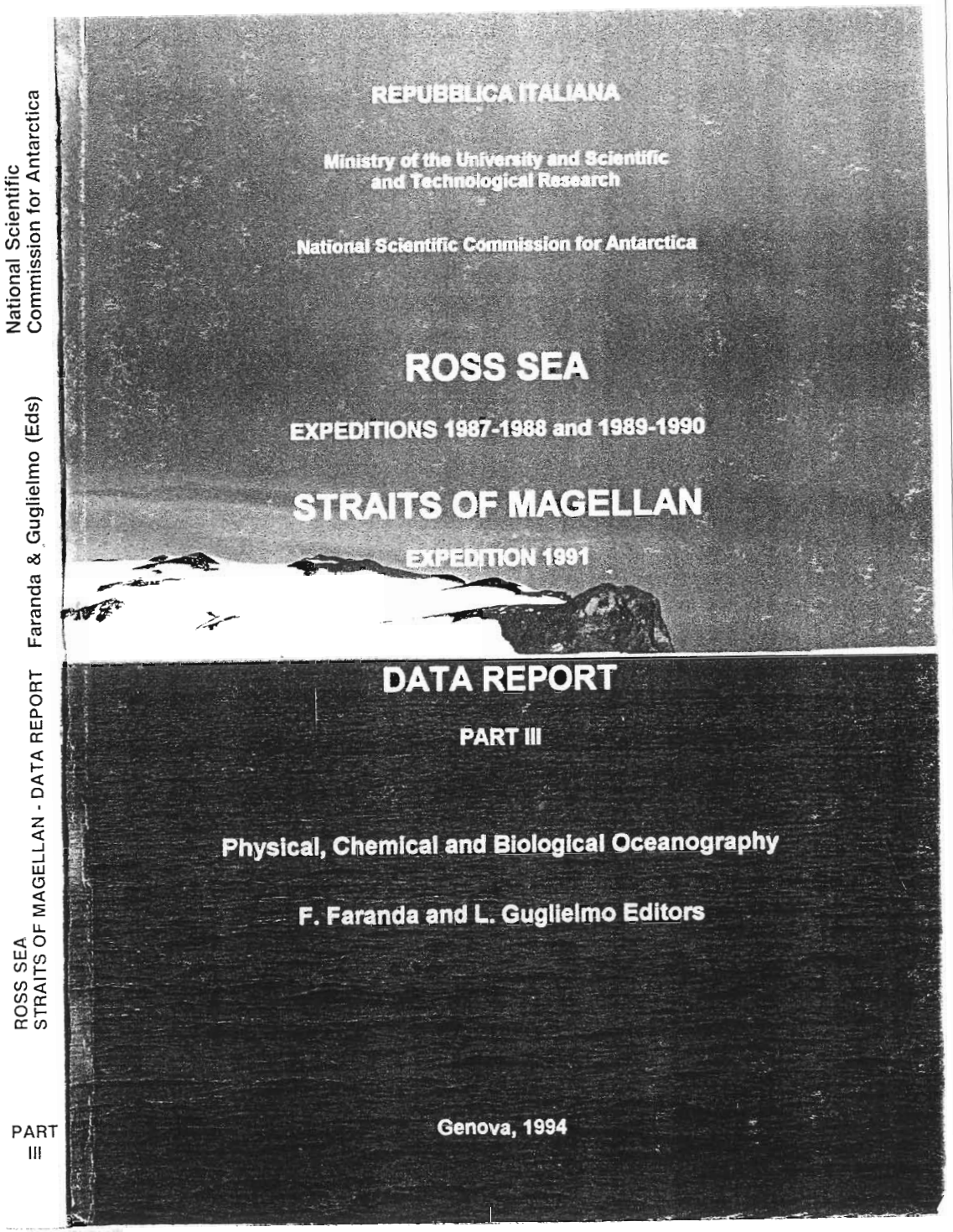
Phytoplankton Ecology: Particles, Gilvin, Fluorescence Spectra, Irradiance and Phytoplankton Species Density in the Ross Sea.



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Ocean.Camp. 1989-90
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PHYTOPLANKTON ECOLOGY: PARTICLES, GILVIN, FLUORESCENCE SPECTRA, IRRADIANCE AND PHYTOPLANKTON SPECIES DENSITY IN THE ROSS SEA. OCEANOGRAPHIC CAMPAIGN 1989-90.

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INTRODUCTION

This report deals with data obtained by the two groups which operated in oceanic and neritic areas, along the Cariboo route (Fig. 1) and in Terra Nova Bay in three stations (Fig. 2), sampled almost daily.

Hydrological, physical and chemical characteristics of the water column, together with temporal and spatial biomass distributions, have already been reported (Innamorati *et al.*, 1989; Innamorati *et al.*, 1990 a,b,c; Innamorati *et al.*,1991; Innamorati *et al.*, 1992 a,b; Lazzara and Nuccio, 1992; Nuccio *et al.*, 1992; Saggiomo *et al.*, 1992; Massi, 1993; Innamorati *et al.*, 1994). Here vertical profiles of underwater quantum and spectral PAR irradiance, suspended particle density and size spectra, some fluorescence excitation and emission spectra, gilvin absorption and phytoplankton species density are reported.

METHODS

Seawater samples have been collected by means of Niskin oceanographic bottles for the analysis carried out immediately.

Surface downwelling, underwater downwelling, upwelling and scalar quantum PAR irradiance have been measured by means of a photoprobe which was designed for this aim by Innamorati, Lazzara and Massi, equipped with cosine and spherical quantum meters (LI-COR). Spectral irradiance has been measured by means of a LI-COR 1800-01 UW spectroradiometer.

The emission and quantum corrected excitation spectra of chlorophyll *a* fluorescence (430ex - 680em) have been measured on *in vivo* phytoplankton suspension with a Perkin Elmer LS5B spectrofluorimeter. Just in a few samples, the spectral *in vivo* fluorescence of phycobilins has also been measured.

Absorption coefficient spectra (1/m) of yellow substance or gilvin was estimated by spectrophotometry, according to Bricaud et al. (1981), with 10 cm quartz cell.

Particle numbers and their size spectra have been determined by means of Coulter Counter Multisizer, equipped with a 140 µm orifice tube. In Table 2 and 3 the total particle number counted per ml of seawater (N/ml) is reported for two size range, 2.8-84 µm and 2.8-45 µm e.s.d., together with the total particle

volume per ml (ppb), for the range 2.8-45 µm. Nearly all the size spectra performed in the Ross Sea stations are reported, whereas for Terra Nova Bay only three situations are shown, representing the maximum bloom at the beginning of January, the intermediate phase in which both particles and biomass decrease at mid January and the final phase at the beginning of February, when a new increase is evident.

Phytoplankton samples have been fixed in Lugol at the final concentration of 1 % and microscopic analysis were performed (Hasle, 1978) with invertoscopes Zeiss IM 35 and Nikon Diaphot (40 x). Species identification was carried out following: Balech (1968; 1976), Chrétiennot-Dinet (1990), Hasle (1964; 1965a; 1965b; 1968), Hendey (1937), Hustedt (1930), Manguin (1949), Ricard (1987), Schiller (1933), Sournia (1986), Sournia *et al.*, (1979).

PRELIMINARY RESULTS

- Particle density and volume:
  Terra Nova Bay (Table 1)
  Ross Sea (Table 2)
- Particle volume size spectra (Figg.3-23)
- Yellow substance absorption (Table 3)
- Fluorescence spectra of phytoplankton suspensions (Figg. 24-25)
- Irradiance depth profiles (Figg. 26-28)
- Underwater downwelling irradiance spectra (Figg. 29-30)
- Phytoplankton density and species composition. Size in µm is the mean of the maximum cell length measured.
  Terra Nova Bay (Tables 4-6)
  Ross Sea (Tables 7-22)

Cell densities and particle volumes have been expressed respectively as cells/dm^3, being the most diffused units, even if values to be significant should be approximated to thousands.

Dates are reported in the Italian notation.

Phytoplankton biomass, both chlorophyll and cell density, in Terra Nova Bay shows a conspicuous bloom during the last decade of December and the beginning of January, a sharp decrease thereafter, and a slight increase at the beginning of February, when sampling was stopped because of bad weather conditions. This second increase can be interpreted as a second bloom before the formation of new pack ice (Innamorati *et al.*, 1992 a,b). The main feature of the phytoplankton composition is the dominance of diatoms over the whole period examined, particularly of the genus *Nitzschia* (*N. curta*, *N.* spp.). Samples obtained from oceanic zones of the Ross Sea, starting with st. 10, point out a low phytoplankton density along the continental slope (st. 10-18) and a highly eutrophic area, along the transect towards the coast (st. 19-27).

Particle density is strictly correlated to phytoplankton biomass. It is then confirmed the almost exclusive phytoplanktonic origin of the suspended particles in the Ross Sea (offshore and in Terra Nova Bay), an area where terrigenous inputs are scarce or do not exist at all. The analysis of particle size spectra shows: a first group characterized by particles of a smaller diameter (4 µm) and a second one, with numerous particles ranging between 11 and 18 µm. These two groups are related to different phases of phytoplankton evolution, the first one to the early phase of the bloom and the second one to a senescent phase (Lazzara e Nuccio, 1992). These two groups are also characterized by different species composition, in the first group *Nitzschia* sec. *Nitzschiella* sp. and *Phaeocystis pouchetii* being dominant, whereas the second one shows the dominance of *Nitzschia* sec. *Fragilariopsis* spp.

The fluorescence spectra of the Ross Sea show a nearly uniform shape, characterized by the typical pigment composition of diatoms and Prymnesiophytes (chlorophyll *a*, *c*, xanthophylls and carotenes). A shift for the maximum towards green wavelength with depth can also be observed and attributed to photoadaptation, as for Neori *et al.* (1984), and Lazzara *et al.* (1992).

The euphotic depth ranges from about 85 m in the oceanic zone (st. 1, 11, 15b) to 13 m in Terra Nova Bay (st. 22, 24, 25, 26). The depth of the euphotic layer is strictly correlated to phytoplankton pigments, which is the dominant factor for the optical properties of these waters (Massi, 1993; Saggiomo *et al.*, 1992), belonging to case I waters (Morel and Prieur, 1977; Morel, 1988). The underwater irradiance spectra in Terra Nova Bay have their maximum within the green band. The upwelling irradiance spectra show the chlorophyll *a* fluorescent emission at 683 nm.

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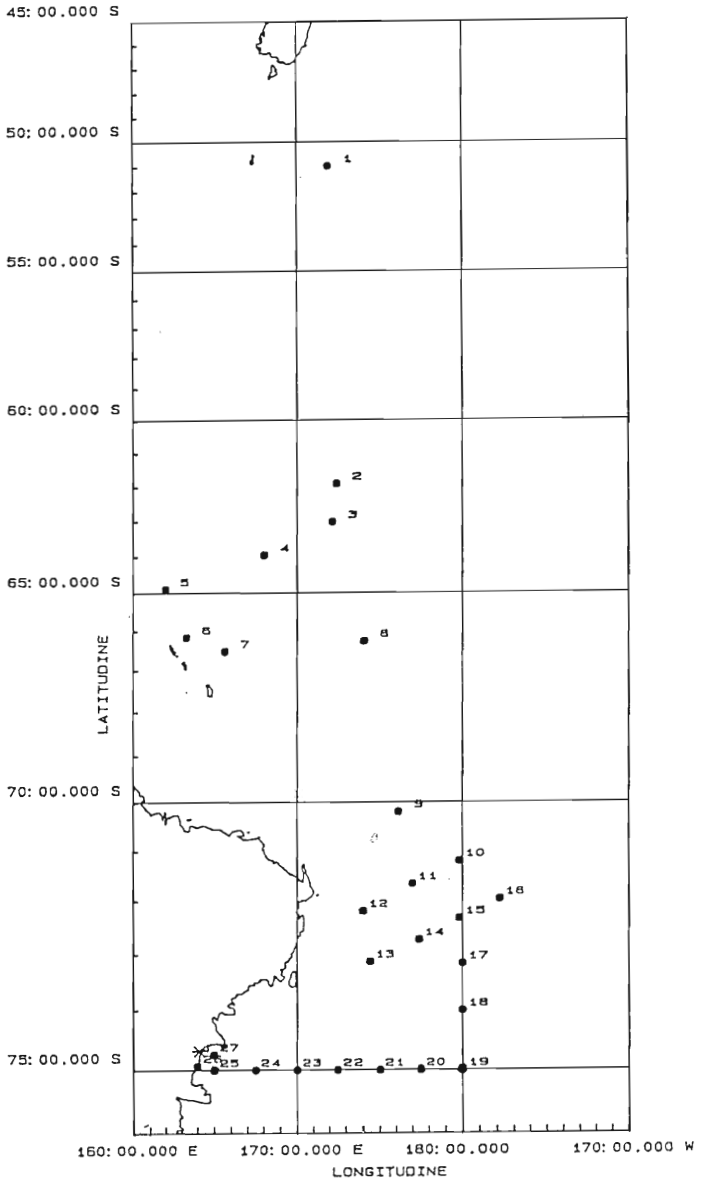


Fig. 1 - Sampling stations of the R/V Cariboo oceanographic cruise.

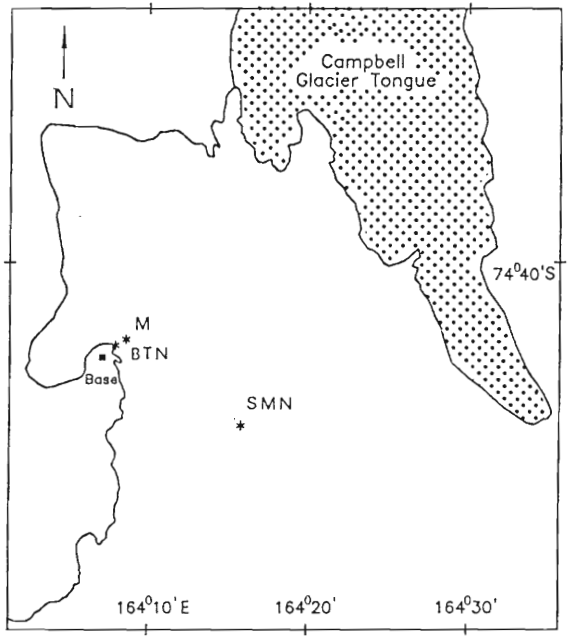


Fig. 2 - Sampling stations at Terra Nova Bay. (SMN = Santa Maria Novella, M = Mergellina, BTN = Baia Terra Nova).

Table 1 – Particle density (N/ml) and volume (ppb) at Terra Nova Bay.

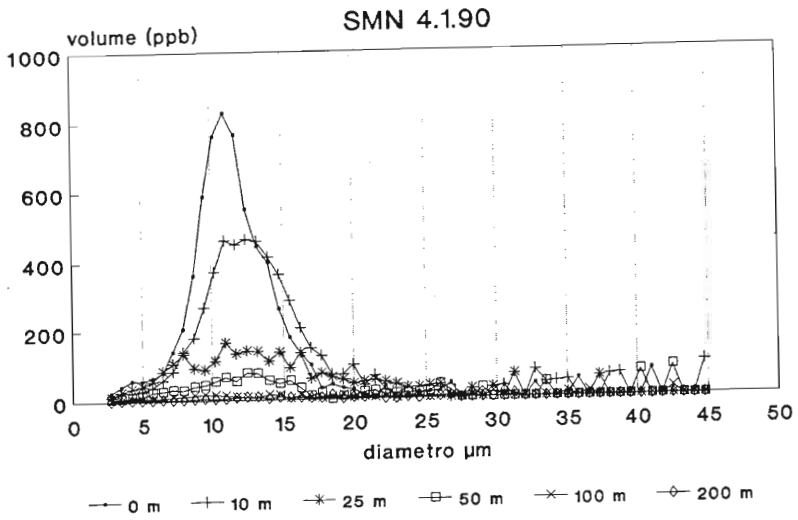
Station BAIA TERRA NOVA									
Date	m	2.8 to 84 μm N/ml	2.8 to 45 μm N/ml	2.8 to 45 μm ppb	Date	m	2.8 to 84 μm N/ml	2.8 to 45 μm N/ml	2.8 to 45 μm ppb
3.1.90	0	14170	10664	5070000	22.1	0	13016	8814	3530000
4.1	0	11448	9042	4600000	23.1	0	15250	6808	3547500
5.1	0	17392	7690	8976000	24.1	0	6918	4945	2127500
6.1	0	12517	1950	6245000	26.1	0	8883	6264	3890000
7.1	0	11758	8069	4925000	27.1	0	6423	5357	2203500
8.1	0	10520	8094	5240000	29.1	0	7605	5613	3234000
9.1	0	12803	8465	5685000	30.1	0	5245	4469	2079000
10.1	0	11500	8995	6515000	31.1	0	4947	4286	2248000
11.1	0	11964	9138	6372000	1.2	0	4673	3872	1363000
12.1	0	10756	7940	5864000	2.2	0	5483	4559	1813500
13.1	0	9107	7303	5345000	4.2	0	4377	3217	1199500
14.1	0	9361	7009	5070000	8.2	0	7544	5858	3062500
15.1	0	8745	6999	4920000	9.2	0	9566	6959	4013000
17.1	0	6576	5365	3437500	10.2	0	8342	5471	2897500

Station MERGELLINA									
Date	m	2.8 to 84 μm N/ml	2.8 to 45 μm N/ml	2.8 to 45 μm ppb	Date	m	2.8 to 84 μm N/ml	2.8 to 45 μm N/ml	2.8 to 45 μm ppb
4.1.90	0	10316	7690	4018000	8.1	0	12391	9535	8030000
	10	13106	9962	5898000		10	13218	10040	9100000
	25	7506	5804	1981000		25	5026	3897	2399500
7.1	0	11926	8715	6080000	10.1	0	13372	9698	7070000
	10	11559	8665	5830000		10	13736	9640	6645000
	25	5114	4225	1805000		25	12696	8464	4956000

Station MERGELLINA									
Date	m	2.8 to 84 μm N/ml	2.8 to 45 μm N/ml	2.8 to 45 μm ppb	Date	m	2.8 to 84 μm N/ml	2.8 to 45 μm N/ml	2.8 to 45 μm ppb
15.1	0	10100	7756	6440000	26.1	0	8232	6312	4085500
	5	14353	9333	8420000		10	8126	6062	3951500
	10	13392	10162	8815000		25	8125	5960	3923000
	15	11859	9155	7930000					
	25	9956	7486	6480000	27.1	0	6774	5018	2444000
						10	8397	6702	3897000
16.1	0	8309	4891	3188000		25	9007	7177	4606000
	10	4464	3371	1954000					
	15	16164	9608	10400000	30.1	0	5230	4240	1940500
	25	4594	3582	1912000		10	5003	3838	2033500
						25	5388	4281	2296500
17.1	0	7693	6400	3726000					
	10	12478	9010	7045000	31.1	0	4300	4232	2575000
	25	6590	5332	4258500		10	6679	4555	3840500
						25	5744	3928	3631000
18.1	0	4670	3535	2073500					
	10	6296	4706	2830500	1.2.90	0	4682	3858	1602000
	25	3947	3237	1652000		10	4562	3739	2300000
						20	4350	3515	2471500
19.1	0	7337	5883	2922500		25	4727	3291	2201000
	10	9800	7346	5630000					
	25	5660	5063	3397500	2.2	0	4777	3961	1689500
						10	4799	3939	1800000
22.1	0	21432				25	4078	3680	2364500
23.1	0	9898	7825	4038500	4.2	0	4908	3767	1387000
	10	11025	2064	1873500		10	4814	3702	1621500
	25	4861	4376	3697500		25	4755	3620	1768500
24.1	0	6897	5198	2417000	8.2	0	7230	4975	2643500
	10	9331		3150000		10	7087	4785	2606500
	15	11795	7424	4623000		20	6420	4488	2382000
	25	5503	4137	2875000		25	6860	5082	2849500

Station SANTA MARIA NOVELLA									
Date	m	2.8 to 84 μm N/ml	2.8 to 45 μm N/ml	2.8 to 45 μm ppb	Date	m	2.8 to 84 μm N/ml	2.8 to 45 μm N/ml	2.8 to 45 μm ppb
4.1.90	0	18970	13862	6660000	14.1	100	822	695	184150
	10	11248	8508	5820000		200	587	391	146400
	25	7976	6558	2640000					
	50	2724	2306	1187000	15.1	0	9353	7566	5270000
	100	1526	926	371150		10	11258	9063	8150000
	200	843		200550					
					16.1	0	13047	9706	7605000
5.1	0	12828	8454	4819000		10	13605	10197	9125000
	10	10070	7874	6518000		25	10832	8091	7620000
	25	8510	6310	4642000					
	50	1580	1014	499250	17.1	0	9616	7141	4930500
	100	995	700	228000		10	12058	9101	715000
	200	854				25	6444	4837	4164500
						50	1927	1445	901000
12.1	0	9478	7270	4420000					
	5	10318	8536	6525000	18.1	0	10191	5800	3518500
	10	13383	7920	7480000		10	7179	5385	3479500
	15	11649	8740	7565000		25	4607	3539	2027500
12.1	25	7085	5823	4025500		50	2122	1650	1178000
	50	1946	1693	393000		100	1118	777	366000
	100	986	742	393000					
	200	712	486	296750	19.1	0	9910	7964	6965000
						10	11005	8193	7925000
13.1	0	11784	9040	7805000		25	8330	6093	7255000
	10	13767	9595	8535000		50	3785	3007	2346500
	25	7486	4862	3569500		100	1113	2009	1015000
	50	1950	1434	1024500					
	100	940	656	414700	22.1	0	5684	4711	2252000
	200	962	632	233050		10	11446	8362	5275000
						25	5942	4628	3203000
14.1	0	10122	7722	5745000		50	2411	2059	1173000
	10	12065	9744	7815000					
	25	7416	5786	4823500	23.1	0	5389	4279	1890500
	50	1482	1087	768000		10	9944	8009	5090000

Station SANTA MARIA NOVELLA									
Date	m	2.8 to 84 μm N/ml	2.8 to 45 μm N/ml	2.8 to 45 μm ppb	Date	m	2.8 to 84 μm N/ml	2.8 to 45 μm N/ml	2.8 to 45 μm ppb
23.1	20	8450	7095	6060000	31.1	10	6040	4616	3702000
	25	3868	3411	1554500		25	4715	3663	3456500
	50	1811	1465	1225000		50	2896	2201	2027500
	100	2839	2055	954000		100	812	691	372100
						200	610	466	194900
24.1	0	7152	5358	2526500					
	10	8493	6620	4261000	1.2.90	0	5649	4561	2058000
	20	9846	7629	5600000		10	6442	4814	3084000
	25	5398	4303	3504000		20	6222	4250	3523000
						25	5126	3589	3234500
30.1	0	6912	4675	3644000		50	2132	1548	1244000
	10	6461	4729	3766500					
	18	6230	4752	3735000	8.2	0	6050	4362	2295000
	25	5398	3864	2938500		10	7087	4955	2718500
	50	3499	2747	2296500		25	7392	5167	3130500
	100	1043	712	362300		50	3613	3024	1773000
	200	503	391	159750		100	1730	1288	998000
						200	1019	715	365200
31.1	0	6415	3994	2233500					



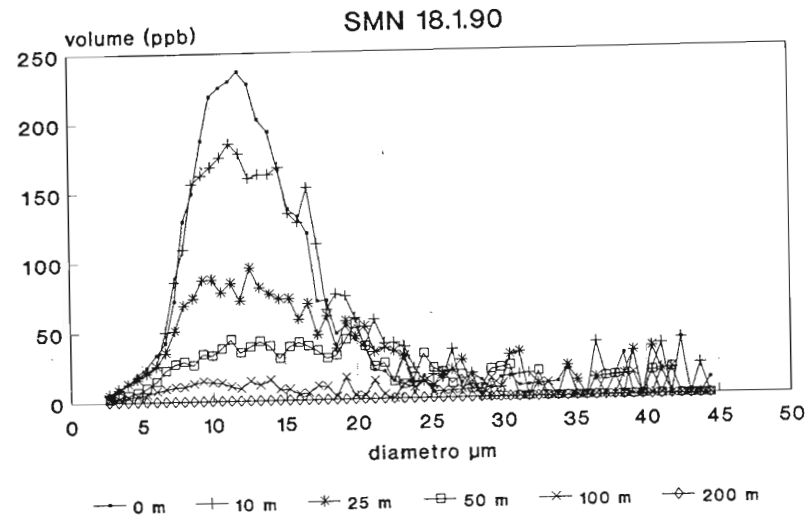
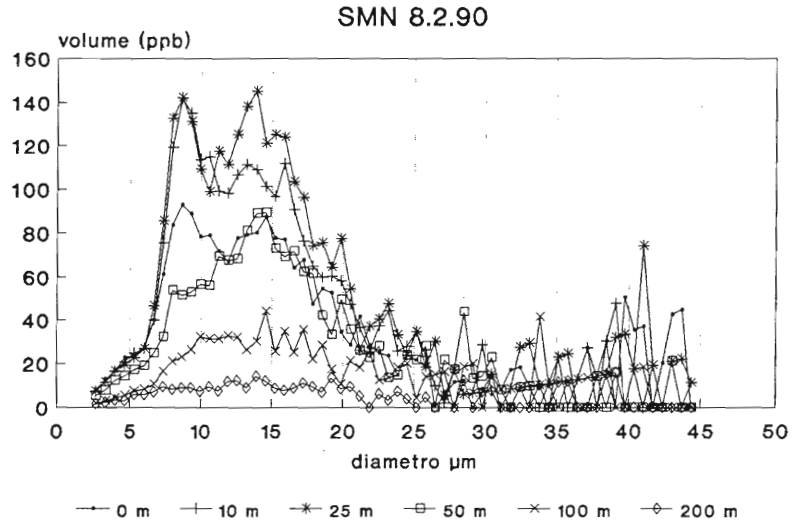


Fig. 3 - Suspended particle volume size spectra (ppb vol/vol).



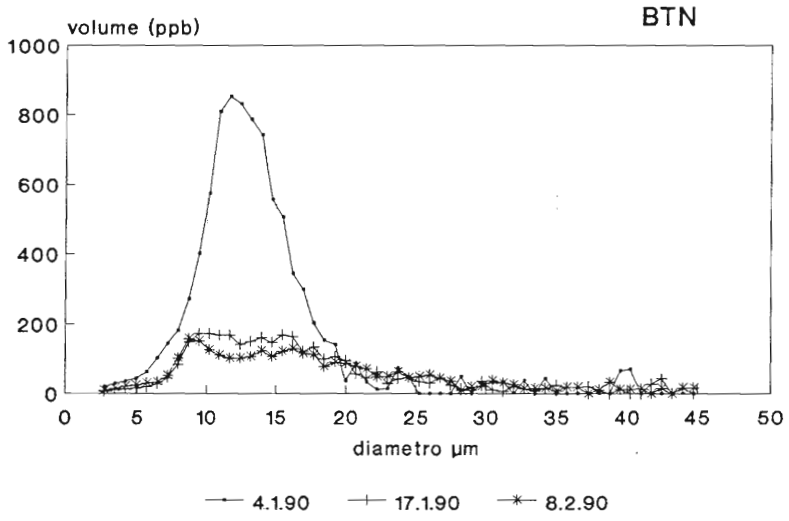
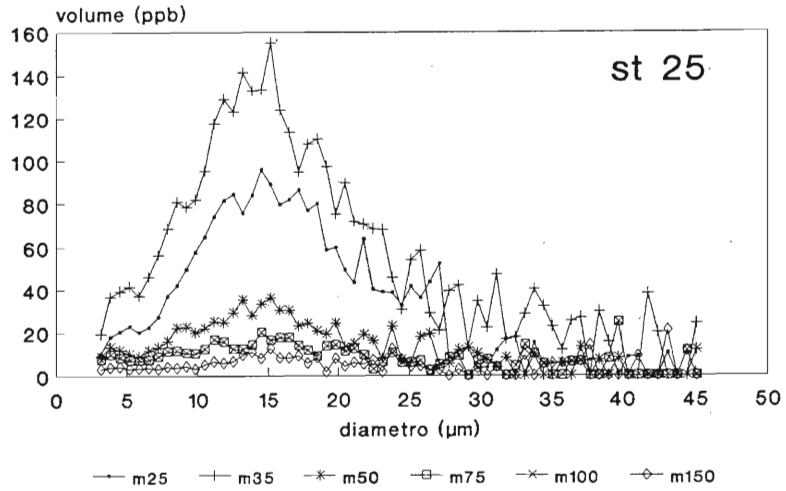


Fig. 4 - Suspended particle volume size spectra (ppb vol/vol).



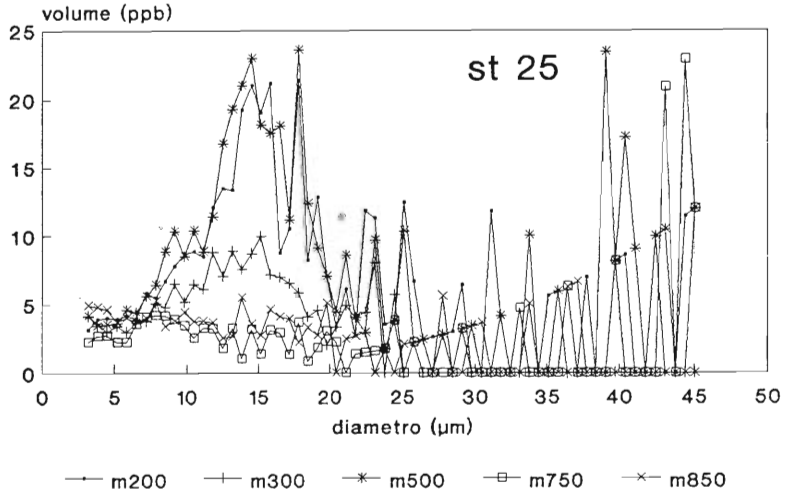
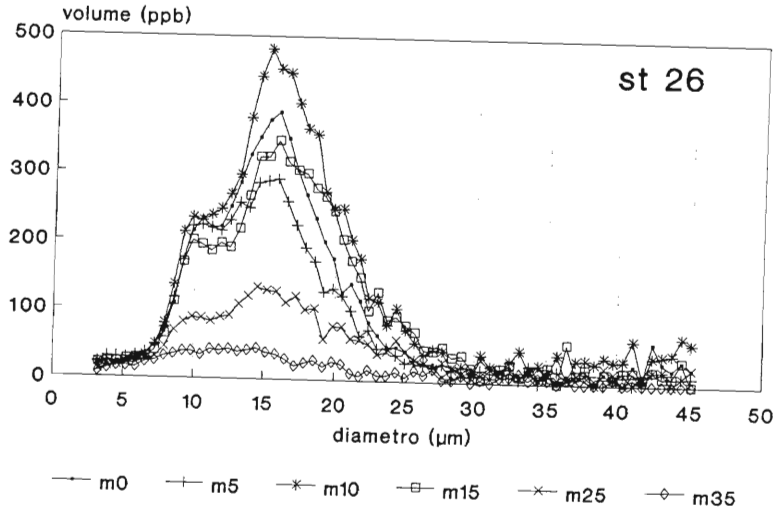


Fig. 21 - Suspended particle volume size spectra (ppb vol/vol).



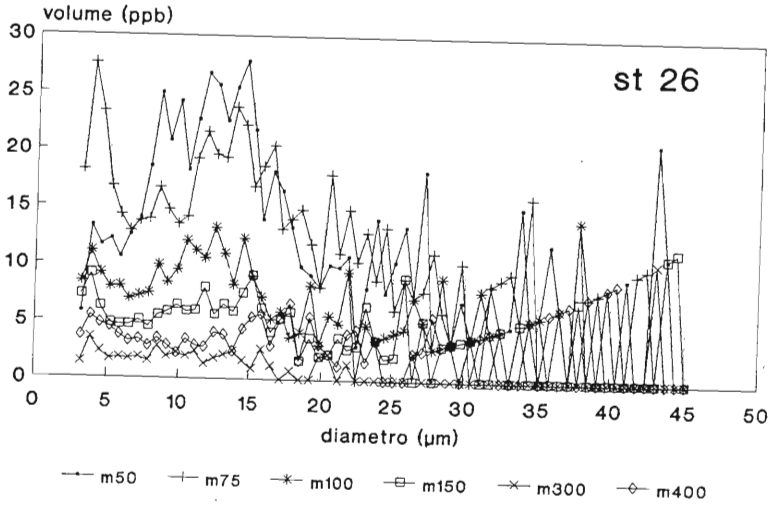


Fig. 22 - Suspended particle volume size spectra (ppb vol/vol).

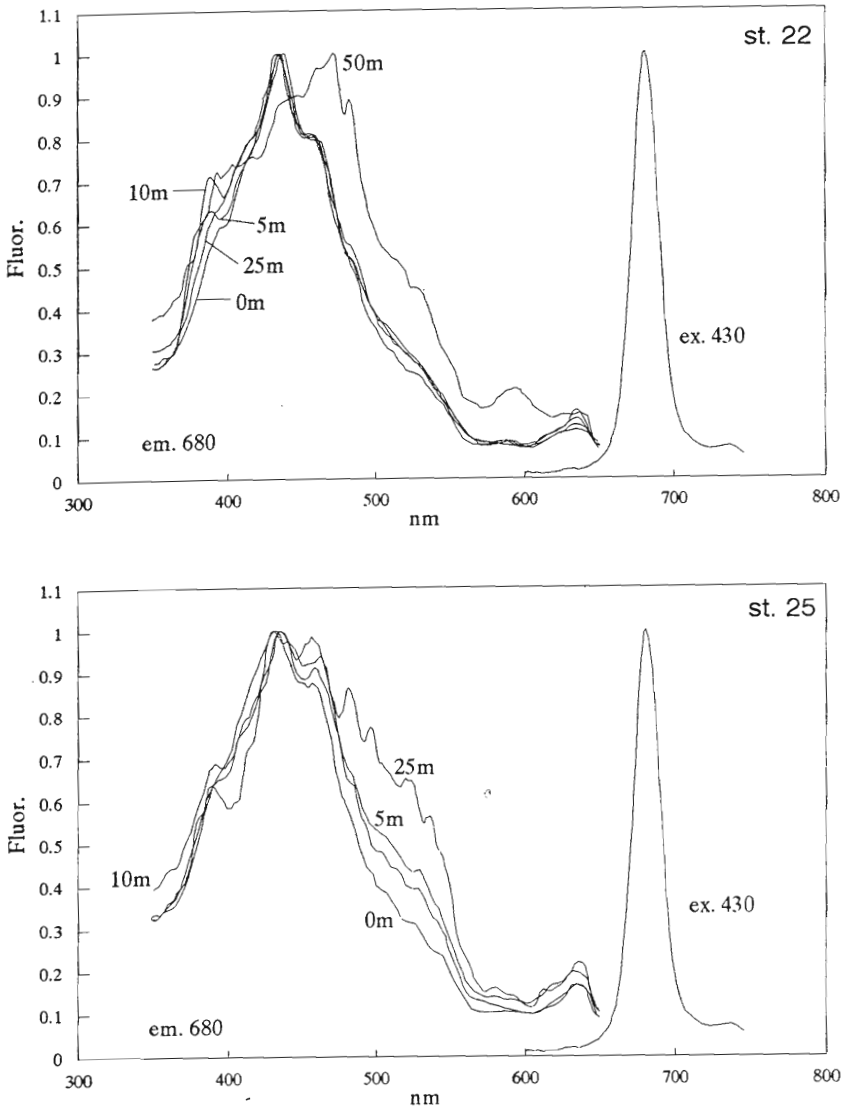


Fig. 24 - *In vivo* fluorescence excitation and emission spectra of chlorophyll *a* normalized by their maxima, for two typical stations: 22 and 25.

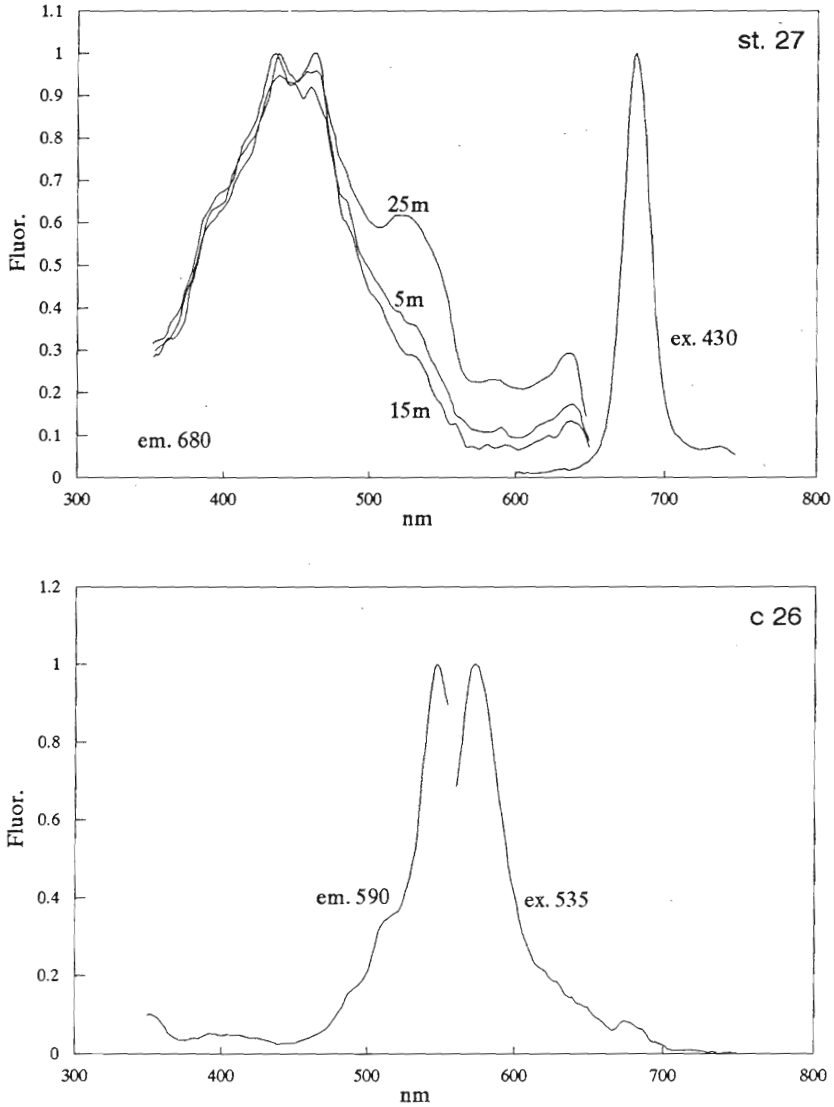


Fig. 25 - *In vivo* fluorescence excitation and emission spectra of chlorophyll *a* (st. 27) and phycoerithrin (surface sample c26: 66° 39'S 177°E) normalized by their maxima.

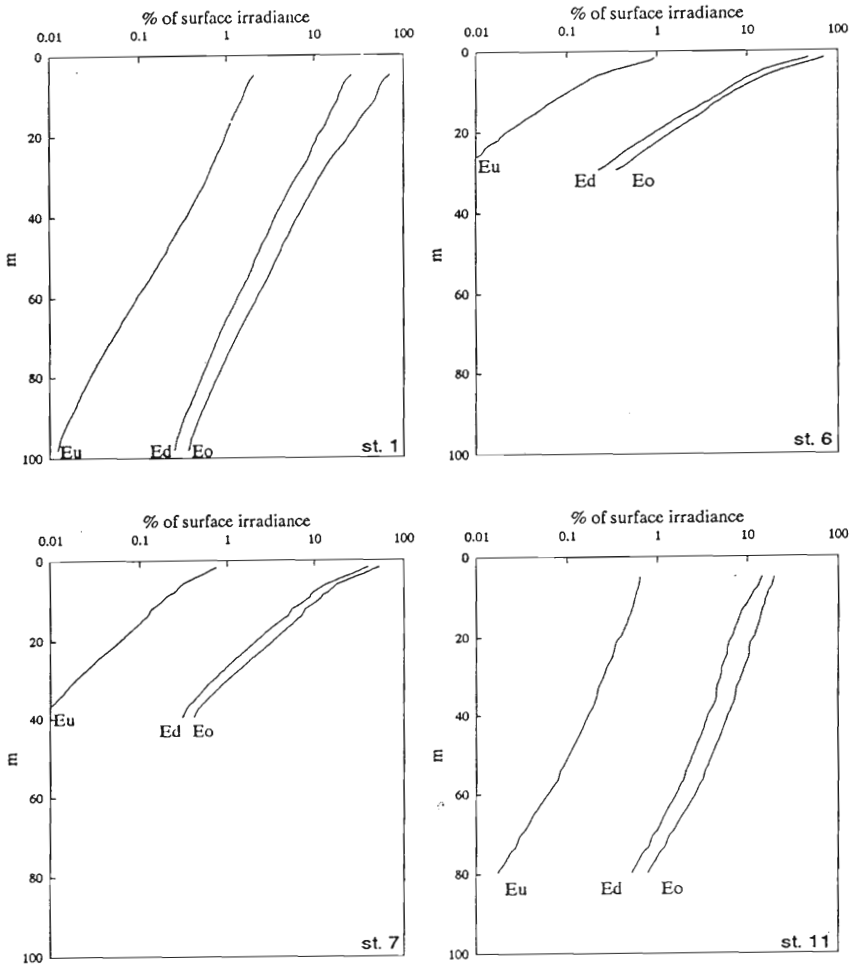


Fig. 26 - Underwater scalar (Eo), downwelling (Ed) and upwelling (Eu) quantum PAR irradiance normalized to surface downwelling irradiance.

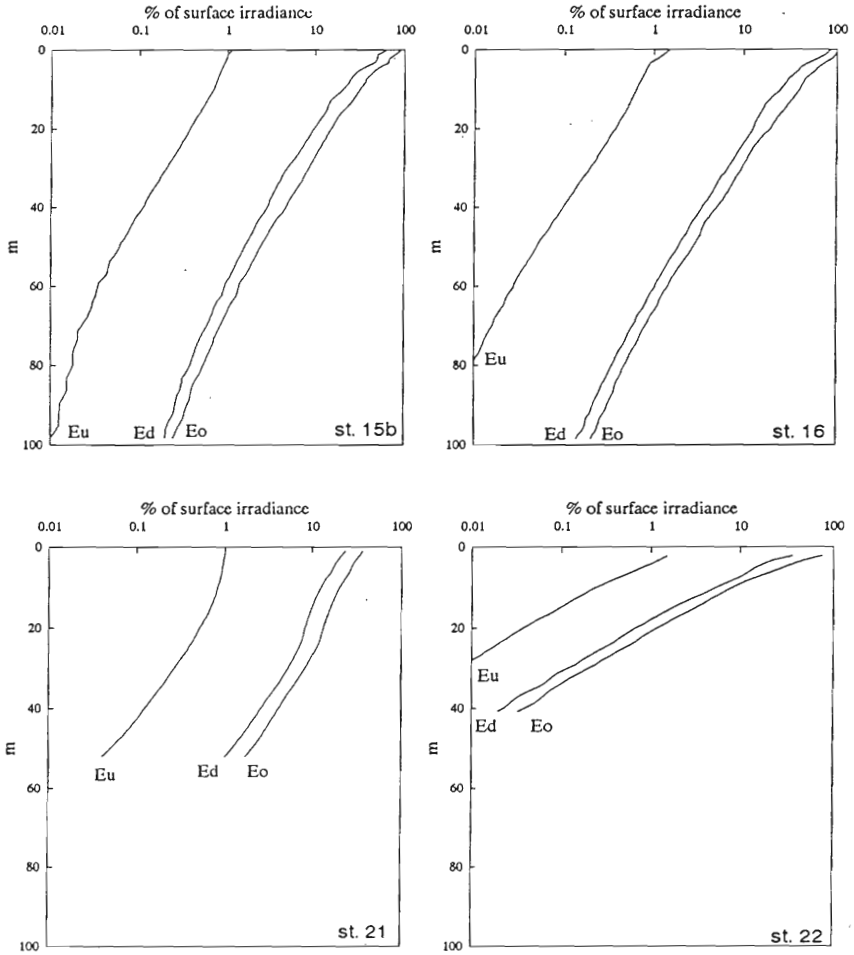


Fig. 27 - Underwater scalar (Eo), downwelling (Ed) and upwelling (Eu) quantum PAR irradiance normalized to surface downwelling irradiance.

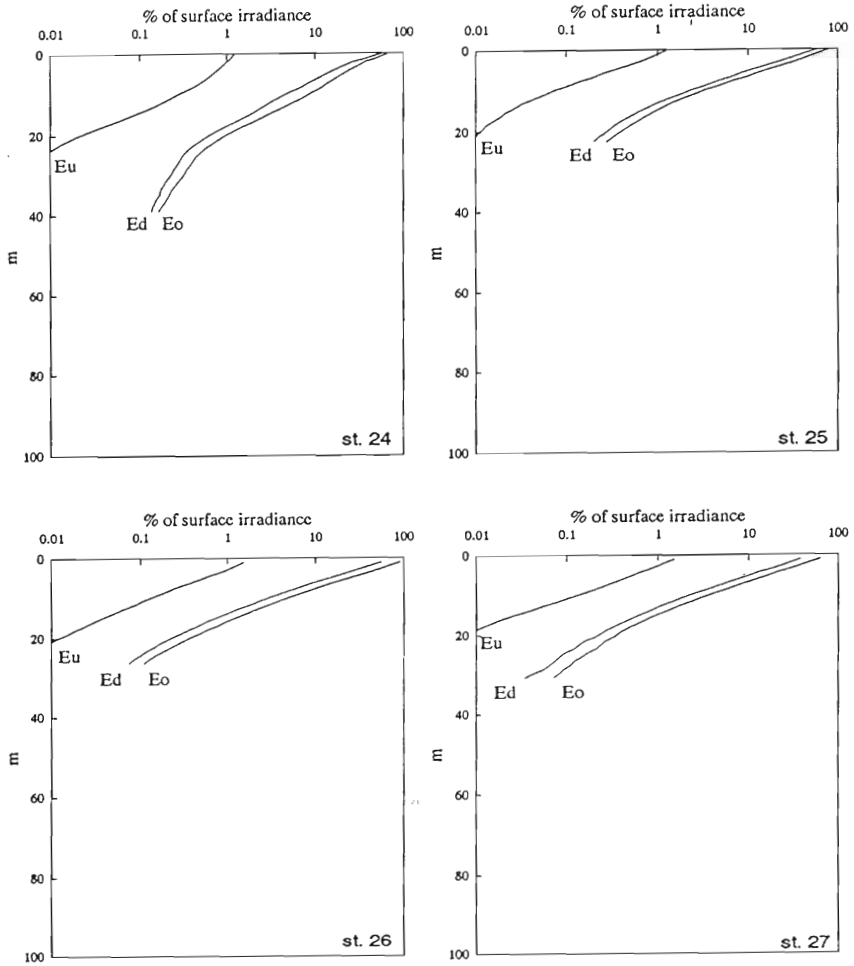


Fig. 28 - Underwater scalar (Eo), downwelling (Ed) and upwelling (Eu) quantum PAR irradiance normalized to surface downwelling irradiance.

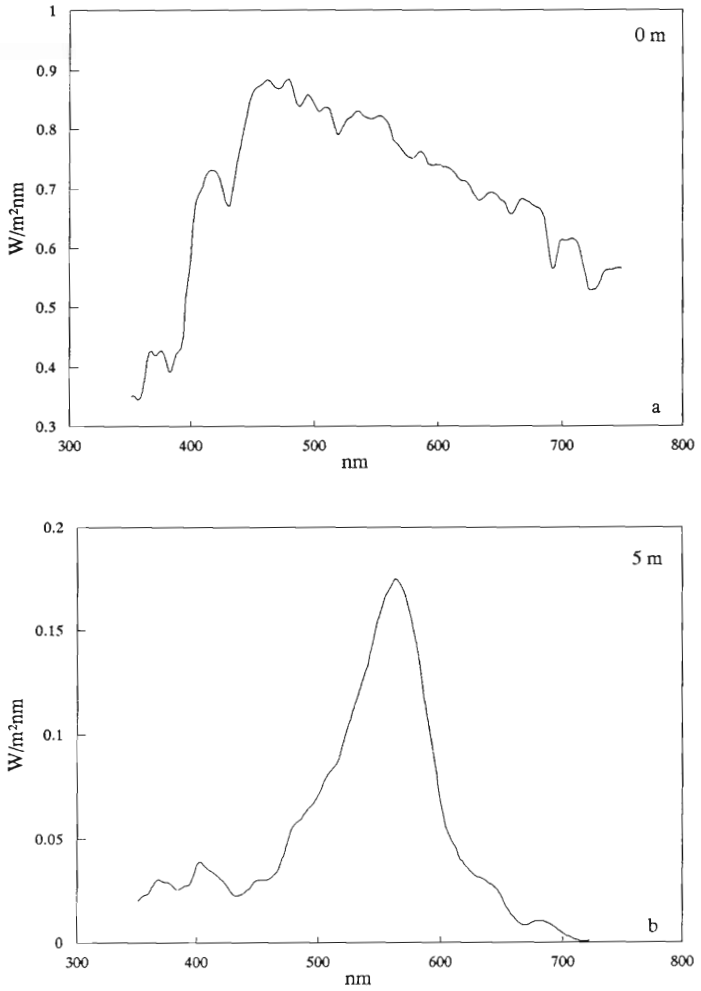


Fig. 29 - Surface downwelling (a), underwater downwelling (b) irradiance spectra (W/m^2nm) at SMN (03.01.90).

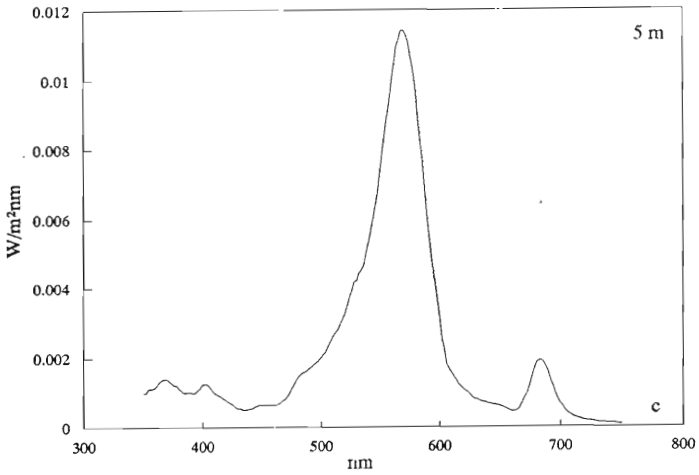


Fig. 29 - Upwelling (c) irradiance spectra (W/m^2nm) at SMN (03.01.90).

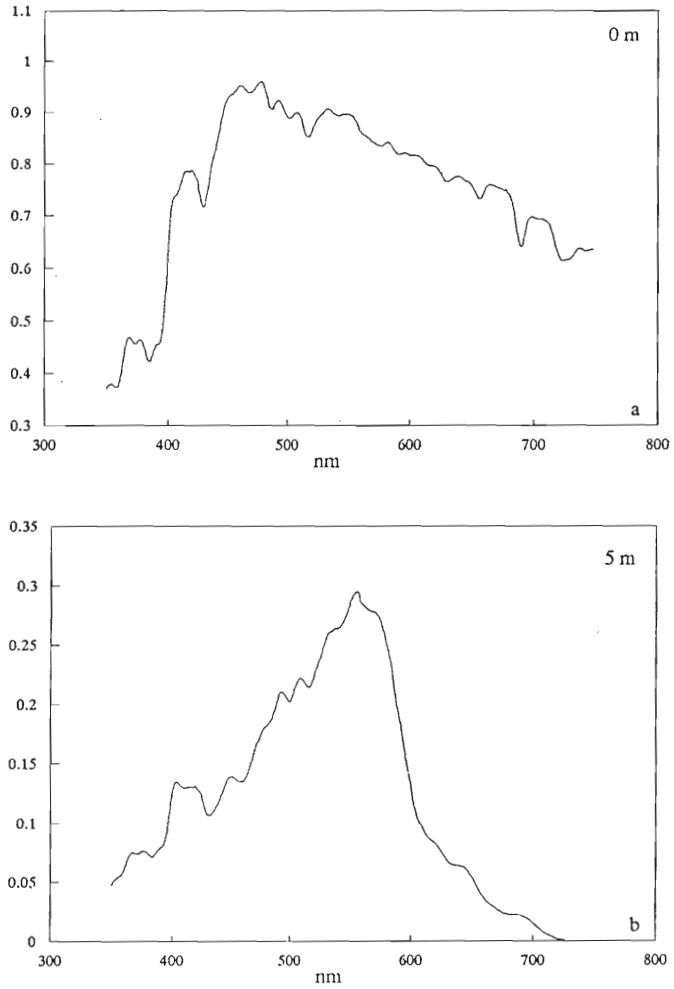


Fig. 30 - Surface downwelling (a) and underwater downwelling (b) irradiance spectra (W/m^2nm) at SMN (12.01.90).

Table 4a. St. BAIA TERRA NOVA - Surface phytoplankton density (cells/dm³)

	Dates 10.12.89	11.12	12.12	13.12	14.12	15.12
Chaetoceros cfr. criophilum	0	0	0	0	0	0
Chaetoceros cfr. dichaeta	0	0	0	0	0	0
Chaetoceros sp. 15 µm	0	0	0	0	0	0
Eucampia balaustium	0	0	0	1463	0	0
Navicula sp. 15 µm	74092	107256	73062	59983	132930	546780
Nitzschia curta	11260	12300	16236	5852	11816	50472
Nitzschia sec. Fragilariopsis spp.	0	0	0	0	0	0
Nitzschia sec. Nitzschiella sp.	595	0	2214	0	2954	6309
Nitzschia sec. Pseudonitzschia sp.	1190	3444	738	1463	0	6309
Rhizosolenia alata	0	0	0	0	0	0
Rhizosolenia truncata	0	0	0	8778	0	0
Thalassiosira sp. 43 µm	0	0	0	0	0	0
Pennate diatom 9 µm	0	1968	9594	125818	200872	2649780
Pennate diatom 40 µm	0	0	0	0	1477	0
Pennate diatom 90 µm	0	0	0	0	0	0
Undetermined diatoms spp.	5333	2952	0	0	0	0
Amphidinium cfr. longum	0	0	0	0	0	0
Amphidinium sp. a (37 µm)	0	0	0	0	0	0
Amphidinium sp. b (9 µm)	0	0	0	0	0	0
Amphidinium sp. c (39 µm)	0	0	0	0	0	0
Amphidinium sp. d (28 µm)	0	0	0	0	0	0
Dinophysis sp. 62 µm	1190	2952	35424	84854	81235	77811
Gymnodiniaceae > 10 µm	0	0	0	0	0	0
Gymnodiniaceae > 20 µm	0	0	0	0	0	0
Gymnodiniaceae > 100 µm	0	0	0	0	0	0
Gymnodinium sp. a (10 µm)	0	0	0	0	0	0
Gymnodinium sp. b (13 µm)	0	0	0	0	0	0
Gymnodinium sp. d (27 µm)	0	0	0	0	0	0
Gymnodinium sp. e (12 µm)	0	0	0	0	0	0
Gyrodinium lachryma	0	0	0	0	1477	0
Prorocentrum cfr. antarcticum	0	0	0	0	0	0
Protoperidinium cfr. adeliense	0	0	0	0	0	0
Protoperidinium antarcticum	0	0	0	0	0	0
Protoperidinium applanatum	0	0	0	0	0	0
Protoperidinium defectum	0	0	0	0	0	0
Protoperidinium cfr. mediocre	0	0	0	0	0	0
Naked dinoflagellates > 10 µm	0	0	0	0	0	0
Thecate dinoflagellates > 10 µm	0	0	0	0	0	0
Thecate dinoflagellates > 20 µm	0	0	0	0	0	0
Phaeocystis pouchetii	4738	1476	0	1463	0	0
Phytoflagellate sp. a (Cryptophyceans?)	0	0	0	0	0	0
Phytoflagellate sp. 1 (6 µm)	0	492	2952	4389	36925	37854
Phytoflagellates < 10 µm	4153	7872	14022	29260	54649	60987
Phytoflagellates < 20 µm						
Diatoms	92470	127920	101844	203357	350049	3259650
Dinoflagellates	1190	2952	35424	84854	82712	77811
P. pouchetii	0	0	0	0	0	0
Undetermined phytoflagellates	8891	9840	16974	35112	91574	98841
TOTAL	102551	140712	154242	323323	524335	3436302

Table 4b. St. BAIA TERRA NOVA - Surface phytoplankton density (cells/dm³)

	Dates 16.12	18.12	23.12	25.12	27.12	30.
Chaetoceros cfr. criophilum	0	0	0	0	0	
Chaetoceros cfr. dichaeta	0	0	2103	0	0	197
Chaetoceros sp. 15 µm	0	0	25236	0	0	4145
Eucampia balaustium	0	0	0	0	0	197
Navicula sp. 15 µm	153519	1108281	90429	7450	7525	
Nitzschia curta	23133	63090	1047715	4382477	2025850	604355
Nitzschia sec. Fragilariopsis spp.	0	0	66875	279733	129310	38575
Nitzschia sec. Nitzschiella sp.	4206	2103	182961	2571740	1070055	149037
Nitzschia sec. Pseudonitzschia sp.	0	6309	14721	110260	42140	27438
Rhizosolenia alata	0	0	0	0	0	
Rhizosolenia truncata	0	0	0	0	0	
Thalassiosira sp. 43 µm	0	0	0	0	0	
Pennate diatom 9 µm	1949481	1903215	111459	0	0	
Pennate diatom 40 µm	0	0	4206	5960	7525	7896
Pennate diatom 90 µm	0	0	0	4470	0	
Undetermined diatoms spp.	0	0	0	0	0	
Amphidinium cfr. longum	0	0	0	0	0	
Amphidinium sp. a (37 µm)	0	0	0	1490	1505	
Amphidinium sp. b (9 µm)	0	0	6309	17880	18060	25662
Amphidinium sp. c (39 µm)	0	0	0	5960	4515	15792
Amphidinium sp. d (28 µm)	0	0	0	0	0	
Dinophysis sp. 62 µm	0	0	0	0	0	
Gymnodiniaceae > 10 µm	42060	166137	2103	0	0	7896
Gymnodiniaceae > 20 µm	0	0	4206	2980	1505	11844
Gymnodiniaceae > 100 µm	2103	0	0	0	0	1974
Gymnodinium sp. a (10 µm)	0	0	4206	13410	0	19740
Gymnodinium sp. b (13 µm)	0	0	2103	25330	7525	11844
Gymnodinium sp. d (27 µm)	0	0	0	0	0	
Gymnodinium sp. e (12 µm)	0	0	4206	2980	1505	11844
Gyrodinium lachryma	0	0	0	0	0	
Prorocentrum cfr. antarcticum	0	0	0	0	1505	1974
Protoperidinium cfr. adeliense	0	0	0	0	0	
Protoperidinium antarcticum	0	0	2103	1490	1505	1974
Protoperidinium applanatum	0	0	0	0	0	
Protoperidinium defectum	0	0	0	0	0	
Protoperidinium cfr. mediocre	0	0	0	0	0	5922
Naked dinoflagellates > 10 µm	0	0	0	0	16555	15792
Thecate dinoflagellates > 10 µm	0	0	4206	0	4515	9870
Thecate dinoflagellates > 20 µm	0	0	2103	1490	0	
Phaeocystis pouchetii	0	0	0	0	0	1974
Phytoflagellate sp. a (Cryptophyceans?)	0	0	8412	43210	39130	63168
Phytoflagellate sp. 1 (6 µm)	0	0	10515	2980	7525	1974
Phytoflagellates < 10 µm	119871	90429	14721	0	0	23688
Phytoflagellates < 20 µm	75708	159828	44163	0	0	
Diatoms	2130339	3082998	1545705	7362090	3282405	8247372
Dinoflagellates	44163	166137	31545	73010	58695	142128
P. pouchetii	0	0	0	0	0	1974
Undetermined phytoflagellates	195579	250257	77811	46190	46655	88830
TOTAL	2370081	3499392	1655061	7481290	3387755	8480304