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ABSTRACT

Sameoto, D., N. Cochrane and M. Kennedy. 2002. Seasonal Abundance, Vertical and Geographic Distribution of Mesozooplankton, Macrozooplankton and Micronekton in the Gully and Western Scotian Shelf (1999-2000). Can. Tech. Rep. Fish. Aquat. Sci. 2427: v + 37p.

This study examined changes in the abundance and community structure of mesozooplankton (animals between 0.2mm and 10mm length), macrozooplankton (animals between 1cm and 4cm) and the micronekton (animals > 4 cm) in the Gully and on the western Scotian Shelf and slope during spring and fall of 1999 and 2000. Data from a variety of zooplankton sampling nets were used to describe the species composition and distribution of mesozooplankton, macrozooplankton and ichthyoplankton in the regions. Acoustic backscattering from frequencies 12, 15, 105, 153 and 200 kHz were used to map the relative abundances of macrozooplankton and fish in the two areas during the spring and fall. The acoustic data provided relative integrated acoustic values for the water column along the survey tracks on the shelf and Gully. . Patterns of 12 and 15 kHz levels demonstrated that during October 1999 and April 2000 the highest values (and in turn the highest biomass) were located on the edge of the slope and that Gully levels were similar to those on the slope. This suggests that micronekton in the Gully were likely an extension of the slope micronekton community. The dominant zooplankton group on both the western Shelf and the Gully were the copepods, with the western Shelf having higher concentrations than the Gully during all surveys. In general there were only minor differences between the Gully and the western Shelf in the variety and abundance of the pelagic organisms examined in this study. The Gully had a larger population of the myctophid *Benthosema glaciale* than was found on the other regions of the slope, but since the number of samples collected was small too much weight should not be placed on this result.

RÉSUMÉ

Sameoto, D., N. Cochrane and M. Kennedy. 2002. Seasonal Abundance, Vertical and Geographic Distribution of Mesozooplankton, Macrozooplankton and Micronekton in the Gully and Western Scotian Shelf (1999-2000). Can. Tech. Rep. Fish. Aquat. Sci. 2427: v + 37p.

Dans l'étude décrite ici, on a examiné les changements dans l'abondance et la structure des communautés de mésozooplancton (animaux ayant de 0,2 à 10 mm de longueur), de macrozooplancton (animaux ayant de 1 à 4 cm de longueur) et de micronecton (animaux de plus de 4 cm) dans le Gully ainsi que dans l'ouest du plateau néo-écossais et sur le talus néo-écossais au printemps et en automne 1999 et 2000. On a utilisé les données recueillies dans l'échantillonnage du zooplancton au moyen de divers filets pour décrire la composition des espèces et la distribution du mésozooplancton, du macrozooplancton et de l'ichthyoplancton dans les zones considérées. La rétrodiffusion acoustique des fréquences 12, 15, 153 et 200 kHz a servi à établir l'abondance relative du macrozooplancton et du poisson dans les deux zones au printemps et en automne. Les données acoustiques ont servi à produire des valeurs acoustiques intégrées relatives de la colonne d'eau le long des transects de relevé sur le plateau et dans le

Gully. Les tendances de rétrodiffusion à des niveaux de 12 et 15 kHz ont révélé qu'au cours d'octobre 1999 et d'avril 2000 les valeurs les plus élevées (et partant les plus fortes biomasses) se trouvaient sur le bord du talus continental et que les valeurs relevées dans le Gully étaient comparables à celles du talus. Cela donne à penser que le micronecton du Gully était vraisemblablement un prolongement de la communauté de micronecton du talus. Le groupe dominant de zooplancton tant dans l'ouest du plateau que dans le Gully était celui des copépodes, mais ceux-ci étaient présents en concentrations plus grandes dans l'ouest du plateau que dans le Gully au cours de tous les relevés. En général, les différences entre le Gully et l'ouest du plateau néo-écossais pour ce qui est de la variété et de l'abondance des organismes pélagiques examinés dans l'étude n'étaient que mineures. On trouvait une plus grande population des poissons-lanternes *Benthosema glaciale* dans le Gully que dans les autres régions du talus, mais comme le nombre d'échantillons recueillis était bas, il ne faudrait pas accorder trop d'importance à ce résultat.

Seasonal Abundance, Vertical and Geographic Distribution of Mesozooplankton, Macrozooplankton and Micronekton in the Gully and Western Scotian Shelf (1999-2000)

By

D. Sameoto, N. Cochrane and M. Kennedy

Introduction

The purpose of this study was to examine seasonal changes in the abundance and community structure of mesozooplankton (animals between 0.2mm and 10mm length), macrozooplankton (animals between 1cm and 4cm) and the micronekton (animals > 4 cm) in the Gully and on the western Scotian Shelf and slope. Gordon and Fenton (2002) give a detailed description of the physical, geological and biological characteristics of the Gully. Zooplankton and micronekton data from the two regions were compared to look for differences that indicate that the Gully had unique features with regard to populations of these pelagic organisms.

Sampling methods

Area of study

The regions of study were the Gully and the Scotian Shelf and adjacent slope west of longitude 61° W (Fig. 1). The Gully is a large shelf-edge canyon on the eastern Scotian Shelf. It is unique among canyons of the Eastern Canadian margin due to its great depth, steep slopes and extension far back onto the continental shelf (i.e. connecting the continental slope to the inner shelf (Harrison and Fenton 1998). The entire Scotian Shelf and Gully were included in the acoustic surveys.

Acoustic frequencies

Acoustic backscatter data from Cruises HUDSON 1999-054 (fall), PARIZEAU 2000-002 (spring), and HUDSON 2000-050 (fall) were analyzed for extensive areas of the Scotian Shelf. Two acoustic frequencies were utilized simultaneously – either 105 or 200 kHz to delineate macro-zooplankton and fish and 12 or 15 kHz to delineate fish alone since macro-zooplankton do not backscatter at detectable levels at the lower frequencies.

Transducers

HUDSON utilized a roughly calibrated RAM-mounted EDO 323B 12 kHz transducer of nominal 30^0 (-3 dB to –3dB) beamwidth which was extended about 1 m below 7 m hull depth. Also used was a precisely calibrated and temperature compensated FURUNO 200-B transducer of nominal 5.4^0 beamwidth temporarily installed to hull depth through a standpipe in HUDSON's aft "General Purpose" Lab. PARIZEAU utilized a broadband (12 – 20 kHz) ELAC LSE 179 transducer at its optimum performance frequency of 15 kHz with a 12^0 nominal beamwidth and a 105 kHz ROSS transducer of 3.5^0 beamwidth, both transducers permanently hull-mounted at about 5 m depth.

Sounders

Tunable DataSonics DFT-210 echosounders were utilized on all three cruises. Fixed sounder time variable gains (TVG 20 log R + Absorption) were applied to the raw echo voltages in real-time over profiling ranges of 5 – 500 m at 12 & 15 kHz and 2 – 200 m at 105 and 200 kHz. On HUDSON, transmit power levels were nominally 400 W at 12 kHz, and 2 kW at 200 kHz. Pulse widths were 2 ms at 12 kHz and 5 ms at 200 kHz, both used in combination with 1 kHz receiver bandwidths. On PARIZEAU, both channels transmitted at 1 kW power using identical 2 ms pulse lengths and 1 kHz receiver bandwidths. The ping repetition rate was 1 ping/s, where high spatial-resolution real-time displays were required, and otherwise 1 ping/10 s.

Data Recording

Bandpass filtered and detected outputs from the DFT-210 sounders were decimated to 1 ping/10s, when necessary, and digitized to 12 bit resolution at rates of either 5 kHz/channel (Cruise 1999-054) or 2.5 kHz/channel (Cruises 2000-002 & 2000-050). On Cruise 1999-054, data was recorded to either 300 or 470 m maximum range. On Cruises 2000-005 and 2000-050 recording was extended to a 1040 m to enable visual examination of deeper water fish concentrations. Data headers affixed to each acoustic ping included computer and GPS time, GPS position and speed, and ship's log speed.

Data Analysis

Acoustic signals were examined in a time window corresponding to 20 to 300 m target depth. Relevant acoustic data were initially pre-processed: Data were read, known offsets in DC levels removed, and time variable gains digitally extended, as required, to full analysis range, using fixed software spreading and absorption parameters matching the TVG characteristics applied by the sounder, then stored. Data were subsequently inspected for general quality using a custom graphics package. Sections displaying obvious sounder malfunctions, frequent extended outages, or extremely high noise levels arising from adverse sea conditions were rejected at this stage.

The edited data sets were then processed using a software echo integration package. Approximate TVG corrections were first refined. Echo levels were finely adjusted to transect-specific acoustic absorption coefficients as computed from measured temperature-salinity (TS) profiles (Francois & Garrison 1982a, 1982b). Subsequently, echo integration was performed between depths of 20 and either 300 m - or to 2 m above acoustic bottom when shallower. The upper integration depth limit was occasionally increased to 30 m to reject deeply convected bubble plumes during stormy weather (Zedel & Farmer 1991). At 105 and 200 kHz, where the TVG ramped comparatively rapidly due to larger absorption compensations, receiver front-end noise became significant between 200 and 300 m range. Prior to integration, squared echo amplitudes were corrected for receiver noise by subtraction of a corresponding squared amplitude noise signal obtained by similar signal acquisition and processing over a 300 ping sample with the transmitter unpowered – negative differences permitted. This methodology permitted variable bottom depths < 300 m to be easily accommodated in the noise correction process. Squared echo amplitudes for each available range bin were averaged over 10 pings (i.e. 100 s assuming 1 ping/10 s) with proper allowance for any missing bins due to bottom truncation, then integrated vertically. After integration, appropriately scaled calibration factors, derived from the digitizer sensitivity, echosounder gains, pulse lengths and shapes, and transducer sensitivities, the latter including the effect of transducer temperature (200 kHz only – Sameoto et al. 1993), were applied to scale the integration result to depth-integrated volume backscattering strength i.e. depth-integrated s_v (non-logarithmic form) by the notation of Clay & Medwin (1977). We henceforth refer to integrated s_v by the notation s_a, the column or areal backscattering strength (also non-logarithmic form). Finally any integration results for which vessel speed dropped below 2 knots were rejected. Slow speeds signify a vessel drifting or stationary on sampling stations where biological acoustic backscatter is frequently contaminated by scattering from sampling nets or bubble clouds churned up by the ship's propellers while station keeping.

Final Editing

Plots of s_a vs. transect ping no. were visually inspected for short duration high amplitude "spikes" arising from either sporadic bubble cloud noise bursts or brief losses of bottom track while passing over extreme bathymetry. Suspected "spikes" were verified by reference to the original echogram sections, then removed.

Acoustic survey conducted simultaneously at two sounder frequencies enabled graphical separation of backscattering horizons of macro-zooplankton – mostly euphausiids or krill – from horizons due to aggregations of pelagic fishes. Net sampling in the upper reaches of the Gully indicated the most common macro-zooplankton to be the euphausiid crustacean *Meganyctiphanes norvegica*. Though variable in length, 2.8 cm constitutes a reasonable average (Sameoto et al. 1993). Marine crustaceans, in contrast to the majority of fishes, lack highly reflective gas-filled body cavities, but rather weakly backscatter sound by virtue of the slightly differing sound speed and velocity contrasts between their tissues and the surrounding seawater. Fig. 2 shows ensemble average theoretical acoustic target strengths for 2.8 cm length *M. norvegica* vs. ensonification frequency using the Stanton et. al. (1993) fluid cylinder "Ray Model" and physical and orientational parameters previously used to model Scotian Shelf euphausiid of this size (Cochrane et al. 2000). Table 1 details predicted target strengths for the specific acoustic frequencies utilized.

Reference to Table 1 shows acoustic target strengths differ by less than 1 dB between the highest frequencies, 105 and 200 kHz. At these frequencies euphausiids scatter in the so-called "geometrical" regime where their size is comparable to or greater than the acoustic wavelength. At the two lower observation frequencies, 12 and 15 kHz, where the organisms scatter well into the "Raleigh" regime characterized by organism sizes much less than the acoustic wavelength target strengths fall by a minimum of 27 dB. The practical consequence is that even quite dense krill aggregations are totally invisible acoustically, i.e. characterized by echo levels below system or ambient background acoustic levels.

The discrimination of the highest acoustic frequency, 200 kHz, in regard to organism size is shown in Fig. 3. Organisms shorter than approximately 2 cm, scatter in the Raleigh regime.

Proceeding from 2.8 cm to smaller 1 cm length organisms results in a target strength drop in excess of 10 dB. Organisms of 0.5 cm length have target strengths are roughly 20 dB lower than that characterizing an average size *M. norvegica.*

Most fishes, by contrast, scatter sound strongly, largely by virtue of their gas filled internal swimbladders (Foote 1985). While the primarily, sharp swimbladder resonance normally lies well below acoustic echosounder frequencies, the swimbladder itself scatters strongly in the geometric regime due to its strong acoustic impedance contrast to enclosing body tissues. Fish body tissues also directly contribute to the backscattering at echosounder frequencies, but to a lesser degree. Empirical laboratory measurements of fish acoustic backscatter have allowed formulation of empirical target strength (*TS*) relationships (McCartney and Stubbs 1971, Goddard and Welsby 1986) of the general form:

$$TS = a \log L + b \log \lambda + c$$

L is total (fish) length and λ the ensonifying wavelength. a, b, and c are species dependent constants. The wavelength scaling parameter, b, has been assigned a wide range of values. Goddard and Welsby (1986) report b values between –2.5 and –5.1 for a variety of gadoids and dogfish while McCartney and Stubbs (1971) report –4.5, all measured at dorsal aspect. Taking the McCartney and Stubbs value of –4.5 as representative, the general formulation above predicts 12 kHz target strengths about 5 dB lower than at 200 kHz. The target strength differential for fish between the "high" and "low" echosounder channels is seen to be at least 22 dB less than that observed for *M. norvegica.* High frequency echograms, relied upon to delineate both the locations and quantitative abundances of macrozooplankton, can be examined for possible contamination by fish backscattering by searching for acoustic horizons simultaneously visible at high and low acoustic frequencies. A convenient operational procedure is to overlay intensity modulated echograms at differing frequencies, each displayed in a different primary colour (Cochrane and Sameoto 1987; Cochrane et al. 1991, 2000).

Table 1. Predicted average acoustic target strengths of 2.8 cm length *M. norvegica.* Density contrast g = 1.05, sound speed contrast, h = 1.03 (Køgeler et. al. 1987), average horizontal orientation assumed with a 30^0 S.D. measured in 3-D space.

Acoustic Frequency (kHz)	Target Strength (dB)
12	-102.5
15	-100.6
105	-74.3
200	-73.9

Acoustic Doppler Current Profiler (ADCP)

The hull-mounted RD Instruments ADCP operating at a frequency of 153 kHz was used to continuously record acoustic backscattering during the two HUDSON cruises, namely the fall of 1999 and the fall of 2000. Data from an earlier survey (April 1999) over the same transects was also included in the analysis. Data were recorded over a depth range of 12 to 300 m and were averaged into 30 s duration bins. The specific data used were the average raw amplitude counts from the four transducers. These data were reduced to profiles of volume backscattering strength vs. water-column depth using the reduction procedures outlined by the manufacturer (RD Instruments 1990).

These procedures utilized instrument-specific calibrations supplied by the manufacturer, together with internal voltages and temperatures continuously recorded during the cruise. Required acoustic absorption coefficients were computed using temperature and salinity data collected with regular CTD casts at all biological sampling stations.

These data were converted to volume backscattering strengths at 4 m bin depth intervals and average backscatter per m^2 (s_a). Data were edited to remove bad values using similar methods as applied to the sounder data.

Net Sampling

Three types of zooplankton nets were used to sample the organisms, a 0.75 m diameter 200 μm mesh ring net, the 20 cm diameter 200 μm bongo nets, and the BIONESS with 0.5m mouth area 250 μm nets. The ring and bongo nets were towed in a vertical mode and the BIONESS was towed obliquely at a speed of 1.5 m/s. A strobe light was mounted on the BIONESS that flashed continuously once every 10 s with the purpose of blinding organisms and thereby reducing the net avoidance reaction (Sameoto et al. 1993). The ring nets and BIONESS were towed to a maximum depth of 600 m or within 2 m of the bottom. Stratified 50 m interval samples were taken with the BIONESS at four stations in the Gully and in Emerald and Roseway basins stratified samples were taken at approximately 30 m intervals (station locations are shown in Fig. 4). All data were entered into the Bio/Chem database. The average integrated numbers for mesozooplankton were calculated from all stations sampled with all types of gear. The average integrated numbers for macrozooplankton and ichthyoplankton were calculated from data only collected with the BIONESS.

Results

Acoustic Surveys

The 1999 and 2000 fall surveys conducted at 12 and 200 kHz showed that for both frequencies depth integrated s_v, i.e. s_a values, in the Gully were lower than those measured over the entire western Shelf. The spring survey, conducted at 15 and 105 kHz, found the 15 kHz s_a values were higher in the Gully than over the western Shelf, whereas the 105 kHz s_a values in the Gully were lower than those on the western Shelf (Table 2). To summarize: The Gully had lower *high frequency* s_a values than the western Shelf during all cruises. The Gully also had lower *low* *frequency* s_a values than the Shelf during the spring but higher values than the Shelf during the fall.

The patterns of s_a for the various frequencies on each of the surveys over the entire Shelf are shown in Fig. 5. The Gully fall, 12 kHz s_a values and the spring, 15 kHz s_a values were similar to those observed along the slope. This suggested a similarity in the abundance and types of backscattering organisms in the Gully and on the slope. The s_a values in the Gully were not larger than those found on the slope, but they were generally higher than s_a values on the Shelf during October, 1999 and April 2000. However, during October 2000 the 12 kHz s_a was higher on the Shelf than in the Gully.

ADCP

The ratio between the Gully s_a and western Scotian Shelf s_a for the spring and fall surveys showed that the western Shelf was consistently characterized by higher s_a values. The s_a ratios between the two areas showed that the western Shelf had approximately three times the integrated backscattering measured in the Gully during the spring and fall (Table 3). Highest s_a were generally found in the region of Emerald, LaHave and Roseway Basins (Fig. 6).

Table 2. Integrated volume backscattering strengths (s_a) at 12, 15 and 200 kHz in the Gully and western Scotian Shelf plus the ratio between s_a in the two regions.

Date	Cruise	s_a backscattering per m2		Frequency	Gully s_a/NSS s_a
		Western Scotian Shelf	Gully		
Oct. 1999	99054	8.16E-06	6.05E-06	12	0.74
"	99054	1.11E-05	4.40E-06	200	0.40
Apr. 2000	200002	4.00E-04	6.88E-04	15	1.72
"	200002	1.30E-04	5.70E-05	105	0.44
Oct. 2000	200050	2.10E-05	4.74E-06	12	0.23
"	200050	1.11E-05	4.24E-06	200	0.38

Table 3. Integrated volume backscattering strengths (s_a) measured with the ADCP at 153 kHz in the Gully and western Scotian Shelf, plus the ratio between the s_a in the two regions.

Date	Cruise	Western Scotian Shelf	Gully	Frequency	Gully s_a/NSS s_a
Apr. 1999	99003	1.25E-06	2.80E-07	153	0.22
Oct. 1999	99054	8.50E-07	2.86E-07	153	0.34
Oct. 2000	200050	1.11E-06	3.14E-07	153	0.28

Mesozooplankton and macrozooplankton

The dominant mesozooplankton in both the Gully and western Scotian Shelf regions were copepods with the Shelf displaying higher column densities, i.e. integrated no. per m^2, on each of the three surveys (Table 4 and Fig. 7). The abundance of different stages of the three main *Calanus* species, *C. finmarchicus, C. glacialis* and *C. hyperboreus* were compared in the two regions to determine if the Gully populations were in anyway different than the Shelf populations. In the spring the Gully had a slightly higher number of stages 1 and 2 of *C. finmarchicus* than the Shelf, which suggested that in the Gully reproduction occurred later in the year. There were no significant differences in the other two species in the spring between the two regions (Fig. 8). In the fall the Shelf had a higher abundance of all three *Calanus* species (Fig. 8). The most abundant copepod genus on the Shelf and in the Gully during April was *Oithona*. In October *Oithona* and *Centropages* were the dominant copepods in both regions (Fig. 9).

In the spring, the dominant non-copepod group of invertebrates in both regions was the appendicularians (Table 5). During the fall of 1999 appendicularians were most abundant in the Gully and on the Shelf, but during the fall of 2000 salps were the most abundant group in both regions (Fig. 10).

Ichthyoplankton and juvenile fish

In the spring the sand lance, *Ammodytes,* dominated the ichthyoplankton in the Gully and was much more abundant in the Gully than on the Shelf. The mesopelagic myctophids *Benthosema* and *Cyclothone* were the next most abundant genera of fish. On Shelf slope *Benthosema* was the dominant genus with no Cyclothones collected on the Shelf slope (Fig. 11).

In the fall of 1999 the Gully was dominated by the silver hake *Merluccius*, whereas in the fall of 2000 there were no *Merluccius* collected in the Gully although they were common on the Shelf. The dominant ichthyoplankton genus on the Shelf in the fall of 2000 was the longfin hake, *Urophycis*, but it was not found in the Gully (Fig. 11).

Table 4. Mesozooplankton taxon abundance per m2 in the Gully and Western Scotian Shelf (WSS) during the fall and spring surveys.

Taxon	Gully Fall 1999	WSS Fall 1999	Gully Spring 2000	WSS Spring 2000	Gully Fall 2000	WSS Fall 2000
BIVALVE LARVAE	162	23425	108	13837	99	4065
CLADOCERA						
EVADNE		2658		1133	47	3222
PODON		2175				453
GASTROPODA						
UNIDENTIFIED	80	2773	346	883	326	3094
LIMACINA	1138	11311	2583	21914	434	3041
OSTRACODA	392	6312	1693	5636	547	3101
POLYCHAETA	79	747	531	2399	10	345
MEDUSAE	56	1116	4	385		5
COPEPODA	91235	372328	176598	228613	73398	209035
CALANUS FINMARCHICUS TOTAL	4851	13157	35952	28153	3034	12690
CALANUS FINMARCHICUS 1	284	1197	15604	6293	32	125
CALANUS FINMARCHICUS 2	340	1410	9623	6280	170	162
CALANUS FINMARCHICUS 3	114	1324	4616	5459	140	291
CALANUS FINMARCHICUS 4	381	3985	2473	5794	451	1650
CALANUS FINMARCHICUS 5	3757	9330	1923	2498	2313	10434
CALANUS FINMARCHICUS 6	355	918	1713	2237	99	562
CALANUS GLACIALIS TOTAL	57	745	977	1663	12	441
CALANUS GLACIALIS 1			399	666		
CALANUS GLACIALIS 2			297	688		
CALANUS GLACIALIS 3			331	524		147
CALANUS GLACIALIS 4	40		50	259	16	182
CALAUNS GLACIALIS 5	47	1450	96	183	11	408
CALANUS GLACIALIS 6	10	41	7	245		168
CALANUS HYPERBOREUS TOTAL	1203	11378	4607	6269	410	4248
CALANUS HYPERBOREUS 1			757	298		
CALANUS HYPERBOREUS 2			371	1703		
CALANUS HYPERBOREUS 3	18	145	2237	3272	13	53
CALANUS HYPERBOREUS 4	977	10054	1444	860	269	2648
CALANUS HYPERBOREUS 5	370	6765	409	1254	124	2466
CALANUS HYPERBOREUS 6	117	1464	67	315	28	624
ACARTIA		1234		6		805
AETIDEUS	330	3469	813	1163	240	1050
BRADYIDIUS						
CALOCALANUS		1365		924	119	1734
CANDACIA	3	1178		580	5	617
CENTROPAGES	26581	78873	2919	12159	9550	52640

CHIRIDIUS	4	4349	102	452	129	376
CLAUSOCALANUS	460	8399	77	10259	6580	7310
CLYTEMNESTRA	311	2253	43	2498	272	709
CORYCAEUS		1179				206
CYCLOPOID				9282		2784
EUCALANUS	13	2417	18		30	364
EUCHAETA	191	1652	2186	2761	329	737
EUCHIRELLA			144	1971		
EURYTEMORA	5					
GAETANUS	1		9		16	
GAIDIUS	93	1884	291	948	104	942
HALITHALESTRIS				24		
HALOPTILUS					19	
HARPACTICOID	3	815	14	112	1	
HARPACTICUS						
HETERORHABDUS	22		59	1065	88	272
LUBBOCKIA					18	
LUCICUTIA	16				27	2445
MACROSETELLA						362
MECYNOCERA	160	5019		1464	882	6502
METRIDIA LONGA	808	4912	2921	4218	1961	3238
METRIDIA LUCENS	3428	18270	4870	13575	10580	12209
MICROCALANUS	386	14241	301	7842	180	6688
MICROSETELLA	9	378	12		13	227
MIRACIA						362
MORMONILLA					31	362
NANNOCALANUS	158	3071		38	2	3740
OITHONA	9513	133656	47923	99617	2263	61851
ONCAEA	147	4692	464	1866	458	2660
PARACALANUS	17773	37868	740	2359	24950	21556
PHAENNA	11					
PLEUROMAMMA	67	3519	292	2615	1027	6029
PSEUDOCALANUS	15141	16772	52066	29600	1222	5409
RHINCALANUS	10	1178	9		36	
SCAPHOCALANUS	9	725			23	
SCOLECITHRICELL	516	2951	4573	2114	1285	1458
SCOTTOCALANUS	2		21		9	
SPINOCALANUS	101	1133	327	1185	308	791
TEMORA	227	19450	2630	5663	10	6121
TORTANUS			50			
UNDEUCHAETA	7				15	
UNDINELLA					8	

Table 5. Macrozooplankton taxon and ichthyoplankton abundance per m2 in the Gully and Western Scotian Shelf (WSS) during the fall and spring surveys.

Macrozooplankton Taxa	**Gully Fall 1999**	**WSS Fall 1999**	**Gully Spring 2000**	**WSS Spring 2000**	**Gully Fall 2000**	**WSS Fall 2000**
APPENDICULARIA	922.6	3396.5	27300.2	15051.1	485.8	1698.3
ASCIDIACEA	13.6	2054.8	13.5		64.0	1245.0
BARNACLE		1450.1	132.2	3421.6		
BRYOZOA		4.5				1504.7
CHAETOGNATH	130.5	2431.9	163.9	240.3	124.3	793.4
CUMACEAN						441.6
DECAPOD	4.1	2.7	142.1	545.4	15.2	33.6
ECHINODERM	147.9	3069.4	407.7	2151.4	405.8	1987.1
HYDROMEDUSA		2.3				2.7
ISOPOD	2.0					
MYSID	9.2	10.6	1.0	1227.3	0.0	311.9
SALP		112.6				
EUPHAUSIACEA					7152.4	11707.1
THYSANOESSA	17.0	306.2	27.0	12.0	46.3	163.1
MEGANYCTHIPHANES NORVEGICA	54.2	4.5	89.9	24.0	28.9	31.9
EUPHAUSIA		13.6	4.6	6.8	6.6	15.4
UNKNOWN EUPHAUSIID	6.6	2.3	0.1	0.5	0.0	0.1
AMPHIPODA	7.7	1025.3	147.3	676.1	239.9	191.8
Ichthyoplankton Taxa						
AMMODYTES	0.4		462.3	3.8		
BENTHOSEMA	1.1	2.3	9.7	6.8	8.1	1.3
CITHARICHTHYS						2.3
CYCLOTHONE	3.0		10.0		4.7	
DIAPHUS			0.3			
GONOSTOMATIDAE	4.7	11.3		2.3		1.9
LUMPENUS				2.3		
MALLOTUS	0.5					
MERLUCCIUS	36.3					27.7
NOTOLEPIS		2.3			1.3	
OSTEICHTHYES			0.0	0.4	0.0	0.0
PEPRILUS						2.3
UROPHYCIS		4.5				452.7

Table 6. Genera and species list of all organisms collected in samples on the entire Scotian Shelf (SS) and Gully during the spring and fall of 1999 and 2000. Presence is indicated by X and absence by a blank.

Species	**Gully Fall**	**Gully Spring**	**SS Fall**	**SS Spring**
CNIDARIA				
UNIDENTIFIED	X		X	X
AGLANTHA DIGITALIS		X	X	X
BEROE CUCUMIS	X		X	
CTENOPHORA	X		X	X
HYDROID			X	
HYDROMEDUSA			X	
LEPTOMEDUSAE	X		X	
OBELIA			X	
PELAGIA NOCTILUCA			X	
PERIPHYLLA PERIPHYLLA	X			
SCHYPHOZOA	X		X	
SIPHONOPHORA				
UNIDENTIFIED	X	X	X	
POLYCHAETA				
UNIDENTIFIED	X	X	X	X
TOMOPTERIS	X	X	X	X
TOMOPTERIS HELGOLANDICUS			X	
TOMOPTERIS SEPTENTRIONALIS			X	X
GASTROPODA				
UNIDENTIFIED	X		X	
BIVALVIA	X	X	X	X
CLIONE LIMACINA		X	X	X
CONCHOECIA	X	X	X	X
EVADNE NORDMANNI	X		X	X
GONATUS	X			
GYMNOSOMATA	X	X	X	X
LIMACINA	X	X	X	X
LIMACINA HELICINA	X	X	X	X
LOLIGO		X		
PODON			X	
PODON LEUCKARTII			X	
COPEPODA				
UNIDENTIFIED	X	X	X	X
ACARTIA				X
ACARTIA CLAUSI			X	
ACARTIA LONGIREMIS			X	
AEGISTHUS MUCRONATUS	X			
AETIDEIDAE	X		X	X

AETIDEUS ARMATUS	X	X	X	X
AMALLOTHRIX EMARGINATA		X		
ANOMALOCERA PATERSONI			X	
CALANUS FINMARCHICUS	X	X	X	X
CALANUS GLACIALIS	X	X	X	X
CALANUS HYPERBOREUS	X	X	X	X
CALOCALANUS			X	
CALOCALANUS PAVO	X		X	X
CANDACIA ARMATA	X		X	X
CENTROPAGES	X	X	X	X
CENTROPAGES BRADYI	X		X	
CENTROPAGES HAMATUS	X	X	X	X
CENTROPAGES TYPICUS	X	X	X	X
CHIRIDIUS	X	X		
CHIRIDIUS ARMATUS			X	
CHIRIDIUS GRACILIS	X	X	X	X
CLAUSOCALANUS	X	X	X	
CLAUSOCALANUS ARCUICORNIS	X		X	X
CLAUSOCALANUS FURCATUS	X	X	X	X
CLAUSOCALANUS PAULULUS			X	
CLAUSOCALANUS PERGENS	X		X	
CLYTEMNESTRA SCUTELLATA	X	X	X	X
CORYCAEUS			X	
CYCLOPOIDA			X	X
EUCALANUS	X	X	X	
EUCALANUS ATLANTICUS	X		X	
EUCALANUS ATTENUATUS	X			
EUCALANUS CRASSUS	X			
EUCALANUS ELONGATUS	X		X	
EUCHAETA NORVEGICA	X	X	X	X
EUCHIRELLA ROSTRATA		X		X
EURYTEMORA HIRUNDOIDES	X			
GAETANUS	X			
GAETANUS KRUPPII	X			
GAETANUS MILES		X		
GAETANUS MINOR	X			
GAIDIUS TENUISPINUS	X	X	X	X
HALITHALESTRIS CRONI				X
HALOPTILUS FONS	X			
HARPACTICOIDA	X	X	X	X
HETERORHABDUS NORVEGICUS	X	X	X	X
LUBBOCKIA	X			
LUBBOCKIA ACULEATA	X			
LUBBOCKIA SQUILLIMANA	X			
LUCICUTIA FLAVICORNIS	X		X	
MACROSETELLA OCULATA			X	
MECYNOCERA CLAUSI	X		X	X

METRIDIA LONGA	X	X	X	X
METRIDIA LUCENS	X	X	X	X
MICROCALANUS	X	X	X	X
MICROCALANUS PUSILLUS			X	
MICROSETELLA NORVEGICA	X	X	X	
MIRACIA EFFERATA			X	
MORMONILLA PHASMA	X		X	
NANNOCALANUS MINOR	X		X	X
OITHONA	X	X		X
OITHONA ATLANTICA	X	X	X	X
OITHONA NANA	X			
OITHONA SIMILIS	X	X	X	X
ONCAEA	X	X	X	X
ONCAEA BOREALIS	X		X	X
ONCAEA CONIFERA	X	X	X	X
ONCAEA MEDIA	X			
ONCAEA VENUSTA	X		X	
PARACALANUS	X	X	X	X
PARACALANUS ACULEATUS	X		X	
PARACALANUS PARVUS			X	
PHAENNA SPINIFERA	X			
PLEUROMAMMA	X	X	X	X
PLEUROMAMMA BOREALIS	X	X	X	X
PLEUROMAMMA ROBUSTA	X	X	X	X
PLEUROMAMMA XIPHIAS	X			
PSEUDOCALANUS	X	X	X	X
RHINCALANUS CORNUTUS	X	X	X	
RHINCALANUS NASUTUS	X	X	X	
SAPPHIRINA			X	
SCAPHOCALANUS	X		X	
SCAPHOCALANUS BREVICORNIS	X		X	
SCAPHOCALANUS ECHINATUS	X			
SCAPHOCALANUS MEDIUS	X			
SCOLECITHRICELLA ABYSSALIS	X			X
SCOLECITHRICELLA MINOR	X	X	X	X
SCOLECITHRICELLA OVATA	X	X	X	X
SCOTTOCALANUS PERSECANS	X	X		
SCOTTOCALANUS SECURIFRONS	X			
SPINOCALANUS		X		
SPINOCALANUS ABYSSALIS	X	X	X	X
TEMORA LONGICORNIS	X	X	X	X
TORTANUS DISCAUDATUS		X		
UNDEUCHAETA MAJOR	X			
UNDEUCHAETA PLUMOSA	X			
UNDINELLA OBLONGA	X			

MYSIDACEA				
UNIDENTIFIED	X	X	X	X
BOREOMYSIS	X		X	X
BOREOMYSIS MICROPS	X			
EUCOPIA			X	
PSEUDOMMA				X
CUMACEA				
UNIDENTIFIED			X	
ISOPODA				
UNIDENTIFIED	X			
AMPHIPODA				
UNIDENTIFIED	X	X	X	X
GAMMARIDEA	X	X	X	
HYPERIIDEA			X	X
PARALYCAEA	X			
PARATHEMISTO	X	X	X	X
PARATHEMISTO GAUDICHAUDI	X	X	X	X
PHRONIMA			X	X
EUPHAUSIIDAE				
EUPHAUSIA KROHNII	X	X	X	X
EUPHAUSIIDAE	X	X	X	X
MEGANYCTIPHANES NORVEGICA	X	X	X	X
NEMATOSCELIS MEGALOPS	X			
NYCTIPHANES COUCHII				X
STYLOCHEIRON	X			
STYLOCHEIRON ELONGATUM	X			
STYLOCHEIRON MAXIMUM			X	
THYSANOESSA			X	
THYSANOESSA INERMIS	X	X	X	X
THYSANOESSA LONGICAUDATA	X	X	X	X
THYSANOESSA RASCHI	X	X	X	X
THYSANOPODA	X	X	X	X
DECAPODA				
UNIDENTIFIED	X		X	X
ACANTHEPHYRA PURPUREA		X		
BRACHYURA		X	X	X
CARIDEA	X			
EUALUS				X
GENNADAS				X
GENNADAS ELEGANS	X	X	X	
PAGURID		X		
PANDALUS	X		X	X

PASIPHAEA MULTIDENTATA	X	X	X	X
SERGESTES ARCTICUS	X	X	X	X
SERGIA ROBUSTA		X		
BRYOZOA				
UNIDENTIFIED			X	
ECHINODERMATA				
UNIDENTIFIED	X	X	X	X
CHAETOGNATHA				
UNIDENTIFIED	X	X	X	X
EUKROHNIA HAMATA	X	X	X	X
SAGITTA	X	X	X	X
SAGITTA ELEGANS	X	X	X	X
SAGITTA MAXIMA	X	X	X	X
SAGITTA SERRATODENTATA	X		X	X
SAGITTA SETOSA		X		
ASCIDIACEA				
UNIDENTIFIED	X	X	X	
APPENDICULARIA	X	X	X	X
FRITILLARIA	X	X	X	X
OIKIOPLEURA	X	X	X	X
OIKIOPLEURA VANHOEFFENI		X		
SALPA			X	
SALPA FUSIFORMIS			X	
SALPA MAXIMA			X	
SALPIDAE	X		X	
THALIA DEMOCRATICA	X		X	
OSTEICHTHYES				
UNIDENTIFIED	X	X	X	X
AMMODYTES				X
AMMODYTES AMERICANUS	X	X		
BENTHOSEMA GLACIALE	X	X	X	X
CITHARICHTHYS ARCTIFRONS			X	
CYCLOTHONE BRAUERI	X	X		
DIAPHUS		X		
GONOSTOMATIDAE	X		X	X
LUMPENUS MACULATUS				X
MALLOTUS VILLOSUS	X			
MERLUCCIUS ALBIDUS			X	
MERLUCCIUS BILINEARIS	X		X	
NOTOLEPIS RISSOI	X		X	
PEPRILUS TRIACANTHUS			X	
UROPHYCIS CHUSS			X	
Sum of taxa	141	91	142	95

Acoustic backscattering in the Gully

The acoustic survey cruise tracks within the Gully crossed the Gully perpendicular to its long axis thereby sampling all depth strata (Fig. 12). The 105 and 200 kHz acoustic data during both the spring and fall surveys showed high s_v values in the northern shallow arms of the Gully with the lesser s_v values in the central and southern regions of the Gully (Figs. 13 and 14). BIONESS sampling in these regions showed that the high s_v regions were those with high euphausiid populations. The low frequency (12 and 15 kHz) data indicated that, during both surveys, there were large populations of fish in regions where the depth was greater than 500 m (Figs. 15 and 16). Sampling showed these were the mesopelagic fish *Benthosema glaciale* and *Cyclothone spp.*. Fish echoes at 12 and 15 kHz were consistently seen near the bottom at depths between 500 and 1000m. These fish echoes were most concentrated in regions with steep crevices with higher echo concentrations on the western side of the Gully (Fig. 17). Euphausiids were concentrated in the northern arms of Gully that extend onto the Shelf while copepods, in contrast, were uniformly distributed throughout the Gully stations (Fig. 18). The mesopelagic fish distribution was centered in the mouth of the Gully and extended onto the slope. The distribution patterns for these animals were similar in the spring and fall of 2000.

Diurnal migration

In October 23, 2000 the ship was on station on the Scotian slope at longitude 61.16° W and latitude 42.24° N between the hours of 14:59 and 10:30. During this period we recorded the acoustic backscatter from the diurnal migration of mesopelagic organisms using the 12 kHz sounder. Fig. 19 shows the migration pattern of organisms migrating from a depth of approximately 400m starting at about 15:00 hr AST and reaching a depth of approximately 25 by about 19:00 hr. After 19:00 hr the main concentration of animals in the layer was located at a depth of 50 m with animals reaching the surface layer; organisms started their downward migration around 04:30. The principle group of animals that were collected in this migrating layer was the mesopelagic fish, *Benthosema sp.* It is know from past sampling that these fish migrate to near the surface at the night to feed (Sameoto 1988).

Discussion

Acoustic surveys provided high-resolution data on the vertical and geographic distributions of pelagic organisms over a wide size range. The 12 and 15 kHz acoustic data allowed the mapping of fish distributions in the larvae to adult size range. Unfortunately, we are unable to determine either the size or species of fish from acoustic data. Nevertheless, BIONESS sampling did provide information on organisms responsible for a portion of the acoustic backscattering at 12 and 15 kHz. However, the BIONESS is limited in the size of animals it is able to capture and the larger species of fish responsible for most of the 12 and 15 kHz backscattering were not collected. Biomass estimates for the micronekton are likely minimal estimates because of the avoidance of the BIONESS by larger organisms. The patterns of 12 and 15 kHz s_a levels demonstrated that during October 1999 and April 2000 the highest s_a values (and in turn the highest biomass) were located on the edge of the slope and that Gully s_a levels were similar to those on the slope. This suggests that micronekton in the Gully were likely an extension of the slope micronekton community. In October 2000 the pattern of 12 kHz s_a was different from that observed in October 1999. The s_a levels on the central shelf appeared to be much higher in 2000 than in 1999, however in 1999 we had less comprehensive 12 kHz sounder coverage of the western shelf due to technical difficulties.

The 200 kHz sounder provided excellent information on the abundance and distribution of macrozooplankton. The dominant macrozooplankton on the shelf and slope responsible for the clearly observed and quantifiable acoustic backscattering are euphausiids and amphipods. Many of the other types of macrozooplankton collected backscatter at very low levels at 200 kHz and their contribution to the total s_a is usually very small compared to that of the euphausiids and amphipods. The pattern of 105 and 200 kHz s_a during surveys showed the levels were highest on the central and western Shelf with the Gully generally having lower levels than these areas but being much higher than the eastern Shelf. The 105 and 200 kHz s_a in the Gully was similar to that found along the slope for each of the surveys.

The ADCP derived s_a showed similar patterns to those seen for the 105 and 200 kHz conventional echosounder derived s_a on the Shelf. The ADCP data were truncated at the edge of the shelf, with no data presented over the slope regions. The highest s_a levels were observed during the April 2000 survey over the western Shelf region. The s_a levels in the Gully during April 2000 and October 1999 were much lower than those found on the western Shelf but higher than levels measured on the eastern Shelf. During October 2000 the Gully had some of the highest recorded s_a levels measured during the survey. We do not know which organisms were responsible for these high s_a levels.

The dominant zooplankton group on both the western Shelf and the Gully were the copepods, with the western Shelf having higher concentrations than the Gully during all surveys. One of the most important copepod genus in the region is *Calanus* and for this reason the growth stages of the three species of *C. finmarchicus, C. glacialis* and *C. hyperboreus* were examined in detail. The growth stages can provide information about the region of origin of the populations, such as offshore or from on the Shelf, and the timing of reproduction. In April, the population of *C. finmarchicus* in the Gully was a little larger and younger than on the western Shelf. The largest numbers of animals were found in the northern end of the Gully. This indicated that the Gully population of *C. finmarchicus* likely originated from the eastern Shelf. In October, the population of *C. finmarchicus* was higher on the western Shelf than in the Gully, however, this could have been an artifact of the BIONESS sampling which was limited to a depth of 600m in the Gully. Other studies (Sameoto and Herman 1990) have shown that over-wintering *C. finmarchicus* populations can extend to depths greater than 800m, therefore a portion of the population in the Gully may have been missed whereas the entire population would have been sampled on the Shelf. Data from the three surveys did not indicate that the Gully was a region of abnormally high concentrations of *Calanus* species.

The most abundant genera of copepod in both the western Shelf and Gully were *Oithona* and *Centropages* from a total of approximately 43 genera. The numbers of species of copepods found in the two regions was similar in both April and October.

The number of macrozooplankton groups was similar in the two regions during April. In October the western Shelf had a few more groups than the Gully but this was likely due to a greater number of samples being taken on the Shelf. In general there was no significant difference between the two regions with regard to the types and abundance of macrozooplankton.

There was little difference in the numbers of ichthyoplankton taxa in the two regions in April and October. *Cyclothone* spp. were only collected in the Gully and *Urophycis spp.* were only found on the Shelf.

In general there were only minor differences between the Gully and the western Shelf in the variety and abundance of the pelagic organisms examined in this study. The Gully did have a larger population of the myctophid *Benthosema* than was found on the other regions of the slope, but since the number of samples collected was small too much weight should not be placed on this result. The shallower northern arms of the Gully had populations of euphausiids, mainly *M. norvegica,* that were as high as those seen in LaHave and Emerald basins, making this region one of the more important areas of euphausiid production and /or accumulation. This study only sampled during two seasons, the spring and the fall, therefore we know virtually nothing about the species composition or abundance of the pelagic zooplankton and micronekton communities during the other seasons. The micronekton community was only marginally sampled with the BIONESS. In order to understand this important component of the pelagic system a seasonal sampling program with fine mesh midwater trawls should be done in addition to the BIONESS sampling. We were limited to a sampling depth of 600 m with the BIONESS and 1000 m with the lower frequency acoustics during this study. In the future acoustic and net sampling gear should be capable of sampling to a depth of at least 2000 m, because many organisms in the Gully vertically migrate to near the surface from depths in this range.

Acknowledgements

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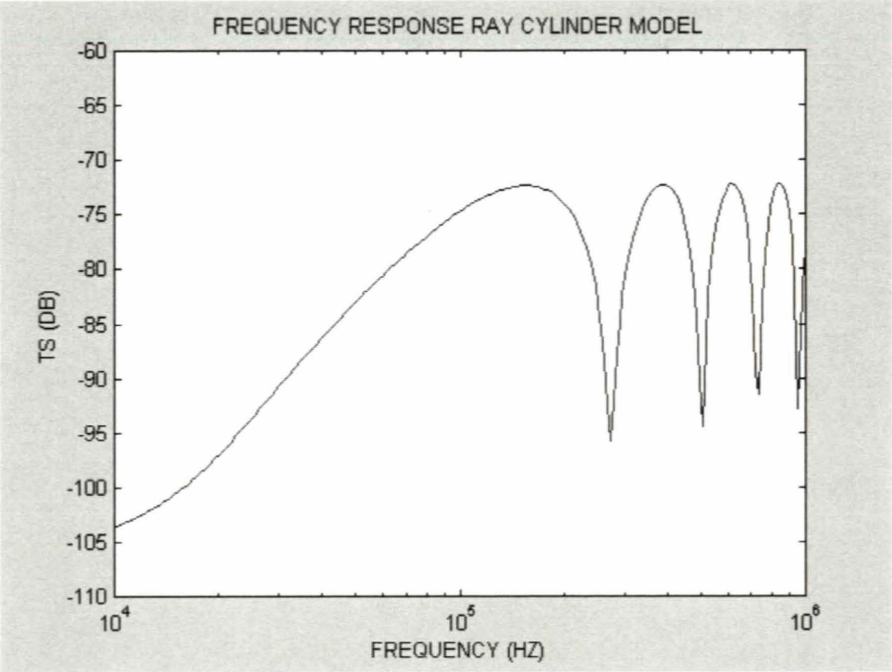


Fig. 2. Ensemble target strength of 2.8 cm length *M. norvegica* vs. ensonification frequency. Stanton et. al. (1993) "Ray" cylinder model, physical parameters g = 1.05, h = 1.03. Average horizontal cylinder orientation with 30^0 S.D. measured in 3-D space.

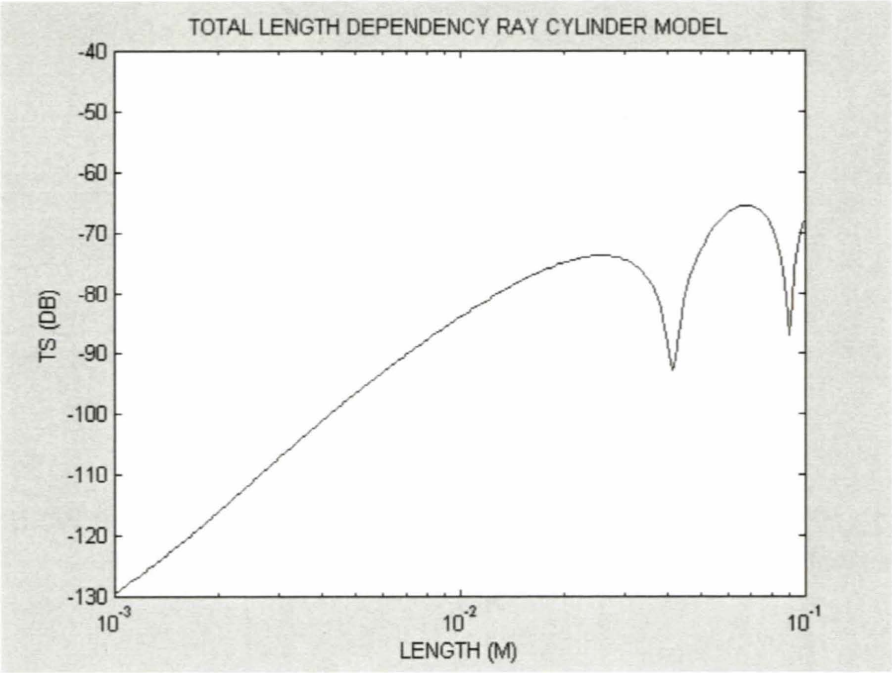


Fig. 3. Target strengths of variable length crustaceans with shape conforming to that of *M. norvegica* at 200 kHz. Stanton et al. (1993) "Ray" cylinder model, physical parameters g = 1.05, h = 1.03. Average horizontal cylinder orientation with 30^0 S.D. measured in 3-D space.

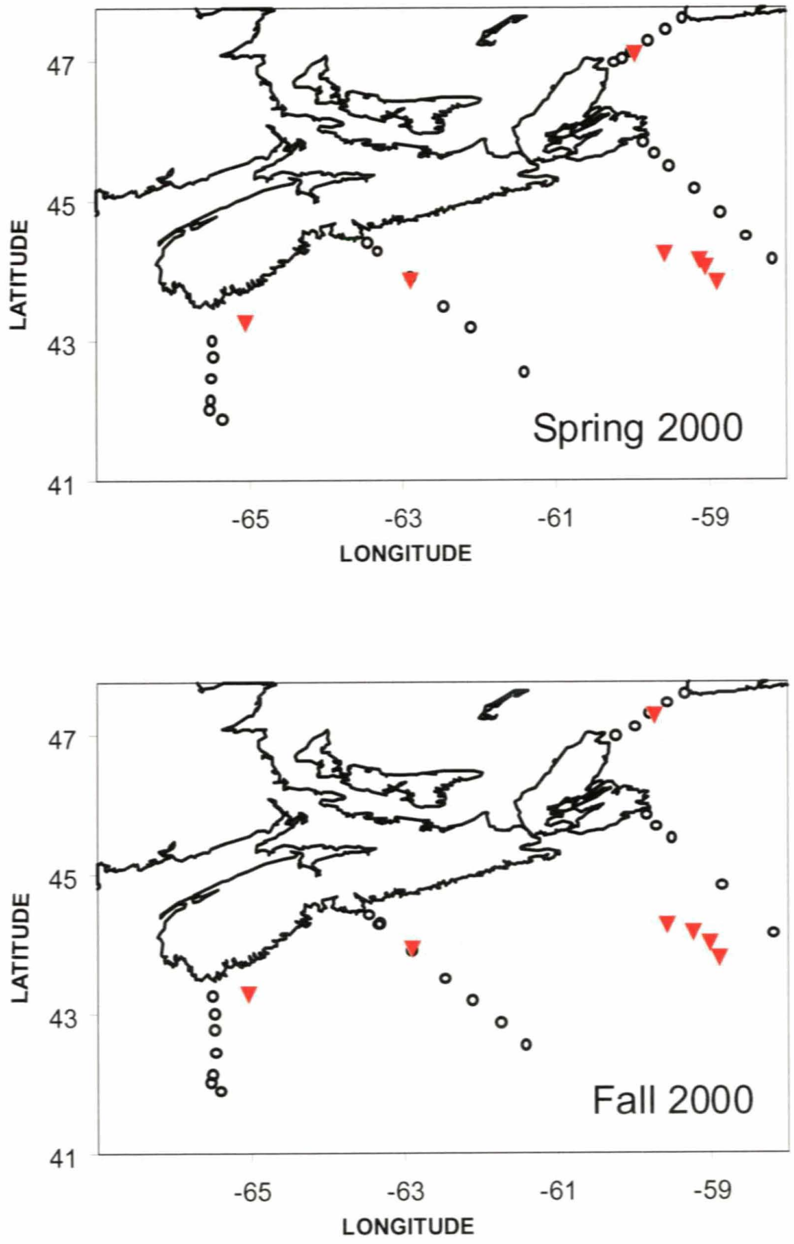


Fig. 4. BIONESS (triangles) and ring net (circles) stations on the Shelf and Gully during spring and fall 2000. Contours are 200m depth.

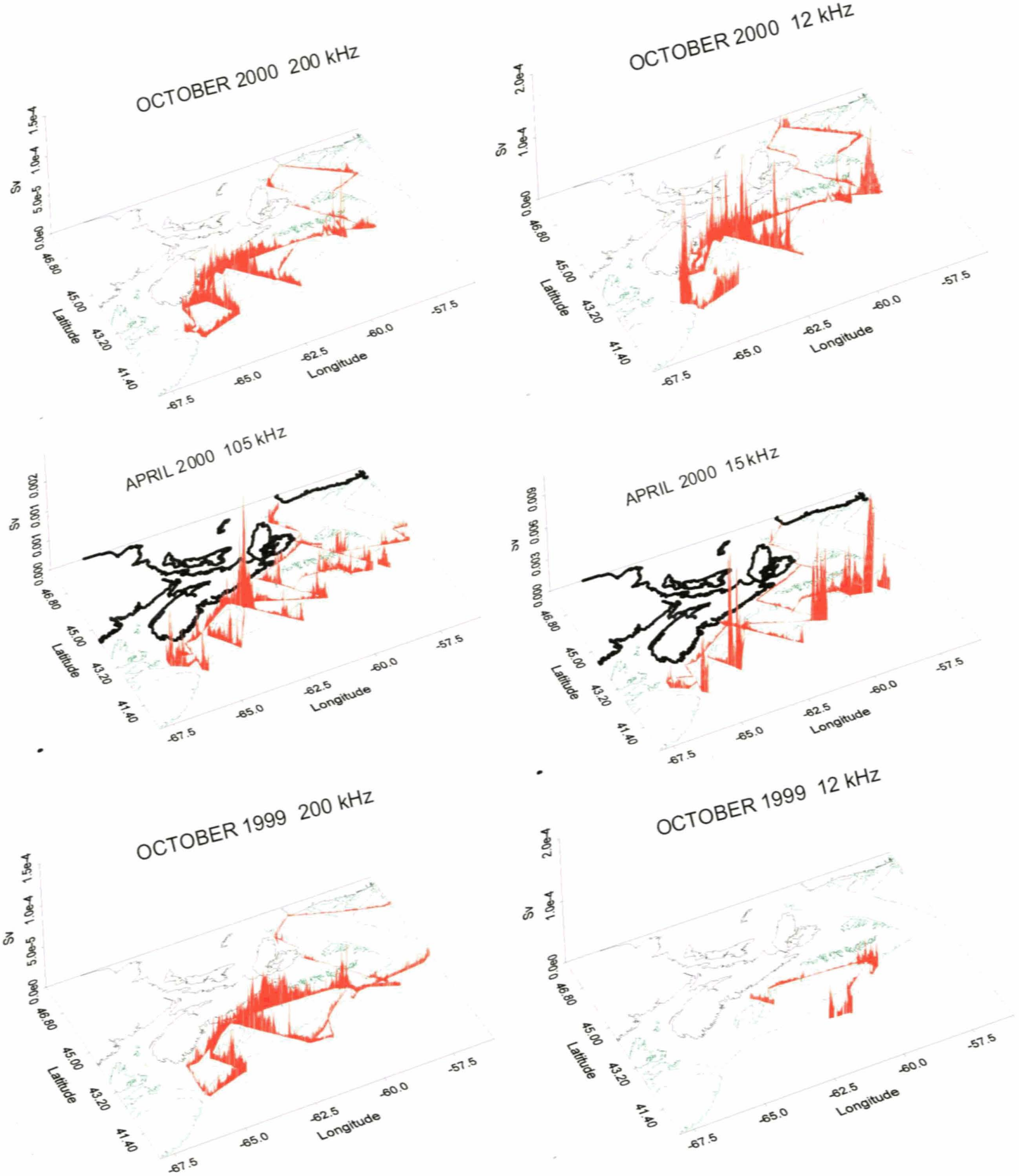


Fig. 5. Sv values for 12, 15 and 200 kHz acoustic surveys on the Scotian shelf and slope.

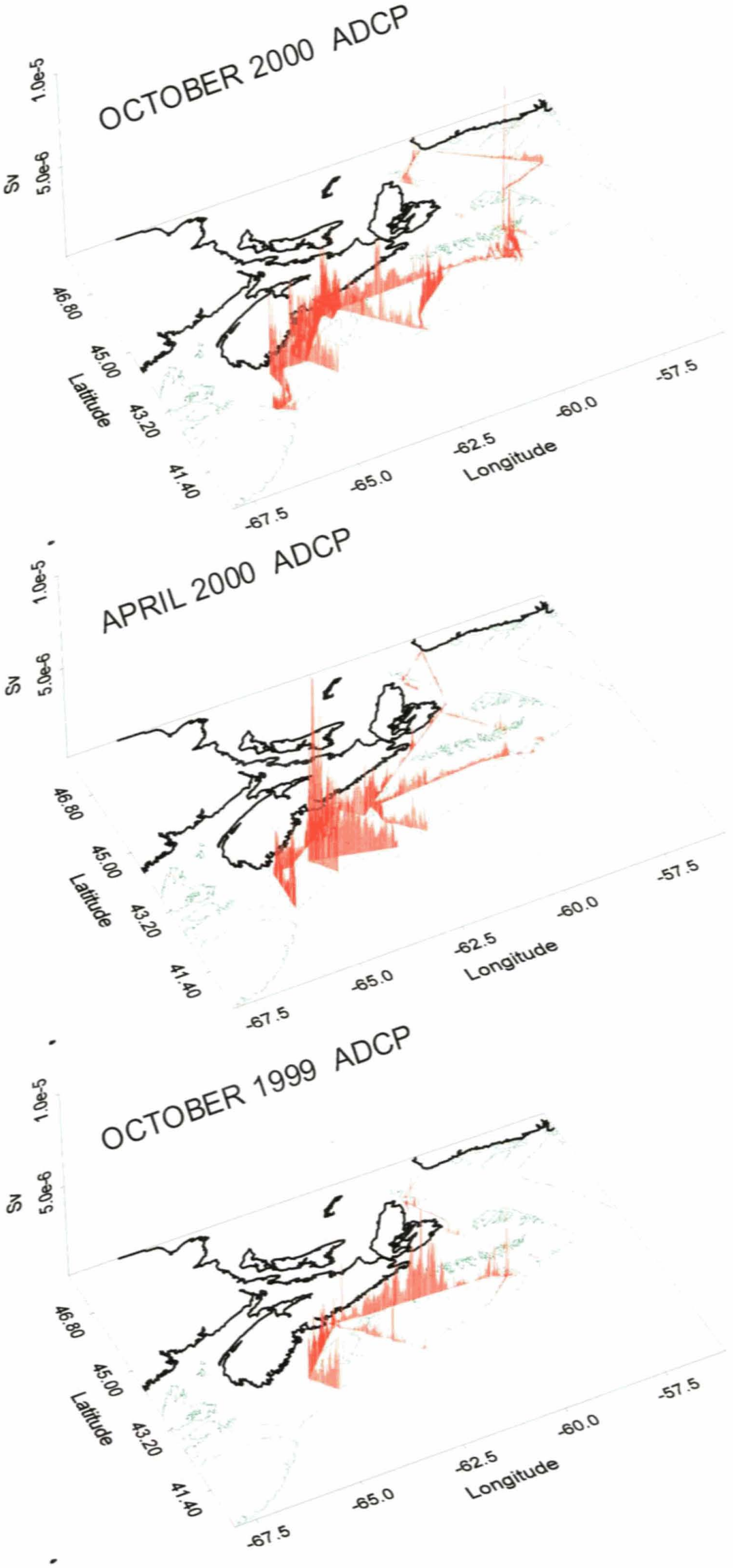


Fig. 6. ADCP S*a* values per m^2 for entire Scotian Shelf and Gully during April and October 1999 and October 2000.

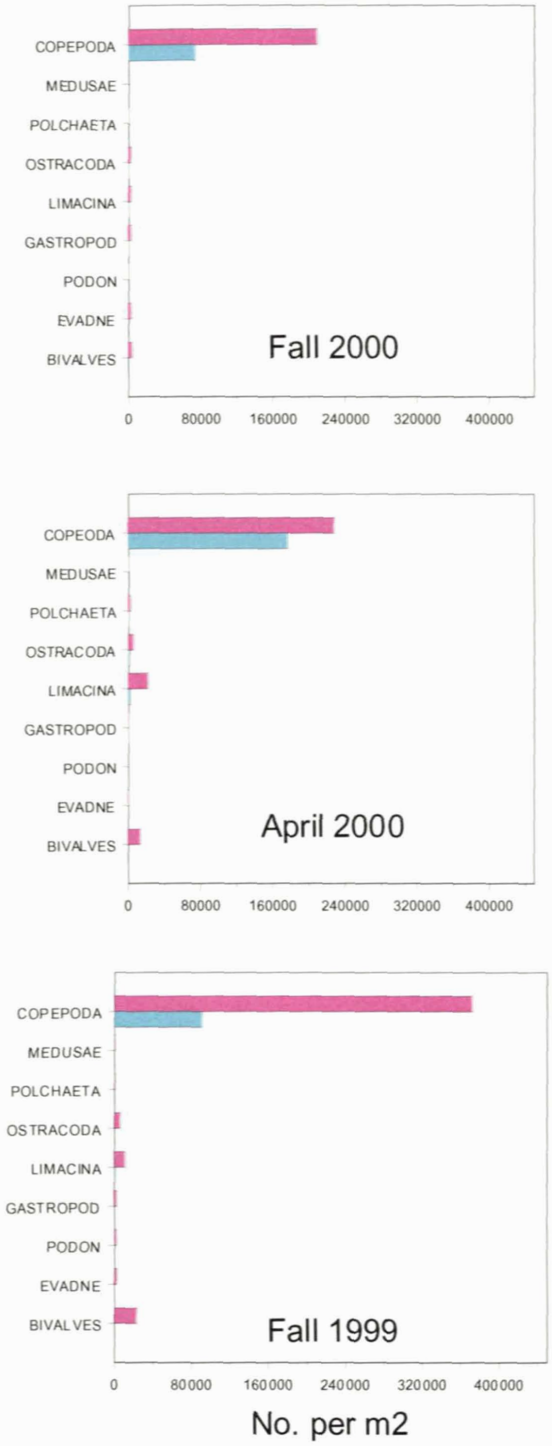


Fig. 7. Numbers per m^2 of various groups of zooplankton in the Gully (blue bars) and in the western Scotian shelf (red bars).

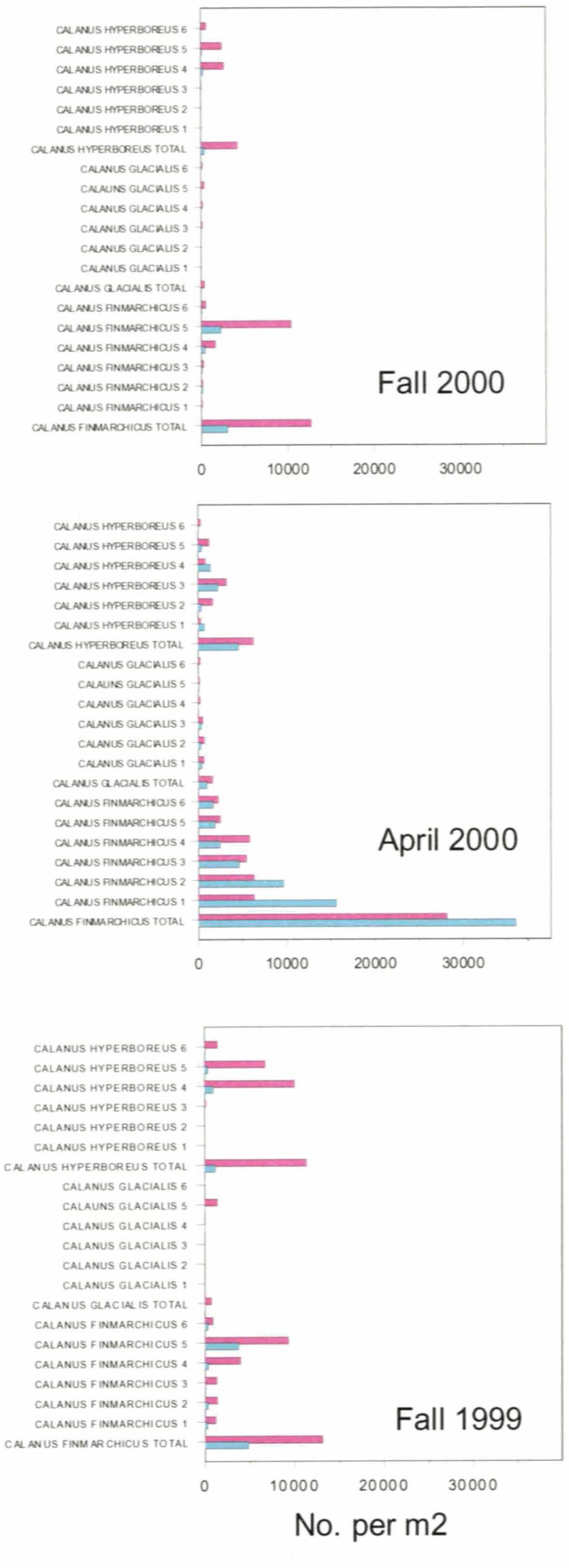


Fig. 8. Numbers per m2 of stages of *Calanus finmarchicus*, *C. glacialis* and *C. hyperboreus* for the Gully (blue bars) and western Scotian shelf (red bars).

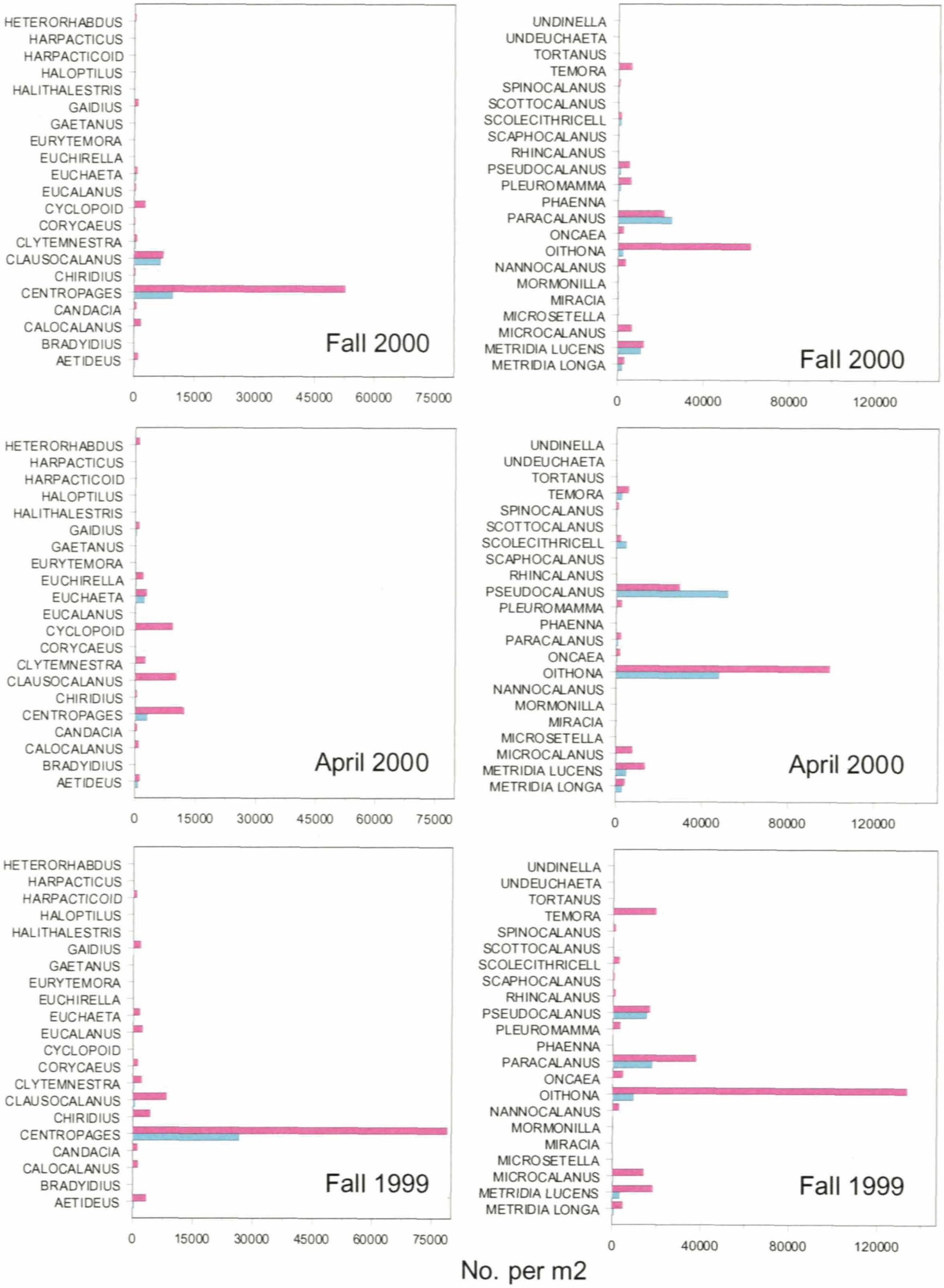


Fig. 9. Numbers per m2 of stages of various copepod genera for the Gully (blue bars) and western Scotian shelf (red bars).

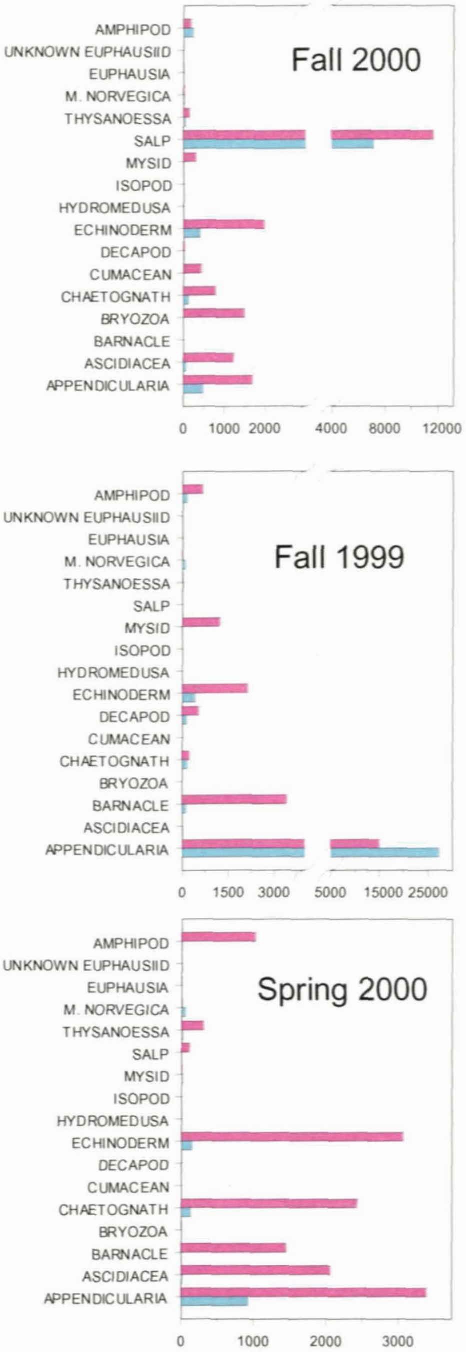
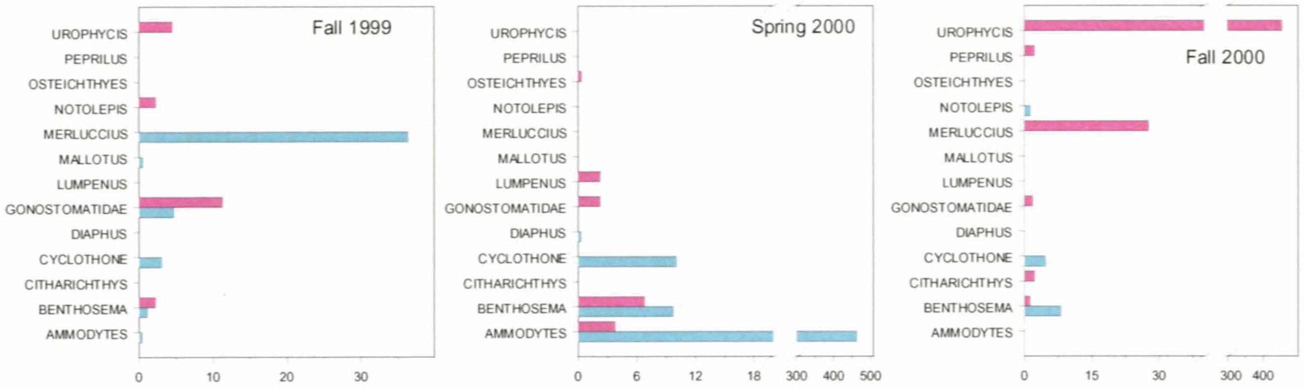
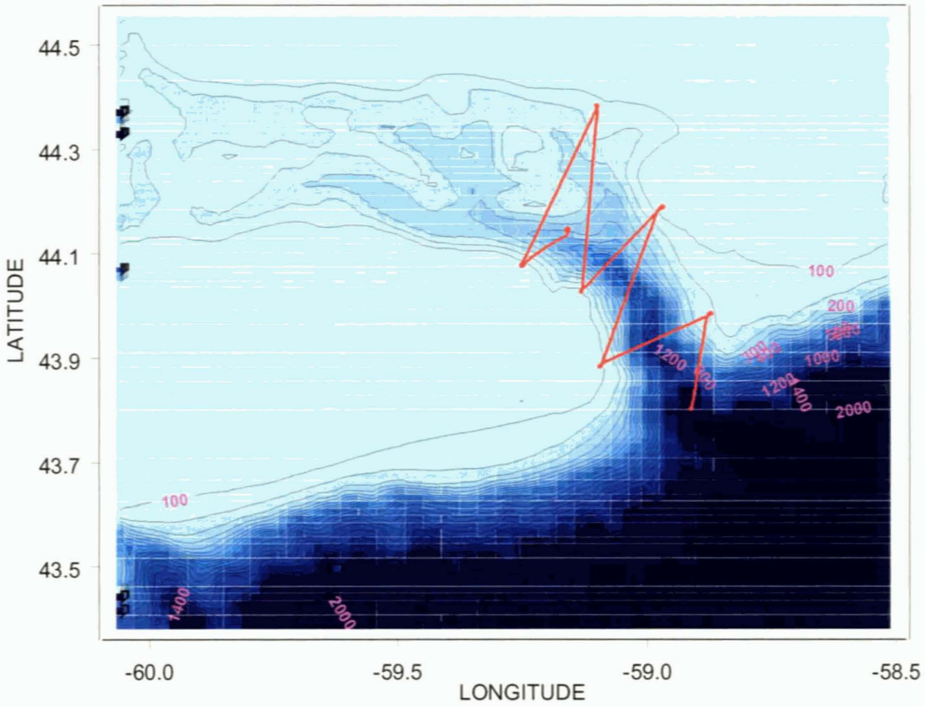


Fig. 10. Numbers of non-copepod invertebrate groups per m2 in the Gully (blue bars) and western Scotian shelf (red bars).



No. per m2

Fig. 11. Numbers of larvae and juvenile fish genera per m2 in the Gully (blue bars) and western Scotian shelf (red bars).


OCTOBER 2000 CRUISE TRACK

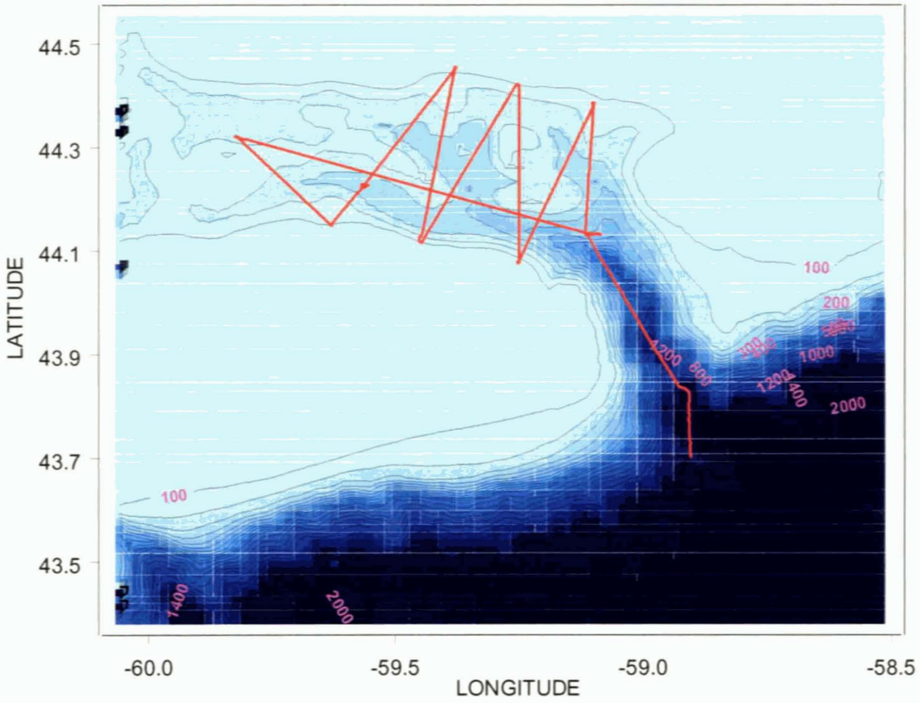

APRIL 2000 CRUISE TRACK

Fig. 12. Acoustic survey cruise tracks for the spring and fall 2000 in the Gully. Dark blue represents greater water depth.

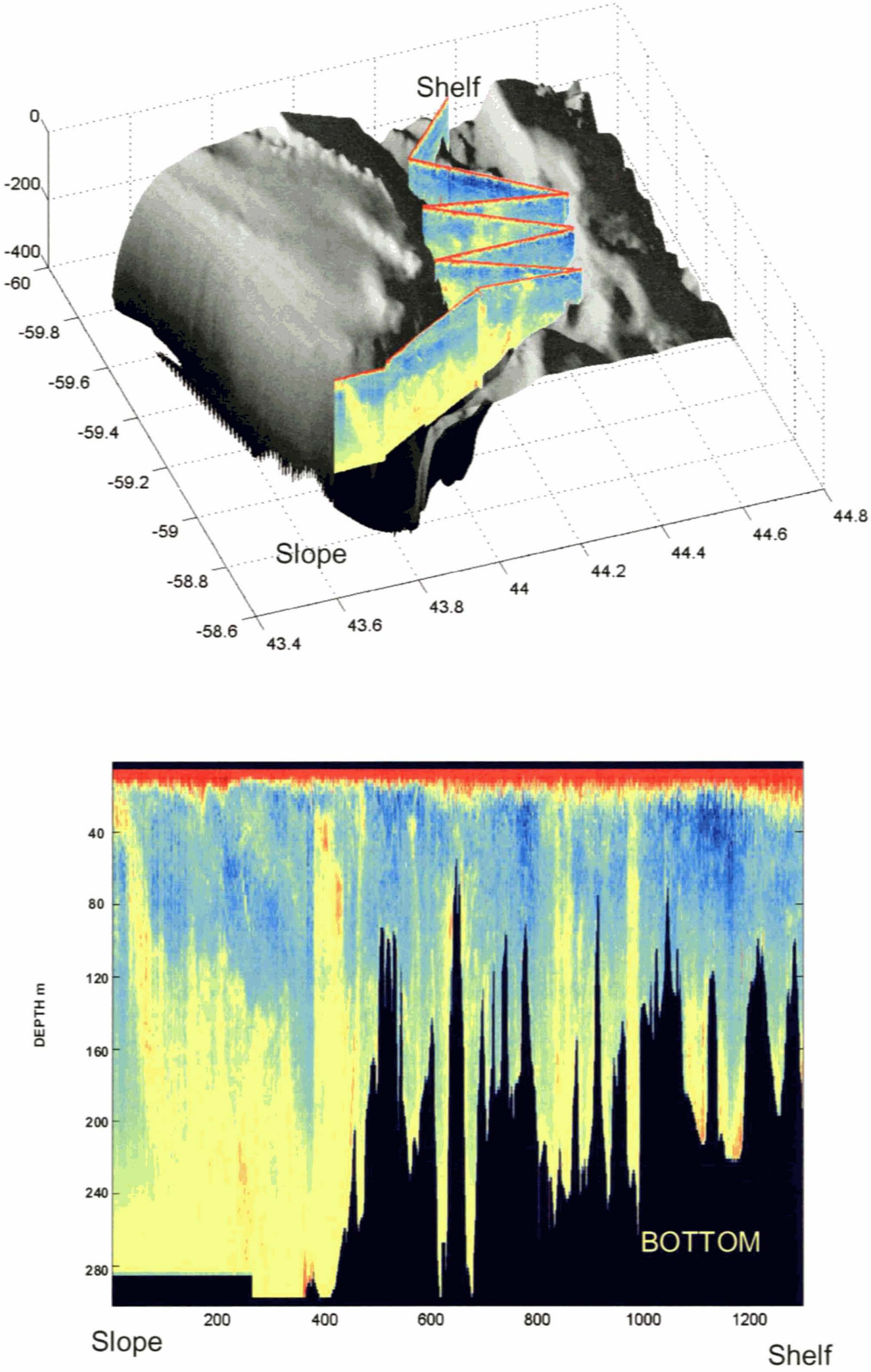


Fig. 13. Sv values from 105 kHz with depth along the Gully cruise track in April 2000. Red represent high values and blue low values of Sv.

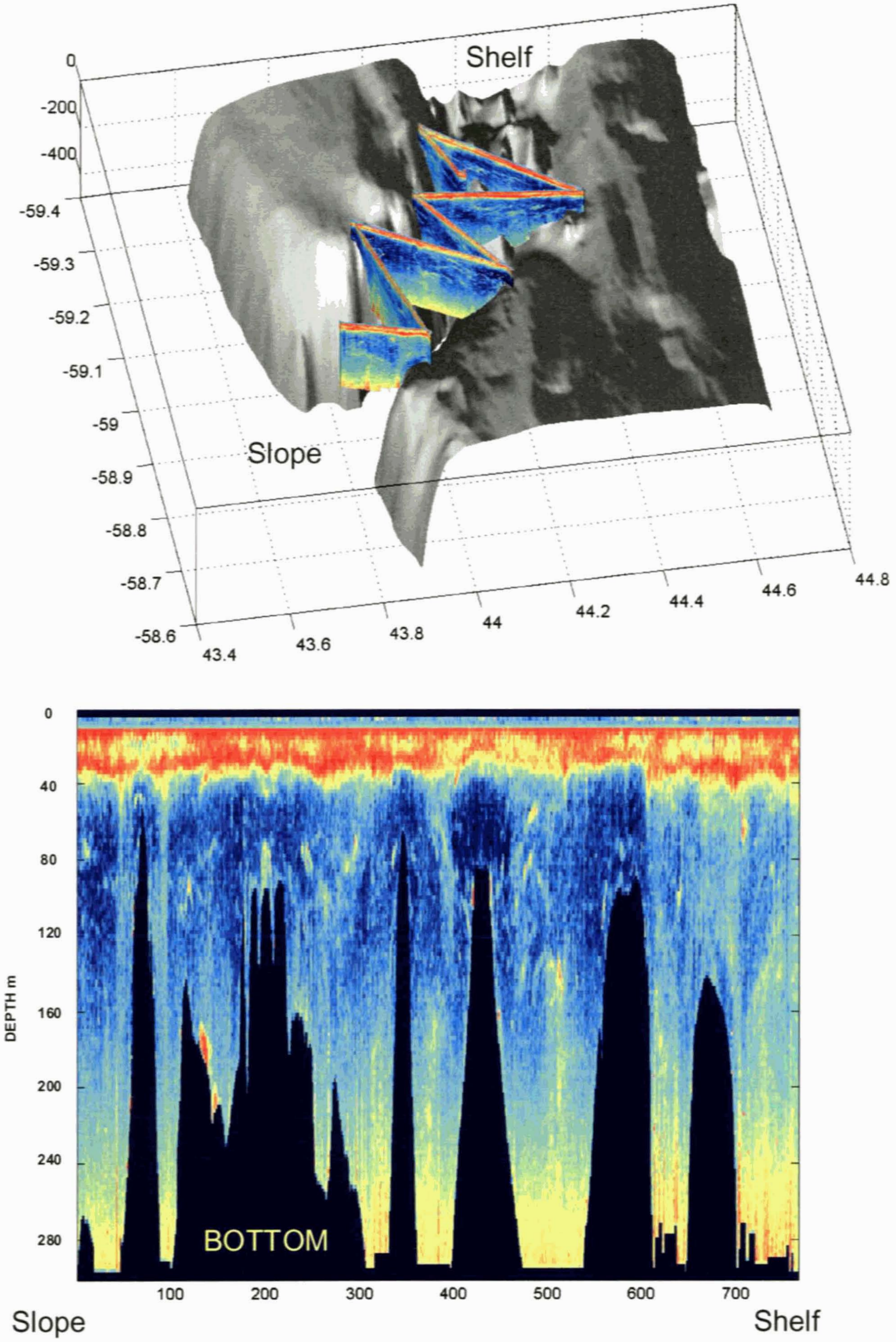


Fig. 14. Sv values from 200 kHz with depth along the Gully cruise track in October 2000. Red represent high values and blue low values of Sv.

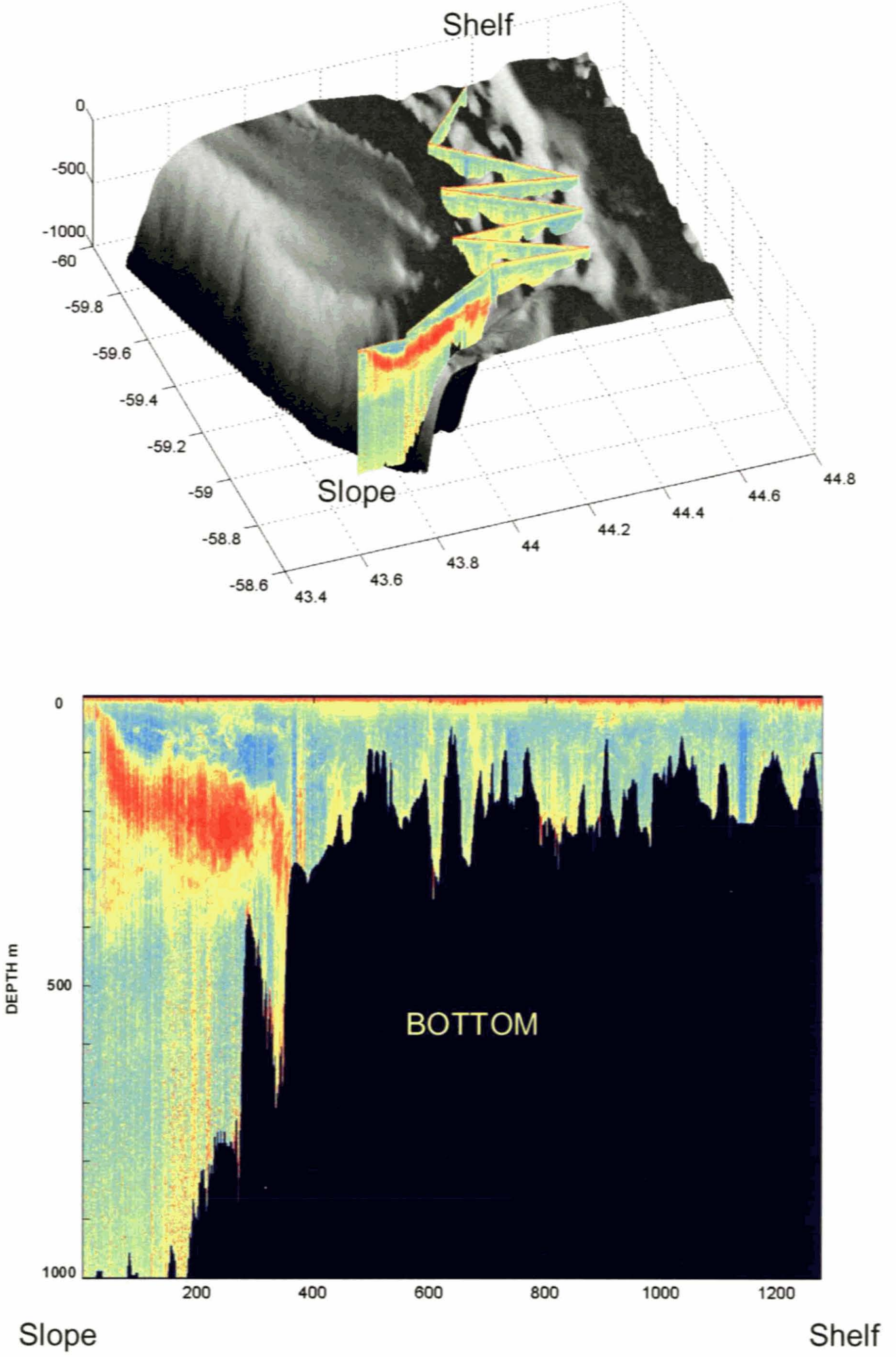


Fig. 15. Sv values from 15 kHz with depth along the Gully cruise track in April 2000. Red represent high values and blue low values of Sv.

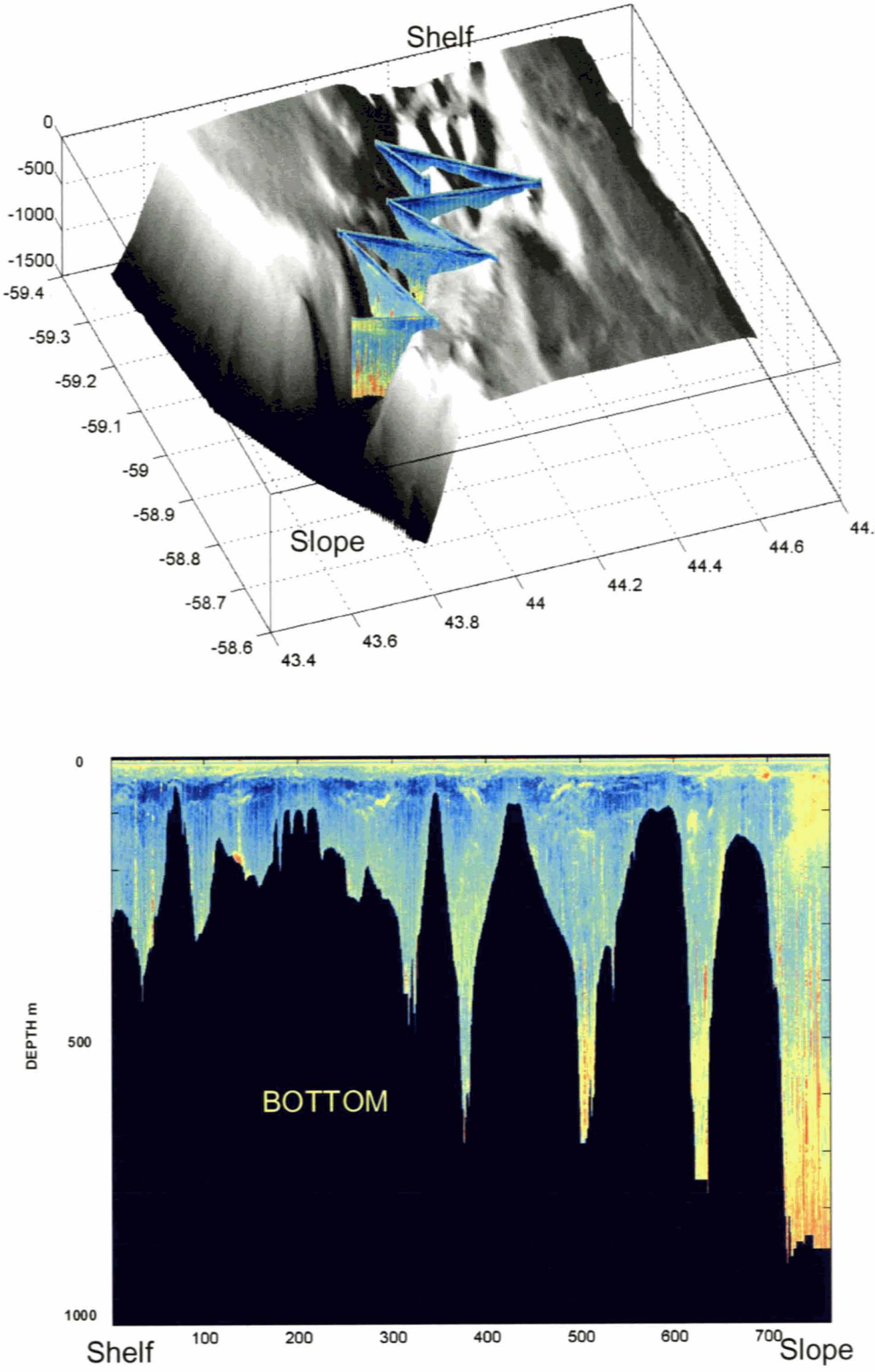


Fig. 16. Sv values from 12 kHz with depth along the Gully cruise track in October 2000. Red represent high values and blue low values of Sv.

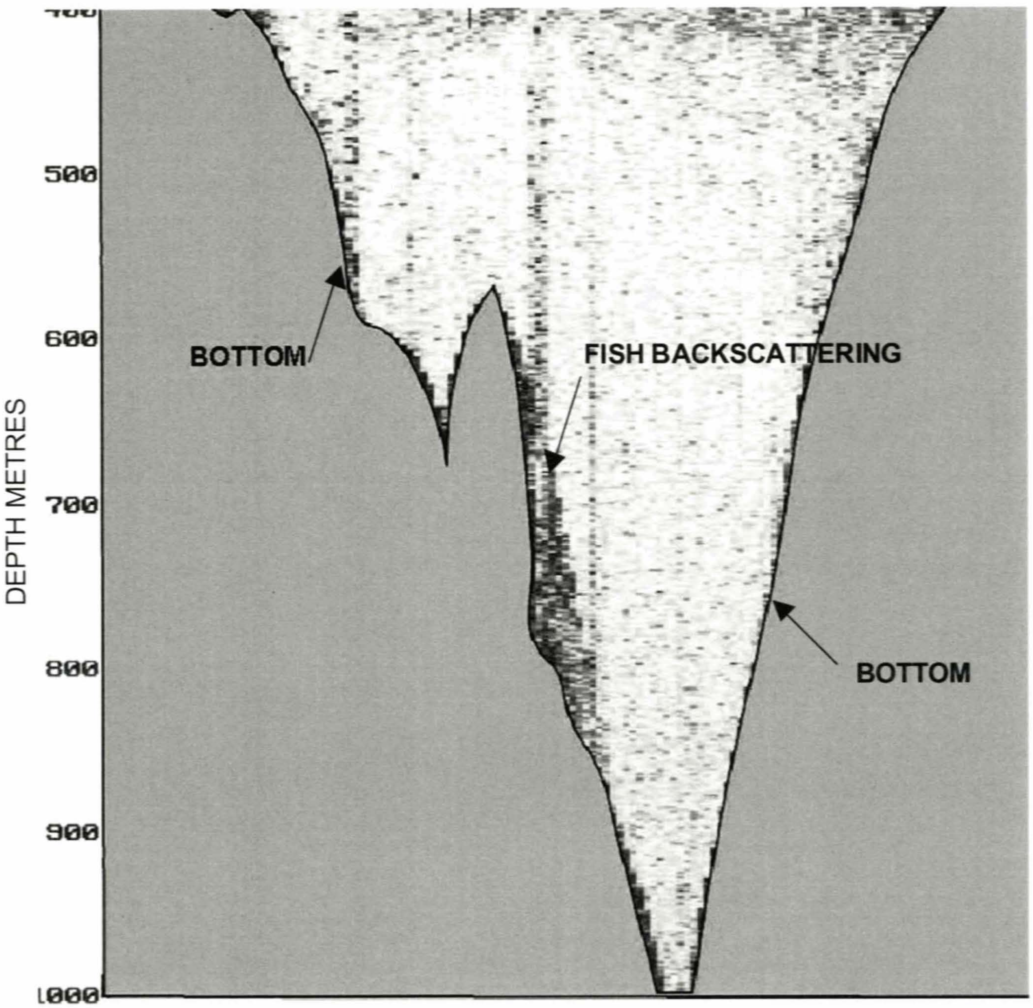


Fig. 17. A example of 15 kHz backscattering from fish near the bottom of the Gully. The horizontal distance of the figure is approximately 9 km.

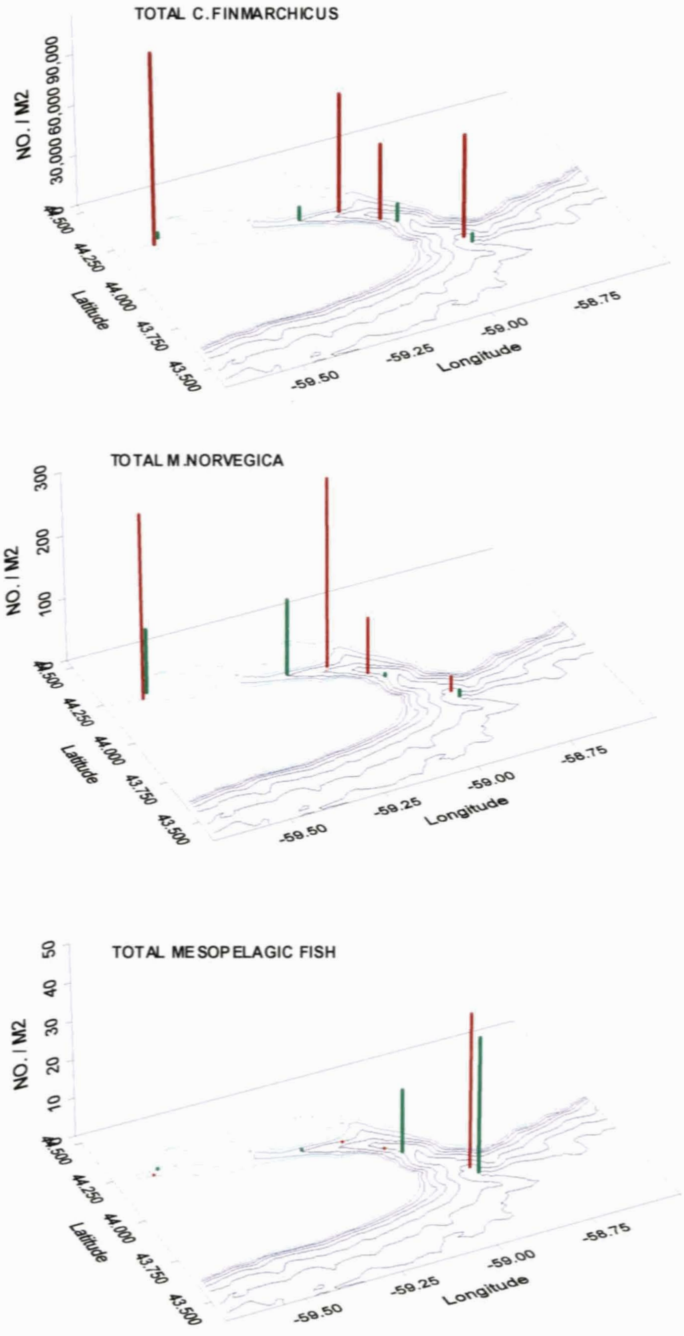


Fig. 18. Numbers of C. finmarchicus, total euphausiids and mesopelagic fish per m2 on BIONESS stations in the Gully. Red bars present April, 2000 and green bars are values from October, 2000.

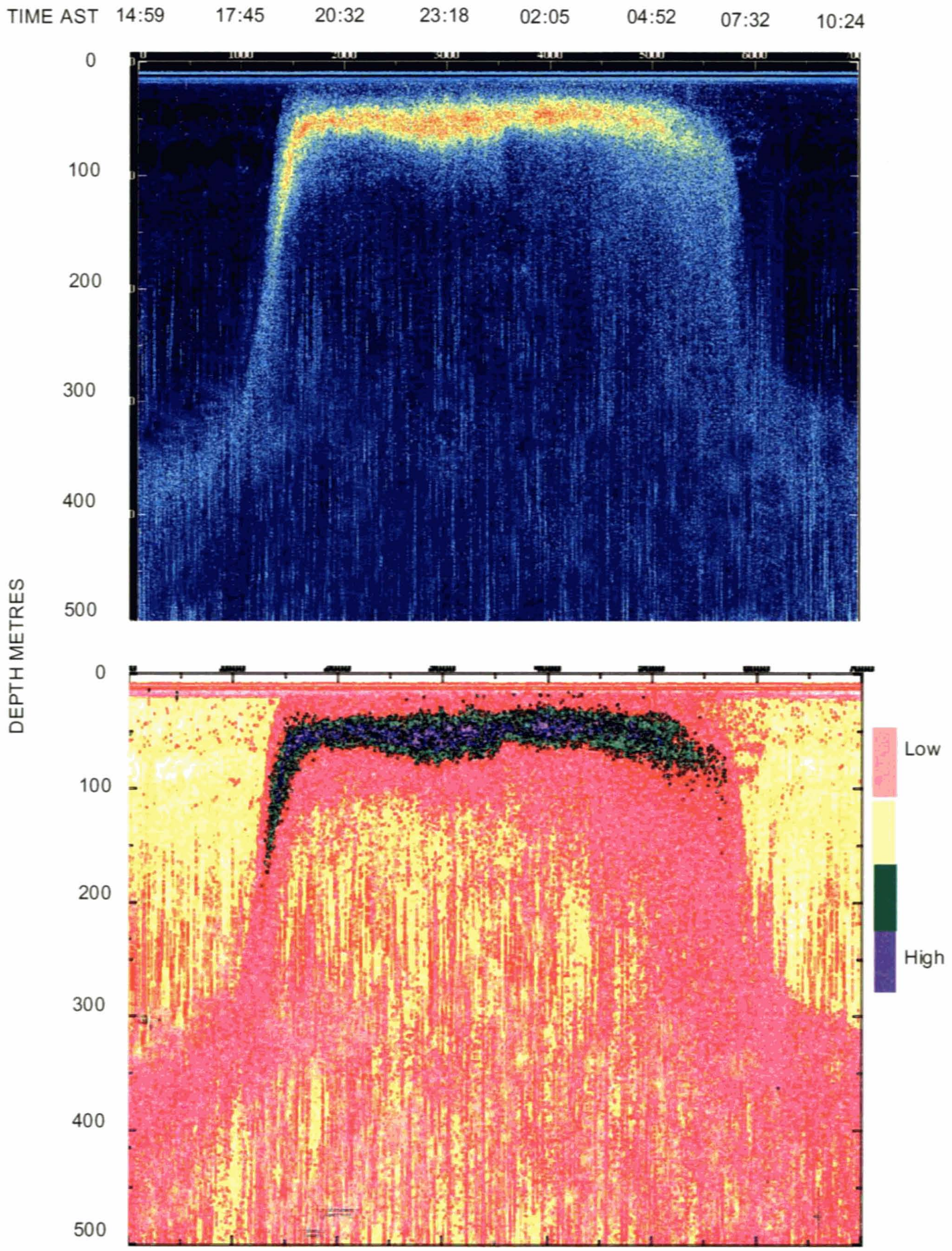


Fig. 19. Echogram recorded at 12 kHz showing the diurnal vertical migration of mesopelagic fish on the slope of the Scotian shelf. The color scale for the intensity of the echos and the abundance of fish ranges from dark blue (low levels) to high levels (top panel). Time is shown on the top of the figure. The bottom panel is an enhanced false colour image that shows the layer reached the surface.