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Summary of Biological Oceanographic Variables in the Newfoundland Region

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[1]This series documents the scientific basis for the evaluation of fisheries resources in Atlantic Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the secretariat.

[1]La présente série documente les bases scientifiques des évaluations des ressources halieutiques sur la côte atlantique du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les Documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au secrétariat.

Abstract

This study provides a preliminary description of the temporal and spatial pattern in the variation of nutrients, phytoplankton and zooplankton in the Newfoundland region based on data from directed and ship-of-opportunity collections (1993-94) as well as using information from the CPR series (1959-1978, 1991, 1992) and from the Mobil Oil survey of the Grand Banks (1980-81). The principle objective was to describe and contrast the depth-dependent seasonal cycle in nutrient and phytoplankton abundance from a single site (station 27) with observations taken in the northern region of the Grand Banks (NAFO area 3L). All nutrients as well as chlorophyll concentrations exhibit strong seasonal cycles. Overall nitrate and phytoplankton concentrations are higher along the shelf edge, in correspondence with the offshore arm of the Labrador current. Phytoplankton concentration appears to show a peak in late April-early May but the precise timing of the spring bloom is uncertain because of the unavailability of data for the period preceding April. Maximum phytoplankton concentrations occur at depths of 30-50 m. It is apparent that there is a strong seasonal cycle at all depths with the greatest overall variability occurring at intermediate depths (10 and 50 m). The seasonal cycle in integrated (0-100 m) fluorescence levels from all CTD observations in NAFO area 3L shows a pattern that is similar to that observed at station 27 as is the cycle in temperature. After taking into account the seasonal cycle, the residual fluorescence levels show a marked regional pattern which is similar to that of temperature residuals but is shifted further south along the shelf, possibly indicating advection of tracers. The seasonal cycle in the abundance of *Calanus finmarchicus* at station 27 is not as marked as that of *Calanus glacialis* or *Calanus hyperboreus*. The abundance of *Pseudocalanus* sp and *Temora longicornis* show higher levels during mid-fall. The seasonal cycles for these five species are similar to those observed from the CPR surveys conducted in NAFO areas 3K and 3L but differ substantially from those for NAFO area 3NO. Differences in the seasonal cycle at station 27 with other parts of NAFO area 3L may be due to local features or processes (e.g., mixing, mixed layer depth, nutrient sources, advection) . However, it is also possible that the variability in the level of some elements on the time scale of less than 30 days limits the degree of comparison possible from ship-of-opportunity collections. There are important questions pertaining to the sampling frequency and spatial resolution that would be essential in order to detect the "climatic" variability. However, the nature of the sampling program required to supply "adequate monitoring" requires extensive evaluation and discussion because ship-of-opportunity based collections require substantial assumptions in the interpretation of data analysis. The current sampling resolution of biological oceanographic variables severely limits the comparison of available observations because of the possible influence of short-term and small-scale variability on the description of the seasonal cycle and in the measurement and understanding of interannual fluctuations about that mean cycle.

Résumé

Cette étude présente une description préliminaire des fluctuations spatio-temporelles de la concentration de nutriants et des populations phytoplanctoniques et zooplanctoniques dans la région de Terre-Neuve. Cette description s'appuie sur des données recueillies lors de campagnes d'échantillonnage ou lors de prélèvements faits à partir de navires occasionnels (1993-1994), ainsi que sur des renseignements tirés de la série CPR (1959-1978, 1991, 1992) et des résultats du relevé de Mobil Oil sur le Grand Banc (1980-1981). L'objectif principal est de décrire le cycle saisonnier de l'abondance des nutriants et du phytoplancton, en fonction de la profondeur, à une station donnée (station 27), et de le comparer aux observations faites dans la partie nord du Grand Banc (division 3L de l'OPANO). Tous les nutriants ainsi que la chlorophylle suivent des cycles saisonniers marqués de concentration. La concentration globale du nitrate et du phytoplancton est plus élevée sur le bord du plateau et coïncide avec la branche océanique du courant du Labrador. Celle du phytoplancton semble atteindre un maximum à la fin avril-début mai; cependant, le moment exact de la prolifération printanière n'est pas établi de façon certaine, faute de données pour la période antérieure au mois d'avril. Les maximums de concentration phytoplanctonique sont observés entre 30 et 50 m de profondeur. L'existence d'un cycle saisonnier marqué paraît évidente à toutes les profondeurs et la plus grande variabilité d'ensemble est relevé aux profondeurs intermédiaires (entre 10 et 50 m). Le cycle saisonnier de l'intensité de la fluorescence (intégrée entre 0 et 100 m), tracé à partir de la somme des observations CTD dans la division 3L de l'OPANO, prend une allure semblable à celle qui a été obtenue à la station 27, comme c'est le cas aussi avec le cycle de la température. Une fois enlevée la composante correspondant au cycle saisonnier, on voit que l'intensité résiduelle de la fluorescence prend un caractère régional prononcé semblable à la courbe résiduelle de température, mais qu'il se produit un décalage vers le sud le long du plateau, ce qui pourrait peut-être témoigner de l'advection des marqueurs. Le cycle saisonnier d'abondance de *Calanus finmarchicus* à la station 27 n'est pas aussi accentué que ceux de *Calanus glacialis* ou de *Calanus hyperboreus*. *Pseudocalanus* sp. et *Temora longicornis* sont plus abondants vers le milieu de l'automne. Les cycles saisonniers de ces cinq espèces sont semblables à ceux qui ont été observés lors des relevés CPR effectués dans les divisions 3K et 3L de l'OPANO; toutefois, ils diffèrent sensiblement de ceux des divisions 3N et 3O de l'OPANO. Les écarts entre le cycle saisonnier observé à la station 27 et ceux d'autres secteurs de la division 3L de l'OPANO sont peut-être attribuables à des processus ou des traits locaux (p. ex., mélange, profondeur de la couche mixte, source de nutriants, advection). Il se peut également que la variabilité de la concentration de certains éléments à une échelle temporelle inférieure à 30 jours limite la comparabilité possible des données recueillies à bord de navires occasionnels. La fréquence d'échantillonnage et la résolution spatiale qui seraient essentielles pour faire ressortir la variabilité «climatique» posent de graves problèmes. Le caractère du programme d'échantillonnage qu'il faudrait mettre en place pour assurer une «surveillance adéquate» doit être évalué et discuté soigneusement pour la raison que la méthode d'échantillonnage, notamment les prélèvements faits à partir de navires occasionnels, nous oblige à faire des suppositions audacieuses au moment de l'analyse des données. La faible résolution associée à l'étude des variables océanographiques biologiques par échantillonnage, nuit considérablement à la comparaison des résultats d'observation dont nous disposons parce qu'il est impossible de déterminer l'effet que peuvent avoir les fluctuations à petite échelle et à court terme sur la description du cycle saisonnier ainsi que sur la mesure et l'analyse des fluctuations interannuelles de part et d'autre du cycle moyen.

Introduction

Variations in climate are considered to be a fundamental driving force of the dynamics of marine organisms. Fluctuations in atmospheric forcing impact directly on nutrient availability which in turn affect the production of phytoplankton. Subsequent impacts on higher trophic levels may be reduced in magnitude. However, the consistent pattern in the recruitment dynamics of diverse fish populations in close geographic proximity suggests that the influence of climate may be a significant contributor to variations in animal abundance.

Despite the potential influence which climatic forcing may have on marine food web, few observations are presently available which detail temporal changes in the abundance of organisms such as phyto-, zoo- and ichthyoplankton. Although surveys such as the Continuous Plankton Recorder (CPR) series do provide a basis for describing the most general cycles, limitations in either temporal (i.e. monthly surveys) or spatial (i.e. single depth) can restrict their usefulness in understanding general food web dynamics.

Beyond the general description of the seasonal cycle in the abundance of diatoms and dominant crustacean zooplankton along the CPR routes (Myers et al. 1994), relatively little is known about the variability many elements of the lower trophic levels in the Newfoundland region. This is in contrast with the basic knowledge of the seasonal and areal patterns in physical oceanographic variables (Colbourne 1995 and references therein) which are more readily monitored using automated methods.

This document provides a preliminary description of the temporal and spatial pattern in the variation of nutrients, phytoplankton and zooplankton in the Newfoundland region. Data from directed and ship-of-opportunity collections obtained primarily in 1993-94, with some limited data from 1995, are summarized and contrasted, when applicable, with similar information either from the CPR series (1959-1978, 1991, 1992) or from the Mobil Oil survey of the Grand Banks (1980-81). The comparative data sets represent the only generally available alternative sources of information for the variables considered. The principle objective was to describe and contrast the depth-dependent seasonal cycle in nutrient and phytoplankton abundance from a single site (station 27) with observations taken in the northern region of the Grand Banks (NAFO area 3L). The objective was to establish the degree of generality in the patterns observed during the recent collections from ships-of-opportunity.

Data Sources

Nutrient (nitrate [NO_3], phosphate [PO_4], silicate [SiO_2]) and chlorophyll concentrations for station 27 were taken at the standard hydrographic depths (surface, 10 m, 20 m, 30 m, 50 m, 75 m, 100 m, and 170 m) throughout the year using ship-of-opportunity collections in 1993 and 1994 with limited collections in 1995. Sample analysis was performed using standard biological oceanographic protocols. On most occasions during the 1993-94 period, triplicate vertical plankton tows (0-100 m) were obtained using a 0.75 m net fitted with 232 mm nitex and a 0.5 m net fitted with 70 mm nitex. All zooplankton from those samples were sorted and identified to the lowest taxonomic level possible. Similar collections were also performed at selected stations along cross-shelf transects during the seasonal physical oceanographic surveys of the northeast Newfoundland shelf (Figure 1).

Data from the 1993-94 collections were contrasted with similar data obtained during the Mobil Oil survey of the Grand Banks (Conover 1981). The data consisted of those obtained from the northern-most transect crossing the Grand Banks (Figure 1) and were collected on a near-monthly basis using sampling and analytical protocols similar to the 1993-94 NAFC sampling. Zooplankton data were also contrasted with CPR collections from NAFO areas 3K, 3L, and 3NO (Myers et al. 1994).

In addition to these data sources, all CTD-mounted fluorometer data for NAFO area 3L (Figure 2) were analyzed to describe the depth-integrated (0-100 m) seasonal cycle in temperature and fluorescence, for the period 1992-95, using first and third order harmonic models, respectively. The spatial distribution of the residuals from those models were then analyzed to ascertain whether there were any consistent regional patterns.

Results

Station 27

All nutrients as well as chlorophyll concentrations exhibit strong seasonal cycles (Figure 3). Phosphate and nitrate concentrations show seasonal minimum concentrations in late April-early May in association with the spring phytoplankton bloom. Surface concentrations of these nutrients remain relatively low throughout the summer months and start to increase during the period of September-October. Silicate concentration shows a seasonal pattern which is highly similar to that of phytoplankton and suggests that results may be indicative of diatom levels and of changes in freshwater input.

Phytoplankton concentration appears to show a peak in late April-early may but the precise timing of the spring bloom is uncertain because of the unavailability of data for the period preceding April (Figure 3). However, it is clear that there is substantial variability in phytoplankton abundance on time scales less than 30 days. It is apparent that there is a strong seasonal cycle at all depths (Figure 3) with the greatest overall variability occurring at intermediate depths (10 and 50 m) (Figure 4). Maximum phytoplankton concentrations occur at depths of 30-50 m. The average integrated phytoplankton levels in the upper 100m also shows weak secondary peaks in August and later October-early November (Figure 5). The pattern obtained in 1993-94 is similar to that obtained at station 2 of the Mobil Oil transect (Figure 6a). The data for 1980-81 indicates a prolonged peak in phytoplankton concentration from early March to late April, with secondary peak concentrations in August and November (Figure 6a). This pattern differs somewhat from that observed at station 7 along the same transect (Figure 6b) at which there appears to be a prolonged phytoplankton peak from late

October into January, with little evidence of nutrient limitation. Note that the seasonal cycle in this figure starts on day 90 due to the collection schedule used during the Mobil surveys.

The seasonal cycle of the different species of *Calanus* at station 27 appears to show peak abundance levels during early summer (Figure 7). The seasonal cycle in the abundance of *Calanus finmarchicus* is not as marked as that of *Calanus glacialis* or *Calanus hyperboreus*. The abundance of *Pseudocalanus* sp and *Temora longicornis* shows higher levels during mid-fall (Figure 7). The seasonal cycles for *C. glacialis* and *C. hyperboreus* at station 27 in 1993-94 are similar to those observed during the seasonal survey of the Grand Bank conducted by Mobil Oil in 1980-81 (Figure 8). This similarity is not apparent in the seasonal cycles for *C. finmarchicus*, *Pseudocalanus* sp., and *T. longicornis*. The seasonal cycles for the five species presented in this analysis are similar to those observed from the CPR surveys conducted in NAFO areas 3K and 3L but differ substantially from those for NAFO area 3NO (Figure 9).

Transects

Although cross-shelf transects in 1993-94 do not correspond directly with the transect occupied during Mobil's seasonal surveys (Figure 1), both nitrate and chlorophyll concentrations show similar seasonal and spatial patterns. Overall nitrate and phytoplankton concentrations are higher along the shelf edge, in correspondence with the offshore arm of the Labrador current (Figure 10 a-d). Furthermore, both nitrate and chlorophyll concentrations from the 1993-94 surveys are greater than the observations obtained during the 1980-81 surveys of the region. As with station 27, there is a subsurface peak in chlorophyll concentration at a depth of 30-50 m across the entire shelf (Figure 10) and the overall variability in nitrate and chlorophyll levels is also greatest at intermediate depths (Figure 11). Despite the similarity in the cross-shelf seasonal cycle with that observed at station 27, there are also substantial differences in the level of seasonal variability along the Mobil transect from 1980-81 (Figure 11).

Regional Information

The seasonal cycle in integrated (0-100 m) fluorescence levels from all CTD observations in NAFO area 3L (Figure 12) shows a pattern that is similar to that observed at station 27 (Figure 5). There is a peak in late April-early May indicating a spring bloom followed by a secondary peak in September-October suggesting a fall bloom (Figure 12). Given the limited nature of the time series, it is impossible to establish whether the difference in the timing of the secondary peak reflect differences in data availability or true differences in the seasonal cycle in coastal and shelf regions. The seasonal cycle in the temperature data from this limited subset of CTD casts in that region shows a pattern that is similar to the seasonal cycle at station 27 which peaks in September-October (Figure 13).

After taking into account the seasonal cycle, the residual fluorescence levels show a marked, although variable, regional pattern (Figure 14). Relatively low fluorescence levels appear to predominate on the shelf, north of the Grand Banks. In offshore waters, as well as on the Grand Banks, residual fluorescence levels appear to be higher. This pattern is similar to the residual temperature levels (Figure 15). However, the residual fluorescence levels appear to be shifted further along the shelf relative to the pattern in residual temperature. This could be indicative of some cross and along shelf advection of tracers.

Discussion

The seasonality of all lower trophic levels observed at station 27 shows general similarities with the seasonal cycle observed in the remainder of NAFO area 3L. However, within that region, there is also substantial variability in the nature of the seasonality. Furthermore, the degree of similarity of station 27 with other areas appears to decrease as the distance away from that site increases.

Differences in the seasonal cycle at station 27 with other parts of NAFO area 3L may be due to local features or processes (e.g., mixing, mixed layer depth, nutrient sources, advection) . However, it is also possible that the variability in the level of some elements on the time scale of less than 30 days limits the degree of comparison possible from ship-of-opportunity collections.

Although there is a strong seasonal cycle in the surface layer, the greatest variability in nutrient and chlorophyll concentrations is found in the subsurface layer at depths of 30-50 m. This is caused by the periodic formation and breakdown, or sinking, of a subsurface chlorophyll maximum. The dynamics of this layer may thus provide a cyclic influx of organic matter to the benthic environment. The importance of this feature to a monitoring program is that tracking surface chlorophyll levels, using remote sensing methods (e.g. satellites), may not be adequate to detect variations in the dynamics of lower trophic levels.

There are important questions pertaining to the sampling frequency and spatial resolution that would be essential in order to detect the "climatic" variability. High frequency temporal patterns may be monitored at a single (e.g. station 27) but corroboration of the pattern of variability at other shelf locations should be undertaken in order to develop a proper understanding of the driving forces of the dynamics of lower trophic levels. For example, it is possible that transport of tracers on the Newfoundland shelf is a major factors influencing the tracers concentrations and the dynamics planktonic organisms. However, the nature of the sampling program required to supply "adequate monitoring" requires extensive evaluation and discussion because ship-of-opportunity based collections require substantial assumptions in the interpretation of data analysis. The following questions represent some of the fundametnal issues that must be addressed in developing a biological oceanographic monitoring program for the Newfoundland region:

General

- What constitutes adequate spatial and temporal resolution in the features of the lower trophic levels to detect or understand climatically induced variations in production and abundance?

Spatial representation

- Is the similarity, or lack thereof, in the seasonal cycle, observed at different times and locations, sufficient to warrant monitoring at a single site (e.g. station 27)?
- How do we overcome "noise" (error) problems associated with small scale patchiness at such a site?
- Does remote sensing offer an appropriate alternative or additional source of information?
- Are subsurface processes (e.g. formation of chlorophyll maximum) important to monitoring issues? Are they important to energy transfer to benthos and demersal fish?

Temporal representation

- What can we learn from knowing that there is relatively more or less of something (e.g. nutrients, phyto- or zooplankton) if we only have an "annual" signal? Do we need to measure interannual variations in the seasonal cycle? Are these important to energetics of pelagic organisms?
- Should the temporal resolution of the sampling ensure resolution of short-term events (e.g. late summer/fall phytoplankton blooms)? Are these processes important?
- What do we need to know about the onset, magnitude and duration of the spring/winter bloom?

The current sampling resolution of biological oceanographic variables severely limits the comparison of available observations because of the possible influence of short-term and small-scale variability on the description of the seasonal cycle and in the measurement and understanding of interannual fluctuations about that mean cycle.

References

Colbourne, E. 1995. Oceanographic conditions and climate change in the Newfoundland region during 1994. *DFO Atlantic Fisheries Research Document 95/3.*

Conover, S.A.M 1981. Introduction. *Grand Banks Oceanographic Studies. Final Report. Volumes 1-4.* Mobil Oil Canada Limited.

Myers, R.A., Barrowman, N.J., Mertz, G., Gamble, J., and Hunt, H.G. 1994. Analysis of continuous plankton recorder data in the Northwest Atlantic 1959-1992. *Can. Tech. Rep. Fish. Aquat. Sci. 1966.*

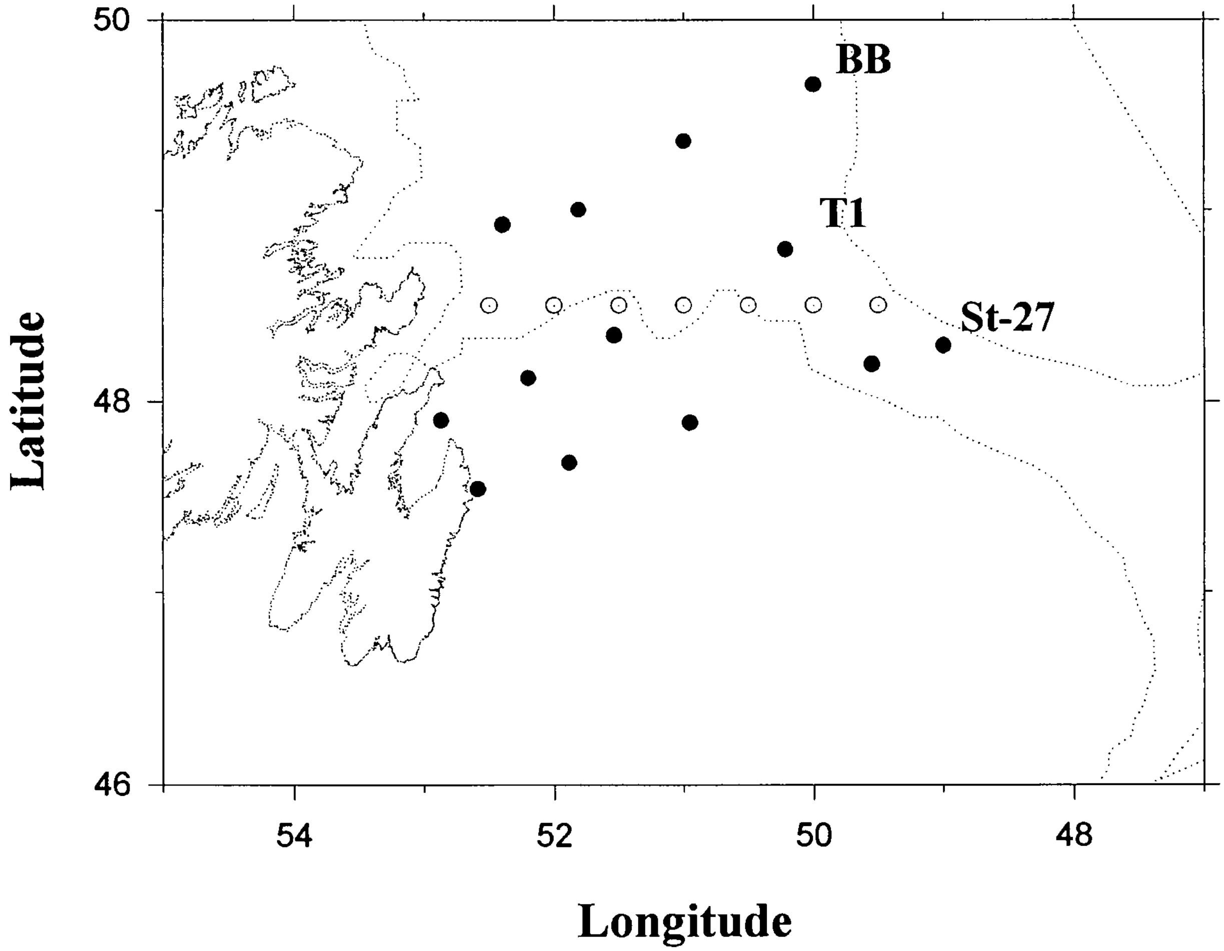

Figure 1. Station locations (closed circles) along the seasonal oceanographic transects (St-27 [May, June 1994], BB [July 1994], T1 [Sept. 1993]) at which biological oceanographic variables were measured.

The open circles indicate locations sampled monthly during the Mobil Oil surveys of the Grand Banks

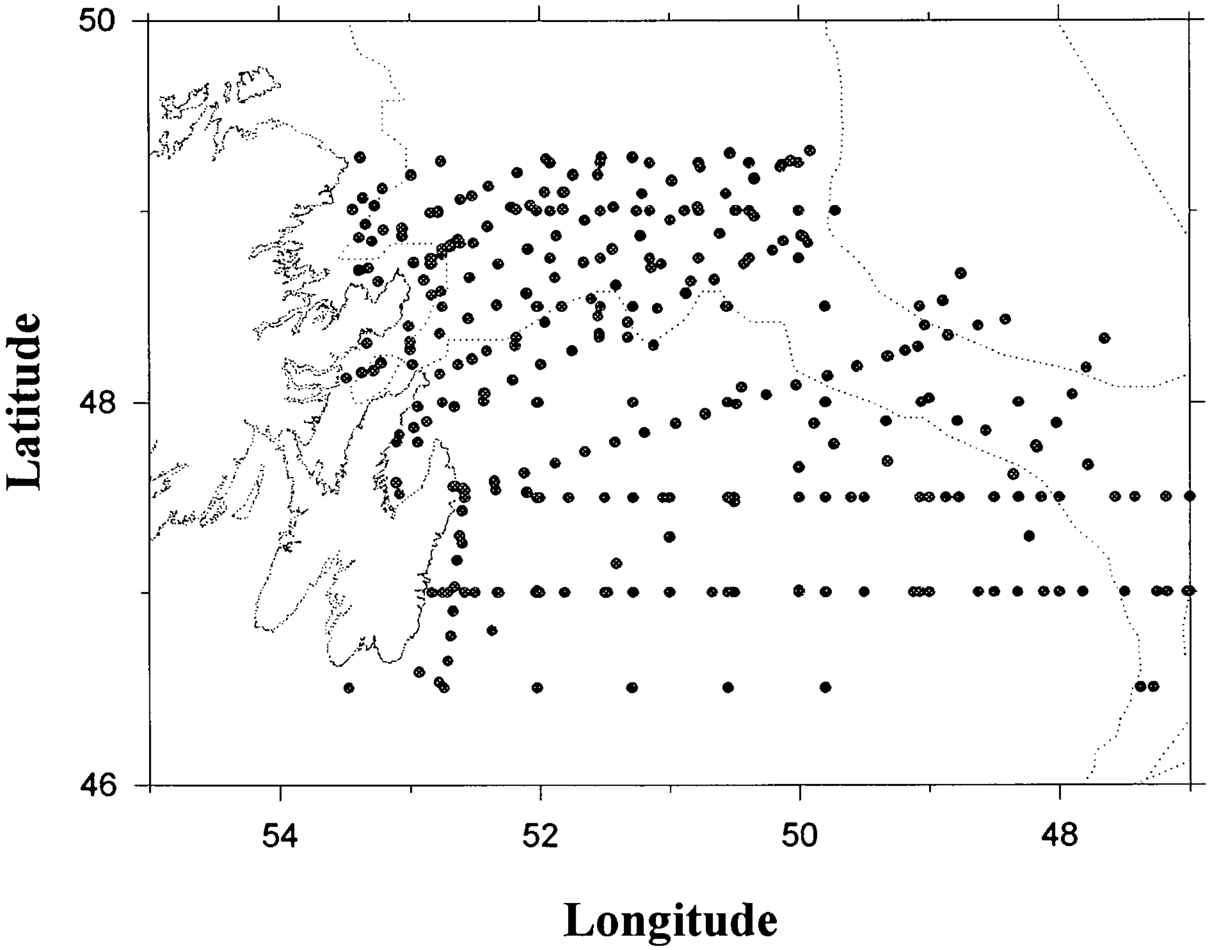

Figure 2. Station locations at which CTD-mounted fluorometer data was available during the period 1992-95.

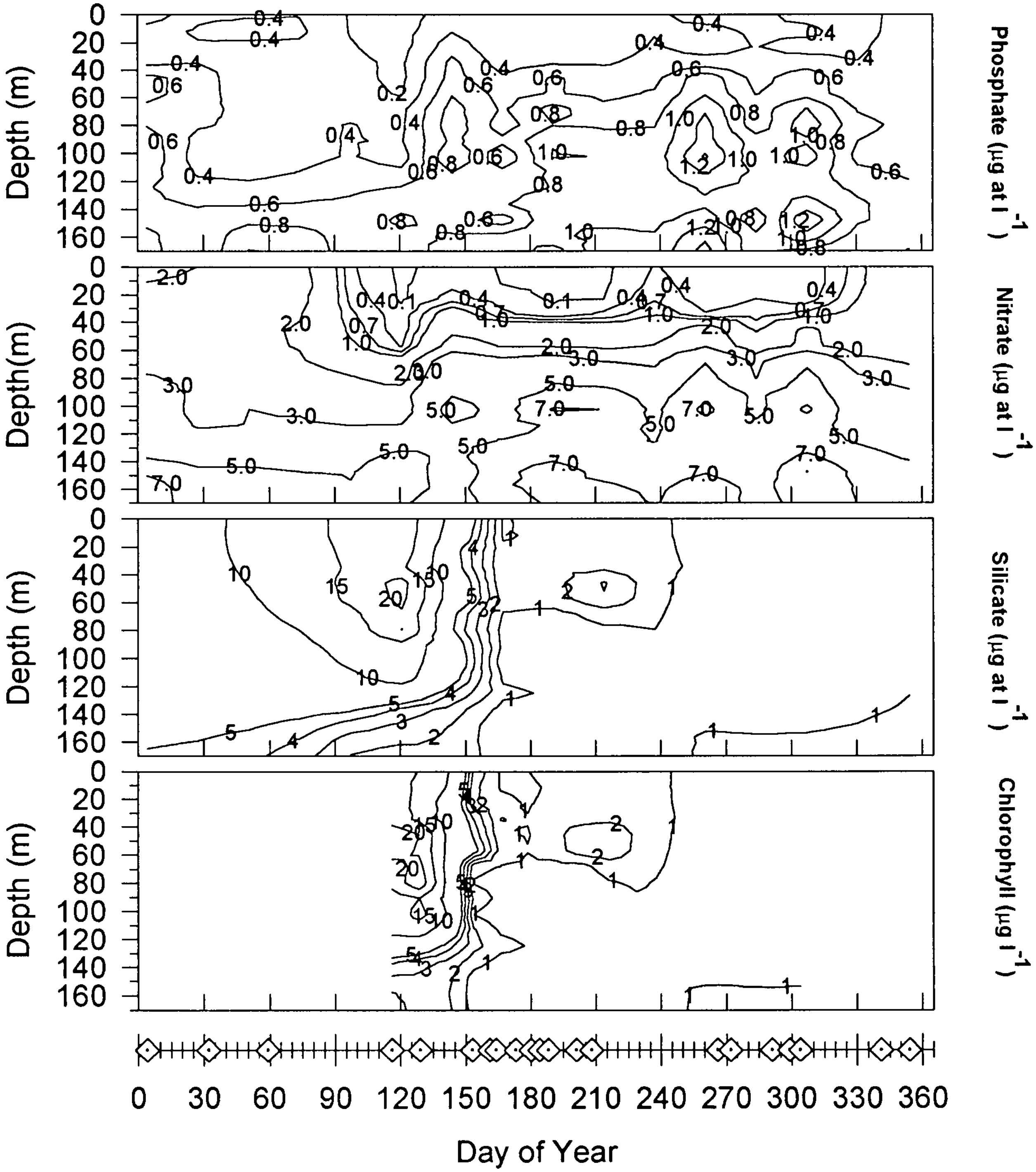

Figure 3. Depth-dependent contour diagrams of phosphate, nitrate, silicate, and chlorophyll concentrations at station 27 in relation to day of year. The diamonds along the time axis indicate sampling dates.

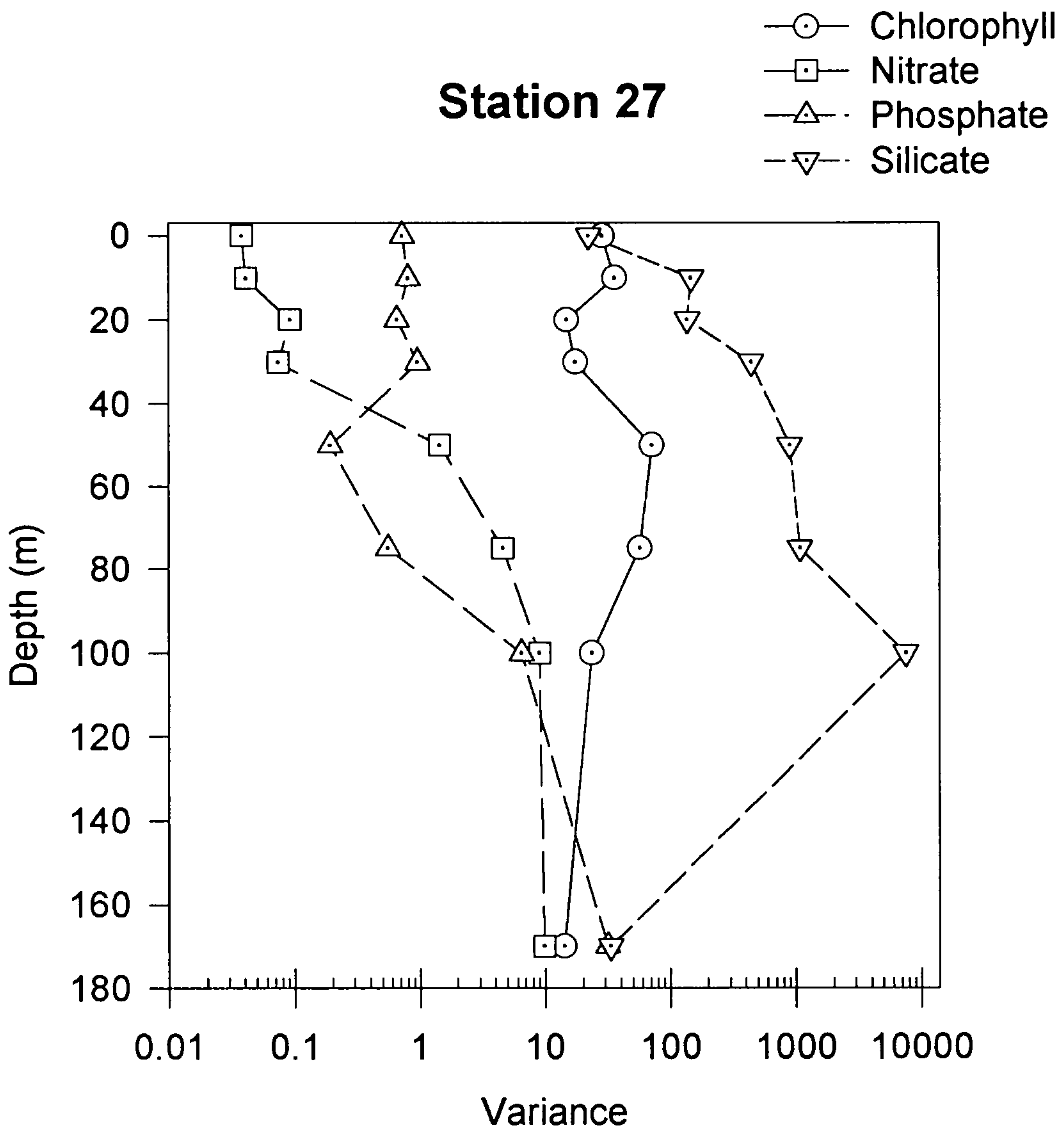

Figure 4. Integrated seasonal variance, for each depth interval, in the four biological variables measured at station 27 during NAFC's sampling in 1993-94.

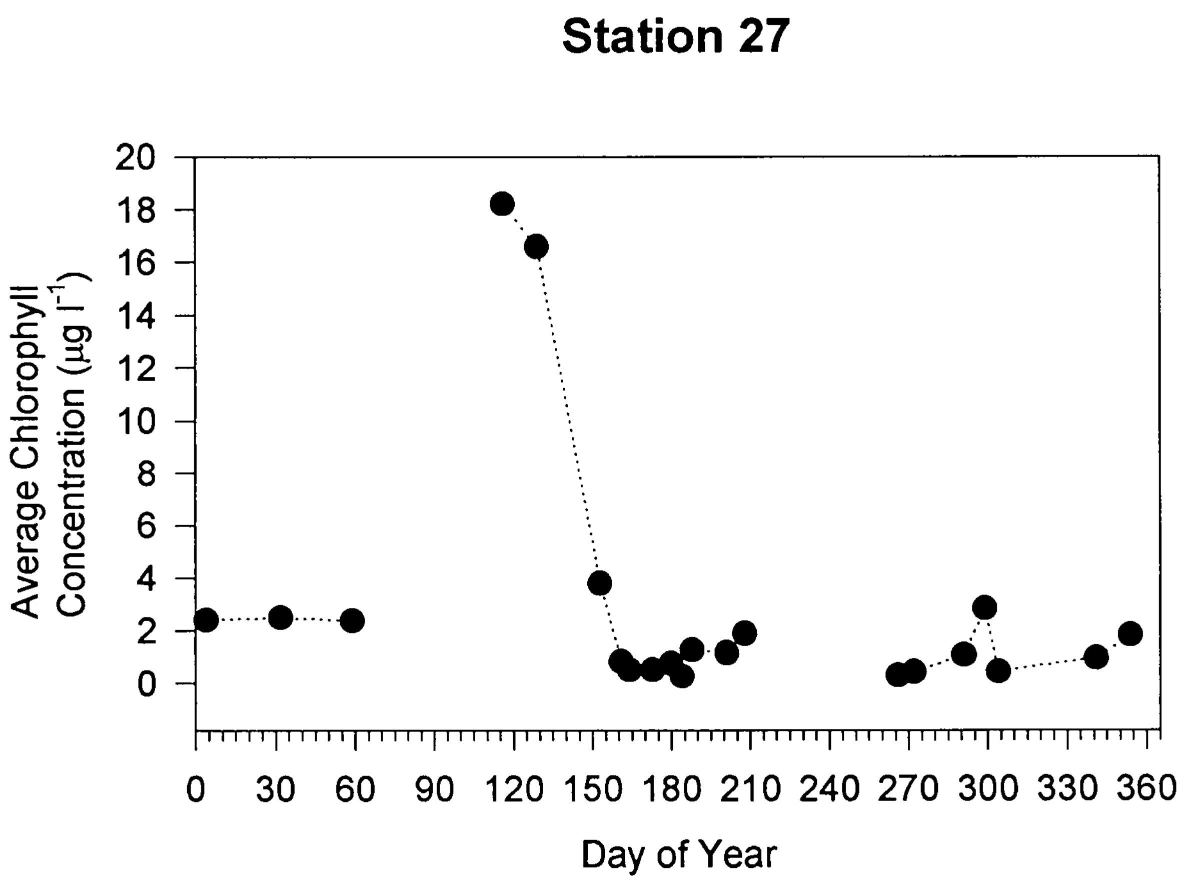

Figure 5. Average chlorophyll concentration estimated for the standard hydrographic depths (0, 10, 20, 30, 50, 75, and 100 m) at station 27. The dotted line is included only to show observations which are separated by less than 40 days.

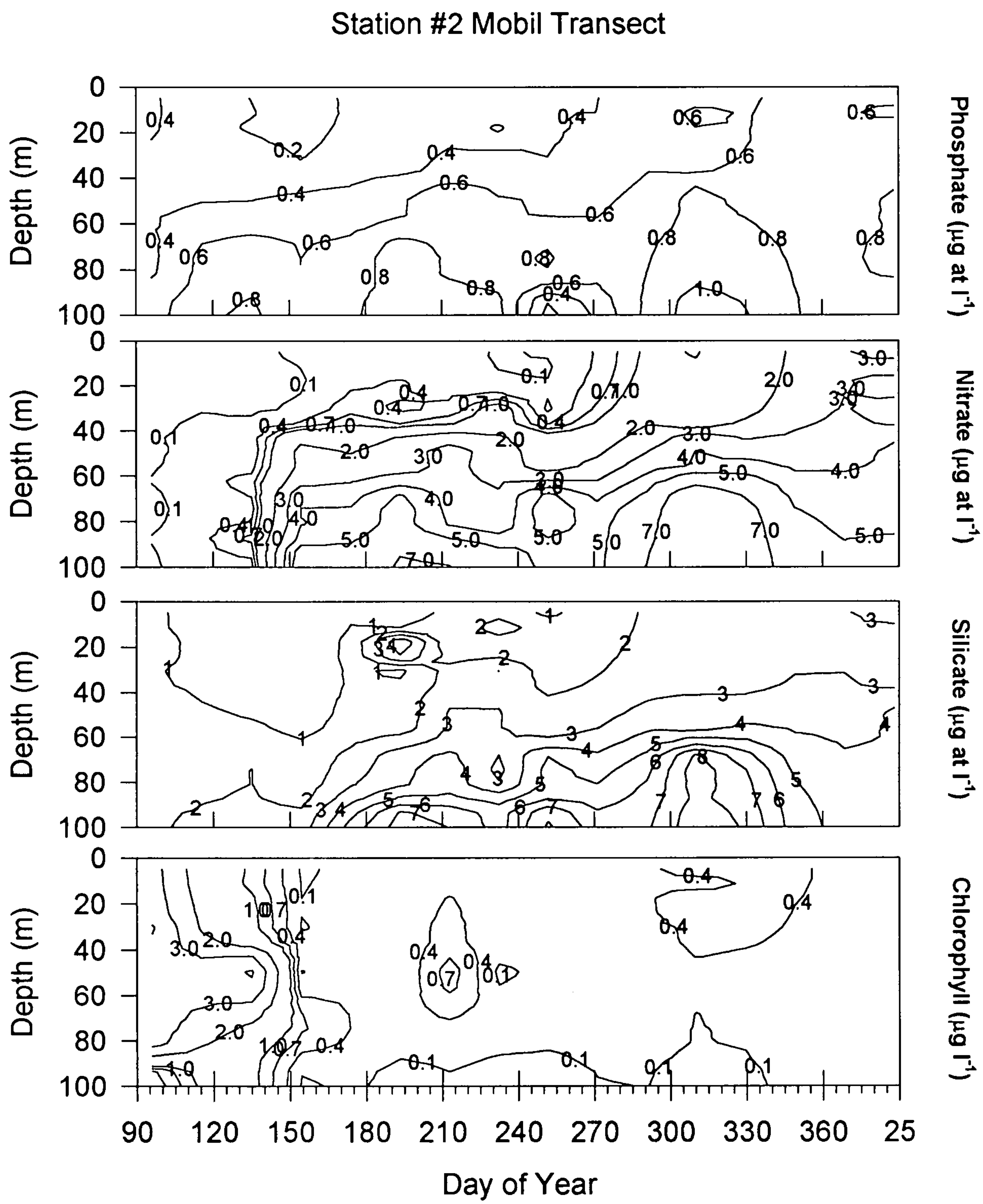

Figure 6a. Depth-dependent contour diagrams of phosphate, nitrate, silicate, and chlorophyll concentrations at station [a] 2 from the Mobil Oil survey transect (1980-81) in relation to day of year.

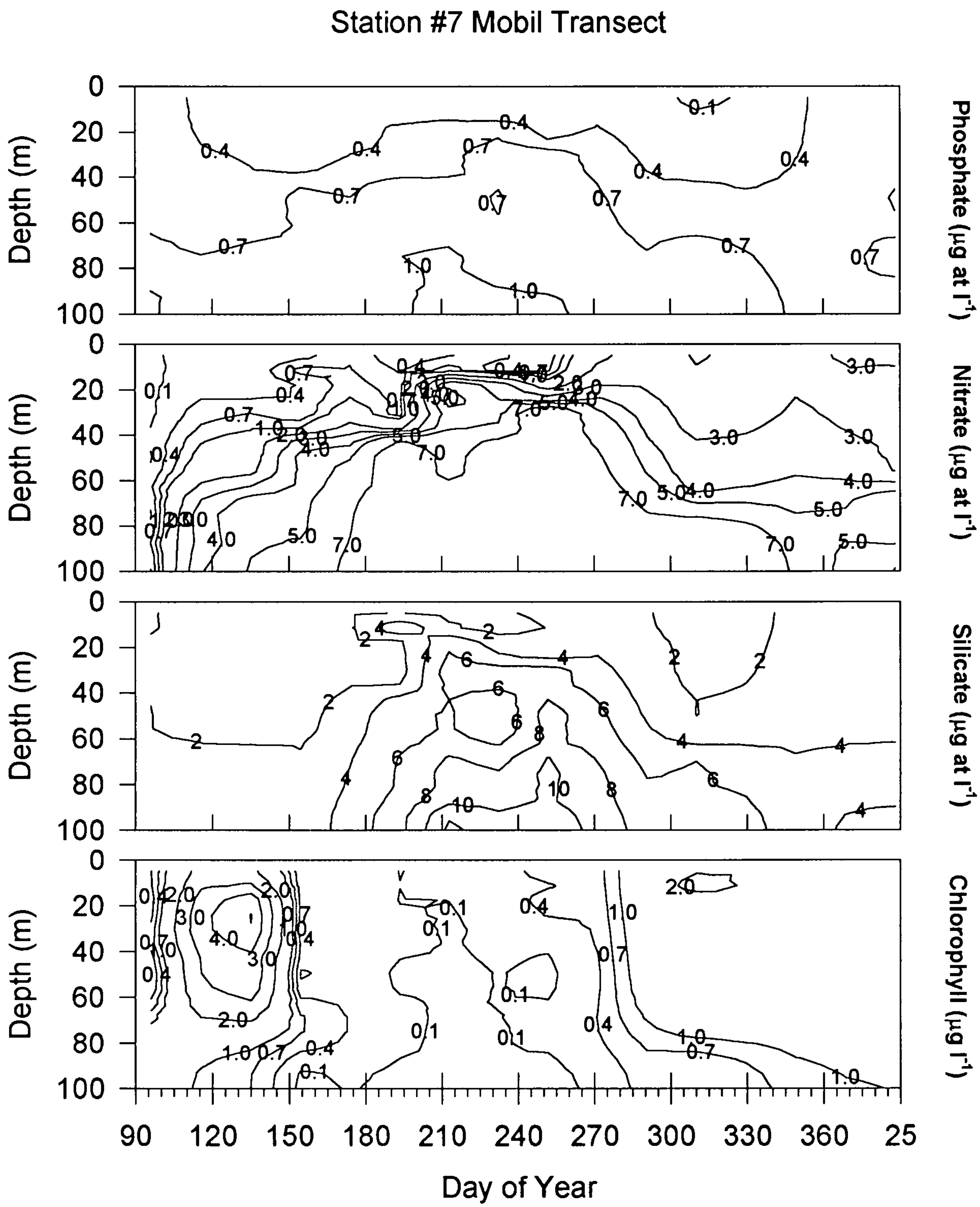

Figure 6b. Depth-dependent contour diagrams of phosphate, nitrate, silicate, and chlorophyll concentrations at station 7 from the Mobil Oil survey transect (1980-81) in relation to day of year.

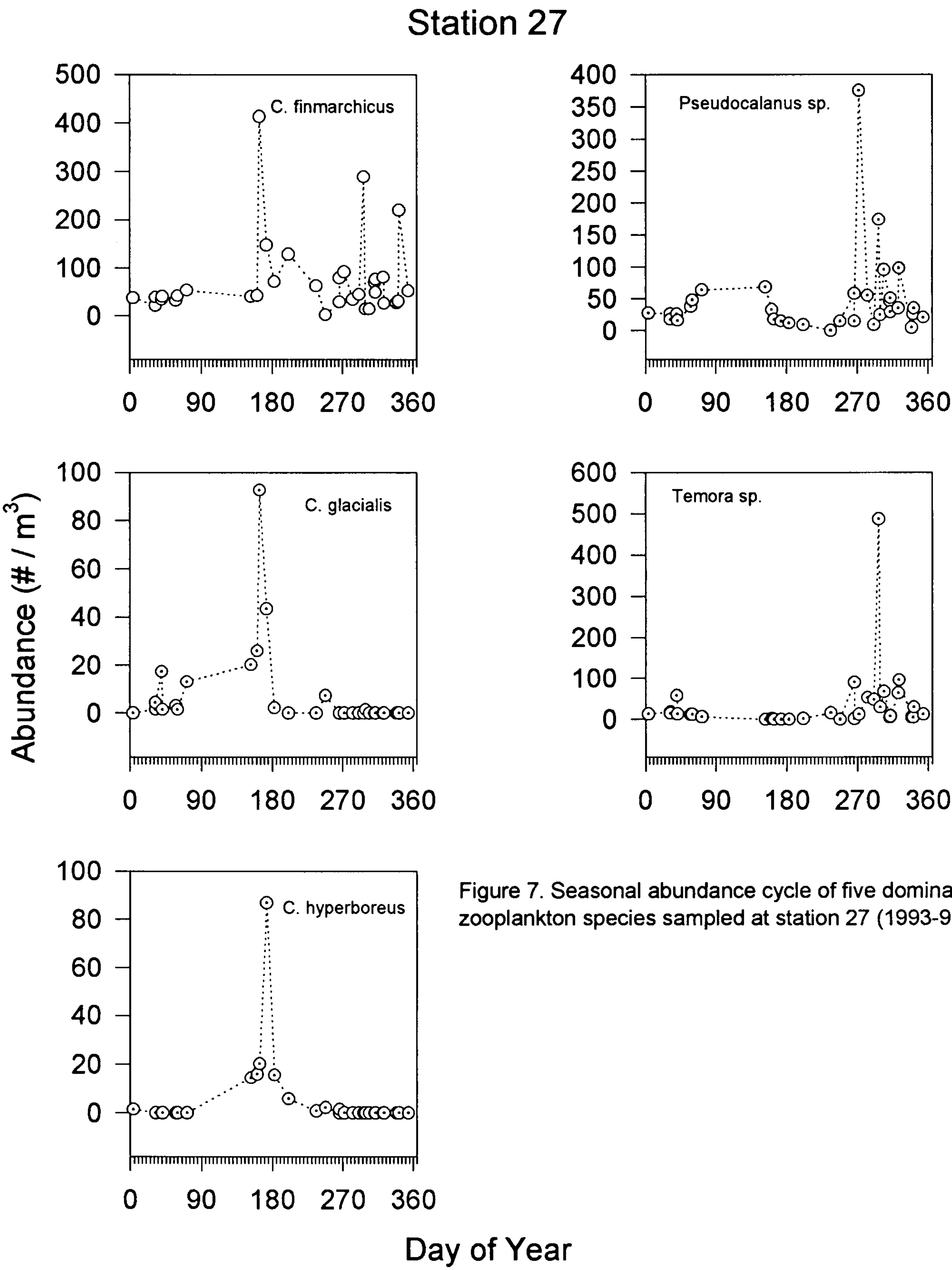

Figure 7. Seasonal abundance cycle of five dominant zooplankton species sampled at station 27 (1993-94).

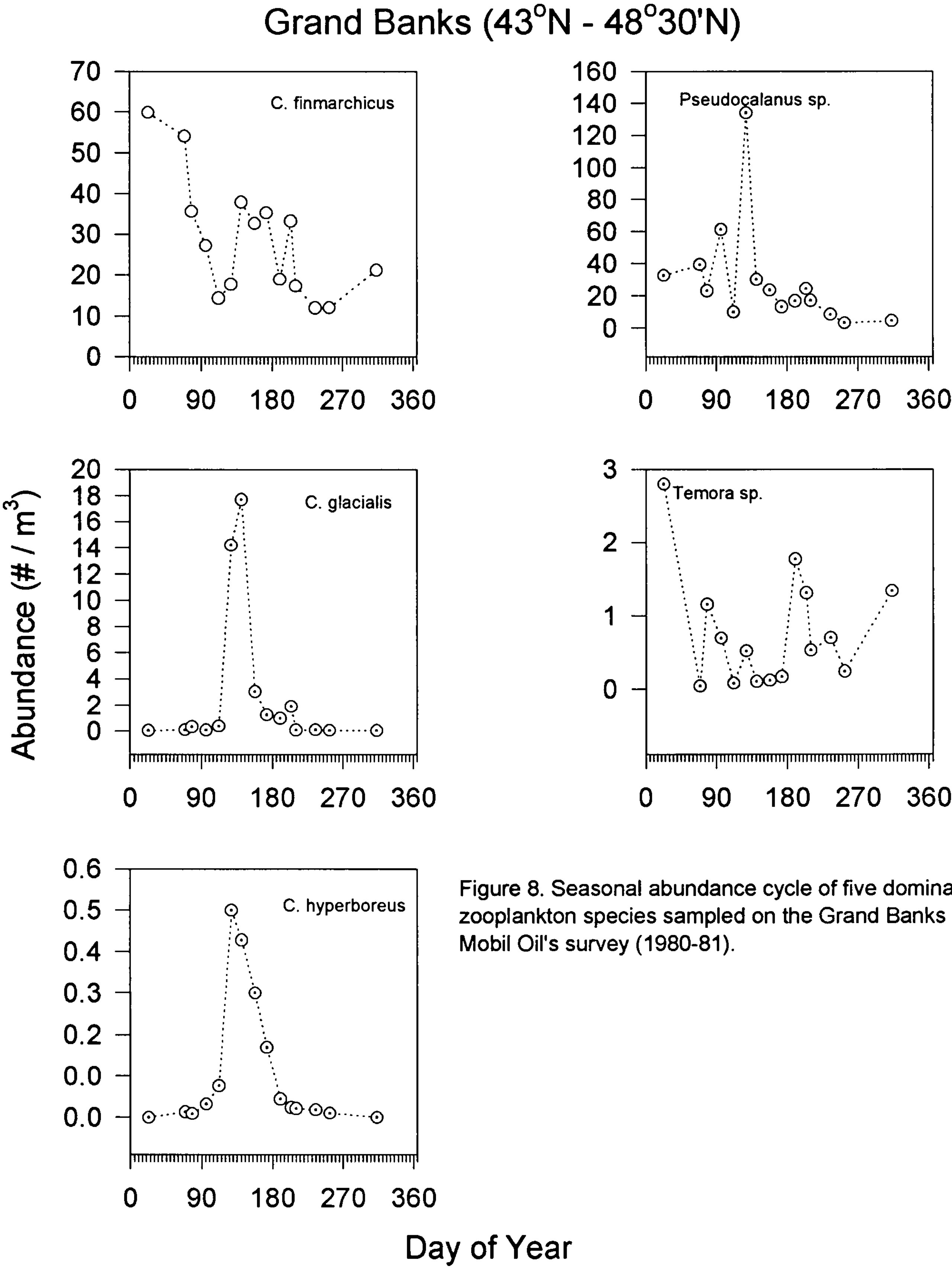

Figure 8. Seasonal abundance cycle of five dominant zooplankton species sampled on the Grand Banks during Mobil Oil's survey (1980-81).

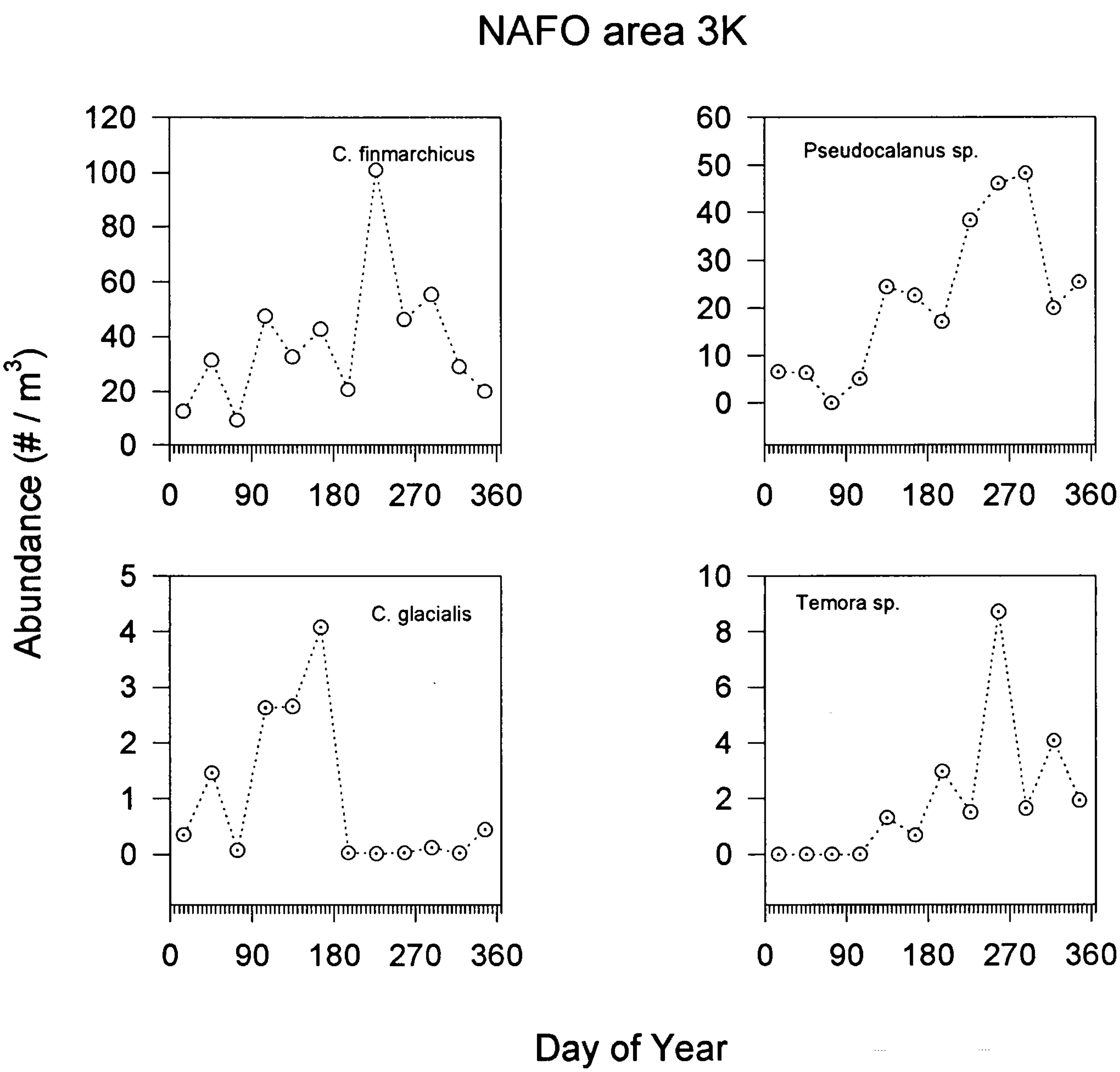

Figure 9a. Seasonal abundance cycle of four zooplankton species sampled by the Continuous Plankton Recorder program (1959-1978, 1991, 1992) for NAFO areas 3K.

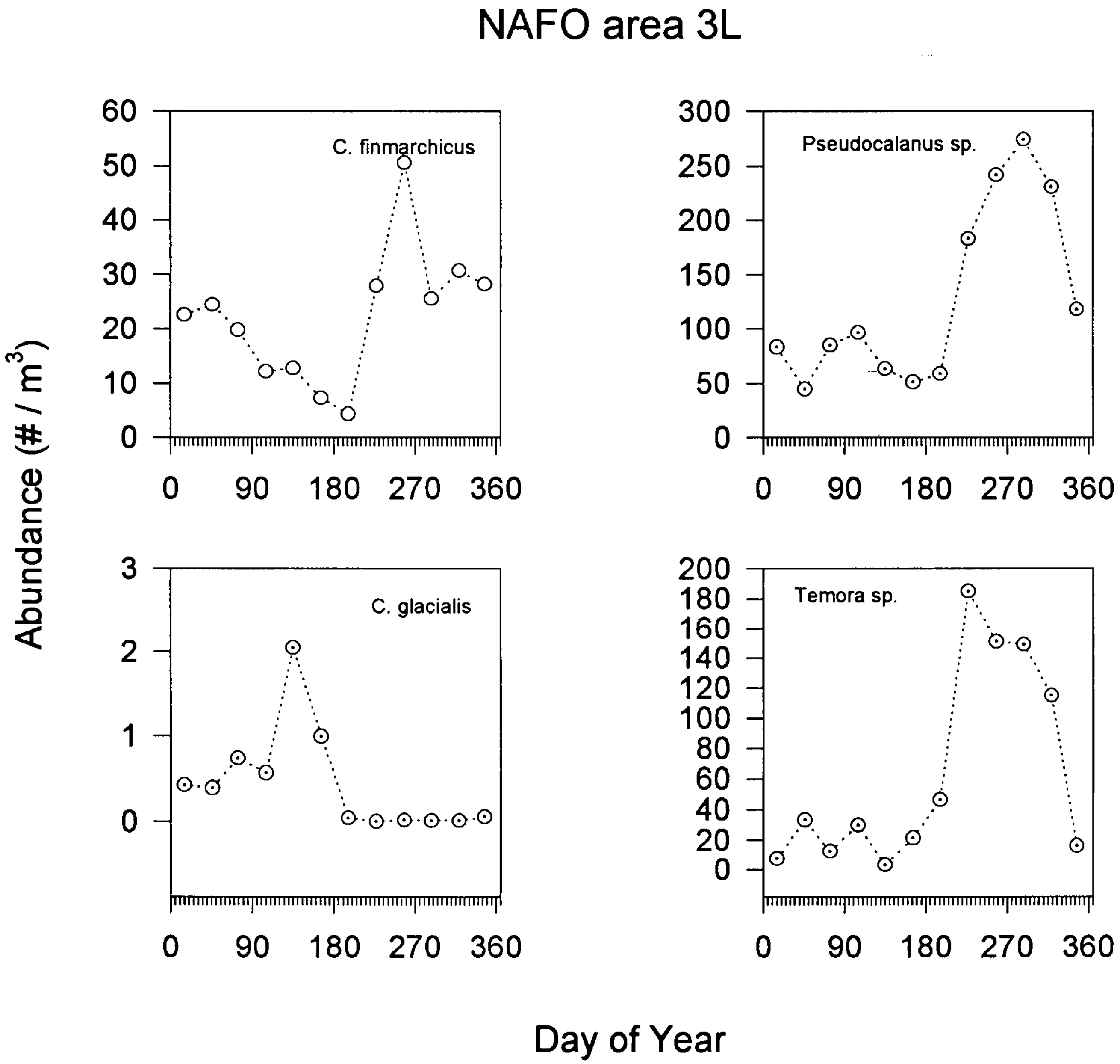

Figure 9b. Seasonal abundance cycle of four zooplankton species sampled by the Continuous Plankton Recorder program (1959-1978, 1991, 1992) for NAFO areas 3L.

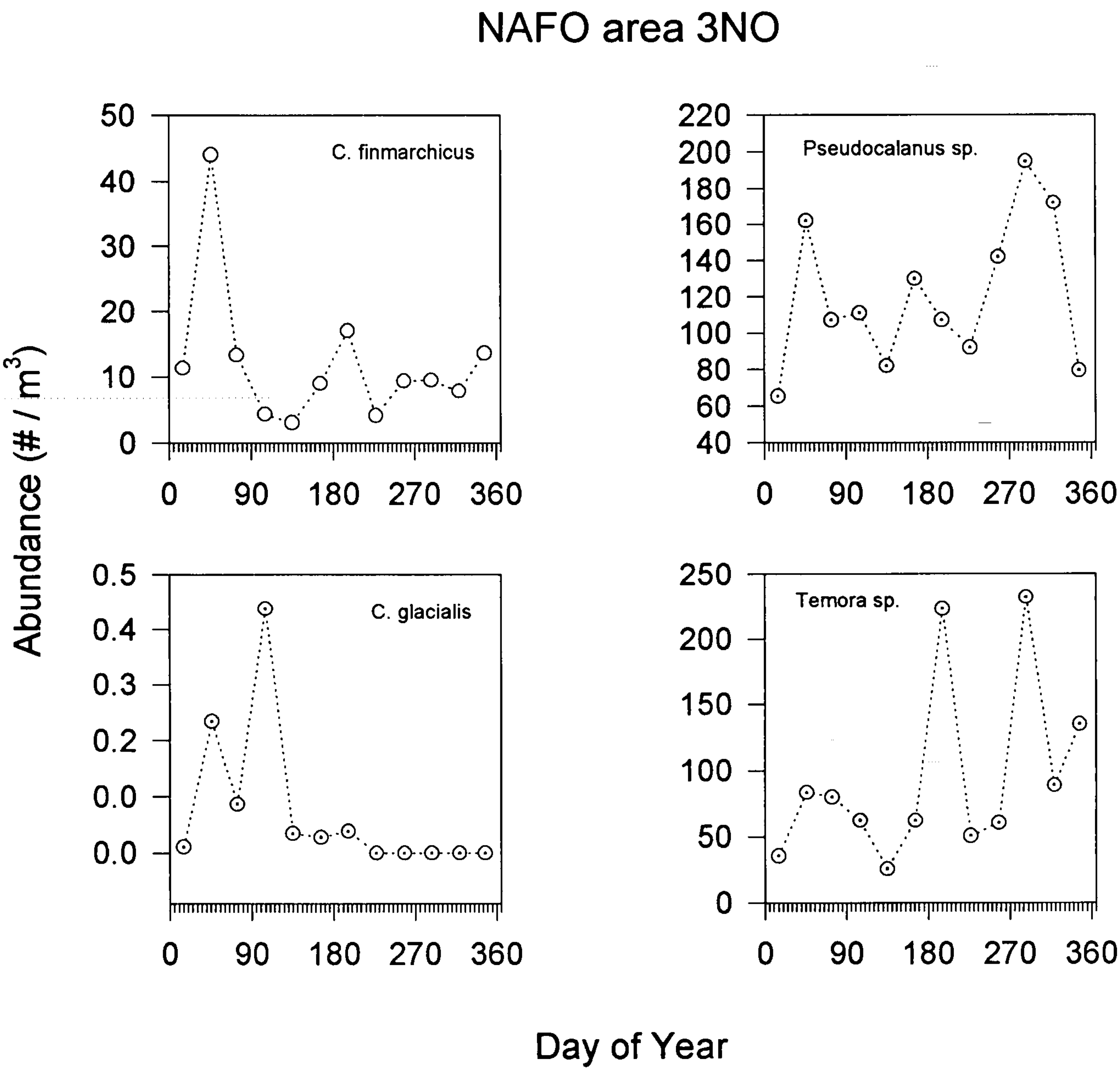

Figure 9c. Seasonal abundance cycle of four zooplankton species sampled by the Continuous Plankton Recorder program (1959-1978, 1991, 1992) for NAFO areas 3NO.

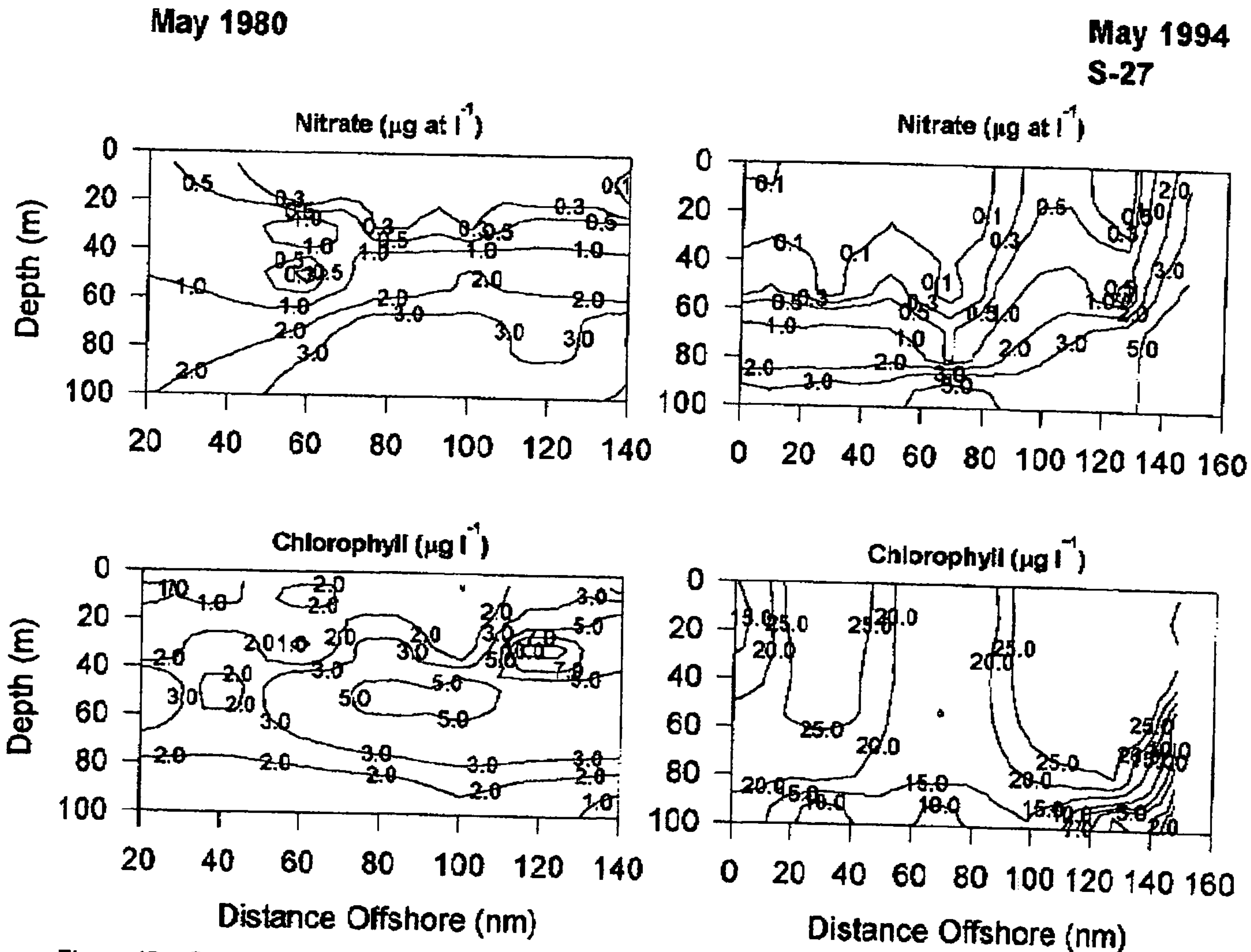

Figure 10a. Cross-shelf distribution of nitrate and chlorophyll concentrations for the Mobil Oil transect [1980-81] (Figure 1) and NAFC's seasonal oceanographic program [1993-94] for the month of May.

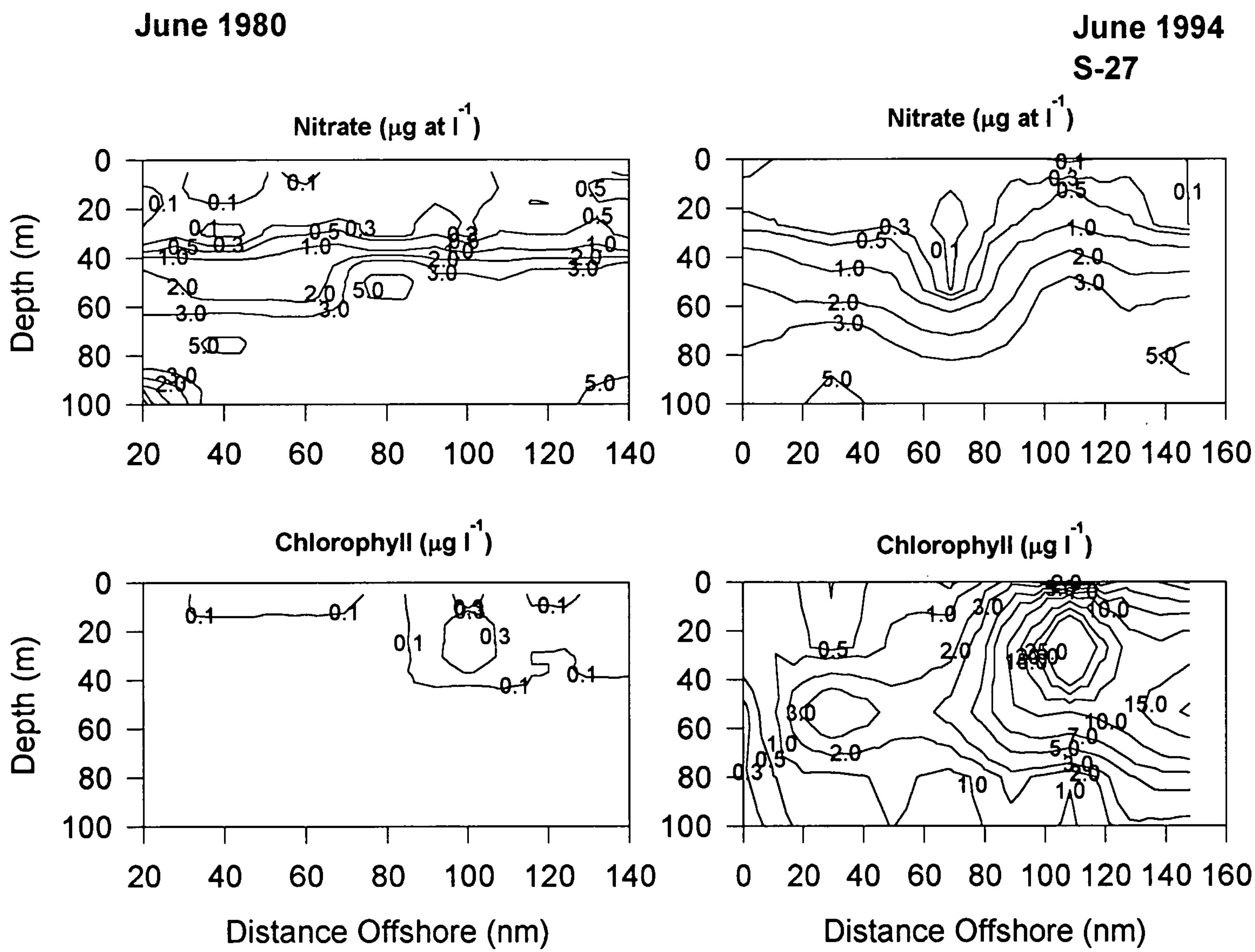

Figure 10b. Cross-shelf distribution of nitrate and chlorophyll concentrations for the Mobil Oil transect [1980-81] (Figure 1) and NAFC's seasonal oceanographic program [1993-94] for the month of June.

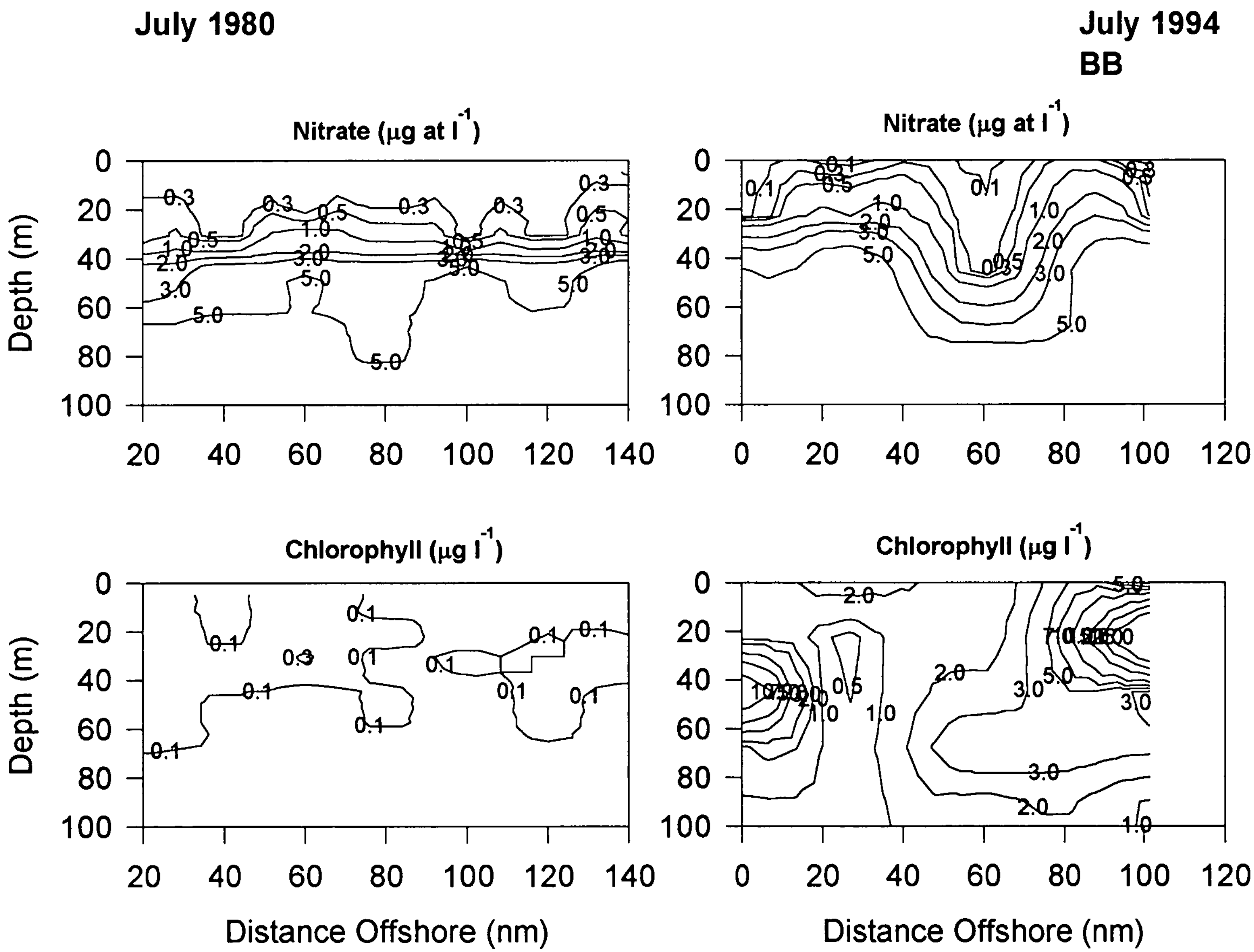

Figure 10c. Cross-shelf distribution of nitrate and chlorophyll concentrations for the Mobil Oil transect [1980-81] (Figure 1) and NAFC's seasonal oceanographic program [1993-94] for the month of July.

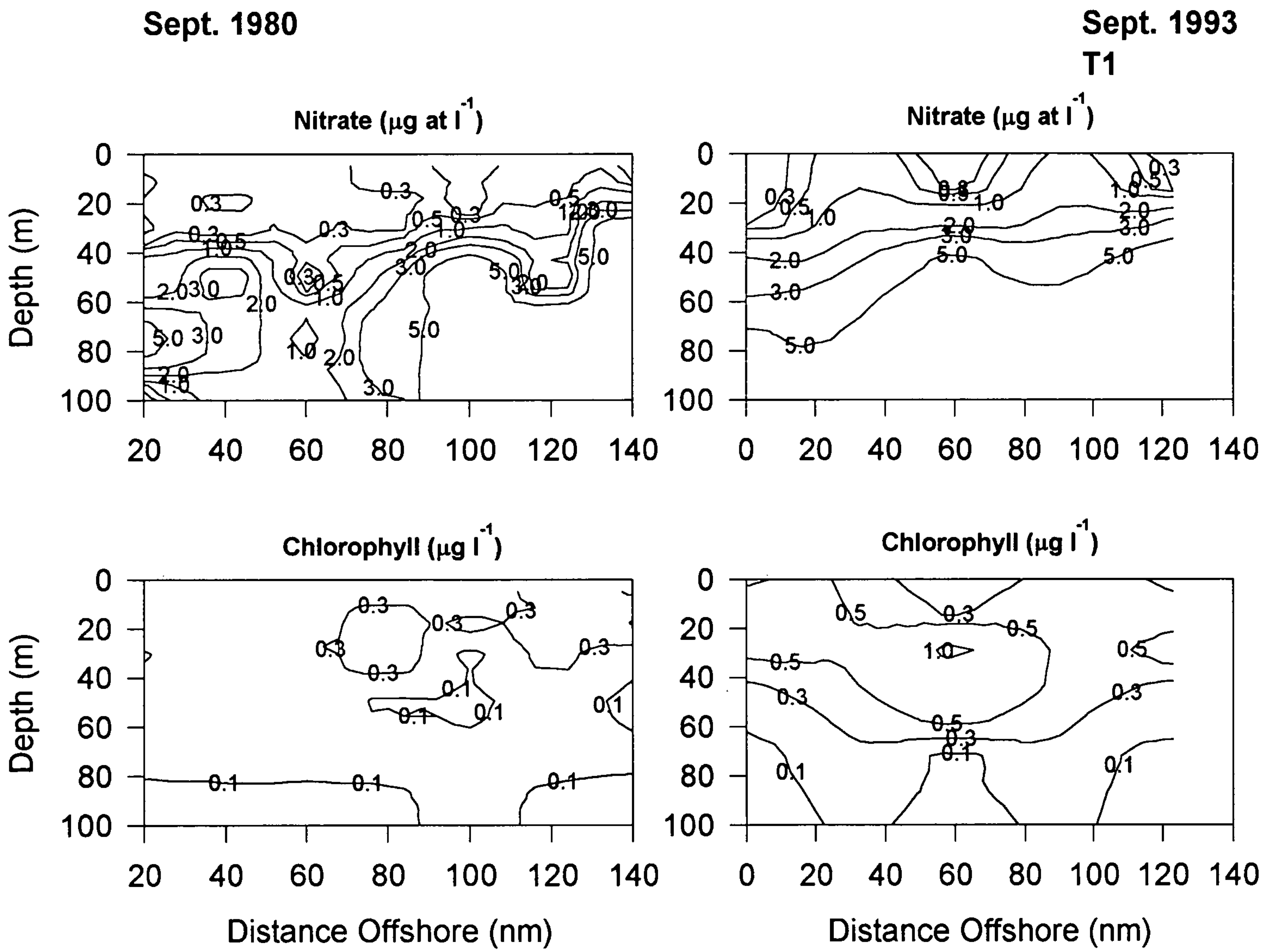

Figure 10d. Cross-shelf distribution of nitrate and chlorophyll concentrations for the Mobil Oil transect [1980-81] (Figure 1) and NAFC's seasonal oceanographic program [1993-94] for the month of September.

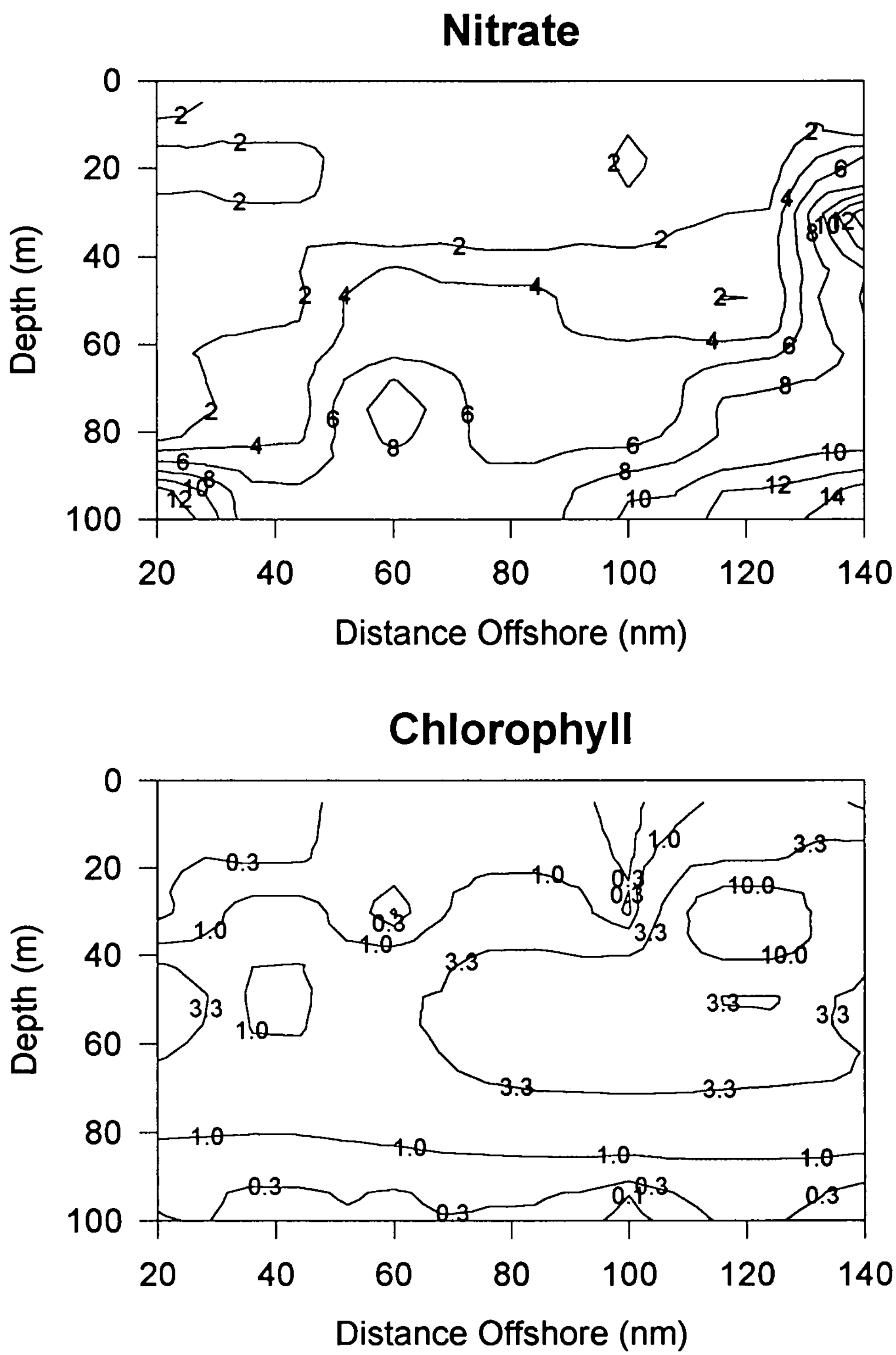

Figure 11. Seasonal variance in nitrate and chlorophyll concentration for standard depths (5, 10, 20, 30, 50, 75, 100 m) in relation to distance from shore along the Mobil Oil survey transect (Figure 1).

Variance estimates are based on samples from April, May, June, July, August, September, November and January [1980-81].

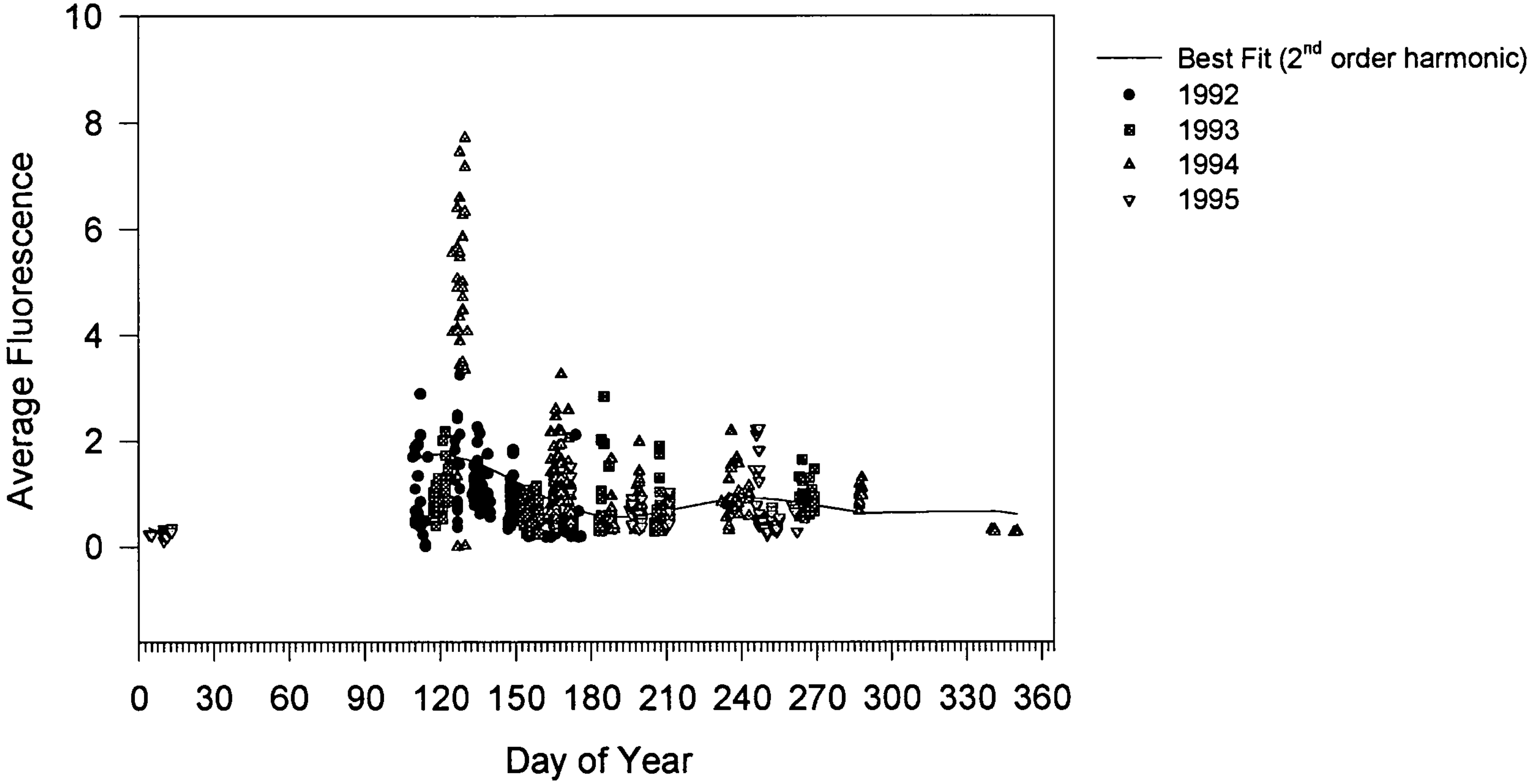

Figure 12. Integrated (0-100 m) seasonal fluorescence cycle (2nd order harmonic) in NAFO area 3L measured using all CTD-mounted fluorometer observations during the period 1992-95.

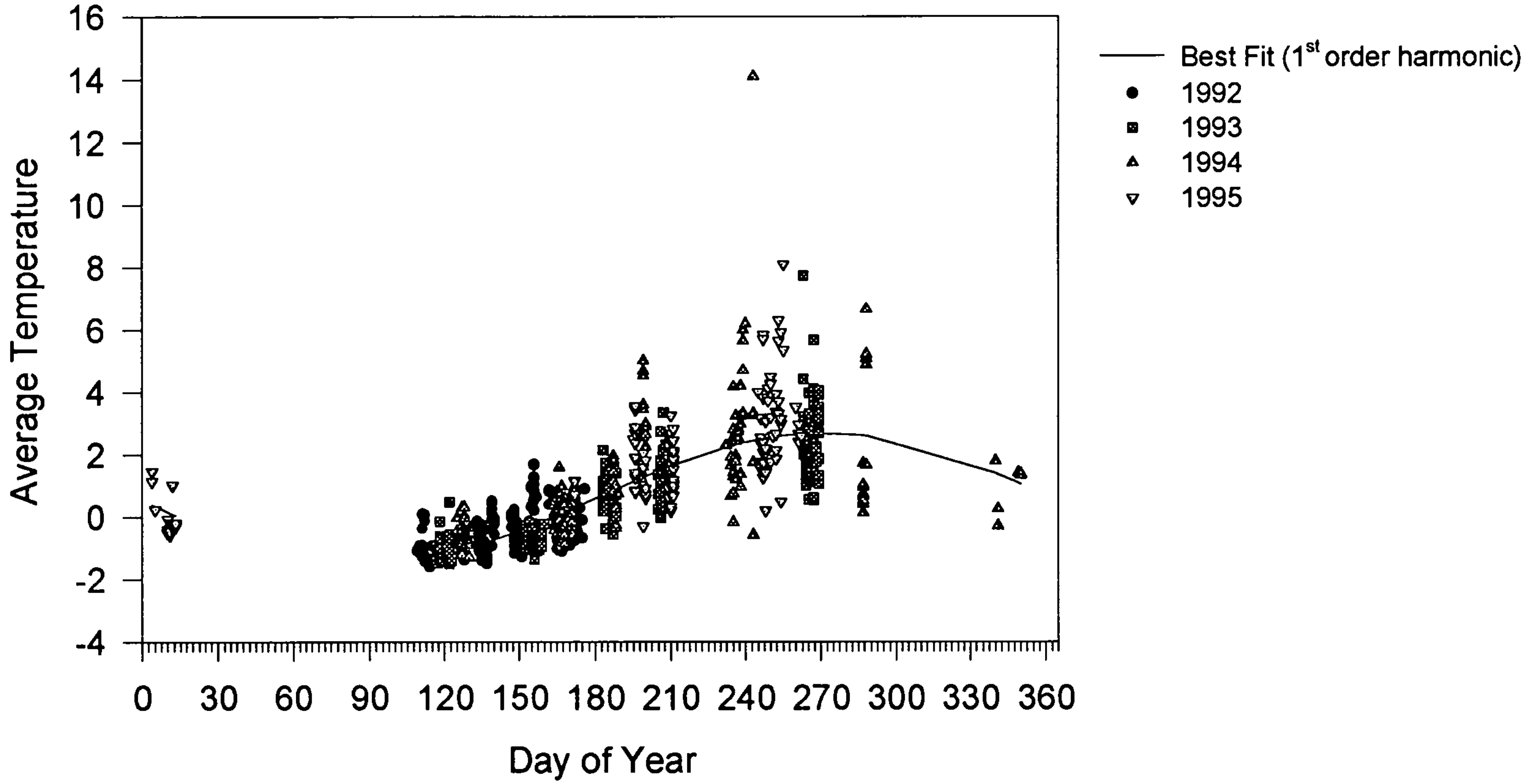

Figure 13. Integrated (0-100 m) seasonal temperature cycle (1st order harmonic) in NAFO area 3L measured using all observations with CTD-mounted fluorometers during the period 1992-95.

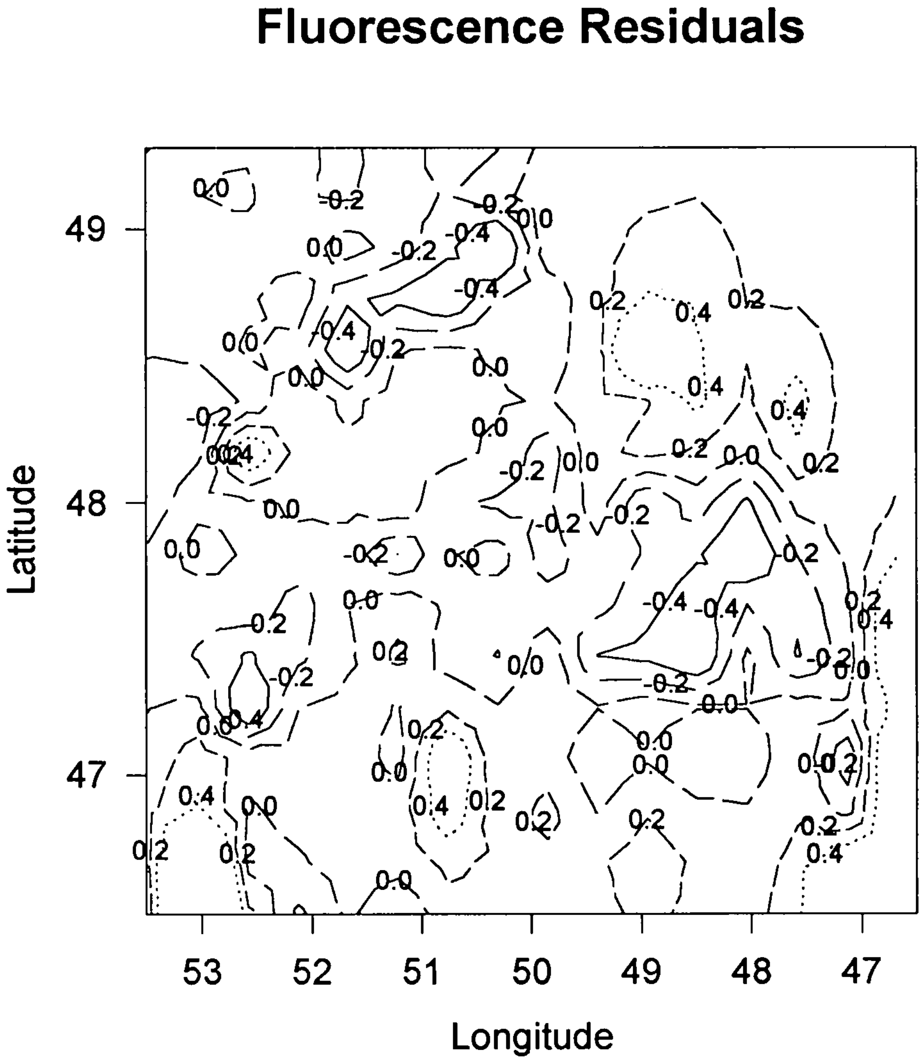

Figure 14. Regional contour diagram of residual (i.e. deseasonalized) fluorescence in NAFO area 3L based on data shown in Figure 12.

Temperature Residuals

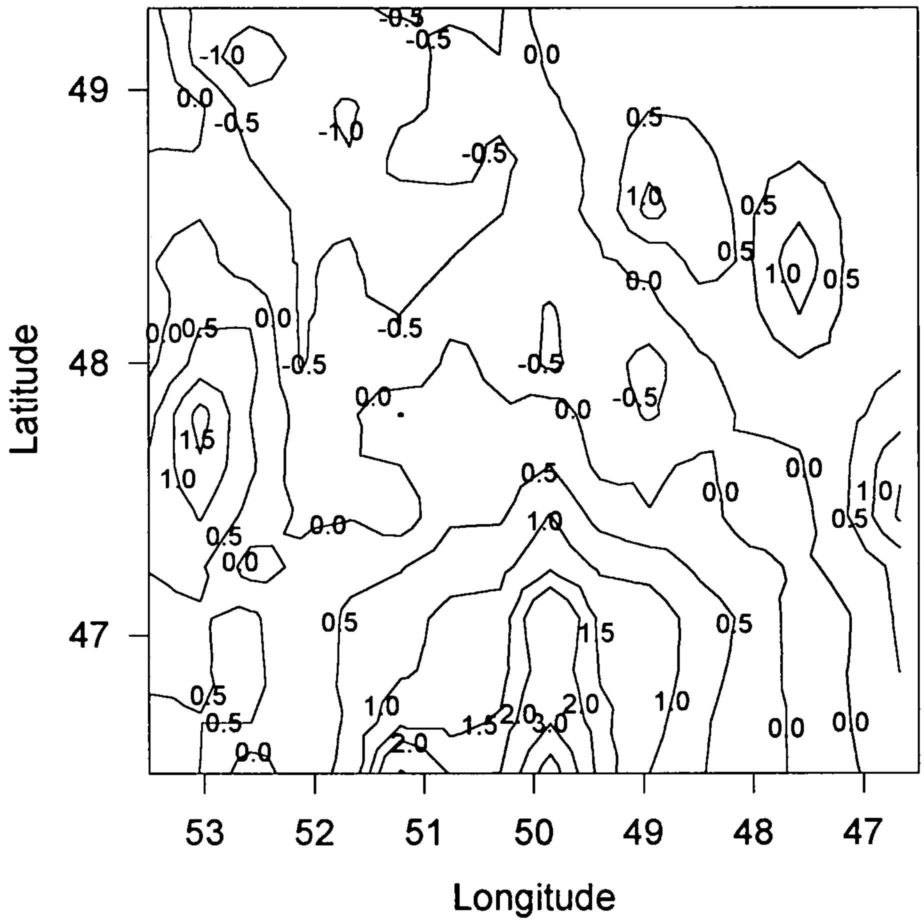

Figure 15. Regional contour diagram of residual (i.e. deseasonalized) temperature in NAFO area 3L based on data shown in Figure 13.