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Habitat preference of *Anemonia sulcata* in intertidal pools in the North-East Atlantic

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Resumen

Preferencia del hábitat de la *Anemonia sulcata* en charcos intermareales en el Atlántico noreste

El Los patrones de distribución y la abundancia de las especies bentónicas de los charcos del intermareal están controlados por factores tanto espaciales, como temporales. *Anemonia sulcata* es un cnidario común en estos hábitats, cuyo estilo de vida se encuentra influidos por las condiciones de luz, la oscilación de mareas y las corrientes marinas. Sin embargo, otros factores aún desconocidos podrían estar afectando a su comportamiento, asentamiento y distribución. Por ello, nuestro objetivo fue conocer el hábitat de preferencia de *A. sulcata* en los charcos del intermareal en la costa norte de Tenerife (Islas Canarias, España). Los resultados muestran que esta especie prefiere sustratos rocosos sobre los sustratos mixtos rocoso-arenosos, además de charcos con un alto número de grietas o cuevas. Dado que estudios previos han probado que *A. sulcata* es un bioindicador de la eutrofización antropogénica, proponemos usar estos resultados preliminares como base para un monitoreo anual, con el fin de detectar las alteraciones en los ecosistemas costeros, e investigar si la presencia de esta especie es natural o inducida por la actividad humana.

Palabras claves: Anémona, cnidario, intermareal, grietas, bioindicador.

Summary

Habitat preference of *Anemonia sulcata* in intertidal pools in the North-East Atlantic

The distribution patterns and abundance of benthic species in intertidal pools are controlled by spatial and temporal factors. *Anemonia sulcata* is a common cnidarian in these habitats and its lifestyle is influenced by light conditions, tidal oscillations and sea currents. However, other unknown factors could be affecting its settlement behaviour and distribution patterns. For these reasons, our aim was to know the habitat preference in intertidal pools of A. sulcata of the North coast of Tenerife (Canary Islands, Spain). Results show that *A. sulcata* prefers rocky substrates over substrates of sand and rock, and also pools with numerous caves. Since previous studies have proven *A. sulcata* to be a bioindicator of anthropogenic eutrophication, we propose to use our first results as a baseline to monitor annually these coastal ecosystems in order to detect alterations on it, and investigate whether they are natural or human induced.

Keyword: Anemone, cnidarian, intertidal pool, caves, bioindicator.

Introduction

Intertidal rocky shores are highly heterogeneous habitats with numerous marine species. The abundance and distribution patterns of the benthic species in these ecosystems are controlled by different spatial and temporal factors such as solar radiation, temperature, salinity, humidity, pH, tidal oscillation, wave exposure, type of substrate and availability of food, among others [8,10,17]. This intertidal zone is well characterized by the presence of three bands: supralittoral, mesolittoral and infralittoral. Each band can be identified regarding the species that are present in them,

Majorensis
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according to the local region of study [17]. For example, in the Canary Islands the supralittoral zone is characterized by the presence of the mollusc Littorina striata King, 1832 the mesollittoral zone by the dominance of the cirriped Chthamalus stellatus (Poli, 1791) and the infralittoral zone by lawns of red and brown algae and a dense bed of Cystoseira abies-marina that marks the end of the intertidal zone [3]. This important area, constantly washed by the tides, constitutes a unique territory in ecological, economic and social terms. For this reason, throughout history, different cultures have been established around these zones, taking advantage of the space and making use of its resources. In the last five years, more than 50% of the coastal zones worldwide have being occupied by humans, and this tendency continues to rise (https://data.worldbank.org)

Fig. 1. Location of the sampling areas around the intertidal rocky shore of Punta del Hidalgo, Tenerife.

Some species living in these habitats can be used as bio-indicators of environmental health or human activity, like the sea anemones group [2]. These kinds of animals are soft-bodied, weakly mobile carnivores that may also obtain part of their nutrition from intracellular algae. Physiologically speaking, they have a simple nervous system but the capacity of interaction in intra and interspecific ways. They are individually distinguished, with a pedal disc for attachment to the substrate, a single opening to the gut for ingestion and digestion, and a set of tentacles surrounding the mouth and the oral disc. They present both sexual and an asexual reproduction, and the capacity of social aggregation [7,8,16].
Many researchers have found that the principal spatial aggregation pattern of anemones is influenced by light conditions, tidal oscillations and sea currents [11,13]. Other relevant factors that could affect anemones attachment behaviour and distribution patterns are still unknown, like its habitat preference.
For these reasons, our aim was to know the habitat preference of *Anemonia sulcata*, so future studies could monitor this bioindicator presence in coastal zones. To our knowledge, there is no published research in which the habitat preference of *A. sulcata* is studied, that is why this study is of great relevance to know the settlement behaviour of *A. sulcata***.**

Materials and methods

Study area and in situ sampling
The survey was performed during May 2017 on the northern coast of Tenerife island, in the locality of Punta del Hidalgo (28 ° 34'5.17 "N 16 ° 19'35.45" W), one of the biggest intertidal rocky zones of the Canary Islands [3] (Fig 1).

A total of 30 tidal pools with similar dimensions (width, length and depth) and environmental conditions were selected around this coast on the fringe of the mesolittoral or middle-lower intertidal, 15 tide pools with *Anemonia sulcata* and other 15 tide pool without this species presence. In each pool, a count of the number of fissures or caves in the rocks (small = 0-11, medium = 11-23 and large > 23) was performed. In this work, we define fissures or caves as small holes or cracks in the volcanic rock, which are increased in size by the erosion of the tide (Fig 2). Also, species of invertebrates and fishes were counted, along with annotations of the coverage of dominant algae, the substrate type and the presence or absence of *A. sulcata* in each tidal pool.

Fig. 2. Fissures or caves with *A. sulcata* in a rock pool in the locality of study.

Data analysis
The PRIMER 6 & PERMANOVA + v.1.0.1. package was used to conduct all statistical procedures.
In order to evaluate the habitat characteristics preferred by this species a univariate analysis of variance was executed using ANOVA. Two different designs were used, the first one with an

Majorensis
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unique factor, Anemonia, with two levels of variation: presence vs absence. The second ANOVA design had the factors Fissure, with three levels: high, medium and low abundance; and Substrate, with two levels: rocky and rock + sand. Abundance data were transformed to the square root, and then Euclidian distances were applied [1]. Finally, error box graphs with the typical deviation were made to represent the results. A significant level of 95% was established (p-values < 0.05)**.**

Results

Tide pools were dominated by algae species of Cystoseira (X coverage = 39.5 %) in combination of species such as Padina pavonica (X coverage = 7.2 %), coralline algae (X coverage = 6 %) and other turf algae, that we define as the red and brown algae with cespite growth (X coverage = 24.5 %). Tidal pools with presence of *Anemonia sulcata* had similar characteristics as tidal pools where *A. sulcata* was absent (Table 1). The total count of species in the surveyed tidal pools was 6 species of fishes, 5 crustaceans, 3 cnidarians, 2 molluscs, 2 polychaetes and 3 echinoderms. The only apparent differences between pools with *A. sulcata* and pools without this cnidarian were the Cystoseira coverage and the diversity of fishes (Table 1).

ANOVA analysis were performed, and showed significant differences for the number of fissures and the presence or absence of *A. sulcata* (Table 2).

Tidal Pool	**Dimension (m^3)**	**Algae Coverage (%)**	**Cystoseira (%)**	**Invertebrates (Nº species)**	**Fishes (Nº species)**
With *A. sulcata*	1.75 ± 1.14	74.27 ± 22.8	30.67 ± 28.65	1.87 ± 1.55	2 ± 1.13
Without *A. sulcata*	4.44 ± 1.43	88.27 ± 24.1	19.33 ± 34.11	1.93 ± 1.43	0.93 ± 0.7

Table 1. Average characteristic with standard deviation (±) of tidal pool sampled with *A. sulcata* and without this species: dimension (m3), algae coverage (%) and number of invertebrates and fishes species.

Source of variation	**df**	**SS**	**MS**	**Pseudo-F**	**P-value**
Anemone	1	1.483	1.483	4.722	0.038*
Residual	28	8.793	0.314		
Total	29	10.276			

*p< 0.05

Table 2. Results of ANOVA analysis for the number of fissures due to factor Anemone (the present or absent of *A. sulcata*) in each tidal pool.

Source of variation	**df**	**SS**	**MS**	**Pseudo-F**	**P-value**
Fissures (Fis)	3	2.041	0.680	5.879	0.012*
Substrate (Su)	1	1.249	1.249	10.795	0.009*
FisxSu	2	0.193	0.097	0.84	0.469
Residual	8	0.926	0.116		
Total	14	3.510			

*p< 0.05

Table 3. Results of ANOVA analysis for the number of *A. sulcata* due to factors Fissures and Substrate in each tidal pool.

Majorensis
ISSN 1697-5529

Discussion

Results show that the abundance of *Anemonia sulcata* is higher in tidal pools with rocky substrate and lower in pools with both sand and rock (Fig. 4). This difference may be due to the fact that the anemone pedal disc is adapted to attach to firm substrates. *A. sulcata* also seems to have preference for pools with a medium and high number of caves, and it could be due to the more protective environment and better ecological condition that these caves or fissures provide.

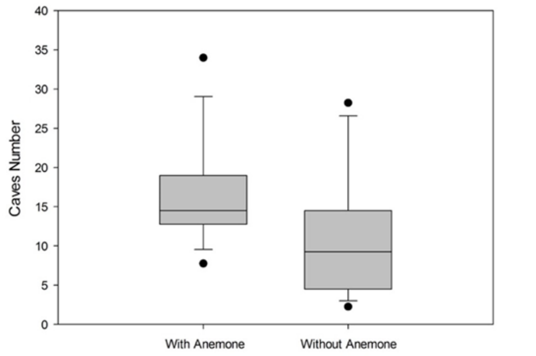

Fig. 3. Error box graph showing the differences in the abundances of fissures and the relationship with the presence or absence of ***A. sulcata*** in the intertidal pools.

These results expand previous knowledge about *A. sulcata* settlement behaviour. Fernández-Betelu [5] indicated that anemones remain in the same place even in non-optimal conditions, such as when the pools are completely dried at low tide [5]. When the rocky pools had a good number of caves a high number of individuals of anemones were found very close together, products of the predominance of asexual reproduction [4]. Besides, the preference for a high number of caves could be explained because it could help *A. sulcata* to live in better environmental conditions. It seems that they show preference for feeding on crustacean remains rather than fish [14], which are typically found hidden in these caves. Also, these anemones are sensitive to light and show some differences in sensitivity at different wavelengths according to the absorption capacity of the tissues involved in photoreception [15]. So, they might select its settlement placement also regarding light conditions. his kind of information will be useful for future environmental studies. *A. sulcata* is a bioindicator of pollution, and its presence denotes areas that are being affected by sewage pipes and recreational human activities (Lozano et al. in print). Their zooxanthellae are able to fix environmental molecular nitrogen, so it is expected to find more abundantly this species in coastal areas near human activities. Being an anemone without the need to feed on prey to grow and develop because of its zooxanthellae, it will thrive in a nitrogen eutrophicated medium [9].

It seems that *A. sulcata* preferred habitats are tidal pools that present caves, where they grow up feeding in a carnivorous way in balance with theirs zooxanthellae photosynthetic activity. This behaviour provides anemones with a yellow colour in their tentacles. However, when the anemones live well outside caves, they are unprotected and have more incidence of the sun, so they present different coloration [18,19]. This is because they have more symbiotic zooxanthellae that provide them with a darker colour. These little symbionts need nutrients that eutrophication can provide [12].

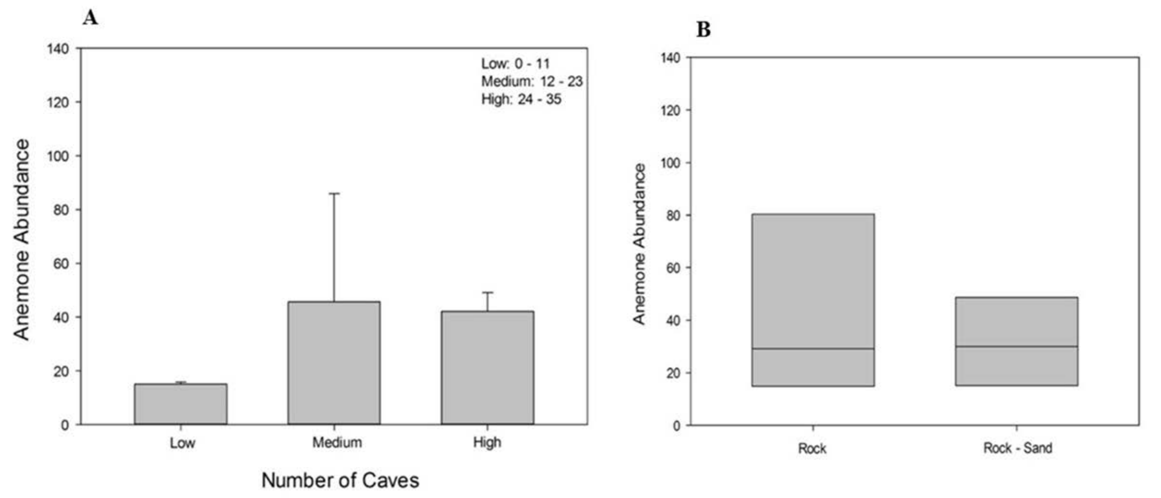

Fig. 4. Error box graph showing the differences in the abundances of *Anemonia sulcata* due to (A) the number of fissures and (B) the type of substrate, in the intertidal pools.

Majorensis
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Our survey was performed in an area of great faunistic diversity and homogeneous geology [3] but where the human activity increase each year. Hence, our findings could serve for future impact studies. We propose to use these first results as a baseline to monitor annually these coastal ecosystems, thus one could be able to detect alterations on them, and investigate whether they are natural or human induced.

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Competing interests

The authors declare that they have no conflict of interest.

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