Modelling Cold Water Coral Growth with SPH

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Journal of Sea Research 192 (2023) 102358

Contents lists available at ScienceDirect

Journal of Sea Research

journal homepage: www.elsevier.com/locate/seares

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Smoothed particle hydrodynamics for modelling cold-water coral habitats in changing oceans

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Cite this article: Hennige SJ *et al.* 2021 Using the Goldilocks Principle to model coral ecosystem engineering. *Proc. R. Soc. B* **288**: 20211260.
https://doi.org/10.1098/rspb.2021.1260

Using the Goldilocks Principle to model coral ecosystem engineering

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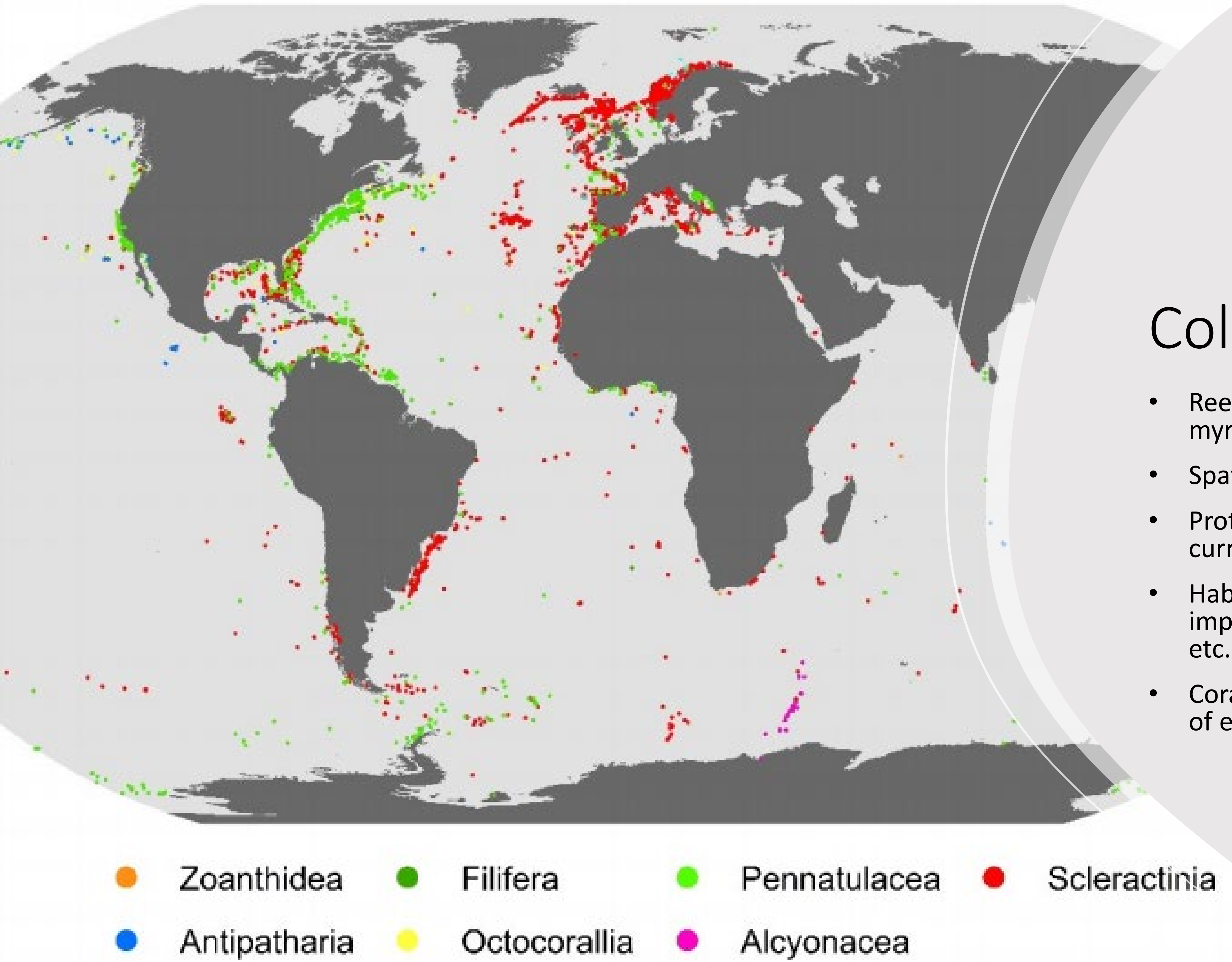


Cold Water Coral

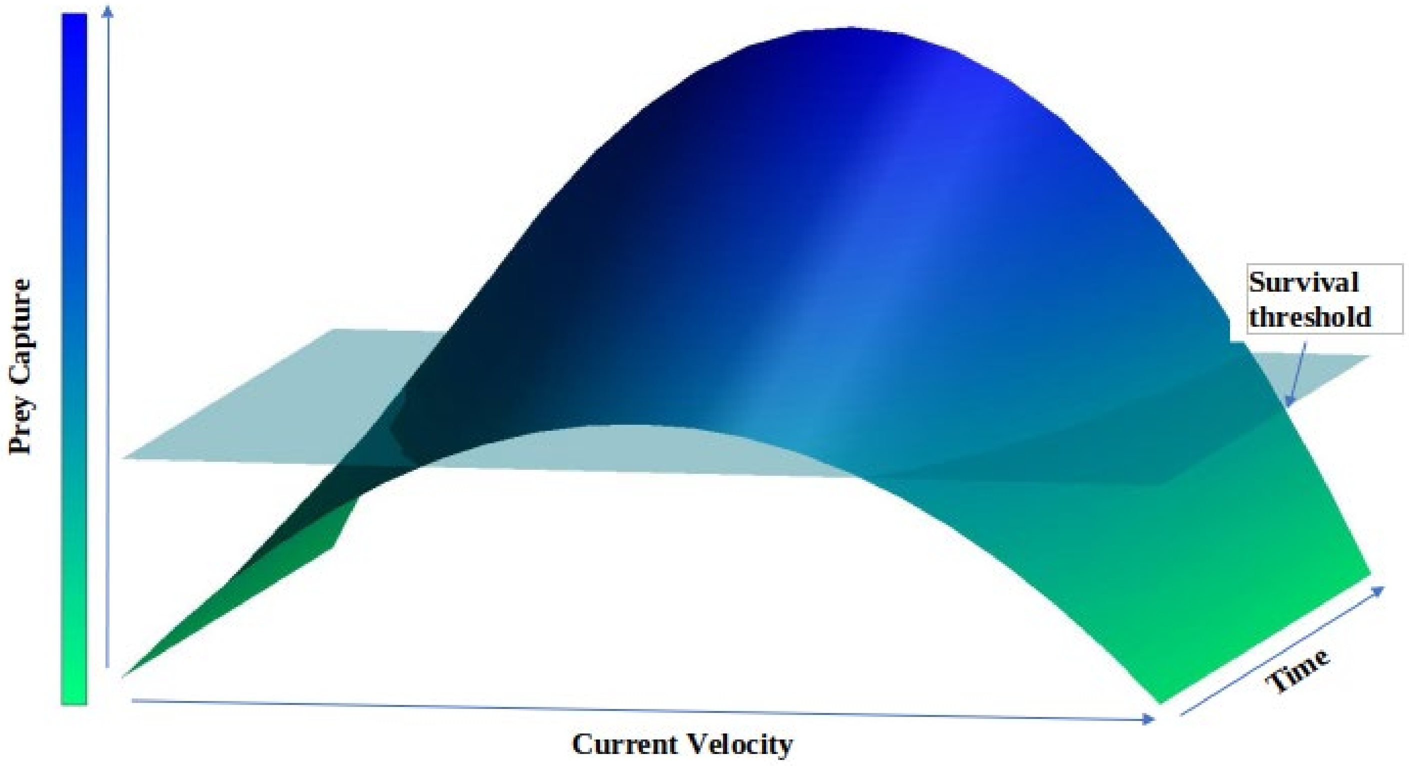
- Reefs provide habitat and support a myriad marine species (>40m)
- Spawning grounds / nurseries
- Protection from strong incoming currents
- Habitat frameworks for commercially important species (cod, halibut, crabs, etc.)
- Coral skeletons serves as paleoarchive of environmental conditions

Cold Water Coral

- Attaches to the exposed rocky surfaces
- Survival depended on ability of polyps to capture prey
- filter-feed on tiny organisms delivered by passing currents
- forms a dense matrix that creates habitat

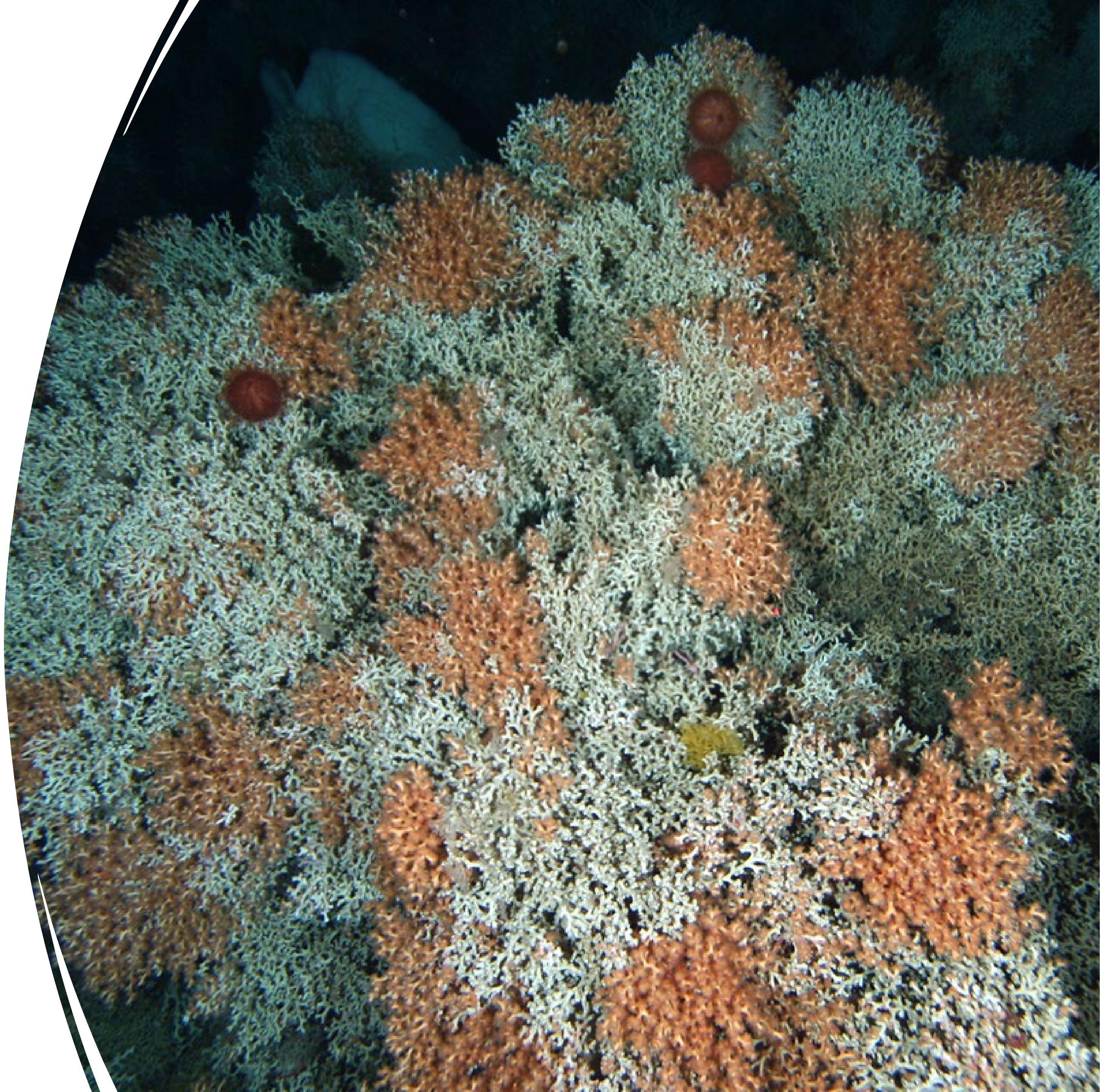
Goldilocks Principle

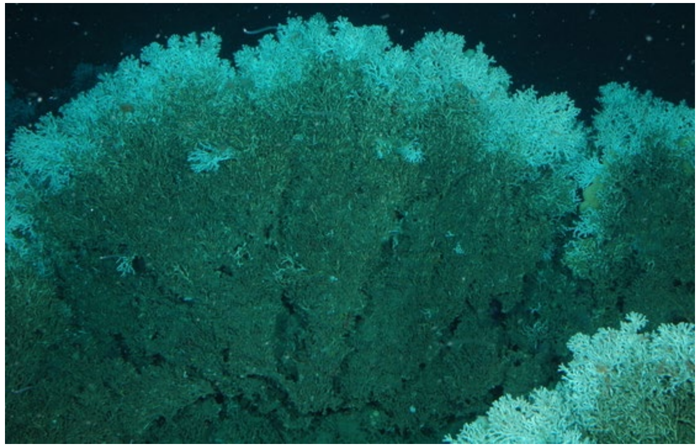
- The “survival threshold” is based upon prey capture.
- Not surpassing this threshold would lead to polyp mortality, leaving exposed “dead” framework.
- Individual polyps can surpass the threshold by either capturing prey in optimal conditions or sub-optimal conditions given adequate time

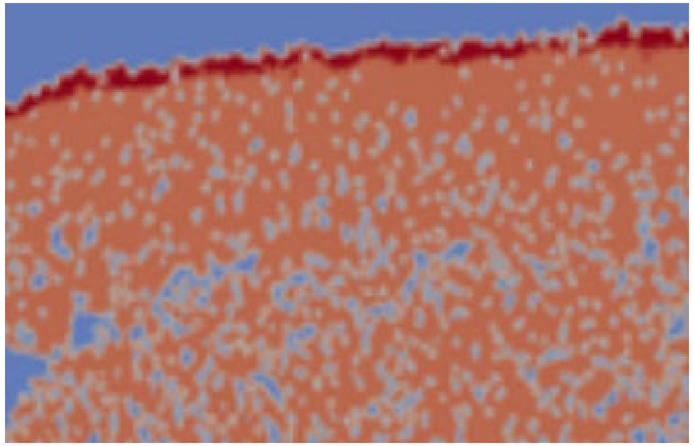


Growth Model

- The model is looking for zones of optimal velocity around a coral colony to identify the direction of growth. Branching occurs spontaneously.
- Growth and death is based on ‘energetic reserves’ – energy that corals can store during optimal conditions, after they meet their energetic demands.
- The energetic reserves decrease or increase dynamically according to the flow conditions.
- If the energetic reserves are depleted and a coral is still exposed to sub-optimal conditions, the coral will be considered dead





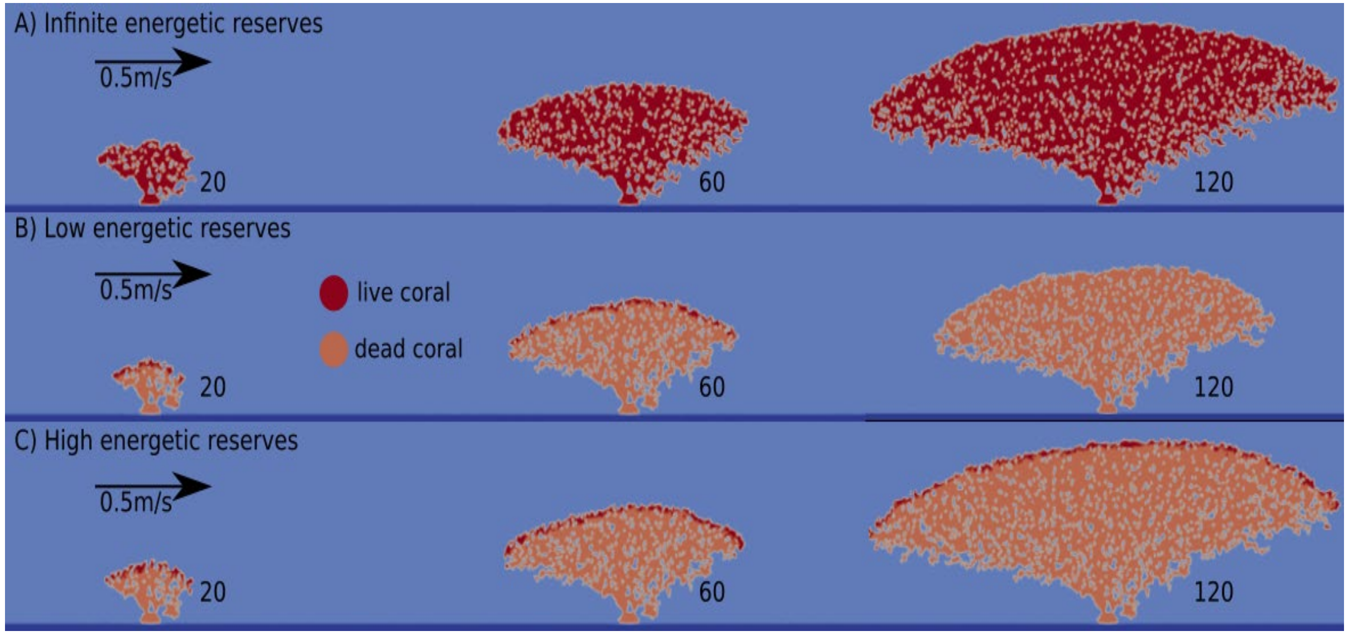


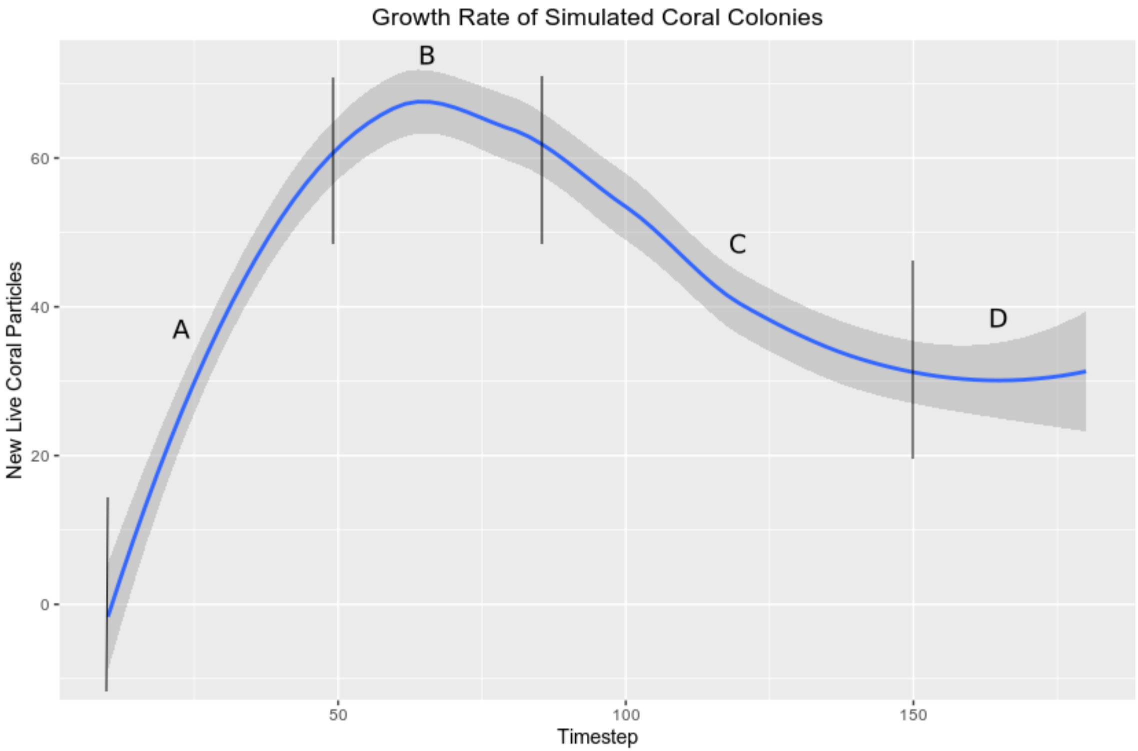
SPH Framework

- SPH provide means for dynamic FSI interaction
- Solves mass and momentum conservation
- Time integration only to monitor growth iteration
- Embed growth and death model

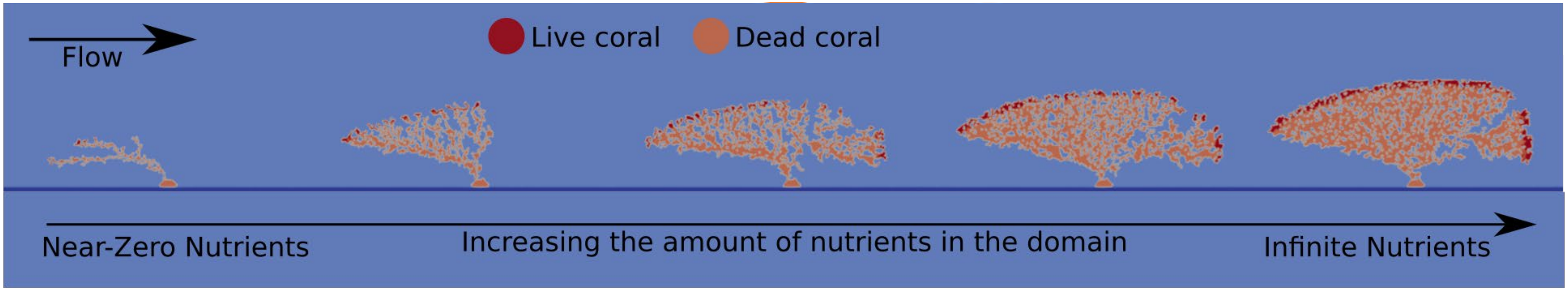
Energetic Reserve Growth Model

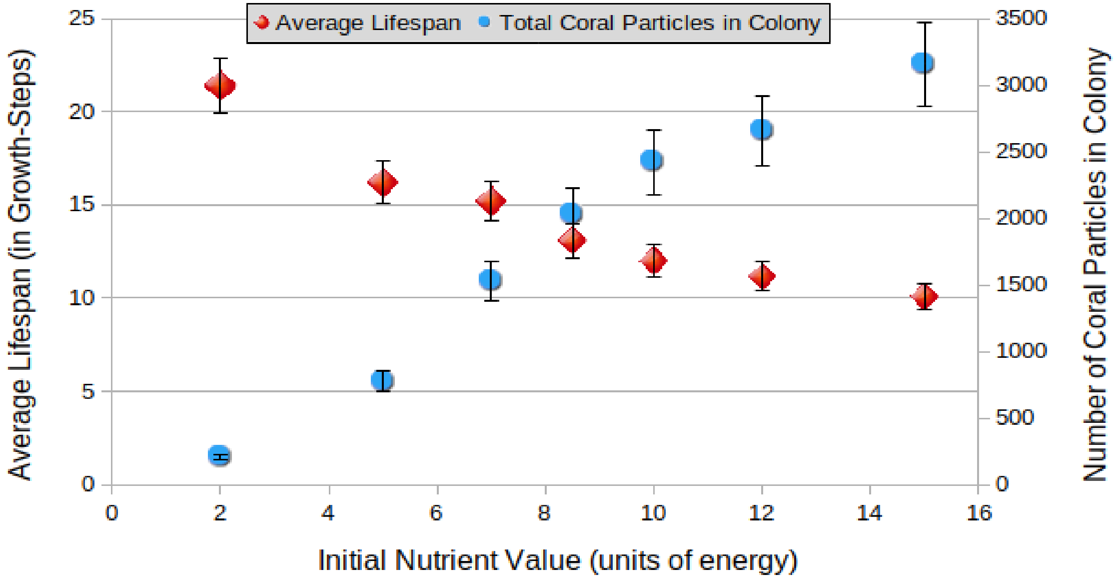
- *In situ* data from a recent study (Vad et al., 2017) showed that the ratio of live coral tissue to dead coral skeleton was between 0.1 and 0.27.
- Additionally, it was shown that the ratio dropped as the colony size became larger and larger.
- Both of these attributes are also true for the simulated corals.



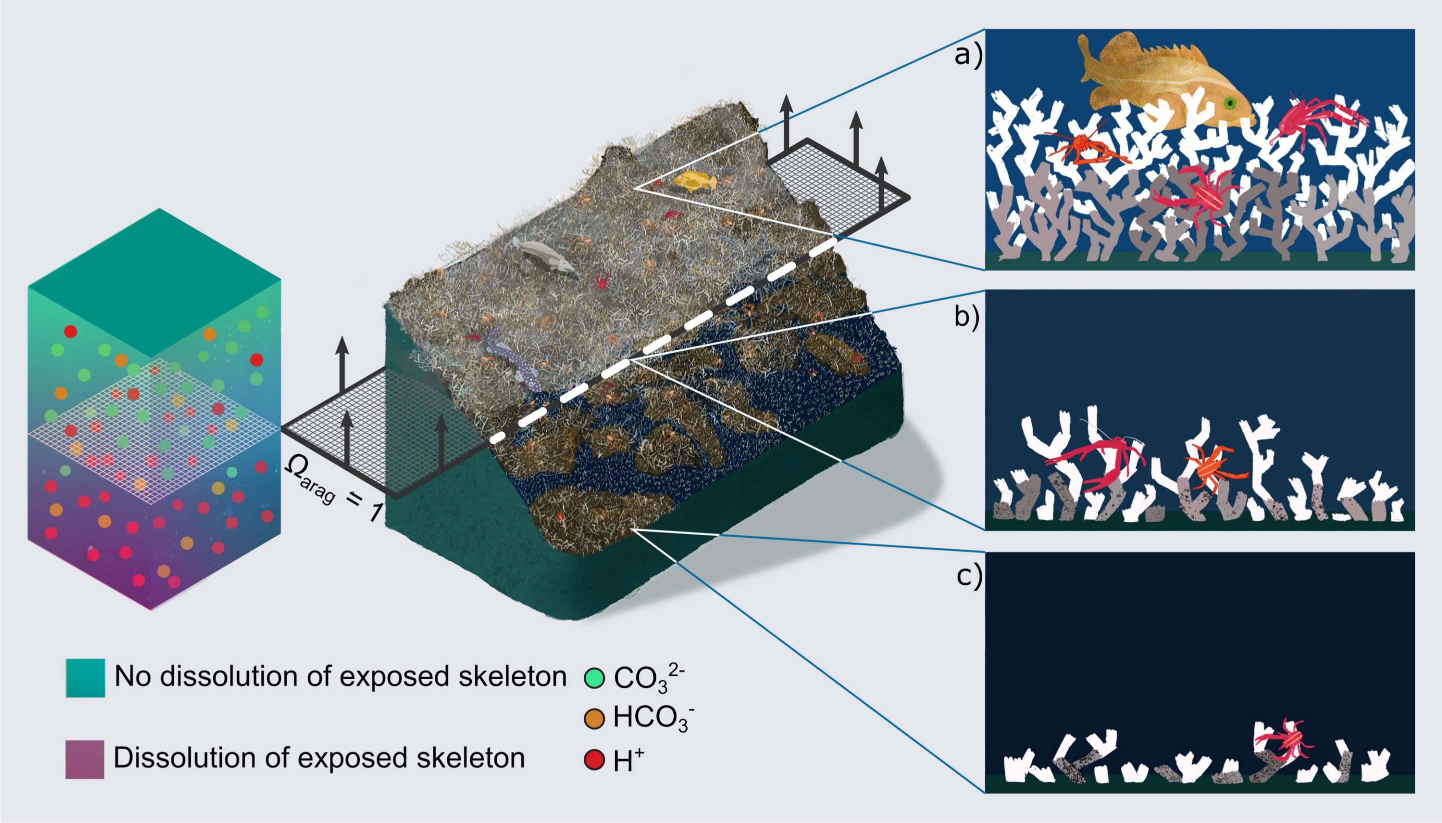


Nutrient Growth Model



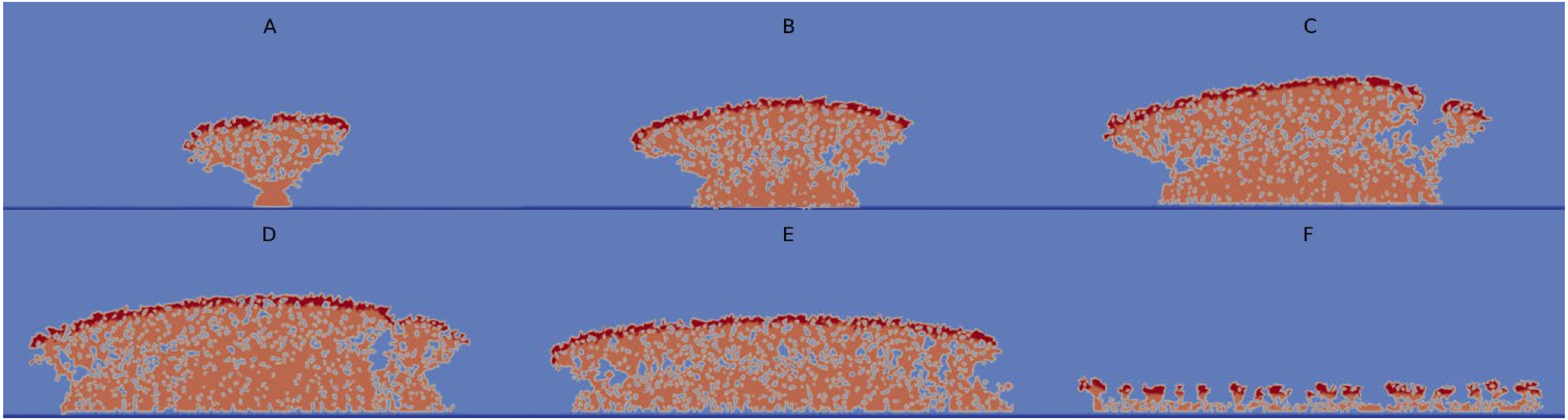


Acidification: Dissolution



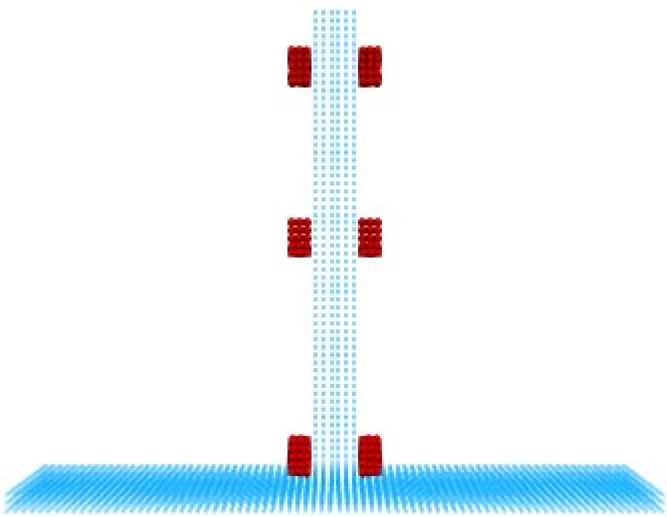
Acidification: Dissolution

Dynamic coral growth, while also increasing the water ‘acidity’ from A to F

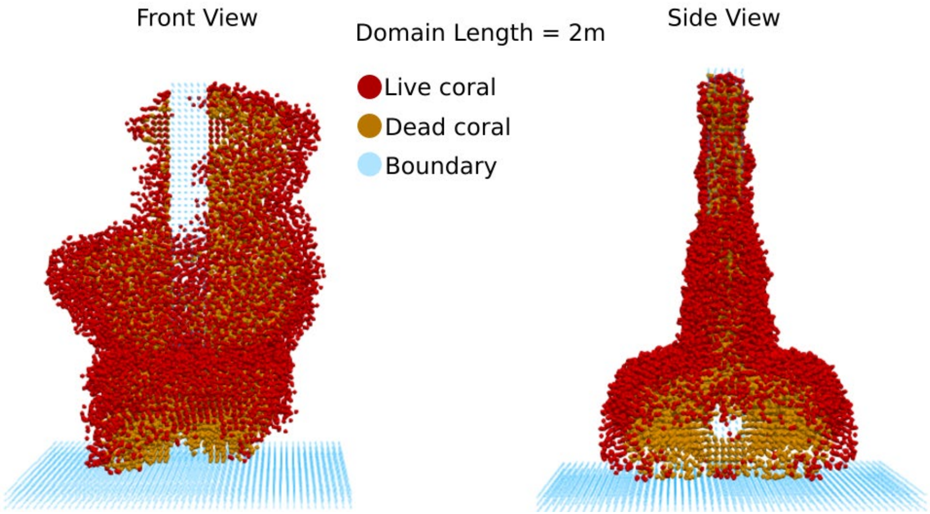


Restoration: FSI with Artificial Structures

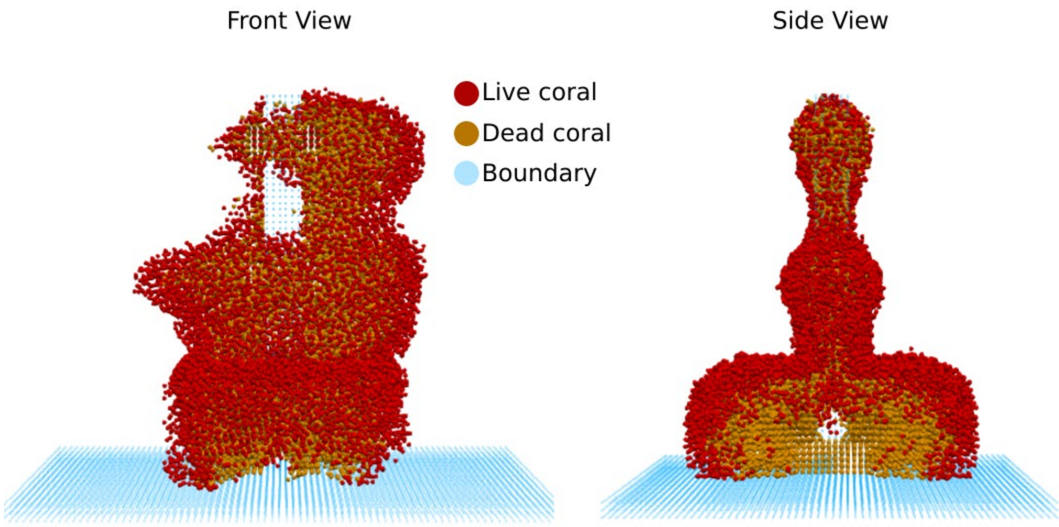
Varying monopile poles sizes



‘Control’

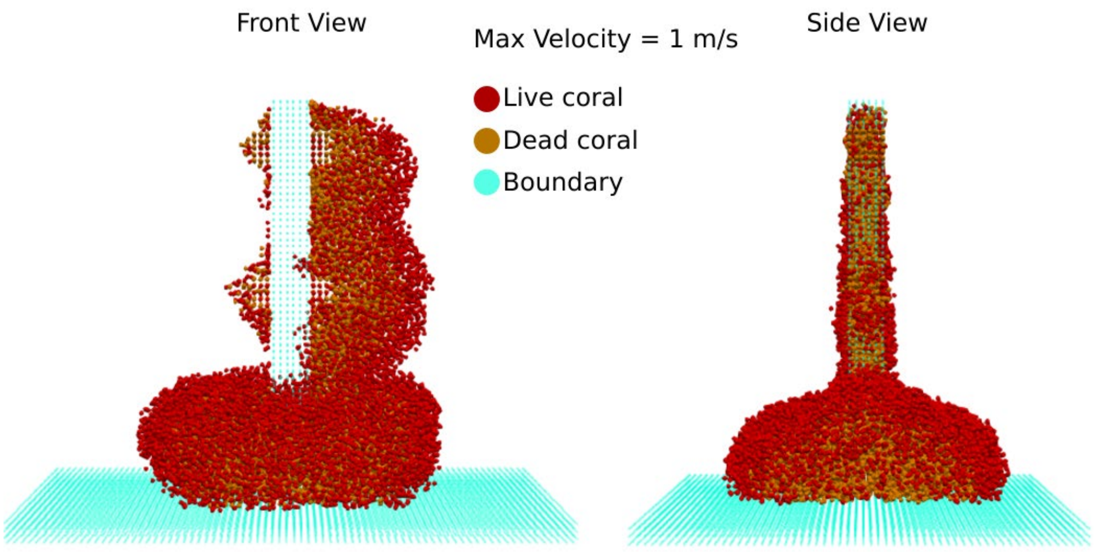


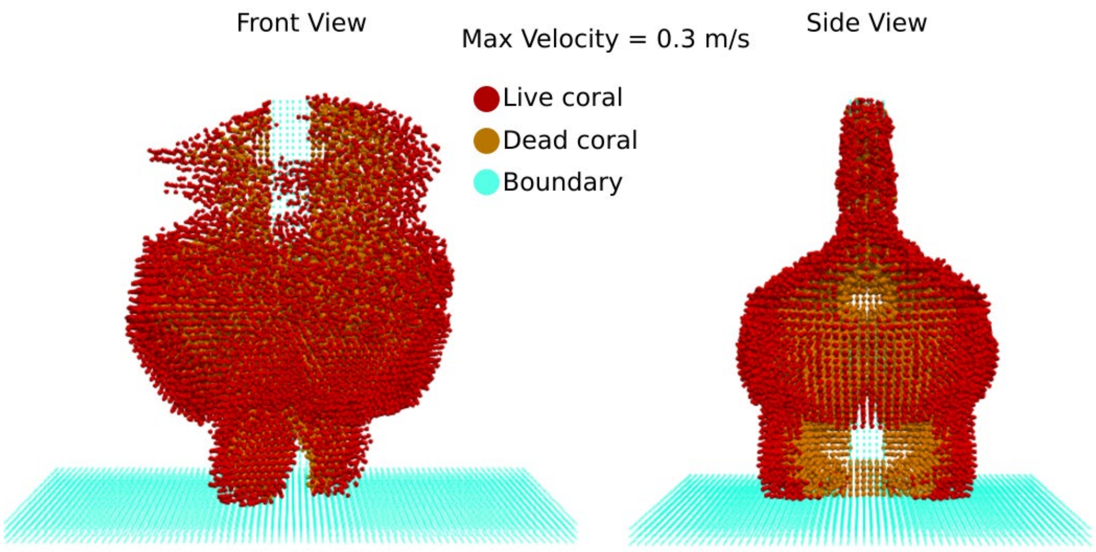
wider poles



Restoration: FSI with Artificial Structures

Varying current velocities





Future Challenges

- 3D models require large execution times – coupling with GPU-accelerated methodology would allow simulation of larger domains and more realistic environments

- To produce a complete model for real restoration practices, multiple variables need to be considered:
  - ➢ Local environmental data (currents), for tropical corals (sunlight, wave & tides)
  - ➢ Coupling with nutrient diffusion model, introduction of additional parameters (temperature, salinity, acidity)
  - ➢ The physical characteristics of the artificial structures
  - ➢ Spacing between the structures, positioning of coral colonies

Acknowledgement

- NERC Doctoral Training Partnership (grant no. NE/L002558/1)
- Interreg EUROSWAC (Project 216)