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A hot-spot of biodiversity in Northern Patagonia, Argentina

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Abstract Located along the Argentine coastline of northern Patagonia, are San Matías (SMG) and San José (SJG) gulfs; although they are regarded as an area with a high-priority conservational status, knowledge on their diversity is currently fragmentary. Studies on molluscs from this area have been historically centred in economic resources and few works have referred to non-commercial species. The present study aims to document the biological diversity of molluscs at the SMG/SJG area, in order to determine the significance of these two gulfs in the context of the Argentine marine fauna; to evaluate how well represented is this fauna in three protected areas; and to compare the fauna present in the protected areas with that of a non-protected area. For that purpose, molluscs coming from 132 sampling stations, ranging from the intertidal to 170 m depth, were studied, and a thorough bibliographic compilation was performed. A total of 196 species of molluscs are reported for the area. Surprisingly, almost one third of these species lacked previous records for SMG/SJG, including several new/possibly new species. The three studied protected areas contain 88.3% of the species recognised for the entire SMG/SJG area.

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Although several species appear as exclusive from one of these three areas, many of them are also present in an intermediately located, non-protected area. Molluscan diversity at the SMG/SJG area is greater than previously thought, comprising about 41.4% of the bivalves and 37.8% of the gastropods present in the Argentine shelf; thus suggesting that the area may be considered as a hot-spot of diversity in the Argentine Sea.

Keywords Coastal protected areas · Inventory · Diversity · Mollusca · Invertebrates · Conservation

Introduction

San Matías Gulf (from now on, SMG) and San José Gulf (SJG) are the northernmost of a series of gulfs located along the Argentine coastline of Patagonia (Fig. 1). They are part of the "North Patagonian Gulfs" ecorregion, a highly vulnerable area, with recommended high-priority for conservation (Machado-Schiaffino et al. 2011; Sullivan Sealey and Bustamante 1999). The significance of this area resides in the fact that it represents a site for feeding, reproduction and resting for numerous species of marine birds and mammals, including several migratory species (FAO 2012; Sullivan Sealey and Bustamante 1999). Furthermore, many benthic invertebrates, cephalopods and fish—including some economically important resources—develop their entire life-cycle within these gulfs, thus constituting populations which are independent from those in the adjacent Argentine sea (Crespi-Abril et al. 2008; Machado-Schiaffino et al. 2011; Morsan et al. 2011; Narvarte and Morsan 2005). Added to the previously-mentioned reasons, is the (potential) impact of several anthropic activities, including some fisheries that have developed in the area and, in the last years, the ongoing growth of touristic activities (Sullivan Sealey and Bustamante 1999).

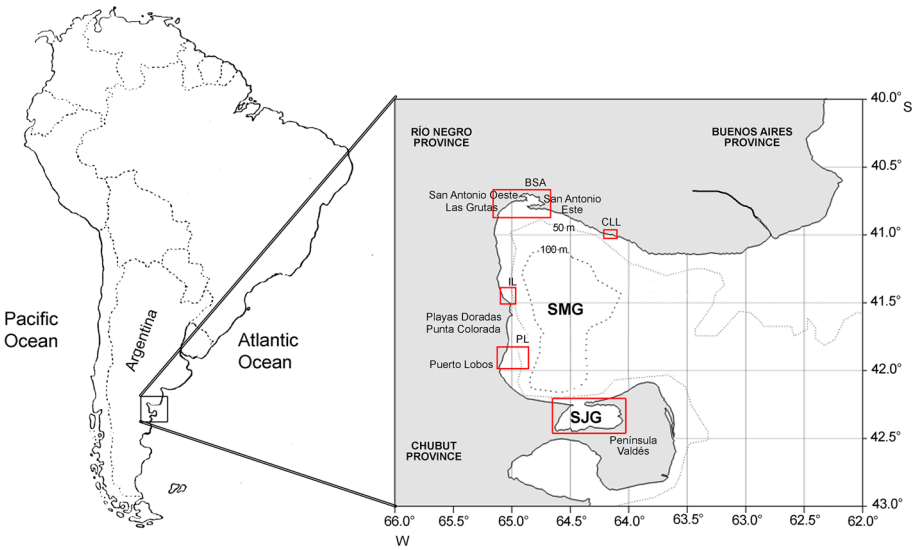

Fig. 1 Geographic location of the San Matías and San José gulfs (SMG/SJG), in northern Patagonia, Argentina. *Polygons* indicate coastal Natural Protected Areas: Caleta de los Loros (CLL), Bahía San Antonio (BSA), Complejo Islote Lobos (IL) and Puerto Lobos (PL), and San José Gulf (SJG) Marine Protected Park

To date, five coastal protected areas have been created in the SMG/SJG area: Caleta de los Loros, Bahía San Antonio, Complejo Islote Lobos and Puerto Lobos Natural Protected Areas, and Península Valdés System, which includes San José "Marine Park" (Fig. 1) (FAO 2012). Despite this high number of protected areas, the current knowledge on the diversity of benthic invertebrates from the GSM/GSJ area as a whole, as well as that of the protected areas in particular, is still in its first steps. Molluscs, one of the dietary components of several marine birds, are not the exception.

Given that SMG and SJG have been historically considered sites of abundant marine resources (Lahille 1900), it is not surprising that most of the past and current studies on the molluscan fauna from this area involve species of economic importance (e.g., Ciocco 1991a, b; Ciocco et al. 1998; Morsan 1997, 2002, 2003, 2007; Morsan and Ciocco 2004, 2011; Morsan and Orensanz 2004; Morsan et al. 2011; Narvarte et al. 2007; Núñez et al. 2013; Signorelli and Alfaya 2014; Zaidman and Morsan 2015). In fact, only a reduced number of studies have previously dealt with the diversity of non-commercial species; and even in this case, these studies have mostly focused in the largest and most frequently found species, such as *Brachidontes rodriguezii*, *Glycymeris longior*, *Pododesmus rudis* and *Chaetopleura isabellei* (Carcelles and Pozzi 1933; d'Orbigny 1834–1847; Lahille 1900). To date, the main source of information on the diversity of non-commercial molluscs from SMG comes from the material obtained in a series of sampling trips performed between 1971 and 1974 (SAO-I to SAO-V campaigns) (Castellanos and Fernández 1972; Olivier et al. 1971; Scarabino 1977), and that from the SJG, from the campaigns SanJo-I and SanJo-II, performed in 1984 (Zaixso 1996, 1997) (Fig. 2). Some other records of the molluscan fauna from these two gulfs are contained on sparse works dealing with species from adjacent areas or taxonomic studies on particular groups/species (e.g. Carcelles 1939, 1941; Castellanos 1970, 1982; Ciocco and Diaz 1983; de Aranzamendi et al. 2014; Güller and Zelaya 2014, 2016a, b; Güller et al. 2015; Ituarte 1979; Pastorino and Chiesa 2014).

The aims of this study are: (1) to document and characterize the biological diversity of molluscs at the SMG/SJG area, with view to determining the significance of this area in the context of the Argentine marine fauna; (2) to evaluate how well represented is this total molluscan fauna, in the coastal protected areas Bahía San Antonio, Puerto Lobos and San José Gulf; and (3) to compare the molluscan fauna present in those three protected areas, with that occurring in an intermediate, non-protected, area.

Materials and methods

Study area

SMG is located between 40°45′ and 42°14′S, and between 65°09′ and 63°46′W, encompassing part of the coasts of Río Negro and Chubut Provinces, in the northern part of the Argentine Patagonia (Fig. 1). It extends for more than 18,000 km^2 (Gagliardini and Rivas 2004), reaching maximum depths of about 200 m in the central area (Escofet et al. 1978; Piola and Scasso 1988). Subordinated to SMG, in the south, and connected by a 7 km wide mouth, is SJG (Fig. 1). This gulf extends for about 800 km^2 and reaches 85 m depth in its centre (Zaixso 1997).

The Bahía San Antonio natural protected area (BSA) is located on the northwest corner of SMG, encompassing 800 km^2 (Fig. 1), out of which about 600 km^2 correspond to the

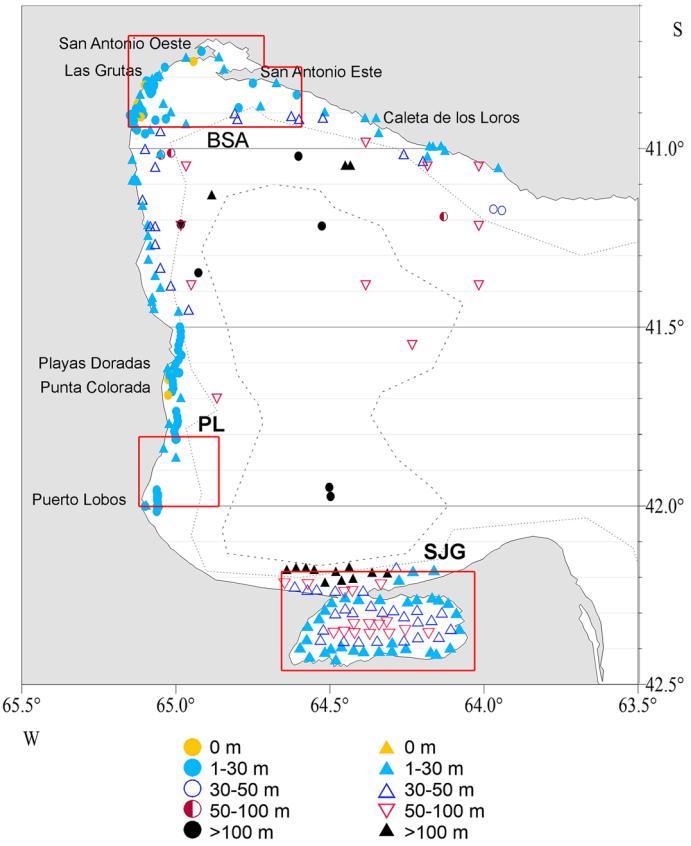

Fig. 2 Stations sampled by the 'SAO I-V' and 'SanJo I-II' campaigns (*triangles*), and stations of material studied herein (*circles*), discriminated by depth range. Polygons indicate the locations of Bahía San Antonio (BSA), Puerto Lobos (PL) and San José Gulf (SJG) protected areas

coast and subtidal area. It includes the cities of San Antonio Oeste and San Antonio Este—the latter with an overseas port—and the largest seaside resort in Patagonia: Las Grutas (Fig. 1). BSA is also the scenario of several local artisanal fisheries (Narvarte et al. 2007). BSA was created with the express purpose of preserving the habitat for marine birds (Provincial Law N° 2670).

Puerto Lobos natural protected area (PL) is located on the southwest corner of SMG (Fig. 1) and extends for about 450 km^2, most of this surface corresponding to the marine realm. Although in this area there are no permanent human establishments or nearby cities, it is a focal place for local artisanal fisheries. The PL area was created with the aim of protecting "the ecosystem characterized by the presence of sea lions, whales and marine birds, both resident and migratory…" (Provincial Law N° 3211; available at: http://www.saij.gob.ar/).

Located between these two protected areas, Playas Doradas (PD) is a recently ongrowing touristic seaside resort (Fig. 1). Although the town is almost exclusively dedicated to tourism, nearby to the south there is a commercial dock, Punta Colorada, associated to the transport of iron obtained in the neighbouring mines of Sierra Grande. This dock has been recently modified into a port for commercial and artisanal fisherboats. For

the purpose of this study, PD was defined as the area comprised between 41.5°S and 41.7°S.

The San José Gulf "Marine Park" (Fig. 1) was created in 1974, with the objective of protecting the habitat of reproduction of the Southern Right Whale (*Eubalaena australis*) and the resting site for several marine birds and mammals. The area is subject of some artisanal fisheries by diving, as well as tourism (Orensanz et al. 2007; Zaixso 1996), but no other major human impacts are performed therein.

The SMG/SJG area is subject to great tidal amplitude (up to 9 m), providing extense intertidals during the low tides. The variety of local environments at this area is complex, being generally composed of an alignment of sandy beaches, intercalated with conglomerate cliffs and sand-bars, and rocky platforms partially covered by mytilid beds. These platforms also present numerous tide-pools, where different types of thalloid plants and algae, including corallines, chlorophytes and cyanophytes, coexist. The northwest part of SMG also presents intertidal sandy and lime-muddy planices, partially covered by salt-marshes, where *Spartina* and *Sarcocornia* appear as dominant elements (GPRN 2013; Escofet et al. 1978). Subtidally, BSA and PD encompass a wide variety of bottom substrates, including sandy, shelly and muddy sediments, and rocky or conglomerate sand-bars (Escofet et al. 1978; pers. obs.). These latter habitats represent areas of high primary and secondary productivity, with very diverse microhabitats (GPRN 2013). In the area of PL, on the contrary, the subtidal is mostly represented by hard-tuff bottoms and gravel or boulders, favouring the presence of large beds of the subtidal mytilids. The subtidal of GSJ is mostly represented by a mixed pattern of soft bottoms (sand, gravel and clay), with several patches of hard-tuff near the coast (Zaixso 1997). In the entire SMG/SJG area, below 30–35 m depth, bottoms become sand-muddy or muddy (Escofet et al. 1978; Orensanz et al. 2007).

Sources of information

The main source of information for this study comes from the material collected during 9 sampling trips to SMG, at 85 random sites ("stations"), located from the intertidal to 25 m depth (Fig. 2). At the intertidal, molluscs were collected by hand and by sieving sediment. In the subtidal, samples were either collected by diving, using a small hand-net, or from small boats using a small trawl. Both samplers contained a 2 mm mesh-size net, which allowed the collection of sediment from the superficial layer (up to 3 cm deep). The hand-net consisted of a 30 × 15 cm metallic frame, with an attached 50 cm long net. The diver collected sediment in an area about 9 m^2 at each station, until the device was full. While diving, large-sized specimens were also hand-collected; conglomerate sand-bars were brushed and, when possible, a fragment of conglomerate was grabbed. The small trawl operated from boats consisted of a 50 × 20 × 50 cm metallic box, with net on the sides and base. This sampler was towed during 5 min at a maximum speed of 2 knots in order to ensure its correct drag at the bottom. Small molluscs were sorted live from the sediment under stereoscopic microscope. Additional information was obtained from samples collected at deeper waters on board the research vessels *B.O. Puerto Deseado* and *M.V. Houssay*, by means of the previously mentioned trawl and a shrimp trawl, and by using a small grab, respectively. Several researchers also handed out material hand-collected. This additional material comes from 53 other sites, between the intertidal and 170 m depth (Fig. 2). Molluscs were identified to the lowest possible taxonomic level, based on the original descriptions and posterior redescriptions of the species, and by studying the type material of those species that required it. Identifications were mainly based on

morphological characters, although some anatomical (radula, jaw, general anatomy) and molecular studies were performed when necessary (e.g., Güller and Zelaya 2014, 2016b).

In addition, a critical compilation of all previous bibliographic records of molluscs from the studied area was performed. This is particularly relevant in the case of SJG, where all the information considered herein comes from the published literature.

Diversity analyses

The studied samples were evaluated for completeness, considering the GSM as a whole, and the material from BSA, PL and PD, independently. Sample-based and coverage-based rarefaction curves were computed in *iNext* online software, v. sept. 2016 (Chao et al. 2016). A total of 100 bootstrap runs were used to estimate 95% confidence intervals, and extrapolations were conducted to double the number of samples. Completeness is regarded as the proportion of sampled species in relation to the number of species predicted by the sample-coverage estimators (Chao and Jost 2012). The obtained total species richness was compared to the expected species richness, estimated by Chao2 index obtained in EstimateS v. 9.1 (Colwell 2013). The number of species restricted to a single sampling station (uniques) or two stations (duplicates) is provided. The most abundant species are indicated, along with those species represented by one (singleton) or two (doubleton) individuals.

Considering the species identified from the material personally studied and the previous bibliographic records, the total species richness and the contribution of each taxonomic Class and Family to the total richness, were determined. For BSA, PL, PD, and SJG we calculated species richness, analysed the number of shared species between them and calculated the complementarity indices between pairs, as the proportion between the sum of unique species, and the total richness of the compared pair (Villareal et al. 2006).

Results

Diversity of molluscs at the SMG/SJG area

A total of 30,481 molluscs were obtained in the studied samples. The rarefaction curves revealed that these samples are representative of the total molluscan fauna from the study area (estimated completeness: 0.9996; Fig. 3).

From the above-mentioned material it was possible to identify 163 species of molluscs, representatives of the Classes Bivalvia, Gastropoda, Polyplacophora, Cephalopoda and Scaphopoda (Supplementary Table 1). The observed species richness was similar to that estimated by Chao2 (180 ± 10 species). The frequency of occurrence of species at different stations revealed only 20 uniques and 9 duplicates, with none of the species present at more than 80 stations. The gastropods were the most abundant Class (17,154 specimens), followed by bivalves (12,694 specimens) and polyplacophorans (623 specimens). Scaphopods and Cephalopods were scarcely represented in the studied material, with one and nine specimens, respectively. Out of the 163 species, 16 species corresponded to singletons and eight, to doubletons. About 50% of the species were represented by less than 30 specimens, although one third, by more than 100 specimens. The most abundant gastropod species was *Parvanachis isabellei* (2,584 specimens), followed by *Tegula patagonica*, *Acteocina candei* and *Carolesia blakei* (1,945; 1,741 and 1,245 specimens, respectively); among bivalves, the most abundant species were *Crenella divaricata* and

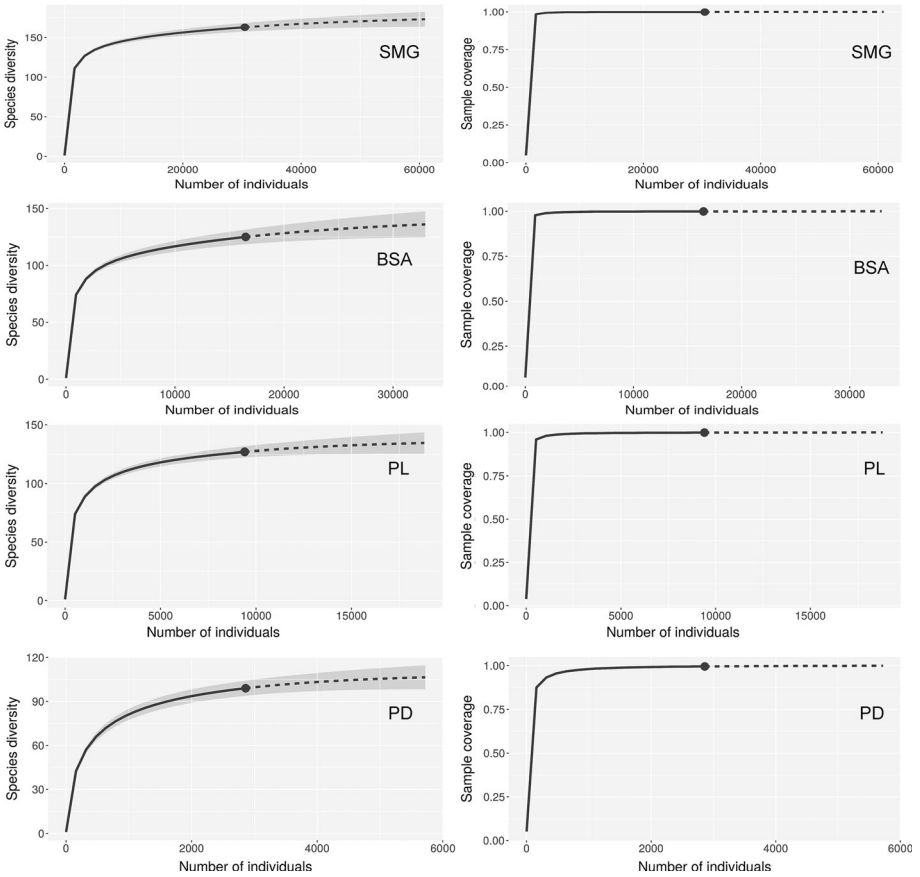

Fig. 3 Plots of species-richness and sample-coverage for rarefied samples (*solid line*) and extrapolated samples (*dashed line*) as a function of the sample size, for the entire amount of studied samples (SMG), and the BSA, PL and PD areas. Observations are denoted by solid dots; 95% confidence intervals (*shaded area*) were obtained by 100 bootstrap replications

Carditamera plata (with 3,437 and 3,329 specimens, respectively), followed by *Diplodonta semiaspera* (1,015 specimens); and among polyplacophorans, *Leptochiton sanmatiensis* (410 specimens), followed by *Chaetopleura isabellei* (120 specimens).

In addition to the 163 species collected as part of this study, 42 other species appear mentioned in the bibliography from the SMG/SJG area. Among them, the presence of two species (*Petricola lapicida* and *Turbonilla strebeli*) is regarded as improbable because they are species proper from other geographic areas, and the material on which those records were based is currently lost; four (*Fissurella cf. oriens*, *Turbonilla americana, Chlamys argentinensis* and *Aeolidia papillosa*) are doubtful identifications, and three others (*Tawera gayi*, *Turbonilla fasciata* and *T. uruguayensis*) are of uncertain presence. For the previously given reasons, these nine species have been excluded from the SMG/SJG species list, and from subsequent analyses.

Considering the 163 species personally studied, and the 33 additional species mentioned in the bibliography and not collected herein, it is possible to recognize a total of 196 valid species of molluscs for SMG/SJG (Supplementary Table 1). Out of them, 110 species

(56.2%) are gastropods and 70 species (35.7%) are bivalves (Fig. 4). Polyplacophorans, cephalopods and scaphopods represent considerably lower components of the molluscan richness at SMG.

The 196 species recognized for the studied area are distributed in 82 families, most of which are represented by a low number of species (mostly by a single species) (Fig. 5). The richest family is Pyramidellidae, represented by a total of 26 species (13.3%); there is a well-marked richness gap between this and all the remaining families. Mytilidae, Veneridae and Tellinidae (among bivalves) and Calliostomatidae, Olividae and Volutidae (among gastropods) are the following most specious families (Fig. 5).

Out of the total diversity recognized for the SMG/SJG area, 107 species (54.6%) reach sizes larger than 15 mm, while the remaining 89 species (45.4%) are smaller than 15 mm, 61 of which (31.1%) are even smaller than 10 mm in maximum size.

Molluscan richness in BSA, PL and SJG protected areas

A total of 16,479 of the specimens considered as part of this study came from BSA and only 2,861 from PL. In spite of these considerable differences in the total number of specimens from each of these two areas, the estimated completeness was greater than 0.995 in both cases, thus revealing that the studied samples are representative of the local richness of each area (Fig. 3). This material, in addition to the species previously mentioned in the bibliography from the area, resulted in the recognition of 142 species at BSA, and 113 species at PL (Supplementary Table 1). The available information from SJG reveals the presence of only 82 mollusc species in that area (Supplementary Table 1). The BSA, PL and SJG, when regarded together, encompass 88.3% of the total species diversity currently known from the SMG/SJG area. Only 52 species (one third of the total) are shared among the three protected areas; several other species are present in two of the considered protected areas; for instance: BSA and PL share 46 species; BSA and SJG share 8 species; and PL and SJG share 6 species (Fig. 6; Supplementary Table 1). On the other hand, BSA has 36 exclusive species, PL 9 species, and SJG 16 species. Consequently, the complementarity indices among these areas are moderate for the pairs SJG-BSA and SJG-PL (0.63 and 0.58, respectively), and somewhat lower for BSA-PL (0.38).

Comparison of the fauna from an unprotected area with that of BSA, PL and SJG

Regarding the samplings of the fauna from the non-protected area PD, the material examined as part of the present study is also representative of the local molluscan diversity (estimated completeness: 0.9986; Fig. 3). From this area, a total of 131 species were recognised, out of which only 10 species (7.6%) were absent from BSA, PL and SJG. The

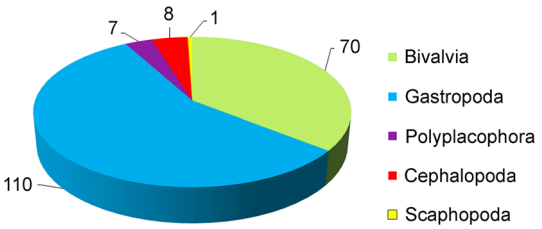

Fig. 4 Specific richness of molluscs from the San Matías Gulf/San José Gulf (SMG/SJG) area, for each taxonomic Class

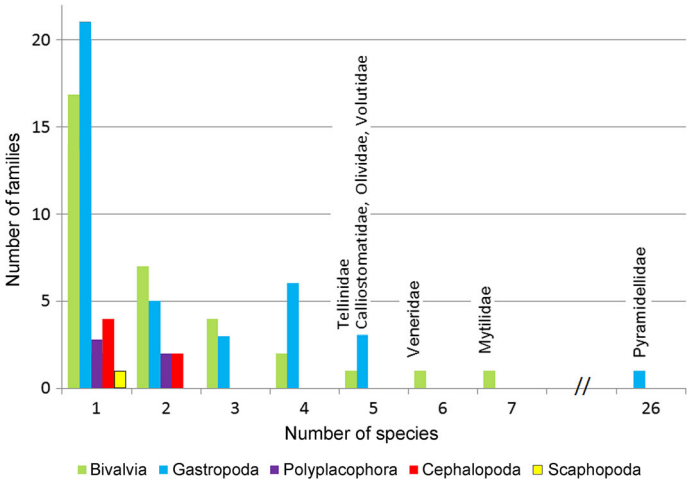

Fig. 5 Number of species per family, for each taxonomic Class. The information here provided refers to the total SMG/SJG diversity

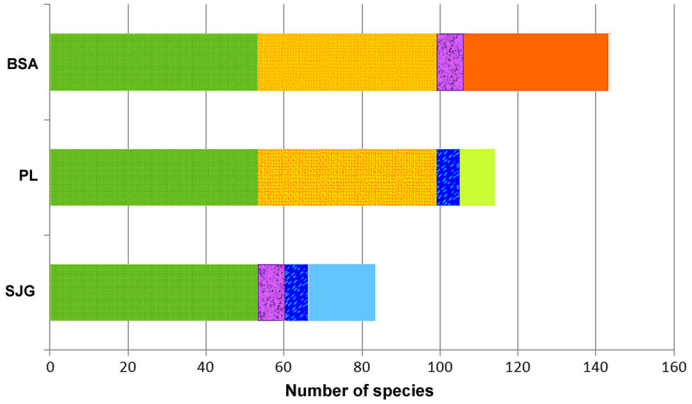

Fig. 6 Number of species found at BSA, PL and SJG protected areas. Same filling patterns indicate shared species between sectors

calculated complementarity indices of PD are relatively low with BSA and PL (0.34 and 0.28, respectively), and moderate with SJG (0.61).

Discussion

Significance of the SMG/SJG area for Argentine marine molluscs

At a local scale, molluscs appear as a widely diversified group of invertebrates in the SMG/SJG area, from where a total of 196 species could be recognised. Out of them, 163 species (83.2%) were obtained in the samples personally studied, while the remaining 33 species (16.8%) appear mentioned in the literature, although they were not collected as part of this

study. Some of these latter species (e.g. *Illex argentinus*, *Doryteuthis gahi*) are actually very common in the area, and were not obtained during this study due to the fact that the sampling methods used herein were not particularly appropriate/adequate for the collection of these taxa. This fact also allows to explain the low number of specimens of cephalopods obtained herein. The number of species here recognised for the SMG/SJG area seems to be representative of the total richness of the area, as evidenced by the rarefaction curves obtained.

Molluscs appear, in addition, as an abundant group of invertebrates in the SMG/SJG area; in fact, molluscs were present in 94% of the total studied samples, usually with a high number of specimens per site of collection.

The present study reveals that previous studies had greatly underestimated the total species richness of molluscs from the SMG/SJG area. In fact, more than one fourth (25.5%) of the total molluscan richness recognised herein (50 taxa) had not been previously mentioned for the area. This considerable number of new findings appears to be a consequence of the sampling methods used in previous studies, which were not particularly directed to the collection of the smallest species. This is certainly not a minor issue: in fact, 31.1% of the species occurring in the SMG/SJG area are smaller than 10 mm of maximum size, and this value is increased to 45.4% when considering species smaller than 15 mm of maximum size. Despite that, only 34.4% of the species smaller than 10 mm, and 66.7% of the species smaller than 15 mm had been previously mentioned for the area. While this constitutes a major advancement in relation to previous efforts, still some micromolluscs (smaller than 2 mm) may have been lost during the sieving of the sediment. Among the main findings arising from the small-sized fauna are the collection of living specimens of *Cochliolepis surensis* and *Teinostoma maldonadense*, two species thus far only known from Holocene deposits at Bahía Blanca, Buenos Aires Province (Farinati 1994); and the finding of 12 new and 13 possibly new species. However, the new findings resulting from this study are not merely circumscribed to micromolluscs. In fact, three species larger than 20 mm of maximum size (*Cardiomya cleryana*, *Spurilla braziliana and Berthella patagonica*) are also here reported for the first time from SMG/SJG. These new findings reveal that the few studies previously performed on the diversity of molluscs from the SMG are also responsible for the limited current knowledge of that fauna. This is also supported by the fact that numerous new findings come from the northern part of SMG, which was one of the most intensively sampled areas in the past.

The significance of the SMG/SJG area for molluscan diversity is clearly evident when the species richness of this area is compared to that of the adjacent Argentine shelf: 41.4% of the total bivalve species and 37.8% of the total gastropod species mentioned for the Argentine shelf (by Zelaya 2015; Rosenberg 2009, respectively) are present in the SMG/SJG area. This fact is particularly notorious when considering that the SMG/SJG area represents only about 2% of the surface of the Argentine shelf, and even more, when considering that most of the species here reported from the SMG/SJG area come from waters shallower than 30 m depth. The high diversity here found in the SMG/SJG area for molluscs is not exclusive of this group. In fact, Arribas et al. (2016) reported that 30% of the known species of echinoderms from the Argentine shelf are present in SMG; and Perier et al. (2011) found that GSM holds 33 and 44% of the shark and batoid species from the Argentine sea, respectively. These convergent results in different groups suggest that SMG is a hot-spot of diversity in the Argentine Sea.

How well is SMG/SJG molluscan fauna represented in BSA, PL and SJG? And how different is this scenario from that of the intermediate non-protected PD area?

Although BSA, PL and SJG were not particularly created to protect marine benthic invertebrates, the majority of mollusc species of SMG/SJG (88.3% of the total diversity) is represented in these three protected areas. Although many species are shared among the three protected areas -or at least between two of them-, there are several species which appear restricted to only one of these areas. These "endemic" components may be reflecting the effect of different physical/environmental conditions (as described in "Materials and methods") On the other hand, water temperature, salinity and water retention times at BSA reach considerably higher values than those at PL and SJG (Gagliardini and Rivas 2004; Zaixso 1997). When considering the unprotected PD area, which is located in an intermediate position between BSA and PL, the "peculiarity" of these two areas partially vanishes: out of the 36 species regarded as exclusive from BSA, 13 species are also present in PD, and out of the 9 species previously regarded as "exclusive" from PL, 7 are also present in PD. It should be noted that the heterogeneity of bottom substrates at PD is comparable with that of BSA (pers. obs.).

The differential anthropic activities in the three considered protected areas do not seem to be tightly related to the observed specific richness. BSA, an area impacted by human establishments for more than one century, harbours higher diversity than PL, where artisanal fisheries are the major impacting activities. However, the specific richness at BSA is similar to that of PD, where human activities are in their first instances. These facts reinforce the idea that environmental conditions would be the main determinants of faunistic differences between the considered areas.

Also interesting to note is the great difference in species richness between BSA (142 species) and SJG (82 species), even when the latter encompasses a larger marine area than the former, and more samples have been taken in SJG than in BSA. In this case, the above-mentioned physical/environmental differences may also be a possible explanation, although the fact that the source of information from this area is exclusively bibliographic cannot be discarded. As previously mentioned, small-sized molluscs have been frequently undersampled in previous studies.

Although there are 26 protected areas along Argentine coast (Bertonatti and Corcuera 2000), knowledge on their diversity of benthic invertebrates is extremely scarce. In fact, this study provides the first inventories of molluscan fauna from Argentine coastal protected areas.

Future perspectives for research in the SMG/SJG area

Historical knowledge on the diversity of marine organisms of SMG/SJG has mainly focused on easily accessible coastal areas (such as San Antonio Bay), a few stations sampled by historical expeditions (such as *R.V. Shinkai Maru* stations) and management of relevant economic resources (see references in the "Introduction"). Consequently, there are many insufficiently sampled areas within the SMG, not only for Mollusca (a group intensively studied herein), but also for many other benthic groups (see for instance Arribas et al. 2016 for Echinodermata; Liuzzi et al. 2011 for Macroalgae; López Gappa 2000 for Bryozoa; López Gappa and Landoni 2005 for Porifera; López Gappa et al. 2006 for Amphipoda). This is particularly notorious in the case of the deeper waters, an area that

deserves further studies with view to to better integrate knowledge on system function for, and implementing future complementary conservation strategies.

To date, conservation of biodiversity at the SMG/SJG area has focused in coastal areas that constitute reproduction and resting sites of migratory birds and sea mammals, and in management strategies to preserve fish stocks and economically important mollusc species (Morsan 2009; FAO 2012). A high number of mollusc species are coincidentally present in BSA, PL and SJG, reinforcing the decision of preserving these areas. The information arising from the present study could represent a relevant tool to be included in future management plans of these protected areas.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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