

# How and to what degree are intertidal assemblages affected by physical complexity in natural and artificial habitats?

## *A quantitative assessment at multiple spatial scales in marine intertidal systems*

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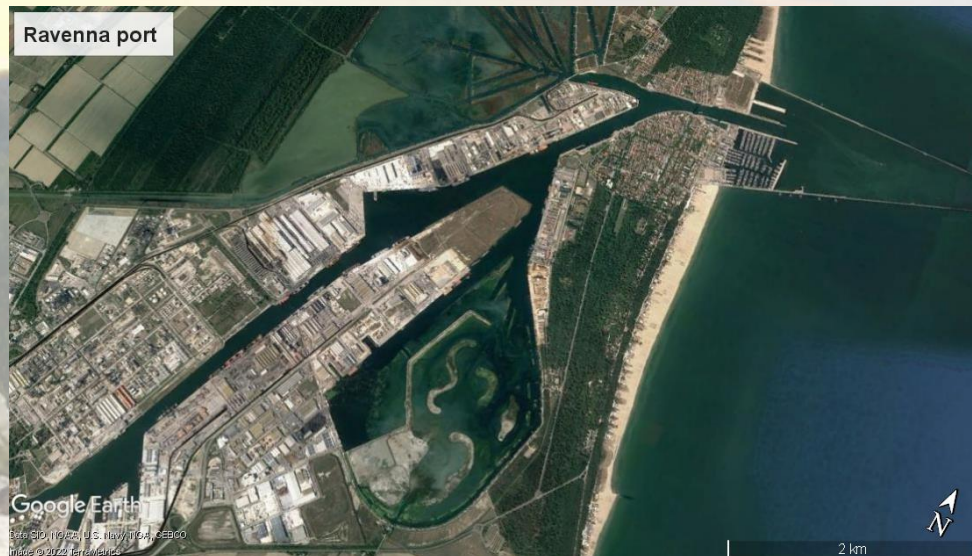
2 : Chioggia Hydrobiological Station “Umberto D’Ancona”, Department of Biology, **University of Padova**, Uo CoNISMa, Chioggia, Italy

3 : Department for the Cultural Heritage and Centro Interdipartimentale di Ricerca per le Scienze Ambientali (CIRSA), **University of Bologna**, Ravenna, Italy

\* : [ferrante.grasselli2@unibo.it](mailto:ferrante.grasselli2@unibo.it)



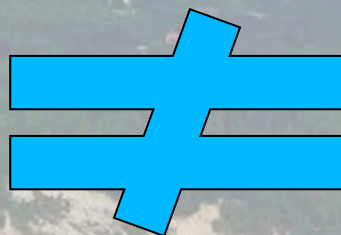
# Ocean sprawl



Images from:  
Google Earth  
<https://genova.repubblica.it/>  
<https://www.spiaggecesenatico.it/>



# Natural rocky reefs vs. Artificial structure



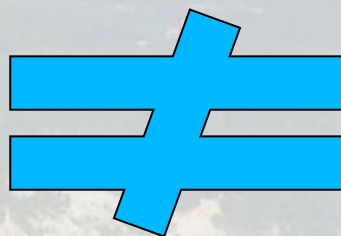


# Physical structure improvement



Images from:  
<https://www.reefdesignlab.com/>  
<https://econcretetech.com/>  
<http://urbanmarineecology.org/>







# Is the lack of physical structure a scientific evidence?



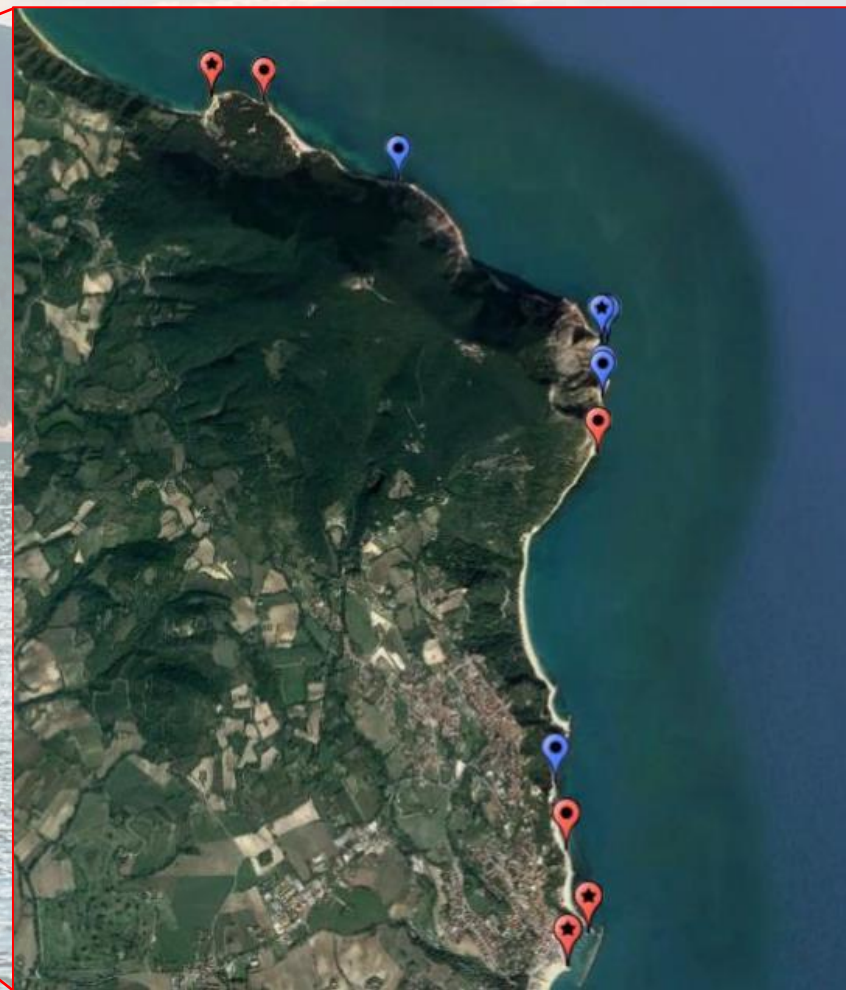
Test how and to what degree physical structure differs between a variety of artificial and natural habitats.

Test if eventual differences are consistent across spatial scales.

Test how and to what degree intertidal biota is affected by physical structure in natural and artificial habitats.



# Study area





# Sampling design

Boulder field (Nat-Irr)



Cliff (Nat-Reg)



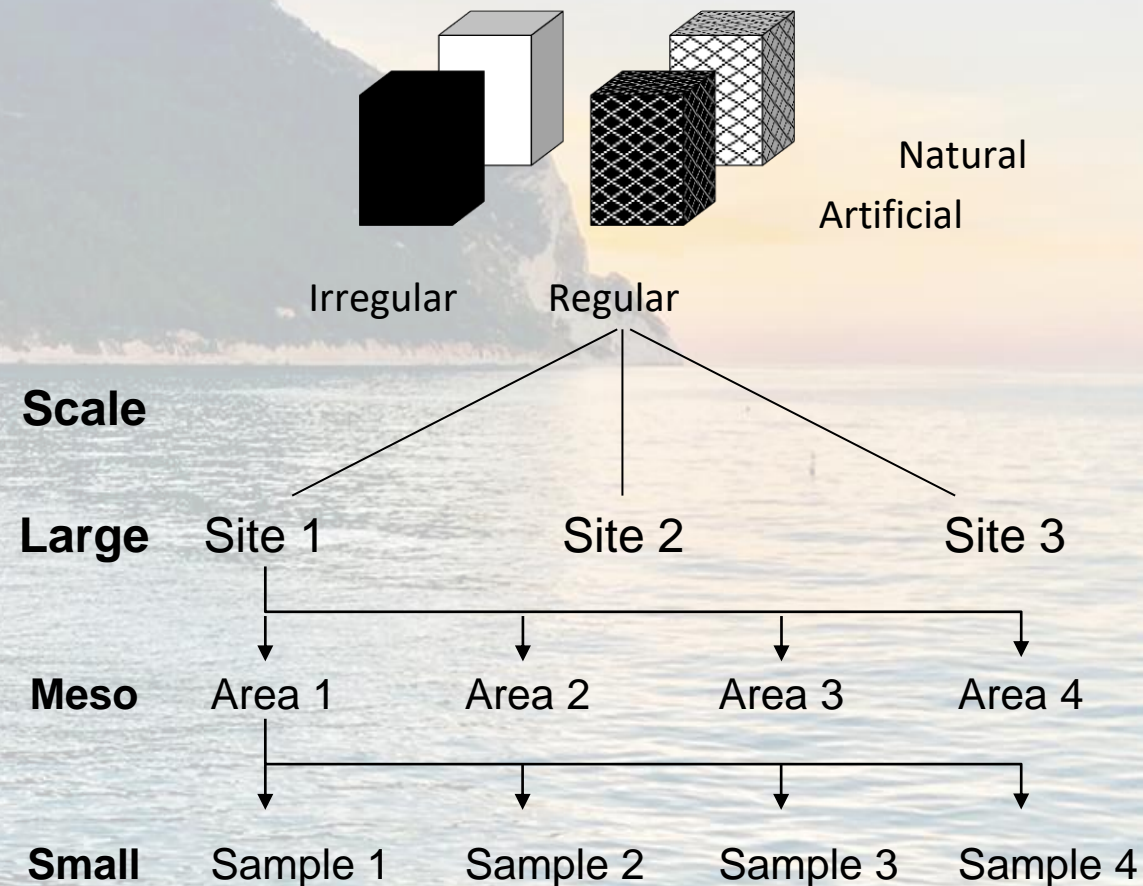
Breakwater (Art-Irr)



Seawall (Art-Reg)



## 4-way ANOVA design





# Sampling procedure

Boulder field (Nat-Irr)



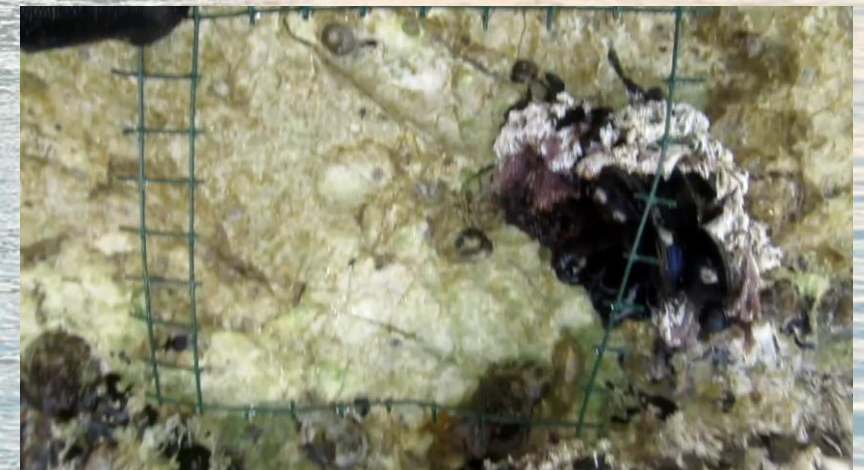
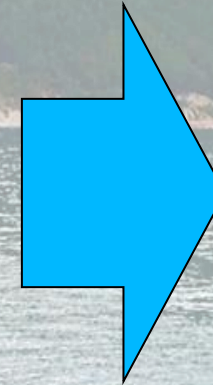
Cliff (Nat-Reg)



Breakwater (Art-Irr)



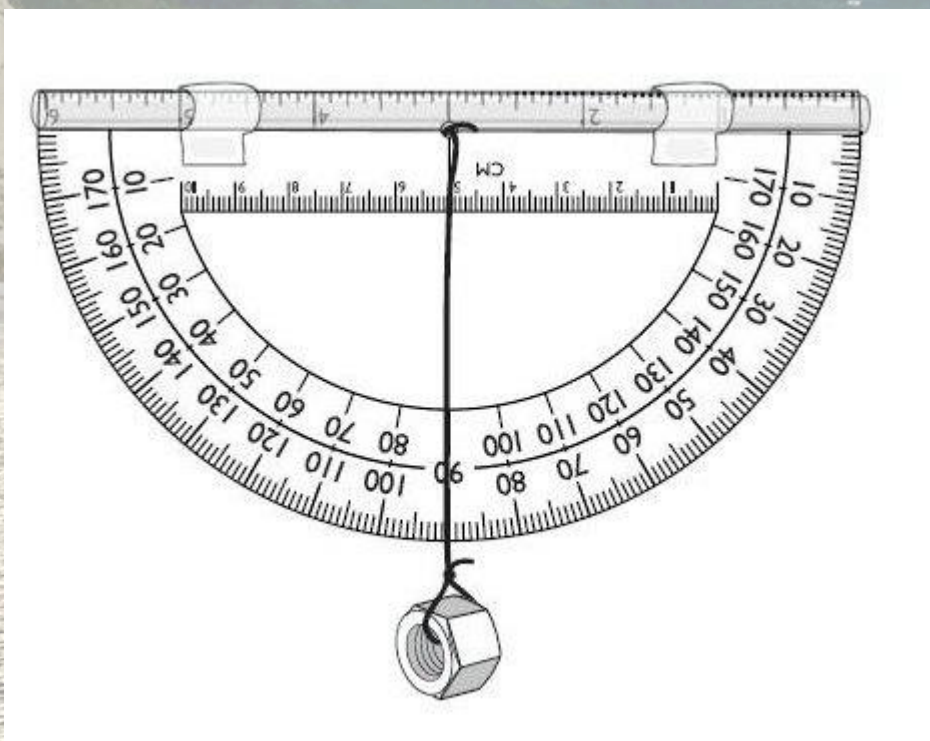
Seawall (Art-Reg)





# Assessment of physical structure

Inclination



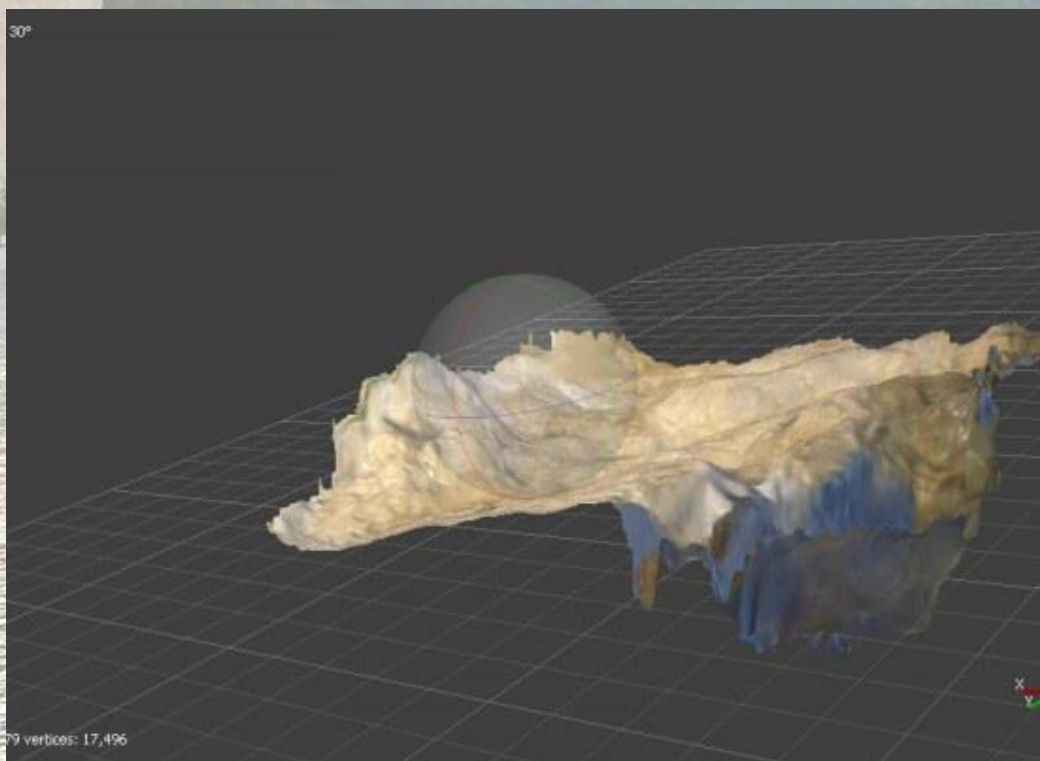
Exposure (Aspect)





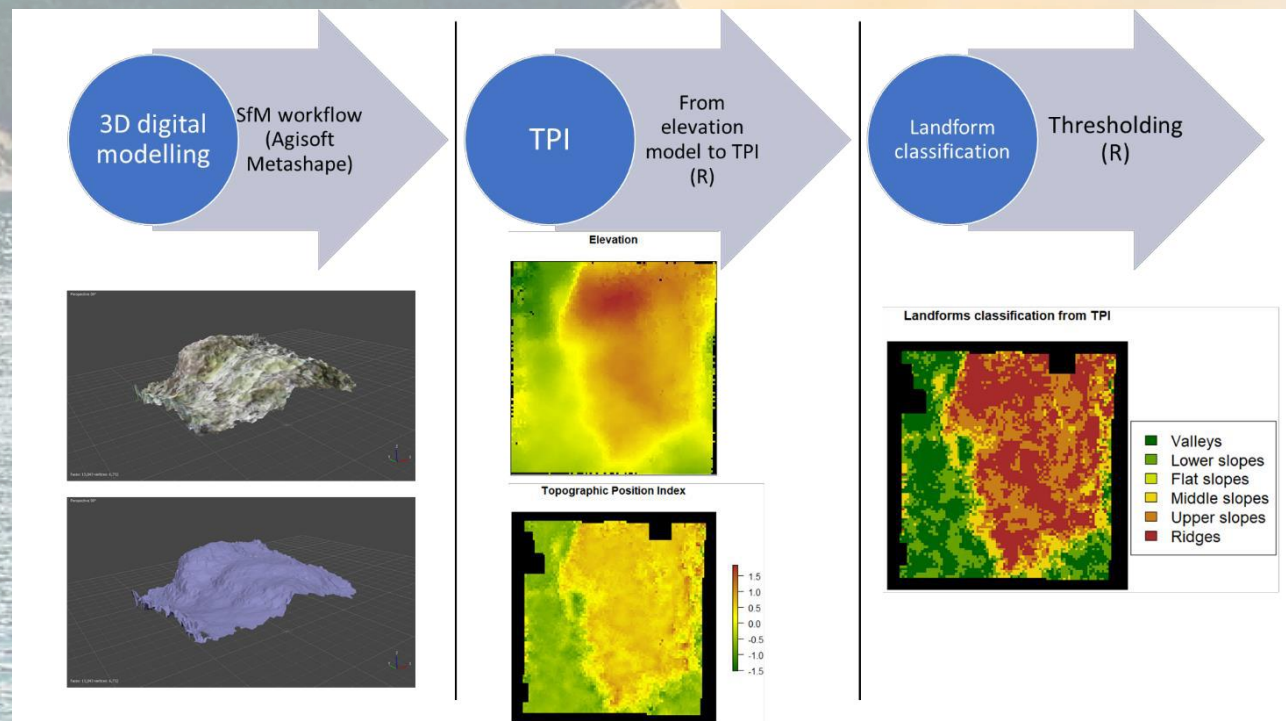
# Assessment of physical structure

## Surface roughness



Software: AGISOFT METASHAPE V. 1.6

## Abundance and Diversity of surface microelements (Shannon H' Entropy)



Grasselli & Airoidi (2021) for details



# Benthic community assessment



Photoquad  
Software

*Ulva* spp.  
*Scytosiphon* sp.  
*Cystoseira* sp.  
Leafy Bangiaceae  
Filamentous Rhodomelaceae  
Articulate Coralline Algae (ACA hereafter)  
Biofilm  
Green Filamentous Algae (GFA)  
Turf

*Mytilus galloprovincialis*  
Ostreidae (a mix of *Ostrea edulis* and  
*Magallana gigas*)  
Barnacles

*Monodonta mutabilis*  
*Patella* spp.

Response datasets:

1. Benthic coverage

2. Cover of algae

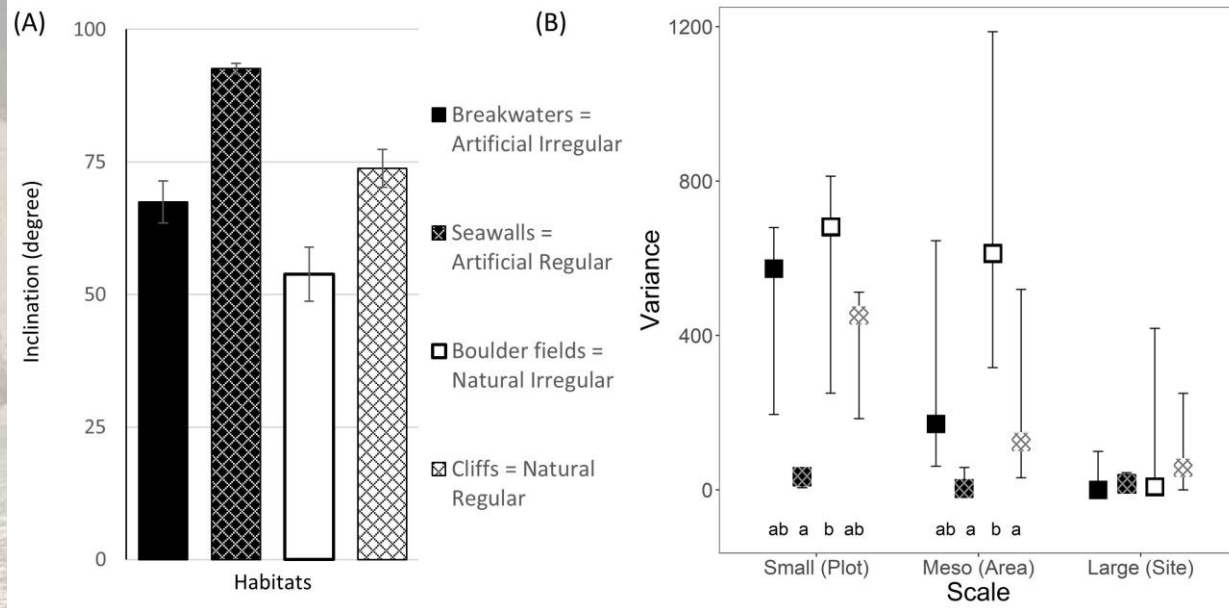
3. Cover of sessile invertebrates

4. Multivariate community structure



# Analysis of physical structure

## Inclination

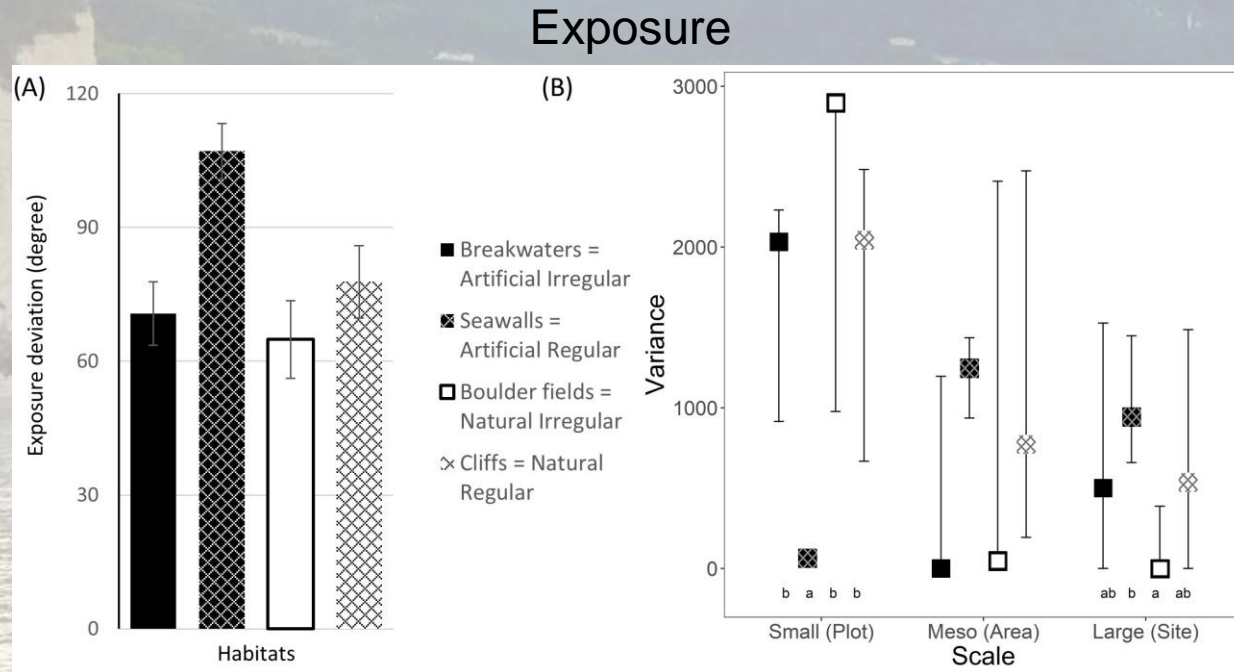


1. Artificial habitats were steeper than natural habitats, and seawalls were more homogeneous



# Analysis of physical structure

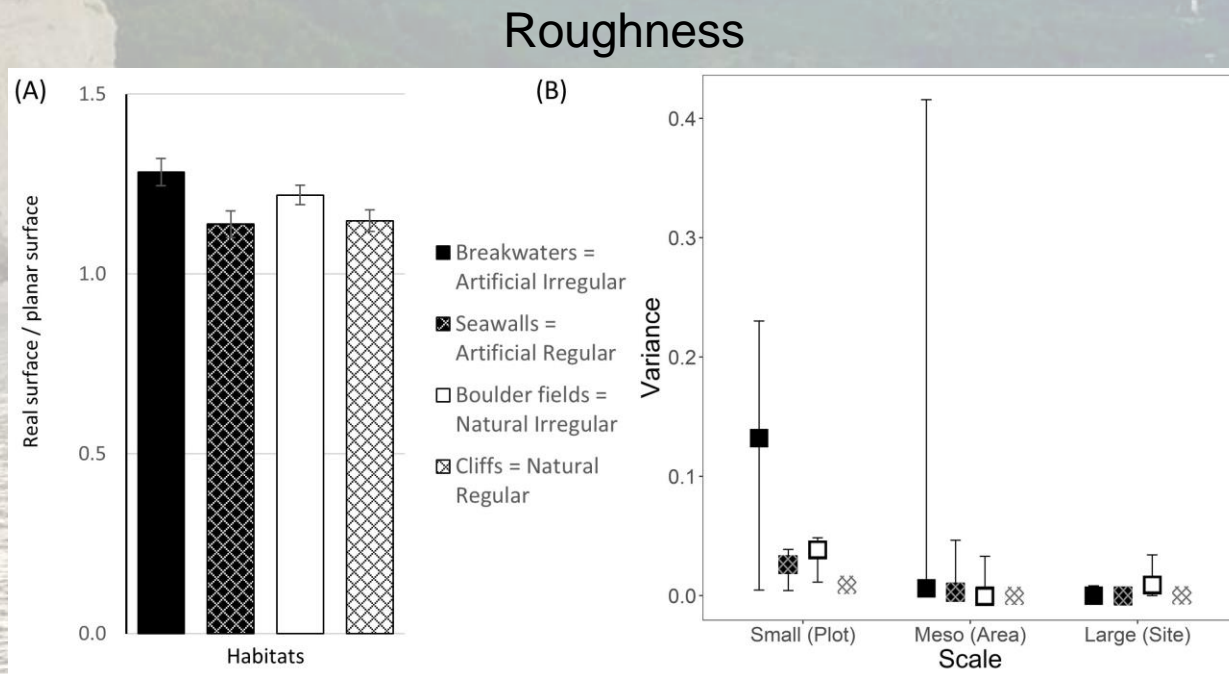
1. Artificial habitats were steeper than natural habitats, and seawalls were more homogeneous
2. Substrates reported statistically similar exposures, but seawalls reported a different spatial pattern





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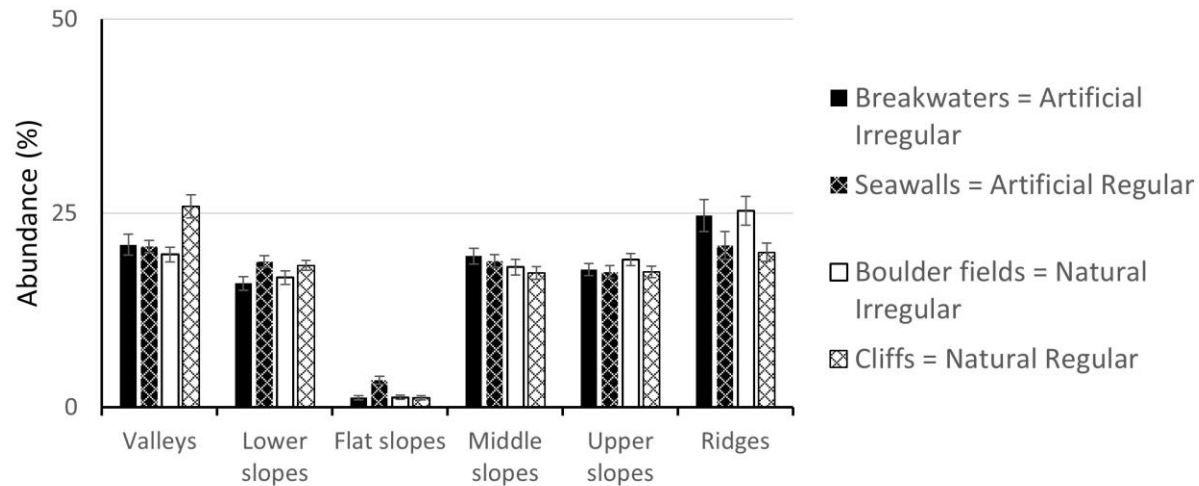
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3. Irregular substrates were rougher than regular substrates





# Analysis of physical structure

Abundance of morphological elements

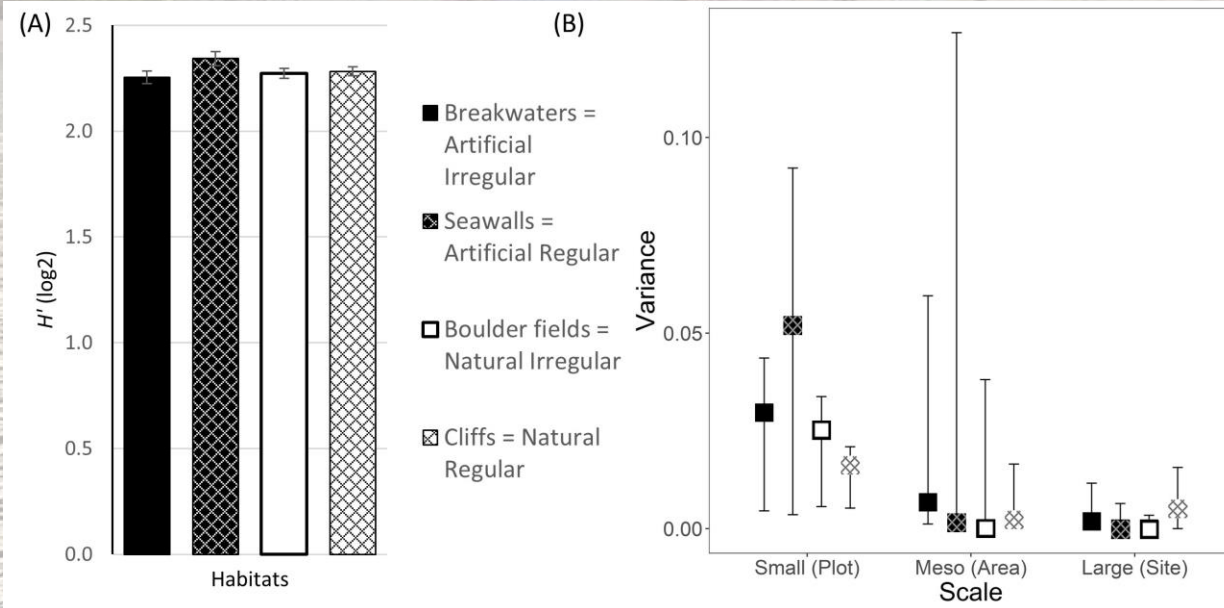


1. Artificial habitats were steeper than natural habitats, and seawalls were more homogeneous
2. Substrates reported statistically similar exposures, but seawalls reported a different spatial pattern
3. Irregular substrates were rougher than regular substrates
4. Differences were detected only between habitat morphologies for “Lower slopes” and “Ridges”



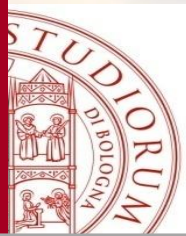
# Analysis of physical structure

## Diversity of morphological elements



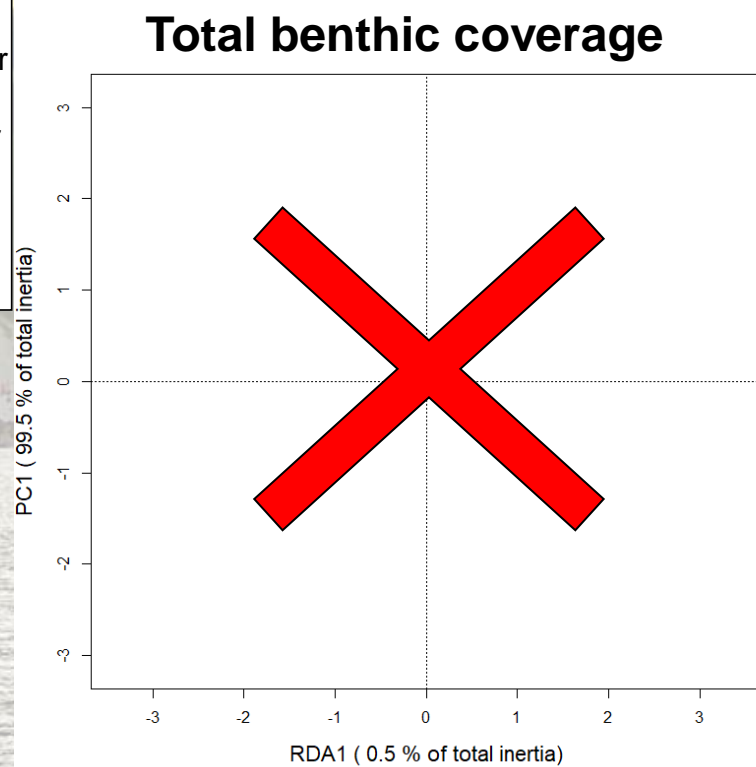
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2. Substrates reported statistically similar exposures, but seawalls reported a different spatial pattern
3. Irregular substrates were rougher than regular substrates
4. Differences were detected only between habitat morphologies for “Lower slopes” and “Ridges”
5. Diversity of morphological elements was comparable among habitat types and morphologies





# Analysis on intertidal assemblages – Redundancy Analysis (RDA)

- Breakwaters = Artificial-Irregular
- ▲ Seawalls = Artificial-Regular
- Boulder fields = Natural-Irregular
- △ Cliffs = Natural-Regular

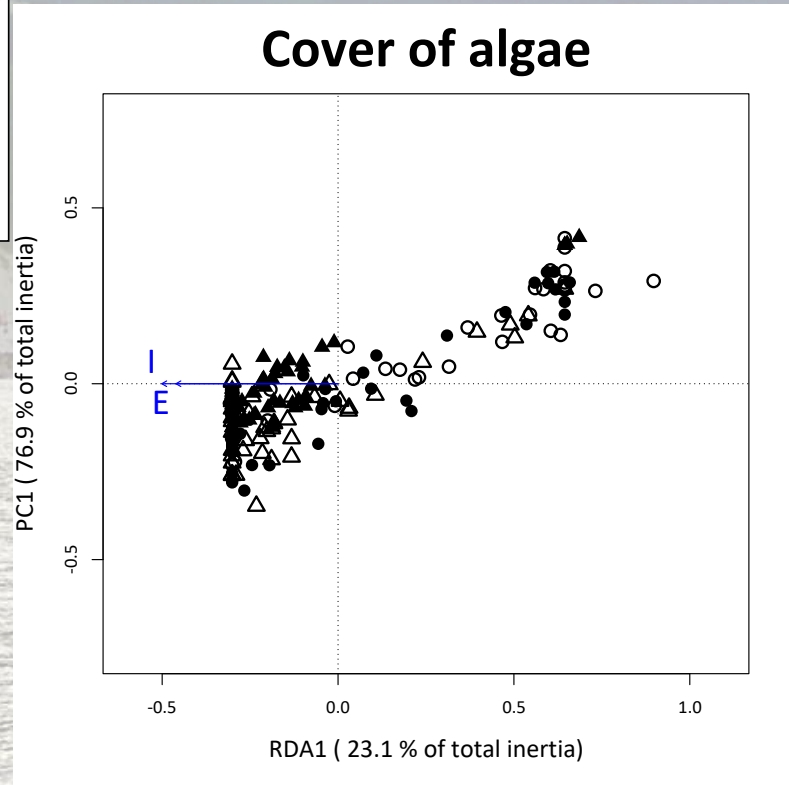


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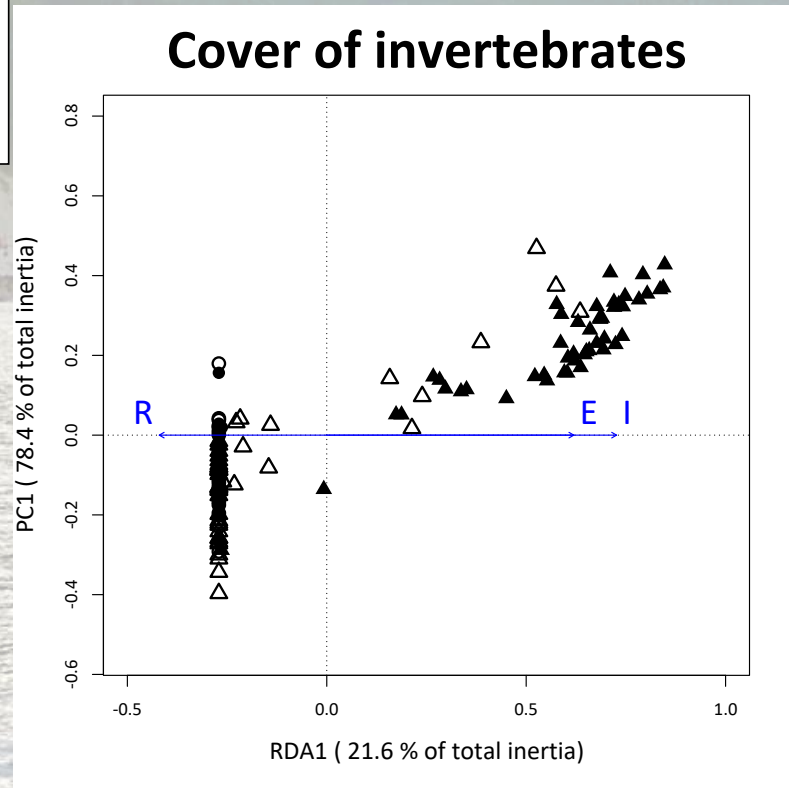


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2. **23.1%** of algal cover variance was explained by **(I)nclination** (10%) and **(E)xposure** (8%)



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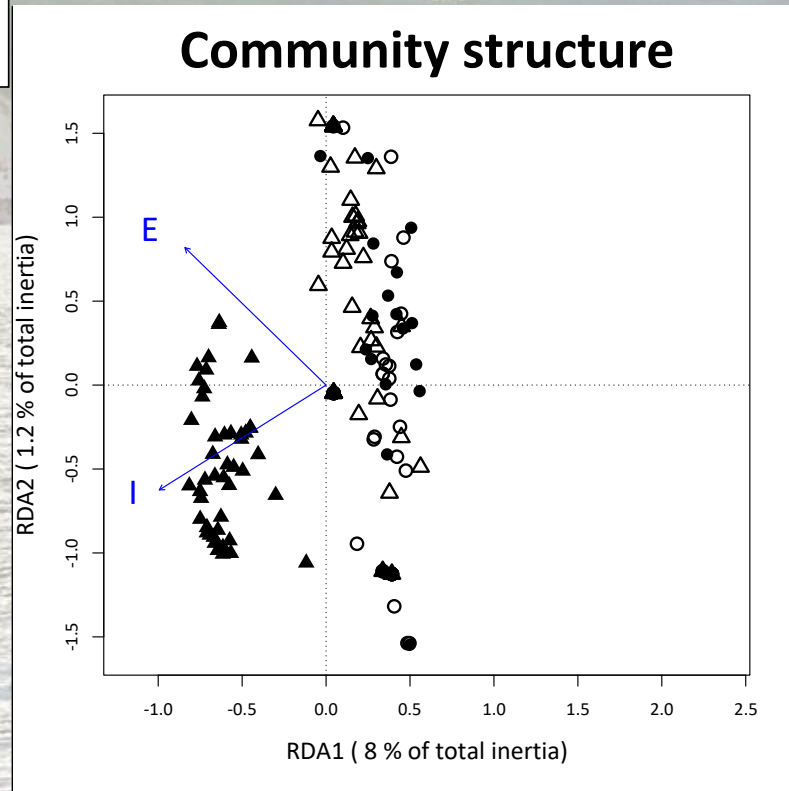


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3. **21.6%** of sessile invertebrate variance was explained by (**I**)nclination (7%), (**E**)xposure (7%) and (**R**)oughness (3.5%)



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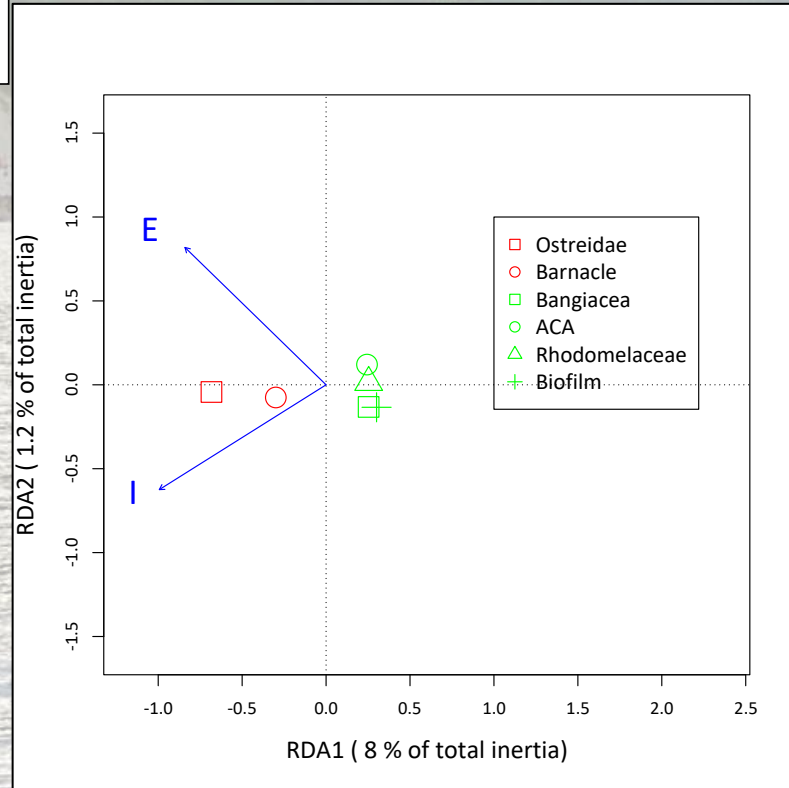


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4. **9.2%** of community structure was explained by Inclination (4.6%) and **E**xposure (3.2%)



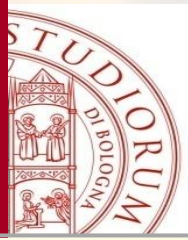
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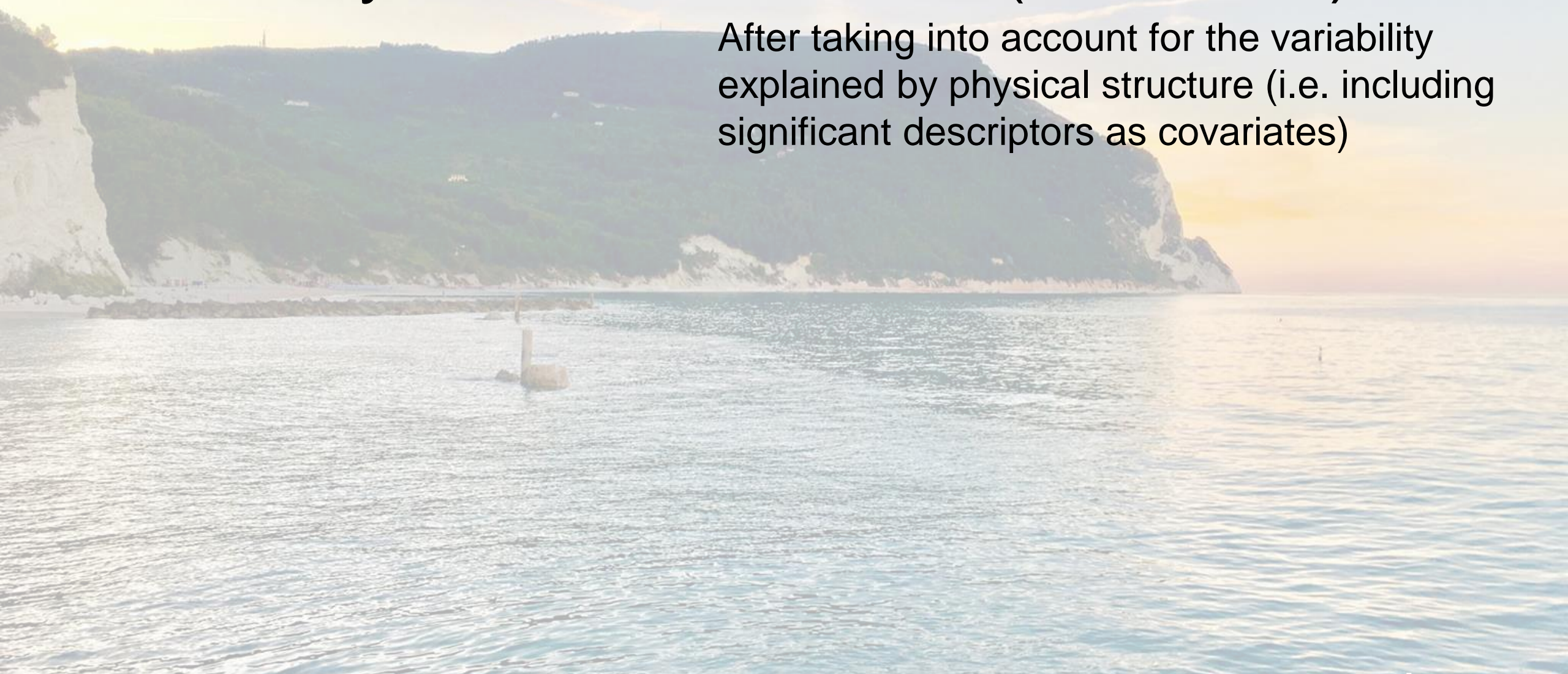
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4. **9.2%** of community structure was explained by Inclination (4.6%) and **E**xposure (3.2%)
5. Main organisms' scores ( $r > 0.5$ ) support previous observation.



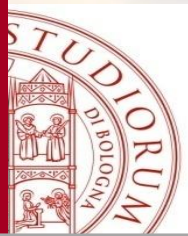


# Analysis of benthic community – Analysis of Covariances (ANCOVA)

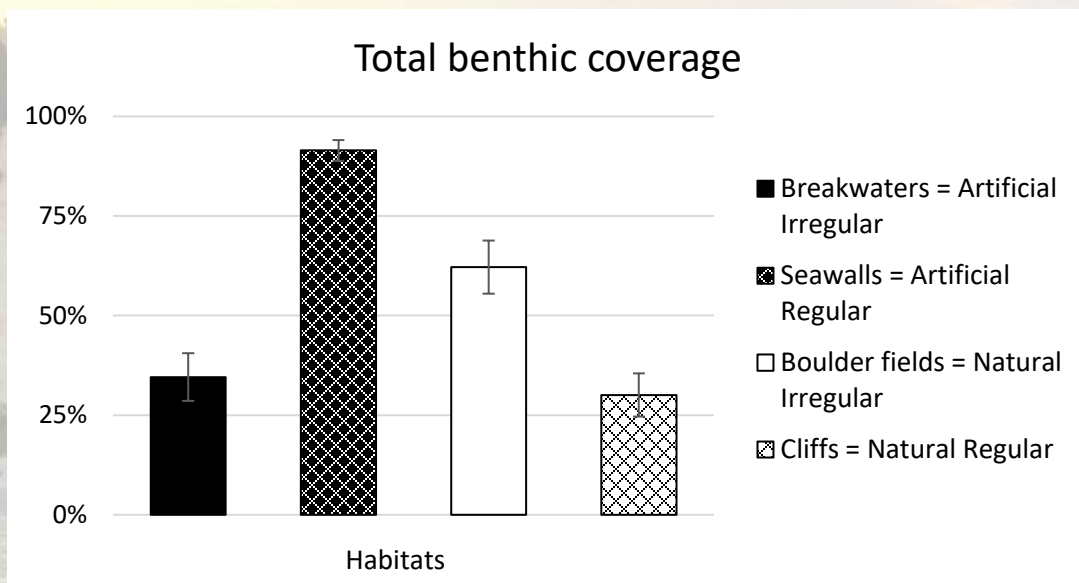
After taking into account for the variability explained by physical structure (i.e. including significant descriptors as covariates)







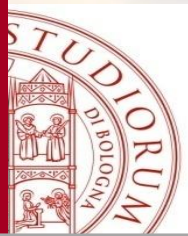
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After taking into account for the variability explained by physical structure (i.e. including significant descriptors as covariates)

1. Total benthic coverage reported differences in habitat type interacting with morphology

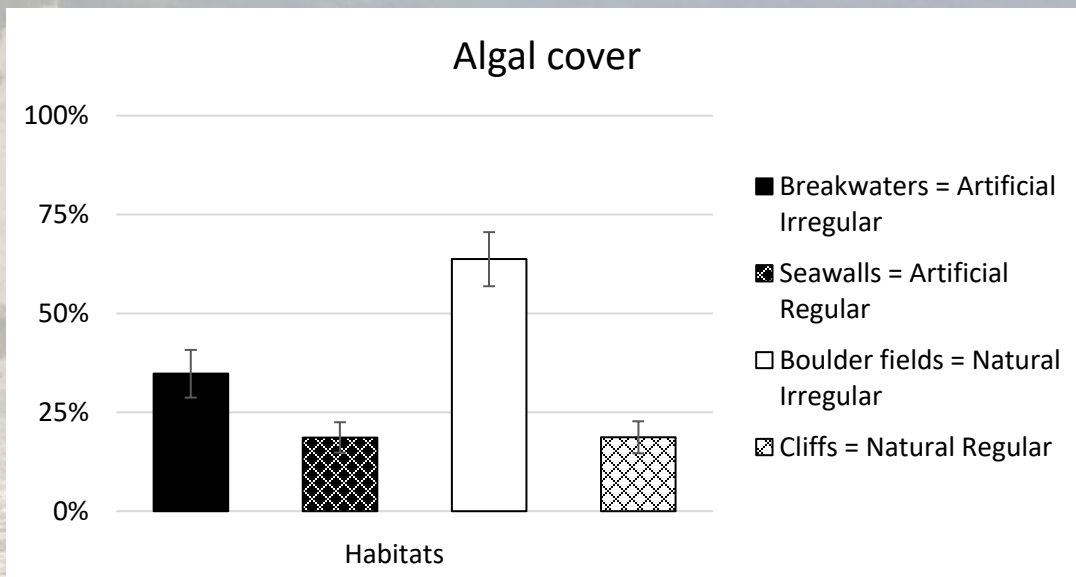




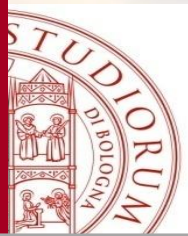
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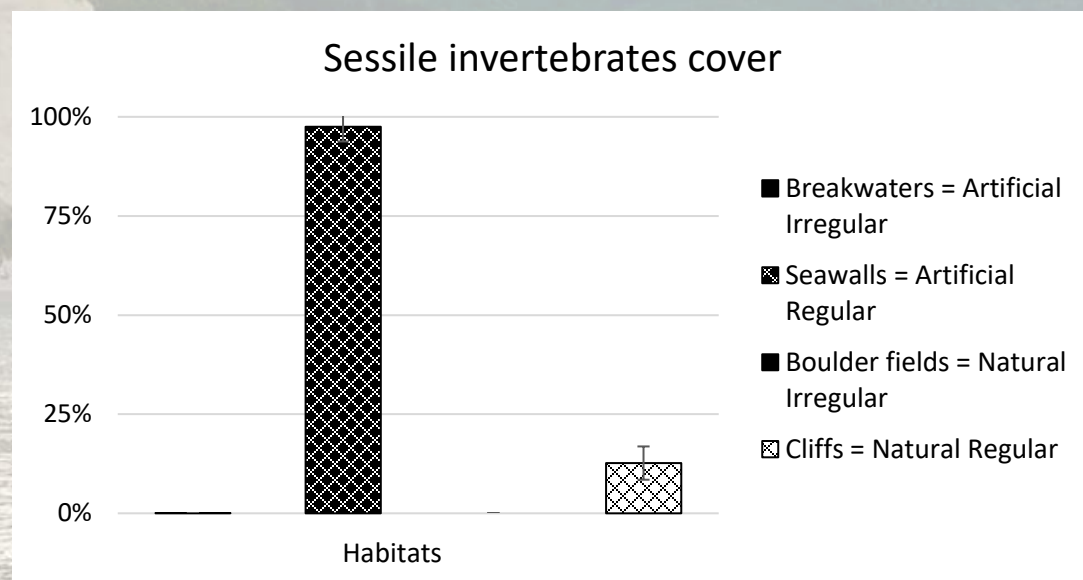






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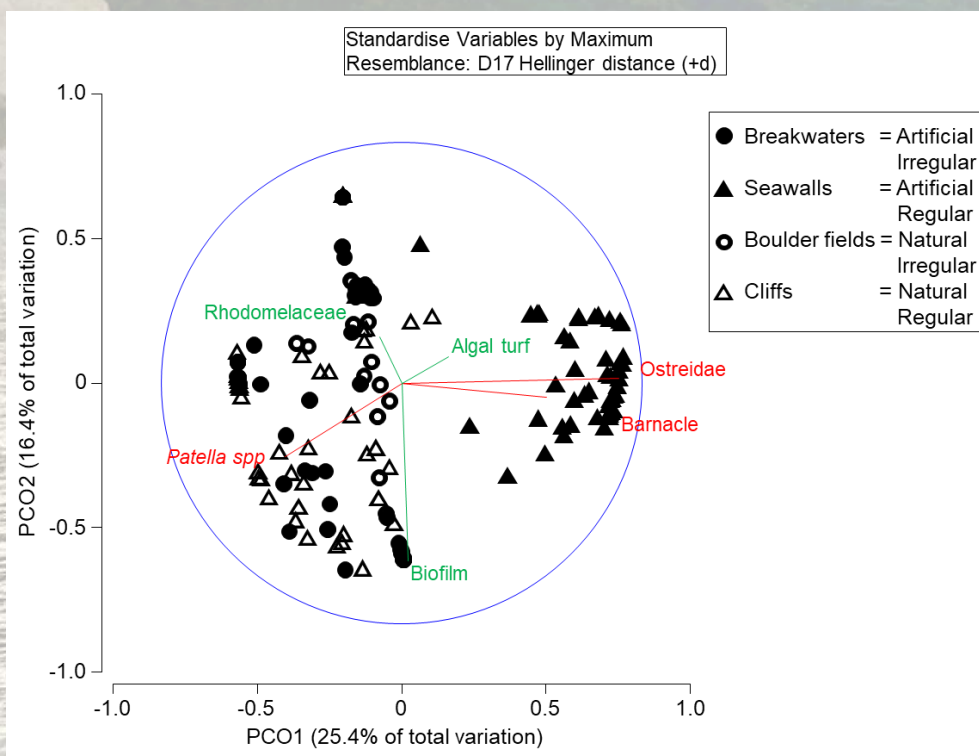
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After taking into account for the variability explained by physical structure (i.e. including significant descriptors as covariates)

1. Total benthic coverage reported differences in habitat type interacting with morphology
2. Algal cover was not affected by substrate type nor habitat morphology
3. Sessile invertebrates reported differences in habitat type interacting with morphology
4. Community structure reported differences in habitat type interacting with morphology. Mainly oysters, barnacles and limpets caused this differentiation





# Not all artificial substrates are equal

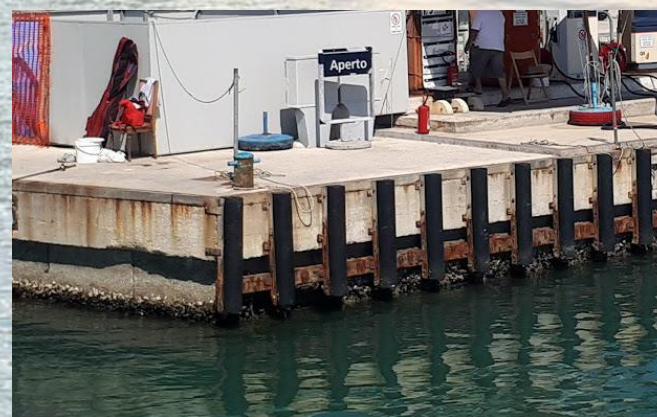
How and to what degree are intertidal assemblages affected by physical complexity in natural and artificial habitats?



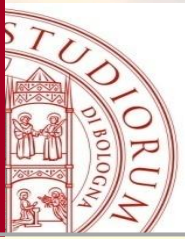
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# What are we missing?

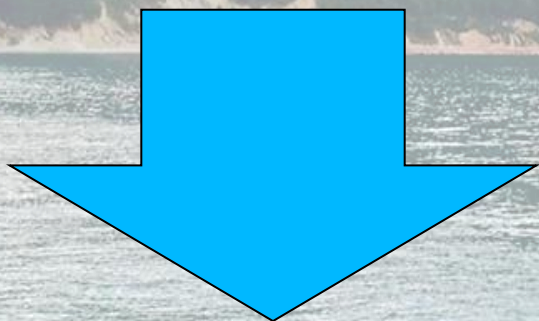
Poor ecological performance of artificial substrates is the product of multiple co-occurring structural and non-structural differences

1. Complexity
2. Composition (i.e. physiochemical properties)
3. Disturbance (type of anthropic use, frequency of maintenance)
4. Surrounding environment
5. Source of pollution
6. Biotic settings (i.e. predation settings)



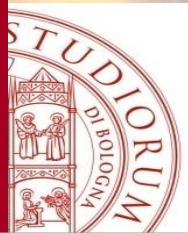
# Take on message

Despite most current greening intervention focus on just physical structure; we encouraged a wider reflection about what makes an infrastructure “greener”



Enhance ecological value through a site-specific multilevel rethinking of artificial substrates for synergistic benefits

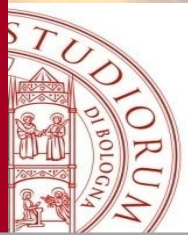




# Thanks







Background image from Wikipedia:

[https://it.wikipedia.org/wiki/Monte\\_Conero#/media/File:Monte\\_Conero\\_visto\\_dalla\\_spiaggia\\_Urbani.jpg](https://it.wikipedia.org/wiki/Monte_Conero#/media/File:Monte_Conero_visto_dalla_spiaggia_Urbani.jpg)