Journal of the Marine Biological Association of the United Kingdom, 2008, 88(2), 227–236.
doi:10.1017/S0025315408000465 Printed in the United Kingdom

New contribution on spatial and seasonal variability of environmental conditions of the Golfo San Jorge benthic system, Argentina

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*A new contribution on spatial and seasonal variability of physico-chemical parameters of the Golfo San Jorge benthic system from autumn 2001 through summer to 2002 is presented. Temperature, salinity, density, oxygen content and chlorophyll-*a *in bottom water as well as concentration of total organic matter, total organic carbon, total nitrogen, total phosphorus, chlorophyll-*a *and phaeopigments in sediments were analysed. The origin and nutritional value of the deposited organic matter were also assessed. The results reflect the existence of: (1) a typical temperate water seasonal cycle; (2) a bimodal cycle in the phytoplanktonic production; and (3) seasonal variations in the chemical variables and in organic matter origin in sediments.*

Three sectors which geographically correspond with those identified in previous studies were defined: (1) the inner area of the gulf; (2) the areas next to the north and south extremes; and (3) the coastal and south-east part.

Keywords: Physico-chemical parameters, Patagonian Gulf, south-western, South Atlantic

Submitted 4 August 2006; accepted 27 November 2007

INTRODUCTION

The south-western South Atlantic is one of the less studied areas in the world. In this context the Golfo San Jorge has reamined poorly studied for decades in spite of other areas such as the Argentine Continental Shelf having been broadly surveyed (Bastida *et al.*, 1992). Its geographical characteristic as forming part of the Patagonian plateau make it different from other areas such as the well known Gulf of Mexico (Grady, 1971) and Carpentaria Gulf (Australia) (Jones, 1987) where important crustacean fisheries have developed.

The Golfo San Jorge is located between latitudes 45° to 47° S and 65° to 30′ W and the coast. Geographical and oceanographical characteristics were described in previous studies (Fernández *et al.*, 2003, 2005).

Available information on the Golfo San Jorge benthic system is limited to spatial distribution of sediment characteristics and chemical composition of surficial sediments, as well as the physico-chemical composition of bottom water (Fernández *et al.*, 2003, 2005) and biological and ecological aspects of the benthic communities of the gulf and adjacent areas (Roux *et al.*, 1995; Roux & Fernández, 1997; Roux, 2000).

The Golfo San Jorge also constitutes an important economic region due to the existence of spawning and breeding areas and commercial interest species fishing grounds. The important species *Pleoticus muelleri* (shrimp) and *Merluccius hubbsi* (hake) are particularly important (Fernández *et al.*, 2003, 2005). The commercial importance of the shrimp fishery has lead to the implementation of seasonal monitorings of the system since 1992 (Roux, *et al.*, 1995; Roux & Fernández, 1997).

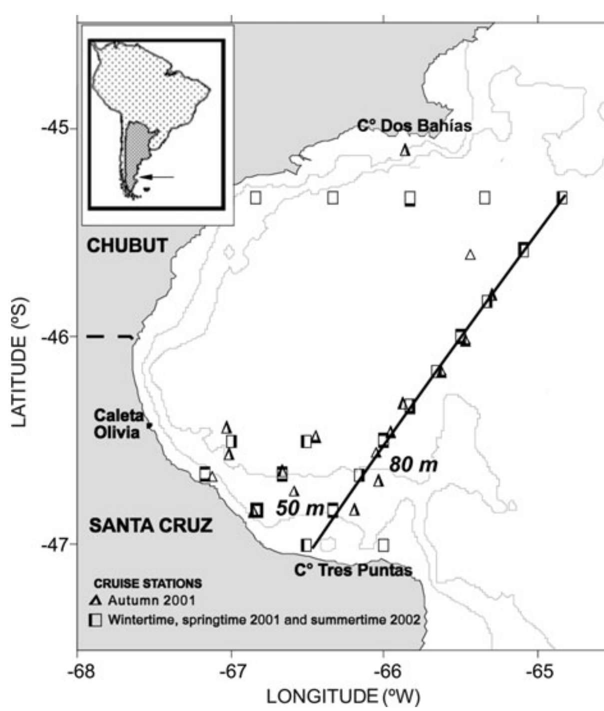

Fig. 1. Geographical location of sampling stations of the research cruises carried out from autumn 2001 to January 2002, in the Golfo San Jorge and position of the transect.

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A new contribution to the knowledge of the spatial and seasonal physico-chemical characterization of the bottom water and sediment factors from autumn 2001 to summer 2002 are presented, in the highest concentration area of *P. muelleri* in the Golfo San Jorge.

MATERIALS AND METHODS

Samplings were obtained during research cruises OB-06/01, OB-11/01, OB-13/01 and OB-01/02, carried out on board the INIDEP RV 'Capitán Oca Balda' in autumn (April–May 2001), winter (September 2001), spring (November 2001) and summer (February 2002) (Figure 1). In the 76 stations where the research was carried out, samples of water and sediments were taken and physical data of the water column were also recorded. Temperature (T), salinity (S) and density (δ_T) were measured with a conductivity–temperature–depth probe 'SBE (SEA-BIRD ELECTRONIC, I MODEL XIX). A fluorometer (Seapoint Chlorophyll Fluorometer) was added to the CTD for *in situ* determinations of fluorescence vertical profiles of phytoplankton. Water samples for dissolved oxygen (O) and chlorophyll-*a* (Chl-*a*) determinations were collected with Niskin bottles, taking samples of bottom water (at 0.50 m from the bottom), mixing layer (above the thermocline) and surface. Sediment samples were obtained with a Phleger gravity corer and a Picard dredge (Fernández *et al.*, 2005).

Analytic techniques to determine dissolved oxygen and Chl-*a* in water, total organic matter (TOM), total organic carbon (TOC), total nitrogen (TN), total phosphorus (TP), nutritional value and origin of the organic matter (C:N ratio), chl-a_s and phaeopigments (Phaeo$_S$) in sediments are clearly described in Fernández (2006).

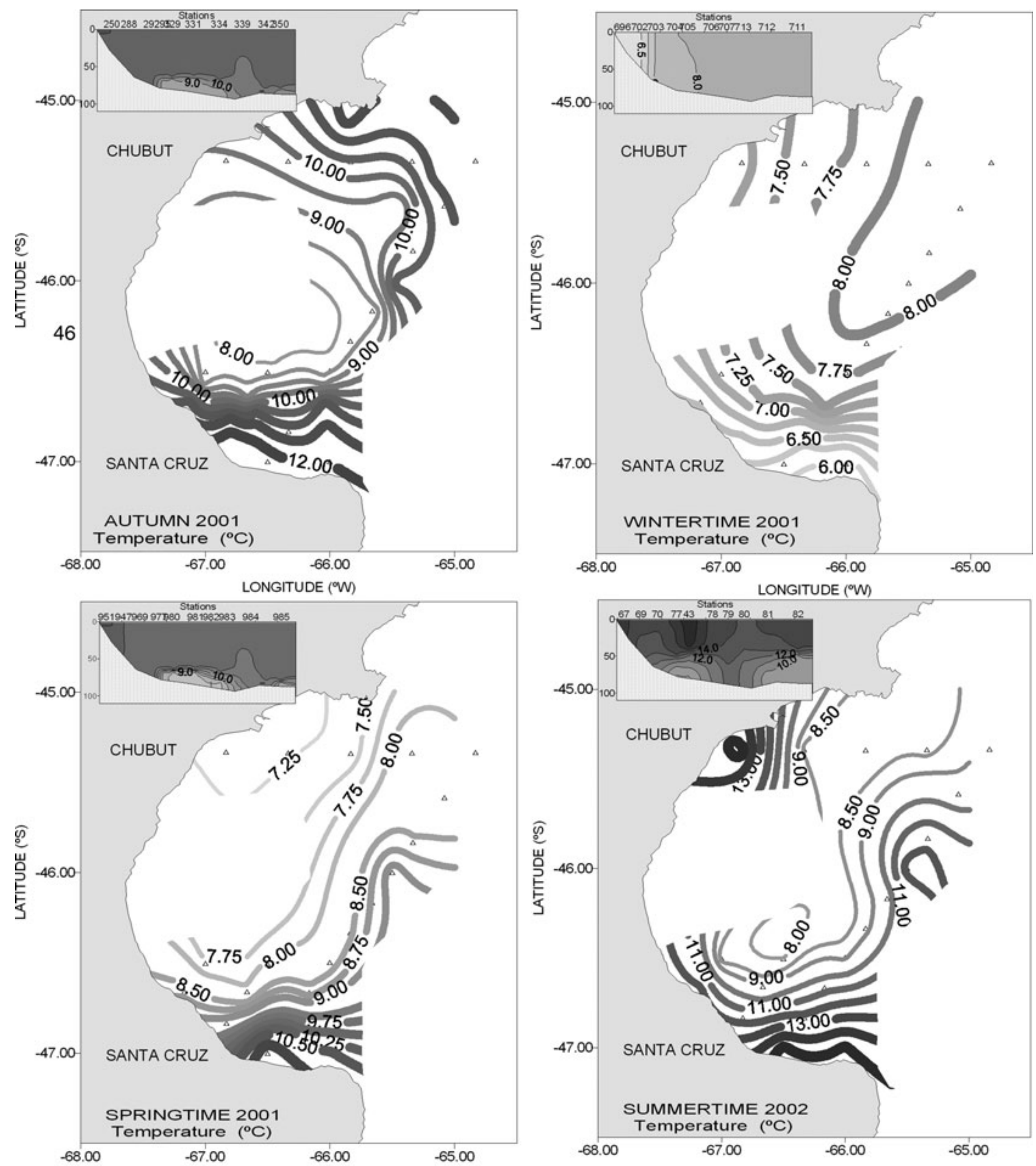

Fig. 2. Horizontal temperature distribution of bottom water in the Golfo San Jorge and cross-section profiles.

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Table 1. Descriptive statistic of the water variables (SW = surficial water, MW = mixing water and BW = bottom water) in the total area (TA) and each defined sector (S1, S2, S3) from Autumn 2001 to Summer 2002.

	Value	Autumn 2001 (F)				Wintertime 2001 (W)				Springtime 2001 (S)				Summertime 2002 (SU)				Dunn test
		TA	S1	S2	S3	TA	S1	S2	S3	TA	S1	S2	S3	TA	S1	S2	S3	
																		F-W **
T(°C) BW	Min.	8.07	8.07	11.07	8.19	5.83	6.52	5.83	6.38	7.21	7.76	8.69	7.21	7.96	7.96	12.07	8.00	F-S ns
	Max.	11.69	10.90	11.69	11.65	8.18	7.79	6.16	8.18	11.41	9.15	11.41	10.01	15.25	8.91	15.21	15.21	F-SU ns
	Mean	9.76	9.09	11.38	9.88	7.36	7.29	6.17	7.82	8.59	8.33	10.22	8.3	10.61	8.38	14.13	10.37	W-S **
	SD	1.44	1.09	0.44	1.67	0.75	0.42	0.35	0.57	1.07	0.72	1.39	0.76	2.48	0.40	1.71	2.15	W-SU **
																		S-SU *
																		F-W ns
S (psu) BW	Min.	33.293	33.293	33.369	33.344	33.057	33.472	33.057	33.226	33.22	33.421	33.220	33.428	33.303	33.544	33.390	33.303	F-S ns
	Max.	33.826	33.627	33.420	33.826	33.604	33.604	33.383	33.529	33.562	33.562	33.416	33.560	33.723	33.723	33.499	33.651	F-SU ns
	Mean	33.498	33.484	33.394	33.573	33.437	33.515	33.236	33.442	33.457	33.510	33.288	33.483	33.498	33.589	33.462	33.477	W-S ns
	SD	0.15	0.14	0.04	0.16	0.14	0.1	0.16	0.09	0.09	0.08	0.11	0.04	0.11	0.08	0.06	0.11	W-SU ns
																		S-SU ns
																		F-W **
δ_T (kg/m^3) BW	Min.	25.810	25.511	25.394	25.439	26.134	26.146	26.039	25.99	25.968	25.859	25.323	25.775	25.65	25.992	24.708	24.879	F-S ns
	Max.	25.394	26.185	25.966	26.130	25.990	26.297	26.208	26.163	25.323	26.181	25.973	26.238	24.708	26.214	25.409	26.313	F-SU ns
	Mean	26.185	25.913	25.680	25.773	26.297	26.209	26.138	26.075	26.238	26.053	25.573	26.034	26.214	26.116	24.963	25.689	W-S ns
	SD	0.31	0.28	0.400	0.35	0.09	0.05	0.09	0.06	0.23	0.17	0.31	0.13	0.49	0.09	0.39	0.41	W-SU **
																		S-SU ns
																		F-W **
O mlO$_2$/l BW	Min.	2.69	2.69	5.68	3.25	6.54	6.54	7.12	6.54	5.36	5.37	5.6	5.36	3.43	3.67	4.50	3.43	F-S ns
	Max.	6.04	5.59	6.03	5.96	7.33	7.02	7.33	6.8	6.66	5.61	5.81	6.66	5.89	5.63	5.89	5.04	F-SU ns
	Mean	4.32	3.60	5.86	4.50	6.73	6.66	7.24	6.66	5.68	5.47	5.7	5.72	4.36	4.43	5.35	4.09	W-S **
	SD	1.45	1.24	0.25	1.45	0.26	0.17	0.11	0.08	0.27	0.12	0.11	0.3	0.71	0.86	0.75	0.46	W-SU **
																		S-SU *
																		F-W ns
Chl-a_{SW} mg/m^3	Min.	0.31	0.31	0.74	0.42	0.41	0.47	0.56	0.41	0.18	0.80	0.31	0.18	0.13	0.46	0.13	0.52	F-S *
	Max.	2.25	1.80	1.20	2.25	2.33	1.74	2.33	0.85	8.72	8.72	4.12	3.25	3.29	1.11	2.57	3.29	F-SU ns
	Mean	0.89	0.73	0.97	1.08	0.93	1.12	1.40	0.62	1.64	4.08	1.94	1.06	1.00	0.79	1.17	1.06	W-S *
	SD	0.53	0.49	0.33	0.68	0.56	0.59	0.89	0.19	2.00	4.13	0.97	0.92	0.75	0.28	1.26	0.78	W-SU ns
																		S-SU *
																		F-W *
Chl-a_{MW} mg/m^3	Min.	0.06	0.06	–	0.32	0.92	0.98	–	0.92	0.36	0.84	–	0.36	0.12	0.18	–	0.14	F-S **
	Max.	2.33	1.95	–	2.33	7.65	7.65	–	3.23	11.66	11.66	–	6.65	1.03	0.55	–	1.03	F-SU ns
	Mean	0.86	0.69	–	0.97	2.19	2.60	–	1.87	3.33	4.72	–	3.04	0.37	0.35	–	0.41	W-S ns
	SD	0.64	0.68	–	0.73	1.73	2.47	–	0.89	3.01	6.02	–	2.24	0.25	0.16	–	0.27	W-SU **
																		S-SU **
																		F-W **
Chl-a_{BW} mg/m^3	Min.	0.03	0.03	0.25	0.04	0.40	0.40	2.00	0.88	0.03	0.10	0.09	0.08	0.03	0.05	0.09	0.09	F-S ns
	Max.	1.26	0.20	0.93	0.61	4.40	1.35	4.40	2.87	2.64	1.91	2.64	1.48	2.92	0.19	2.92	0.64	F-SU ns
	Mean	0.28	0.09	0.59	0.28	1.63	1.02	2.97	1.65	0.58	0.73	1.52	0.35	0.36	0.10	1.22	0.26	W-S **
	SD	0.36	0.07	0.48	0.25	0.98	0.51	1.26	0.76	0.75	1.02	1.30	0.37	0.64	0.06	1.49	0.22	W-SU **
																		S-SU ns

Min, minimum; Max, maximum; SD, standard deviation.
*0.01 $< P <$ 0.05; **$P <$ 0.01 – ns $P >$ 0.05.

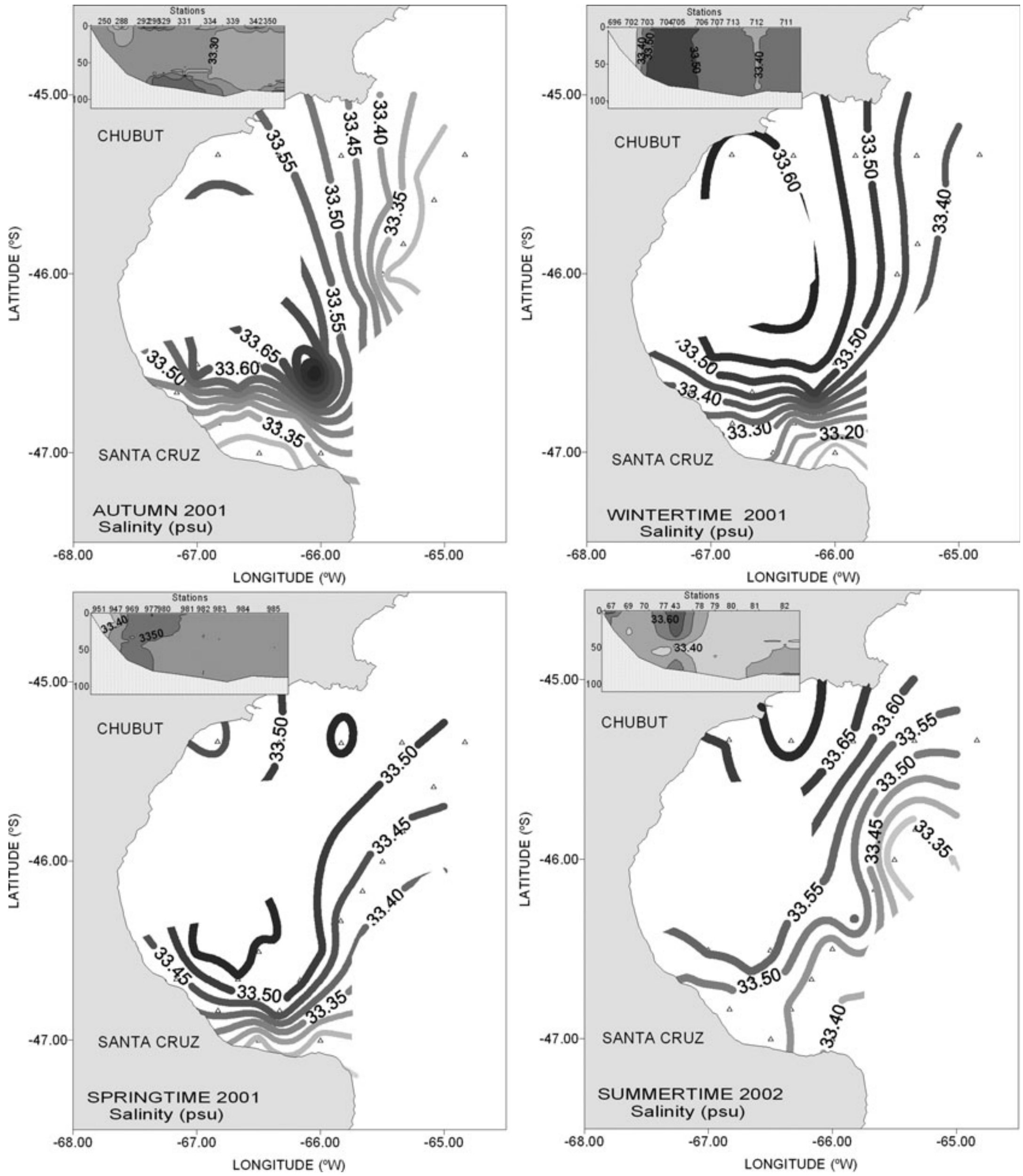

Fig. 3. Horizontal salinity distribution of bottom water in the Golfo San Jorge and cross-section profiles.

The seasonal analyses of the variables, were developed applying the multiple comparisons Dunn test. The 'environmental variable × sampling site' matrices of each season expressed as standardized values were analysed using cluster analysis (classification). The statistical analysis was performed using the statistical program 'Statistica' version 5.5 (1998). Mapping of variables was elaborated with the graphic program 'Surfer', version 7; the kriging method was used for interpolation (Fernández *et al.*, 2003, 2005).

RESULTS

Hydrographical characteristics

The seasonal cycle of bottom water temperature distribution showed large amplitude ranging from 5.83°C in winter to 15.25°C in summer. In spring, summer and autumn spatial thermal gradients were observed; the minimum values corresponded to the central deep sector and the maximum were detected towards the coast. In winter the opposite behaviour was observed. The vertical transect of temperature registers showed the formation of a thermocline in spring and summer and the thermocline descends in autumn. The statistical analysis indicated highly significant differences ($P < 0.01$) among winter and the rest of the seasons and significant differences ($0.01 < P < 0.05$) among spring and summer (Figure 2; Table 1).

As regards salinity of bottom water, the seasonal cycle showed scarce amplitude; with minimum values in winter and spring and maximum values in autumn. In the analysed periods a salinity gradient between the south-east and west region of the gulf was observed. Seasonal salinity profiles allowed for differentiation of values lower than 33.40 psu in

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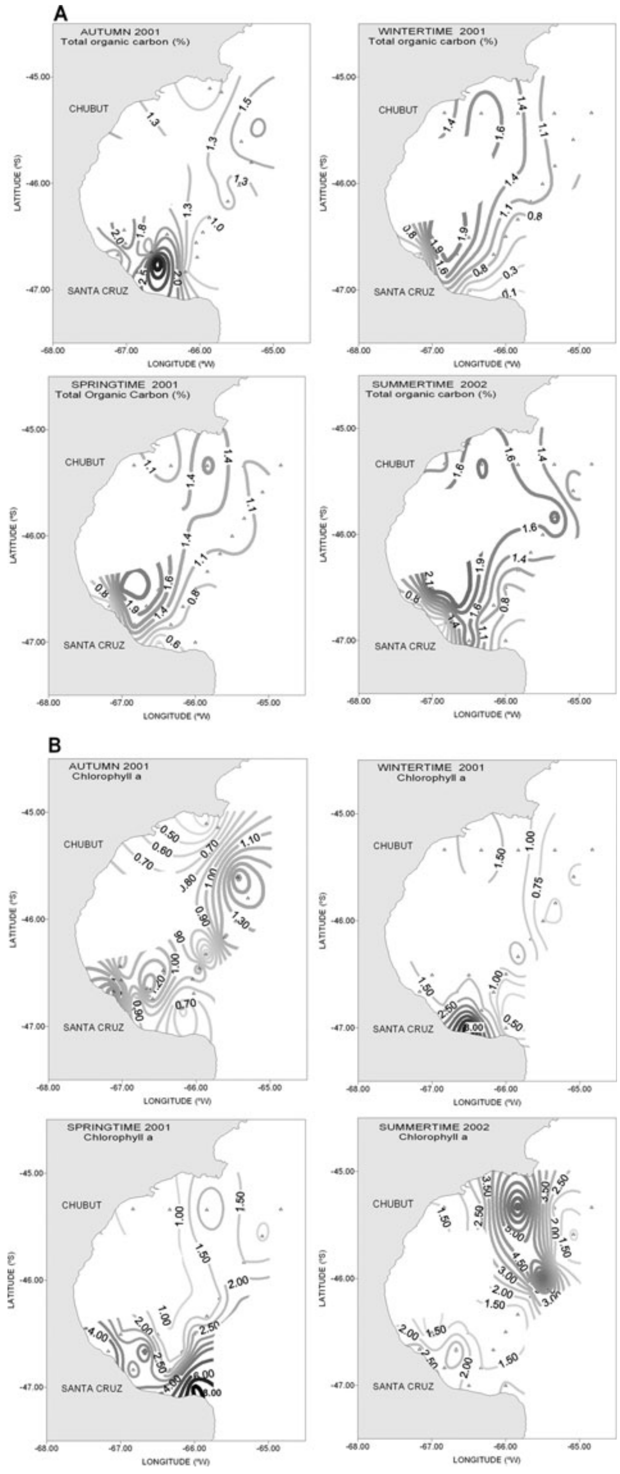

Fig. 4. (A) Horizontal distribution of total organic carbon concentration (%) and (B) horizontal distribution of chlorophyll-*a* concentration (μg/g) in the surficial sediments in the Golfo San Jorge.

the sector next to the coast. The statistical analysis indicated non-significant differences ($P > 0.05$) (Figure 3; Table 1).

Bottom water density beahviour was similar to that of temperature (Table 1).

Chemical characteristics of water

Horizontal distribution of oxygen concentration in bottom water showed the maximum values in winter and the minimum values in autumn, with a decrease from spring to autumn and a significant increase in winter. In spring, summer and autumn, spatial gradients were observed with minumum values towards the centre of the gulf and maximum values in the coastal sectors. The statistical analysis showed highly significant differences ($P < 0.01$) among winter and the rest of the seasons and significant differences ($0.01 < P < 0.05$) among spring and summer (Table 1).

Seasonal Chl-*a* concentration in bottom water showed maximum values in winter. The horizontal distribution of Chl-*a* was characterized by minimum values towards the central sector and maximum concentrations in the south. The statistical analysis showed highly significant differences ($P < 0.01$) among winter and the rest of the seasons (Table 1). Considering the surficial water and the mixing layer, the maximum concentrations were observed in spring (Table 1).

Chemical characteristics of surficial sediments

Sediment maximum values of concentration of TOM, TOC, TP and C:N ratio were observed in autumn, while maximum concentrations of TN, chl-a_s and $Phaeo_S$ were observed during spring. Horizontal distribution values of TOM, TOC (Figure 4A), TN, C:N ratio and $Phaeo_S$ showed the maximum values towards the central sector of the gulf, while the maximum of Chl-a_s and TP were located in the south, in winter and spring and in the northern area of the threshold in summer (Figure 4B). The statistical analysis only indicated differences in the variables TP and Chl-a_s (Table 2).

Spatial-temporal analysis of station and physico-chemical variables

The cluster analysis of the 13 physico-chemical variables revealed the existence of three associations for autumn, winter and spring (Figure 5A): Group 1, was characterized by TOM, TOC, TN and $Phaeo_S$; Group 2 by S, δ_T and depth, mainly; and Group 3 by T, O and Chl-a_{BW}, the C:N ratio being integrated to this last group in autumn, TP and Chl-a_s in winter and C:N ratio and Chl-a_s in spring. In summer Groups 1 and 2 did not present differences, forming together a single group.

The cluster analysis of the sampling stations also revealed three associations (Figure 5B): Group 1, integrated by stations located in the central area of the gulf; Group 2, by those located in the south; and Group 3, by the ones located in the mouth of the gulf. This last group incorporated the stations located in the north in spring and summer. The characteristics that defined Sectors 1, 2 and 3 (Figure 6) are presented in Tables 1 and 2.

DISCUSSION

The results obtained using a classification technique based on the spatial distribution of chemical variables of the surficial sediments and the bottom water physico-chemical variables (during autumn, winter and spring of 2001 and summer of 2002) in the Golfo San Jorge allowed for the characterization of three well differentiated sectors. These coincide

Table 2. Descriptive statistic of sediment variables in the total area (TA) and each defined sector (S1, S2, S3) from autumn 2001 to summertime 2002.

	Value	Autumn 2001 (F)				Wintertime 2001 (W)				Springtime 2001 (S)				Summertime 2002 (SU)				Dunn test
		TA	S1	S2	S3	TA	S1	S2	S3	TA	S1	S2	S3	TA	S1	S2	S3	
																		F-W ns
TOM (%)	Min.	2.94	5.16	5.50	2.94	1.66	6.41	1.66	3.05	1.91	5.87	1.91	3.47	1.96	7.32	1.96	3.94	F-S ns
	Max.	9.24	9.24	7.44	4.58	9.03	9.03	2.66	5.97	9.19	8.54	4.89	9.19	9.20	9.20	4.43	6.94	F-SU ns
	Mean	5.83	7.08	6.47	3.74	5.13	7.57	2.02	4.28	5.28	7.47	3.33	5.22	5.68	8.51	3.16	5.16	W-S ns
	SD	1.93	1.45	1.37	0.62	2.25	0.96	0.56	0.96	1.78	1.41	1.49	1.41	2.04	1.37	1.24	0.95	W-Su ns
																		S-SU ns
																		F-W ns
TOC (%)	Min.	0.79	1.09	1.28	0.79	0.09	1.15	0.09	0.72	0.28	1.74	0.28	0.85	0.29	1.88	0.39	0.80	F-S ns
	Max.	4.64	2.35	2.01	1.05	2.07	2.07	0.31	1.27	2.16	2.16	0.81	1.97	2.36	2.26	1.84	1.97	F-SU ns
	Mean	1.59	1.72	1.65	0.90	1.11	1.69	0.23	0.95	1.18	1.96	0.49	1.15	1.35	2.15	0.92	1.28	W-S ns
	SD	0.94	0.46	0.52	0.10	0.56	0.30	0.13	0.17	0.50	0.21	0.28	0.32	0.59	0.20	0.80	0.31	W-SU ns
																		S-SU ns
																		F-W ns
TN (%)	Min.	0.10	0.12	0.10	0.10	0.06	0.16	0.06	0.10	0.06	0.17	0.05	0.10	0.11	0.24	0.12	0.11	F-S ns
	Max.	0.41	0.37	0.28	0.22	0.36	0.36	0.08	0.33	0.51	0.51	0.10	0.41	0.51	0.51	0.26	0.26	F-SU ns
	Mean	0.21	0.25	0.19	0.14	0.17	0.24	0.07	0.15	0.22	0.33	0.07	0.23	0.21	0.31	0.18	0.17	W-S ns
	SD	0.10	0.09	0.13	0.04	0.09	0.08	0.01	0.07	0.12	0.17	0.03	0.09	0.09	0.13	0.07	0.06	W-SU ns
																		S-SU ns
																		F-W ns
C:N	Min.	3.60	3.95	4.52	3.60	1.42	4.89	1.42	3.44	2.06	3.84	4.72	2.06	1.20	3.70	1.52	3.38	F-S ns
	Max.	20.13	9.62	20.13	9.94	11.10	11.10	4.34	9.79	11.98	10.26	7.95	11.98	11.88	10.00	11.88	10.10	F-Su ns
	Mean	8.09	7.35	12.32	7.12	6.61	7.40	3.22	7.12	6.16	6.93	6.72	5.87	7.18	7.75	5.99	7.79	W-S ns
	SD	3.95	2.44	11.04	2.45	2.35	1.90	1.57	1.91	2.54	3.21	1.75	2.66	2.98	2.81	5.32	1.98	W-SU ns
																		S-SU ns
																		F-W ns
TP (%)	Min.	0.052	0.058	0.060	0.052	0.004	0.004	0.052	0.051	0.036	0.047	0.036	0.036	0.016	0.016	0.026	0.031	F-S **
	Max.	0.072	0.072	0.065	0.069	0.068	0.068	0.063	0.064	0.058	0.058	0.049	0.058	0.071	0.071	0.046	0.052	F-SU **
	Mean	0.062	0.064	0.063	0.060	0.056	0.050	0.060	0.060	0.047	0.051	0.043	0.046	0.040	0.043	0.036	0.040	W-S **
	SD	0.005	0.005	0.003	0.006	0.018	0.030	0.010	0.010	0.007	0.006	0.006	0.007	0.011	0.022	0.010	0.070	W-SU **
																		S-SU ns
																		F-W ns
Chl-a_S (ug/g)	Min.	0.25	0.98	0.75	0.25	0.09	1.86	0.09	0.51	0.50	2.55	3.49	0.50	0.49	0.49	1.66	0.89	F-S *
	Max.	1.79	1.63	1.79	1.08	8.65	1.19	8.25	1.84	8.27	4.23	8.27	2.61	7.25	2.41	2.86	7.25	F-SU *
	Mean	1.05	1.29	1.27	0.63	1.54	1.45	3.50	0.95	2.33	3.12	5.59	1.47	2.29	1.85	2.20	2.44	W-S ns
	SD	0.43	0.19	0.73	0.32	1.80	0.23	4.54	0.50	1.83	0.97	2.44	0.66	1.79	1.14	0.61	2.24	W-SU ns
																		S-SU ns
																		F-W ns
Phaeo$_S$ (ug/g)	Min.	7.09	25.58	22.59	7.09	0.08	33.29	13.56	9.50	11.92	40.35	11.92	14.96	1.91	21.48	5.07	1.91	F-S ns
	Max.	40.99	40.99	22.72	19.43	33.59	32.89	15.27	33.59	60.53	60.53	24.03	37.66	34.57	34.22	11.47	29.64	F-SU ns
	Mean	24.22	33.80	22.65	13.42	20.50	28.66	9.64	17.77	28.08	52.40	19.87	24.62	18.32	29.31	8.74	15.69	W-S ns
	SD	10.65	5.37	0.09	4.43	9.02	3.43	8.32	6.80	13.40	10.64	6.89	8.54	9.78	5.65	3.30	7.35	W-SU ns
																		S-SU ns

Min, minimum; Max, maximum; SD, standard deviation.
*0.01< P < 0.05; ** P < 0.01 – ns P > 0.05.

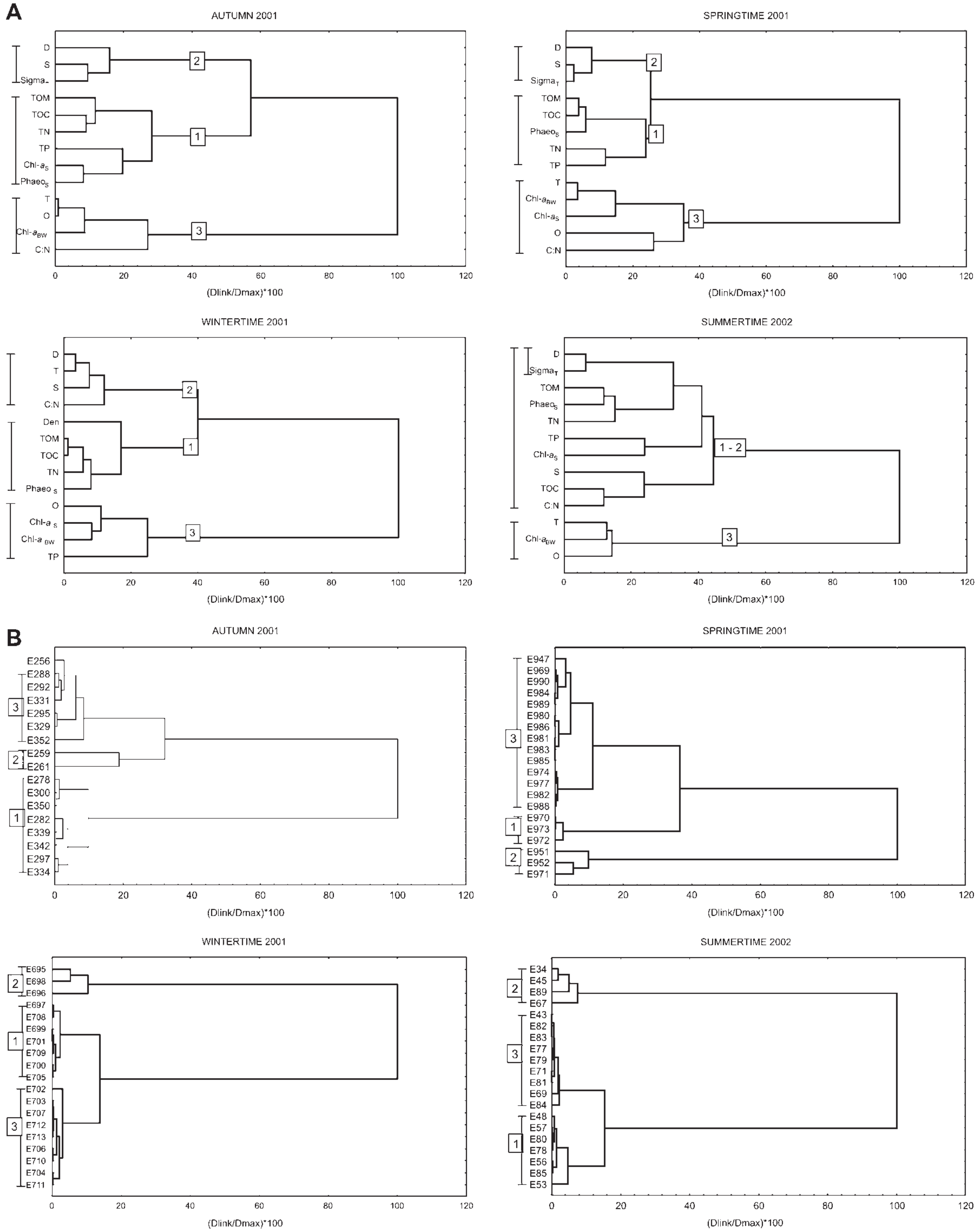

Fig. 5. Dendrograms of similarity (A) among variables and (B) among stations.

geographically with the sectors identified previously (Fernández *et al.*, 2003, 2005) based on the textural degree and the chemical factors of sediments, as well as the physical factors that regulate water mass dynamics.

Sector 1 is the deepest sector and comprises the central area of the gulf, corresponding to the depositional environment described by Fernández *et al.* (2003). This environment is characterized by low and stable hydrodynamic conditions which facilitate the sedimentation processes. The system shows a typical seasonal cycle of temperate waters and the associated formation and breakdown of the thermocline.

Seasonal variations of phytoplanktonic and biomass production follow a typical bimodal cycle of temperate waters, with a main peak during spring and a secondary one during autumn (Cucchi Colleoni & Carreto, 2003).

Surficial sediments are characterized by the prevalence of fine grains of silts and clays as well as for the accumulation of organic detritus coming from the water column, which is

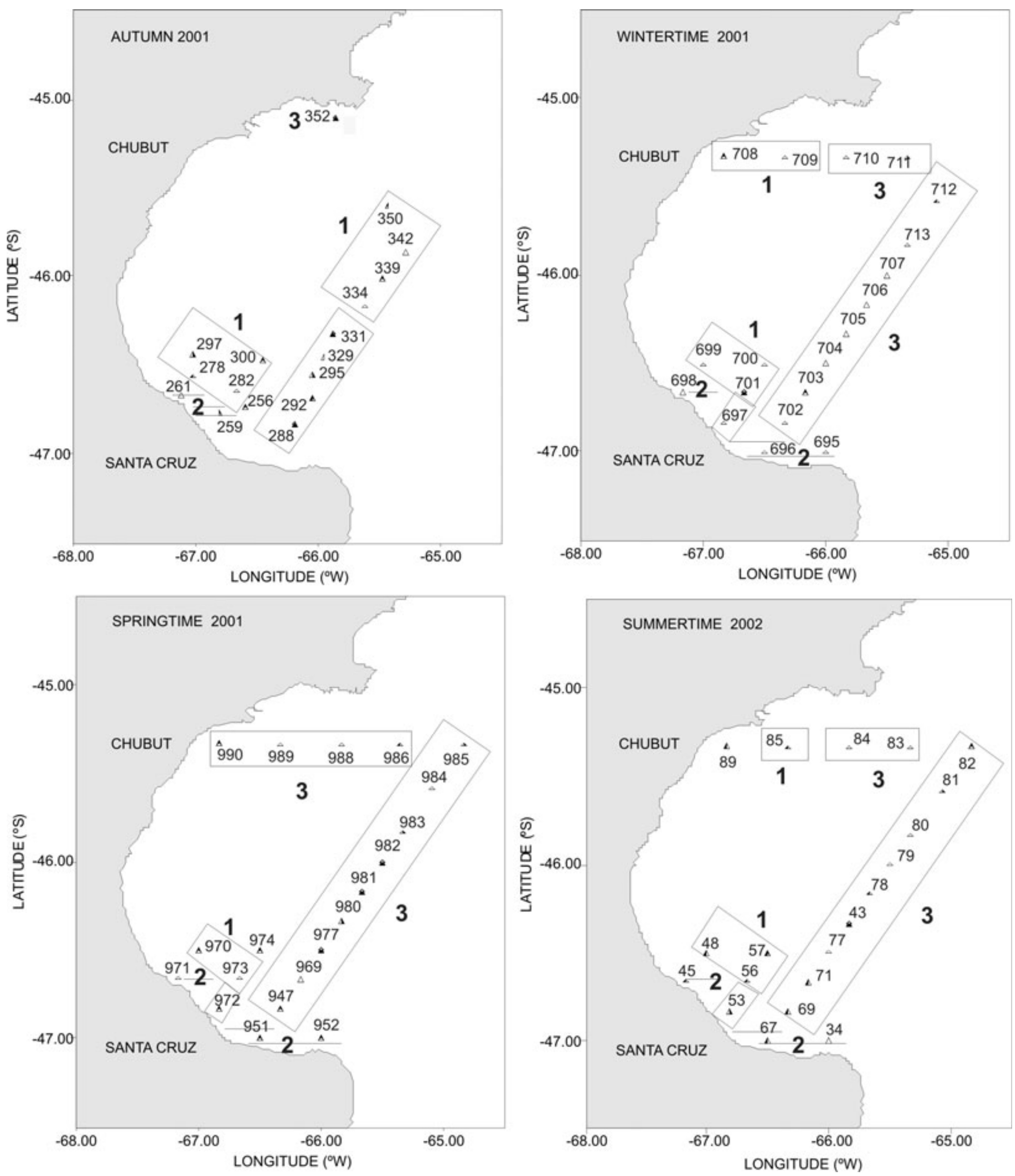

Fig. 6. Differentiated sectors in the Golfo San Jorge.

reflected in the detection of high concentrations of TOM, TOC, TN and $Phaeo_S$. According to Fernández *et al.* (2005), the flow of carbon towards sediments would not be synchronized with seasonal production pulses of the euphotic layer. This lack of synchronicity suggests that the labile compounds of carbon have been degraded by heterotrophic organisms in the surficial layer limited by the thermocline and that only a small proportion of larger particles (particulary faecal pellets) and macroaggregates are deposited in sediments. Our results show larger concentrations of TN, Chl-a_s and $Phaeo_S$ in sediments during spring. This characteristic of the sediments added to the value of the C:N ratio of 6.93 indicates a larger quantity of marine component of planktonic origin which is highly nitrogenated and has important nutritional value (Sargent *et al.*, 1983).

For the period of study, organic matter of sediment presented a concentration that indicated a peak in spring, suggesting conditions that favour the vertical export of primary and secondary production through the pycnocline, as observed by Olesen & Lundsgaard (1995) in Kattegat Bay (North Sea), Cailliau *et al.* (1999) in the Indian sector of the Southern Ocean and Pesant *et al.* (2002) in the East Greenland Shelf.

Sector 2 which comprises the south coastal area of the gulf including the area next to Cabo Tres Puntas according to Fernández *et al.* (2003, 2005) corresponds to an erosive environment. This is characterized by the flow or continuous movement of water. The action of tide currents and the influx of coastal waters arriving from the Magellan Strait are responsible for the water flow. These particularities determine the spatial variability that identifies the coastal sector, which can comprise only the area next to the south extreme of the gulf (Cabo Tres Puntas) or extend itself northward up to the coastal area of Caleta Olivia (Figure 1). The sediments of this sector consist of gravels, very coarse sands, carbonates and low concentrations of TOM, TOC, TN and $Phaeo_S$. In this system the formation of thermocline was not observed. The dynamics of the environment contribute to the oxygenation processes of the water column. According to Fernández *et al.* (2005), in this sector contrary to Sector 1 the flow of carbon towards the sediments would be synchronized with the seasonal pulses of euphotic layer production, possibly as a consequence of the lowest depth and the lack of physical barriers in the water column.

The maximum Chl-a_s and $Phaeo_S$ concentrations in sediments and Chl-a_s concentrations in water were observed during spring, coinciding with those mentioned above.

Sector 3 that comprises the mouth area of the gulf as well as the north sector during spring and summer belongs to transitional environments of the gulf according to Fernández *et al.* (2003, 2005). This environment presents intermediate characteristics to those mentioned for the depositional and erosive one. The differences are: (1) characteristic of flow or erosive environment, such as, lower depth and high hydrodynamism which does not allow the stratification of the water column in its coastal area; and (2) characteristic of the depositional environment as low hydrodynamism and seasonal thermocline in the deep area of the mouth and north of the gulf. According to Fernández *et al.* (2005) the spatial variability that presents in this sector would be determined by the hydrography of the gulf that favours the development of tidal and thermohaline fronts which increase its productive capacity (Cucchi Colleoni & Carreto, 2003). The sediments of this sector are composed of fine sands and present moderate TOM, TOC, TN and $Phaeo_S$ concentrations whose distribution is adjusted to a positive gradient that increases with the increment of depth and decrease of kinetic energy (Fernández *et al.*, 2005). Based on Fernández *et al.* (2005), in this environment as in the depositional environment the flow of carbon towards the sediments would not be synchronized with the seasonal pulses of production of the euphotic zone. The largest organic material concentrations of planktonic origin in the sediments were registered during winter with the rupture of the thermocline. In the present survey, in this sector, the largest TN, Chl-a_s and $Phaeo_S$ values in sediments were observed during spring, as observed for Sector 1. These characteristics would indicate a bigger quantity of marine component of planktonic origin and important nutritional value constituting the organic matter of the sediments during spring 2001. This fact as indicated for Sector 1, could be related to the development of processes linked to the action of the winds and certain hydrodynamic conditions that break the pycnocline, favouring the autochthonous material export from the euphotic layer towards the depth.

Our results in relation to the Chl-*a* values in water in Sectors 1, 2 and 3, coincide with those recorded in previous years by Fernández *et al.* (2005), where the maximum values were observed during spring. Cucchi Colleoni & Carreto (2003) also indicate for spring 2001, a larger phytoplanktonic production with regard to what was observed for spring 1999 and 2000, according to the studies of Chl-*a* Wide Field Scanner monthly images of the years 1999, 2000, 2001, 2002 and 2003. These differences in phytoplanktonic production could be interpreted as a consequence of the dynamics that characterize this process, which is subject to the variability of environmental conditions (Cucchi Colleoni & Carreto, 2003).

The total phosphorus TP concentration values measured in sediments of the Golfo San Jorge were lower than those reported in environments characterized by eutrophication processes, contamination of anthropogenic effluents and phosphoric fertilizer (El Sabrouti *et al.*, 1997). The values were similar to those of the Pomerania Bay in the Baltic Sea system without indications of contamination (Burska *et al.*, 1999). From the spatial point of view, the larger TP concentrations were observed in Sector 1 and they are related to the fine granulometric fractions of the sector that determine strong associations of phosphorus as phosphate form with clay minerals (Price, 1976). Seasonally, the minimum concentrations were recorded in spring and summer, possibly as a consequence of a phosphorus demand in the system due to an increment of biological activity that could have caused the liberation of the phosphorus from the sediments (Sondergaard *et al.*, 2003).

It is necessary to highlight that there are no previous studies in the Argentine Continental Shelf on total phosphorus concentration. Only the study of Robles (1984) carried out in La Plata River observed phosphorus values of between 0.01 and 0.16% in suspension sediments.

The results obtained in this paper have to be added to those previously developed during the past decade with the aim of characterizing the Golfo San Jorge, Patagonia, Argentina where important commercial fisheries have developed and interesting environmental processes are taking place.

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https://doi.org/10.1017/S0025315408000465 Published online by Cambridge University Press