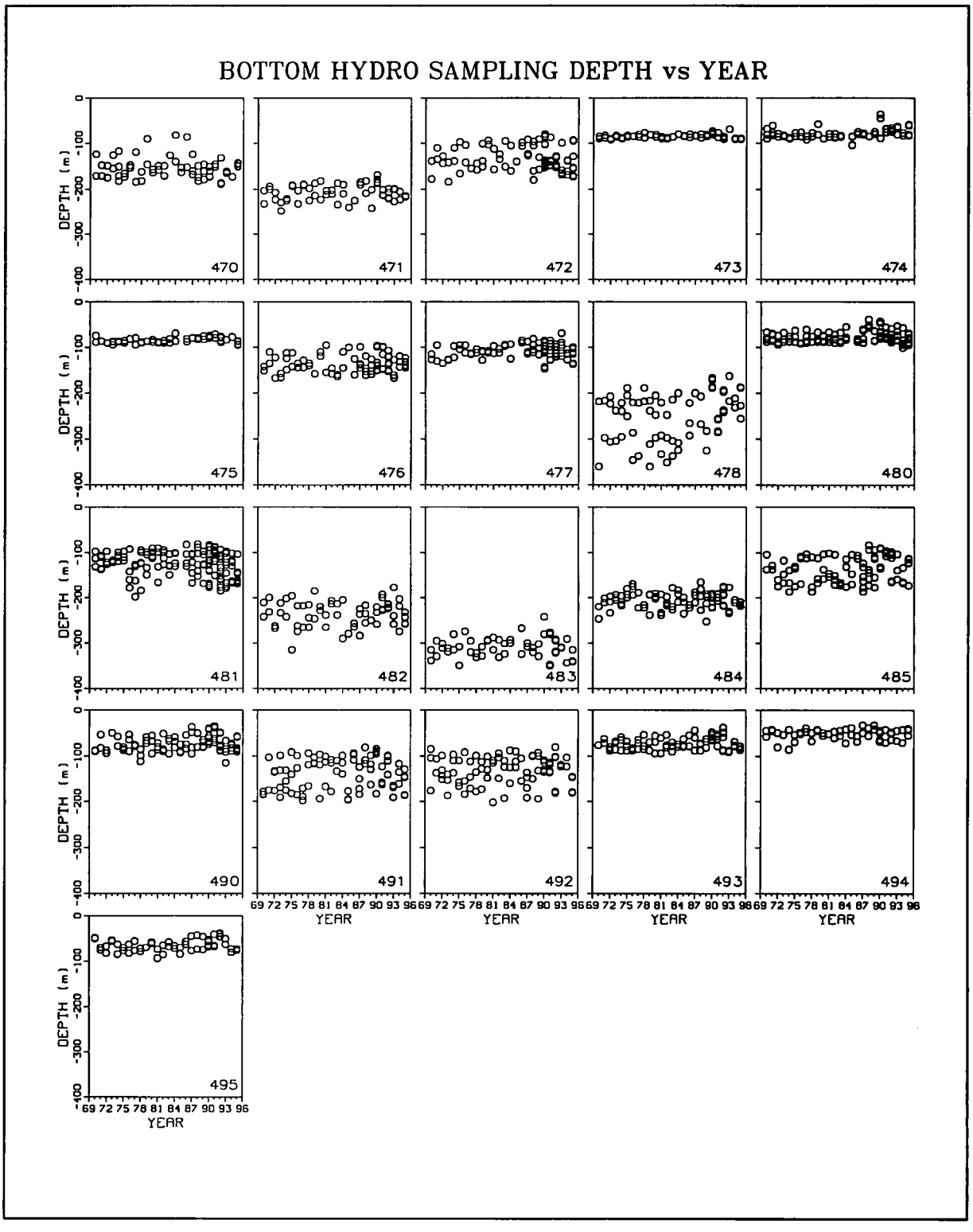

Figure 25: continued

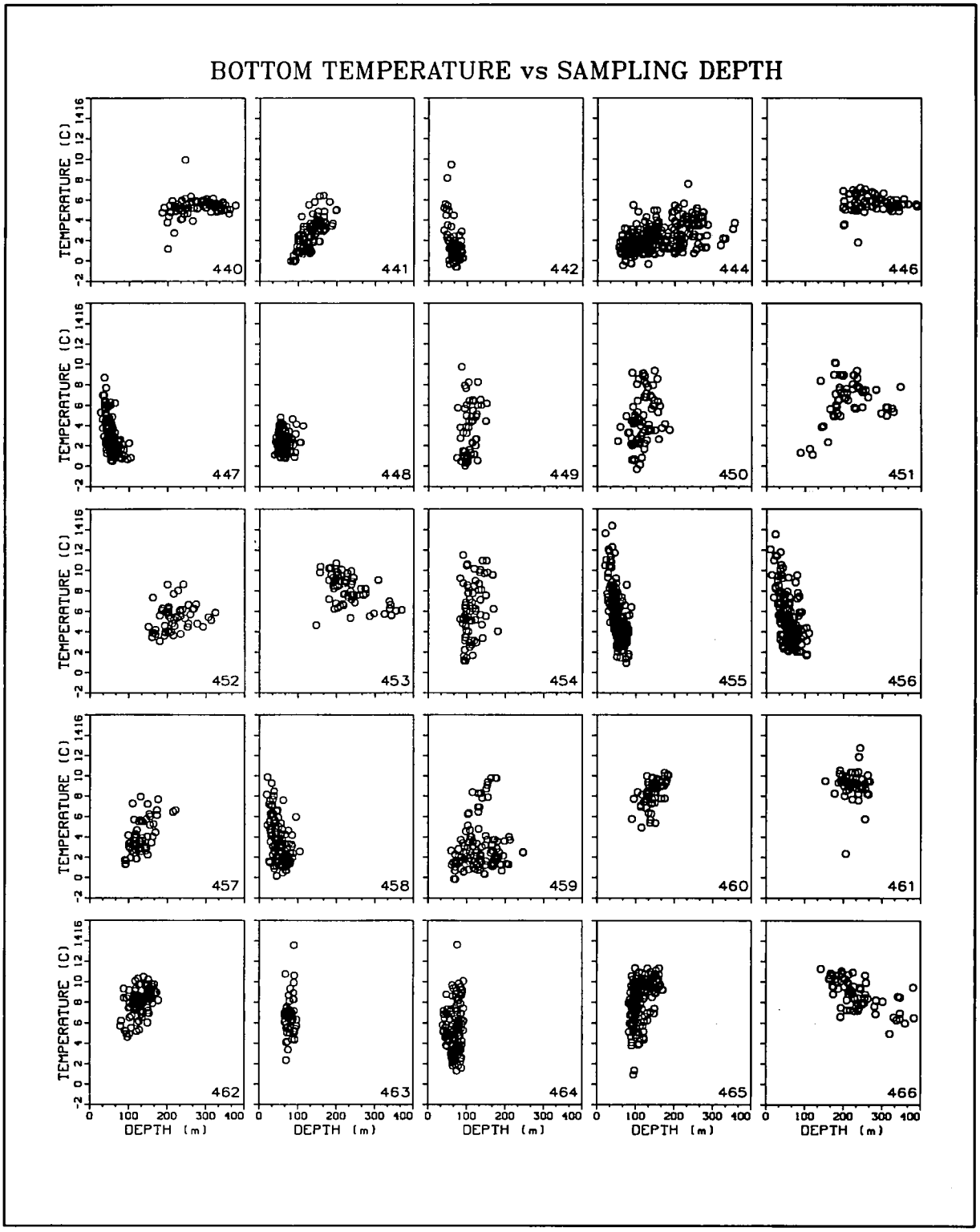

Figure 26: Near-bottom temperatures within the summer 4VWX surveys in relation to sampling depth. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

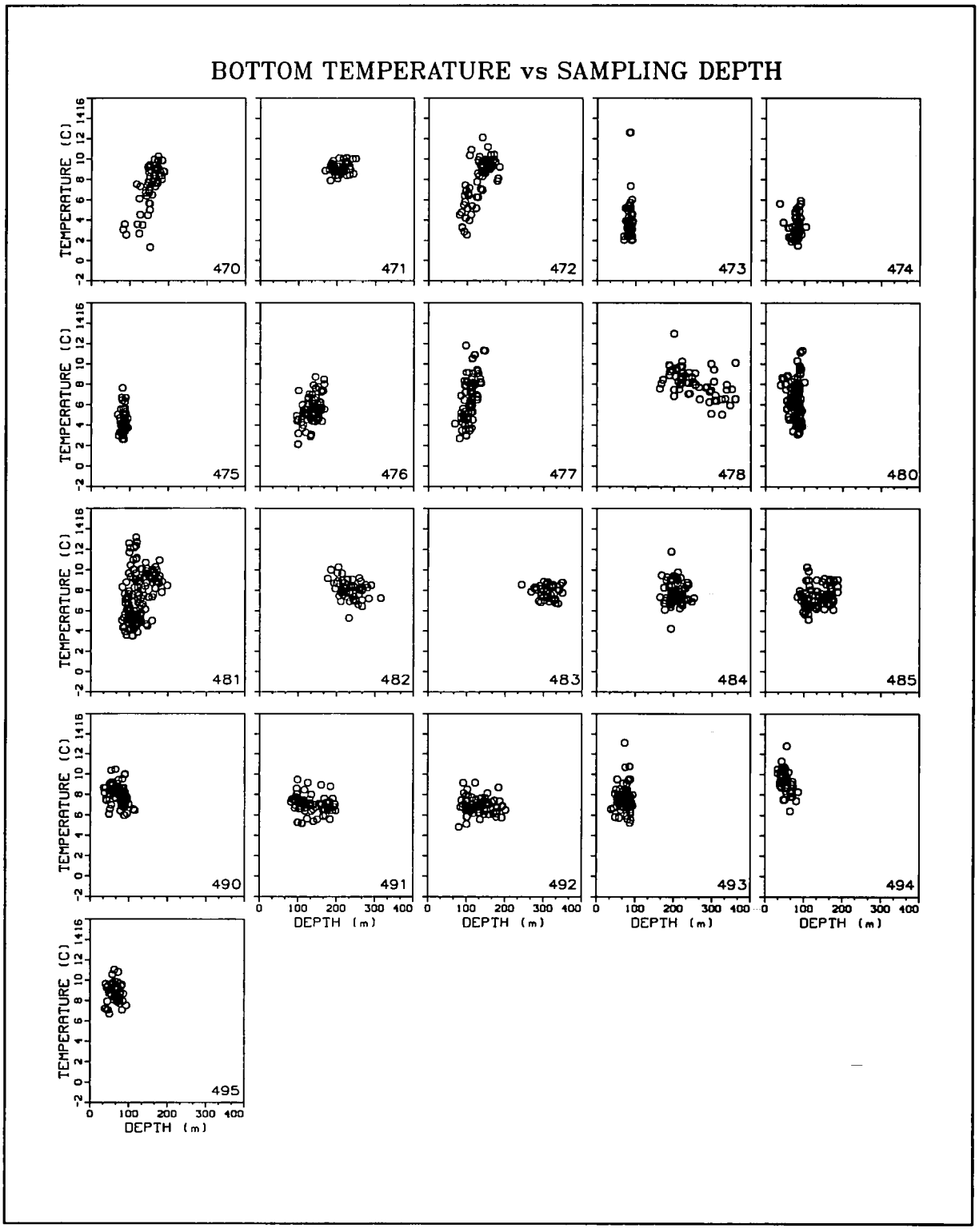

Figure 26: continued

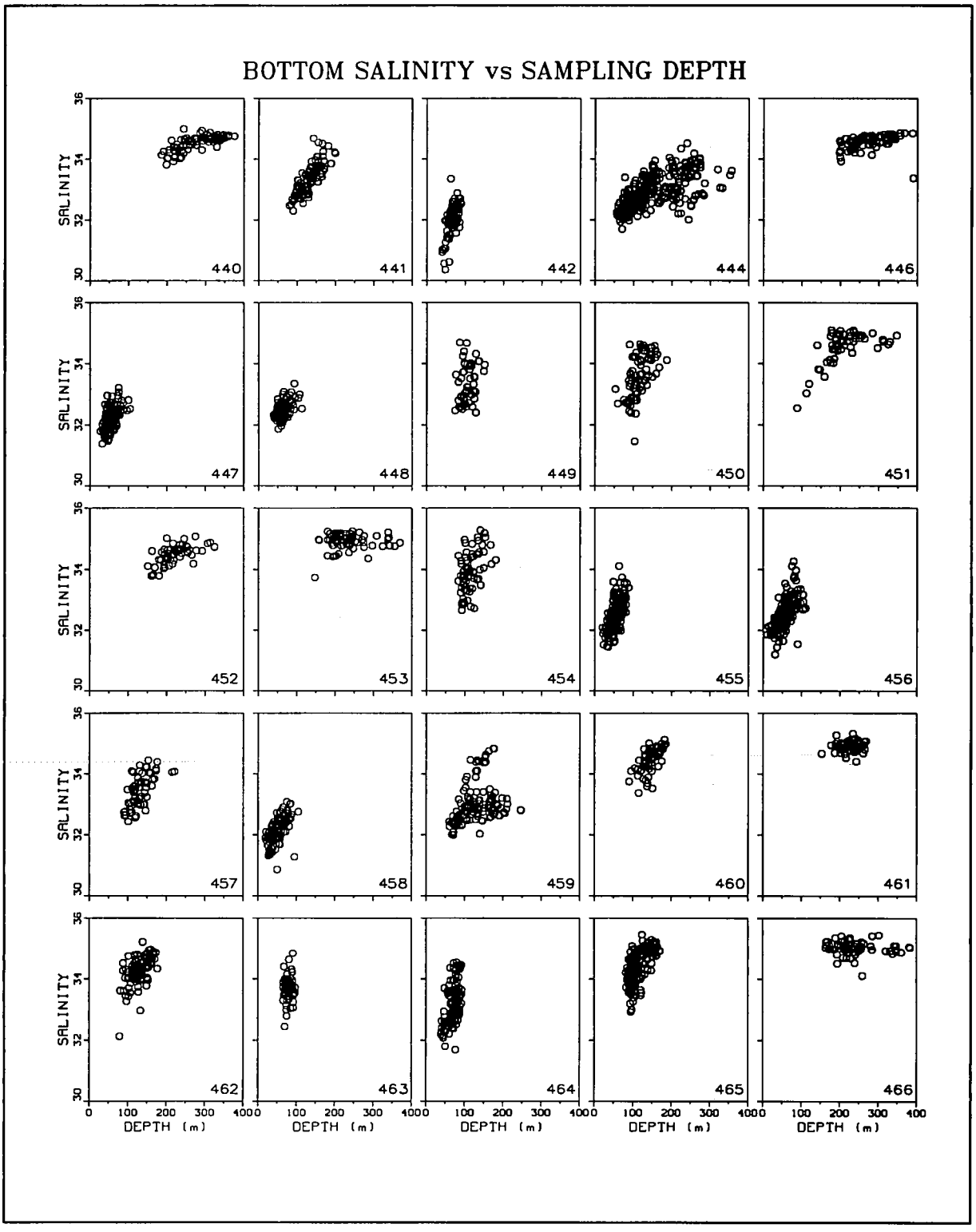

Figure 27: Near-bottom salinities within the summer 4VWX surveys in relation to sampling depth. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

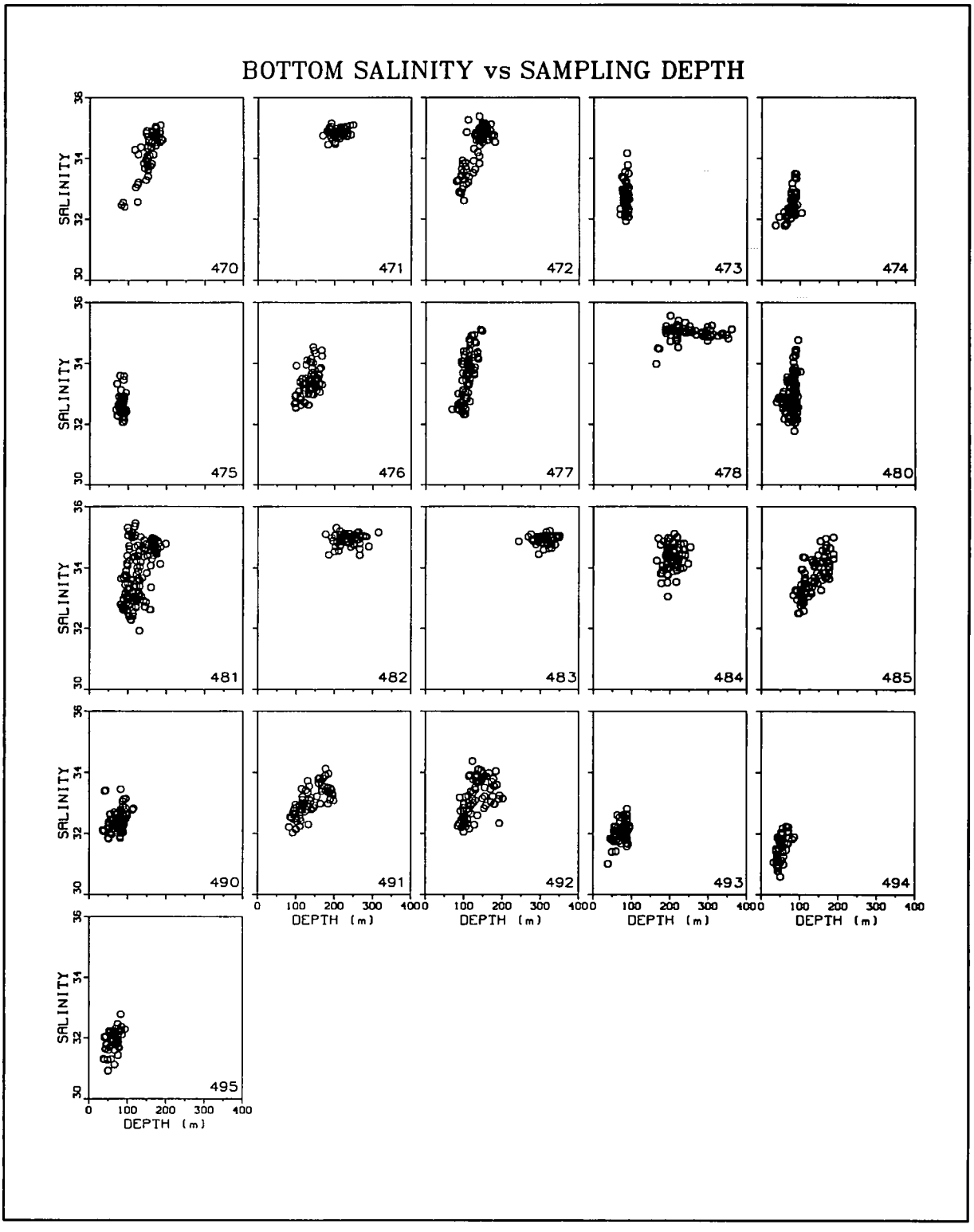

Figure 27: continued

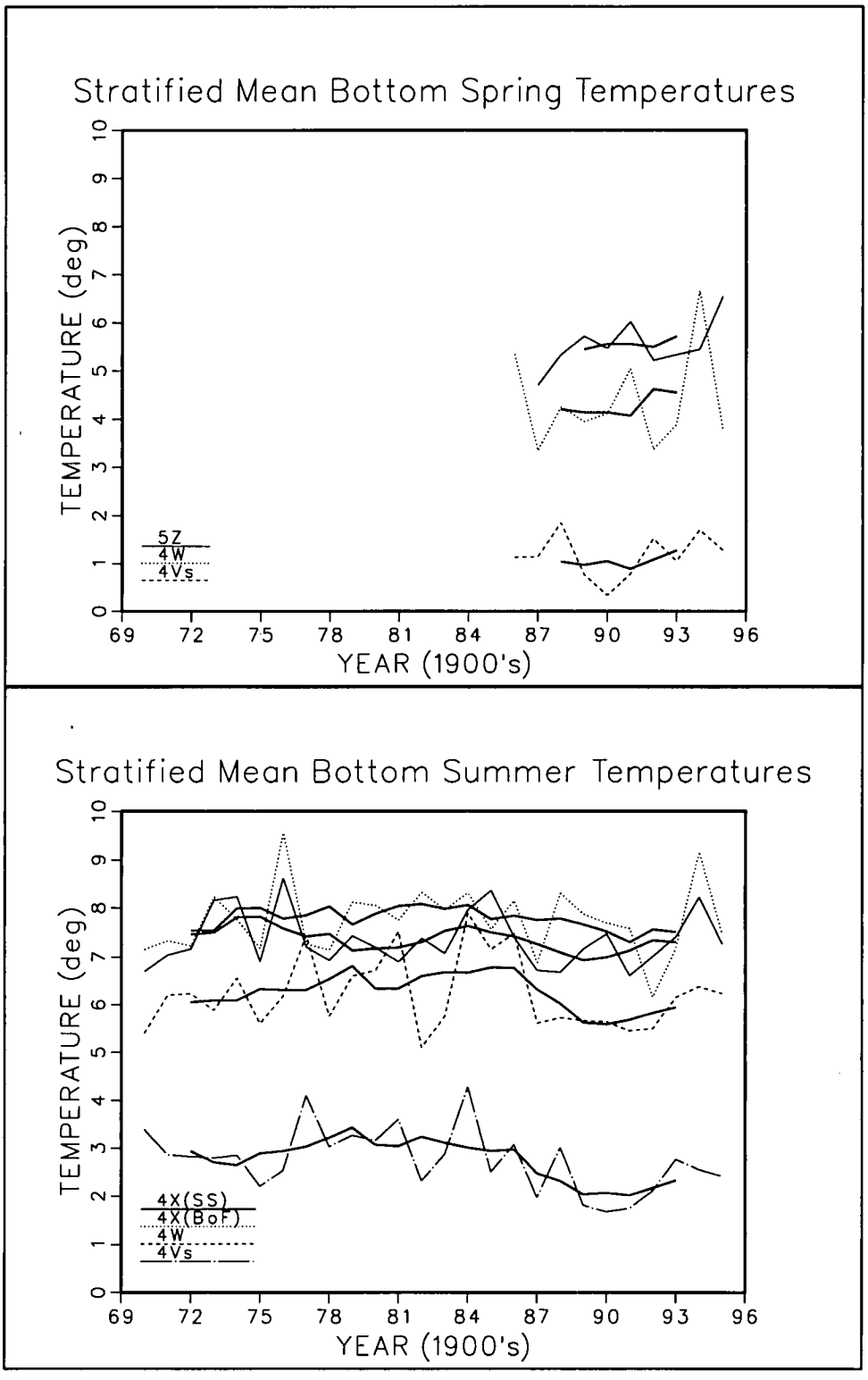

Figure 28: Time series of stratified mean near-bottom temperatures for spring (upper panel: 4Vs, 4W and 5Z) and summer Canadian research vessel groundfish surveys (lower panel: 4X Bay of Fundy, 4X Scotian Shelf, 4W and 4Vs). The smooth curves running through each series is a five year running mean.

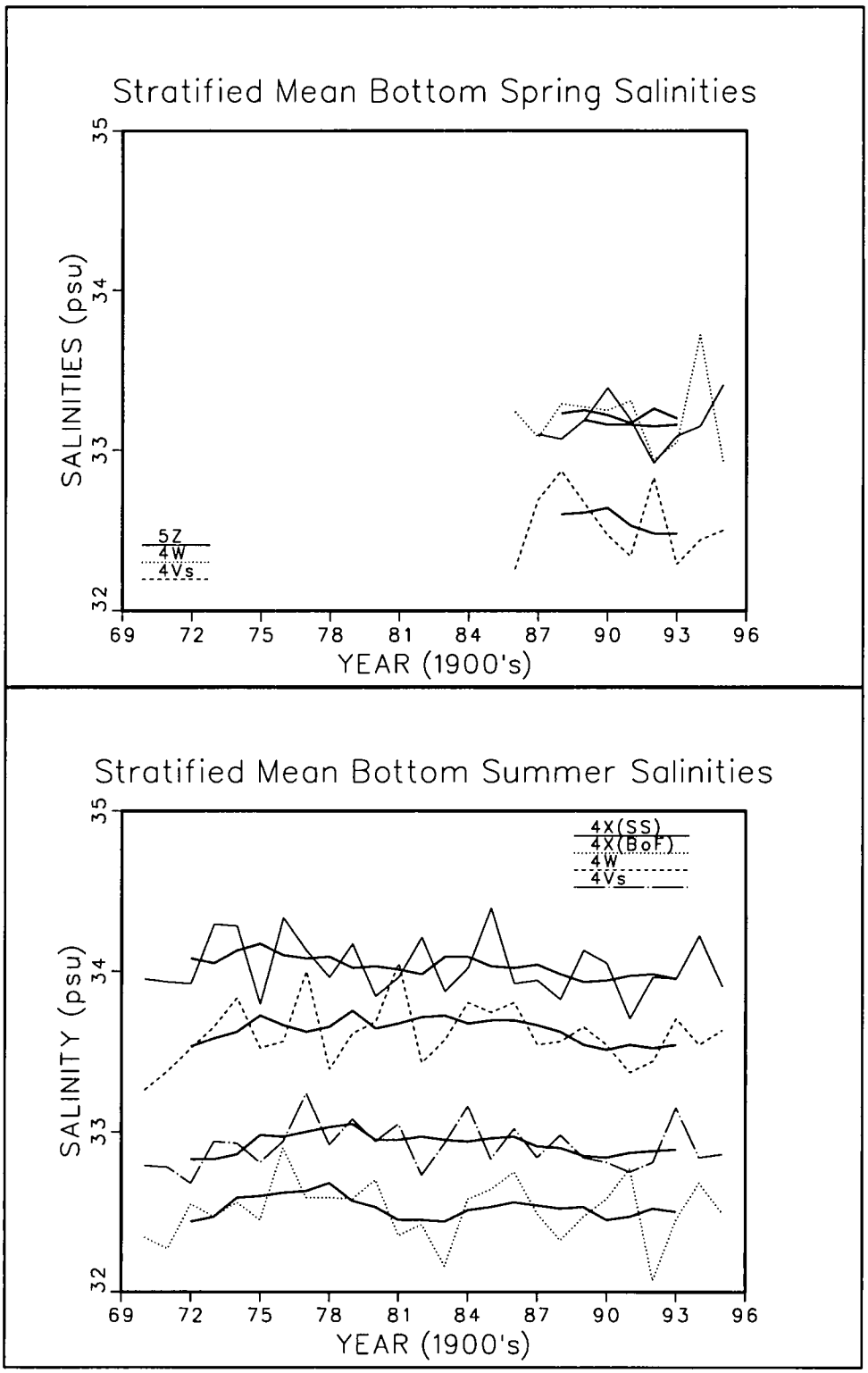

Figure 29: Time series of stratified mean near-bottom salinities for spring (upper panel: 4Vs, 4W and 5Z) and summer Canadian research vessel groundfish surveys (lower panel: 4X Bay of Fundy, 4X Scotian Shelf, 4W and 4Vs). The smooth curves running through each series is a five year running mean.

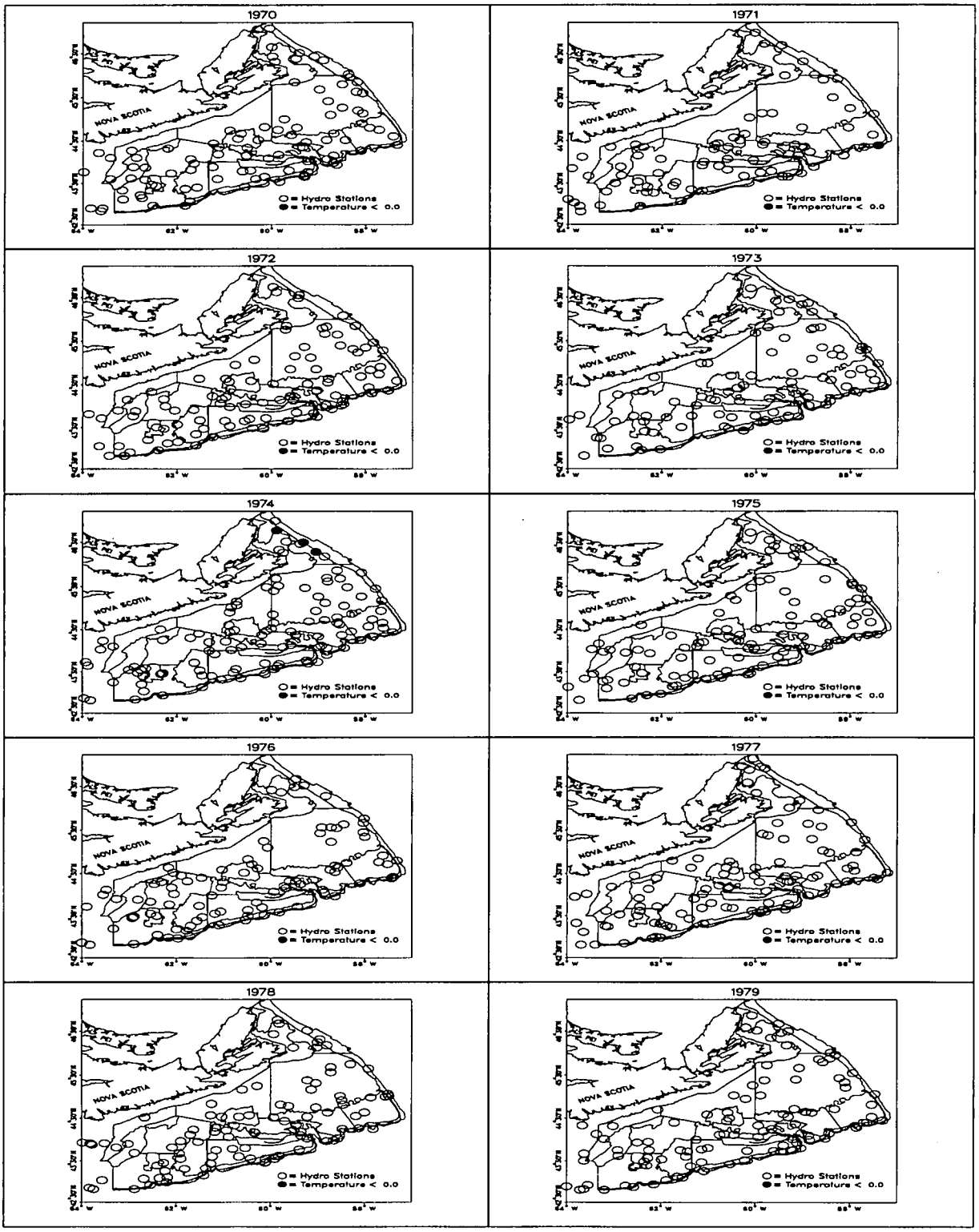

Figure 30: Time series of maps showing the location of hydrographic stations in which water temperatures less than 0.0 C were recorded somewhere in the water column for summer groundfish surveys.

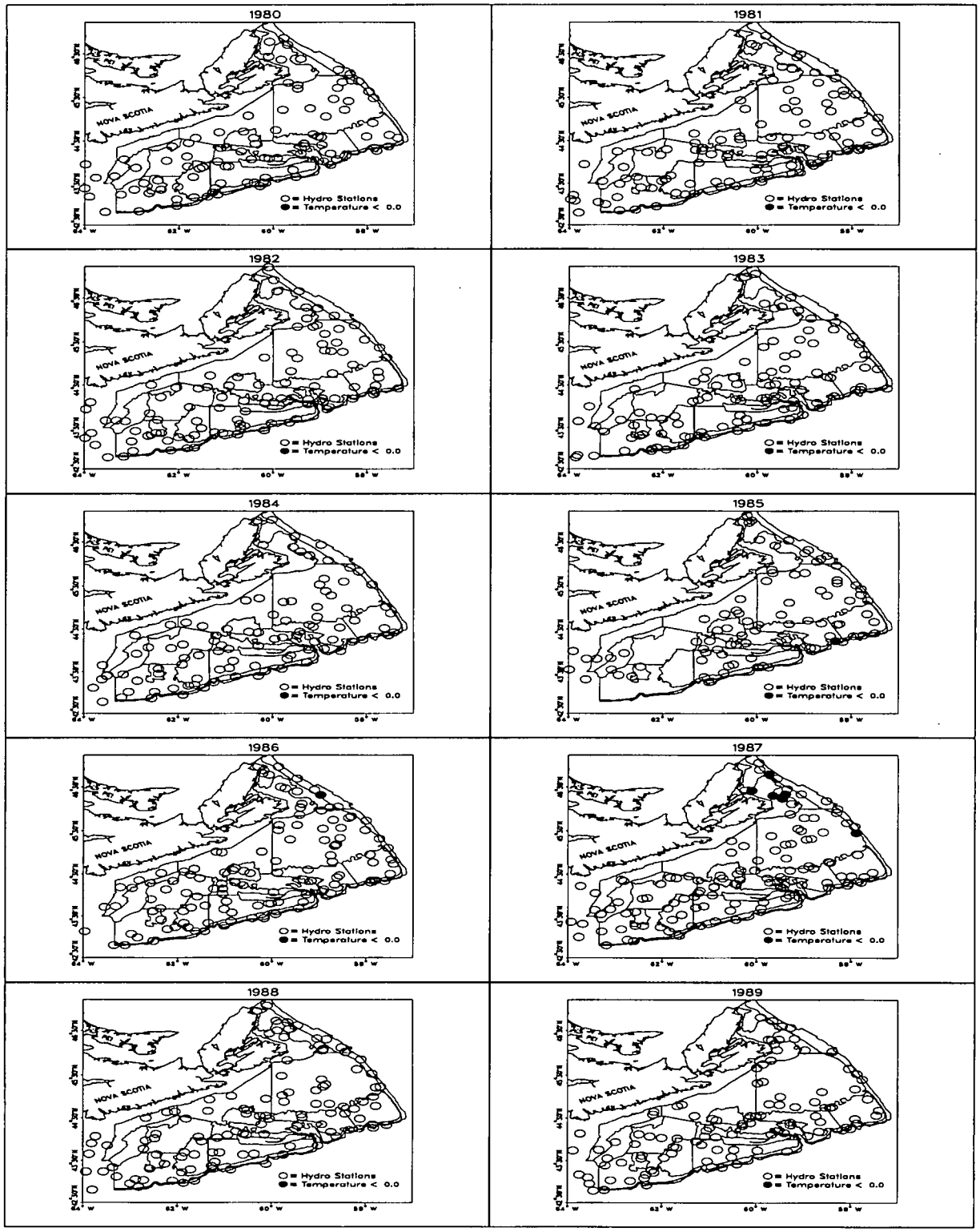

Figure 30: continued

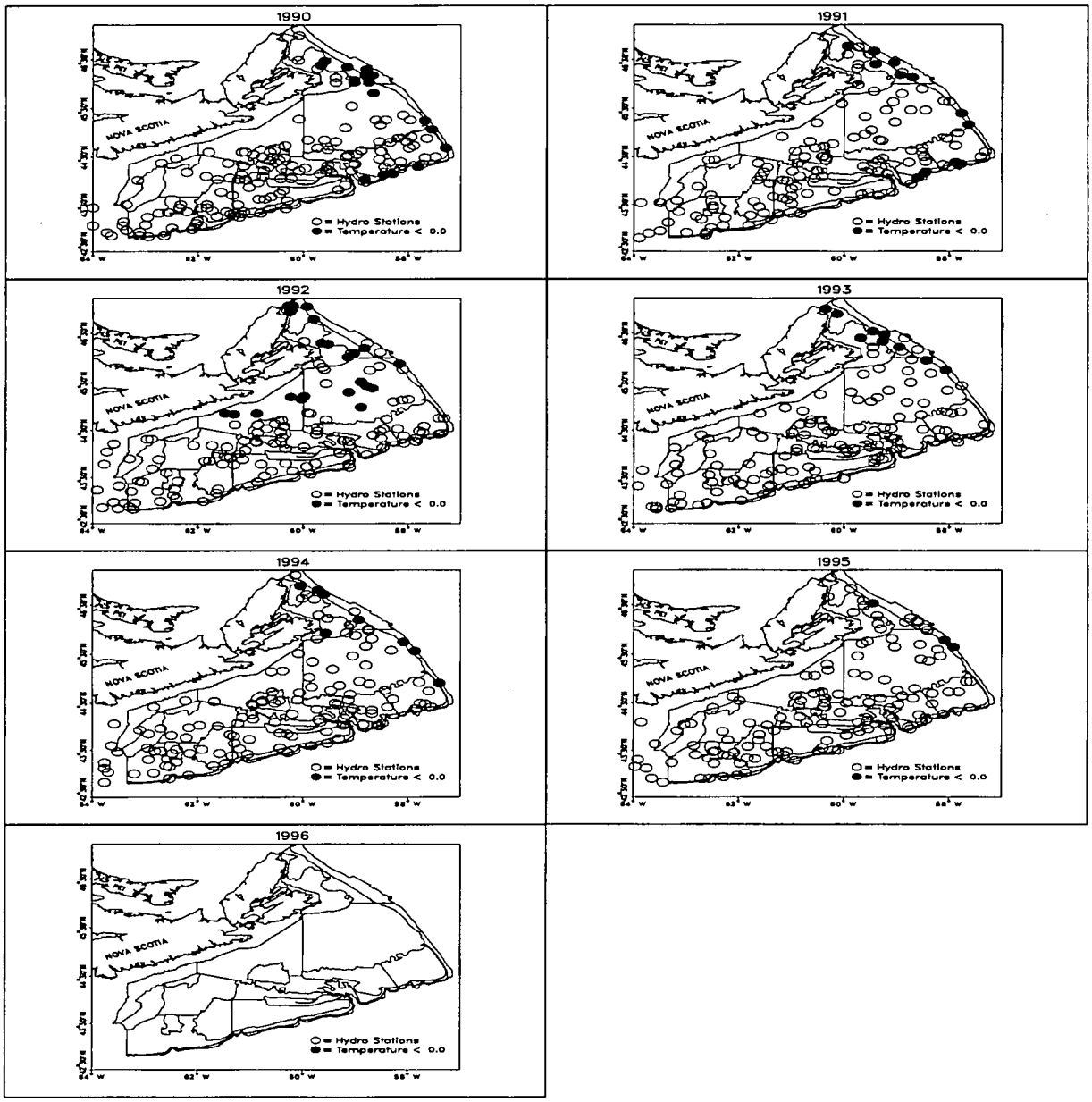

Figure 30: continued

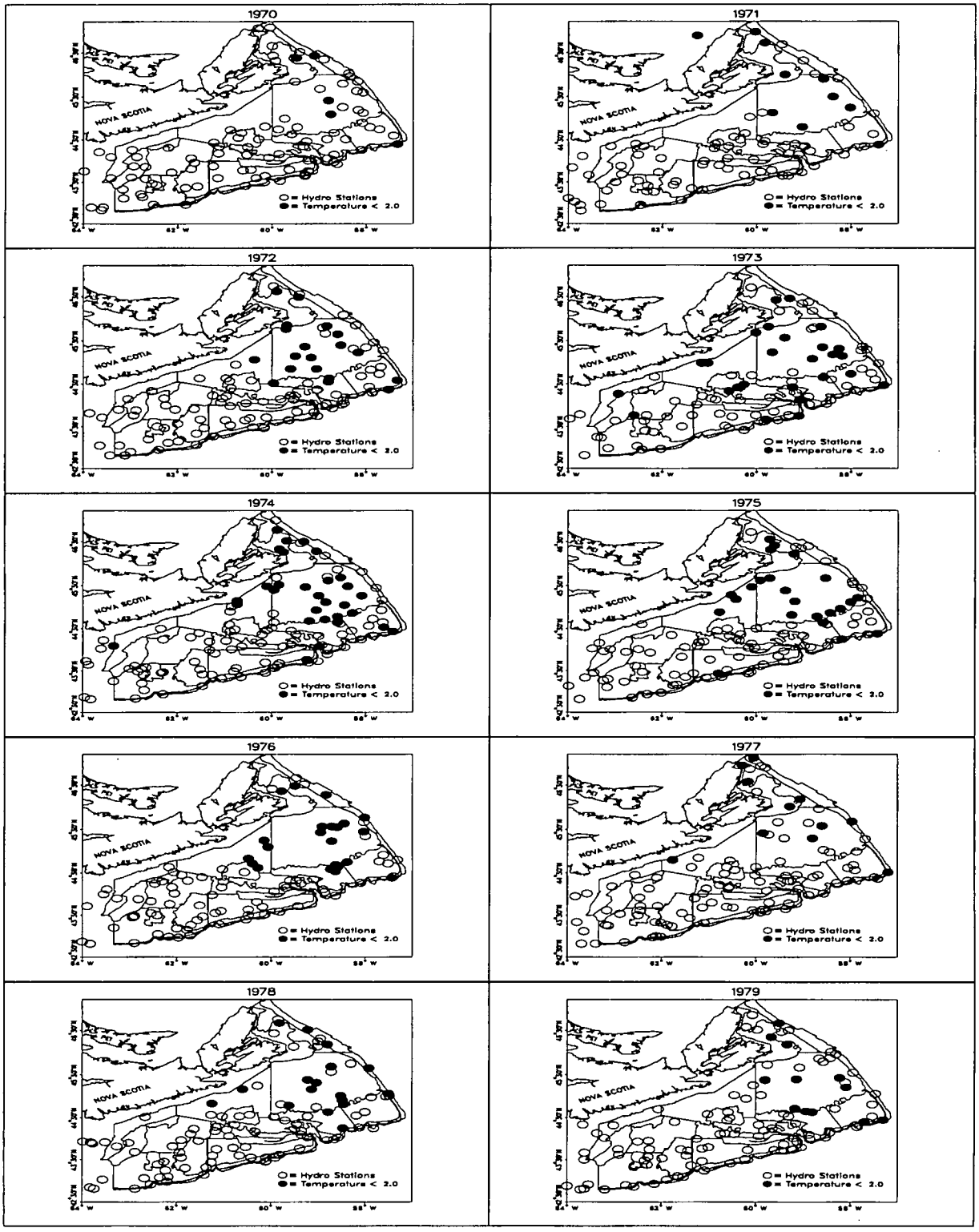

Figure 31: Time series of maps showing the location of hydrographic stations in which water temperatures less than 2.0 C were recorded somewhere in the water column for summer groundfish surveys.

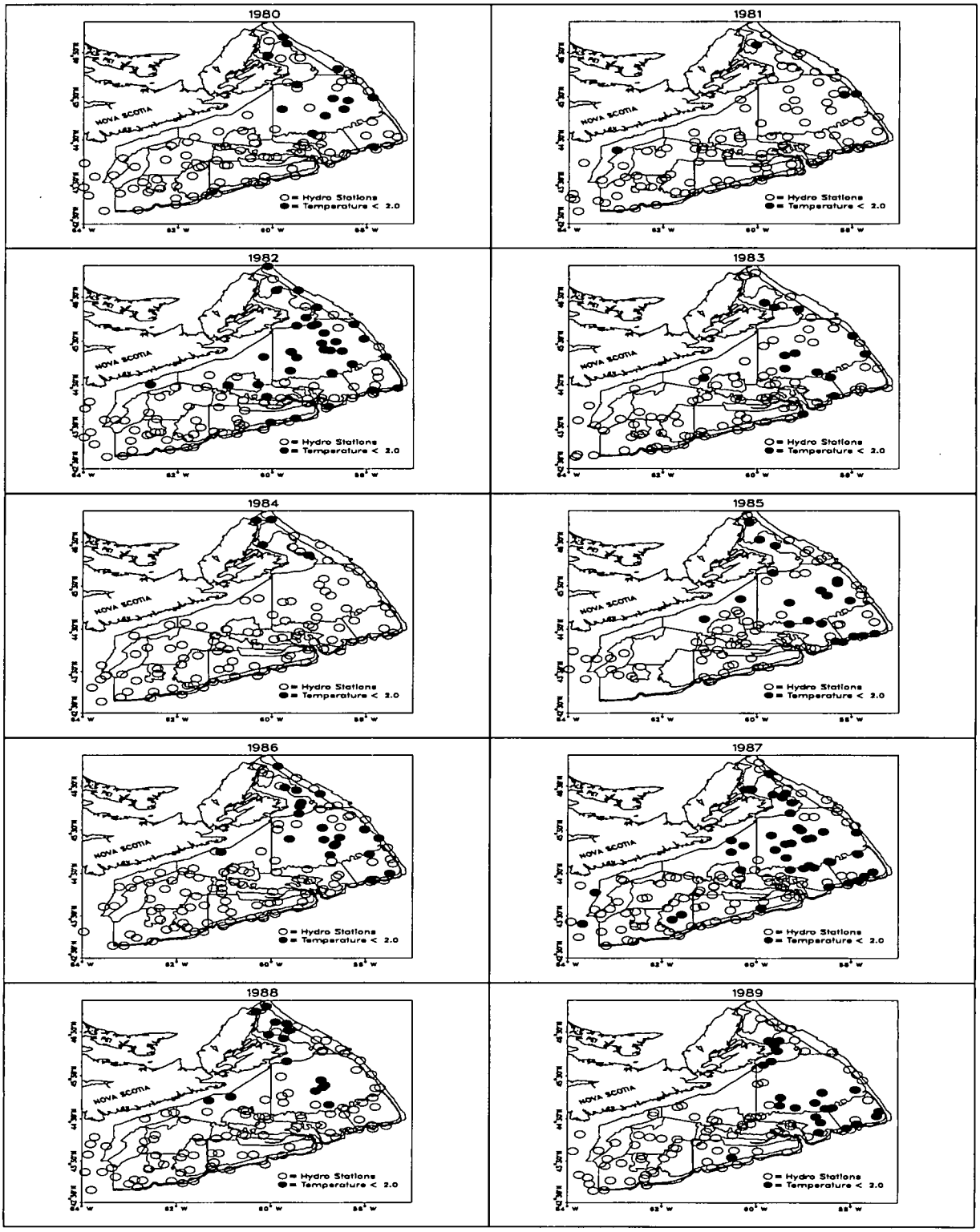

Figure 31: continued

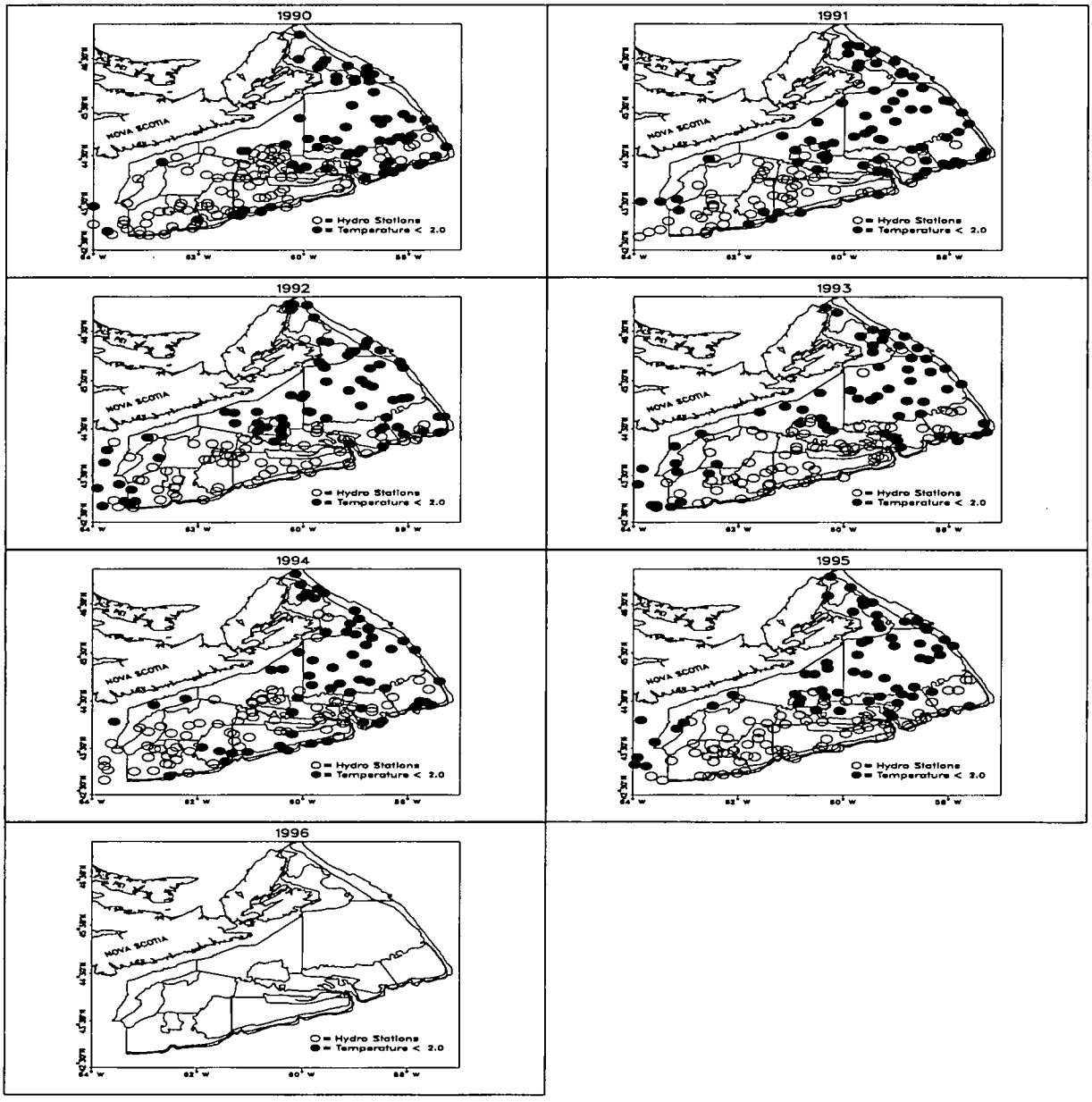

Figure 31: continued