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Echinoderms in San Matías Gulf, Southwestern Atlantic Ocean

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Abstract Echinoderms are often of ecological importance in intertidal and subtidal waters, especially as predators and herbivores but also as prey. Several groups of echinoderms respond in a different way to environmental variables, contributing to some of the biodiversity patterns found along latitudinal gradient. This work listed the echinoderms species of San Matías Gulf surrounding the coast of Río Negro Province and analyzed the current state of knowledge of this group by previous works, collection items of the Museo Argentino de Ciencias Naturales "Bernardino Rivadavia," and from samples taken since 2009 to the present. A total of 35 species of echinoderms corresponding to four classes were recorded. The 34.29 % corresponds to Asteroidea, 31.43 % to Ophiuroidea, 20 % to Echinoidea, and 14.28 % to Holothuroidea. Crinoidea has not been reported for San Matías Gulf. Asteroidea and Ophiuroidea were the most representative groups followed by Echinoidea and Holothuroidea, with only five species in the last class. About 30 % of the country's species are present in Río Negro Province. This high number of species may be due to the heterogeneity of environments that are possible to find in San Matías Gulf and a transition zone between the Magellanic and Argentine biogeographic provinces that can provide particular physical and climatic characteristics explaining as consequence the faunal composition.

Keywords Echinoderms · Biogeographic provinces · San Matías Gulf · Southwestern Atlantic Ocean

Introduction

The identification of species patterns at different scales arouses particular interest when investigating possible factors that regulate diversity, useful in conservation and ecological studies (Dulvy et al. 2003). Despite their role in the ecosystem, there is a lack of global assessments about echinoderms, as they are ecologically relevant as predators or herbivores at the intertidal and on shallow water systems (Paine et al. 1985; Benedetti-Cecchi and Cinelli 1995) and also as prey (Aminur Rahman et al. 2014). For example, the sea stars as "keystone" predate on mussel beds maintaining a diverse community since they remove present mussels, creating free spaces for other species (Paine 1966). Likewise, the sea cucumbers are critical to the structure of sediments in subtidal environments and tidal pools, recycling organic particles and enhancing the substrate by adding nutrients (e.g., ammonium) that could be a source of nitrogen for primary producers (Uthicke 2001; Ruiz et al. 2007). Moreover, an important ecological role of deposit-feeding holothurians are as bioturbators of sediment which, as a result, decrease the stability of sediments, increase aeration, and facilitate organic particles to return to the water column (Uthicke 1999; Ravest Presa 2001).

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The coastal area is of ecological importance as a region with high energy and productivity (Leigh et al. 1987), supporting a high echinoderm diversity compared to deep waters (Price et al. 1999). The high number of species in coastal areas probably reflects the high heterogeneity of habitats and environmental conditions compared to deep areas (Gray 1997; Price et al. 1999). Oceanographic conditions have been shown to determine limits of species distribution (Menge et al. 1997; Wieters et al. 2012) being the population parameters, as well as survival of species, affected by temperature, productivity, or salinity (Menge et al. 1997; Kashenko 2003; Blanchette et al. 2006). In the Southwestern Atlantic Ocean, coastal biogeographic provinces are indirectly influenced by warm-temperate water from the Brazil current (flowing from north) and the sub-Antarctic Malvinas current (flowing from south). Both water masses flowing in opposite directions and their physico-chemical oceanographic characteristics influence the species distribution (Liuzzi and López Gappa 2008; Brogger et al. 2013a).

The Río Negro Province coast is entirely contained inside the northern sector of San Matías Gulf, the first of the North Patagonian gulfs. Within this gulf, it is possible to recognize zones with distinct oceanographic parameters: the north and east areas present high temperature, high salinity, and low concentrations of nitrates, while the south and southeast are characterized by lower temperatures and salinities (Gagliardini and Rivas 2004). Besides physical characteristics, climatic differences, and the presence of a transition zone between warm-temperate waters and the Magellanic region (Ramírez 1996; Gagliardini and Rivas 2004; Spalding et al. 2007; Balech and Ehrlich 2008) give San Matías Gulf their unique signature, reflected on species composition (Escofet et al. 1978; Ramírez 1996).

Relatively few studies have been conducted about the echinoderms of San Matías Gulf, including the classes Asteroidea, Echinoidea, Ophiuroidea, and Holothuroidea (Bernasconi 1953, 1964, 1966, 1973, 1980; Bernasconi and D'Agostino 1971, 1974, 1975, 1977; Escofet et al. 1978; Brogger et al. 2013a; Martinez et al. 2013), but without reports of Crinoidea. A recent publication has removed the only reported endemic ophiuroid from Argentina *Amphilepis sanmatiensis* and treated it as a synonym of *Amphioplus lucyae* (Brogger and O'Hara 2015).

The purpose of the present work was to summarize the knowledge about the echinoderm species and the proportion within each class in San Matías Gulf, Río Negro Province. Besides, we discuss the environmental conditions that can lead to the current species composition. Additionally to the bibliography survey, we studied material from the invertebrates' collection of the Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", and recent material sampled in rocky intertidal and shallow waters of San Matías Gulf. Representation of the different groups of echinoderms and their distribution ranges are discussed.

Materials and Methods

Study Area

The study was conducted in San Matías Gulf (Río Negro Province; Fig. 1). This gulf covers an area of 17,000 km^2, the deepest zone retains relatively wastewater whose temperature is stable throughout the year, between 11 and 12 °C, and the maximum depth (~200 m) is very close to the geographic center (Escofet et al. 1978). Water circulation is dominated by two eddies, one with cyclonic gyre in the North and the other with anticyclonic gyre in the South. An intense thermohaline front divides two water masses with different oceanographic conditions: relatively cold-fresh waters placed south of the front, while warm-salty waters placed north of the front (Piola and Scasso 1988; Morsan 2009). Bottom sediment close to the coastline is characterized by sand and gradually mixed with shell fragments, gravel, and mud (muddy sediment is predominant beyond 50 m depth; Morsan 2009; Morsan et al. 2010). In particular, the northern region consists of sandy and gravelly strips, and the southern part has rocky volcanic outcrops (Kokot et al. 2004). This province has a macrotidal regime (average tidal amplitude is 7.62 m with maximum of 9.2 m) with cliffs and sedimentary abrasion platforms that alternate with sandy beaches (Morsan 2009; Arribas et al. 2013). Information about sea surface temperature and chlorophyll-*a* in different sampling sites are available in previous works (Escofet et al. 1978; Arribas et al. 2013; Bagur et al. 2013).

Sampling

A revision of echinoderm fauna was surveyed by information from lots of the collection of the Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", from references and field work data since 2009 to the present in the following locations:

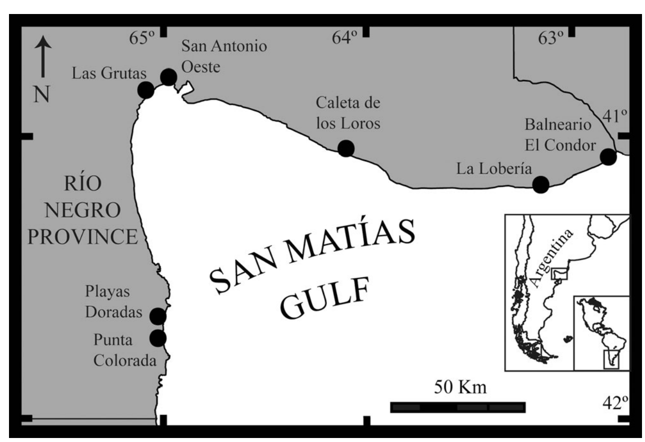

Fig. 1 Map of San Matías Gulf surrounding the coast of Río Negro Province, Southwest Atlantic Ocean

Balneario El Cóndor (41° 3′ 32″ S–62° 50′ 13″ W), El Espigón (41° 7′ 6″ S–63° 0′ 23″ W), Caleta de los Loros (41° 0′ 54″ S–64° 11′ 8″ W), Las Grutas (40° 49′ 26″ S–65° 6′ 2″ W), Playas Doradas (41° 38′ 18″ S–65° 1′ 22″ W), and Punta Colorada (41° 42′ 7″ S–65° 1′ 23″ W). Field samples were collected during diurnal time from intertidal to 10 m depth without a fixed sampling design. Up to 10 individuals were sampled and stored in 96 % ethanol. In some cases, samples were stored in 4 % formaldehyde. As during low tides, almost all echinoderm species are protected under rocks, the sampling method was performed turning the rocks. Some species as holothurians can be found in the sediment too. For sampling sediment, samples were taken and carefully filtered through a 500-μm mesh to separate the individuals. The identification of each group was following taxonomic keys, and in the case of holothurians, the calcareous ossicles were used to identify individuals to species level.

The analyzed lots from the Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" (label as MACN) by taxonomical class were as follows:

Class Asteroidea MACN-In: 6526, 6527, 8966, 8967, 8970, 9077, 13377, 13378, 15984, 15985, 15986, 15987, 15988, 21326, 21327, 21328, 27244, 27854, 27855, 27856, 27857, 28199.
Class Echinoidea MACN-In: 6525, 9076, 13370, 13376, 13762, 15992, 15993, 15994, 18415, 21324, 21325, 23682, 25553, 25912.
Class Holothuroidea MACN-In: 6528, 15990, 15991, 18412, 18414, 20552, 21331, 25211.
Class Ophiuroidea MACN-In: 6524, 13379, 15846, 15989, 18413, 20571, 20572, 21329, 21330, 23683, 25210, 27699, 27853, 27862, 27868, 34376.

The percentage of species of the different classes of echinoderms was calculated to San Matías Gulf, and the data was compared with information from the Pacific, Atlantic, Caribbean, and Argentina waters extracted from Pérez-Ruzafa et al. (2013).

Results

A total of 16 species were found during intertidal and subtidal field samplings from 2009 to the present in San Matías Gulf. Asteroidea and Holothuroidea were the classes with more species followed by the other two classes (Echinoidea and Ophiuroidea) which only presented 3 species in each group (Table 1, Fig. 2). From review bibliography, we found 33 species of echinoderms with distribution in San Matías Gulf, being Asteroidea and Ophiuroidea the classes more studied in the area (Table 1). In the museum samples, we found 40 lots corresponding to echinoderms where the most representative class was Asteroidea (Table 1).

Of all the information gathered in this study, a total of 35 species of echinoderms were found in San Matías Gulf. Around a 34.29 % of the species of echinoderms from San Matías Gulf were Asteroidea, 31.43 % Ophiuroidea, 20 % Echinoidea, and 14.28 % Holothuroidea (Fig. 3). No members of Crinoidea were found in San Matías Gulf. Asteroidea and Ophiuroidea were the most abundant classes, followed by Echinoidea and Holothuroidea, being the last one represented by only 5 species (Table 1).

The percentage of Asteroidea in San Matías Gulf was similar to that found in the South Pacific Ocean (34.29 and 29 % respectively), and the species percentages of Ophiuroidea and Echinoidea classes were comparable with the Caribbean and Atlantic Ocean (Fig. 3). The holothuroidea pattern found in San Matías Gulf was different from all the distribution shown by Pérez-Ruzafa et al. (2013) for the Pacific, Argentina, and Atlantic and Caribbean waters and further exhibited the lowest percentage value (Fig. 3).

Discussion

After the recompilation of the book *Echinoderms from Latin-America* (Alvarado and Solís-Marín 2013), this is the first study that lists all echinoderm fauna from San Matías Gulf, reckoning 35 species. A total of 130 species are cited for Argentine waters (Brogger et al. 2013a), being about 30 % present in San Matías Gulf. Bearing in mind that those species are found along 370 km of Río Negro Province coast (5 % of the total Argentine Sea coastal perimeter), it represents a high diversity zone in the South Atlantic Ocean, very likely as result of the habitat heterogeneity found in San Matías Gulf (Escofet et al. 1978; Morsan 2009). Furthermore, seasonal variations provide the gulf differences at geographical and temporal scales. In this water mix region (Ramírez 1996), we can find species from southern waters like the sea cucumber *Hemioedema spectabilis* and species from temperate waters like the brittle star *Ophioplocus januarii*. Also, the recent described species *Havelockia pegi* and *Chiridota pisanii*, which are distributed in temperate and cold waters from Patagonia and Buenos Aires Province, were found in San Matías Gulf (Pawson 1969; Hernández 1981; Martinez et al. 2013). In particular, *C. pisanii* is also at the magellanic area and gives evidence about the influence of southern waters in San Matías Gulf. Cold and low salinity waters which get into San Matías Gulf from the southeast (Piola and Scasso 1988) may bring new species. Even though the gulf hosts a great diversity—i.e., 30 % of the Argentine Sea echinoderm fauna—no crinoids were reported for this area. One of

Table 1 List of species corresponding to the four classes of echinoderms present in San Matías Gulf extracted by bibliography, collection items from the Museo Argentino de Ciencias Naturales (MACN-In), and field sampling, with depth data from literature

Species	Bibliography	MACN-In	Field sampling	Depth (m)
Asteroidea				
Allostichaster capensis (Perrier, 1875)	Bernasconi 1964	8967	X	0–100
Anasterias minuta Perrier, 1875	Bernasconi 1973		X	0–100
Anasterias pedicellaris Koehler, 1923	Bernasconi 1973			0–120
Astropecten brasiliensis Müller & Troschel, 1842	Bernasconi 1964	9077		0–360
Cosmasterias lurida (Philippi, 1858)	Bernasconi 1973	6526, 21328	X	0–650
Ctenodiscus australis Lütken, 1871	Bernasconi 1973		X	70–4605
Cycethra verrucosa (Philippi, 1857)	Bernasconi 1973; Bernasconi 1964	21327, 15984, 6527, 13378	X	0–500
Diplasterias brandti (Bell, 1881)	Bernasconi 1973	15988		0–450
Diplodontias singularis (Müller & Troschel, 1843)	Bernasconi 1962			0–84
Ganeria falklandica Gray, 1847	Bernasconi 1973; Bernasconi 1964	21326, 8970, 15986, 8966		0–135
Henricia obesa (Sladen, 1889)	Bernasconi 1973; Bernasconi 1980	15987		22–210
Luidia ludwigi scotti Bell, 1917		27857		33–126
Echinoidea				
Abatus cavernosus (Philippi, 1845)	Bernasconi 1953; Bernasconi 1966	25553	X	1–676
Abatus philippii Lovén, 1871	Bernasconi 1953			71–225
Arbacia dufresnii (Blainville, 1825)	Bernasconi 1973	21324, 25912, 15994, 6525, 18415, 13370, 13376, 23682	X	1–137
Austrocidaris canaliculata (A. Agassiz, 1863)	Bernasconi 1973	9076		1–424
Pseudechinus magellanicus (Philippi, 1857)	Bernasconi 1973	21325, 15993	X	1–361
Sterechinus agassizii Mortensen, 1910	Bernasconi 1973			24–470
Tripylaster philippii (Gray, 1851)	Bernasconi 1973	15992		13–595
Holothuroidea				
Chiridota marenzelleri Perrier R., 1904	Hernández 1981	18412	X	40–150
Chiridota pisanii Ludwig, 1887			X	0–159
Havelockia pegi Martinez et al. 2013	Martinez et al. 2013		X	10–48
Hemioedema spectabilis (Ludwig, 1883)	Hernández 1981	21331, 25211, 6528, 20552	X	2–160
Pentactella leonina (Semper, 1867)	Hernández 1981		X	0–340
Ophiuroidea				
Amphipholis squamata (Delle Chiaje, 1828)	Bernasconi and D'Agostino 1971; Bernasconi and D'Agostino 1977		X	0–250
Amphioplus lucyae Tommasi, 1971	Brogger and O'Hara 2015	27862		0–510
Amphioplus albidus (Ljungman, 1867)	Bernasconi and D'Agostino 1977			1–500
Amphiura crassipes Ljungman, 1867	Bernasconi and D'Agostino 1977	27699		0–54
Amphiura eugeniae Ljungman, 1867	Bernasconi and D'Agostino 1977			0–146
Amphiura magellanica Ljungman, 1867	Bernasconi and D'Agostino 1977			0–183
Amphiura princeps Koehler, 1907	Bernasconi and D'Agostino 1977	20572		0–107
Gorgonocephalus chilensis (Philippi, 1858)	Bernasconi and D'Agostino 1971			0–500
Ophiacantha vivipara Ljungman, 1870	Bernasconi 1973	34376		0–1097
Ophiactis asperula (Philippi, 1858)	Bernasconi and D'Agostino 1971; Bernasconi and D'Agostino 1977		X	0–310
Ophioplocus januarii (Lütken, 1856)	Bernasconi and D'Agostino 1971; Bernasconi and D'Agostino 1977	6524, 13379, 15989	X	0–180

the explanations could be the low number of samples taken at greater depths, where Crinoidea are more abundant (Mortensen 1918; Brogger et al. 2013a).

Asteroidea and Ophiuroidea were the most abundant classes in San Matías Gulf. This pattern has also been observed around the globe, finding between 2000 and 2200 species for

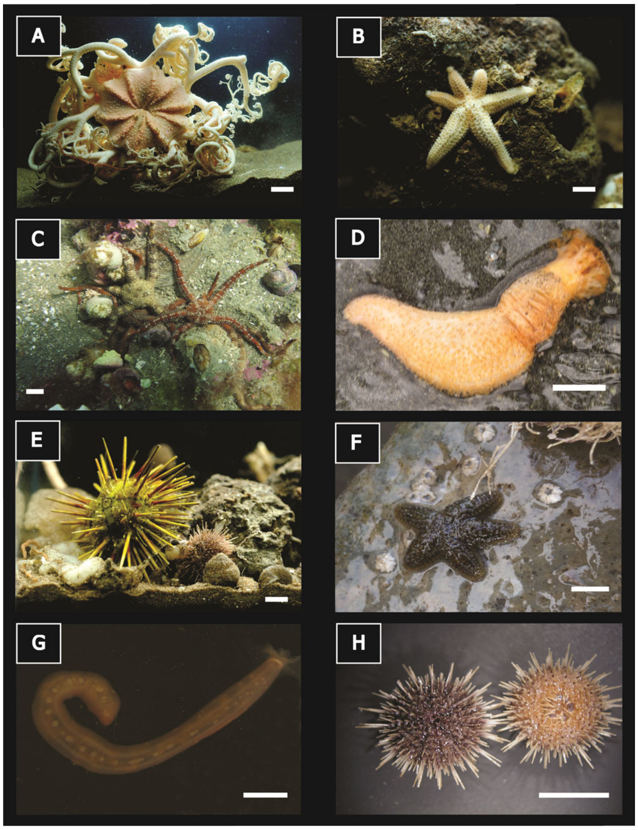

Fig. 2 Two representatives of each class of echinoderms present in San Matías Gulf: **a** *Gorgonocephalus chilensis*; **b** *Allostichaster capensis*; **c** *Ophioplocus januarii*; **d** *Hemioedema spectabilis*; **e** *Arbacia dufresnii* and *Pseudechinus magellanicus*; **f** *Anasterias minuta*; **g** *Chiridota pisanii*; **h** *Pseudechinus magellanicus*. Scale 1 cm

these two classes (Pawson 2007). In our study, Echinoidea presented higher number of species than Holothuroidea, contrary to the pattern worldwide (1600 species of Holothuroidea and 800 of Echinoidea; Pawson 2007). A biased sampling, due to holothurians that can live both endofaunal and epifaunal, can lead to a wrong result. Increased sampling effort in Holothuroidea and sampling on deepest waters could lead to different results.

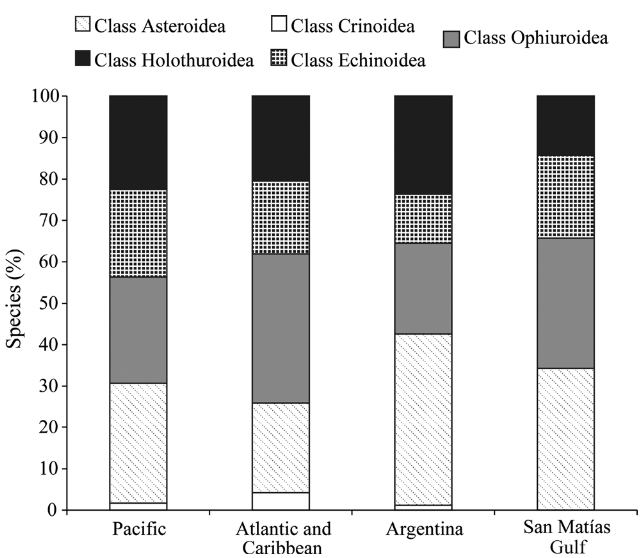

Fig. 3 Percentage of species of the different classes of echinoderms in the Pacific, Atlantic, Caribbean, Argentina, and San Matías Gulf waters. Data from the Pacific, Atlantic, Caribbean, and Argentina modified from Pérez-Ruzafa et al. (2013)

Comparing echinoderm fauna of San Matías Gulf with the Atlantic, Caribbean, and Pacific (see Pérez-Ruzafa et al. 2013) waters up to 200 m depth, we found a mixed pattern in relation with percentage of species in each class. Asteroidea in San Matías Gulf presented higher species percentage compared with Pacific, Atlantic, and Caribbean waters, but lower percentage in relation with Argentine Sea. Otherwise, Ophiuroidea percentage presented higher percentage of species than in Pacific and Argentine waters. This result shows the unique relation among echinoderm classes that we can find in San Matías Gulf compared with the Argentine Sea, Atlantic, Caribbean, and Pacific, and besides, the high proportion of echinoderm fauna found in San Matías Gulf (i.e., 35 species in 370 km of the 130 cited for Argentine waters) could be attributed to the different microhabitats that compound the Gulf (Escofet et al. 1978; Morsan 2009) and local environmental characteristics (Piola and Scasso 1988; Arribas et al. 2013; Bagur et al. 2013).

Species such as *Ophioplocus januarii*, with distribution in San Matías Gulf, reproduced all along the year and may present a mixed reproductive pattern with transitional tropical/subtropical continuous reproduction with a temperate reproductive cycle and a clear seasonality of spawning (Brogger et al. 2013b). Moreover, in this area, we can find brooders species, such as *Anasterias minuta*, *Abatus cavernosus*, and *Ophiacantha vivipara* (Gil and Zaixso 2007; Gil et al. 2009; Martín-Ledo et al. 2013). Brooding behavior has been described for many temperate, sub-Antarctic and Antarctic echinoderms (McEuen and Chia 1991; Sewell 1994; Gil and Zaixso 2007; Hamel et al. 2007; Gil et al. 2009; Martinez et al. 2011; Martín-Ledo et al. 2013), in contrast with tropical and subtropical species (Gil and Zaixso 2007). Temperature and photoperiod are important environmental factors that could regulate biological functions (Pearse et al. 1986; Gil et al. 2009; Mercier and Hamel 2009; Pérez et al. 2010; Gil et al. 2011; Martinez et al. 2011; Brogger et al. 2013b). The cyclic reproductive pattern in some echinoderms is generally associated with local environmental factors (i.e., mainly water temperature and photoperiod), and these factors seem to affect the population aggregation and the spawning associated with reproductive success (Hamel and Mercier 1995; Marzinelli et al. 2006; Mercier and Hamel 2009). Despite the lack of seasonal reproductive information in relation with oceanographic parameters of brooders species such as *A. minuta*, *A. cavernosus*, and *O. vivipara*, or species with free-swimming larvae in San Matías Gulf, we can suggest that environmental conditions (i.e., northern warmer and southern colder waters in the Gulf) are important features to host species with different biological needs and reproductive habits.

Global biodiversity is under increasing pressure from environmental variation threatened by anthropogenic global climate change (Harley et al. 2006; Wernberg et al. 2011) which affects large-scale oceanographic variables such as pH, salinity, and sea surface temperature (Harley et al. 2006). Responses of organisms to a gradual climate change are expressed in the latitudinal modification in species abundance and migration of biogeographic boundaries (Barry et al. 1995; Blockley et al. 2007; Harley 2011). Understanding species variation allows identifying the importance of environmental controls on population structure and anticipates potential consequences of regional changes on local populations (Helmuth et al. 2006). Fluctuations in oceanographic parameters as temperature, salinity, and oxygen can have significant influences on population parameters (e.g., growth Blanchette et al. 2006) or mortality (Lathlean et al. 2010). In the case of salinity, it may affect the species triggering a reduction in the survival rate (MacGinitie 1939; Watts and Lawrence 1990). For example, in asteroids, the feed rate and the ratio of activity have decreased in response to the stress generated upon exposure to different concentrations of salt (Held and Harley 2009). In San Matías Gulf, species are exposed to warm waters with high salinity, and cold waters with low salinity (Gagliardini and Rivas 2004), being possible important areas of biodiversity stability facing a climate change.

We conclude that in order to amplify the information of this high diversity region, more studies must take place in deepest regions of San Matías Gulf, where low number of samples have been taken. This will enlarge the list of species and could lead to find crinoids in this region. Moreover, the study of transitional areas could give some clues about the pattern of biogeographical regions in the Argentine Sea increasing the previous knowledge (Spalding et al. 2007; Balech and Ehrlich 2008) in this North Patagonian gulf.

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References

Agassiz A (1863) List of the echinoderms sent to different institutions in exchange for other specimens, with annotations. Bull Mus Comp Zool Harv Univ 1:17–28

Alvarado JJ, Solís-Marín FA (2013) Echinoderms research and diversity in Latin America, 1st edn. Springer-Verlag, Berlin, p 658

Aminur Rahman M, Arshad A, Yusoff FM (2014) Captive breeding, seed production, grow-out culture and biomedicinal properties of the commercially important sea urchins (Echinodermata: Echinoidea). Int J Adv Chem Eng Biol Sci 1(2):187–192

Arribas LP, Bagur M, Klein E, Penchaszadeh P, Palomo MG (2013) Geographic distribution of two mussel species and associated assemblages along the northern Argentinian coast. Aquat Biol 18: 91–103

Bagur M, Richardson CA, Gutiérrez JL, Arribas LP, Doldan MS, Palomo MG (2013) Age, growth and mortality in four populations of the boring bivalve *Lithophaga patagonica* from Argentina. J Sea Res 81:49–56

Balech E, Ehrlich M (2008) Esquema biogeográfico del Mar Argentino. Rev Invest Desarr Pesq 19:45–75

Barry JP, Baxter CH, Sagarin RD, Gilman SE (1995) Climate-related, long-term faunal changes in a California rocky intertidal community. Science 267:672–675

Bell FJ (1881) Account of the zoological collections made during the survey of H.M.S. "Alert" in the Straits of Magellan and on the coast of Patagonia. Proc Zool Soc London 1881:87–101

Bell FJ (1917) Echinodermata. 1. Actinogonidiata. British Antarctic “Terra Nova” Expedition, 1910. Zoology 4:1–10

Benedetti-Cecchi L, Cinelli F (1995) Habitat heterogeneity, sea urchin grazing and the distribution of algae in littoral rock pools on the west coast of Italy (western Mediterranean). Mar Ecol Prog Ser 126:203–212

Bernasconi I (1953) Monografía de los equinoideos Argentinos, vol 6. Anales del Museo de Historia Natural de Montevideo, Montevideo, p 1, 58

Bernasconi I (1962) Asteroideos argentinos. III. Familia Odontasteridae. Rev Mus Argentino de Cien Nat 9:1–25

Bernasconi I (1964) Asteroideos argentinos, claves para los órdenes, familias, subfamilias y géneros. Physis 24:241–277

Bernasconi I (1966) Descripción de una nueva especie de *Calyptraster* (Asteroidea, Pterasteridae). Physis 26:95–99

Bernasconi I (1973) Los equinodermos colectados por el “Walter Herwig” en el Atlántico Sudoeste. Rev Mus Argentino de Cien Nat 3:287–334

Bernasconi I (1980) Asteroideos argentinos. VII. Familia Echinasteridae. Rev Mus Argentino de Cien Nat 5:247–258

Bernasconi I, D’Agostino MM (1971) Ofiuroideos argentinos claves para los órdenes, subórdenes, familias, subfamilias y géneros. Physis 30: 447–469

Bernasconi I, D’Agostino MM (1974) Ampliación del área de distribución de *Amphiura crassipes* Ljungman, 1866 (Ophiuroidea, Amphiuridae). Physis 33:135–138

Bernasconi I, D’Agostino MM (1975) Nueva especie de ofiuroideo argentino *Amphilepis sanmatiensis* sp. nov. (Ophiuroidea, Amphilepididae). Physis 34:355–358

Bernasconi I, D’Agostino MM (1977) Ofiuroideos del mar epicontinental argentino. Rev Mus Argentino de Cien Nat 5:65–114

Blainville HMDd (1825) Oursin, Echinus (Actinozoaires). Dictionnaire des Sciences Naturelles F.G. Levrault, Strasbourg & Paris, p 59–98

Blanchette CA, Broitman BR, Gaines SD (2006) Intertidal community structure and oceanographic patterns around Santa Cruz Island. CA, USA. Mar Biol 149:689–701

Blockley DJ, Cole VJ, People J, Palomo MG (2007) Effects of short-term rain events on mobile macrofauna living on seawalls. J Mar Biol Assoc U K 87(5):1069–1074

Brogger MI, O’Hara TD (2015) Revision of some ophiuroid records (Echinodermata: Ophiuroidea) from Argentina. Zootaxa 3972(3): 432–440

Brogger MI, Gil DG, Rubilar T, Martinez MI, Díaz de Vivar E, Escolar M, Epherra L, Pérez AF, Tablado A (2013a) Echinoderms from Argentina: biodiversity, distribution and current state of knowledge. In: Alvarado JJ, Solís-Marín FA (eds) Echinoderms research and diversity in Latin America. Springer, Berlin, pp 359–402

Brogger MI, Martinez MI, Zabala S, Penchaszadeh PE (2013b) Reproduction of *Ophioplocus januarii* (Echinodermata: Ophiuroidea): a continuous breeder in northern Patagonia, Argentina. Aquat Biol 19:275–285

Delle Chiaje S (1828) Memoire sulla Storia e Notomia degli Animali senza vertebre del Regno di Napoli. Vol.3. Fratelli Fernandes, Napoli 74–79

Dulvy NK, Sadovy Y, Reynolds JD (2003) Extinction vulnerability in marine populations. Fish Fish 4:25–64

Escofet AM, Orensanz JM, Olivier SR, Scarabino V (1978) Biocenología bentónica del Golfo San Matías (Río Negro, Argentina): metodología, experiencias y resultados del estudio ecológico de un gran espacio geográfico en América Latina. Anales del Centro de Ciencias del Mar y Limnología 5:59–82

Gagliardini DA, Rivas AL (2004) Enviromental characteristics of San Matías Gulf obtained from Landsat-TM and ETM+ data. Gayana 68:186–193

Gil DG, Zaixso HE (2007) The relation between feeding and reproduction in *Anasterias minuta* (Asteroidea: Forcipulata). Mar Biol Res 3: 256–264

Gil DG, Zaixso HE, Tolosano JA (2009) Brooding of the sub-Antarctic heart urchin, *Abatus cavernosus* (Spatangoida: Schizasteridae), in southern Patagonia. Mar Biol 156:1647–1657

Gil DG, Escudero G, Zaixso HE (2011) Brooding and development of *Anasterias minuta* (Asteroidea: Forcipulata) in Patagonia, Argentina. Mar Biol 158:2589–2602

Gray JE (1851) Descriptions of some new genera and species of Spatangidae in the British museum, 2nd Series. Ann Mag Nat Hist 7:130–134

Gray JE (1847) Descriptions of some new genera and species of Asteriadae. Proc Zool Soc London 1847:72–83

Gray JS (1997) Marine biodiversity: patterns, threats and conservation needs. Biodivers Conserv 6:153–175

Hamel J-F, Mercier A (1995) Spawning of the sea cucumber *Cucumaria frondosa* in the St Lawrence Estuary, eastern Canada. SPC Beche-de-mer Information Bulletin 7:12–18

Hamel J-F, Becker P, Eeckhaut I, Mercier A (2007) Exogonadal oogenesis in a temperate holothurian. Biol Bull 213:101–109

Harley CDG (2011) Climate change, keystone predation, and biodiversity loss. Science 334:1124–1127

Harley CDG, Hughes AR, Hultgren KM, Miner BG, Sorte CJB, Thornber CS, Rodriguez LF, Tomanek L, Williams SL (2006) The impacts of climate change in coastal marine systems. Ecol Lett 9: 228–241

Held MBE, Harley CDG (2009) Responses to low salinity by the sea star *Pisaster ochraceus* from high- and low-salinity populations. Invertebr Biol 128(4):381–390

Helmuth B, Broitman BR, Blanchette CA, Gilman S, Halpin P, Harley CDG, O'Donnell MJ, Hofmann GE, Menge BA, Strickland D (2006) Mosaic patterns of thermal stress in the rocky intertidal zone: implications for climate change. Ecol Monogr 76:451–479

Hernández DA (1981) Holothuroidea de Puerto Deseado (Santa Cruz, Argentina). Rev Mus Argentino de Cien Nat 4:151–168

Kashenko SD (2003) The reaction of the starfish *Asterias amurensis* and *Patiria pectinifera* (Asteroidea) from Vostok Bay (Sea of Japan) to a salinity decrease. Russ J Mar Biol 29(2):110–114

Koehler R (1907) Révision de la collection des ophiures du Muséum National d'Histoire Naturelle de París. Bull Sci France Belg 41: 279–351

Koehler R (1923) Astéries et Ophiures recueillis par I'Expédition Antarctique Suédoise 1901-1903. Further Zool Res Swed Antarct Exped 1(1):1–145

Kokot RR, Codignotto JO, Elissondo M (2004) Vulnerabilidad al ascenso del nivel del mar en la costa de la provincia de Río Negro. Rev Asoc Geol Argent 59(3):477–487

Lathlean JA, Ayre DJ, Minchinton TE (2010) Supply-side biogeography: geographic patterns of settlement and early mortality for a barnacle approaching its range limit. Mar Ecol Prog Ser 412:141–150

Leigh EG, Paine RT, Quinn JF, Suchanek TH (1987) Wave energy and intertidal productivity. Proc Natl Acad Sci U S A 84:1314–1318

Liuzzi MG, López Gappa J (2008) Macrofaunal assemblages associated with coralline turf: species turnover and changes in structure at different spatial scales. Mar Ecol Prog Ser 363:147–156

Ljungman A (1870) Om tvänne nya arter Ophiurider. Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar, Stockholm 27(5):471–475

Ljungman AV (1867) Ophiuroidea viventia huc usque cognita enumerata. Öfversigt af Kongliga Vetenskaps-Akademiens Förhandlingar, Stockholm 1866:303–336

Lovén S (1871) Om Echinoideernas byggnad. Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar 28(8):1065–1111

Ludwig HL (1883) Verszeichniss der Holothurien des Kiehler Museums. Bericht der Oberhessischen Gesellschaft für Natur-und Heilkunde 4(10)

Ludwig H (1887) Die von G. Chierchia auf der Fahrt der Kgl. Italianische Corvette Vettor Pisani gesammelten Holothurien. Zoologische Jahrbücher 2:1–36

Lütken C (1871) Fortsatte kritiske org beskrivende Bidrag til Kundskab om Sostjernerne (Asteriderme). Videnskabelige Meddelelser Dan Naturhist Foren 1872:227–304

Lütken CF (1856) Bidrag til kundskab om Slangestjerneme. II. Oversigt over de vestindiske Ophiurer. Videnskabelige Meddelelser fra Dansk Naturhistorisk Förening i Kjøbenhavn 1855. 7:1–19

MacGinitie GE (1939) Some effects of fresh water on the fauna of a marine harbor. Am Midl Nat 21:681–686

Martinez MI, Giménez J, Penchaszadeh PE (2011) Reproductive cycle of the sea cucumber *Psolus patagonicus* Ekman 1925, off Mar del Plata, Buenos Aires, Argentina. Invertebr Reprod Dev 55:124–130

Martinez MI, Thandar AS, Penchaszadeh PE (2013) A new species of *Havelockia* Pearson, 1903 from the Argentine Sea (Holothuroidea: Dendrochirotida: Sclerodactylidae). Zootaxa 3609:583–588

Martín-Ledo R, Sands CJ, López-González PJ (2013) A new brooding species of brittle star (Echinodermata: Ophiuroidea) from Antarctic waters. Polar Biol 36:115–126

Marzinelli EM, Bigatti G, Giménez J, Penchaszadeh PE (2006) Reproduction of the sea urchin *Pseudechinus magellanicus* (Echinoidea: Temnopleuridae) from Golfo Nuevo, Argentina. Bull Mar Sci 79:127–136

McEuen FS, Chia F-S (1991) Development and metamorphosis of two psolid sea cucumbers, *Psolus chitonoides* and *Psolidum bullatum*, with a review of reproductive patterns in the family Psolidae (Holothuroidea: Echinodermata). Mar Biol 109(2):267–280

Menge BA, Daley BA, Wheeler PA, Strub PT (1997) Rocky intertidal oceanography: an association between community structure and nearshore phytoplankton concentration. Limnol Oceanogr 42:57–66

Mercier A, Hamel J-F (2009) Endogenous and exogenous control of gametogenesis and spawning in echinoderms. Adv Mar Biol 55: 1–302

Morsan EM (2009) Impact on biodiversity of scallop dredging in San Matías Gulf, northern Patagonia (Argentina). Hydrobiologia 619: 167–180

Morsan E, Zaidman P, Ocampo-Reinaldo M, Ciocco N (2010) Population structure, distribution and harvesting of southern geoduck, *Panopea abbreviata*, in San Matías Gulf (Patagonia, Argentina). Sci Mar 74(4):763–772

Mortensen TH (1910) The echinoidea of the Swedish South Polar expedition. Wiss Erg Schw Südpolar Exp 6(2):1–114

Mortensen T (1918) The crinoidea of the Swedish antarctic expedition. Wiss Ergebn Schwed Südpolar Exp 8:1–23

Müller J, Troschel FH (1842) System der Asteriden. F. Vieweg und Sohn, Braunschweig

Müller J, Troschel FH (1843) Neue Beiträge zur Kenntnis der Asteriden. Archiv für Naturgeschichte 9:113–131

Paine RT (1966) Food web complexity and species diversity. Am Nat 100:65–75

Paine RT, Castillo JC, Cancino J (1985) Perturbation and recovery patterns of starfish-dominated intertidal assemblages in Chile, New Zealand, and Washington state. Am Nat 125(5):679–691

Pawson DL (1969) Holothuroidea from Chile report no. 46 of the Lund University Chile expedition 1948–1949. Sarsia 38:121–146

Pawson DL (2007) Phylum Echinodermata. Zootaxa 1668:749–764

Pearse JS, Pearse VB, Davis KK (1986) Photoperiod regulation of gametogenesis and growth in the sea urchin *Strongylocentrus purpuratus*. J Exp Zool 237:107–118

Pérez AF, Boy C, Morriconi E, Calvo J (2010) Reproductive cycle and reproductive output of the sea urchin *Loxechinus albus* (Echinodermata: Echinoidea) from Beagle Channel, Tierra del Fuego, Argentina. Polar Biol 33:271–280

Pérez-Ruzafa A, Alvarado JJ, Solís-Marín FA, Hernández JC, Morata A, Marcos C, Abreu-Pérez M, Aguilera O, Alió J, Bacallado-Aránega JJ, Barraza E, Benavides-Serrato M, Benítez-Villalobos F, Betancourt-Fernández L, Borges M, Brandt M, Brogger MI, Borrero-Pérez GH, Buitrón-Sánchez BE, Campos LS, Cantera JR, Clemente S, Cohen-Renfijo M, Coppard SE, Costa-Lotufo LV, del Valle-García R, Díaz de Vivar ME, Díaz-Martínez JP, Díaz Y, Durán-González A, Epherra L, Escolar M, Francisco V, Freire CA, García-Arrarás JE, Gil DG, Guarderas P, Hadel VF, Hearn A, Hernández-Delgado EA, Herrera-Moreno A, Herrero-Pérezrul MD, Hooker Y, Honey-Escandón MBI, Lodeiros C, Luzuriaga M, Manso CLC, Martín A, Martinez MI, Martínez S, Moro-Abad L, Mutschke E, Navarro JC, Neira R, Noriega N, Palleiro-Nayar JS, Pérez AF, Prieto-Ríos E, Reyes J, Rodríguez-Barreras R, Rubilar T, Sancho-Mejías TI, Sangil C, Silva JRMC, Sonnenholzner JI, Ventura CRR, Tablado A, Tavares Y, Tiago CG, Tuya F, Williams SM (2013) Latin America echinoderm biodiversity and biogeography: patterns and affinities. In: Alvarado JJ, Solís-Marín FA (eds) Echinoderms research and diversity in Latin America. Springer, Berlin, pp 511–542

Perrier E (1875) Révision de la collection de stellérides du Museum d'Histoire naturelle de Paris. Arch Zool Exp Gen 4:265–450

Perrier R (1904) Sur une nouvelle espèce de Chiridota. Bulletin Muséum National Histoire Naturelle, Paris, 10:370–371

Philippi RA (1845) Beschreibung einiger neuer Echinodermen nebst kritischen Bemerkungen Über einige weniger bekannte Arten. Archiv fur Naturgeschichte 11:344–359

Philippi RA (1857) Vier neue Echinodermen des Chilenischen Meeres. Archiv fur Naturgeschichte 23(1):130–134

Philippi RA (1858) Beschreibung einiger neuer Seesterne aus dem Meere von Chiloe. Archiv fur Naturgeschichte 24(1):264

Piola AR, Scasso LM (1988) Circuación en el Golfo San Matías. Geoacta 15:33–51

Price ARG, Keeling MJ, O'Callaghan CJ (1999) Ocean-scale patterns of "biodiversity" of Atlantic asteroids determined from taxonomic distinctness and other measures. Biol J Linn Soc 66:187–203

Ramírez FC (1996) Composición, abundancia y variación estacional del zooplancton de red del Golfo San Matías. Frente Marítimo 16:157–167

Ravest Presa C (2001) *Athyonidium chilensis*, La bêche-de-mer - Bulletin de la CPS, 13

Ruiz JF, Ibáñez CM, Cáceres CW (2007) Morfometría del tubo digestivo y alimentación del pepino de mar *Athyonidium chilensis* (Semper, 1868) (Echinodermata: Holothuroidea). Rev Biol Mar Oceanogr 42(3):269–274

Semper C (1867) Holothurien. Reisen im Archipel der Philippinen 1:1–288

Sewell MA (1994) Small size, brooding and protandry in the Apodid sea cucumber *Leptosynapta clarki*. Biol Bull 187:112–123

Sladen PW (1889) Report on the Asteroidea dredged by HMS "Challenger" during the years 1873-1876. Voyage of HMS "Challenger" Reports on the Scientific Results. Zool 30(51):1–893

Spalding MD, Fox HE, Allen RG, Davidson N, Ferdaña ZA, Finlayson M, Halper BS, Jorge MA, Lobana A, Lourie SA, Martin DK, Mcmanus E, Molnar J, Recchia CA, Robertson J (2007) Marine Ecoregions of the world: a bioregionalization of coastal and shelf areas. Bioscience 57:573–583

Tommasi LR (1971) Equinodermes do Brasil. I. Sobre algumas novas espécies e outras pouco conhecidas, para o Brasil. Boletim do Instituto Oceanográfico, São Paulo 20:1–21

Uthicke S (1999) Sediment bioturbation and impact of feeding activity of Holothuria (Halodeima) atra and Stichopus chloronotus, two sediment feeding holothurians, at Lizard Island, Great Barrier Reef. Bull Mar Sci 64:129–141

Uthicke S (2001) Interactions between sediment-feeders and microalgae on coral reefs: grazing losses versus production enhancement. Mar Ecol Prog Ser 210:125–138

Watts SA, Lawrence JM (1990) The effect of temperature and salinity interactions on righting, feeding and growth in the sea star *Luidia clathrata* (Say). Mar Behav Physiol 17:159–165

Wernberg T, Russell BD, Moore PJ, Ling SD, Smale DA, Campbell A, Coleman MA, Steinberg PD, Kendrick GA, Connell SD (2011) Impacts of climate change in a global hotspot for temperate marine biodiversity and ocean warming. J Exp Mar Biol Ecol 400:7–16

Wieters EA, McQuaid C, Palomo G, Pappalardo P, Navarrete SA (2012) Biogeographical boundaries, functional group structure and diversity of rocky shore communities along the Argentinean coast. PLoS ONE 7(11):e49725. doi:10.1371/journal.pone.0049725