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Overview of Temperature and Salinity Conditions within the Scotia-Fundy Region, NAFO areas 4VWX and 5Z, during 1994 Groundfish Research Vessel Surveys

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) 1994 Canadian research vessel bottom-trawl surveys are summarized. The regional warming trend that began in 1992 has continued in most strata such that in 1994 the spring and summer temperatures and salinities in the 5Z and 4VsW surveys ranged above or near baseline means. The temperatures in 4Vs, although warmer than in the early 1990's are still below baseline means. The trends in salinity are, for the most part, similar to those in temperature. As in previous years the conditions within most strata are confounded by changes in sampling date and location (horizontal and vertical). The problem is strongest for the spring 5Z and 4VsW surveys.

RÉSUMÉ

On présente ici un sommaire des températures et des salinités de l'eau à proximité du fond mesurées au cours des relevés de recherche canadiens au chalut de fond du printemps (5Z et 4VsW) et de l'été (4X et 4VW) 1994. La tendance régionale au réchauffement qui a commencé en 1992 s'est maintenue dans la plupart des strates, si bien que les températures et les salinités de printemps et d'été observées dans les relevés de recherche réalisés dans 5Z et 4VsW se situaient au-dessus ou à proximité des moyennes de référence. Dans 4Vs, toutefois, les températures, quoique plus chaudes que celles du début des années 1990, sont encore inférieures aux moyennes de référence. Quant aux salinités, elles présentent pour l'essentiel des tendances comparables à celles des températures. Comme les années précédentes, les conditions dans la plupart des strates subissent l'influence confusionnelle de changements dans les dates et les sites d'échantillonnage (horizontal et vertical). C'est dans les relevés de printemps dans 5Z et dans 4VsW que le problème est le plus marqué.

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 1995 unpublished manuscript).

The temperatures and salinities measured during these surveys are summarized on an annual basis (eg. Page, Losier and McRuer 1994). 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 proceedures may be identified. These conditions can then be examinined more fully to address their influence on estimates and interpretations of biological and fisheries data considered during the regional stock assessment process (eg. Smith and Page 1994). These latter analyses must be species and stock specific since each species and stock may show unique associations with hydrographic conditions (Page et al. 1994, Smith et al. 1994).

In this overview we present a summary of sampling effort and the resulting estimates of water temperatures and salinities during the 1994 Canadian bottom-trawl surveys conducted within NAFO statistical areas 4VsW and 5Z during the spring and 4VWX during the summer. The summary focuses on the near-bottom conditions since these are 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 Ocean's 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 1994 surveys.

In 1994 three standard groundfish bottom-trawl surveys were conducted within the Scotia-Fundy region. These included two spring surveys and one summer survey. The spring surveys were within NAFO area 4VsW and 5Z and the summer survey was within 4VWX. The latter survey consisted of two cruises, one covering the western Scotian Shelf and another the eastern Scotian Shelf. Each of the surveys utilizes 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 environmantal conditions observed during the 1994 surveys into an historical context similar surveys conducted in the spring in unit areas 4VW and 5Z from 1986/7-94 inclusive and during the summer in unit area 4VWX from 1970-94 inclusive are also considered. A list of these surveys is given in Table 2.

Temperature and Salinity Measurement Techniques

Within the 1994 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 $mmin^{-1}$. After 5 minutes at the maximum depth or afterthe 10 m equilibration period a water sample and water temperature recording were obtained by mechanically triggering a reversing thermometer and Niskin water bottle. When a CTD was not available surface water temperatures were taken with a thermometer and near-bottom temperatures were taken with a reversing thermometer. A laboratory salinometer was used to obtain near-bottom salinities from water samples taken with a Niskin bottle. At some stations XBT (expendable bathythermograph) temperature profiles were taken.

In the years, 1970 to 1989, profiles of temperature and salinity were taken at only 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 recorded with bucket thermometers 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.

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 of were calibrated with the reversing thermometer estimates of temperature and the salinities estimated from the water bottle samples. The edited data has been entered into GSHYD, the Scotia-Fundy regional hydrographic ORACLE 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 1994 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 (Page and Losier 1994). However, due to some corrections and additions to the database some minor changes to the baseline means have occurred. The new baseline means are reported in Table 4.

RESULTS

Strata Specific Conditions

Spring Survey: 4VsW

The 4VsW spring survey has been conducted since 1979. The present strata definitions (Fig.1) have been used since 1986. Water temperatures and salinities were measured at 121 bottom-trawl stations (Fig.1, Table 1). CTD (conductivity, temperature and depth) profiles of temperature and salinity were taken at 75 of these stations. Two of these profiles were in the deep Laurentian Channel and outside the domains of the defined strata. XBT (expendable bathythermograph) temperature profiles were taken at 14 stations and reversing thermometer and water bottle samples were taken at 32 stations. Relative to previous years 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. For example, in strata 401 the samples were restricted to the southern portion of the strata, in strata 402 no samples were included in the northeastern corner of the strata and in strata 403 no samples were located within the eastern portion of the strata.

In 1994 the near-bottom temperatures varied between -1.36 and 12.09°C, a range of 13.45°C (Table 3a). In strata with more than one hydrographic observation the range in temperatures varied from 0.48 to 10.74°C with the greatest range existing within strata 406 and the least range within strata 411. The near-bottom strata mean temperatures varied between 0.75 and 10.66°C with the means increasing from the northeast to southwestern portions of the survey domain (Fig.2). All of the near-bottom strata mean temperatures were above their 1987-90 baseline means (Fig. 2, Table 4a).

The near-bottom salinities in 1994 varied between 31.41 and 35.32psu, a range of 3.91psu (Table 3a). In strata with more than one hydrographic observation the range in salinities varied from 0.07 to 3.18psu with the greatest range existing within strata 406 and the least range within strata 404. The near-bottom strata mean salinities varied between 31.76 and 35.11psu with salinities generally increasing from east to west (Fig.3). With the exception of strata 403, the strata mean salinities within all strata were above their 1987-90 baseline means (Fig. 3, Table 4a). In two of these strata the means were less than 0.50psu above the baseline means.

The strata specific time series of near-bottom temperatures and salinities are shown in Figures 4 and 5. The temperature means increased relative to 1993 in six strata (401, 402, 406, 407, 408 and 410), decreased in two strata (405 and 409) and remained nearly the same in another strata (403). The salinity means increased relative to 1993 in seven strata (401, 402, 405, 406, 407, 408 and 410) and decreased in two strata (403 and 409). Low frequency time trends (Fig. 4 and 5) are indicated in only two of the strata (405 and 409). In strata 405 the mean temperature and salinity decreased from 1986 to 1990. The temperatures increased from 1986 to 1993 and decreased from 1993 to 1994 whereas the salinities increased from 1986 to 1994. In strata 409 the mean temperatures and salinities remained relatively constant from 1986 to 1990-91 and increased from 1990-91 to 1994. 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 4w, 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 inbetween these two ranges and are therefore not a good indicator of conditions within the strata.

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 survey has been conducted progressively earlier since 1987 (Fig.6). In most strata the temperatures and salinities do not generally vary systematically with the date of sampling (Fig.7 and 8). 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 monotonic trend in temperatures and salinities noted for strata 409 may be an artifiact of the changes in sampling time. The range of sample depths has remained relatively constant in all strata, except strata (411) in which the temperature decreases with depth (Fig.9). On the other hand, the central tendency of the sampled depths in all strata has changed throughout the years and in most strata near-bottom temperature and salinity (401, 402, 403, 404, 405, 406, 408, 409, 410) increases with depth (Fig. 10 and 11). This combination undoubtedly has an influence on the pattern of observed temperatures and salinities although this influence is not obvious in most of the time trends, perhaps because of the low sample sizes and the random nature of the changes in sample depth. In strata 404 the depth of the sampling has monotonically increased since 1986.

Spring Survey: 5Z

The 5Z spring survey has been conducted since 1985. The present strata definitions (Fig.12) have been used since 1987. Water temperatures and salinities were measured at 46 bottom-trawl stations (Fig.12, Table 1). CTD profiles of temperature and salinity were taken at 41 of these stations. Limited temperature and salinity measurements were taken with reversing thermometers and water bottles at an additional 5 stations. As in the previous year sampling effort was restricted largely to unit areas $5Z_j$ and $5Z_m$ resulting in no bottom trawl sets, and hence no hydrographic measurements, being taken in strata $5Z_5$, $5Z_6$, $5Z_7$ or $5Z_8$

(Fig. 12). It also resulted in the sampling within strata $5Z_4$ being restricted to the eastern portion of the strata.

In 1994 the near-bottom temperatures varied between 3.96 and 11.56°C, a range of 7.60°C (Table 3b). Temperature ranges within individual strata varied from 0.93 to 5.92°C with the largest temperature range being within strata $5Z_1$ and the smallest being within $5Z_3$. The strata mean temperatures varied between 4.35 and 8.43°C (Table 3a) with the deep strata along the northeast edge of Georges Bank (5Z1) being warmer than those within the shallow strata on top of the bank (5Z2-4, Fig. 13). The means for all four sampled strata were above their 1987-90 baseline means (Tables 3b and 4a). In strata $5Z_2$ and $5Z_3$ the means were within 1.00°C of their 1987-90 baseline means whereas in strata $5Z_1$ and $5Z_4$ the means were between 2-3°C and between 1 to 2°C above baseline means, respectively.

In 1994 the near-bottom salinities varied between 32.76 and 34.86psu, a range of 2.10psu (Table 3b). The means increased relative to 1993 in all four of the sampled strata ($5Z_1$, $5Z_2$, $5Z_3$, $5Z_4$). Salinities within strata $5Z_{1-4}$ varied between 32.18 and 34.94 psu, a range of 2.76 psu. Salinity ranges within individual strata varied from 0.21 to 1.54 psu with the largest range being within strata $5Z_1$ and the smallest being within $5Z_3$. The strata mean salinities varied between 32.88 and 34.06psu and were greatest within the deep strata along the northeastern flank of Georges Bank ($5Z_1$). All of the strata means were within +/-0.50psu of their baseline means with $5Z_{1,2 \text{ and } 4}$ being above baselines and $5Z_3$ being below baseline (Fig.14, Tables 3b and 4a).

The strata specific time series of near-bottom temperatures and salinities are shown in Figures 4 and 5. Low frequency time trends are indicated in all four of the sampled strata ($5Z_1$, $5Z_2$, $5Z_3$, $5Z_4$). The mean temperatures and salinities in strata 5Z1 increased from 1986 to 1987, decreased from 1987 to 1992 and increased from 1992 to 1994. In the reamining three strata temperatures increased from 1987 to 1991, decreased from 1991 to 1993 and increased in 1994. In the reamining three strata salinities decreased from 1987 to 1988, increased from 1987 to 1990, decreased from 1990 to 1992-3 and increased in 1994.

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 strong trend in its timing (Fig.6). 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 the survey was once again conducted early in the year, approximately 20-30 days earlier than in 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 the day of sampling for the sampled strata (Fig. 7 and 8). The range of sample depths has remained relatively narrow and constant in two of the strata ($5Z_2$ and $5Z_4$) and little relationship exists between temperature or salinity and depth within these strata (Fig's. 9-11). In strata $5Z_1$ and $5Z_3$ the sampling of deep waters has been sporadic and water temperatures and salinities tend to increase with depth in these strata (Fig's. 9-11). Therefore, the variability in sampling depth may also contribute to the trends in temperature and salinity for these later strata.

Summer Surveys: 4VWX

The 4VWX summer surveys have been conducted since 1970. The present strata boundaries (Fig.15) have been used throughout this period. Water temperatures and salinities were measured at 195 bottom-trawl stations (Fig.15). CTD profiles of temperature and salinity were taken at 185 of these stations. Limited temperature and salinity measurements were taken with reversing thermometers and water bottles at an additional 10 stations. The level of sampling effort is consistent with previous years (1991-1993) in which a CTD was used. Relative to previous years 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. For example, in strata 460, 484, 485 and 481 the samples were restricted to small subareas of the strata.

Summer Survey: 4VW

In 1994 the near-bottom temperatures varied between 0.21 and 11.34°C, a range of 11.13°C (Table 3c). In strata with more than one hydrographic observation the range in temperatures varied from 0.12 to 10.40°C with the greatest range existing within strata 455 and the least range within strata 451. The near-bottom strata mean temperatures varied between 0.60 and 10.22°C and are generally less than those on the western shelf and in the Bay of Fundy (Fig.16). The means increased relative to 1993 in eleven strata (440, 441, 442, 444, 447, 458, 459, 460, 461, 462 and 463), decreased in eight strata (449, 450, 451, 452, 453, 454, 464 and 466) and remained nearly the same in another six strata (446, 448, 455, 456, 457, 465). Most of the means for strata over the eastern Scotian Shelf were within -1.00°C of their baseline means whereas those for strata within the central shelf region tended to be above baseline means (Fig.16, Tables 3c and 4b).

In 1994 the near-bottom salinities varied between 31.39 and 35.14psu, a range of 3.75psu (Table 3c). In strata with more than one hydrographic observation the range in salinities varied from 0.00 to 2.48psu with the greatest range existing within strata 459 and the least range within strata 461. The near-bottom strata mean salinities varied between 31.94 and 35.07psu with the salinities in much of 4VW being less than those in the deep central and western Scotian Shelf strata (Fig. 17). The means increased relative to 1993 in eight strata (440, 441, 442, 459, 460, 461, 462 and 463), decreased in fourteen strata (444, 447, 448, 449, 450, 452, 453, 454, 455, 456, 457, 458, 464, 465) and remained nearly the same in three strata (446, 451 and 466). Most of the strata means were within +/-0.50psu of their baseline means (Fig.17, Tables 3c and 4b).

The strata specific time series of near-bottom temperatures and salinities are shown in Figures 18 and 19. Low frequency time trends are suggested in several of the strata. The reversal of the cooling trend that occurred in twelve of the strata (441, 442, 444, 447, 448, 450, 451, 454, 455, 457, 458 and 459) during the period of the middle 1980's until 1991 has continued into 1994 for only seven of the strata. In five of the strata (450, 451,454,455,457) the temperature decreased relative to 1993. The trend of increasing near-bottom temperatures in strata 453 and 466 stopped in 1994 with temperatures decreasing relative to 1993. The remaining strata on the eastern Scotian Shelf (446, 456, 460, 461, 462, 464, 465) continued to show little time trend in temperature, although in strata 461 and 462

temperatures increased over the past 2-3 years. Unlike the temperature time series only a few strata have systematic trends (Fig. 19). The trend of increasing salinities in strata 447 did not continue in 1994 and the reversal of the trend of decreasing salinities in 441 that began in 1992 continued in 1994. The trend of decreasing salinities in strata 454 and 457 that began in the mid 1980's continued in 1994.

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 the random changes in the 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. 20). 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's. 21 and 22). For most strata the range of depths sampled has been reasonably consistent over the survey period (Fig. 23). 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.24), 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 a the trend toward shallower sample depths. In the remaining strata the temperature and salinity interactions with depth 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

In 1994 the near-bottom temperatures varied between 3.37 and 13.16°C, a range of 9.97°C (Table 3d). In strata with more than one hydrographic observation the range in temperatures varied from 0.02 to 7.89°C with the greatest range existing within strata 481 and the least range within strata 471. The near-bottom strata mean temperatures varied between 3.59 and 10.29°C and are generally greater than those on the eastern shelf (Fig.16). The means increased relative to 1993 in fifteen strata (470, 471, 473, 474, 475, 480, 481, 484, 485, 490, 491, 492, 493, 494 and 495), decreased in three strata (476, 478 and 482) and remained nearly the same in three strata (472, 477 and 483). Most of the stratified means for strata within 4X were above their baseline means although many of these were only within 1.00°C of baselines (Fig.16, Tables 3d and 4b).

In 1994 the near-bottom salinities varied between 31.19 and 35.45psu, a range of 4.26psu (Table 3d). In strata with more than one hydrographic observation the range in salinities varied from 0.00 to 2.65psu with the greatest range existing within strata 481 and the least range within strata 475. The near-bottom strata mean salinities varied between 31.70 and 35.06psu with the salinities in much of 4X being similar to those in the deep central and greater than those within the eastern Scotian Shelf strata (Fig. 17). The means increased relative to 1993 in eighteen strata (470, 471, 472, 473, 474, 475, 477, 478, 480, 481, 484,

485, 490, 491, 492, 493, 494 and 495), decreased in two strata (476 and 482) and remained nearly the same in another strata (483). Most of the strata means were above baselines although within 0.50psu of the baselines (Fig.17, Tables 3c and 4b).

The strata specific time series of near-bottom temperatures and salinities are shown in Figures 18 and 19. 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 declining during the late 1980's to 1992 and increasing since 1992. This recent increase also occurred in the strata off southwest Nova Scotia as well (471, 480, 481, 482, 483, 484, 485). 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 above mentioned regions interannual variation in the time and location of sampling has occurred (Fig's. 20 and 23). 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 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. 21). 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 depths sampling has remained relatively constant (Fig. 23). Therefore, even though temperature and salinity varies with depth in many of the strata (Fig's. 24 and 25) this probably does contribute strongly to the temperature and salinity trends because of the consistency in the range of depths sampled each year.

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 by presenting composite patterns for the major unit areas. The composites presented are the time series of stratified mean near-bottom temperatures and salinities (Fig's. 26 and 27) and the time series of maps showing the location of hydrographic stations in which water temperatures less than 0 and 2°C were recorded somewhere within the water column (Fig.'s 28 and 29).

Stratified Means

The time series of stratified mean near-bottom temperatures and salinities all show low amplitude low frequency trends (Fig's 26 and 27). The spring series for both temperature and salinity are short, highly variable, and are confounded with changes in sample time and depths. They are therefore not discussed further. The summer series are considerably longer and are not confounded was much by changes in sample times and depths. Although the series are still variable the trends are indicated by the five year running means passed

through each series. All four temperature series show some degree of common coherency although the 4X series tend to be distinct from the 4VsW series as noted by Page and Losier (1994). 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 declined throughout the 1980's until about 1991 and increased from 1991 to 1993/4. The salinity series 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. Figure 27 shows the distribution of these stations for the full 1970-1994 time period. With the exception of 1987 and perhaps 1974, temperatures below 0°C were generally not observed prior to 1990. However, since 1989, subzero temperatures have been routinely recorded in the northeastern portion of the survey area with the greatest occurrence being in 1992. Although this suggested increase in cold water 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. A similar presentation based on the presence of water temperatures below 2°C also suggests the volume of cold water increased in the early 1990's (Fig. 28).

DISCUSSION

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

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 is influenced by the location and timing of the sampling. This is discussed more fully in Page et al. 1994. The spring surveys are particulalry affected by interannual changes in the timing of the surveys and hence the trends in temperatures and salinities observed during the surveys are not good indicators of actual changes in the hydrographic regime. 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 extented over much of the northeastern portion of the survey area. The extent of this area seems to havel reduced in recent years.

In 1994 the near-bottom temperatures tended to be warmer than in the previous year. During the spring surveys the temperatures in all four of the strata sampled on Georges Bank increased relative to 1993. The temperatures within the spring 4VsW survey increased in 1994 relative to 1993 only in the inner shelf strata. Within the outer shelf strata the temperatures decreased or remained unchanged. This pattern persisted into the summer where temperatures within the inner shelf and Bay of Fundy were greater than in 1993 and those along the shelf edge decreased or remained unchanged.

Whether the changes are climatic in nature or not does not alter the fact that the changes are indicative of interannual differences in the type of hydrographic habitat sampled. As such they may be related to interannual variations in estimates of 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 (Smith, Perry and Fanning 1991). When the proportion of the CIL is large (small), and hence the temperatures are relatively cool (warm), the estimate of cod abundance is relatively low (high). The suggested trends in temperatures may therefore be associated with changes in the distribution and abundance of cod within at least the 4VW area. This connection has been explored more fully by Smith and Page (1995 unpublished manuscript).

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TABLE 1: Summary of 1994 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 1994.

SAMPLING AREA	STRATA	CRUISE (vessel-cruise no.)	SAMPLING DATES day/month	NO. of UNIQUE SAMPLING STATIONS
4VsW Spring	401-411	N201	27/02 (58) 10/03 (69)	121 total 75 CTD 14 XBT 32 bottle
5Z Spring	$5Z_1$-$5Z_4$	N200	16/02 (47) 24/02 (55)	46 total 41 CTD 5 bottle
4VWX Summer	440-495	N221/222	04/07 (185) 28/07 (209)	195 total 185 CTD 10 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 1994 and 5Z during 1987 to 1994 inclusive. In the cruise column N referes 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
4VsW					
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
N182	1993	79	37	47	RT/B/CTD
N200	1994	45	41	91	RT/B/CTD
5Z					
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
N149	1991	94	68	72	RT/B/CTD
N166	1992	75	24	32	RT/B/CTD
T134	1993	65	64	98	RT/B/CTD
N201	1994	95	87	92	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 1994 inclusive. In the cruise column A referes to the A. Cameron, N referes 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/N87	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

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 1994. (n is the sample number)

STRATA	TEMPERATURE					SALINITY				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
401	5	1.41	0.59	2.78	2.19	5	32.24	32.05	32.56	0.51
402	11	3.07	1.12	6.99	5.87	11	32.92	32.09	32.85	2.76
403	6	0.75	-1.36	6.47	7.83	5	31.76	31.41	32.59	1.18
404	2	6.36	4.72	7.99	3.27	2	34.89	34.85	34.92	0.07
405	9	5.07	-0.92	8.20	9.12	4	34.43	34.25	34.69	0.44
406	11	4.22	-0.20	9.83	10.03	10	33.05	31.48	34.67	3.18
407	6	4.71	-0.02	8.32	8.34	4	33.47	32.78	34.18	1.40
408	10	7.97	1.35	12.09	10.74	6	33.68	31.99	34.91	2.92
409	15	4.52	1.02	9.47	8.45	14	32.81	31.83	34.29	2.46
410	8	10.66	9.86	11.60	1.74	8	35.11	34.83	35.32	0.49
411	2	10.02	9.78	10.26	0.48	1	35.23	35.23	35.23	0.00

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 1994. (n is the sample number)

STRATA	TEMPERATURE					SALINITY				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
5Z1	5	8.43	5.64	11.56	5.92	5	34.06	33.32	34.86	1.54
5Z2	22	5.00	4.34	6.49	2.15	22	33.06	32.81	33.56	0.75
5Z3	9	4.35	3.96	4.89	0.93	9	32.88	32.76	32.96	0.21
5Z4	4	5.67	4.40	8.11	3.71	4	32.16	32.88	33.83	0.95
5Z5	0	-	-	-	-	0	-	-	-	-
5Z6	0	-	-	-	-	0	-	-	-	-
5Z7	0	-	-	-	-	0	-	-	-	-
5Z8	0	-	-	-	-	0	-	-	-	-

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 1994. (n is the sample number)

STRATA	TEMPERATURE					SALINITY				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
440	4	5.91	5.85	5.96	0.11	4	34.69	34.62	34.73	0.11
441	5	3.30	1.17	6.46	5.29	5	33.49	32.70	34.51	1.81
442	4	0.60	0.21	0.91	0.70	4	32.30	31.83	32.71	0.88
444	14	2.09	0.78	3.31	2.53	14	32.96	32.10	33.55	1.45
446	3	5.68	5.51	5.78	0.27	3	34.56	34.30	34.73	0.43
447	6	2.57	0.98	4.74	3.76	6	31.94	31.53	32.49	0.96
448	7	2.56	2.25	3.19	0.94	7	32.24	31.86	33.35	1.49
449	2	0.98	0.86	1.09	0.23	2	32.59	32.51	32.68	0.17
450	3	3.27	2.17	4.11	1.94	3	33.27	32.45	33.81	1.36
451	2	5.71	5.65	5.77	0.12	2	34.45	34.35	34.54	0.19
452	2	4.05	3.91	4.19	0.28	2	33.93	33.78	34.07	0.29
453	2	5.50	4.66	6.33	1.67	2	34.09	33.73	34.45	0.71
454	2	2.93	2.48	3.38	0.90	2	33.22	32.97	33.48	0.51
455	10	5.53	0.94	11.34	10.40	10	32.00	31.44	32.56	1.12
456	5	5.02	2.59	9.24	6.65	5	32.28	31.62	33.02	1.39
457	1	2.67	2.67	2.67	0.00	1	32.93	32.93	32.93	0.00
458	7	4.12	2.37	7.15	4.78	7	31.98	31.39	32.76	1.37
459	6	3.50	1.24	9.76	8.52	6	33.15	32.27	34.75	2.48
460	3	8.71	6.80	9.98	3.18	3	34.41	33.84	34.82	0.99
461	2	10.22	10.08	10.35	0.27	2	35.07	35.07	35.07	0.00
462	4	10.01	9.72	10.32	0.60	4	34.76	34.64	34.86	0.21
463	2	8.79	8.66	8.92	0.26	2	34.19	34.16	34.23	0.08
464	6	3.73	1.32	6.23	4.91	6	32.96	32.08	33.67	1.59
465	10	8.74	5.07	11.32	6.25	10	34.38	33.55	35.14	1.59
466	2	8.72	8.49	8.95	0.46	2	35.06	35.03	35.08	0.05

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 1994. (n is the sample number)

STRATA	TEMPERATURE					SALINITY				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
470	2	10.08	9.91	10.25	0.34	2	34.91	34.85	34.98	0.13
471	2	10.07	10.06	10.08	0.02	2	34.97	34.97	34.98	0.01
472	4	9.81	9.40	10.38	0.98	4	34.78	34.61	34.99	0.38
473	2	3.59	3.48	3.69	0.21	2	32.78	32.75	32.82	0.07
474	2	3.67	3.37	3.97	0.60	2	32.76	32.67	32.86	0.19
475	1	5.55	5.55	5.55	0.00	1	32.61	32.61	32.61	0.00
476	3	5.11	4.59	5.52	0.93	3	33.14	32.98	33.31	0.34
477	5	6.50	5.79	7.66	1.87	5	33.60	33.35	33.88	0.53
478	2	8.21	8.16	8.26	0.10	2	35.06	35.06	35.06	0.00
480	8	7.55	5.58	11.30	5.72	8	33.13	32.51	34.77	2.26
481	9	8.88	5.27	13.16	7.89	9	34.16	32.79	35.45	2.65
482	3	8.53	8.15	8.91	0.76	3	34.87	34.70	35.02	0.33
483	2	8.48	8.45	8.50	0.05	2	35.02	35.02	35.02	0.00
484	2	8.74	8.46	9.02	0.56	2	34.50	34.41	34.60	0.19
485	3	9.03	8.94	9.11	0.17	3	34.37	34.18	34.53	0.35
490	4	9.33	8.45	9.94	1.49	4	32.42	32.17	32.57	0.40
491	3	8.47	7.99	8.95	0.96	3	33.38	33.12	33.82	0.70
492	2	8.84	8.52	9.16	0.64	2	33.34	32.30	34.37	2.07
493	3	8.64	8.37	9.11	0.74	3	32.30	32.17	32.54	0.37
494	2	10.29	9.28	11.30	2.02	2	31.70	31.19	32.21	1.03
495	2	10.11	9.41	10.81	1.40	2	32.02	31.77	32.26	0.49

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*				

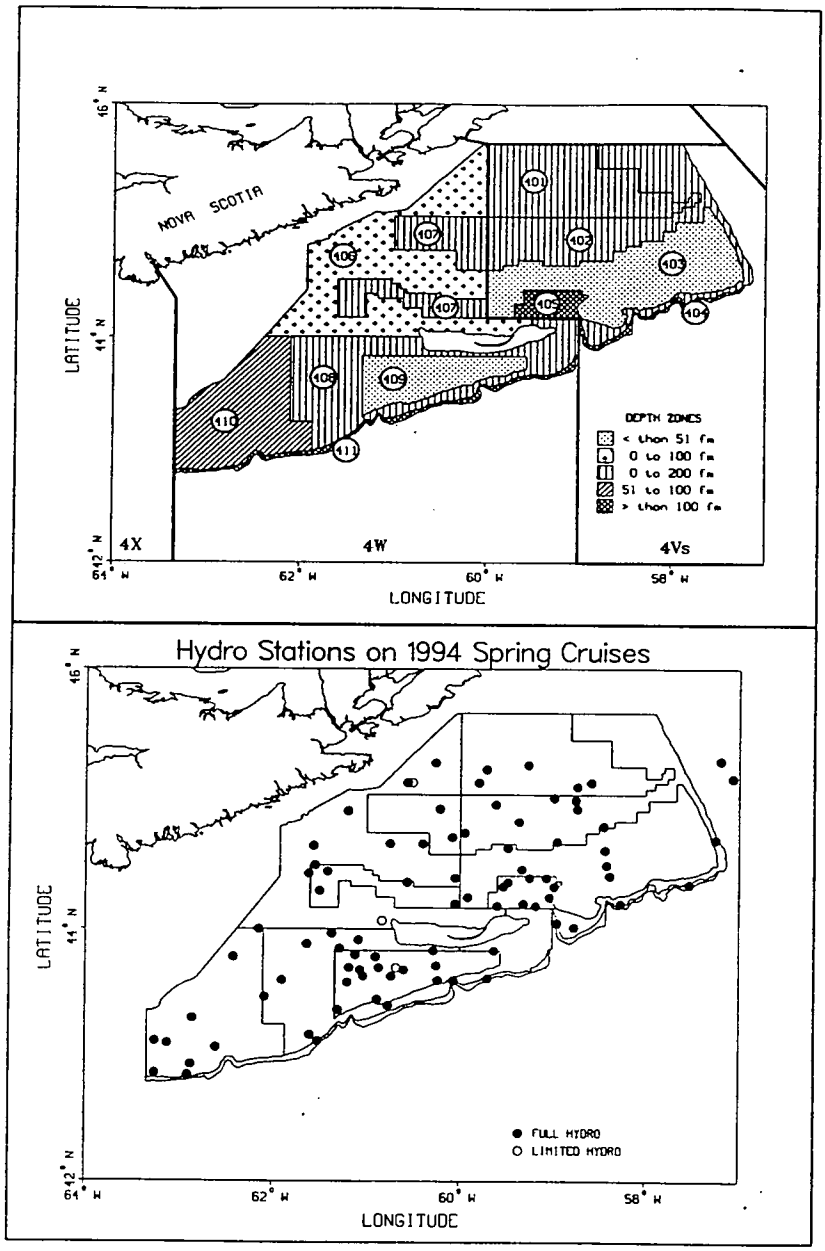


Figure 1: Survey domain and strata boundaries for the Canadian spring groundfish bottom-trawl research vessel surveys conducted within NAFO area 4VsW from 1986-1994 (top panel) and the location of hydrographic sampling stations taken during the 1994 spring survey (bottom panel). In the top panel the numbers enclosed within circles are the strata designations. In the bottom panel a solid circle indicates a trawl station where a CTD cast was obtained and an open circle indicates a trawl station where only surface temperatures and bottom temperatures and salinities were measured.

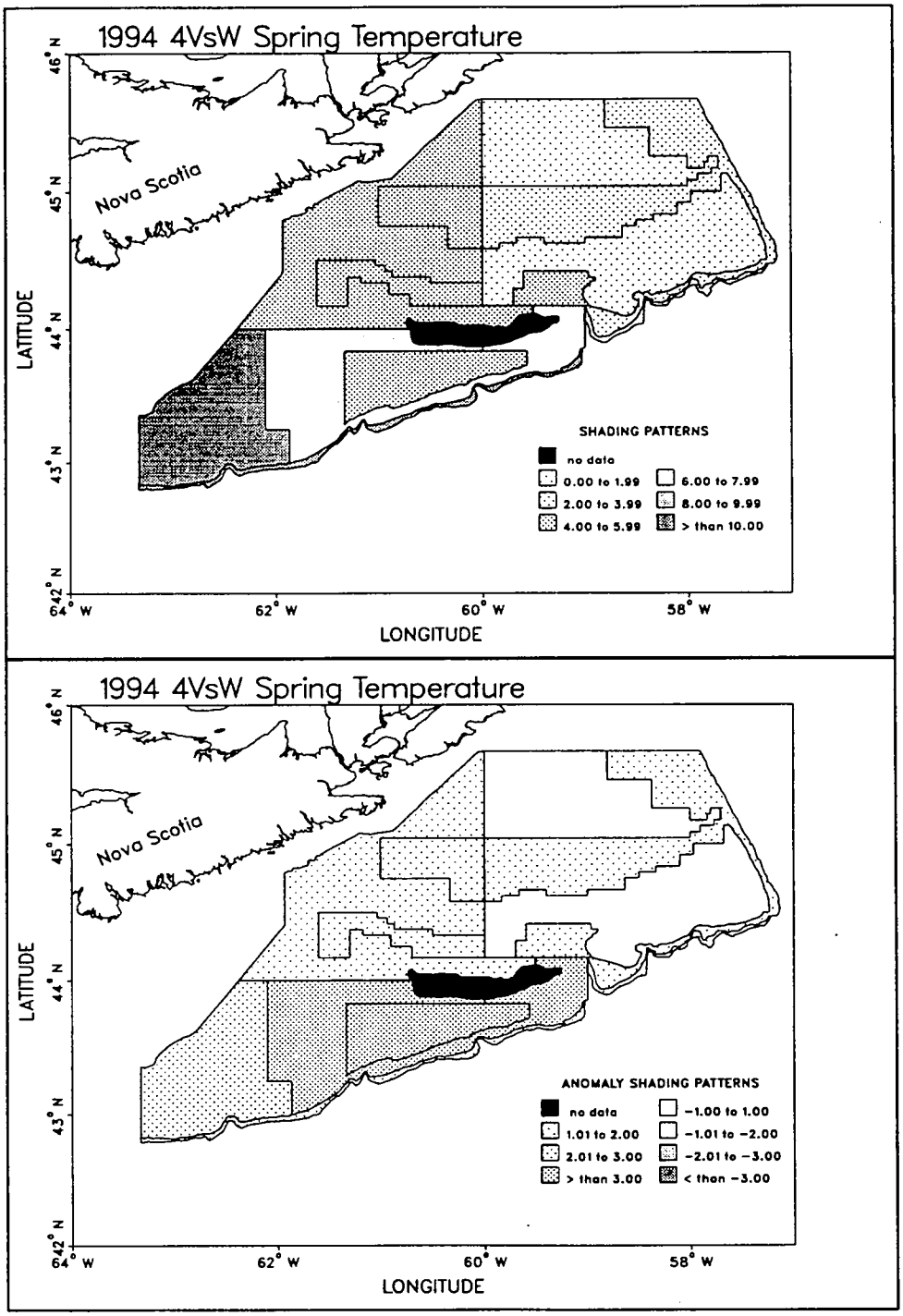


Figure 2: Map of near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VsW during the Canadian research vessel bottom-trawl survey conducted during the spring of 1994.

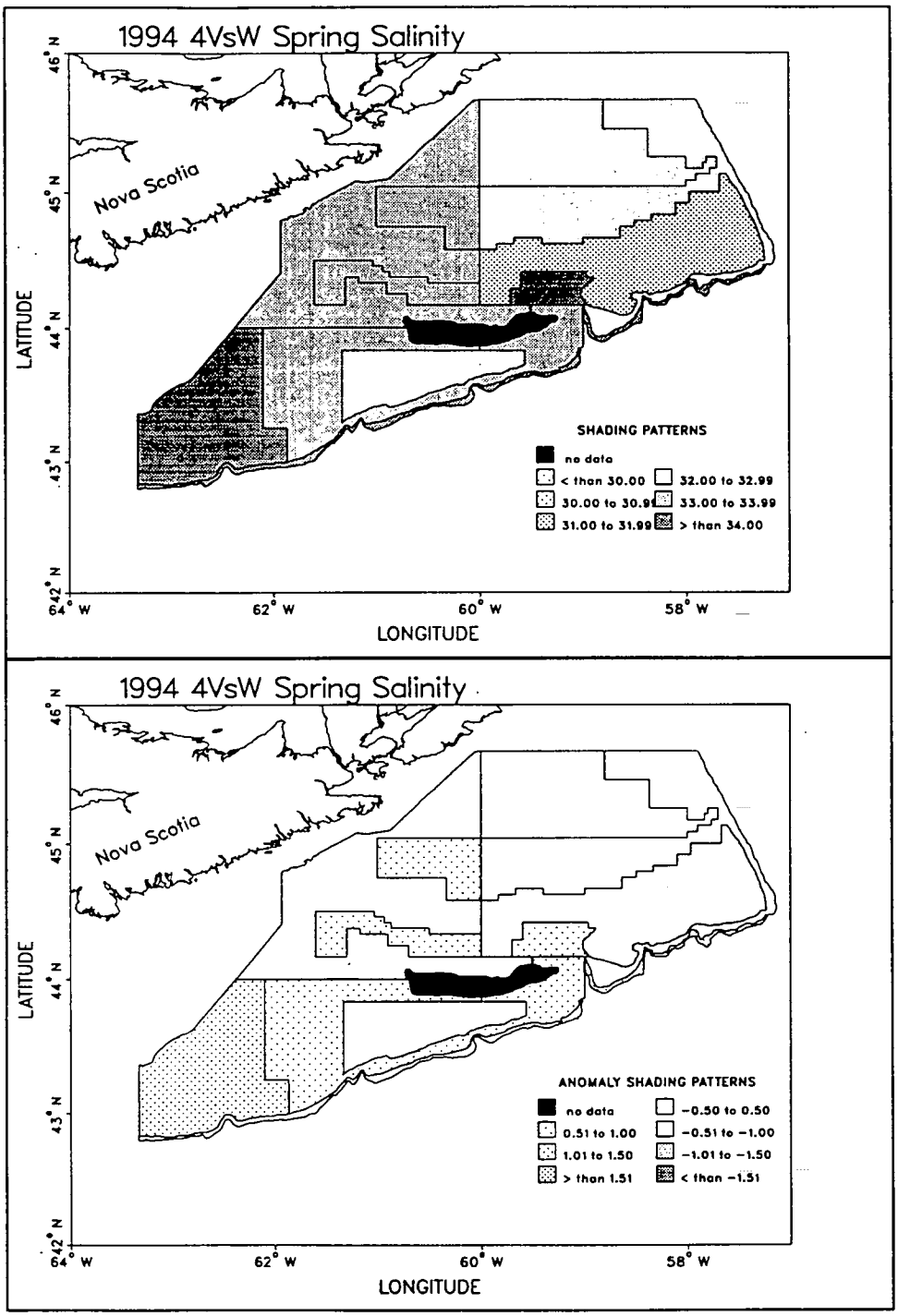


Figure 3: Map of near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VsW during the Canadian research vessel bottom-trawl survey conducted during the spring of 1994.

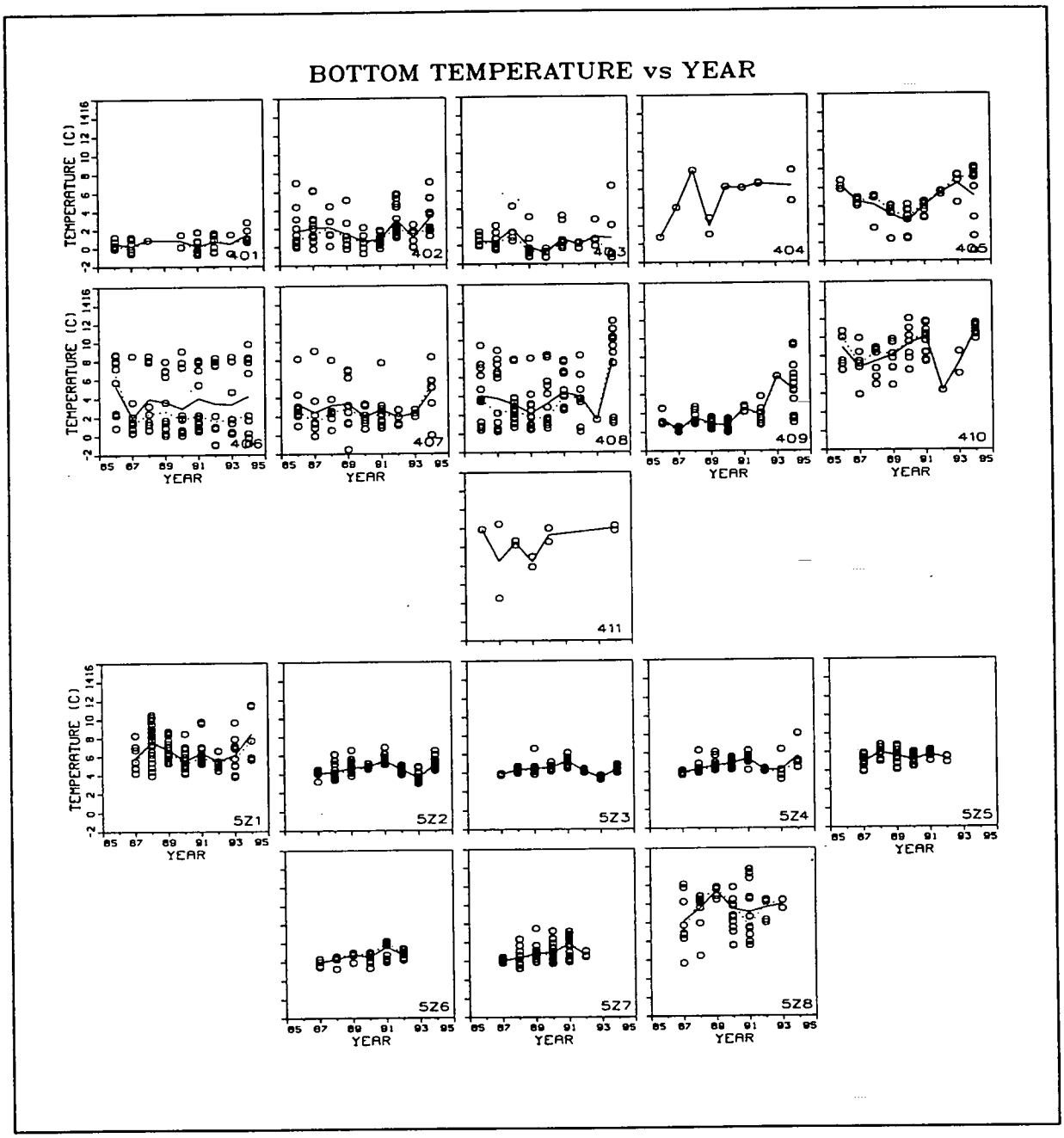


Figure 4: Time series of near-bottom temperatures within the spring 4VsW and 5Z surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

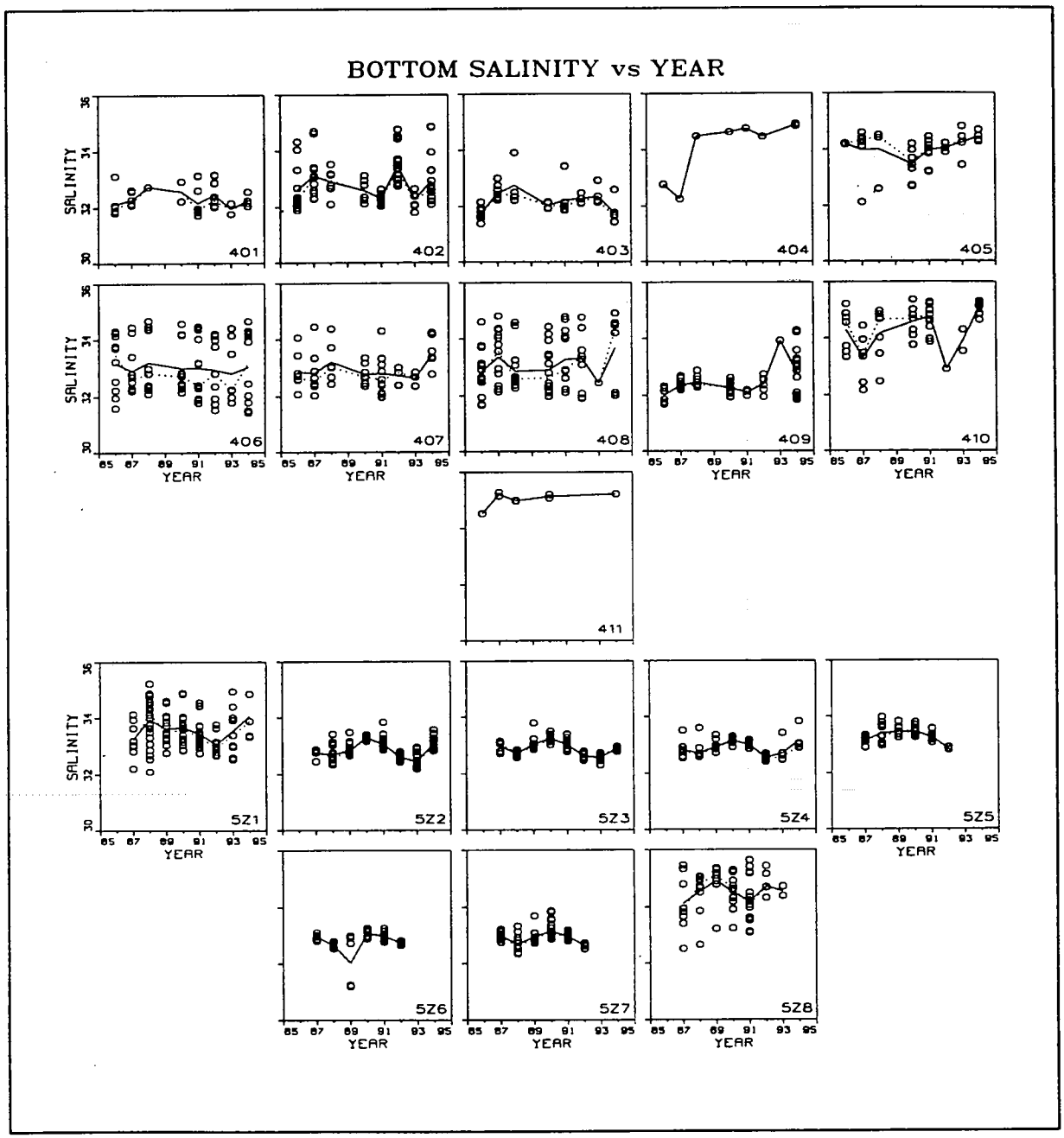


Figure 5: Time series of near-bottom salinities within the spring 4VsW and 5Z surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

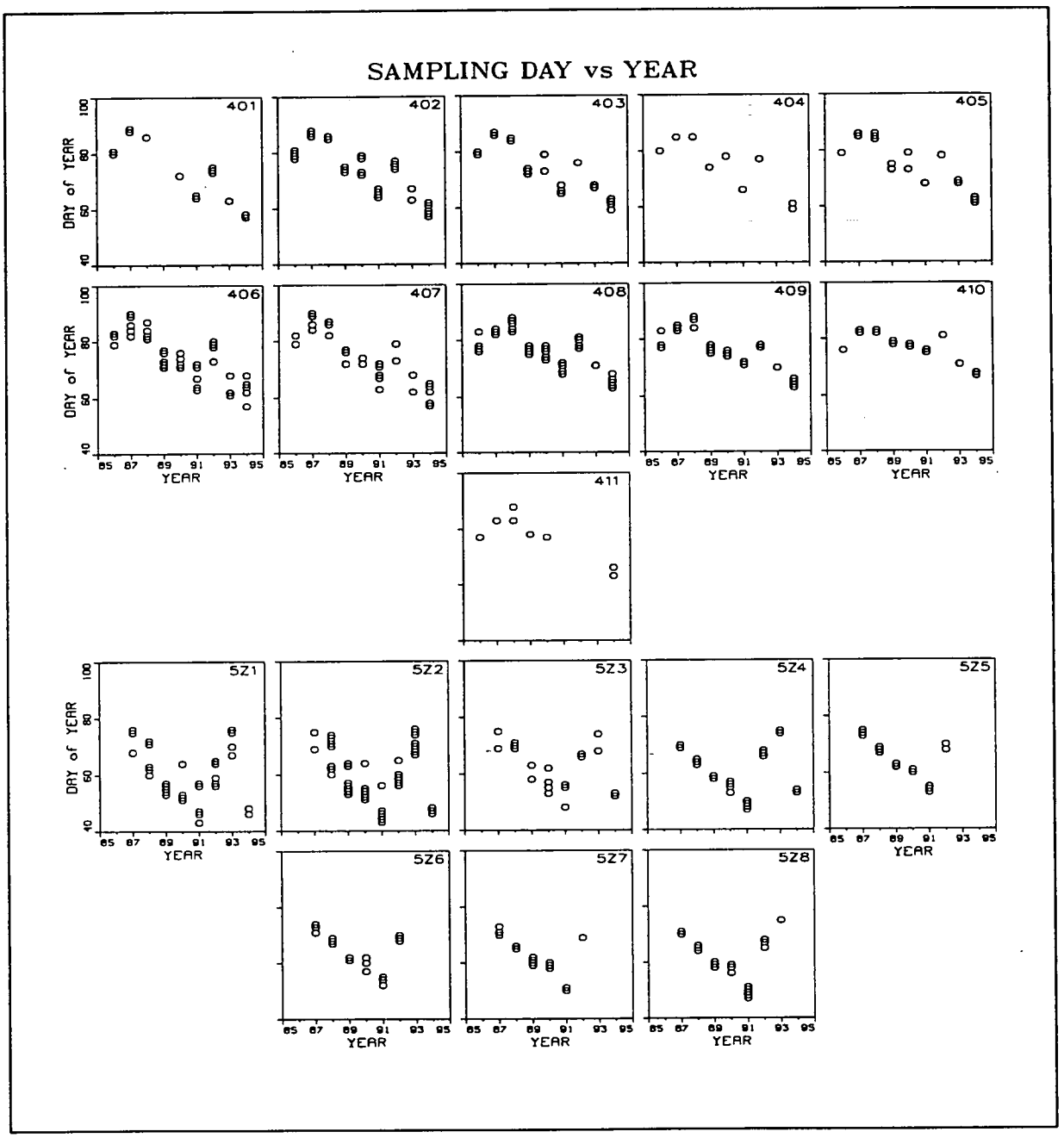


Figure 6: Time series of the consecutive day of sampling within the spring 4VsW and 5Z groundfish bottom-trawl surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.

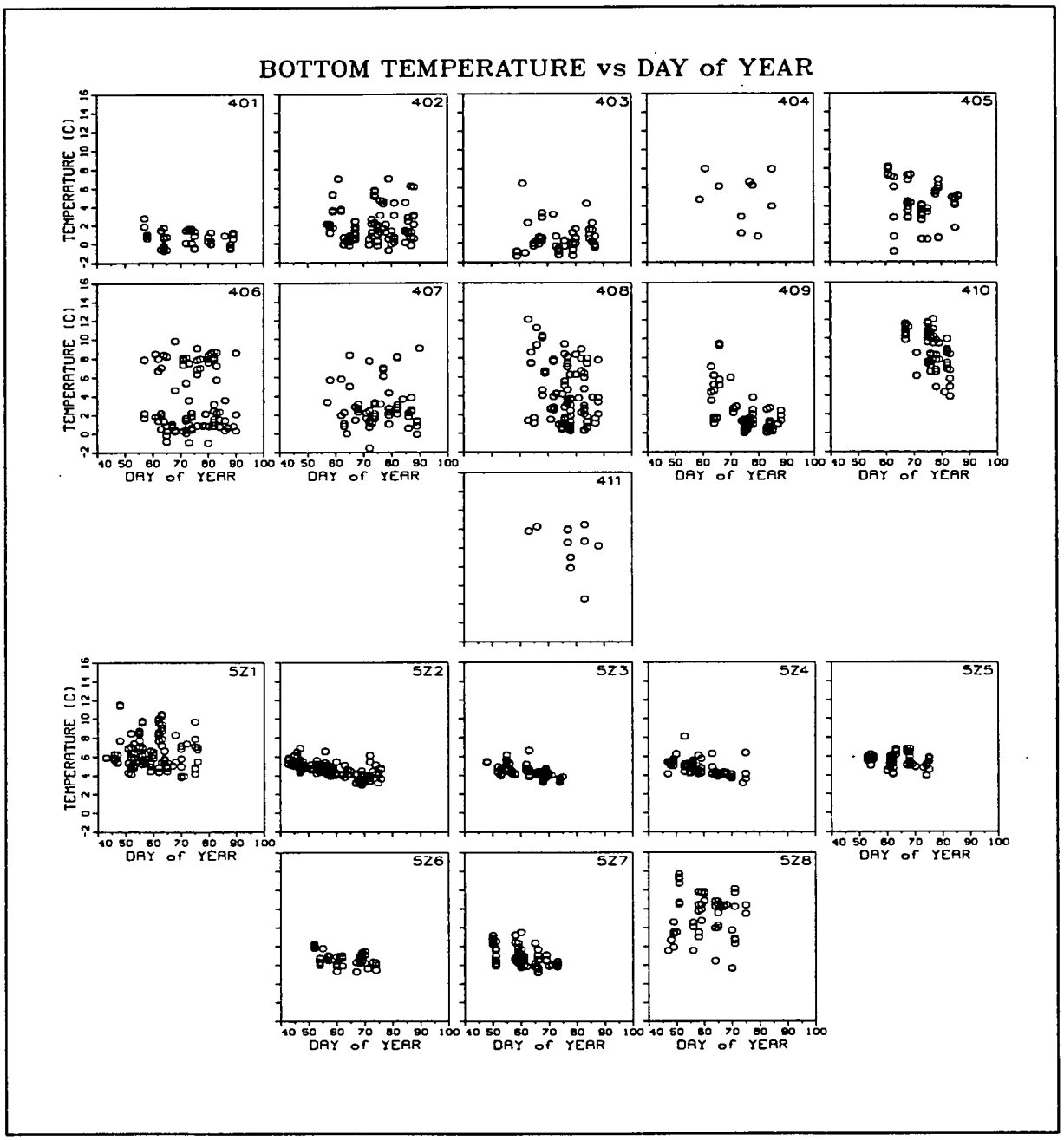


Figure 7: Near-bottom temperatures within the spring 4VsW and 5Z surveys in relation to day of the year. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the values at one hydrographic station.

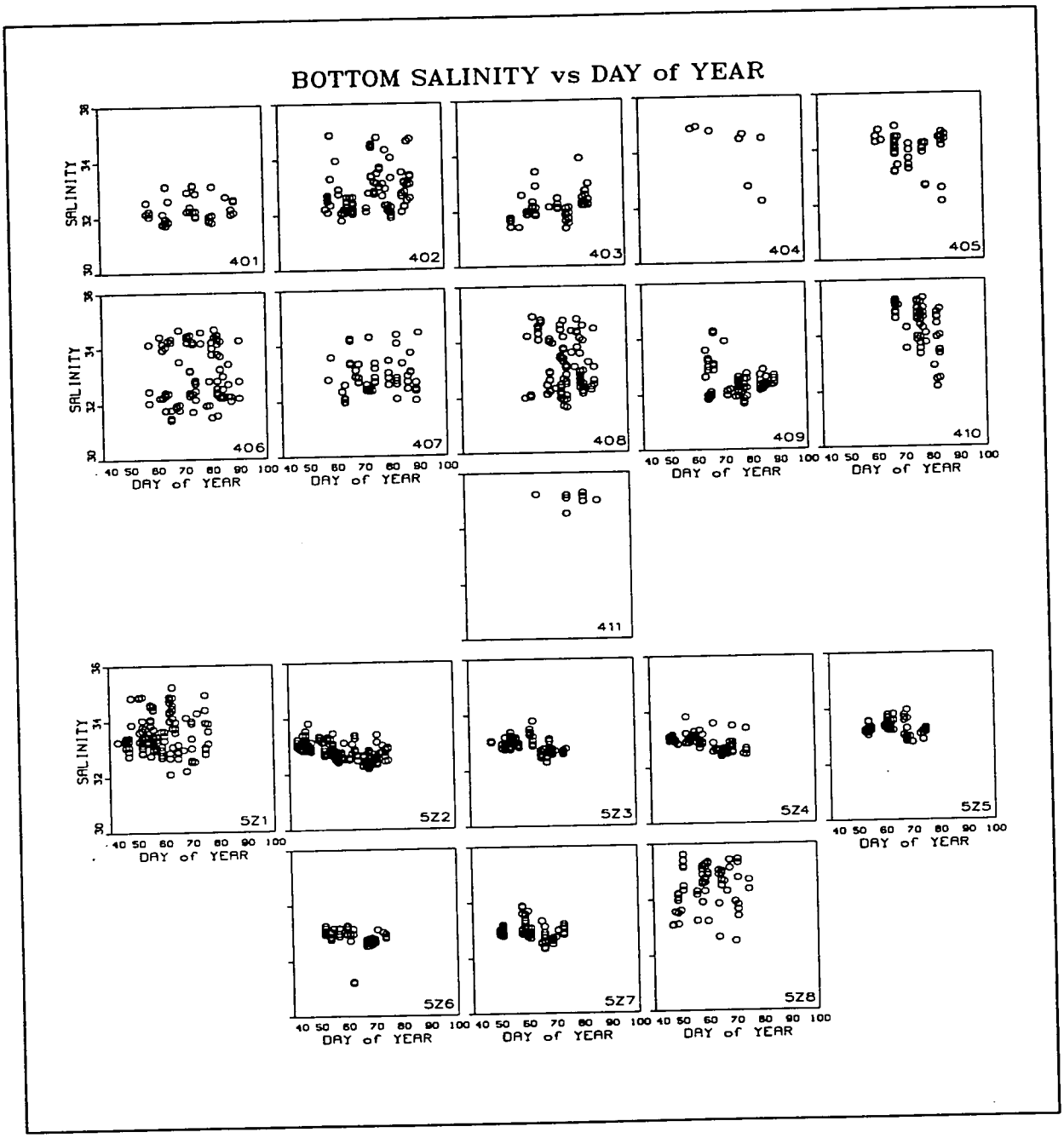


Figure 8: Near-bottom salinities within the spring 4VsW and 5Z surveys in relation to day of the year. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the values at one hydrographic station.

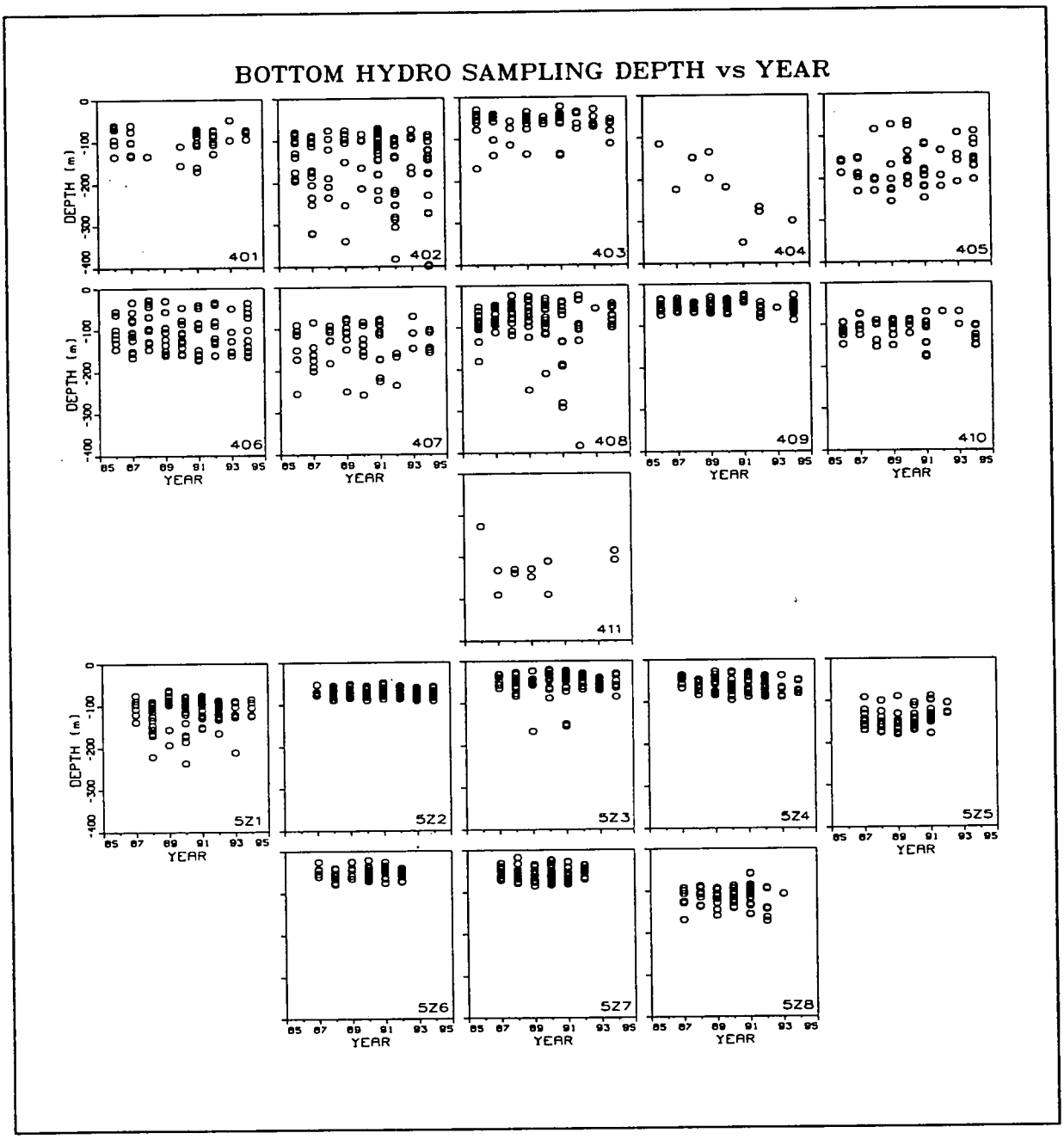


Figure 9: Time series of the near-bottom sampling depth for each hydrographic station within the spring 4VsW and 5Z surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the near-bottom sampling depth of one hydrographic station.

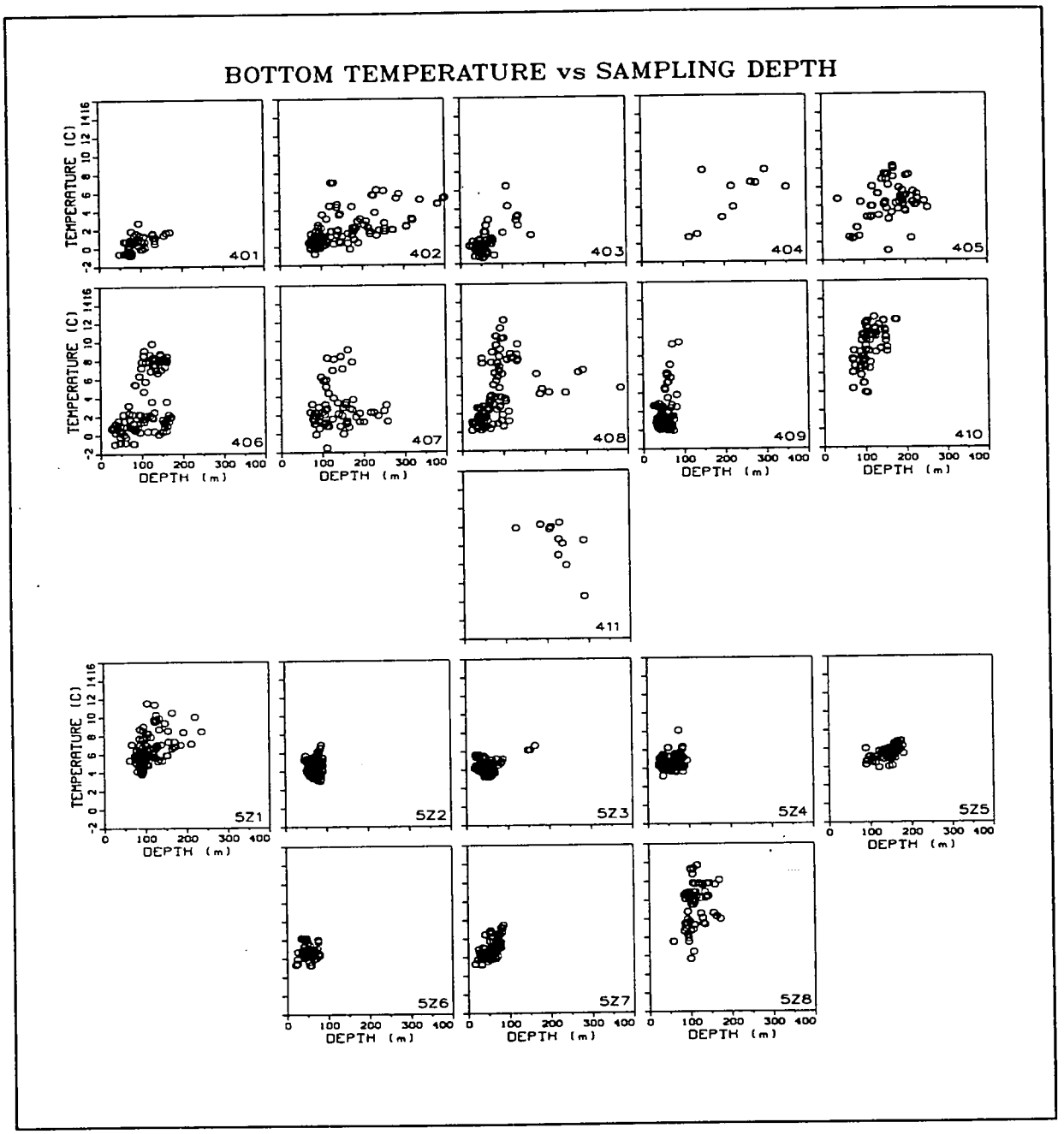


Figure 10: Near-bottom temperatures within the spring 4VsW and 5Z surveys in relation to sampling depth. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the values at one hydrographic station.

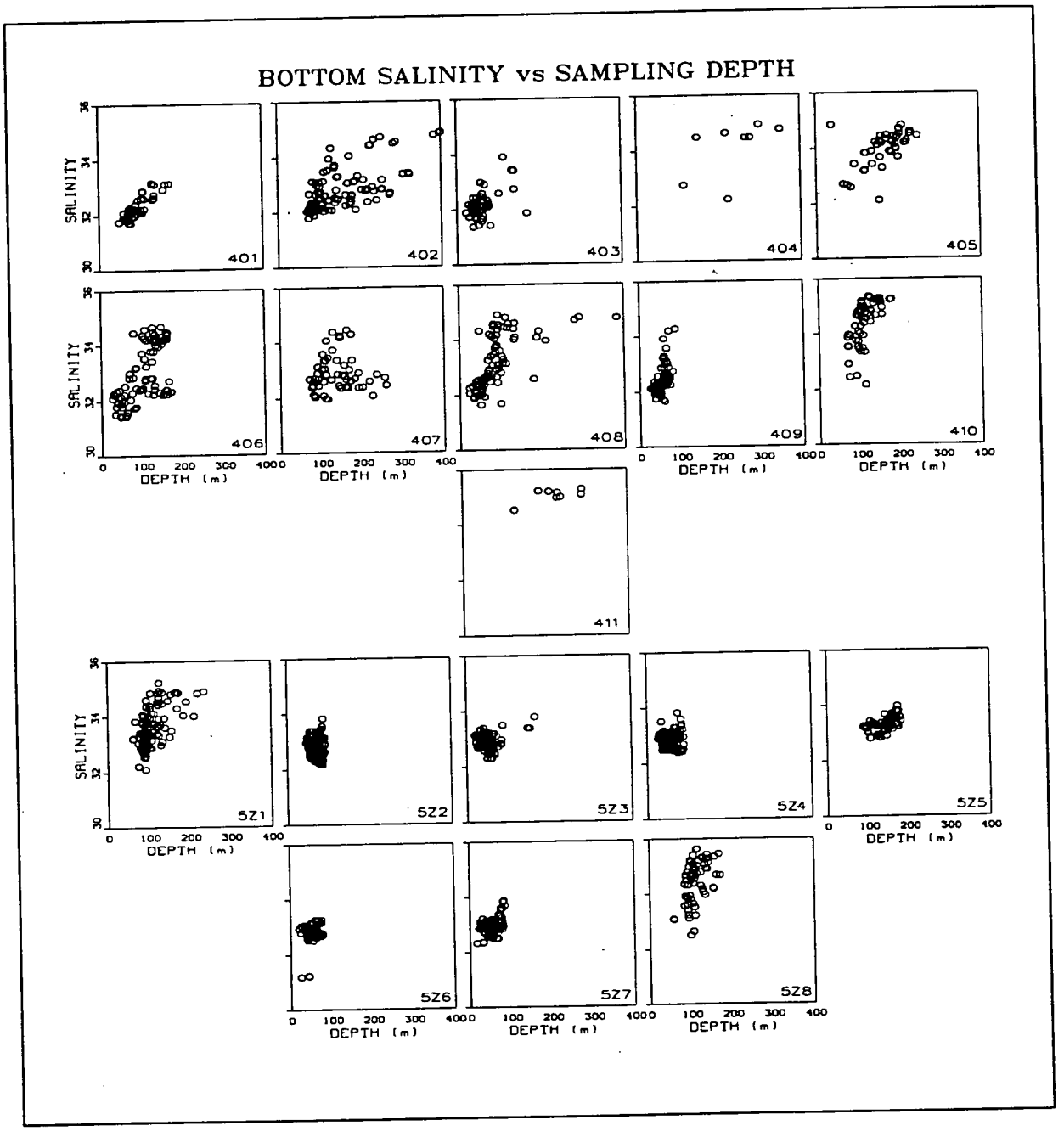


Figure 11: Near-bottom salinities within the spring 4VsW and 5Z surveys in relation to sampling depth. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the values at one hydrographic station.

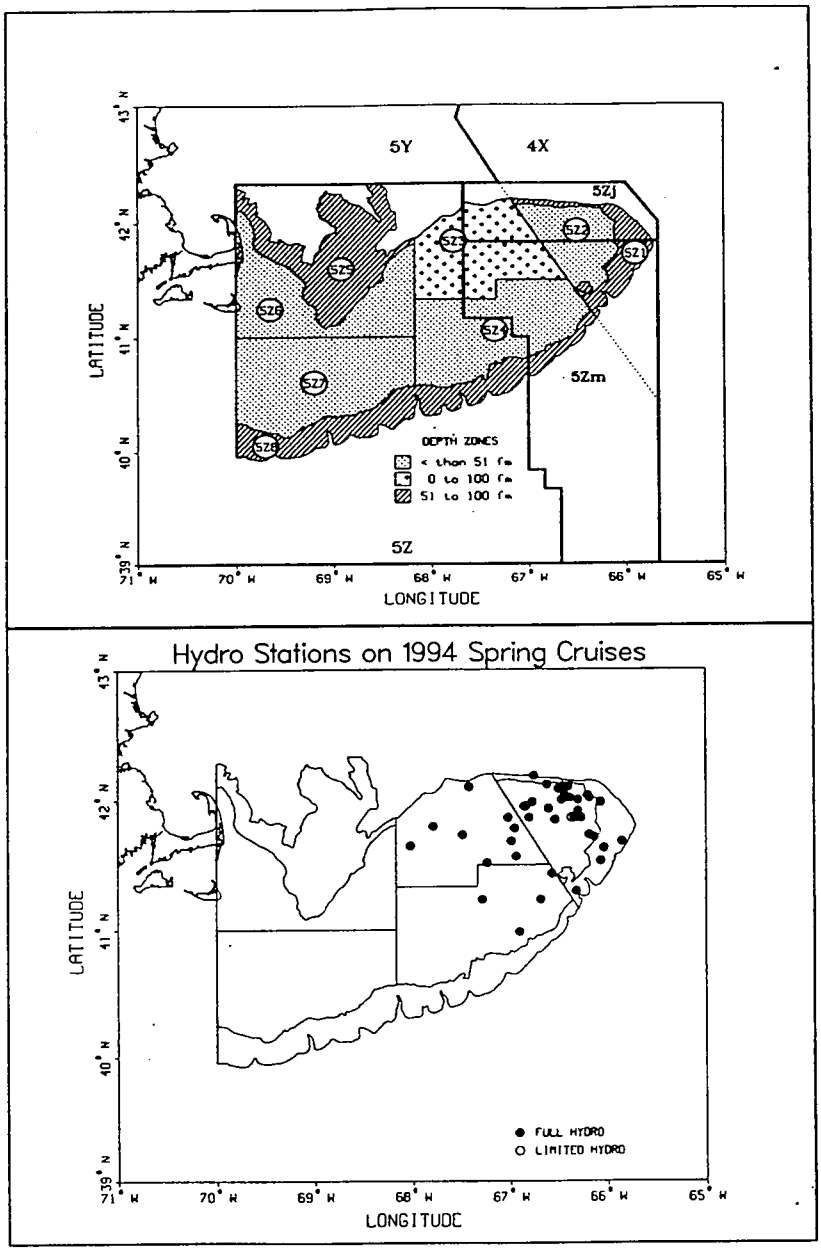


Figure 12: Survey domain and strata boundaries for the Canadian spring groundfish bottom-trawl research vessel surveys conducted within NAFO area 5Z from 1987-1994 (top panel) and the location of hydrographic sampling stations taken during the 1994 spring survey (bottom panel). In the top panel the numbers enclosed within circles are the strata designations. In the bottom panel a solid circle indicates a trawl station where a CTD cast was taken and an open circle indicates a station where only surface temperatures and bottom temperatures and salinities were measured.

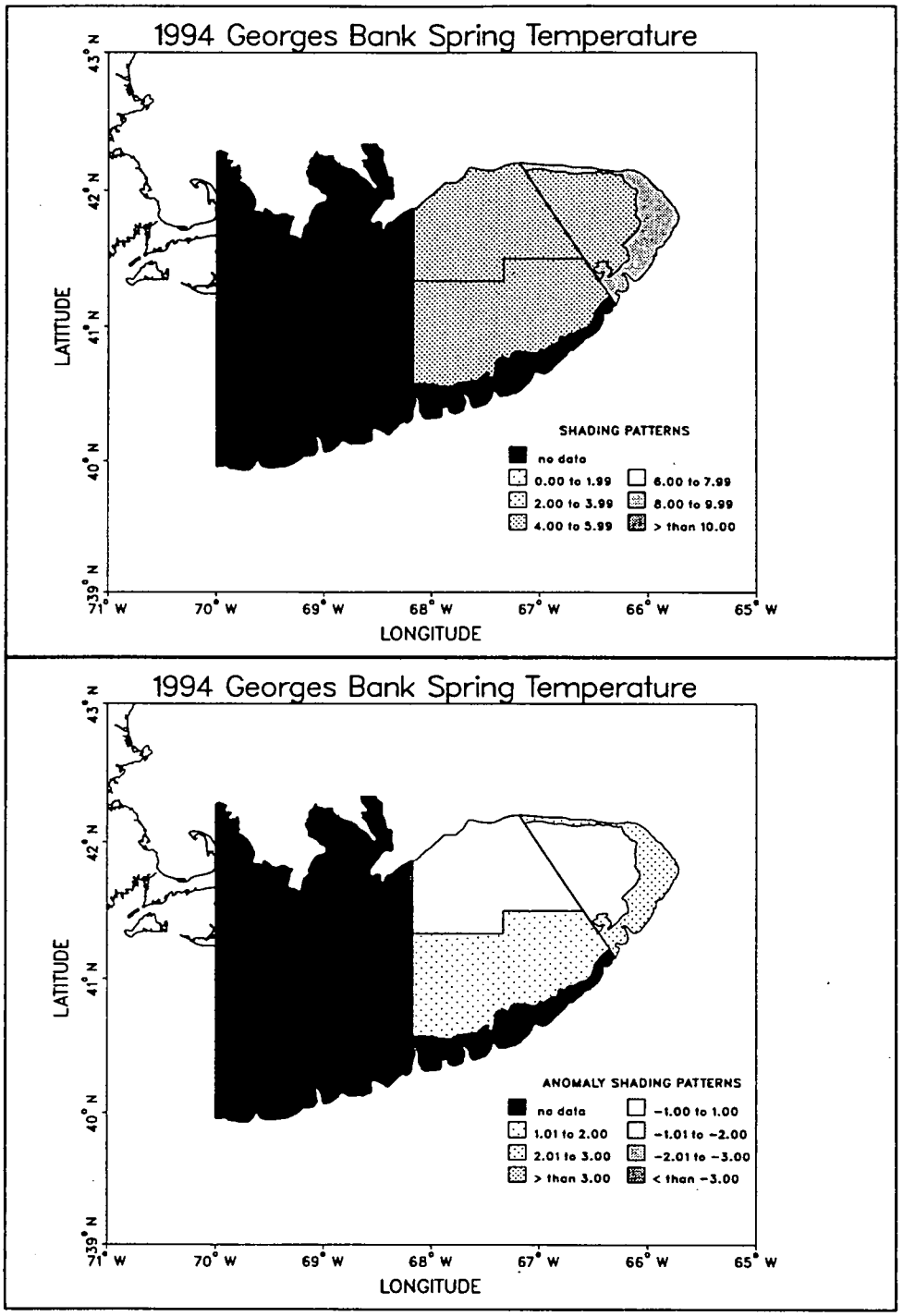


Figure 13: Map of near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 5Z during the Canadian research vessel bottom-trawl survey conducted during the spring of 1994.

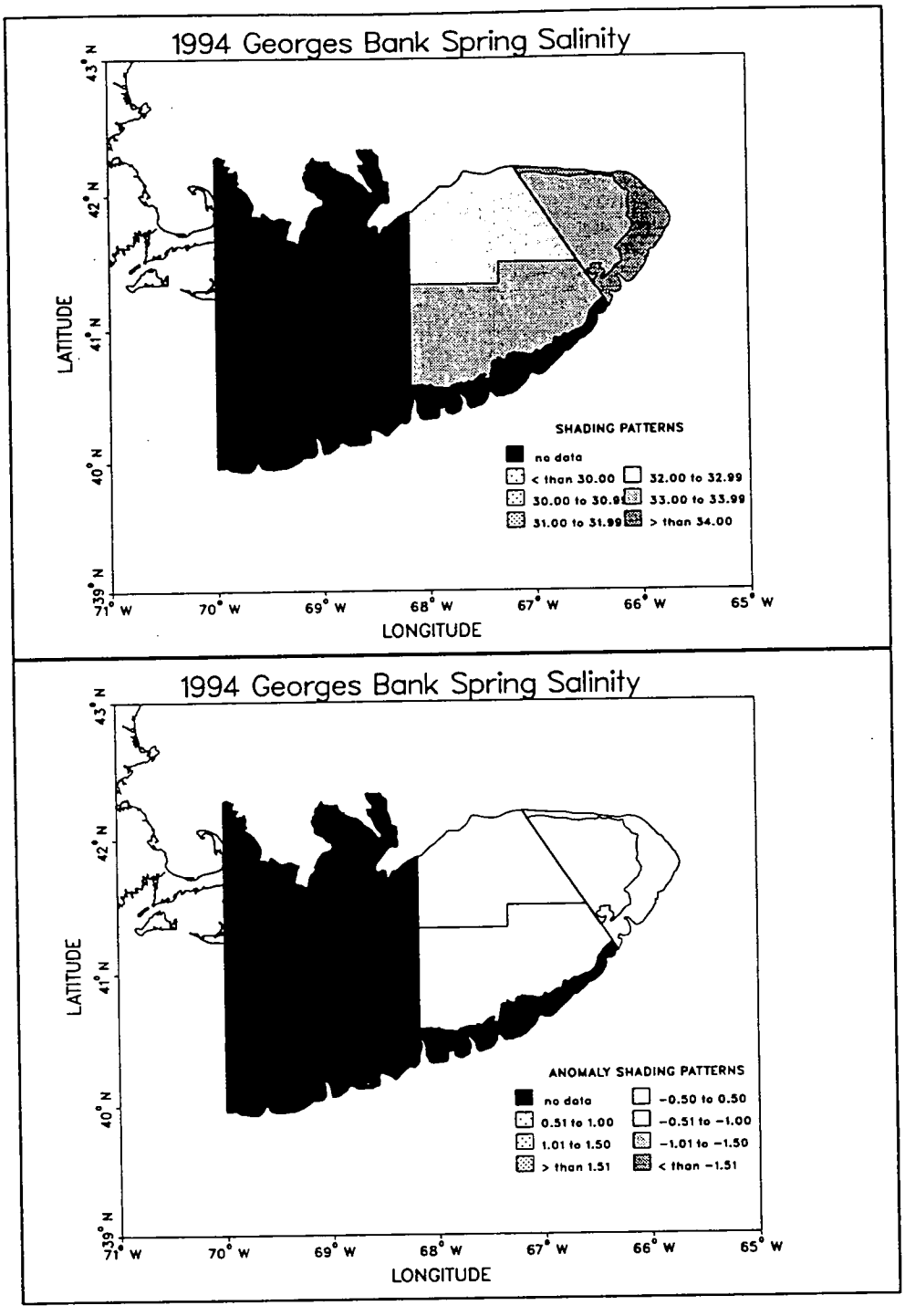


Figure 14: Map of near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 5Z during the Canadian research vessel bottom-trawl survey conducted during the spring of 1994.

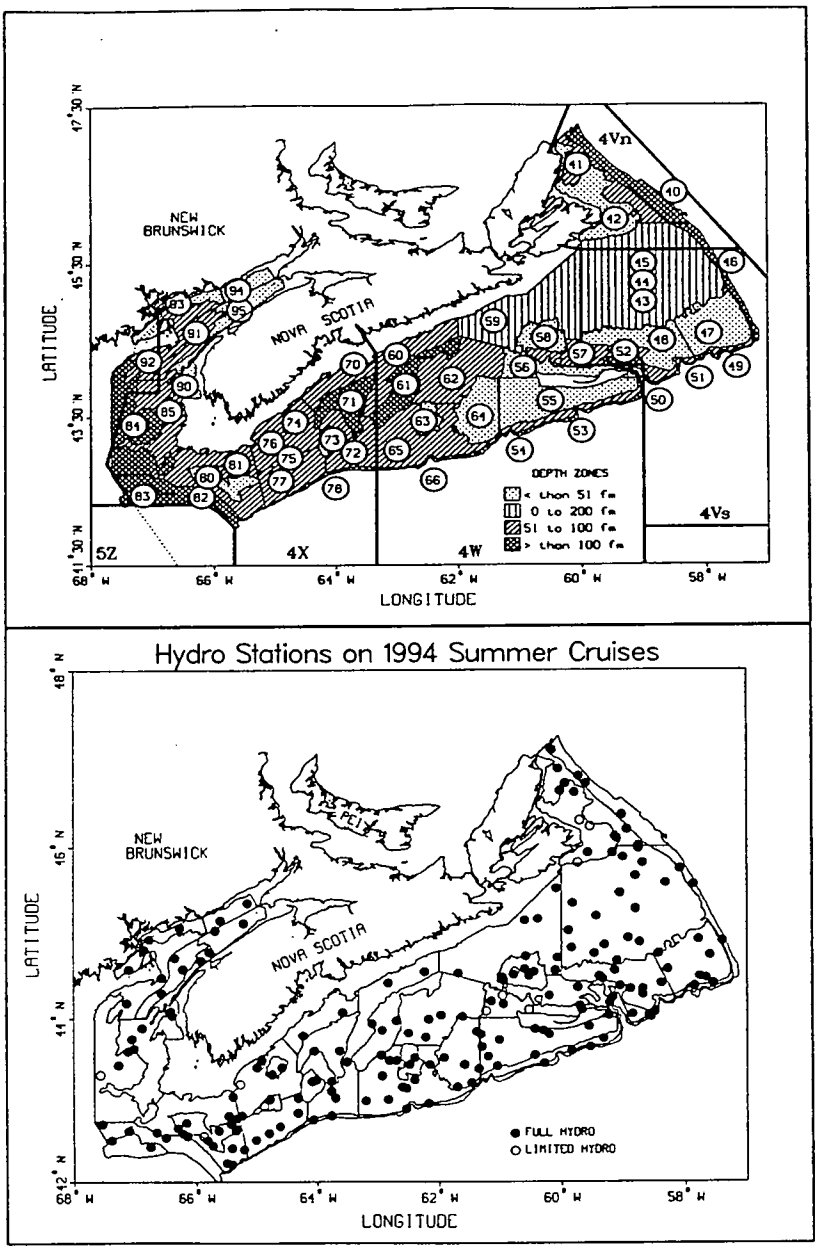


Figure 15: Survey domain and strata boundaries for the Canadian summer groundfish bottom-trawl research vessel surveys conducted within NAFO area 4VWX from 1970-1994 (top panel) and the location of hydrographic sampling stations taken during the 1994 summer survey (bottom panel). In the top panel the numbers enclosed within circles are the strata designations. Only the last two digits of the summer strata designations are shown. In the bottom panel a solid circle indicates a trawl station where a CTD cast was taken and an open circle indicates a trawl station where only surface temperatures and bottom temperatures and salinities were measured.

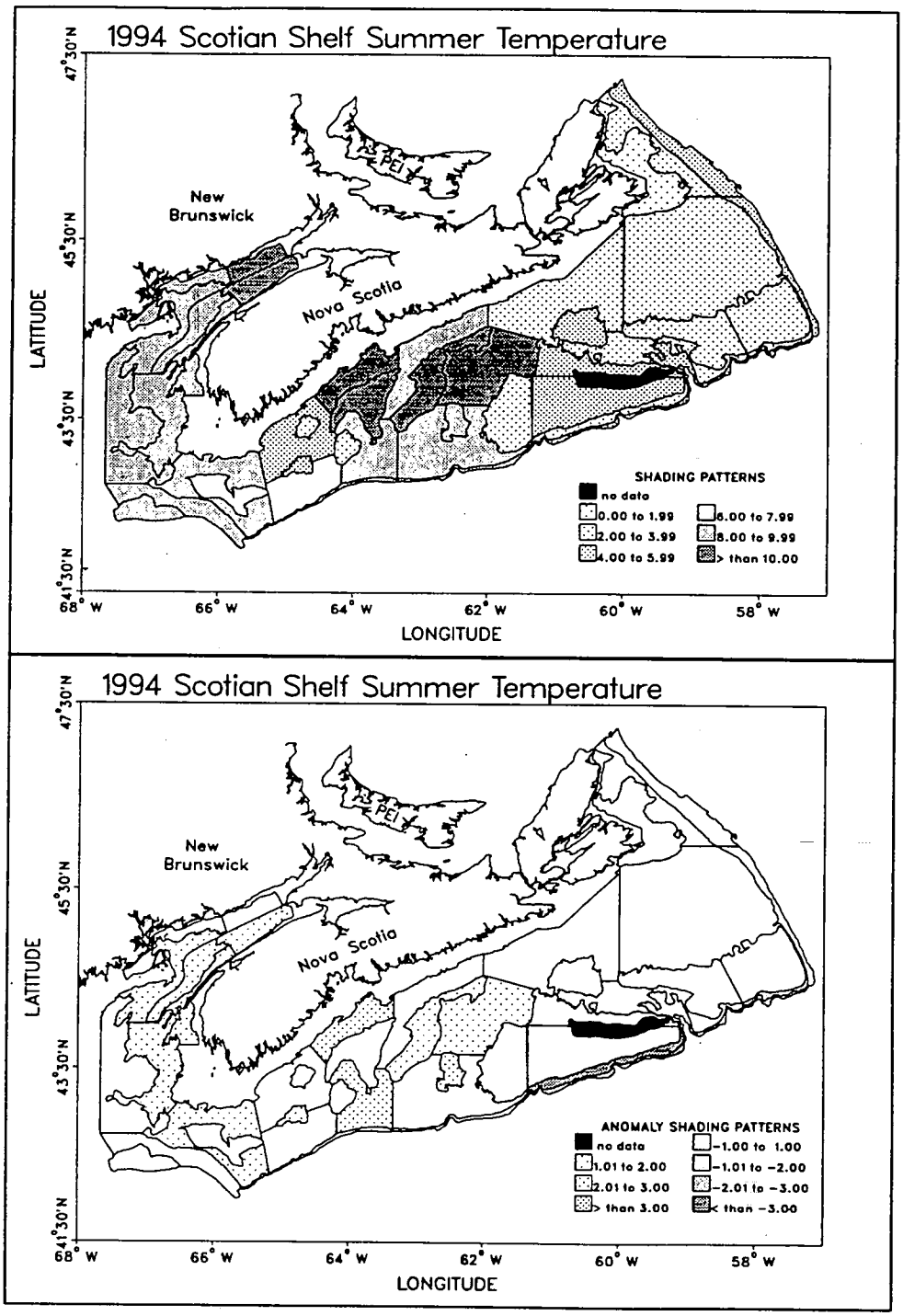


Figure 16: Near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1994.

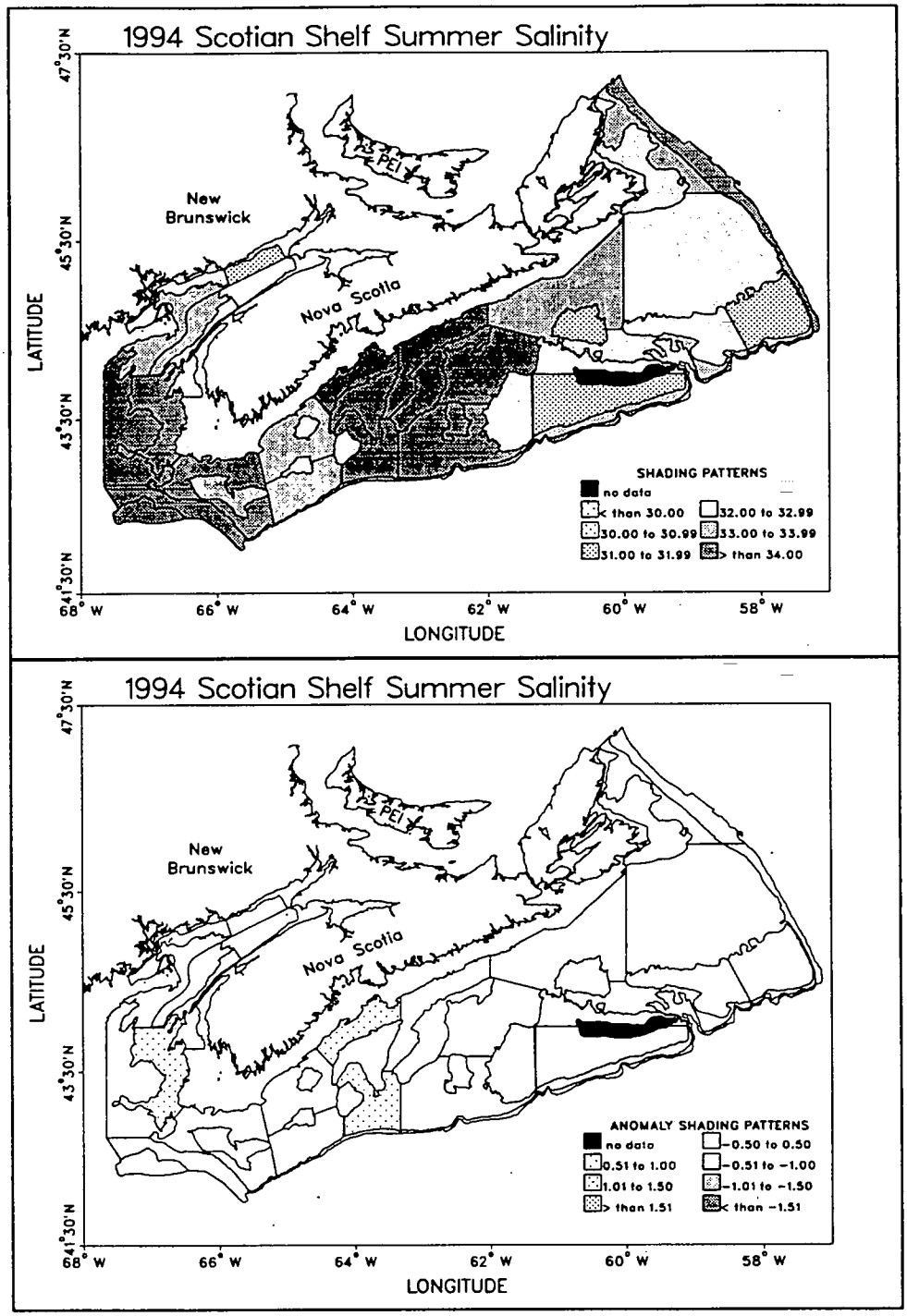


Figure 17: Near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1994.

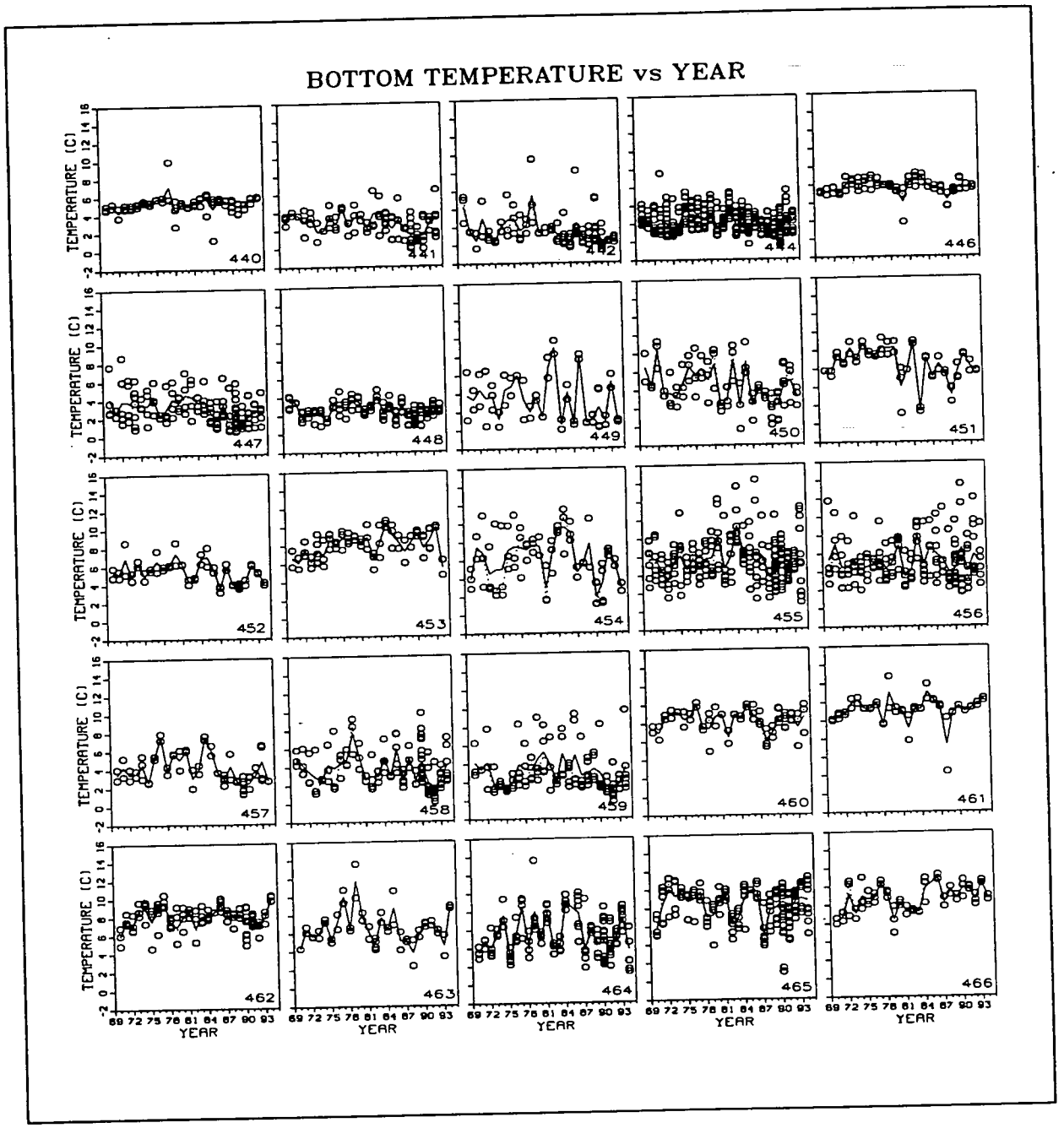


Figure 18: Time series of near-bottom temperatures within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

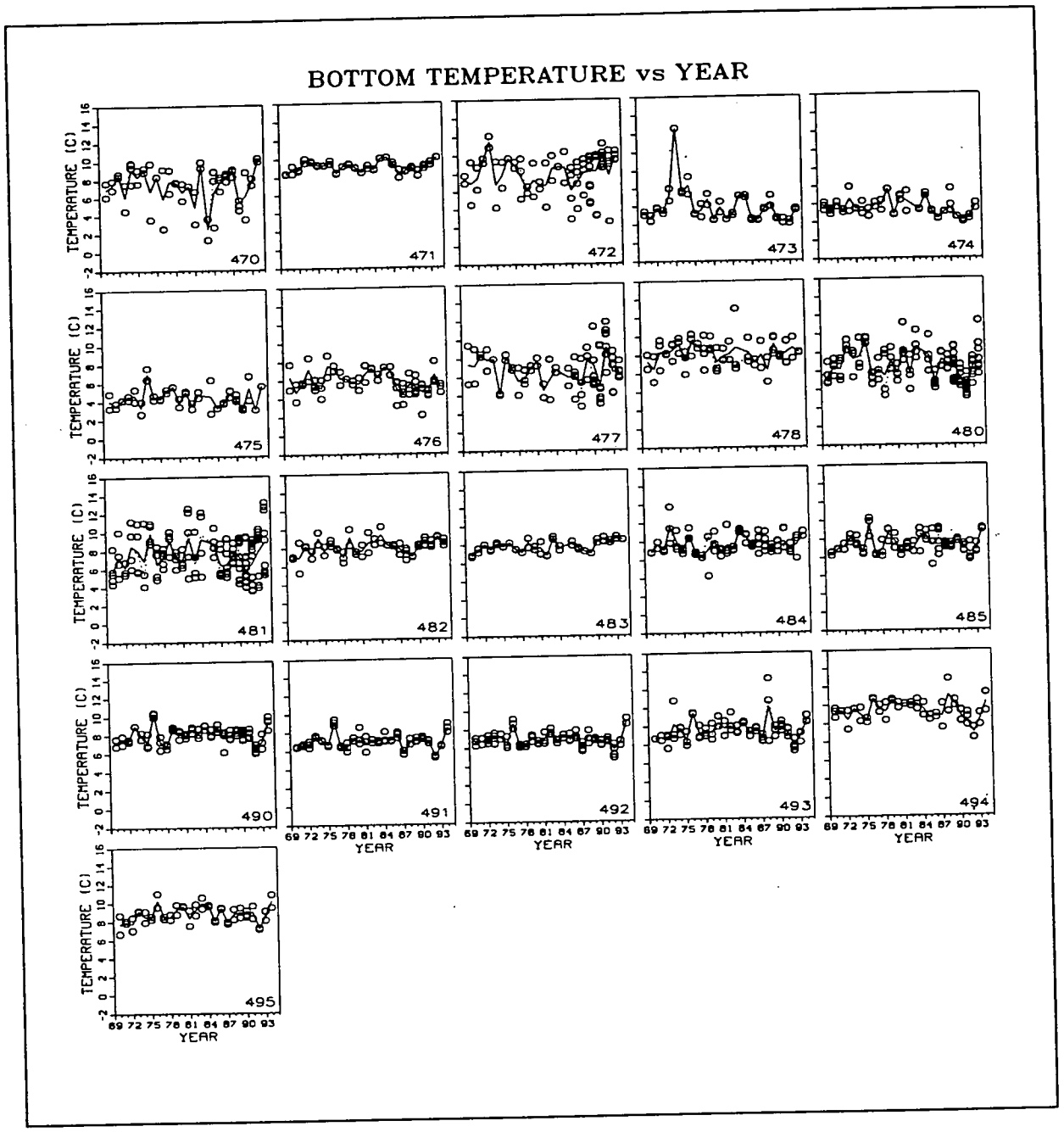


Figure 18: continued

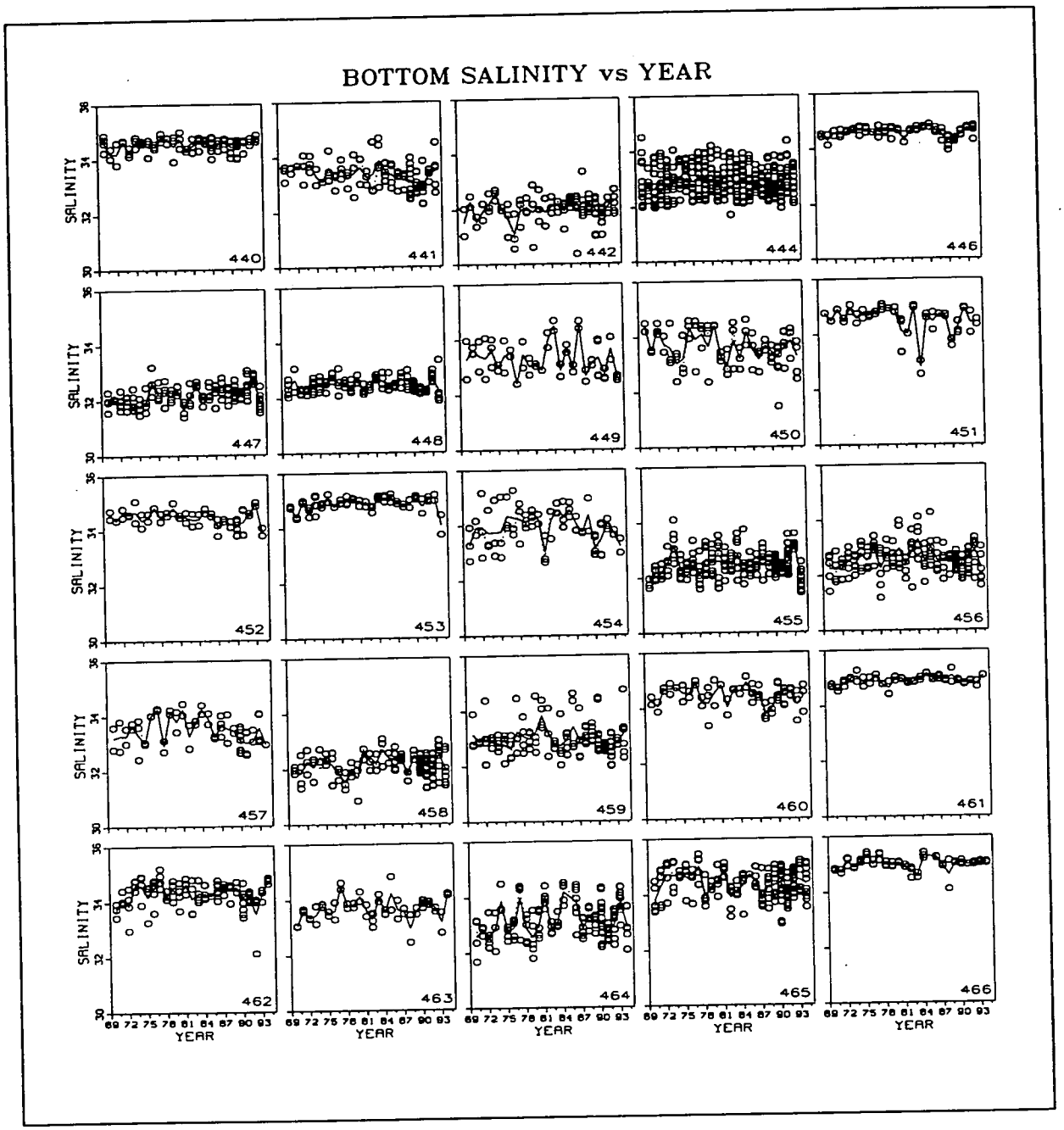
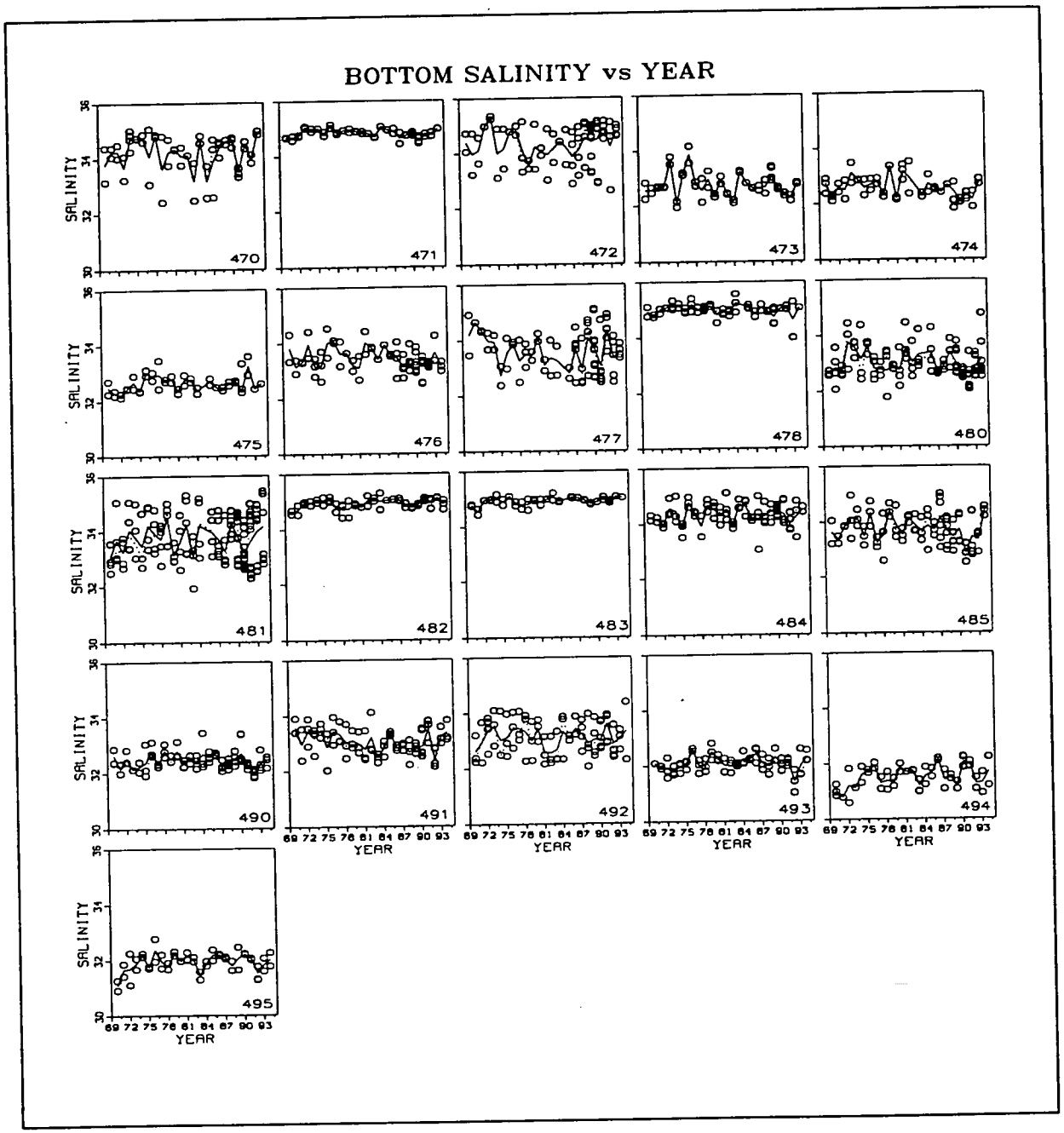


Figure 19: Time series of near-bottom salinities within the summer 4VWX surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.



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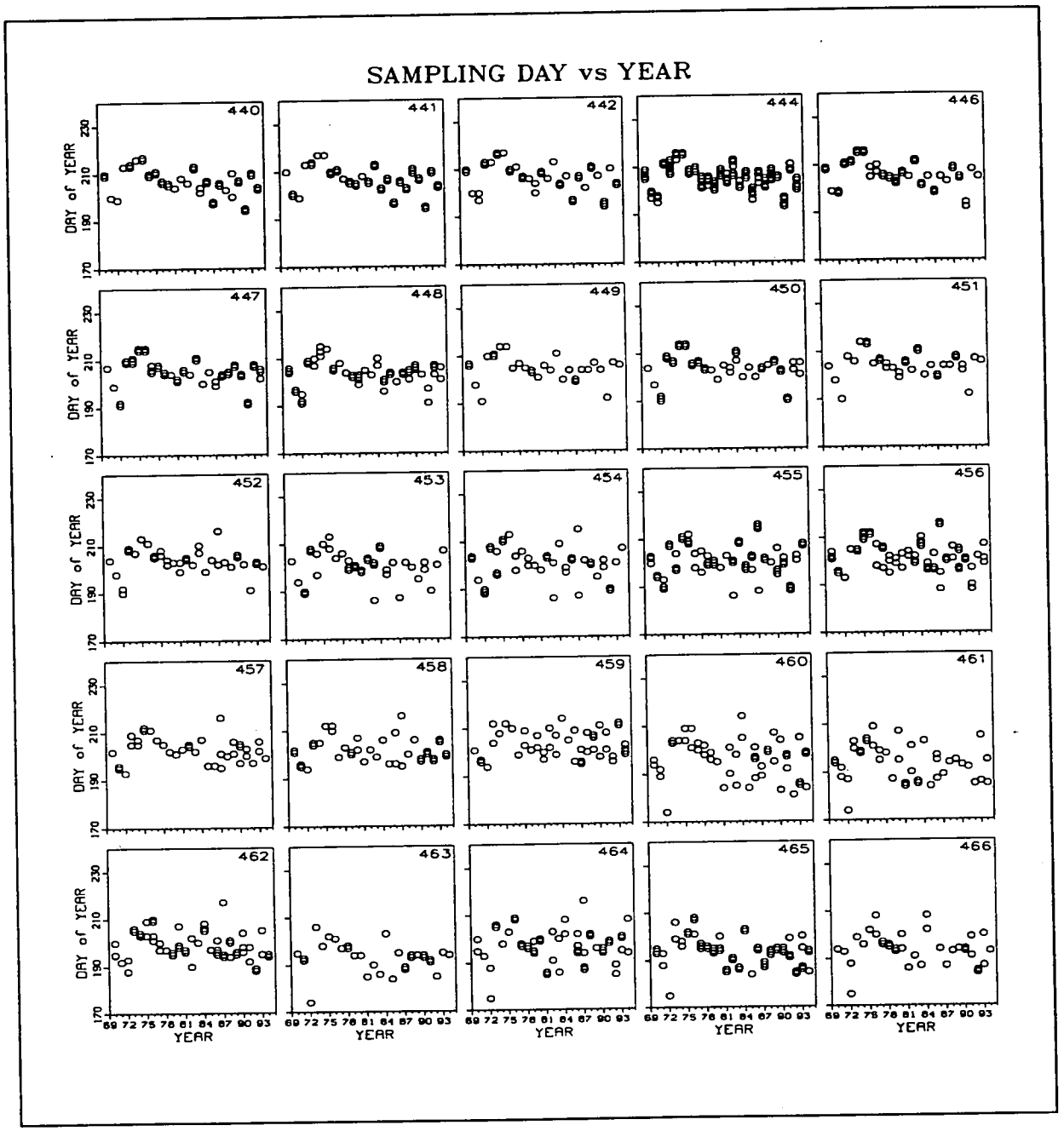


Figure 20: Time series of the day of sampling within the summer 4VWX surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.

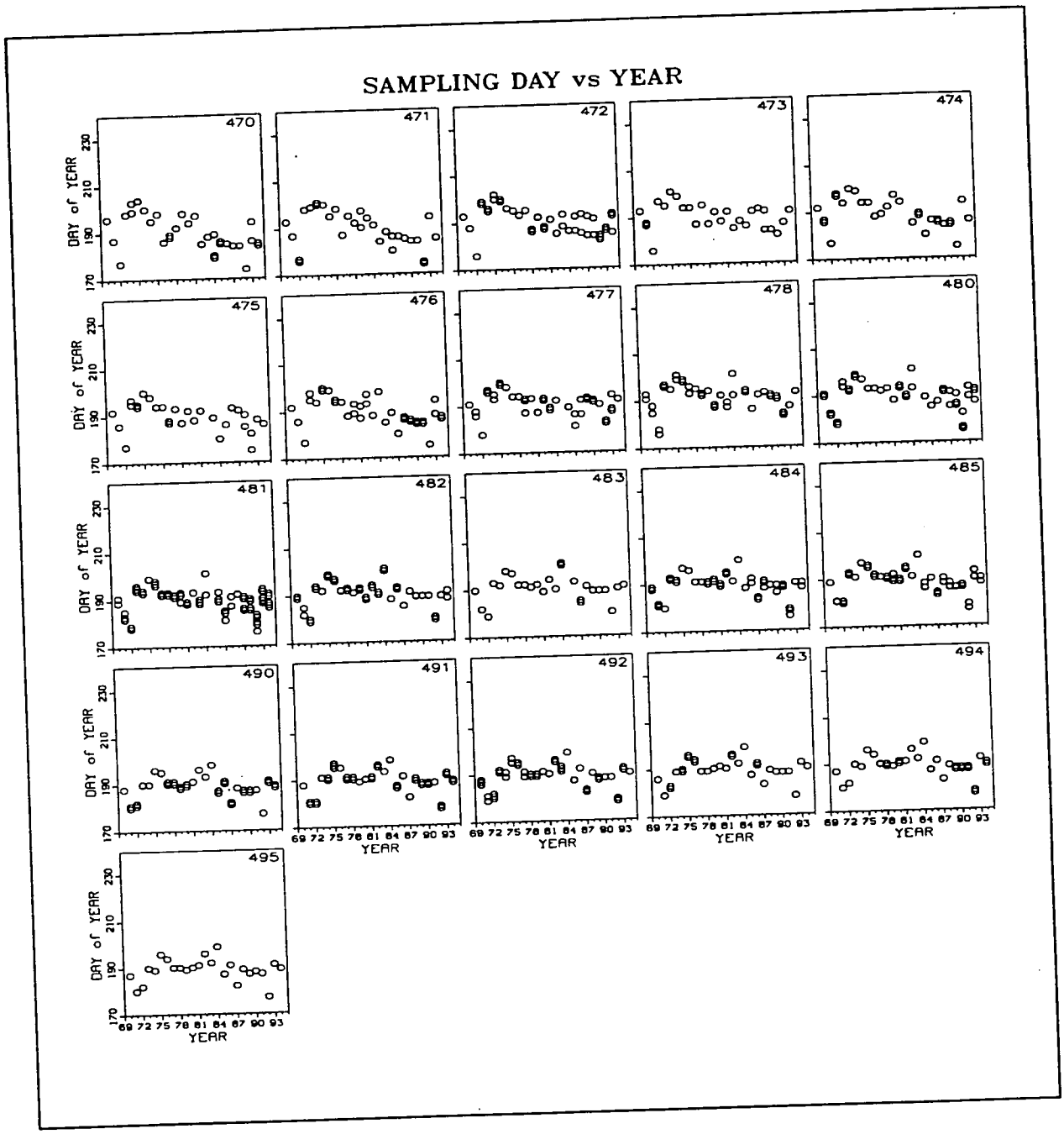


Figure 20: continued

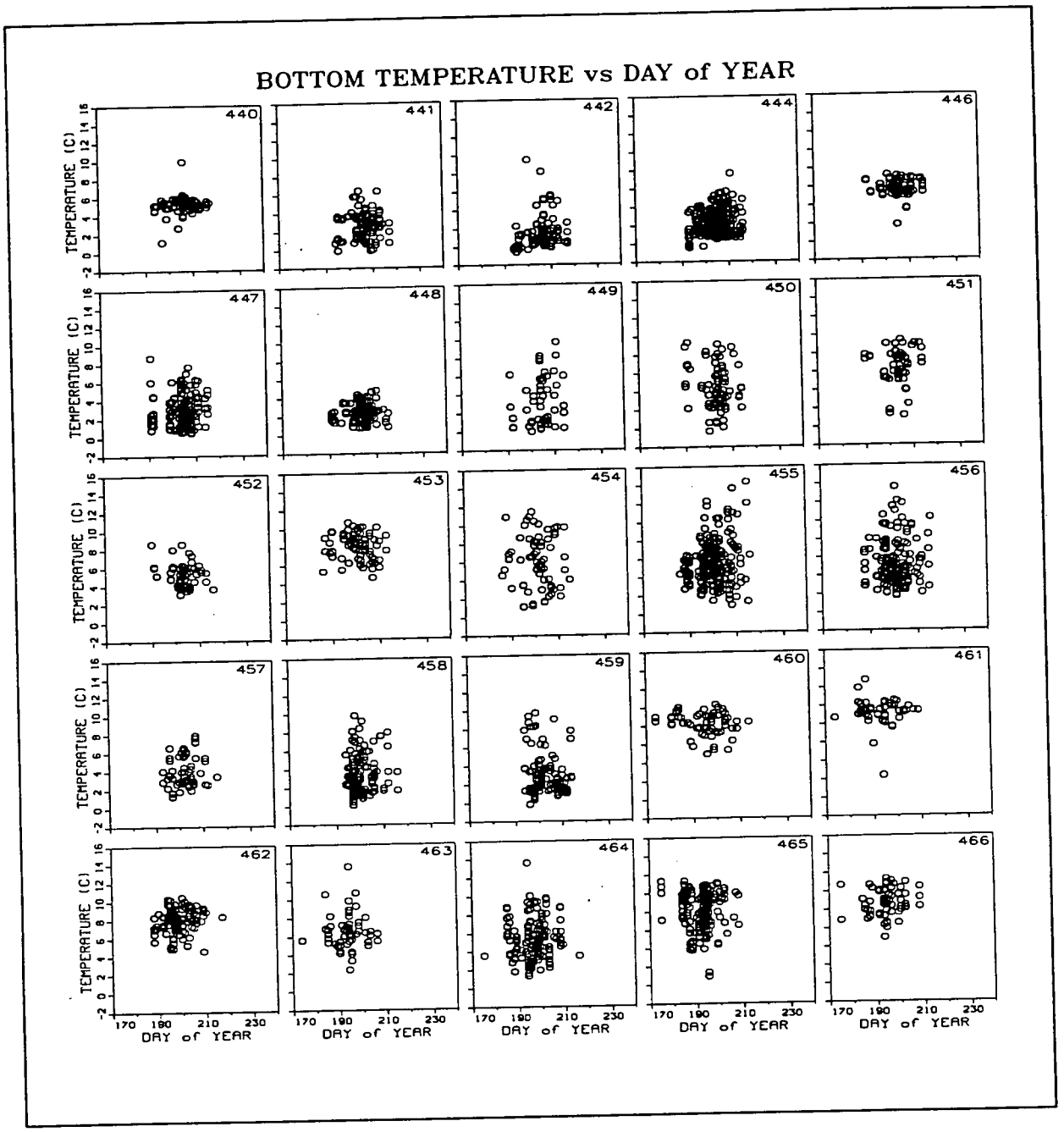
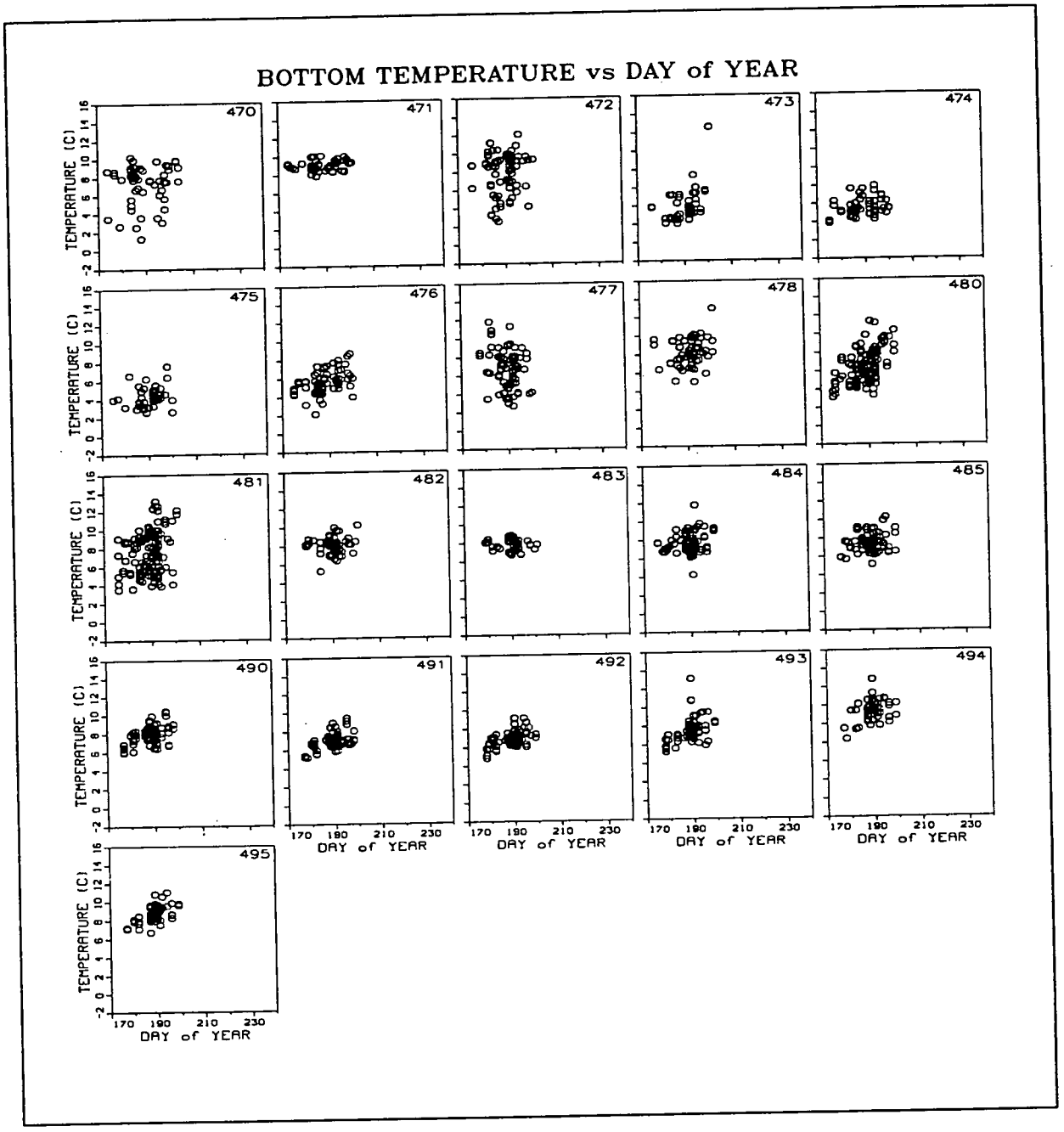


Figure 21: Near-bottom temperatures within the summer 4VWX surveys in relation to day of the year. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.



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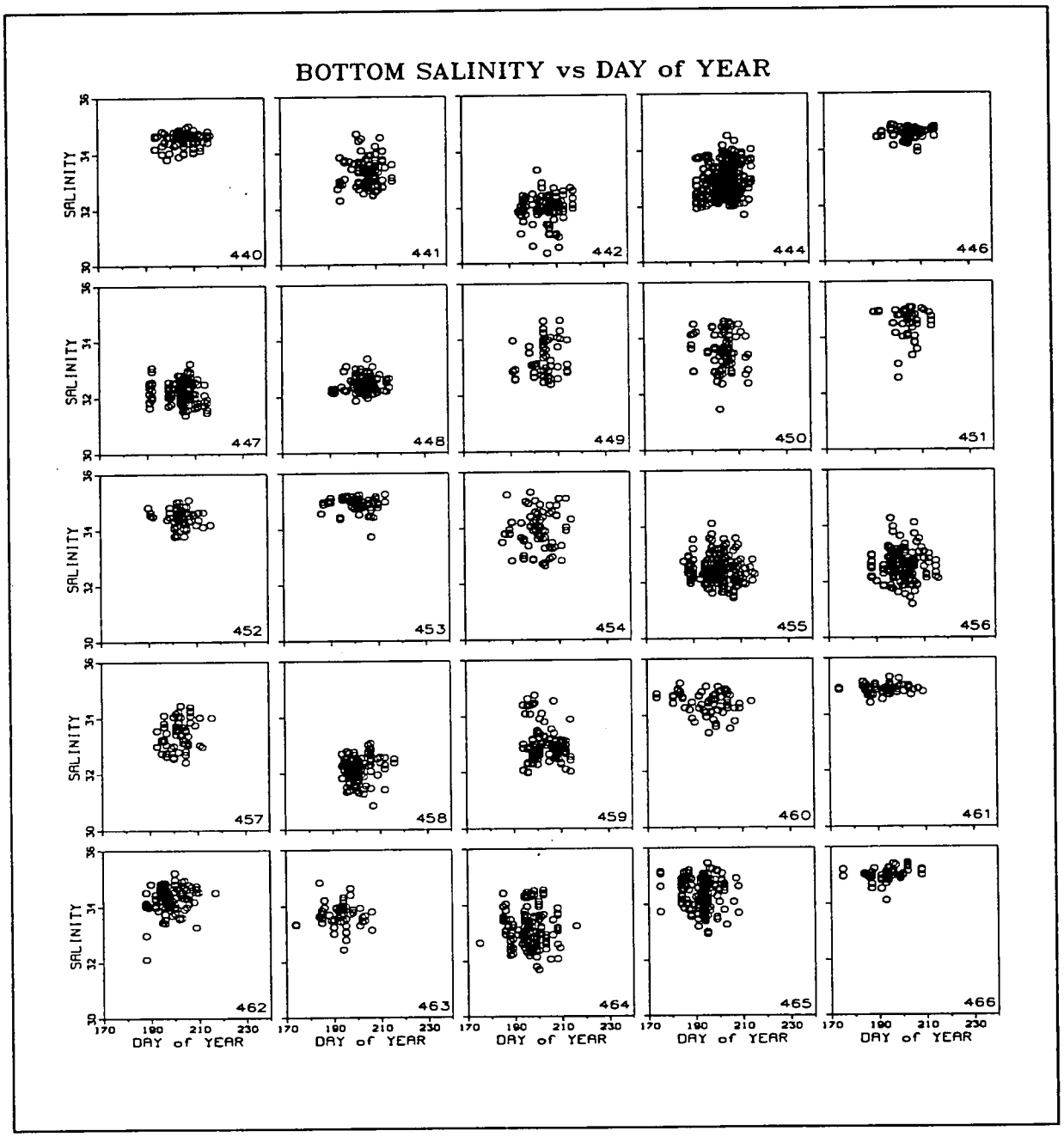


Figure 22: Near-bottom salinity within the summer 4VWX surveys in relation to day of the year. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

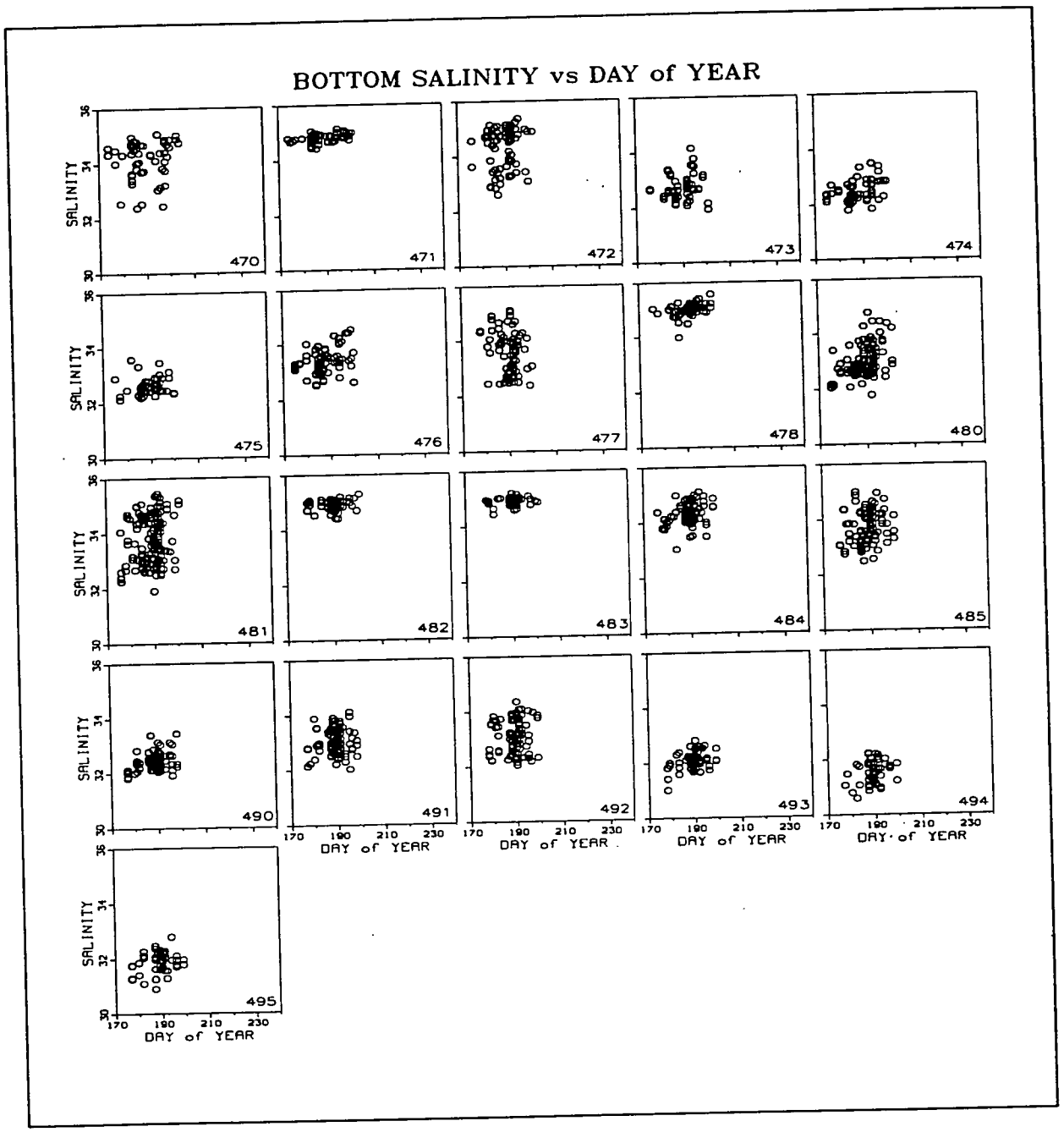


Figure 22: continued

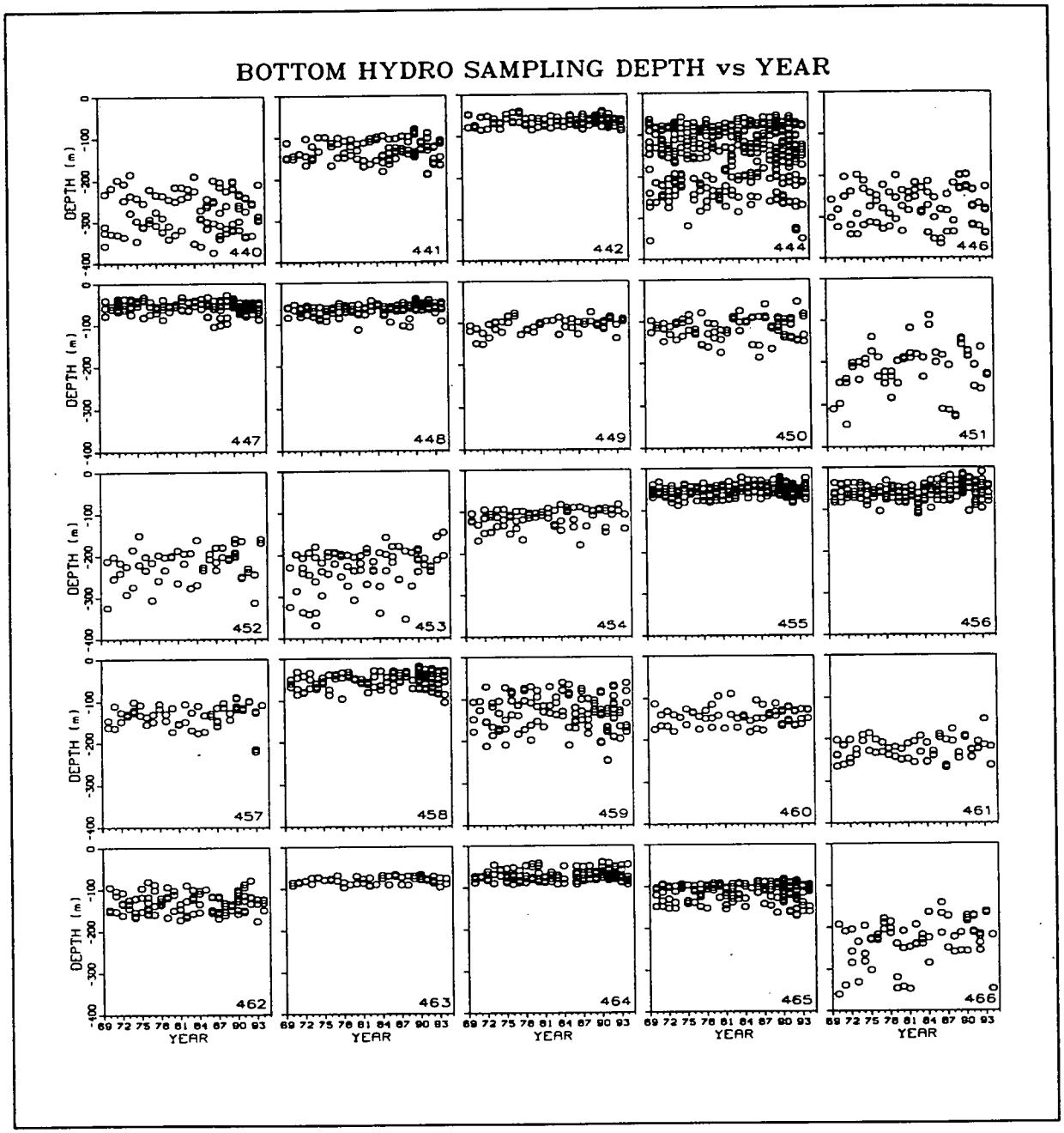


Figure 23: Time series of the near-bottom sampling depth for each hydrographic station within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the near-bottom sampling depth of one hydrographic station.

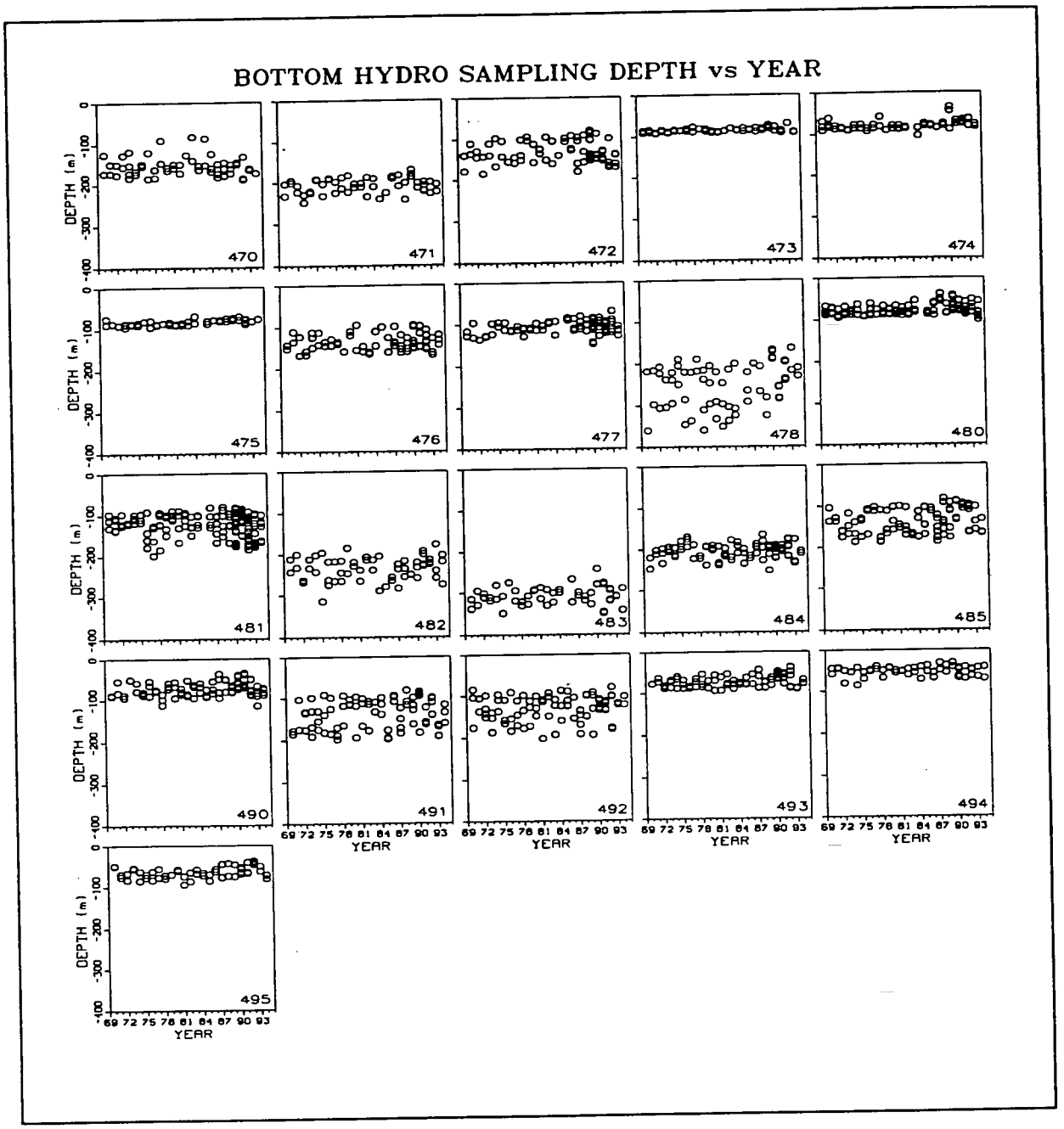


Figure 23: continued

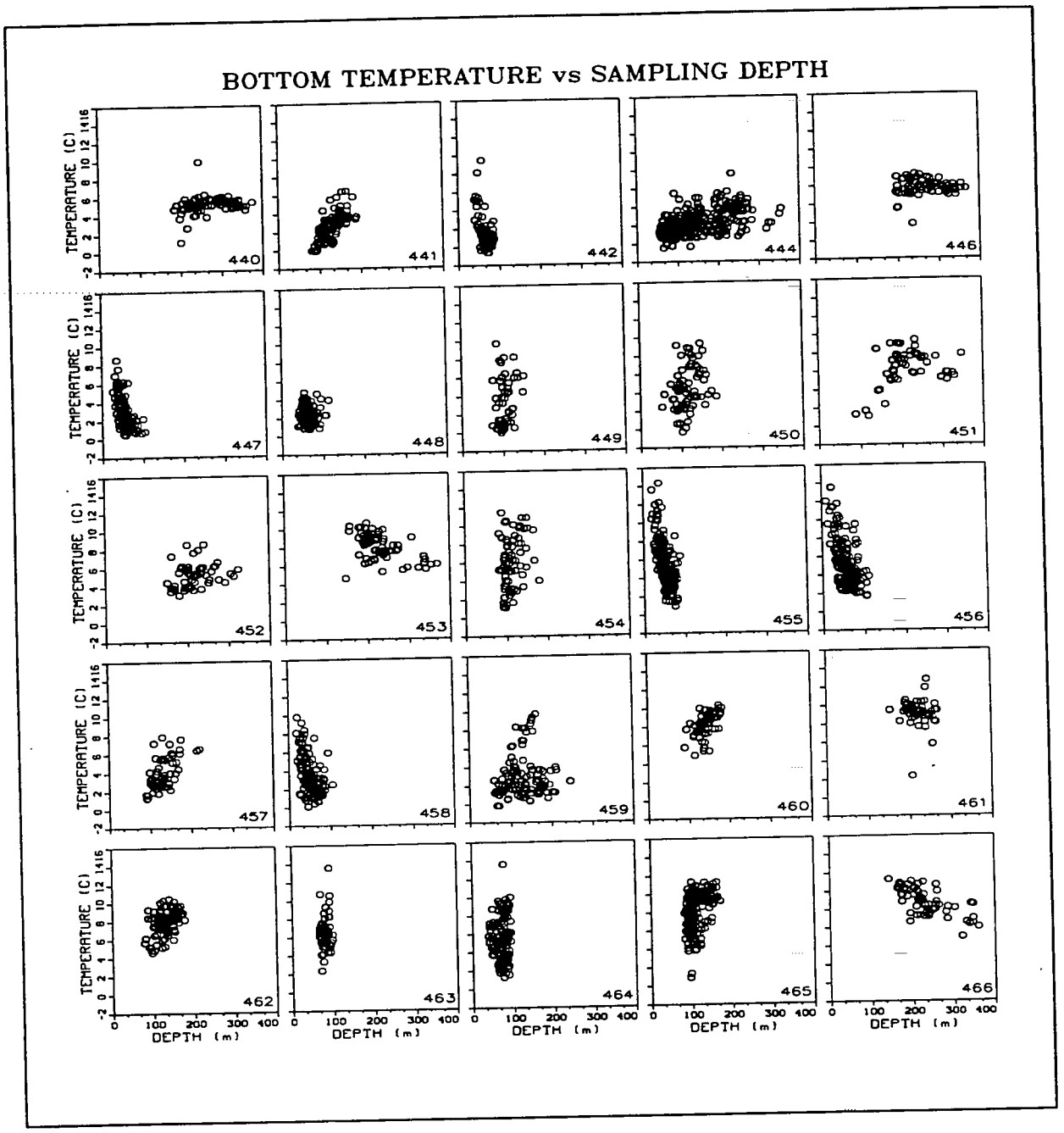
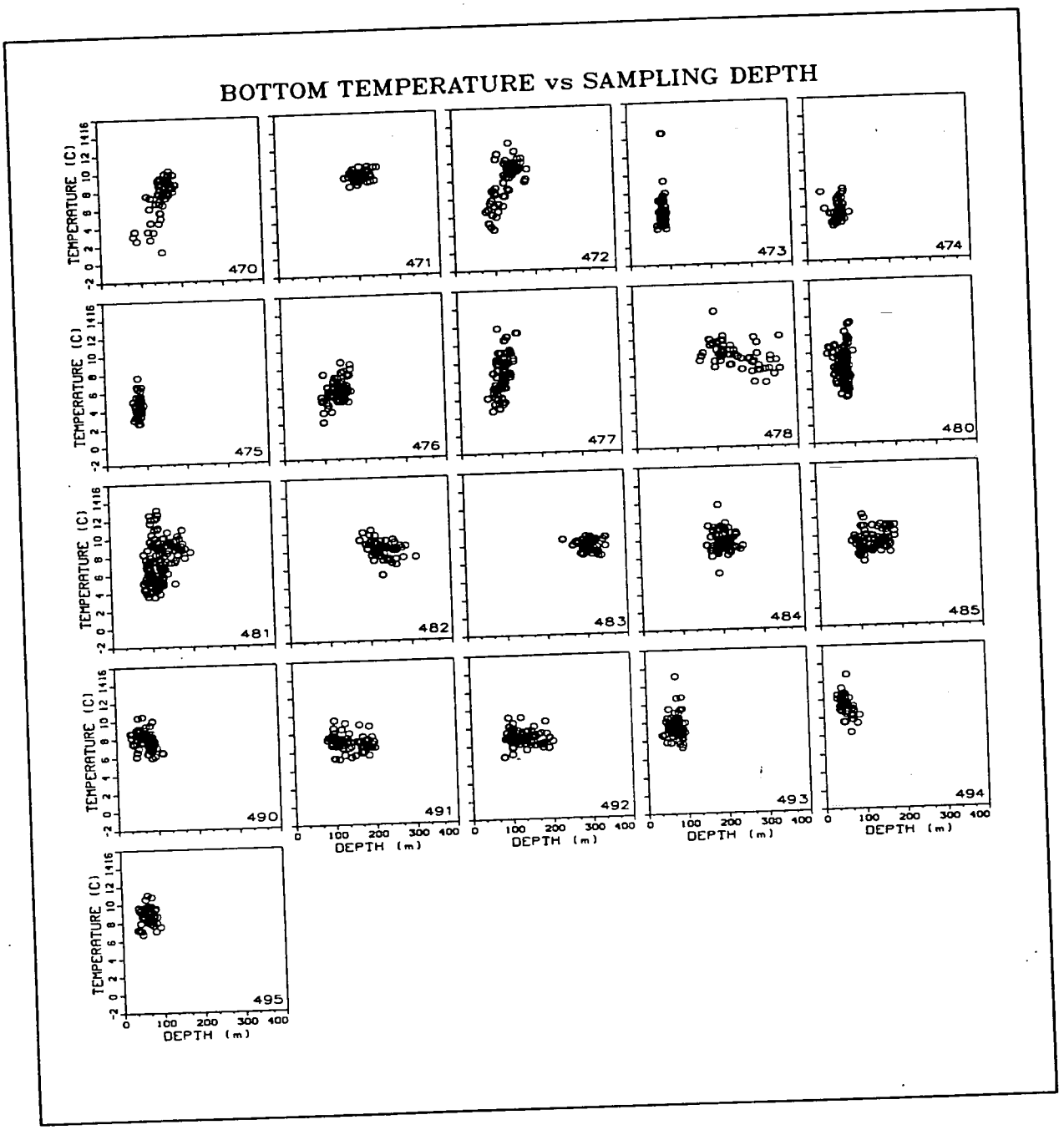


Figure 24: Near-bottom temperatures within the summer 4VWX surveys in relation to sampling depth. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.



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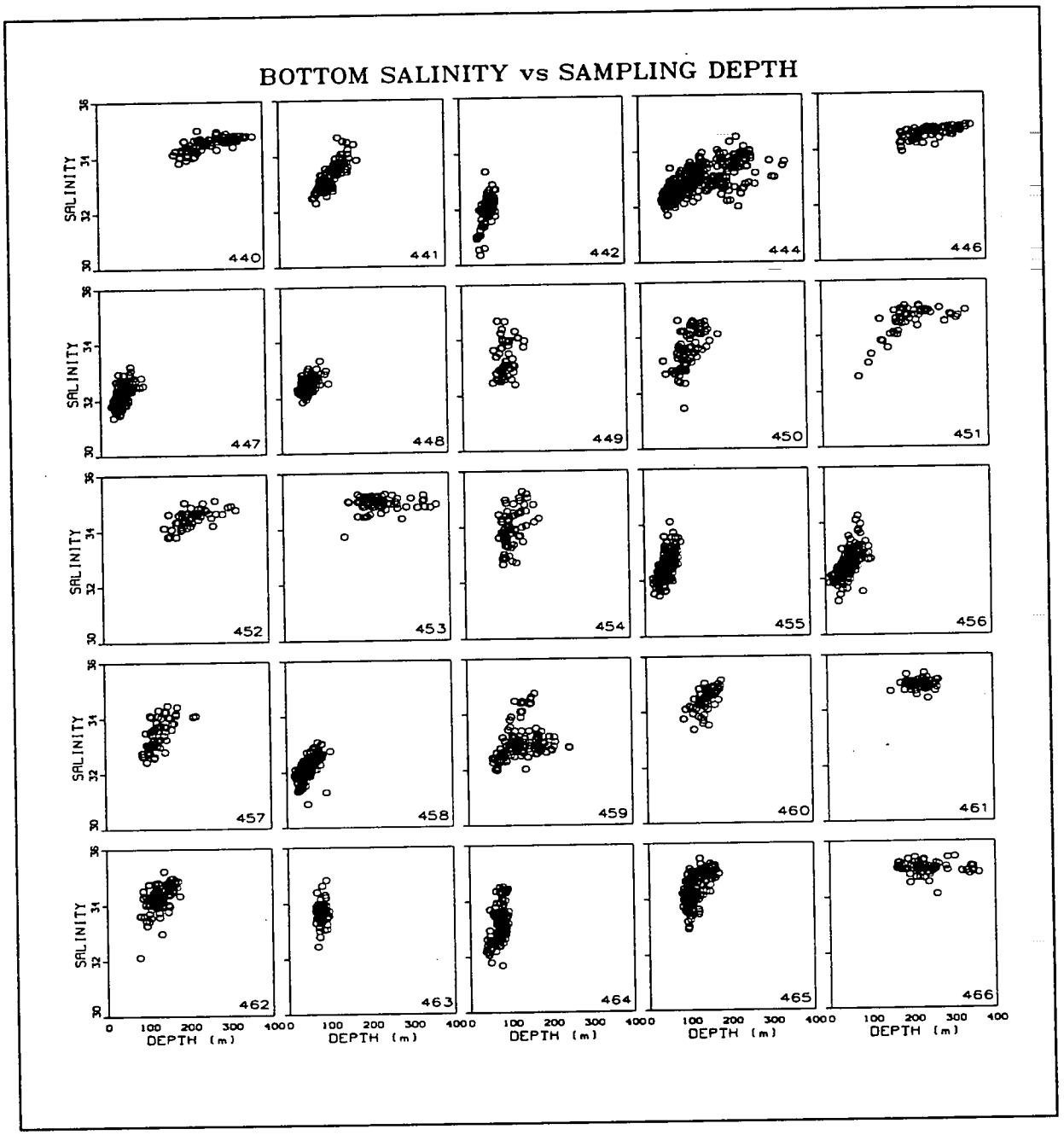


Figure 25: Near-bottom salinity within the summer 4VWX surveys in relation to sampling depth. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

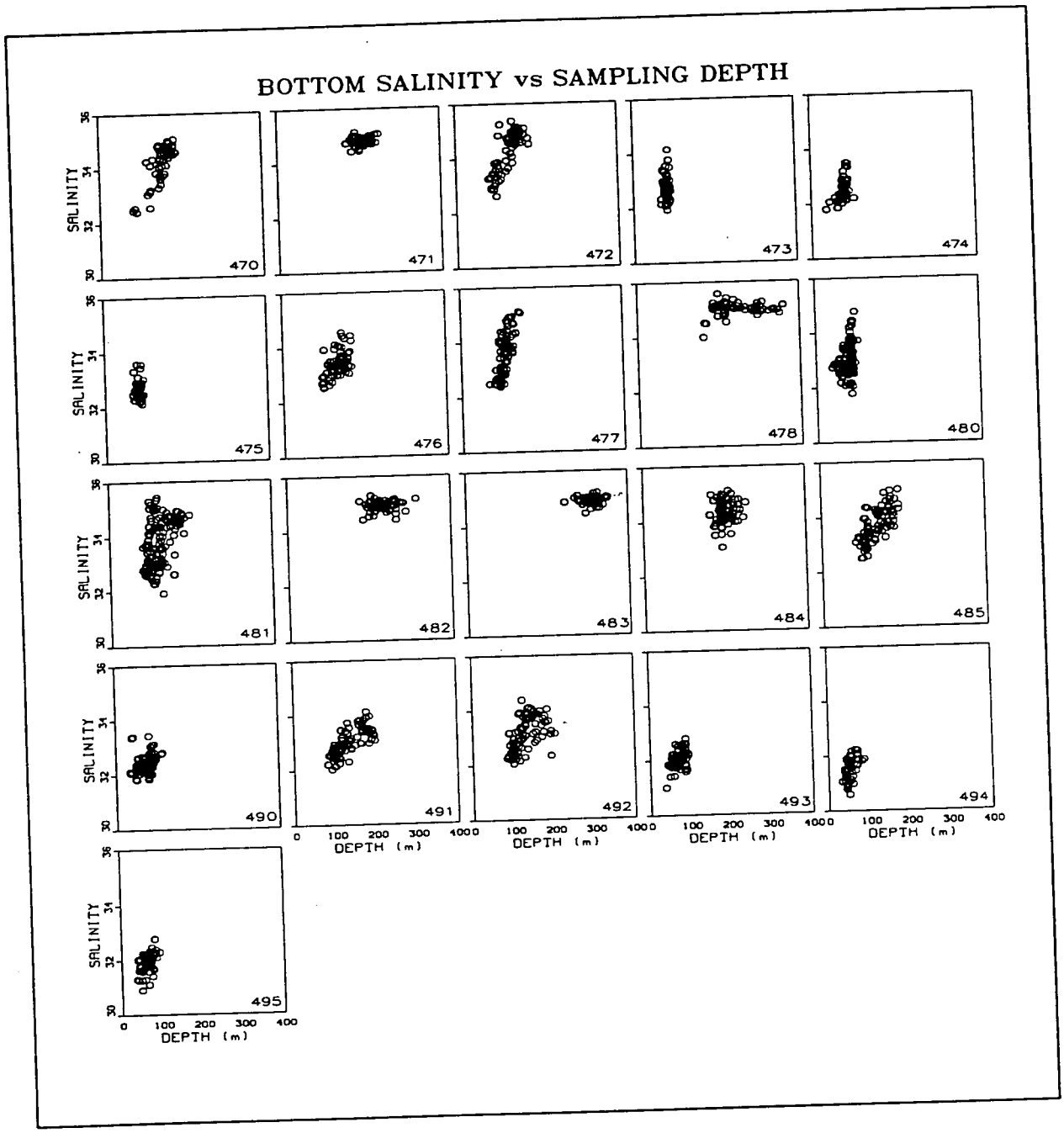
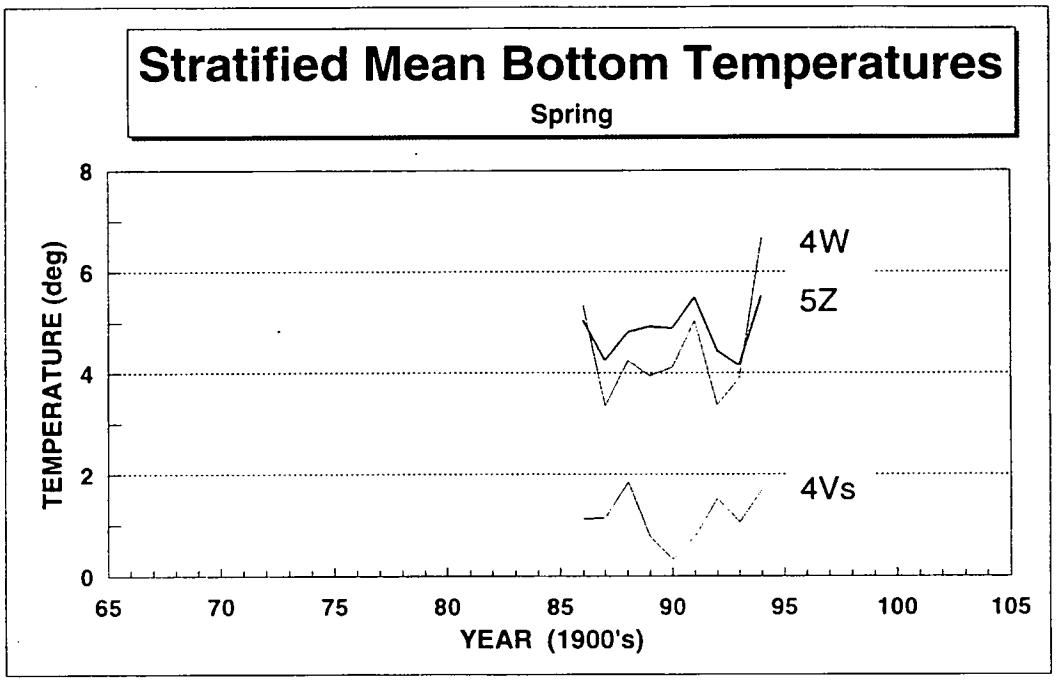


Figure 25: continued



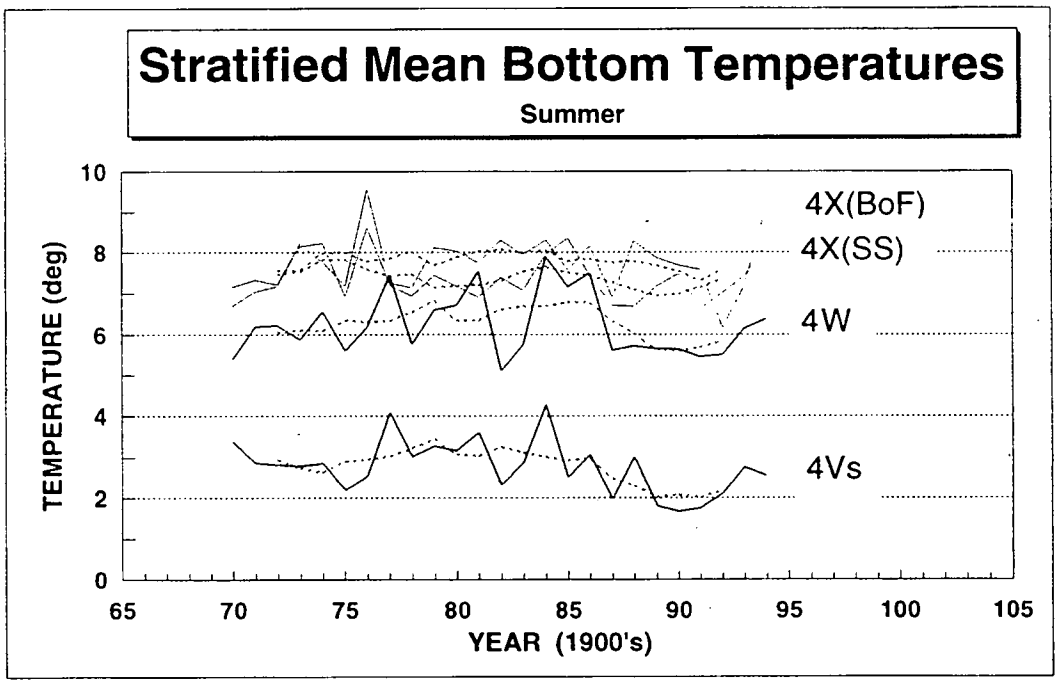
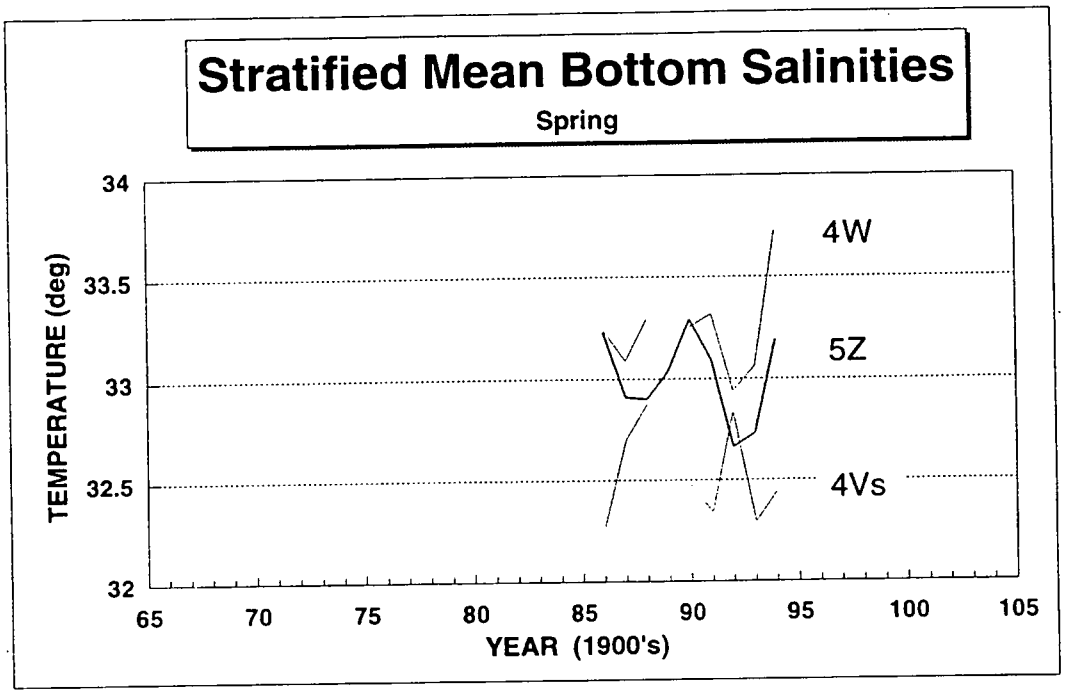


Figure 26: Time series of stratified mean near-bottom temperatures for spring (upper panel: 4Vs, 4W and 5Z) and summer Canadian research vessel groundfish surveys (lower panel: 4X Bay of Fundy, 4X Scotian Shelf, 4W and 4Vs). The smooth curves running through each series is a five year running mean.



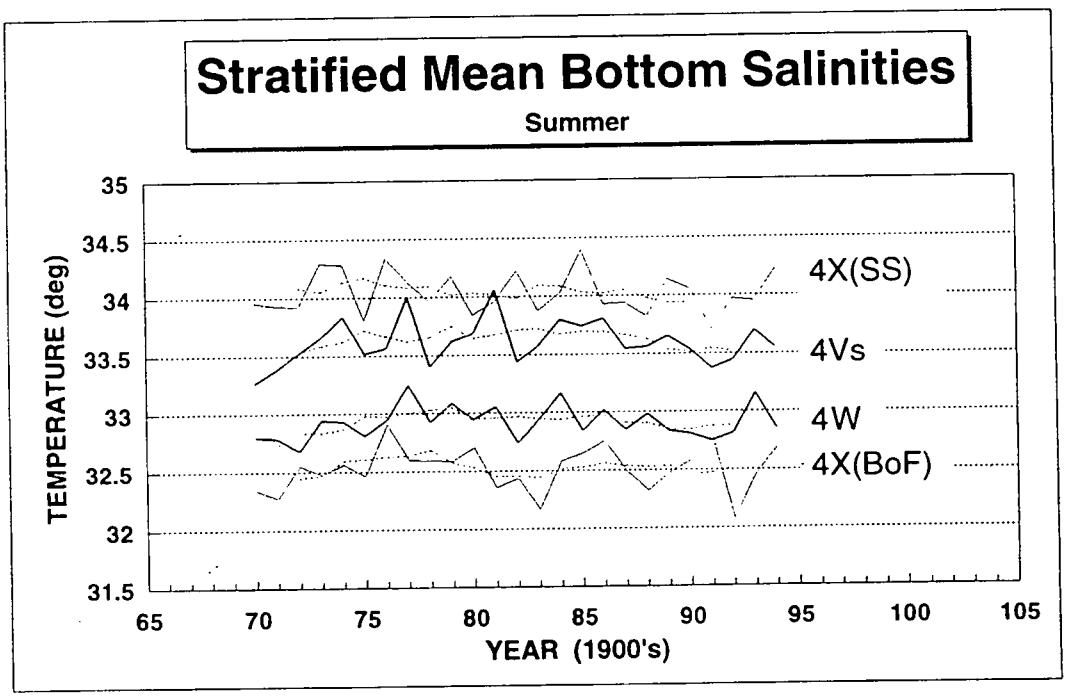


Figure 27: Time series of stratified mean near-bottom salinit
for spring (upper panel: 4Vs, 4W and 5Z) and summer Canadian
research vessel groundfish surveys (lower panel: 4X Bay of Fu
4X Scotian Shelf, 4W and 4Vs). The smooth curves running thro
each series is a five year running mean.

Summer Temperatures < 0.0

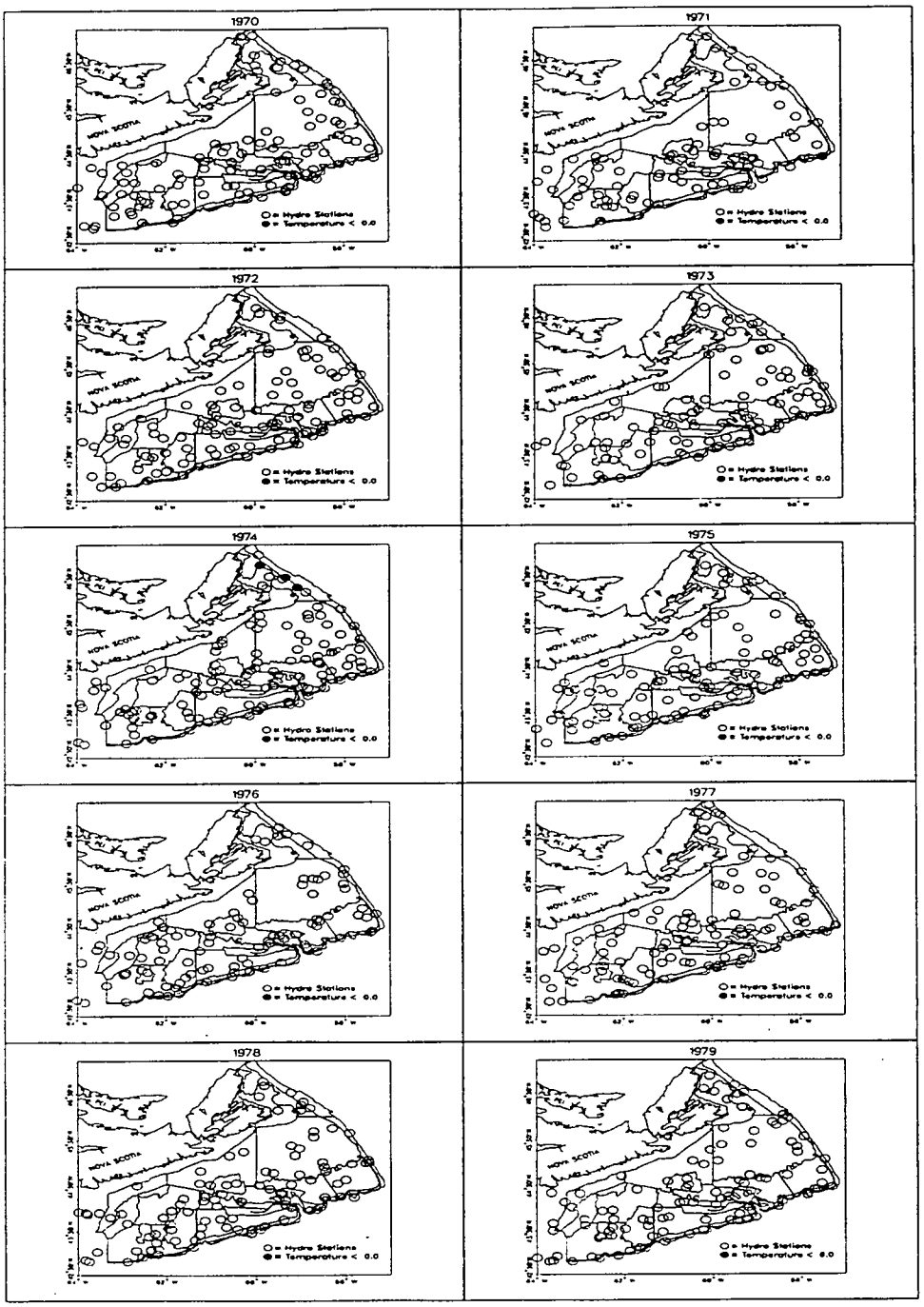


Figure 28: Time series of maps showing the location of hydrographic stations in which water temperatures less than 0°C were recorded somewhere in the water column.

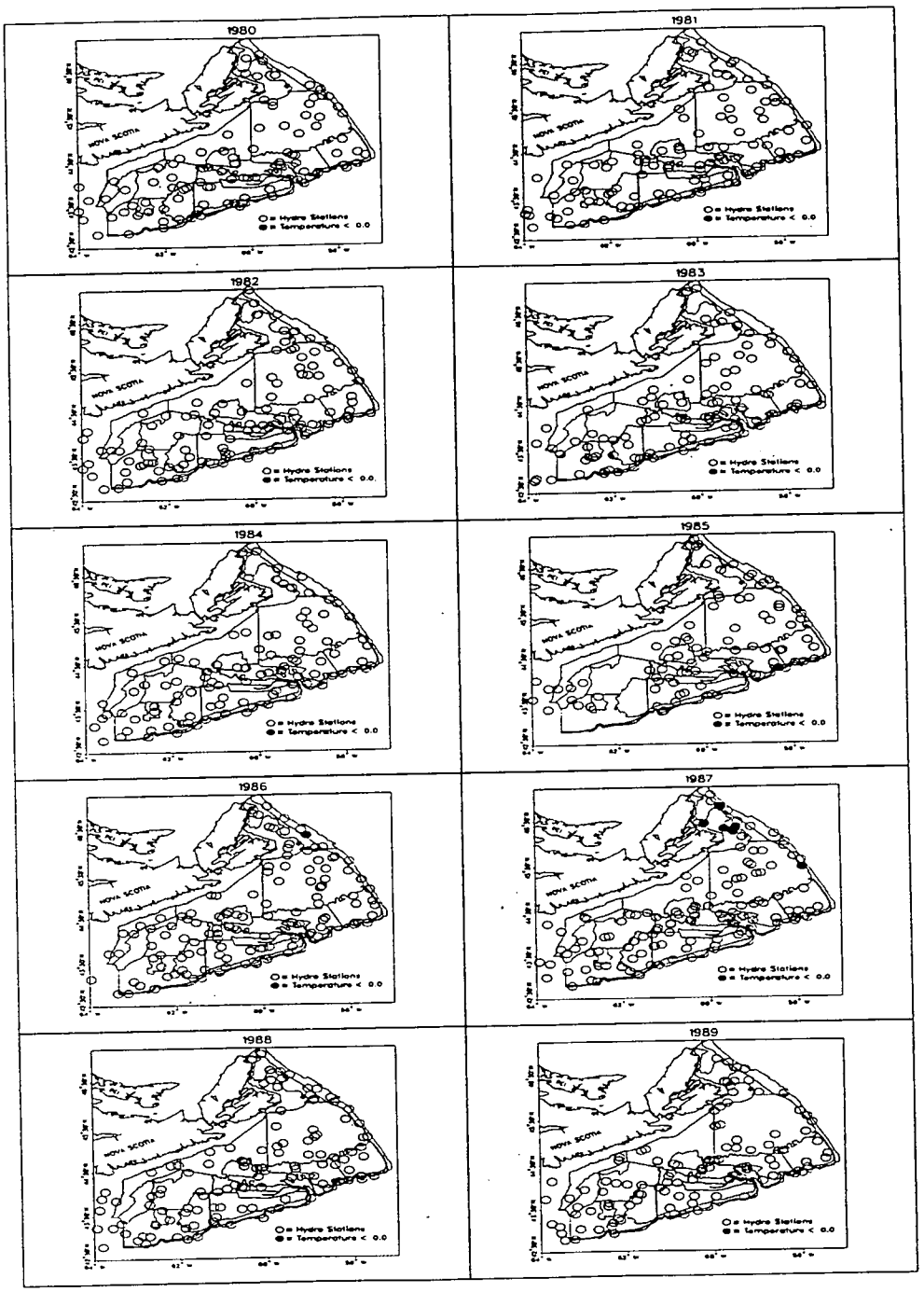


Figure 28: continued

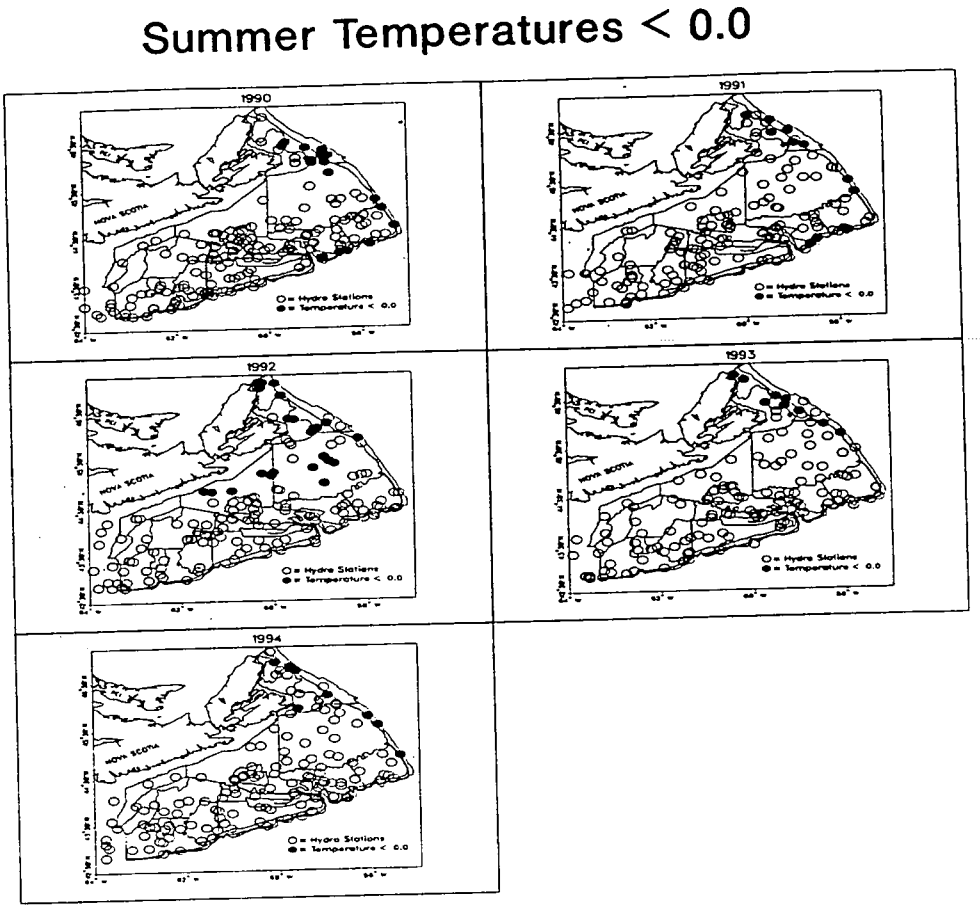


Figure 28: continued

Summer Temperatures < 2.0

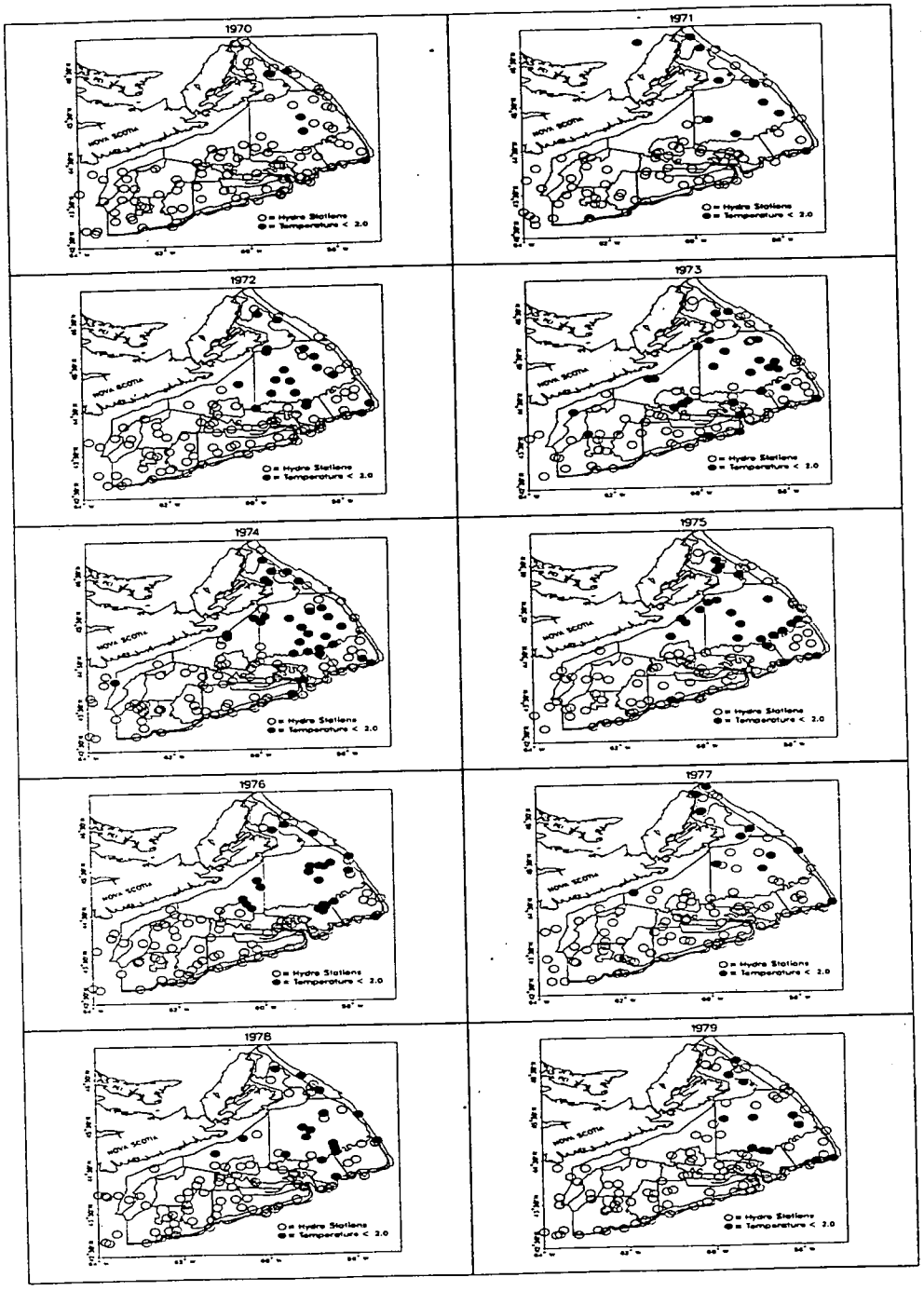


Figure 29: Time series of maps showing the location of hydrographic stations in which water temperatures less than 2°C were recorded somewhere in the water column.

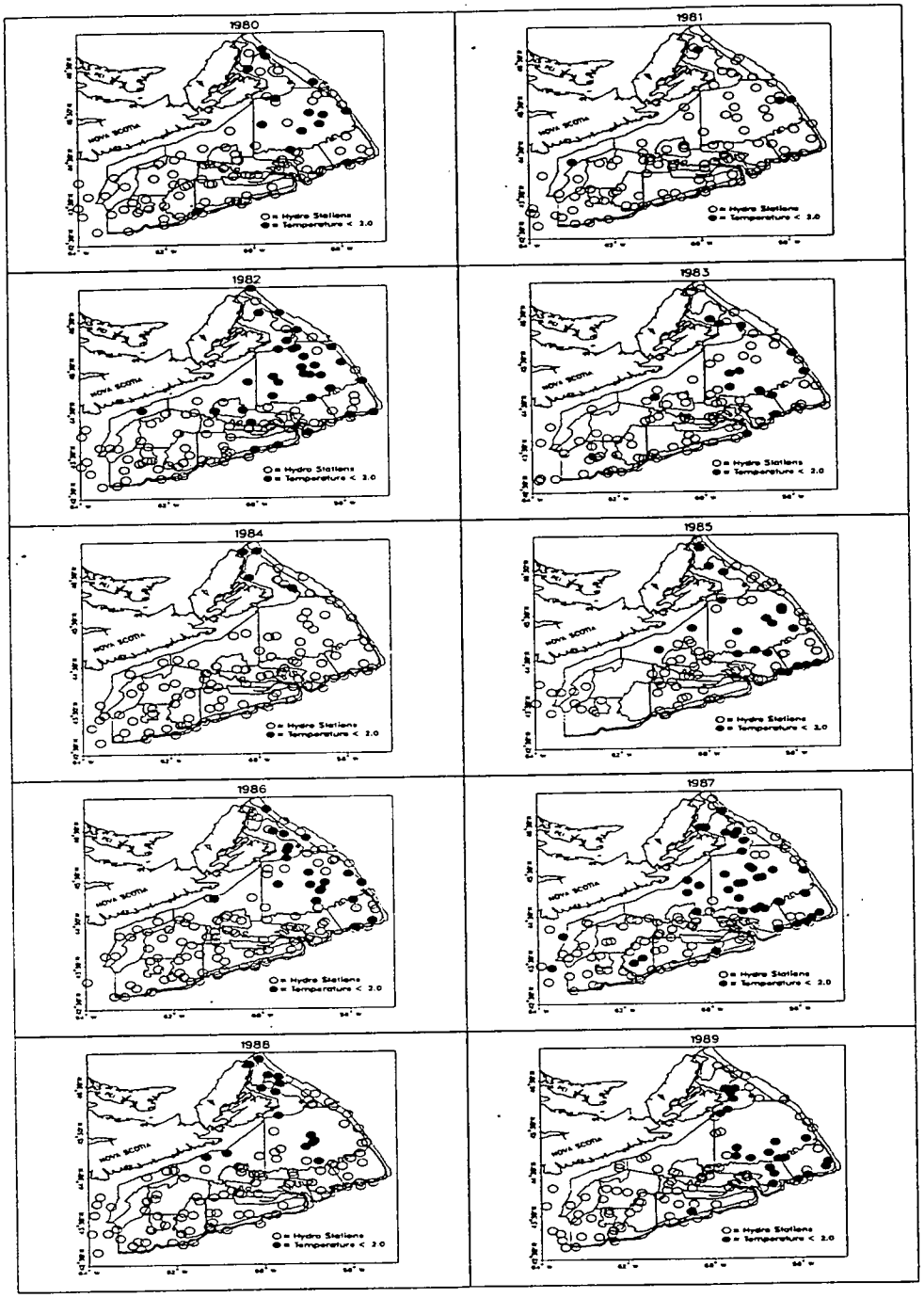


Figure 29: continued

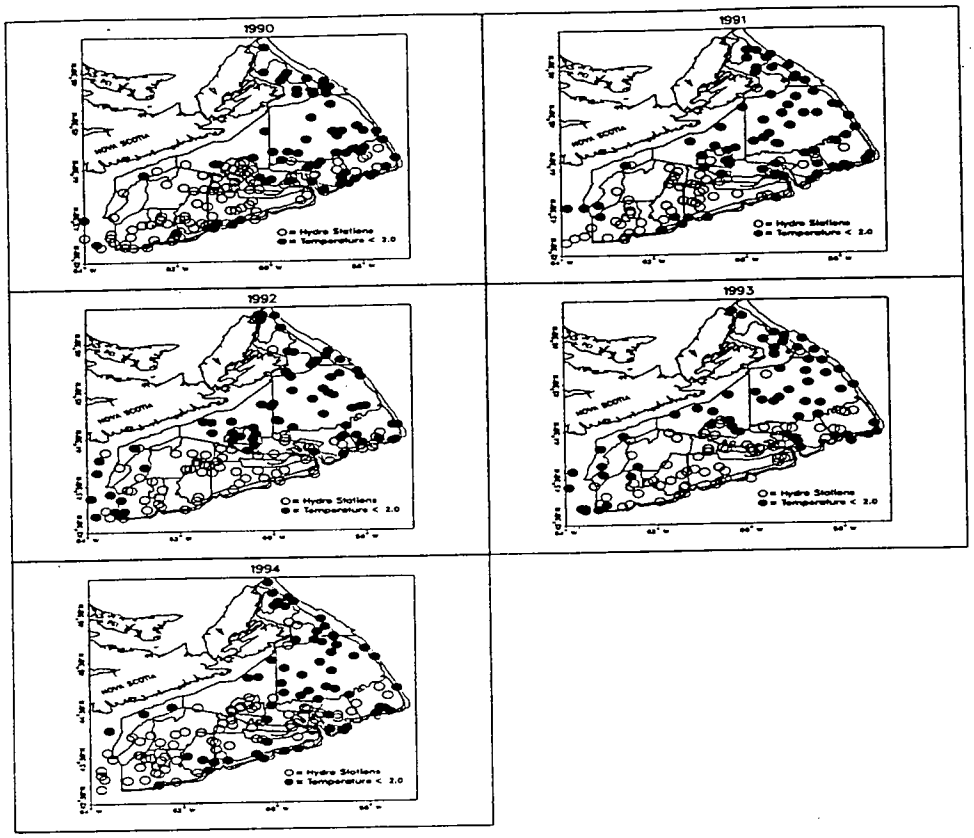


Figure 29: continued