

Polychaete Assemblages in the San José Gulf (Chubut, Argentina), in Relation to Abiotic and Biotic Factors

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With 8 figures and 5 tables

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Abstract. The composition and distribution of the polychaete assemblages of the San José Gulf (Chubut, Argentina) are described in relation to environmental variables using indicator species (TWINSPAN) and canonical correspondence analysis (CCA). The polychaetes were collected during a benthic cruise in October 1984. Sediments were collected at 110 sampling sites using a 0.25 m² van Veen bottom grab or by divers in near-shore areas and sieved with 1 mm mesh. A total of 73 polychaete taxa were collected and identified. Both analyses revealed the presence of four main assemblages distributed according to depth as well as bivalve and seaweed abundance gradients: ‘*Syllis-Eunice*’ and ‘*Harmothoe-Eunice*’ assemblages occurred at the same depths (0–185 m) and substrata (poorly sorted rock and coarse sand), but were separated by bivalve and seaweed abundance, whereby the highest abundances of bivalves and the minimum abundances of seaweeds corresponded to the ‘*Syllis-Eunice*’ association. The ‘*Ninole-Glycera*’ and ‘*Aglaophamus-Fabriciinae* indet. 6’ assemblages also occurred at similar depths (0–60 m) and substrata (very well-sorted medium-fine sand), but differed in their composition of bivalves and seaweed abundances; the ‘*Aglaophamus-Fabriciinae* indet. 6’ association corresponded with minimum bivalve and maximum seaweed abundances.

Problem

The San José Gulf accommodates multiple human activities. It is also an important mating and breeding zone for the southern right whale, for several sea birds and a foraging area for migratory birds. It supports an important tourist industry and the diverse fauna here, such as mussels, pectinids and fishes, are extracted by divers from artisanal fisheries and favored as “delicatessen” foods. The ecotonal characteristics of the macrobenthos assemblages are well known (Boschi & Fenocchi, 1972; Orensanz, 1986;

Zaixso, 1996a; Zaixso *et al.*, 1998), and the San José Gulf is considered to be an important reservoir of biodiversity. For these reasons the government established the area as a provincial wildlife reserve. This has required considerable negotiation between different interests.

The present contribution is the first focusing on polychaete associations in the Gulf. Previous papers have described macrobenthos in general (Escofet *et al.*, 1979; Zaixso *et al.*, 1998) or specifically examined mussels or tehuelche scallop assemblages (Bala, 1989; Ciocco, 1985; Zaixso, 1996b, 1997). Additional studies have described benthic communities in the nearby San Matías and Nuevo Gulfs (Escofet *et al.*, 1978; Carriquiriborde *et al.*, 1983; Varela, 1985). All these papers provide the names of dominant polychaete species only.

Comparable information on polychaete habitat types and associated dominant species is rare for South Atlantic coasts and virtually non-existent for the sublittoral areas of north Argentine Patagonia Gulfs.

One of the main objectives of this paper is to improve the inventory of polychaetes for the biodiversity reservoir of the San José Gulf and to delimit polychaete distribution patterns based on depth, temperature, sediment type and the abundance of more important bivalve filter feeders and seaweeds, as elucidated by Indicator Species Analysis and Canonical Correspondence Analysis. Combining these analytical techniques is an objective and informative procedure for delineating assemblages that respond differentially to a set of complex environmental variables (Zaixso *et al.*, 1998).

Material and Methods

1. Study area

San José Gulf is located in the northern part of Península Valdés (42° 14' to 42° 26' S; 64° 02' to 64° 36' W) on the Atlantic coast of South America (Chubut province, Argentina) (Fig. 1). It is a nearly rectangular gulf, 43 km long and 20 km wide. The gulf has an average depth of 30 m and a maximum depth of 85 m. Outside the gulf entrance the depth increases abruptly to 200 m whilst inside it presents a patchy distribution of sublittoral substrates such as fine sand, pebbles and rocks (Zaixso, 1997).

Tidal currents are the most important water movements, in particular near the opening of the gulf. The regime is semi-diurnal, ranging from 4 to 7 m. San José Gulf area is situated in the arid Patagonia region, characterized by low and irregular rain regimes (173 mm per year) and strong, frequent winds. The coastal area is characterised by rock outcrops of easily eroded materials like marine sedimentites, sandstones, tuffs and siltstones (Haller, 1981). The average surface water temperature is 13.5 °C, ranging between 9.8 °C (August – September) and 16.5 °C (February). The average surface salinity is 33.8. The spring phytoplankton bloom starts in early October with a second smaller bloom in late February. The mean chlorophyll *a* concentration is 0.5 mg · m⁻³ and primary production is limited by nitrate availability (Charpy & Charpy, 1977; Charpy-Roubaud *et al.*, 1982).

2. Sampling techniques and treatment

During a two-month cruise with the R/V 'Austral' in the San José Gulf and adjacent areas (September and October, 1984), 110 bottom samples were taken. Samples were obtained with a 0.25 m² van Veen bottom grab or by divers (the same area) in near-shore areas. As soon as the grab was on board, the water was poured off carefully and a vertical cylindrical Plexiglas core subsample (10 cm deep) was taken from the grab. This sediment sample was deep-frozen for transport and storage (-20 °C). The remaining grab contents were washed through a 1 mm screen to determine polychaete composition. The residual sample was preserved in 10 %

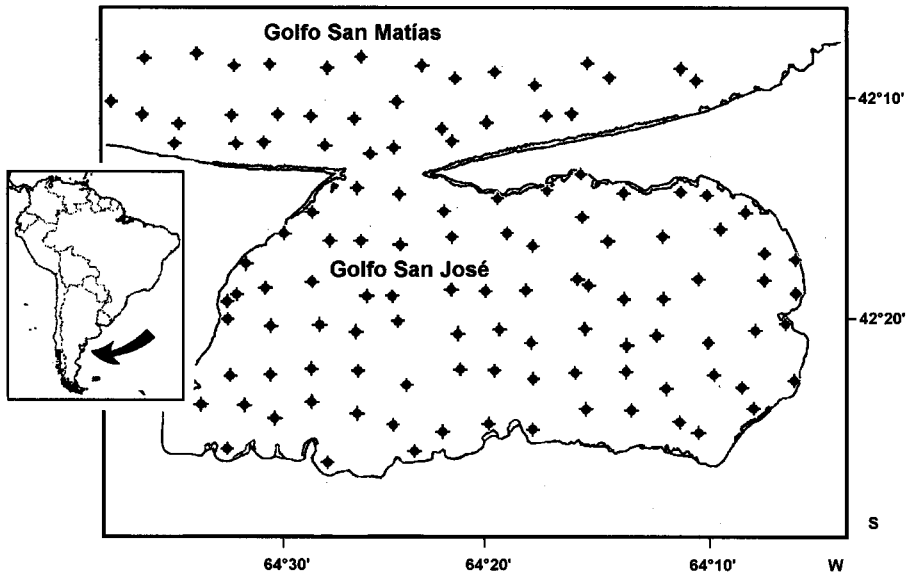


Fig. 1. San José Gulf and southern San Matías Gulf showing sampling sites.

formaldehyde for subsequent laboratory analysis. Polychaetes were counted and identified to species level as far as possible and feeding habits recorded (Dauer *et al.*, 1981; Escofet, 1983; Monro, 1930; Hartmann, 1953, 1966; Wesenberg-Lund, 1962; Hartmann-Schröder & Hartmann, 1965; Fauchald, 1976; Fauchald & Jumars, 1979; Kudenov, 1977; Orensanz, 1972, 1973a, b, 1974a, b, 1975, 1990). Bivalves and seaweeds were also counted and identified. The total density per square metre of *Chlamys tehuélcha* and *Chlamys patagonica* are given in Zaixso (1996b), the total density of *Aulacomya atra atra* in Zaixso (1999) and relative abundance of *Ulva* sp. in Boraso *et al.* (1999). The averages and standard deviations of these three biotic variables are given in Tables 1 and 2.

Based on the grain-size frequency distribution, including the fraction $< 50 \mu\text{m}$, the median grain size was determined by dry sieving. Particle-size distribution was expressed as median grain size. These data are summarized in Fig. 2 and presented as a contour map. Sorting coefficients and asymmetric coefficient were determined following Trask *et al.* (1932). In each sampling site, depth and bottom temperature were recorded (Figs. 3, 4). Figures 2, 3 and 4 were generated using the surface mapping system Surfer version 5.0 (Golden Software, Golden, CO, U.S.A.).

Table 1. Maximum and minimum values, averages and standard deviations (SD) of abiotic and biotic variables.

variable	max.	min.	average	SD
depth [m]	185.2	0.0	49.7	42.27
temperature [°C]	9.90	9.00	9.41	0.28
median grain size [μm]	8 000.00	41.80	958.05	1 994.59
sorting coefficient [index]	1.20	0.10	0.62	0.26
<i>Aulacomya a. atra</i> density [indiv. $\cdot \text{m}^{-2}$]	220.00	0.00	7.00	27.13
<i>Chlamys tehuélcha</i> density [indiv. $\cdot \text{m}^{-2}$]	28.00	0.00	1.24	3.84
<i>Chlamys patagonica</i> density [indiv. $\cdot \text{m}^{-2}$]	44.00	0.00	2.22	7.19
<i>Ulva</i> sp. [relative abundance]	2	0	0.22	0.58

Table 2. Averages and standard deviations (SD) of abiotic and biotic variables for each polychaete assemblages (TWINSPAN results).

	A	B	C	D	E
depth [m]	48.4 (20.54)	55.8 (52.96)	42.8 (32.73)	36.0 (34.00)	36.1 (27.23)
sorting coefficient [index]	0.75 (0.23)	0.59 (0.29)	0.64 (0.19)	0.30 (0.10)	0.57 (0.23)
<i>Aulacomya a. atra</i> density [indiv. · m ⁻²]	59.33 (85.33)	7.02 (18.70)	1.30 (6.51)	20.00 (20.00)	0.00
<i>Chlamys tehuelcha</i> density [indiv. · m ⁻²]	3.33 (5.84)	1.69 (5.16)	0.78 (1.79)	2.00 (2.00)	0.00
<i>Ulva</i> sp. [relative abundance]	0.0	0.40 (0.74)	0.11 (0.43)	0.50 (0.50)	0.00

3. Analysis of data

Two-way Indicator Species Analysis (TWINSPAN; Hill, 1979), a divisive classification method based on correspondence analysis, was used to define species assemblages. The analysis was based on presence or absence of species in samples. The accepted level of significance was 0.05.

CCA, a direct-gradient method (ter Braak & Verdonschot, 1995), was used to explore relationships between polychaete distributions and biotic and abiotic factors. In CCA, axes are selected as linear combinations of environmental variables that maximize the dispersion of species scores, so species are related directly to a set of biotic and abiotic factors. This ordination analysis was performed using the computer program CANOCO 3.1 (ter Braak, 1990). Forward selection of environmental and biotic variables and Monte Carlo permutations were used to identify a subset of the measured variables that exert significant and independent influences on the benthic polychaete distributions. Abiotic and biotic variables data were not transformed and presented low variance inflation factors (< 2).

The abiotic variables included in CCA analysis were: depth (dep); median grain size (mgs); sorting coefficient (sco) and bottom temperature (tem). The biotic variables were abundance of the ribbed mussel *Aulaco-*

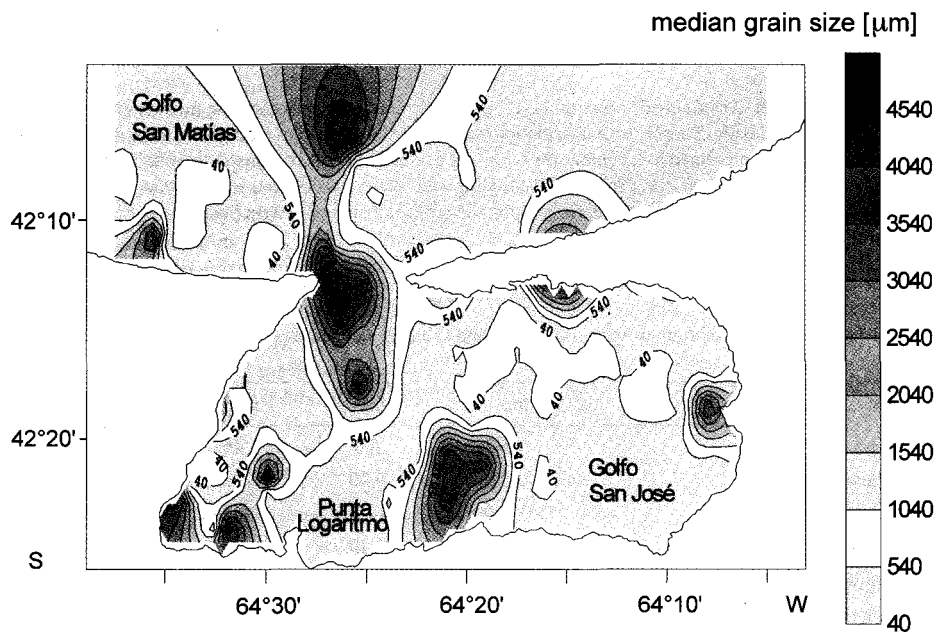


Fig. 2. Sediment distribution in San José Gulf and southern San Matías Gulf, based on median grain size (µm).

mya atra atra (Molina) (Aul); abundance of the scallops *Chlamys tehuelcha* (d'Orbigny) (Cte) and *Chlamys patagonica* (King) (Cpa) as individuals per square metre, and relative abundance of the benthic seaweed *Ulva* sp. (Ulv) divided in three classes: 0: scarce; 1: frequent; 2: abundant.

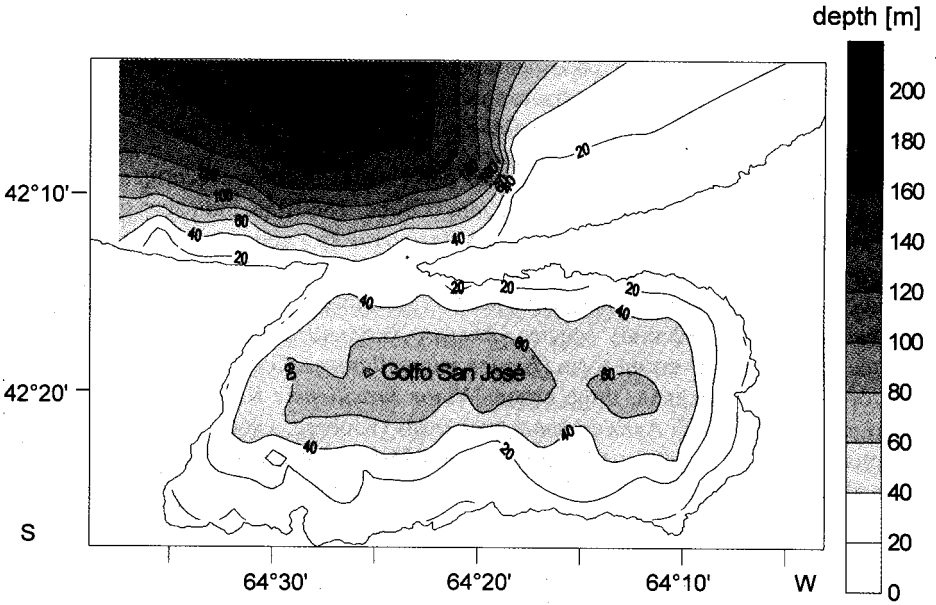


Fig. 3. San José Gulf and southern San Matías Gulf bathymetry. Depth in metres below the average low tidal level.

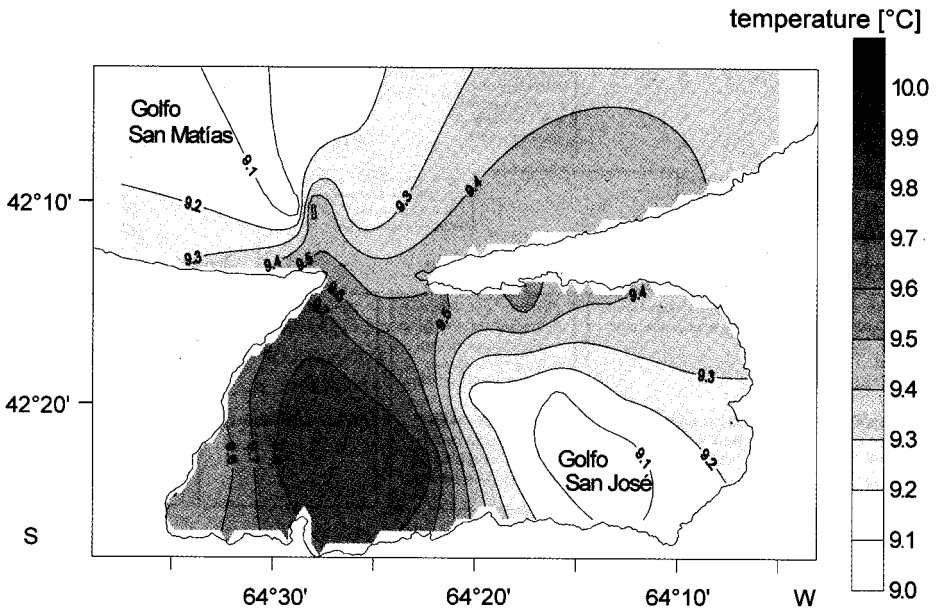


Fig. 4. San José Gulf and southern San Matías Gulf bottom temperatures during October [°C].

Results

1. Distribution of benthic polychaete assemblages in San José Gulf

Five sample groups (A, B, C, D, E) were identified (Fig. 5) using TWINSpan by including 110 samples and 73 polychaete species in the analysis and limiting the classification to major TWINSpan divisions (levels 1–4).

Group A (12 species) presents two errant polychaetes [*Eunice argentinensis* (Treadwell, 1929) and *Syllis (Typosyllis) variegata* (Grube, 1860)] as indicator species, two associated sedentary species (*Rhodine* sp.; *Raricirrus* sp.) and one errant (*Halosydna patagonica* Kinberg, 1855) form. Group B (51 species) contains two errant polychaetes as indicator species (*Harmothoe maguellanica* McIntosh, 1885; *Eunice argentinensis*) and two associated sedentary species [*Pherusa kerguelarum* (Grube, 1878); *Petaloproctus* sp. 3] and one errant form (*Eunice maguellanica*). Group C (60 species) consists of five indicator taxa, three errant [*Ninoe brasiliensis* Kinberg, 1865; *Glycera americana* Leidy, 1855; *Aglaophamus praetiosus* (Kinberg, 1866)] and two sedentary polychaetes [*Petaloproctus tenuis borealis* Arwidsson, 1911 and *Notomastus (Clistomastus)* aff. *luridus* Verrill, 1873]. Associated species include three sedentary [*Scoloplos cirratus*, *Clymenella minor*, *Cerathocephale* sp., *Arcatama proboscidata*]

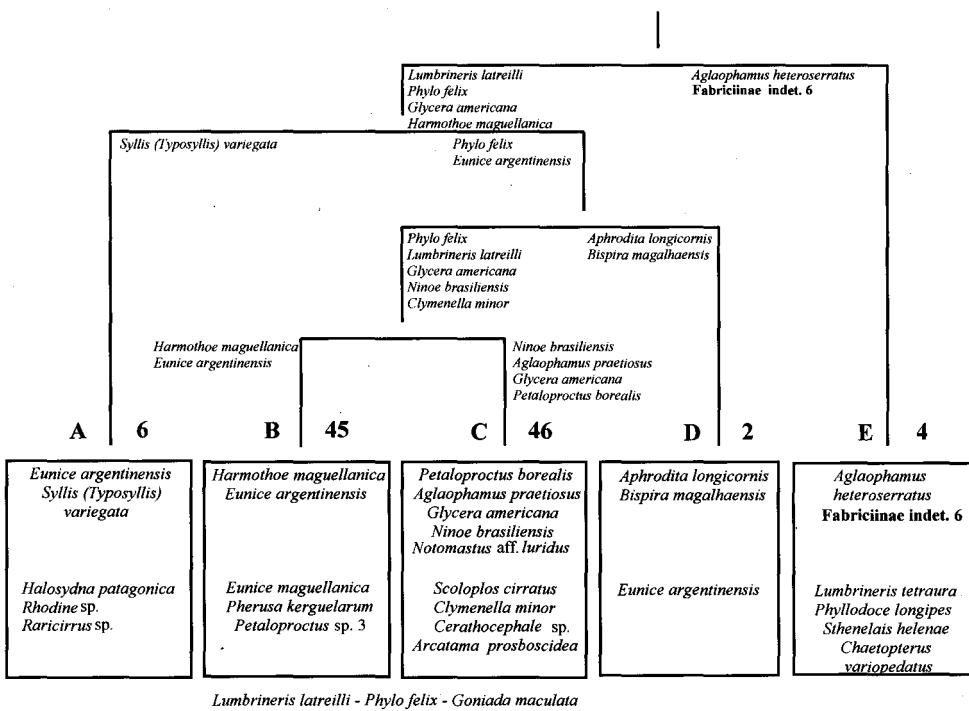


Fig. 5. Polychaete assemblages (TWINSpan results). Indicator species determined at each dichotomy are shown. The assemblages were characterized by their name (letter) and the sample units (number), indicator species and preferential species. Below the B-C groups the non-preferential species are indicated.

Table 3. Polychaete species components of TWINSPAN groups. The values express the presence of the species in TWINSPAN assemblages (A, B, C, D, E). * preferential species, ** indicator species.

species	family	TWINSPAN groups					abbrev.
		A	B	C	D	E	
1 <i>Syllis (Typosyllis) variegata</i> (Grube, 1860)	Syllidae	3*					Tva
2 <i>Raricirrus</i> sp.	Cirratulidae	2**					Rar
3 <i>Halosydna patagonica</i> Kinberg, 1855	Polynoidae	2**	6				Hpa
4 <i>Harmothoe maguellanica</i> (McIntosh, 1885)	Polynoidae	3	25*	6			Hma
5 <i>Rhodine</i> sp.	Maldanidae	2**	4	1			Rho
6 <i>Neoleprea</i> sp.	Terebellidae	1	2	1			Neo
7 <i>Ceratocephale</i> sp.	Nereidae	1	2	10**			Cer
8 <i>Pholoe</i> sp.	Sigalionidae	1	9	2			Pho
9 <i>Eunice argentinensis</i> (Treadwell, 1929)	Eunicidae	3*	14*	6	1**		Ear
10 <i>Chaetopterus</i> aff. <i>variopedatus</i> (Ronier, 1804)	Chaetopteridae	1	7	1	1**		Cva
11 <i>Therebellides stroemi kerguelensis</i> McIntosh, 1885	Terebellidae	1		3			Tke
12 <i>Phyllodoce longipes</i> (Kinberg, 1866)	Phyllodocidae	1			1**		Plo
13 <i>Eteone</i> sp.	Phyllodocidae		2				Ete
14 <i>Notocirrus virginis</i> (Kinberg, 1865)	Arabellidae		2				Nvi
15 <i>Timarete</i> sp.	Cirratulidae		5				Tim
16 <i>Petaloproctus</i> sp. 3	Maldanidae		9**				Pp3
17 <i>Lumbrineris latreilli</i> Audouin & Milne Edwards, 1834	Lumbrineridae		20	17			Lla
18 <i>Eunice maguellanica</i> McIntosh, 1885	Eunicidae		19**	6			Ema
19 <i>Pherusa kerguelarum</i> (Grube, 1878)	Flabelligeridae		14**	4			Pke
20 <i>Phylofelix</i> Kinberg, 1866	Orbinidae		13	22			Pfe
21 <i>Goniada maculata</i> Oersted, 1843	Goniadidae		10	13			Gma
22 <i>Euclymene grossa</i> (Baird, 1873)	Maldanidae		8	4			Egr
23 <i>Clymenella minor</i> Arwidsson, 1911	Maldanidae		7	17**			Cmi
24 <i>Laonereis</i> sp.	Nereidae		5	1			Lae
25 <i>Scoloplos (Leodamas) cirratus</i> (Ehlers, 1897)	Orbinidae		6	11**			Sci
26 <i>Dreilonereis falcata</i> Moore, 1811	Arabellidae		4	1			Dfa
27 <i>Notomastus (C.)</i> aff. <i>luridus</i> Verrill, 1873	Capitellidae		4	16*			Clu
28 <i>Arcatama proboscidea</i> Malmgren, 1866	Terebellidae		4	12**			Arr
29 <i>Steggoa</i> sp.	Phyllodocidae		2	1			Ste
30 <i>Gruvignella</i> sp.	Ampharetidae		2	5			Gru
31 <i>Eunoe opalina</i> Kinberg, 1855	Polynoidae		3	2			Eun
32 <i>Cistenides ehlersi</i> (Hessle, 1917)	Pectinariidae		3	2			Ceh
33 <i>Platynereis australis magalhaensis</i> Kinberg, 1866	Nereidae		3	2			Pma
34 <i>Kimbergonuphis dorsalis</i> (Ehlers, 1897)	Onuphidae		3	1			Kor
35 <i>Sthenelais tehuelcha</i> Ichazo, 1985	Sigalionidae		3	2			Shu
36 <i>Phyllochaetopterus</i> aff. <i>socialis</i> Claparede, 1870	Chaetopteridae		2	1			Pso
37 <i>Petaloproctus</i> sp. 2	Maldanidae		2	1			Pp2
38 Serpulidae indet.			2	1			Pla
39 <i>Pilargis</i> sp.	Pilargiidae		2	1			Pil
40 <i>Lanice flabelum</i> (Baird, 1865)	Terebellidae		2	2			Lfl
41 <i>Aeonides</i> sp.	Spionidae		2	4			Aeo
42 <i>Petaloproctus tenuis borealis</i> Arwidsson, 1911	Maldanidae		1	16*			Pbo
43 <i>Eutelepus</i> sp. 1	Terebellidae		1	2			Ed1

species	family	TWINSPAN groups					abbrev.
		A	B	C	D	E	
44 <i>Naireneis</i> sp.	Orbiniidae	1	3				Nai
45 Sabellidae indet. 5		1	2				Sd5
46 <i>Owenia</i> sp.	Owenidae	1	3				Owe
47 Sabellidae indet. 3		1	3				Sd3
48 <i>Euthelepus</i> sp. 2	Terebellidae	1	1				Ed2
49 <i>Proceraea</i> sp.	Syllidae	1	1				Pro
50 Sabellidae indet. 4		1	1				Sd4
51 <i>Glyceria americana</i> Leidy, 1855	Glyceridae	7	21*	1			Gam
52 <i>Aphrodita longicornis</i> Kinberg, 1855	Afroditidae	1	2	2*			Alo
53 <i>Aglaophamus praetiosus</i> (Kinberg, 1866)	Nephtyidae	6	18*	1			Apr
54 <i>Aglaophamus heteroserratus</i> Hartmann-Schröder, 1965	Nephtyidae	3	3	2*			Ahe
55 <i>Bispira magalhaensis</i> (Kinberg, 1867)	Sabellidae	4		2*			Bma
56 <i>Ophioglycera eximia</i> (Ehlers, 1900)	Glyceridae	1					Oex
57 <i>Schistomeringos rudolphi</i> (Delle Chiaje, 1828)	Dorvilleidae	1					Sru
58 <i>Chaetozone</i> sp.	Cirratulidae	1					Cha
59 <i>Lumbrineris cingulata</i> (Ehlers, 1897)	Lumbrineridae	1					Lci
60 <i>Piromis arenosa</i> Kinberg, 1867	Flabelligeridae	1					Par
61 Nephtyidae indet.		1					Nep
62 <i>Poecilochaetus australis</i> Nonato, 1963	Poecilochaetidae	1					Pri
63 Sigalionidae indet.		1					Ssp
64 <i>Streblosoma bairdi antarctica</i> Monro, 1936	Terebellidae	1					San
65 <i>Maldanella</i> sp.	Maldanidae		1				Mal
66 <i>Clymaldane</i> sp.	Maldanidae		1				Cly
67 <i>Polycirrus</i> sp.	Terebellidae		1				Pol
68 <i>Ninoe brasiliensis</i> Kinberg, 1865	Lumbrineridae		25*				Nbr
69 <i>Scalibregma inflatum</i> Rathke, 1843	Scalibregmidae		4				Sin
70 Sabellidae indet. 2			4				Sd2
71 Fabriciinae indet. 6	Sabellidae					2*	Fd6
72 <i>Sthenelais helenae</i> Kinberg, 1855	Sigalionidae					1**	She
73 <i>Lumbrineris tetraura</i> (Schmarda, 1861)	Lumbrineridae					1**	Lte

plos (*Leodamas*) *cirratus* Ehlers, 1897; *Clymenella minor* Arwidsson, 1911; *Arcatama proboscidea* Malmgren, 1866] and one errant form (*Ceratocephale* sp.). Group D (3 species) contains one errant polychaete as an indicator species (*Aphrodita longicornis* Kinberg, 1855) and one sedentary (*Bispira magalhaensis*) form. *Eunice argentinensis* is also an associated species of this group. The fifth group (E, 7 species) consists of one errant taxon (*Aglaophamus heteroserratus* Hartmann-Schroeder, 1965) and one sedentary (Fabriciinae indet. 6) as indicator species. Associated species include three errant species [*Lumbrineris tetraura* (Schmarda, 1861); *Phyllodoce longipes* (Kinberg, 1866); *Sthenelais helenae* Kinberg, 1855] and one sedentary polychaete [*Chaetopterus* aff. *variopedatus* (Ronier, 1804)].

The distribution of polychaete assemblages (based on TWINSPAN results) and a list of the 73 species found in San José Gulf are given in Fig. 6 and in Table 3, respectively.

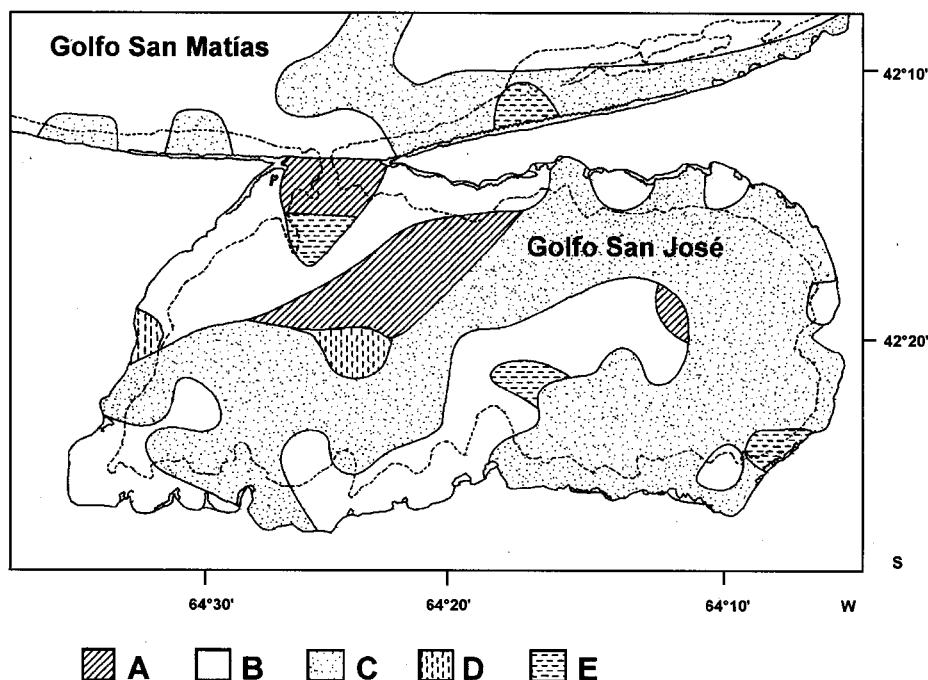


Fig. 6. Polychaete assemblages in San José Gulf and southern San Matías Gulf based on TWINSpan results.

Averages and standard deviations of abiotic and biotic variables for each polychaete assemblages (TWINSpan results) are given in Table 2.

2. Relationships between benthic polychaete distributions and environmental variables

a. Abiotic and biotic variables

The bathymetry of San José and southern San Matías Gulfs is given in Fig. 3. The deepest areas inside the gulf occur in the middle and near the opening, as well as in the San Matías Gulf.

October bottom temperatures here are shown in Fig. 4. The highest bottom temperatures were recorded along the south-west coast.

Granulometry (Fig. 2) as median grain size shows several areas containing coarse sand. Two of the largest areas occur at both sides of the opening of the Gulf and one small is in the middle of the Gulf near the south coast, in front of Punta Logaritmo.

Maximum and minimum values, averages and standard deviations of abiotic and biotic variables are given in Table 1.

b. CCA analysis between polychaete presence data and relationships with the environmental variables

The results of CCA, after forward selection of environmental variables are shown in Fig. 7. Following ter Braak & Verdonschot (1995) the length of an arrow reflects the importance of an environmental variable. Accordingly, the more important variables have longer arrows. Figure 7 indicates that the most important variable is depth. The triplot shows a similar distribution of samples and species along the depth gradient. The abundances of *Aulacomya atra atra* and *Chlamys tehuelcha* are important as well. The relative abundance of *Ulv* sp. and the sorting coefficient of sediments are less impor-

Table 4. Summary of CCA ordination.

axes	1	2	3	4
Eigenvalues	0.238	0.203	0.175	0.135
species-environment correlations	0.796	0.752	0.736	0.620
cumulative percentage variance of species data	1.800	3.400	4.700	5.700
cumulative percentage variance of species-environment relation	28.100	52.100	72.800	88.700
sum of all canonical Eigenvalues		0.846		
sum of all unconstrained Eigenvalues		13.065		

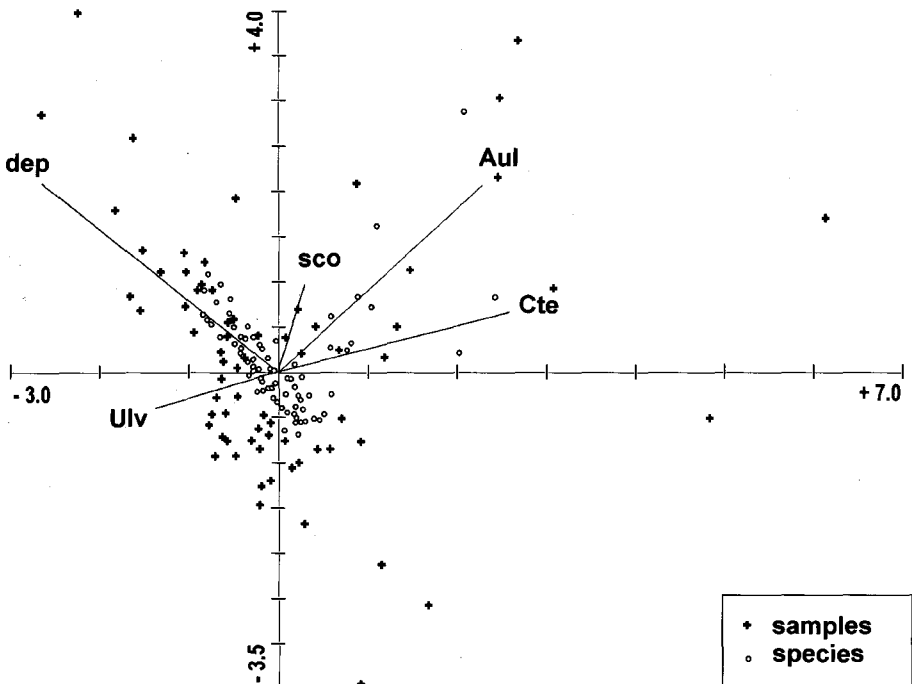


Fig. 7. Ordination triplot obtained from Canonical Correspondence Analysis of samples, species and environmental variables: dep = depth [m]; Aul = *Aulacomya atra atra* density [$\text{indiv.} \cdot \text{m}^{-2}$]; Cte = *Chlamys tehuelcha* density [$\text{indiv.} \cdot \text{m}^{-2}$]; Ulv = *Ulv* sp. (relative abundance); sco = sorting coefficient of sediments (index).

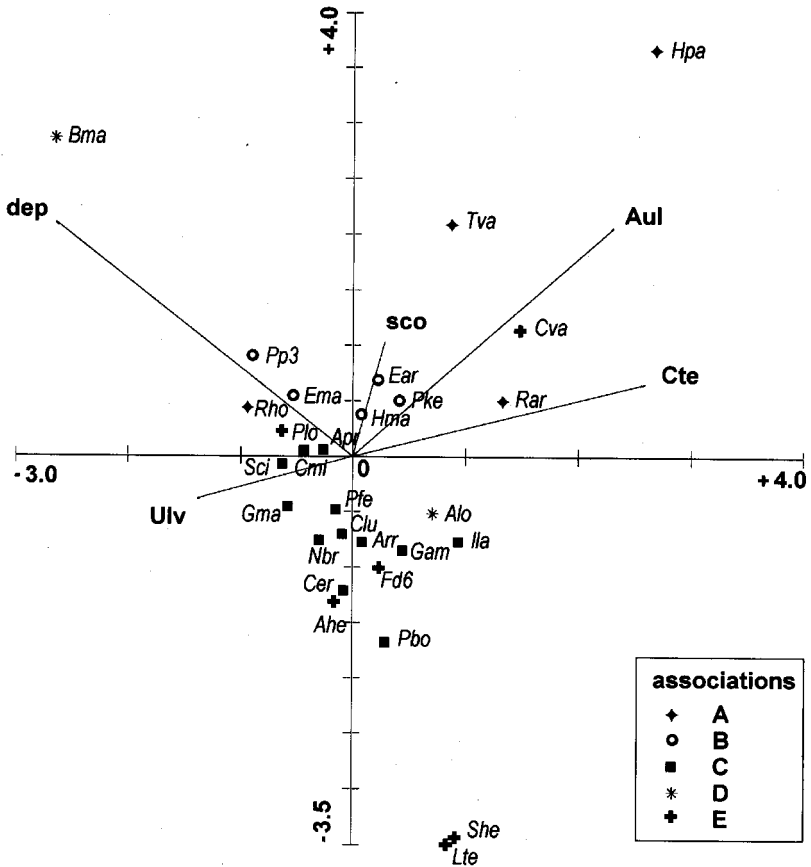


Fig. 8. Ordination biplot obtained from Canonical Correspondence Analysis of environmental variables and indicator and preferential species (TWINSPAN results). Environmental variables: dep = depth [m]; Aul = *Aulacomya atra atra* density [indiv. · m⁻²]; Cte = *Chlamys tehuelcha* density [indiv. · m⁻²]; Ulv = *Ulva* sp. (relative abundance); sco = sorting coefficient of sediments (index). Species: Tva = *Syllis (Typosyllis) variegata*; Rar = *Rarecirrus* sp.; Rho = *Rhodine* sp.; Hpa = *Halosydna patagonica*; Hma = *Harmothoe maguellanica*; Ear = *Eunice argentinensis*; Ema = *Eunice maguellanica*; Pke = *Perusa kerguelarum*; Pp3 = *Petaloproctus* sp.3; Pbo = *Petaloproctus borealis*; Apr = *Aglaophamus praetiosus*; Gam = *Glycera americana*; Nbr = *Ninoe brasiliensis*; Clu = *Notomastus* aff. *luridus*; Sci = *Scoloplos cirratus*; Cmi = *Clymenella minor*; Cer = *Ceratocephale* sp.; Arr = *Arcatama prosboscoidea*; Alo = *Aphrodita longicornis*; Bma = *Bispira magalhaensis*; Ahe = *Aglaophamus heteroserratus*; Fd6 = *Fabriciinae* indet. 6; Lte = *Lumbrineris tetraura*; Plo = *Phyllodoce longipes*; She = *Sthenelais helenae*; Cva = *Chaetopterus variopedatus*.

tant. Median grain size, bottom temperature and the abundance of *Chlamys patagonica* were not selected by the CCA analysis.

Axes 1, 2 and 3 explain 28.1 %, 24 % and 20.7, respectively, of the variance of species-environment relation (Table 4). The ordination shows that the depth ($r = -0.539$; $|r| = 0.436$) and the abundance of *Aulacomya a. atra* ($r = 0.468$; $|r| = 0.432$) are related to axes 1 and 2 and that *Chlamys tehuelcha* ($r = 0.527$) is related to axis 1. Moreover, the relative abundance of *Ulva* sp. ($r = -0.576$) is related to axis 3 and the sorting coefficient of sediments ($r = 0.591$) to axis 4 (Table 5).

Table 5. Weighted correlation matrix of environmental variables (Inter set correlations of environmental variables with axes, forward selection). dep: depth; Aul: density of *Aulacomya atra atra* per square metre; Cte: density of *Chlamys tehuelcha* per square metre; sco: sorting coefficient of sediment; Ulv: relative abundance of *Ulva* sp.

	species axis 1	species axis 2	species axis 3	species axis 4
dep	-0.539	0.436	-0.084	-0.300
Aul	0.468	0.432	0.329	0.170
Cte	0.527	0.139	-0.187	-0.190
sco	0.060	0.203	-0.312	0.591
Ulv	-0.282	-0.084	-0.576	0.180

The CCA biplot species-environmental variables (Fig. 8) show that four sample groups (A, B, C, E) selected by TWINSpan analysis are distributed along depth, sediment sorting and mussel and seaweed abundance gradients. The '*Syllis (Typosyllis) variegata-Eunice argentinensis*' assemblage (A) is related to moderate depth, poorly sorted sediments, high density of mussels and scallops and low abundance of seaweeds. The '*Harmothoe maguellanica - Eunice argentinensis*' assemblage (B) reflects moderate to shallow depths, moderately sorted sediments, moderate density of mussels and scallops and low abundance of seaweeds. The '*Ninoe brasiliensis - Glycera americana*' assemblages (C) is related to moderate to low depths, moderately to well sorted sediments, low density of bivalves and moderate to high abundances of seaweeds. The '*Aglaophamus heteroserratus-Fabriciinae* indet. 6' assemblage (E) belongs to the lowest depths, very well-sorted sediments, low density of bivalves and high abundance of seaweeds.

Aglaophamus praetiosus, *Harmothoe maguellanica* and *Clymenella minor* are projected close to the origin of the axes. This means that these species are ubiquitous and distributed widely over all the sampling sites.

Discussion

This paper attempts to explain the distribution of polychaete assemblages based on sedimentary characteristics, depth, temperature, mussel density and seaweed abundance.

Based on patterns derived from TWINSpan and CCA analyses four different polychaete assemblages were identified in San José Gulf and nearby areas. The assemblages clearly reflected depth and bivalve density gradients and to a lesser degree seaweed abundance and sediment sorting coefficient.

Earlier studies (Boschi & Fenocchi, 1972; Orensanz, 1986) hypothesized that benthic assemblages in San José Gulf were distributed following a depth-temperature gradient. In the present study, however, temperature was not identified as an important factor. Our results agree with those observed along Chilean coasts (Carrasco & Gallardo, 1983; Carrasco *et al.*, 1988; Carrasco, 1996, 1997), where the sublittoral macrofaunal assemblages, dominated by polychaetes, are distributed along depth and sediment gradients. Similar results have been reported in the northern hemisphere (Massad & Brunel, 1979).

The selection of bivalve density as the second and third factor is probably associated with the role of bivalves in the ecosystem. Beds of filter feeding bivalves formed by the subantarctic ribbed mussel (*Aulacomya atra atra*) and the warm-temperature tehuelche

scallop (*Chlamys tehuelcha*) in San José Gulf are related to very diverse communities (Orensanz, 1986; Ciocco, 1988; Zaixso, 1997; Zaixso *et al.*, 1998), even in sedimentary substrates. These beds probably function as material processors in the San José ecosystem (Dame, 1993), moving large quantities of nutrients from the water column to the bottom sediments by biodeposition (Kautsky & Evans, 1987). Moreover, if they not are harvested, their biomass contributes to increasing organic matter in the area (Kaspar *et al.*, 1985). Tokeschi (1995), studying a littoral rocky coast of Perú, found that mussel bed environments on hard substrata are a major habitat for polychaetes, especially errant forms.

The selection of *Ulva* sp. abundance as the fourth factor is probably associated with the presence of additional microhabitats, food resources and shelter from both physical factors and predation.

The predominantly rock and poorly sorted coarse sand (> 1 000 µm) areas of the Gulf, located between 0–185 m depth, accommodate the 'Harmothoe-Eunice' or 'Syllis-Eunice' assemblages covarying with bivalve density (*A. atra atra* and *Chlamys tehuelcha*) and seaweed abundance (*Ulva* sp.).

The 'Harmothoe-Eunice' association was related with moderate density of mussels and *Ulva* sp. abundance. This association was clearly characterized by three errant-carnivore-pursuer forms (*Harmothoe maguellanica*, *Eunice maguellanica*, *Eunice argentinensis*) and three sedentary-sub-surface-deposit-feeders [*Pherusa kerguelarum*, *Petaloproctus* sp.3, *Euclymene grossa* (Baird, 1863)].

The 'Syllis-Eunice' association was related to high densities of mussels and very low *Ulva* sp. abundance. This association was characterized by one errant-surface-deposit-feeder [*Syllis* (*T.*) *variegatus*], two errant-carnivore-pursuer forms (*Eunice argentinensis*, *Halosydna patagonica*) and two sedentary-sub-surface-deposit-feeders (*Rhodine* sp., *Raricirrus* sp.). *Eunice argentinensis*, a characteristic species of the Argentine province, is an indicator species in both assemblages. This suggests that it is commonly present and is not influenced by mussel density.

Based on a previous paper (Zaixso *et al.*, 1998) I found that these two polychaete assemblages belong to the benthic community with the ophiurid *Ophiactis asperula* (Philippi), the echinoid *Arbacia dufresnei* Blainville and the mussels *Aulacomya a. atra*, *Chlamys tehuelcha* and *Chlamys patagonica* as indicator species. These assemblages are probably closely related to a community reported for neighbouring areas like the east coast of San Matías Gulf, between 0–30 m on rock or coarse sand (Escofet *et al.*, 1978), and Nuevo Gulf, coarse sand belt (groups AI and AII) between 0–70 m (Carriquiriborde *et al.*, 1983; Varela, 1985).

Gulf areas with well-sorted medium-fine sand and silt (< 1 000 µm) at 0–60 m depth, with moderate abundances of mussels and moderate to high abundance of *Ulva* sp. support the 'Ninno-Glycera' association. It was characterized by two sedentary-sub-surface-deposit-feeders (*Notomastus* aff. (*C.*) *luridus*; *Petaloproctus borealis*) and three errant-carnivore-pursuers (*Ninno brasiliensis*, *Glycera americana*, *Aglaophamus praetiosus*).

Furthermore, this soft-bottom polychaete assemblage has the bivalve *Corbula lyoni* Pilsbry and the crustaceans Cirolanidae (indet.) and *Ampelisca* sp. as indicator species (Zaixso *et al.*, 1998).

Gulf areas with very well-sorted medium-fine sand and silt (< 1 000 µm) at 0–60 m and very low mussel densities support the polychaete assemblage 'Aglaophamus heteroserratus-Fabriciinae indet. 6'. This assemblage was characterized by one errant-carnivore-pursuer and one filter feeder. The crustaceans *Macrochiridotea stebbingi* Ohlin,

1901, *Monoculopsis valentini* Stebbing, 1914 and the bivalve *Tellina gibber* Ihering are the most common species in this macrobenthic community.

Based on tidal currents inside the gulf (Palma & Serman, 1975), the '*Syllis-Eunice*' and the '*Aglaphamus heteroserratus*-Fabriciinae indet. 6' assemblages are commonly distributed in the areas of highest tidal currents. In contrast, the '*Harmothoe-Eunice*' assemblage occurs in moderate tidal current velocities and the '*Ninoe-Glycera*' assemblage in the lowest tidal current velocities of the gulf. The hydrodynamic regime probably plays an important role for the polychaete fauna by influencing sediment properties (Creutzberg *et al.*, 1984).

Summary

Ecological information on polychaete habitat types and associated dominant species is rare in South Atlantic coastal areas and it is necessary to increase our knowledge of faunal biodiversity here.

One of the main objectives of this paper was to delimit distribution patterns of benthic polychaete assemblages in San José Gulf based on depth, temperature, sediment type, the density of key bivalve filter feeders and seaweed abundance; this was done by Indicator Species Analysis and Canonical Correspondence Analysis. I found four different polychaete assemblages in the San José Gulf and nearby areas, distributed according to depth, bivalve density gradients and to a lesser degree to seaweed abundance and sorting coefficient. These patterns were elucidated with TWINSpan and CCA.

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