Resolving biogeographic patterns in the deep sea using species distribution modeling

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Biogeography of *Lophelia pertusa*

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1. What niche space does *L. pertusa* occupy in the Gulf of Mexico?
2. What is the likely distribution?
3. Can we predict occurrences accurately enough to inform field operations?

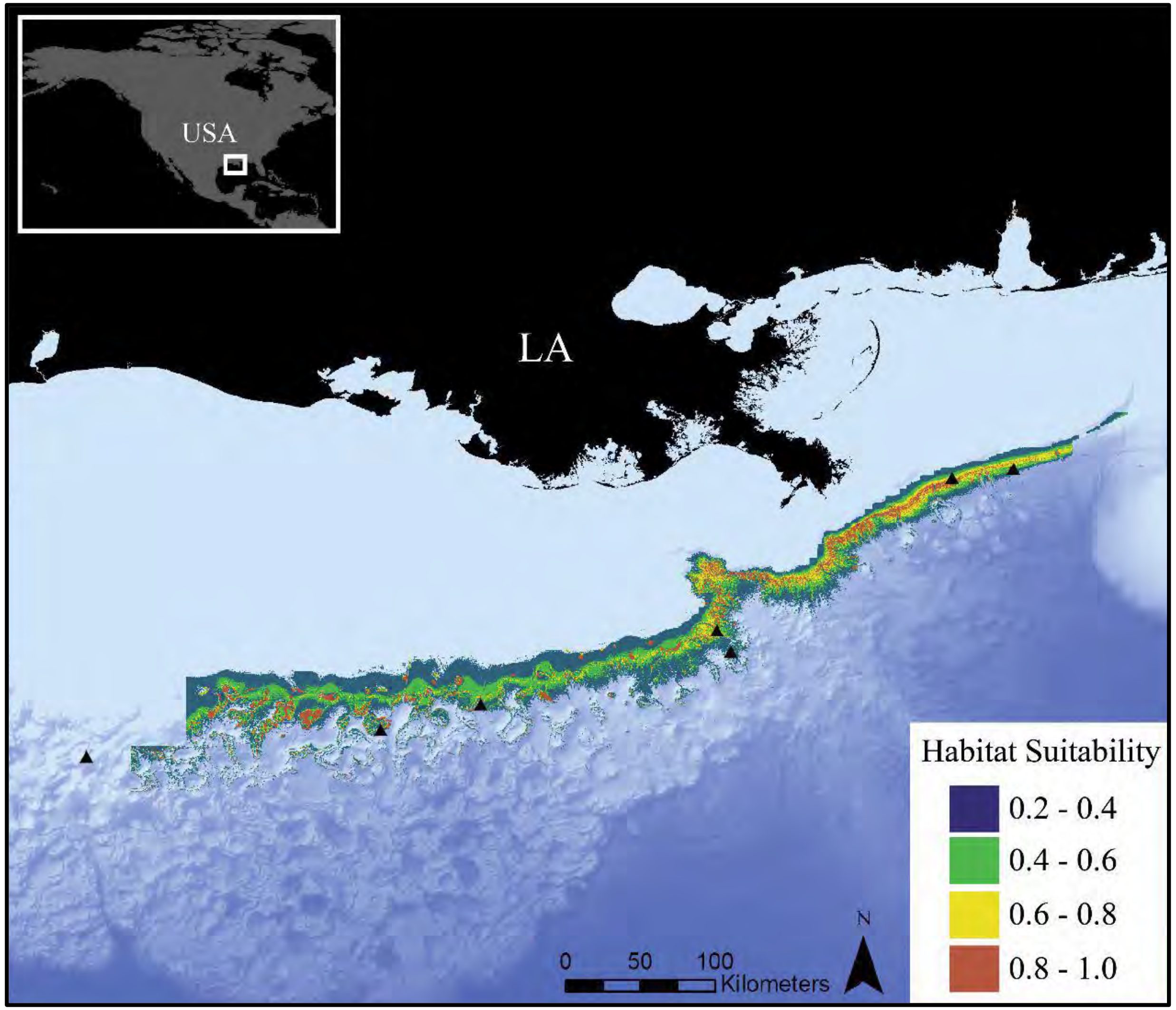
BOEM
Bureau of Ocean Energy Management

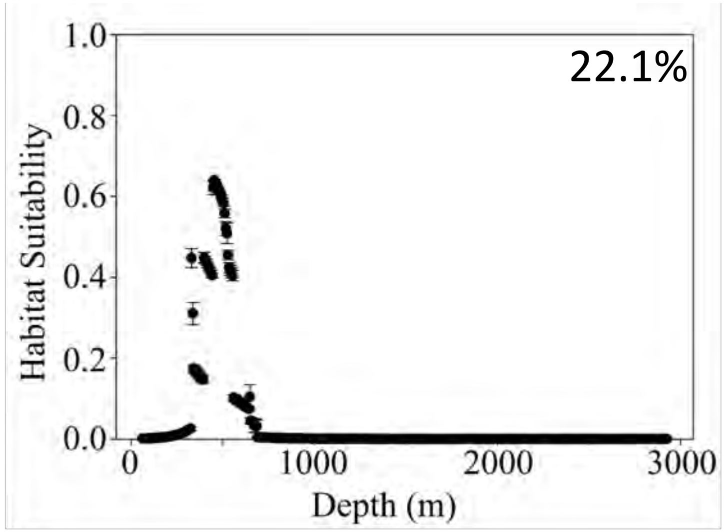
Erik Cordes
William Shedd

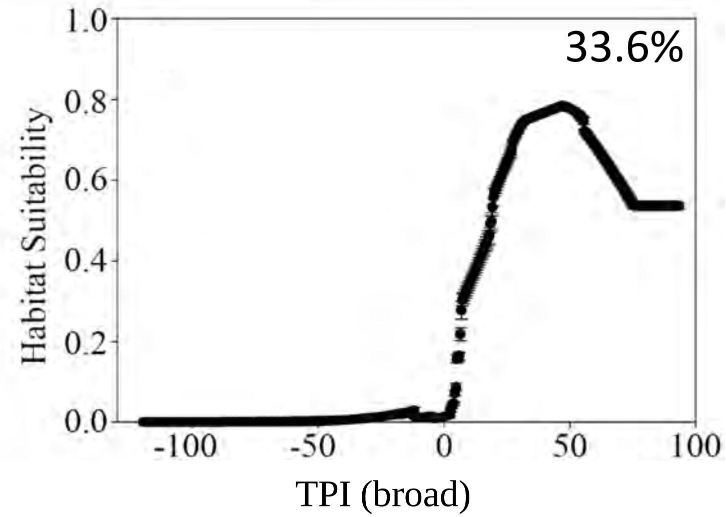
Maxent Modeling

- Broad scale model: 25 m
- Fine scale models (7 sites): 5-8 m
- Variables:
  - -Rugosity
  - -Slope
  - -Eastness/Westness
  - -Curvature (plan/profile/tangential)
  - -Seismic (hard bottoms)
  - -Topographic Position Index (fine/broad scales)
  - -Omega aragonite
  - -POC flux

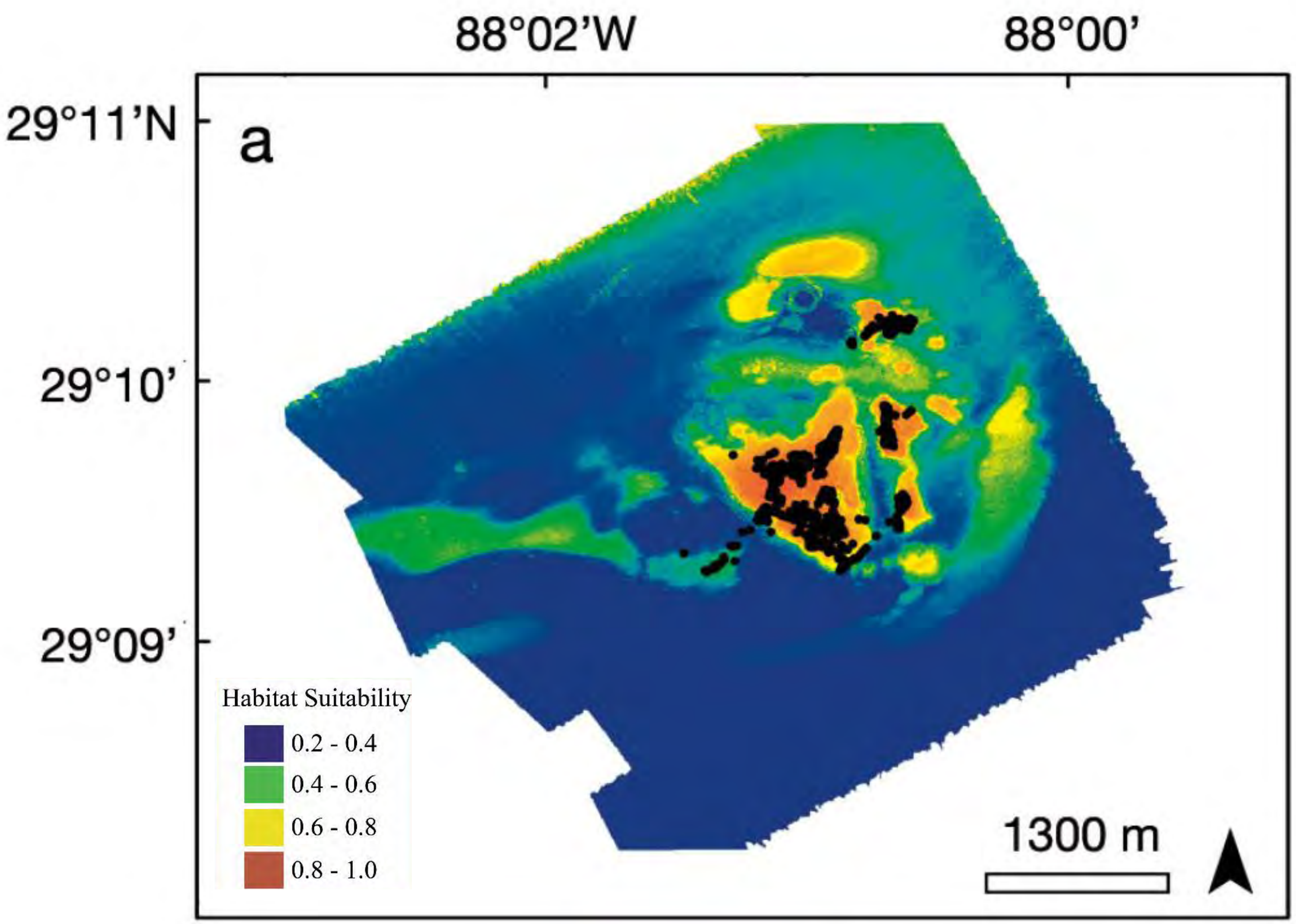
Broad scale (25 m) model

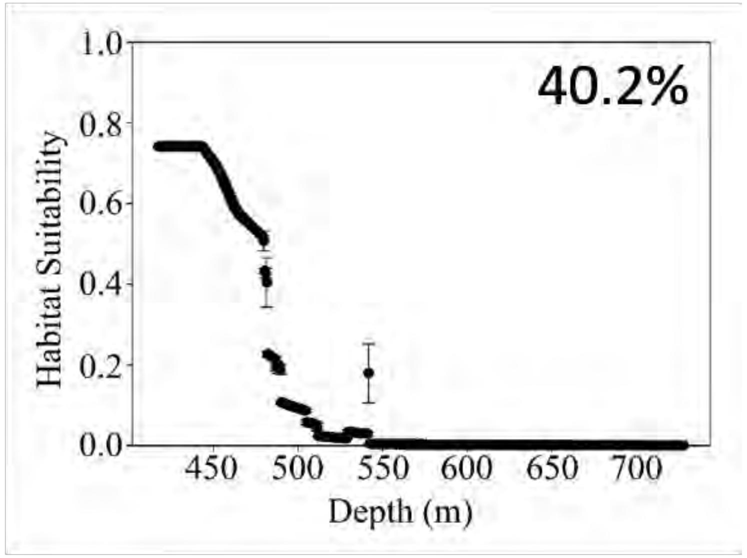


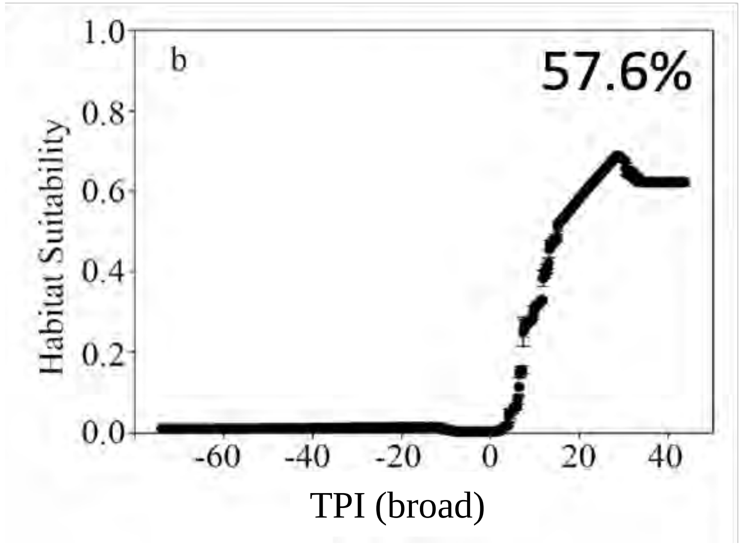




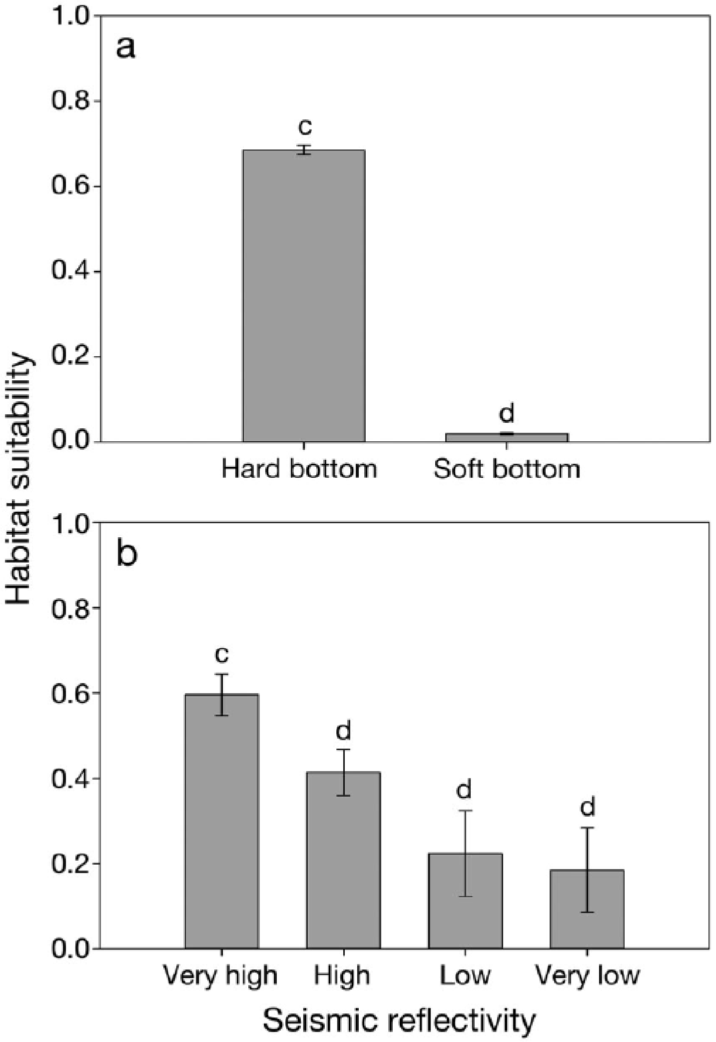
Viosca Knoll 826 model







Importance of hard substrate

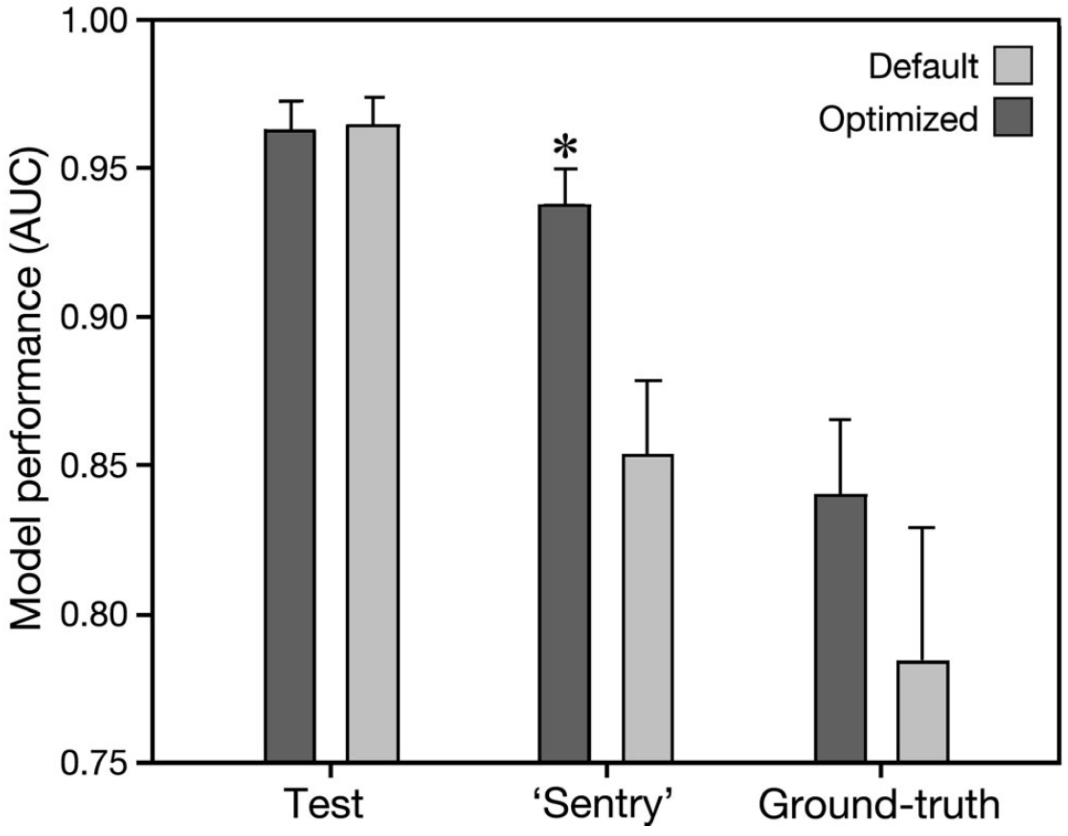


- Broad scale model
- Location of hard bottom polygons from BOEM seismic and geologic data analysis
- Model contribution: 43%

- Fine scale model
- Binning of high-resolution seismic reflectivity survey at each site
- Average model contribution: 25%

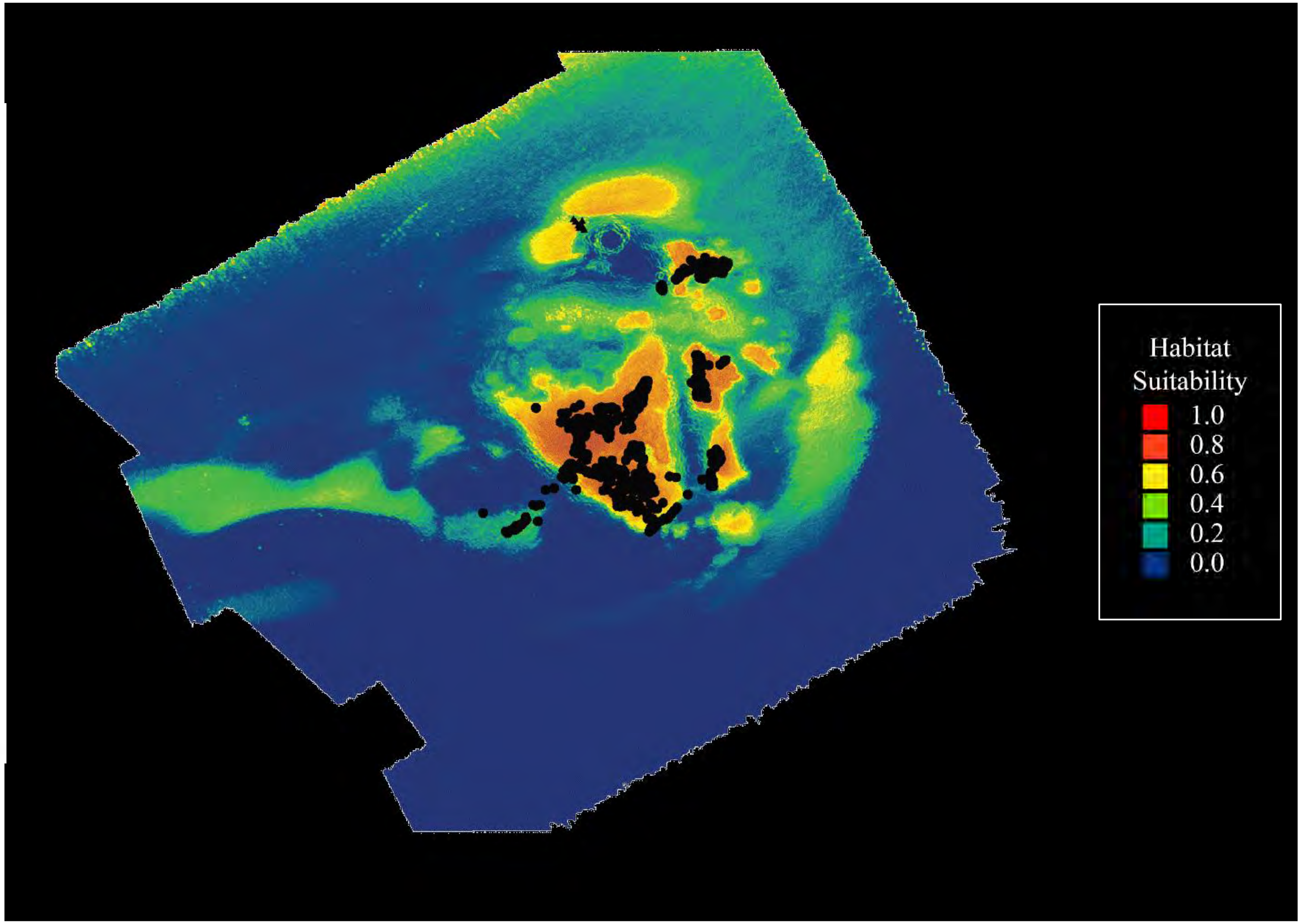
Model validation

- Regularization parameter tuned
  - Controls model complexity
- Model performance assessed via:
  - Training data (75%)
  - Testing data (25%)
  - Ground-truthing data
  - Independent AUV survey
    - 7 random transects over site
    - 3,000+ images analyzed

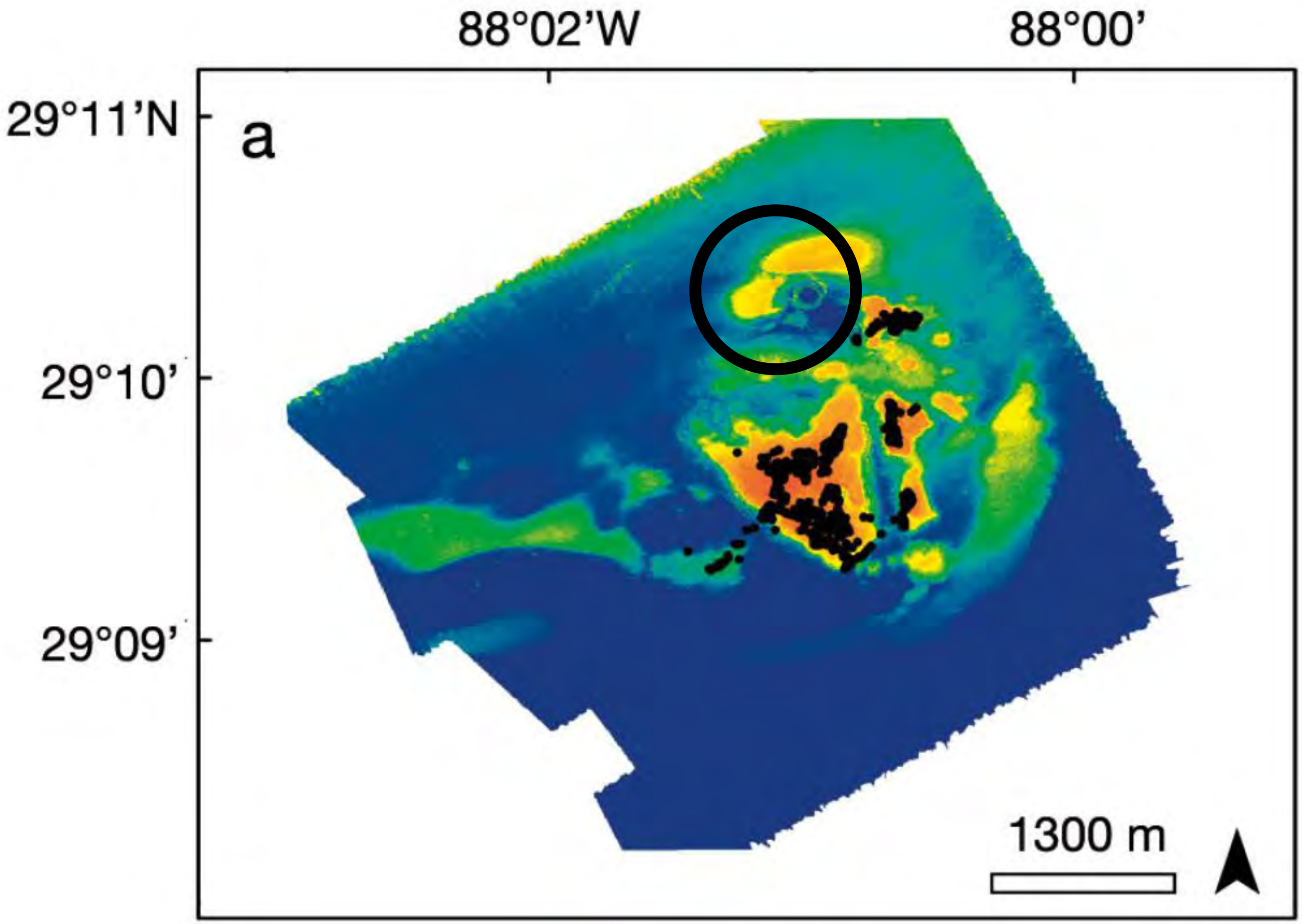


Transferability of the model

Site	AUC 'Sentry'	AUC Ground truth	Spearman's ρ	Overlap (*I*)
Viosca Knoll				
VK826	0.972	0.928		
VK862/VK906	0.961	0.881	0.813	0.891
Mississippi Canyon				
MC751	0.926	0.769	0.256	0.456
MC885	0.952	0.847	0.564	0.714
Garden Banks				
GB535	0.958	0.891	0.643	0.895
Green Canyon				
GC354	0.914	0.820	0.550	0.782
GC234	0.878	0.742	0.643	0.721



Groundtruthing Viosca Knoll



Groundtruthing Viosca Knoll

Conclusions

- *L. pertusa's* distribution delineated with a few variables*:* substrate, terrain, depth
- Clear preference for elevated, irregular topography with hard substrate
- Not hard to get models that perform well, need independent validation and ground-truthing
- Default settings test well but do not transfer to new sites
- Likely many undiscovered *L. pertusa* sites in the Gulf of Mexico

Ecological speciation in the deep sea

- How is diversity in the deep-sea generated?
- Testing the depth-divergence hypothesis (Rex & Etter 2010)

Key Questions:

1. Do closely related species of cold-water corals occupy distinct ecological niches?
2. Is niche divergence important in the evolution of these species?

Temple University
Erik Cordes
Andrea Quattrini

Maxent Modeling

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- Resolution: 5, 25 m
- Variables:
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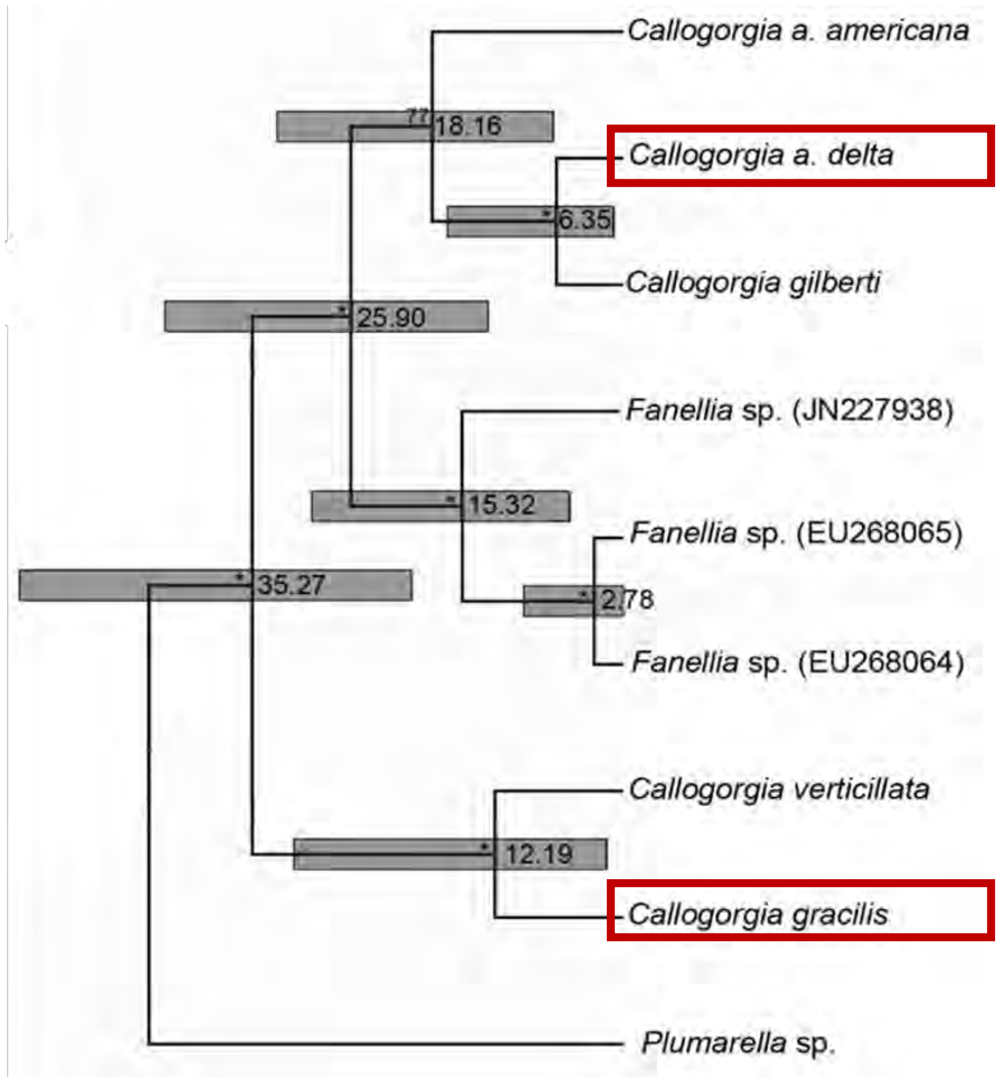
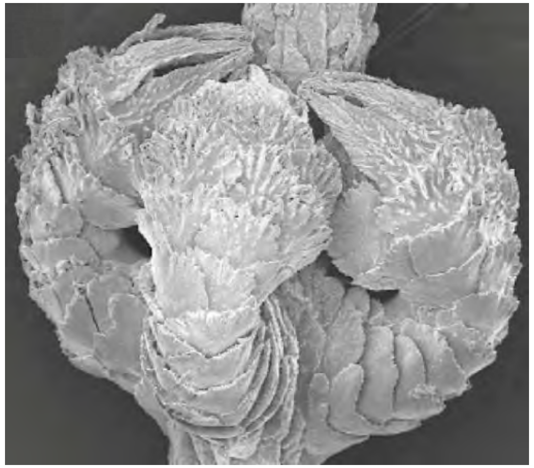
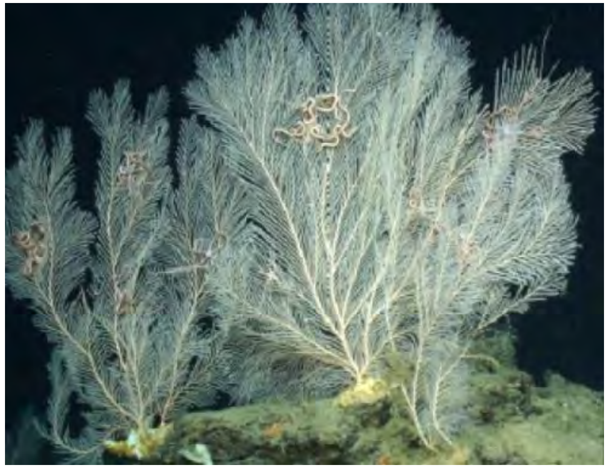
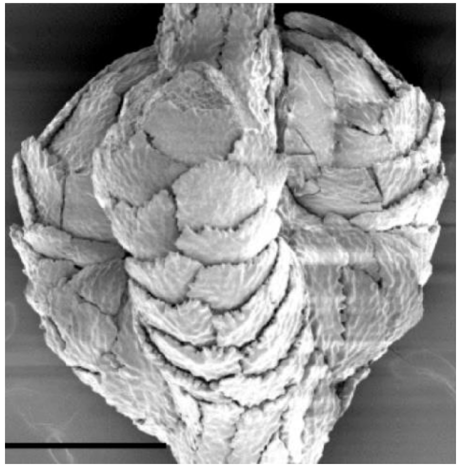
  - -Slope
  - -Eastness/Westness
  - -Curvature (plan/profile/tangential)
  - -Seismic (hard bottoms)
  - -Topographic Position Index (fine/broad scales)
  - -Omega calcite
  - -POC flux
  - -Dissolved oxygen
  - -Salinity
  - -Temperature
  - -Presence of seep

Genetically and morphologically distinct









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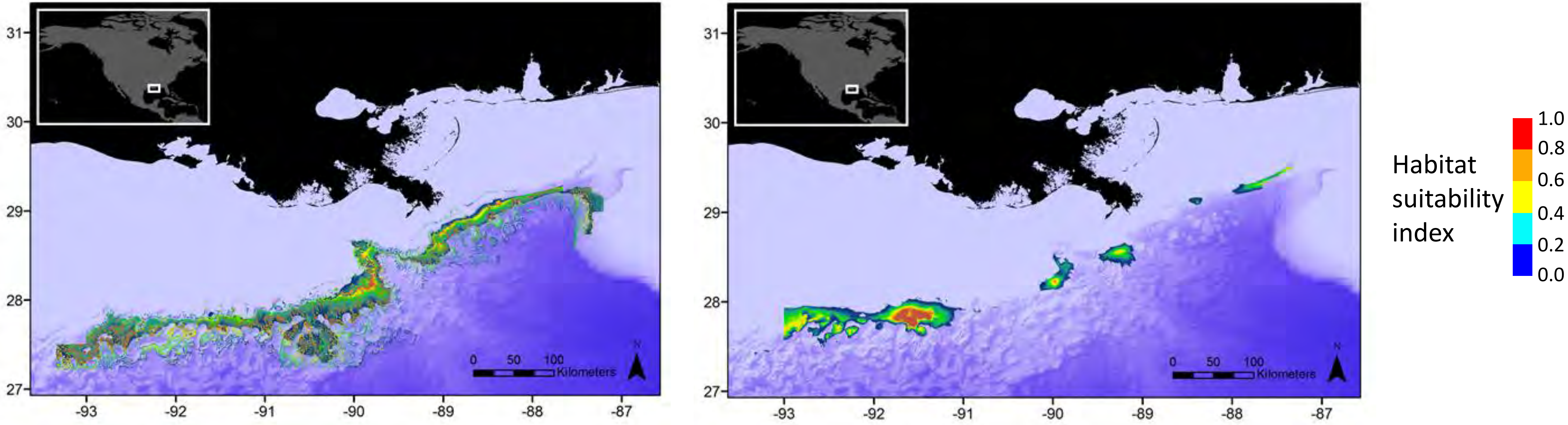
Ecologically distinct?

C. a. delta

C. gracilis



Callogorgia niche space

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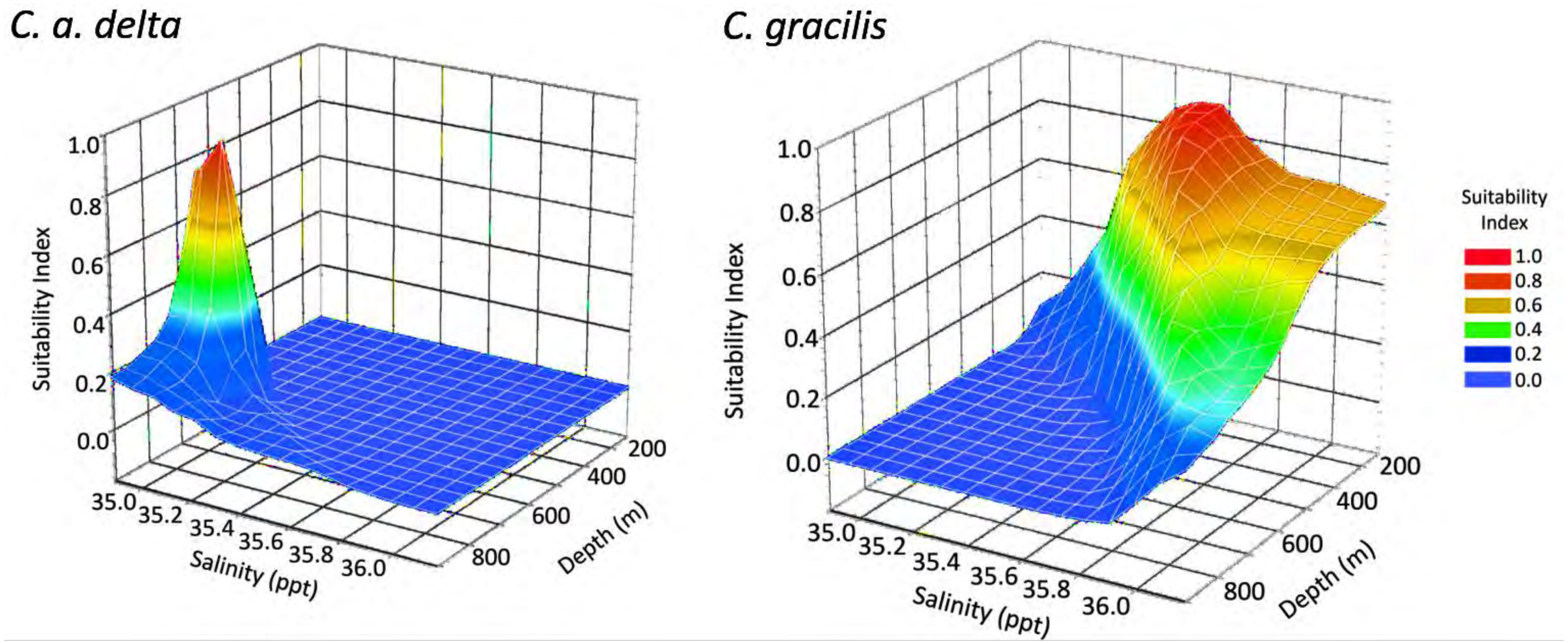
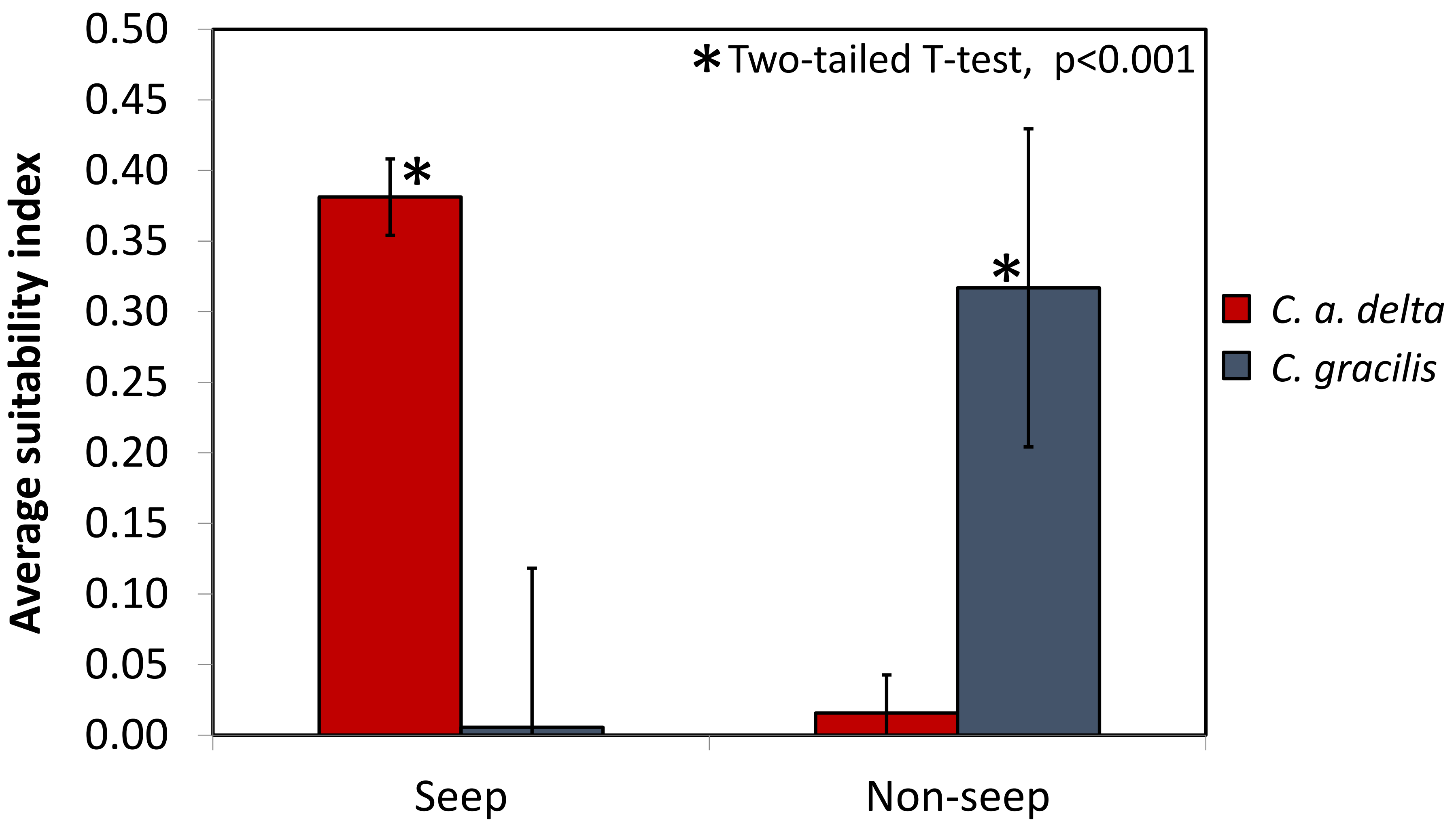


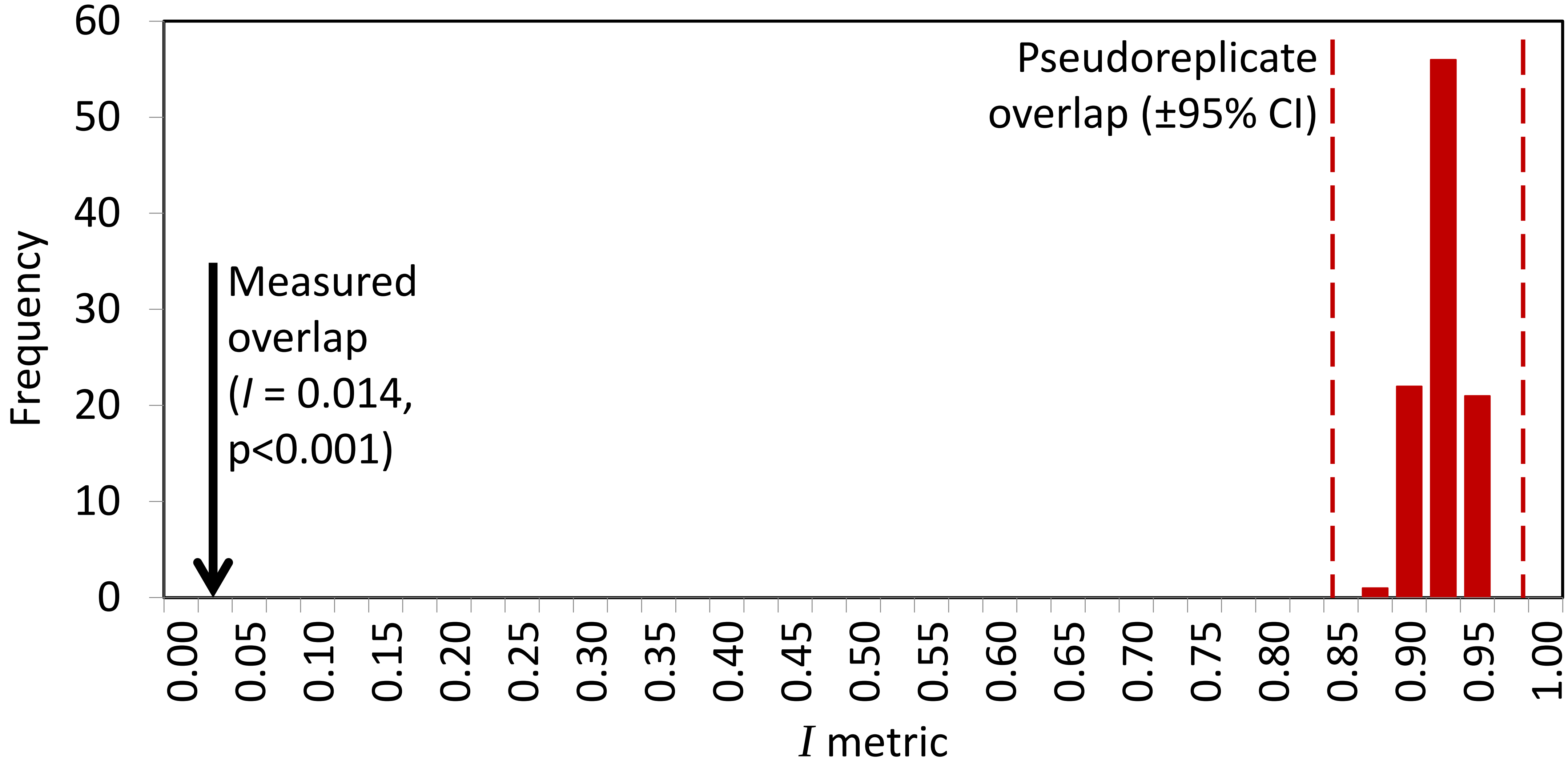
Seep presence – 58.3%
Calcite – 19.8%
Salinity – 9.4%
AUC=0.995±0.002

Depth – 70.6%
Salinity – 10.7%
Dissolved oxygen – 9.3%
AUC=0.977±0.004

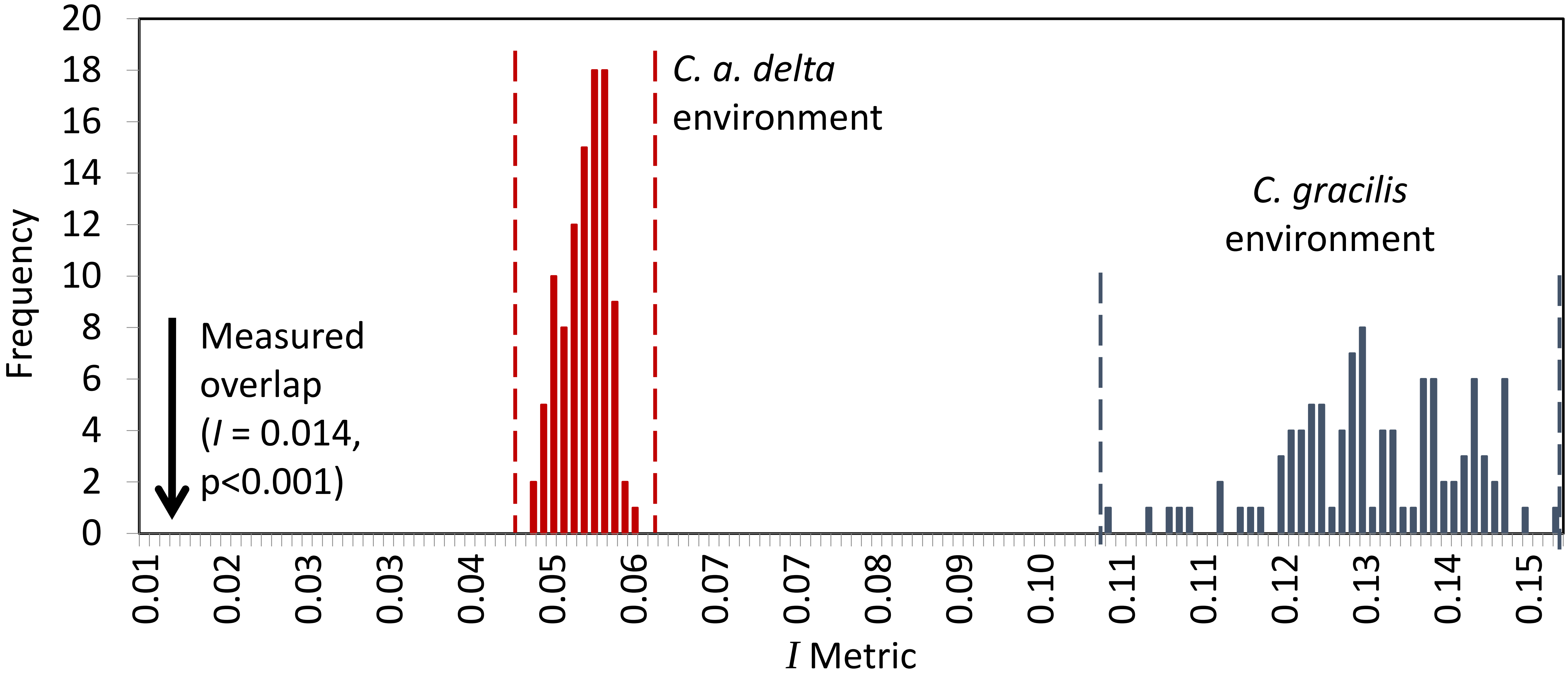
Ecological speciation in the deep sea



Identity test (ENM Tools)



Background test (ENM Tools)



Ecological speciation in the deep sea

- *C. a. delta* – a non-seep organism with a clear seep preference
- *C. gracilis* and *C. a. delta* occupy distinct niches
- Our results support the depth-divergence hypothesis
- Depth or depth-related variables?
- Did ecology drive speciation, or did niches diverge after speciation?

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