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Habitat characterization of intertidal populations of the purple sea urchin, *Paracentrotus lividus* (Lamark, 1816), in north Portugal

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Introduction:
Examining patterns of distribution of intertidal species is key to understand the dynamics of this highly variable habitat and has been a goal of ecological studies for decades. However, sea urchin populations are still poorly known, particularly the Atlantic populations , which may be the target of management plans due to their ecological and economic relevance. This study aims to increase the understanding of the habitat preference of *P. lividus* on intertidal rocky shores, an habitat which suffers strong human impacts and should be the object of regulations, including the implementation of MPAs.

Fig 1. Specimen of *Paracentrotus lividus*

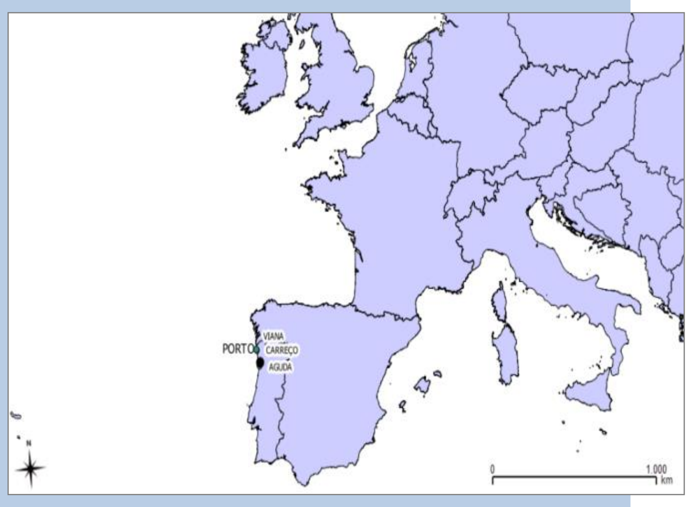

Fig 2. Geographic location of the sampled rocky shore

Fig 3. Geographic location of the sampled rock pools

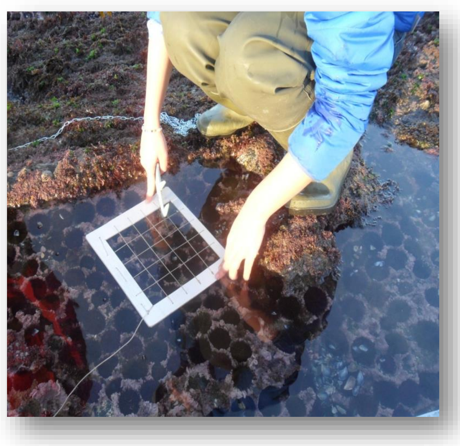

Fig 4. Sampling of sea urchin density and size.

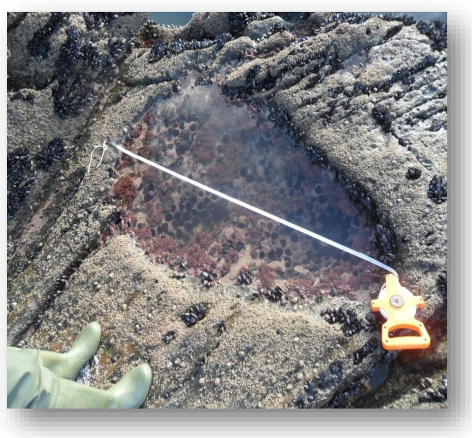

Fig 5.Sampling of the area of the pool .

Fig 6. Sampling of pool volume

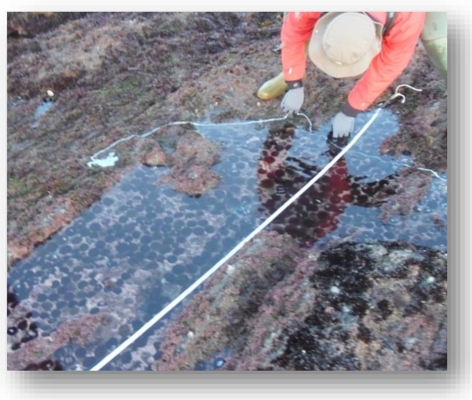

Fig 6. Sampling of rugosity index.

Methodology:

Experimental design:
Intensive sampling (spring tides in Feb 2013) in one representative beach (Praia Norte, Viana do Castelo):45 pools, 3 replicates.

Sampling:(unit: quadrate 0.3 x 0.3 m)

- **Sea urchin density** (total and by size classes) Fig 4.
  Class **1** <30mm; 30mm ≤ Class **2** <50mm; 50mm ≤ Class **3** ≥50 mm
- **Substrate cover** :
  - % of *Sabellaria alveolata* and blue mussel *Mytilus galloprovincialis* (possible competitors for space)
  - % of medium size stones, sand and bare rock (features possibly relative to urchin mobility)
- **Latitude and longitude** (GPS)
- **Area of the surface.** Fig 5.
- **Maximum depth**
- **Volume** (difference of salinity method). Fig 6. $V = v*Si / (Si - Sf)$
- **Tidal height** (time uncovered + observed tides)
- **Hydrodynamics index** (plaster cubes dissolution method)
- **Topographic complexity** by **rugosity index** inside the pool (chain method). Fig 7.

Statistical analysis:
1º Transformation and standardization of variables
2º Correlation analysis to avoid redundancy
3º Classification **CLUSTER analysis** to look for natural groupings of pools.
4º Ordination **PCA** analysis to identify the most influencing variables for each group
5º One-way **ANOVA** to test for significant differences in abundances (total and by size-class) of each cluster group

Results:

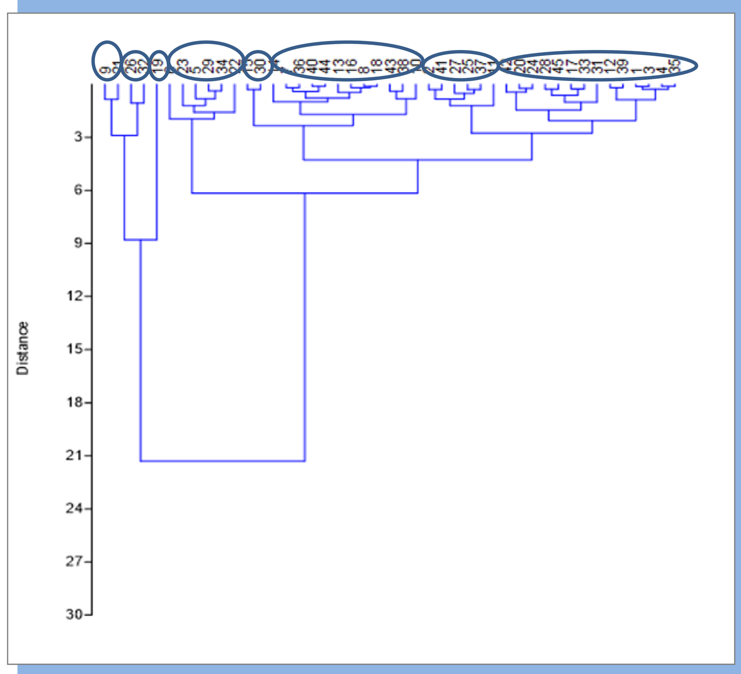

Fig 8. Dendrogram resulting from Cluster analysis using Ward´s algorithm. Cophenetic correlation index =0,85

CLUSTER	VOLUME	HEIGHT	DEPTH	TOPO	AREA	HIDRO	SABEL. COVER	MUSSEL COVER	STONES COVER	BARE ROCK	TOTAL URCHIN	CL I	CL II	CL III
I	499,13	0,93	22,50	0,75	2,17	0,58	33,50	0,00	0,00	0,00	9,17	0,67	8,33	0,17
II	694,43	1,46	35,25	0,61	1,14	0,50	14,50	0,83	6,50	1,50	7,33	1,00	5,50	0,83
III	1326,50	0,81	37,00	0,48	2,99	0,55	4,00	0,00	0,00	0,00	12,00	0,67	9,33	2,00
IV	174,20	1,40	26,33	0,63	0,91	0,54	11,44	0,67	4,00	1,83	10,89	1,56	8,17	1,17
V	18,36	1,85	9,50	0,65	0,20	0,51	8,50	0,00	2,67	5,67	13,00	4,17	8,83	0,00
VI	24,63	1,62	15,49	0,92	0,68	0,90	12,38	0,59	1,80	2,09	10,48	3,08	7,49	0,80
VII	28,91	1,06	18,25	0,48	0,24	0,62	8,08	2,67	0,00	0,33	7,83	1,22	6,50	0,78
VIII	48,48	1,33	13,54	0,73	0,63	0,57	5,62	1,26	2,76	0,93	10,76	3,15	7,67	0,33

Fig 9. Average values for each variable in each group of pools identified by the cluster analysis. TOPO= Rugosity index; HIDRO= hydrodynamics index; Cl= size class

Class I: higher abundances related to small volume and area and higher height of the pool

Class I: lower abundances related to higher volume, area and depth, and smaller height

Class III: lower abundances related to higher rugosity index

CLUSTER	*S. Alveolata* COVER	STONES COVER	BARE ROCK COVER	MUSSEL COVER	AREA	VOLUME	HEIGHT	RUGOSITY INDEX
I	x				x			
II	x	x	x					
IV	x	x	x					
V	x		x					
VI	x	x			x	x	x	
VII	x			x	x			x
VIII	x	x		x	x			

Fig 10. Variables presenting the major loadings (>0.4) in the Principal Components of each cluster. Note that cluster III is not part in this analysis, because it is formed by only one pool.

The only variables not presenting significant loadings for any of the Principal Components of the cluster groups: **Hydrodynamics index and Maximum depth**

One-way ANOVA showed highly significant differences between the abundances of each cluster ($p=2.065E^{-11}$)***
Tukey´s pair wise comparison showed that no significant difference was found only between Class II and Total number abundances.

	TOTAL NUMBER	CLASS I	CLASS II
CLASS I	**0.00017****		
CLASS II	0.7604	**0.00017****	
CLASSIII	**0.00017****	**0.02932***	**0.00017****

Conclusions:
(i) Present results confirm a great variability at the smaller spatial scales (cm);
(ii) Urchins of different size classes show different habitat preferences;
(iii) Some of the variables considered as potential responsible for the distribution patterns were not relevant for the studied scale (hydrodynamics index and maximum depth), while others gave a considerable contribution to the observed variability.
- Substrate covers contribution could indicate competition for space and/or relevance of mobility processes.
- Not significance of hydrodynamics variability could indicate sea urchins' adaptation to this habitat trait.

Future research:
- Manipulative experiments on the impact of the most relevant habitat traits.
- Analysis of processes affecting distribution over different spatial scales

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