6.3 Biological Oceanography - Plankton

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6.3.1 Distribution and Seasonal Cycles of Phytoplankton

6.3.1.1 Sources of data

Five sources of data will be used in the analysis of distribution and seasonal cycles of phytoplankton. These are: (1) surface chlorophyll determinations made during the Scotian Shelf Icthyoplankton Program (SSIP), 1978-1982 (O'Boyle *et al.*, 1984), (2) surface chlorophyll maps derived from colour satellite images of the Coastal Zone Color Scanner (CZCS) which collected data from 1978-1986 (Feldman *et al.* 1989), (3) depth profiles of chlorophyll concentrations collected either in July 1993 during a training cruise run out of Wood's Hole by the Sea Education Association (Robinson *et al.*, 1993; Chief Scientist, R. Bohrer) or (4) during missions of the CSGS Hudson (July 1995, June 1996, April and October-November 1997) and CSGS Parizeau (November 1996) (Head, unpubl. data) and (5) estimates of chlorophyll concentration derived from Secchi depth observations made in July 1993 and 1994 (Simard, 1995).

Winter conditions

During winter, the water column over the Scotian Shelf mixes from top to bottom due to storm activity, supplying nutrients (*e.g.* nitrate) to the near-surface layers. At this time, seasonal near surface light levels are relatively low, limiting the rate at which phytoplankton can grow (photosynthesize). In addition, the deep mixing means that individual cells will spend much of their time at depths at which their metabolic requirements exceed their photosynthetic capacity, resulting in slow growth. Thus, in the winter SSIP data (February, Fig. 6.3.1), surface chlorophyll concentrations were generally low. For a few stations (including one in the Gully) chlorophyll levels were higher, but the significance of this feature cannot be ascertained from the limited data available. No usable winter data was available from the CZCS ocean colour satellite.

Spring conditions

During spring, the surface layer warms up as vertical mixing decreases. Solar radiation also increases and the combination of water column stability, increased light intensity and high near-surface nutrient concentrations leads to the development of a "spring bloom". On the Scotian Shelf the bloom progresses temporally from west to east, and from the shelf break to the inshore. Based on the SSIP data (1979, 1981) the spring bloom was apparent over on the shelf west of Halifax in April and persisted on the eastern shelf into

May (Fig. 6.3.1). By contrast, in April in 1997 (Fig. 6.3.2), concentrations of chlorophyll (surface and column-intergrated) were comparable in the western and eastern areas of the shelf and low levels were seen only over Emerald Basin and at stations further offshore on the Halifax Section. During April 1997, although phytoplankton concentrations (surface and integrated) were high in the Gully, they were not markedly higher than at stations on the eastern Scotian Shelf or in the Laurentian Channel. Surface and integrated chlorophyll concentrations were generally well-correlated over the shelf (Fig. 6.3.3) although distributional patterns differed along the Gully section; surface concentrations were highest offshore while integrated concentrations were highest at the inner-most station. At the inner-most station, surface chlorophyll concentration was relatively low and the subsurface chlorophyll layer was thicker (i) than at the two outer Gully stations, (ii) than at the four farthest offshore stations of the Louisbourg Line (Fig. 6.3.4), and (iii) than at most other stations of the survey (data not shown). Surface chlorophyll distributions in spring derived from CZCS satellite imagery (composites of ~25 individual images for 1979 and ~25 images for 1980) showed that high phytoplankton concentrations extended well beyond the shelf edge but highest concentrations were observed inshore; there was no evidence of enhanced surface chlorophyll concentrations in the vicinity of the Gully (Figs. 6.3.5 and 6.3.6).

Summer conditions

During summer, phytoplankton commonly exhaust surface nutrients (see Section 6.2) and their growth and biomass accumulation shifts to subsurface depths where optimal conditions of light intensity and nutrients persist (Cullen, 1982). Summer phytoplankton growth and biomass accumulation will continue in surface waters, however, in regions where nutrient supply is maintained. In the June SSIP data, the relatively high surface chlorophyll levels in the mid- and western regions of the shelf were likely a consequence of the vertical mixing of deep nutrient-rich water from upwelling along the coast or at the shelf break and tidal mixing over Brown's Bank and into the Gulf of Maine (Fig. 6.3.1). During a CSGS Hudson voyage in June 1996, surface chlorophyll concentrations were low everywhere, but integrated chlorophyll concentrations were higher on and around Banquereau Bank which was likely the result of the upwelling of slope water at the Bank's offshore margin (Fig. 6.3.7). Surface and integrated chlorophyll concentrations were not well correlated (Fig. 6.3.3); phytoplankton were generally concentrated in sharp subsurface peaks at depths of 30-40 m. Over Banquereau Bank and at its offshore margin the chlorophyll maximum depth was still at 30-40 m, but concentations were much higher than elsewhere. In the August SSIP data, surface chlorophyll concentrations were uniformly low (Fig. 6.3.1), although at this time of year they may not be representative of the total concentration of phytoplankton in the water column because of the subsurface accumulation of biomass. CZCS satellite composites for summer 1979 (based on ~22 individual images) and 1980 (based on ~24 individual images) showed that phytoplankton biomass was extremely low seaward of the shelf break with low concentrations on the central shelf and higher concentrations to the west and east. Surface concentrations were higher on the eastern shelf than during spring. No enhancement of phytoplankton biomass was apparent for the Gully region compared to the rest of the shelf (Figs. 6.3.5 & 6.3.6).

It has been proposed that deep nutrient-rich slope water is mixed to the near surface layers in the Gully which results in an enhancement of productivity there (Houghton *et al.*, 1978; Simard, 1995). It is expected that summer would be the season for which the effects of such a process would be most beneficial and most obvious. The observations of chlorophyll concentration in the SSIP data and satellite images show no enhancement of phytoplankton biomass in the surface layers of the Gully, but observations within the water column do suggest some effects. Researchers on the July 1993 cruise of the Sea Education Association ran a transect between Sable Island Bank and Banquereau Bank, near the mouth of the Gully. They observed a “doming” of the isotherms and isopycnals over the deepest region of the section. This is consistent with circulation models suggesting a cyclonic (counter-clockwise) gyre centred near the mouth of the Gully which brings deep water, if not to the surface, then to the near surface layers (see Section 6.1). Their observations of chlorophyll profiles also showed increased levels over the deep water of the Gully compared with values over the Banks, but only at depths of 20-40 m and then only to concentrations of ~1 mg l^{-1} (Fig. 6.3.8). Simard (1995) ran transects near the mouth of the Gully, across it and along its axis, during the same period (July 1993) and in July of the following year on which he determined Secchi depths (an index of water transparency). The shallowest Secchi readings and thus maximum concentration of light absorbing material (*i.e.* phytoplankton) were over the deep water near the entrance to the Gully. From his maximum attenuation coefficients in both years (*ca.* 0.14-0.16), a chlorophyll concentration of ~1-2 mg l^{-1} can be derived (Sathyendranath and Platt, 1988) which is consistent with that found in the Sea Education Association study in 1993. Although these observations suggest that there was vertical transport of nutrient-rich water towards the surface in this region of the Gully, this is not the only area of the Scotian Shelf where such processes can occur. For example, elevated chlorophyll concentrations of a similar magnitude were seen at 30-40 m at the shelf break on the Halifax Section in July 1995 (Head, unpubl. data) and, as discussed above, more significant enhancements of phytoplankton growth due to vertical mixing processes were seen in several areas in June during the SSIP survey (Fig. 6.3.1).

Fall conditions

Increasing turbulence in the water column during fall caused by intensifying seasonal winds results in water column mixing deep enough to bring nutrients to the surface, but not so deep as to mix the phytoplankton to depths where they cannot photosynthesize efficiently. The consequence of this is a "fall bloom" of phytoplankton which is often comparable to or larger in magnitude than that which occurs in the spring. In the SSIP data, increases in surface chlorophyll concentrations were seen over the Western Shelf in September and over most of the Shelf in November (Fig. 6.3.1). The CZCS colour satellite composites (1979 from ~16 individual images, 1980 from ~20 individual images) also showed clearly a shelf-wide fall bloom (1979) or one confined to the eastern shelf (1980) (Figs. 6.3.5 & 6.3.6). The surface chlorophyll concentrations in the Gully were no higher than concentrations elsewhere, however, based on SSIP and satellite data. In contrast to the data from 70s and 80s, there were low surface concentrations of chlorophyll in the falls of 1996 and 1997, suggesting that the fall blooms in these years were not important or missed (Fig. 6.3.9). Surface chlorophyll levels did appear to be reasonably representative of integrated concentrations in the fall of 1996 (Fig. 6.3.9), but the correlation was not in fact significant (Fig. 6.3.3). In the fall of 1997, at a station in the Gully, surface and integrated chlorophyll concentrations were similar to those seen elsewhere on the Scotian Shelf (Fig. 6.3.9).

6.3.2 Annual cycles of zooplankton biomass and abundance on the Scotian Shelf and in the Gully region.

6.3.2.1 Sources of data

Four sources of data will be used in the discussion concerning zooplankton. These are: (1) zooplankton abundance and biomass estimates (>333 µm) between 0 and the bottom (or 200 m), which were collected during the SSIP survey throughout the year between 1978-1982 (O'Boyle *et al.*, 1984); (2) zooplankton abundance and biomass estimates (>233 µm) made during missions of the CSGS Hudson in April, 1995, June 1996 and April, 1997 (Head, unpubl. data); (3) zooplankton abundance estimates using the BIONESS net sampling system in fall, 1989 (Sameoto, unpubl. data); and, (4) observations of macroplankton (*i.e.* krill) and small fish using acoustic backscattering in August, 1984 and April, 1997 (Cohrane, unpubl. data).

Definition of terms

Note that in this report the term zooplankton will be applied to animals > 200 µm in size. There are zooplanktonic organisms < 200 µm on the Scotian Shelf, the so-called microzooplankton, a group which includes unicellular protozoa, (*e.g.* heterotrophic dinoflagellates, ciliates) and the young life stages of some metazoans (*e.g.* invertebrate larvae, copepod nauplii). Elsewhere these are known to be very abundant at times, but information relating to their distribution and biomass on the Scotian Shelf is very limited, and for the Gully region it is non-existent, so that useful discussion is not possible.

Amongst the zooplankton 200-2000 µm in size, the so-called mesozooplankton, the most important in terms of biomass and abundance are the copepods, which are shrimp-like crustaceans which generally make up ca. 80 % of the total biomass. Although ca. 10-20 copepod species occur on the Scotian Shelf either year-round or during particular seasons, the most important in terms of biomass is *Calanus finmarchicus.* This species has as part of it life-history a requirement to overwinter at depths of >200 m, which make it particularly interesting in a discussion of the role of the Gully in the Scotian Shelf ecosystem, as will be seen below.

Another group of zooplankton, which also have particular significance for the Gully, are the euphausiids, or krill. These shrimp-like animals range in size between < 1 cm and 2 or 3 cms, depending on their age and species, and are generally referred to as macrozooplankton. They generally exhibit strong diurnal migration behaviour, spending the day at depths of > 200 m, and coming to the surface to feed on phytoplankton at night. They may also feed carnivorously on copepods, probably in the deep water during winter, and they also exhibit strong net avoidance behaviour, which means that without special precautions being taken, they will generally be underestimated in net hauls, although they are sufficiently large to be "seen" using acoustic backscattering at high frequencies.

6.3.2.2 Biomass of zooplankton on the Scotian Shelf at depths < 200 m

Winter conditions

The zooplankton net tows from the SSIP survey gave estimates of total of zooplankton biomass on the Scotian Shelf which were relatively low in the February, with levels being a little higher at stations in the east than at stations in the west (Fig. 6.3.10). The stations in or around the Gully did not show especially high values in February.

Spring conditions

The overall biomass levels of zooplankton as determined in the SSIP survey increased greatly between February and April (Fig. 6.3.10). This increase was largely due to the ascent of overwintering *C. finmarchicus* and its subsequent reproduction and growth in the near-surface layers. *C. finmarchicus* appearing on the shelf in April can derive from one of several overwintering populations. Firstly, there are populations which overwinter in the shelf basins, such as Emerald Basin. These start to ascend to the near surface layers in March and for Emerald Basin the ascent is complete by April (Herman, pers. comm.). Secondly, there is a population which overwinters in the Gulf of St. Lawrence. This population can "seed" the eastern Scotian Shelf, where its levels are higher in May than in April, and it may ascend to the near-surface layers later (*e.g.* April-May) than the Emerald Basin population. This population is carried to the Scotian Shelf in the outflow from Cabot Strait, and which runs south-east along the eastern shore of Cape Breton and then splits to form (i) the Nova Scotia Current, which flows south-west along the coastline until Halifax, and then diffuses out to the south-west over Emerald Basin and the western Scotian Shelf; and (ii) a second branch which flows along the western boundary of the Laurentian Channel and then turns at its mouth to flow south-west along the shelf break. There is a third population which overwinters in the deep water off the shelf break, which contributes to high concentrations of *C. finmarchicus* which are seen at the shelf break in April and May. According to Planque *et al*. (1997) *C. finmarchicus* overwintering in the deep water south of Newfoundland start to ascend to the surface layers in January. Given that the generation time for the species is ca. 2 months, the population occurring along the Scotian Shelf break in April and May probably includes individuals from both the previous and this year's generations. High concentrations of *C. finmarchicus* have been observed at the shelf break on Halifax Section on several occasions: April 1995 and 1997 (Fig. 6.3.11) and May 1996 (Head, unpubl. data). These animals can be advected on to the shelf in this region, so as to contribute to the biomass seen over Emerald Bank and at stations on the western Scotian Shelf.

Levels of biomass of *C. finmarchicus* at the shelf break off Banquereau Bank (eastern Scotian Shelf) in April 1995 were much higher than those seen in April 1997 (Fig. 6.3.11). By contrast, however, the biomass of another copepod species, *Calanus hyperboreus*, was somewhat higher in April 1997 compared with April 1995 (Fig. 6.3.12). *C. hyperboreus* has a life history similar to that of *C. finmarchicus*, but its overwintering period generally begins and ends earlier in the season and it may take 2 or 3 years to reach maturity, whereas *C. finmarchicus* generally produces 1 or 2 generations per year on or around the Scotian Shelf. *C. hyperboreus* is abundant in the Gulf of St. Lawrence, where it can overwinter, and in the cold surface waters of the onshore branch of the Labrador Current, which flows south and west through the deep channels of the South Newfoundland Shelf. Thus, off Banquereau Bank in 1997, compared with 1995, the zooplankton species composition suggests there may have been an increased contribution of water either from the Gulf of St. Lawrence via the Laurentian Channel, or from the inshore branch of the Labrador Current via the Newfoundland Shelf and the current at the shelf break. It appears that the second route is the most likely one, firstly because one copepod species (*Temora*) which was abundant in samples collected in western Cabot Strait (*i.e.* the Gulf outflow) in April 1997 was largely absent from samples collected at the shelf break (L. Harris, pers. comm.), and secondly, because hydrographic characteristics of water off St Pierre Bank (upstream, in the shelf break current) showed a significantly greater input of Newfoundland Shelf water in 1997 compared with 1995 (data not shown).

In the Gully in April 1997, *C. finmarchicus* biomass levels were higher than those at stations to the north and east, and *C. hyperboreus* biomass levels were lower (excluding the shallow station on Banquereau Bank) (Figs. 6.3.11 & 6.3.12). *Calanus* spp. in the surface layers of the Gully in April may derive from one or more sources: the population of the eastern Scotian Shelf, via advection in the near surface layers; the shelf break population, via intrusion of shelf break waters at depth; or a population which overwinters in the Gully itself. *C. finmarchicus* do accumulate the deep waters of the Gully in fall (see below), and it appears that the physical processes occurring there would enable them to remain there during winter, but the importance of the input from other sources cannot be assessed at this time. In terms of total zooplankton biomass, in the SSIP data (Fig. 6.3.10) and in April 1997 (Fig. 6.3.13), levels were not generally higher in the Gully than at the other nearby stations.

<u>Summer conditions</u>

C. finmarchicus dominated the biomass of zooplankton on the Scotian Shelf in June in the SSIP data (Fig. 6.3.10). By August most *C. finmarchicus* had left the near-surface layers and retreated to their overwintering depths, and although they remained among the most abundant copepods in the SSIP net tows, other smaller species which were becoming more abundant (*e.g. Centropages*) probably outnumbered them in the water column. This suggestion is made because a relatively large mesh net (333 mm) was used in the SSIP surveys, which would have lead to serious underestimation of the abundances of the smaller copepod species. Levels of zooplankton biomass were not especially high in the Gully in summer compared with levels at other stations.

<u>Fall conditions</u>

Zooplankton biomass levels remained high in September and November in the SSIP data (Fig. 6.3.10). At this time of year water temperatures, phytoplankton concentrations and primary productivity rates are high, leading to high growth rates amongst the zooplankton. The most important species at this time of year are relatively small in size (*e.g. Centropages*, *Pseudocalanus*, *Nannocalanus* etc.), and thus undersampled in the SSIP surveys, and species diversity is relatively high. *C. finmarchicus* in the surface layers at this time of year probably represent members of the second generation. Zooplankton biomass levels in the Gully in the fall at depths of < 200 m were no higher than those at other nearby stations.

6.3.2.3 Biomass of zooplankton in BIONESS tows to depths of >200 m

As has been discussed above, *C. finmarchicus* accumulate in deep water to overwinter in the fall. The Gully is one deep water area in which they accumulate and, for comparison, Emerald Basin is another. During a voyage on the CSGS Parizeau in October 1989 zooplankton tows were made in both the Gully and Emerald Basin, over series of stratified depths using the BIONESS sampling system. *C. finmarchicus* were more abundant at the deep stations in the Gully and were most concentrated at depths of 200-400 m (Fig. 6.3.14). Areal abundances at the deep stations in the Gully were ca. 6 times lower than those found in Emerald Basin, where the animals were also most concentrated at depths of >200 m (Fig. 6.3.15). That there are differences in the abundances of overwintering copepods in each location is not surprising, since their sources are different: *C. finmarchicus* overwintering in Emerald Basin probably derive from the Gulf of St. Lawrence, via the Nova Scotia Current, and from the nearby banks (Emerald and Western Banks); *C. finmarchicus* overwintering in the Gully may derive from the shelf break population or from the eastern Scotian Shelf. In addition, however, numbers of *C. finmarchicus* overwintering in Emerald Basin have varied between a high of > 300,000 m^{-2} (1986) and a low of < 35,000 m^{-2} (1996) between 1984 and 1996 (Sameoto, unpubl. data), which may be related to variations in productivity and circulation patterns. It seems likely that variations may also occur in the number of *C. finmarchicus* overwintering in the Gully, but annual variations in the two areas are not be expected to be closely linked. Thus, while the abundance of *C. finmarchicus* in Emerald Basin in 1989 was in the middle of the 12 year observed range, the same might not have been true for the population in the Gully.

Abundances of euphausiids (krill) were also determined in the BIONESS net hauls carried out in October 1989. The bulk of the population of *C. finmarchicus* in October had retreated to overwinter at depths of >200 m at both the Gully and Emerald Basin stations (Figs. 6.3.14 & 6.3.15), but krill at this time were apparently still performing their diel migrations, so that their vertical distribution was related to both time of day and water depth (Figs 6.3.16 & 6.3.17). Areal abundances of krill at stations within the Gully were very variable, but they were generally higher (up to 30 times higher) in the Gully than at the one station sampled in Emerald Basin (cf. Figs. 6.3.16 & 6.3.17). It is known that abundances of krill within Emerald Basin, which are determined quite regularly, vary considerably from year-to-year (Sameoto, pers. comm.) and the same is probably true for the Gully, although there is no reason to expect abundances in the two locations to co-vary. Thus, it cannot be ascertained from this one set of measurements whether krill abundances are generally higher in the Gully than in Emerald Basin.

6.3.3 Observations of macroplankton (krill and small fish) densities using high frequency acoustic backscattring

During the CSGS Hudson voyage in April 1997, observations of macroplankton densities were made using a hull-mounted 200 kHz acoustic system. The backscattering signal strength is proportional to the biomass of target organisms, which at this frequency includes animals of 2.5 cm and greater. The first track starts outside Halifax Harbour at a little before dusk and continues overnight into Emerald Basin. During this period euphausiids would have been either moving into, or occupying, the near surface layers (Fig. 6.3.18). The integrated acoustic backscattering signal in the 30-200 m depth range increased as the ship moved offshore, and remained high at stations in Emerald Basin until 1 or 2 h after dawn (A-F). Thereafter the signal decreased and remained low (F-J), presumably because the primary target organisms (krill) spend the daylight hours at depths of >200 m. As the ship started to move out of the Basin, a couple of hours before dusk (K-L, Fig. 6.3.18 & 6.3.19), the signal strength increased and then decreased as the ship moved into shallow water after dark (L-M). The “spikiness” in the signal between M and R was probably due to bad weather conditions, but it appears that there were higher concentrations of organisms in the deeper areas: N-O, on the outer flank of Emerald Bank; Q-R and S-T, at the shelf break (Fig. 6.3.19). After dawn the signal remained low, presumably because of vertical migration of the target organisms to depths of >200 m.

The acoustic record of ship’s approach to the entrance to the Gully starts where the depth was about the 3000 m (Fig. 6.3.20, A). Between points A and D the water depth was over 2000 m. The integrated backscattering signal increased between points B and D, just before dusk. Thereafter, it decreased rapidly (C-D) and then slowly increased (D-F), until the ship reached the shelf break, where there was an abrupt increase in signal strength (ca. point G). As the ship crossed the edge of Sable Island Bank (G-H) the signal strength decreased dramatically, but it increased equally dramatically in the deep water across the entrance to the Gully (H-I). After dawn, as the ship proceeded up the Gully’s axis, the signal strength remained low while the ship was over deep water (J-L). At the most northerly occupied stations where the bottom depth was ca. 200-300 m (Fig. 6.3.20, L-M; Fig. 6.3.21, M-O) the signal strength increased, even though it was still daytime. This may be because some (or all) of the target organisms were not migrating to depths of >200 m in this area, because of the restricted depth (cf. Tows 3 & 4, Fig. 6.3.16). Thereafter, when the ship passed over shallow water (O-Q) the signal was low, but surprisingly, since it was after dusk, it did not increase much over the deep water (Q-R).

Over Banquereau Bank the signal strength decreased (R-S) and at the shelf break (T) there was a sharp peak. The signal strength remained high until the ship moved into water deeper than 2000 m (T-V). After dawn the signal strength was low, with a small peak between points Z and AA as the ship was over water ca. 1000 m in depth.

The magnitude of the backscattering signal is proportional to biomass, but any organisms larger than 2.5 cm can contribute. On this voyage, a second acoustic system which measured backscattering at 12 kHz was used. The targets for this frequency are animals with air bladders, *i.e.* fish. By comparing the backscattering at the two frequencies, the relative contributions of euphausiids and small fish to the 200 kHz backscattering can be assessed. From these comparisons it was concluded that for areas at the shelf break and in the entrance of the Gully some part of the signal was due to small fish. Within Emerald Basin and the Gully, however, the signal was derived from krill alone. Thus, on the basis of the acoustic estimates it appears that concentrations of krill in some areas of the Gully were higher than those in Emerald Basin. During this voyage, net tows were made using a configuration of the BIONESS system especially designed to collect krill (*i.e.* flashing lights to prevent net avoidance) in Emerald Basin and the Gully, but the samples have not yet been analysed.

6.3.4 Summary

<u>Phytoplankton</u>

The phytoplankton data analyzed to date do not suggest that the Gully is a dictinctly productive feature on the Scotian Shelf. A statistical comparison (t-tests) of biomass levels in the proximity of the Gully with those in the surrounding Shelf waters shows no significant differences; if anything, biomass levels over the Gully are generally lower (Table 6.3.1). It should be pointed out, however, that the data summarized in this document provide information largely on the biomass at the sea surface and may not reliably assess the total phytoplankton biomass and productivity of the region *per se*. To the extent that a significant component of the biomass and growth of phytoplankton occurs below the sea surface, the data presented here and conclusions drawn from it should be considered incomplete. In order to more accurately characterize phytoplankton biomass and primary productivity in the Gully region, further study is needed.

Table 6.3.1. Surface chlorophyll concentrations ($\mu g\ l^{-1}$) from SSIP cruises: Mean ($\pm$ S.D.). The Gully-Core is represented by the three SSIP standard stations located in the central part of the Gully as defined by the 200m contour, the Gully is represented by the Core stations plus 7 additional stations on the adjoining eastern and western SSIP lines, and the Eastern Shelf is represented by all SSIP stations east of 62W Longitude.

Season	Year	Shelf	E. Shelf	Gully	Gully-Core
Winter	80	0.43(0.24)	0.57(0.17)	0.77(0.35)	1.17(0.00)
	81	0.30(0.19)	0.28(0.22)	0.29(0.13)	0.23(0.11)
Spring	79	2.76(5.17)	3.87(6.10)	2.67(4.93)	0.31(0.11)
	80	0.40(0.37)	0.42(0.36)	0.66(0.54)	0.90(0.93)
	81	4.06(2.41)	4.14(2.26)	5.29(1.50)	4.93(0.82)
Summer	78	0.41(0.38)	0.42(0.27)	0.35(0.09)	0.41(0.09)
	79	0.56(0.85)	0.42(0.17)	0.29(0.05)	0.33(0.01)
	80	1.47(2.75)	0.95(1.21)	0.58(0.94)	0.24(0.16)
	81	0.26(0.11)	0.26(0.13)	0.20(0.03)	0.21(0.03)
Fall	79	1.00(0.68)	0.80(0.41)	0.76(0.29)	0.59(0.09)
	80	2.32(2.41)	1.96(1.87)	2.08(1.57)	2.48(1.89)
	81	0.90(0.95)	0.84(0.40)	0.74(0.39)	0.54(0.01)

Zooplankton

The zooplankton data analyzed to date do not support the idea that mesozooplankton are especially abundant in the Gully compared with other areas of the Scotian Shelf. Statistical tests (t-tests) using the SSIP data show that abundances of *C. finmarchicus* and *C. hyperboreus* and total plankton volume are no higher in the Gully-Core or Gully regions than average abundances on either the Eastern Scotian Shelf, or the entire Shelf, during any of the months for which zooplankton were collected in the Gully-Core region (Table 6.3.2). The same is true for the relative abundances of two smaller copepod species (*Centropages*, *Pseudocalanus* spp.) and indeed, concentrations of *Centropages* were actually lower (*i.e.* zero) in the Gully region than average values over the entire Scotian Shelf in May and June (Table 6.3.2). Because the Gully is an area of deep water, however, it harbours overwintering populations of *C. finmarchicus* at depths of >200 m and krill, which spend the daylight hours at depths of > 200 m and the night-time hours in the near surface layers. In the case of the macroplankton (krill) it is unclear whether concentrations in the Gully are generally higher than those in other Basins on the Scotian Shelf. Equally, from existing data it cannot be determined whether the Gully is an area of intrusion of the very abundant off-shore population of *C. finmarchicus* on to the Shelf in spring, as is the case further to the south and west in the area of the Halifax section. If it is, then it may provide an important source of copepods for Sable Island and Western Banks in spring. In order to answer these important questions more study is needed.

Table 6.3.2. Abundances of large (*Calanus finmarchicus, Calanus hyperboreus*) and relative abundances of small (*Centropages* sp., *Pseudocalanus* sp.) copepod species (#s x 1000 m^{-2}) and plankton volume (ml m^{-2}) from SSIP cruises. Region designations as in Table 6.3.1.

Calanus finmarchicus ***Calanus hyperboreus***

MONTH	Shelf	E. Shelf	Gully	Gully-Core	MONTH	Shelf	E. Shelf	Gully	Gully-Core
MAY					MAY				
Mean	43.04	63.61	150.39	126.61	Mean	5.80	8.98	9.19	16.19
Std. Dev.	67.55	74.98	132.18	74.33	Std. Dev.	8.10	8.63	7.25	7.40
No. of stns.	138	88	8	3	No. of stns.	138	88	8	3
JUNE					JUNE				
Mean	45.61	34.38	68.09	74.65	Mean	2.37	3.69	3.47	6.07
Std. Dev.	41.44	29.21	28.77	21.61	Std. Dev.	5.67	7.24	2.70	2.95
No. of stns.	153	85	7	2	No. of stns.	153	85	7	2
AUGUST					AUGUST				
Mean	12.12	10.03	13.74	50.98	Mean	0.27	0.46	0.01	0.00
Std. Dev.	14.38	11.46	19.01		Std. Dev.	1.20	1.55	0.02	
No. of stns.	38	22	5	1	No. of stns.	38	22	5	1
SEPT.					SEPT.				
Mean	12.09	16.97	21.91	7.99	Mean	0.70	1.11	0.00	0.00
Std. Dev.	13.89	16.01	13.92		Std. Dev.	2.09	2.63	0.00	
No. of stns.	88	51	2	1	No. of stns.	88	51	2	1
NOV.					NOV.				
Mean	11.50	16.95	16.59	35.08	Mean	0.93	1.43	1.52	4.48
Std. Dev.	12.61	13.92	15.17	9.39	Std. Dev.	1.99	2.26	2.43	2.14
No. of stns.	117	65	6	2	No. of stns.	117	65	6	2

Total plankton volume

MONTH	Shelf	E. Shelf	Gully	Gully-Core	MONTH	Shelf	E. Shelf	Gully	Gully-Core
MAY					SEPT.				
Mean	88.96	87.88	189.53	198.09	Mean	37.41	43.81	101.97	30.58
Std. Dev.	87.51	77.22	158.04	129.31	Std. Dev.	37.36	44.25	71.38	
No. of stns.	138	88	8	3	No. of stns.	88	51	2	1
JUNE					NOV.				
Mean	78.10	76.71	85.18	75.83	Mean	38.22	46.66	68.70	64.47
Std. Dev.	51.62	55.80	83.45	5.42	Std. Dev.	31.86	36.44	66.28	20.68
No. of stns.	153	85	7	2	No. of stns.	117	65	6	2
AUGUST									
Mean	32.16	39.56	61.75	100.61					
Std. Dev.	30.76	35.77	57.50						
No. of stns.	38	22	5	1					

Table 6.3.2. (cont'd)

Centropages sp.

MONTH	Shelf	E. Shelf	Gully	Gully-Core
MAY				
Mean	0.04	0.05	0.00	0.00
Std. Dev.	0.28	0.34	0.00	0.00
No. of stns.	138	88	8	3
JUNE				
Mean	0.36	0.06	0.00	0.00
Std. Dev.	1.11	0.22	0.00	0.00
No. of stns.	153	85	7	2
AUGUST				
Mean	11.69	14.51	5.24	18.78
Std. Dev.	12.97	13.88	6.97	
No. of stns.	38	22	5	1
SEPTEMBER				
Mean	39.46	54.35	118.52	30.17
Std. Dev.	92.34	119.18	88.35	
No. of stns.	88	51	2	1
NOVEMBER				
Mean	14.52	15.00	17.14	29.08
Std. Dev.	18.00	21.59	18.71	26.74
No. of stns.	117	65	6	2

Pseudocalanus sp.

MONTH	Shelf	E. Shelf	Gully	Gully-Core
MAY				
Mean	8.19	11.57	15.11	22.55
Std. Dev.	12.44	12.15	10.79	9.73
No. of stns.	138	88	8	3
JUNE				
Mean	6.10	6.03	11.76	9.00
Std. Dev.	7.38	7.83	16.32	0.71
No. of stns.	153	85	7	2
AUGUST				
Mean	2.83	2.39	3.83	6.98
Std. Dev.	6.90	2.64	3.94	
No. of stns.	38	22	5	1
SEPTEMBER				
Mean	4.79	2.63	1.64	0.98
Std. Dev.	10.45	3.98	0.67	
No. of stns.	88	51	2	1
NOVEMBER				
Mean	4.66	4.64	5.27	8.61
Std. Dev.	4.69	5.24	4.18	4.64
No. of stns.	117	65	6	2

It should be noted that if all SSIP stations had been sampled on each cruise, there would have been: 3 stations in the Gully-Core; 9 in the Gully region (3 within the Gully-Core and 3 on adjacent lines); 110 on the Eastern Scotian Shelf; and *ca.* 189 over the entire survey grid.

6.3.5 General comments

Overall, the present data suggest that the Gully has some features which are characteristic of a Shelf Basin and some which are characteristic of the Shelf Break, which when put together make it a somewhat unique area of the Scotian Shelf. It does not appear to be an area of particularly high primary production, although its depth makes it an overwintering area for copepods and an area where krill congregate. The existing knowledge base is quite limited, however, and in order to gain a better understanding of the productivity of the region and its role in the ecology of the Scotian Shelf, a directed seasonal sampling programme would be needed.

6.3.6 References

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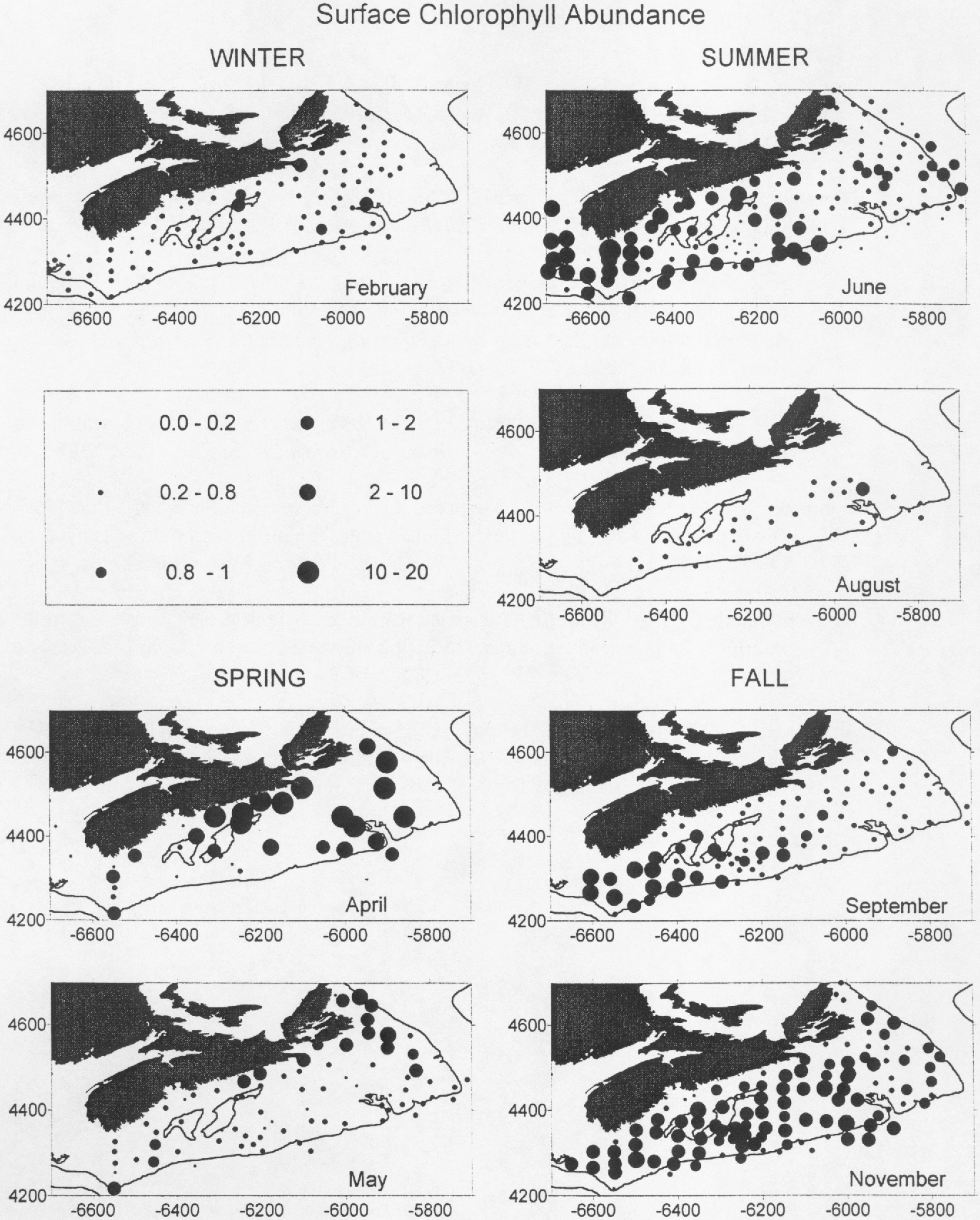
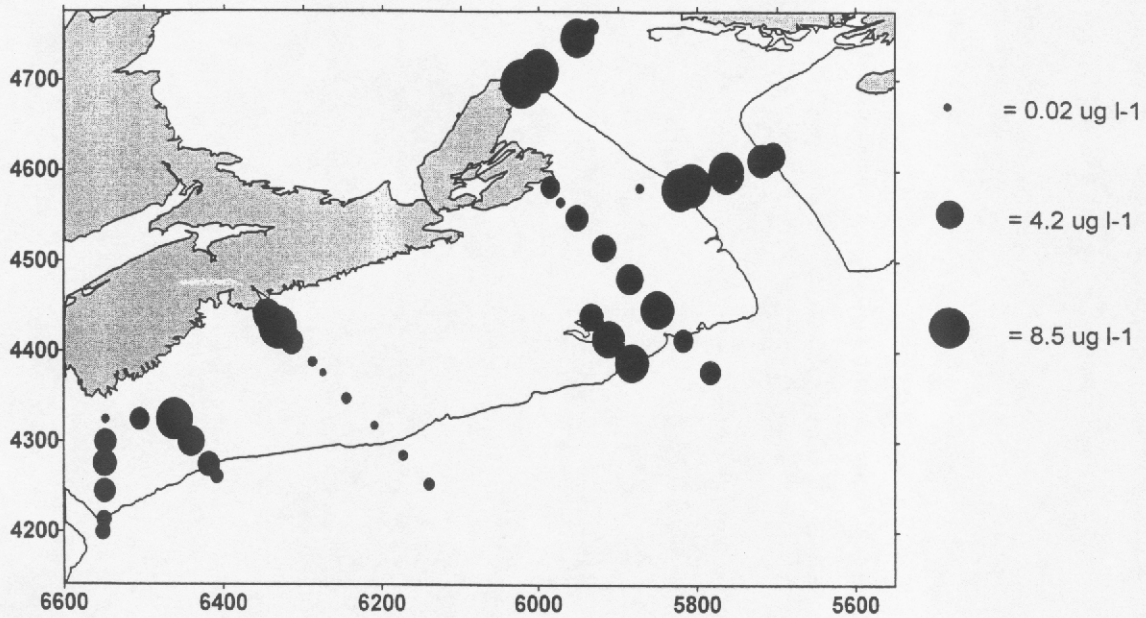


Fig. 6.3.1. Surface chlorophyll concentrations ($\mu g\ l^{-1}$) on the Scotian Shelf for cruises during the SSIP survey between 1978-1981.

SURFACE CHLOROPHYLL CONCENTRATIONS - APRIL 1997



INTEGRATED CHLOROPHYLL CONCENTRATIONS - APRIL 1997

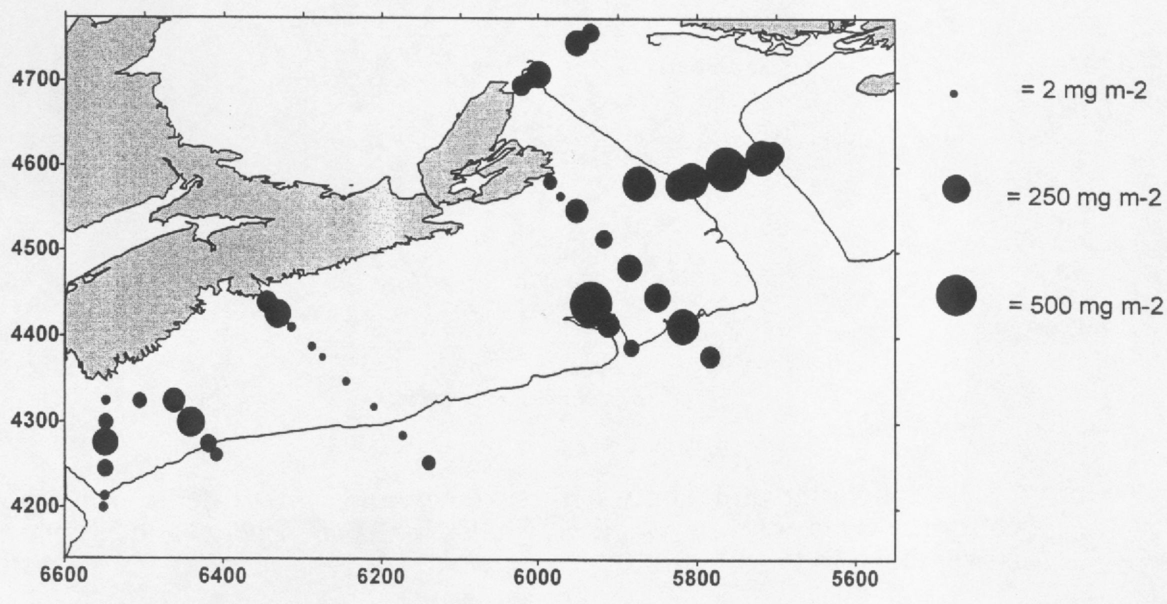


Fig. 6.3.2. Surface ($\mu g\ l^{-1}$) and integrated ($mg\ m^{-2}$) chlorophyll concentrations on the Scotian Shelf in April 1997.

Relationship between surface and integrated chlorophyll concentrations
- in spring, summer and fall

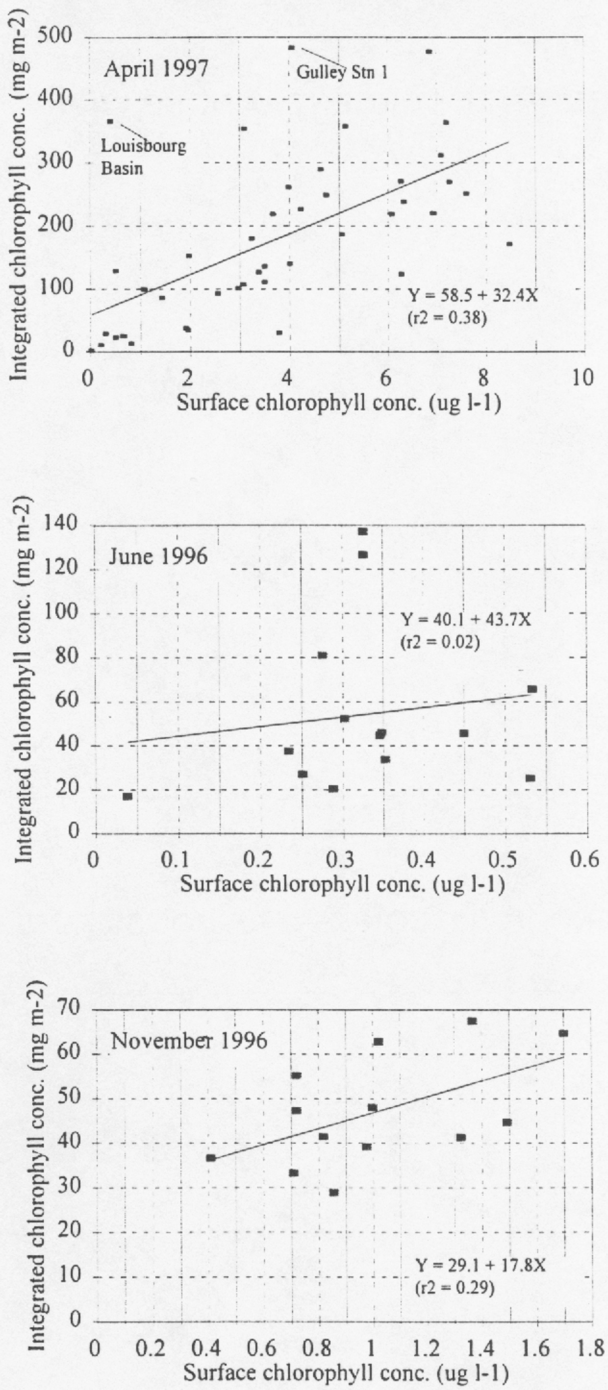


Fig. 6.3.3. Relationship between surface and integrated chlorophyll concentrations on the Scotian Shelf in April 1997, and June and November 1996.

Chlorophyll profiles in the Gulley and on the Louisbourg Line - April 1997
(Units are ug l-1)

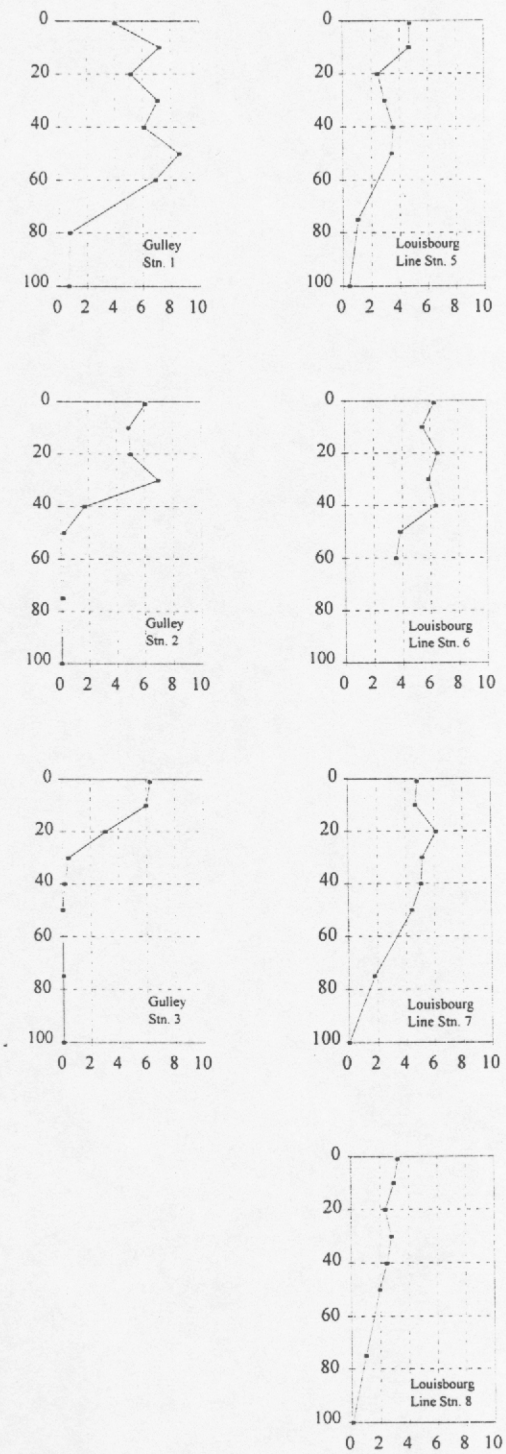


Fig. 6.3.4. Profiles of chlorophyll concentration ($\mu g\ l^{-1}$) in the Gully and on the Louisbourg Line in April 1997.

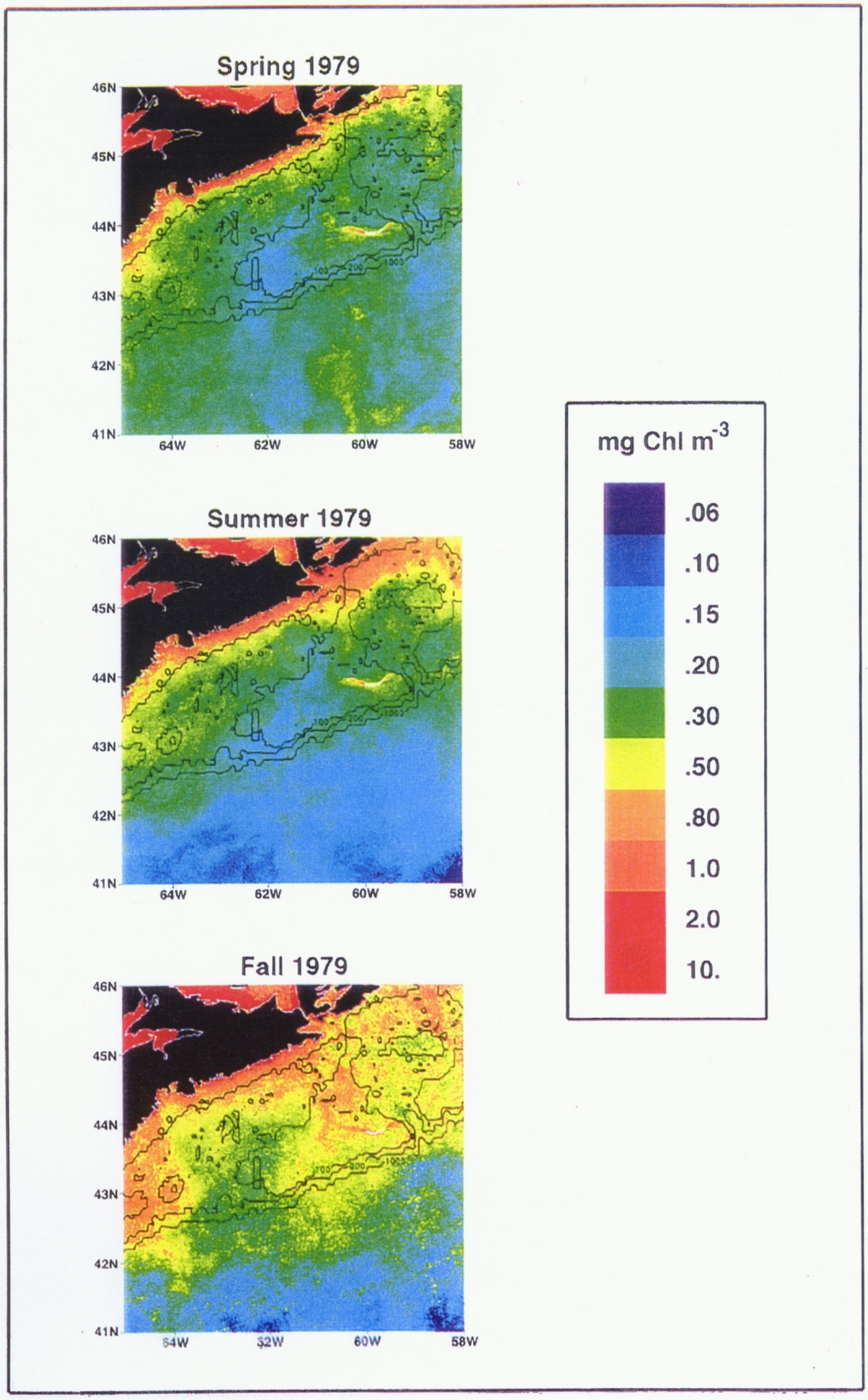


Fig. 6.3.5. Composite images of chlorophyll concentration in the near surface layers as recorded by the CZCS colour satellite during spring, summer and fall 1979.

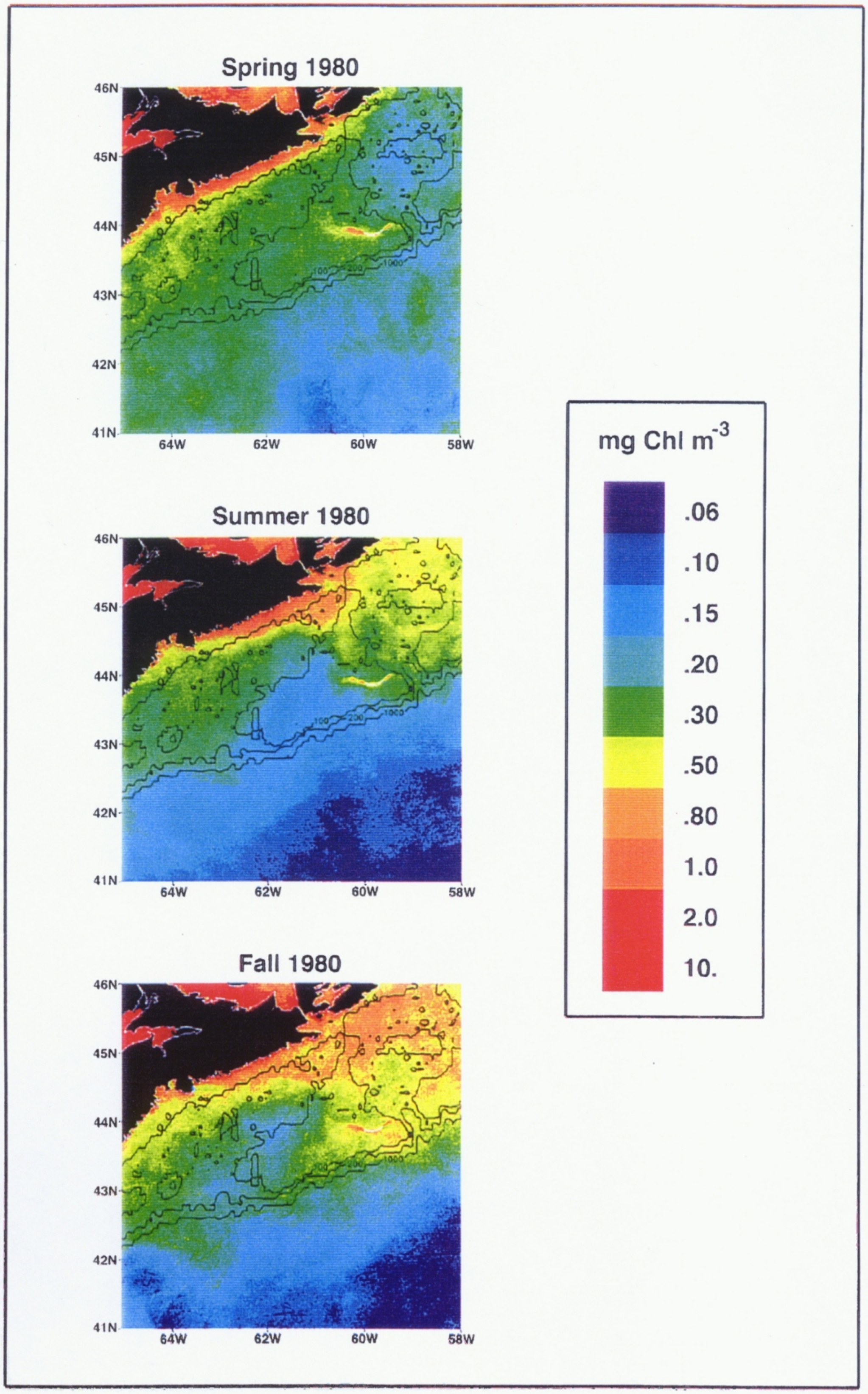
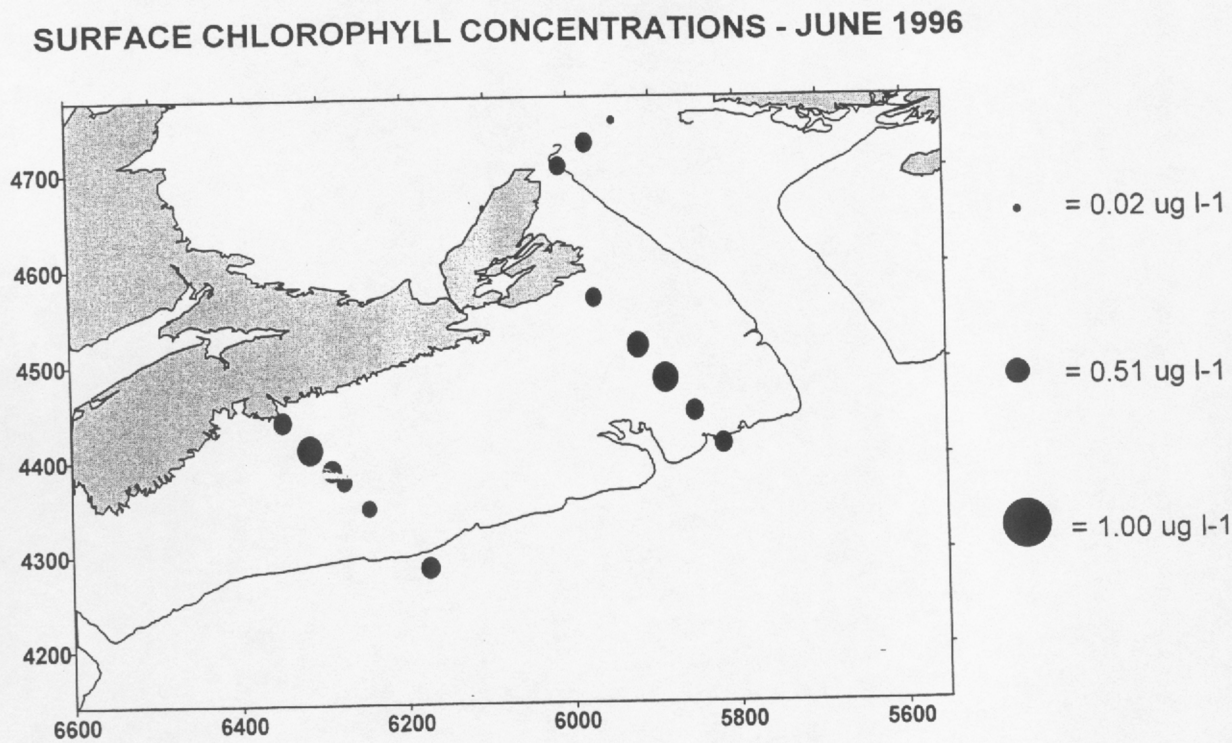


Fig. 6.3.6. Composite images of chlorophyll concentration in the near surface layers as recorded by the CZCS colour satellite during spring, summer and fall 1980.



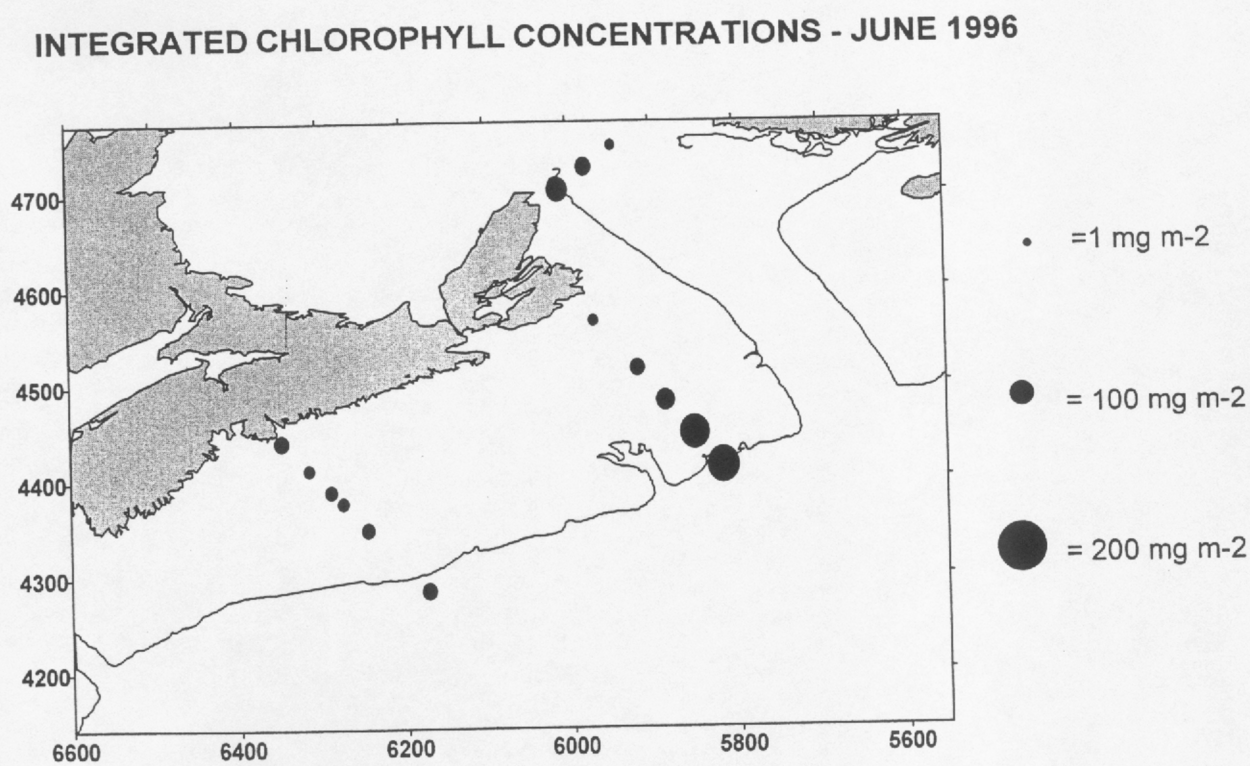


Fig. 6.3.7. Surface ($\mu g\ l^{-1}$) and integrated ($mg\ m^{-2}$) chlorophyll concentrations on the Scotian Shelf during June 1996.

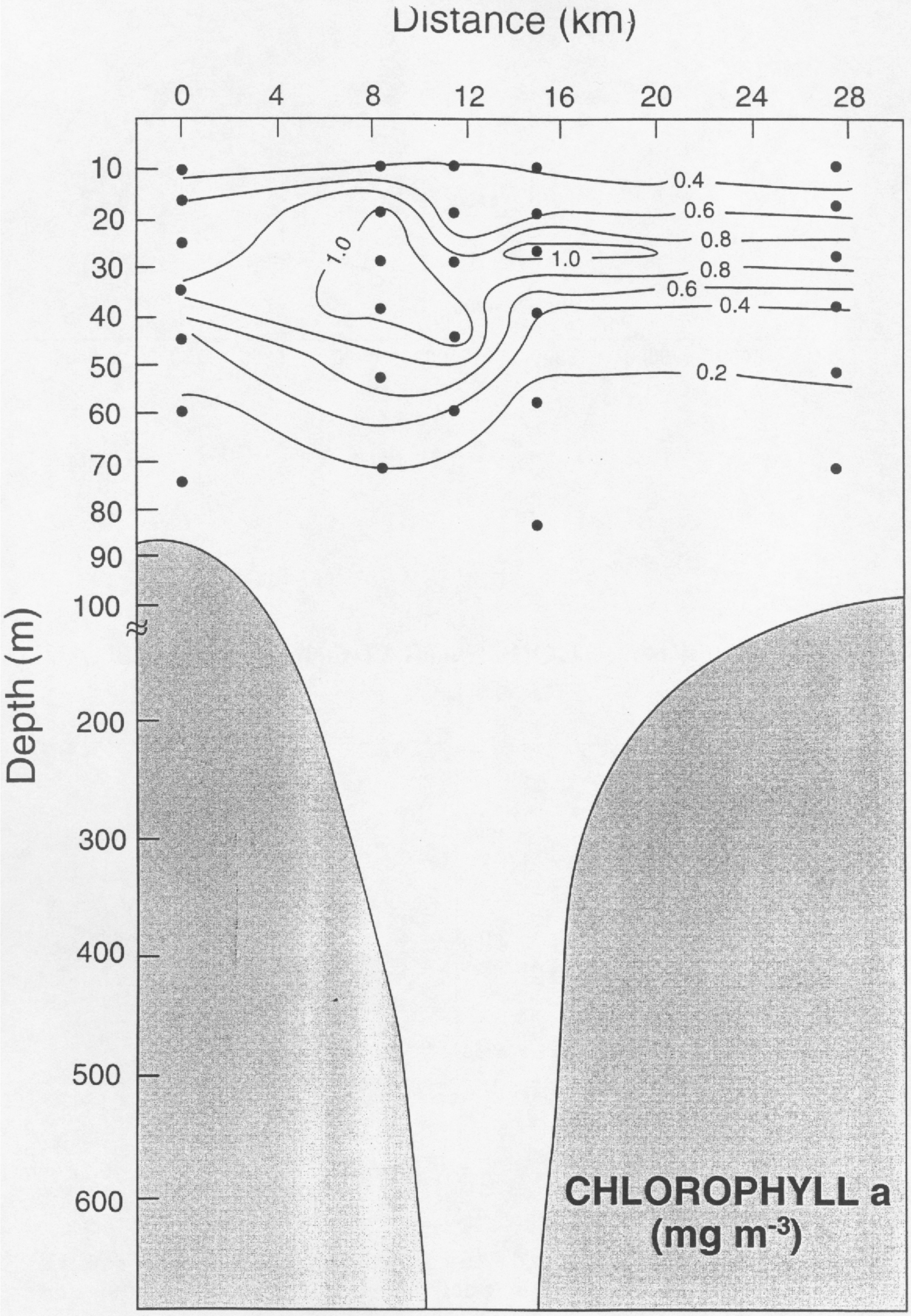
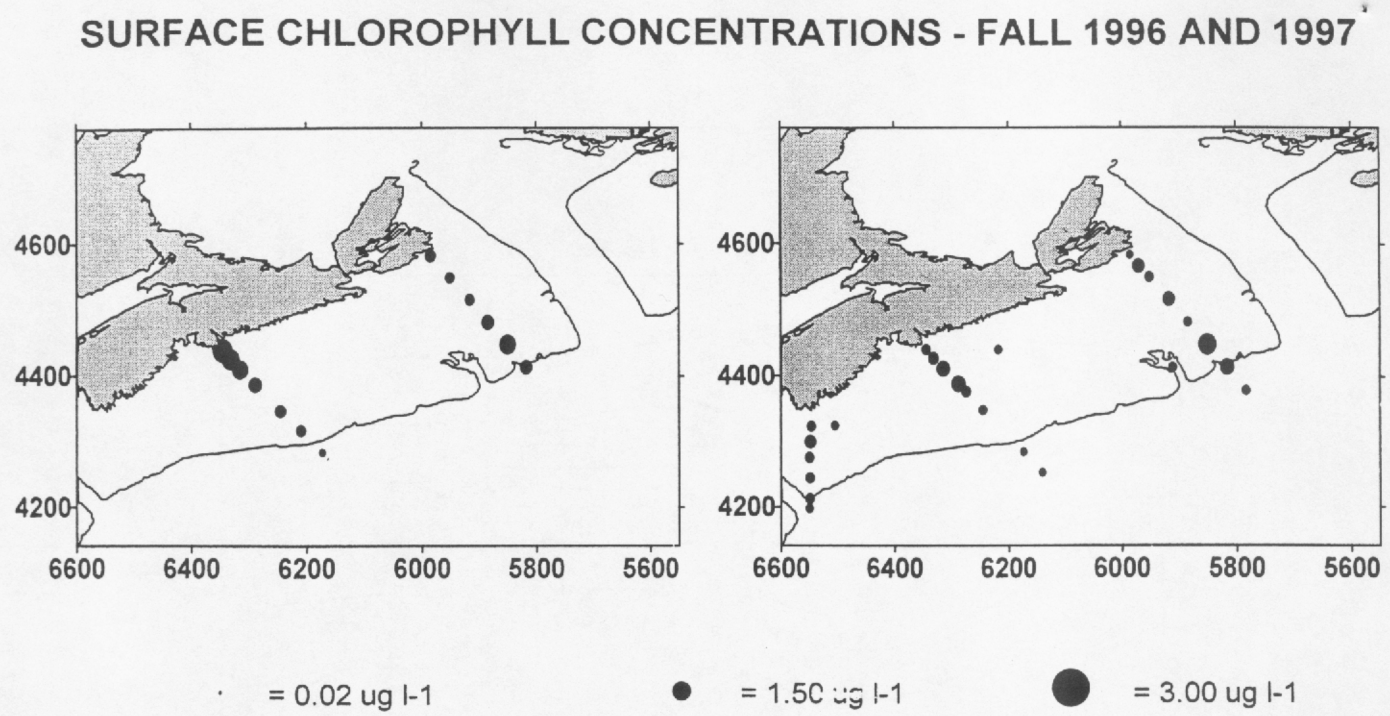


Fig. 6.3.8. Profiles of chlorophyll concentration (μg l^{-1}) across the Gully from Sable Island Bank to Banquereau Bank in July 1993.



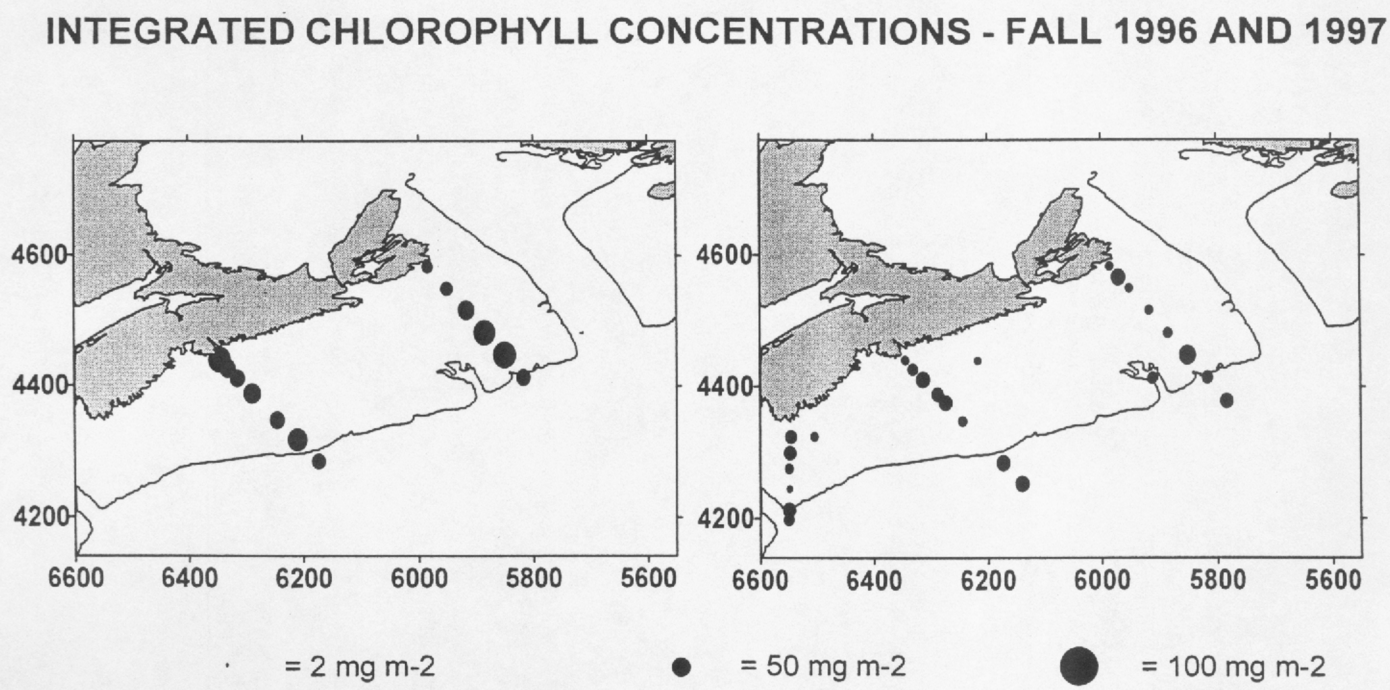


Fig. 6.3.9. Surface ($\mu g\ l^{-1}$) and integrated ($mg\ m^{-2}$) chlorophyll concentrations on the Scotian Shelf during November 1996 and October-November 1997.