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Implications of Temperature and Haddock Associations on Survey Abundance Trends

by

S. J. Smith

Department of Fisheries and Oceans,
Bedford Institute of Oceanography,
Dartmouth, Nova Scotia, B2Y 4A2

and

F. Page

Department of Fisheries and Oceans,
Biological Station,
St. Andrews, New Brunswick, E0G 2X1

Abstract

Temporal trends in haddock abundance and depth distribution on the Scotian Shelf (NAFO areas 4VWX) were estimated from the Canadian groundfish bottom trawl surveys and compared with trends in near-bottom water temperatures. On the eastern Scotian Shelf (NAFO area 4VW) haddock abundance has declined, particularly in 4V which comprises approximately 10% of the 4VW haddock resource. The decline coincides with a decrease in water temperature and a reduction in the proportion of near-bottom water above 2°C, a lower threshold temperature for haddock. On the western Scotian Shelf (NAFO area 4X) haddock abundance has decreased on some of the offshore banks and this also coincides with decreasing temperatures. However, changes in the haddock abundance for 4X as a whole do not appear to be related to changes in water temperature. Therefore, while declining near-bottom temperatures appear to be associated with lower abundance indices of haddock in 4V and parts of 4W, declining near-bottom temperatures by themselves cannot explain the lower abundance indices in all areas.

Résumé

On a estimé les tendances temporelles de l'abondance de l'aiglefin et de la distribution de ce dernier selon les profondeurs sur la plate-forme néo-écossaise (zones 4VWX de l'OPANO) en se fondant sur les relevés de recherche du poisson de fond au chalut réalisés par le Canada, et on les a comparées aux tendances des températures de l'eau à proximité du fond. Dans l'est de la plate-forme néo-écossaise (zones 4VW de l'OPANO), l'abondance de l'aiglefin est en recul, en particulier dans 4V, où se trouve environ 10 % de la ressource en aiglefin de 4VW. Ce recul coïncide avec une baisse de la température de l'eau et une diminution à proximité du fond du pourcentage des eaux de plus de 2 °C, seuil extrême de température pour l'aiglefin. Dans l'ouest de la plate-forme (zone 4X de l'OPANO), l'abondance de l'aiglefin a diminué sur certains des bancs de pêche hauturière, ce qui coïncide aussi avec une baisse des températures. Toutefois, les tendances de l'abondance de l'aiglefin dans l'ensemble de 4X ne semblent pas liées à des changements de température. Par conséquent, s'il apparaît que la baisse des températures des eaux situées près du fond s'accompagne d'une diminution de l'abondance des indices d'aiglefin dans 4V et dans certaines parties de 4W, cette baisse de température ne peut, en soi, expliquer le recul de l'abondance dans toutes les zones.

Introduction

Recently, there have been a number of studies describing the associations between catches of groundfish in survey bottom trawl sets and associated hydrographic conditions, particularly depth, temperature and salinity (Scott 1982, Smith 1990, Sinclair 1992, D'Amours 1993, Page et al. 1994, Perry and Smith 1994, Smith et al. 1994). In general, the studies indicate species specific associations with the hydrographic variables and in at least one case, interannual variation in hydrographic conditions corresponds with variation in estimates of fish abundance (Smith et al. 1991).

Hydrographic conditions in the eastern Scotian Shelf have changed in recent years (Page et al. 1994) as have estimates of the abundance of commercial fish species such as cod and haddock (Sinclair 1993). More specifically, the number of sampling stations with sub-zero water was anomalously high during the 1991 and 1992 research vessel summer surveys and the near-bottom temperatures in some survey strata decreased during the 1986–92 period (Page et al. 1994). Preliminary analyses suggested that the strata in which hydrographic conditions were changing the most were also the strata in which cod abundances were changing (Page and Losier, unpublished manuscript).

The purpose of the present paper is to explore the relationship between changes in near-bottom temperature and the changes in the haddock abundance index. Haddock are "temperature keepers" (Perry and Smith 1994, Smith et al. 1994). They are seldom found below 2°C and they maintain a similar range of temperatures during the spring, summer and fall by changing their seasonal depth distributions. Their distribution and abundance indices within specific areas are therefore likely to be affected by the movement of anomalously cold water into their distribution area.

Material and Methods

The fish catch and hydrographic data sets presented here were obtained from the standard groundfish trawl surveys of the Scotian Shelf conducted by the Marine Fish Division (Bedford Institute of Oceanography, Dartmouth, N.S.) and Biological Station (St. Andrews, N.B.) of the Canadian Department of Fisheries and Oceans. These surveys use a stratified random survey design (Cochran 1977, Smith 1988). The Scotian Shelf strata for the summer surveys (1970–1993, Fig. 1) are primarily based on depth boundaries of 50, 100 and 200 fathoms (91, 183 and 366 m). Further delineations of the strata boundaries reflect species/stock distributions (Doubleday 1981, Halliday and Koeller 1981). The strata for the March surveys (1979–1984) were the same as those used in the summer survey (Fig. 1). Since 1986 the strata in Fig. 2 were used for the March survey. These new strata were derived from the historical spatial distributions of cod observed during surveys in March 1979–1982 in 4VsW (Smith and Gavaris 1993).

The sample unit for the survey is defined as the area over the bottom covered by a trawl of a specific width (12.5 m) towed at 3 knots for a distance of 1.75 nautical miles. These sample units or sets were selected before the cruise and randomly located in each stratum.

The hydrographic data were collected immediately following each bottom trawl. Prior to 1990, this collection consisted of surface and near-bottom temperature and salinity measurements at all stations. At a subset of stations, consisting of about 30% of the trawl stations occupied during each cruise, temperature and salinity measurements were taken at standard hydrographic depths

using reversing thermometers, water bottles and a laboratory salinometer. After 1989 profiles of temperature and salinity were taken at each station with either a Sea-Bird[1] model 19 or 25 CTD (Conductivity, Temperature and Depth) profiler. Water samples and reversing thermometer measurements were taken near the surface and bottom at each station for use in calibrating the CTD's. Note that sampling the hydrography in this way cannot resolve variability and fish-environment associations at scales finer than the length of a tow.

All of the hydrographic data has been edited and put through quality control procedures using range and variance checks and checks for density inversions. Only the near-bottom temperatures and salinities, those taken within about 20 m of the bottom, are used in this report. Depths used for the analyses corresponded to the depth at which hydrographic measurements were taken.

Results

NAFO Area 4VW

The general trend for stratified mean numbers per tow from the summer survey of NAFO area 4VW (strata 440–466) shows that haddock were least abundant in both 4V and 4W in the early 70's with a rapid increase in 4W after 1976 (Fig. 3). The survey index peaked in 4W at 136.05 in 1983 and has oscillated at a lower level of around 70 since then. The increase in 4V began much later (1981), peaked in 1982 and then declined back to pre-1975 levels by 1989. In both areas the indices for ages 1–3 were the first to show the increases followed by the older ages (Zwanenburg 1992). However, the increase in 4W began with the 1975 and 1976 yearclasses which did not appear in the 4V survey in any numbers. The increase in 4V was mainly due to the 1981 yearclass which was also strong in 4W (Tables 1, 2).

The spring survey series of NAFO area 4VW was initiated in 1979 and was replaced with a new stratification scheme in 1986. No survey was made of the area in 1985. While the entire 4VW area was included in the survey plans, ice often restricted the vessel so that only the 4VsW (strata 443–466) area received consistent coverage, although there was limited coverage of 443–445 in some years. The post-1986 survey was designed for 4VsW only.

The general trends for 4VW haddock from the spring survey were similar to those of the summer survey in that they both indicate an increase in the early 1980's (Fig. 3–4). However, the trends differ in other respects. In the summer series the abundance in 4V peaked a year before the abundance in 4W (Fig. 3) and in the spring series the 4V abundance peaked several years after that in 4W (Fig. 4). The abundance declined rapidly after 1981–84 in both spring series and in the summer 4V series but in the summer 4W series the abundance stabilized after about 1985.

Temperatures in 4W in both spring and summer were warmer on average than in 4V in either season (Fig. 5). All series show a decline since the mid-1980's and evidence for recent warming trends. Note that average temperatures in 4V have dipped below 2°C in 1989–1991 in the summer series and in every year but 1981 and 1984 in the spring series. The threshold of 2°C is a critical one in that haddock are seldom found below 2°C (Smith et al. 1994).

The median depth that the haddock were associated with appears to have declined during the early 1980's and increased during the late 1980's and early 1990's in 4W and 4V during the spring survey and summer surveys (Fig. 6). These recent increases in depth in 4V suggest that either

[1] Sea-Bird Electronics, Inc, 1808-136th Place NE Bellevue WA 98005, USA

the fish have moved into deeper water in 4V or into the 4W area, or that there have always been haddock in the deeper water and their abundance in shallow water has been reduced due to recent increases in fishing pressure. The 1993 spring survey point in 4V is not comparable to the other years since severe storms and equipment failures limited hydrographic sampling to mainly shallow areas.

Summer

Haddock were not widely spread throughout the survey area and in fact, exhibit quite persistent localized distributions. In 4V (Fig. 7) almost all of the trend in Fig. 3 can be explained by catches in the Banquereau strata (447,448,449,450,451). The Sable Island and Western Bank strata (454,455,456,464) explain most of the trend in 4W with minor contributions from Middle Bank (457,458) and Emerald Bank (463,465) (Fig. 8).

Historically, 4V temperatures were warmer on Banquereau than in other areas in 4V combined until recently where temperatures have dropped to below 2°C in all areas (Fig. 9, Table 3). The series for 4W indicates that the coolest temperatures were in the Middle Bank area while the warmest were on Emerald (Fig. 10, Table 4). The trend on Middle Bank is parallel to the series in 4V although somewhat warmer.

Smith et al. (1994) showed that haddock were almost always associated with water $\geq$ 2°C in the surveys and we present the trends for the proportion of bottom water in the survey that was $\geq$ 2 and $\geq$ 3°C over the time series for the Banquereau strata in Fig. 11. Note that these proportions have been generally decreasing since 1984. Fitting smoothed curves to these data using locally weighted regression methods (Cleveland 1979) and overlaying these curves on the plot for stratified mean number per tow for the Banquereau strata shows that the decline in the prevalence of this warm water appears to be coincident with the decline in the survey index since 1980 (Fig. 12). The smooth curves make it look like the declines in the proportions of water $\geq$ 2°C and $\geq$ 3°C were parallel whereas in reality the decline of the latter type of water began after 1981 in step with the decline of the haddock abundance index while the former appeared to decrease after 1984 (Fig. 11).

The proportion of water $\geq$ 2°C in 4W was much higher than for 4V (Fig. 13). The only area where conditions resembled those in 4V was on Middle Bank. The trend for the proportion of water $\geq$ 3°C on Middle Bank indicates that much of the warmer water that was available was between 2 and 3°C in the most recent years.

Spring

The strata in 4V where most of the haddock were consistently caught in during the spring survey were not quite the same as those for the summer series. While the Banquereau strata were important, it was the deeper strata (449, 450 and 451) as well as strata 452 in the Gully that were most important during 1979–1984 (Table 5). The deep strata 402 which encircles Banquereau, 404 and 405 in the Gully were the most important in 1986–1994 period. During 1979–1984, Sable, Emerald and the deeper water around Emerald Bank contained most of the haddock caught. Very few haddock were found on Middle Bank during this period (Table 6). More recently, the haddock appear to be confined to strata 408 and 410 which comprise the western end of Sable (including Western Bank) and the deeper water around Emerald Bank.

Mean temperatures in the shallow strata on Banquereau during 1979–1984 (447, 448) and 1986–1994 (403) were consistently below 2°C (Table 7). Similarly, mean temperatures in many of the shallow strata (455, 456, 458; 409) in 4W were often below 2°C (Table 8).

The trends for the proportion of bottom water $\geq$ 2°C in the key strata for 4V and 4W described above are presented in Fig. 14. The areas covered by the new strata and old strata around Banquereau coincide reasonably well and the series indicates that the proportion of warm water has decreased in the most recent time (recall that 1993 was a questionable point). The trends for 4W are less meaningful because the strata around Sable and Emerald Bank for the old and new designs are not quite coincident.

NAFO Area 4X

Summer

The trends for the stratified mean number and mean temperature for haddock in NAFO subdivision 4X are presented in Fig. 15. Mean numbers of haddock have fluctuated widely over the last 24 years with peaks in 1968, 1977, 1981–82 and 1985. The 1993 estimate of 11.52 is the lowest in the series. In the last two years only two strata (480 — Browns Bank; 490 — N.S. Bay of Fundy, Digby Bight, German Bank) appear to be contributing most of the signal to the stratified mean (Table 9). In the past strata 470, 472–477 had contributed more to the overall mean abundance.

The mean temperature does not appear to show any specific trend over the series and was well up in the range that haddock associate with (Fig. 15). Mean temperatures by stratum likewise do not seem to indicate much of a problem for most of the strata, although the East Banks area (strata 473–475 = LaHave, Roseway and Baccaro Banks, respectively) appear to be quite cold compared to the other strata (Table 10). This trend not only deviates from that of the area as a whole but from the deeper areas in the same region (East offshore) as well (Fig. 16). However, because the East Banks strata cover smaller areas relative to the size of the offshore strata, their catches do not contribute significantly to the survey index. Browns Bank shows some cooling in the recent years but the mean temperature is still above 4°C. Therefore, cooling on the banks themselves can not explain the decrease in the survey index for the entire 4X area.

Discussion

If we assume that haddock are limited to bottom water with temperatures of $\geq$ 2°C, then it appears that available habitat may be decreasing in 4V during the time of the spring and summer surveys. In both seasons, haddock appear to be found in deeper (and warmer) water for the most part, supporting this hypothesis.

The trend in 4W spring is not as clear mainly because the areas covered by the new and old strata are not coincident. In the summer survey of 4W, the bottom water does not seem to be limiting in the Sable and Emerald strata and the mean number of haddock in these areas appears to have been stable since 1985. However, cooler water appears to be intruding onto Middle Bank and the survey abundance there is down compared to the peak in 1983.

Although, the distribution of haddock in 4X appears to have become restricted in recent years, it does not appear that a decline in the temperature of the bottom water can account for this change

in distribution. It is interesting to note that the temperatures on the banks in the East Banks area (strata 473–475) have declined, but these banks contribute only a small amount to the overall index because of their small area.

In conclusion, declining near-bottom water temperatures appear to have reduced available habitat for haddock in 4V and parts of 4W which may in part account for the lower abundance indices in these areas. However, declining temperatures by themselves cannot explain the lower abundance indices in all areas.

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Table 1. Mean number of haddock for each stratum in 4V from the summer survey of the Scotian Shelf.

	Stratum Number												
Year	440	441	442	443	444	445	446	447	448	449	450	451	452
1970	0.00	0.75	2.33	0.00	0.00	0.00	0.00	4.25	29.00	0.00	0.00	0.00	0.00
1971	0.00	0.50	0.00	0.50	0.00	0.00	0.00	0.00	0.50	6.50	9.50	0.00	1.50
1972	0.00	0.50	0.00	0.00	6.40	0.00	0.00	1.83	0.00	7.50	36.67	0.00	0.00
1973	0.00	0.33	0.00	0.00	0.25	0.00	0.00	1.00	0.50	1.50	1.50	0.00	1.00
1974	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	7.00	0.00	4.50
1975	0.00	3.67	0.00	0.00	0.25	0.00	0.00	2.50	0.00	0.00	3.33	1.50	2.50
1976	0.00	0.00	1.00	0.00	0.00	0.00	0.00	12.00	0.50	0.50	6.67	0.00	0.50
1977	0.00	0.00	1.33	0.00	0.43	0.00	0.00	9.67	2.50	0.00	5.33	0.00	0.00
1978	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00
1979	0.00	0.67	0.00	0.00	0.50	0.00	0.00	0.25	0.00	1.50	6.67	0.00	3.00
1980	0.00	1.67	0.67	1.30	0.50	0.00	0.00	1.40	10.30	5.00	4.33	0.50	8.50
1981	0.00	4.00	1.67	0.00	2.80	0.00	0.00	0.25	1.80	3.00	7.00	0.50	0.00
1982	0.00	11.33	0.33	1.00	4.00	0.00	0.00	148.50	24.30	67.00	470.67	30.00	9.50
1983	0.33	2.33	1.33	3.30	1.17	0.00	0.00	113.75	0.00	33.00	136.67	38.00	1.50
1984	0.00	17.00	0.00	2.00	1.50	0.25	0.00	53.25	52.30	19.00	283.00	5.00	17.00
1985	0.25	24.00	3.67	0.00	12.25	2.60	0.00	66.00	10.25	95.50	6.70	58.00	4.50
1986	0.00	35.20	0.00	0.83	5.83	0.33	0.33	25.80	55.20	9.53	18.30	6.00	29.00
1987	0.40	7.50	0.67	0.17	4.50	0.50	0.00	57.14	26.80	2.50	5.70	12.00	2.00
1988	0.33	7.00	0.71	0.25	1.25	0.00	0.00	24.00	0.00	17.50	68.70	2.00	51.00
1989	0.25	5.50	0.60	0.50	0.17	0.25	1.33	1.33	1.80	0.50	25.30	21.00	1.00
1990	0.00	3.00	0.00	0.50	0.14	0.00	6.67	1.13	0.33	6.50	69.30	83.00	23.00
1991	0.25	1.00	0.00	0.00	0.13	0.00	0.67	0.86	0.17	21.50	1.30	104.00	3.70
1992	0.00	1.20	0.33	0.00	0.00	0.00	5.00	2.43	0.17	0.00	3.00	12.00	14.00
1993	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.57	2.17	25.50	24.67	8.50	2.00

Table 2. Mean number of haddock for each stratum in 4W from the summer survey of the Scotian Shelf.

	Stratum Number													
Year	453	454	455	456	457	458	459	460	461	462	463	464	465	466
1970	0.00	5.00	12.90	3.40	0.00	7.67	16.00	10.00	0.67	27.67	51.00	20.00	22.70	3.00
1971	0.00	0.00	4.50	79.00	5.50	3.67	5.50	0.00	0.00	14.00	45.00	44.70	17.20	0.00
1972	0.00	8.33	2.00	3.70	0.00	4.67	1.00	17.50	0.00	4.75	29.00	8.60	13.00	0.00
1973	0.00	2.33	0.00	7.20	2.00	2.33	1.00	19.50	0.00	0.33	27.00	28.30	9.80	0.00
1974	0.00	0.33	4.60	0.00	0.33	0.33	0.00	2.00	0.00	0.25	4.00	78.00	29.80	1.00
1975	0.00	0.67	4.50	3.20	0.00	0.00	0.25	16.00	0.50	46.00	172.00	21.50	29.80	0.00
1976	1.67	6.33	5.00	25.00	0.50	0.00	13.00	2.00	0.00	11.25	64.00	8.00	43.40	0.00
1977	0.00	5.33	73.30	14.30	4.50	3.00	45.25	4.00	0.00	31.25	391.00	191.80	36.00	0.00
1978	0.00	22.67	99.10	34.00	72.50	71.33	5.75	34.50	3.50	22.75	28.00	156.60	188.40	0.67
1979	0.00	5.67	198.00	57.00	5.50	88.00	6.25	7.50	0.00	34.25	533.00	96.20	24.40	0.00
1980	0.00	10.33	75.30	69.00	22.00	72.67	4.75	36.00	0.00	43.83	NA.00	389.80	7.00	0.00
1981	0.00	19.00	262.10	148.20	0.00	1.67	50.75	54.50	2.00	43.75	336.00	112.80	97.90	0.00
1982	0.67	385.67	116.60	51.60	15.50	8.67	41.33	28.50	0.50	75.00	230.00	226.80	120.80	1.00
1983	0.00	147.00	517.70	212.70	199.50	442.00	26.50	13.50	4.00	39.00	169.00	89.20	112.40	0.00
1984	0.00	270.67	273.90	334.70	15.00	117.67	16.00	24.50	15.00	78.25	53.00	190.80	41.00	0.00
1985	0.33	76.00	232.00	96.00	5.00	56.30	21.20	3.50	0.50	43.80	124.00	118.00	67.00	10.30
1986	0.00	11.30	262.00	80.00	39.00	168.60	35.70	5.67	2.00	24.00	169.00	159.00	58.00	4.00
1987	0.00	24.00	110.00	194.00	0.25	9.60	3.20	15.33	0.00	10.20	113.00	41.00	91.00	2.00
1988	0.00	44.50	92.00	905.00	16.50	76.00	25.50	17.67	0.00	2.50	84.00	110.00	61.00	1.50
1989	0.00	38.50	64.00	371.00	3.50	43.30	16.20	20.33	0.00	6.80	390.00	82.00	160.00	0.50
1990	0.33	11.00	108.00	423.00	2.50	27.60	54.20	5.00	0.00	30.20	100.00	156.00	47.00	0.00
1991	10.50	4.50	549.00	226.00	97.50	5.80	0.40	0.33	0.50	30.60	39.00	176.00	39.00	0.00
1992	22.50	53.50	238.00	37.00	0.50	14.90	12.30	0.00	0.00	5.30	51.00	91.00	56.00	3.00
1993	19.50	287.50	138.80	154.00	1.50	13.90	1.30	31.70	0.00	12.70	25.50	99.60	27.60	19.00

Table 3. Mean bottom temperature for each stratum in 4V from the summer survey of the Scotian Shelf.

	Stratum Number												
Year	440	441	442	443	444	445	446	447	448	449	450	451	452
1970	4.80	3.30	4.35	2.01	2.70	3.30	5.20	4.20	3.60	3.80	6.60	5.80	5.30
1971	5.10	3.90	1.53	1.56	2.30	3.00	5.20	2.70	3.50	3.40	4.50	5.50	5.20
1972	4.30	3.70	0.86	1.11	1.70	3.40	5.40	3.90	1.90	4.40	8.20	7.50	6.90
1973	5.00	3.00	2.99	0.94	2.00	4.40	5.00	3.80	2.40	3.50	3.70	6.60	4.90
1974	5.00	3.50	1.03	1.16	2.40	2.90	6.10	3.40	2.20	3.70	3.70	8.30	6.40
1975	5.20	1.90	0.44	1.13	1.10	2.00	6.30	3.50	2.10	1.20	3.40	7.00	5.00
1976	5.60	2.00	2.07	1.00	2.10	1.50	5.90	3.40	1.40	4.40	4.80	8.70	5.70
1977	5.30	3.50	2.78	2.11	3.90	4.60	6.20	4.60	3.10	4.80	6.50	7.70	6.60
1978	5.80	2.70	2.92	1.91	2.30	3.80	6.30	2.20	3.20	6.00	5.70	7.40	5.80
1979	5.90	4.50	1.56	1.50	2.90	4.40	6.20	2.90	2.50	3.30	6.30	8.30	6.10
1980	7.20	2.40	2.13	1.52	2.00	3.80	5.90	4.00	3.60	2.00	5.10	8.20	7.40
1981	4.30	3.40	5.47	2.71	2.60	4.50	5.90	3.70	3.50	3.50	6.80	8.30	6.20
1982	5.30	3.60	1.29	0.92	1.30	2.40	5.30	4.50	2.30	1.40	2.20	4.00	4.30
1983	5.00	2.30	1.60	2.16	2.00	2.60	4.00	4.30	2.90	6.80	3.10	5.90	4.70
1984	5.30	3.80	1.78	2.74	4.00	4.40	6.20	3.70	4.10	9.00	7.30	8.80	6.80
1985	5.70	4.10	1.10	0.80	1.80	2.40	6.60	3.90	2.30	0.57	2.40	1.50	7.00
1986	5.70	3.10	1.15	1.59	2.50	2.90	6.60	2.50	3.20	4.12	7.10	7.20	5.60
1987	4.70	2.20	0.45	1.00	1.70	2.60	5.80	1.70	1.70	0.75	2.30	5.10	3.50
1988	5.60	3.20	2.40	1.92	2.30	2.60	5.50	3.40	3.00	7.94	4.10	6.50	5.90
1989	5.50	1.80	0.78	0.95	1.40	1.40	5.40	1.80	1.60	0.76	3.30	5.50	4.00
1990	5.20	1.60	0.61	0.98	1.10	1.70	4.30	2.20	1.70	1.17	2.20	3.10	3.90
1991	5.00	1.30	1.63	0.59	1.20	1.80	5.30	1.40	2.20	2.42	2.30	5.10	5.00
1992	5.00	1.40	0.76	0.56	1.40	2.90	5.80	2.10	2.10	0.95	4.60	7.50	6.10
1993	5.62	2.80	0.38	0.98	2.12	3.87	5.63	2.57	2.75	5.26	4.98	6.21	5.22

Table 4. Mean bottom temperature for each stratum in 4W from the summer survey of the Scotian Shelf.

	Stratum Number													
Year	453	454	455	456	457	458	459	460	461	462	463	464	465	466
1970	6.6	4.0	5.7	5.4	3.5	5.0	4.1	7.4	8.1	5.9	4.3	3.5	5.8	6.3
1971	6.1	7.5	5.8	7.0	4.3	4.2	3.4	7.0	8.8	7.8	6.4	4.6	8.5	6.8
1972	7.6	6.8	4.5	4.5	3.5	3.5	4.2	8.8	8.8	7.2	5.6	4.1	10.1	9.3
1973	6.2	4.6	3.5	4.5	3.6	2.9	1.8	9.1	9.9	8.8	5.9	5.7	9.3	7.1
1974	7.9	5.0	5.4	5.3	4.4	2.6	2.0	9.3	10.2	9.0	7.4	7.6	9.7	9.0
1975	7.0	5.1	6.1	4.2	2.6	4.2	1.2	8.5	9.3	7.6	5.2	3.1	8.8	8.7
1976	8.6	7.1	4.6	4.6	5.3	3.9	2.0	8.8	9.3	8.5	7.3	5.5	9.1	8.8
1977	8.1	7.5	5.7	4.9	7.6	4.3	3.9	10.1	9.8	9.7	10.0	8.4	9.7	10.4
1978	8.8	7.4	4.7	5.4	3.9	4.8	3.4	7.5	7.6	7.5	6.5	4.2	7.0	9.2
1979	8.7	7.2	5.8	4.4	5.7	7.7	3.2	8.7	11.0	6.9	11.8	8.1	7.2	6.4
1980	8.9	7.7	5.8	5.0	5.0	5.1	4.5	8.8	9.1	8.0	NA	5.3	9.0	8.1
1981	8.4	7.5	8.1	6.9	6.1	2.7	5.2	9.0	9.1	8.5	6.0	7.9	9.5	7.4
1982	8.9	2.9	4.4	3.7	3.0	2.9	3.9	6.5	7.1	6.8	4.9	4.1	6.2	7.4
1983	6.4	6.6	6.0	4.1	4.0	2.9	2.1	9.0	9.3	8.1	7.7	4.3	6.9	7.2
1984	8.3	9.3	9.3	8.0	7.5	5.0	5.0	8.6	9.2	8.2	6.4	9.0	9.1	9.9
1985	10.3	9.6	6.5	4.9	6.1	2.9	3.0	9.9	11.1	8.6	8.7	NA	9.9	NA
1986	9.1	9.0	6.0	6.6	3.6	5.8	4.9	9.4	10.2	9.3	5.1	7.9	9.8	11.0
1987	8.3	4.6	6.4	6.0	2.9	2.7	2.7	8.4	9.5	8.3	5.1	4.2	5.0	8.3
1988	7.3	5.6	6.0	5.4	4.3	4.9	2.9	6.1	5.3	7.9	3.8	6.0	7.8	9.5
1989	8.3	7.8	3.7	4.0	2.7	2.5	3.3	7.0	8.8	8.4	5.9	4.3	8.0	8.8
1990	9.2	1.9	4.2	4.3	2.2	4.3	2.8	8.2	9.5	7.3	6.9	4.6	8.1	9.9
1991	7.8	3.5	5.3	6.6	2.5	2.2	1.4	8.4	8.9	7.8	7.0	4.0	7.4	9.7
1992	8.6	7.0	4.9	4.0	3.3	1.4	1.2	9.3	NA	6.8	6.3	5.2	8.7	9.1
1993	9.9	5.6	5.4	5.9	4.8	2.3	1.7	7.5	9.7	8.0	4.5	7.3	9.0	10.5

Table 5. Mean number of haddock for each stratum in 4V from the March survey of the Scotian Shelf. Note no survey conducted in 1985 and stratification scheme changed in 1986. a) Survey scheme in Fig. 1, b) Survey Scheme in Fig. 2.

a)

	Stratum Number									
Year	443	444	445	446	447	448	449	450	451	452
1979	0.00	0.67	0.00	0.33	0.00	0.00	12.00	41.00	0.00	25.00
1980	NA	0.50	NA	39.50	0.00	0.00	1.00	59.00	0.00	5.00
1981	0.00	3.50	0.00	0.00	0.00	0.00	199.00	47.00	0.00	6.00
1982	NA	NA	NA	NA	1.30	2.00	156.00	72.00	1229.00	178.50
1983	1.30	7.50	0.50	4.33	60.00	14.00	131.00	475.00	39.00	35.00
1984	0.00	13.33	4.60	0.00	4.30	0.00	109.00	2221.00	0.00	8.50

b)

	Stratum Number				
Year	401	402	403	404	405
1986	0.00	75.00	47.00	400.00	81.00
1987	0.00	37.14	0.00	84.00	665.20
1988	0.00	17.17	1.80	6.00	2.30
1989	3.40	3.38	3.20	14.00	14.30
1990	0.00	0.83	0.50	219.00	60.40
1991	0.00	0.08	0.00	172.00	3.80
1992	0.00	0.92	0.00	26.00	0.00
1993	0.00	3.14	0.00	22.00	5.00
1994	0.00	4.46	3.30	24.00	3.10

Table 6. Mean number of haddock for each stratum in 4W from the March survey of the Scotian Shelf. Note no survey conducted in 1985 and stratification scheme changed in 1986. a) Survey scheme in Fig. 1, b) Survey Scheme in Fig. 2.

a)

	Stratum Number													
Year	453	454	455	456	457	458	459	460	461	462	463	464	465	466
1979	0.00	14.00	2.00	8.84	3.40	0.00	0.00	88.00	6.18	8.40	80.00	239.00	16.00	9.95
1980	0.00	317.00	0.00	12.20	NA	NA	0.45	13.30	0.35	11.30	374.00	73.00	59.00	0.00
1981	0.00	240.00	35.00	58.81	25.00	21.70	60.78	114.00	1.17	113.80	7016.00	409.00	1048.00	0.00
1982	7.40	934.00	38.00	24.01	349.10	3.30	8.33	34.10	2.38	11.00	733.00	95.00	249.00	24.05
1983	0.00	48.00	110.00	0.12	237.60	0.00	5.19	54.40	0.92	22.80	484.00	1330.00	163.00	0.61
1984	0.00	278.00	115.00	0.00	1.00	0.00	10.91	7.90	2.73	39.30	956.00	891.00	98.00	0.00

b)

	Stratum Number					
Year	406	407	408	409	410	411
1986	49.25	1.00	327.40	0.50	104.00	0.00
1987	17.00	3.00	152.80	0.00	174.00	0.00
1988	13.55	0.67	113.30	1.30	235.00	0.00
1989	1.90	0.88	68.40	0.40	475.00	3.00
1990	1.91	0.38	72.00	0.00	311.00	0.50
1991	1.05	0.00	38.60	0.00	91.00	0.00
1992	2.60	0.00	8.60	0.00	23.00	0.00
1993	0.38	0.00	0.50	1.00	27.00	0.00
1994	1.10	6.50	26.50	6.10	79.00	1.50

Table 7. Mean temperature for each stratum in 4V from the March survey of the Scotian Shelf. Note no survey conducted in 1985 and stratification scheme changed in 1986. a) Survey scheme in Fig. 1, b) Survey Scheme in Fig. 2.

a)

	Stratum Number									
Year	443	444	445	446	447	448	449	450	451	452
1979	-0.41	1.70	3.40	6.80	0.48	0.45	5.60	3.20	4.80	3.40
1980	NA	2.20	NA	4.80	0.26	0.33	1.50	2.70	6.60	5.90
1981	2.23	3.00	3.20	5.00	1.35	1.73	7.15	4.30	6.20	6.30
1982	NA	NA	NA	NA	-0.20	0.27	0.67	1.10	4.00	5.20
1983	0.90	1.30	2.80	3.60	1.41	1.84	2.75	2.90	5.30	3.20
1984	2.13	3.20	4.20	6.00	0.49	1.77	4.95	5.50	4.90	6.70

b)

	Stratum Number				
Year	401	402	403	404	405
1986	0.47	2.02	0.47	0.71	6.40
1987	0.23	2.09	0.35	4.00	4.60
1988	0.86	2.14	1.78	7.97	4.20
1989	NA	1.38	-0.20	1.94	3.10
1990	0.77	0.56	-0.76	6.23	2.50
1991	0.15	0.70	0.62	6.12	4.00
1992	0.66	2.93	0.08	6.58	5.50
1993	0.43	1.00	0.90	NA	6.40
1994	1.41	3.07	0.75	6.36	5.10

Table 8. Mean temperature for each stratum in 4W from the March survey of the Scotian Shelf. Note no survey conducted in 1985 and stratification scheme changed in 1986. a) Survey scheme in Fig. 1, b) Survey Scheme in Fig. 2.

a)

	Stratum Number													
Year	453	454	455	456	457	458	459	460	461	462	463	464	465	466
1979	8.40	7.90	1.53	3.22	1.30	1.62	1.70	8.30	9.10	9.20	6.50	2.40	7.20	9.10
1980	8.20	3.30	1.01	1.98	NA	NA	1.80	9.10	9.00	9.50	6.70	3.70	8.60	9.50
1981	7.00	7.60	3.05	2.73	4.90	2.55	3.20	8.70	9.40	8.10	3.20	4.30	7.60	8.20
1982	6.10	4.30	0.49	0.66	3.50	0.73	1.30	8.00	8.00	8.40	4.80	2.40	7.10	7.50
1983	6.80	5.40	3.40	2.42	3.10	1.64	3.80	8.60	8.70	8.20	6.60	5.50	10.00	8.10
1984	8.70	8.30	2.89	2.77	4.90	2.43	4.40	7.20	9.30	7.70	7.00	6.50	9.60	7.70

b)

	Stratum Number					
Year	406	407	408	409	410	411
1986	5.60	3.30	4.10	1.40	9.00	9.90
1987	2.00	2.40	3.80	0.27	6.80	6.50
1988	4.00	3.20	3.10	1.55	7.40	8.50
1989	3.60	3.30	2.10	0.90	8.10	6.40
1990	2.90	2.00	3.10	0.75	9.30	9.30
1991	3.90	2.60	4.30	2.54	10.00	NA
1992	3.40	1.90	3.90	1.83	4.30	NA
1993	3.30	2.30	1.50	5.92	7.30	NA
1994	4.50	4.70	7.40	4.72	10.80	10.00

Table 9. Mean number of haddock for each stratum in 4X form the July groundfish survey.

	Stratum Number																	
Year	470	471	472	473	474	475	476	477	478	480	481	482	483	484	485	490	491	495
1970	3.00	0.00	12.00	95.00	47.00	58.00	0.00	45.00	1.50	106.00	49.00	2.00	2.50	0.00	47.00	24.50	4.00	11.00
1971	0.50	0.00	36.00	9.50	22.00	54.00	69.00	29.00	1.50	200.00	31.00	3.00	0.00	0.50	9.00	42.00	0.00	14.00
1972	6.00	2.00	15.50	88.50	27.00	19.00	8.50	26.00	0.67	86.00	30.00	0.00	3.50	0.00	4.00	0.50	9.00	7.00
1973	4.00	0.00	8.50	44.50	33.00	51.00	0.00	26.00	0.50	164.00	113.00	0.00	0.00	0.33	30.00	51.50	3.70	2.50
1974	NA	NA	23.50	57.00	60.00	92.00	30.00	132.00	2.33	222.00	234.00	5.00	1.50	0.33	9.70	308.50	20.30	15.50
1975	NA	0.50	37.50	10.50	83.00	20.00	43.00	34.00	3.33	127.00	25.00	3.50	1.50	0.33	7.70	31.70	2.30	1.00
1976	0.50	0.00	29.50	102.50	66.00	89.00	1.00	52.00	9.00	58.00	58.00	4.00	26.00	5.00	14.30	83.00	2.00	3.50
1977	196.00	0.50	11.50	134.50	22.00	41.00	424.00	19.00	4.33	442.00	9.00	10.00	10.50	0.33	31.00	191.70	15.70	23.50
1978	4.00	0.50	10.00	22.50	86.00	78.00	38.50	37.00	4.50	104.00	63.00	7.50	1.50	0.50	14.70	61.30	9.00	32.00
1979	32.00	0.50	27.00	63.50	244.00	61.00	0.00	39.00	2.00	79.00	70.00	17.30	8.00	14.33	9.70	396.00	3.70	24.00
1980	2.50	2.50	234.50	30.00	22.00	62.00	17.50	44.00	1.33	202.00	129.00	10.00	25.00	2.67	57.50	293.00	11.70	4.50
1981	5.50	3.00	144.00	9.00	106.00	40.00	10.50	40.00	0.67	162.00	28.00	6.50	27.00	1.67	13.30	1177.70	11.70	5.00
1982	0.00	5.00	143.50	130.00	132.00	49.00	5.50	101.00	2.67	72.00	171.00	25.00	60.00	6.50	25.30	516.30	32.00	37.00
1983	34.00	4.00	39.50	37.00	61.00	55.00	63.00	85.00	15.67	93.00	42.00	8.50	5.50	1.33	11.00	241.00	34.00	11.50
1984	11.50	0.50	47.50	55.50	NA	276.00	8.50	147.00	16.00	173.00	69.00	21.50	32.00	4.00	24.30	729.00	28.70	3.00
1985	1.00	0.00	75.50	185.50	140.00	101.00	363.50	93.00	21.00	126.00	19.00	1.50	15.00	3.00	86.00	178.30	15.00	5.50
1986	40.00	0.50	71.00	156.50	46.50	155.00	23.00	113.00	8.70	98.00	158.00	2.00	12.50	0.67	37.30	30.00	3.00	0.00
1987	8.50	2.50	27.80	78.00	3.00	15.00	24.30	42.00	20.50	52.00	31.00	29.30	10.50	0.00	2.80	48.00	1.00	0.00
1988	6.30	0.00	33.00	12.00	1.50	14.00	7.80	57.00	11.00	82.00	25.00	21.00	20.00	1.25	9.10	123.00	0.25	1.00
1989	4.50	0.00	37.00	12.00	1.50	22.00	8.80	42.00	0.00	186.00	29.00	17.70	1.50	1.00	1.80	132.00	0.00	0.00
1990	1.50	0.00	19.50	40.30	32.00	54.00	5.00	23.00	13.00	216.00	20.00	39.30	40.00	1.00	12.00	167.00	0.67	17.00
1991	0.00	0.00	20.80	95.00	6.50	23.00	8.80	42.00	0.00	386.00	35.00	20.70	44.50	0.00	107.30	82.00	1.33	0.00
1992	1.00	0.00	8.00	5.50	6.50	16.00	12.30	41.00	2.30	205.00	26.00	1.70	4.50	0.00	21.00	93.00	3.67	0.00
1993	0.50	0.00	7.50	0.50	8.50	9.00	2.80	14.00	3.50	76.00	42.00	6.70	3.50	0.67	7.70	19.00	4.67	0.00

Table 10. Mean temperature for each stratum in 4X from the July groundfish survey.

	Stratum Number																	
Year	470	471	472	473	474	475	476	477	478	480	481	482	483	484	485	490	491	495
1970	7.7	8.4	7.4	3.3	4.0	4.1	6.4	7.4	7.3	5.5	5.8	7.0	6.8	6.9	6.4	7.2	6.5	7.7
1971	7.4	8.8	6.9	2.7	3.2	3.6	4.7	7.2	6.5	6.5	7.5	8.7	7.4	7.7	6.9	7.4	6.7	8.0
1972	8.5	8.8	7.5	3.8	4.0	4.2	5.7	8.4	8.4	6.2	6.2	8.2	8.1	7.1	7.2	7.4	6.8	7.8
1973	6.0	9.8	9.4	3.4	3.2	4.4	7.2	7.9	8.2	8.8	8.6	7.3	7.5	9.7	8.1	9.0	7.6	9.1
1974	NA	NA	11.5	5.3	4.5	4.7	5.7	8.0	8.6	8.0	8.0	9.1	8.3	8.0	7.7	7.9	7.2	8.5
1975	NA	9.3	6.8	12.6	3.5	3.3	5.1	4.1	9.2	7.6	6.9	7.7	7.8	7.0	6.6	7.3	6.7	8.4
1976	9.1	9.3	7.9	5.6	3.6	7.0	7.5	8.1	7.4	9.3	9.9	8.5	8.2	8.7	9.5	10.3	9.1	10.3
1977	6.7	9.6	9.7	6.4	3.0	4.4	6.2	6.9	9.3	5.3	8.0	7.9	7.5	6.7	6.3	7.2	6.5	8.5
1978	8.4	8.4	8.9	3.2	3.9	4.3	6.2	5.5	9.0	6.1	7.3	7.0	7.2	6.4	6.8	6.8	6.4	8.2
1979	5.9	9.2	7.7	3.5	3.8	5.1	6.2	5.9	7.7	5.8	9.1	9.1	8.2	7.1	8.4	8.9	7.2	9.3
1980	7.8	9.4	6.2	4.8	5.6	5.6	5.7	6.9	9.1	6.6	7.0	7.5	7.6	7.9	7.3	8.2	7.6	9.7
1981	7.7	9.0	7.3	2.5	2.8	3.8	5.6	7.6	7.2	5.8	6.9	7.7	7.6	6.9	6.6	8.0	6.8	8.4
1982	6.6	8.5	6.7	3.9	4.5	5.0	6.7	4.4	7.9	8.6	9.9	8.6	6.8	7.6	7.2	8.6	7.1	9.3
1983	7.3	9.1	6.7	2.5	4.2	3.5	7.3	5.7	8.1	5.7	7.0	8.7	8.7	7.2	6.9	8.2	7.0	10.0
1984	4.9	8.8	8.6	3.1	NA	4.7	6.3	6.7	8.8	8.6	9.2	9.4	7.6	9.1	8.0	8.9	7.4	9.7
1985	9.6	10.0	8.7	5.2	3.3	NA	NA	NA	NA	NA	7.4	NA	8.3	8.4	8.3	8.1	7.1	8.0
1986	2.5	10.1	8.6	5.1	4.9	4.5	7.0	5.9	8.3	7.6	8.7	8.2	8.1	7.5	7.2	8.7	7.7	9.4
1987	5.3	9.4	6.1	2.4	3.1	3.2	4.7	6.0	7.1	4.9	6.4	7.8	7.5	7.9	7.9	7.7	5.7	7.8
1988	7.7	8.3	7.0	2.4	2.3	3.8	4.5	5.0	8.0	7.2	6.4	7.4	7.2	7.9	7.3	7.9	6.9	8.7
1989	8.1	8.6	8.2	3.7	3.0	4.7	5.5	7.7	6.3	6.7	7.6	7.0	7.0	7.2	7.2	8.3	7.1	8.9
1990	9.1	9.0	8.2	3.9	3.4	4.1	5.2	7.2	9.1	6.7	7.3	8.2	8.3	7.8	7.8	8.1	7.3	8.8
1991	5.3	8.4	8.2	2.6	2.4	3.1	4.6	5.1	7.8	5.2	5.6	8.7	8.5	7.9	7.1	8.0	7.0	8.9
1992	6.1	9.0	10.0	2.3	2.1	5.3	4.6	9.0	8.2	4.2	6.5	8.3	8.3	6.9	6.4	6.5	5.3	7.2
1993	7.7	9.5	7.8	2.2	2.4	3.0	6.6	6.4	8.7	6.3	7.9	9.2	8.7	7.6	6.9	7.2	6.5	8.6

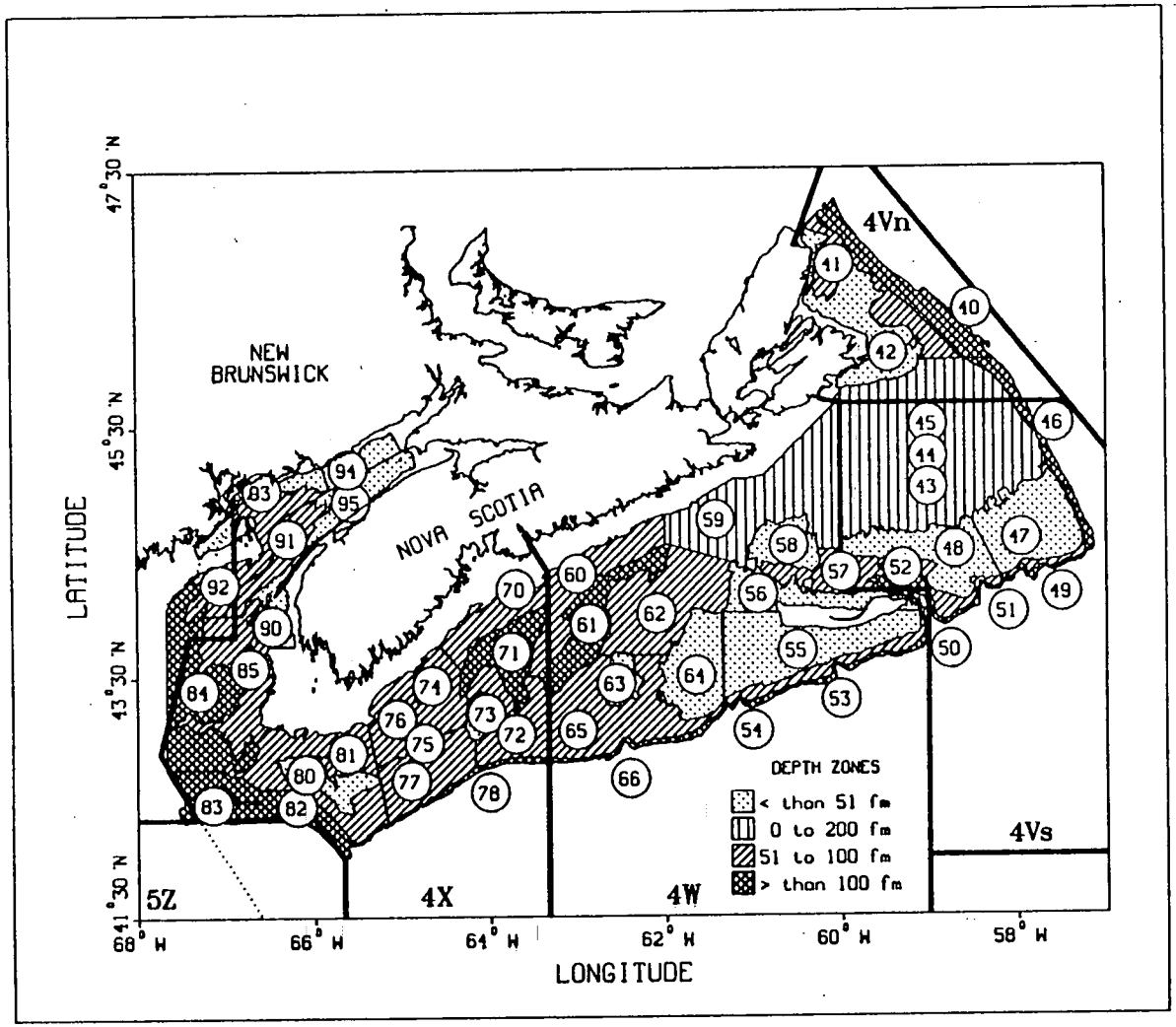

Fig. 1. Stratification map for the Scotian Shelf surveys. Stratum boundaries are based primarily on depth ranges. The numbers on the map identify each stratum.

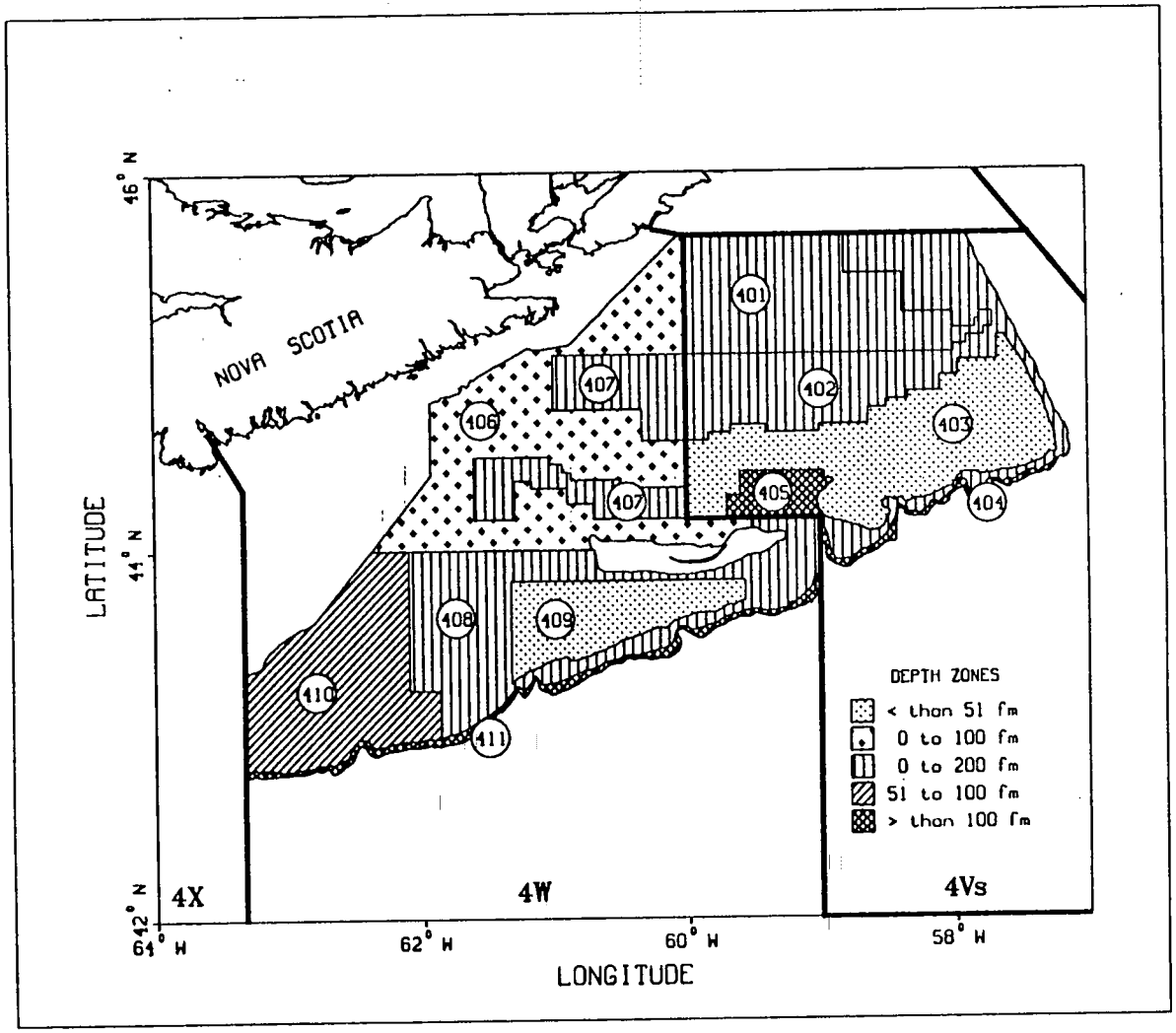

Fig. 2. Stratification map for the Eastern Scotian Shelf surveys (1986–present). Stratum boundaries are based primarily on the average spatial distribution of Atlantic cod from 1979–1982. The numbers on the map identify each stratum.

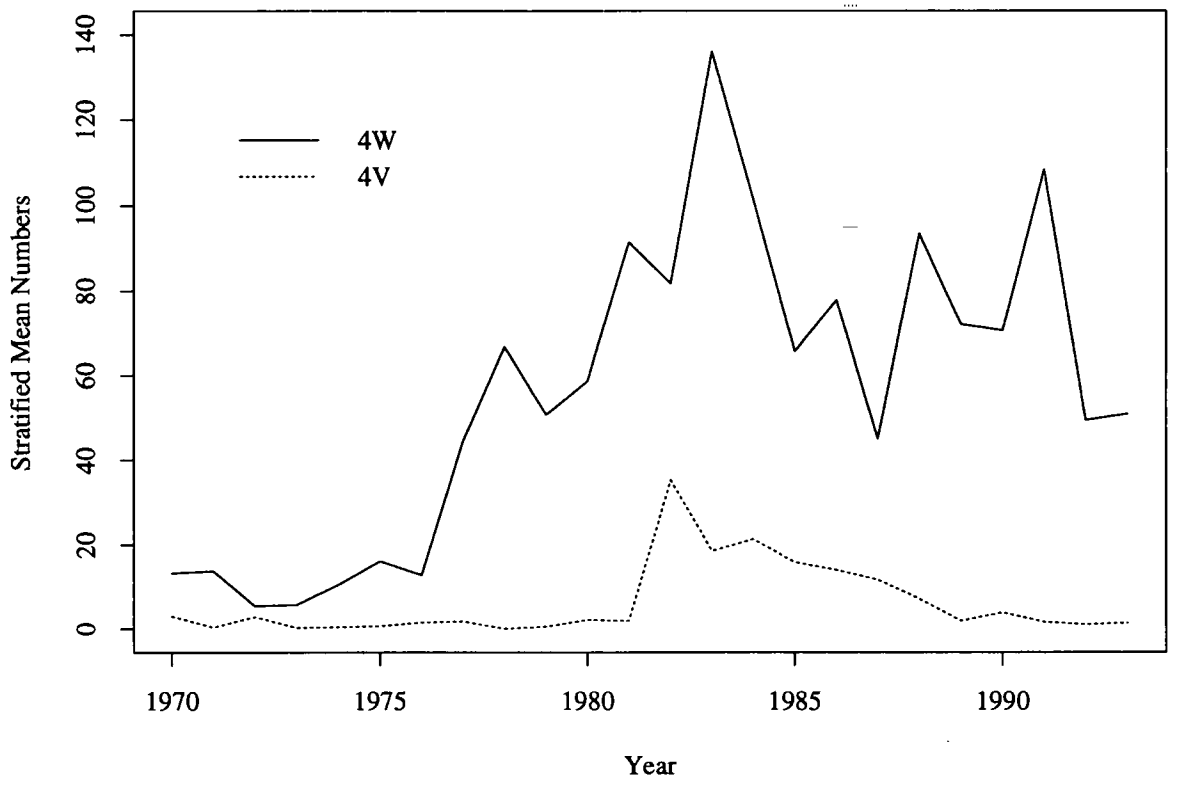

Fig. 3. Trends in stratified mean number per tow for haddock by NAFO subdivision from the July Scotian Shelf survey.

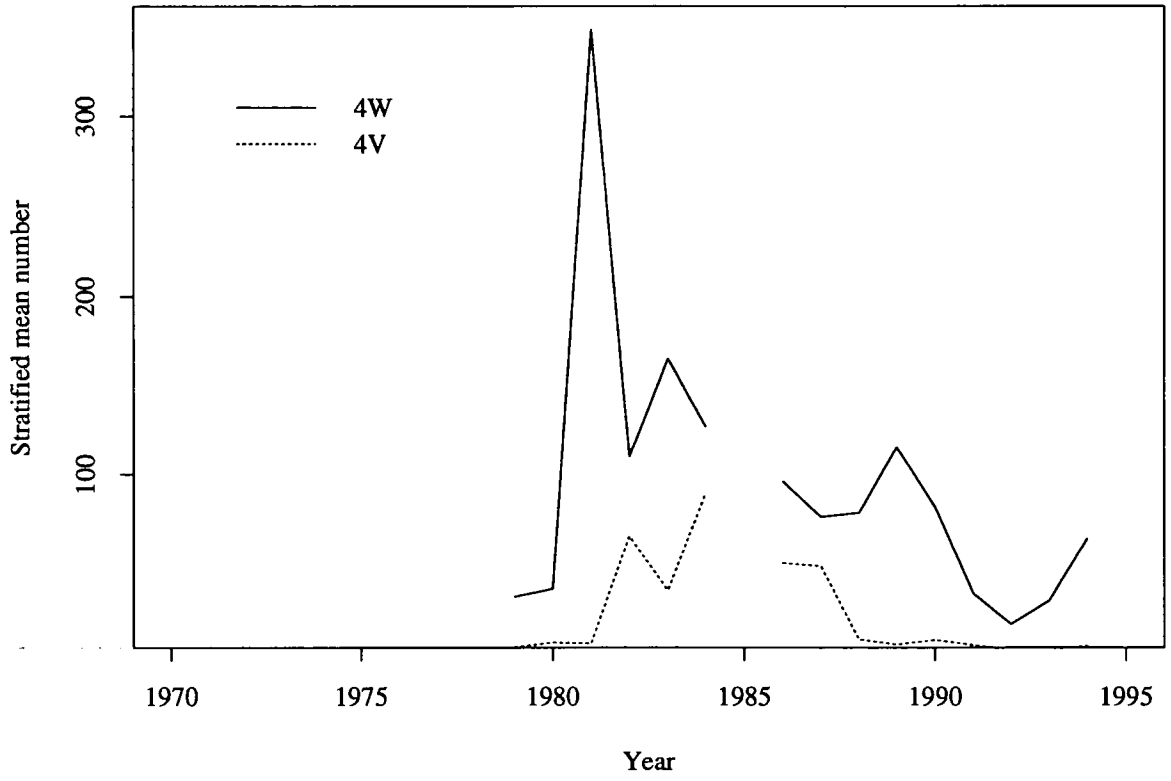

Fig. 4. Trends in stratified mean number per tow for haddock by NAFO subdivision from the March Scotian Shelf survey. (Note: no survey in this area in 1985.)

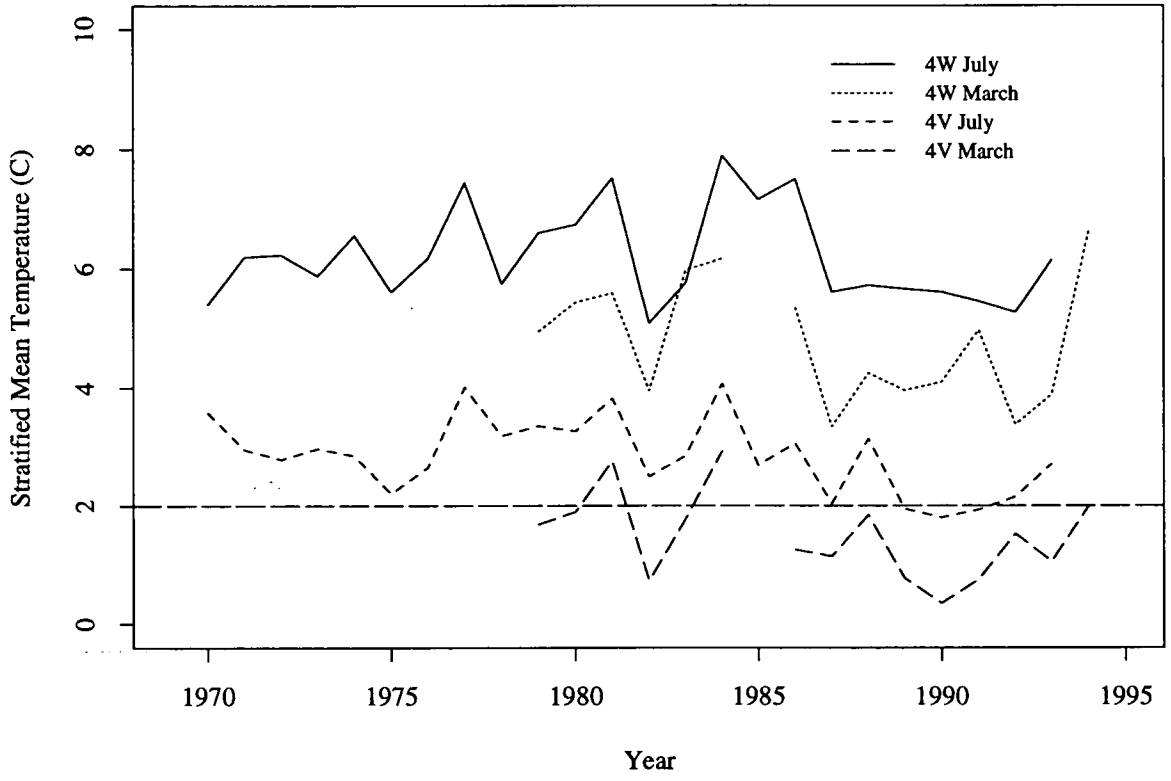

Fig. 5. Trends in stratified mean temperatures for both March and July surveys of Scotian Shelf.

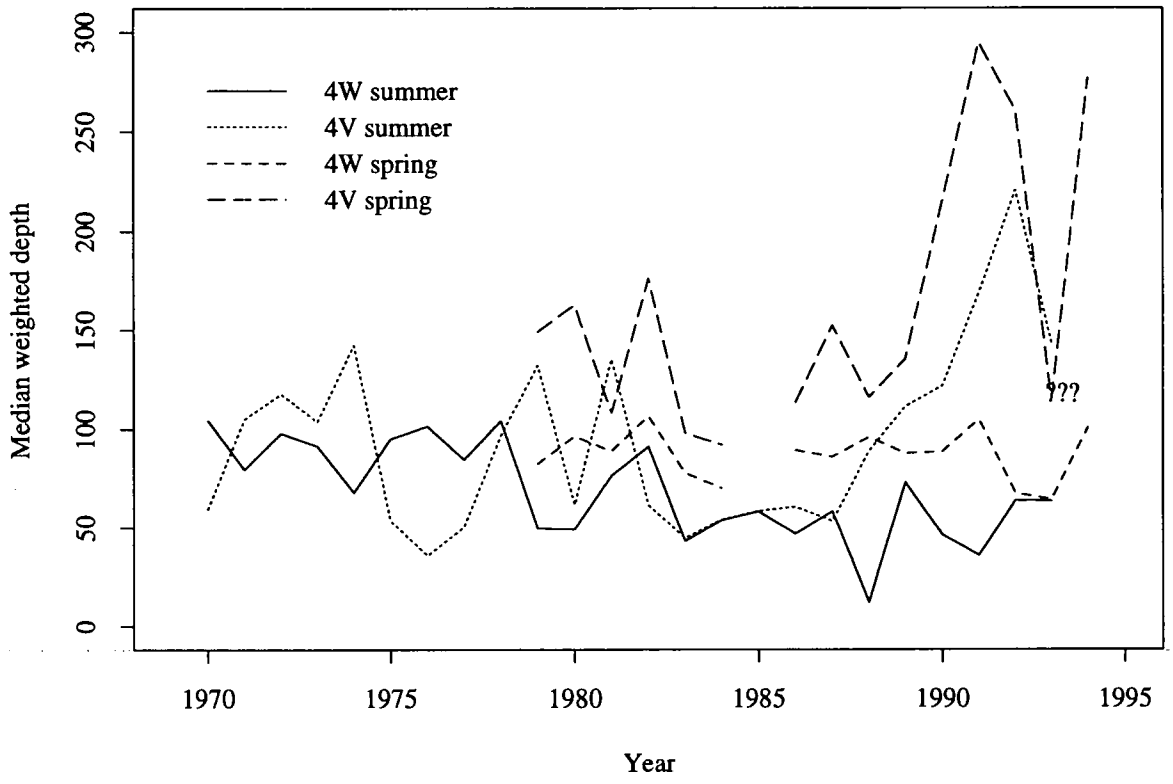

Fig. 6. Trends in catch weighted median-depth for haddock caught in March and July surveys of the Scotian Shelf. ???: the 1993 March survey hydrographic measurements are not representative of the whole area due to sampling being restricted to mainly shallow areas because of bad weather and equipment problems.

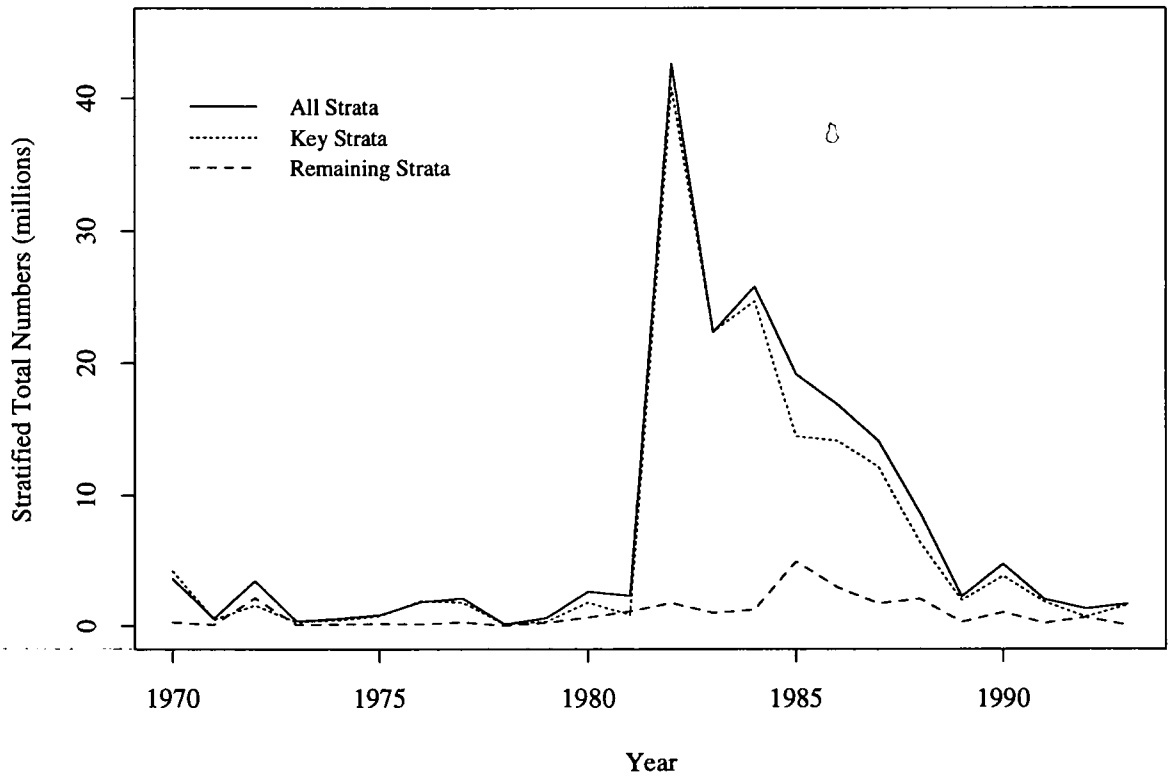

Fig. 7. Trends in key strata (447–451) for the estimates of abundance for haddock in NAFO subdivision 4V from July surveys of the Scotian Shelf.

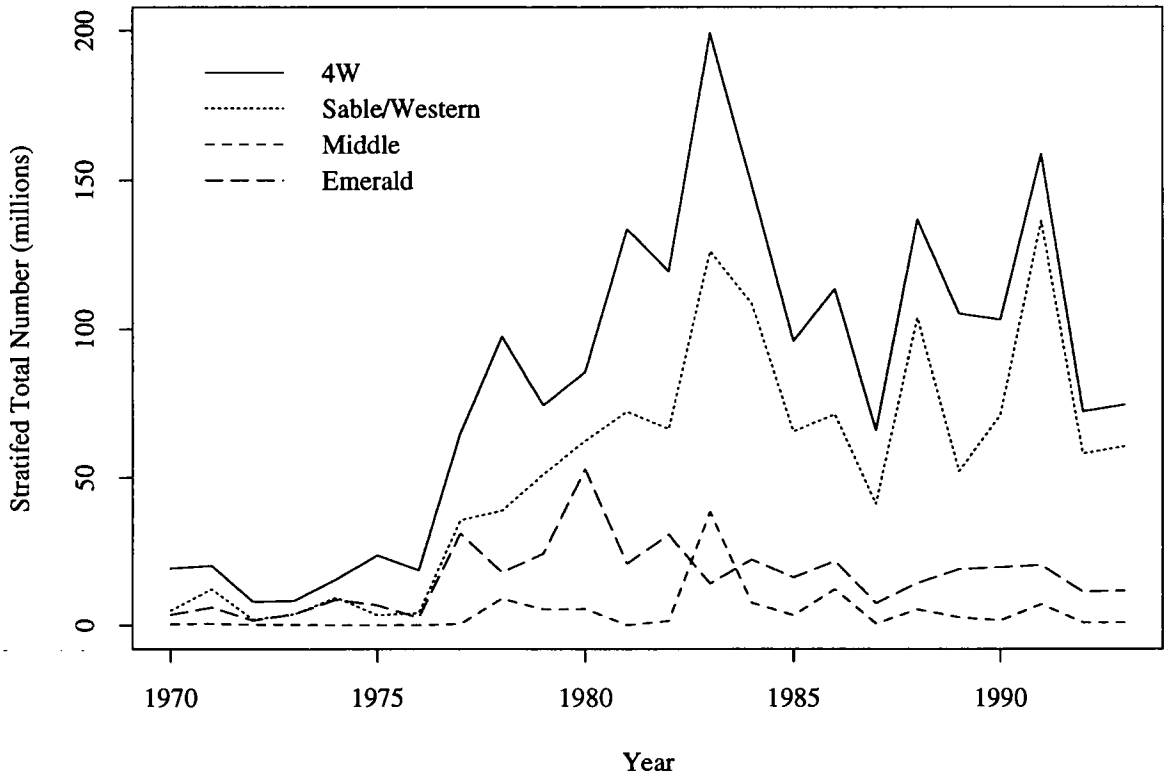

Fig. 8. Trends in key strata (Sable/Western = 454–456; Middle = 457–458; Emerald = 463,465) for the estimates of abundance for haddock in NAFO subdivision 4W from July surveys of the Scotian Shelf.

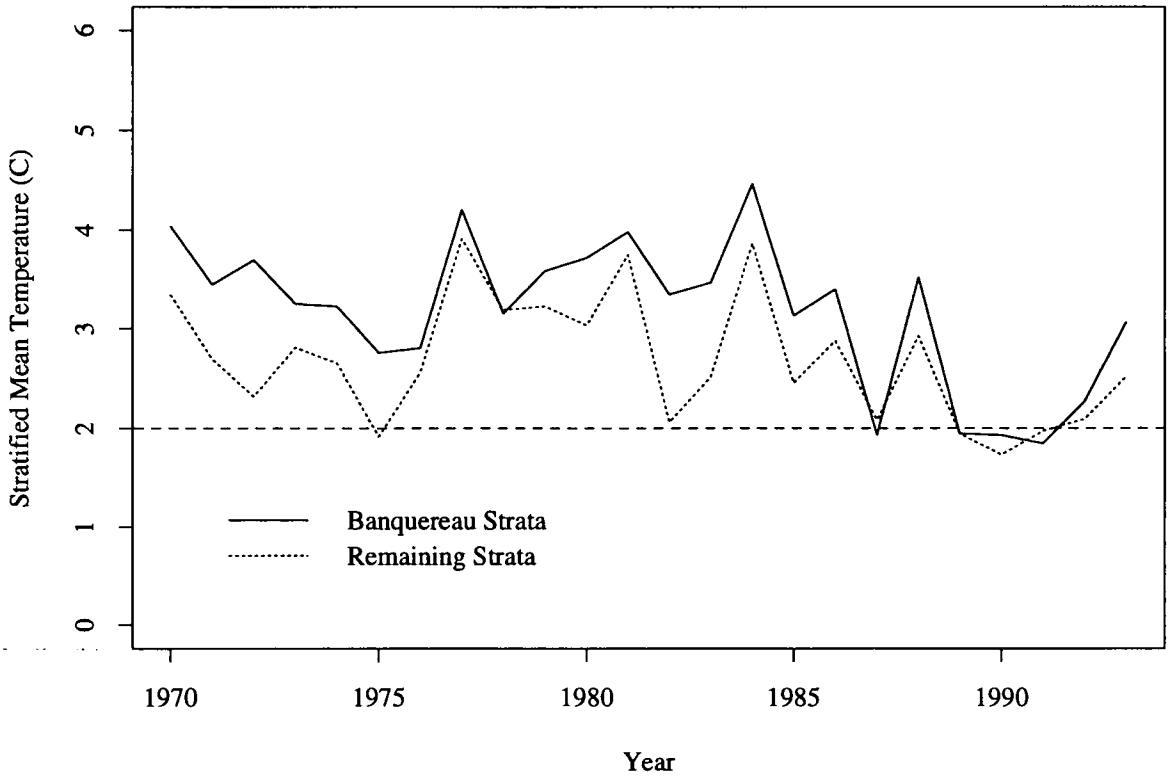

Fig. 9. Temperature trends in key strata (Banquereau = 447–451) and other strata in NAFO subdivision 4V from July surveys of the Scotian Shelf.

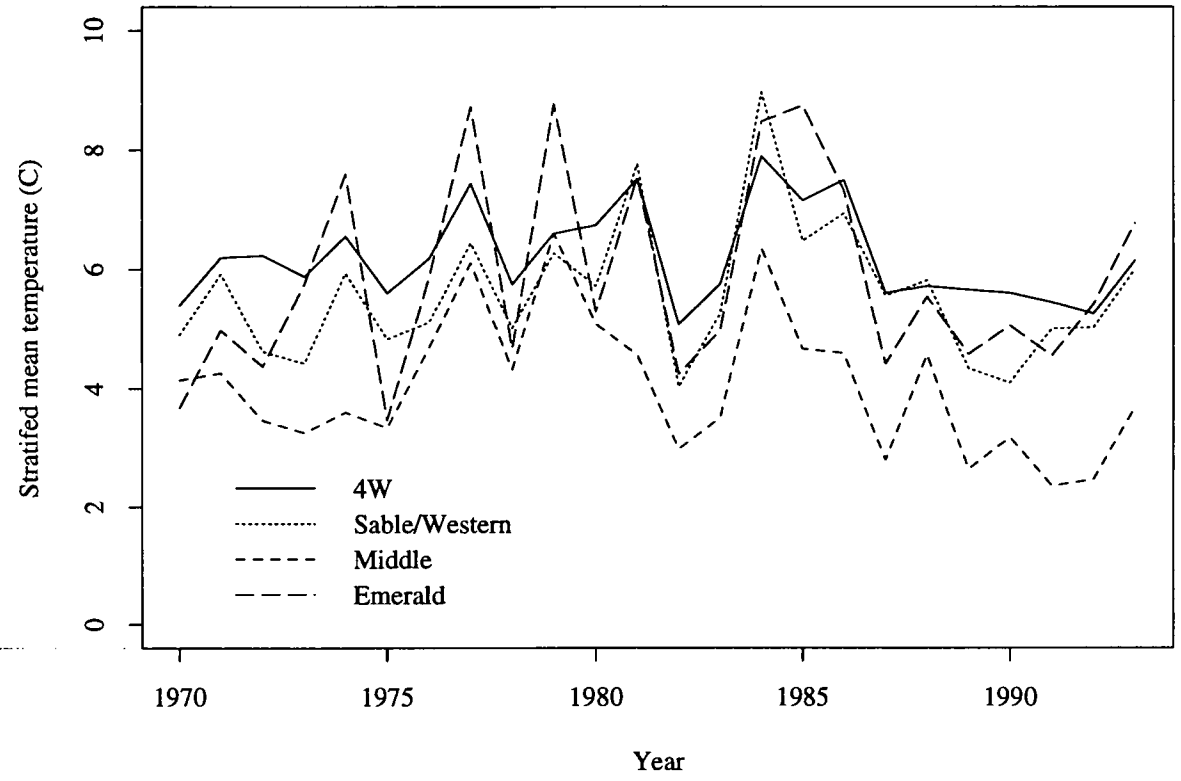

Fig. 10. Temperature trends in key strata (Sable/Western = 454–456; Middle = 457–458; Emerald = 463,465) and other strata in NAFO subdivision 4W from July surveys of the Scotian Shelf.

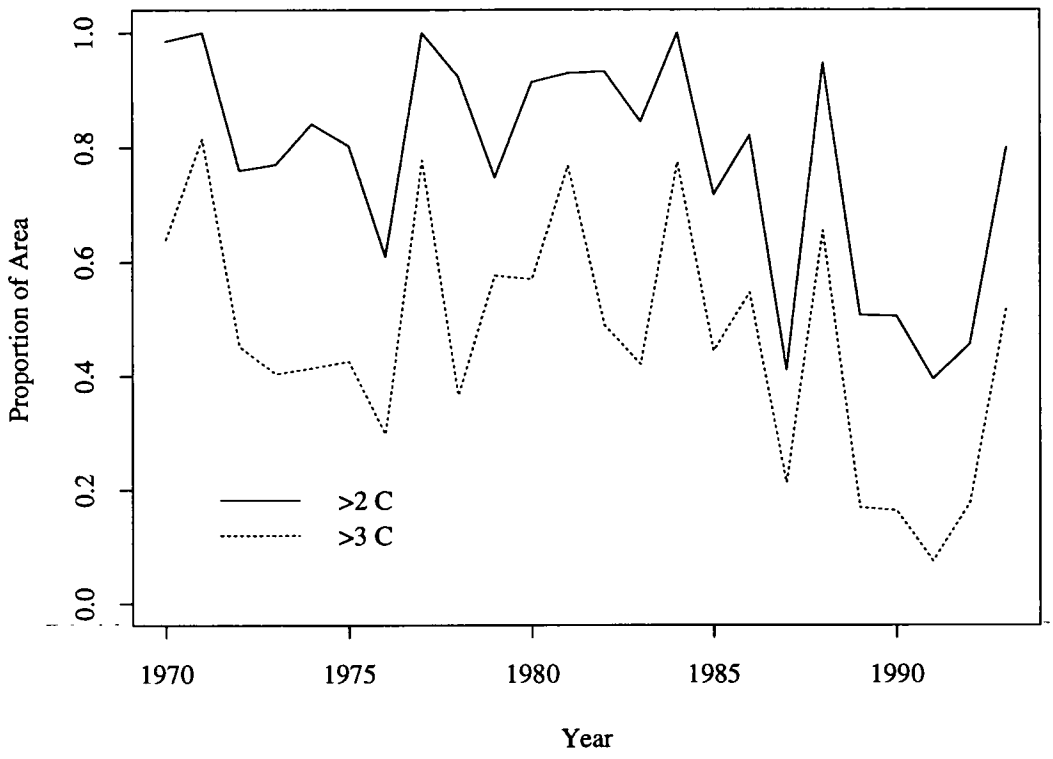

Fig. 11. Trends in proportion of bottom water ≥ 2°C and ≥ 3°C in the key strata (447–451) in NAFO subdivision 4V from July surveys of the Scotian Shelf.

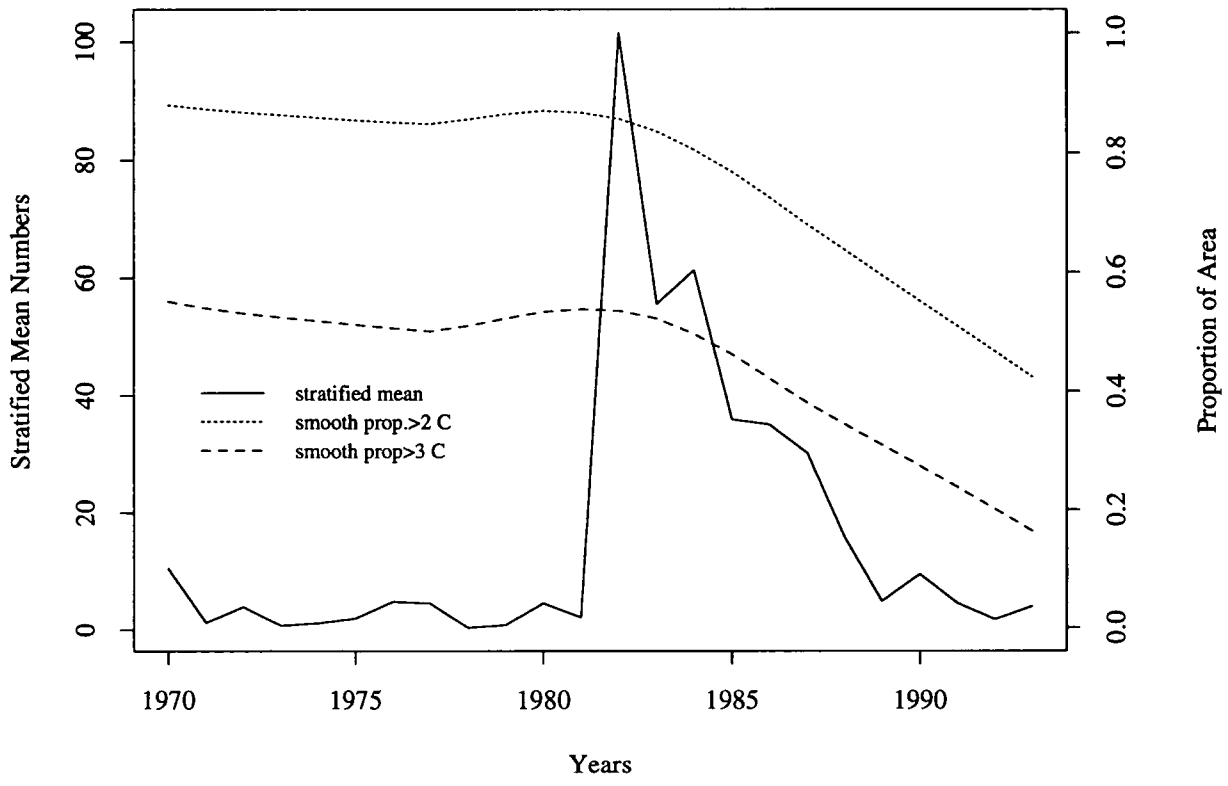

Fig. 12. Overlay of trends of lowess curve for proportion of bottom water $\geq$ 2°C and $\geq$ 3°C with the trend for stratified mean numbers in the key strata (447–451) in NAFO subdivision 4V from the July surveys of the Scotian Shelf.

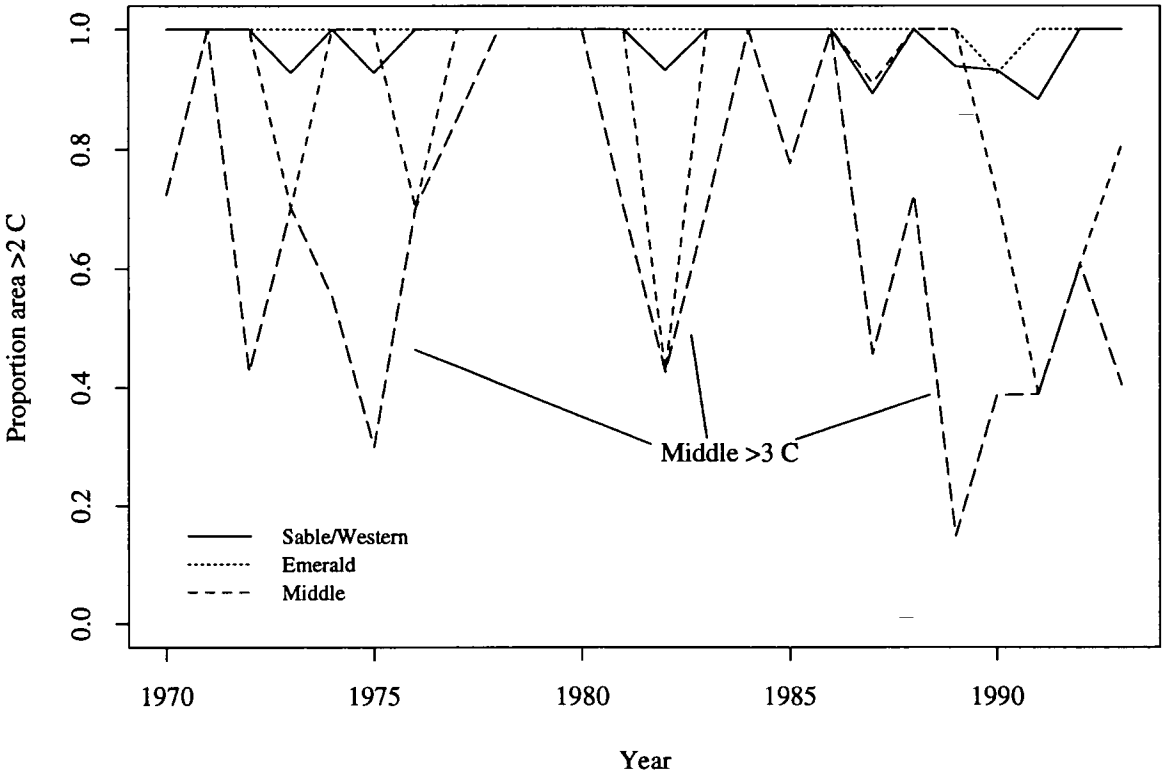

Fig. 13. Trends in proportion of bottom water $\geq$ 2°C (and $\geq$ 3°C for Middle Bank) in the key strata (Sable/Western = 454–456; Middle = 457–458; Emerald = 463,465) in NAFO subdivision 4W from July surveys of the Scotian Shelf.

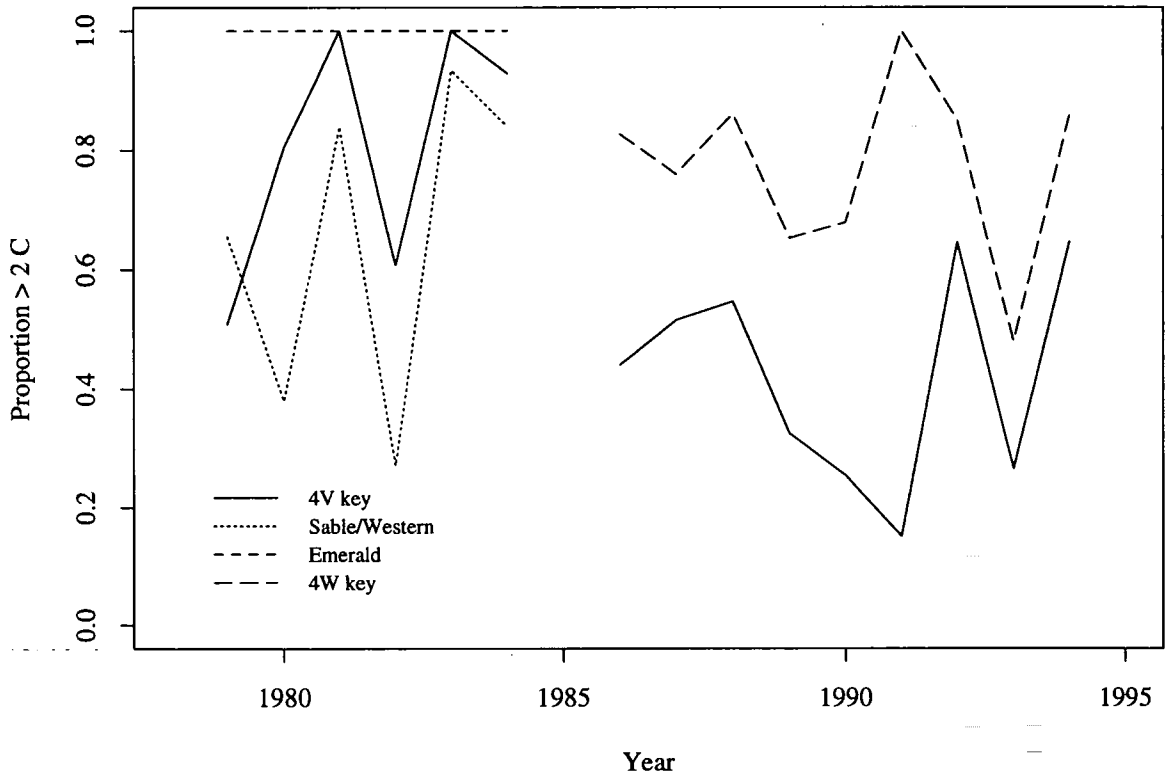

Fig. 14. Trends in proportion of bottom water ≥ 2°C and ≥ 3°C in the key strata in NAFO subdivision 4V (449–452 [1979–1984]; 402,404,405 [1986–1994])and 4W (Sable/Western = 454–456; Emerald = 463,465 4W key = 408,410) from March surveys of the Scotian Shelf.

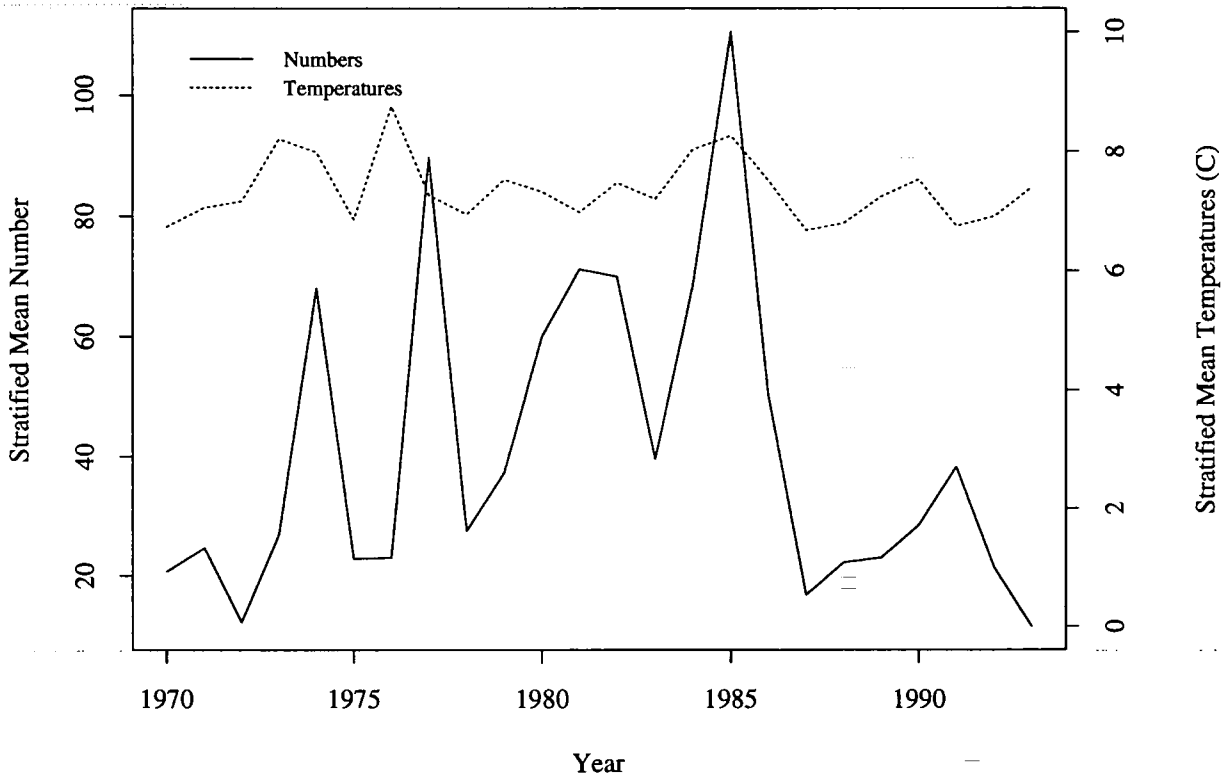

Fig. 15. Trends in stratified mean number of haddock and mean temperature from July surveys of NAFO subdivision 4X.

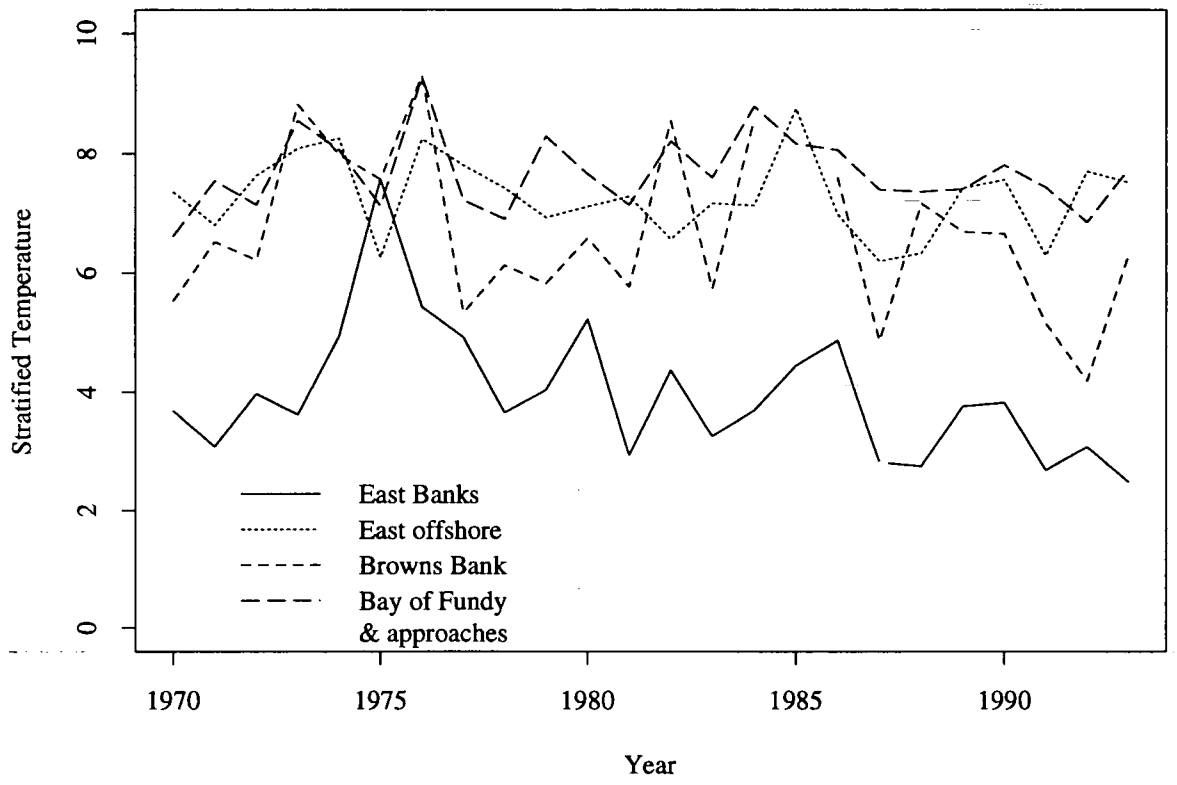

Fig. 16. Trends in stratified mean temperature for different areas from July surveys of NAFO area 4X. East Banks = strata 473–475; East offshore = strata 470–472,476–478; Browns Bank = strata 480; and Bay of Fundy and approaches = strata 481–485, 490,491,495.