Photogrammetric Analysis Reveals Distinct Topographic Structure for Stony Corals in Dry Tortugas National Park

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FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION

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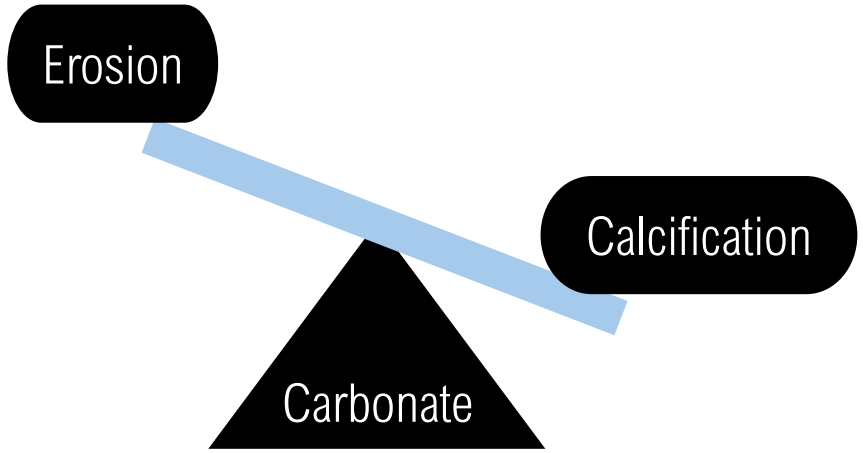
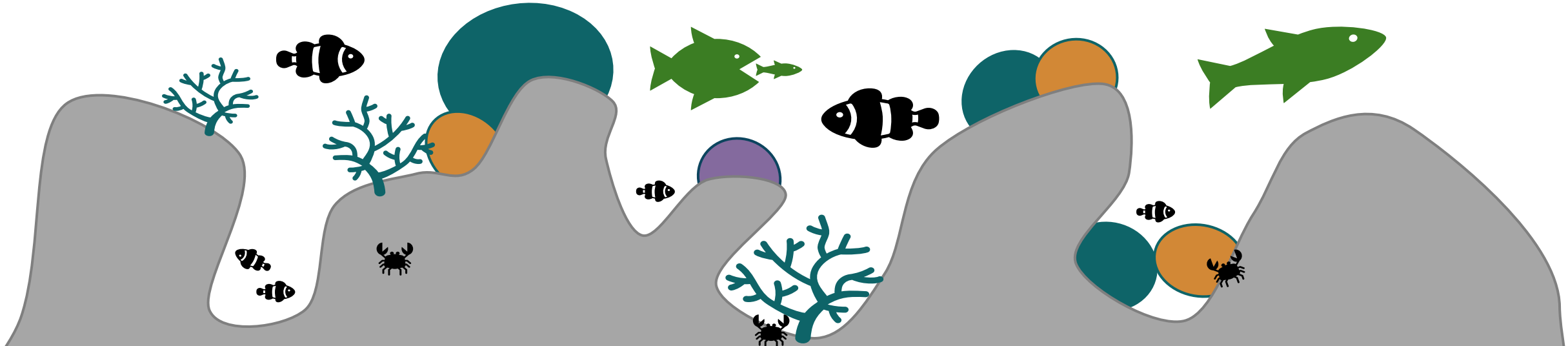
The importance of structure





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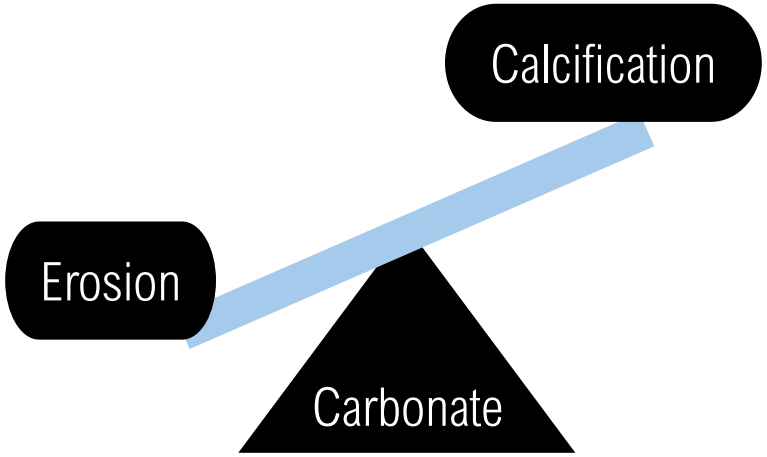
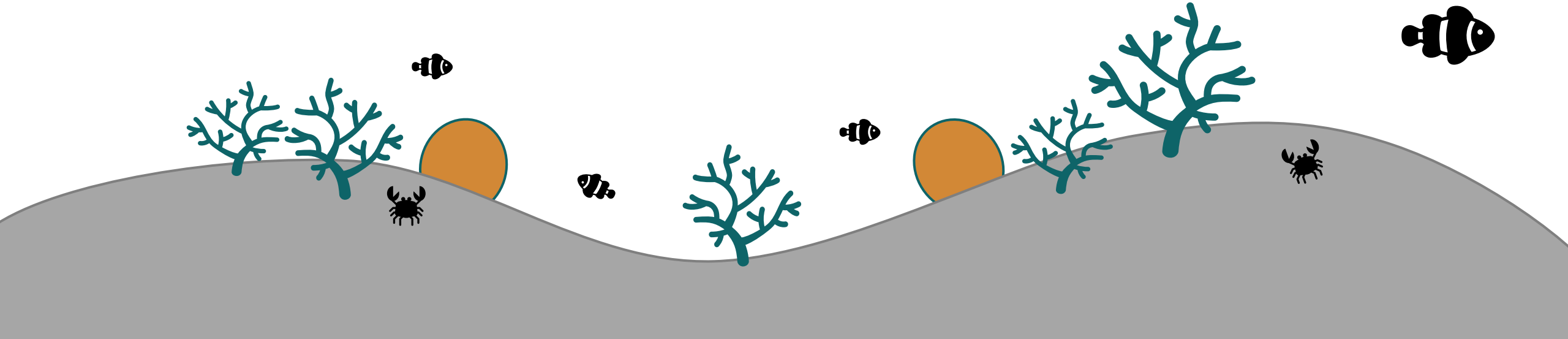
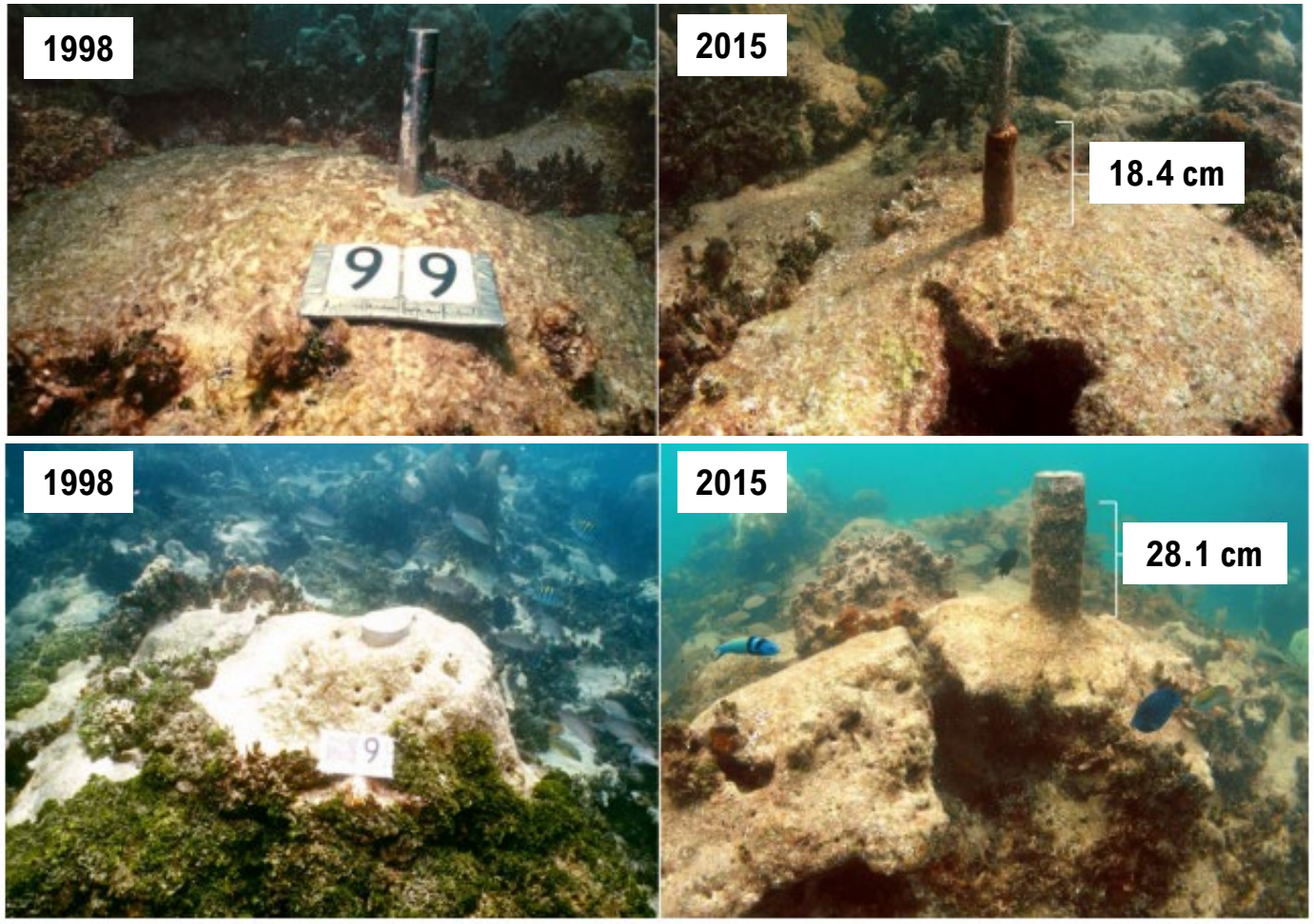




The importance of structure

Hen and Chickens, Islamorada, Florida



"Improving estimates of coral reef construction and erosion with in situ measurements"
Kuffner *et al.* 2019

- Mean annual erosion rate of **5.5 mm per year** in the Florida Keys over 17 years

The importance of structure

Traditional rugosity metrics:

- Visually on a graded scale
- In situ measures such as ‘tape-and-chain’ method
- Combination of the two

Limitations:

- Observer bias
- High variation according to placement
- Non-repeatability
- Two dimensional

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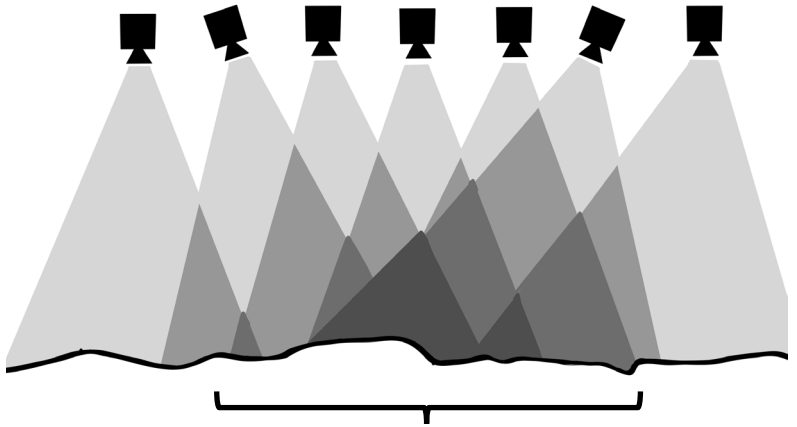
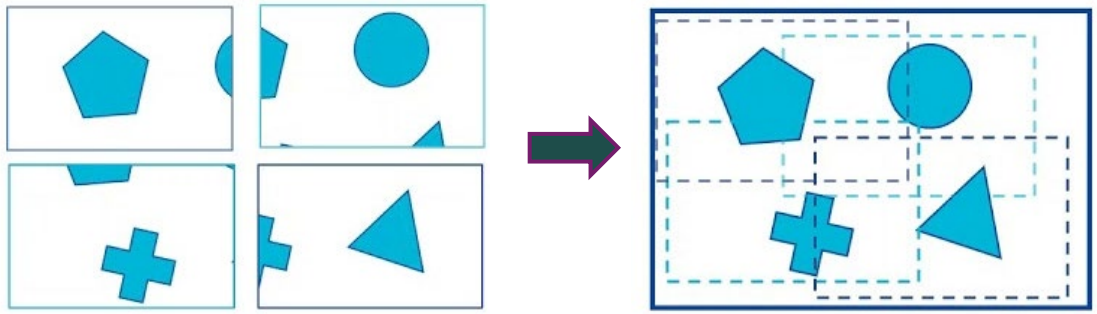
Structure-from-Motion Photogrammetry






Dry Tortugas National Park, Florida
Davis Rock
Texas Rock
Temptation Rock
The Maze
Mayers Peak
5 study sites: high-relief pinnacle habitat
FWC Coral Reef Evaluation & Monitoring Project (CREMP)
Collected in 2019-2020

The importance of structure

- Coral assemblages in the Dry Tortugas are shifting dramatically
- Massive reef-building corals are more susceptible to stressors vs. smaller weedier genera
- Quantifying structural footprints of susceptible corals will help to determine how reef functionality will be impacted in varying scenarios of decline

STUDY OBJECTIVES

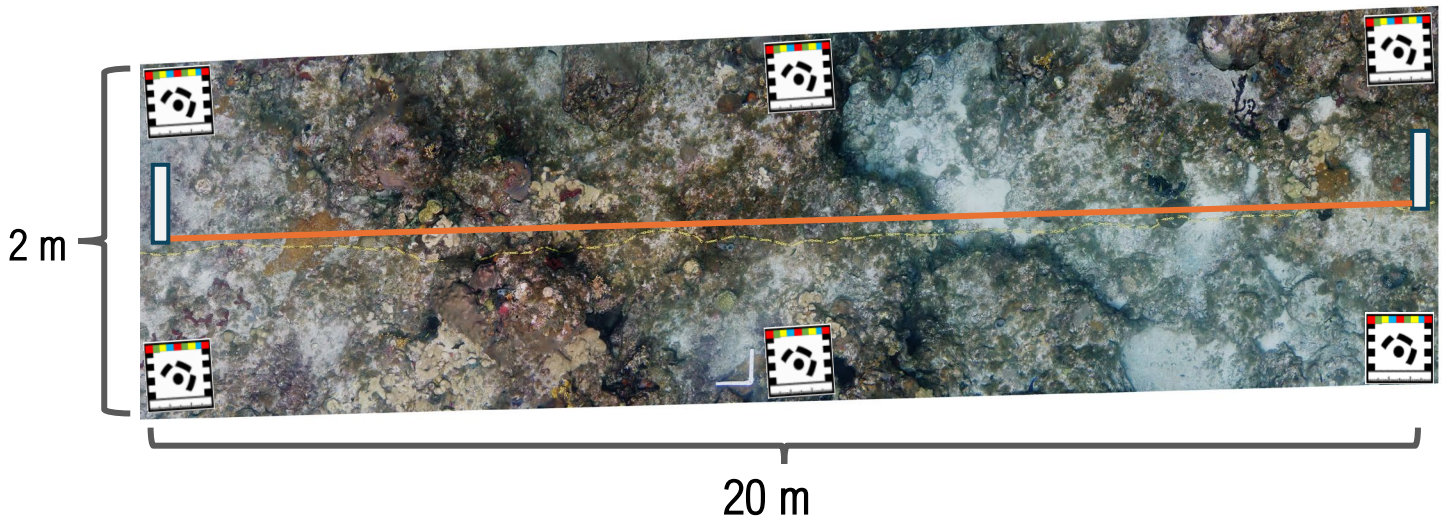
1. Reconstruct benthic habitat using SfM photogrammetry

2. Derive several fine-scale terrain attributes previously shown to be ecologically meaningful

3. Is there significantly distinct topographic structure between coral genera and functional groups of corals (massive vs. weedy)?

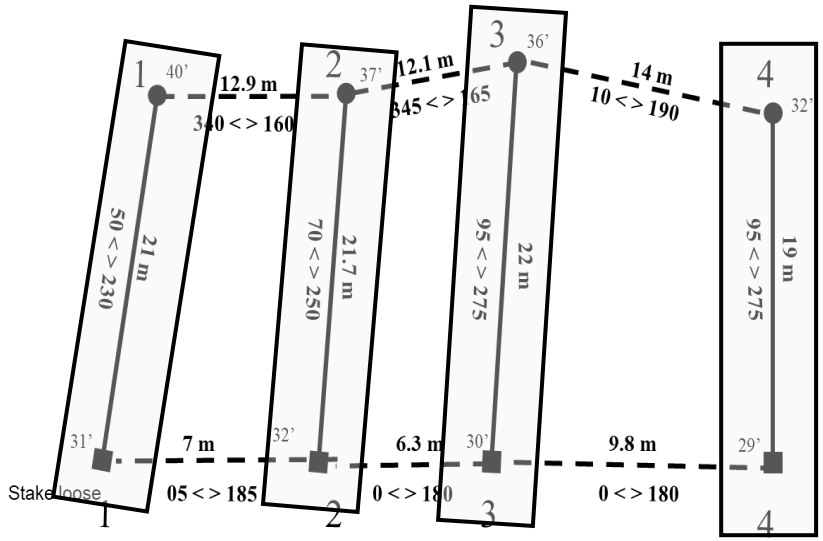
Structure-from-Motion workflow

- Imagery collected by diver swimming two passes 2 m above the substrate
- Results in between 1,000 and 1,500 images per transect with 90% overlap
- 4 ground control points (GCPs): GPS coordinates (x, y), depth (z), and 5 cm scale



4 transects per site

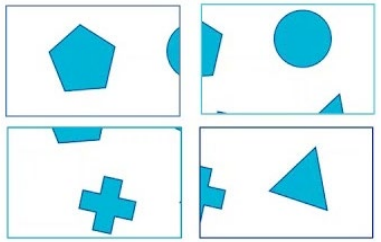
~160 m^2 per site



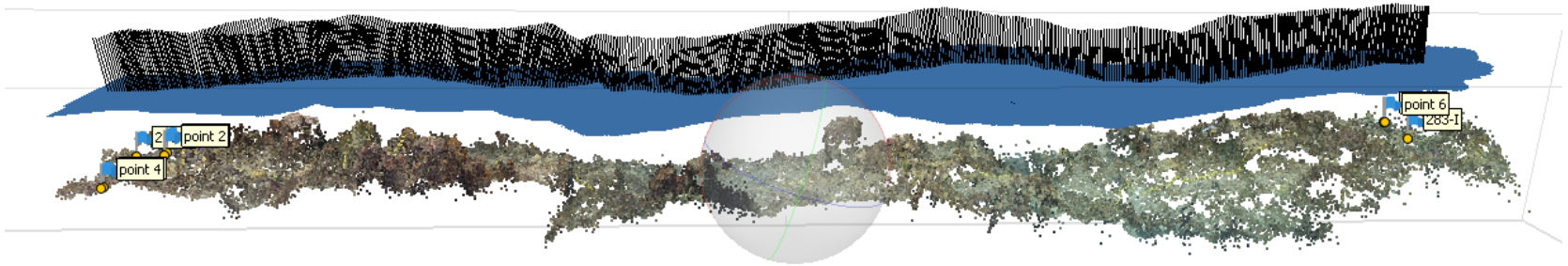
Structure-from-Motion workflow

Metashape

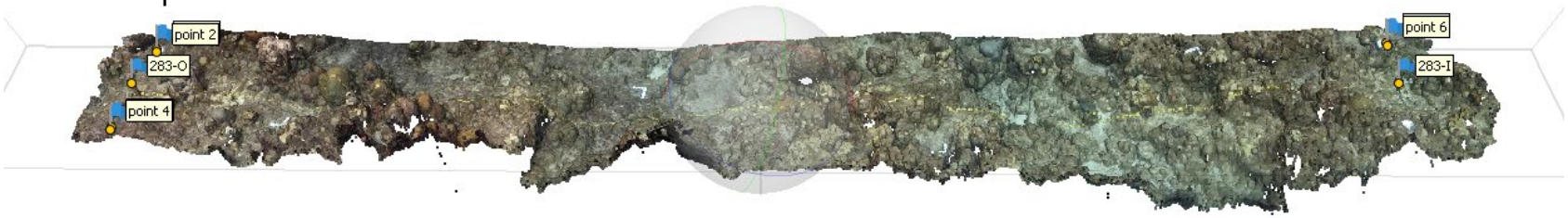
Input imagery



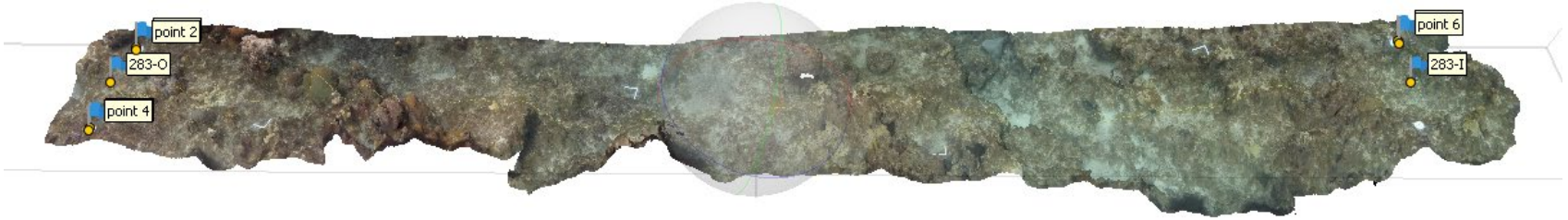
Sparse point cloud



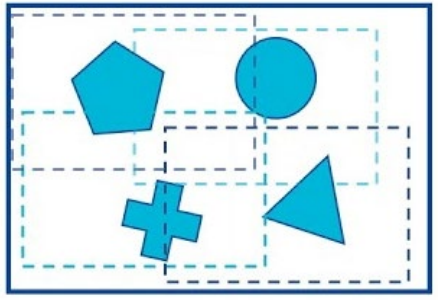
Dense point cloud



Solid 3D mesh



Export rasters



1. True color orthomosaic
2. Digital Surface Model (DSM)

Quantification of terrain attributes

Low elevation — High elevation

Annotated Corals

Digital Surface Model

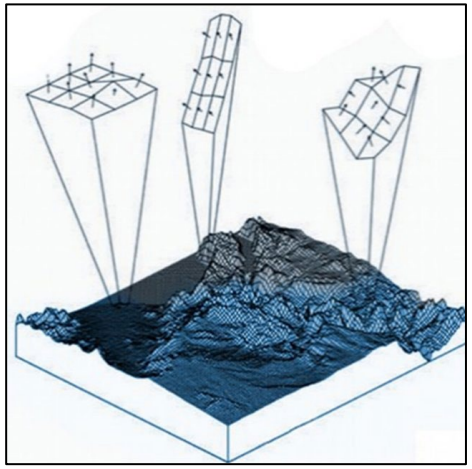
True Color Orthomosaic

- Colpophyllia
- Dichocoenia
- Diploria
- Eusimilia
- Meandrina
- Montastraea
- Mycetophyllia
- Orbicella
- Porites
- Siderastrea
- Stephanocoenia

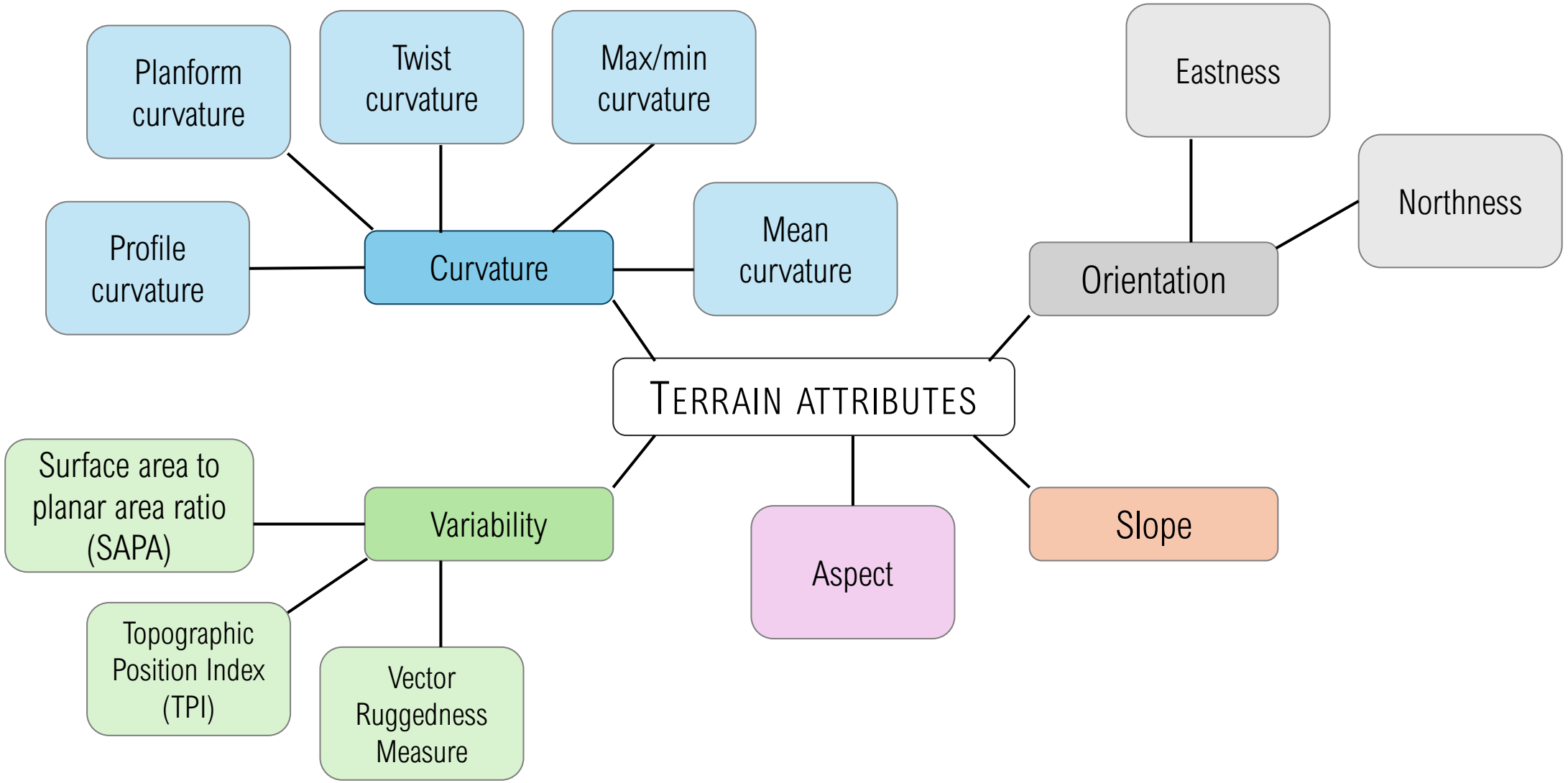
N

0 1 2 4 m

cell size = 1 cm
cell window = 9x9 = 81 cm^2

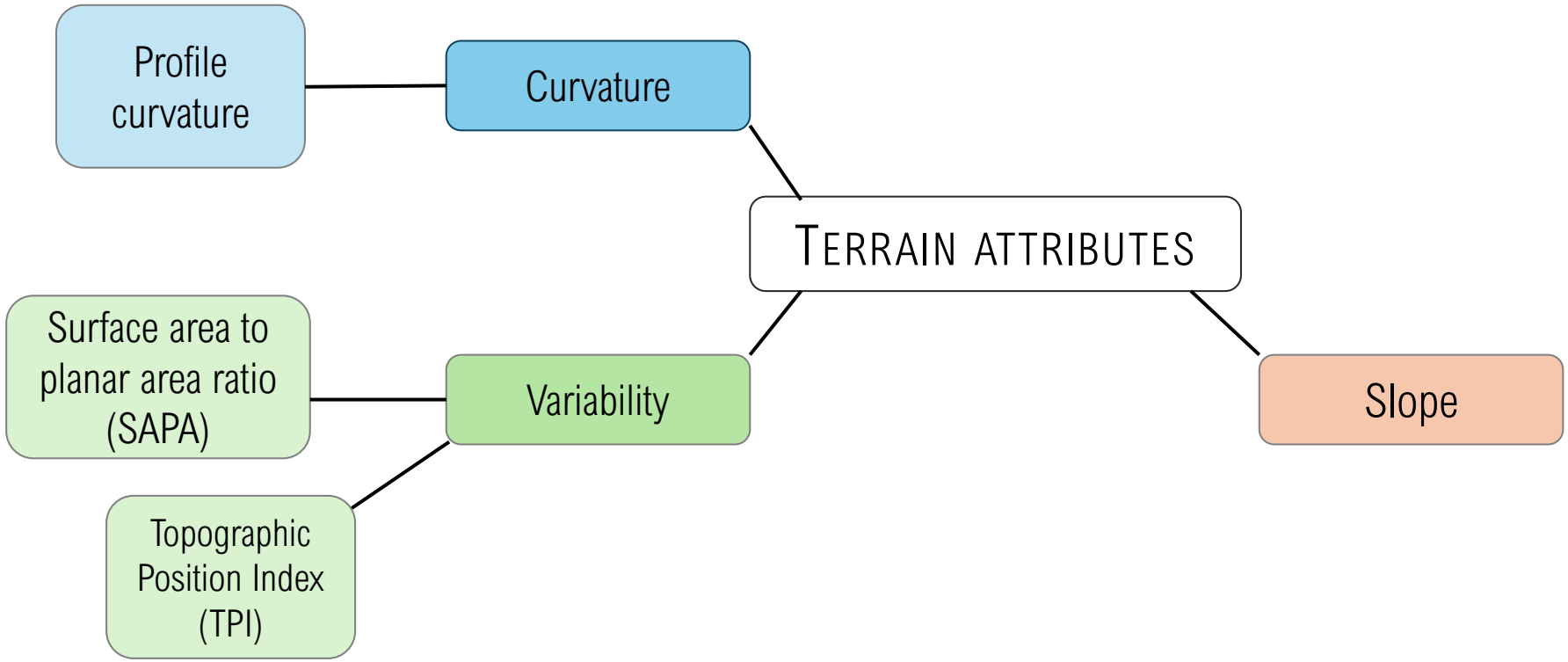


Quantifying structural footprints

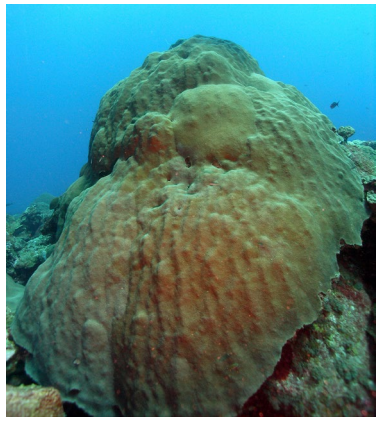


Quantifying structural footprints

Shown in studies to be ecologically important for explaining the distribution and abundance of marine benthic organisms



Massive, Reef-builders



ORBICELLA

COLPOPHYLLIA

MONTASTRAEA

PSEUDODIPLORIA

Weedy, Opportunistic

SIDERASTREA

PORITES

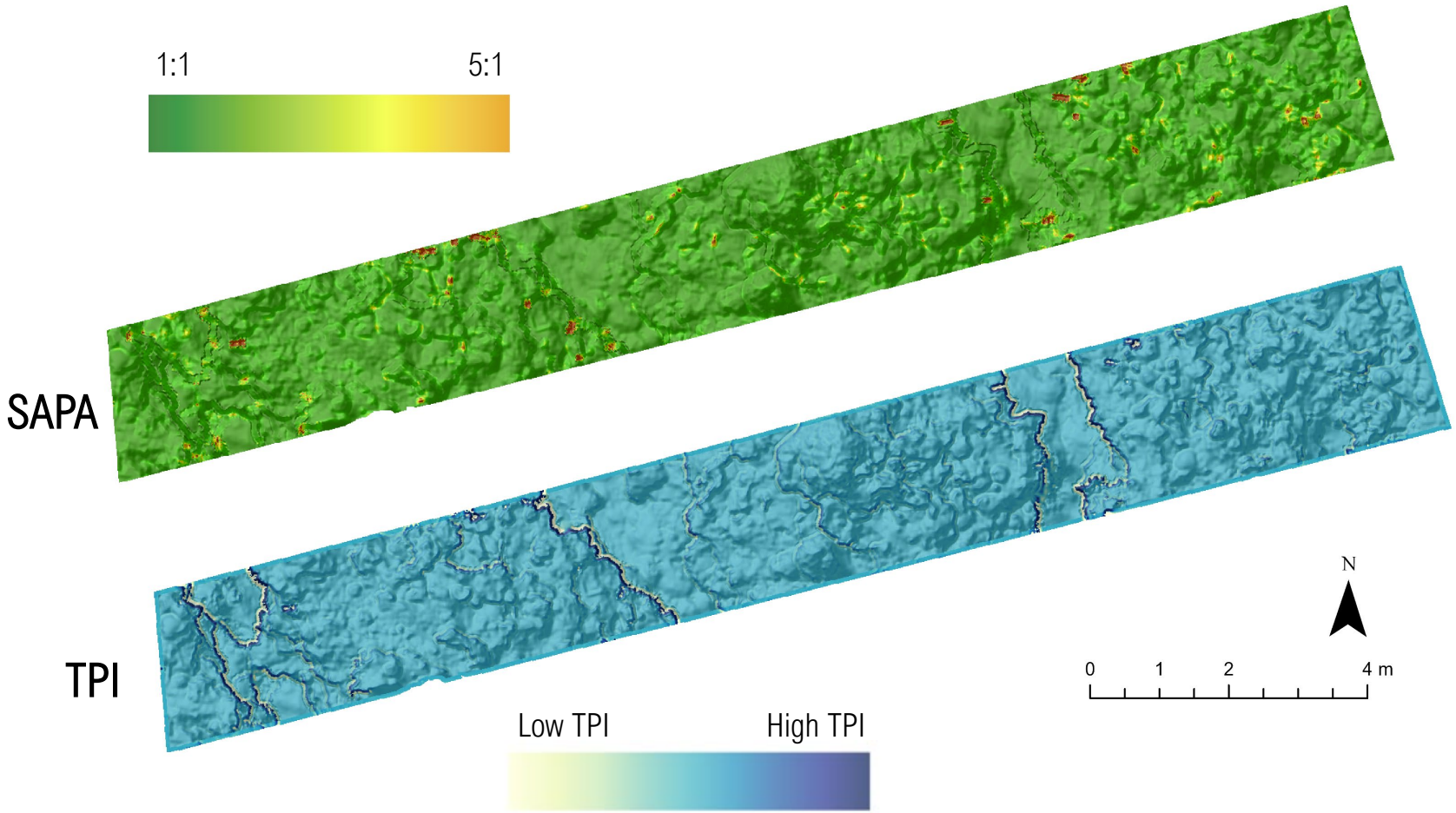
STEPHANOCOENIA

Control

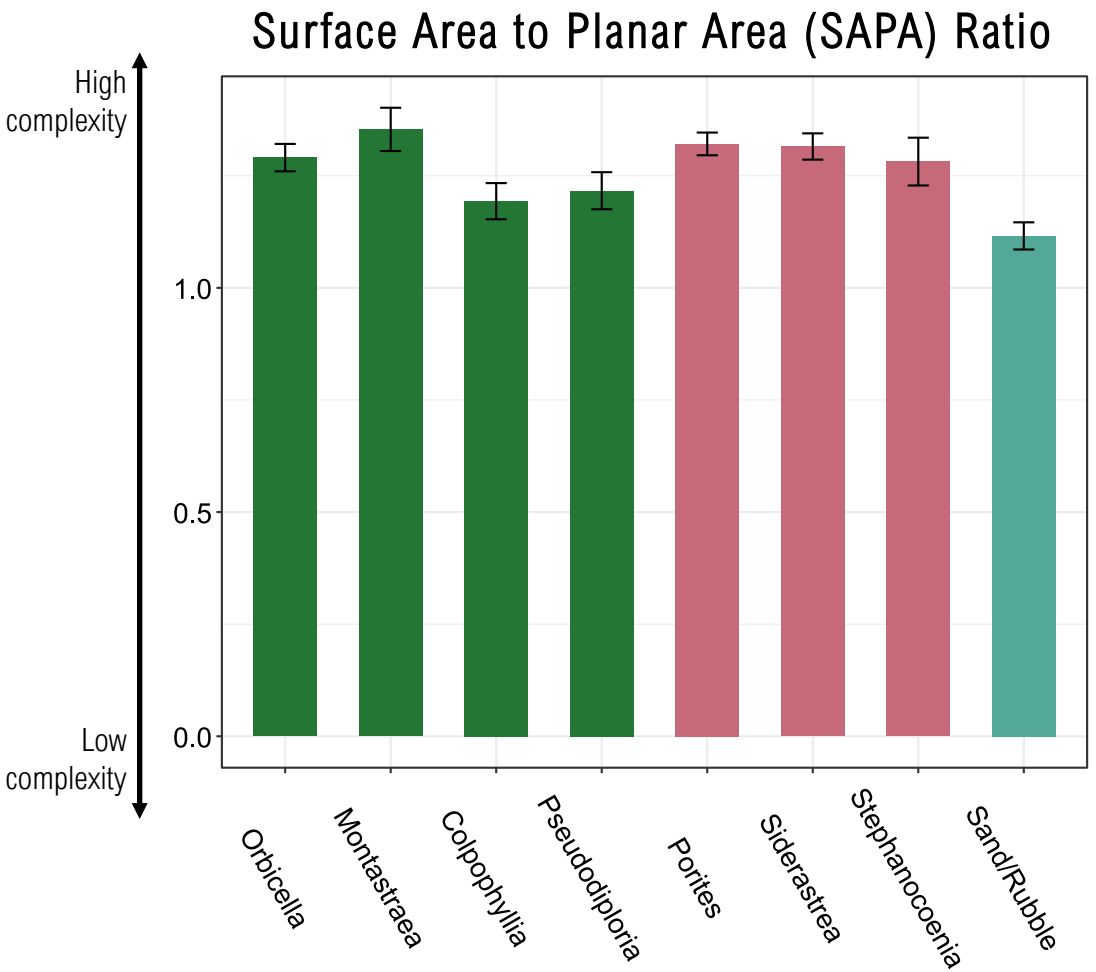
RUBBLE

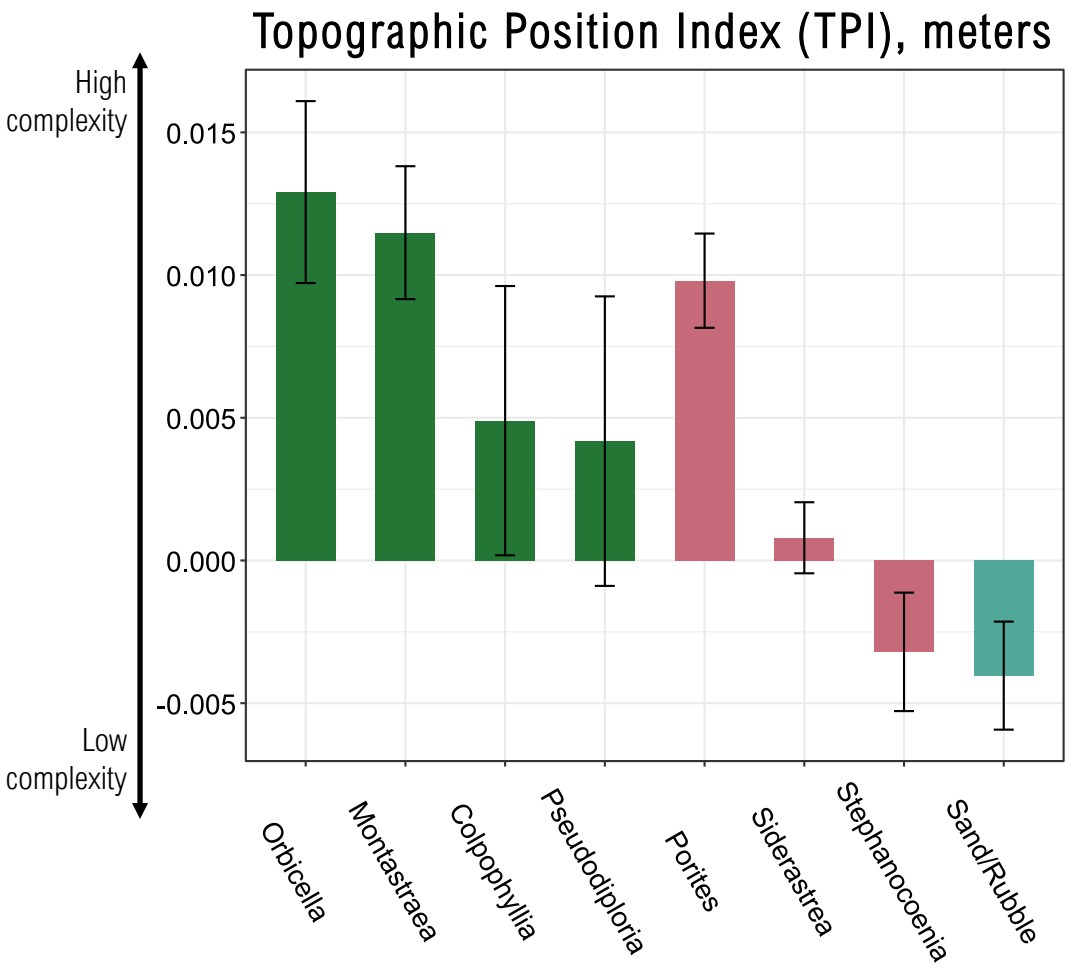
Variability

- Surface area to planar area ratio: Ratio between contour distance (3D) and linear distance (2D)
- Topographic Position Index: Difference between depth of focal cell and mean depth of surrounding cells



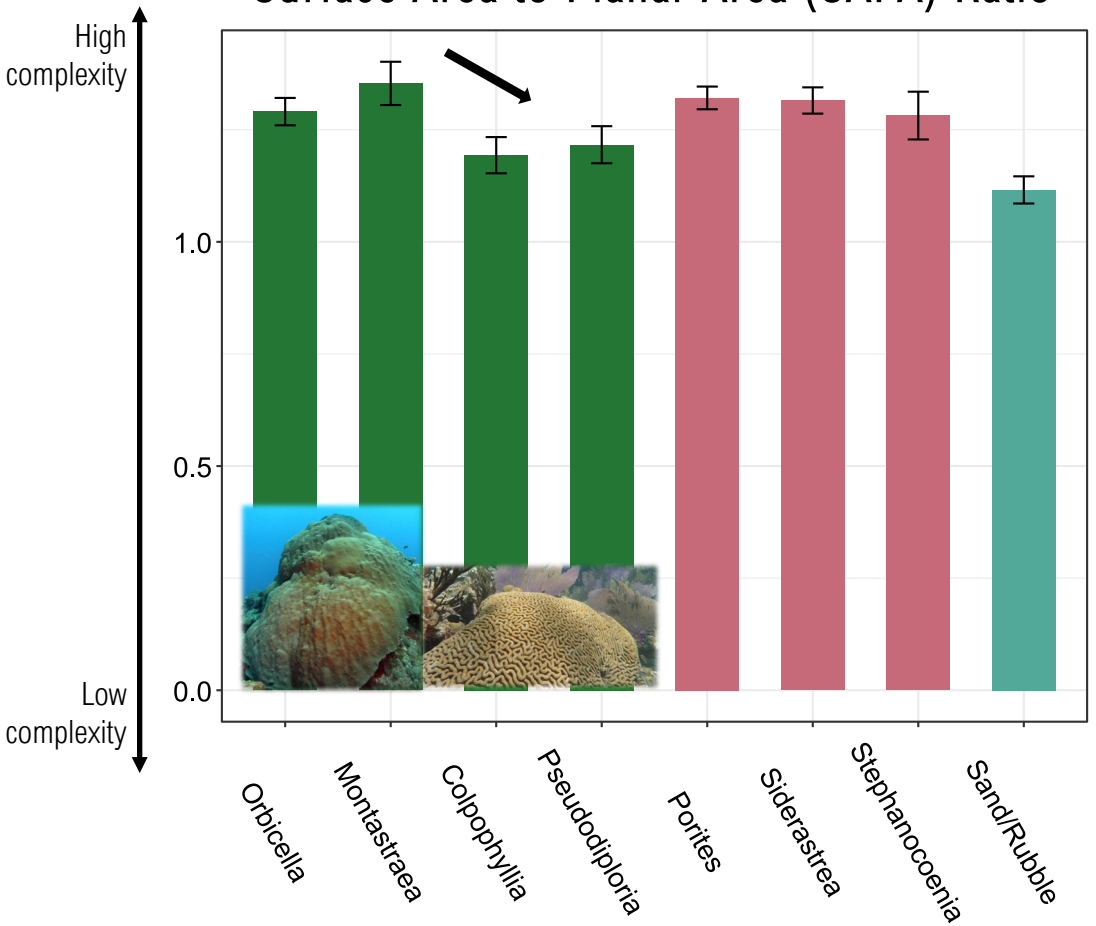
Surface variability attributes

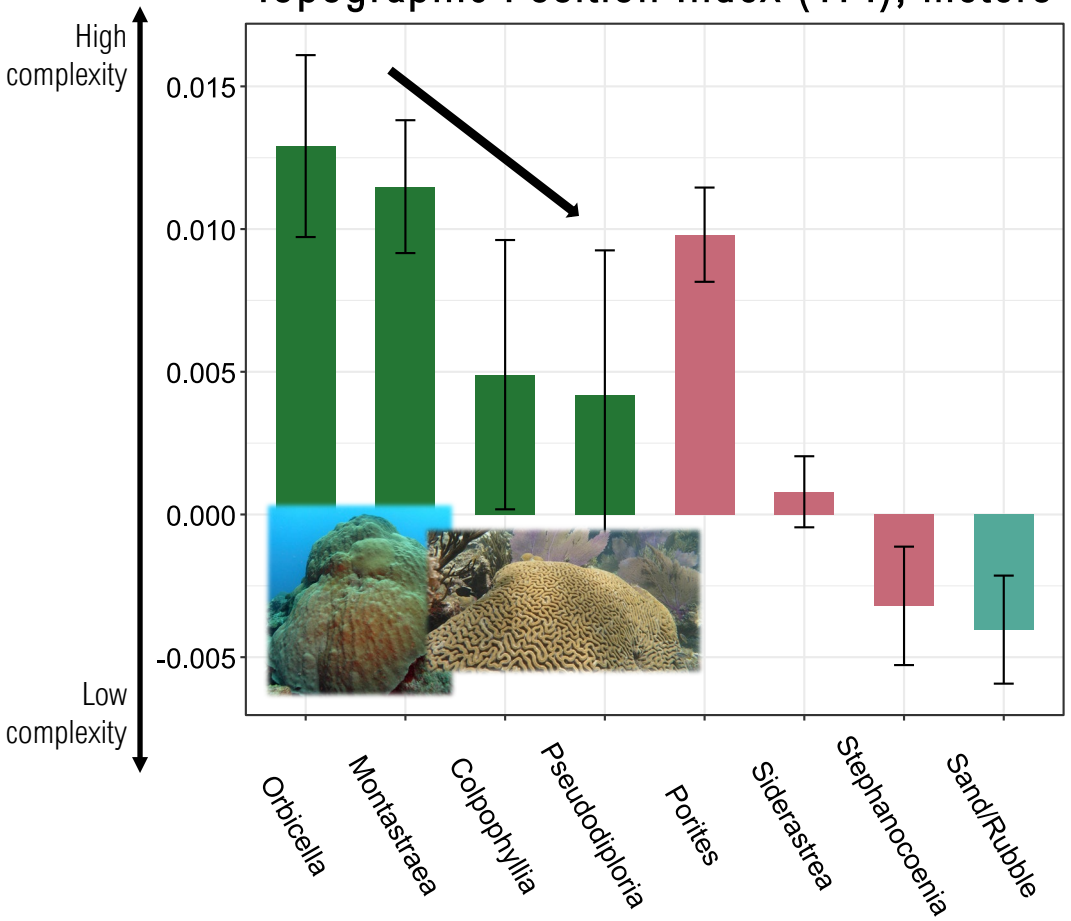




Massive Weedy Rubble

Surface variability attributes





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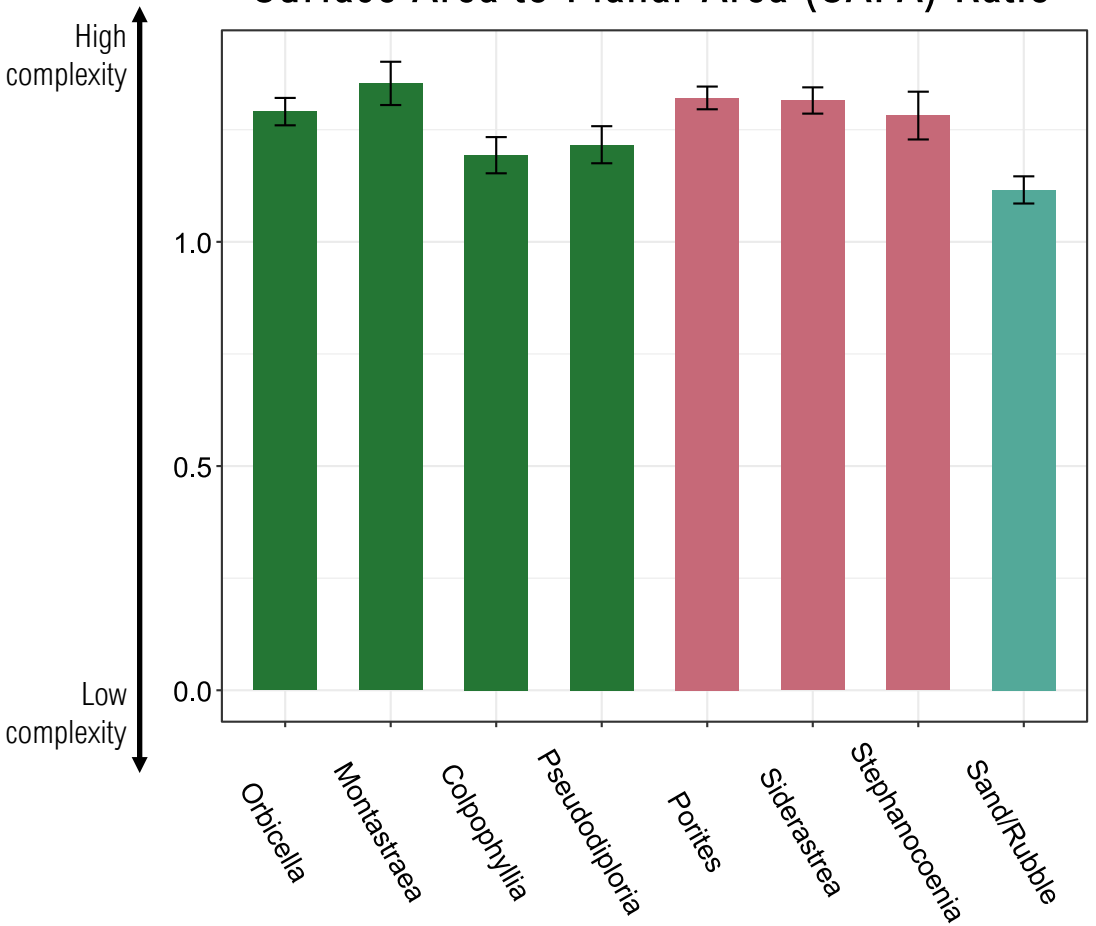

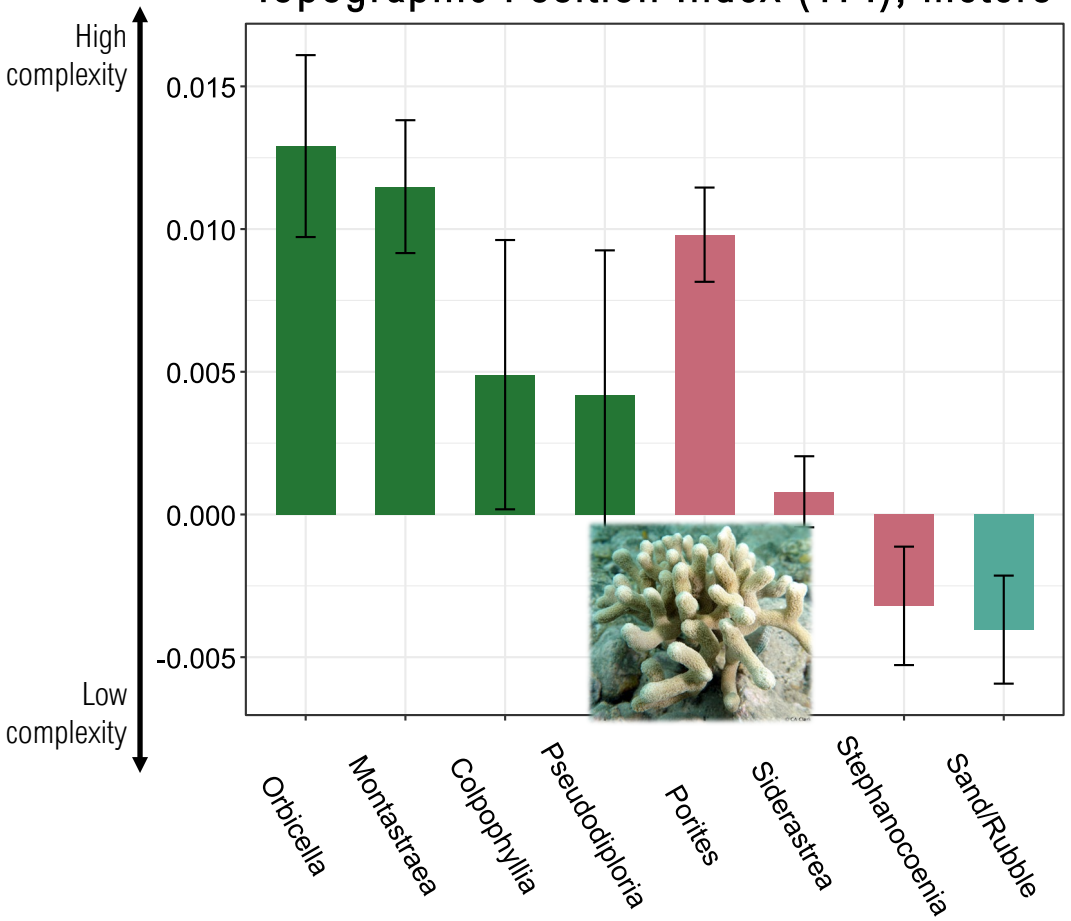

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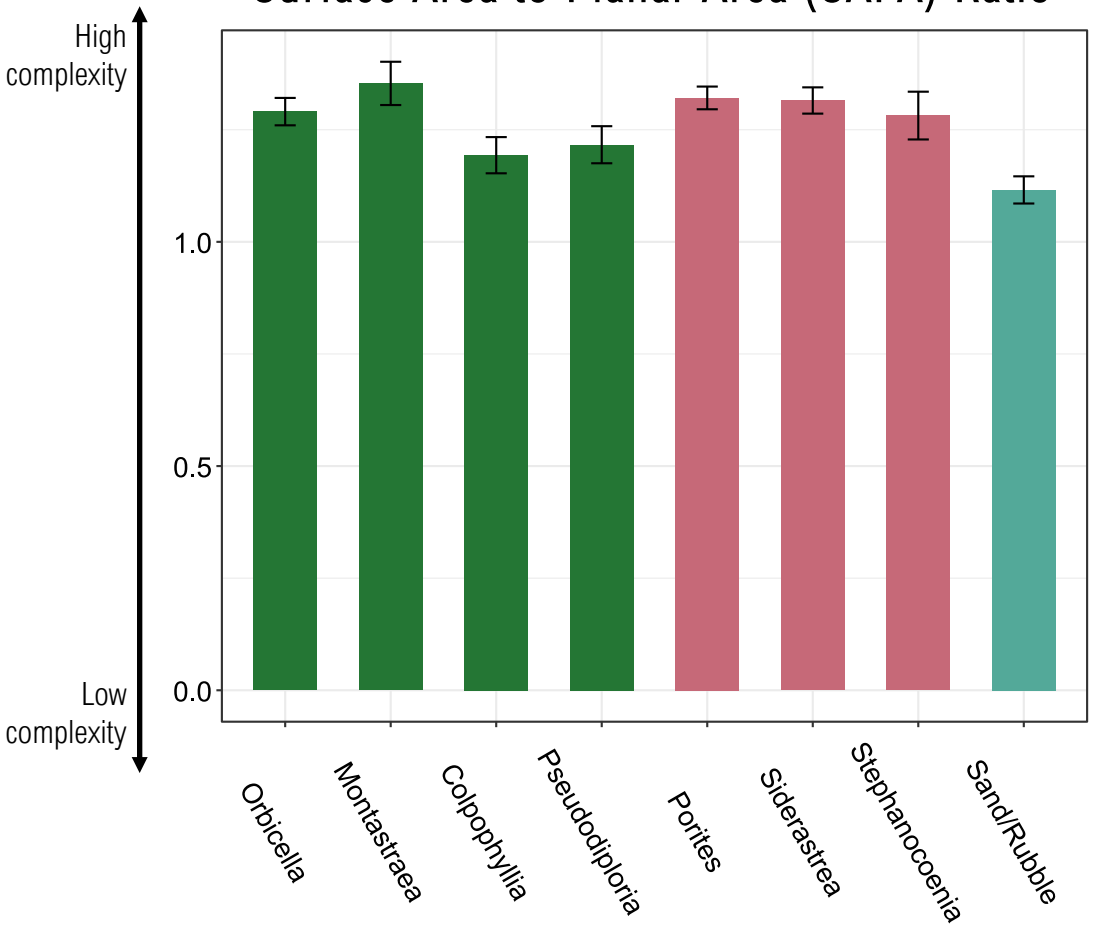
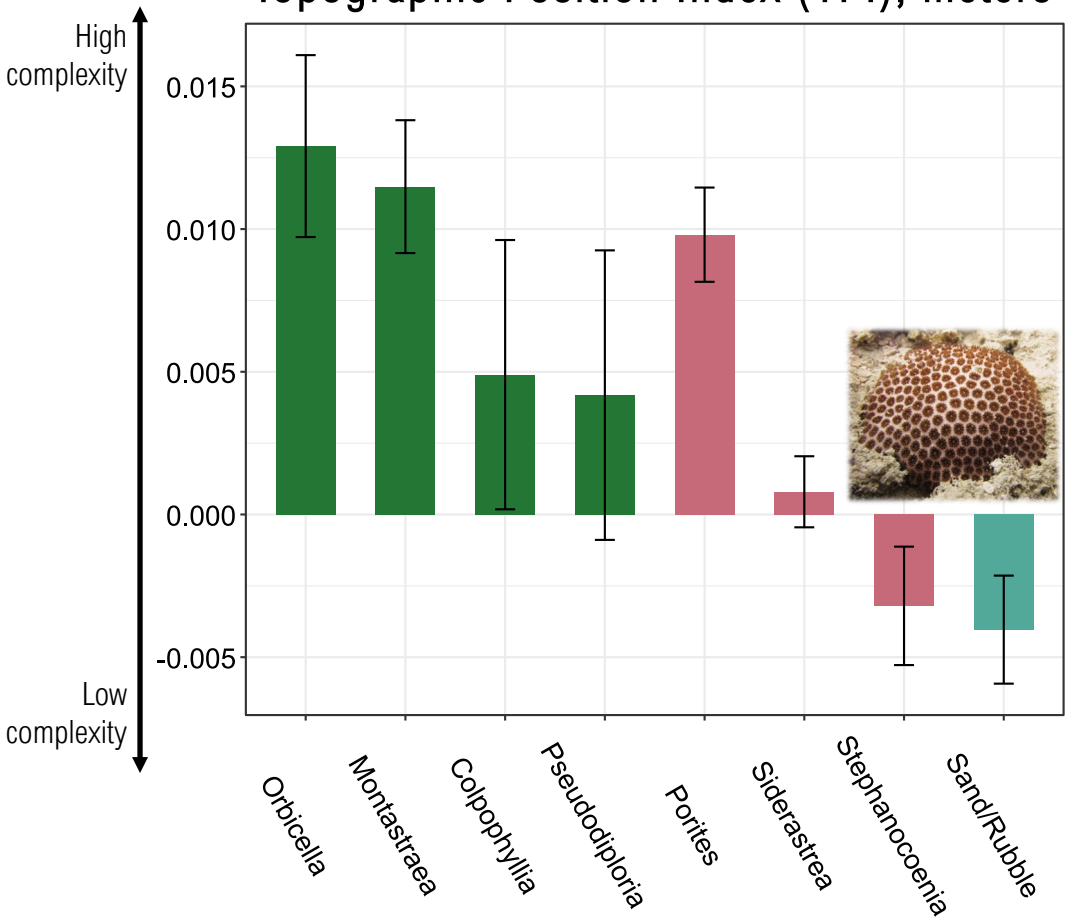
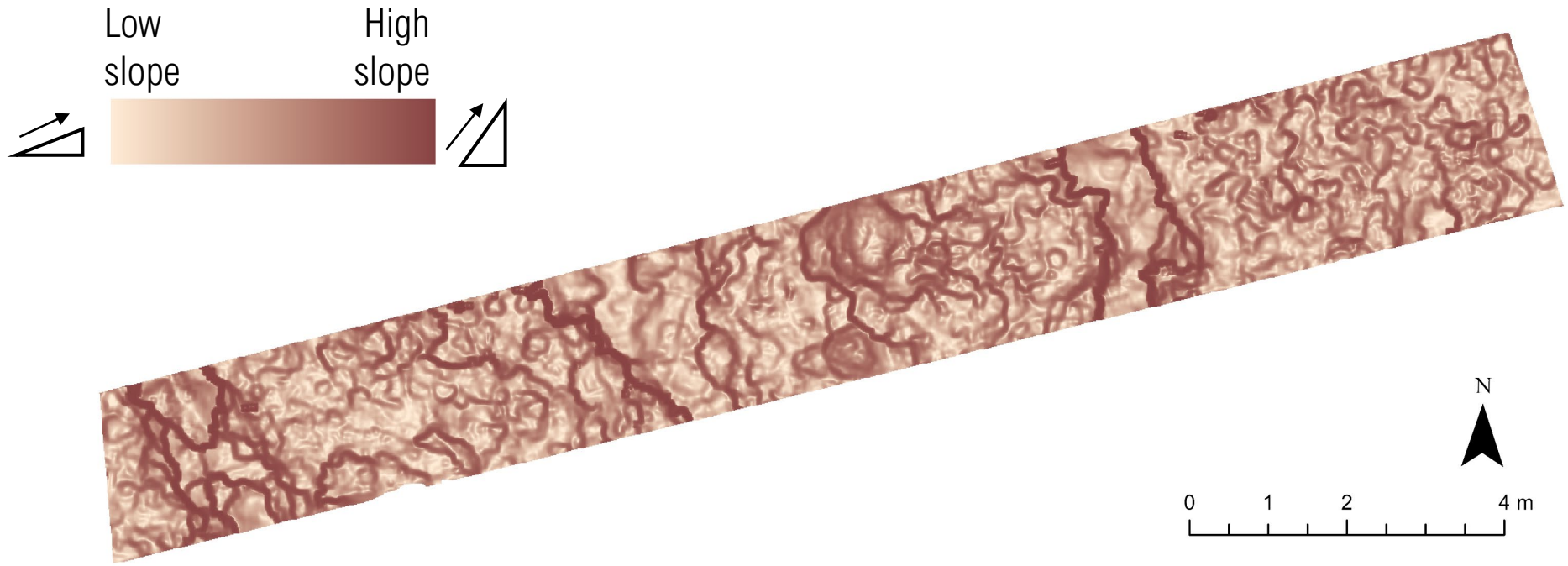




Massive Weedy Rubble

Terrain attributes

Slope Maximum rate of elevational change (in degrees)



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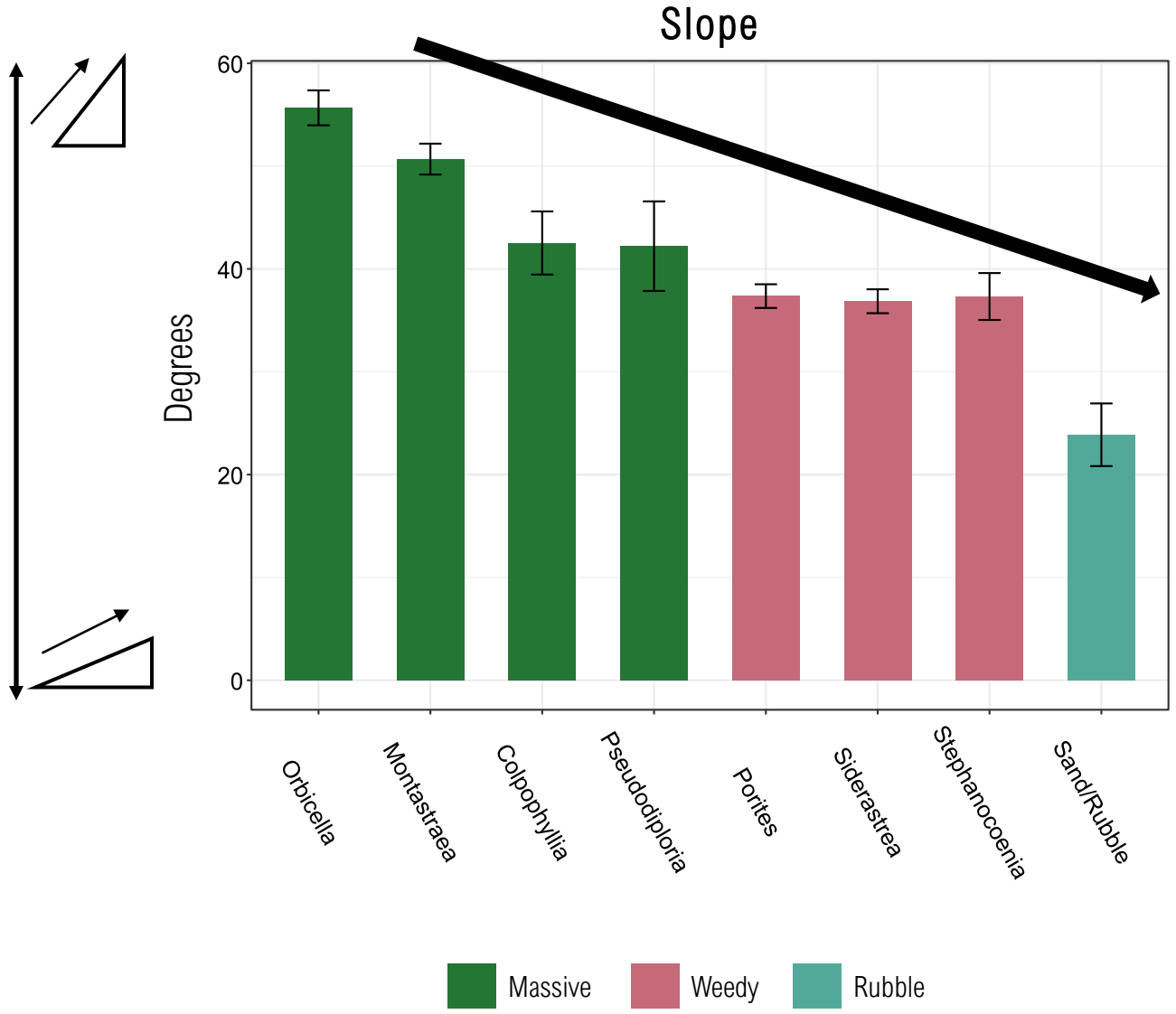

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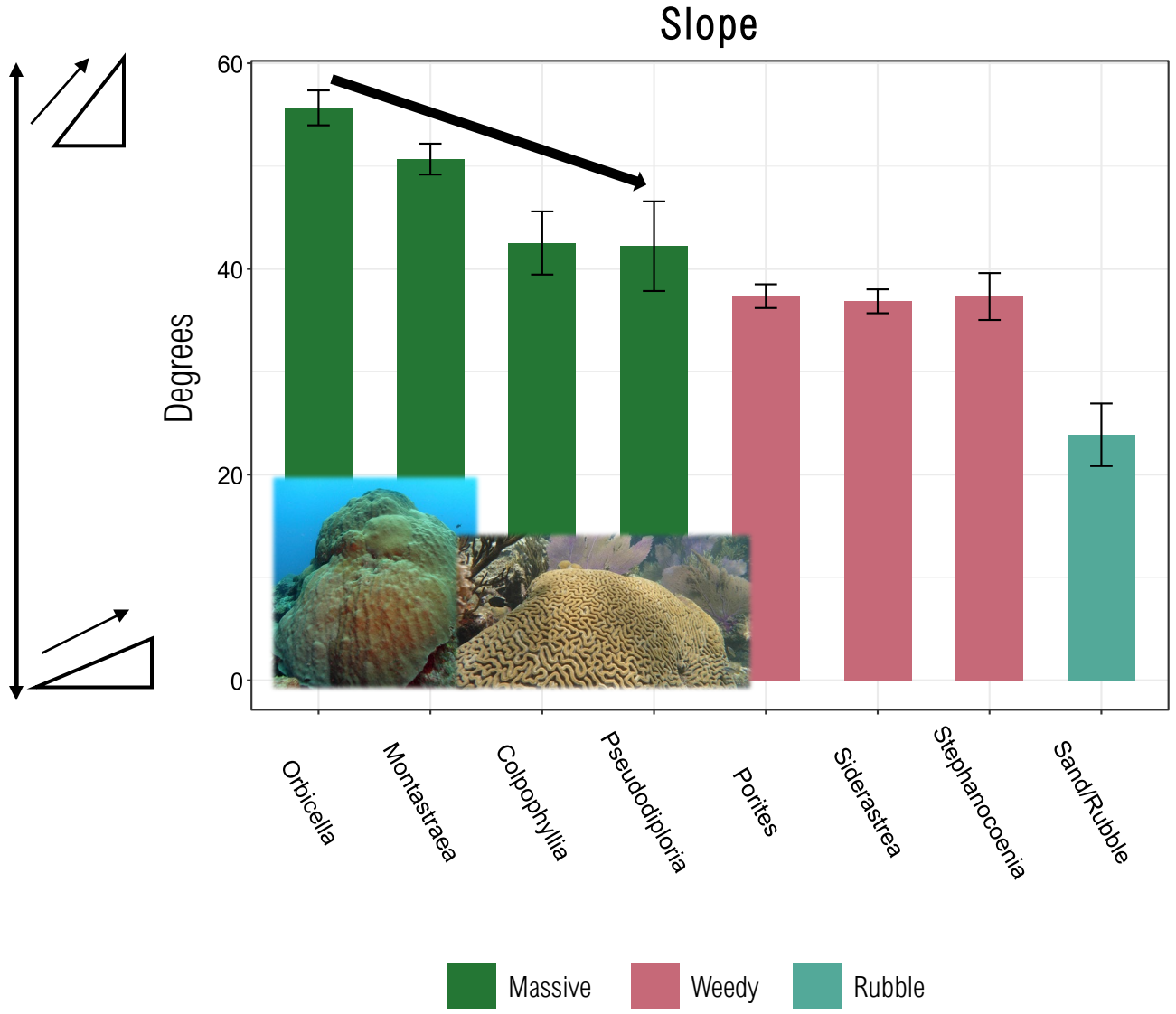

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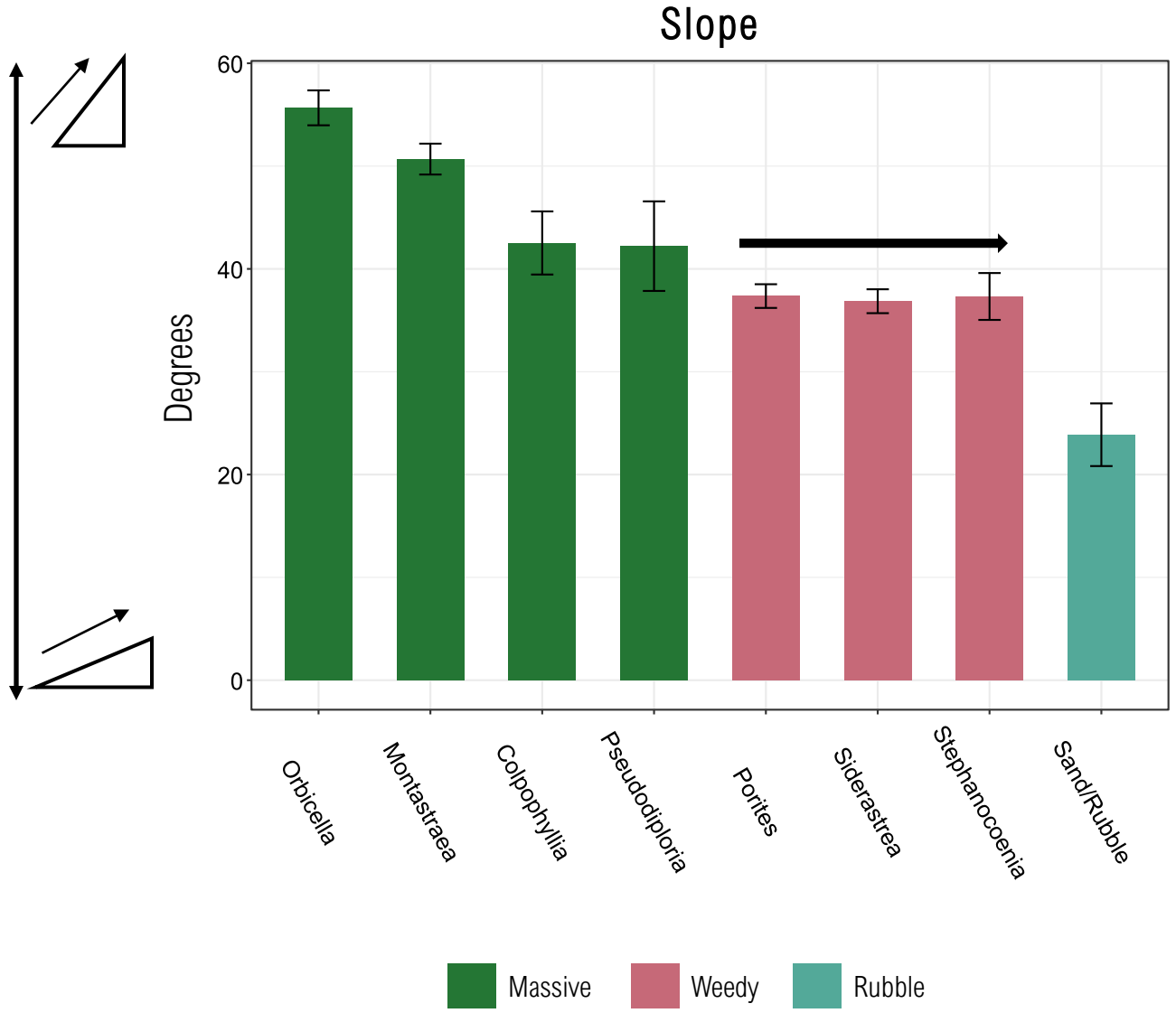
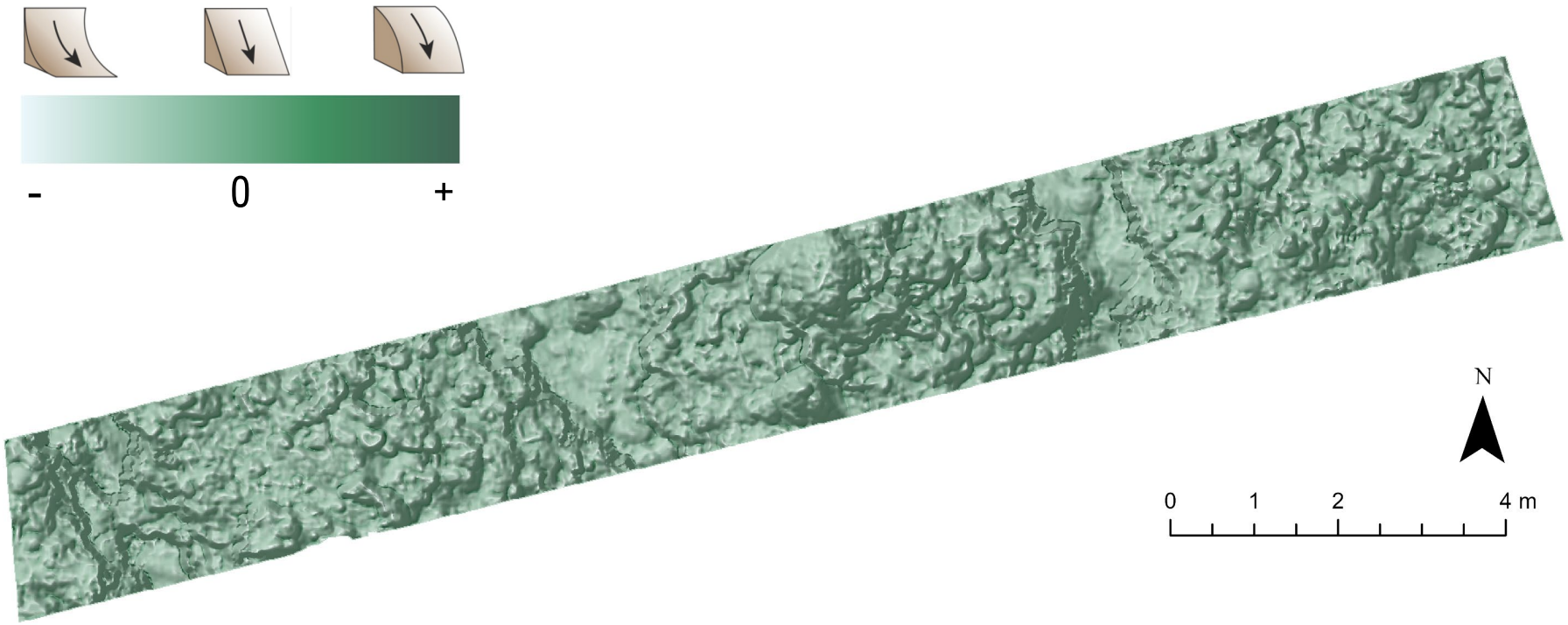


Terrain attributes

Curvature | **Profile curvature**

2nd derivative of slope - indicates horizontal **concave** (-) or **convex** (+) forms



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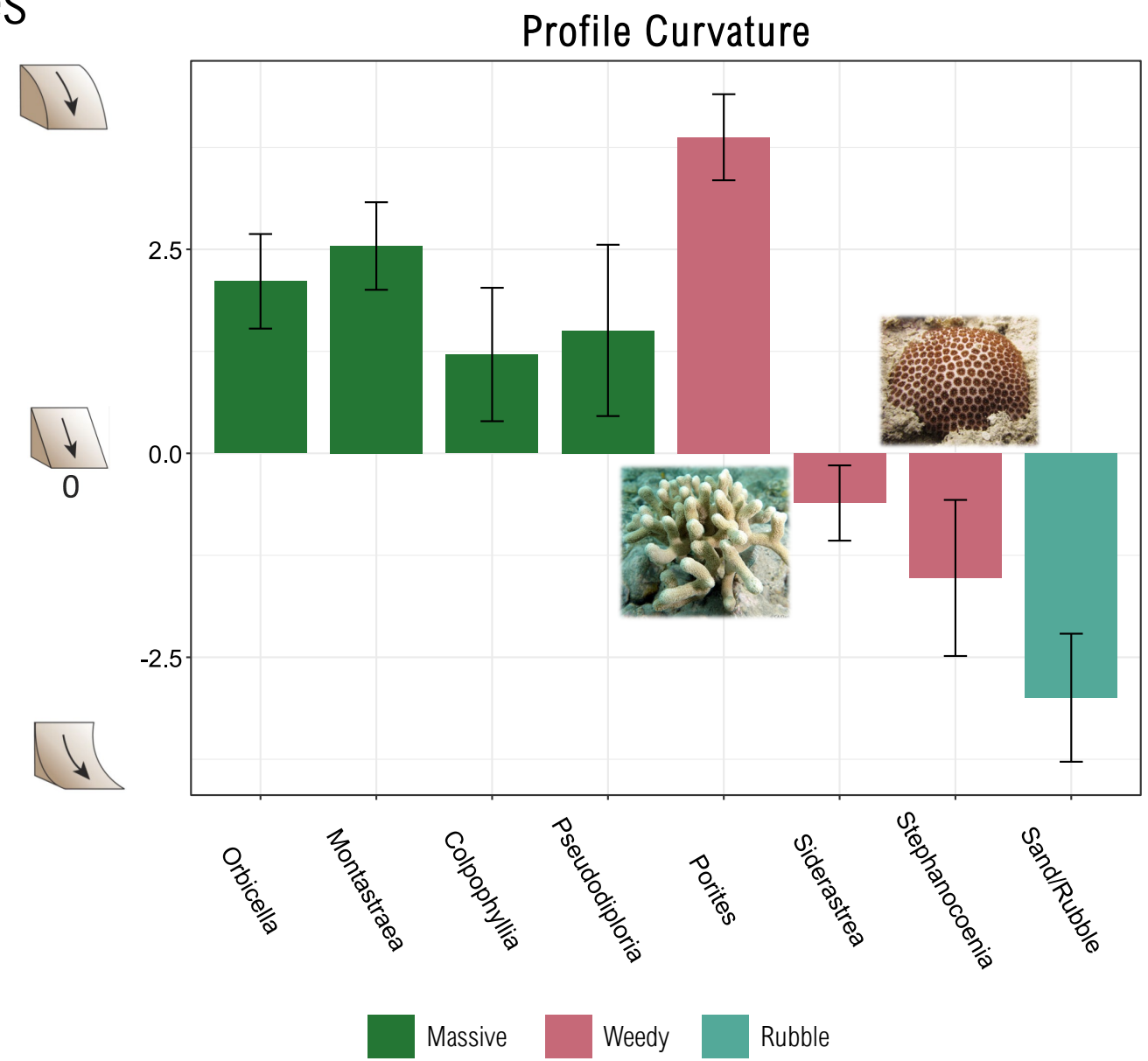
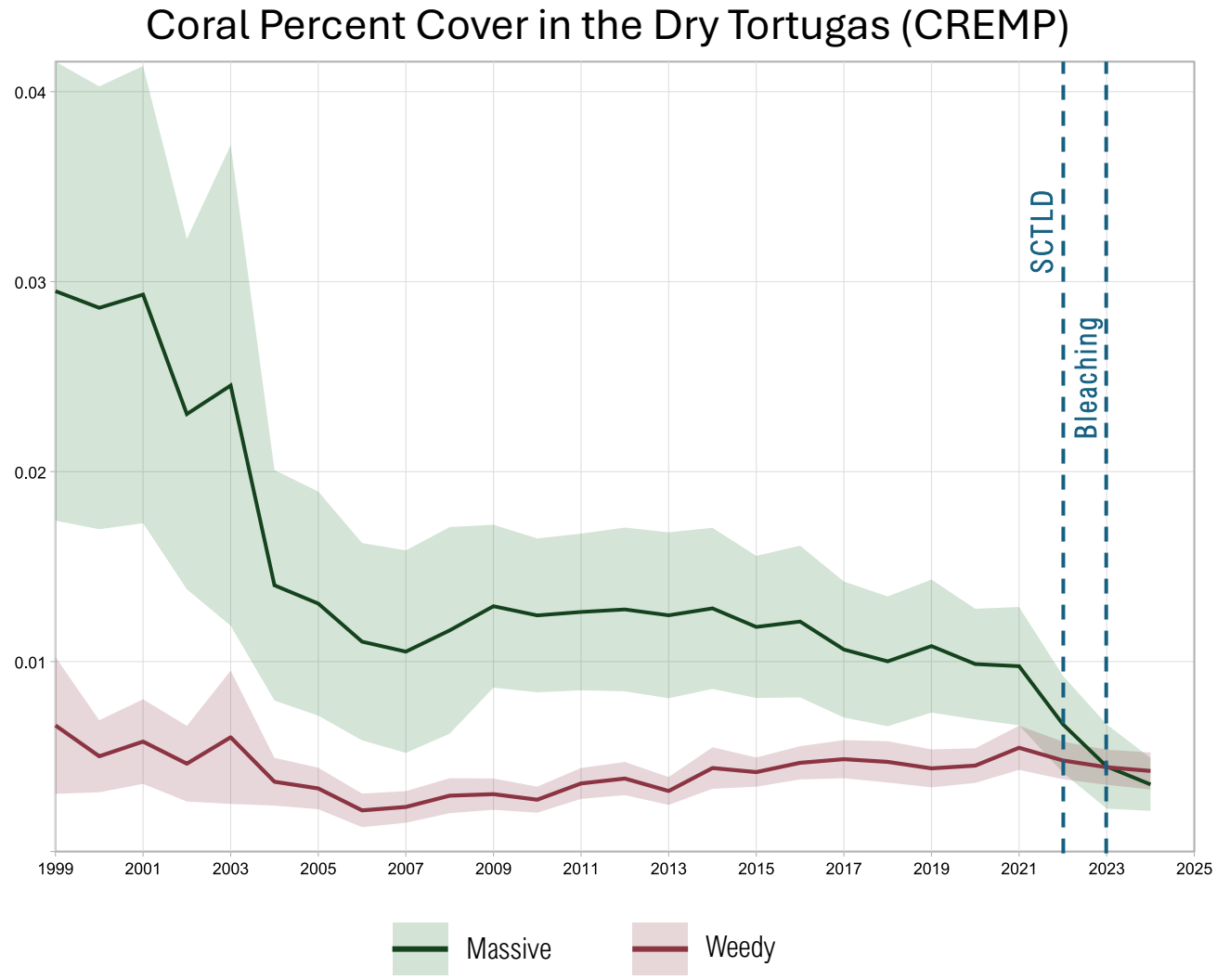


Summary of conclusions

MASSIVE CORALS

Exhibited highest complexity (TPI) and slope/positive profile curvature, indicative of steep topography with convex forms

Distinction between star corals and brain corals



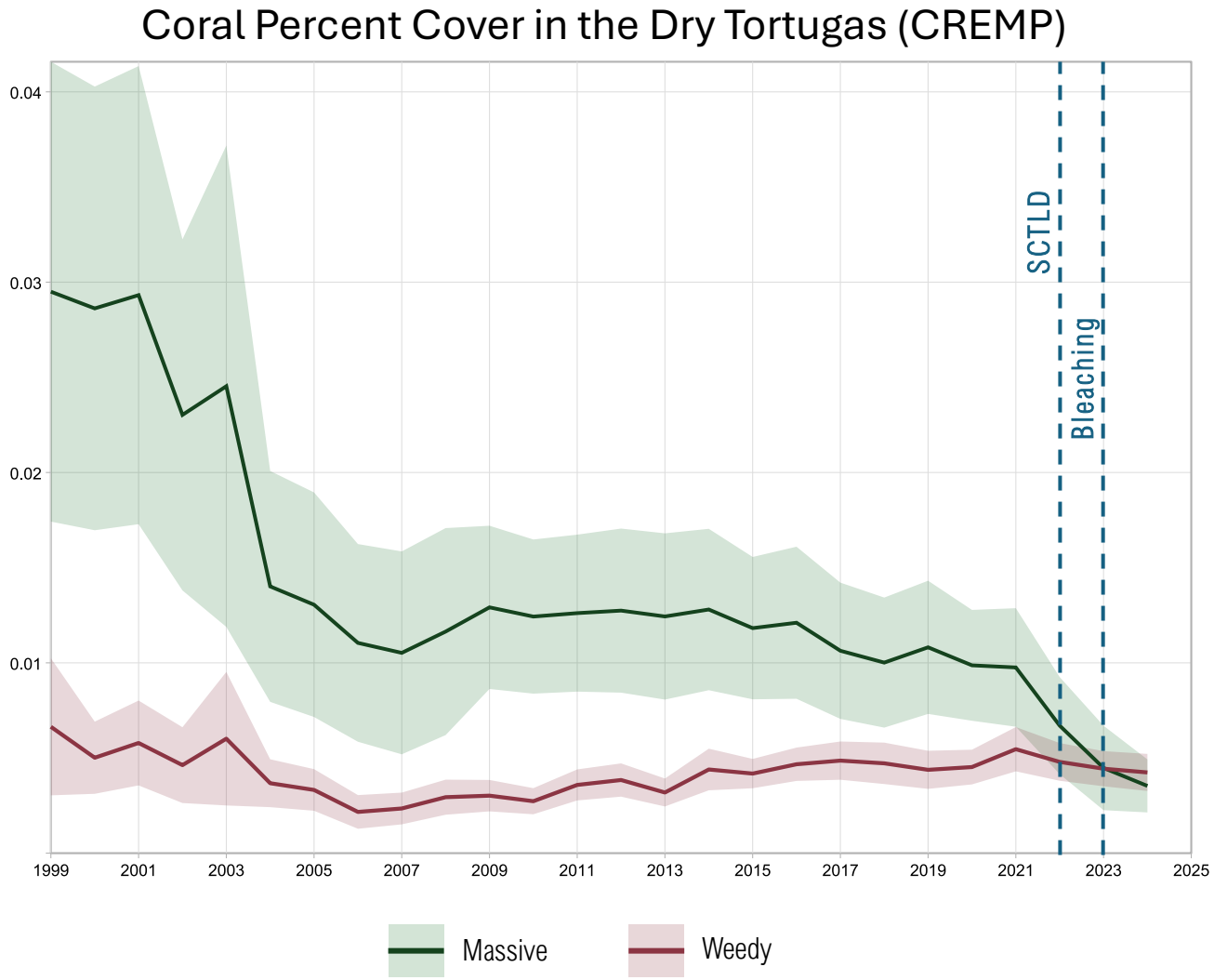
Summary of conclusions

WEEDY CORALS

Exhibited highest SAPA, although range in SAPA between all corals was narrow: artifact of only tracing live tissue

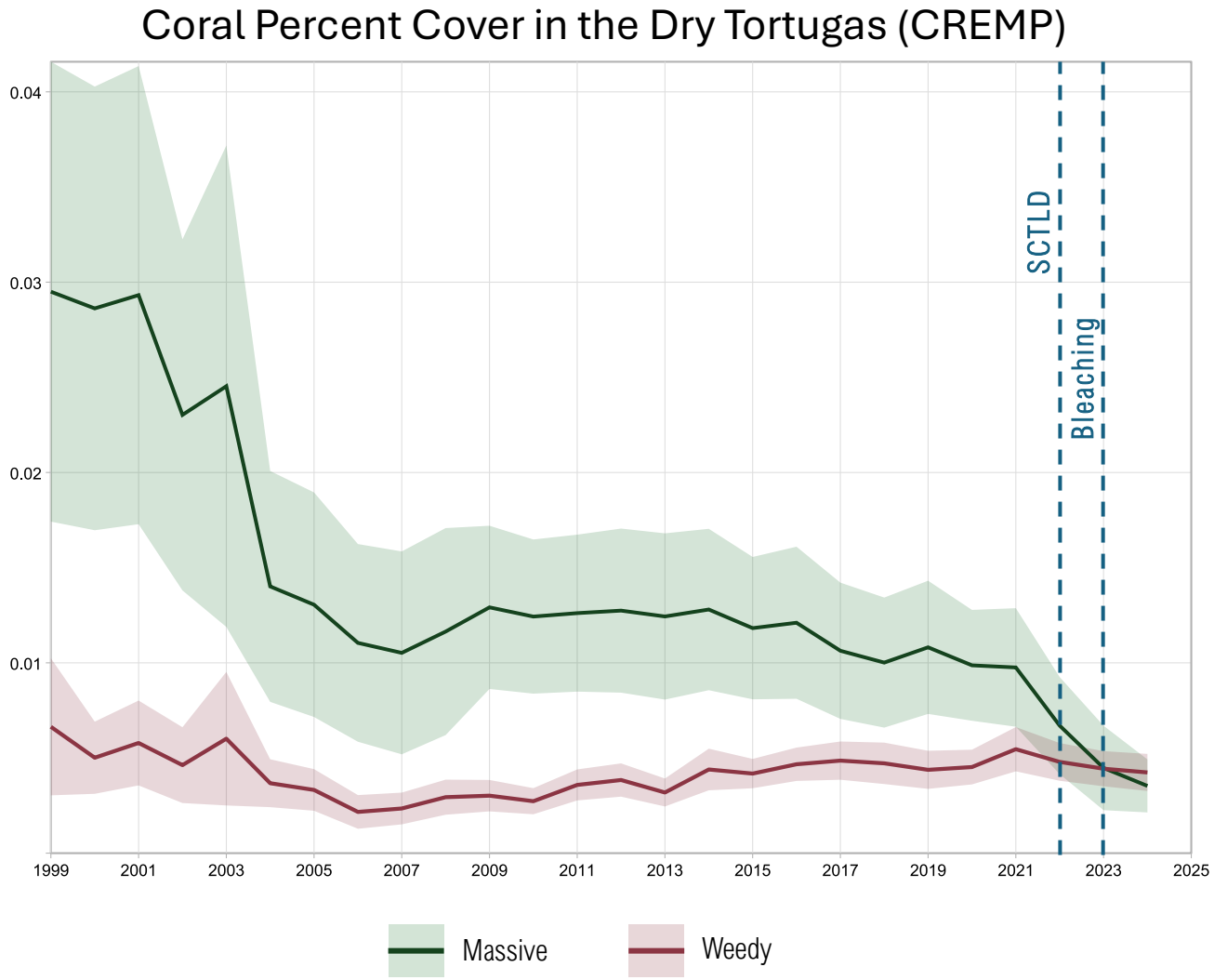
Porites exhibited highest complexity and positive profile curvature
- *Porites porites* is the only branching species to be included in analysis

Siderastrea & Stephanocoenia had lower slope and negative profile curvature, indicative of flat and concave form



Summary of conclusions

Quantifying structural "contributions" of susceptible genera helps to determine how reef functionality will be impacted in varying scenarios of decline



Significance & Future Directions

Methodology

SfM is an effective and accurate tool for cataloguing fine-scale topography – ‘topographic signatures’

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Changes Over Time

Continuation of imagery collection along CREMP transects to assess temporal changes in reef structure

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Ecological Context

Make predictions for how changes/loss in coral structure will impact ecological processes and reef organisms

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Restoration Context

Blueprint for prioritizing coral genera for nursery propagation and outplanting goals & monitoring tool for restoration sites

Acknowledgements

FWC Coral Reef Evaluation & Monitoring Project

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Bridging Ecological and Spatial Sciences

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