Rev. Mus. Argentino Cienc. Nat., n.s.
27(1): 119-128, 2025
ISSN 1514-5158 (impresa)
ISSN 1853-0400 (en línea)

Seasonal population structure of the sea star *Anasterias antarctica* in intertidal boulders of the Protected Natural Area Puerto Lobos, Atlantic Patagonia

Lorena P. ARRIBAS[1,2,*], Martín I. BROGGER[1], Ariana B. ALARCÓN SAAVEDRA[1], Sol A. REBOLLEDO[2], José E. F. ALFAYA[1,2] & Gregorio BIGATTI[1,2,3]

[1]LARBIM, Instituto de Biología de Organismos Marinos (IBIOMAR-CONICET), Bvd. Brown 2915, U9120ACV Puerto Madryn, Argentina. [2]Universidad Nacional de la Patagonia "San Juan Bosco"-Sede Puerto Madryn, Bvd. Brown 3051, U9120ACV Puerto Madryn, Argentina. [3]Universidad Espíritu Santo, Ecuador. *Corresponding author. Lorena P. Arribas, lorearribas@gmail.com. LARBIM-IBIOMAR, CENPAT (CONICET).

Abstract: Intertidal boulders are complex marine environments which support unique marine assemblages, including species generally restricted to tide-pools, and also characteristics which make them ideal for experimental studies to further understanding ecological patterns. The goals of this study were to describe the seasonal population structure of the sea star *Anasterias antarctica* over two years and test the effects of environmental conditions over sea stars population in intertidal boulders of the Protected Natural Area Puerto Lobos in San Matías Gulf, Atlantic Patagonia. Our results showed seasonal differences in biomass and size of *A. antarctica* population over the two years sampled, although not significant relation was observed due to environmental conditions measured. To better understand *A. antarctica* population structure in the intertidal boulder fields of Puerto Lobos area more environmental variables need to be measured, as well as carrying out specific sampling to detect the smallest sizes of sea stars after the release of juveniles. These findings underscore the necessity of incorporating seasonal dynamics into monitoring programs for species that play key roles in communities, enabling us to detect potential changes driven by anthropogenic pressure or climate change, highlighting the importance of the study of these unique and poorly known rocky environments in Atlantic Patagonia.

Key words: Asteroidea, Intertidal boulder fields, Environmental variables, Puerto Lobos Protected Natural Area, Patagonia

Resumen: Estructura poblacional estacional de la estrella de mar *Anasterias antarctica* en campos de bloques de roca intermareales del Área Natural Protegida Puerto Lobos, Patagonia Atlántica. Los campos de bloques de rocas intermareales son entornos marinos complejos que sustentan conjuntos marinos únicos, incluidas especies generalmente restringidas a pozas de marea, y también características que los hacen ideales para estudios experimentales para comprender mejor los patrones ecológicos. Los objetivos de este estudio fueron describir la estructura poblacional estacional de la estrella de mar *Anasterias antarctica* durante dos años y analizar los efectos de las condiciones ambientales sobre la población de las estrellas de mar en los campos de rocas intermareales del Área Natural Protegida Puerto Lobos en el Golfo San Matías, Patagonia Atlántica. Nuestros resultados mostraron diferencias estacionales en la biomasa y el tamaño de la población de *A. antarctica* durante los dos años muestreados, aunque no se observó una relación significativa con las condiciones ambientales medidas. Para comprender mejor la estructura poblacional de *A. antarctica* en el campo de bloques de rocas intermareales de la zona de Puerto Lobos sería necesario medir más variables ambientales, así como realizar muestreos específicos para detectar los tamaños más pequeños de estrellas de mar tras la liberación de juveniles. Estos hallazgos evidencian la necesidad de incorporar dinámicas estacionales en los programas de monitoreo de especies que desempeñan roles clave en las comunidades, lo que permitirá detectar cambios ocasionados por la presión antropogénica o el cambio climático, destacando la importancia del estudio de estos ambientes rocosos únicos y poco conocidos en la Patagonia Atlántica.

Palabras clave: Asteroidea, Campo de bloques de rocas intermareales, Variables ambientales, Área Natural Protegida Puerto Lobos, Patagonia

INTRODUCTION

The rocky intertidal areas of Atlantic Patagonia are exposed to extreme physical conditions during low tides, with large tidal amplitudes that reach *ca.* 4 meters along the coastline (Bertness *et al.*, 2006; Rechimont *et al.*, 2013; Barclay *et al.*, 2023), which intensifies the exposure time to harsh environmental conditions. Although many organisms are adapted to these severe environments such as mussels, which provide shelter to a diverse assemblage of small mobile invertebrates to avoid physical stress (Gutiérrez *et al.*, 2003, 2020; Bertness *et al.*, 2006; Gil *et al.*, 2018; Arribas *et al.*, 2019), other mobile species take refuge under boulder fields during periods of low tide (Chapman, 2002a; Le Hir & Hily, 2005; Gil & Zaixso, 2008; Arribas *et al.*, 2017).

Boulders are complex marine environments considered as discrete patches of habitat, separated from other boulders by different types of habitats, such as mud and soft sediment (Chapman, 2002a; Palmer, 2010). These characteristics result in species living on and under boulders showing greater spatial variability, and this variation is also related with the type of boulder (size and material), differences in wave action, and disturbance (Wilson, 1987; Chapman, 2002a, b; Franz *et al.*, 2021). Although most studies on boulder fields focus on species diversity, spatial variability, and their role as habitat for the colonization or as nursery for intertidal species (Chapman, 2002a; Aldana *et al.*, 2016), others analyze the importance of boulder fields as a method of habitat restoration in areas severely impacted by anthropogenic disturbances (Chapman, 2002b, 2012; Liversage & Chapman, 2018). However, few studies have been published on intertidal boulders from Atlantic Patagonia (Gil & Zaixso, 2008; Arribas *et al.*, 2017; Archuby & Gordillo, 2018; Burgueno Sandoval *et al.*, 2021). Intertidal boulder fields support unique marine assemblages including species generally restricted to tide pools, and also possess characteristics that make them ideal for experimental studies to further understanding ecological patterns (Chapman, 2005; Palmer, 2010). Previous works have registered that boulder habitats are rapidly colonized by mobile animals, including generalists and specialist species which are uncommon from intertidal habitats (Chapman, 2012), although the larger mobile invertebrates living on the underneath of boulders are mainly mollusks and echinoderms (Chapman, 2002a, 2005).

In the intertidal rocky shores of Patagonia, the brooding sea star *Anasterias antarctica* (Lütken, 1857) can be found under mussel bed matrix (Gil *et al.*, 2018) or under boulder fields, common in rocky intertidal areas of San Matías Gulf (Arribas *et al.*, 2017). This species is the most abundant asteroid in the intertidal area of central and south Patagonian Atlantic coasts (Salvat, 1985; Gil & Zaixso, 2008), and it is distributed from the mid-intertidal zone to 80 m depth (Bernasconi, 1964; Hernandez & Tablado, 1985). Previous works of the sea star *A. antarctica* have related population changes such as feeding rate, heat shock proteins Hsp70 expression and oxygen demand of the brooding juveniles with environmental variations (Gil & Zaixso, 2007, 2008; Rodríguez Ruíz, 2011; Arribas *et al.* 2017, 2022). Other works include studies of metals concentrations (Arribas *et al.*, 2023), oxidative metabolism (Pérez *et al.*, 2015), reproduction (Salvat, 1985; Pérez *et al.*, 2017; Gil *et al.*, 2011; Fraysse *et al.*, 2021) and interspecific competition (Storero *et al.*, 2020). Human activities are increasing in coastal areas around the world (Harley *et al.*, 2006) highlighting the importance of preserving the complex boulder field environments due to generate habitat for grazers, predators or detrital feeder species, whether sessile or mobile with different patterns of dispersion (Le Hir & Hily, 2005; Chapman, 2007; Aldana *et al.*, 2016; Arribas *et al.*, 2017). The marine Protected Natural Area Puerto Lobos, located in the south of San Matías Gulf, Atlantic Patagonia, is a poorly studied area without an established human population. Only a few recreational activities are carried out in the area, mainly related to coastal whale watching and artisanal fishing (Storero *et al.*, 2010; Güller & Zelaya, 2017), which gives it a unique feature for biodiversity studies since anthropogenic effects are almost null. Hence, these environments can help to provide baseline data against future species loss in coastlines under anthropic pressure or affected by climate change, because they offer refuge buffering against harsh climatic conditions (McGuinness & Underwood, 1986; Le Hir & Hily, 2005).

The goals of this study were to describe the population structure of the sea star *A. antarctica* and test the effects of environmental conditions on its seasonal structure over two years in the intertidal boulder fields of the Protected Natural Area Puerto Lobos in Atlantic Patagonia.

MATERIALS AND METHODS

The study was conducted in the rocky intertidal shores of Puerto Lobos (41°58'50'' S - 65°4'1" W, Fig. 1). In the studied zone, boulder fields of rocky outcrops belong to a group of volcanic and marine sediments with large pyroclastic contribution (Kokot *et al.*, 2004). The area has a semidiurnal macrotidal regime with rocky abrasion platforms alternating with sandy beaches. The maximal tidal amplitude is around 6 m (Miloslavich *et al.*, 2016).

To evaluate the density (ind m^{-2}), biomass (± 0.1, g m^{-2}), and size (measured as the longest arm length R with Vernier calipers ± 0.01 mm) of the sea star *Anasterias antarctica*, between 2 and 3 transect (10 m long and 2 m wide) parallel to the coastline were performed seasonally (austral autumn, winter, spring and summer) over two years (2022-2023) in the boulder field of the mid-low intertidal level of Puerto Lobos Protected Natural Area (Fig. 1B). All boulders and cobbles inside transects were turned around to search for sea stars (and then returned to their original position).

To describe the physico-chemical conditions at the study sites seasonally sea surface temperature (SST), pH and salinity were quantified. Sea surface temperature was recorded using ElectricBlue loggers (with interval sampling every 1hs), and *in situ* salinity (optical refractometer "Alla France" ATC 0-100ppt) and pH were registered with a digital sensor (Milwaukee pH55) during each sampling campaign.

Data analysis

To test the density, biomass and size of the sea star *Anasterias antarctica* a nested ANOVA was carried out. Population structure of *A. antarctica* and environmental variables were analyzed including the factor Season (4 levels, random) nested within Year (2 levels, random). Heterogeneity of variances was checked by Cochran's test, and data were appropriately transformed when necessary (Underwood, 1997). A sqrt transformation was applied to *A. antarctica* density to achieve normality.

Sea star size was pooled from the replicate transects sampled for each season over the two years, allowing for a visual assessment of size class distribution. Chi-squared tests were conducted to compare the number of *A. antarctica* individuals in each size class seasonally over the two years sampled.

Pearson's correlations were performed to identify which environmental variable (sea surface temperature, pH, and salinity) has the greatest influence on the seasonally density, biomass and size of *A. antarctica* population over the two years sampled.

RESULTS

The highest density of *Anasterias antarctica* under boulders was found during spring 2023 in Puerto Lobos rocky intertidal, although no significant differences were found among seasons or between years (Fig. 2A, Table 1). Otherwise, biomass and size of *A. antarctica* showed significant differences in seasons nested within years (Table 1). Autumn 2022 showed lower biomass of *A. antarctica* compared to autumn 2023 during the sampling period, while summer 2023 showed higher sizes compared with all seasons of 2022 and spring 2023 (Fig. 2B and C). Size frequency distributions of *A. antarctica* were significantly different among seasons and between years (Fig. 3, Table 2). Spring 2022 showed higher frequency in size range from 5-15 and 20-30 mm compared with the other seasons within the same year. Spring 2023 seems to increase in the same size ranges as spring 2022 although intra-annual size frequency distribution showed significant differences among all seasons sampled in 2023 (Fig. 3). Summer and autumn of 2022 presented low frequency of the smallest size ranges (< 5mm) compared with summer and autumn 2023 where this size range was not registered. Moreover, during these seasons we did not find the size range from 5 to 10 mm. On the contrary, 2023 showed the largest size range (>30 mm) in all seasons while in 2022 this size was only represented in winter and spring (Fig. 3).

Environmental variables of the year 2022 (Fig. 4) presented a mean annual sea surface temperature of 13.44 (± 2.62 °C), a pH of 7.98 (± 0.05) and a salinity of 39.31 (± 0.83). The year 2023 presented a mean annual sea surface temperature of 13.94 (± 3.11 °C), a pH of 8.08 (±0.09) and a salinity of 37.27 (± 0.36). The environmental variables SST and pH showed significant differences of seasons nested within years (Nested-ANOVA $_{SST}$: $F_{1,6} = 4300.62$, $p < 0.001$, Nested-ANOVA $_{pH}$: $F_{1,6} = 4.35$, $p < 0.05$, Fig. 4A and B). Sea surface temperature showed higher values in almost all seasons of the year 2023 compared to year 2022, except in spring 2023 which showed lower values than spring 2022 (Fig 4A). With respect to the differences in pH levels, higher values were observed in winter

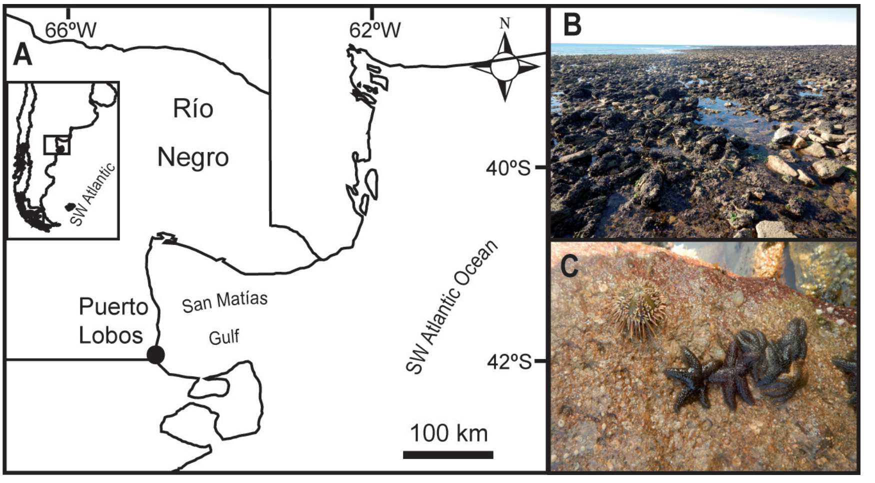

Fig. 1. A. Sampling site at the Puerto Lobos Protected Natural Area in San Matías Gulf, Atlantic Patagonia. B. Intertidal boulder field during low tide at Puerto Lobos rocky shore. C. Sea stars *Anasterias antarctica* (Autumn 2023).

and spring 2023 compared with summer 2023 (Fig. 4B). Salinity showed significant differences between years with lower values in the year 2023 (Nested-ANOVA= $F_{1,6} = 20.24$, $p < 0.001$, Fig. 4C). Parameters of the sea star *A. antarctica* (density, biomass and size) did not show correlation with none of the environmental variables measured (Table 3).

DISCUSSION

Our results suggest that biomass and size of sea stars *Anasterias antarctica* living under intertidal boulders of Puerto Lobos are influenced by seasons and years sampled, with observable shifts in size ranges over time. Biomass of *A. antarctica* showed the lowest values during autumn 2022 which could be related to the energy effort allocated for reproduction and a consequent reduction in somatic investment (Llodra, 2002), although in autumn 2023 the biomass showed the highest value. Moreover, differences in size of *A. antarctica* were observed seasonally between years sampled with higher sizes in summer 2023 compared with all seasons of 2022. With respect to densities of the sea star population, the highest values were observed during spring in both years sampled, with a maximum peak in spring 2023, although no significant differences were found among seasons or between years. In our study, the year 2023 seems to show higher population values for the sea star *A. antarctica* than 2022, although environmental parameters measured in our study do not explain the seasonal and annual variations found over the two years sampled. Echinoderm population increases, besides to being affected by physico-chemical variables, are related to high productivity and prey availability (McClintock *et al.*, 1988; Lawrence, 2013; Zolotarev, 2022). In a previous study Arribas *et al.*, (2017) found a relationship between *A. antarctica* biomass and water velocity, which can regulate the available food (Feder, 1970; Cahalan *et al.*, 1989). Additionally, growth and body size in asteroids depend on the quantity and quality of food and favorable feeding conditions (Feder, 1970; McClintock *et al.*, 1988; Lawrence, 2010, 2013). Chlorophyll-a concentration (widely used as a proxy for phytoplankton biomass) is a biological variable that can have effects over marine populations (Pardal *et al.*, 2021; Williams *et al.*, 2021). Central Patagonian Shelf presents elevated concentrations of chlorophyll-a, characterized by two well-defined maxima, a stronger spring bloom and a weaker fall bloom, with an increasing trend in chlorophyll concentrations through the years (Rivas *et al.*, 2006; Nocera *et al.*, 2024). Promptly, in the southwestern area of San Matías Gulf, a bimodal phytoplankton cycle can be observed, with maximum values in autumn and spring (Williams *et al.*, 2018; Williams *et al.*, 2021). This chlorophyll-a pattern in San Matías Gulf could have an effect through food webs over species biomass, as thus was found in our study, where an increase in sea stars biomass was observed from autumn 2022 to 2023, year where an increase in phytoplankton blooms was detected (Nocera *et al.*, 2024). Regarding the size of the sea stars, although we observed higher values in almost all seasons of 2023 (except spring

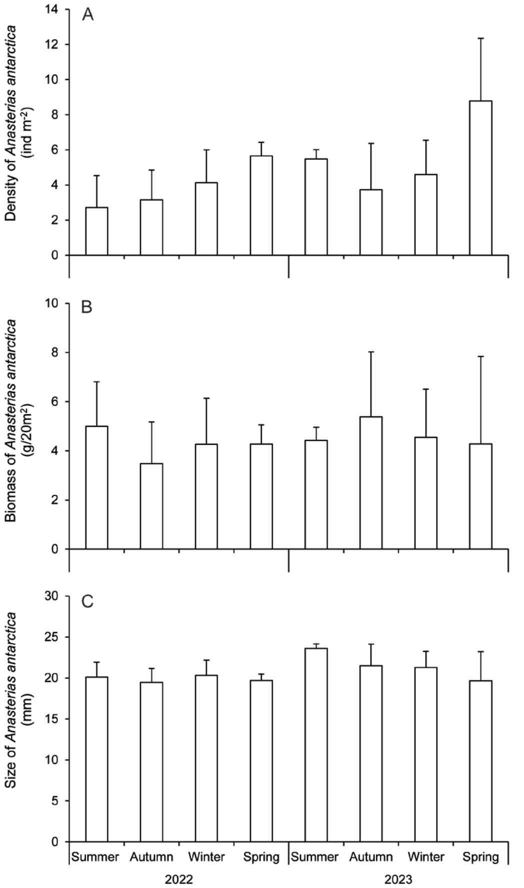

Fig. 2. Sea star *Anasterias antarctica* **A.** Mean density (ind m^{-2} ± SD) **B.** Mean biomass ($g/20m^2$ ± SD) and **C.** Mean size (mm ± SD) at intertidal boulder field of Puerto Lobos rocky shore at the four seasons sampled (summer, autumn, winter and spring) over two years.

Table 1. Nested ANOVA testing factors governing *Anasterias antarctica* density (ind m^{-2}), biomass (g m^{-2}) and size (mm) seasonally over the two years sampled in intertidal boulder fields at Puerto Lobos Protected Natural Area. * $p < 0.05$.

		Anasterias antarctica density		*Anasterias antarctica* biomass		*Anasterias antarctica* size	
	df	MS	F	MS	F	MS	F
Year	1	0.63	1.47	0.75	1.03	12.06	3.70
Season (Year)	6	0.43	1.60	0.74	3.32*	3.34	3.52*
Error	11	0.27		0.22		0.95	

Sqrt transformation was applied to *A. antarctica* density to achieved ANOVA assumptions. Legend: df = degree of freedom, MS = mean square, F = F-statistic

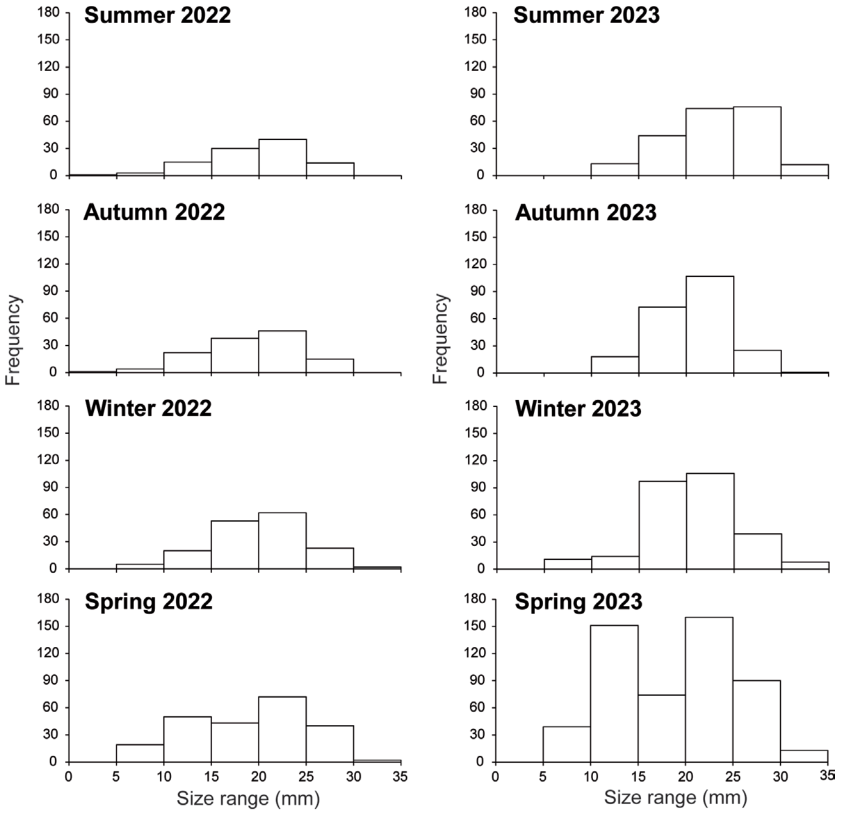

Fig. 3. Size range (mm) frequency distributions of *Anasterias antarctica* population sampled seasonally over two years from intertidal boulder field of Puerto Lobos Protected Natural Area.

2023) compared with 2022, we did not find any relationship with environmental variables measured. Perhaps this variation in the size of the individuals could be given by a favorable food quality due to an increase in temperature. A slight increasing tendency in SST has been observed in the last years in Patagonian shelf (Belkin, 2009; Rivas, 2010) and more bloom alerts have appeared in the last 20 years in San Matías Gulf which can have implications for the marine food webs on this coast (Nocera *et al*., 2024). This reflects a need to measure more physical, biogeochemical and biological parameters (*e.g.* phytoplankton biomass and nutrient availability), to better understand population structure in the intertidal boulder fields of Puerto Lobos.

Organisms size gradients in intertidal are usually explained in terms of responses to physical stress (Chapman, 1994). In our study, *A. antarctica* size frequency distribution showed a shift in ranges among seasons in the two years sampled that could be associated with temporal heterogeneity (Rumrill, 1989; Chapman, 1994). Smallest sizes were more represented during spring in both years sampled, while were absent during summer and autumn 2023. This temporally shift could be associated with favorable environmental variables during spring, and also an increase in food supply. Besides, temporal changes in smallest *A. antarctica* size distribution during summer and autumn 2023 could be associated with a migration into shallow waters to avoid warmer intertidal environmental (Moran, 1999). Another factor that could be associated with the temporal size fluctuation is the brooding season. Gil *et al*., (2011) found that in exposed areas the sizes at which 50% of the females were brooding (R_{50}) was 21.2 mm. During autumn (initial brooding period) an increase in the 20-25 mm size range of *A. antarctica* was observed in 2023 which can be related with favorable environmental conditions at mid-low intertidal level in Puerto Lobos area, and its impact in increased brooding individuals (17% increase in sea star brooders from 2022 to 2023, *unplub. data).* The brooding sea star *A. antarctica* release juveniles

Table 2. Chi-square test results for differences in the size frequency distribution of *Anasterias antarctica* in each size class among seasons over two years sampled. In all cases df = 7.

Seasonal intra-annual size frequency of *A. antarctica*	χ^2	**p**
Year 2022		
Summer - Autumn	5.01	0.66
Summer - Winter	25.36	< 0.001
Summer - Spring	75.03	< 0.001
Autumn - Winter	13.56	0.06
Autumn - Spring	55.12	< 0.001
Winter - Spring	39.25	< 0.001
Year 2023		
Summer - Autumn	248.13	< 0.001
Summer - Winter	86.79	< 0.001
Summer - Spring	225.76	< 0.001
Autumn - Winter	29.24	< 0.001
Autumn - Spring	231.74	< 0.001
Winter - Spring	200.60	< 0.001
Seasonal inter-annual size frequency of *A. antarctica*		
Summer 2022 - Summer 2023	82.96	< 0.001
Autumn 2022 - Autumn 2023	57.44	< 0.001
Winter 2022 - Winter 2023	55.13	< 0.001
Spring 2022 - Spring 2023	176.28	< 0.001

Table 3. Correlation coefficient values (r) between *A. antarctica* parameters (density, biomass and size) and environmental variables (sea surface temperature "SST", pH and salinity) measured seasonally over two years in intertidal boulder fields at Puerto Lobos Protected Natural Area. In all cases, Pearson correlation coefficients did not significantly differ from zero.

Anasterias antarctica parameters	SST	pH	Salinity
Density	0.08	0.28	-0.57
Biomass	0.21	0.51	-0.31
Size	0.41	-0.02	-0.63

at the end of winter/beginning of spring with a mean size of 1.39 (± 0.15) mm in a southernmost area (Gil *et al.*, 2011). This smallest size could be difficult to sample since they could be hidden inside mussels matrix or in the soft sediment searching for protection against Patagonian harsh physical stress or predators, so it would be necessary to carry out specific sampling to detect the smallest sizes of sea stars after the release of juveniles in the studied area. This information – unsampled in our study – is important to evaluate more accurately the size distribution of *A. antarctica* population.

Intertidal boulder habitats present a rich biodiversity as species take refuge under rocks to avoid harsh environmental conditions during low tides (Chapman & Underwood, 1996; Chapman 2005, 2007; Liversage & Chapman, 2018), a characteristic common on Patagonian environments. Therefore, preserving these natural environments highlights the importance of the conservation of species richness especially in intertidal benthos that plays a key role in coastal marine food webs.

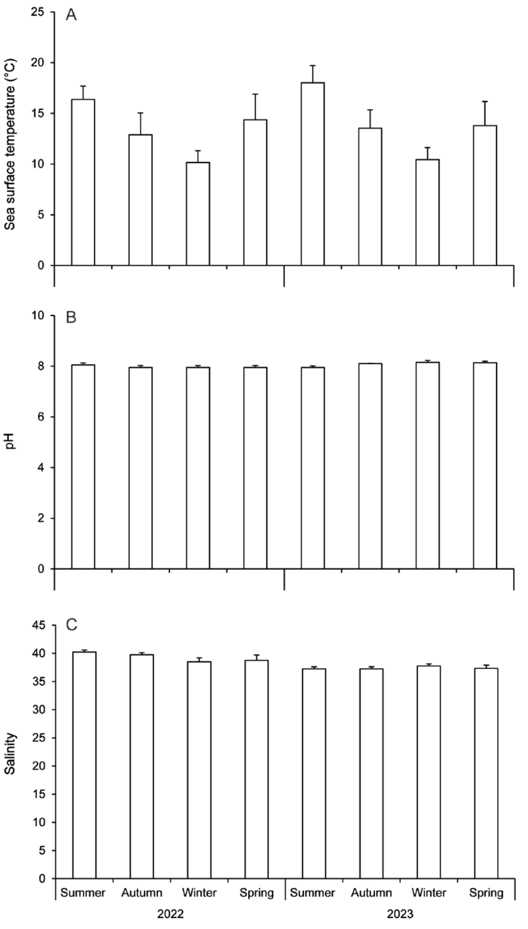

Fig. 4. Seasonal environmental variables **A.** Mean sea surface temperature (°C ± SD) recorded by ElectricBlue loggers **B.** Mean pH (± SD) and **C.** Mean salinity (± SD) over the two years sampled in the intertidal boulder fields of Puerto Lobos Protected Natural Area.

CONCLUSIONS

The present study highlights the importance of understanding the long-term seasonal and annual variations in the population of the sea star *Anasterias antarctica* in the intertidal boulder field of the Protected Natural Area Puerto Lobos. These findings underscore the necessity of incorporating seasonal dynamics into monitoring programs for species that play key roles in communities, enabling to detect potential changes driven by anthropogenic pressure or climate change. Our research contributes valuable baseline data that can be useful in future conservation efforts. By advancing our understanding of the factors that shape intertidal benthic populations in Atlantic Patagonian boulder fields, this study emphasizes the need to intensify research in these unique rocky shore environments. Protecting these areas is crucial, as they support a rich biodiversity and play an important role in maintaining the health of coastal marine ecosystems.

ACKNOWLEDGEMENTS

This research was carried out with the corresponding sampling permits. We thank María Soledad Zabala and Jonathan Flores for their support in field work, and the Ministerio de Ambiente y Control del Desarrollo Sustentable de la provincia de Chubut and Secretaría de Ambiente y Desarrollo Sustentable de la provincia de Río Negro for their support. This work was partly supported by CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina) under PICT 0969 to GB, and PICT-2549 to MIB, and by UNPSJB (Universidad Nacional de la Patagonia San Juan Bosco) under PI 1751 to LPA. This manuscript was further improved by comments of two anonymous reviewers. This is the contribution Nº 204 of LARBIM.

REFERENCES

Aldana, M., Maturana, D., Pulgar, J. & M.R. García-Huidobro. 2016. Predation and anthropogenic impact on community structure of boulder beaches. *Scientia Marina* 80(4): 543-551.

Archuby, F. & S. Gordillo. 2018. Drilling predation traces on recent limpets from northern Patagonia, Argentina. *Palaeontologia Electronica* 21.3.36A: 1-23

Arribas, L.P., Bagur Creta, M., Palomo, M.G. & G. Bigatti. 2017. Population biology of the sea star *Anasterias minuta* (Forcipulatida: Asteriidae) threatened by anthropogenic activities in rocky intertidal shores of San Matías Gulf, Patagonia, Argentina. *Revista de Biología Tropical* 65(1): 73-84.

Arribas, L.P., Gutiérrez, J.L., Bagur, M., Soria, S.A., Penchaszadeh, P.E. & M.G. Palomo. 2019. Variation in aggregate descriptors of rocky shore communities: a test of synchrony across spatial scales. *Marine Biology* 166: 1-7.

Arribas, L.P., Alfaya, J.E., Palomo, M.G., Giulianelli, S., Vilela, R.A.N., & G. Bigatti. 2022. Ocean warming lead to heat shock protein expression and decrease in the feeding rate of the Patagonian sea star *Anasterias minuta*. *Journal of Experimental Marine Biology and Ecology* 546, 151661.

Arribas, L.P., Márquez, F., Brogger, M.I. & G. Bigatti. 2023. Baseline metals concentration in the sea star *Anasterias minuta* in San Matías Gulf. *Revista del Museo Argentino de Ciencias Naturales n. s.*, 25(1): 143-149.

Barclay, V.M., Neill, S.P. & A. Angeloudis. 2023. Tidal range resource of the Patagonian shelf. *Renewable Energy* 209: 85-96.

Belkin, I.M. 2009. Rapid warming of large marine ecosystems. *Progress in oceanography* 81(1-4): 207-213.

Bernasconi, I. 1964. Asteroideos argentinos. Centro de Investigación de Biología Marina.

Bertness, M.D., Crain, C.M., Silliman, B.R., Bazterrica, M.C., Reyna, M.V., Hildago, F. & J.K. Farina. 2006. The community structure of western Atlantic Patagonian rocky shores. *Ecological Monographs* 76(3): 439-460.

Burgueno Sandoval, G.M., Narvarte, M.A. & F.N. Firstater. 2021. Epibiosis in sedimentary coastal environments: Effects of an introduced barnacle on a native mussel. *Marine Ecology* 42: e12674.

Cahalan, J.A., Siddall, S.E. & M.W. Luckenbach. 1989. Effects of flow velocity, food concentration and particle flux on growth rates of juvenile bay scallops *Argopecten irradians*. *Journal of Experimental Marine Biology and Ecology* 129(1): 45-60.

Chapman, M.G. 1994. Small-scale patterns of distribution and size-structure of the intertidal littorinid *Littorina unifasciata* (Gastropoda: Littorinidae) in New South Wales. *Marine and Freshwater Research* 45(4): 635-652.

Chapman, M.G. 2002a. Patterns of spatial and temporal variation of macrofauna under boulders in a sheltered boulder field. *Austral Ecology* 27(2): 211-228.

Chapman, M.G. 2002b. Early colonization of shallow subtidal boulders in two habitats. *Journal of Experimental Marine Biology and Ecology* 275(2): 95-116.

Chapman, M.G. 2005. Molluscs and echinoderms under boulders: tests of generality of patterns of occurrence. *Journal of Experimental Marine Biology and Ecology* 325(1): 65-83.

Chapman, M.G. 2007. Colonization of novel habitat: tests of generality of patterns in a diverse invertebrate assemblage. *Journal of Experimental Marine Biology and Ecology* 348(1-2): 97-110.

Chapman, M.G. 2012. Restoring intertidal boulder-fields as habitat for “specialist” and “generalist” animals. *Restoration Ecology* 20(2): 277-285.

Chapman, M.G. & A.J. Underwood. 1996. Experiments on effects of sampling biota under intertidal and shallow subtidal boulders. *Journal of Experimental Marine Biology and Ecology* 207: 103-126.

Clark, A.M. & M.E. Downey. 1992. *Starfishes of the Atlantic*. Chapman & Hall Press, London, 794 pp.

Feder, H.M. 1970. Growth and predation by the ochre sea star, *Pisaster ochraceus* (Brandt), in Monterey Bay, California. *Ophelia* 8(1): 161-185.

Franz, M., von Rönn, G.A., Barboza, F.R., Karez, R., Reimers, H.C., Schwarzer, K. & M. Wahl. 2021. How do geological structure and biological diversity relate? Benthic communities in boulder fields of the Southwestern Baltic Sea. *Estuaries and Coasts* 44: 1994-2009.

Fraysse, C.P., Boy, C.C. & A.F. Pérez. 2021. Reproductive traits of the intertidal sea star *Anasterias antarctica* (Echinodermata: Asteroidea) from the Beagle Channel, Argentina. *Marine Biology* 168: 1-19.

Gil, D.G. & H.E. Zaixso. 2007. The relation between feeding and reproduction in *Anasterias minuta* (Asteroidea: Forcipulata). *Marine Biology Research* 3(4): 256-264.

Gil, D.G. & H.E. Zaixso. 2008. Feeding ecology of the subantarctic sea star *Anasterias minuta* within tide pools in Patagonia, Argentina. *Revista de Biología Tropical* 56(3): 311-328.

Gil, D.G., Escudero, G. & H. E.Zaixso. 2011. Brooding and development of *Anasterias minuta* (Asteroidea: Forcipulata) in Patagonia, Argentina. *Marine Biology* 158(11): 2589-2602.

Gil, D.G., Reartes, M.B., Mutti, C., Tolosano, J.A. & H. E. Zaixso. 2018. Living under intertidal mussels: distribution, reproduction, and condition indices in a brooding sea star, *Anasterias minuta*, in Patagonia, Argentina. *Marine biology* 165: 1-14.

Güller, M. & D.G. Zelaya. 2017. A hot-spot of biodiversity in Northern Patagonia, Argentina. *Biodiversity and Conservation* 26: 3329-3342.

Gutiérrez, J.L., Jones, C.G., Strayer, D.L. & O.O. Iribarne. 2003. Mollusks as ecosystem engineers: the role of shell production in aquatic habitats. *Oikos* 101(1): 79-90.

Gutiérrez, J.L. 2020. Ecosystem engineers in the world coasts: case studies and conceptual linkages. *Diversity* 12(6): 243.

Harley, C.D., Randall Hughes, A., Hultgren, K.M., Miner, B.G., Sorte, C.J., Thornber, C. S., Rodriguez, L.F., Tomanek, L. & S.L. Williams. 2006. The impacts of climate change in coastal marine systems. *Ecology letters* 9(2): 228-241.

Hernandez, D.A. & A. Tablado. 1985. Asteroidea de Puerto Deseado (Santa Cruz, Argentina). *Studies on Neotropical Fauna and Environment* 22(3): 155-166.

Kokot, R.R., Codignotto, J.O. & M. Elissondo. 2004. Vulnerabilidad al ascenso del nivel del mar en la costa de la provincia de Río Negro. *Revista de la Asociación Geológica Argentina,* 59, 477-487.

Lawrence, J.M. 2010. Energetic costs of loss and regeneration of arms in stellate echinoderms. *Integrative and comparative biology* 50(4): 506-514.

Lawrence, J.M. 2013. *Starfish: Biology and Ecology of the Asteroidea*. Johns Hopkins University Press, Estados Unidos, 267 pp.

Le Hir, M. & C. Hily. 2005. Macrofaunal diversity and habitat structure in intertidal boulder fields. *Biodiversity & Conservation* 14: 233-250.

Liversage, K. & M.G. Chapman. 2018. Coastal ecological engineering and habitat restoration: incorporating biologically diverse boulder habitat. *Marine Ecology Progress Series* 593: 173-185.

Llodra, E.R. 2002. Fecundity and life-history strategies in marine invertebrates. *Advances in Marine Biology* 43: 87-170.

McClintock, J.B., Pearse, J.S. & I. Bosch. 1988. Population structure and energetics of the shallow-water Antarctic sea star *Odontaster validus* in contrasting habitats. *Marine biology* 99: 235-246.

McGuinness, K.A. & A.J. Underwood. 1986. Habitat structure and the nature of communities on intertidal boulders. *Journal of Experimental Marine Biology and Ecology* 104(1-3): 97-123.

Miloslavich, P., Cruz-Motta, J.J., Hernández, A., Herrera, C., Klein, E., Barros, F., Bigatti, G., Cárdenas, M., Carranza, A., Flores, A., Gil-Kodaka, P., Gobin, J., Gutiérrez, J., Krull, M., Lazarus, J.F., Londoño, E., Lotufo, T., Macaya, E., Mora, E., Navarrete, S., Palomo, G., Parragué, M., Pellizzari, F., Rocha, R., Romero, L., Retamales, R., Sepúlveda, R., Silva, M.C. & S. Soria. 2016. Benthic assemblages in South American intertidal rocky shores: biodiversity, services, and threats. In: R. Riosmena-Rodriguez (ed.), *Marine benthos: biology, ecosystems, functions and environmental impact*, pp. 83-137, Departamento de Biología Marina, Universidad Autónoma de Baja California Sur, Mexico.

Moran, A.L. 1999. Size and performance of juvenile marine invertebrates: potential contrasts between intertidal and subtidal benthic habitats. *American zoologist* 39(2): 304-312.

Nocera, A.C., Schloss, I.R. & G.N. Williams. 2024. Phytoplankton bloom detection and trends in satellite inherent optical properties over the last two decades in a heterogeneous Patagonian coastal system. *International Journal of Remote Sensing* 45(17): 5946-5977.

Palmer, S. 2010. The ecological role of a common seastar (*Patiriella* spp.) within intertidal cobble fields. *Master Thesis*, School of Biological Sciences, Victoria University of Wellington.

Pardal, A., Cordeiro, C.A., Ciotti, A.M., Jenkins, S.R., Gimenez, L., Burrows, M.T. & R.A. Christofoletti. 2021. Influence of environmental variables over multiple spatial scales on the population structure of a key marine invertebrate. *Marine Environmental Research* 170: 105410.

Pérez, A.F., Boy C.C., Calcagno J. & G.F. Malanga. 2015. Reproduction and oxidative metabolism in the brooding sea star *Anasterias antarctica* (Lütken, 1957). *Journal of Experimental Marine Biology and Ecology* 463: 150-157.

Pérez, A.F., Fraysse, C.P., Boy, C.C., Epherra, L. & J.A. Calcagno. 2017. Reproductive biology and energetics of the brooding sea star *Anasterias antarctica* (Echinodermata: Asteroidea) in the Beagle Channel, Tierra del Fuego, Argentina. *Revista de Biología Tropical* 65(1): 221-232.

Rechimont, M.E., Galván, D.E., Sueiro, M.C., Casas, G., Piriz, M.L., Diez, M.E., Primost, M., Zabala, M.S., Márquez, F., Brogger, M.I, Alfaya, J.E.F. & G. Bigatti. 2013. Benthic diversity and assemblage structure of a north Patagonian rocky shore: a monitoring legacy of the NaGISA project. *Journal of the Marine Biological Association of the United Kingdom* 93(8): 2049-2058.

Rivas, A.L., Dogliotti, A.I. & D.A. Gagliardini. 2006. Seasonal variability in satellite-measured surface chlorophyll in the Patagonian Shelf. *Continental Shelf Research* 26(6): 703-720.

Rivas, A.L. 2010. Spatial and temporal variability of satellite-derived sea surface temperature in the southwestern Atlantic Ocean. *Continental Shelf Research* 30(7): 752-760.

Rodríguez Ruíz, M.C. 2011. Efecto de la temperatura sobre el comportamiento y costo de incubación en *Anasterias antarctica* (Lutken, 1856) (Echinodermata: Asteroidea). Thesis, Universidad de Valparaíso.

Rumrill, S.S. 1989. Population size-structure, juvenile growth, and breeding periodicity of the sea star *Asterina miniata* in Barkley Sound, British Columbia. Marine ecology progress series. *Oldendorf* 56(1): 37-47.

Salvat, M.B. 1985. Biología de la reproducción de *Anasterias minuta* Perrier (Echinodermata, Asteroidea): Especie incubadora de las costas patagónicas. Thesis, Universidad de Buenos Aires.

Storero, L.P., Ocampo-Reinaldo, M. & R.A. González. 2010. Growth and life span of the small octopus *Octopus tehuelchus* in San Matías Gulf (Patagonia): three decades of study. *Marine Biology* 157: 555-564.

Storero, L.P., Ocampo Reinaldo, M., Narvarte, M.A. & O.O. Iribarne. 2020. Predation and interaction strength of octopuses and sea stars on different functional groups of the rocky intertidal shores of the Patagonian coast. *Aquatic Ecology* 54(1): 193-203.

Underwood, A.J. 1997. *Experiments in ecology: their logical design and interpretation using analysis of variance*. Cambridge University Press, Cambridge, 504pp.

Williams, G.N., Solís, M.E. & J.L. Esteves. 2018. Satellite-measured phytoplankton and environmental factors in North Patagonian Gulfs. In: M. Hoffmeyer, M. Sabatini, F. Brandini, D. Calliari, & N. Santinelli (eds.), *Plankton Ecology of the Southwestern Atlantic*, pp. 307-325, Springer, Cham.

Williams, G.N., Pisoni, J.P., Solís, M.E., Romero, M.A., Ocampo-Reinaldo, M., Svendsen, G.M., Curcio, N.S., Narvarte, M.A., Esteves, J.L. & R.A.C. González. 2021. Variability of phytoplankton biomass and environmental drivers in a semi-enclosed coastal ecosystem (San Matías Gulf, Patagonian Continental Shelf, Argentina) using ocean color remote sensing (MODIS) and oceanographic field data: implications for fishery resources. *Journal of Marine Systems* 224: 103615.

Wilson, M.A. 1987. Ecological dynamics on pebbles, cobbles, and boulders. *Palaios* 2(6): 594-599.

Zolotarev, P. 2002. Population density and size structure of sea stars on beds of Iceland scallop, *Chlamys islandica*, in the southeastern Barents Sea. *Sarsia* 87(1): 91-96.

Doi: 10.22179/REVMACN.27.859

Recibido: 29-VI-2024
Aceptado: 11-IV-2025