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Variation in September near-bottom temperatures in the southern Gulf of St. Lawrence, 1971-1992

by

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Abstract

September bottom temperatures in the southern Gulf of St. Lawrence are described for the period 1971-1992 using data from annual groundfish abundance surveys. At depths between 40 and 59 m, bottom temperatures tended to be relatively warm in the 1970's and relatively cold since the mid-1980's. At depths between 60 and 149 m, bottom temperatures in 1990-1992 were among the coldest in the 1971-1992 time series. This is reflected in an unusually large area of bottom with subzero temperatures in September in these recent years. In 1992, an estimated 60% of the survey area had bottom temperatures below 1°C, with 15% below 0°C. Compared to a 1980-1990 baseline, 1992 temperature anomalies were negative in all depth zones and in 21 of 24 strata.

Résumé

On présente les températures de septembre au fond du golfe du Saint-Laurent pour la période 1971-1992, en se fondant sur les données provenant des relevés annuels d'abondance du poisson de fond. A des profondeurs se situant entre 40 et 59 m, ces températures avaient tendance à être relativement chaudes dans les années 1970 et relativement froides à partir du milieu des années 1980. A des profondeurs s'échelonnant entre 60 et 149 m, les températures de 1990 à 1992 étaient parmi les plus basses de la série chronologique 1971-1992. Cela s'est traduit par des températures inférieures au point de congélation dans une portion inhabituellement vaste des fonds marins en septembre ces dernières années. On a estimé que dans 60 % de la zone étudieé en 1992 la température des fonds marins était inférieure à 1 °C (et à 0 °C dans 15 % de cette zone). Comparativement aux données de référence de 1980-1990, les anomalies de température de 1992 étaient négatives dans toutes les zones de profondeur et dans 21 des 24 strates.

Introduction

Environmental conditions may influence both the population dynamics and assessment of commercially important groundfish resources. Water temperature is likely to be a key environmental factor in this regard (e.g., Fry 1971). Temperature is an important determinant of metabolic costs in fishes, and is expected to influence most aspects of population dynamics (i.e., rates of growth, reproduction and mortality). Water temperature also affects groundfish distribution (e.g., Rose and Leggett 1989; Smith et al. 1991; Sinclair 1993), and thus may influence stock assessment through effects on catchability and availability.

The purpose of this paper is to describe variation in near-bottom water temperatures in the southern Gulf of St. Lawrence over the period 1971-1992, and to relate the conditions in 1992 to those during a baseline period of 1980-1990. These comparisons use data from the annual groundfish abundance survey of the southern Gulf, conducted each September since 1971.

Material and Methods

The southern Gulf of St. Lawrence (NAFO division 4T) comprises a shallow shelf (mostly less than 75 m in depth) bordered on the north by the Laurentian Channel (Fig. 1). A goundfish abundance survey has been conducted in the southern Gulf each fall since 1971. This survey has used a stratified random design (Fig. 2). Strata 401-403 have been included in the survey only since 1984, and are not included in the analyses reported here. Survey timinghas varied between 31 Aug - 24 Sep in 1987 to 09 Sep - 06 Oct in 1978.

Near-bottom temperature was measured at most sampling stations. Measurements were made with reversing thermometers and mechanical bathythermographs (MBT) in 1971-1983, MBT's in 1984-1988, an electronic BT (Femto Model 8720) in 1989-1990, and a Seabird SBE-19 CTD in 1991-1992. The MBT's used in 1984-1988 permitted temperature measurements only to a depth of 145 m. Stations at depths greater than 155 m were omitted from all analyses for this period. (Only one station used in the 1984-1988 period was at a depth over 150 m). Bottom temperatures and depths were taken from the survey set files. Plots of bottom temperature against depth, and stratum-by-stratum time series plots were used to identify extreme temperatures. These were verified by reference to the original data sheets or profile files. Sample sizes by stratum and year are given in Table 1.

Spatial and annual variation in bottom temperature were examined using stratum-by-stratum plots of the individual observations and their annual means, time series plots of mean temperature by depth zone, and contour maps of bottom temperature. Interpolation for contour maps was by ordinary point kriging, with variograms fitted using GEOEAS. The 41x41 grid estimated using kriging was smoothed to a 201x201 grid using the SPLINE SMOOTH function of SURFER. SURFER was used to draw contour maps and to estimate for each year the area within the survey region with bottom temperatures below 0°C and 1°C. Grids for these latter analyses were estimated omitting stations at depths over 155 m in all years (to avoid bias relative

to the 1984-1988 results). The survey region used in these latter analyses omitted strata 415, 425 and 439 (where all stations were deeper than 155 m). Stratified mean temperature was calculated for each year omitting strata 415, 425, 426, 437, 438 and 439 (the strata with a high proportion of sets deeper than 155 m). To calculate this stratified mean, missing values for strata 424 and 428 in 1978 and for 421 in 1983 and 1988 were replaced by the average of the stratum means in the two years preceding and the two years following the missing value.

Conditions in 1992 were compared to a 1980-1990 baseline (the baseline period requested by the Chairman of the Fisheries Oceanography Subcommittee of the Department of Fisheries and Oceans). Comparisons were by stratum and depth zone. The baseline for strata 415, 425, 426, 437, 438 and 439 was calculated omitting the 1984-1988 period. A contour map of 1992 anomalies was drawn as follows. 41x41 grids were estimated for 1992 and each year between 1980 and 1990, omitting all sets deeper than 155 m. An anomaly grid was calculated by subtracting the mean of the 1980-1990 grids from the 1992 grid. This grid was smoothed to a 201x201 grid and plotted using SURFER.

Results

1992 Conditions

Station locations in 1992 are shown in Figure 3. Bottom temperatures were recorded from all strata. The minimum coverage per stratum was 2 stations, and the maximum coverage 22 stations (Table 1).

Near-bottom water temperatures are mapped in Figure 4. Bottom temperatures were less than 1°C over 60% of the survey region. Subzero bottom temperatures occurred over much of strata 423, 429 and 431 (15% of the survey area).

Within-Stratum Temperature Variation

Time series plots of bottom temperature by stratum are shown in Figure 5. Within-year variability in bottom temperature differs widely among strata. Variablility tended to be least in very deep strata (e.g., 415) and in strata at intermediate depths where temperatures were uniformly cold (e.g., 423, 427). Variability tended to be greatest in the strata straddling substantial depth changes in the shallow to intermediate depth range (e.g., 420, 422, 433). Extreme temperatures tended to be associated with extreme depths (i.e., unusually shallow or deep stations for the stratum in question). For example, the outliers in strata 425, 439, 423, 434, 436, 429 and 431 occurred at unusually shallow depths for these strata.

Annual variation in mean temperature within strata was high. Again, extreme means often reflected extremes in the depths sampled. Few clear annual trends in bottom temperature are apparent within strata (Fig. 5). A tendency for bottom temperatures to be relatively warm in the late 1970's and early 1980's and relatively cold in recent years is apparent in some strata (e.g., 417, 418, 422, 435). The stratified mean bottom temperature (omitting strata 415, 425, 426, 437, 438, 439) is shown in Figure 6. Mean bottom temperature tended to relatively high in the period

1978-1982 and relatively low since then. The stratified mean temperature was highest in 1980 and lowest in 1984.

Temperature Variation Within Depth Zones

Time series plots of temperature by depth zone are shown in Figure 7. At shallow depths (0-59 m), bottom temperature tended to be warm early in the time series (1971 to about 1980) and cold in recent years. This tendency was strongest in the 40-59 m depth interval. Bottom temperature varied less widely in the deeper depth intervals. At the intermediate depths (60-99 and 100-149 m), mean bottom temperatures in the 1990-1992 period were among the coldest recorded in the 1971-1992 time series.

Areal Extent of Low Bottom Temperature

Time series plots of the area within the survey region (excluding strata 415, 425 and 439) with bottom temperatures below 0°C and 1°C are shown in Figure 8. Maps of the area with bottom temperatures below 0°C are shown in Figure 9 for selected years. The estimated area with bottom temperatures below 0°C was exceptionally large in 1972, 1984, and 1990-1992. The estimated area with bottom temperatures below 1°C was also relatively large for 1990-1992.

1992 Anomalies from the 1980-1990 Baseline

1992 anomalies from the 1980-1990 baseline are shown by stratum and depth zone in Figure 10. Figure 11 shows contour maps of the 1980-1990 baseline and 1992 anomalies. The 1992 anomalies were negative in all strata except 419, 427 and 439. Anomalies were greatest in strata 418, 421, 428 and 435, all relatively shallow strata. The 1992 anomalies were negative in all depth zones. These negative anomalies were greatest in the shallow depth zones. The 1992 anomalies were negative over the entire survey area, except for small regions of positive anomaly southeast of the Magdalen Islands, east of Miscou Island, and at the head of Chaleur Bay (Fig. 11).

Summary and Conclusions

Identification of annual trends in bottom temperature in the southern Gulf from time series plots by stratum is hampered by erratic fluctuation in annual means in many strata. This variability results at least partly from annual variation in the depths sampled within strata. Time series plots within depth zones indicate that bottom temperatures in the 40-59 m zone were relatively warm in the 1970's and cold since the mid-1980's. At intermediate depths (60-149 m), bottom temperatures in 1990-1992 were among the coldest in the 1971-1992 time series. The area of subzero bottom temperatures was much larger in 1990-1992 than in all other years in the time series except 1972 and 1984. Compared to a 1980-1990 baseline, 1992 bottom temperature anomalies were negative in all depth zones and in all but 3 of 24 strata.

Literature Cited

Fry, F. E. J. 1971. The effect of environmental factors on the physiology of fish. p. 1-98. *In* W. S. Hoar and D. J. Randall [eds.] Fish Physiology, Vol. VI. Academic Press, New York, NY. 559 p.

Rose, G. A., and W. C. Leggett. 1989. Interactive effects of geophysically-forced sea temperatures and prey abundance on mesoscale coastal distributions of a marine predator, Atlantic cod (*Gadus morhua*). Can. J. Fish. Aquat. Sci. 46: 1904-1913.

Sinclair, A. 1993. Fish distribution and partial recruitment: the case of eastern Scotian Shelf cod. J. Northw. Atl. Fish. Sci. 13: 14-25.

Smith, S. J., R. I. Perry, and L. P. Fanning. 1991. Relationships between water mass characteristics and estimates of fish population abundance from trawl surveys. Environmental Monitoring and Assessment 17: 227-245.

Table 1. Numbers of stations with bottom temperature records in the fall groundfish abundance surveys of the southern Gulf of St Lawrence, 1971-1992.

Stratum	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
401	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	3	3	3	4	2	3	3
402	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	4	4	1	0	2	0	3
403	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	1	2	3	3
415	3	3	3	3	3	2	2	2	3	3	3	3	3	0	0	0	0	0	6	5	7	5
416	6	6	6	5	4	6	3	5	6	6	6	6	5	5	4	8	8	5	7	7	9	8
417	5	5	5	6	4	5	3	6	6	5	6	4	4	5	3	7	6	5	6	4	5	3
418	3	3	3	2	4	3	3	3	3	4	4	5	5	5	4	6	6	4	6	3	4	2
419	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4	3	3	6	3	4	3
420	4	4	4	4	3	4	2	3	5	3	3	3	3	4	3	6	6	3	5	5	8	7
421	2	2	2	2	2	1	1	2	3	2	2	2	0	3	2	3	3	0	3	2	3	4
422	4	5	6	5	5	5	3	5	6	6	5	4	5	9	6	11	10	6	11	9	9	11
423	3	4	5	4	4	4	4	2	4	4	4	4	4	3	4	9	6	3	19	20	22	22
424	2	3	3	3	3	3	1	0	3	3	3	3	2	4	2	6	6	3	7	6	9	8
425	2	2	2	2	2	2	2	1	2	2	2	2	2	0	0	0	0	0	4	3	5	4
426	2	2	2	2	2	2	1	2	2	2	2	2	2	2	1	3	1	2	4	3	3	3
427	3	2	2	2	2	2	2	2	3	2	2	2	2	1	1	3	4	1	8	6	7	7
428	2	3	2	2	2	2	2	0	2	2	2	2	2	1	2	3	3	2	4	2	3	3
429	4	3	3	3	3	3	3	3	3	3	2	3	2	5	3	6	6	3	11	11	15	11
431	3	3	3	3	3	1	2	3	3	5	3	3	3	4	1	7	4	2	11	9	14	10
432	2	2	2	2	2	2	2	2	2	2	1	2	2	4	1	2	2	2	3	3	4	3
433	2	3	3	3	3	3	2	3	3	3	3	3	3	7	3	9	9	4	11	9	11	9
434	2	3	3	3	3	3	3	3	4	3	3	3	3	5	2	7	6	3	8	8	14	8
435	2	3	3	2	2	1	2	2	2	2	2	2	2	4	2	5	5	2	4	3	6	4
436	2	2	2	2	2	2	2	2	2	2	2	2	2	5	3	5	5	1	8	8	10	7
437	3	3	3	3	3	3	2	3	3	3	3	3	3	2	1	3	3	0	5	4	5	3
438	2	2	2	2	2	2	2	2	2	2	2	2	4	1	1	2	2	0	3	3	4	3
439	2	2	2	2	2	2	2	2	2	2	2	2	2	0	0	0	0	0	4	2	5	2

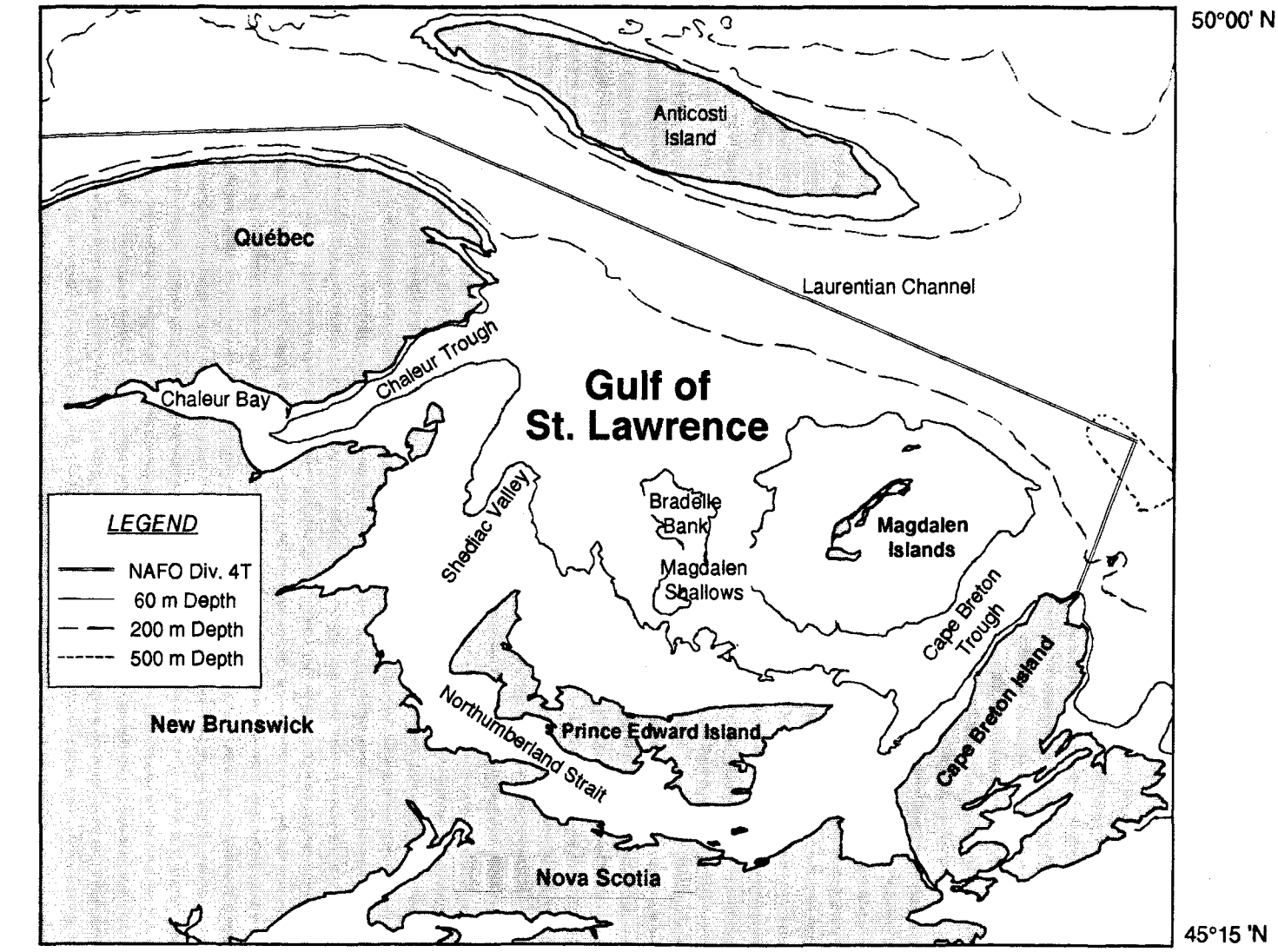

Figure 1. Bathymetric map of the southern Gulf of St. Lawrence.

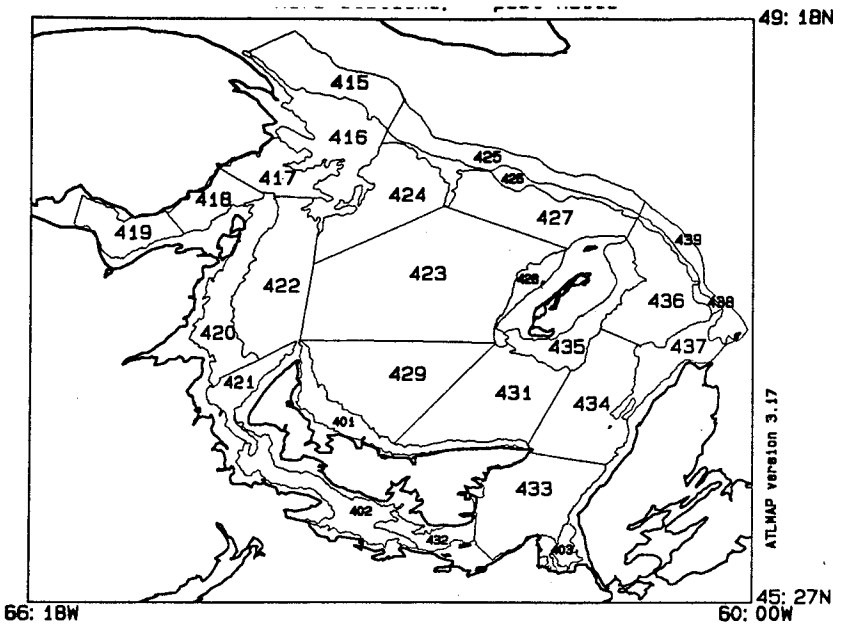

Figure 2. Strata for the groundfish abundance surveys of the southern Gulf of St. Lawrence.

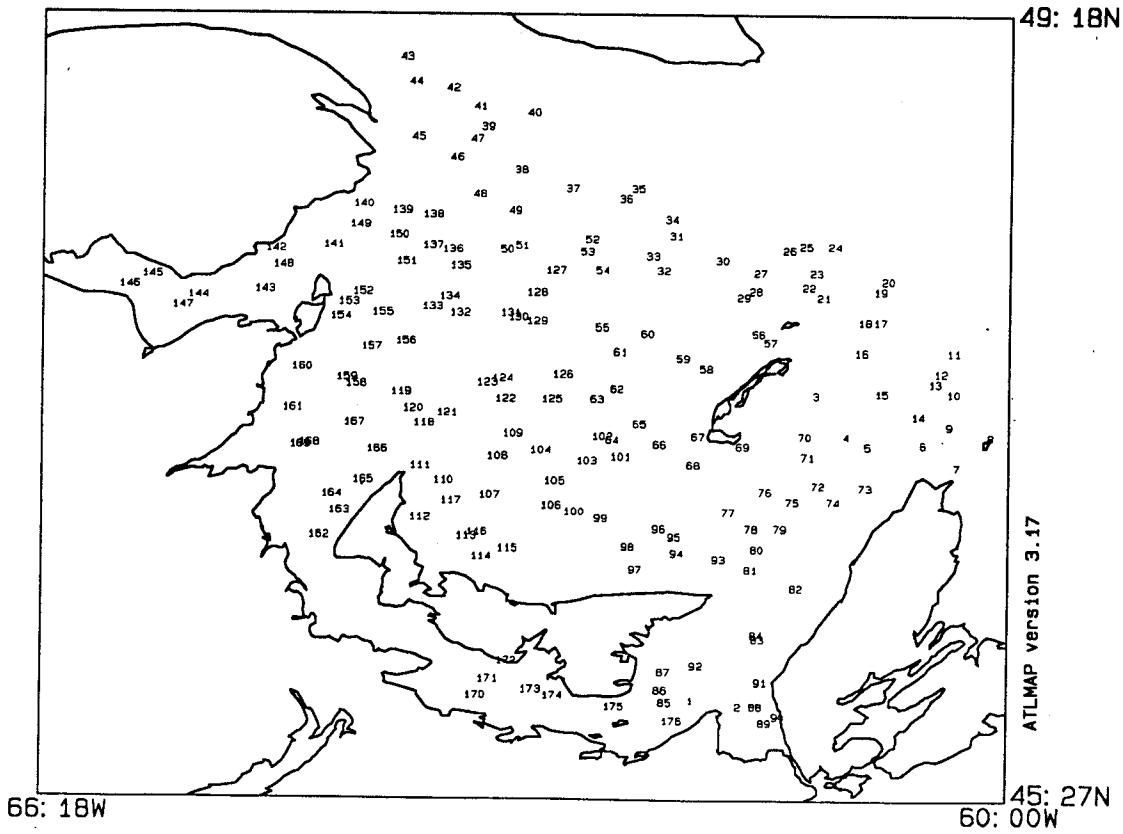

Figure 3. Station locations of the 1992 groundfish abundance survey of the southern Gulf of St. Lawrence (N178).

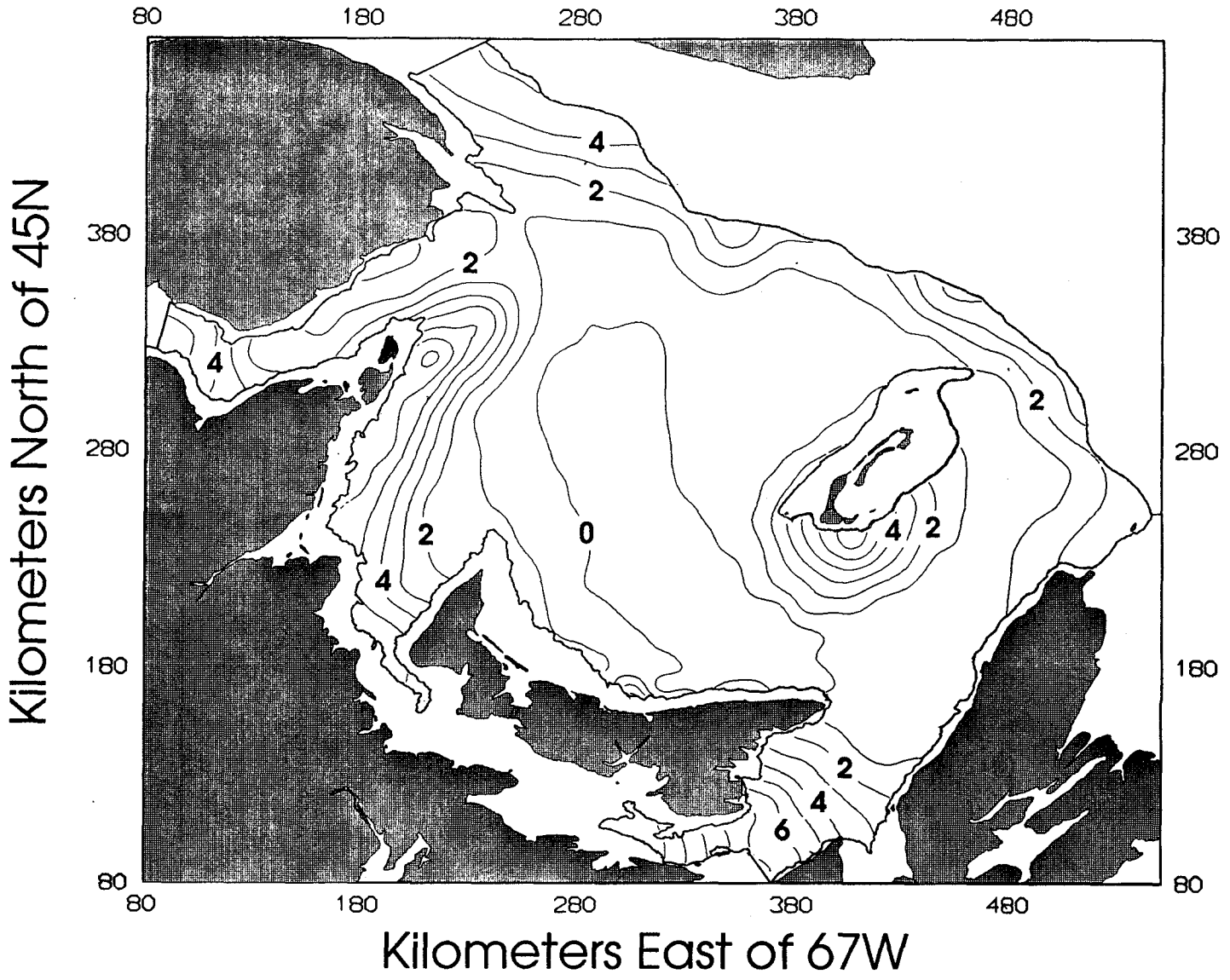

Figure 4. Bottom temperature in the southern Gulf of St. Lawrence, September 1992. Contour interval is 1°C.

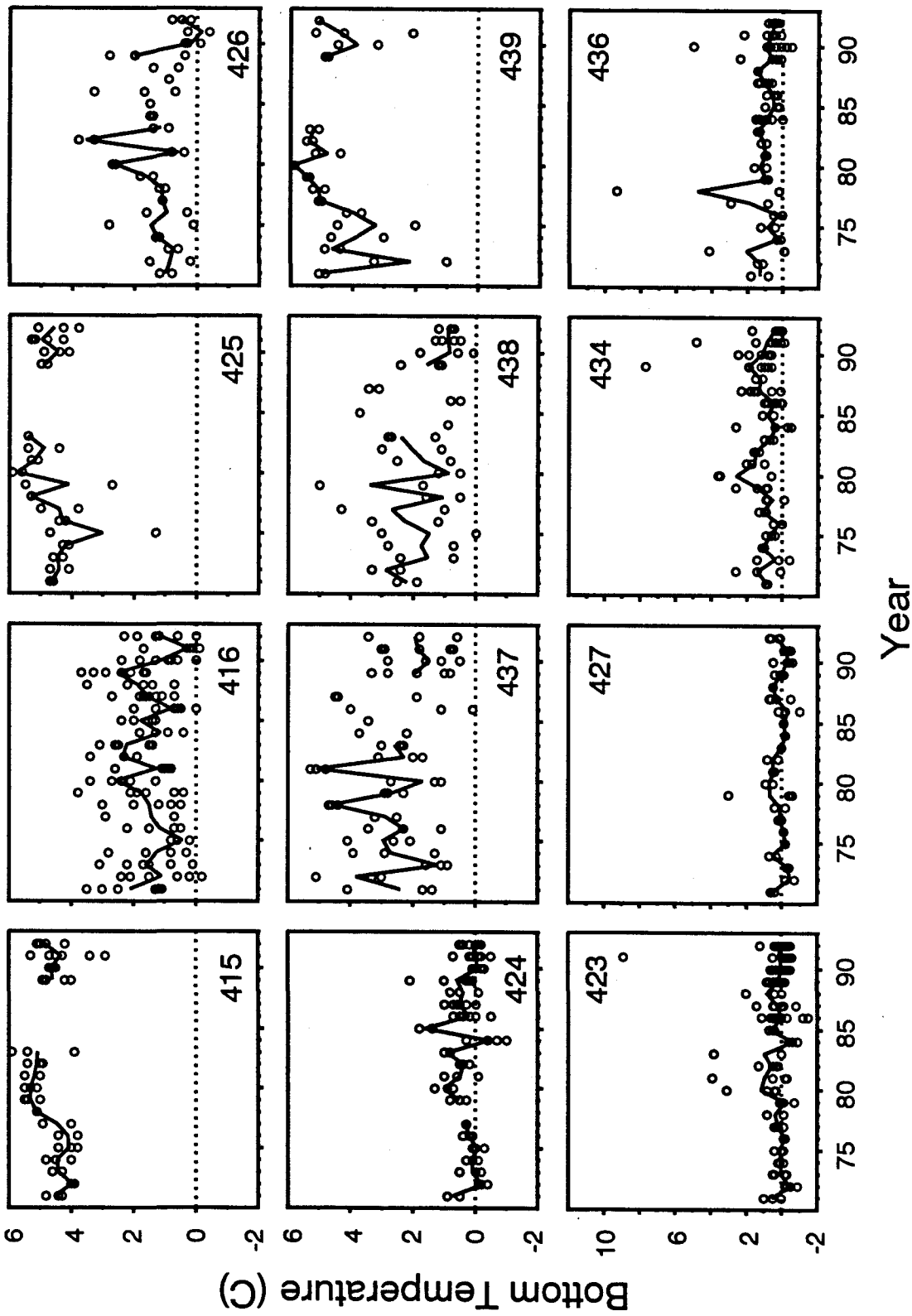

Figure 5. Near-bottom temperatures recorded during September groundfish abundance surveys of the southern Gulf of St. Lawrence, 1971-1992. Labels in panel corners indicate stratum; circles are individual observations; solid lines show annual stratum means.

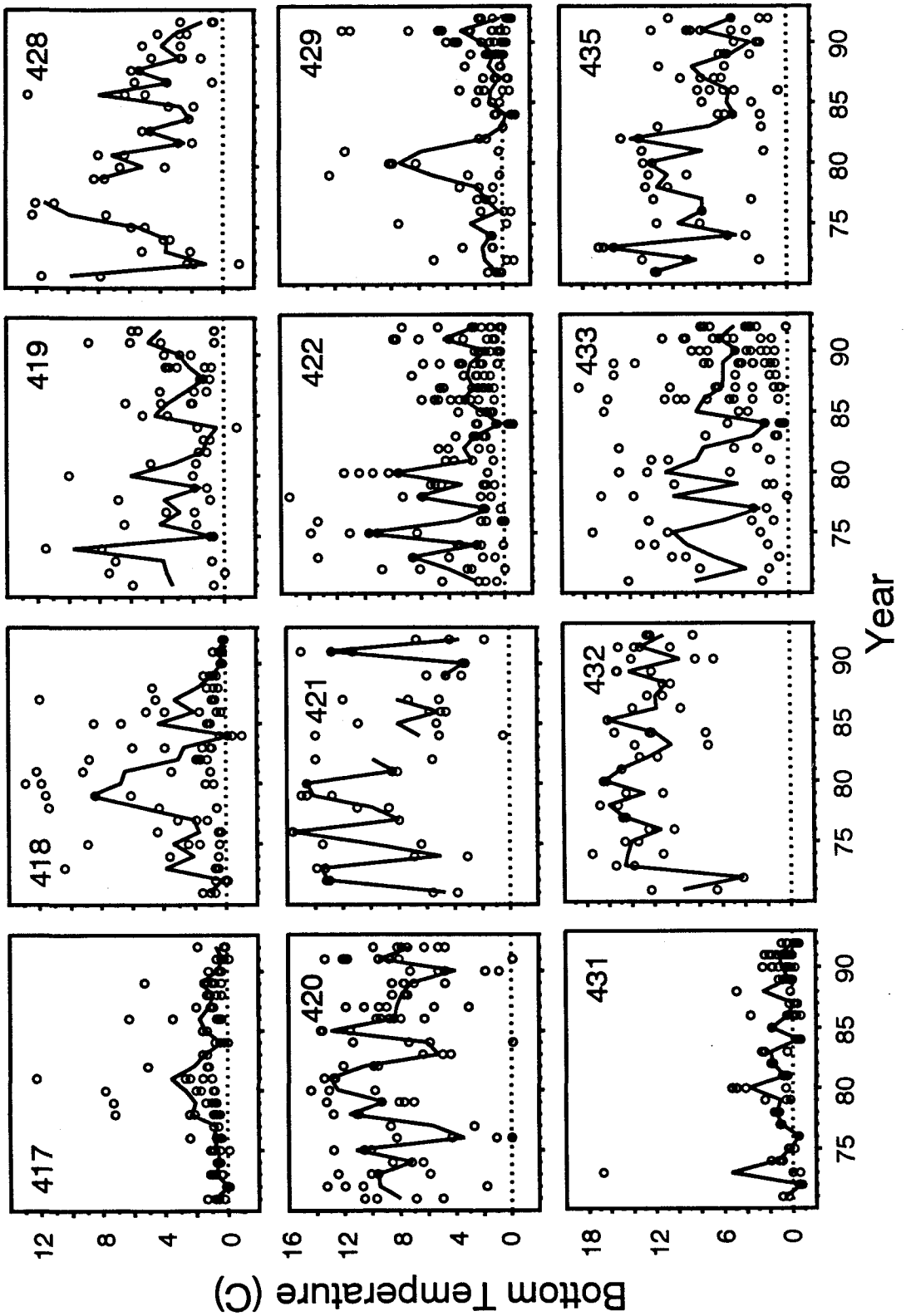
Bottom Temperature (C)
Year
417
418
419
428
420
421
422
429
431
432
433
435
75
80
85
90
0
4
8
12
16
18
6

Fig. 5. Cont'd.

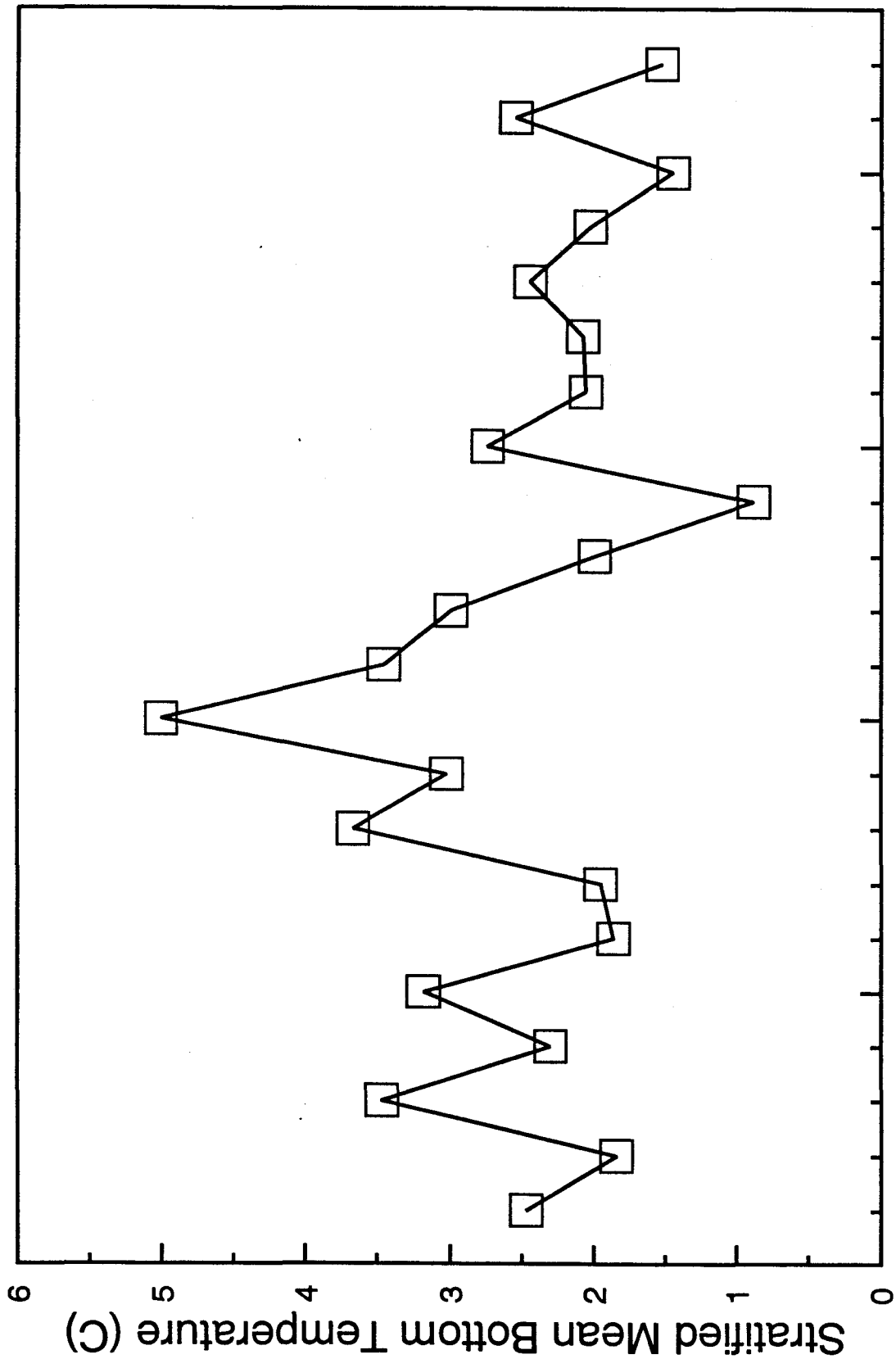

Figure 6. Stratified mean bottom temperatures in September groundfish abundance surveys of the southern Gulf of St. Lawrence, 1971-1992. Strata 415, 425, 426, 437, 438 and 439 omitted due to missing values for depths over 155 m in 1984-1988.

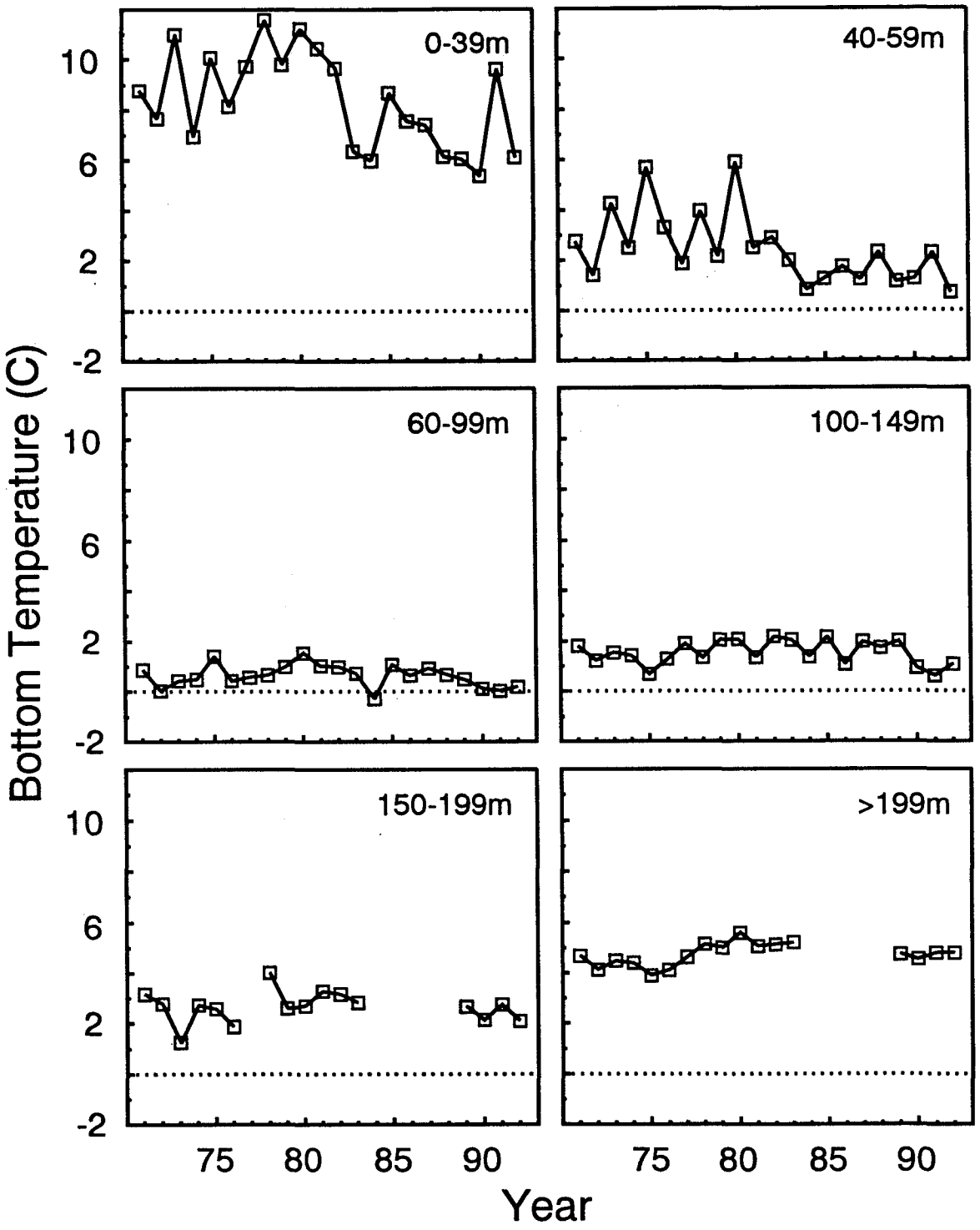

Figure 7. Annual mean bottom temperatures by depth zone in the southern Gulf of St. Lawrence, 1971-1992.

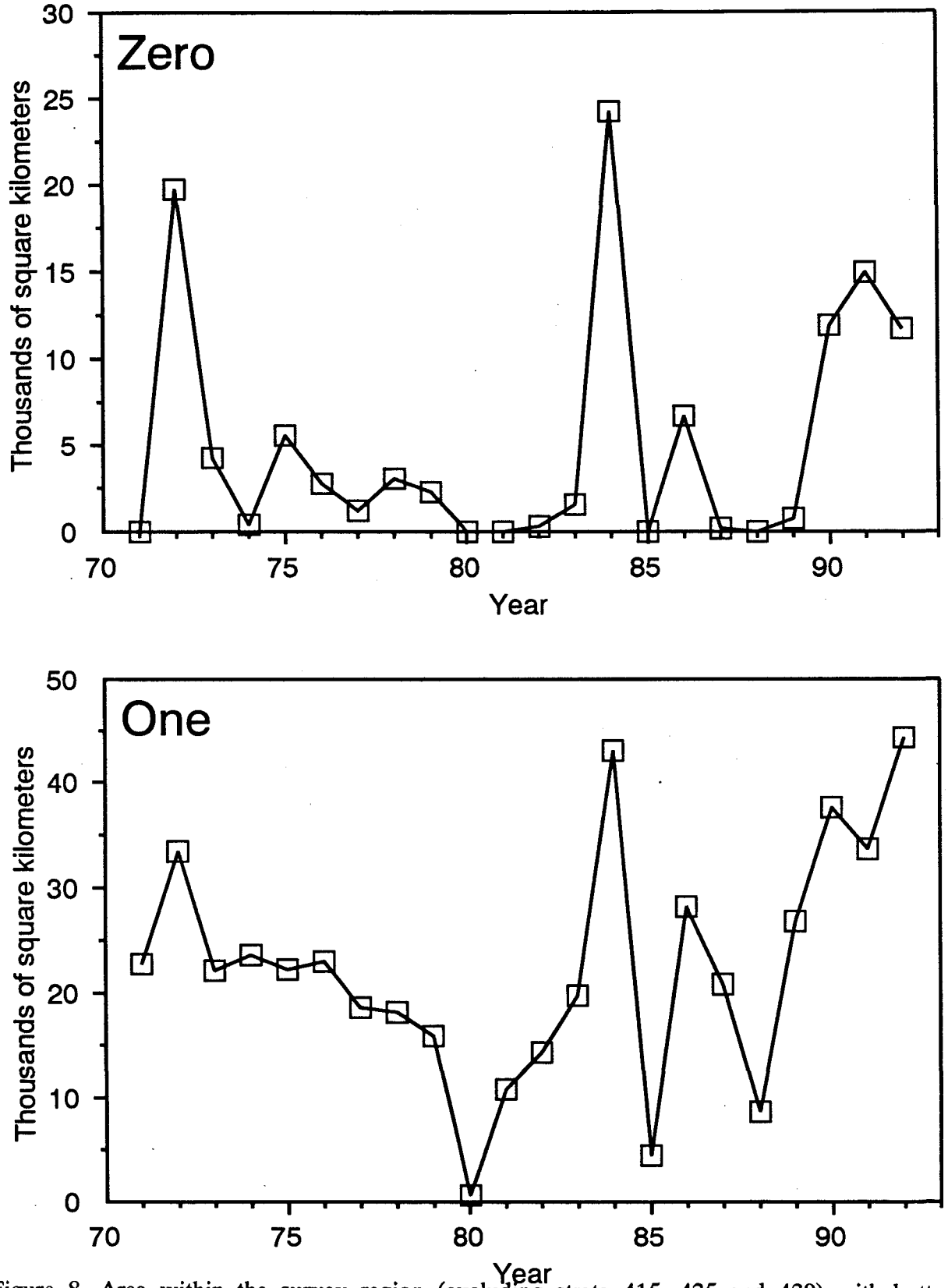

Figure 8. Area within the survey region (excluding strata 415, 425 and 439) with bottom temperature below 0°C (upper panel) or 1°C (lower panel) for each year between 1971 and 1992.

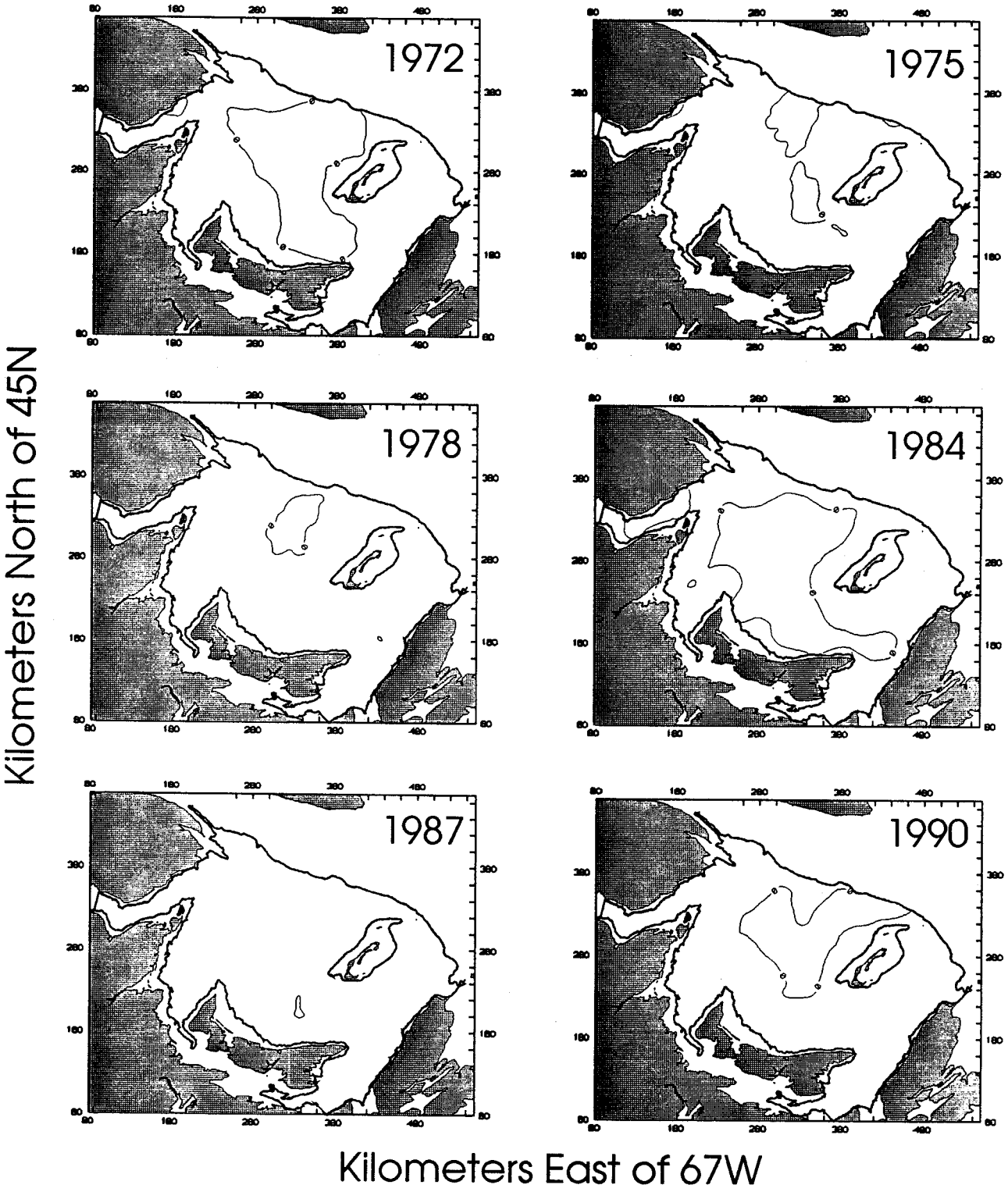

Figure 9. The 0° contour in September in the southern Gulf of St. Lawrence for selected years in the 1971-1992 time series.

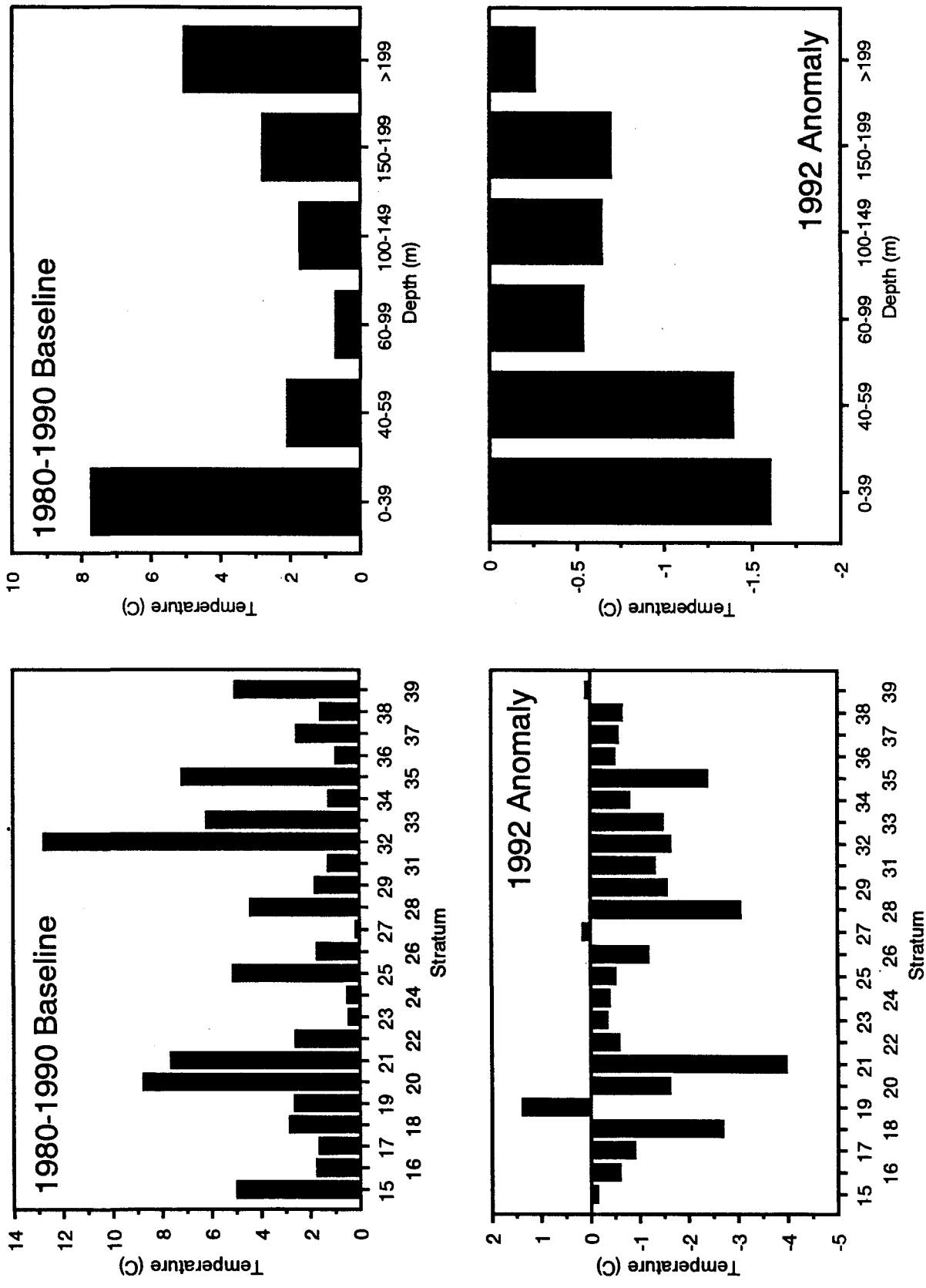

Figure 10. Bottom temperatures in the 1980-1990 baseline and 1992 anomalies from the baseline by stratum and depth zone.

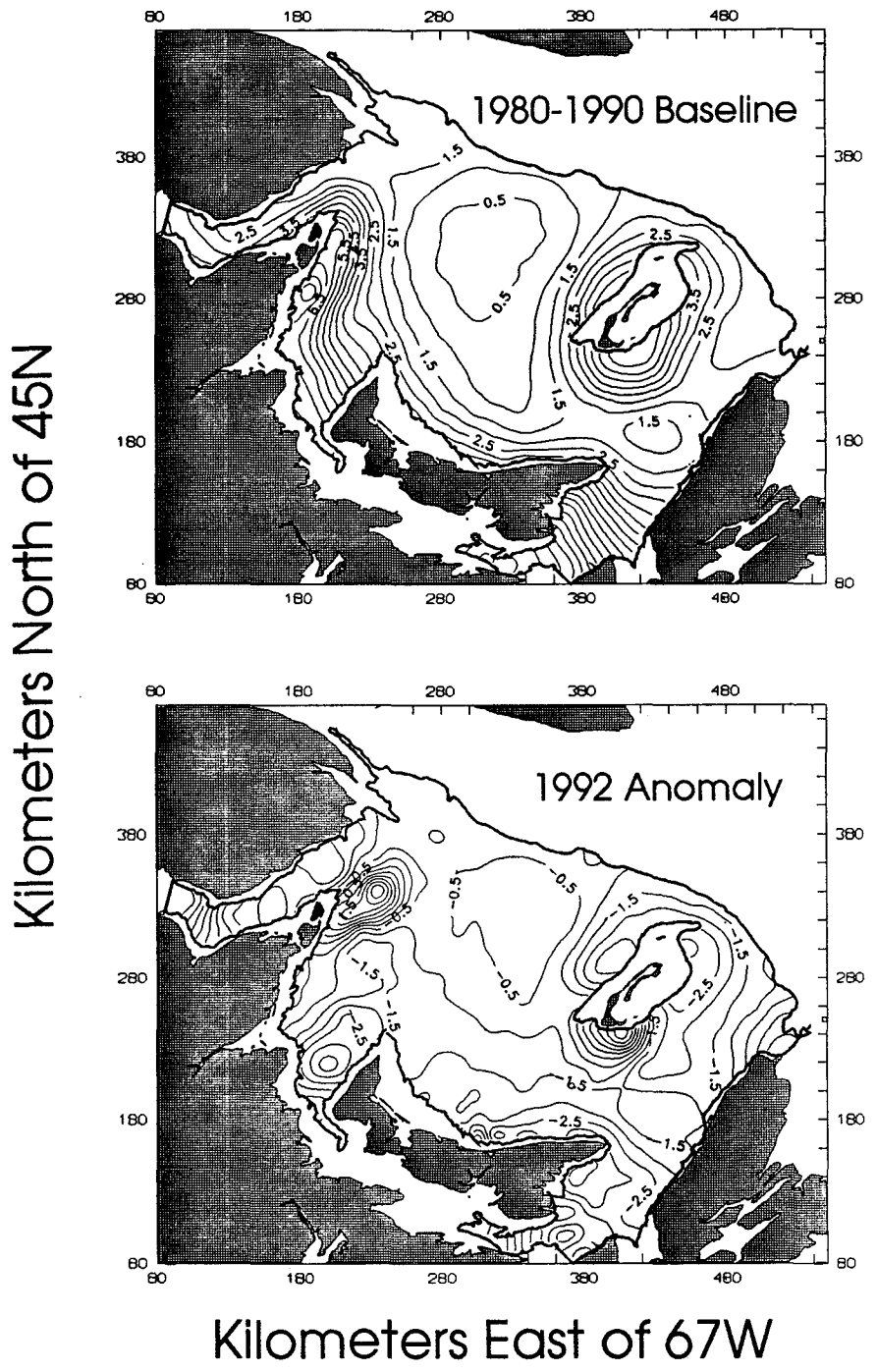

Figure 11. Contour maps of average September bottom temperatures in the 1980-1990 baseline and of 1992 anomalies from the baseline in the southern Gulf of St. Lawrence.