



ELSEVIER

Contents lists available at ScienceDirect

Journal of Sea Research

journal homepage: www.elsevier.com/locate/seares

Fouling assemblages of native, non-indigenous and cryptogenic species on artificial structures, depths and temporal variation

Mariano J. Albano^{a,*}, Sandra M. Obenat^b

^a Centro Austral de Investigaciones Científicas (CADIC-CONICET), Ushuaia, Argentina

^b Laboratorio de Invertebrados, Facultad de Ciencias Exactas y Naturales, Instituto de Investigaciones Marinas y Costeras (IIMyC), Universidad Nacional de Mar del Plata and Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICET), Funes 3350, Mar del Plata 7600, Argentina

ARTICLE INFO

Keywords:

Fouling community
Marine non-indigenous species
Artificial substrates
Southwest Atlantic
Mar del Plata port
Argentina

ABSTRACT

Non-indigenous species (NIS) are prominent constituents of fouling communities. NIS can cause biodiversity loss and change community structure through the local elimination of native species. Ports are the main focus of NIS and artificial structures are becoming spots of introduction. Community composition can vary with depth and time. In this context, this work aimed to assess substrate (concrete and wood), vertical position (near-surface and near-bottom) and month variations on the abundance of fouling invertebrates' assemblages represented by native, NIS and cryptogenic species within the Mar del Plata port, Argentina. Monthly subtidal samples were taken scraping from fouling assemblages on substrates and vertical position in the port. Assemblages on substrate, depth and time showed similar species composition patterns. Native, NIS and cryptogenic species vary in mean abundances on each substrate, depth and month. Diversity indices on concrete and on near-bottom revealed higher values. High species specific response of NIS (compared to native), found in this study along the temporal fluctuations in fouling communities was registered. A long term monitoring and future studies might consider including more substrates type and an intermediate depth, since they will provide better knowledge about the fouling invasions.

1. Introduction

Non-indigenous species (NIS) are considered as one of the causes of biodiversity loss after habitat destruction, even exceeding the environmental problems caused by pollution and overfishing (Carlton, 1996; Rilov and Galil, 2009). Almost all regions of the world's oceans have experienced the introduction of NIS (Orensanz et al., 2002; Leppäkoski et al., 2002; Robinson et al., 2005; Smith et al., 2011). They are known to change community structure through the local elimination of native species and are among the greatest threats to marine ecosystems (Ruiz et al., 2000; Ruiz et al., 1997; Grosholz et al., 2000; Carlton, 2001; Stachowicz et al., 2002; Stachowicz et al., 1999; Ranasinghe et al., 2005). Ports are the main sites of introduction of NIS (Carlton et al., 1993; Ruiz and Carlton, 2003; Schwindt et al., 2014) a variety of vectors identified for the introduction of marine invasive species to ports around the world has been through fauna and algae attached to the ship's hull (fouling), the discharge of ballast water and sea chest (intake chambers in vessel hulls) (Gollasch, 2002; Godwin, 2003; Hewitt et al., 2004; Coutts and Dodgshun, 2007).

Since 1970 there has been a notable increase in recorded NIS with

port environments becoming the main focus of invasion (Carlton, 1981; Ruiz et al., 1997; Hewitt, 2002; Leppäkoski et al., 2002). At the same time, coastal marine habitats in many places are becoming increasingly urbanized and consequently new structures with hard surfaces are appearing in locations where none existed before (Ruiz et al., 1997; Bacchiocchi and Airoldi, 2003). Since space is an especially limiting resource for epibenthic marine organisms (Jackson, 1977; Russ, 1982), new surfaces in the form of artificial structures could allow an increase in the recruitment of early successional species. It is suggested that the creation of new marine habitats by urbanization not only increases the diversity of habitats, but also stimulates an increase in biodiversity (Rebele, 1994). The type of surface (e.g. wooden piles), size or shape (e.g. pontoons and concrete piles) (Connell and Glasby, 1999) might affect the composition, abundance, richness (number of species) and diversity of fouling assemblages of NIS and native organisms in these environments. These new surfaces are normally associated with shipping and aquaculture, which are often also linked to the transfer of marine NIS (Carlton, 1996; Hewitt et al., 2004). The NIS are reported as rapid colonizers on most surfaces (Byers, 2002; Alpert, 2006; Gittenberger and van der Stelt, 2011), and may therefore out-compete

* Corresponding author at: Centro Austral de Investigaciones Científicas (CADIC-CONICET), Ushuaia, Bernardo Houssay 200, Ushuaia V9410CAB, Argentina.
E-mail address: mariano.albano@cadic-conicet.gob.ar (M.J. Albano).

<https://doi.org/10.1016/j.seares.2018.10.002>

Received 12 January 2018; Received in revised form 24 September 2018; Accepted 7 October 2018

Available online 09 October 2018

1385-1101/ © 2018 Elsevier B.V. All rights reserved.

with native species for resources (Byers, 2002), resulting in a restructuring of the established food web (Levine, 2000; Byers, 2002).

Vertical zonation has been recorded in several marine subtidal communities around the world. The main feature of vertical zonation is the arrangement of communities in belts with distinctive species compositions and dominance. Community changes with depth concern not only the composition, but also the organization of the communities (Garrahou et al., 2002).

In the Southwest Atlantic, Orensanz et al. (2002) provided a comprehensive review of marine NIS and cryptogenic species. In Argentina, the most vulnerable ports to the introduction of NIS are those with a major intercontinental and local transport (e.g. Buenos Aires, San Antonio Este, Puerto Madryn, Comodoro Rivadavia and Ushuaia). Trans-oceanic freighters with large volumes of ballast water and organisms (in all their life stages) present on the sea chest or attached to their hulls can seed new species into these ports from origins often thousands of km away (Boltovskoy et al., 2011). The marine fouling invasions in ports of Patagonia (Argentina) were recently surveyed by Schwindt et al. (2014). In the Mar del Plata port, early studies on fouling communities date from the 1960's (Bastida, 1968; Bastida, 1972; Bastida and Torti, 1972; Stupak et al., 1980; Pezzani et al., 1992), however, none of these studied the effects of artificial structures, such as concrete wall and wooden pilings, the importance of depth and time fluctuation on the abundance of invertebrates assemblages, or providing new settlement sites for NIS and cryptogenic species as has been well documented in other port areas (Minchin, 2007; Neves et al., 2007; Ruiz et al., 2009).

The goal of this study was to assess three factors: substrate (concrete and wood), vertical position (near-surface and near-bottom) and month variations on the abundance of fouling invertebrates' assemblages represented by native, NIS and cryptogenic species within the Mar del Plata port, Argentina. More precisely, we evaluated differences in the averages of diversity, species richness, evenness, abundance and community composition on two substrates, two depths and twelve months. The working hypothesis is that assemblages on substrate, depths and month will differ in their diversity indices and abundance. Native, NIS and cryptogenic species will differ in their species-specific responses on each substrate, depth and month.

2. Material and method

2.1. Study area

The Mar del Plata port (Argentina) (38° 02' S - 57° 31' 30" W), is a relatively small facility (1.4 Km²) built in 1922 and is a semi-enclosed area, protected by two artificial breakwaters (North and South) that delimit the mouth (Fig. 1). The North Breakwater is located in an area closer to the mouth of the port, approximately 300-m wide, with greater maximum depth (8 m). The yacht club the "Club Náutico Mar del Plata" is set in an intermediate zone (4 m maximum depth), semi-closed and with a higher concentration of recreational boats. The average salinity is no < 32 psu, indicating a marine environment (Schwindt et al., 2010). In the whole port the mean water depth is 5 m, ranging between 3 and 12 m. A navigational channel is maintained to a depth of 10 m. Mean monthly water temperature ranges from 9.3 °C in July (winter) to 20.9 °C in February (summer) (<http://www.hidro.gov.ar/ceado/Ef/Mdp.asp>). High levels of total hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), copper and tributyltin) have been found in the docks, as well as, high water turbidity, low pH and high levels of organic matter from industrial and sewage effluents (Penchaszadeh et al., 2001; Goldberg et al., 2004; Albano et al., 2013; Laitano et al., 2015). Silty-clay sediments of the inner sector, with higher levels of organic matter and phytopigments, are dominated by opportunistic nematodes and *Capitella* sp., usually associated worldwide to polluted habitats. Despite the evidence of local pollution in sediment (Rivero et al., 2005; Albano et al., 2013), in the recreational

area the breakwater and marinas are covered by a high abundance and richness of fouling species (Albano and Obenat, 2009).

2.2. Field sampling and laboratories procedure

Subtidal samples were taken from two different artificial substrates, the vertical concrete wall to the North Breakwater and wood piles from yacht club. Replicates were obtained monthly at high tide on the inner side of the North Breakwater from April 2007 to March 2008, except for October, using SCUBA (Fig. 1). In order to determine differences in the fouling community composition a stratified sampling at 2 different vertical positions or depths was used: 1 m from surface (hereafter "near-surface") and 8 m from surface ("near-bottom"). At each month and depth three independent replicates ($N = 3$) were obtained using an epibenthic net (mesh 0.5 mm) galvanized wire frame 25 × 25 cm (0.0625 m²) and with metal spatula. All samples were taken 2 m from each other. Fouling assemblages targeted were those which were attached to the concrete wall. For each independent sample, they were washed in a 0.5 mm mesh sieve and subsequently fixed using 70% ethanol. Fouling invertebrates retained by the sieve were separated and identified at the lowest taxonomic level possible with keys and consulting local taxonomic experts. The taxonomic nomenclature of all identified species was verified using the World Register of Marine Species (WoRMS, 2017). However, Nematoda, Sipuncula, Echiurida, Pycnogonida could not be identified to species level due to the lack of qualified taxonomists, and so were considered one species each in the comparison of community similarity.

Sampling at the marinas of the yacht club (Fig. 1) was performed from April 2007 to March 2008. Samples were collected monthly by SCUBA diving at a depth of 1–3 m and also a stratified sampling was used at 2 different vertical positions or depths: 1 m from surface ("near-surface") and 4 m from surface ("near-bottom"). Each month, 3 independent replicates from each depth were collected at random (following the epibenthic net sampling method described above) from different vertical wooden piles. Sample analysis was carried out in the same manner as described for the concrete wall samples.

Samples were analyzed under binocular microscope to estimate abundance (ind. m⁻²) of mobile and solitary sessile organisms. Colonial organisms were also collected and identified, but are not dealt with in the present study. Algae were excluded from the present study too.

2.3. Detection of fouling species status (natives, NIS and cryptogenic)

In this study we categorized the species status following Carlton (1996) as: native (that is, indigenous or endemic taxa, including pre-historical invasion), NIS (that is, historical invasions and human-mediated introduction, whereas natural range expansion was not taken into account as introduction see (Ojaveer et al., 2014)) and cryptogenic (crypt-, Greek, *Kryptos*, secret; -genic, Latin, *genic*, origin) as species that is not demonstrably native or NIS. To establish the status we consider literature search for historical records of the species, their geographical range and records of introductions in other localities. Even species restricted to the Atlantic, but well known to colonize artificial substrata or often found in ports were classified as cryptogenic.

2.4. Statistical analysis

2.4.1. Community composition

Multivariate analysis (Bray–Curtis similarity index, square root transformation and the resemblance matrix) was used with fouling abundance data using PRIMER version 6.1 (Clarke and Warwick, 1994; Clarke and Gorley, 2006). Similarity percentage procedure (SIMPER) was performed to establish the percent dissimilarity of fouling community composition (natives, NIS and cryptogenic) among substrate, vertical position and month, 0% indicates no difference and 100% maximum difference (Clarke and Warwick, 1994). SIMPER was also

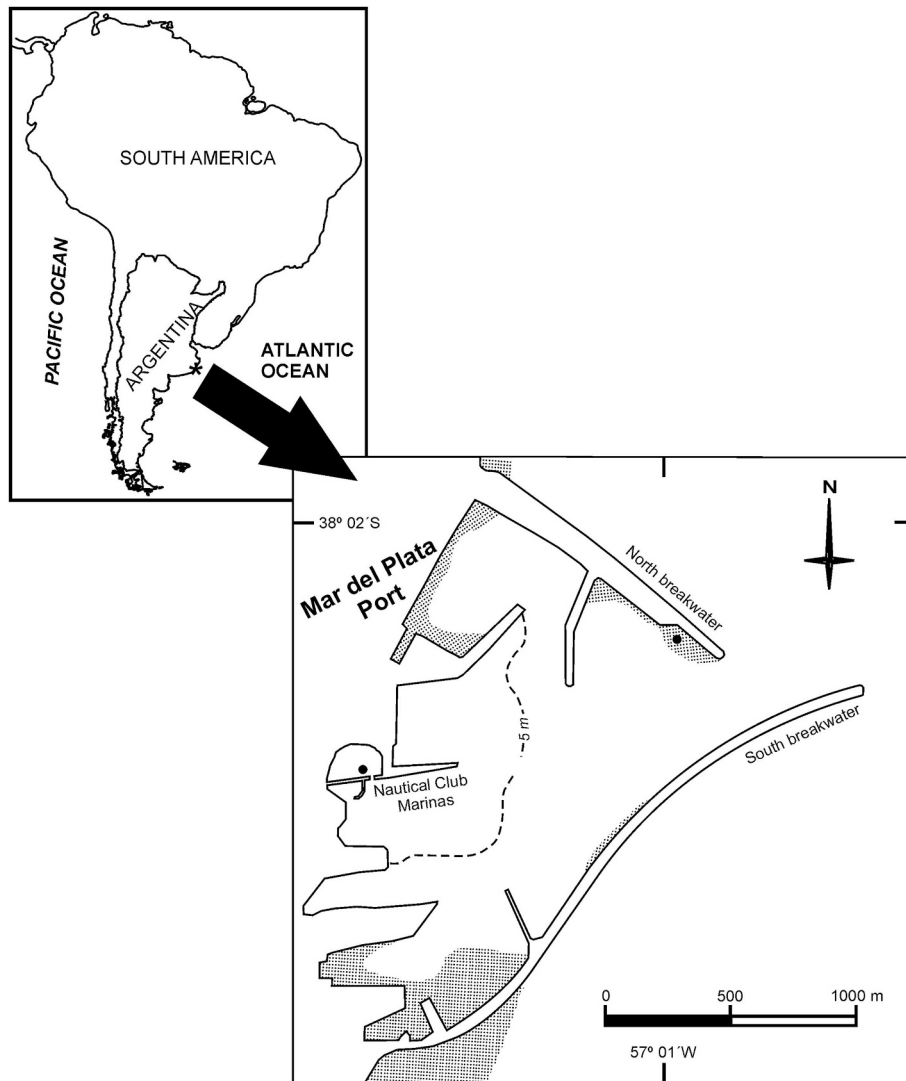


Fig. 1. Map of the Mar del Plata port, Argentina, showing sampling sites.

used to determine which taxa were primary contributors to the differences in fouling community at each substrate, vertical position and month during the study period. Lists of species were truncated when contribution percentage do not exceeded 9%.

2.5. Fouling assemblages

A three-factor permutational multivariate analysis of variance (PERMANOVA) was used to test the effect of substrate, vertical position and month on the abundance of fouling invertebrates, with substrate and vertical position as fixed factors; and month as random factor. This was done with PRIMER v6.0 with the PERMANOVA+ add-on (PRIMER-E Ltd., Plymouth, UK). The data were square root transformed, and a resemblance matrix was created using Bray–Curtis similarity. The PERMDISP function was used to test for homogeneity of multivariate dispersions between groups (Anderson, 2001). A significant result for PERMDISP indicates that a PERMANOVA result is influenced by the dispersion within groups as well as the distance between them. A significant PERMDISP result should be interpreted with caution, as the magnitude of the difference between groups (i.e. substrate or vertical position) can be due to both their influence on the fouling community, as well as differences in the variability of the within-group communities. Principal coordinate ordinations (PCO) were used to visualize the similarities or dissimilarities between

substrate, vertical position and month. To better visualize trends, vector lines for species (natives, NIS and cryptogenic) with a Pearson correlation > 0.5 were overlaid on the PCO to show their correlation with various treatments.

2.6. Diversity measures and total abundance

Of each sampling unit and taking into account the whole fouling community (natives, NIS and cryptogenic) mean Shannon–Wiener diversity index (H' , \log_2), species richness (S , total number of species) Pielou evenness (J' , H'/H_{MAX}) and total abundance (ind. m⁻²) were calculated by DIVERSE routine of the PRIMER package (Clarke and Gorley, 2006). A univariate PERMANOVA was performed to test the effect of substrate, vertical position and month on these measures. A Euclidean distance resemblance matrix was used. The PERMDISP function was used to determine if the differences in dispersion between groups occurred. A pairwise test was used to examine differences among groups.

2.7. Species-specific response to substrates, vertical position and month

For each species status the species-specific responses to substrate, vertical position and months were surveyed using univariate PERMANOVA with substrate and vertical position as fixed factors; and month

Table 1
List of total taxa recorded in the Mar del Plata port.

| Taxa | |
|--|--|
| CNIDARIA | <i>Palaemon macrodactylus</i> Rathbun, 1902 |
| <i>Tricnidactis errans</i> Pires, 1988 | <i>Sphaeroma serratum</i> (Fabricius, 1784) |
| <i>Anthothoe chilensis</i> (Lesson, 1830) | <i>Idotea</i> sp. |
| <i>Sagartia troglodytes</i> (Price in Johnston, 1847) | <i>Limmoria tripunctata</i> Menzies, 1951 |
| PLATYHELMINTES | <i>Balanus glandula</i> Darwin, 1854 |
| <i>Phrikoceros mopsis</i> (Marcus, 1952) | <i>Amphibalanus amphitrite</i> (Darwin, 1854) |
| <i>Thysanozoon brocchii</i> (Risso, 1818) | <i>Pilumnoides hassleri</i> Milne Edwards, 1880 |
| <i>Thysanozoon mirtae</i> sp. nov. (Bulnes, 2011) | <i>Pilumnus reticulatus</i> Stimpson, 1860 |
| <i>Notoplana</i> sp | <i>Halicarcinus planatus</i> (Fabricius, 1775) |
| NEMERTEA | <i>Pachycheles laevidactylus</i> Ortmann, 1892 |
| <i>Lineus bonaerensis</i> Moretto, 1998 | <i>Cyrtograpsus altimanus</i> Rathbun, 1914 |
| NEMATODA sp. 1 | <i>Cyrtograpsus angulatus</i> Dana, 1851 |
| ANNELIDA | <i>Pelía rotunda</i> Milne Edwards, 1875 |
| <i>Lumbrineris</i> sp. | <i>Pyromaia tuberculata</i> (Lockington, 1877) |
| Nephtyidae sp. 1 | <i>Joeropsis dubia</i> Menzies, 1951 |
| Syllidae sp1 | <i>Pycnogonida</i> sp. 1 |
| <i>Hydroides elegans</i> (Haswell, 1883) | MOLLUSCA |
| <i>Hydroides dianthus</i> (Verrill, 1873) | <i>Siphonaria lessoni</i> Blainville, 1824 |
| <i>Hydroides plateni</i> (Kinberg, 1867) | <i>Brachidontes rodriguezii</i> (d'Orbigny, 1846) |
| <i>Ficopomatus enigmaticus</i> Fauvel, 1923 | <i>Chaetopleura (Chaetopleura) angulata</i> (Spengler, 1797) |
| <i>Pherusa</i> sp. | <i>Entodesma</i> sp. |
| Hesionidae sp. 1 | <i>Turbonilla uruguayensis</i> Pilsbry, 1857 |
| Questidae sp. 1 | <i>Fissurella</i> sp. |
| Eunicidae sp. 1 | Gasteropoda sp. 1 |
| Terebellidae sp. 1 | <i>Epitonium georgettinum</i> (Kiener 1839) |
| <i>Halosydne australis</i> Kinberg, 1856 | <i>Bostrycapulus odites</i> Collin, 2005 |
| Phyllodocidae sp. 1 | <i>Hiatella</i> sp. |
| Cirratulidae sp. 1 | <i>Anachis isabellei</i> (d'Orbigny, 1841) |
| Nereididae sp. 1 | <i>Columbella paessleri</i> Strebel, 1905 |
| <i>Schistomeringos rudolphi</i> (Delle Chiaje, 1828) | <i>Eatoniella</i> sp. |
| Spionidae sp. 1 | <i>Thecacera darwini</i> Pruvot-Fol, 1950 |
| <i>Phyllochaetopterus socialis</i> (Claparède, 1870) | <i>Polycera marplatensis</i> Franceschi, 1928 |
| Orbiniidae sp. 1 | <i>Janolus</i> sp. |
| SIPUNCULA sp1 | ECHINODERMATA |
| ECHIURA sp. 1 | <i>Ophioplocus januarii</i> (Lütken, 1856) |
| ARTHROPODA | CHORDATA |
| <i>Monocorophium acherusicum</i> (Costa, 1857) | UROCHORDATA |
| <i>Erichthonius punctatus</i> (Bate, 1853) | <i>Ciona intestinalis</i> (Linnaeus, 1767) |
| <i>Jassa alonsoae</i> Conlan, 1990 | <i>Styela plicata</i> (Lesueur, 1823) |
| <i>Caprella dilatata</i> Krøyer, 1843 | <i>Asciidiella aspersa</i> (Müller, 1776) |
| <i>Caprella equilibra</i> Say, 1818 | <i>Ascidia interrupta</i> Heller, 1878 |
| Leptocheliidae sp. 1 | <i>Molgula manhatensis</i> (De Kay, 1843) |
| <i>Tanais dulongii</i> (Audouin, 1826) | VERTEBRATA |
| <i>Nauticaris magellanica</i> (A. Milne Edwards, 1891) | <i>Hyleurochilus fissicornis</i> (Quoy y Gaimard, 1824) |

as random factor. PERMANOVA is designed in a way that it is applicable to non-parametric univariate analysis (Anderson, 2001). Data were square root transformed and a Euclidean distance resemblance matrix used. The PERMDISP function was used to determine whether differences in dispersion between groups occurred. A pairwise test was done on the single species data to interpret significant treatment effects for each species.

3. Results

3.1. Community composition

The total number of fouling taxa recorded throughout this study was 78, when concrete had the greatest number of taxa (77) meanwhile wood had 55, (Table 1) of which 52 were clearly identified to the species level. The status of these species were: 30 native (57.7%), 17

NIS (32.7%) and 5 cryptogenic (9.6%) (Table 2). Between natives were, 10 crustaceans (33.3%), 10 mollusks (33.3%), 3 polychaetids (10.0%), 2 cnidarian (6.6%), 2 polychaetes (6.6%), 1 nemertean (3.3%), 1 echinoderm (3.3%) and 1 vertebrata (3.3%). Considering NIS, 9 crustaceans (52.94%), 4 tunicates (23.52%), 3 polychaetes (1.64%) and 1 cnidarian (5.88%), whereas cryptogenic species comprised 2 crustaceans (40%), 2 polychaetes (40%), 1 tunicate (20%). New record of alien species includes the serpulid polychaete *Hydroides dianthus*.

The fouling community on concrete substrate was dominated by native species; meanwhile on wood the number of species was very similar between natives and NIS. On concrete a total of 48 species were recorded: 29 native (60.4%), 14 NIS (29.2%) and 5 cryptogenic (10.4%). On wood, fouling from a total of 39 species recorded 17 were native (43.6%), 17 NIS (43.6%) and 5 cryptogenic (12.8%). Results in different vertical position on concrete wall near-surface showed that had a slightly higher number of total species recorded (39): 23 native (58.9%), 13 NIS (33.3%) and 3 cryptogenic (7.6%) species. On the near-bottom, 37 species were register: 20 native (54.0%), 13 NIS (35.1%) and 4 cryptogenic (10.8%). On wood piles at the near-surface, 34 species were recorded 15 native (44.1%), 15 NIS (44.1%) and 4 cryptogenic (11.7%). On the near-bottom 37 species were recorded 17 native (45.9%), 16 NIS (43.2%) and 4 cryptogenic (10.8%).

SIMPER analyses showed the average dissimilarity between substrates was 79.24%. Also between vertical positions (considering each substrate), concrete near-surface vs. concrete near-bottom 75.05% and wood near-surface vs. wood near-bottom 74.44%. Taking into account months the average dissimilarities ranges from 55.69% (January vs March) to 86.22% (February vs. July). The major contributors to the average dissimilarities between substrate and vertical position was the NIS amphipod *Monocorophium acherusicum*; between months were *M. acherusicum* and the serpulid polychaete *Hydroides elegans*.

3.2. Fouling assemblages

The species composition of the fouling assemblages differed among substrate, vertical position and month, all had significant interactions among these three factors (Table 3). A principal coordinate analysis plot (PCO) showed a separation between assemblages on concrete and wood substrates (Fig. 2). Pearson correlations vectors indicate that all species status were abundant on both substrates. Native species such as the gastropod *Turbonilla uruguayensis* was abundant on concrete and the Varunidae crab *Cyrtograpsus altimanus* on wood. The NIS like the oriental shrimp *Palaemon macrodactylus*, *H. dianthus*, *M. acherusicum*, and the ascidians *Asciidiella aspersa*, *Styela plicata* and *Ciona intestinalis* they were abundant on wood. The cryptogenic amphipod *Caprella equilibra* was abundant on both substrates (Fig. 2).

On vertical position they differed too, taking into account both substrates. PCO showed segregation between assemblages on near-surface and near-bottom (Fig. 2). The correlation vectors show that native *T. uruguayensis*, the NIS *S. plicata* and *A. aspersa* were abundant on near-surface. The NIS *P. macrodactylus*, *M. acherusicum*, *H. dianthus*, *C. intestinalis* and the native *C. altimanus* were abundant on near-bottom. The cryptogenic *C. equilibra* was abundant on both vertical positions (Fig. 2).

PCO showed segregation among assemblages on month (between April 2007 and March 2008; Fig. 2). Pearson correlations vectors indicate that native species *C. altimanus* and *T. uruguayensis* were abundant on November and December (austral spring), respectively. The NIS *C. intestinalis*, *H. dianthus* and *S. plicata* they were abundant in April and in May (austral autumn), respectively. *A. aspersa* and *P. macrodactylus* were abundant in September and November (spring), respectively. *M. acherusicum* and the cryptogenic *C. equilibra* both were abundant in February (austral summer) (Fig. 2).

Table 2
Alien and cryptogenic species registered in the Mar del Plata port.

| NIS species | Source | Surfaces in the Mar del Plata port | Region of origin | Distribution | Distribution in the southwestern Atlantic |
|----------------------------------|--|------------------------------------|---|---|---|
| <i>Sagartia troglodytes</i> | Excoffon et al. (1999); Genzano et al. (2011) | C-W | Eastern Atlantic. | NE Atlantic Ocean, N Sea, Mediterranean and Baltic Seas. | Subtidal rocky reefs off Mar del Plata. |
| <i>Hydroïdes elegans</i> | Bastida (1972), as <i>H. norvegica</i> ; Zibrowius (1971); Knight-Jones and Knight-Jones (1991) | C-W | Australia. | Widely distributed in the tropics and subtropics regions. | Mar del Plata port (fouling community). |
| <i>Hydroïdes ditanthus</i> | Valentinuzzi De Santos (1971) | C-W | East coast of the USA. | Widely distributed in warm and warm-temperate regions. | Puerto Belgrano (fouling community). |
| <i>Ficopomatus enigmaticus</i> | Monro (1938); Rioja (1943); Orensanz and Estivariz (1971); Scarabino et al. (2006); Nión (1979) (all as <i>Mercierella enigmaticus</i>); Knight-Jones and Knight-Jones (1991) | W | Australia and regions of the Indian Ocean. | Widely distributed in subtropical/temperate estuaries. | Estuarine environments of Uruguay; Mar Chiquita coastal lagoon (estuarine reefs), Puerto Quequen, Mar del Plata (fouling community) (Argentina) Mar del Plata port (fouling community). |
| <i>Monocorophium acherusicum</i> | Albano et al. (2013) | C-W | North Atlantic. | Widely distributed, in temperate and warm waters of both hemispheres. | Mar del Plata port and San Antonio Bay Brazil, Mar del Plata port. |
| <i>Erichthonius punctatus</i> | Rumbold et al. (2016) | C-W | North Atlantic. | Widely distributed, uncertain distribution because of the many wrong identifications. | Mar del Plata port (fouling community). |
| <i>Sphaeroma serratum</i> | Roux and Bremec (1996); Kittlein, (1991); Doti et al., (2012) | C-W | North Atlantic Ocean. | NE Atlantic, from Europe to N Africa, Mediterranean and Black Sea; S Africa, W Australia, SW Atlantic. | Buenos Aires Province (Argentina), La Paloma (Uruguay), Rio de Janeiro (Brazil). |
| <i>Limnoria tripunctata</i> | Bastida and Torti (1972) | W | It may have an Indo-Pacific origin. | Australia, India, Gulf of Mexico, Mediterranean, North Atlantic. | Mar del Plata. |
| <i>Joeropsis dubia</i> | Lini et al. (1995); Albano et al. (2013); Schotte (2014) | C-W | Unknown. | NE Pacific, SW Atlantic. | Brazil, Mar del Plata. |
| <i>Balanus glandula</i> | Spivak and L'Hoste (1976); Bastida and Brankevich (1982); Newman (1976); Schwindt et al. (2014) | C-W | Pacific coast of USA. | NE Pacific (Aleutians to Baja California); introduced to the SW Atlantic. | San Clemente del Tuyu to Comodoro Rivadavia, Argentina. |
| <i>Amphibalanus amphitrite</i> | Bastida (1972); Spivak and L'Hoste (1976); Newman (1976); Schwindt et al. (2014) | C-W | West Pacific and Indian Oceans from Southeastern Africa to Southern China. | E, NW, SW, Pacific and Pacific Islands; WE, NE and SW Atlantic. | Introduced in historical Times to the port of Mar del Plata, where it is a component of the Fouling assemblage. Also found in Quequén. |
| <i>Pyrosoma tuberculata</i> | Schejter and Spivak (2002) | C-W | NE Pacific, from the West Coast of the USA to Panama. | Exotic in Brazil, Argentina, Japan, Australia and New Zealand. | Buenos Aires Province (Argentina). |
| <i>Palaeon macrodactylus</i> | Spivak et al. (2006); Martorelli et al., (2012); Vázquez et al. (2012); Ashelby et al., (2013); Lejeune et al. (2014) | W | Native to estuaries and coastal waters of the Northwest Pacific. | Introduced to the East and West coasts of North America, England, the Netherlands, Belgium, Germany, Spain and Argentina. | From Mar del Plata port, Rio Salado, Puerto Quequen, San Antonio Bay, Estuarine environments of Bahía Blanca and Rio Negro. |
| <i>Ascidella aspersa</i> | Tatián et al. (2010); Albano et al. (2013) | C-W | Southern Norway to the Mediterranean. | Introduced in to the East coast of USA, Argentina, South Africa, India, Australia, and New Zealand. | Mar del Plata port, San Antonia Este, Puerto Madryn and Puerto Deseado. |
| <i>Syella plicata</i> | Vannname (1945); Albano et al. (2013) | C-W | Currently unknown, but evidence suggests that it is native to the NW Pacific. | Widely distributed globally in subtropical waters. | Uruguay, mostly from La Paloma Port. Mar del Plata port. |
| <i>Ciona intestinalis</i> | Vannname (1945); Amor, (1964); Kott (1969); Bastida (1972); Pisanó et al. (1971); Traustedt (1885) | C-W | North Atlantic. | Often confined to port areas; presumably dispersed worldwide, except Antarctica, by vessels. | Mar del Plata (fouling community), Punta Arenas (Magellan Strait). |
| <i>Molgúla manhattensis</i> | Vannname (1945); Amor, (1964); Bastida (1972) | C-W | Native to the East and Gulf Coasts of USA. | Europe, Japan, Australia, Argentina, and the West Coast of USA. | Mar del Plata port (fouling community). |
| Cryptogenic species | Source | Surfaces in the Mar del Plata port | Region of origin | Distribution | Distribution in the southwestern Atlantic |
| <i>Tanais dilongii</i> | Giambiagi (1922) (Giambiagi, 1923, as <i>T. gallardoi</i>); Sieg (1983a), Sieg, 1983b); Sueiro et al., (2011); Rumbold et al. (2015) | C-W | Mediterranean Sea off Egypt and north Europe. | Scattered regions along temperate coasts. | Mar del Plata, Quequen port, San Antonio Bay and Puerto Madryn. |

(continued on next page)

Table 2 (continued)

| Cryptogenic species | Source | Surfaces in the Mar del Plata port | Region of origin | Distribution | Distribution in the southwestern Atlantic |
|------------------------------------|--|------------------------------------|-----------------------------------|--|---|
| <i>Caprella equilibra</i> | McGain (1968); McGain and Gray (1971) | C–W | NW Atlantic. | East coast of the USA, Gulf of Mexico and Venezuela. | Brazil and Argentina, interrupted in the Magellanic region. |
| <i>Ascidia interrupta</i> | M. Tátian and C. Lagger, (pers. comm.) | W | American tropical Atlantic coast. | Panama, the Caribbean and northeast Brazil. | Mar del Plata port. |
| <i>Schistomeringos rudolfi</i> | Orensanz (1974), (as <i>Stauronereis rudolfi</i>) | C-W | Naples, Italy, Mediterranean sea. | Widely distributed in temperate and tropical seas, in shallow water. | Uruguay to San Matias Gulf; most abundant in polluted environments of Mar del Plata port. |
| <i>Phyllochaetopterus socialis</i> | Obenat et al. (2001); Albano and Obenat (2009) | C-W | Naples Gulf, Italy. | Widely distributed (under discussion) in hard substrata. | Uruguay, Mar del Plata (Argentina) and Brazil. |

Source: primary record in the southwestern Atlantic; substrate, C: Concrete; W: Wood; Region of origin: native range; Distribution: general geographic distribution; Current distribution in the southwestern Atlantic.

Table 3

Multivariate PERMANOVA analysis of the effect of substrate, vertical position, month and interaction between the three factors.

| Source | df | MS | P (perm) |
|---------------------------------------|-----|--------|----------|
| Substrate | 1 | 32,098 | 0.001 |
| Vertical position | 1 | 20,475 | 0.001 |
| Month | 11 | 8010 | 0.001 |
| Substrate X Vertical position | 1 | 11,029 | 0.032 |
| Substrate X Month | 10 | 5460.5 | 0.001 |
| Vertical position X Month | 11 | 3247.8 | 0.001 |
| Substrate X Vertical position X Month | 8 | 3372.9 | 0.001 |
| Residual | 94 | 1492.4 | |
| Total | 137 | | |

Not significant $p > 0.05$; significant $0.05 > p > 0.01$; highly significant $p < 0.01$, p -values were obtained using 999 permutations.

3.3. Diversity measures and total abundance

There were significant interactions between substrate and month for mean species richness (S) and total abundance (Table 4). The pairwise test showed that S , at different substrates x month, at concrete was greater than wood and showed maximum values during May–June (autumn), August, November–December (spring), while maximum value for wood was observed in April (Fig. 3a). Total abundance registered a dissimilar pattern since, wood was statistically higher from concrete and maximum value was in April and December (Fig. 3b).

Shannon diversity (H'), S and abundance showed significant interactions when vertical position and month were combined (Table 4). The pairwise test revealed that H' and S in the near-bottom significantly higher than near-surface. H' maximum values showed for vertical position were in May, June and August (Fig. 4a) meanwhile S was on near-bottom from April to June. On the near-bottom were in May, June and August (Fig. 4b). Evenness (J') was greater in the bottom in May (Fig. 4c). The total abundance showed that in the near-surface, highest values were in April and March. The pattern observed, for both depths, was that the rest months remain similar (Fig. 4d). Although there was a difference in dispersion (PERMDISP < 0.05) for species richness and abundance, and this warrants caution interpreting the results above mentioned.

3.4. Species-specific response to substrates

The results for the mean abundances showed an effect between different substrates in 2 natives, 4 NIS and 1 cryptogenic species (Table 5). The pairwise test showed that the natives *C. altimanus* and the polychaete *Halosydnella australis* had higher average abundances on wood. There was a difference in dispersion (PERMDISP < 0.05) for *C. altimanus* and this warrants caution interpreting the results. Same pattern was shown by NIS, since *P. macrodactylus*, *H. dianthus*, *C. intestinalis* and *S. plicata* were greater on wood, although there was a difference in dispersion (PERMDISP < 0.05) for NIS and this warrants caution interpreting the results. *C. equilibra* was the only cryptogenic species that showed greater average abundance on concrete.

3.5. Species-specific response to vertical position

Four natives, 3 NIS and 1 cryptogenic species were statistically different in mean abundance on vertical positions (Table 5). Among natives, the solitary anemone *Trinidactis errans* was greater on surface, *C. altimanus* in bottom, the mussel *Brachidontes rodriguezii* in surface although there was a difference in dispersion (PERMDISP < 0.05) for *B. rodriguezii* and this warrants caution interpreting the results. The average abundance of NIS such as: *S. plicata*, *A. aspersa* and *Molgula manhattensis* showed a pattern with maximum values on bottom. For cryptogenic species the tanaidacea *Tanais dulongii* was greater on surface, while there was a difference in dispersion (PERMDISP < 0.05) for

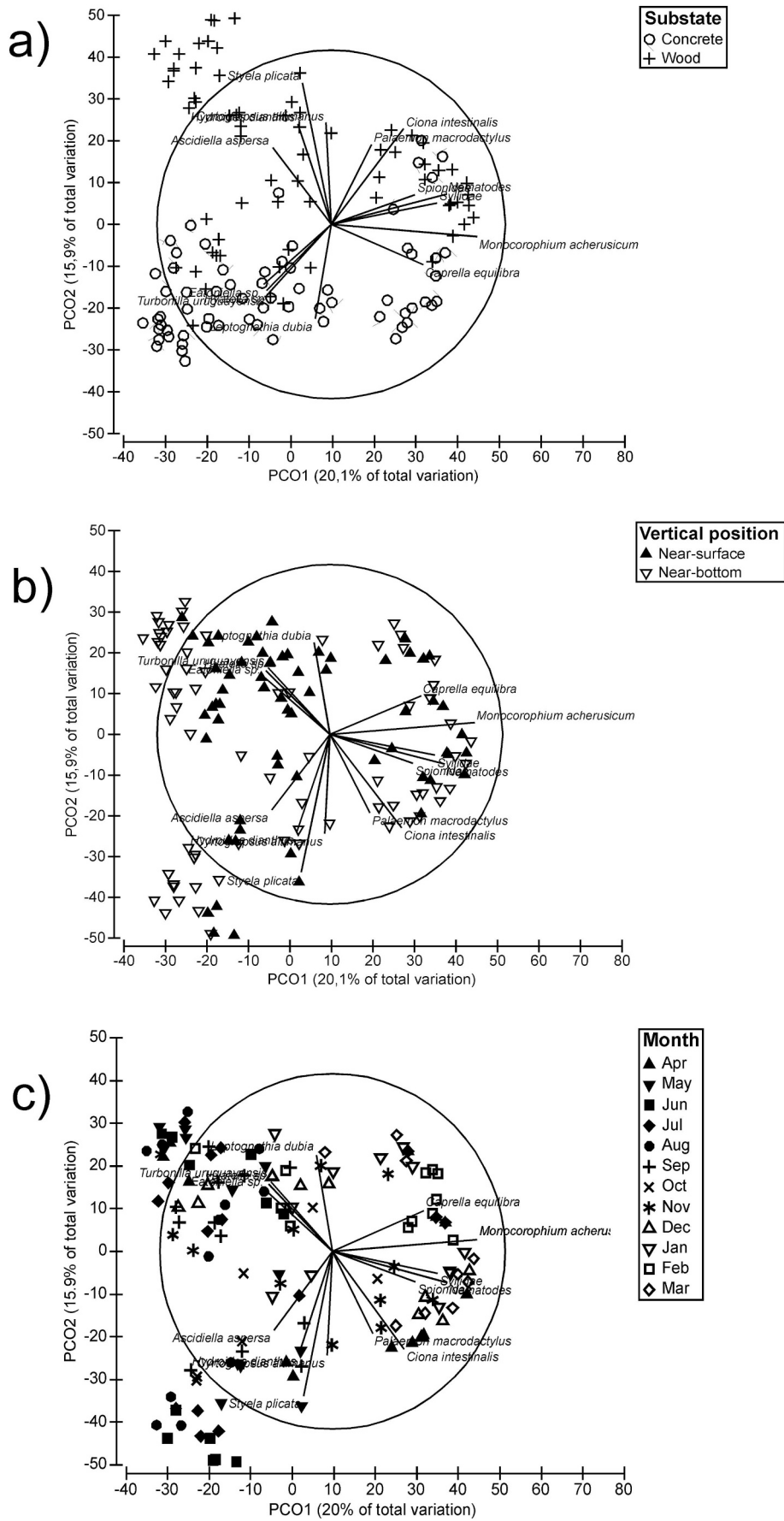


Fig. 2. A principal coordinate analysis plot for the fouling assemblages found at different (a) substrate, (b) vertical position and (c) month. The vector lines show species that were strongly correlated (Pearson correlation > 0.5) to the three factors.

Table 4

Univariate PERMANOVA analysis of mean Shannon diversity (H' , \log_2), species richness (S), evenness (J') and total abundance (ind. m⁻²) for substrate, vertical position, month and interaction between the three factors.

| Source | df | H' , \log_2 | | | S | | |
|---------------------------------------|-----|-----------------|---------|-----|--------|---------|--|
| | | MS | P(perm) | df | MS | P(perm) | |
| Substrate | 1 | 22.423 | 0.017 | 1 | 388.32 | 0.031 | |
| Vertical position | 1 | 12.175 | 0.001 | 1 | 1072.2 | 0.002 | |
| Month | 11 | 0.85561 | 0.001 | 11 | 56.237 | 0.004 | |
| Substrate X Vertical position | 1 | 0.3688 | 0.61 | 1 | 171.19 | 0.2 | |
| Substrate X Month | 10 | 0.28704 | 0.177 | 10 | 65.571 | 0.001 | |
| Vertical position X Month | 11 | 0.43668 | 0.015 | 11 | 51.615 | 0.004 | |
| Substrate X Vertical position X Month | 8 | 13.053 | 0.941 | 8 | 95.938 | 0.129 | |
| Residual | 94 | 0.20075 | | 94 | 18.22 | | |
| Total | 137 | | | 137 | | | |

| Source | df | J' | | | Abundance | | |
|---------------------------------------|-----|------------|---------|-----|------------|---------|--|
| | | MS | P(perm) | df | MS | P(perm) | |
| Substrate | 1 | 1.08E + 02 | 0.17 | 1 | 1.33E + 09 | 0.072 | |
| Vertical position | 1 | 1.22E + 02 | 0.096 | 1 | 12,302 | 0.599 | |
| Month | 11 | 4.05E + 02 | 0.001 | 11 | 1.28E + 09 | 0.001 | |
| Substrate X Vertical position | 1 | 5.84E-01 | 0.951 | 1 | 2864.2 | 0.783 | |
| Substrate X Month | 10 | 4.52E + 01 | 0.12 | 10 | 35,470 | 0.003 | |
| Vertical position X Month | 11 | 4.38E + 01 | 0.161 | 11 | 43,269 | 0.001 | |
| Substrate X Vertical position X Month | 8 | 1.62E + 01 | 0.754 | 8 | 45,200 | 0.432 | |
| Residual | 94 | 2.93E + 01 | | 94 | 12,030 | | |
| Total | 137 | | | 137 | | | |

Not significant $p > 0.05$; significant $0.05 > p > 0.01$; highly significant $p < 0.01$, p-values were obtained using 999 permutations

T. dulongii this warrants caution interpreting the results.

3.6. Species-specific response to months

The monthly mean abundances variations showed differences in 5 native species (Table 5) and were represented by *T. errans* with higher average abundances in April–May (fall), *C. altimanus* in April and June, *B. rodriguezii* in December, *H. plateni* in April–May and June (fall) and *H. australis* in September, November and December (spring). Also, average abundance of 11 NIS were statistically different (Table 5) and they were *M. acherusicum* with maximum values registered in April, November–December, February–March (spring-summer), the amphipod *Erichthonia punctatus* in April and February, the isopod *Sphaeroma serratum* in April–May (fall) and December, the barnacle *Balanus glandula* in April–May (fall), September, November and December (spring), *P. macrodactylus* in October and November (spring), *H. elegans* and *H. dianthus* both presented the same pattern with maximum mean abundance in April–May (fall), June and October only for *H. dianthus*, *C. intestinalis* in April–May–June (fall), January and March (summer), *S. plicata* from April until December (fall, winter and spring), *A. aspersa* and *M. manhatensis* from June until November–December (winter and spring). Finally, 2 cryptogenic species showed differences (Table 5) *C. equilibra* average abundance was higher in April and in February–March summer, while *T. dulongii* were in November–December (spring).

4. Discussion

This paper is the first research work which focuses on fouling assemblages of native, NIS and cryptogenic species on substrate type,

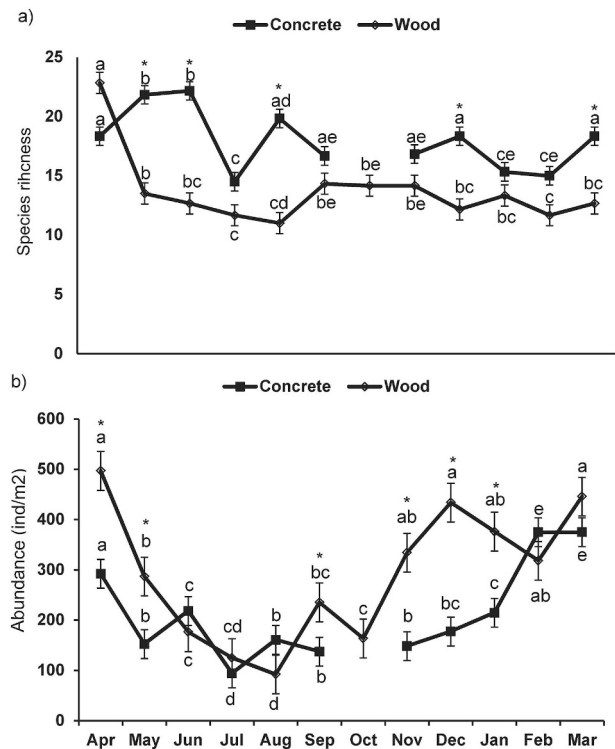


Fig. 3. Mean (a) species richness and (b) total abundance at different substrates x month, plotted with \pm SEs bars. Asterisks (*) indicate significant differences between concrete vs. wood and different letters indicate the average values of indices that were significantly different for each substrate along months according to pairwise test ($p < 0.05$). (On concrete October was not included due to the lack of replicates).

depth and time in the Mar del Plata port. Substrate, depth and time affected the fouling assemblages of native, NIS and cryptogenic. Assemblages on substrate, depth and time show a similar species composition patterns. Concrete and near-bottom has the highest monthly diversity, species richness and abundance. All species status varied in mean abundances on each substrate, depth and month.

The total taxa of invertebrates registered in this work were 78 and 52 were recorded to species level. Of the remaining 26 taxa were recognized to phylum, family and genera (e.g. see Table 1; Sipuncula, Hesionidae, *Janolus* sp.) so it is likely that natives, NIS and cryptogenic species in the study area are underestimated. Nevertheless, we registered a new record of NIS which includes *Hydroides dianthus*. The number of native, NIS and cryptogenic invertebrates found were higher in relation to a Patagonian port (Rico and López Gappa, 2006; Rico et al., 2010), also native and NIS were higher in comparison with a Brazilian Bay (Neves et al., 2007). Considering only NIS they were higher than in other ports of Patagonia (Schwindt et al., 2014).

In Mar del Plata port, the NIS amphipod *Monocorophium acherusicum* was dominant at different substrate and vertical position. *M. acherusicum* and the polychaete *Hydroides elegans*, were dominant along months and both belong to the fouling fauna in other regions of the world (e.g. Hayes et al., 2005; Gollasch et al., 2009; Ruiz et al., 2011). Artificial structures along the world's coastlines and ports are increasingly (Glasby and Connell, 1999; Bulleri et al., 2005). On the other hand, differences in the species composition of fouling communities on different artificial substrates have long been recognized (Karlson, 1978; Anderson and Underwood, 1994; Bulleri et al., 2005). Moreover, in recent years, some studies have examined the importance of the species status (native, NIS or cryptogenic) on different substrates (e.g. Neves et al., 2007; Tyrrell and Byers, 2007; Tracy and Reys, 2014).

In terms of species composition, the assemblages show a similar

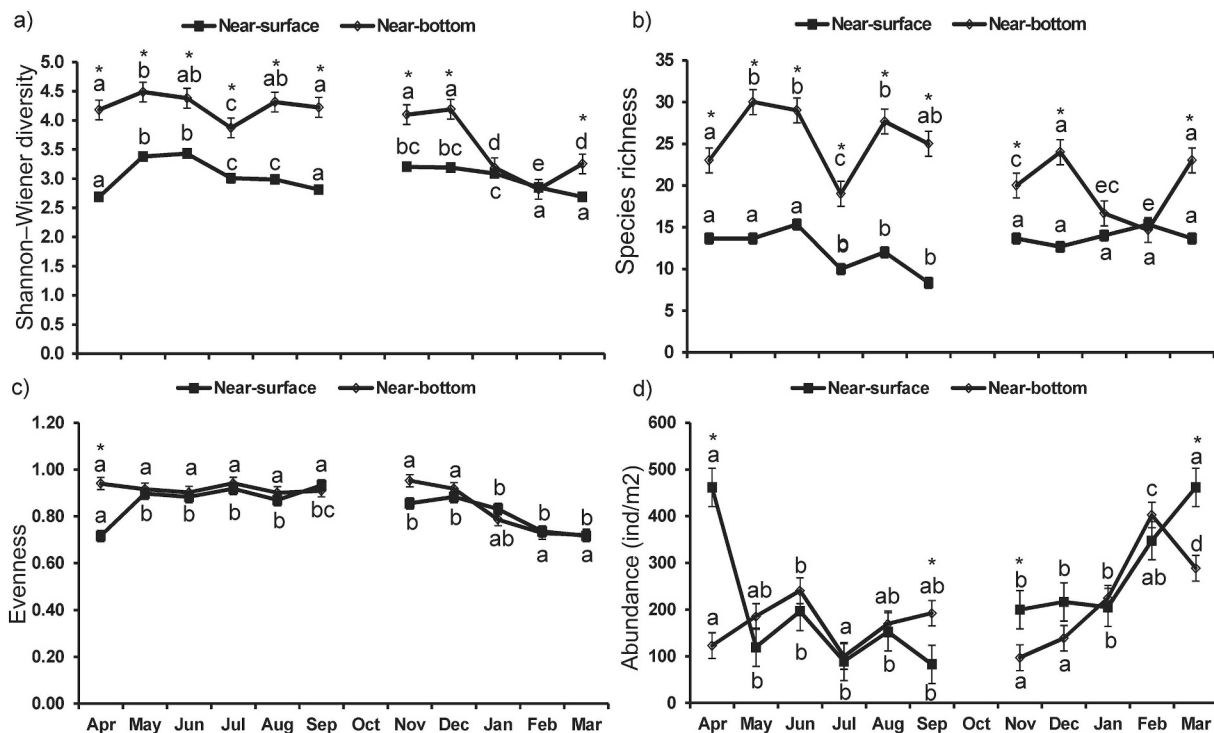


Fig. 4. Mean (a) Shannon–Wiener diversity, (b) species richness, (c) evenness and (d) total abundance on vertical positions \times month plotted with \pm SEs. Asterisks (*) indicate significant differences between near-surface vs. near-bottom and different letters indicate the average values of indices that were significantly different for each vertical positions along months according to pairwise test ($p < 0.05$). (October was not included in due to the lack of replicates).

pattern on substrate, depth and month. *T. uruguayensis* has been registered on the Uruguayan coast by (Scarabino et al., 2006). Nevertheless, there are no previous studies done in order to know if this specie was recorded in other artificial structures in port areas of the Southwestern Atlantic. *C. altimanus* it is a very well-known grapsid belonging to the fouling assembles in ports of the Argentine coast (e.g. see Bastida, 1968; Bastida and Brankevich, 1982). Among the associated macrofauna with fouling organisms was *C. altimanus*, an endemic decapod of the region that is distributed from Rio Grande do Sul (Brazil) to Chubut Argentina (Spivak, 1997). These crabs, small in size, inhabit the oceanic coasts and invade the estuaries when there are suitable habitats such as hard substrates to hide in (Spivak, 1997). The NIS such as *Palaemon macrodactylus*, *Hydroides dianthus*, *M. acherusicum*, *Ascidella aspersa*, *Styela plicata* and *Ciona intestinalis*, are well known to be global invaders. Adults of *P. macrodactylus* were recorded by Spivak et al., (2006) among wood piles and marinas in the Mar del Plata port. *H. dianthus*, *C. intestinalis* and the cryptogenic *Caprella equilibra* are registered in early studies on the fouling assemblages in Mar del Plata, Puerto Madryn and Puerto Belgrano ports by Bastida (1972) Actually, these species in addition to *M. acherusicum*, *A. aspersa* and *S. plicata* has been record in the Mar del Plata port adhered to wooden docks (Rumbold et al., 2016; Velazquez et al., 2017).

Despite the abundance of *T. uruguayensis* on near-surface, Roux and Bremec (1996) found a different pattern on deeper (> 43 m) areas off Mar del Plata coast. Giberto et al. (2004) also found a similar pattern to Roux and Bremec (1996), since they record *T. uruguayensis* as an in-faunal species in a similar areas and depths. Dafforn et al. (2009) studied the early development of fouling assemblages was compared on settlement plates attached to fixed or moving experimental structures at depths of 0.5 m and 2 m. They found the percentage of cover of *S. plicata* also varied with depth and were greater on shallow than deep frames. Tatián et al. (2010) deployed 15 settlement plates in six Patagonians ports, in the subtidal zone at 2–3 m depth during low tide, in order to quantify the abundance of *A. aspersa*. The highest abundance was found in Puerto Deseado port, with maximum values of colonized

plates (93%) and density (mean 3.6 individuals per plate). The native *C. altimanus* and the NIS *P. macrodactylus*, *M. acherusicum*, *H. dianthus*, *C. intestinalis* were abundant on near-bottom. The cryptogenic *C. equilibra* was abundant on both vertical positions. In the Mar del Plata port, *C. altimanus* and *P. macrodactylus* has been found on bottom among fouling (Albano pers. obs.). *C. equilibra* it is found on near-surface in two marinas, El Rompido (Huelva) and La Línea (Cádiz), Spain (Guerra-García and Baeza-Rojano, 2015); as well as in Mar del Plata port (Velazquez et al., 2017). Fouling communities in shallow waters can be described as being fueled by photosynthetic organisms – many fouling animals are suspension- and filter-feeders (e.g. barnacles, tunicates and bivalve mollusks) which directly extract photosynthetic phytoplankton or their zooplankton grazers from the water column (Kingsbury, 1981). The availability of adequate supplies of microphagous food is crucial in the growth and development of fouling assemblages. In shallow coastal waters there is normally an adequate supply of food (Pérez, 1982). Fouling assemblages show segregation throughout months. The abundances of *T. uruguayensis* in the Argentine coast, there are no records so far. Velazquez et al. (2017), they studied the population dynamics and reproductive biology of *Caprella dilatata* and *C. equilibra* in order to provide the basis for understanding the ecological role of both species in Mar del Plata port. Caprellids and organisms from the fouling community were obtained by sampling in the port, monthly (from April 2014 to March 2015). They found a similar pattern, but in very low mean abundance, of *C. altimanus* in November. *C. intestinalis* show the same pattern with high abundances in April. *S. plicata* show very low abundance but in the same season (autumn). *A. aspersa* reveal a dissimilar pattern, with very low abundance in summer months. *M. acherusicum* show, a dissimilar pattern, higher abundance in December and the cryptogenic *C. equilibra* show the same pattern with higher abundances in February. *H. dianthus* was record in abundances, during the first studies on fouling organisms in Puerto Belgrano port, by Bastida (1972) in fall and this agrees with the values found in this work in Mar del Plata port. *P. macrodactylus* has been extensively recorded in Mar del Plata port where a stable and dense population has been

established throughout the year (Vázquez et al., 2012). With few exceptions (Albano and Obenat, 2009; Rico and López Gappa, 2006; Rico et al., 2012; Rico et al., 2010), benthic assemblages of ports in the Southwestern Atlantic coast remain almost unknown. As marine fouling assemblages adversely affect human activities in the sea, and decision-

making depends on knowledge of their variability in time, assemblages of native, NIS and cryptogenic invertebrates on substrate type, depth and time has not yet to be documented as we have done in this study.

Concrete had the highest species richness and abundance values. However, despite these differences, this study suggests that alternative

Table 5

Univariate PERMANOVA analysis of mean abundance for the species composition and their status (natives, NIS and cryptogenic) responses to substrate, vertical position and months.

| Natives | | | | | | |
|--------------------------------------|-----|--------|-------------------------------|-----|--------|---------|
| <i>Tricnidactis errans</i> | | | <i>Cyrtograpsus altimanus</i> | | | |
| Source | df | MS | P(perm) | df | MS | P(perm) |
| Substate | 1 | 193.79 | 0.109 | 1 | 472.18 | 0.019 |
| Vertical position | 1 | 55.704 | 0.039 | 1 | 157.33 | 0.003 |
| Month | 11 | 133.33 | 0.001 | 11 | 50.235 | 0.025 |
| Substate X Vertical position | 1 | 9.662 | 0.821 | 1 | 90.913 | 0.071 |
| Substate X Month | 10 | 68.557 | 0.853 | 10 | 60.428 | 0.129 |
| Vertical position X Month | 11 | 8.778 | 0.975 | 11 | 12.955 | 0.873 |
| Substate X Vertical position X Month | 8 | 1.6638 | 1 | 8 | 21.193 | 0.555 |
| Residual | 94 | 24.788 | | 94 | 24.483 | |
| Total | 137 | | | 137 | | |

| Natives | | | | | | |
|--------------------------------------|-----|--------|--------------------------|-----|--------|---------|
| <i>Brachidontes rodriguezii</i> | | | <i>Hydroides plateni</i> | | | |
| Source | df | MS | P(perm) | df | MS | P(perm) |
| Substate | 1 | 195.87 | 0.062 | 1 | 142.04 | 0.265 |
| Vertical position | 1 | 367.51 | 0.014 | 1 | 226.67 | 0.012 |
| Month | 11 | 44.881 | 0.001 | 11 | 226.11 | 0.001 |
| Substate X Vertical position | 1 | 347.94 | 0.239 | 1 | 46.208 | 0.214 |
| Substate X Month | 10 | 39.247 | 0.569 | 10 | 106.79 | 0.128 |
| Vertical position X Month | 11 | 46.925 | 0.769 | 11 | 33.1 | 0.156 |
| Substate X Vertical position X Month | 8 | 31.908 | 0.193 | 8 | 25.935 | 0.34 |
| Residual | 94 | 13.062 | | 94 | 22.617 | |
| Total | 137 | | | 137 | | |

| Native | | | NIS | | | |
|--------------------------------------|-----|--------|----------------------------------|-----|--------|---------|
| <i>Halosydnella australis</i> | | | <i>Monocorophium acherusicum</i> | | | |
| Source | df | MS | P(perm) | df | MS | P(perm) |
| Substate | 1 | 1401.7 | 0.002 | 1 | 1096.3 | 0.634 |
| Vertical position | 1 | 402.37 | 0.084 | 1 | 18,308 | 0.115 |
| Month | 11 | 366.52 | 0.001 | 11 | 32,196 | 0.001 |
| Substate X Vertical position | 1 | 1.9782 | 0.9 | 1 | 3371.2 | 0.643 |
| Substate X Month | 10 | 170.79 | 0.244 | 10 | 4572.8 | 0.085 |
| Vertical position X Month | 11 | 125.58 | 0.697 | 11 | 6022.8 | 0.034 |
| Substate X Vertical position X Month | 8 | 152.66 | 0.426 | 8 | 14,852 | 0.611 |
| Residual | 94 | 46.435 | | 94 | 2704.7 | |
| Total | 137 | | | 137 | | |

| NIS | | | | | | |
|--------------------------------------|-----|--------|---------------------------|-----|--------|---------|
| <i>Erichthonius punctatus</i> | | | <i>Sphaeroma serratum</i> | | | |
| Source | df | MS | P(perm) | df | MS | P(perm) |
| Substate | 1 | 1096.3 | 0.634 | 1 | 8.8146 | 0.802 |
| Vertical position | 1 | 18,308 | 0.115 | 1 | 63.898 | 0.408 |
| Month | 11 | 32,196 | 0.001 | 11 | 73.864 | 0.015 |
| Substate X Vertical position | 1 | 3371.2 | 0.643 | 1 | 1368.9 | 0.287 |
| Substate X Month | 10 | 4572.8 | 0.085 | 10 | 151.79 | 0.184 |
| Vertical position X Month | 11 | 6022.8 | 0.034 | 11 | 93.772 | 0.423 |
| Substate X Vertical position X Month | 8 | 14,852 | 0.132 | 8 | 59.517 | 0.072 |
| Residual | 94 | 2704.7 | | 94 | 31.064 | |
| Total | 137 | | | 137 | | |

(continued on next page)

Table 5 (continued)

| NIS | | | | | | |
|--------------------------------------|-----|--------|-------------------------------|-----|--------|---------|
| <i>Balanus glandula</i> | | | <i>Palaemon macrodactylus</i> | | | |
| Source | df | MS | P(perm) | df | MS | P(perm) |
| Substate | 1 | 18.062 | 0.508 | 1 | 484.05 | 0.008 |
| Vertical position | 1 | 23.691 | 0.592 | 1 | 32.526 | 0.124 |
| Month | 11 | 41.276 | 0.077 | 11 | 59.458 | 0.001 |
| Substate X Vertical position | 1 | 16.147 | 0.455 | 1 | 42.391 | 0.091 |
| Substate X Month | 10 | 36.707 | 0.256 | 10 | 44.867 | 0.127 |
| Vertical position X Month | 11 | 81.851 | 0.553 | 11 | 11.158 | 0.659 |
| Substate X Vertical position X Month | 8 | 28.216 | 0.462 | 8 | 11.989 | 0.562 |
| Residual | 94 | 28.776 | | 94 | 14.294 | |
| Total | 137 | | | 137 | | |

| NIS | | | | | | |
|--------------------------------------|-----|--------|---------------------------|-----|--------|---------|
| <i>Hydroides elegans</i> | | | <i>Hydroides dianthus</i> | | | |
| Source | df | MS | P(perm) | df | MS | P(perm) |
| Substate | 1 | 3449.2 | 0.161 | 1 | 719.55 | 0.019 |
| Vertical position | 1 | 1148.9 | 0.205 | 1 | 193.59 | 0.045 |
| Month | 11 | 1808.1 | 0.003 | 11 | 142.43 | 0.001 |
| Substate X Vertical position | 1 | 1405.1 | 0.236 | 1 | 45.379 | 0.277 |
| Substate X Month | 10 | 1496.9 | 0.386 | 10 | 111.64 | 0.112 |
| Vertical position X Month | 11 | 579.26 | 0.256 | 11 | 36.305 | 0.472 |
| Substate X Vertical position X Month | 8 | 879.42 | 0.071 | 8 | 34.955 | 0.478 |
| Residual | 94 | 454.42 | | 94 | 35.868 | |
| Total | 137 | | | 137 | | |

| NIS | | | | | | |
|--------------------------------------|-----|--------|-----------------------|-----|--------|---------|
| <i>Ciona intestinalis</i> | | | <i>Styela plicata</i> | | | |
| Source | df | MS | P(perm) | df | MS | P(perm) |
| Substate | 1 | 2348.4 | 0.017 | 1 | 1255.6 | 0.017 |
| Vertical position | 1 | 83.054 | 0.882 | 1 | 438.42 | 0.002 |
| Month | 11 | 143.71 | 0.001 | 11 | 75.283 | 0.001 |
| Substate X Vertical position | 1 | 78.486 | 0.124 | 1 | 85.472 | 0.124 |
| Substate X Month | 10 | 179.05 | 0.872 | 10 | 130.49 | 0.986 |
| Vertical position X Month | 11 | 83.226 | 0.149 | 11 | 30.292 | 0.149 |
| Substate X Vertical position X Month | 8 | 134.64 | 0.134 | 8 | 31.553 | 0.134 |
| Residual | 94 | 50.1 | | 94 | 19.707 | |
| Total | 137 | | | 137 | | |

| NIS | | | | | | |
|--------------------------------------|-----|--------|----------------------------|-----|--------|---------|
| <i>Ascidella aspersa</i> | | | <i>Molgula manhatensis</i> | | | |
| Source | df | MS | P(perm) | df | MS | P(perm) |
| Substate | 1 | 24.95 | 0.528 | 1 | 85.472 | 0.972 |
| Vertical position | 1 | 959.99 | 0.001 | 1 | 72.118 | 0.025 |
| Month | 11 | 68.439 | 0.001 | 11 | 26.231 | 0.043 |
| Substate X Vertical position | 1 | 8.4784 | 0.755 | 1 | 161.01 | 0.039 |
| Substate X Month | 10 | 65.392 | 0.954 | 10 | 47.333 | 0.308 |
| Vertical position X Month | 11 | 51.478 | 0.101 | 11 | 35.037 | 0.600 |
| Substate X Vertical position X Month | 8 | 74.08 | 0.100 | 8 | 24.235 | 0.086 |
| Residual | 94 | 16.026 | | 94 | 14.151 | |
| Total | 137 | | | 137 | | |

| Cryptogenic | | | | | | |
|---------------------------|----|--------|------------------------|----|--------|---------|
| <i>Caprella equilibra</i> | | | <i>Tanais dulongii</i> | | | |
| Source | df | MS | P(perm) | df | MS | P(perm) |
| Substate | 1 | 3897.2 | 0.014 | 1 | 29.335 | 0.501 |
| Vertical position | 1 | 2814.4 | 0.115 | 1 | 3897.3 | 0.008 |

(continued on next page)

Table 5 (continued)

| Source | Cryptogenic | | | | | |
|--------------------------------------|---------------------------|--------|------------------------|-----|--------|---------|
| | <i>Caprella equilibra</i> | | <i>Tanais dulongii</i> | | | |
| | df | MS | P(perm) | df | MS | P(perm) |
| Month | 11 | 2375.7 | 0.001 | 11 | 401.77 | 0.009 |
| Substate X Vertical position | 1 | 1973.6 | 0.137 | 1 | 127.06 | 0.269 |
| Substate X Month | 10 | 405.75 | 0.247 | 10 | 48.803 | 0.965 |
| Vertical position X Month | 11 | 951.35 | 0.300 | 11 | 389.93 | 0.500 |
| Substate X Vertical position X Month | 8 | 720.43 | 0.080 | 94 | 155.23 | 0.659 |
| Residual | 94 | 311.87 | | 137 | | |
| Total | 137 | | | | | |

Not significant $p > 0.05$; significant $0.05 > p > 0.01$; highly significant $p < 0.01$, p-values were obtained using 999 permutations.

materials are more suitable for promoting settlement of invertebrates. For further studies we should include more substrates type (e.g. PVC, steel, rubber) in order to assess diversity and abundance. According to Ushiyama et al. (2016), concrete may have similar properties to the sandstone and deserves further evaluation, particularly given that new concrete mixes are being custom made for the marine environment. Knott et al. (2004) indicated that orientation may be of greater influence on the biological diversity of epibiota on subtidal reefs than whether reefs are natural or artificial. Concrete is the most common substrate in Europe for construction of artificial reefs because it ensures good stability and allows the realization of modules of various shapes and sizes (Fabi et al., 2011). Bombace (1997) found higher species richness on concrete modules in respect to coal-ash ones and a selective settlement of the burrowing bivalve *Pholas dactylus* on the horizontal surfaces of coal-ash blocks.

Wood reveals that species-specific response effect with, four natives and three NIS, higher mean abundances than concrete. The native crab *Cyrtograpsus altimanus* and the polychaete *Halosydnella australis* both were more abundant on wood, as previously recorded in the Mar del Plata port by Bastida (1968; 1971–1972) and Bastida (1968) on experimental rafts. The same pattern was shown by NIS, since the oriental shrimp *Palaemon macrodactylus*, the serpulid polychaete *Hydroides dianthus*, the ascidians *Ciona intestinalis* and *Styela plicata* were more abundant on wood. The amphipod *Caprella equilibra* was the only cryptogenic species that showed greater average abundance on concrete. On the other hand, *C. equilibra* is found on wooden docks (Velazquez et al., 2017). Notably the invasive *P. macrodactylus* had a stable population in the Mar del Plata port throughout the year (Vázquez et al., 2012) and was only found in wood. Similarly to a pattern observed in this study with *H. dianthus*, Ushiyama et al. (2016) found in the wood the serpulid worm *Pomatoceros* sp. but in lower abundances.

The near-bottom had the highest mean diversity and species richness. A similar pattern to the observed in substrate, but they show similar values in abundance. In order to know which depth will be more diverse and abundant, in futures studies, we would include an intermediate depth. This will give us a better knowledge which vertical position will have more diversity and species richness.

Near-surface shows that species-specific response effect with two natives, *Trindactis errans* and *Brachidontes rodriguezii*, and one cryptogenic, *Tanais dulongii*, with higher mean abundance than near-surface. Excoffon et al. (1999) studied the macrobenthos associated with a population of *Anthothoe chilensis* on rocky substrata between 2 and 3 m deep in the Mar del Plata port. On the fauna associated, *T. errans* was found to coexist with *A. chilensis* but it occurred in lower abundance. *B. rodriguezii* and *T. dulongii* are present on near-surface fouling community adhered to docks into the port and with high mean abundances (see Rumbold et al., 2015; Velazquez et al., 2017).

The near-bottom shows that species-specific response effect with, two natives and three NIS, higher mean abundances. The natives were *C. altimanus* and *Hydroides plateni*. The NIS *Styela plicata*, *Asciidiella*

aspersa and *Molgula manhattensis* show a pattern with maximum values on bottom. *C. altimanus* has been registered in moderate mean abundances in the Mar del Plata port since many decades ago, during the first fouling studies (Bastida, 1968), until the present (Velazquez et al., 2017). Albano et al. (2013) studied the associated macrofauna in the aggregates of the polychaete *Phyllochaetopterus socialis* in the Mar del Plata port. These were found at about 6 m depth, on the border between the break-water rocks and soft sediments, and *H. plateni* was present in high abundances. The NIS ascidians *S. plicata*, *A. aspersa* and *M. manhattensis* are well known to invade worldwide ports. For example, during an epibenthic community structure survey in Port Phillip Bay (Australia) *S. plicata* and *A. aspersa* were collected at 30 depth-stratified stations (Cohen et al. 2000). *M. manhattensis* was recorded at 3 m depth on anchoring lines at Ria de Ferrol (Galicia, Spain) (e.g. Vázquez and Urgorri, 1992). The major's forcing factors determining subtidal fouling assemblages are light levels, temperature and pressure, food supplies and water currents. The latter are important to sessile assemblages for two main reasons: (a) they maintain the amounts of hard substrata available and (b) they influence the distribution and recruitment of planktonic larvae. Currents influence the nature of the substratum available for colonization by epifauna: strong currents prevent sedimentation and leave bare hard substrata or coarse sediments, whereas weak currents result in high sedimentation rates and lead to silty or muddy substrata (Pérez, 1982; Rogers, 1994). Sessile organisms that produce planktonic larvae also rely on currents to disperse their larvae and populations of these species are maintained by the recruitment of competent larvae from the water column. These factors combine with others such as competition and predation (Paine, 1974; Sebens, 1986) and the biology and physiology of individual species to influence the bathymetric distribution of epifaunal species and communities, producing vertical zones on natural and man-made hard substrata.

Mean and species richness on concrete was greater than wood and shows maximum values during autumn and spring. In the Mar del Plata port, Albano et al. (2013) registered a similar pattern with higher average species richness in May. Velazquez et al. (2017) show a dissimilar pattern with higher total species richness in summer and mean abundance in May. As in the case of present study, Underwood and Chapman (2000) also note that species diversity in most habitats and ecosystems show a wide range of variation both on spatial and temporal scales. This paper shows that, in both substrates, the near-bottom was more diverse and richness through the months. A likely explanation for these differences may be to the presence of *P. socialis* polychaete tubes at the bottom. In this study we consider *P. socialis* as a cryptogenic species which is found in both substrates (see Table 2). This species is considered an ecosystem engineer (Jones et al., 1994) that houses an assemblage of macroinvertebrates living within these tubes (Albano and Obenat, 2009). During the summer higher average volumes of these tubes were found, hosting more NIS than the surface. In turn, the near-bottom was the only depth where variations were found in the mean values of species richness, diversity and evenness throughout the study period; therefore, this pattern might be due to the presence of

polychaete ecosystem engineer in that depth. On the other hand, the pattern observed by average abundance showed in the near-surface, highest values in April and March. It is likely that factors associated with proximity to the surface (e.g. light) might have some of the strongest effects on the development of epibiota assemblages in the subtidal (Glasby, 1999; Saunders and Connell, 2001). In turn, changes in the structure of the community through a vertical gradient are generally related to the physical factors which vary with depth such as the action of the waves and the attenuation of light (Witman and Dayton, 2001).

The monthly variations average abundances reveal that species-specific response effect differences in 5 natives and 11 NIS. Given the high species specific response of NIS (compared to native), found in this study along the temporal fluctuations in fouling communities, we suggest that this deserves attention for management measures in order to prevent more invasive species introductions in the future. Invasive species management has been recognized as a global issue of concern (e.g. IMO, 2017). The importance of fouling as a vector for invasive species translocation is being increasingly recognized (Lewis and Coutts, 2010). All ships have some degree of fouling, even those which may have been recently cleaned or had a new application of an anti-fouling system. Management measures may be applied at various points in the process of invasion, starting from prevention of introductions, to early detection of NIS or founder populations and rapid response there to – in the form of eradication or containment – and long-term control of invasive populations.

The present study highlighted the importance of the relationship between the fouling assemblages of native, NIS and cryptogenic species with different kind of substrates, two depths and temporal variations. This is the first study which focuses on community composition of native, NIS and cryptogenic species on substrate type, depth and time in the Mar del Plata port. Understanding when, where and how the NIS were establish in ports will allow us design monitoring programs to prevent arrival and settle of these species.

Acknowledgments

The authors wish to thank the following experts for their taxonomic work: A. Garese (Anthozoa), V. Bulnes (Polychaetida), R. Elías (Polychaeta), C. Rumbold (Tanaidacea y Gammaridae), E. Spivak (Cirripedia) and G. Vázquez (Decapoda), E. Ocampo (Gasteropoda), C. Muniain (Opisthobranchia), M. Tatian and C. Lagger (Tunicata). Also to A. Rosenthal, J. Lancia, J. Seco Pon, C. Rumbold and N. Farias for their support during the SCUBA diving sampling and for his assistance on land. To Club Náutico (Yacht Club) who facilitated the access to the marinas. We would like to thank the reviewers for their critical revision of the manuscript and the suggestions received that improved the final result of the manuscript. This work was supported by UNMdP (Universidad Nacional de Mar del Plata) EXA 430/08.

References

Albano, M., Obenat, S.M., 2009. Assemblage of benthic macrofauna in the aggregates of the tubicolous worm *Phyllochaetopterus socialis* in the Mar del Plata harbour, Argentina. *J. Mar. Biol. Assoc.* 89, 1099.

Albano, M.J., da Cunha Lana, P., Bremec, C., Elías, R., Martins, C.C., Venturini, N., Muniz, P., Rivero, S., Vallarino, E.A., Obenat, S., 2013. Macrobenthos and multi-molecular markers as indicators of environmental contamination in a south American port (Mar del Plata, Southwest Atlantic). *Mar. Pollut. Bull.* 73, 102–114.

Alpert, P., 2006. The advantages and disadvantages of being introduced. *Biol. Invasions* 8, 1523–1534.

Amor, A., 1964. Ascidiar nuevas para la fauna argentina. *Physis* 24 (67-70), 351.

Anderson, M.J., 2001. A new method for non-parametric multivariate analysis of variance. *Austral Ecol.* 26, 32–46.

Anderson, M.J., Underwood, A.J., 1994. Effects of substratum on the recruitment and development of an intertidal estuarine fouling assemblage. *J. Exp. Mar. Biol. Ecol.* 184, 217–236.

Ashley, C.W., De Grave, S., Johnson, M.L., 2013. The global invader *Palaemon macrondactylus* (Decapoda, Palaemonidae): an interrogation of records and a synthesis of data. *Crustaceana* 86 (5), 594–624.

Bacchiocchi, F., Airoldi, L., 2003. Distribution and dynamics of epibiota on hard structures for coastal protection. *Estuar. Coast. Shelf Sci.* 56, 1157–1166.

Bastida, R., 1968. Preliminary Notes of the Marine Fouling at the Port of Mar del Plata Argentina.

Bastida, R., 1972. Studies of the Fouling Communities along Argentine Coasts.

Bastida, R., Brankevich, G., 1982. Estudios ecológicos sobre las comunidades incrustantes de Puerto Quequen (Argentina). II. Características del macrofouling. *CIDEPINT An.* pp. 155–193.

Bastida, R., Torti, M., 1972. Organismos perforantes de las costas Argentinas I. La presencia de *Lyrodus pedicellatus* (Quatrefages, 1849) (Mollusca, Pelecypoda).

Boltovskoy, D., Almada, P., Correa, N., 2011. Biological invasions: assessment of threat from ballast-water discharge in Patagonian (Argentina) ports. *Environ. Sci. Pol.* 14, 578–583.

Bombace, G., 1997. Protection of biological habitats by artificial reefs. In: Proceedings of the 1 Conference of the European Artificial Reef Research Network, pp. 1–15.

Bulleri, F., Chapman, M.G., Underwood, A.J., 2005. Intertidal assemblages on seawalls and vertical rocky shores in Sydney Harbour, Australia. *Austral Ecol.* 30, 655–667.

Byers, J.E., 2002. Impact of non-indigenous species on natives enhanced by anthropogenic alteration of selection regimes. *Oikos* 97, 449–458.

Carlton, J.T., 1981. History, Biogeography, and Ecology of the Introduced Marine and Estuarine Invertebrates of the Pacific Coast of North America.

Carlton, J.T., 1996. Biological invasions and cryptogenic species. *Ecology* 77, 1653–1655.

Carlton, J.T., 2001. 13 the scale and ecological consequences of biological invasions in the World's oceans. *Invasive species Biodivers. Manag.* 24, 195.

Carlton, J.T., Geller, J.B., James, T., 1993. Ecological roulette: the global transport of nonindigenous marine organisms. *Science* 80, 78–82.

Clarke, K.R., Gorley, R.N., 2006. PRIMER V6: User Manual-Tutorial. Plymouth Marine Laboratory.

Clarke, K.R., Warwick, R.M., 1994. An Approach to Statistical Analysis and Interpretation. *Chang. Mar. Communities* 2.

Cohen, B.F., Currie, D.R., McArthur, M.A., 2000. Epibenthic community structure in Port Phillip Bay, Victoria, Australia. *Mar. Freshw. Res.* 51 (7), 689–702.

Connell, S.D., Glasby, T.M., 1999. Do urban structures influence local abundance and diversity of subtidal epibiota? A case study from Sydney Harbour, Australia. *Mar. Environ. Res.* 47, 373–387.

Coutts, A.D.M., Dodgshun, T.J., 2007. The nature and extent of organisms in vessel sea-chests: a protected mechanism for marine bioinvasions. *Mar. Pollut. Bull.* 54, 875–886.

Dafforn, K.A., Johnston, E.L., Glasby, T.M., 2009. Shallow moving structures promote marine invader dominance. *Biofouling* 25, 277–287.

Doti, B., Schwindt, E., Scarabino, F., 2012. First record of the exotic isopod *Sphaeroma serratum* (Crustacea: Isopoda) from Uruguayan waters (southwestern Atlantic). *Zootaxa* 3565 (1), 68.

Excóffon, A.C., Genzano, G.N., Zamponi, M.O., 1999. Macrobenthos associated with a population of *Anthothoe chilensis* (Lesson, 1830) (Cnidaria, Actiniaria) in Mar del Plata harbor, Argentina. *Ciencias Marinas* 25 (2), 177–191.

Fabi, G., Spagnolo, A., Bellan-Santini, D., Charbonnel, E., Çiçek, B.A., Goutayer García, J.J., Jensen, A.C., Kallianiotis, A., Neves, M., Santos, D., 2011. *Braz. J. Oceanogr.* 59, 155–166.

Garrabou, J., Ballesteros, E., Zabala, M., 2002. Structure and dynamics of North-Western Mediterranean rocky benthic communities along a depth gradient. *Estuar. Coast. Shelf Sci.* 55, 493–508.

Genzano, G., Giberto, D., Bremec, C., 2011. Estudios del bentos de arrecifes naturales y artificiales de Mar del Plata, Argentina, Atlántico sudoccidental. *Lat. Am. J. Aquat. Res.* 39, 553–556.

Giambiagi, D., 1922. Cuatro nuevos isopodos de la Argentina. *Physis* 5, 230–244.

Giambiagi, D., 1923. Una nueva especie de Tanais. *Physis (Argentina)* 6, 248–251.

Giberto, D.A., Bremec, C.S., Acha, E.M., Mianzan, H., 2004. Large-scale spatial patterns of benthic assemblages in the SW Atlantic: the Rio de la Plata estuary and adjacent shelf waters. *Estuar. Coast. Shelf Sci.* 61, 1–13.

Gittenberger, A., van der Stelt, R.C., 2011. Artificial structures in harbors and their associated ascidian fauna. *Aquat. Invasions* 6, 413–420.

Glasby, T.M., 1999. Differences between Subtidal Epibiota on Pier Pilings and Rocky Reefs at Marinas in Sydney, Australia. *Estuar. Coast. Shelf Sci.* 48, 281–290.

Glasby, T., Connell, S., 1999. Urban Structures as Marine Habitats.

Godwin, L.S., 2003. Hull fouling of maritime vessels as a pathway for marine species invasions to the Hawaiian Islands. *Biofouling* 19 (Suppl), 123–131.

Goldberg, R.N., Averbuj, A., Cledón, M., Luzzatto, D., Sbarbati Nudelman, N., 2004. Search for triorganotins along the Mar del Plata (Argentina) marine coast: finding of tributyltin in egg capsules of a snail *Adelomelon brasiliana* (Lamarck, 1822) population showing imposex effects. *Appl. Organomet. Chem.* 18, 117–123.

Gollasch, S., 2002. The Importance of Ship Hull Fouling as a Vector of Species Introductions into the North Sea. *Biofouling* 18, 105–121.

Gollasch, S., Haydar, D., Minchin, D., Wolff, W.J., Reise, K., 2009. Introduced aquatic species of the North Sea coasts and adjacent brackish waters. *Biol. Invasions Mar. Ecosyst.* 507–528.

Grosholz, E.D., Ruiz, G.M., Dean, C.A., Shirley, K.A., Maron, J.L., Connors, P.G., 2000. The impacts of a nonindigenous marine predator in a California bay. *Ecology* 81, 1206–1224.

Guerra-García, J.M., Baeza-Rojano, E., 2015. Seasonal fluctuations and dietary analysis of fouling caprellids (Crustacea: Amphipoda) from marinas of southern Spain. *Mar. Biol. Res.* 11, 703–715.

Hayes, K., Sliwa, C., Migus, S., Mcennulty, F., Dunstan, P., 2005. National Priority Pests: Part II Ranking of Australian Marine Pests. *Dep. Environ. Herit. by CSIRO.*

Hewitt, C.L., 2002. Distribution and biodiversity of Australian tropical marine bioinvasions. *Pac. Sci.* 56, 213–222.

- Hewitt, C.L., Campbell, M.L., Thresher, R.E., Martin, R.B., Boyd, S., Cohen, B.F., Currie, D.R., Gomon, M.F., Keough, M.J., Lewis, J.A., Lockett, M.M., Mays, N., McArthur, M.A., O'Hara, T.D., Poore, G.C.B., Ross, D.J., Storey, M.J., Watson, J.E., Wilson, R.S., 2004. Introduced and cryptogenic species in Port Phillip Bay, Victoria, Australia. *Mar. Biol.* 144, 183–202.
- IMO. International Maritime Organization, 2017. <http://www.imo.org/en/OurWork/Environment/Biofouling/Pages/default.aspx>, Accessed date: 1 July 2017.
- Jackson, J.B.C., 1977. Competition on marine hard substrata: the adaptive significance of solitary and colonial strategies. *Am. Nat.* 111, 743–767.
- Jones, C.G., Lawton, J.H., Shachak, M., 1994. Organisms as Ecosystem Engineers, in: *Ecosystem Management*. Springer, pp. 130–147.
- Karlson, R., 1978. Predation and space utilization patterns in a marine epifaunal community. *J. Exp. Mar. Biol. Ecol.* 31, 225–239.
- Kingsbury, R., 1981. Marine fouling of North Sea installations. *Mar. Fouling Offshore Struct* 12.
- Kittlein, M.J., 1991. Population biology of *Sphaeroma serratum* Fabricius (Isopoda, Flabellifera) at the Port of Mar del Plata, Argentina. *J. Nat. Hist.* 25 (6), 1449–1459.
- Knight-Jones, P., Knight-Jones, E.W., 1991. Ecology and distribution of Serpuloidea (Polychaeta) round South America. *Ophelia* 5, 569–586.
- Knott, N.A., Underwood, A.J., Chapman, M.G., Glasby, T.M., 2004. Epibioti on vertical and on horizontal surfaces on natural reefs and on artificial structures. *J. Mar. Biol. Assoc. United Kingdom* 84, 1117–1130.
- Kott, P., 1969. Antarctic ASCIDIACEA. A monographic account of the known species based on specimens collected under US government auspices 1947 to 1963. *Antarctic Research Series* 13, 239.
- Laitano, M.V., Castro, I.B., Costa, P.G., Fillmann, G., Cledón, M., 2015. Butyltin and PAH contamination of Mar del Plata port (Argentina) sediments and their influence on adjacent coastal regions. *Bull. Environ. Contam. Toxicol.* 95, 513–520.
- Lejeune, C., Latchere, O., Petit, N., Rico, C., Green, A.J., 2014. Do invaders always perform better? Comparing the response of native and invasive shrimps to temperature and salinity gradients in south-west Spain. *Estuar. Coast. Shelf Sci.* 136, 102–111.
- Leppäkoski, E., Olenin, S., Gollasch, S., 2002. The Baltic Sea—A Field Laboratory for Invasion Biology. In: *Invasive Aquatic Species of Europe. Distribution, Impacts and Management*. Springer, pp. 253–259.
- Levine, J.M., 2000. Species diversity and biological invasions: relating local process to community pattern. *Science* 80, 852–854.
- Lewis, J.A., Coutts, A., 2010. Biofouling invasions. *Biofouling* 348–365.
- Lini, R.M., Roux, A.M., Scelzo, M.A., 1995. Sobre la presencia del isópodo *Joeropsis dubia* Menzies, 1951 en aguas marplatenses, Provincia de Buenos Aires, Argentina (Isopoda, Asellota, Jaeropsidae). In: *COLACMAR 60, Congr Latinoam Ciencias del Mar, Mar del Plata, Argentina*.
- Martorelli, S.R., Alda, P., Marcotegui, P., Montes, M.M., La Sala, L.F., 2012. New locations and parasitological findings for the invasive shrimp *Palaemon macrondactylus* in temperate southwestern Atlantic coastal waters. *Aquat. Biol.* 15 (2), 153–157.
- McCain, J.C., 1968. The Caprellidae [Crustacea: Amphipoda] of the Western North Atlantic. (place unknown).
- McCain, J.C., Gray, W.S., 1971. Antarctic and Subantarctic Caprellidae (Crustacea: Amphipoda). *Biol. Antarct. Seas* IV. 111–139.
- Minchin, D., 2007. Rapid coastal survey for targeted alien species associated with floating pontoons in Ireland. *Aquat. Invasions* 2, 63–70.
- Monro, C.C.A., 1938. XXXII.—on a small collection of Polychaeta from Uruguay. *J. Nat. Hist.* 2, 311–314.
- Neves, C.S., Rocha, R.M., Pitombo, F.B., Roper, J.J., 2007. Use of artificial substrata by introduced and cryptogenic marine species in Paranaguá Bay, southern Brazil. *Biofouling* 23, 319–330.
- Newman, W.A., 1976. Revision of the Balanomorph barnacles; including a catalog of the species. *Mem. S. Diego Soc. Nat. Hist.* 9, 1–108.
- Niño, H., 1979. Zonación del macrobentos en un sistema lagunar litoral oceánico. *Memorias del Semin. sobre Ecol. Bentónicas y Sedimentación la Plataforma Cont. del Atlántico Sur* 1, 225–235.
- Obenat, S., Ferrero, L., Spivak, E., 2001. Macrofauna associated with *Phyllochaetopterus socialis* aggregations in the southwestern Atlantic. *Vie Milieu* 51, 131–139.
- Ojaveer, H., Galil, B.S., Minchin, D., Olenin, S., Amorim, A., Canning-Clode, J., Chainho, P., Copp, G.H., Gollasch, S., Jelmer, A., Lehtiniemi, M., McKenzie, C., Mikuš, J., Miossec, L., Occhipinti-Ambrogi, A., Pečarić, M., Pederson, J., Quilez-Badia, G., Wijsman, J.W.M., Zenetos, A., 2014. Ten recommendations for advancing the assessment and management of non-indigenous species in marine ecosystems. *Mar. Policy* 44, 160–165.
- Orensanz, J.M., 1974. Los anélidos poliquetos de la provincia biogeográfica Argentina. VI. Arabellidae. [The Polychaetous Annelids of the Argentine Biogeographic Province. VI. Arabellidae]. *Physis* 33, 381–408.
- Orensanz, J.M., Estivariz, M.C., 1971. Los anélidos poliquetos de aguas salobres de la provincia de Buenos Aires. *Rev. del Mus. La Plata nueva Ser. Zool.* 11, 95–104.
- Orensanz, J.M.L., Schwindt, E., Pastorino, G., Bortolus, A., Casas, G., Darrigran, G., Elías, R., Gappa, J.J.L., Obenat, S., Pascual, M., Penchaszadeh, P., Piriz, M.L., Scarabino, F., Spivak, E.D., Vallarino, E., 2002. No longer the pristine confines of the world ocean: a survey of exotic marine species in the southwestern Atlantic. *Biol. Invasions* 4, 115–143.
- Paine, R.T., 1974. Intertidal community structure. *Oecologia* 15, 93–120.
- Penchaszadeh, P.E., Averbuj, A., Cledón, M., 2001. Imposax in gastropods from Argentina (South-Western Atlantic). *Mar. Pollut. Bull.* 42, 790–791.
- Pérez, J.M., 1982. Major Benthic Assemblages. In: Kinne, O. (Ed.), *Ocean Management*. John Wiley & Sons, Chichester, pp. 373–521.
- Pezzani, S., Pérez, M., Stupak, M., 1992. Macrofouling Community at Mar del Plata Harbor (1991–1992). *Recruitment and Structure* 39–51.
- Pisanó, A., Rengel, D., Bustuabad, O., 1971. Finding of *Ciona robusta* in Argentine seas. *Annu. dell'Istituto e Mus di Zool dell'Università di Napoli* 19, 1–10.
- Ranasinghe, J.A., Mikel, T.K., Velarde, R.G., Weisberg, S.B., Montagne, D.E., Cadien, D.B., Dalkey, A., 2005. The prevalence of non-indigenous species in southern California embayments and their effects on benthic macroinvertebrate communities. *Biol. Invasions* 7, 679–686.
- Rebele, F., 1994. Urban ecology and special features of urban ecosystems. *Glob. Ecol. Biogeogr. Lett.* 173–187.
- Rico, A., López Gappa, J.L., 2006. Intertidal and subtidal fouling assemblages in a Patagonian harbour (Argentina, Southwest Atlantic). *Hydrobiologia* 563, 9–18.
- Rico, A., Peralta, R., López Gappa, J.L., 2010. Recruitment variation in subtidal macrofouling assemblages of a Patagonian harbour (Argentina, South-Western Atlantic). *J. Mar. Biol. Assoc. United Kingdom* 90, 437–443.
- Rico, A., Peralta, R., López Gappa, J., 2012. Succession in subtidal macrofouling assemblages of a Patagonian harbour (Argentina, SW Atlantic). *Helgol. Mar. Res.* 66, 577–584.
- Rilov, G., Galil, B., 2009. Marine Bioinvasions in the Mediterranean Sea—History, Distribution and Ecology: Biological Invasions in Marine Ecosystems. Springer, pp. 549–575.
- Rioja, E., 1943. Estudios Anelidológicos IX: La presencia de la *Mercierella enigmatica* Fauvel, en las costas argentinas. In: *An. del Inst. Biol. UNAM*. Vol. 14, pp. 547–551.
- Rivero, M.S., Elías, R., Vallarino, E.A., 2005. First survey of macrofauna in the Mar del Plata Harbor (Argentina), and the use of polychaetes as pollution indicators. *Rev. Biol. Mar. Oceanogr.* 40.
- Robinson, T., Griffiths, C., McQuaid, C., Rius, M., 2005. Marine alien species of South Africa — status and impacts. *Afr. J. Mar. Sci.* 27, 297–306.
- Rogers, A.D., 1994. The biology of seamounts. *Adv. Mar. Biol.* 30, 305–350.
- Roux, A.M., Bremec, C.S., 1996. Comunidades bentónicas relevadas en las transecciones realizadas frente al Río de la Plata (35° 15'S), Mar del Plata (38° 10'S) y Península Valdés (42° 35'S), Argentina. *Secretaría de Agricultura, Pesca y Alimentación. Instituto Nacional de Investigación y Desarrollo Pesquero-INIDEP*.
- Ruiz, G.M., Carlton, J.T., 2003. Invasion Vectors: A Conceptual Framework for Management. *Invasive Species Vectors Manag. Strateg.* 459–504.
- Ruiz, G.M., Carlton, J.T., Grosholz, E.D., Hines, A.H., 1997. Global invasions of marine and estuarine habitats by non-indigenous species: mechanisms, extent, and consequences. *Am. Zool.* 37, 621–632.
- Ruiz, G.M., Fofonoff, P.W., Carlton, J.T., Wonham, M.J., Hines, A.H., 2000. Invasion of Coastal Marine Communities in North America: Apparent patterns, Processes, and Biases. *Annu. Rev. Ecol. Syst.* 31, 481–531.
- Ruiz, G.M., Freestone, A.L., Fofonoff, P.W., Simkanin, C., 2009. Habitat Distribution and Heterogeneity in Marine Invasion Dynamics: The Importance of Hard Substrate and Artificial Structure. In: *Marine Hard Bottom Communities*. Springer, pp. 321–332.
- Ruiz, G., Fofonoff, P., Steves, B., Dahlstrom, A., 2011. Marine Crustacean Invasions in North America: A Synthesis of Historical Records and Documented Impacts. In: *The Wrong Place—Alien Marine Crustaceans: Distribution, Biology and Impacts*. Springer, pp. 215–250.
- Rumbold, C.E., Obenat, S.M., Spivak, E.D., 2015. Comparison of life history traits of *Tanais dulongii* (Tanaisidae: Tanaisiidae) in natural and artificial marine environments of the South-Western Atlantic. *Helgol. Mar. Res.* 69, 231–242.
- Rumbold, C.E., Barlett, T.R., Gavio, M.A., Obenat, S.M., 2016. Population dynamics of two invasive amphipods in the Southwestern Atlantic: *Monocorophium acherusicum* and *Erichthonius punctatus* (Crustacea). *Mar. Biol. Res.* 12, 268–277.
- Russ, G.R., 1982. Overgrowth in a marine epifaunal community: Competitive hierarchies and competitive networks. *Oecologia* 53, 12–19.
- Saunders, R.J., Connell, S.D., 2001. Interactive effects of shade and surface orientation on the recruitment of spirorbid polychaetes. *Austral Ecol.* 26, 109–115.
- Scarabino, F., Zaffaroni, J.C., Carranza, A., Clavijo, C., Nin, M., 2006. Gasterópodos marinos y estuarinos de la costa uruguaya: faunística, distribución, taxonomía y conservación. Bases para la Conserv. y el manejo la costa uruguaya. *Vida Silv. Uruguay, Montevideo*, pp. 143–155.
- Schejter, L., Spivak, E., Luppi, T.A., 2002. Presence of *Pyromia tuberculata* (Lockington, 1877) adults and larvae in the Argentine continental shelf (Crustacea: Decapoda: Majoidea). *Proc. Biol. Soc. Wash.* 115, 605–610.
- Schotte, M., 2014. Excavation Stebbing. In: Schotte, M., Boyko, C.B., Bruce, N.L., Poore, G.C.B., Taiti, S., Wilson, G.D.F. (Eds.), *World marine, freshwater and terrestrial isopod crustaceans database*. Accessed through: *World Register of Marine Species*.
- Schwindt, D.E., Darrigran, G., Repizo, I.H., 2010. Evaluación Nacional de Situación en Materia del Agua de Lastre en el Litoral Marino y Fluvial. Argentina. *Informe Final Proyecto Globalballast* 334 pp.
- Schwindt, E., López Gappa, J., Raffo, M.P., Tatián, M., Bortolus, A., Orensanz, J.M., Alonso, G., Diez, M.E., Doti, B., Genzano, G., Lager, C., Lovrich, G., Piriz, M.L., Mendez, M.M., Savoya, V., Sueiro, M.C., 2014. Marine fouling invasions in ports of Patagonia (Argentina) with implications for legislation and monitoring programs. *Mar. Environ. Res.* 99, 60–68.
- Sebens, K.P., 1986. Spatial relationships among encrusting marine organisms in the New England subtidal zone. *Ecol. Monogr.* 56, 73–96.
- Sieg, J., 1983a. Crustaceorum Catalogo 6. JSTOR.
- Sieg, J., 1983b. Contribution to the Knowledge of the Tanaisiidae (Crustacea) of Brazil. 1. The Family Tanaisiidae Dana, 1849. *Papéis Avulsos Zool. São Paulo* 35, 31–39.
- Smith, C.R., Grange, L.J., Honig, D.L., Naudts, L., Huber, B., Guidi, L., Domack, E., 2011. A large population of king crabs in Palmer Deep on the west Antarctic Peninsula shelf and potential invasive impacts. *Proc. R. Soc. Lond. B Biol. Sci.* 279 (1730), 1017–1026.
- Spivak, E.D., 1997. Cangrejos estuariales del Atlántico sudoccidental (25°–41°S) (Crustacea: Decapoda: Brachyura) (Crustacea: Decapoda: Brachyura). pp. 105–120.
- Spivak, E.D., L'Hoste, S.G., 1976. Presencia de cuatro especies de Balanus en la costa de la

- provincia de Buenos Aires: distribución y aspectos ecológicos. ED Spivak et SG L'Hoste.
- Spivak, E.D., Boschi, E.E., Martorelli, S.R., 2006. Presence of *Palaemon macrodactylus* Rathbun 1902 (Crustacea: Decapoda: Caridea: Palaemonidae) in Mar del Plata harbor, Argentina: first record from southwestern Atlantic waters. *Biol. Invasions* 8, 673–676.
- Stachowicz, J.J., Whitlatch, R.B., Osman, R.W., 1999. Species Diversity and Invasion Resistance in a Marine Ecosystem. *Source Sci. New Ser.* 286, 1577–1579.
- Stachowicz, J.J., Terwin, J.R., Whitlatch, R.B., Osman, R.W., 2002. Linking climate change and biological invasions: ocean warming facilitates nonindigenous species invasions. *Proc. Natl. Acad. Sci.* 99, 15497–15500.
- Stupak, M.E., Bastida, R.O., Arias, P.J., 1980. Las incrustaciones biológicas del puerto de Mar del Plata (Argentina); período 1976/77. The fouling Communities of Mar del Plata harbour (Argentina): 1976/77 period. *CIDEPINT Anales*, pp. 175–231.
- Sueiro, M.C., Bortolus, A., Schwindt, E., 2011. Habitat complexity and community composition: relationships between different ecosystem engineers and the associated macroinvertebrate assemblages. *Helgol. Mar. Res.* 65 (4), 467.
- Tatián, M., Schwindt, E., Lagger, C., Varela, M.M., 2010. Colonization of Patagonian harbours (SW Atlantic) by an invasive sea squirt. *Spixiana* 33, 111–117.
- Tracy, B.M., Reyns, N.B., 2014. Spatial and temporal patterns of native and invasive ascidian assemblages in a Southern California embayment. *Aquat. Invasions* 9, 441–455.
- Traustedt, M.P.A., 1885. *Ascidiae simplices* fra det Stille Ocean. (place unknown).
- Tyrrell, M.C., Byers, J.E., 2007. Do artificial substrates favor nonindigenous fouling species over native species? *J. Exp. Mar. Biol. Ecol.* 342, 54–60.
- Underwood, A.J., Chapman, M.G., 2000. Variation in abundances of intertidal populations: consequences of extremities of environment. *Hydrobiologia* 426, 25–36.
- Ushiyama, S., Smith, J.A., Suthers, I.M., Lowry, M., Johnston, E.L., 2016. The effects of substratum material and surface orientation on the developing epibenthic community on a designed artificial reef. *Biofouling* 32, 1049–1060.
- Valentinuzzi De Santos, S., 1971. Estudio preliminar sobre las comunidades intercotidales del Puerto Ing. White Physis (Argentina). Vol. 30. pp. 407–416.
- Vanname, W.G., 1945. North and South American ascidians. *Bull. Am. Mus. Nat. Hist.* 84, 1–462.
- Vázquez, E., Ugorri, V., 1992. Cinco especies del género *Molgula* Forbes & Hanley, 1848 (Ascidacea, Molgulidae) en la ría de Ferrol (NO península ibérica). In: *Miscel·lània Zoològica*. Vol. 16. pp. 129–137.
- Vázquez, G.M., Bas, C.C., Spivak, E.D., 2012. Life history traits of the invasive estuarine shrimp *Palaemon macrodactylus*; (Caridea: Palaemonidae) in a marine environment (Mar del Plata, Argentina). *Sci. Mar.* 76, 507–516.
- Velazquez, S.N., Rumbold, C.E., Obenat, S.M., 2017. Population dynamics of *Caprella dilatata* and *Caprella equilibra* (Peracarida: Amphipoda) in a Southwestern Atlantic harbour. *Mar. Biol. Res.* 13, 888–898.
- Witman, J.D., Dayton, P.K., 2001. Rocky subtidal communities. *Mar. community Ecol.* 339–366.
- WoRMS Editorial Board. *World Register of Marine Species*. 2017. [accessed 2017 Jan 23]. <http://www.marinespecies.org> at VLIZ.
- Zibrowius, H., 1971. Les espèces Méditerranéennes du genre *Hydroides* (Polychaeta Serpulidae): remarques sur le prétendu polymorphisme de *Hydroides uncinata*. *Tethys* 2, 691–746.