



**DIAL CORDY  
AND ASSOCIATES INC**

*Environmental Consultants*

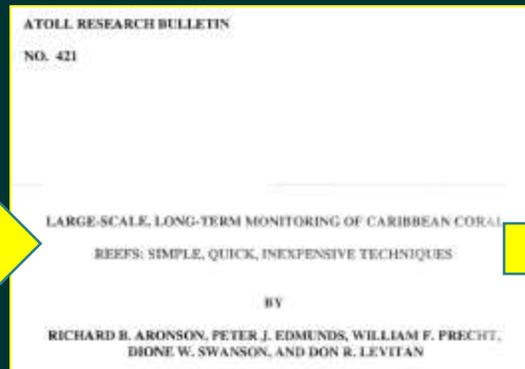
# 3D Mapping of Reefs

Visualization, Characterization, and Quantification through  
Permanent, Extensive, and Information-rich Data Sets

**Precht, W., Walser, E., Walser, J., Hunsaker, D., Rice, M. Robbart, M., and Dial, S.**

# Video Monitoring of Coral Reefs We've Come a Long Way!

Y. Loya (1978). Plotless and transect methods. In: Monographs on Oceanic Methodology. Coral Reefs: Research Methods. D.R. Stoddart and R.E. Johannes (eds.). UNESCO Press, 5: 197-21...



3D

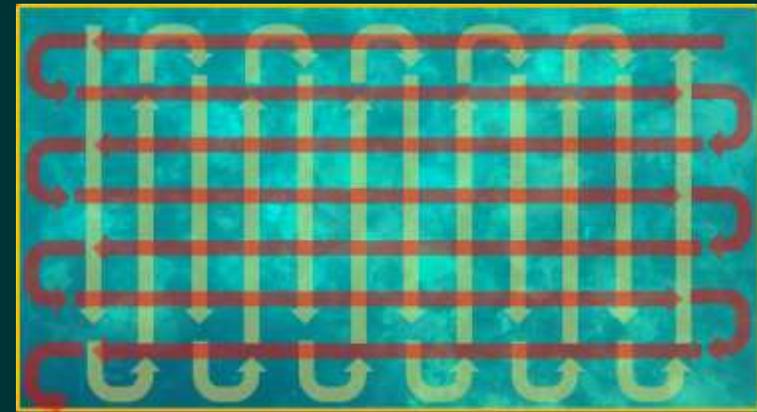


# 3D Mapping Process: Imagery Collection



Dial Cordy's first field test:

432,000 photographs collected in 40 min



- Reef community imagery collected using digital still photography and ultra-high definition (4K) videography at 1-2 meter height above bottom
- We collected 432,000 separate 8.3 MB photos at ~1 mm resolution over our test plot in a 40 minute period
- Over our recommended 2.5 acre plots, each data set will consist of ~1.3 million separate digital photographs at ~1 mm resolution
- These data sets will provide a permanent and richly detailed record that documents change over time.



10% buffer on all margins to ensure complete coverage

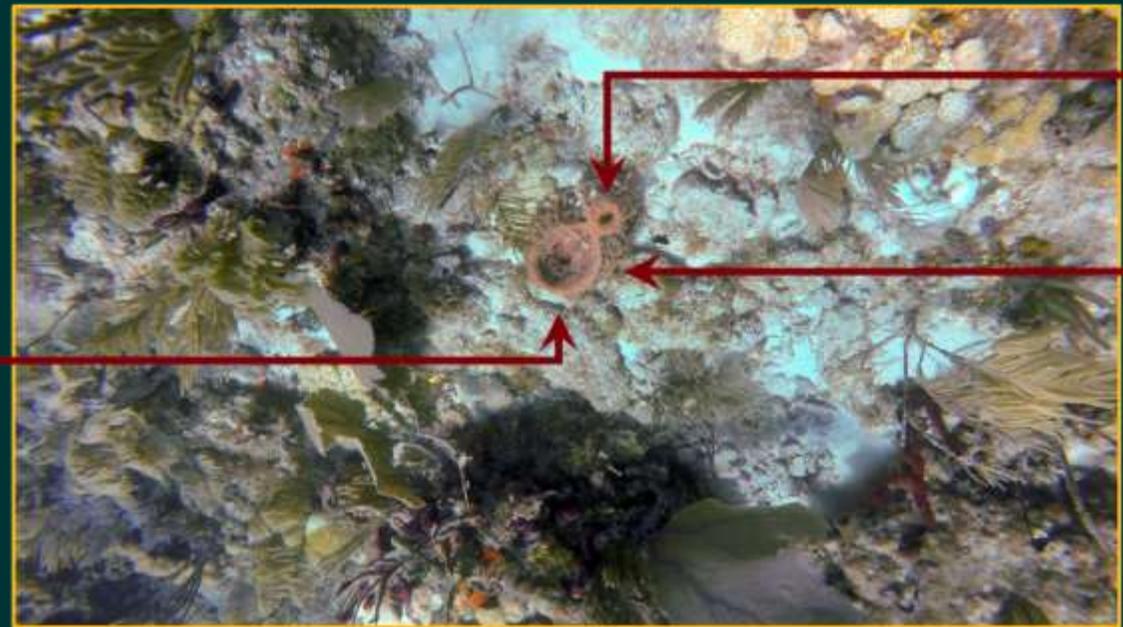
# 3D Mapping Process: Image Processing



Each frame of 4K video (8.3 megapixels) and 20 megapixel still image is color-corrected and saved as a separate image file



Multiple photographs over each portion of the reef provide multiple perspectives of every organism in the plot



# 3D Mapping Process: Creating the Virtual Reef Model

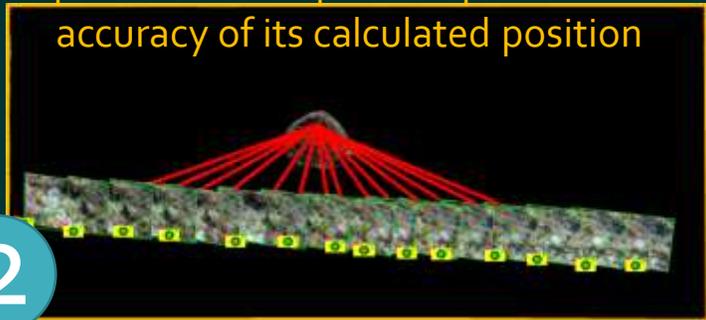
Traditional stereo photogrammetry uses a single stereo pair of images taken by precise metric cameras to determine the 3D position of a point that appears in the image pairs

1



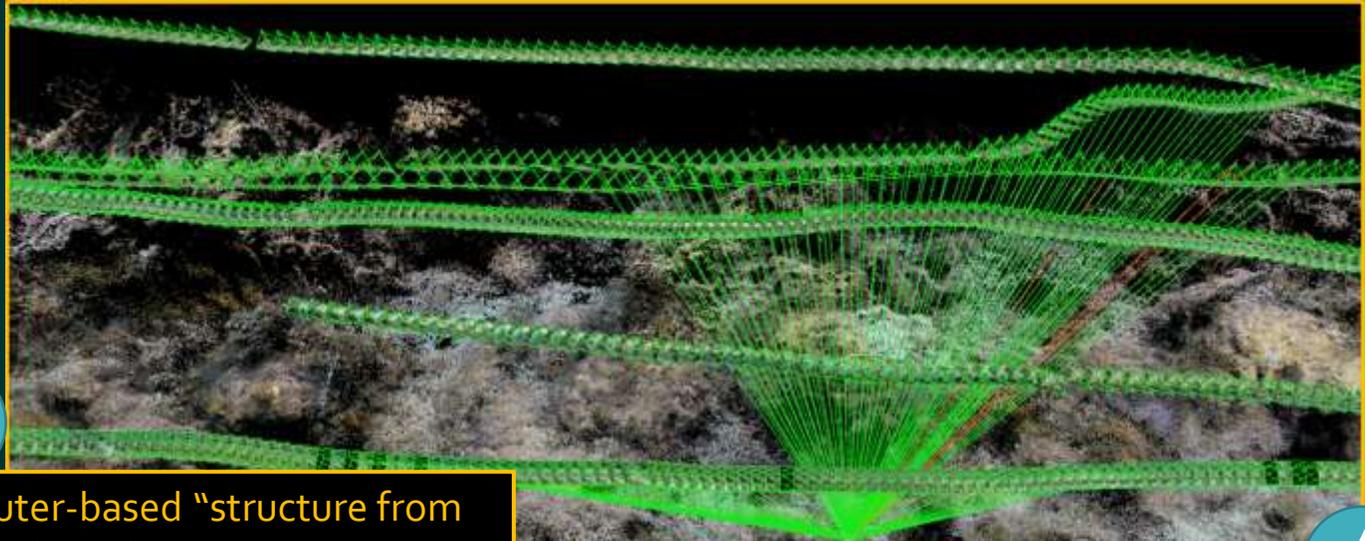
Using multiple images to extract the 3D position of the point improves the accuracy of its calculated position

2



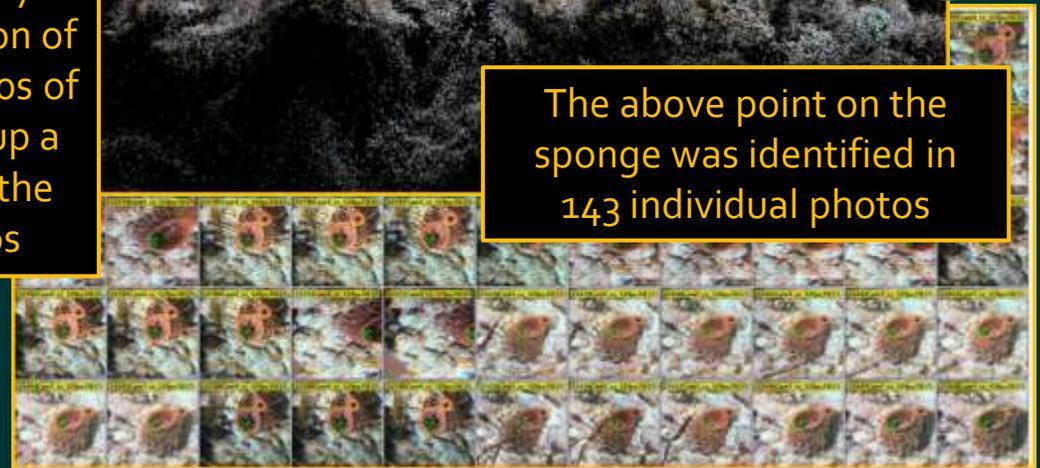
3

Computer-based "structure from motion algorithms can use 100s of consumer-grade photos to very accurately determine the position of a point, and repeat that for 1,000s of points in each photo, building up a precise 3D data set that spans the content of 100,000s of photos

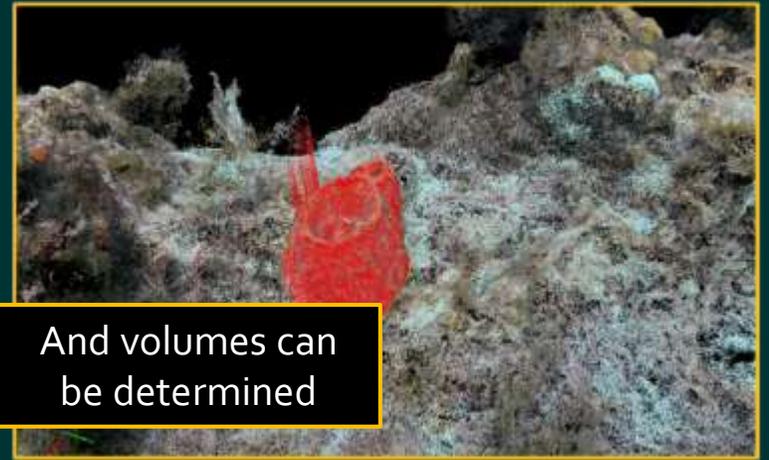
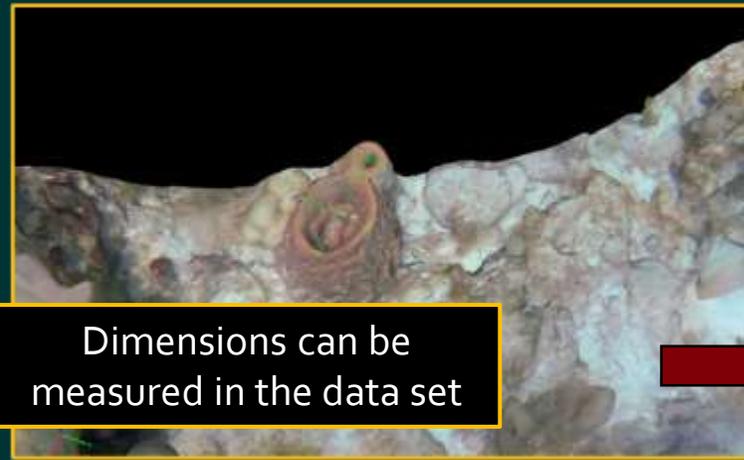
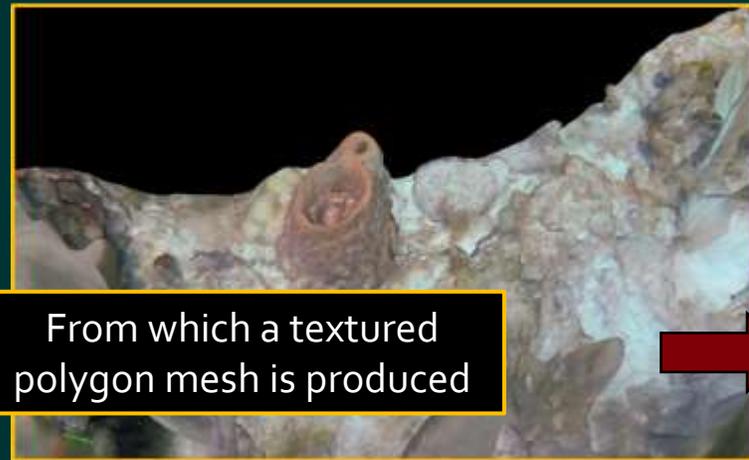
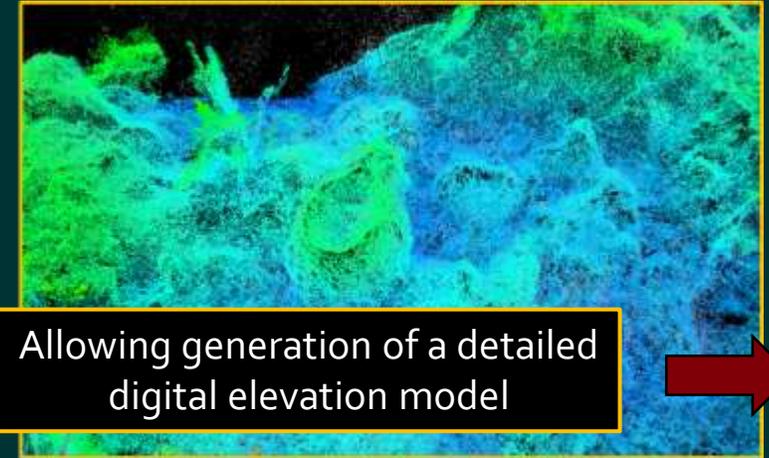


4

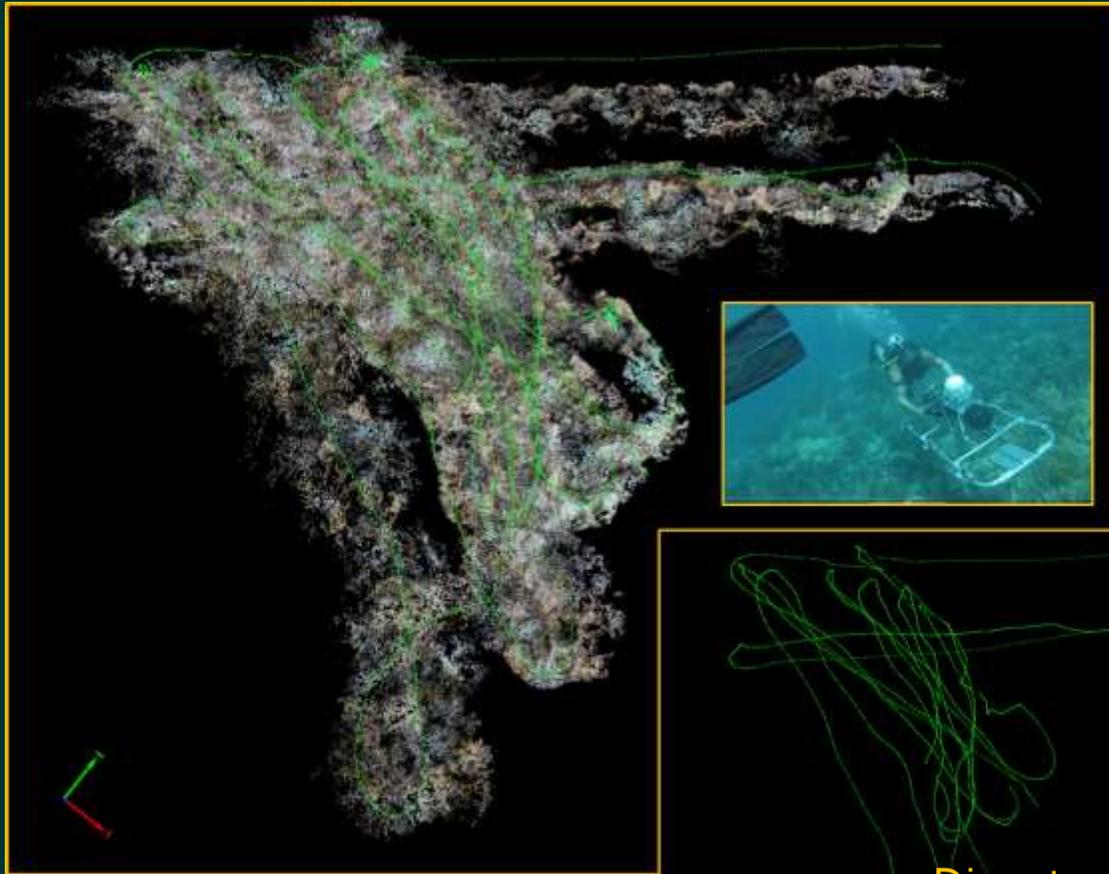
The above point on the sponge was identified in 143 individual photos



# Creation of and Analytics in a Virtual Reef



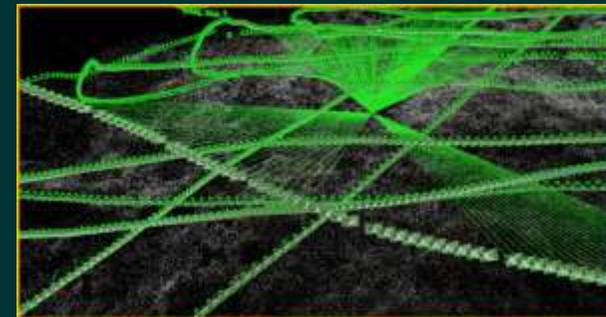
# 3D Mapping can be Performed over Large Areas



- Area to the left is 150 meter<sup>2</sup> subset of Dial Cordy test plot
- Sparse point cloud shown was produced from 6,461 separate photos



Diver track; each dot denotes an image position



Multiple perspectives from many different images; above point visible in 380 images

2.5 acre plot  
(~2 hr to collect)



X 20



X 4

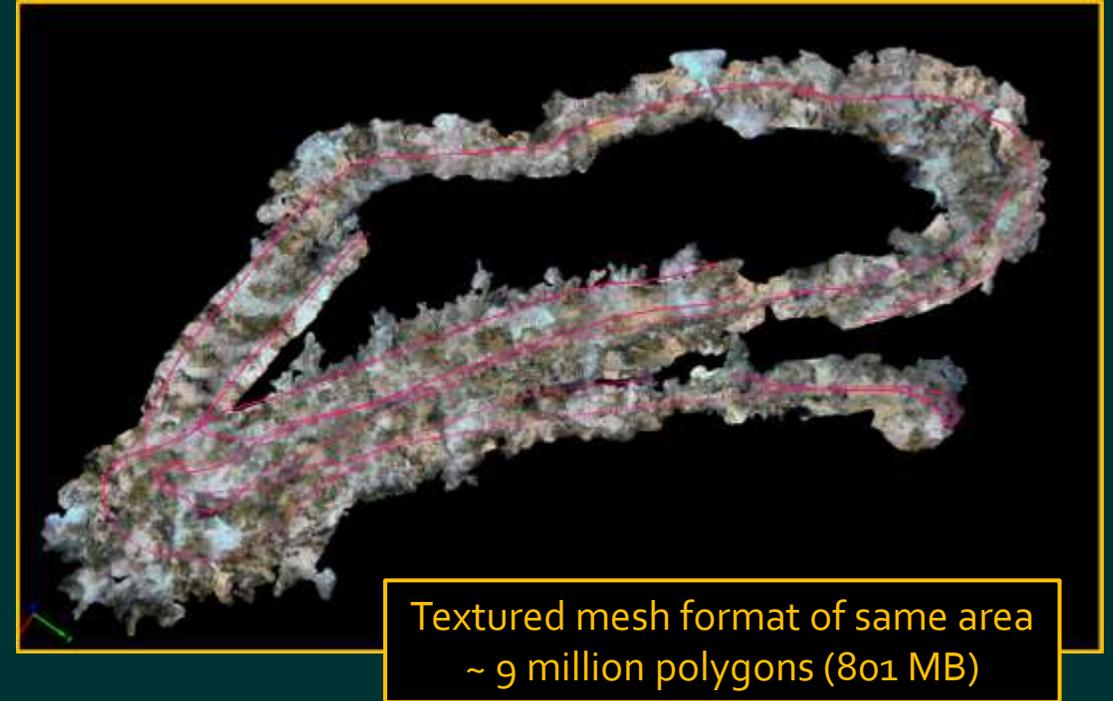
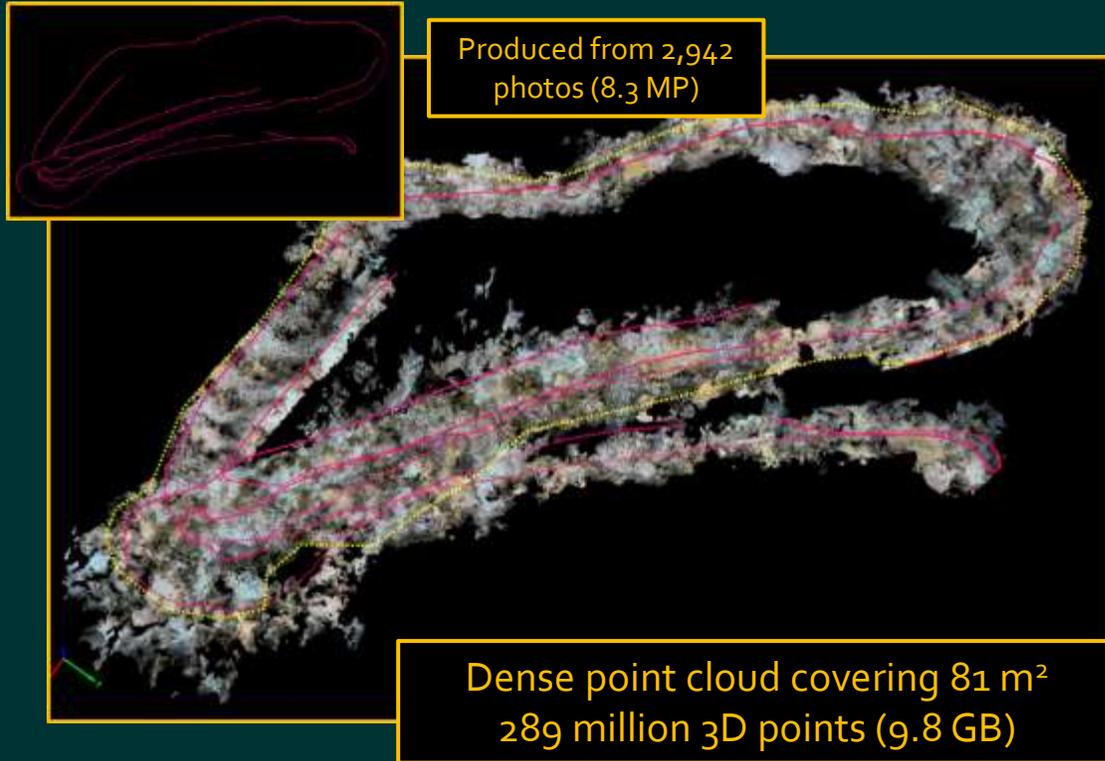
40 h of 4K  
ultra HD video  
separated  
into 4.32M  
million  
individual  
8.3 megapixel  
photos

14,400  
individual  
24.0  
megapixel  
photos

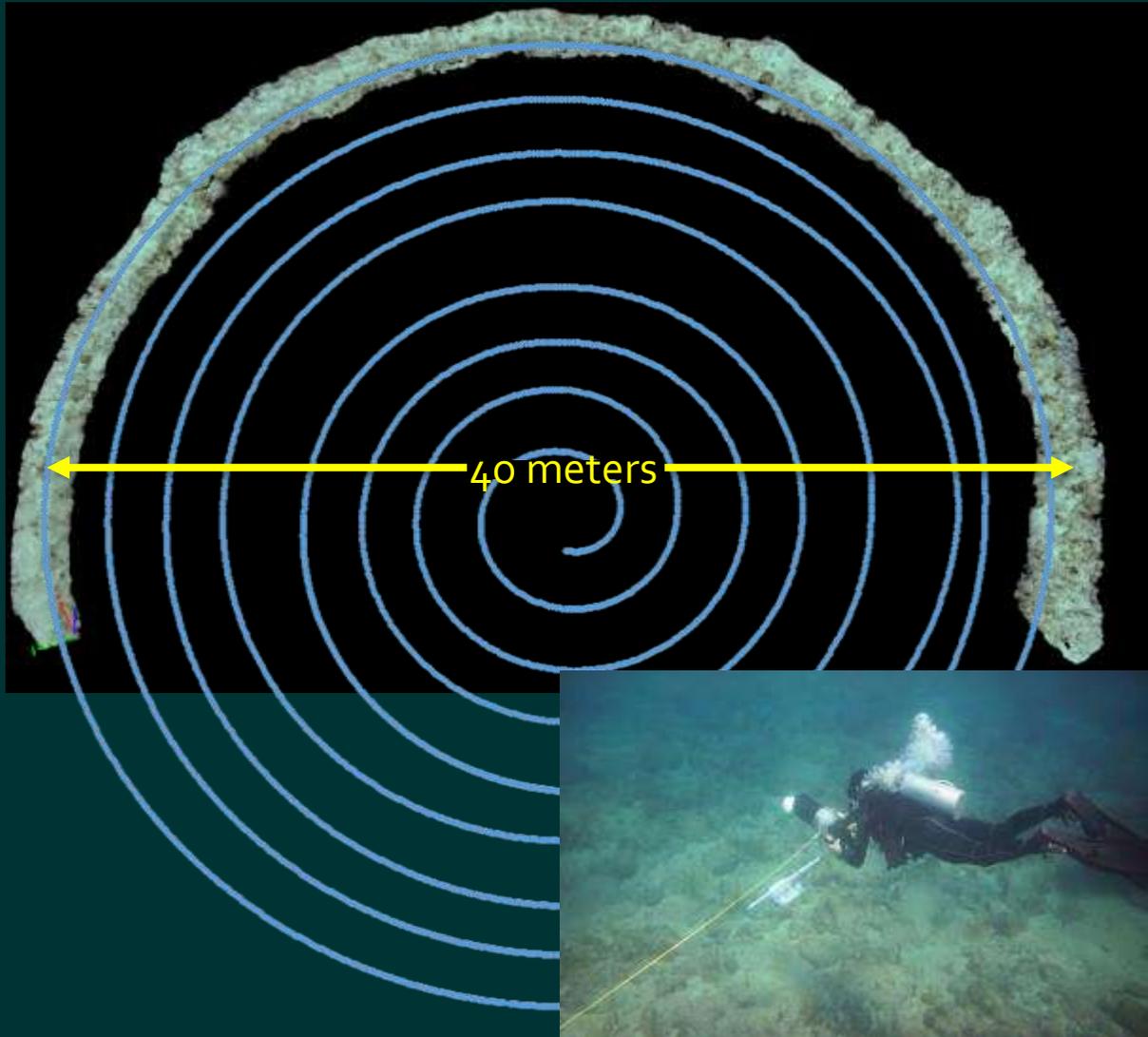
~36 terapixels of  
imagery over each 2.5  
plot on each date



# Models can be created in both Point Cloud and Polygonal Mesh formats



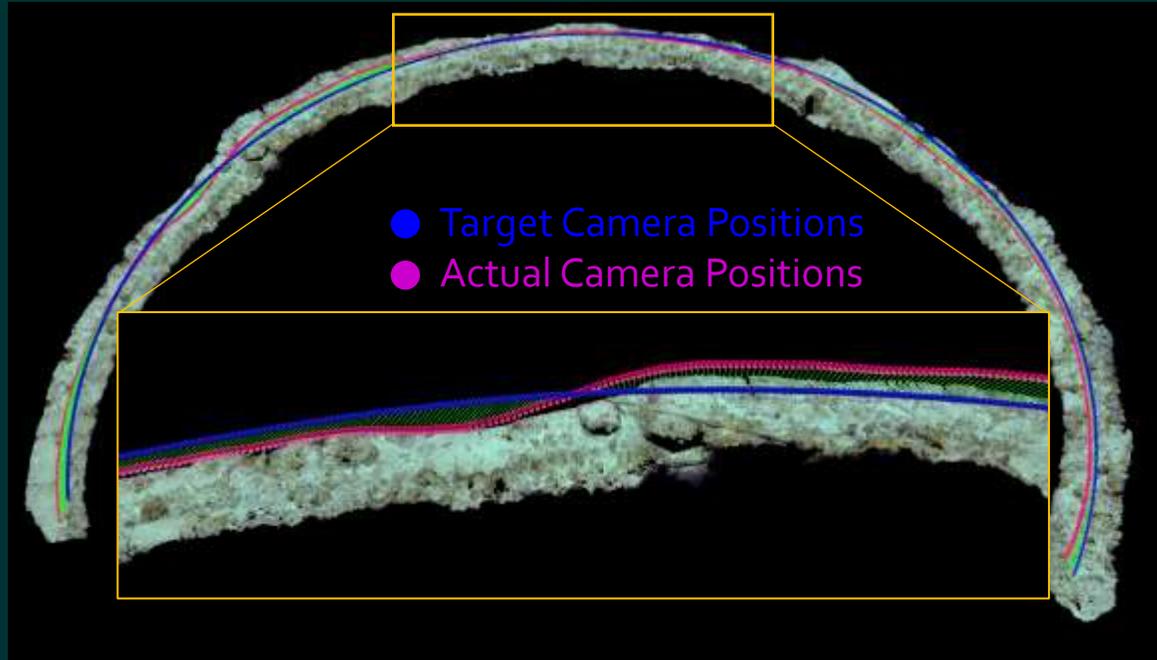
# 3D Point Cloud over Portion of Test Site



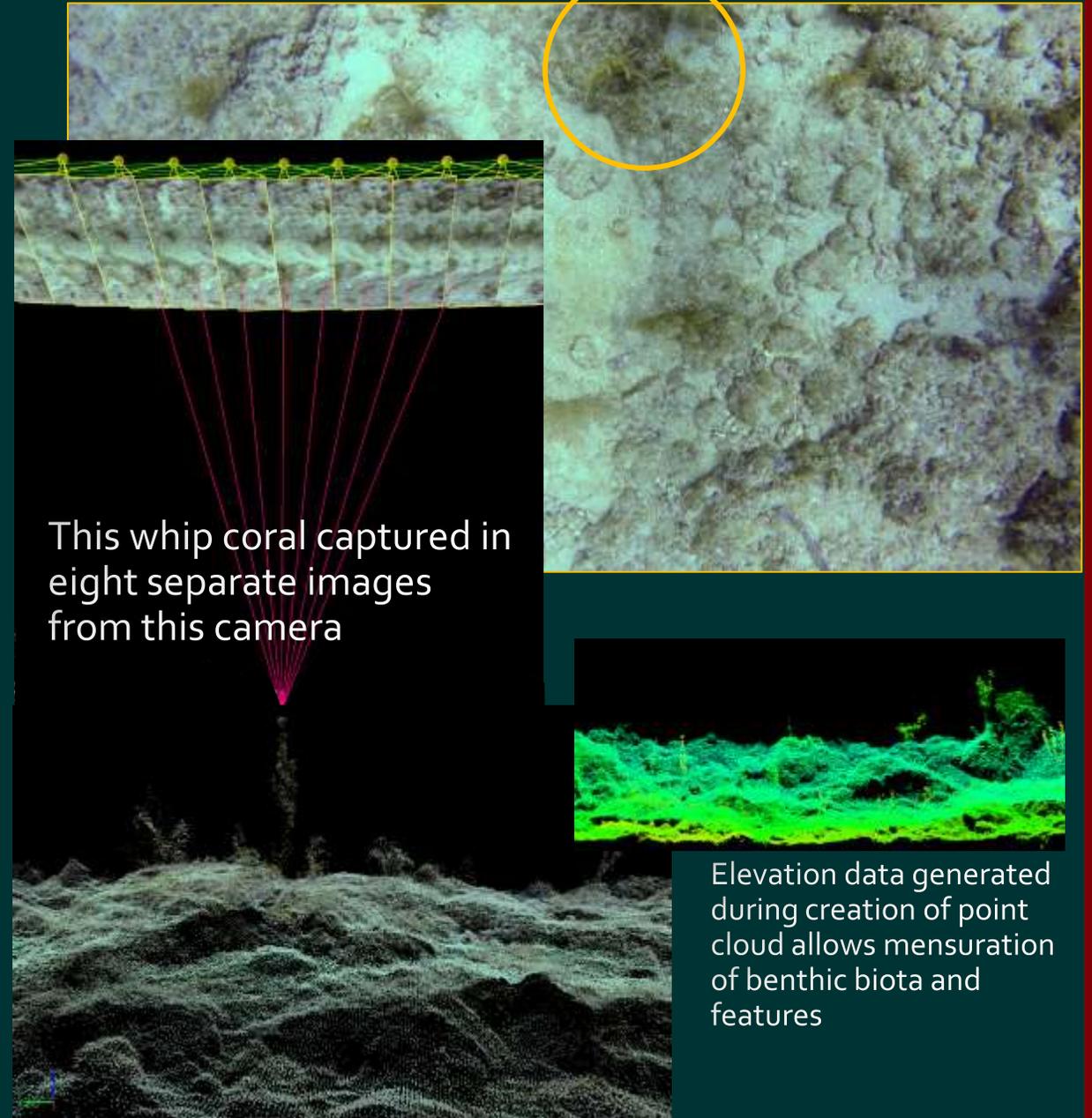
- Point cloud shown generated from 699 separate images from a single camera, out of 4,858 total images from that camera
- Required 16.2 minutes to collect entire 1,256 m<sup>2</sup> site (0.3 acres)
- 10 cameras simultaneously collecting 4K video, yielding 290,000 separate 12 Mpixel images over site
- ~49,000 total images extracted from 4K video for image processing
- Length along 3D point cloud shown here is ~130 meters (~280 m<sup>2</sup>)



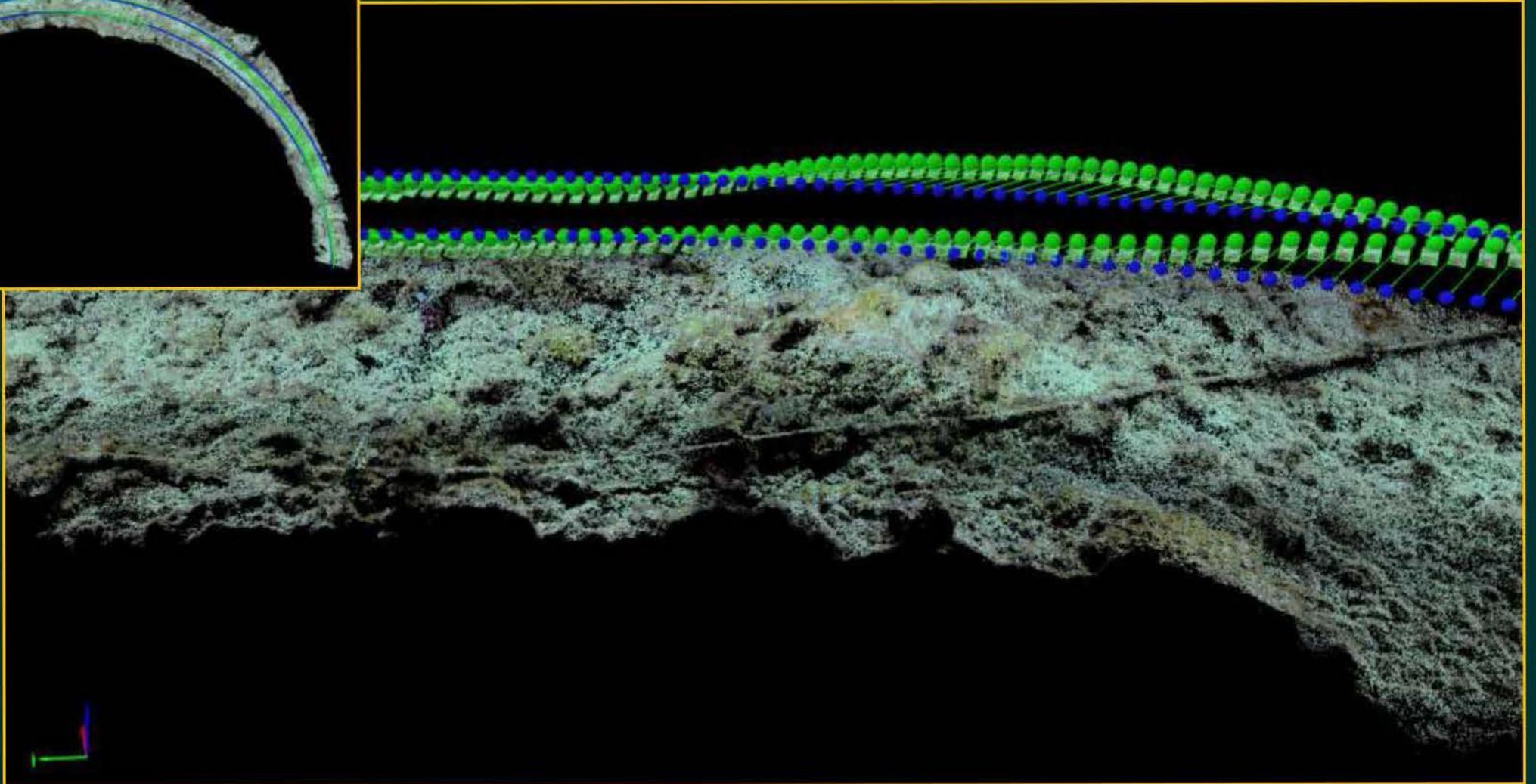
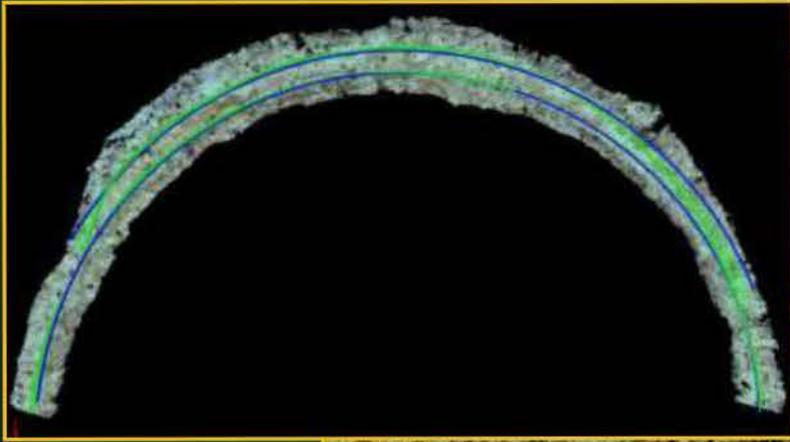
# Point Cloud Detail



- This point cloud generated using images from just 1 of 10 total cameras used
- Additional cameras, with video acquired from different look angles, will allow us to “flesh out” this point cloud=



# Subset Generated from Multiple Cameras



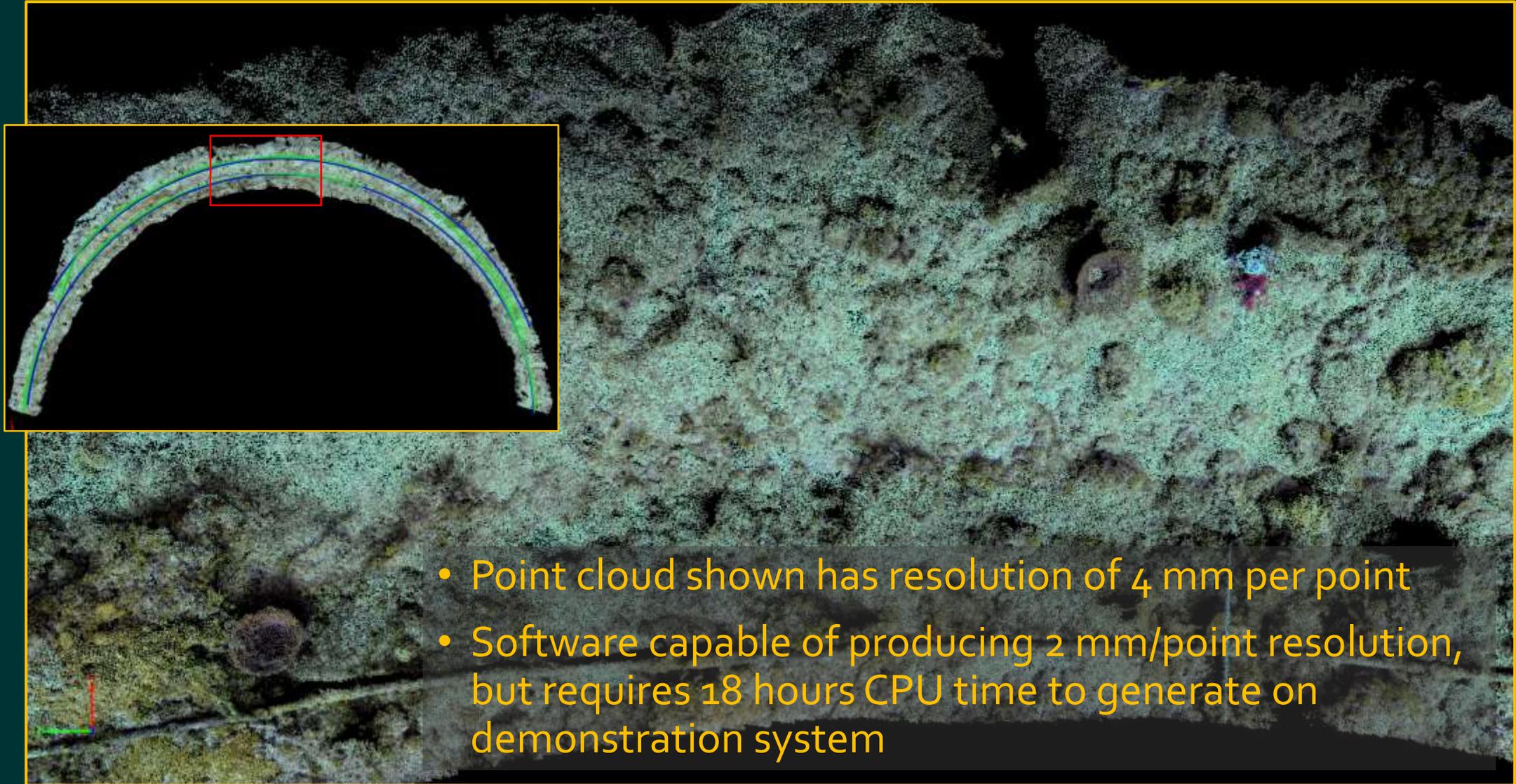
Port Everglades Inlet Reef Monitoring



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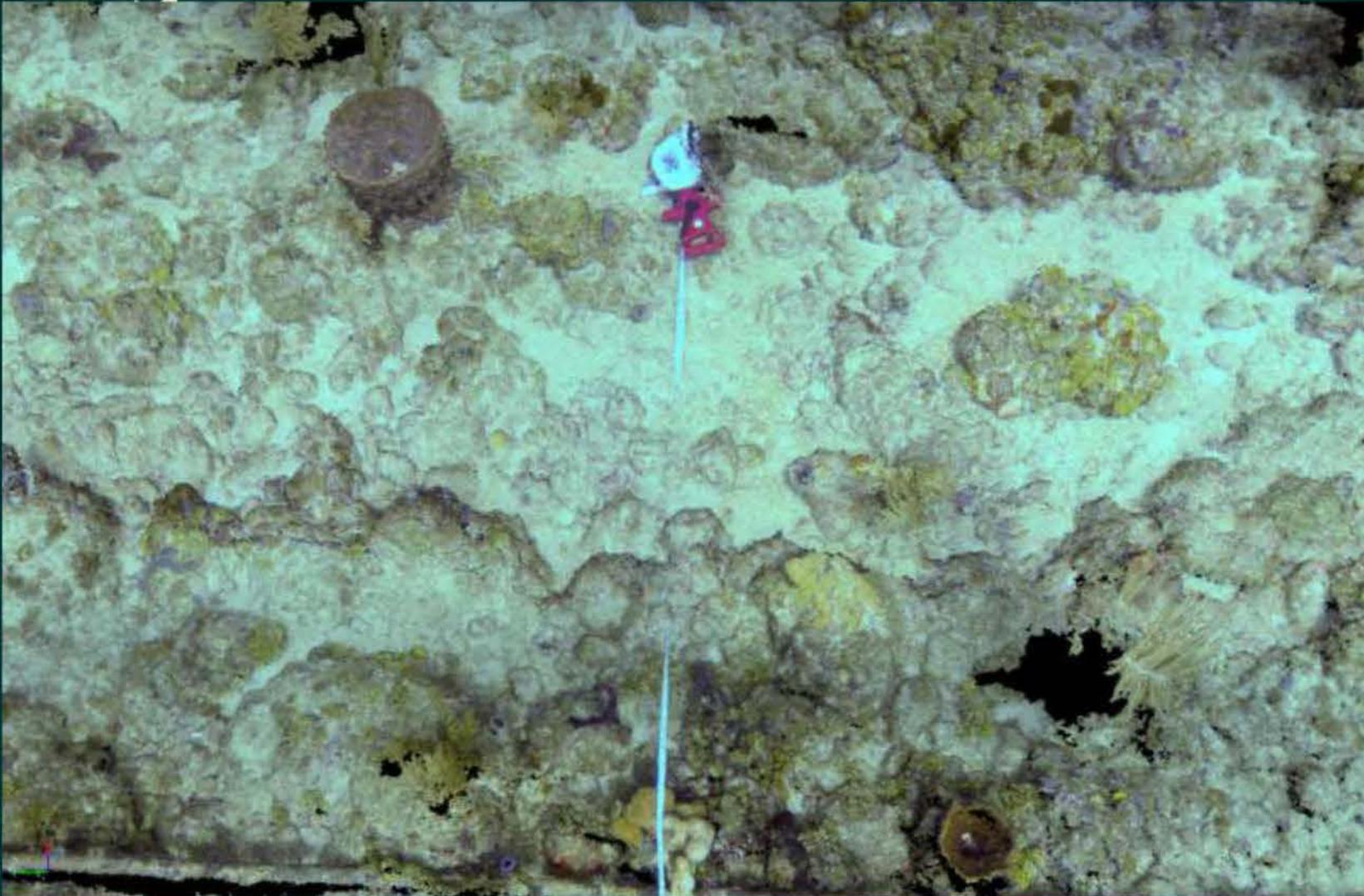
# Low Density Point Cloud



- Point cloud shown has resolution of 4 mm per point
- Software capable of producing 2 mm/point resolution, but requires 18 hours CPU time to generate on demonstration system



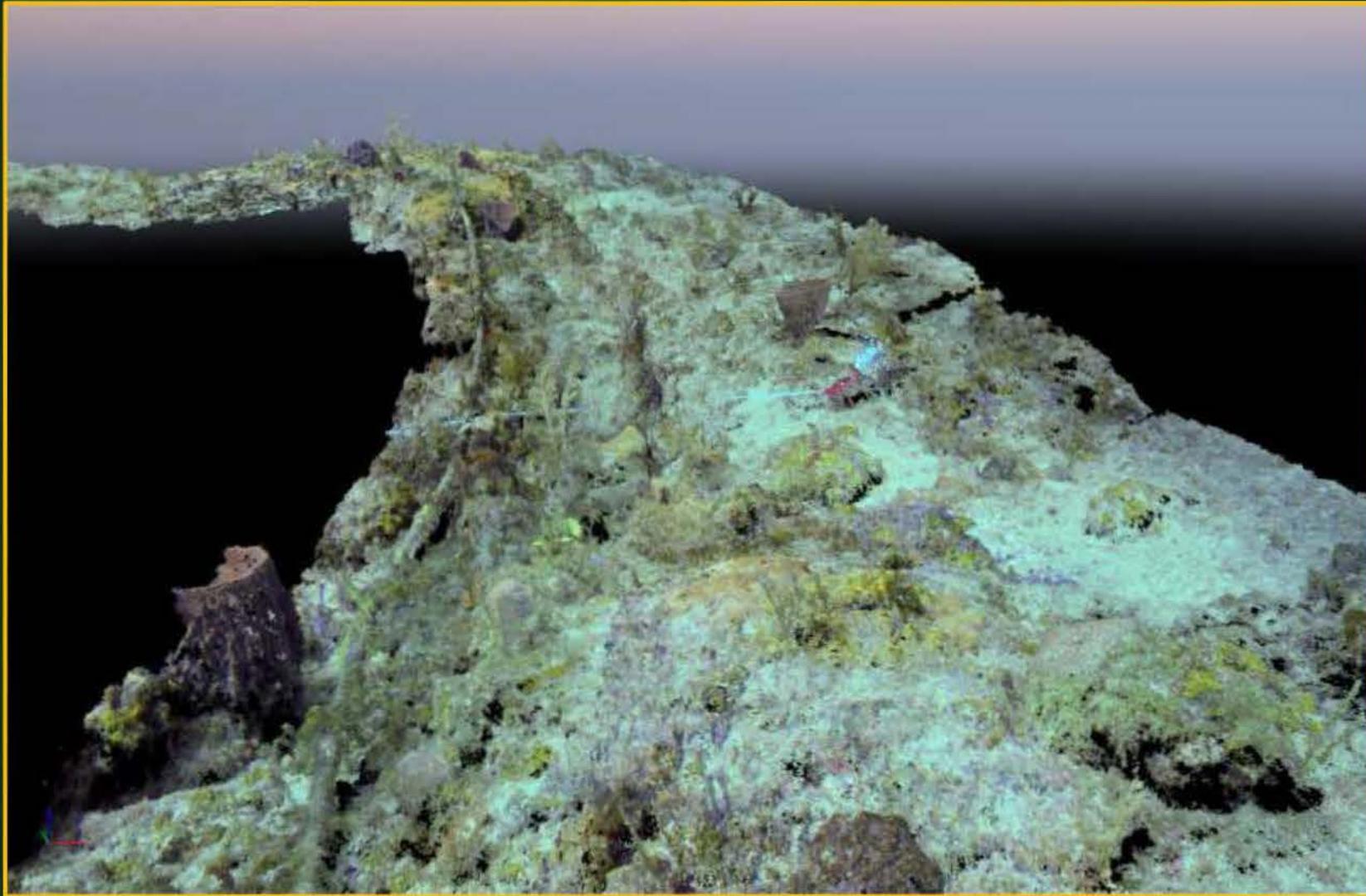
# Higher Resolution Point Cloud



- Point cloud shown has resolution of ~2 mm/point



# Oblique Views in Point Clouds



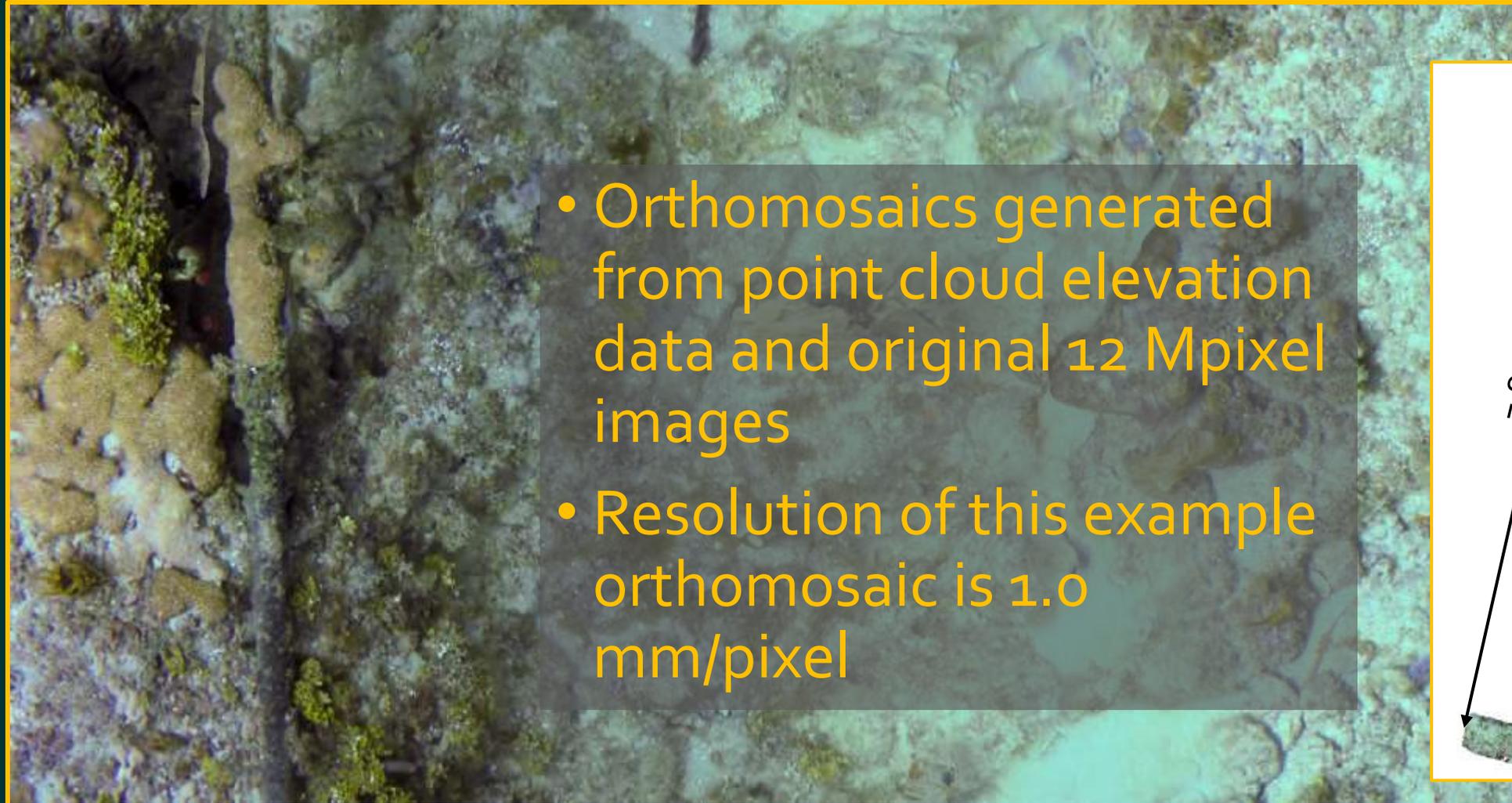
Port Everglades Inlet Reef Monitoring



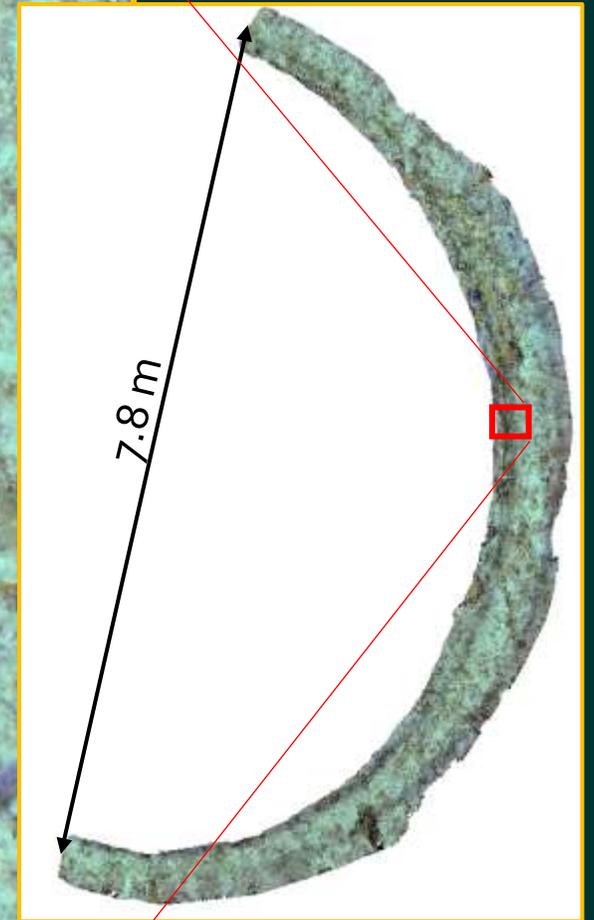
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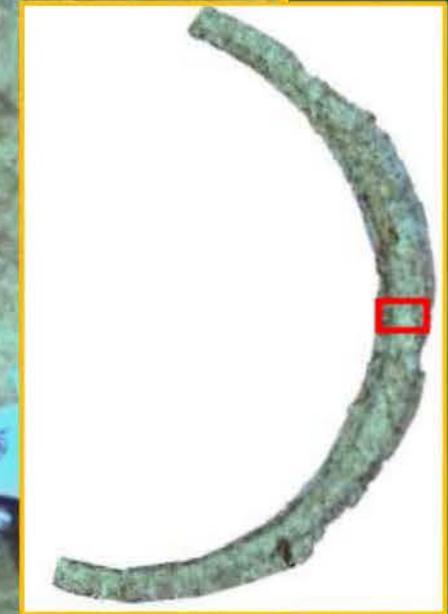
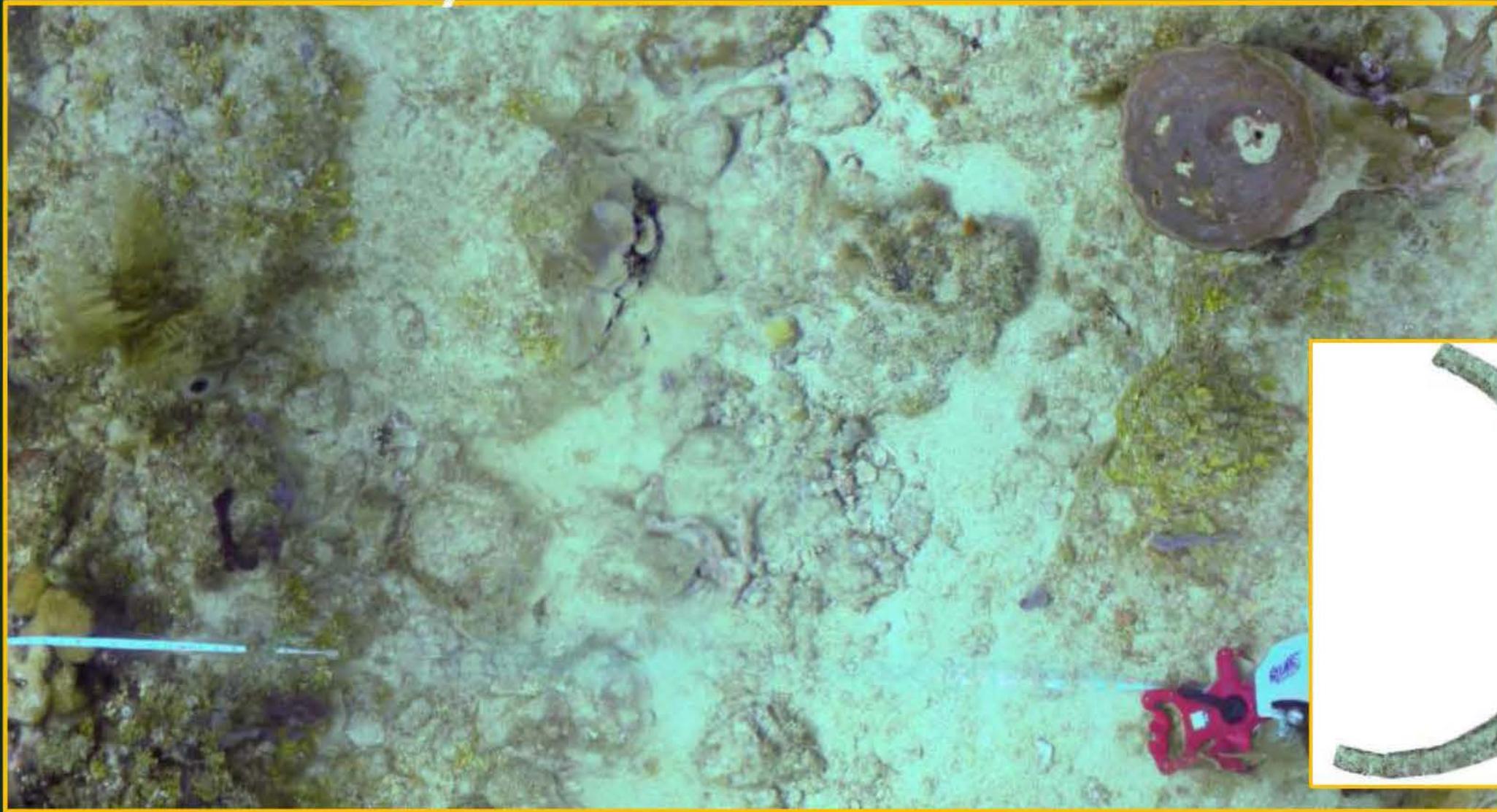
# GIS-ready High Resolution Orthomosaic



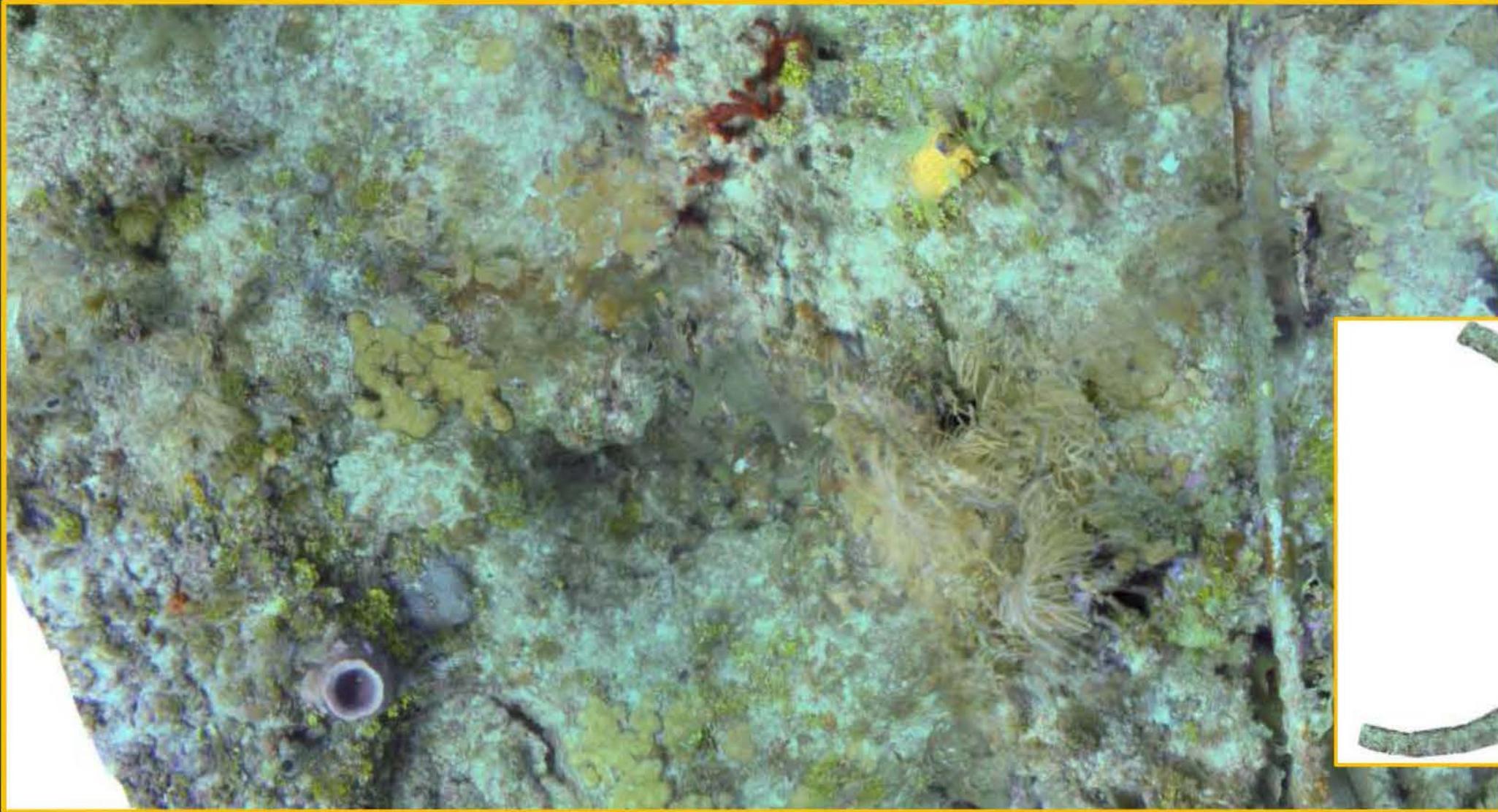
- Orthomosaics generated from point cloud elevation data and original 12 Mpixel images
- Resolution of this example orthomosaic is 1.0 mm/pixel



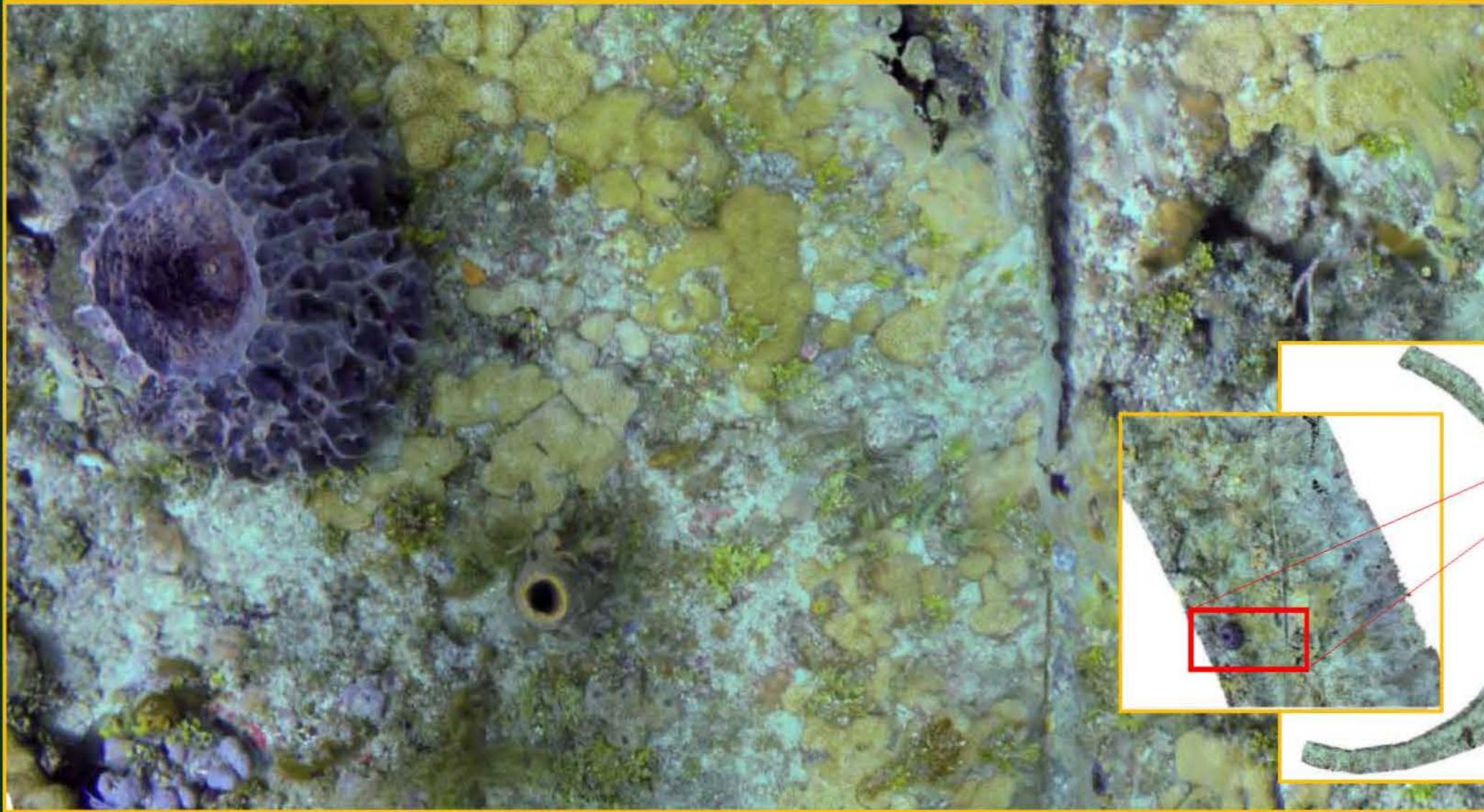
# GIS-ready Orthomosaics



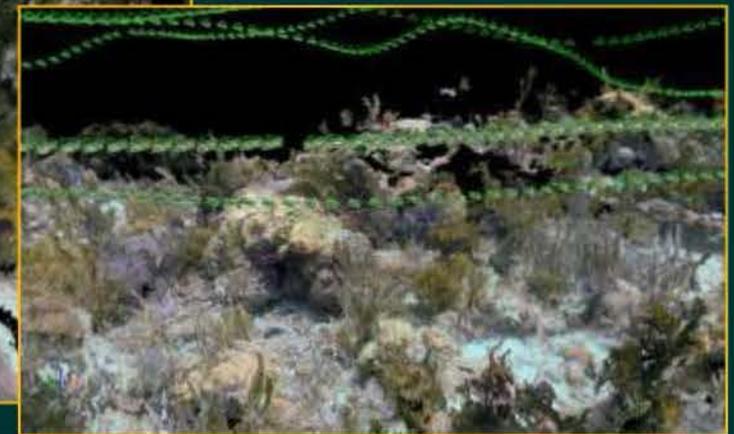
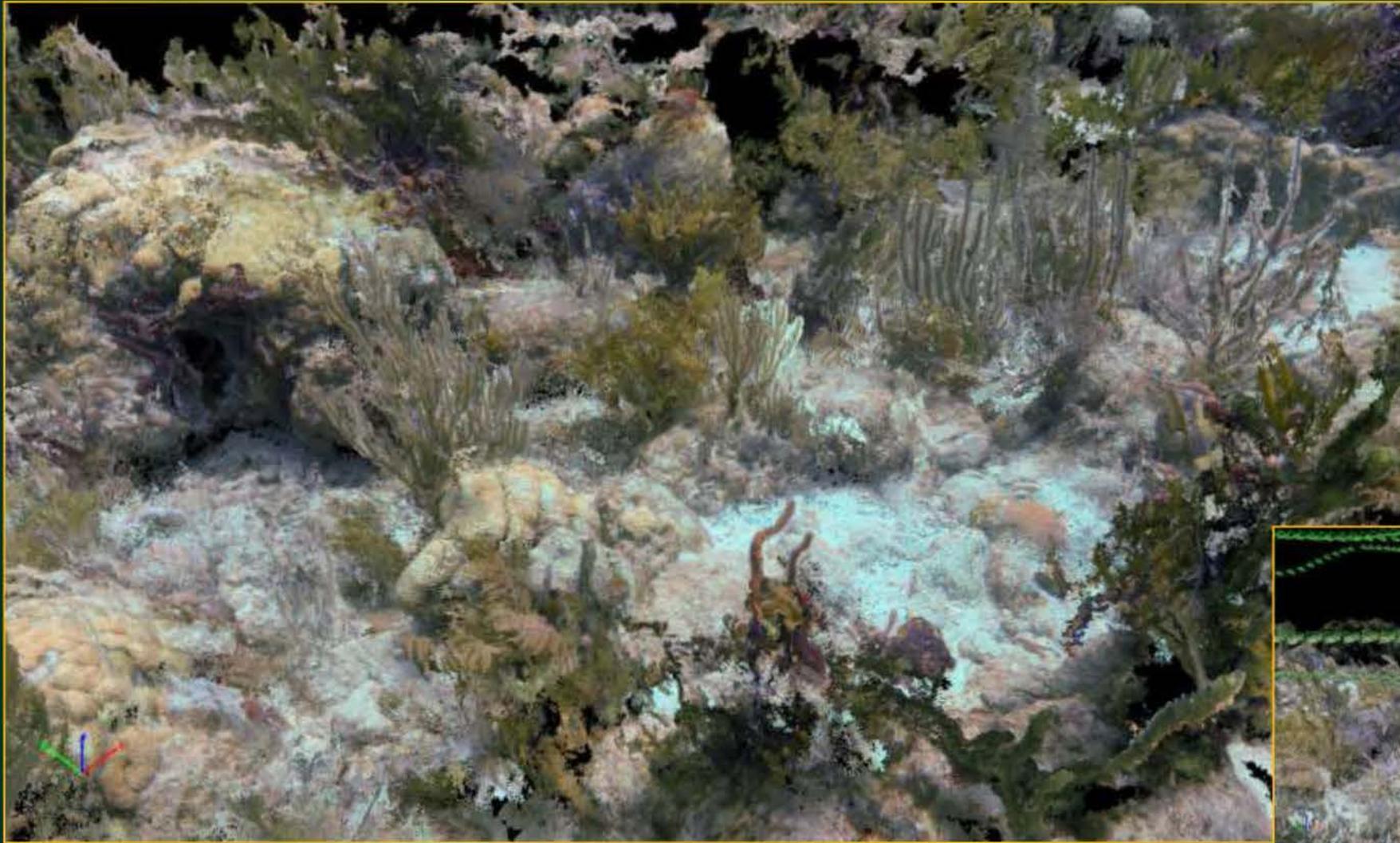
# GIS-ready Orthomosaics



# GIS-ready Orthomosaics



# Capturing a Complex Environment...



Port Everglades Inlet Reef Monitoring



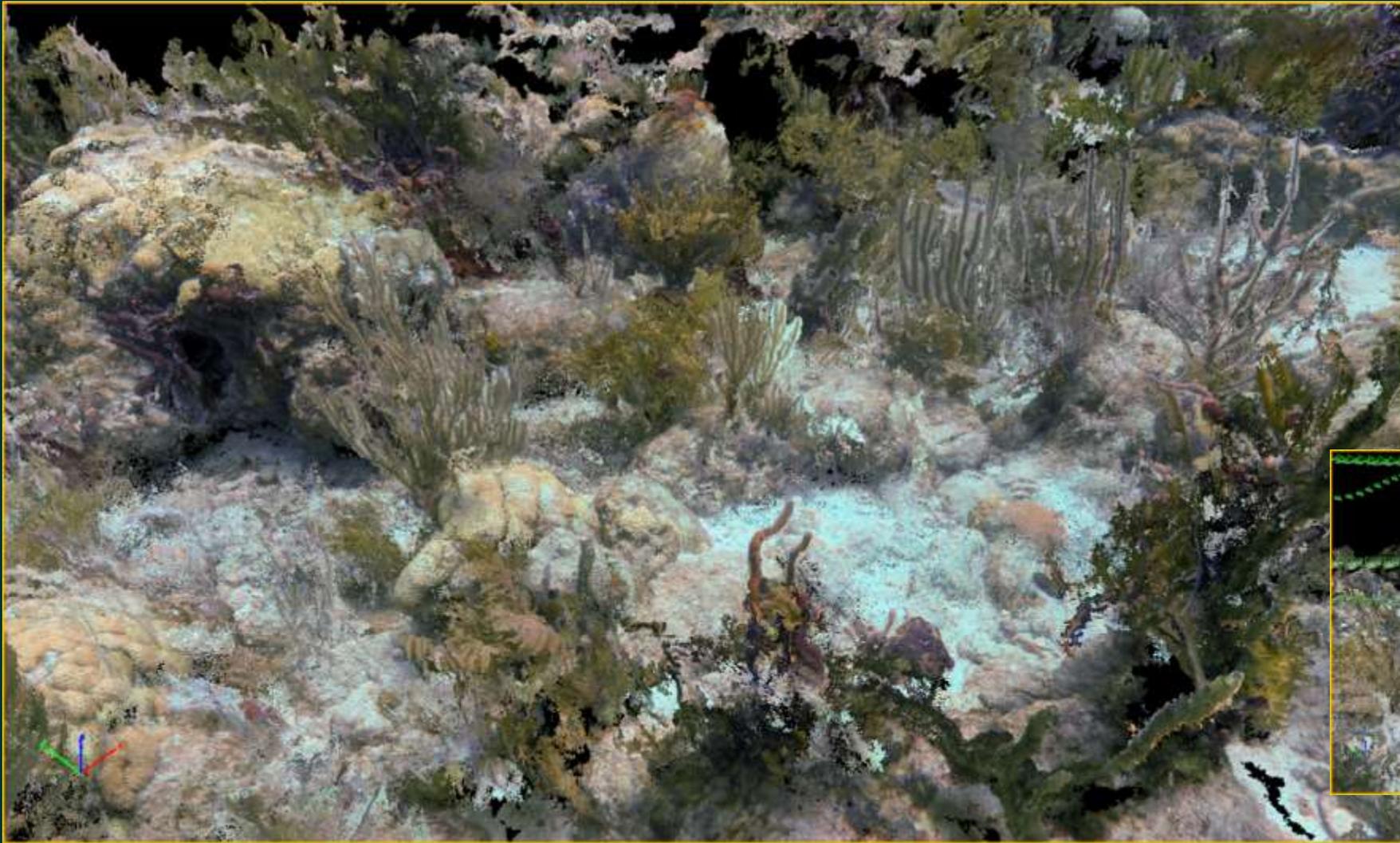
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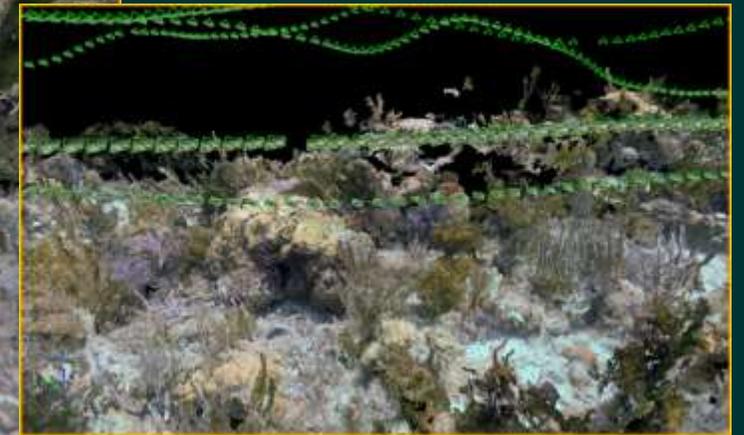
# ...With Sufficient Detail to...



# Capturing a Complex Environment...



- Fast frame rate of GoPro allows accurate 3D modeling of slowly undulating soft corals



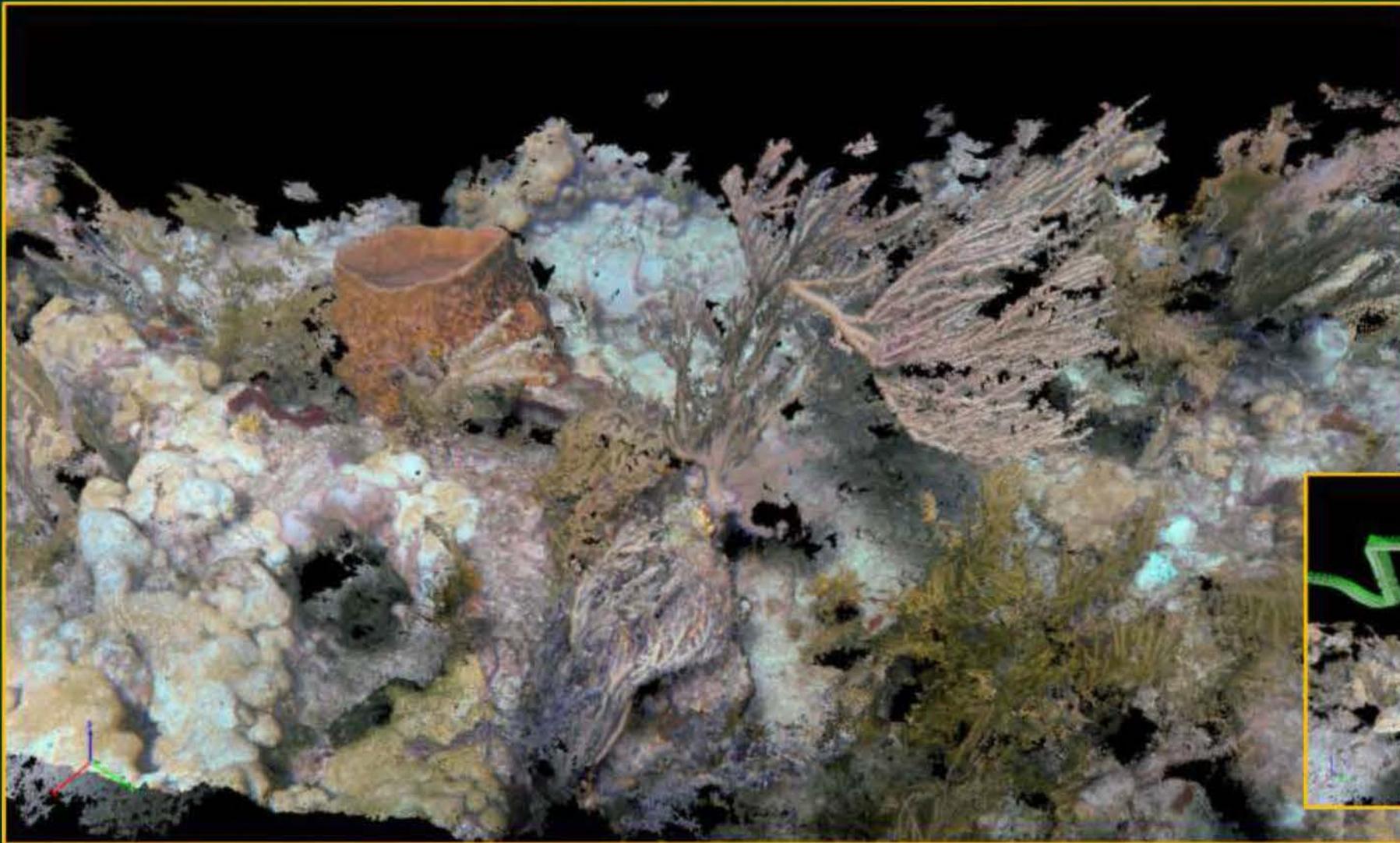
# ...With Sufficient Detail to...



- Identify individual species and track condition of individual organisms through time



# Volumes and Shapes



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# Multiple Canopy Analysis



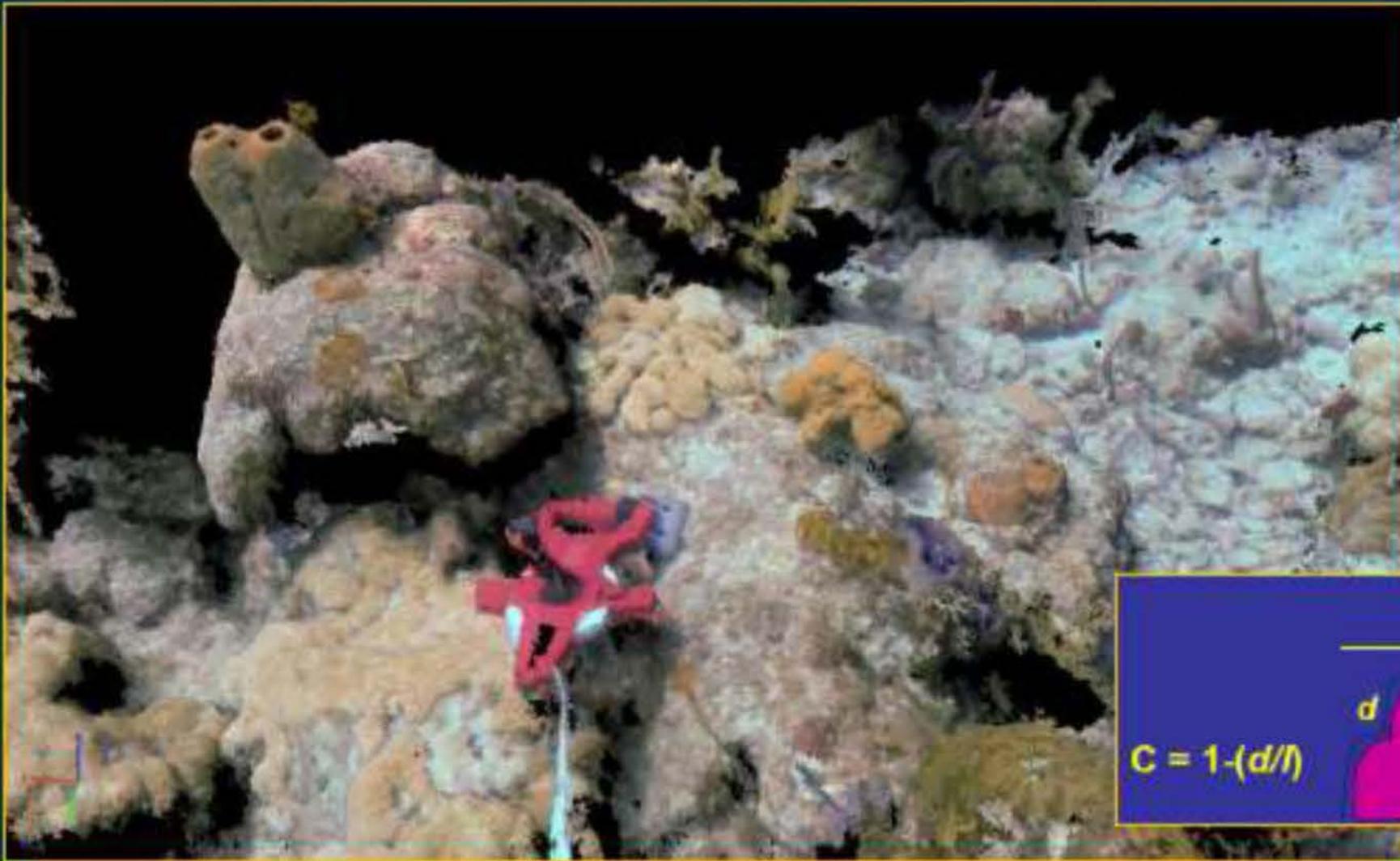
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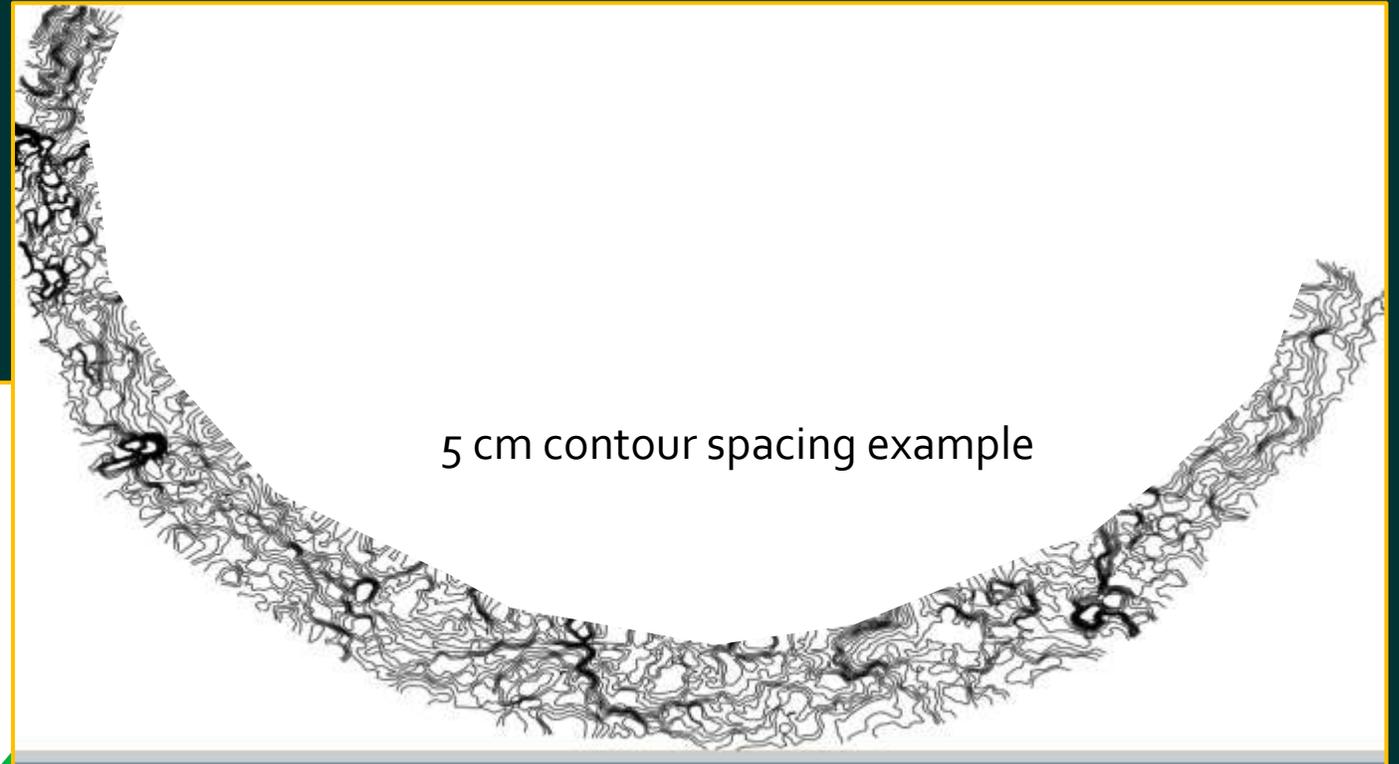
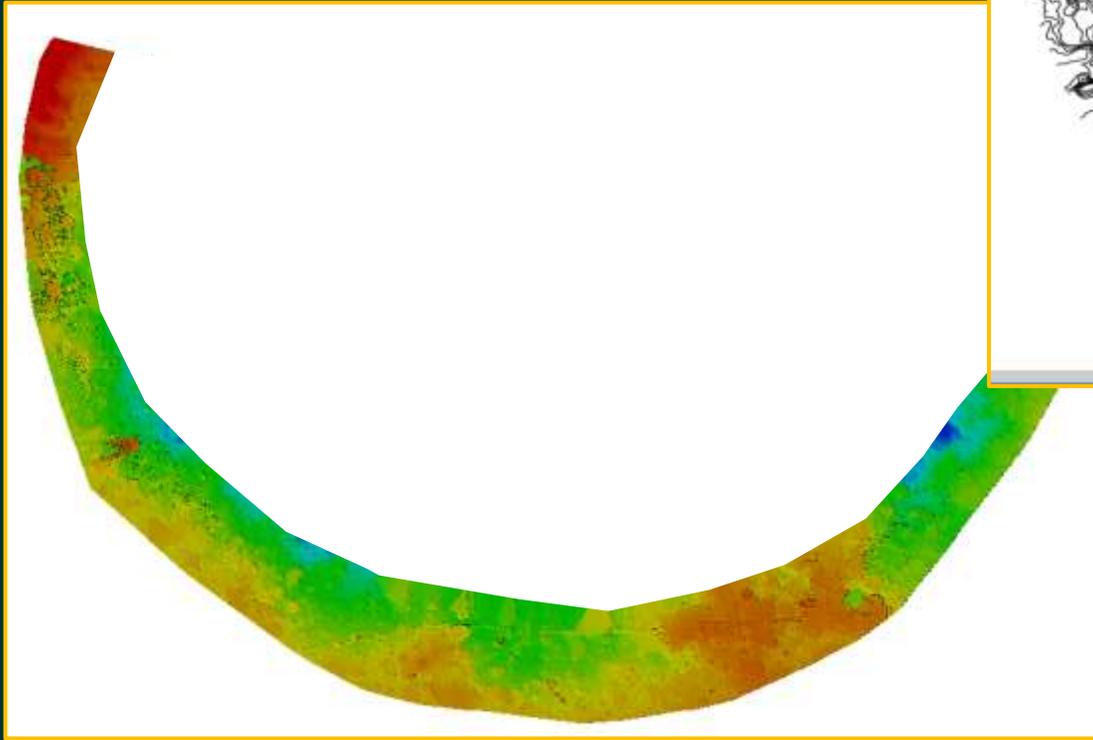
# Structural Complexity (Rugosity Measures)



By making measurements in the point cloud representation of the habitat, rather than measuring in the field



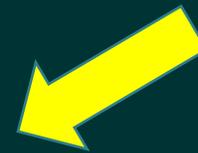
# Additional Point Cloud Products



- High Resolution Digital Elevation Maps



# Non-Traditional Survey Applications



Sites rich in octocorals  
and sponges

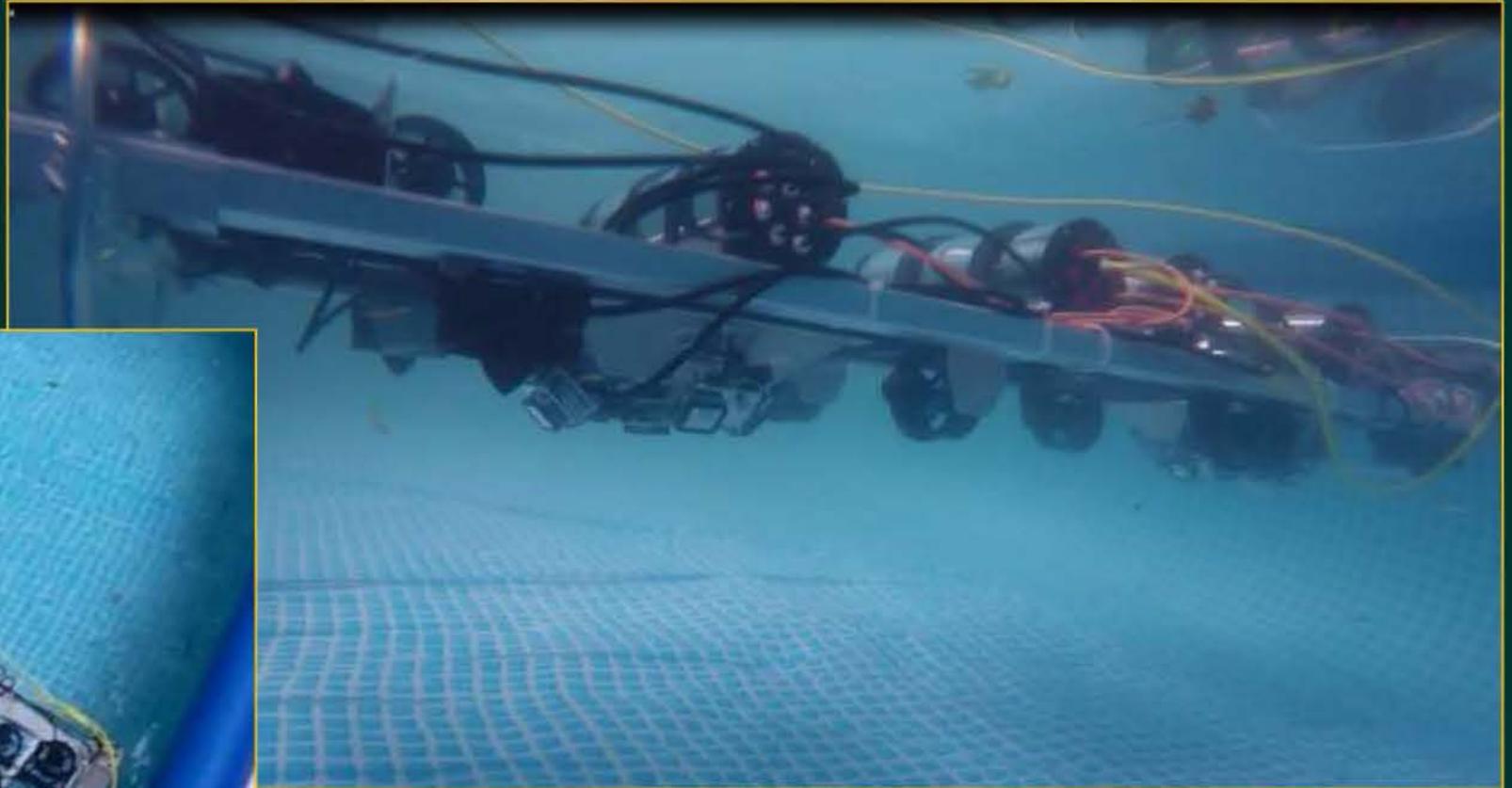


# Can be Deployed off Multiple Platforms

- Hand-Held Diver
- Scooter Mounted Diver
- ROV's
- AUV's



# Initial Remote System Configuration



# Incorporating 3D Mapping Dramatically Improves Reef Monitoring



Reduce costly underwater time



Perform coral/reef damage assessments



Perfect tool for monitoring complex colonies of ESA listed corals



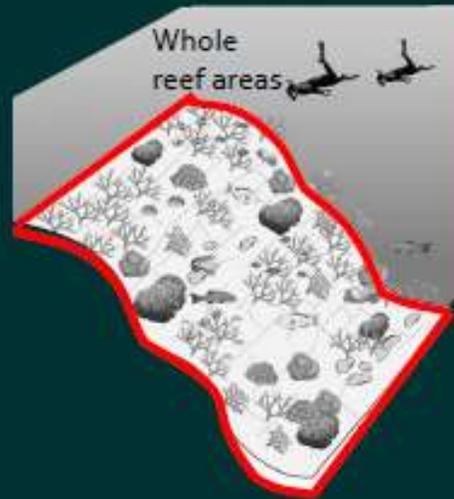
Monitor benthic communities in time and space with greater accuracy



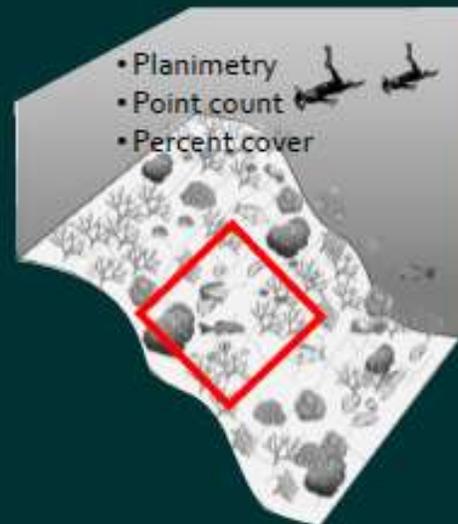
# One Data Set – Multiple Uses

We can Perform Nested Surveys on 3-D Mosaics after Collection

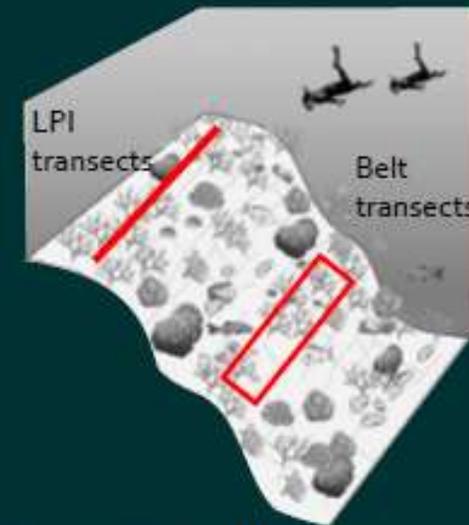
Large Seascape



Quadrats



Transects



Any length, any area, any time!



Precht, L., Gintert, B., Lirman, D. (2010) Assessing populations of the Threatened elkhorn coral, *Acropora palmata*, at Horseshoe and South Carysfort Reefs within the Florida Keys National Marine Sanctuary. Linking Science to Management – Conference & Workshop on the Florida Keys Marine Ecosystem. Duck Key, FL



# Application of 3D Mosaics

- Baseline Surveys
- Long-Term (Repeated Measures) Monitoring
- One-Off Surveys
- Impact Analyses (Construction, Dredging, Vessel Groundings)
- Fate Surveys (Bleaching, Disease)
- Community Level Surveys
- Small or Large Areas can be Mapped
- Non-Traditional Applications



# Advantages of 3D Mosaics

- Rapid Capture of Information
- Reduced Field Time (Underwater)
- Large Amounts of Data can be Collected on Single Dives
- Higher Power than Traditional Survey Methods
- Can Perform Multiple Types of Statistical Analysis with Single Data Sets
- Permanent Record
- Data can be Shared/Exchanged for Independent Analysis



# What 3D Mapping Provides

- An virtual record of the spatial relationships between complex reef topography and the biota inhabiting it
- A digital indexing capability that can identify individual organisms across hundreds of individual digital photographs (2D or 3D)
- An ability to measure reef topography and the volume and dimensions of every individual benthic organism in the survey area
- A virtual environment in which impacts, if any, can be measured and characterized from multiple visual perspectives
- A permanent synoptic record that can be used to more completely characterize changes to biota and reef topography between sampling dates
- The ability to precisely measure material removal/burial over large areas

