Assemblage of benthic macrofauna in the aggregates of the tubiculous worm *Phyllochaetopterus socialis* in the Mar del Plata harbour, Argentina

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The assemblage and the temporal changes of benthic macrofauna inhabiting the Phyllochaetopterus socialis *(Polychaeta: Chaetopteridae) aggregates were analysed during 2004 and May 2005 in the Mar del Plata harbour, Buenos Aires (Argentina). Species composition, abundance, richness and diversity were estimated from monthly or bimonthly samples obtained by SCUBA diving. Multivariate (MDS) and SIMPER analyses were applied to analyse the structure of benthic communities. In the mats, a total of 57 species (invertebrates and chordates) belonging to 11 phyla were associated to* P. socialis: *crustaceans and molluscs were the most abundant species and crustaceans and polychaetes were the most diverse groups (14 and 11 species richness, respectively). The mean abundance ranged from 79.67 ± 57.47 ind/250 ml to 718.75 ind/250 ml (mean $\pm$ SD). The amphipod* Monocorophium insidiosum, *the gastropod* Anachis isabellei *and the tanaidacean* Leptognathia *sp. were the most representative species in the mats. Richness and diversity in* P. socialis *aggregates were higher than in surrounding sediments. Results show significant differences among months in composition, abundance and feeding guilds of the macrofauna associated with the mats. The assemblage of benthic macrofauna with permanent and temporary organisms in* P. socialis *aggregates suggests the existence of microhabitats in the mats that provide substrate, refuges for predation and availability of food increasing richness and diversity. These results allow considering* P. socialis *as an autogenic ecosystem engineer in the Mar del Plata harbour.*

Keywords: assemblage, benthic macrofauna, aggregates, tubiculous worm, *Phyllochaetopterus socialis*, Mar del Plata harbour, Argentina

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INTRODUCTION

The biological habitat generation and the possible interactions between the organisms have been observed in a wide range of benthic marine environments (Bruno & Bertness, 2001). Animals (sedentary and sessile) and plants commonly form dense aggregations that create, modify and support a new habitat (Jones *et al.*, 1994; Jackson 1997, 2001; Bruno & Bertness, 2001) through their intricate architectonic shape. Such structures are colonized by different species looking for food and refuge against predators or physical disturbance (Obenat *et al.*, 2001) so species richness and diversity can be altered (Jones *et al.*, 1994; Bruno & Bertness, 2001). Also, they act as nursery for larval and juvenile forms (Nalesso *et al.*, 1995). Many groups can modify hard and soft bottom sites: seagrasses, mollusc valves, seaweeds, corallinaceous algae, corals and polychaetes (Laubier, 1966; Gettleson *et al.*, 1985; Nalesso *et al.*, 1995; Obenat, 2002; Gutierrez *et al.*, 2003).

Polychaete aggregates can be considered an autogenic ecosystem engineer because their physical structure enhances the availability of food resources for other species (Jones *et al.*, 1994, 1997; Crooks, 2002). The tubiculous polychaetes of the Chaetopteridae (Malmgren, 1867) family build tubes made of chitin (corneous), some bury them in sand or mud, while others attach them to hard substrates and form a biogenic structure that can alter habitats both ecologically and physically (Obenat *et al.*, 2001). Predominantly, *Phyllochaetopterus socialis* Claparède, 1870 is a little worm that builds corneous tubes with ramifications forming dense mats (aggregates) in shallow and deep waters in New Zealand, South Africa, India (including Pakistan, Ceylon, Burma and Malaya), the Mediterranean Sea, US, Mexico, Costa Rica and South America (Rioja, 1941; Fauvel, 1953; Day, 1967; Bhaud & Amouroux, 1975; Probert & Wilson, 1984; Gettleson *et al.*, 1985; Ariño, 1987; Abbiati *et al.*, 1994; Nalesso *et al.*, 1995; Dean, 1996; Obenat *et al.*, 2001). These mats can host worm densities reaching up to 100,000 worms/m² (Gilbert, 1984).

The mats of *P. socialis* are associated with hard substrata such as rocks, empty mollusc shelves and handmade hard objects (Nalesso *et al.*, 1995; Obenat *et al.*, 2001; Albano *et al.*, 2006a; Barreto *et al.*, 2007). They provide structural complexity due to their intricate arrangement of tubes acting as ecosystem engineers like other benthic organisms already mentioned. Although morphological differences in

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the host species could reflect differences in faunal assemblages, Virnstein & Howard (1987 a, b) argue that species with similar architectures have similar faunal assemblages.

The aim of this research is to describe and analyse temporal changes in the benthic macrofauna assemblage that inhabit the aggregates of the polychaeta *P. socialis* Claparède, 1870, in the anthropogenically polluted site of the Mar del Plata harbour.

MATERIALS AND METHODS

Study area

The study was carried out in the Mar del Plata harbour (38° 02′S 57° 31′30″W; Figure 1) Buenos Aires, Argentina, which is one of the most important harbours in the country due to naval traffic, commercial trade and size. The environmental conditions correspond to those of a polluted site having low water turbidity as well as low salinity, dissolved oxygen and pH (Rivero *et al.*, 2005). Industrial and sewage effluents contribute to the increment of organic matter (Bastida *et al.*, 1971). The harbour area is limited by two artificial breakwaters (north and south) mainly composed of orthoquartzite blocks, and has an approximately 300-m wide mouth. Mean water depth is around 5 m, ranging between 3 and 10 m.

P. socialis in southern South America

Phyllochaetopterus socialis was recorded for the first time in South America in 1901, off the Argentinian coast at 100 m depth (Buenos Aires Province shelf waters), on dark grey mud and described as the sub-species *Phyllochaetopterus socialis platensis* (Hartman, 1953). Beyond these records, *P. socialis* was cited for the region by Rullier & Amoureux (1979), Pastor de Ward (2000), Obenat *et al.* (2001), Capítoli (2002), Giberto (2003) and Giberto *et al.* (2004). The presence of *P. socialis* aggregates in the Mar del Plata harbour was recorded for the first time by Albano *et al.* (2006b). It is possible that the registers of *P. pictus* published by Hartmann-Schröder (1983) could correspond to the same

Fig. 1. *Phyllochaetopterus socialis*. Mar del Plata harbour (Argentina) and the sampling site (■).

species (Orensanz, personal communication). Besides, *P. socialis* was reported as fishery bycatch of the 'caracol fino' *Zidona dufresnei* (Donovan, 1823) in the north-eastern zone of the Uruguayan continental shelf (34°S and 35°W) (Riestra *et al.*, 2006). Likewise, tubes of an indeterminate species of *Phyllochaetopterus* registered during the fishery bycatch of scallop *Zygochlamys patagonica* (King & Broderip, 1832) in Reclutas Banks (39°S and 39°30′S) near the continental slope (Schejter, 2005), could probably be assigned to *P. socialis*. In recent years, several studies of the aggregates were performed in the rocky shore of São Sebastiao and Espírito Santo, Brazil (Nalesso *et al.*, 1995; Barreto *et al.*, 2007), in estuarine areas of the Rio de la Plata (Obenat *et al.*, 2001) and in the Mar del Plata harbour (Albano *et al.*, 2006a).

Sampling

Depending on weather conditions, during 2004 and in May 2005, monthly or bimonthly samples were collected near the mouth of the north breakwater in the Mar del Plata harbour. Three samples were randomly selected by SCUBA diving. Each mat was kept in plastic bags *in situ* underwater and was then fixed at the laboratory with formaldehyde solution (4%). After that, water column displacement was performed in order to estimate the volume of the mats. Polychaete tubes were carefully separated and washed through a 0.35 mm square mesh sieve and the retained organisms were preserved with alcohol (70%). Macrofauna was separated, identified at the lowest possible taxonomic level and counted under 20× binocular microscope for abundance estimation (number of individuals (mean $\pm$ SD)/250 ml of displacement volume), richness and diversity.

Statistical analysis

Both null hypothesis of no difference on the mean abundance (ind/250 ml) of vagile macrofauna and the mean abundance of the associated biota among the sampling period (February, March, April, June, August, October and December, 2004; May 2005) were evaluated by a one-way ANOVA. Comparisons among means were performed using an *a posteriori* Tukey test (Zar, 1999).

To assess the relative importance of sessile and colonial associated biota (sponges, hydrozoans, sea anemones, bryozoans and tunicates) along the sampled seasons, qualitative dominance (Bouderesque, 1971) was used considering their frequency of occurrence (%). This author defined five categories: occasional (0–20%), scarce (21–40%), common (41–60%), abundant (61–80%) and very abundant (81–100%).

Species richness (*S*, total number of species) was estimated performing a non-parametric estimator, and also Shannon–Wiener (H' $\log_2$), Simpson (D, $1/1 - \sum \mathrm{pi}^2$), and Evenness (J', H'/H_{MAX}) indices were calculated (Krebs, 1989). A one-way ANOVA and an *a posteriori* Tukey test (Zar, 1999) were developed to assess the null hypothesis of no difference of these parameters along the months.

According to feeding types, the organisms found in the mats (vagiles and sessile) were classified as deposit feeders (DF), herbivorous (HE), carnivores and/or scavengers (C/S), filter or suspension feeders (F/S) and omnivores (OM). These pre-established trophic groups were assigned following
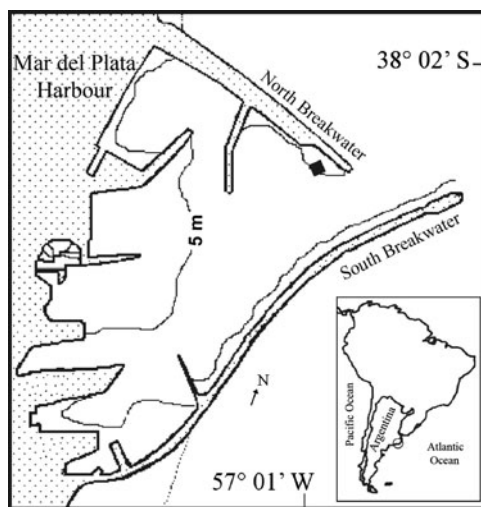
the related literature (Fauchald & Jumars, 1979; Giberto *et al.*, 2004). Crustacean decapods were excluded from the analysis due to the lack of information on their feeding modes (Spivak, personal communication). The null hypothesis of no difference between feeding modes along the sampled months was assessed using a one-way ANOVA test (Zar, 1999).

To run the different ANOVAs, data were transformed using square root when necessary to accomplish assumptions of normality and variance homoscedasticity (Zar, 1999). For all the analyses, the significance level was fixed at 0.05.

Non-parametric multivariate analyses were performed using the PRIMER v5.0 software package (Clarke & Gorley, 2001). Similarities and differences in macrofaunal communities based on species abundance (excluding sessile and colonial), species presence, and feeding types were explored using non-metric multidimensional scaling (nMDS) and analyses of similarity (ANOSIM; Clarke, 1993). In both analyses, Bray–Curtis similarity indices were calculated and when necessary, data were transformed by $\log_{10} (X + 1)$. The SIMPER procedure (similarity percentage analysis) was used to determine the percentage of dissimilarity (or similarity) of samples, and the particular taxa responsible for differences between groups (Clarke, 1993).

RESULTS

At the beginning of this study, aggregates of *P. socialis* were observed only inside the Mar del Plata harbour, in the inner area of the north breakwater, between 5 to 10 m of depth on hard and soft substrata, with a mean volume of 224.2 ml ± 124.7 (mean ± SD, N = 25).

Community composition

The community inhabiting the mats was conformed by a total richness of 57 species (invertebrates and chordates, all samples combined) belonging to 11 phyla. The total number of vagile organisms recorded during the period was 3865 in a total volume of 5065 ml; the mean volume of the aggregates was 224.2 ml ± 124.7 (mean ± SD, N = 25). Macrofaunal mean total abundance (expressed as number of individuals/250 ml (mean ± SD)) ranged from 79.67 ± 57.47 ind/250 ml in December to 718.75 ind/250 ml in March; differences along the sampling period were significant (one-way ANOVA, F = 3.841, df = 6; N = 25; P = 0.013). The Tukey test showed that March differed from all other months with the exception of August and May (Figure 2). The most abundant taxa were Crustacea (51%), Mollusca (39%) and Polychaeta (6%). Crustaceans and polychaetes were the most diverse groups with 14 and 11 species, respectively.

Mean crustacean and mollusc abundance was different among sampling periods (one-way ANOVA, F = 5.502, df = 6; N = 25; P = 0.003 and F = 3.971, df = 6; N = 25; P = 0.011, respectively) while polychaetes and all minority groups combined showed no significant differences (one-way ANOVA: F = 1.955, df = 6; N = 25; P = 0.129 and F = 2.986, df = 6; N = 25; P = 0.035 respectively). The Tukey test revealed that in March the abundance of crustaceans differed from all other months (P < 0.05) while May differed from June, October and December (P < 0.05).
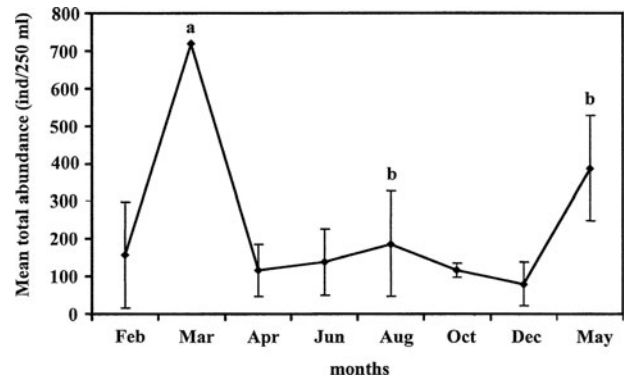

Fig. 2. *Phyllochaetopterus socialis*. Mean total abundance ± SD of the macrobenthic species along the sampling period (only ± SD was not included in March due to the lack of replicates). Different letters indicate the average values of macrofauna that were significantly different between months (P < 0.05).

Mollusc abundance differed significantly in May in relation to February and December (P < 0.05) (Figure 3).

The best represented crustacean taxa in the aggregates were Amphipoda, Tanaidaecea and Brachyura (Figure 4). Amphipods reached their maximum density in March (673.7 ± 0 ind/250 ml), and then oscillated between 136.27 ± 142.8 ind/250 ml and 0.83 ± 0 ind/250 ml during the rest of the year *Monocorophium insidiosum* (Crawford, 1937; an invasive species) being the most abundant species. The tanaidacean *Leptognathia* sp. (Bamber, personal
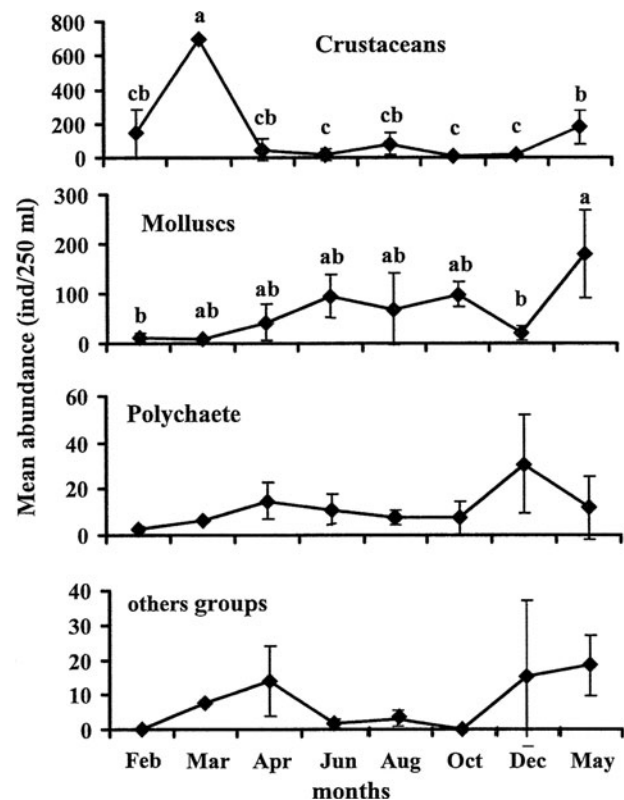

Fig. 3. *Phyllochaetopterus socialis*. Monthly variation of the most abundant taxa. Mean abundance ± SD (only ± SD was not included in March due to the lack of replicates). Different letters indicate the average values of taxa that were significantly different between months (P < 0.05).
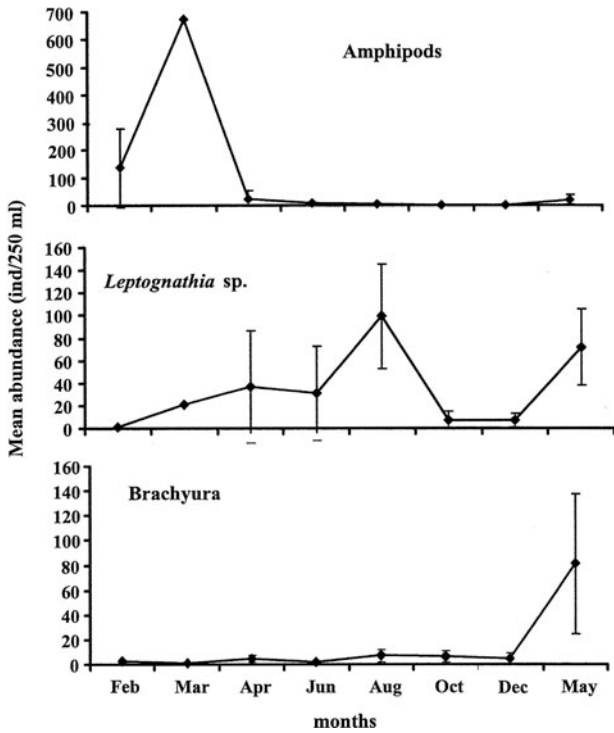
Fig. 4. *Phyllochaetopterus socialis*. Monthly variation of the most abundant crustaceans. Mean abundance ± SD (only ± SD was not included in March due to the lack of replicates). Amphipods: *Monocorophium insidiosum*, an indeterminate species of the suborder Gammaridea and *Caprella dilatata*; tanaidacea *Leptognathia* sp. and Brachyura: *Pilumnus reticulatus*, *Pyromaia tuberculata*, *Pilumnoides hassleri*, *Pelia rotunda*, *Acontholobulus schmitti*, *Halicarcinus planatus* and *Pachycheles laevidactylus*.

Fig. 5. *Phyllochaetopterus socialis*. Monthly variation of the most abundant molluscs. Mean abundance ± SD (only ± SD was not included in March due to the lack of replicates).

Fig. 6. *Phyllochaetopterus socialis*. Monthly variation of the most abundant polychaetes. Mean abundance ± SD (only ± SD was not included in March due to the lack of replicates).

communication) showed two peaks: in August (98.9 ± 46.1 ind/250 ml) and in May (75.6 ± 36.7 ind/250 ml). The mean total abundance of the infraorder Brachyura Latreille, 1802 (seven species) was constant along the period and ranged between 1.25 ± 0 ind/250 ml and 6.84 ± 5.00 ind/250 ml reaching the highest value in May (81 ± 56.5 ind/250 ml).

Among molluscs, two of the three most abundant recorded species showed a seasonality pattern around the year. The gastropod belonging to the family Buccinidae *Anachis isabellei* (d'Orbigny, 1841) showed two peaks, one in June (74.2 ± 51.5 ind/250 ml) and the other in May (64.45 ± 55.11 ind/250 ml) while *Crepidula argentina* Simone, Pastorino & Penchaszadeh, 2000 and *Crepidula aculeata* (Gmelin, 1791) peaked in October (58.62 ± 16.9; 20.7 ± 10.33 ind/250 ml) and May (67.76 ± 49.75; 25.55 ± 11.86 ind/250 ml), respectively (Figure 5). However, the abundance of both species of *Crepidula* could have been overestimated due to the difficult task of separating complete organisms and empty shells.

The most abundant polychaetes belonged to Lumbrineridae Schmarda, 1861, Serpulidae Latreille, 1825 and Polynoidae Malmgren, 1867 (Figure 6). Both species of *Lumbrineris* Blainville, 1828 attested their highest densities in December (9.6 ± 7.2 and 5.3 ± 6.1 ind/250 ml). The high serpulid *Hydroides plateni* (Kinberg, 1867) mean density was 6.2 ± 5.5 ind/250 ml in January while the polynoid *Halosydnella australis* (Kinberg, 1855) showed the highest mean abundance in May (4.6 ± 8.5 ind/250 ml).
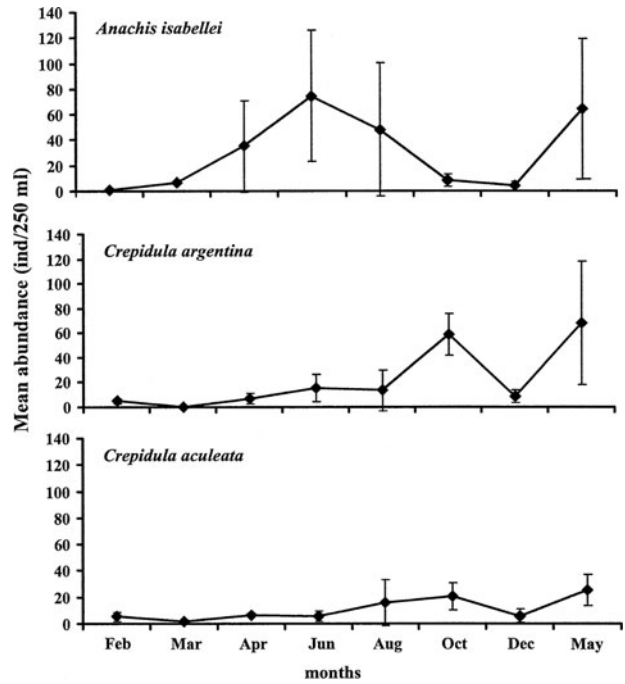
Table 1. Qualitative dominance (%) (Bouderesque, 1971) of sessile and colonial biota along the sampling period. Categories: occasional (0–20%); scarce (21–40%); common (41–60%); abundant (61–80%); very abundant (81–100%).

	Porifera	Hydrozoa	Anthozoa	Bryozoa	Tunicata
February	Very abundant	Occasional	Scarce	Very abundant	Occasional
March	Occasional	Very abundant	Very abundant	Very abundant	Occasional
April	Occasional	Occasional	Occasional	Very abundant	Occasional
June	Scarce	Common	Scarce	Very abundant	Abundant
August	Very abundant	Abundant	Very abundant	Very abundant	Occasional
October	Abundant	Common	Common	Abundant	Occasional
December	Scarce	Occasional	Very abundant	Very abundant	Scarce
May	Very abundant	Scarce	Scarce	Very abundant	Occasional

Juveniles belonging to different groups were also recorded in the aggregates. As an example, juvenile molluscs (poliplacophora and bivalvia) occurred in February, April, August and May at low densities (4 ind/250 ml and 14 ind/250 ml, respectively). Asteroidea (3 ind/250 ml) and ofiuroidea (2 ind/250 ml) were registered in May 2005. Ovigerous females of *P. hassleri* and *P. reticulatus* (Brachyura) were also observed, but they were not quantified in this study.

Among sessile organisms, Bryozoa presented the highest relative frequency. They occurred in all samples at different months (Table 1). Instead, Tunicata were occasionally found and were scarce, with the exception of June. The cnidarians (Hydrozoa and Anthozoa) were abundant and very abundant in March, August, and December while sponges were recorded as scarce or occasional in March, April, June and December, but were abundant in all other months.

Fig. 7. *Phyllochaetopterus socialis*. Mean $\pm$ SD of vagile taxa richness (S), Shannon (H'), evenness (J') and Simpson index (D) along the months. Different letters indicate the average values of indices that were significantly different between months ($P < 0.05$) (only $\pm$ SD was not included in March due to the lack of replicates).

Diversity measures

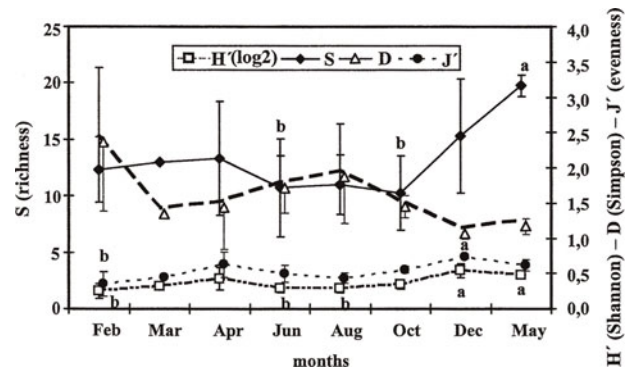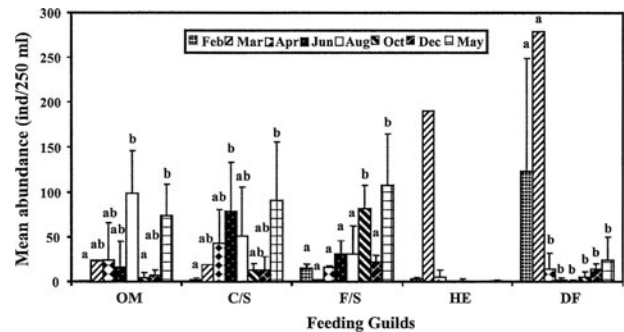Diversity of the vagile organisms (S = 42) during the complete period was $H' = 3.69$, $D = 1.13$ and evenness was $J' = 0.68$. The one-way ANOVA showed differences in these parameters (S, H' and J') among months (F = 3.294, df = 6; N = 25; $P = 0.025$; F = 5.088, df = 6; N = 25; $P = 0.004$ and F = 4.341, df = 6; N = 25; $P = 0.008$, respectively) except for the Simpson index (F = 2.663, df = 6; N = 25; $P = 0.052$) (Figure 7).

Feeding guilds

Results of the one-way ANOVAs showed differences in mean abundance among months and feeding types (N = 29): omnivores (OM), carnivores and/or scavengers (C/S), filter or suspension feeders (F/S) and deposit feeders (DF) (F = 6.203, df = 6, N = 25; $P = 0.001$; F = 4.098, df = 6, N = 25; $P = 0.01$; F = 7.757, df = 6, N = 25; $P = 0.001$; F = 5.121; df = 6, N = 25; $P = 0.004$, respectively), except herbivorous (HE) (F = 1.360, df = 6, N = 25; $P = 0.286$) (Figure 8). In August and May, omnivores presented differences (Tukey test) both with February and October ($P < 0.05$). Carnivores and/or scavengers showed significant differences in June and May with February ($P < 0.05$). Abundance of filter feeders was significantly higher in May and October ($P < 0.05$) and abundance of deposit feeders was significantly different in February and March with respect to the other months ($P < 0.05$).

Fig. 8. *Phyllochaetopterus socialis*. Mean abundance + SD of feeding guilds along sampling period (only + SD was not included in March due to the lack of replicates). Different letters indicate the average values of feeding guilds that were significantly different between months ($P < 0.05$). OM, omnivores; C/S, carnivores and/or scavengers; F/S, filter or suspension feeders; HE, herbivorous; DF, deposit feeders.

Multivariate analyses

Analyses of similarities showed that the macrobenthic community structure differed among the analysed months for presence–absence of all species (N = 57) (global R = 0, 54, $P = 0.001$), abundance of vagile species (N = 42) (global R = 0.733, $P = 0.001$) and abundance of feeding guilds (N = 29) (global R = 0.450 $P = 0.001$; Table 2).

Results of MDS of species presence–absence showed that samples collected in May were well separated but the other

Table 2. One-way ANOSIM considering: presence–absence of all the species (N = 57), abundance of vagile species (N = 42) and abundance of feeding guilds (N = 29). *R*-statistics values only for significant pair-wise comparisons of species composition.

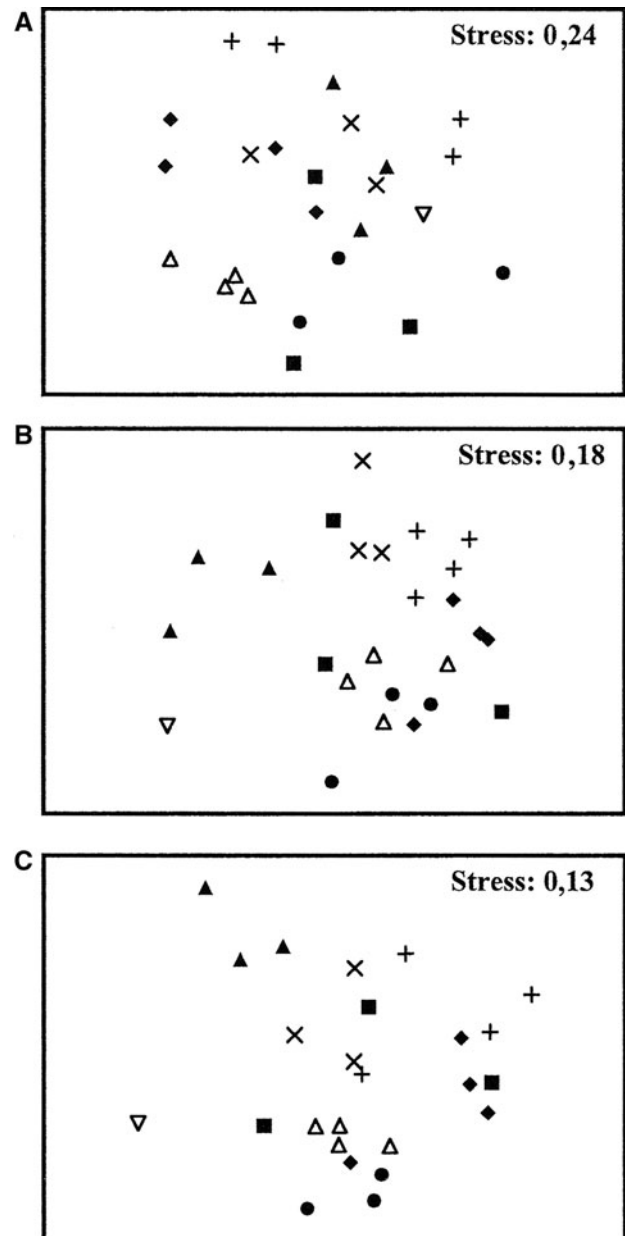| Groups	Presence–absence	Abundance	Feeding guilds
	R	R	R
Feb vs Jun		1	1
Feb vs Aug		1	1
Feb vs Oct		0.981	0.963
Feb vs Dec		0.926	
Feb vs May	0.944	0.981	0.963
Mar vs Apr		0.778	1
Mar vs Jun		1	1
Mar vs Aug		1	1
Mar vs Oct		1	1
Mar vs Dec		1	1
Mar vs May	1	1	1
Apr vs May	0.741		
Apr vs Oct			0.759
Jun vs Aug	0.713		
Jun vs Oct	0.651	0.781	
Jun vs Dec		0.907	0.75
Jun vs May	0.938	0.833	
Aug vs May	0.667	0.368	
Aug vs Oct		0.963	0.944
Aug vs Dec		1	0.833
Oct vs Dec		0.741	0.857
Oct vs May	0.896	0.958	0.875
Dec vs May	0.981	1	0.929

vs, versus.

months presented some overlapping indicating similarities (Figure 9A). Taking into account the abundance of species (excluding sessile and colonial), samples in February, March, October and December were each clustered while in April, May and August samples presented overlapping (Figure 9B). According to feeding guilds (Figure 9C), February and March samples (summer months) were clearly separated from autumn, winter and spring samples.

According to presence–absence of all species, the SIMPER procedure (Table 3) showed that the species (taxa) which most contribute to differences in February were: the gastropods *C. argentina*, *C. aculeata*, the amphipods *M. insidiosum* and *C. dilatata*, the polychaetes *Eunice argentinensis* and *Lumbrineris* sp. 1. In April, June, August, October and December, differences were mainly due to the gastropod *A. isabellei*, although *Brotryllus schlosseri* Pallas, 1766, *C. argentina*, *Leptognathia* sp. and *Pyromaia tuberculata* were also well represented. In May, similar percentages of bryozoans and ascidians (sessiles) and gastropods and crustaceans (vagiles) explained the differences compared with other months.

The SIMPER procedure for species abundance contributions (Table 3) showed that in February the species explaining differences with the other months was *M. insidiosum*, while in April and June it was the mollusc *A. isabellei*. In August and May, differences were due to the abundance of the tanaidacean *Leptognathia* sp. while for October, the species that explained differences were the molluscs *C. argentina* and *C. aculeata*. The polychaete *Lumbrineris* sp. explained the differences in December.

Finally, considering the abundance of feeding guilds, the SIMPER procedure showed that deposit feeders were responsible for differences in February (Table 4). The carnivores

Fig. 9. *Phyllochaetopterus socialis*. MDS ordination of months using (A) presence–absence; (B) abundance of species (excluding sessile and colonial); and (C) feeding guilds. Months: ▲, February; ▽, March; ■, April; ◆, June; ●, August; +, October; ×, December; and △, May.

and/or scavengers contributed to the differences in April, June and May while filter or suspension feeders were dominant in October, December and May. In August, omnivorous were the most abundant trophic guild.

DISCUSSION

Phyllochaetopterus socialis aggregates constitute a diversity reservoir inhabited by 57 species. These aggregates represent a stable environment for permanent and transitory residents. The assemblage of benthic macrofauna in *P. socialis* aggregates suggests the existence of microhabitats that provide substrate, refuge for predation, and availability of food which increase richness and diversity. The results also show

Table 3. SIMPER analysis of species contributions (%) for each taxon at each month according to presence–absence and abundance during the study period (March not included due to the lack of replicates).

Taxa	Presence–absence							Abundance						
	Feb	Apr	Jun	Aug	Oct	Dec	May	Feb	Apr	Jun	Aug	Oct	Dec	May
Porifera	5.26			5.43					16.56					
Nematoda			12.44										5.42	
Anoplodactylus petiolatus Krøyer, 1844		12.91							6.44					
Pyromaia tuberculata (Lockington, 1877)					19.39									
Pilumnoides hassleri Milne-Edwards, 1880							5.62							
Pelia rotunda Milne-Edwards, 1875							5.62		6.44					
Pachycheles laevidactylus Ortman, 1892				5.43			5.62							10.47
Sphaeroma serratum (Fabricius, 1787)							5.62							
Monocorophium insidiosum (Crawford, 1937)	13.68	12.91	5.96			9.68	5.62	80.86	12.95					
Amphipoda genus et species indeterminate														
Caprella dilatata Krøyer, 1843	13.68													
Leptognathia sp. (Bamber, personal communication)				14.45		9.68					84.60		9.72	24.97
Bowerbankia gracilis Leidy, 1855														
Bugula neritina (Linnaeus, 1758)		12.91	5.68				5.62							
Bugula stolonifera Ryland, 1960														
Cryptosula pallasiana (Moll, 1803)			12.44				5.62							
Eunice argentinensis (Treadwell, 1929)	13.68	5.68				9.68							5.46	
Lumbrineris sp. 1 Blainville, 1828	5.26					9.68							22.96	
Hydroides plateni (Kinberg, 1867)										5.22				
Crepidula argentina Simone, Pastorino, Penchaszadeh, 2000	13.68		12.44	14.45	19.39	9.68	5.62		17.92	15.74		65.41	18.95	18.93
Crepidula aculeata (Gmelin, 1791)	13.68		12.44		19.39	9.68	5.62					20.32	10.20	7.33
Anachis isabellei (d'Orbigny, 1841)		12.91	12.44	14.45	19.39	9.68	5.62		20.00	70.01	7.29	8.24		13.29
Epitonium sp Röding, 1798							5.62							6.00
Brotryllus schlosseri Pallas, 1766				14.45										
Ascidiella aspersa (Müller, 1776)							5.62							

Table 4. SIMPER analysis of species contributions (%) according to feeding guilds during the study period. Deposit feeders (DF), herbivorous (HE), carnivores and/or scavengers (C/S), filter or suspension feeders (F/S) and omnivores (OM) (March not included due to the lack of replicates).

Feeding type	Feb	Apr	Jun	Aug	Oct	Dec	May
DF	77.32	9.44	—	—	—	29.56	—
HE	—	—	—	—	—	—	—
C/S	—	47.48	65.68	16.33	10.82	11.13	25.48
F/S	17.75	40.90	32.69	9.17	86.61	51.73	40.82
OM	—	—	—	73.41	—	—	29.33

notorious temporal changes in composition, abundance and feeding guilds of the macrofauna associated with the mats.

The benthic macrofauna inhabiting the studied mats show a slightly lower species richness if compared to that observed in mats of other areas of the south-western Atlantic such as the rocky littoral in Aracá beach, Brazil (Nalesso *et al.*, 1995: 68 species) and the Rio de La Plata estuary, Argentina (Obenat *et al.*, 2001: 63 species). However, species richness is much higher in Mar del Plata harbour mats than in the surrounding soft sediments (Rivero *et al.*, 2005: 35 species). In terms of number of species, the best represented taxa are crustaceans (14), polychaetes (11), molluscs (7), bryozoans (6) and cnidarians (5). As other researchers have found, it seems that high values in terms of abundance of certain groups such as crustaceans, polychaetes and molluscs as hosts in the aggregates and in other biotic substrate are common (Obenat *et al.*, 2001; Giberto *et al.*, 2004; Riestra *et al.*, 2006; Barreto *et al.*, 2007). Obenat *et al.* (2001) found that polychaetes, bryozoans, cnidarians, nematodes and cirripedia crustaceans presented high abundance although data were analysed in a relative frequency scale. In other biotic substrates, crustaceans and molluscs were the most abundant taxa in a study of benthic macroinvertebrates bycatch of the snail *Zidona dufresnei* in Uruguay (Riestra *et al.*, 2006) and in benthic assemblages in the Rio de la Plata estuary and adjacent waters (Giberto *et al.*, 2004). *Zidona patagonica* and *Z. dufresnei* can be considered ecosystem engineers like *P. socialis* because they are capable of providing benthic organisms a structural complexity for settlement, shelter and food availability.

Taking into account the benthic fauna found in the soft sediment surrounding mats in the Mar del Plata harbour, the highest values of abundance corresponded to nematodes and polychaetes (Rivero *et al.*, 2005) while crustaceans and molluscs represent <1% of total dominance.

As regards vagile organisms, the invasive amphipod *Monocorophium insidiosum* showed higher densities within the mats mainly during summer. In a similar way, Bastida *et al.* (1980) had observed *M. insidiosum* in the fouling community of the harbour. This species commonly occurs at high abundance levels in other harbours and in natural areas around the world (Prato & Biandolino, 2006). *Anachis isabellei* (as *Pyrene isabellei*) was also registered by Bastida *et al.* (1980) in the Mar del Plata harbour but in lower densities than those observed in this research. Giberto *et al.* (2004) found this gastropod (also as *Pyrene isabellei*) in the Rio de la Plata estuary and adjacent waters at low salinity conditions (<15 psu). Considering the third most abundant species, *Leptognathia* sp., more detailed taxonomic studies should be carried out to establish if it corresponds to a new species or it could be assigned to a Brazilian one (Bamber, personal communication).

As Obenat *et al.* (2001) observed in the Rio de la Plata estuary in terms of relative abundance, the best represented sessile organisms are six species of bryozoans, but quite different results estimated by means of relative abundance scale were reported by Bastida *et al.* (1980) in the fouling community of the Mar del Plata harbour. Five species reported in the present work were considered exotic by Orensanz *et al.* (2002). On these grounds, abundance could have increased in the last years, thus explaining the variation with findings in the 1980s.

There are few studies to compare richness and diversity indices obtained in *P. socialis* mats. The highest values of *H'* in the months of summer and autumn were similar to those registered by Nalesso *et al.* (1995) in Brazil, but this research work also recorded high diversity in winter and they did not find significant differences among sampling periods. On the other hand, data obtained for the Argentinian continental shelf showed that richness and diversity were higher in the *P. socialis* mats than in sediments (Roux & Bremec, 1996; Obenat *et al.*, 2001; Rivero *et al.*, 2005) and slightly higher than in mollusc bycatch (Schejter, 2005; Riestra *et al.*, 2006).

The structural complexity and the presence of temporary organisms (juveniles of different taxa and Brachyura ovigerous females) in the assemblages suggest the role of *P. socialis* as shelter providing refuges for recruits that will later migrate to other areas. Furthermore, the enhancement of richness and diversity is one of the main effects assigned to ecosystem engineers. Both results observed in this study allow to consider that *P. socialis* act as an ecosystem engineer in the Mar del Plata harbour.

In the harbours, human activities change natural substrata replacing them with man-made structures particularly vertical surfaces (e.g. sandstone walls and piling). Complex surfaces such as natural and artificial substrates in harbours can provide sites for settlement and improved opportunities for attachment, growth and survivorship of organisms (Walters & Wethey, 1996). Moreover, an increase in the size of habitat often increases the number of species (Simberloff & Abele, 1982) and this can happen at relatively small scales for subtidal epibiota (Butler, 1991). The addition of pilings or pontoons involves the creation of additional patches of hard substratum increasing the dispersal of sessile native organisms and also facilitates the invasion of exotic taxa (Connell, 2001). Connell & Glasby (1999) and Connell (2001) in Sidney Harbour found that artificial structures may increase the abundance and diversity of subtidal epibiota in spite of the pollution of the harbour. In Otago Harbour (New Zealand), Grove & Probert (1999) found in an area considered vulnerable to anthropogenic impacts a total of 92 taxa mainly represented by annelids, molluscs and crustaceans.

In Mar del Plata harbour, it is hypothesized that strong hydrodynamics affect the region of the mouth, as shown by low organic content. During sieving, dominance of sandy sediments was evident in outer sampling location according with the Rivero *et al.* (2005) and Bastida *et al.* (1971) results which show that sandy sediments characterize the outer region. In the inner harbour, poor environmental conditions are due to restricted water movement and the prevalence of high values of organic matter was measured. Along the environmental gradient, outer areas present high water dynamics, whereas the inner area shows high pollution level, and intermediate stations present an intermediate degree of stress of both hydrodynamics and pollution gradient (Rivero *et al.*, 2005).

According to presence–absence of all species, the analysis shows that the species (taxa) which most contribute to temporal

variability are gastropods, tanaidaceans, amphipods, polychaetes, ascidians and bryozoans, probably indicating seasonality of certain species or recruitment at different developmental stages. Also, tanaidaceans, amphipods and gastropods are the species that contribute to separate samples when considering the abundance of vagile species among different months.

Differences due to the abundance of feeding guilds could indicate a temporal succession of permanent residents during the sampling period. This could be explained taking into account the availability of organic matter (phytoplankton or residual material generated by zooplankton grazing, decomposition and other processes in the water column) and the presence of preys and predators between the tubes of *P. socialis*. Thus, the abundance of sediment and filter feeders in the months of summer and spring could be attributed to primary production and to residual organic matter in the water column. Since the structural complexity of the tubes causes the accumulation of sediment and organic matter (Nalesso *et al.*, 1995; Obenat *et al.*, 2001), higher densities of sediment feeders like amphipods and polychaetes were observed. In contrast, during the winter and autumn months, the presence of carnivores and/or scavengers could indicate that the main food sources for the associated macrofauna are preys between the tubes. As observed in other studies of *P. socialis* aggregates (Gettleson *et al.*, 1985; Nalesso *et al.*, 1995; Obenat *et al.*, 2001; Barreto *et al.*, 2007), the presence of organisms belonging to different feeding guilds suggests a complex food web within the mats.

Temporal changes in abundance, richness, diversity and trophic groups observed in the mats do not agree with the study of Nalesso *et al.* (1995) in San Sebastián, Brazil. However, temporal changes were observed in the settlement of fouling organisms in the Mar del Plata harbour (Bastida *et al.*, 1980; Trivi de Mandri *et al.*, 1984). This is the first research work on temporal variability of a particular microhabitat in the Mar del Plata harbour: the *P. socialis* mats. Future studies of other habitats in this harbour will surely permit the production of a model of temporal changes in a very complex site due to the characteristics of environmental variables (salinity, pH and dissolved oxygen), extensive urban, industrial and harbour development and the natural and artificial surfaces suitable for benthic fauna settlement. Also, these studies will contribute to the knowledge of the very important role this Chaetopteridae worm has in the benthic community.

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