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Original Article

Spatial distribution of *Echinolitorina peruviana* (Lamarck, 1882) for intertidal rocky shore in Antofagasta (23° S, Chile).

Distribuição espacial de *Echinolitorina peruviana* (Lamarck, 1882) para costa rochosa entremarés em Antofagasta (23 ° S, Chile)

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Abstract

The intertidal rocky shores in continental Chile have high species diversity mainly in northern Chile (18-27° S), and one of the most widespread species is the gastropod *Echinolittorina peruviana* (Lamarck, 1822). The aim of the present study is do a first characterization of spatial distribution of *E. peruviana* in along rocky shore in Antofagasta town in northern Chile. Individuals were counted in nine different sites that also were determined their spectral properties using remote sensing techniques (LANDSAT ETM+). The results revealed that sites without marked human intervention have more abundant in comparison to sites located in the town, also in all studied sites was found an aggregated pattern, and in six of these sites were found a negative binomial distribution. The low density related to sites with human intervention is supported when spectral properties for sites were included. These results would agree with other similar results for rocky shore in northern and southern Chile.

Keywords: *Echinolittorina peruviana*, rocky shore, intertidal environment, spectral properties, negative binomial distribution.

Resumo

As costas rochosas entremarés no Chile continental apresentam alta diversidade de espécies, principalmente no norte do país (18-27 ° S), e uma das espécies mais difundidas é o gastrópode *Echinolittorina peruviana* (Lamarck, 1822). O objetivo do presente estudo é fazer uma primeira caracterização da distribuição espacial de *E. peruviana* no costão rochoso da cidade de Antofagasta no norte do Chile. Os indivíduos foram contados em nove locais diferentes onde também foram determinadas suas propriedades espectrais usando técnicas de sensoriamento remoto (LANDSAT ETM +). Os resultados revelaram que os locais sem intervenção humana marcada apresentam maior abundância em comparação aos locais localizados no município. Também em todos os locais estudados foi encontrado um padrão agregado, sendo que em seis desses locais foi encontrada uma distribuição binomial negativa. A baixa densidade relacionada a sites com intervenção humana é suportada quando as propriedades espectrais para sites foram incluídas. Esses resultados concordariam com outros resultados semelhantes para costões rochosos no norte e no sul do Chile.

Palavras-chave: *Echinolittorina peruviana*, costão rochoso, ambiente intertidal, propriedades espectrais, distribuição binomial negativa.

1. Introduction

The rocky intertidal environments in Chilean coast is characterized by the high species diversity, including molluscs, that has a marked geographic distribution pattern (Santelices, 1992; Broitman et al., 2001; Lee et al., 2008). The rocky shore is markedly exposed to waves among a wide latitudinal gradient in Chile (17-41°S), whereas in extreme southern Chile the coast is characterized by the presence of islands and inner seas with different patterns in species reported (Santelices, 1992; Camus et al., 2013; Velásquez et al., 2016).

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The literature about intertidal invertebrates revealed that these species can have a gregarious behaviour, as protection against drying during low tide, or for efficient use of food resources (Rojas et al., 2000), many of these species inhabits in rocky cracks or under rocks, or macroalgae basal disks. (Santelices, 1980; Camus and Andrade, 1999; Cerda and Castilla, 2001). Also, the distribution patterns can be affected due the topography of rocky shores, involving recruitment patterns of small gastropods (Underwood, 2004). Considering these antecedents, there are interspecific competence between intertidal gastropods and monoplacophora due shelter availabilities (Aguilera and Navarrete, 2011; 2012), that can generate that some species can have diurnal or nocturnal activity (Aguilera and Navarrete, 2011).

The northern Chile (18-27° S), is a zone with high species diversity due high productivity of these coasts (Santelices, 1992, Camus and Andrade, 1999), that would have complex trophic interactions between involved species (Camus and Andrade, 1999), one of the most widespread species is the gastropod *Echinolittorina peruviana* that inhabits among rocky shores along Chilean territory (Santelices, 1992; Lee et al., 2008), specifically in upper levels (Castillo and Brown, 2010) and southern Perú (Paredes, 1974; Tejada-Perez et al., 2018). The aim of the present study is do a first descriptive analysis of *E. peruviana* adults (10-15 mm total length) in different rocky intertidal environments in Antofagasta town, northern Chile, with the aim of determine the presence of defined spatial distribution patterns.

2. Material and Methods

Field works and study site: the ten sites are located in the coastal town of Antofagasta, northern Chile, six sites are located within town, whereas as external group, was included a four sites in a rocky shore located at 20 km of the town, with low or practically null human intervention (Figure 1, Table 1). The studied sites were visited in summer 2019, for each site, was thrown out random (Ríos and Arancibia, 2018; Ríos and Carreño, 2020), 10 * 10 cm quadrants (n = 40 for each site), considering the relative small size of considered species (Underwood, 2004; Underwood and Chapman, 2005; Ahmad et al., 2011; Ríos and Carreño, 2020).

Spectral properties: Satellite data was obtained from LANDSAT/ETM+ image obtained dated from January 2018 (Table 1) provided by the Land Processes Distributed Active Archive Center (LP DAAC), U.S. Geological Survey (http://LPDAAC.usgs.gov). The bands of visible, near, and mid-infrarred were calibrated radiometrically to spectral irradiance and then to reflectance with atmospheric correction being applied (Table 1).

Data analysis: in a first step, it was compared the *E. peruviana* abundances for each site, and for two groups of sites, homocedasticity and normality were determined for data, and due the absence of both conditions it was done a non-parametric tests (Zar, 1999) using software R (R Development Core Team, 2009), Wilcoxon for compare sites with presence or absence of human intervention, and a Kruskall-Wallis for comparison among sites using the PGIRMESS R package (Giraoudoux et al., 2018). For these analyses one site that has *E. peruviana* absence has not considered.

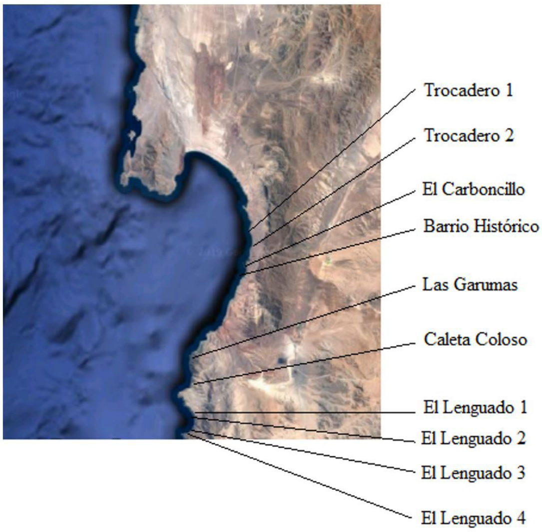

Figure 1. Map of sites included in the present study. [Source, Google Earth: https://www.google.cl/maps/place/Antofagasta,+Regi%C3%B3n+de+Antofagasta/@-23.6283354,-70.6850999,90966m/data=!3m1!1e3!4m5!3m4!1s0x96a58a1999656469:0x9fbe15f44d1e6f96!8m2!3d-23.6509279!4d-70.3975022].

To each specie counting data, was obtained in first instance a variance mean ratio, first for determine if the specie has random if the value is 1, uniform if the value is lower than 1, or aggregated distribution, if the value is upper than 1, (Brower et al., 1998; Zar, 1999; Fernandes et al., 2003; De Los Ríos Escalante, 2017; De Los Ríos Escalante and Mansilla, 2017; Ríos and Arancibia, 2018). Once determined the spatial pattern, random, uniform or aggregated, it determined if the species have Poisson, binomial or negative binomial distribution respectively, the analysis was done manually using Excel software and literature descriptions (Zar, 1999; Fernandes et al., 2003; De Los Ríos Escalante, 2017; De Los Ríos Escalante and Mansilla, 2017; Ríos and Arancibia, 2018). For these analyses one site that has *E. peruviana* absence has not considered.

Finally, for spectral properties data and *E. peruviana* abundance mean, a principal component analysis was done using the Factoextra R package (Kassambara and Mundt, 2017) with the aim of determine potential grouping patterns in studied sites.

3. Results

The obtained results revealed that the sites without human intervention have marked high abundances in comparison to sites located in the town, and the results of spatial distribution, revealed the presence of aggregated pattern for eight sites, and one site with uniform distribution (Barrio Histórico) (Table 1). The results revealed that seven sites has negative binomial distribution, and only two sites (Caleta Coloso and El Lenguado 1) have not negative binomial distribution (Figure 2).

Table 1. Geographical location, abundance (ind/quadrant; 1 quadrant = 10 x 10 cm), (mean, variance, and mean variance ratio), and reflectance (B1, B2, B3, B4, B5, B6, B7 bands ETM+) values for studied sites.

Site	El Lenguado 4	El Lenguado 3	El Lenguado 2	El Lenguado 1	Coloso	Las Garumas	Barrio Historico	El Carboncillo	Trocadero 2	Trocadero 1
Geographical location	23°46'25.2"S 70°28'38.9" W	23°46'25.5"S 70°28'31.4"W	23°46'21.7"S 70°28'26.1"W	23°46'09.5"S 70°28'22.2"W	23°45'35.6"S 70°27'41.9"W	23°43'38.2"S 70°26'16.5"W	23°38'31.4"S 70°23'49.5"W	23°38'20.7"S 70°23'57.2"W	23°34'57.2"S 70°23'40.5"W	23°34'48.4"S 70°23'36.4"W
Abundances	7.475	7.975	10.800	2.550	5.375	0.000	3.075	2.725	11.050	2.525
Variance	2.77	24.98	31.20	31.95	40.96	0.000	2.61	3.97	3.74	18.56
Variance / Mean ratio	1.08	2.31	3.91	4.27	7.62	No data	0.96	1.29	1.48	1.68
B1	0.155	0.155	0.155	0.155	0.147	0.154	0.159	0.143	0.189	0.143
B2	0.137	0.137	0.137	0.137	0.125	0.130	0.138	0.121	0.170	0.119
B3	0.123	0.123	0.123	0.123	0.092	0.108	0.118	0.092	0.154	0.081
B4	0.124	0.124	0.124	0.124	0.067	0.080	0.079	0.064	0.123	0.062
B5	0.147	0.147	0.147	0.147	0.047	0.047	0.052	0.038	0.111	0.041
B6	0.162	0.162	0.162	0.162	0.026	0.023	0.035	0.023	0.052	0.022
B7	0.127	0.127	0.127	0.127	0.017	0.022	0.023	0.016	0.033	0.014

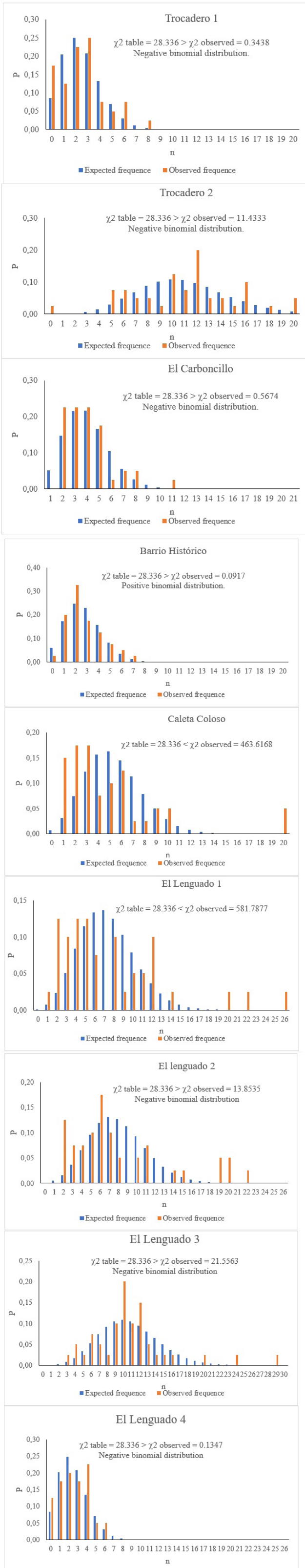

Figure 2. Graphs of distributional patterns for *E. peruviana* included in the present study.

The results of correlation matrix only show significant correlations between abundances with B2, B3, B4 and B5 reflectances, B1 with B3, B4 with B2, B4 with B3, B5 with B3, B5 with B4, B6 with B4, B6 with B5, B7 with B4, B7 with B5, and B7 with B6 (Table 2). The results of PCA revealed that abundances are the main factor is abundances (Table 3), and for axis 1 the main factors are all reflectance values, whereas for the axis 2 the main factor is the abundance of *E. peruviana* (Figure 3). Finally, the PCA results revealed the existence of two main groups, the first group corresponded to sites with high reflectance and low abundances (El Lenguado 1, El Lenguado 2, El Lenguado 3), and one site with relative low abundance (El Lenguado 4)(Figure 3). The second group joined sites with low reflectance, corresponded to sites with marked human intervention and low abundances (Trocadero 2, Carboncillo, Barrio Histórico, Las Garumas, Coloso), and one site with high abundance (Trocadero 1)(Figure 3).

The heat map obtained from PCA, revealed two main groups, one that has sites Trocadero 1, Coloso (with human intervention), Lenguado 1, Lenguado 2 and Lenguado 3 (these three without human intervention). The second group has one main sub-group with human intervention (Trocadero 2, Carboncillo, Barrio Histórico), one without human intervention (El Lenguado 4), and finally one with human intervention (Las Garumas)(Figure 4).

4. Discussion

The results of abundances, would indicate that many of the studied sites with high *E. peruviana* abundances corresponded to low or null human intervention, that is associated to low reflectance (El Lenguado 1, El Lenguado 2, El Lenguado 3 and El Lenguado 4) whereas sites located in the town at north, have high reflectance and low *E. peruviana* abundances (Trocadero 1, Trocadero 2, El Carboncillo, Barrio Histórico), finally an intermediate situation would occur in sites with human intervention with high reflectance and low *E. peruviana* abundance (Coloso) and absence (Las Garumas). The marked differences between sites with different kind of human intervention, in studied sites probably is due to the presence of *Pyura praeputialis* that is a kind of key species that regulate the species composition in rocky shores in northern Chile (Castilla et al., 2004), in this context, in the present study the human altered sites have not *P. praeputialis*. Also, the low abundances in sites with marked human intervention agree with results for central Chilean rocky shore (Durán and Castilla, 1989) that is similar to the observations for European rocky shore (Stevčić et al., 2018) and Arabian Sea in India (Pandey et al., 2018; Savurirajan et al., 2018)

The results about negative binomial distribution agree with similar observations for inland water benthic invertebrates (Gray, 2005; De Los Ríos Escalante, 2017; De Los Ríos Escalante and Mansilla, 2017; Ríos and Arancibia, 2018). Also, in recent studies, it has described the use of negative binomial distribution for intertidal environments, specifically in middle intertidal zone, in rocky shores without seaweeds, similar to sites in the present study (Philippe et al., 2016; Checon et al.,

Table 2. Correlation matrix for variables included in the present study, "p" values lower than 0.05 denotes significant associations.

	B1	B2	B3	B4	B5	B6	B7
Abundance	0.5734	0.6479	0.6461	0.6764	0.6454	0.4966	0.4636
	P = 0.0830	P = 0.0427	P = 0.0435	P = 0.0317	P = 0.0438	P = 0.1442	P = 0.1771
B1		0.9872	0.8957	0.5607	0.3583	0.0899	0.0588
		P < 0.0001	P = 0.0004	P = 0.0917	P = 0.3093	P = 0.8048	P = 0.8716
B2			0.9470	0.6733	0.4918	0.2373	0.2051
			P < 0.0001	P = 0.0328	P = 0.1487	P = 0.5090	P = 0.5696
B3				0.8379	0.6877	0.4863	0.4627
				P = 0.0024	P = 0.0279	P = 0.1540	P = 0.1780
B4					0.9694	0.8702	0.8570
					P < 0.0001	P = 0.0010	P = 0.0015
B5						0.9582	0.9475
						P < 0.0001	P < 0.0001
B6							0.9985
							P = 0.0021

Table 3. Eigenvalue for considered sites in the present study.

Eigenvalue	Variance percent	Cumulative variance	Percentage
Abun	14.0000	99.0000	99.9420
B1	0.0077	0.0534	99.9954
B2	0.0006	0.0044	99.9998
B3	< 0.0001	0.0001	100.0000
B4	< 0.0001	< 0.0001	100.0000
B5	< 0.0001	< 0.0001	100.0000
B6	< 0.0001	< 0.0001	100.0000
B7	< 0.0001	< 0.0001	100.0000

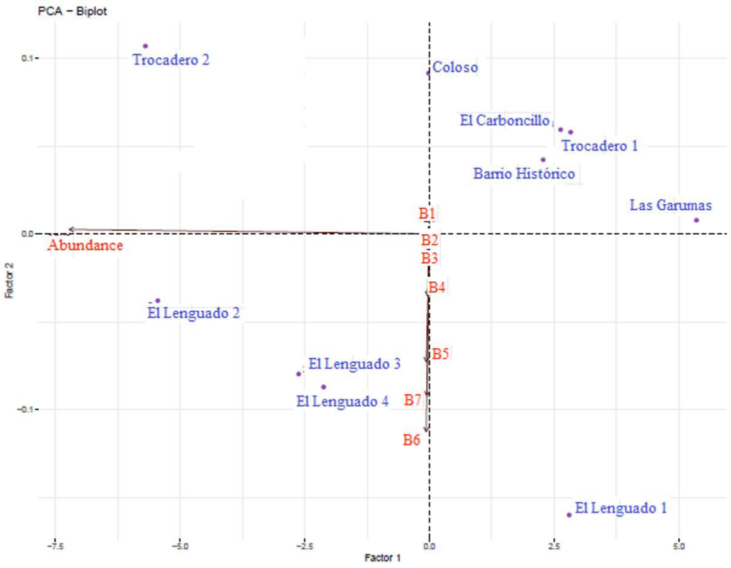

Figure 3. PCA results for spectral properties and *E. peruviana* abundances in sites included in the present study.

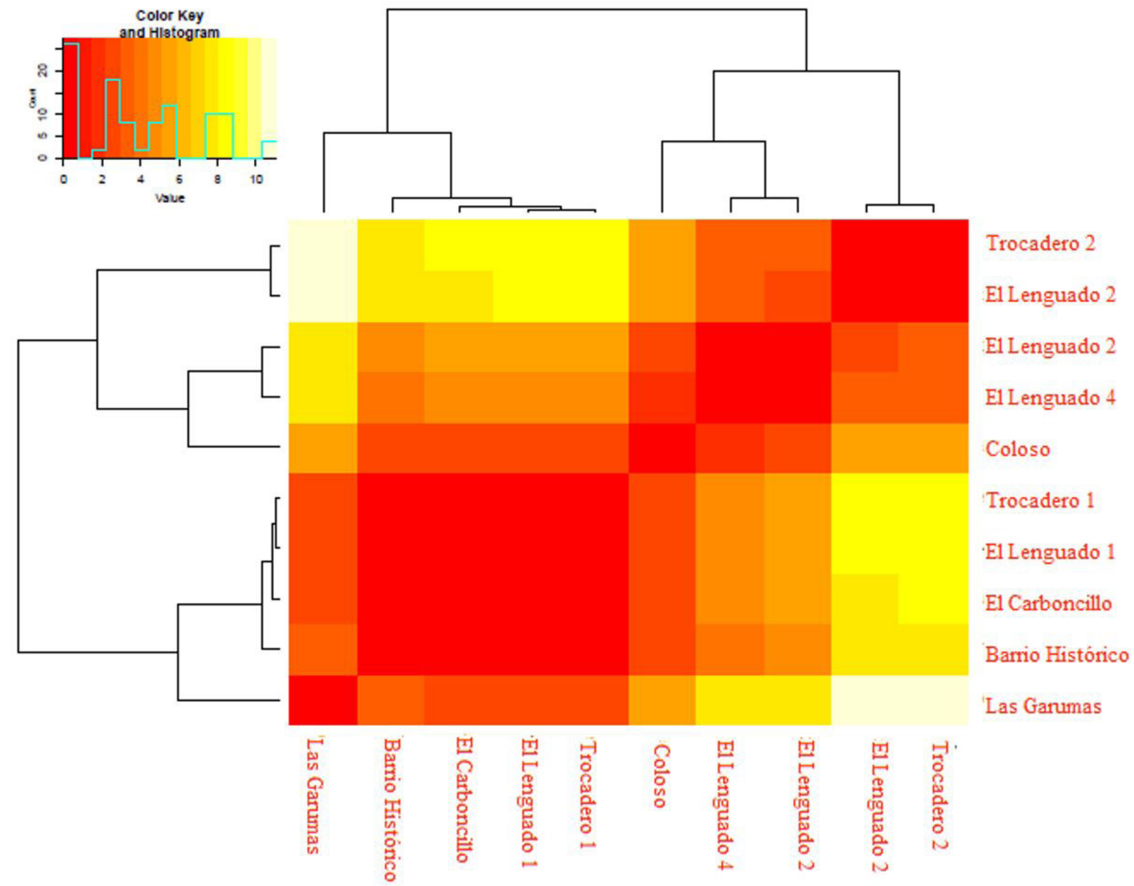

Figure 4. Heat map of PCA for spectral properties and *E. peruviana* abundances in sites included in the present study.

2017; Sibaja-Cordero, 2018; Ríos and Arancibia, 2018). In this context Rojas et al. (2000) studied the aggregated pattern of intertidal gastropod *Nodolittorina peruviana*, nevertheless they did not focus in interpretative equations for explain its absolute abundance, but they remark the role of aggregation behaviour for avoid dehydration during low tide. Similar description was done in the first studies on intertidal decapods (Bahamonde and López, 1969). The literature for other similar ecosystems proposed as survival strategy the joining of groups for avoid dehydration due temperature increase at low tide (Atta et al., 2014; Shanks et al., 2014; Mortensen and Dunphy, 2016). About the absence of negative binomial distribution observed in sites such as Caleta Coloso and El Lenguado 1 would be probably to interspecific behaviour mediated probably by topographic differences (Underwood, 2004), that would provide shelters for optimizate the use of trophic resources (Hidalgo et al., 2008; Aguilera and Navarrete, 2011, 2012).

Other important factor that would explain differences in aggregated pattern probably would be the insolation exposure that would generate dehydration stress, this condition was studied for other gastropods of the Littorinidae family (Erlandsson et al., 1999; Lauzon-Guay and Scheibling, 2009; Miller and Denny, 2011; Rickards and Boulding, 2015), including *E. peruviana* (Muñoz et al., 2008). Also, the topographical differences in rocky shores, can generate sites with different insolation or wave gradient exposure that would regulate the aggregated pattern of the individuals (Lauzon-Guay and Scheibling, 2009). If it integrated these antecedents, the study site is characterized by irregularities in topography in rocky shores, and wave exposure that would generate a complex scenario that would have consequences in aggregation patterns in intertidal marine invertebrates (Guiller, 1959; Pacheco and Castilla, 2000).

As conclusion it suggests do more ecological studies considering the importance of the marine invertebrates in these ecosystems as important preys for littoral fishes and/or marine birds, that would understand the ecological community structure and process in Chilean rocky shores.

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References

AGUILERA, M.A. and NAVARRETE, S.A., 2011. Distribution and activity patterns in an intertidal grazer assemblage: influence of temporal and spatial organization on interspecific associations. *Marine Ecology Progress Series*, vol. 431, pp. 119-136. http://dx.doi.org/10.3354/meps09100.

AGUILERA, M.A. and NAVARRETE, S.A., 2012. Interspecific competition for shelters in territorial and gregarious intertidal grazers: consequences for individual behaviour. *PLoS One*, vol. 7, no. 9, pp. e46205. http://dx.doi.org/10.1371/journal.pone.0046205. PMid:23049980.

AHMAD, O., FANG, T.P. and YAHYA, K., 2011. Distribution of intertidal organisms in the shores of Teluk Aling, Pulau Pinang, Malaysia. *Publications of the Seto Marine Biological Laboratory*, vol. 41, pp. 51-61. http://dx.doi.org/10.5134/159483.

ATTA, M.H., MUJAHID, A., and CHAGHTAI, F., 2014. Population density of *Cellana* and *Acmea* (Mollusca: Gastropoda) at various tidal zones on the rocky coast of Manora, Karachi, Pakistan. *International Journal of Biological Research*, vol. 2, no. 2, pp. 143-146.

BAHAMONDE, N. and LÓPEZ, M.T., 1969. *Cyclograpsus cinereus Dana, en biocenosis supramareales de Chile. Boletin Mensual del Museo Nacional de Historia Natural.* Santiago: Museo Nacional de Historia Natural.

BROITMAN, B.R., NAVARRETE, S.A., SMITH, F. and GAINES, S.D., 2001. Geographic variation of southeastern Pacific intertidal communities. *Marine Ecology Progress Series*, vol. 224, pp. 21-34. http://dx.doi.org/10.3354/meps224021.

BROWER, J.E., ZAR, J.H. and VON ENDE, C.N., 1998. *Field and laboratory methods for general ecology*. 4th ed. Dubuque: WCB McGraw Hill.

CAMUS, P.A. and ANDRADE, Y.N., 1999. Diversidad de comunidades intermareales rocosas del norte de Chile y el efecto potencial de la surgencia costera. *Revista Chilena de Historia Natural*, vol. 72, no. 3, pp. 389-410.

CAMUS, P.A., ARANCIBIA, P.A. and AVILA-THIEME, M.I., 2013. A trophic characterization of intertidal consummers on Chilean rocky shores. *Revista de Biología Marina y Oceanografía*, vol. 48, no. 3, pp. 431-450. http://dx.doi.org/10.4067/S0718-19572013000300003.

CASTILLA, J.C., LAGOS, N.A. and CERDA, M., 2004. Marine ecosystem engineering by the alien ascidian *Pyura praeputialis* on a mid-intertidal rocky shore. *Marine Ecology Progress Series*, vol. 268, pp. 119-130. http://dx.doi.org/10.3354/meps268119.

CASTILLO, V.M. and BROWN, D.I., 2010. *Echinolittorina peruviana* (Lamarck, 1822): antecedentes de la especie. *Amici Molluscarum*, vol. 18, pp. 39-42.

CERDA, M.A. and CASTILLA, J.C., 2001. Diversidad y biomasa de macroinvertebrados en matrices intermareales del tunicado *Pyura praeputialis* (Heller, 1878) en la bahía de Antofagasta, Chile. *Revista Chilena de Historia Natural*, vol. 74, no. 4, pp. 841-853. http://dx.doi.org/10.4067/S0716-078X2001000400011.

CHECON, H.H., CORTE, G.N., SILVA, C.F., SCHAEFFER-NOVELLI, Y. and AMARAL, A.C.Z., 2017. Mangrove vegetation decreases density but does not affect species richness and trophic structure of intertidal polychaete assemblages. *Hydrobiologia*, vol. 795, no. 1, pp. 169-179. http://dx.doi.org/10.1007/s10750-017-3128-0.

DE LOS RÍOS ESCALANTE, P. and MANSILLA, A., 2017. Spatial patterns of *Pisidium chilense* (Mollusca Bivalvia) and *Hyalella patagonica* (Crustacea, Amphipoda) in an unpolluted stream in Navarino Island (54° S; Cape Horn Biosphere Reserve). *Journal of King Saud University - Sciences*, vol. 29, no. 1, pp. 28-31. http://dx.doi.org/10.1016/j.jksus.2016.07.003.

DE LOS RÍOS ESCALANTE, P., 2017. Non randomness in spatial distribution in two inland water species malacostracans. *Journal of King Saud University - Sciences*, vol. 29, no. 2, pp. 260-262. http://dx.doi.org/10.1016/j.jksus.2016.12.002.

DE LOS RÍOS ESCALANTE, P. and ARANCIBIA, E. I., 2018. Niche sharing and spatial distribution in intertidal decapods on the rocky shores of Easter island. *Crustaceana*, vol. 91, no. 11, pp. 1319-1325. http://dx.doi.org/10.1163/15685403-00003831.

DE LOS RÍOS ESCALANTE, P. and CARREÑO, E., 2020. Spatial distribution in marine invertebrates in rocky shore of Araucania region (38°S, Chile). *Brazilian Journal of Biology = Revista Brasileira de Biologia*, vol. 80, no. 2, pp. 362-367. http://dx.doi.org/10.1590/1519-6984.208863. PMid:31389484.

DURAN, L.R. and CASTILLA, J.C., 1989. Variation and persistence of the middle rocky intertidal community of central Chile, with and without human harvesting. *Marine Biology*, vol. 103, pp. 555-562. http://dx.doi.org/10.1007/BF00399588.

ERLANDSSON, J., KOSTYLEV, V. and ROLÁN-ALVAREZ, E., 1999. Mate search and aggregation behaviour in the Galician hybrid zone of *Littorina saxatilis. Journal of Evolutionary Biology*, vol. 12, no. 5, pp. 891-896. http://dx.doi.org/10.1046/j.1420-9101.1999.00087.x.

FERNANDES, M.G., BUSOLI, A.C. and BARBOSA, J.C., 2003. Distribucao espacial de *Alabama argillacea* (Hubner) (Lepidoptera: Noctuidae) em algodoeiro. *Neotropical Entomology*, vol. 32, no. 1, pp. 107-115. http://dx.doi.org/10.1590/S1519-566X2003000100016.

GIRAOUDOUX, P., ANTONIETTI, J.-P., BEALE, C., PLEYDELL, D. and TREGLIA, M., 2018 [viewed 2 May 2020]. *Package: "pgirmess"* [online]. Available from https://cran.r-project.org/web/packages/pgirmess/pgirmess.pdf

GRAY, B.R., 2005. Selecting a distributional assumption for modeling relative densities of benthic macroinvertebrates. *Ecological Modelling*, vol. 185, no. 1, pp. 1-12. http://dx.doi.org/10.1016/j.ecolmodel.2004.11.006.

GUILLER, E.R., 1959. Intertidal belt-forming species on the rocky coast of northern Chile. *Papers and Proceedings of the Royal Society of Tasmania*, vol. 93, pp. 33-58.

HIDALGO, F.J., FIRSTATER, F.N., FANJUL, E., BAZTERRICA, M.C., LOMOVASKY, B.J., TARAZONA, J. and IRIBARNE, O.O., 2008. Grazing effects of periwinkle *Echinolittorina peruviana* at a central Peruvian high rocky intertidal. *Helgoland Marine Research*, vol. 62, pp. 73-83. http://dx.doi.org/10.1007/s10152-007-0086-3.

KASSAMBARA, A. and MUNDT, F., 2017. [viewed 2 May 2020]. *Package "factoextra"* [online]. Available from https://cran.r-project.org/web/packages/factoextra/factoextra.pdf

LAUZON-GUAY, J.-S. and SCHEIBLING, R.E., 2009. Food dependent movement of periwinkles (*Littorina littorea*) associated with feeding fronts. *Journal of Shellfish Research*, vol. 28, no. 3, pp. 581-587. http://dx.doi.org/10.2983/035.028.0322.

LEE, M.R., CASTILLA, J.C., FERNÁNDEZ, M., CLARKE, M., GONZÁLEZ, C., HERMOSILLA, C., PRADO, L., ROZBACZYLO, N. and VALDOVINOS, C., 2008. Free-living benthic marine invertebrates in Chile. *Revista Chilena de Historia Natural*, vol. 81, no. 1, pp. 51-67. http://dx.doi.org/10.4067/S0716-078X2008000100005.

MILLER, L.P. and DENNY, M.W., 2011. Importance of behaviour and morphological traits for controlling body temperature in littorinid snails. *The Biological Bulletin*, vol. 220, no. 3, pp. 209-223. http://dx.doi.org/10.1086/BBLv220n3p209. PMid:21712229.

MORTENSEN, B.J.D. and DUNPHY, B.J., 2016. Effect of tidal regime on the thermal tolerance of the marine gastropod *Lunella smaragda* (Gmelin, 1791). *Journal of Thermal Biology*, vol. 60, pp. 186-194. http://dx.doi.org/10.1016/j.jtherbio.2016.07.009. PMid:27503732.

MUÑOZ, J.L.P., CAMUS, P.A., LABRA, F.A., FINKE, G.R. and BOZINOVIC, F., 2008. Thermal constraints on daily patterns of aggregation and density along an intertidal gradient in the periwinkle *Echinolittorina peruviana. Journal of Thermal Biology*, vol. 33, no. 3, pp. 149-156. http://dx.doi.org/10.1016/j.jtherbio.2007.10.002.

PACHECO, C.J. and CASTILLA, J.C., 2000. Ecología trófica de los ostreros *Haematopus palliatus pitanay* (Murphy 1925) and *Haematopus ater* (Vieillot et Oudart 1825) en mantos del tunicado *Pyura praeputialis* (Heller 1878) en la Bahía de Antofagasta, Chile. *Revista Chilena de Historia Natural*, vol. 73, no. 3, pp. 533-541. http://dx.doi.org/10.4067/S0716-078X2000000300017.

PANDEY, V., THIRUCHITRAMBALAM, G. and SATYAM, K., 2018. Habitat heterogeneity determines structural properties of intertidal gastropod assemblages in a pristine tropical island ecosystem. *Indian Journal of Geo-Marine Sciences*, vol. 47, no. 4, pp. 846-853.

PAREDES, C., 1974. El modelo de zonación en la orilla rocosa del departamento de Lima. *Revista Peruana de Biología*, vol. 1, pp. 168-191.

PHILIPPE, A.S., PINAUD, D., CAYATTE, M.-L., GOULEVANT, C., LACHAUSSÉE, N., PINEAU, P., KARPYTCHEV, M. and BOCHER, P., 2016. Influence of environmental gradients on the distribution of benthic resources available for shorebirds on intertidal mudflats of Yves Bay, France. *Estuarine, Coastal and Shelf Science*, vol. 174, pp. 71-81. http://dx.doi.org/10.1016/j.ecss.2016.03.013.

R DEVELOPMENT CORE TEAM, 2009. *R: A language and environment for statistical computing*. Version 2.1 [software]. Vienna: R Foundation for Statistical Computing.

RICKARDS, K.J.C. and BOULDING, E.G., 2015. Effects of temperature and humidity on activity and microhabitat selection by *Littorina subrotundata. Marine Ecology Progress Series*, vol. 537, pp. 163-173. http://dx.doi.org/10.3354/meps11427.

ROJAS, J. M., FARIÑA, J. M., SOTO, R.E. and BOZINOVIC, F., 2000. Variabilidad geográfica en la tolerancia térmica y economía hídrica del gastrópodo intermareal Nodilittorina peruviana (Gastropoda: Littorinidae, Lamarck, 1822). *Revista de Chilena de Historia Natural*, vol. 73, no. 3, pp. 543-552. http://dx.doi.org/10.4067/S0716-078X2000000300018.

SANTELICES, B., 1980. Quantitative sampling of intertidal communities in central Chile. *Archivos de Biologia y Medicina Experimentales*, vol. 13, no. 4, pp. 413-424. PMid:7185325.

SANTELICES, B., 1992. Algas marinas de Chile. Distribución, ecología, utilización y diversidad. Santiago: Ediciones Pontificia Universidad Católica de Chile.

SAVURIRAJAN, M., EQUBAL, J., LAKRA, R.K., SATYAM, K. and THIRUCHITRAMBALAM, G., 2018. Species diversity and distribution of seagrasses from the South Andaman, Andaman and Nicobar Islands, India. *Botanica Marina*, vol. 61, no. 3, pp. 225-234. http://dx.doi.org/10.1515/bot-2017-0109.

SHANKS, A.L., WALSER, A. and SHANKS, L., 2014. Population structure, northern range limit, and recruitment variation in the intertidal limpet *Lottia scabra. Marine Biology*, vol. 161, no. 5, pp. 1073-1086. http://dx.doi.org/10.1007/s00227-014-2400-3.

SIBAJA-CORDERO, J.A., 2018. Spatial distribution of macrofauna within a sandy beach on the Caribbean coast of Costa Rica. *Revista de Biología Tropical*, vol. 66, no. 1-1, pp. S176-S186.

STEVČIĆ, C., PEREZ-MIGUEL, M., DRAKE, P., TOVAR-SANCHEZ, A. and CUESTA, J.A., 2018. Macroinvertebrate communities on rocky shores: impact due to human visitors. *Estuarine, Coastal and Shelf Science*, vol. 211, pp. 127-136. http://dx.doi.org/10.1016/j.ecss.2017.11.026.

TEJADA-PÉREZ, C.A., VILLASANTE, F., LUQUE-FERNÁNDEZ, C. and TEJADA-BEGAZO, C.L., 2018. Mollusk richness and vertical distribution along the rocky shore of Islay, Arequipa, Southern Peru. *Journal of Marine and Coastal Sciences*, vol. 10, no. 1, pp. 47-66. http://dx.doi.org/10.15359/revmar10-1.4.

UNDERWOOD, A.J. and CHAPMAN, M.G., 2005. Design and analysis in benthic surveys in environmental sampling. In: A. Eleftheriou and A. Mcintyre, eds. *Methods for the study of marine benthos.* Oxford: Blackwell Science, pp. 1-42.

UNDERWOOD, A.J., 2004. Landing on one's foot: small-scale topographic features of habitat and the dispersion of juvenile intertidal gastropods. *Marine Ecology Progress Series*, vol. 268, pp. 173-182. http://dx.doi.org/10.3354/meps268173.

VELÁSQUEZ, C., JARAMILLO, E., CAMUS, P.A., MANZANO, M. and SÁNCHEZ, R., 2016. Biota del intermareal rocoso expuesto de la Isla Grande de Chiloé, Archipiélago de Chiloé, Chile: patrones de diversidad e implicancias ecológicas y biogeográficas. *Revista de Biología Marina y Oceanografía*, vol. 51, no. 1, pp. 33-50. http://dx.doi.org/10.4067/S0718-19572016000100004.

ZAR, J., 1999. *Biostatistical analysis.* New Jersey: Prentice Hall