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Overview of Temperature and Salinity Conditions within the Scotia-Fundy Region, NAFO areas 4VWX and 5Z, during 1993 Groundfish Research Vessel Surveys

by

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ABSTRACT

Water temperature and salinity conditions measured during the spring (5Z and 4VW) and summer (4X and 4VW) 1993 Canadian research vessel bottom-trawl surveys are summarized. The analyses of the 1993 hydrographic data indicates that for the most part near-bottom spring temperatures and salinities in the 5Z and 4VsW surveys ranged below and near to baseline means. The anomalies within the 5Z survey are aliased by changes in the dates of the survey. The near-bottom temperatures observed in many of the strata sampled during the sumer survey in 4VWX were below and near to baseline means on the eastern and western Scotian Shelf and above baseline means in the central Scotian Shelf. The coldest temperatures appear to have occurred in 1991. Since 1991 temperatures have been increasing in many of the strata that previously had decreasing trends. Salinities were near normal for most of the Scotian Shelf. Only salinities in the Sable Island - Banquereau area were above baseline.

RÉSUMÉ

La température et la salinité de l'eau ont été mesurées durant les relevés de recherche au chalut de fond réalisés au printemps (5Z et 4VW) et en été (4X et 4VW) 1993. L'analyse des données hydrographiques de 1993 révèle que dans l'ensemble les températures et salinités observées près du fond au printemps dans les divisions 5Z et 4VsW se situaient en dessous ou près des moyennes de référence. Les anomalies constatées dans le relevé de recherche dans 5Z sont dues à des changements dans les dates du relevé. Les températures observées à proximité du fond dans un bon nombre des strates échantillonnées durant le relevé de recherche réalisé en été dans 4VWX se situaient en dessous ou près des moyennes de référence dans l'est et l'ouest du plateau néo-écossais, et au-dessus des moyennes de référence au centre du plateau. C'est en 1991 que les températures semblent avoir été les plus basses. Depuis, elles ont augmenté dans de nombreuses strates où elles tendaient auparavant à diminuer. Les salinités étaient proches de la normale sur la plus grande partie du plateau néo-écossais. Seules celles de la région de l'île de Sable et du Banquereau étaient supérieures à la moyenne de référence.

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 because it is recognized that changes in environmental conditions may influence the behaviour, distribution, physiology 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).

The temperature and salinity data collected during these surveys is reviewed and summarized on an annual basis (eg. Page and Losier 1992 unpublished). The intent of these annual overviews is to briefly describe the extent and nature of water temperature and salinity conditions within recent resource assessment surveys and to place these conditions within an historical context. In so doing it is hoped that hydrographic conditions that may significantly influence estimates and interpretations of biological and fisheries data considered during the stock assessment process may be identified and targeted for more extensive analyses.

In this report we present a summary of water temperatures and salinities measured during the 1993 Canadian bottom-trawl surveys conducted within NAFO statistical areas 4VWX during the summer and within 4VsW and 5Z during the spring. The conditions observed during these surveys is considered in the context of trends and conditions observed during previous surveys.

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 bottom-trawl research vessel surveys conducted in NAFO unit areas 4VWX and 5Z as part of the fish stock assessment process. Particular emphasis is placed on the 1993 surveys.

In 1993 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. Survey designations, sampling dates, sampling gear and the number of sampling stations are summarized in Table 1.

In order to place the environmantal conditions observed during the above 1993 surveys into an historical context similar surveys conducted in the spring in unit areas 4VW and 5Z from 1987-92 inclusive and during the summer in unit area 4VWX from 1970-93 inclusive are also considered. A list of these surveys is given in Table 2.

Temperature and Salinity Measurement Techniques

Within the 1993 bottom-trawl surveys profiles of water temperature and salinity were 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 off the bottom at a rate of approximately 30-40 $mmin^{-1}$. After 5 minutes at the maximum depth 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 salinometer was used to obtain near-bottom salinities from water samples taken with a Niskin bottle. The CTD measurements of near-bottom temeperature and salinity were calibrated with the reversing thermometer estimates of temperature and salinities estimated from the measurements on the water bottle samples.

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 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 1993 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 1992 (Page and Losier 1992 unpublished).

RESULTS

5Z Spring Survey

The 5Z spring survey has been conducted since 1985. The present strata definitions (Fig.1) have been used since 1987. The 1993 survey (T134) was conducted during March 9-18. The dates for this survey decreased from 1987 to 1991. In 1992 the trend was reversed and in 1993 the survey dates were similar to the dates of the initial 1987 survey (Fig. 2).

Water temperatures and salinities were measured at 64 bottom-trawl stations (Fig.1). Profiles of temperature and salinity were taken at 63 of these stations and near-bottom samples were taken at an additional station. 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 $5Z_5$, $5Z_6$ or $5Z_7$.

The range of near-bottom depths sampled during the 1993 survey was similar to that sampled in previous years (Fig. 3).

Within the spring 5Z bottom-trawl survey near-bottom temperatures varied between 2.97 and 10.39 °C, a range of 7.42 °C. Temperature ranges within individual strata varied from 0.46 to 5.87°C with the largest temperature range being within strata $5Z_1$ and the smallest being within $5Z_3$. The strata mean temperatures varied between 3.46 and 9.94 °C (Table 3a) with the deep strata surrounding Georges Bank (5Z1 and 5Z8) being warmer than those within the shallow strata on top of the bank (5Z2-4, Fig. 4). The strata means were within +/-1.00°C of their baseline means.

Salinities within strata $5Z_{1-8}$ varied between 32.18 and 34.94 psu, a range of 2.76 psu. Salinity ranges within individual strata varied from 0.34 to 2.42 psu with the largest range being within strata $5Z_1$ and the smallest being within $5Z_8$. The strata mean salinities varied between 32.44 and 34.54 psu and were greatest within the deep strata along the southern and southeastern flanks of Georges Bank ($5Z_1$ and $5Z_8$, Fig.5). The strata means were within +/-0.50psu of their baseline means or below.

The time series of near-bottom temperatures (Fig. 6) show little indication of a time trend in the deeper strata ($5Z_1$, $5Z_5$ and $5Z_8$). In the shallow strata ($5Z_2$, $5Z_3$, $5Z_4$, $5Z_6$ and $5Z_7$) the temperatures increased from 1987 to 1991 and decreased from 1991 to 1993. This time trend is largely an artifact of changes in the timing of the surveys rather than an indication of interannual variablility in hydrographic conditions since the temperatures in shallow strata vary with the date of sampling (Fig.8).

The time series of near-bottom salinities in the shallow strata ($5Z_2$, $5Z_3$, $5Z_4$, $5Z_6$ and $5Z_7$) is one of increasing salinity from 1987 to 1990-91 and decreasing salinity from 1991 to 1993 (Fig.7). As with the temperatures this trend is an artifact of changes in the timing of the surveys (Fig.9). The trend in strata $5Z_5$ may also be related to changes in the timing of the survey.

In several of the strata ($5Z_1$, $5Z_5$ and $5Z_7$) the temperatures and salinities increase with depth (Fig's. 10 and 11). However, because of the interannual consistency in the range of depths sampled these trends should not have a systematic influence on the time trends in temperature and salinity.

4VsW Spring Survey

The 4VsW spring survey has been conducted since 1979. The present strata definitions (Fig.12) have been used since 1986. The 1993 survey (N182) was conducted during March 3-13. These sampling dates are 20-30 days earlier than in 1987 when the trend toward earlier survey dates began (Fig. 2).

Water temperatures and salinities were measured at 44 bottom-trawl stations (Fig.12). Profiles of temperature and salinity were taken at 37 of these stations. Two of these profiles were in the deep Laurentian Channel and outside the domains of the defined strata. Near-bottom temperatures and salinities and surface temperatures were measured at an additional 7 stations. In comparison to the previous year (1992) a relatively high number of CTD profiles were taken. Never-the-less, sampling effort remained very low in the southern strata (408-411) with no near-bottom measurements obtained from strata 404 and 411. The sampling within strata 401 and 406 was not dispersed throughout the strata. Hydrographic information was obtained from only 2 stations in strata 401 and in strata 406 information was obtained from only the central portion of the strata. No hydrographic data was collected in strata 404.

The range of near-bottom depths sampled during the 1993 survey was smaller than in previous years (Fig. 3). In several strata (401, 402, 403, 407, 408 and 409) the sampling did not extend to as great depths as in previous years. Although no samples were taken in strata 404 in 1993 it should be noted that sampling depths became deeper in this strata during the 1986 to 1992 period.

Near-bottom temperatures varied between -0.59 and 8.47°C, a range of 9.06°C (Table 3b). In strata with more than one hydrographic observation the range in temperatures varied from 0.74 to 8.23°C with the greatest range existing within strata 406 and the least range within strata 407. There were no near-bottom observations within strata 404 and 411 (Fig.12). The near-bottom strata mean temperatures varied between 0.42 and 7.27°C with no dominant spatial pattern (Fig.13).

With the exception of strata 405 and 409 the near-bottom strata mean temperatures were within +/-1.00°C of baseline means. The means for strata 403, 405 and 406 were above baseline means whereas the means for strata 401, 402, 407, 408 and 410 were below baseline means (Tables 3b and 4a).

Salinities within strata 401-411 varied between 31.76 and 34.42 psu, a range of 2.66 psu (Table 3b). Salinity ranges within individual strata varied from 0.38 to 2.64 psu with the largest range being within strata 406 and the smallest within 401. The strata mean salinities varied between 31.95 and 34.22 psu with most means being within +/-0.50psu of baseline means. Means in strata 404, 405 and 408 were below baseline means and those in strata

401, 402, 406 and 407 were above strata means (Fig. 14). The mean for strata 403 was within 0.25 psu of the baseline mean.

The time series of near-bottom temperatures (Fig. 6) show little indication of a time trend in strata (401, 403, 404, 406, 410 and 411). Distinct trends are evident in strata 405, 407 and 409. In strata 405 the temperature decreases from 1986 to 1990 and increases thereafter. In strata 407 the temperatures slowly decreased throughout much of the 1986 to 1993 period whereas they increased in strata 409 after 1990. Although the possibility exists that these trends are artifacts of changes in the timing of the surveys rather than an indication of interannual variablility in hydrographic conditions, the temperatures do not generally vary systematically with the date of sampling (Fig.8). The trend of temperatures in strata 409 are a possible exception.

Although less distinct, the time series of near-bottom salinities (Fig.7) show trends that are similar to the trends in temperature. None of these can easily be attributed to changes in the timing of the survey since salinity appears to be independent of sampling date (Fig.9).

In several of the strata the temperatures and salinities increase with depth (Fig's. 10 and 11). With the exception of strata 404, the interannual consistency in the range of depths sampled suggests that these trends should not have a systematic influence on the time trends in temperature and salinity. In strata 404 the increase in sample depths may mask a time trend in water temperature and salinity.

4VWX Summer Survey

The 4VWX summer surveys have been conducted since 1970. The present strata definitions (Fig.15) have been used throughout this period. The 1993 survey (N189/190) was conducted during July 5 to August 1. These sampling dates are generally similar to those for previous surveys in this series (Fig. 16).

Water temperatures and salinities were measured at 186 bottom-trawl stations (Fig.15). Profiles of temperature and salinity were taken at 180 of these stations. Near-bottom temperatures and salinities and surface temperatures were measured at an additional 6 stations. The level of sampling effort is consistent with the years (1991-1992) in which a CTD was used.

The range of near-bottom depths sampled during the 1993 survey was similar to that sampled in previous years (Fig. 17).

Within the summer 4VWX bottom-trawl survey near-bottom temperatures varied by 11.35°C from -0.17 to 11.18 °C. With the exception of temperatures in the mouth of the Bay of Fundy (strata 491-3) and over the shallow banks within 4X (strata 480 and 473-6) the temperatures in the eastern portion of the region were generally colder than in the western portion (Fig.18). Temperatures within 4VW varied between -0.17 and 9.68°C, a range of 9.85°C and within 4X varied between 2.06 and 8.90°C, a range of 6.84°C. In 4VW strata with more than one water sample within strata temperatures varied from 0.01 to 4.67 °C. In 4X temperatures within each strata varied from 0.06 to 5.62 °C. In 4VW the greatest (least)

temperature ranges existed within strata 456(461) and within 4X the greatest (least) temperature ranges existed within strata 481(474).

Strata mean temperatures over the eastern and western portions of the Scotian Shelf were within 0.50°C of the baseline means or below baseline means by -.51 to -1.50°C (Fig.18). With the exception of several of the shallow bank strata (63, 73-75) and strata 60 means within the central Scotian Shelf region were generally near or above baseline means.

Salinities within 4VWX varied between 31.01 and 35.15 psu, a range of 4.14 psu. The strata mean salinities in the shallower regions of the Bay of Fundy (strata 490 and 493-95), those over the many of the shallow banks within 4X and 4VW (strata 480, 473, 474, 458 and 447-8) and those inshore off Cape Breton (440) were generally lower than in the rest of 4VWX (Fig.19). The highest mean salinities were within the central Scotian Shelf strata (460-61, 463-6 and 471-72) and along the edge of the Fundian Channel (482-83). Within 4VW salinities varied between 31.06 and 35.12 psu, a range of 4.05 psu and within individual strata salinity ranges varied from 0.01 to 1.96 psu. The greatest (least) salinity ranges existed within strata 462(463). Salinities within 4X varied between 31.01 and 35.15 psu, a range of 4.14 psu. Salinity ranges within individual strata varied from 0.08 to 2.73 psu. The greatest (least) salinity ranges existed within strata 481(483). For most strata mean salinities were within 0.25 psu of baseline means. In four strata (47, 58, 55, 64 and 95) the means were above baselines by as much as 0.75 psu and in seven strata (59, 60, 63, 73, 74, 85 and 94) the means were below baselines by as much as -0.50 psu.

The cooling trend that occurred in the eastern Scotian Shelf strata (441, 442, 444, 447, 448, 449, 450, 451, 454, 455, 457, 458 and 459) during the period of the middle 1980's until 1991 has not continued (Fig.20). The reversal began in 1992 and continued in 1993. Near-bottom temperatures in strata 453 and 466 continued to increase whereas the remaining strata on the eastern Scotian Shelf,which are mainly central shelf strata (446, 456, 460, 461, 462, 464, 465), and most strata on the western Scotian Shelf (470, 471, 473, 474, 475, 476, 478, 481-485, 490-495) continued to show little time trend in temperature. The warming trend in strata 477 has continued since 1989-90. These patterns appear to be indicative of temporal variability in hydrographic conditions and not an artifact of the sampling time and procedures. In the Scotian Shelf strata (440-485) near-bottom temperature is not related to the day of sampling (Fig.21) whereas in the Bay of Fundy strata (490-95) temperature increases with the day of sampling. This will not systematically affect the time trends in temperature because the sampling dates have been consistent throughout the survey series. Similarly, although temperature varies with depth in many of the strata (Fig.22) the range of depths sampled has been consistent over the survey period. The existence of distinct time trends in strata from the western, central and eastern Scotian Shelf is consistent with the findings of Page and Losier (1994).

Unlike the temperature time series few systematic trends exist in the salinity series (Fig.23). Salinities in strata 447 and 477 continue to increase. Salinity appears to be independent of sampling date in all strata (Fig.24), with the possible exception of strata 471 and 482 in which salinity increases marginally with sampling date. In many strata salinity increases with depth (Fig. 25). As with the temperatures these trends do not determine the time trends in salinity because of the temporal consistency in sampling dates and depths.

DISCUSSION

Within the Scotia-Fundy region the oceanographic climate has been consistently monitored 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 surveys began in 1970 and the spring surveys began in 1987. Hence they have been conducted during the recent warm period. Never-the-less, in the summer surveys many strata show a trend toward decreasing temperatures. 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 source of the cold water, at least for the shallow and intermediate depths (30-150m) is most likely the cold intermediate layer formed within the Gulf of St. Lawrence. This water flows out of the Gulf through Cabot Strait and onto the Scotian Shelf via either the inshore Scotian Current or an offshore current that follows the edge of the continental shelf.

The spatial patterns in near-bottom temperatures and salinities were consistent with previous records (Page and Losier 1992). During the spring groundfish bottom-trawl surveys the near-bottom waters within NAFO area 5Z, Georges Bank, were several degrees warmer and less variable than within area 4VsW, the eastern Scotian shelf. The near-bottom salinities also conformed to previous patterns in that the salinities were less variable within NAFO area 5Z than within area 4VsW and the salinities within 5Z were for the most part within the extremes observed within 4VsW. During the summer bottom-trawl surveys the near-bottom waters within NAFO unit area 4VW, eastern Scotian Shelf, were colder and more variable than within area 4X, the western Scotian shelf. The near-bottom salinities within NAFO areas 4VW and 4X were similar with salinities within 4VW.

There are several factors contributing to the observed variability in near-bottom temperatures measured during the bottom-trawl surveys. Two important sources are inter-annual variation in both the timing of sampling and the location of the sampling stations. These are particularly significant for shallow strata since waters within the Scotia-Fundy region exhibit pronounced seasonal cycles. The amplitudes of these are greatest near the surface and decrease with depth. Therefore trends in the timing of surveys may cause trends in

observed temperatures because of aliasing with the seasonal temperature cycle. Throughout the 1987-91 period the 5Z and 4VW bottom-trawl surveys were conducted progressively earlier such that the 1991 surveys were conducted about 30 d earlier than the 1987 surveys (Page and Losier 1992). This trend in sampling date corresponds with the trend in near-bottom temperatures in several strata. The timing of the 1992 surveys returned to dates typical of earlier surveys and therefore the trend in sapling time is not continued. However, the variation in cruise timing is still contributing to the observed interannual variation in temperature conditions. This process is not a problem for the summer 4VWX surveys.

A second factor contributing to the within strata variance in bottom-temperatures is the presence of spatial gradients in temperatures coupled with the aliasing effects of inter-annual variability in the location of sampling stations and the fact that in many strata sampling locations are too few in number to be fully distributed throughout the strata. Within the 4VW spring survey the gradients are about 1°C across strata near Sable Island and in the eastern region of the survey domain. The gradients can be up to 6°C throughout the remainder of the domain. Within the 5Z spring survey the within strata gradients are of order 1°C across a strata. During the summer surveys the gradients are of order 1°C across a strata within the eastern and western ends of the survey domain and only marginally stronger within the central region of the survey area (Page and Losier 1992).

They were several strata (403, 404, 407 and 410) within the 1992 spring 4VsW survey that had three or fewer near-bottom temperature and salinity records and several strata in which the distribution of the stations was limited to a small region within the strata domain. Within strata 403 and 410 the tow stations occurred only in the eastern half of the strata and within strata 407 sampling occurred only in the northern portion of the strataum. Within the spring 5Z survey two strata, 5Z5 and 5Z8, had three or fewer stations and several strata, 5Z3, 5Z5, 5Z7 and 5Z8, had stations poorly distributed throughout the strata. As a result the observed temperature and salinity conditions within these strata are unlikely to be representative of conditions within these strata because of the expected spatial gradients within these strata and caution should be exercised when relating strata statistics to the distribution or abundance of fish within the strata. Station distribution within the summer 4VWX surveys was generally much better.

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 trend toward cooler temperatures may therefore be associated with cahnges in the distribution and abundance of cod within the 4VWX area.

Summary and Conclusions

The analyses of the 1993 hydrographic data indicates that for the most part near-bottom spring temperatures and salinities in the 5Z and 4VsW surveys ranged below and near to baseline means. The anomalies within the 5Z survey are aliased by changes in the dates of the survey. The near-bottom temperatures observed during the sumer survey in 4VWX were below and near to baseline mean on the eastern and western Scotian Shelf and above baseline means in the central Scotian Shelf. Salinities were near normal for most of the Scotian Shelf. Only salinities in the Sable Island - Banquereau area were above baseline.

Although the near-bottom water temperatures continue to be below baseline means in several areas, the coldest temperatures appear to have occurred in 1991. Since 1991 temperatures have been increasing in the strata that previously had decreasing trends.

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TABLE 1: Summary of 1993 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 and T refers to the Wilfred Templeman. In the sampling date column the numbers in brackets indicate the consecutive day within 1993.

SAMPLING AREA	STRATA	CRUISE (vessel-cruise no.)	SAMPLING DATES day/month	NO. of SAMPLING STATIONS
4VsW Spring	401-411	N182	03/03 (62) 13/03 (72)	44 total 37 ctd 7 bottle
5Z Spring	$5Z_1$-$5Z_8$	T134	09/03 (68) 18/03 (77)	64 total 63 ctd 1bottle
4VWX Summer	440-495	N189/190	05/07 (186) 01/08 (213)	186 total 180 ctd 6 bottle

TABLE 2: Listing of the summer Canadian research vessel summer stratified random groundfish cruises conducted within NAFO Statistical Areas 4VWX during 1970 to 1993 inclusive. The intensity of hydrographic sampling during each cruise is also indicated. (RT = reversing thermometer; B = water bottle; CTD = conductivity, temperature and depth profiler)

CRUISE(S)	YEAR	NUMBER of COMPLETED SETS	NUMBER of T & S PROFILES	PROPORTION of T & S PROFILES	GEAR USED
A175/A176	1970	143	44	31	RT/B
A188/A189	1971	126	39	31	RT/B
A200/A201	1972	150	35	23	RT/B
A212/A213	1973	135	40	30	RT/B
A225/A226	1974	155	38	24	RT/B
A236/A237	1975	143	38	27	RT/B
A250/A251	1976	136	42	31	RT/B
A265/A266	1977	144	42	29	RT/B
A279/A280	1978	141	42	30	RT/B
A292/A293	1979	147	20	14	RT/B
A306/A307	1980	145	21	14	RT/B
A321/A322	1981	143	34	24	RT/B
H80/H81	1982	150	38	25	RT/B
N12/N13	1983	147	27	18	RT/B
N31/N32	1984	143	29	20	RT/B
N48/N49	1985	152	8	5	RT/B
N65/N66	1986	99	23	23	RT/B
N85/N86	1987	102	28	27	RT/B
N105/N106	1988	186	25	13	RT/B
N123/N124	1989	179	16	9	RT/B
N139/N140	1990	224	124	55	RT/B/CTD
N154/H231	1991	195	195	100	RT/B/CTD
N173/N174	1992	200	194	97	RT/B/CTD
N189/N190	1993	190	183	96	RT/B/CTD

Table 3a: Summary of near-bottom temperature and salinity statistics for Canadian groundfish bottom-trawl surveys conducted within NAFO area 5Z in the spring of 1993. (n is the sample number)

STRATA	TEMPERATURE					SALINITY				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
5Z1	9	6.12	3.81	9.68	5.87	9	33.52	32.52	34.94	2.42
5Z2	35	3.59	2.97	4.79	1.82	35	32.44	32.18	32.94	0.76
5Z3	11	3.46	3.26	3.72	0.46	11	32.55	32.29	32.73	0.44
5Z4	6	4.17	3.17	6.38	3.20	6	32.69	32.47	33.41	0.94
5Z5	0	-	-	-	-	0	-	-	-	-
5Z6	0	-	-	-	-	0	-	-	-	-
5Z7	0	-	-	-	-	0	-	-	-	-
5Z8	2	9.94	9.49	10.39	0.90	2	34.54	34.37	34.71	0.34

TABLE 3b: Summary of near-bottom temperature and salinity statistics for Canadian groundfish bottom-trawl surveys conducted within NAFO area 4VsW in the spring of 1993. (n is the sample number)

STRATA	TEMPERATURE					SALINITY				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
401	2	0.42	-0.59	1.44	2.03	2	31.95	31.76	32.14	0.38
402	6	1.00	-0.10	2.38	2.48	6	32.26	31.79	32.64	0.85
403	5	0.89	-0.0.7	2.81	2.88	5	32.34	32.13	32.91	0.78
404	0	-	-	-	-	0	-	-	-	-
405	4	6.44	4.37	7.34	2.97	4	34.22	33.43	34.81	1.38
406	8	3.34	0.24	8.47	8.23	8	32.82	31.78	34.42	2.64
407	3	2.31	1.95	2.69	0.74	3	32.62	32.35	32.84	0.49
408	1	1.46	1.46	1.46	-	1	32.44	32.44	32.44	-
409	1	5.92	5.92	5.92	-	1	33.91	33.91	33.91	-
410	2	7.27	6.08	8.47	2.39	2	33.91	33.53	34.29	0.76
411	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 1993. (n is the sample number)

STRATA	TEMPERATURE					SALINITY				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
440	3	5.62	5.23	5.86	0.63	3	34.62	34.49	34.73	0.11
441	4	2.81	1.88	3.39	1.51	4	33.35	33.08	33.53	0.45
442	4	0.38	-0.27	0.47	0.20	4	32.13	31.84	32.41	0.57
444	17	2.44	0.80	5.65	0.48	17	33.13	32.42	34.34	1.92
446	2	5.62	5.35	5.90	0.45	2	34.73	34.69	34.76	0.07
447	7	2.57	0.91	3.51	2.60	7	32.76	32.56	32.97	0.39
448	6	2.75	1.85	3.49	1.64	6	32.72	32.54	32.99	0.45
449	2	5.26	4.50	6.02	0.77	2	33.66	33.24	34.08	0.84
450	3	4.98	2.45	6.51	4.06	3	33.85	33.17	34.27	1.10
451	2	6.20	5.62	6.79	1.17	2	34.43	34.05	34.82	0.77
452	2	6.10	6.03	6.17	0.14	2	34.58	34.53	34.63	0.09
453	2	8.61	7.53	9.68	2.15	2	35.03	34.95	35.12	0.17
454	2	7.01	6.86	7.15	0.29	2	34.07	33.94	34.21	0.27
455	10	4.89	3.14	6.32	3.18	10	32.57	32.06	33.55	1.48
456	7	4.04	2.07	6.74	4.67	7	32.61	32.03	32.98	0.95
457	1	3.34	3.34	3.34	0.00	1	33.04	33.04	33.04	0.00
458	8	1.37	0.13	4.44	4.31	8	32.00	31.37	32.51	1.14
459	6	1.10	-0.17	4.00	4.17	6	32.56	31.99	33.15	1.16
460	2	8.64	8.26	9.02	0.76	2	34.57	34.44	34.70	0.27
461	2	9.29	9.28	9.29	0.01	2	34.88	34.87	34.89	0.02
462	4	6.79	5.71	7.20	1.49	4	33.55	32.13	34.08	1.96
463	2	6.28	6.26	6.29	0.03	2	33.71	33.71	33.72	0.01
464	7	5.21	4.27	5.99	1.72	7	33.00	32.26	33.55	1.29
465	10	8.69	6.73	9.63	2.90	10	34.57	33.86	34.95	1.09
466	1	9.11	9.11	9.11	0.00	1	35.03	35.03	35.03	0.00

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 1993. (n is the sample number)

STRATA	TEMPERATURE					SALINITY				
	n	MEAN	MIN	MAX	RANGE	n	MEAN	MIN	MAX	RANGE
470	2	6.13	3.51	8.74	5.23	2	34.47	34.35	34.59	0.24
471	2	9.03	8.90	9.15	0.25	2	34.74	34.68	34.81	0.13
472	4	10.04	8.97	11.18	2.21	4	34.90	34.73	35.15	0.42
473	2	2.33	2.08	2.58	0.50	2	32.38	32.33	32.43	0.10
474	2	2.09	2.06	2.12	0.06	2	32.28	32.20	32.36	0.16
475	2	5.33	4.02	6.63	2.61	2	33.25	32.92	33.58	0.66
476	4	4.60	4.25	4.95	0.70	4	33.19	33.10	33.31	0.21
477	5	9.04	6.32	10.90	4.58	5	34.35	33.58	34.91	1.33
478	3	8.16	7.07	9.42	2.35	3	35.03	34.98	35.12	0.14
480	8	4.18	3.13	5.75	2.62	8	32.42	32.05	33.40	1.35
481	9	6.55	3.52	9.14	5.62	9	33.63	32.27	34.99	2.73
482	3	8.34	8.01	8.73	0.72	3	34.93	34.71	35.05	0.34
483	2	8.29	8.16	8.42	0.26	2	34.88	34.84	34.92	0.08
484	4	7.08	6.76	7.71	0.95	4	34.02	33.76	34.39	0.63
485	3	6.42	5.71	7.64	1.93	3	33.43	32.85	34.37	1.52
490	4	6.47	5.97	6.89	0.92	4	31.95	31.82	32.11	0.28
491	3	5.30	5.21	5.41	0.20	3	32.39	32.14	32.78	0.64
492	3	5.79	5.14	6.35	1.21	3	32.88	32.45	33.55	1.10
493	3	5.96	5.55	6.57	1.02	3	31.42	31.01	31.82	0.80
494	2	6.96	6.40	7.52	1.12	2	31.27	31.06	31.47	0.41
495	2	7.15	7.08	7.22	0.14	2	31.52	31.28	31.76	0.48

TABLE 4a: Long-term (1987-90) strata mean near-bottom temperatures and salinities for spring Canadian groundfish bottom-trawl surveys conducted within NAFO statistical areas 4VsW and 5Z.

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	4.43	32.89
403	0.29	32.41		5Z3	4.30	32.99
404	5.04	33.79		5Z4	4.43	32.90
405	3.60	33.83		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	3.04	33.02		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) strata mean near-bottom temperatures and salinities for summer Canadian groundfish bottom-trawl surveys conducted within NAFO statistical areas 4VWX.

STRATA	MEAN TEMP. (°C)	MEAN SALINITY (psu)		STRATA	MEAN TEMP. (°C)	MEAN SALINITY (psu)
440	5.40	34.55		470	7.06	34.11
441	2.85	33.38		471	9.13	34.84
442	1.69	32.08		472	7.47	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	34.44		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	6.05	32.53		484	7.76	34.38
456	5.36	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	8.26	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	8.67	34.89				

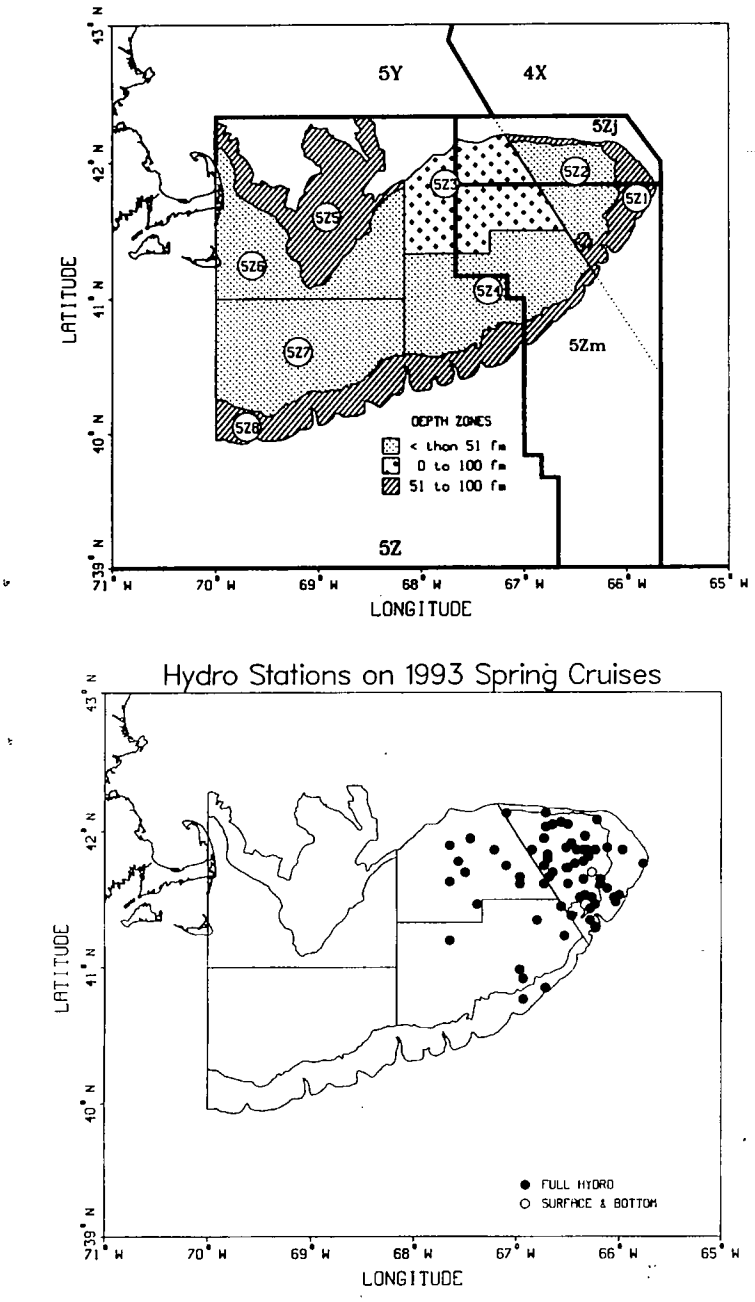

Figure 1: Survey domain and strata boundaries for Canadian groundfish bottom-trawl research vessel surveys conducted within the NAFO area 5Z (top panel) during the spring of 1993 and the location of hydrographic sampling stations taken during the survey (bottom panel). In the top panel the numbers enclosed within circles are the strata designations. In the bottom panel a full 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.

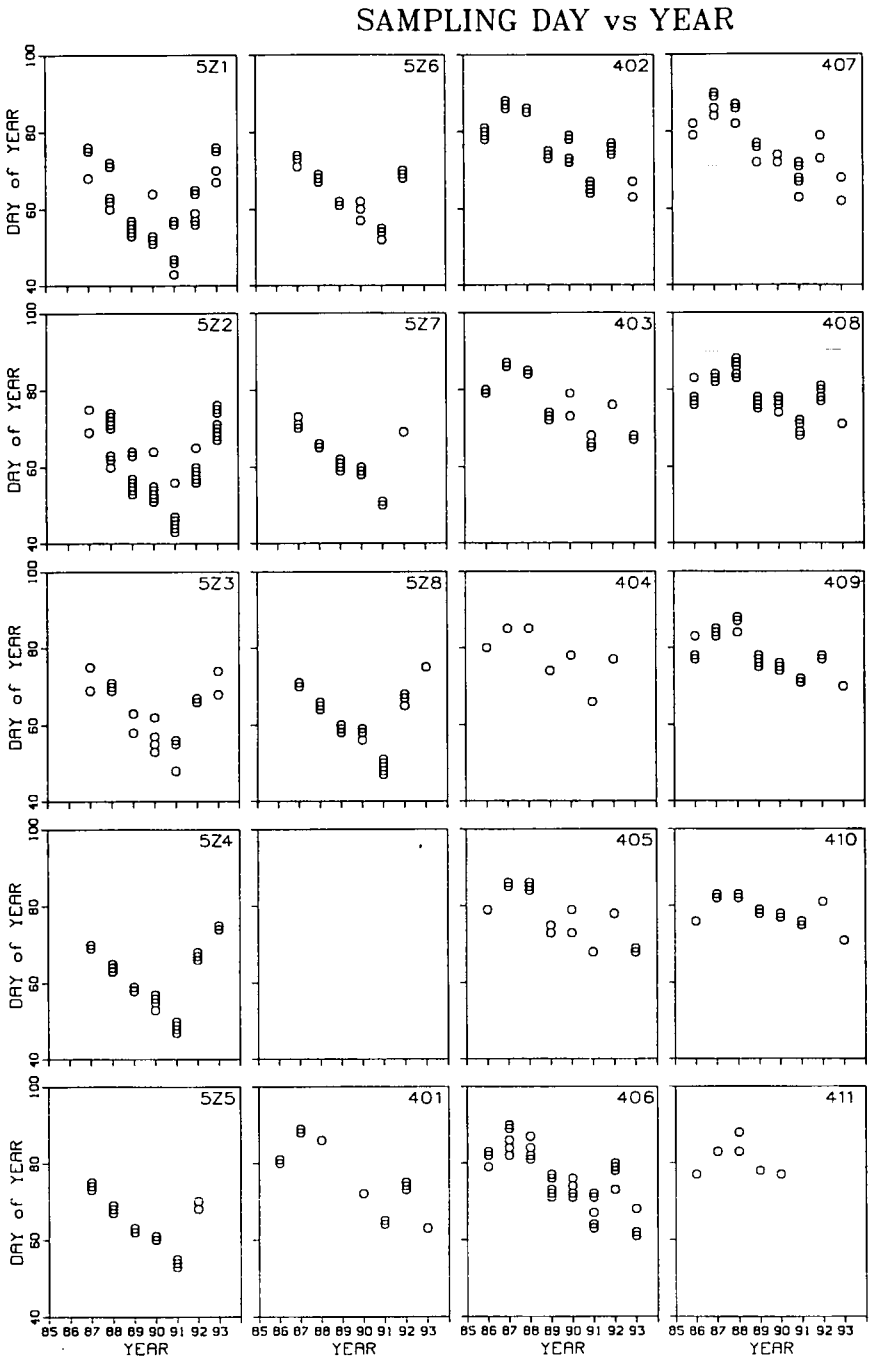

Figure 2: Time series of the day of sampling within the spring 5Z and 4VsW surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.

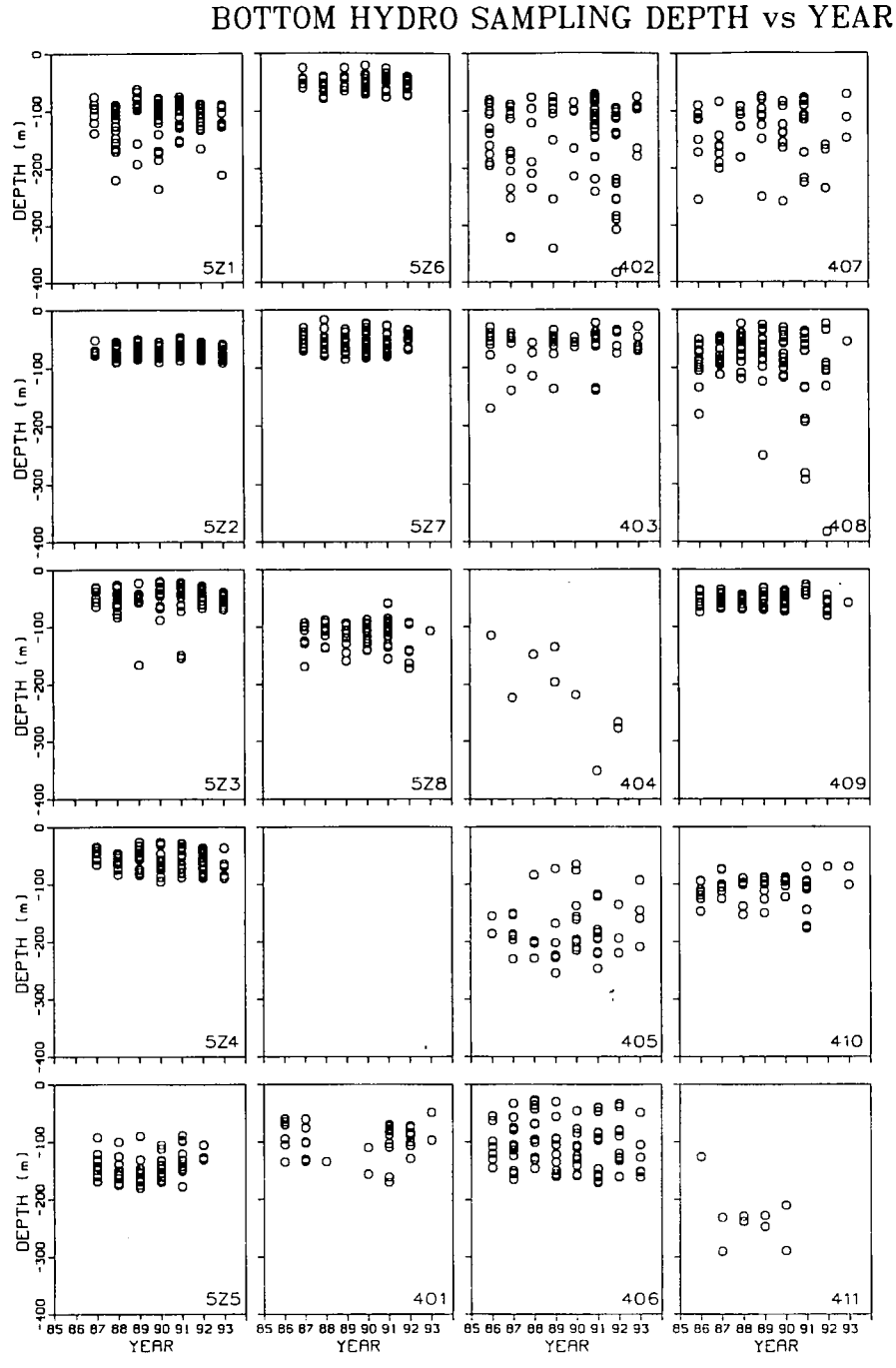

Figure 3: Time series of the near-bottom sampling depth for each hydrographic station within the spring 5Z and 4VsW surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the near-bottom sampling depth of one hydrographic station.

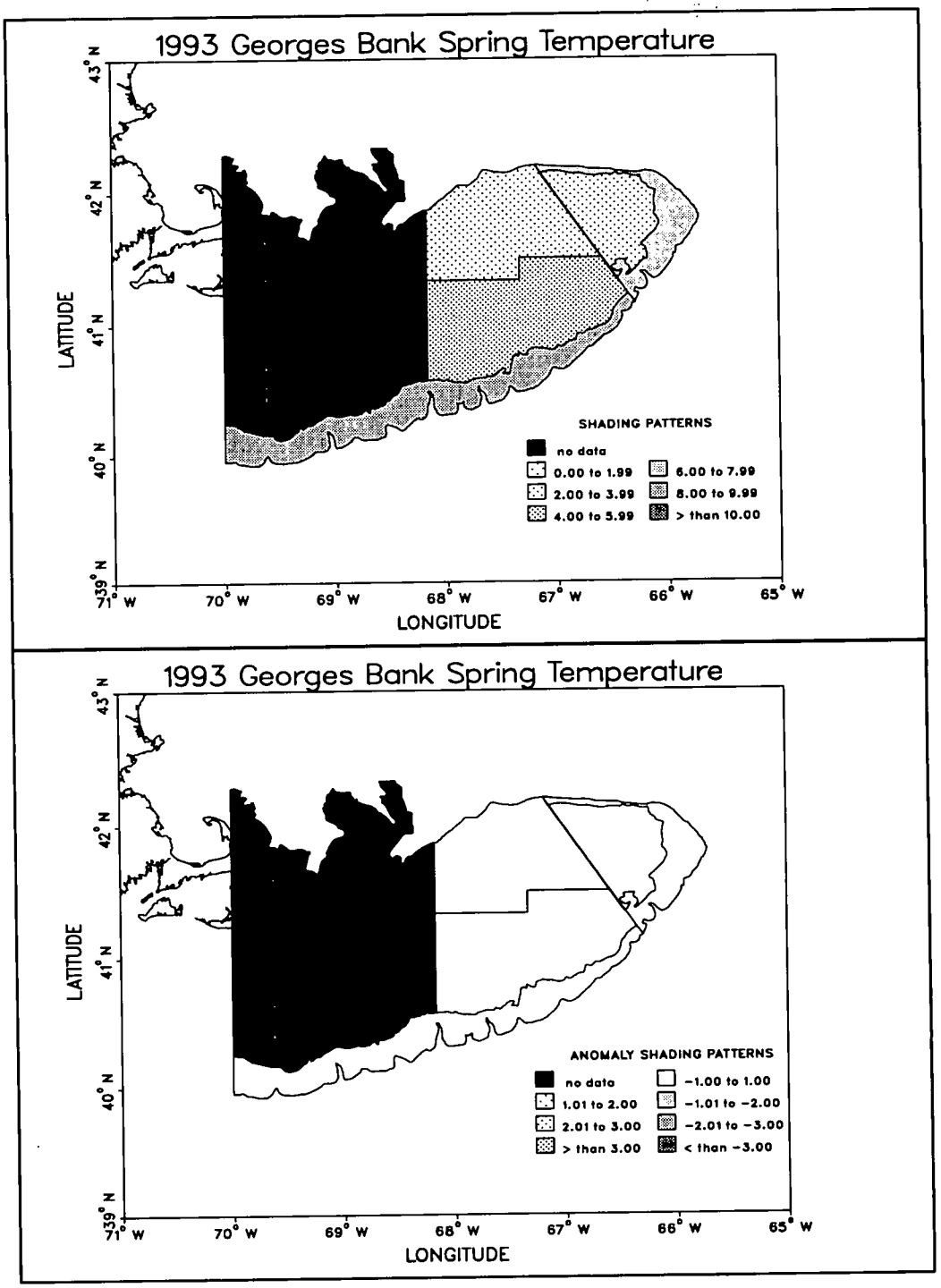

Figure 4: Near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 5Z during the Canadian research vessel bottom-trawl survey conducted during the spring of 1993.

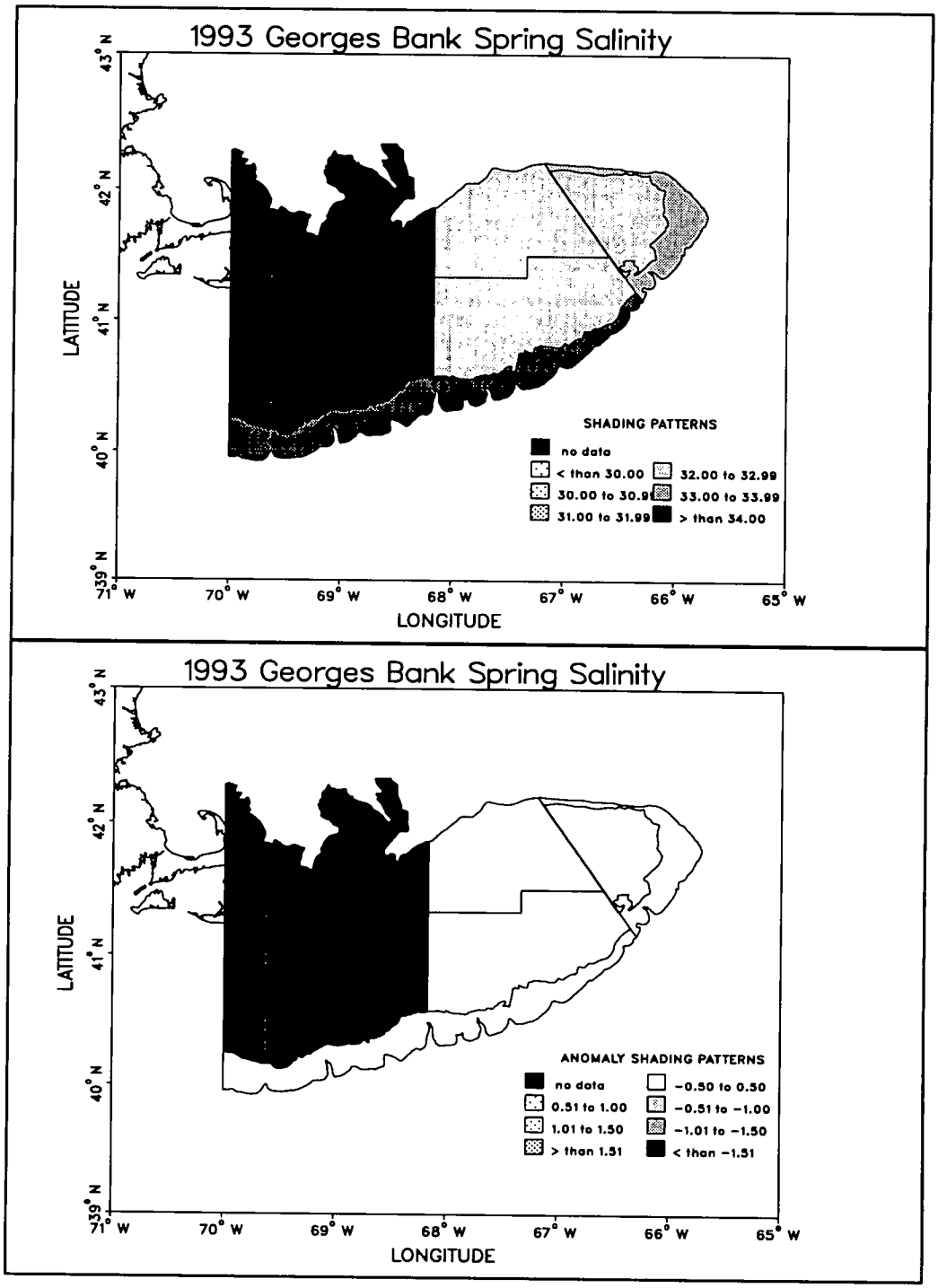

Figure 5: Near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 5Z during the Canadian research vessel bottom-trawl survey conducted during the spring of 1993.

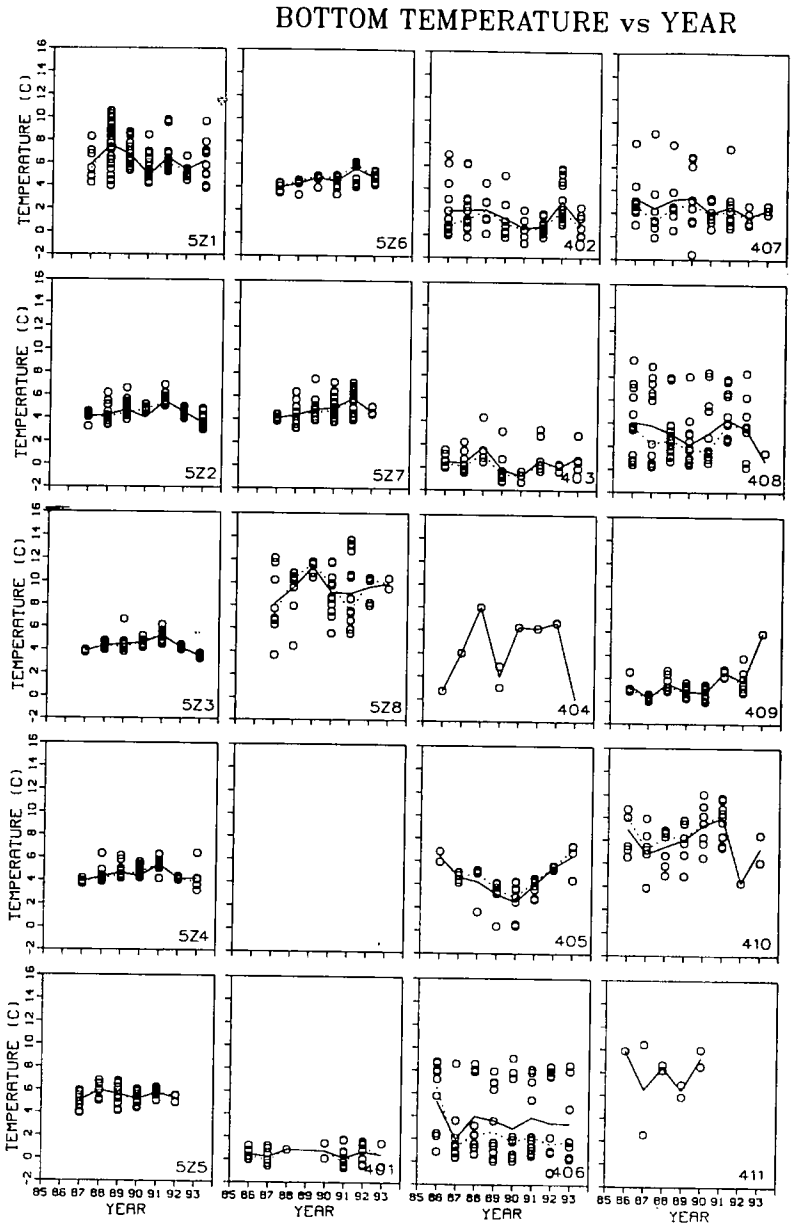

Figure 6: Time series of near-bottom temperatures within the spring 5Z and 4VsW surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

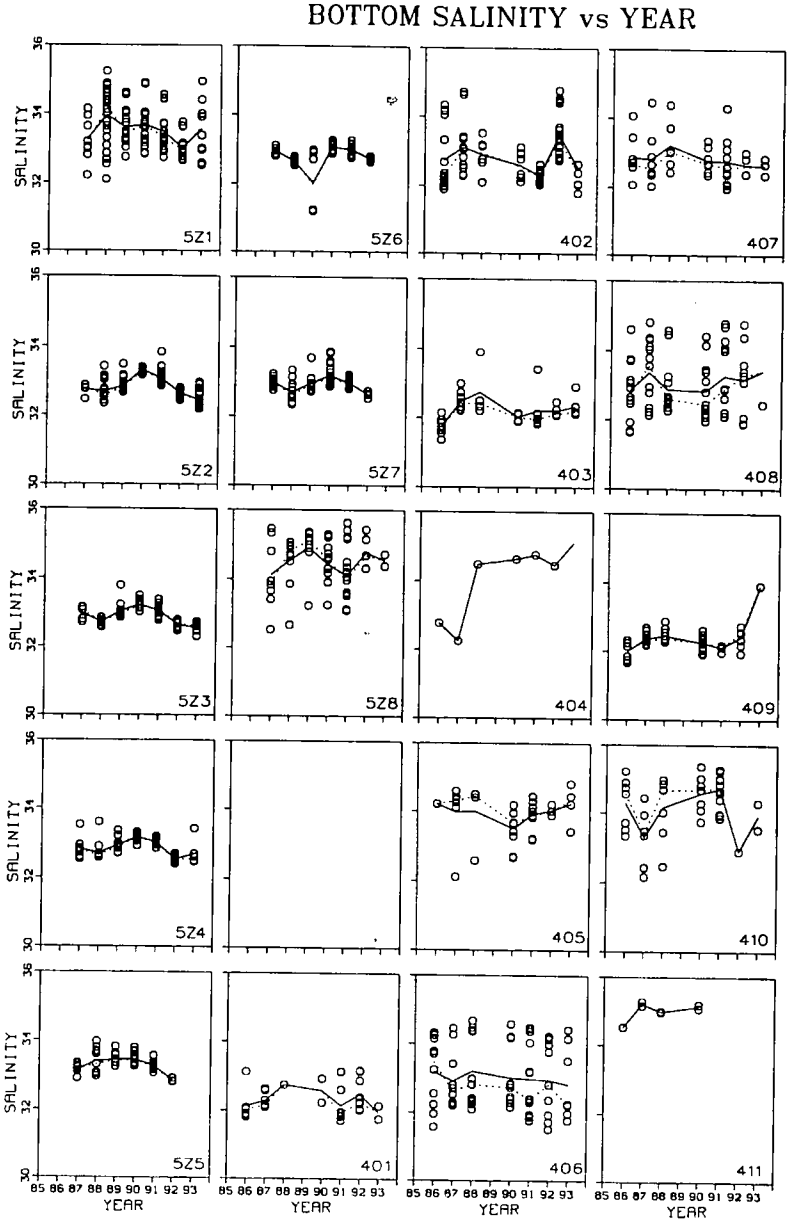

Figure 7: Time series of near-bottom salinities within the spring 5Z and 4VsW surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

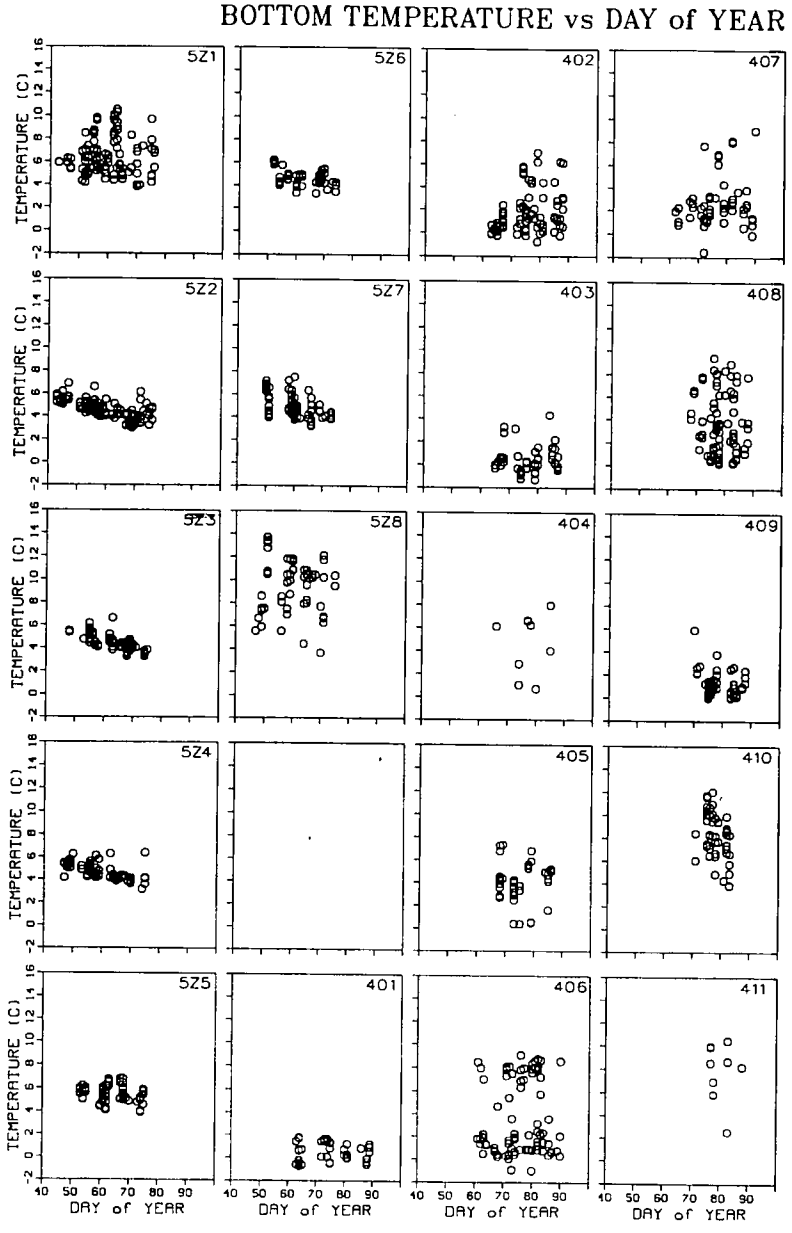

Figure 8: Near-bottom temperatures within the spring 5Z and 4VsW surveys in relation to day of the year. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

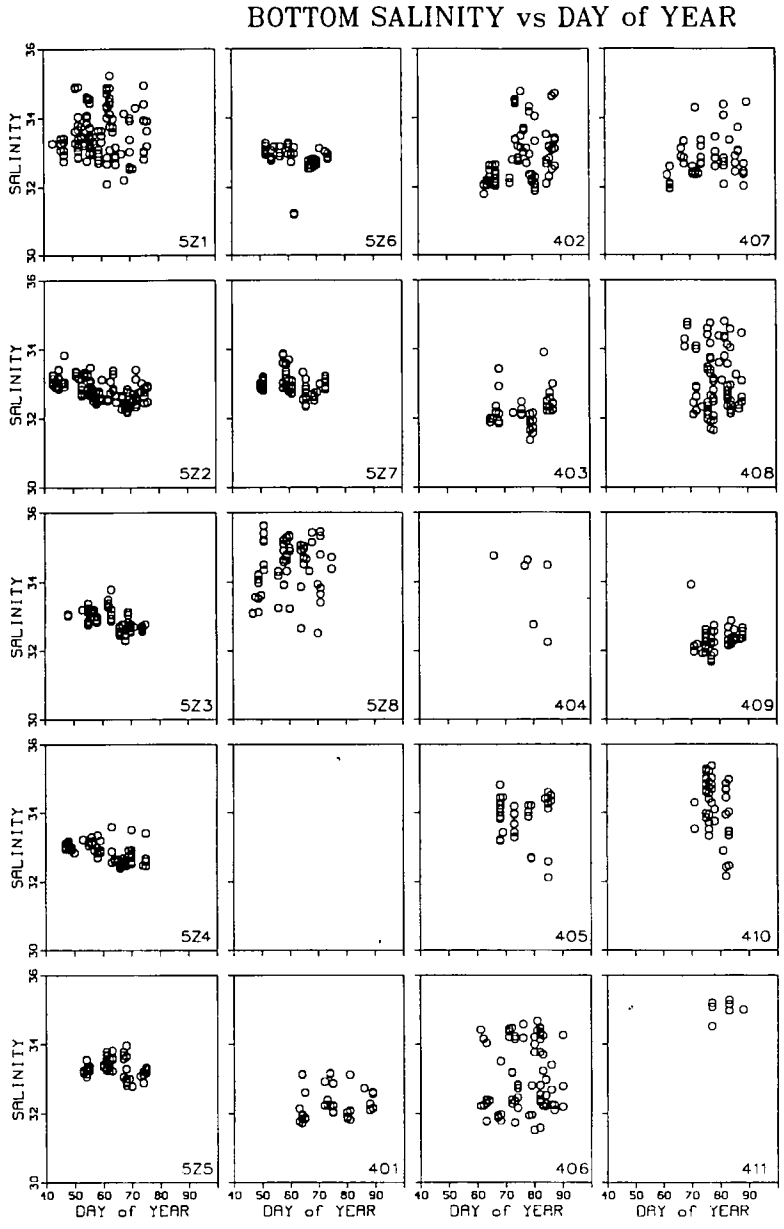

Figure 9: Near-bottom salinity within the spring 5Z and 4VsW surveys in relation to day of the year. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

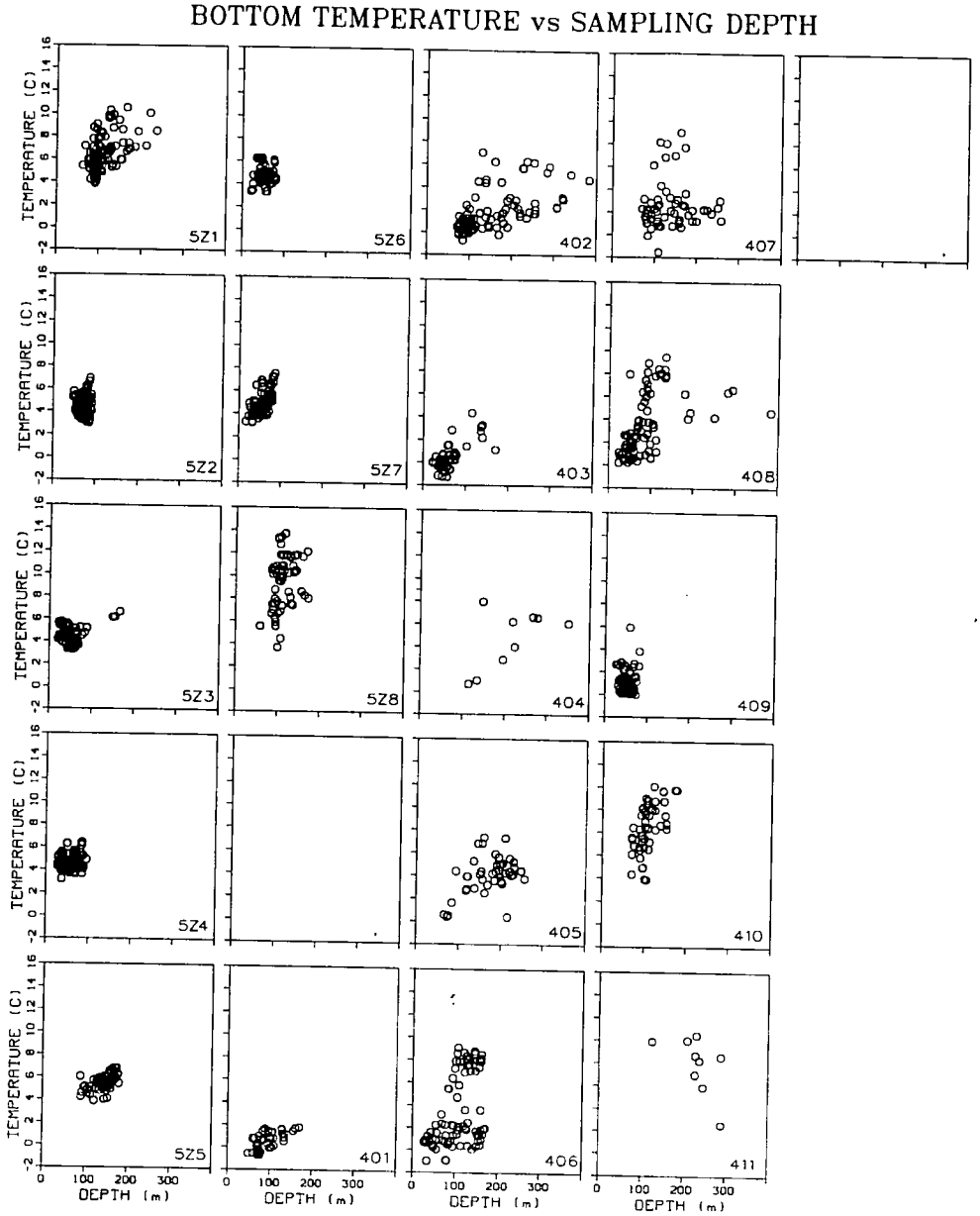

Figure 10: Near-bottom temperatures within the spring 5Z and 4VsW surveys in relation to sampling depth. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

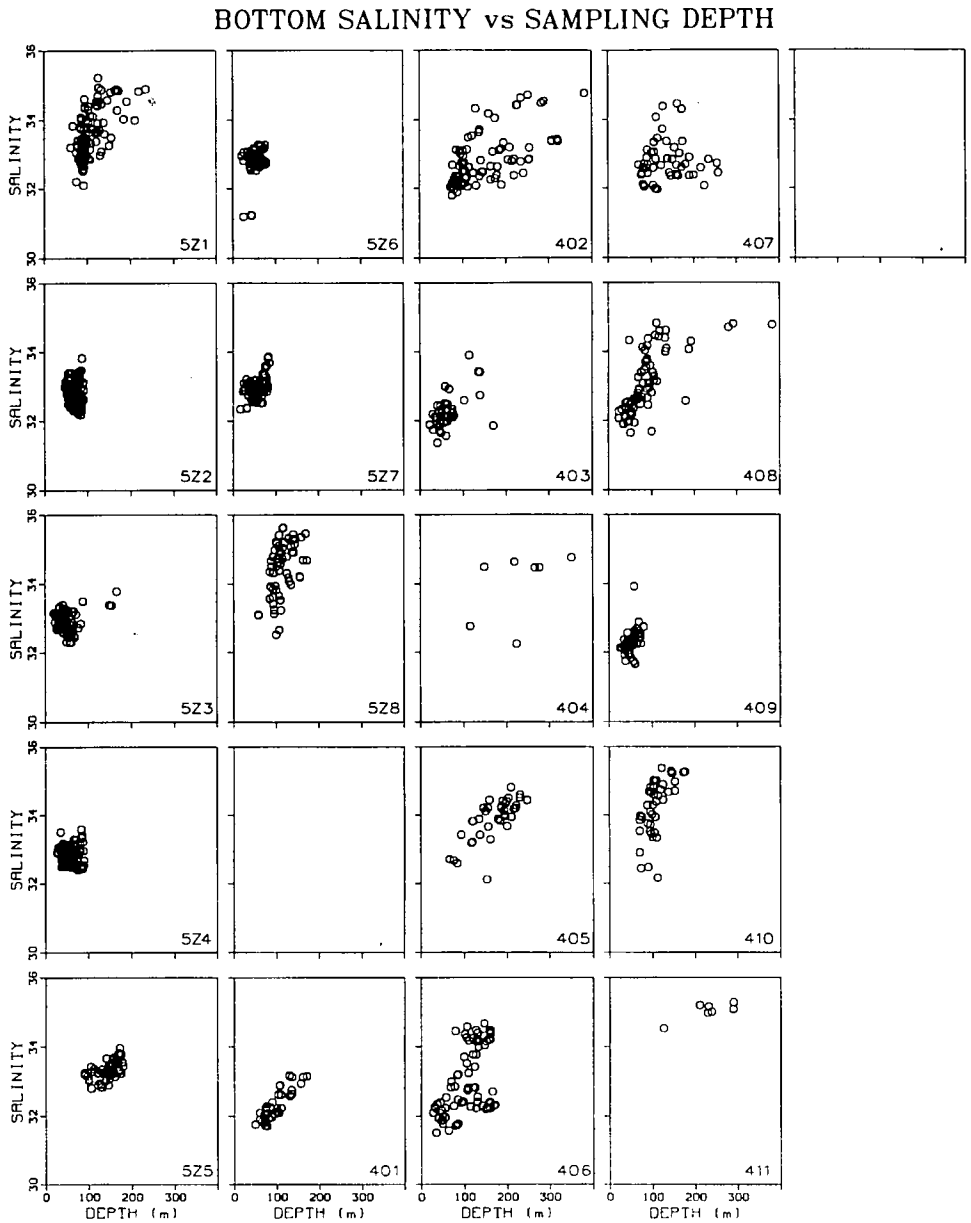

Figure 11: Near-bottom salinity within the spring 5Z and 4VsW surveys in relation to sampling depth. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

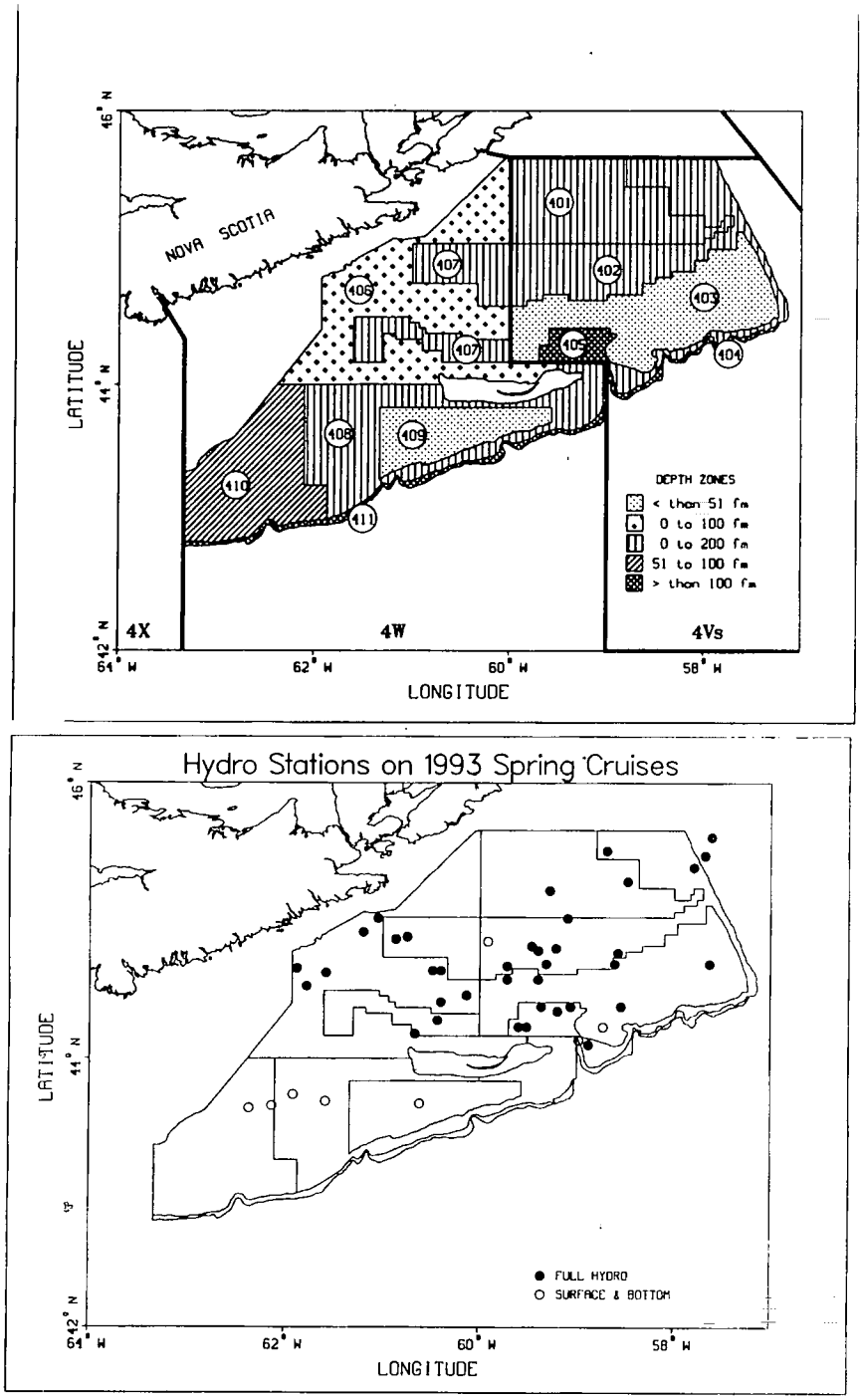

Figure 12: Survey domain and strata boundaries for the Canadian groundfish bottom-trawl research vessel surveys conducted within the NAFO area 4VsW (top panel) during the spring of 1993 and the location of temperature and salinity sampling stations taken during the survey (bottom panel). In the top panel the numbers enclosed within circles are the strata designations. In the bottom panel a full 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.

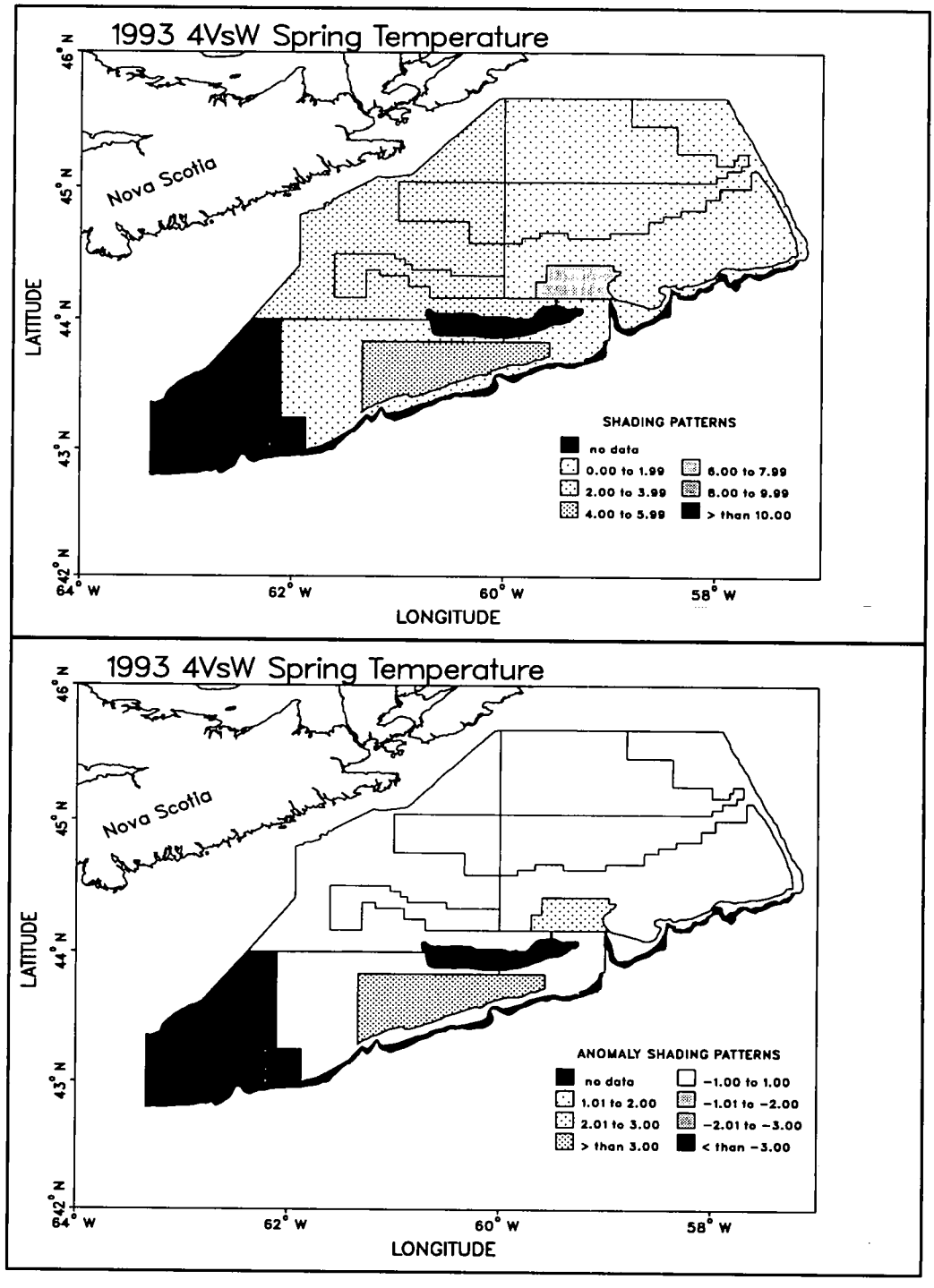

Figure 13: Near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VsW during the Canadian research vessel bottom-trawl survey conducted during the spring of 1993.

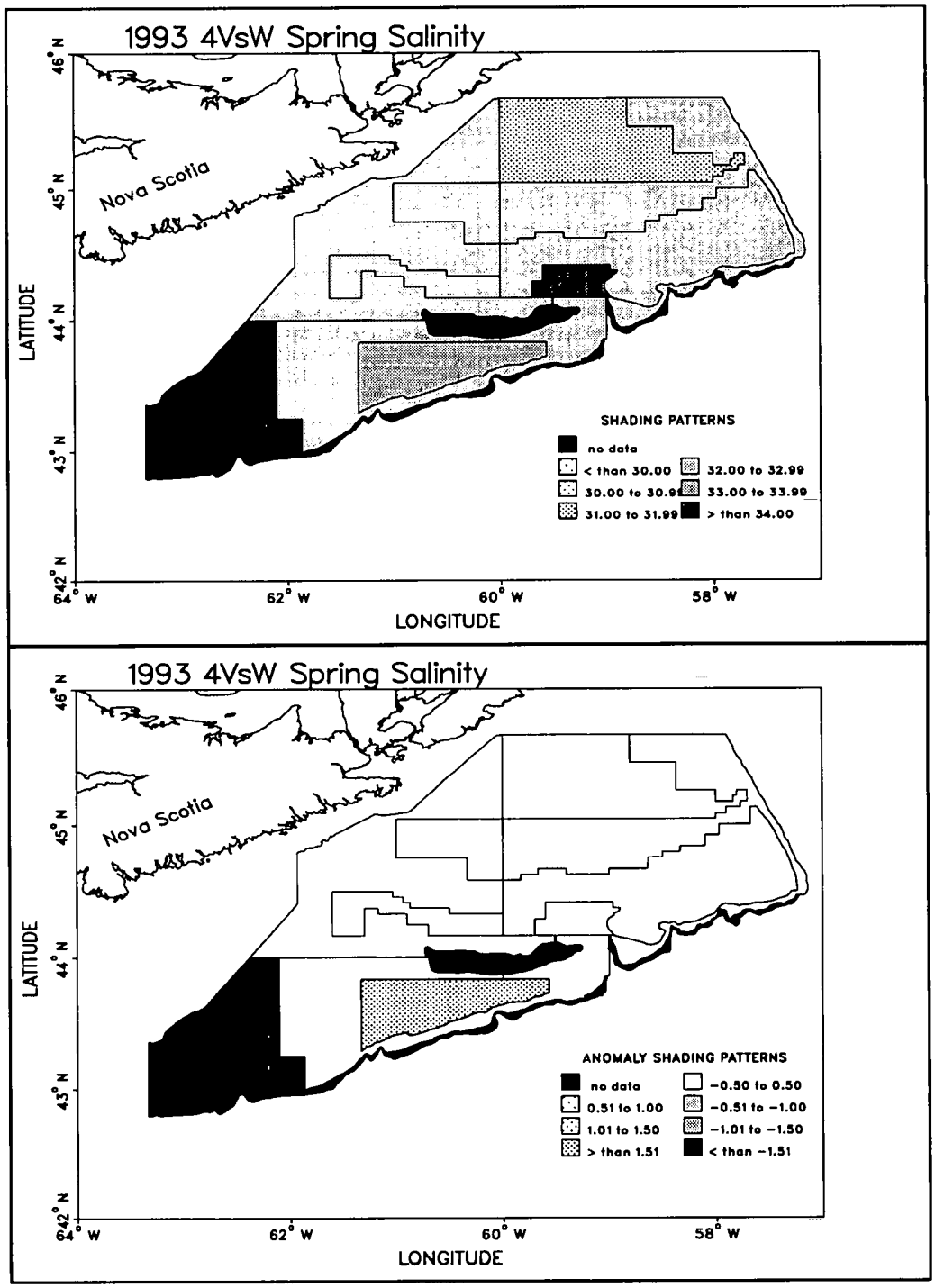

Figure 14: Near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VsW during the Canadian research vessel bottom-trawl survey conducted during the spring of 1993.

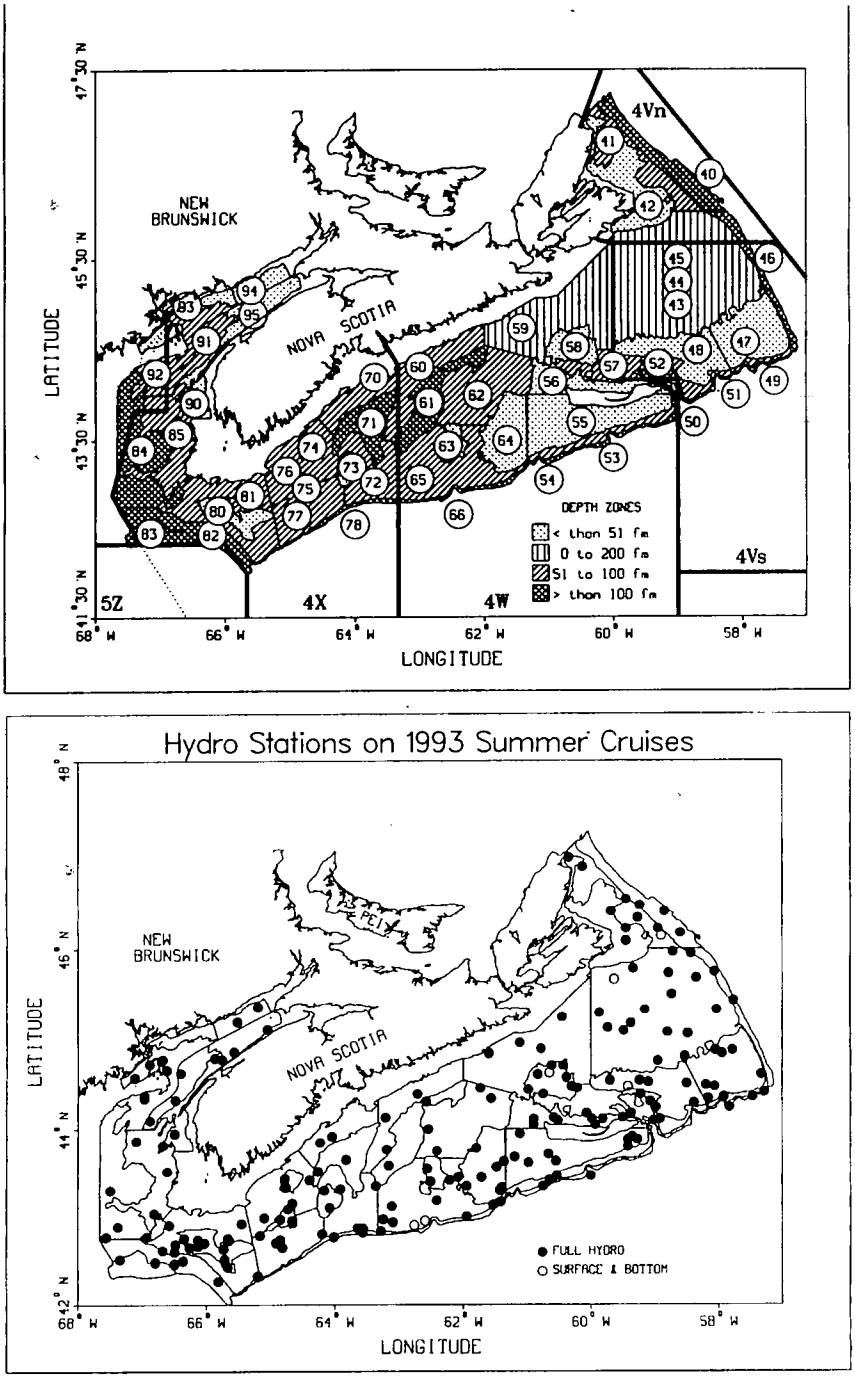

Figure 15: Survey domain and strata boundaries for Canadian groundfish bottom-trawl research vessel surveys conducted within the 4VWX region (top panel) during the summer of 1993 and the location of temperature and salinity sampling stations taken during the survey (bottom panel). In the top panel the 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 full 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.

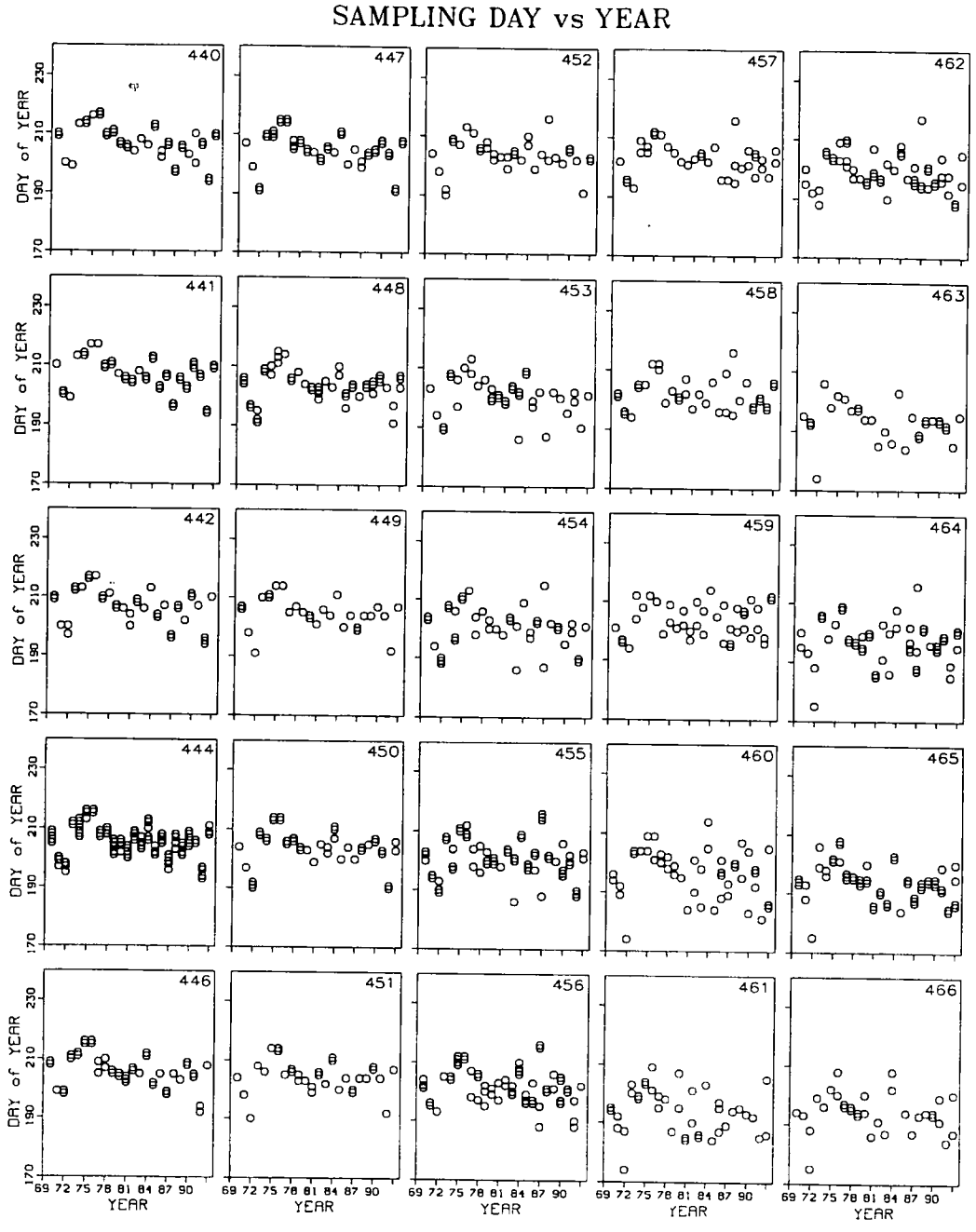

Figure 16: Time series of the day of sampling within the summer 4VWX surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.

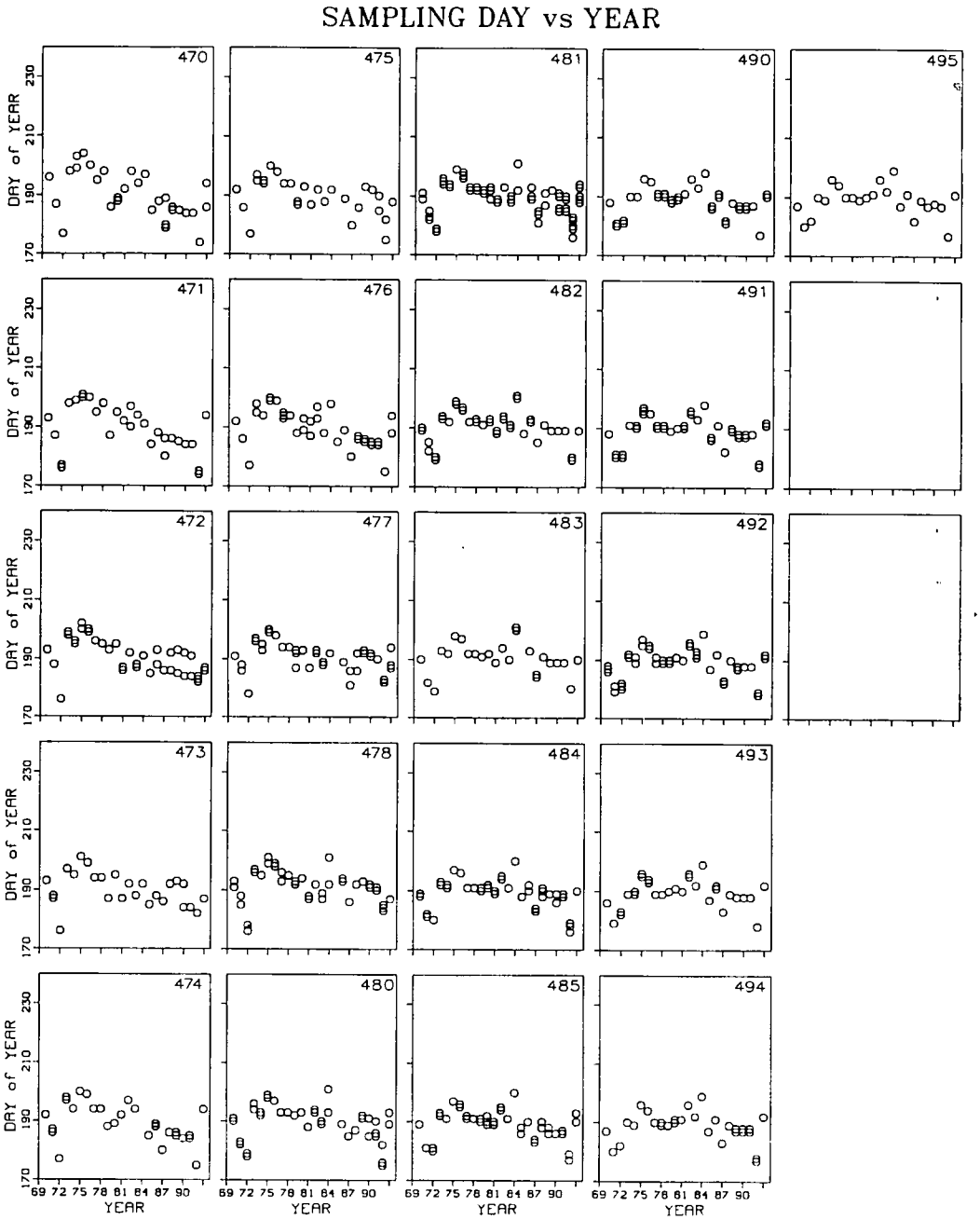

Figure 16: continued

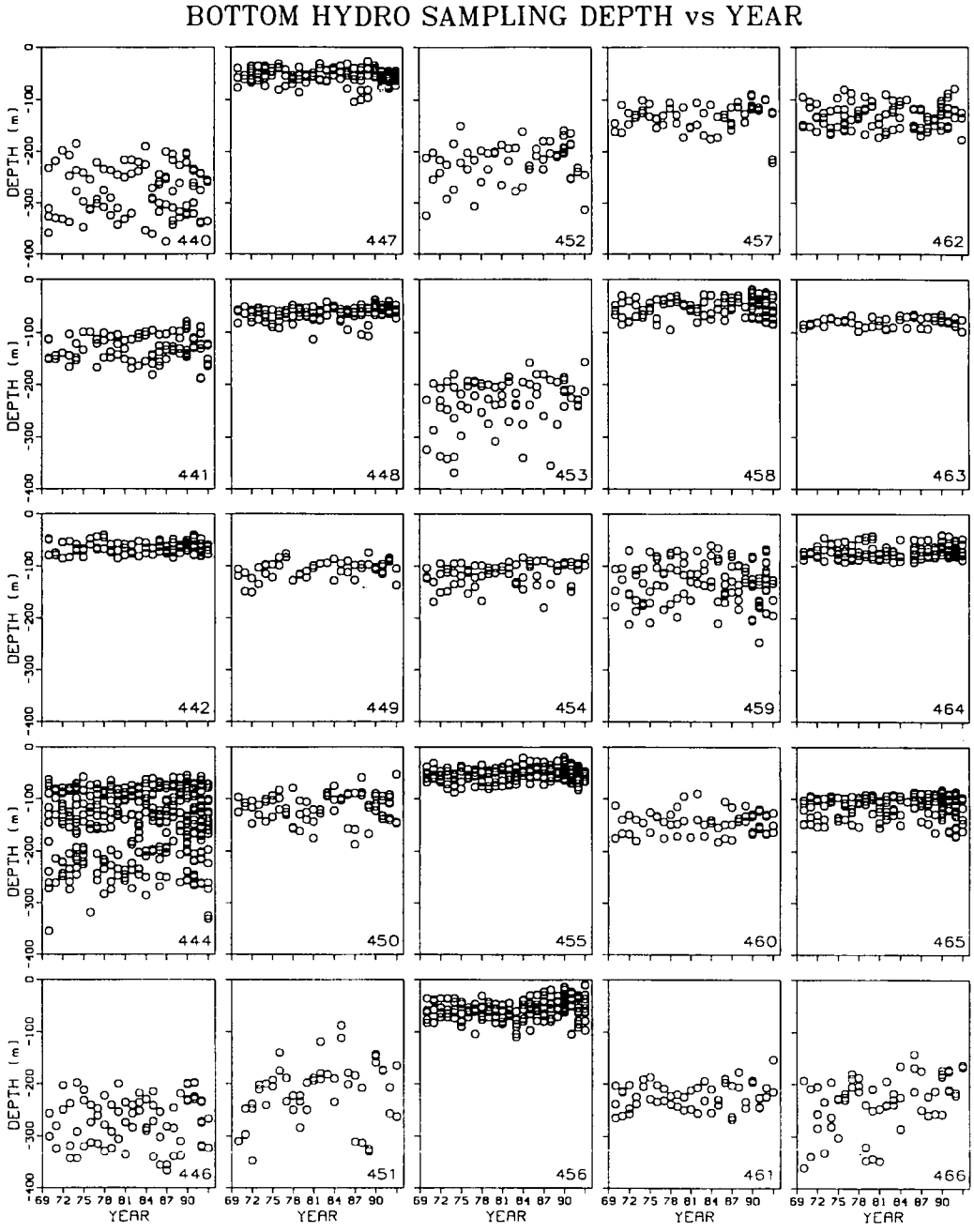

Figure 17: Time series of the near-bottom sampling depth for each hydrographic station within the summer 4VWX surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the near-bottom sampling depth of one hydrographic station.

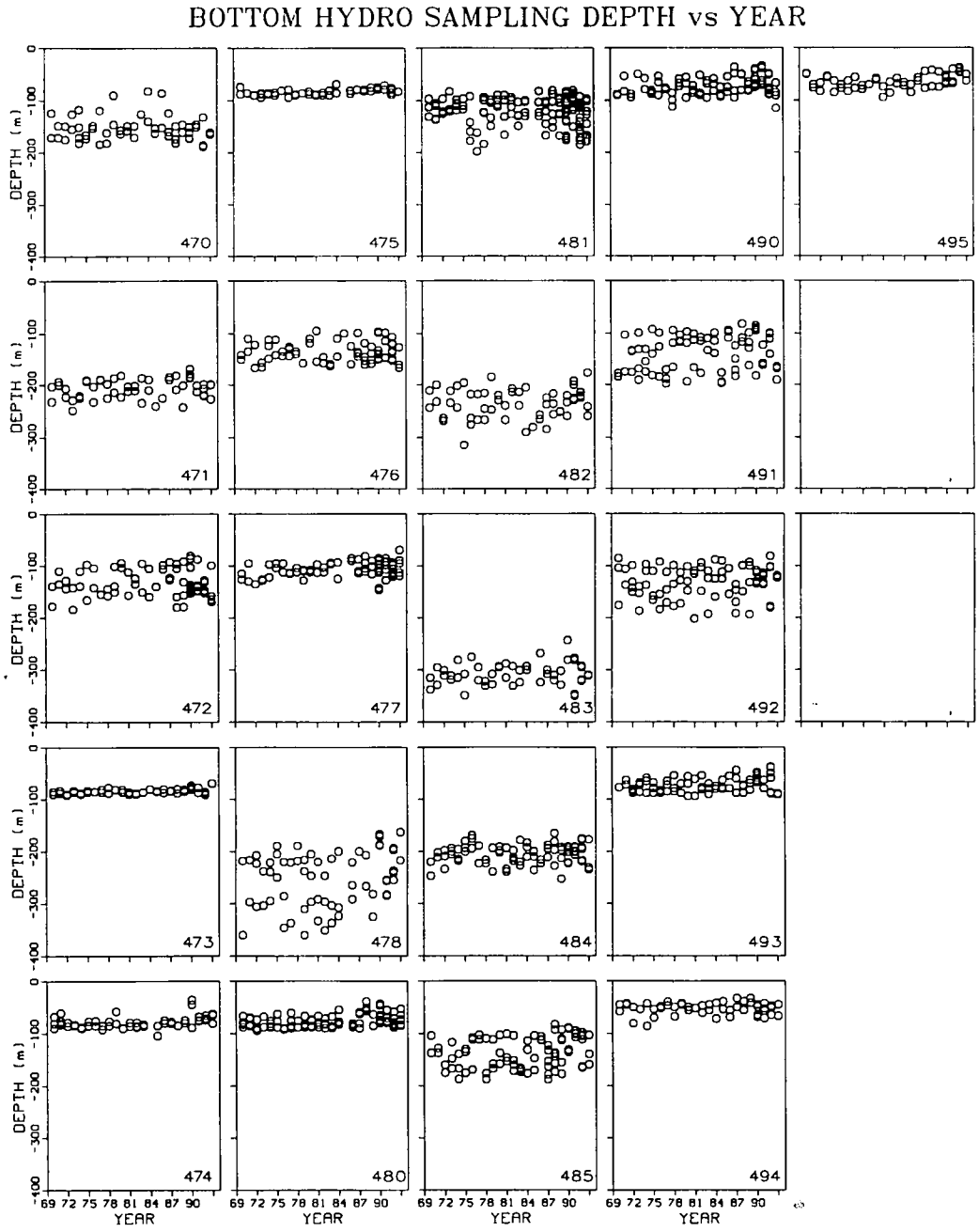

Figure 17: continued

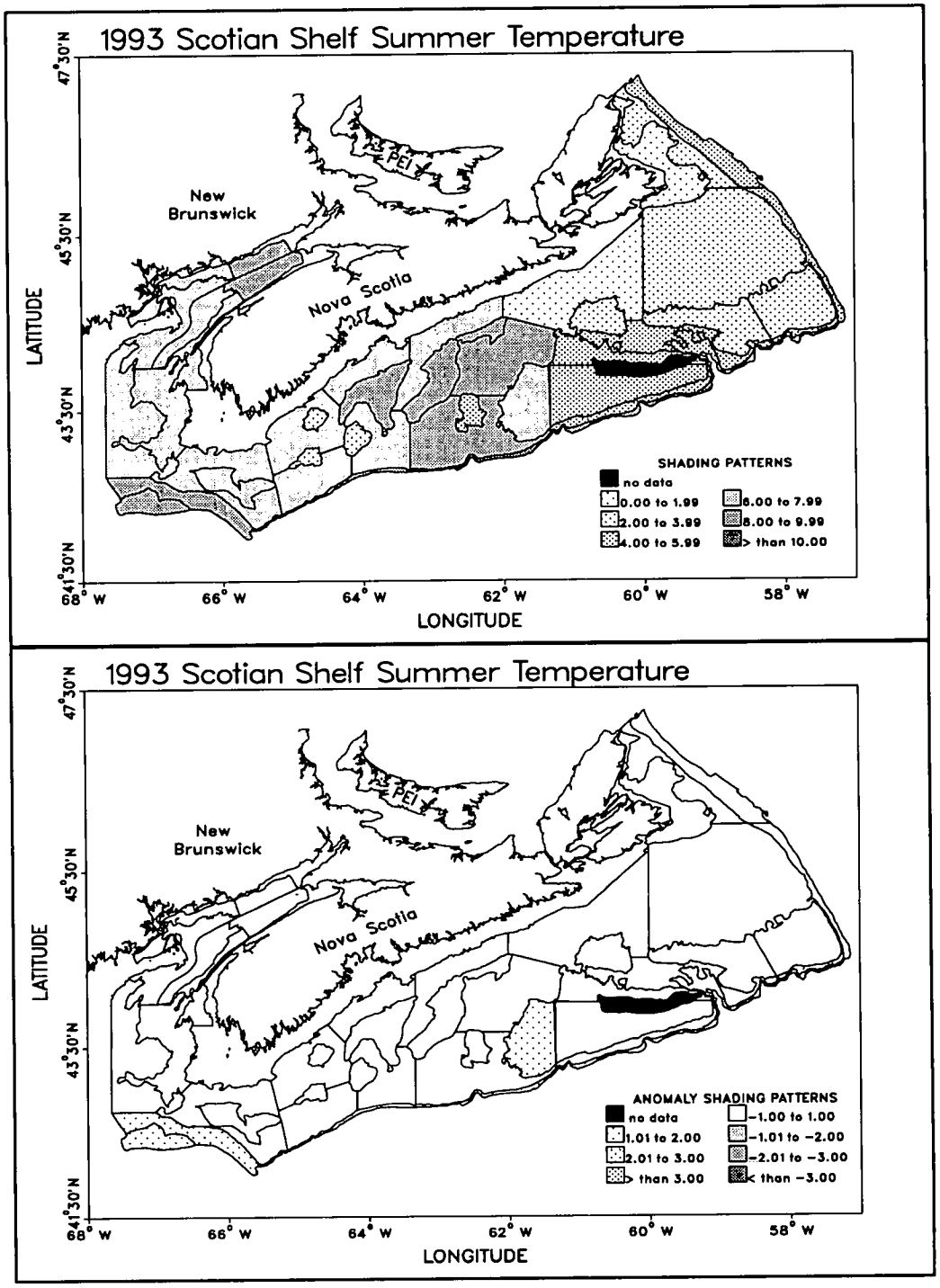

Figure 18: Near-bottom strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1993.

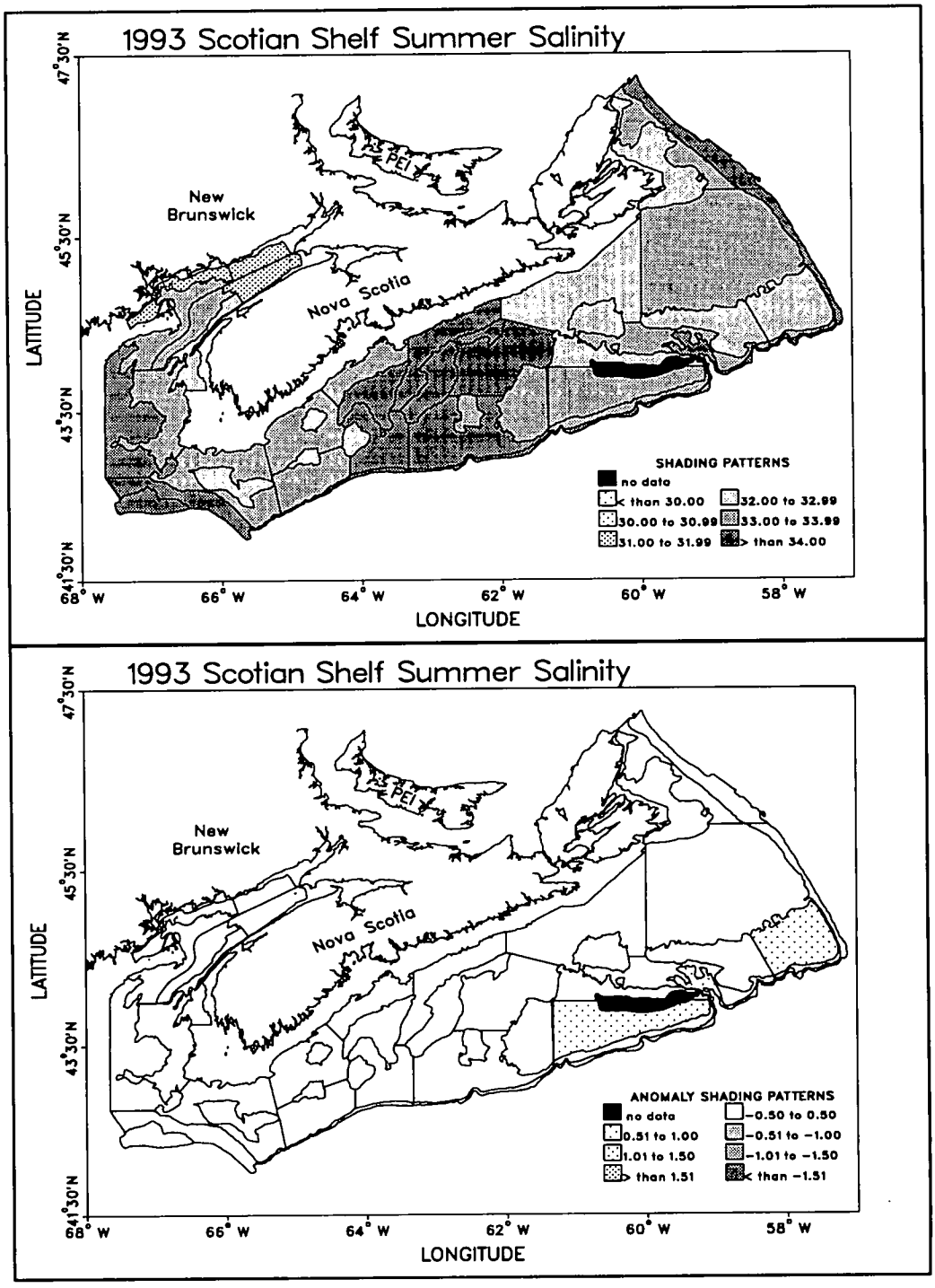

Figure 19: Near-bottom strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1993.

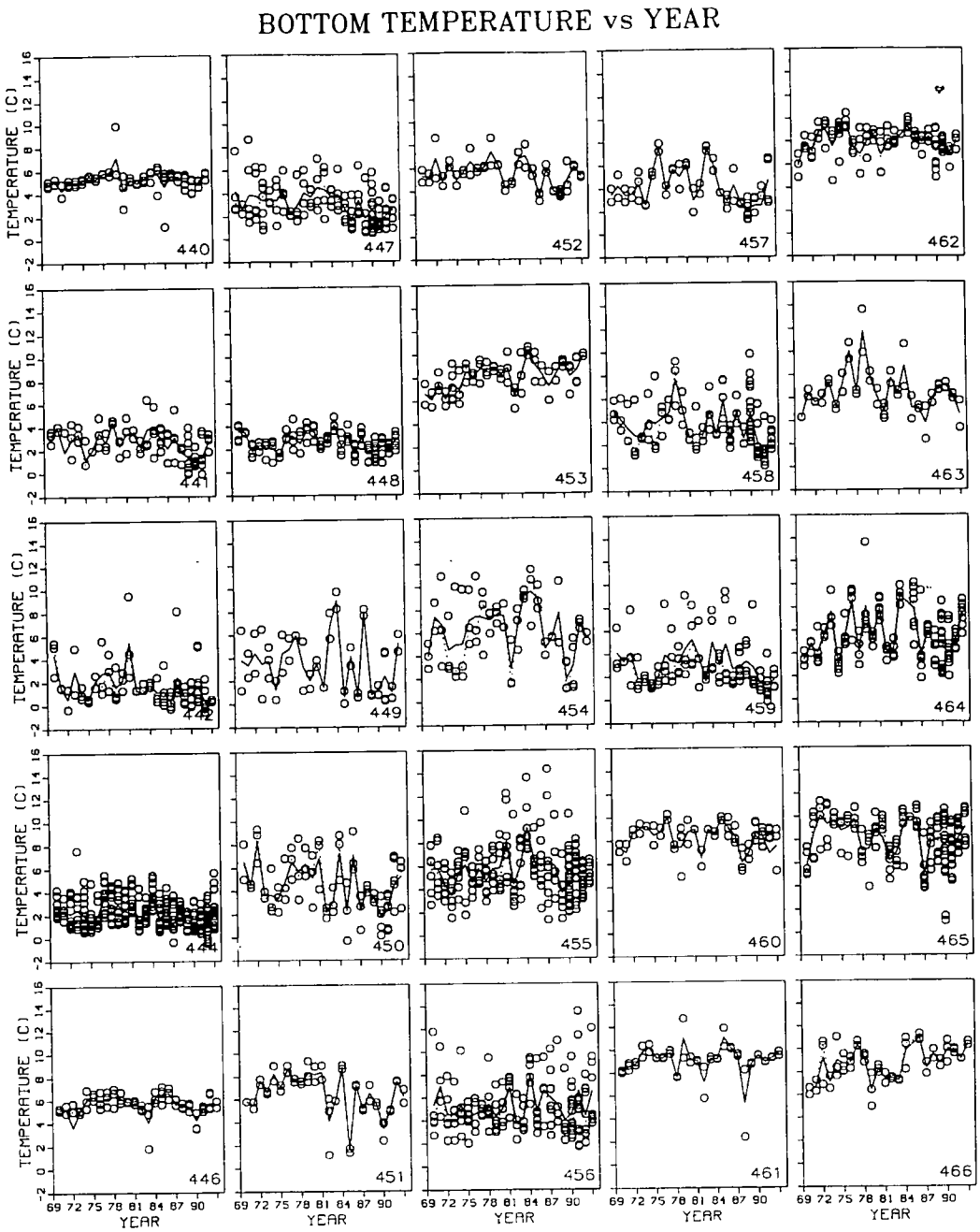

Figure 20: Time series of near-bottom temperatures within the summer 4VWX surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

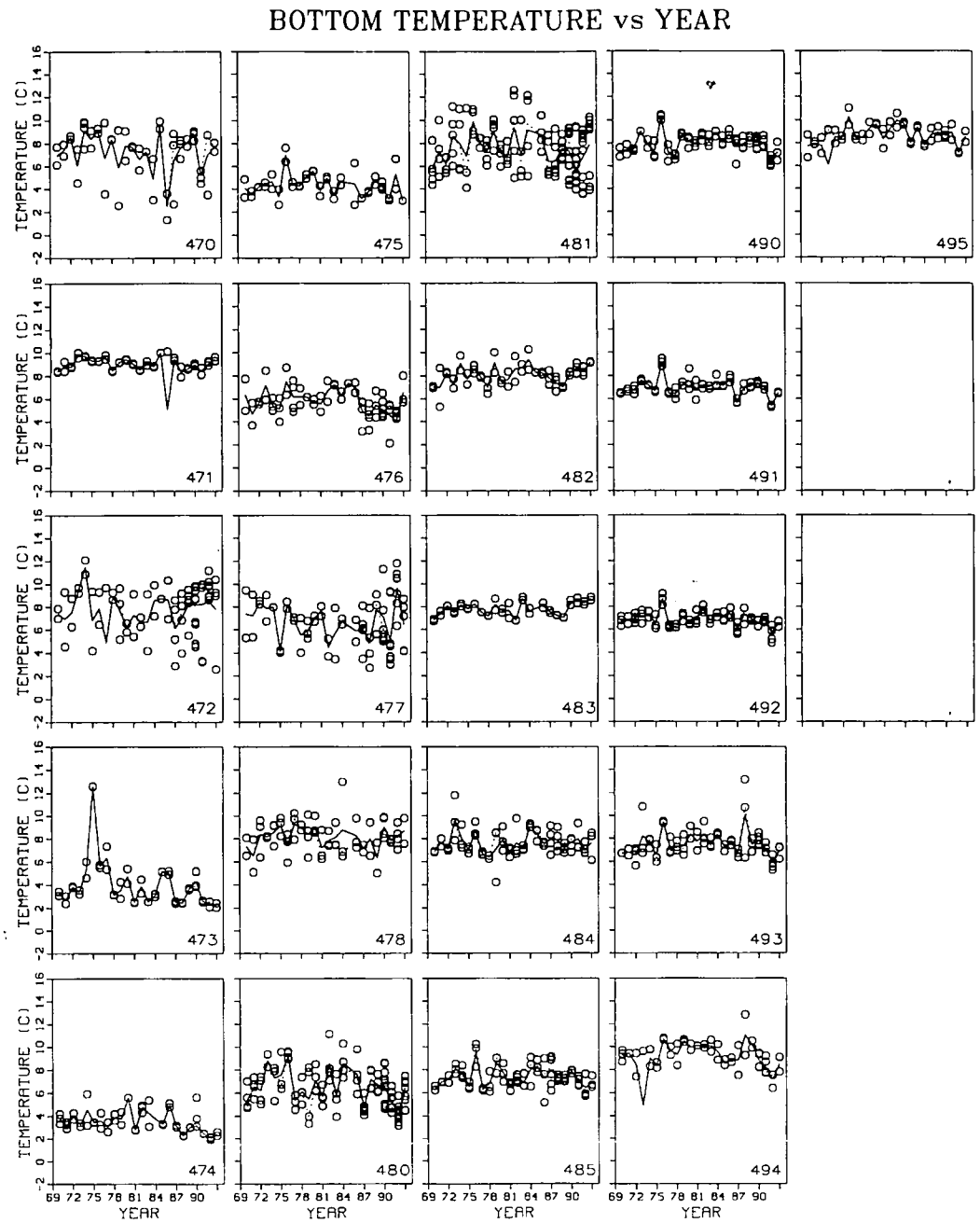

Figure 20: continued

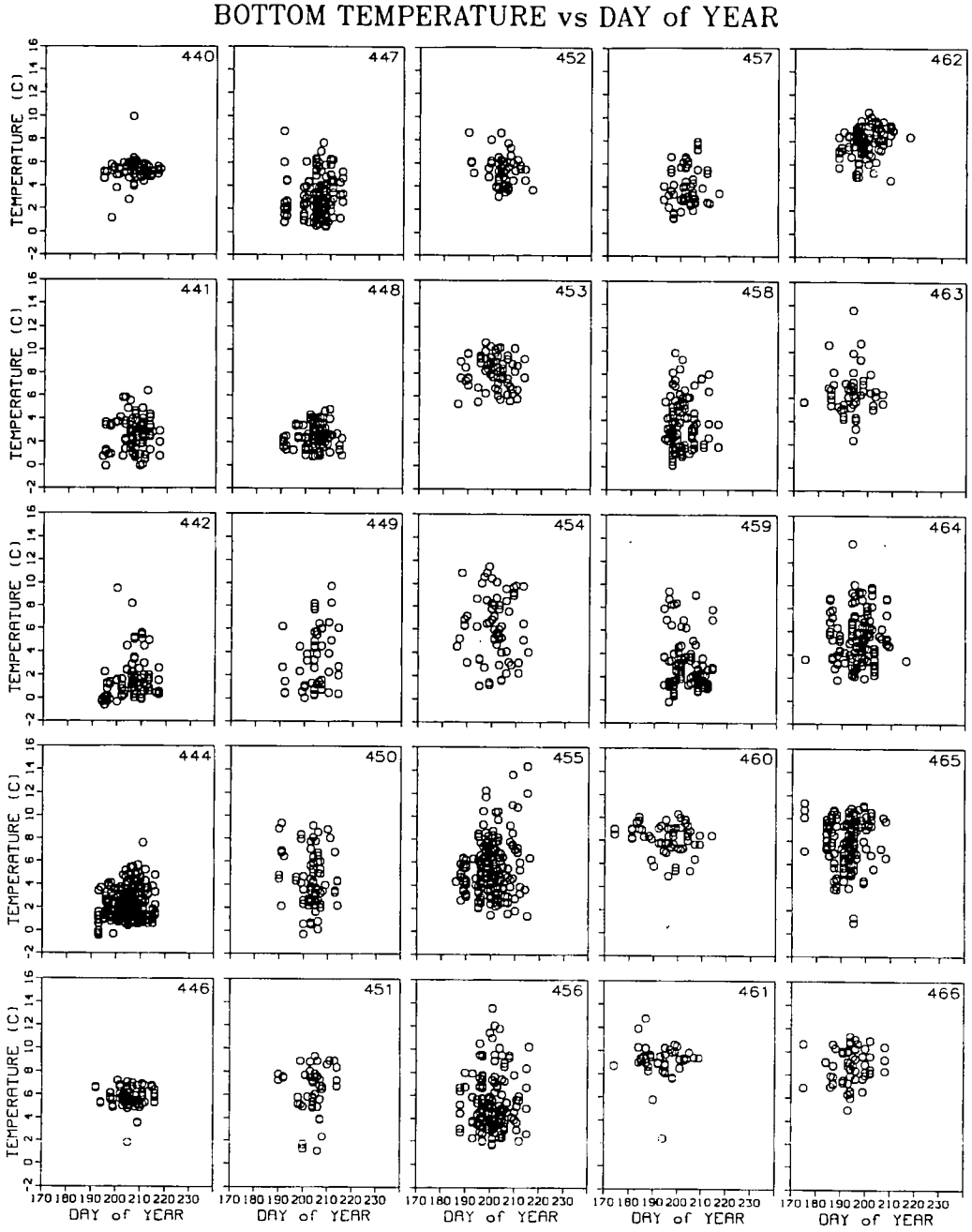

Figure 21: Near-bottom temperatures within the summer 4VWX surveys in relation to day of the year. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

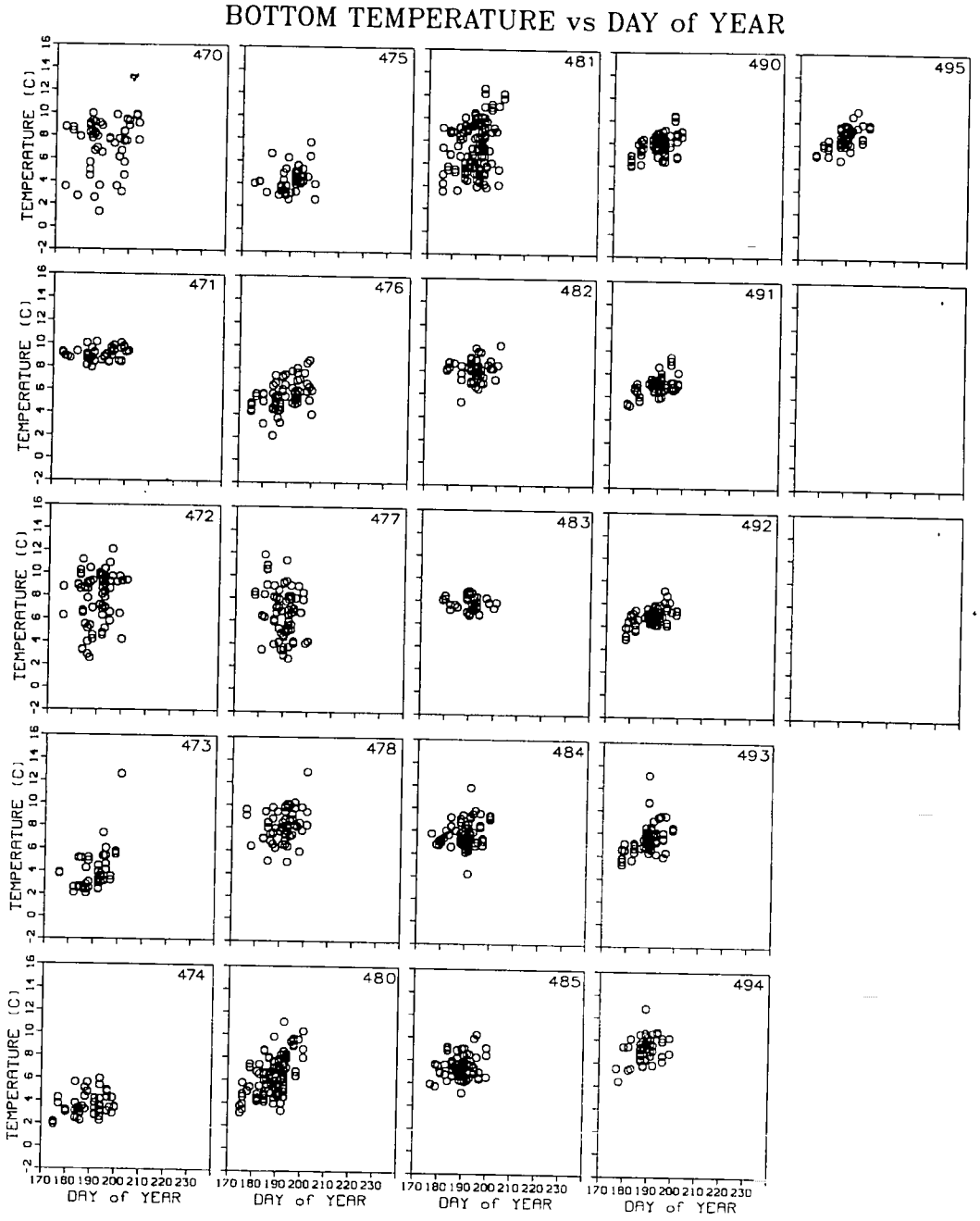

Figure 21: continued

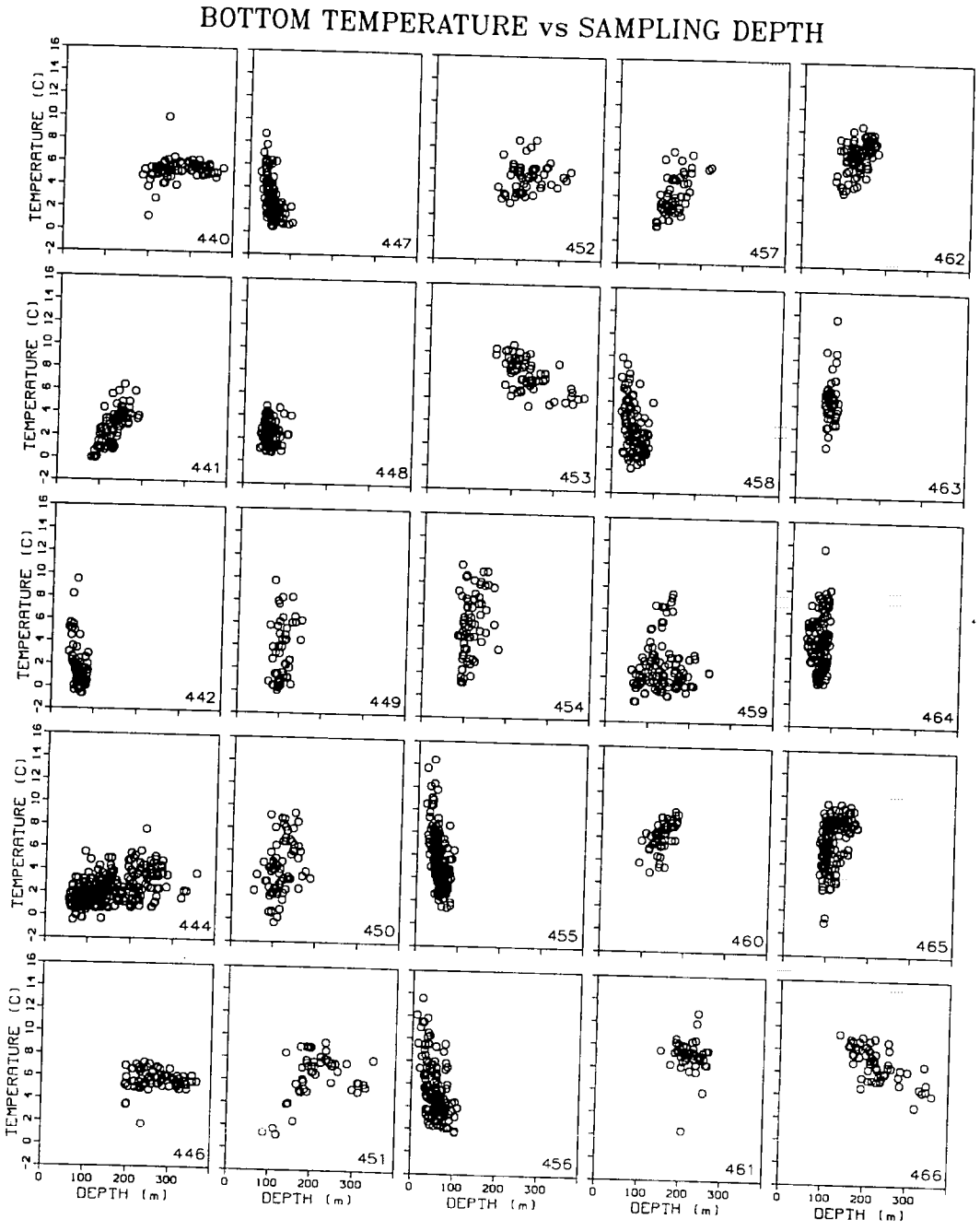

Figure 22: Near-bottom temperatures within the summer 4VWX surveys in relation to sampling depth. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

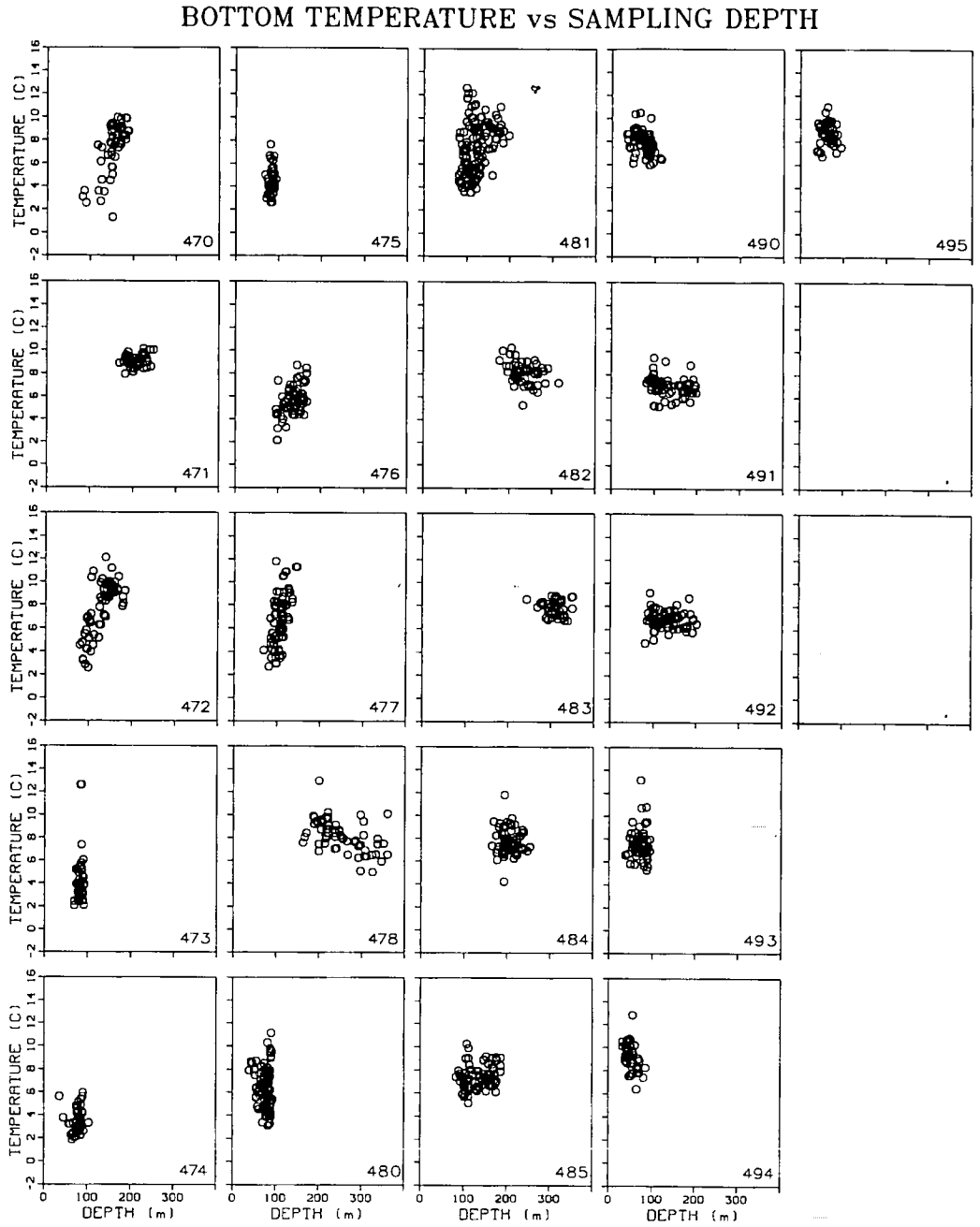

Figure 22: continued

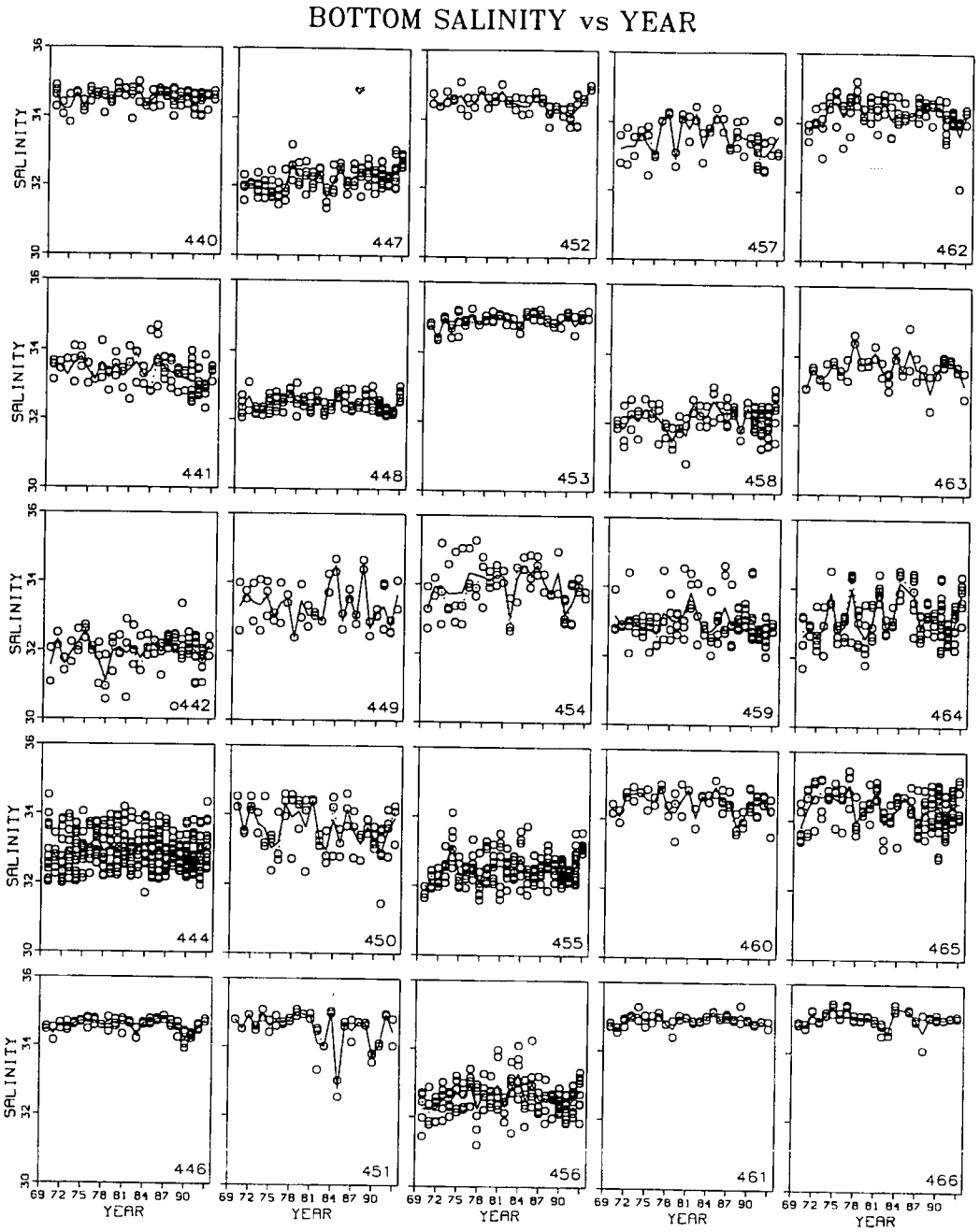

Figure 23: Time series of near-bottom salinities within the summer 4VWX surveys. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

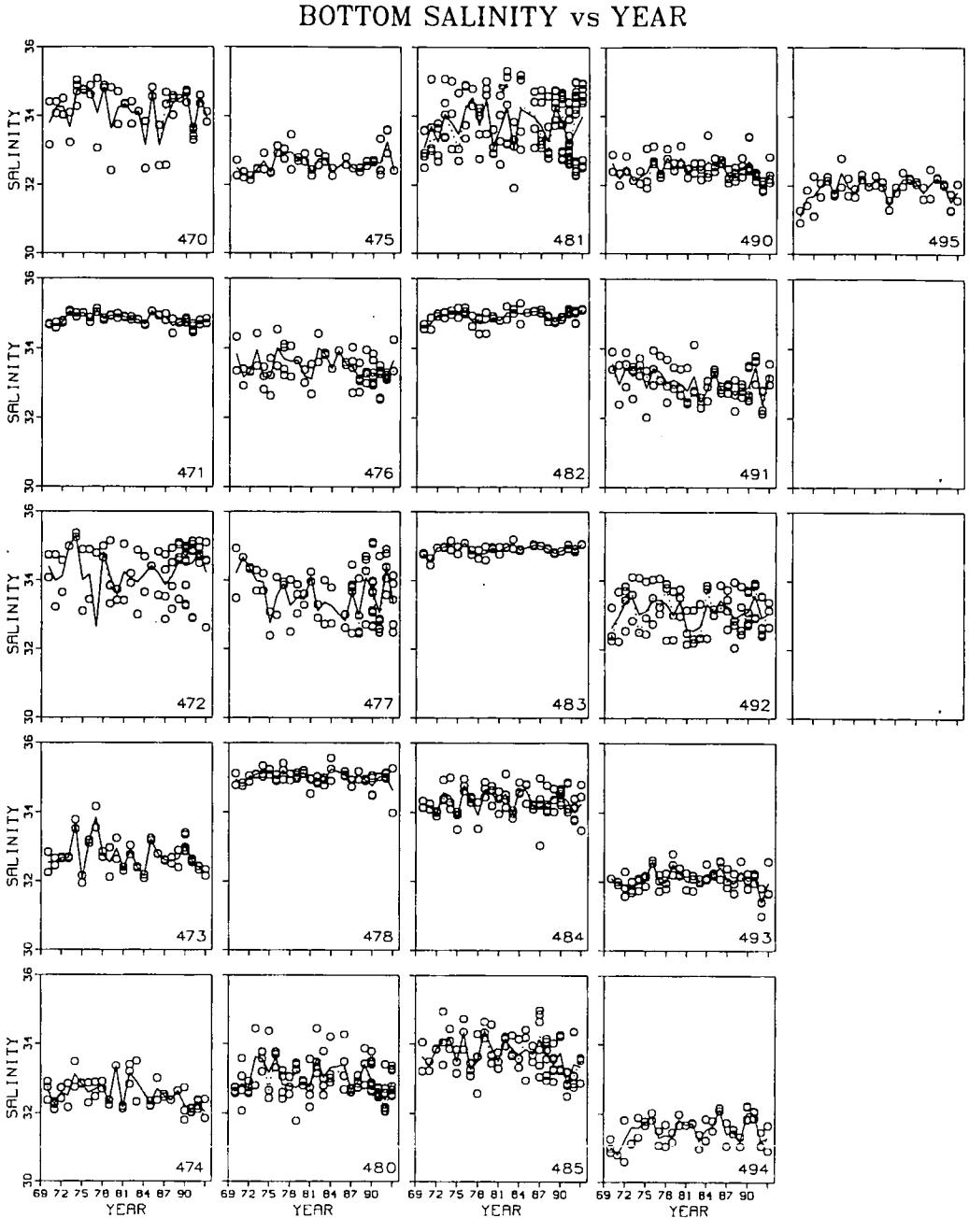

Figure 23: continued

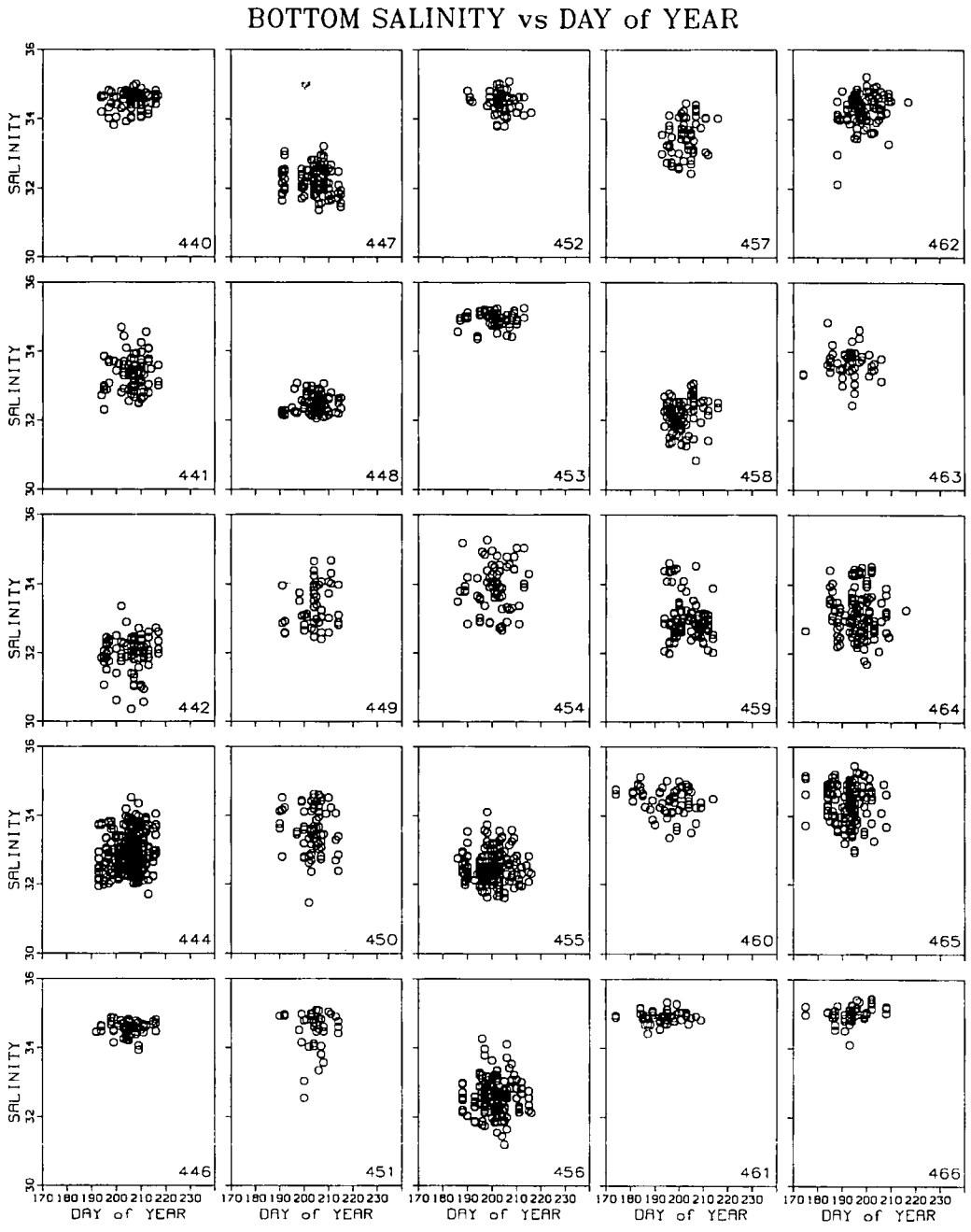

Figure 24: Near-bottom salinity within the summer 4VWX surveys in relation to day of the year. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

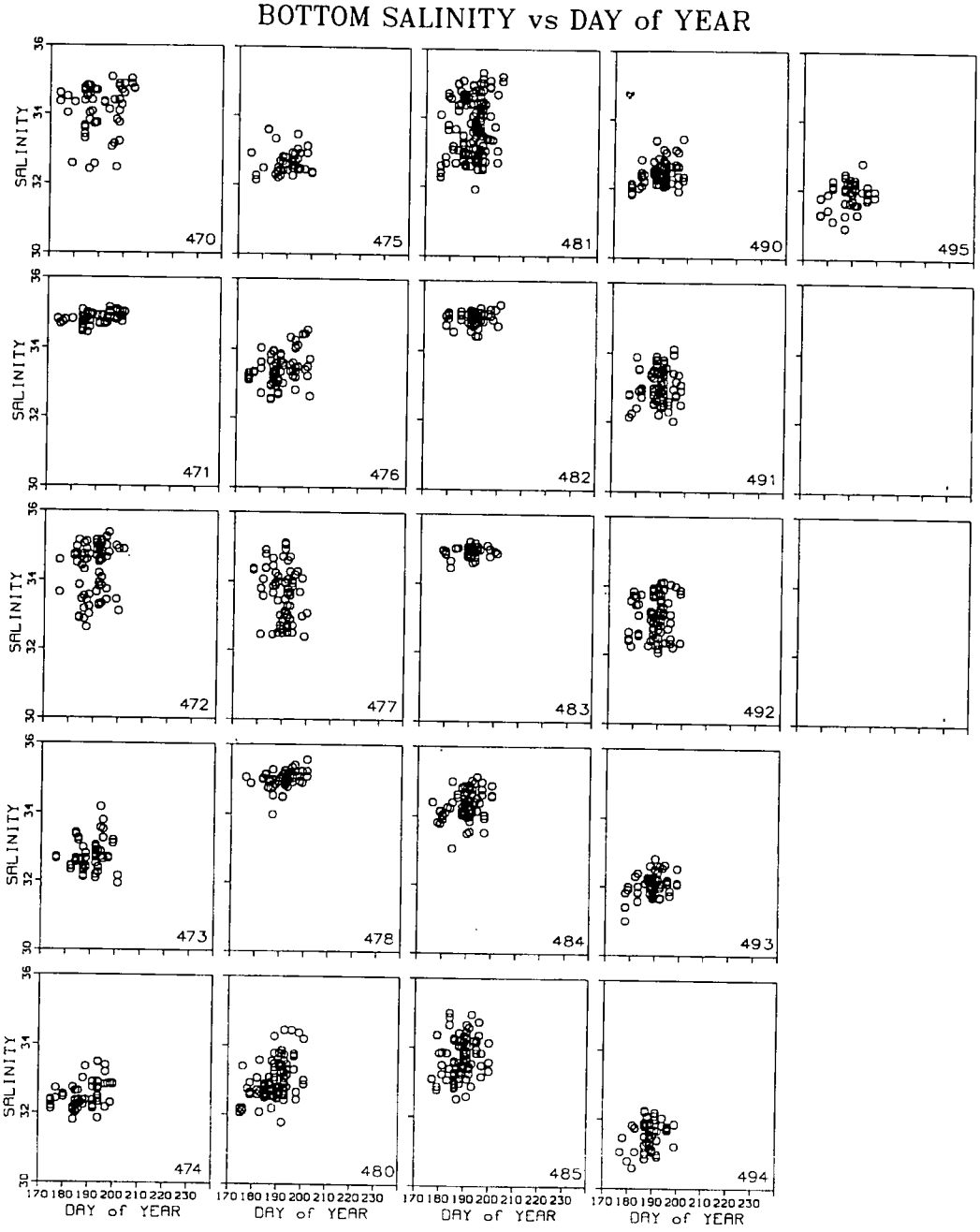

Figure 24: continued

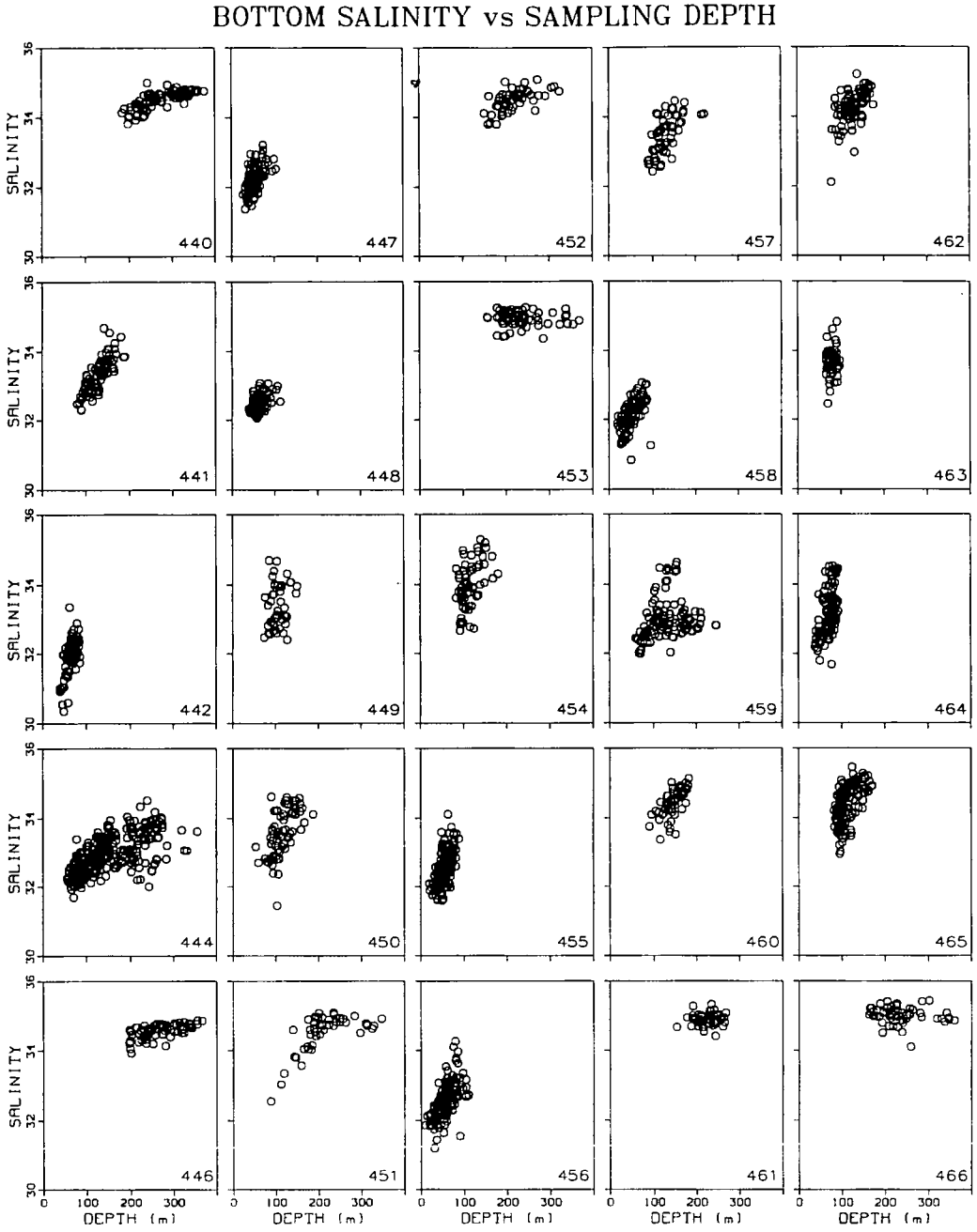

Figure 25: Near-bottom salinity within the summer 4VWX surveys in relation to sampling depth. The numbers and letters in the top right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

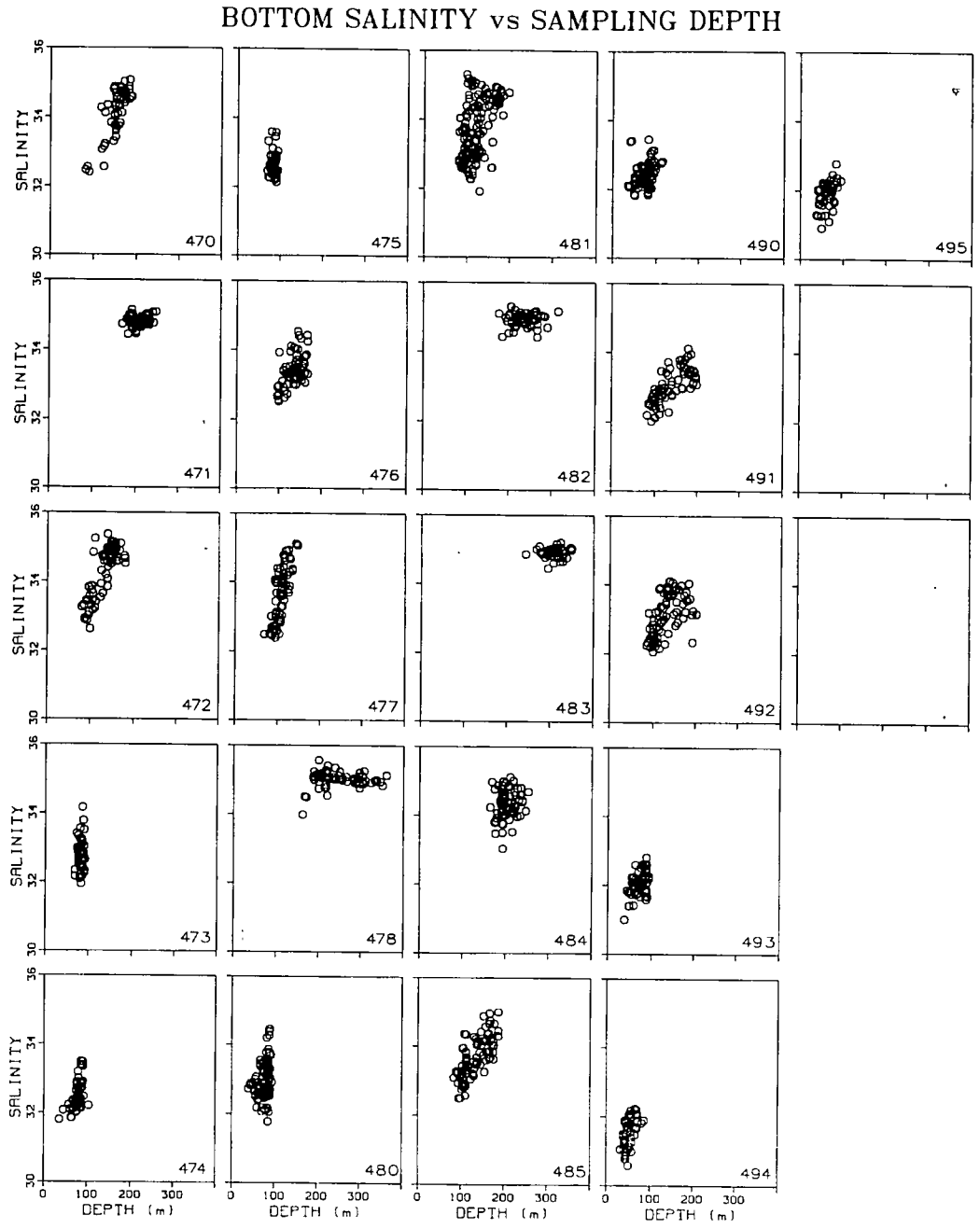

Figure 25: continued