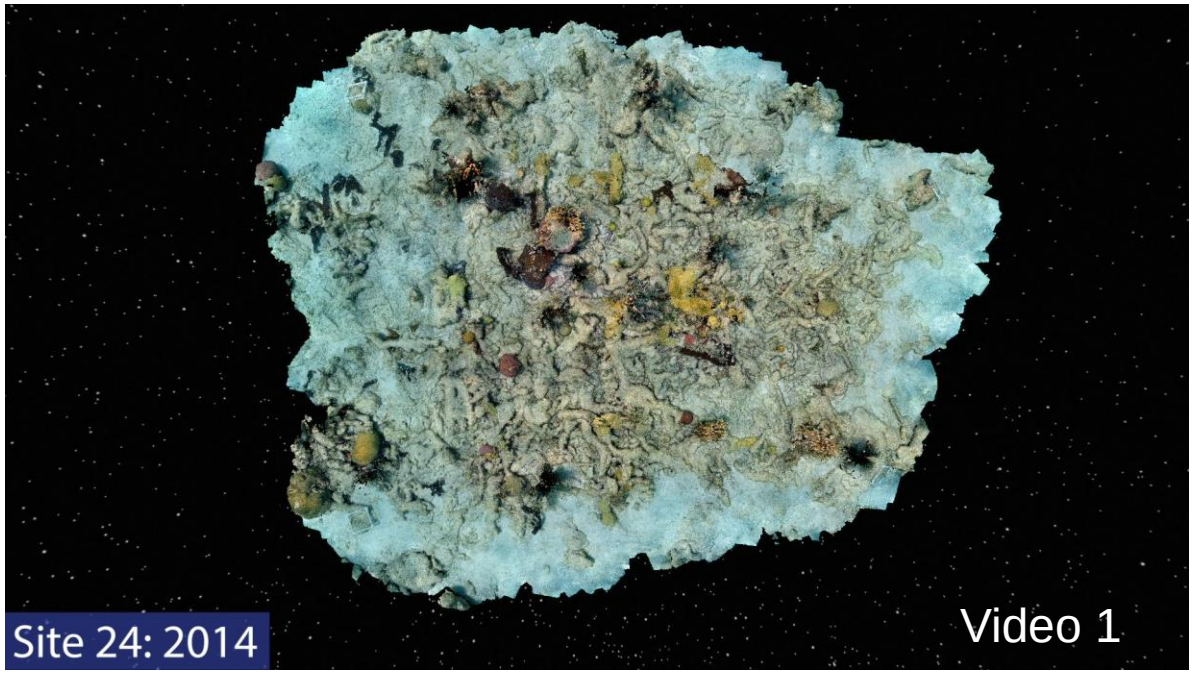
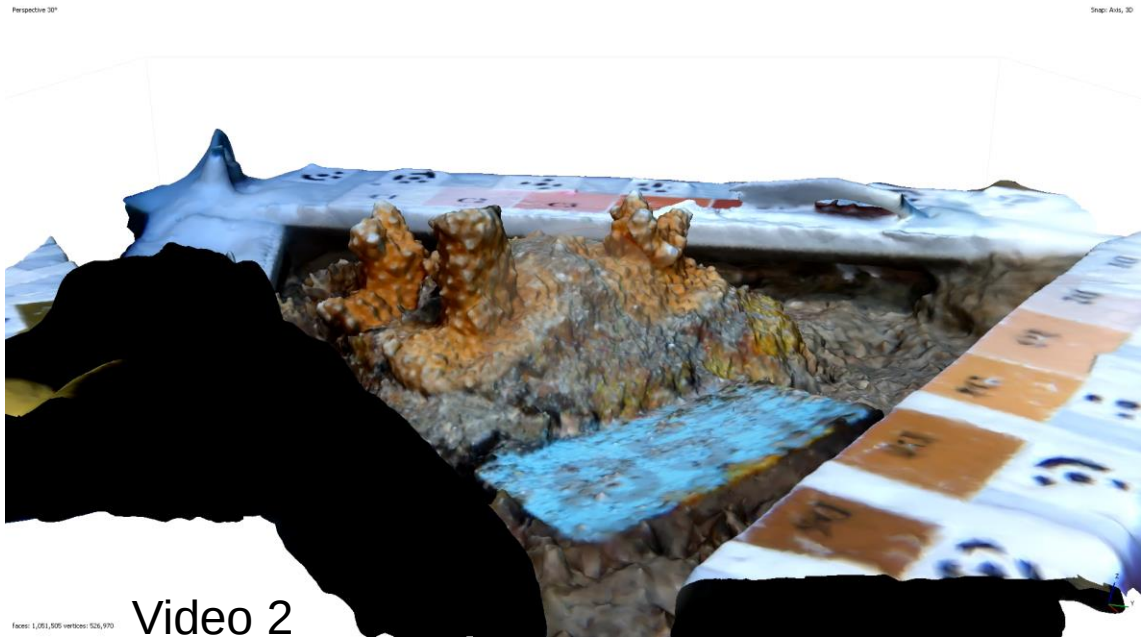
Large-area imaging of coral reefs for monitoring and restoration

Art Gleason



Model from Lisa Carne, Fragments of Hope



Model from Kelsey Johnson-Sapp, University of Miami

Caribbean Coral Restoration Roadmaps Initiative at Florida Keys Eco-Discovery Center in Key West, Florida

June 9th – 14th, 2024

AGRRA

cordap Coral Research & Development Accelerator Platform

MPA connect

UNIVERSITY OF MIAMI

A note on terminology

I used to call this technology *underwater landscape imaging*, but my preferred term now is **Large-Area Imaging** (LAI)

Photomosaic is also very common term and that's OK too.

Other commonly used terms:

- remote sensing
- photogrammetry
- photogrammetric models
- underwater landscape imagery/mosaics
- photomosaics
- structure from motion (SfM)

Compared to LAI

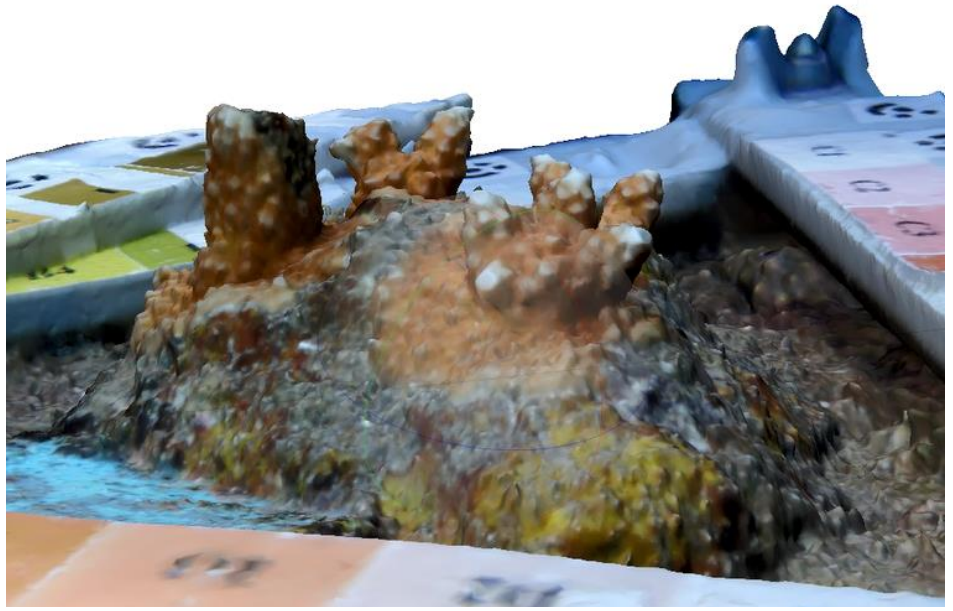
too general

(best match)

too specific

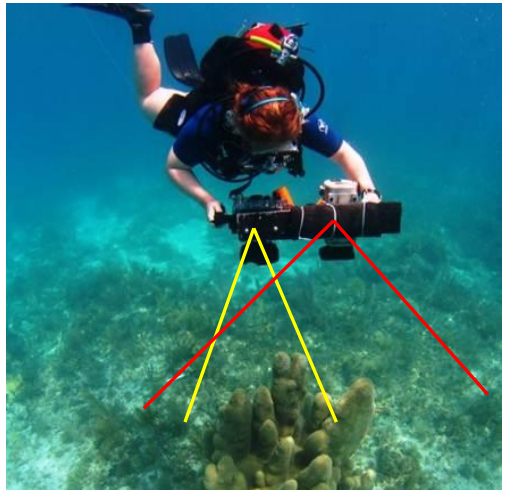
Consider these synonyms for the purposes of this talk.

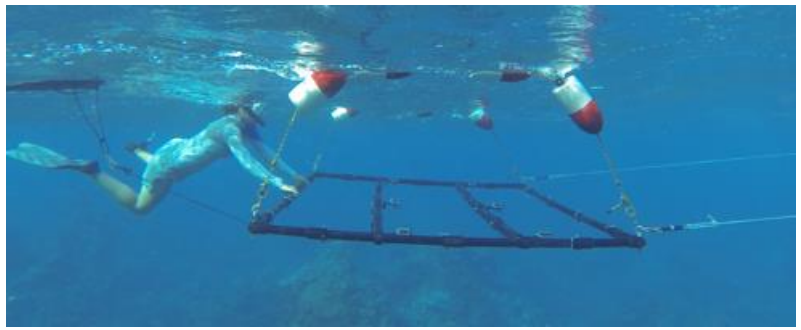
A landscape

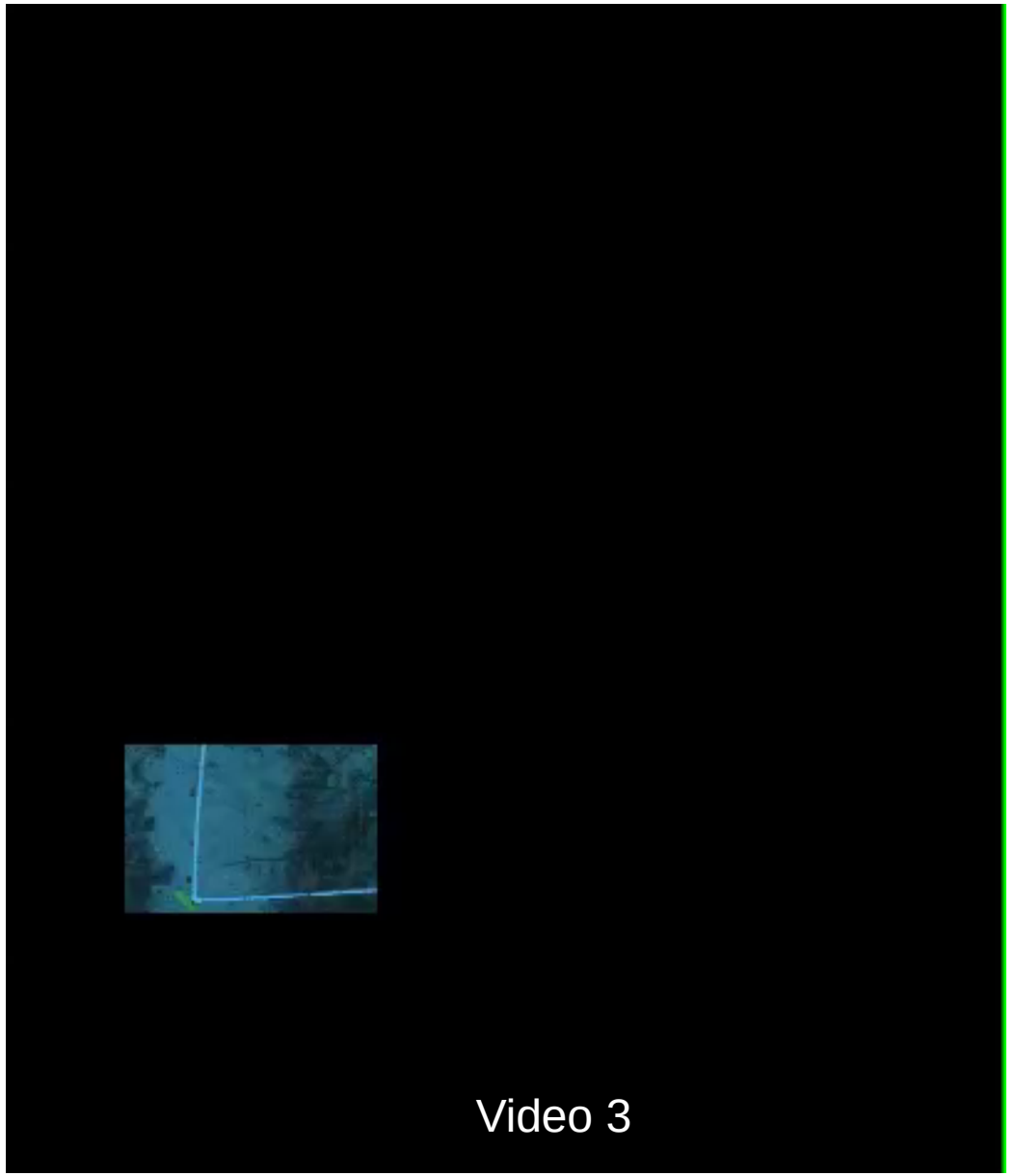


Not a landscape (but the same imaging technology)

Whatever you call it, what is the basic idea?



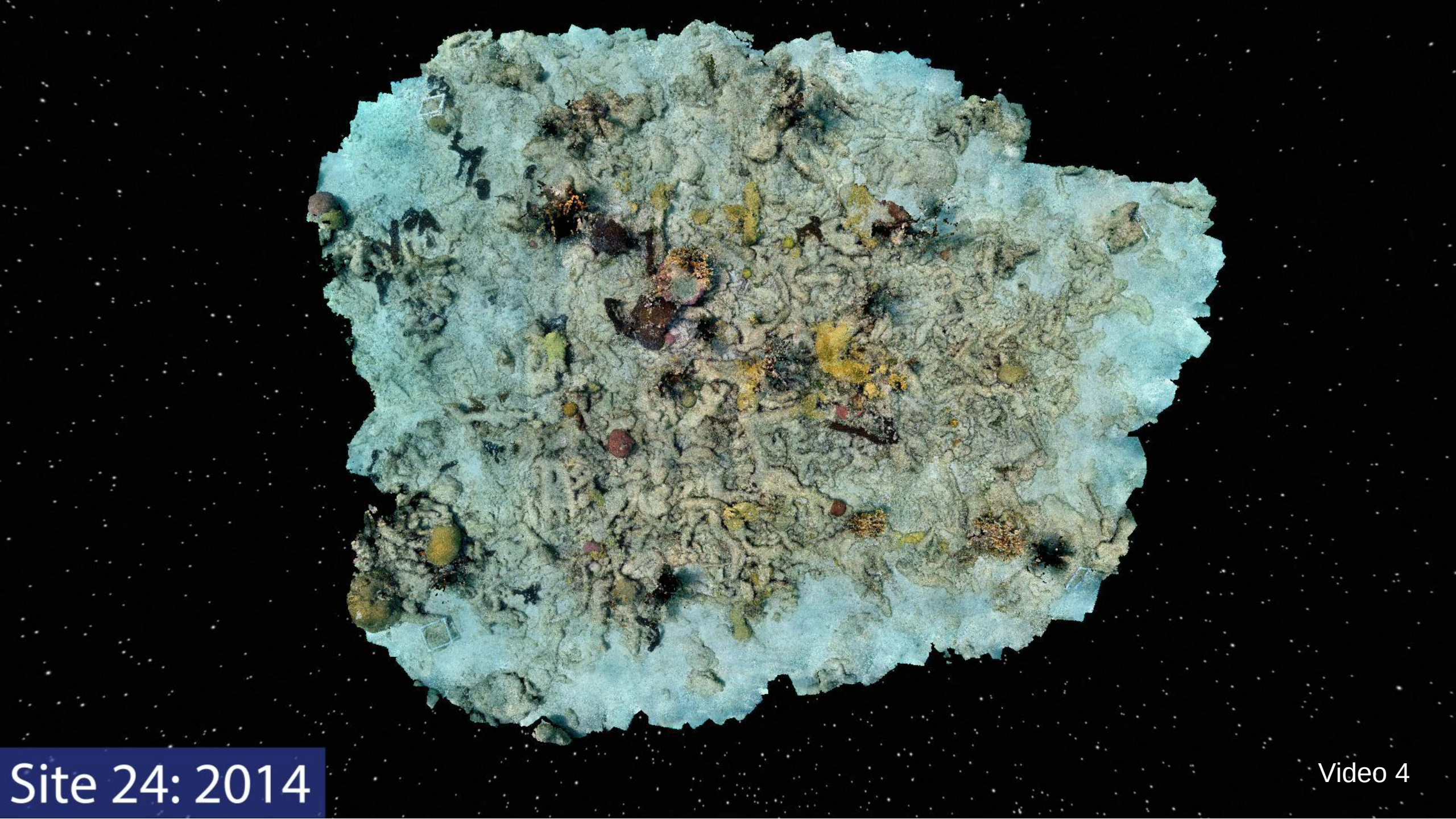




How is this useful?

- Benthic Cover
- Rugosity
- Demographics
- Fate tracking (disease / bleaching)
- Damage assessment (hurricanes/ship grounding)
- Growth or erosion rates
- Communication

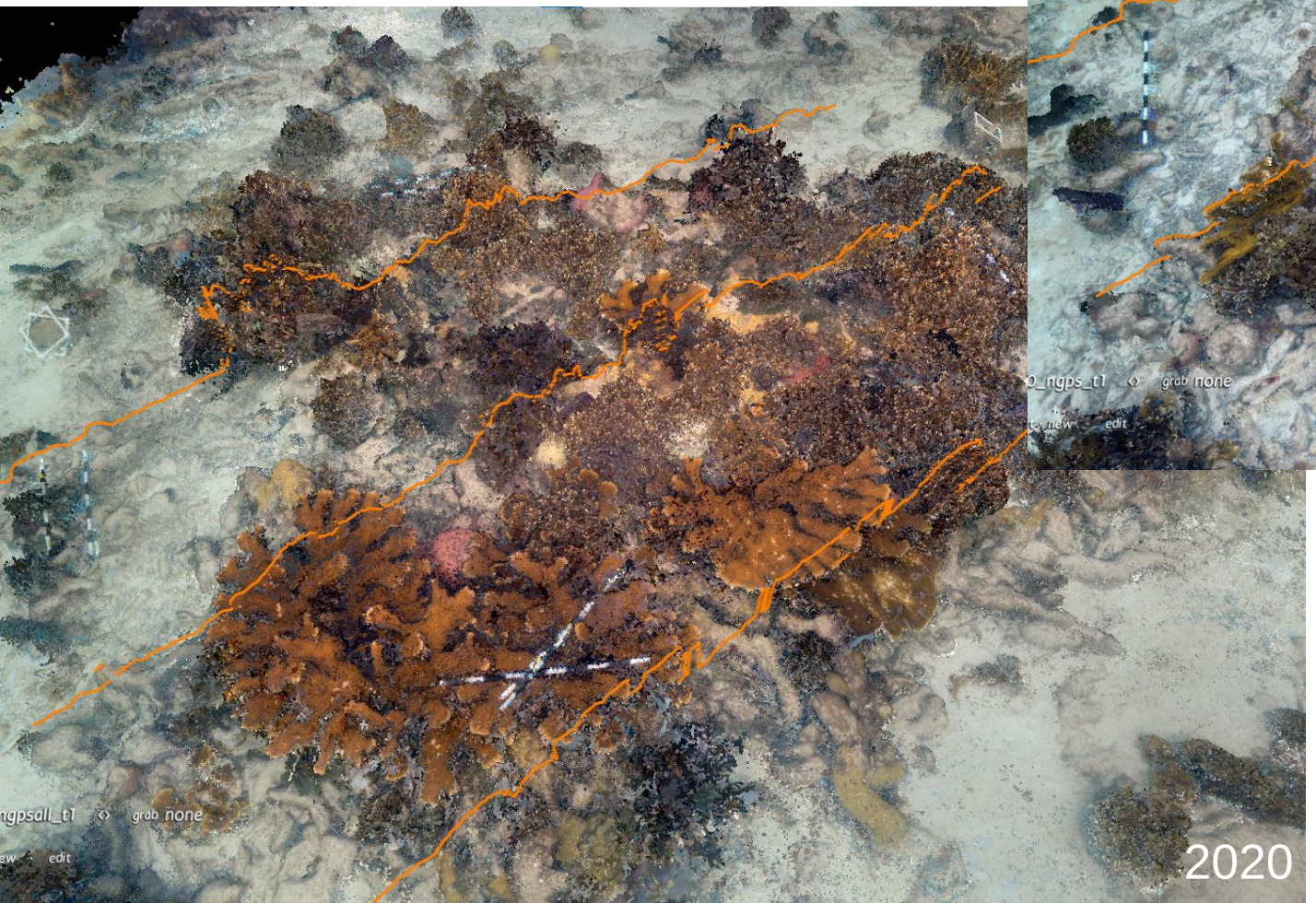
etc... What do *you* want to measure?

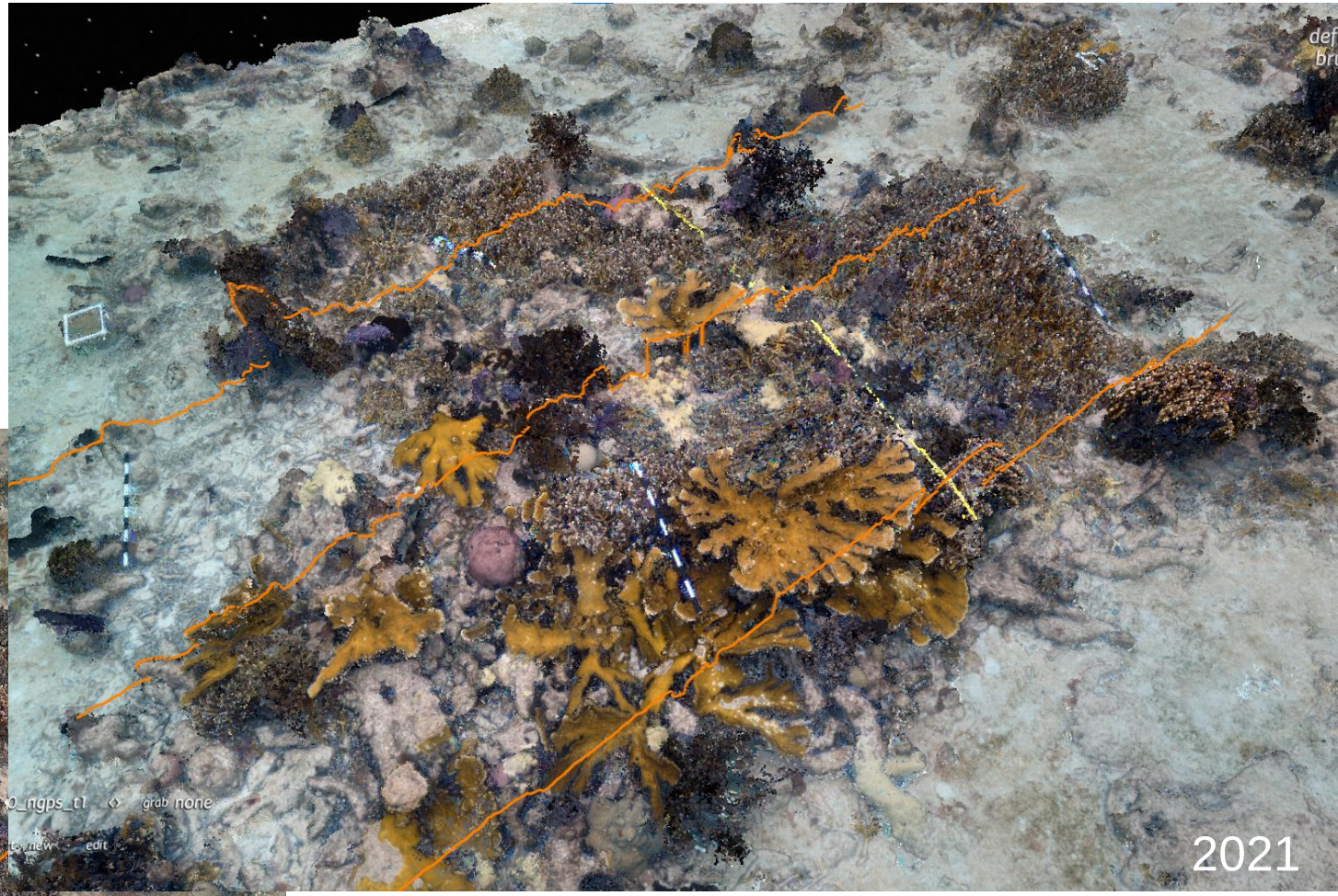


Site 24: 2014

Video 4

Rugosity

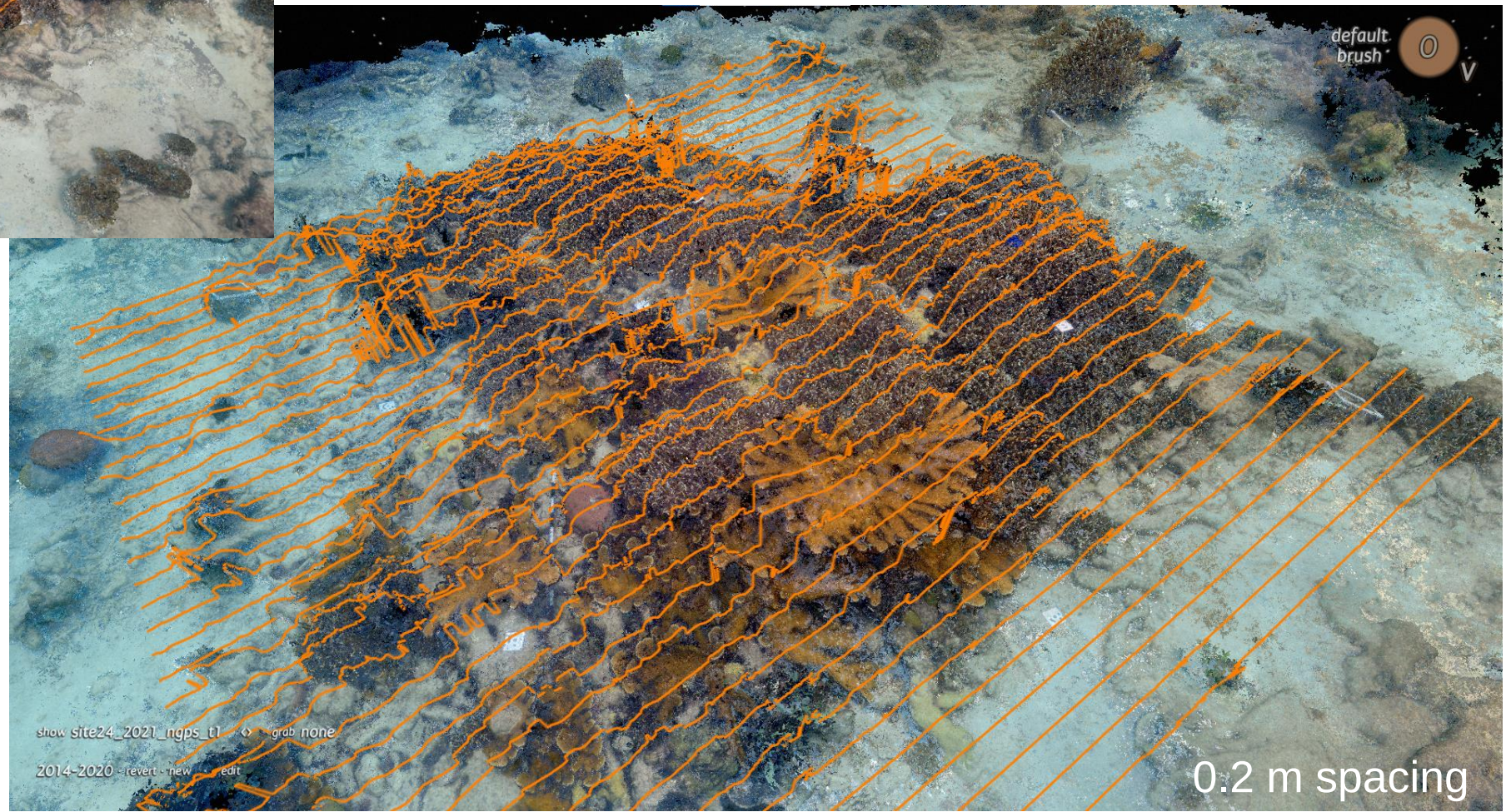


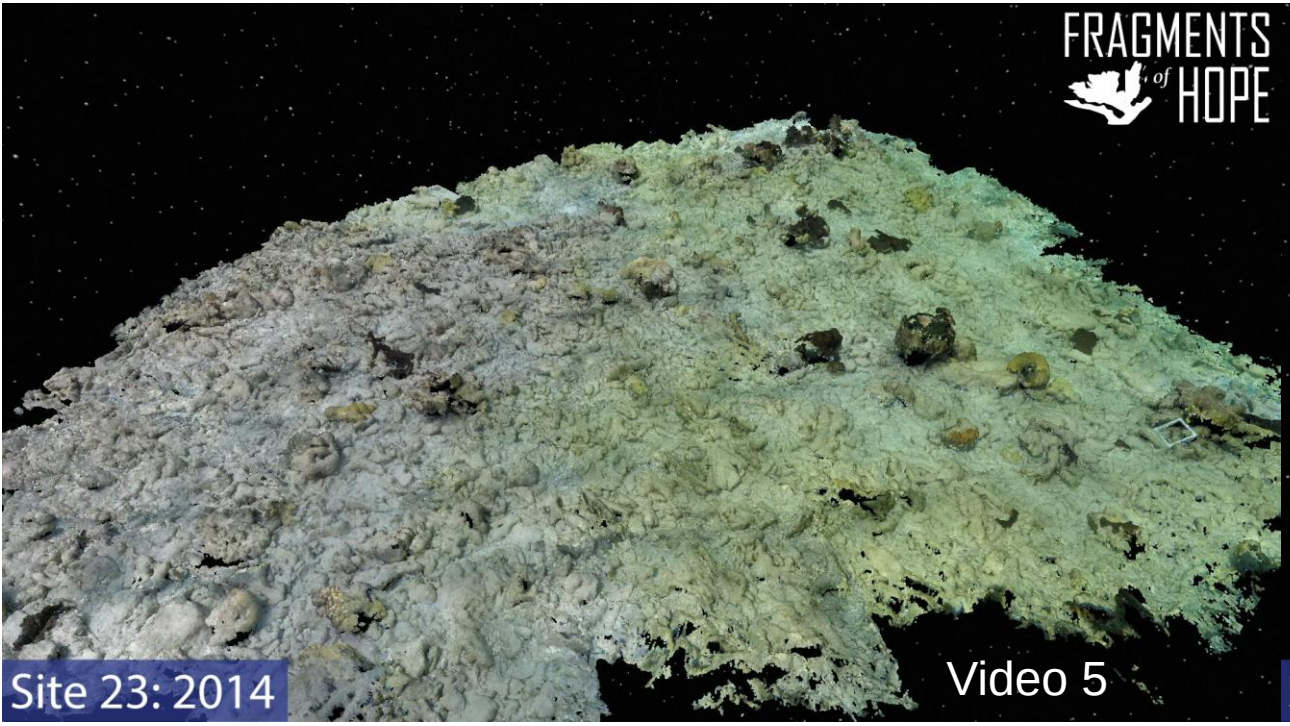


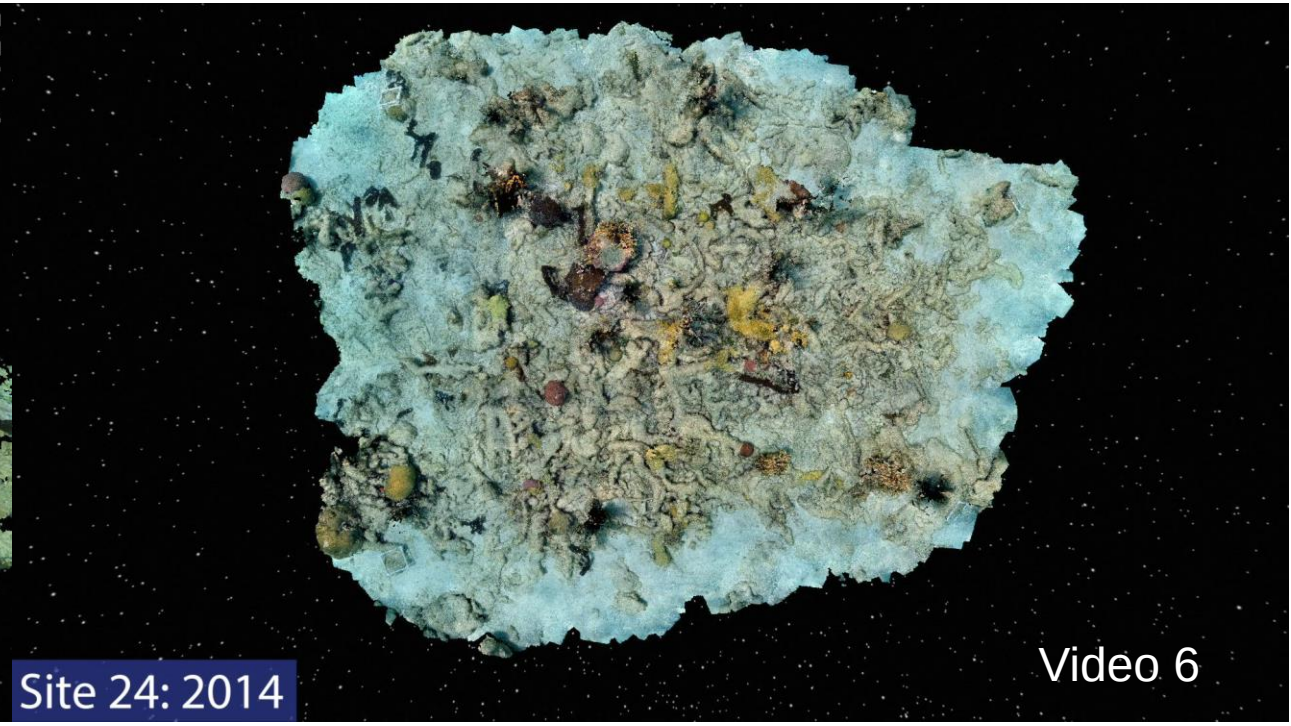
Example virtual rugosity transects
(from site in the movie previous slide)

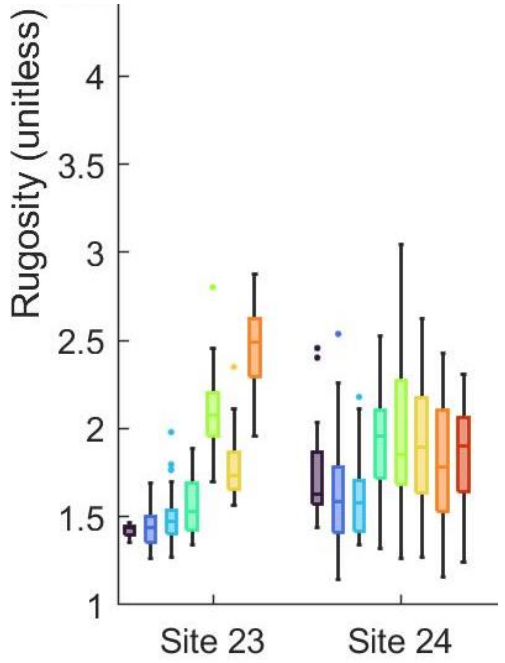
Rugosity

Replicate transects accounts for intra-site variability



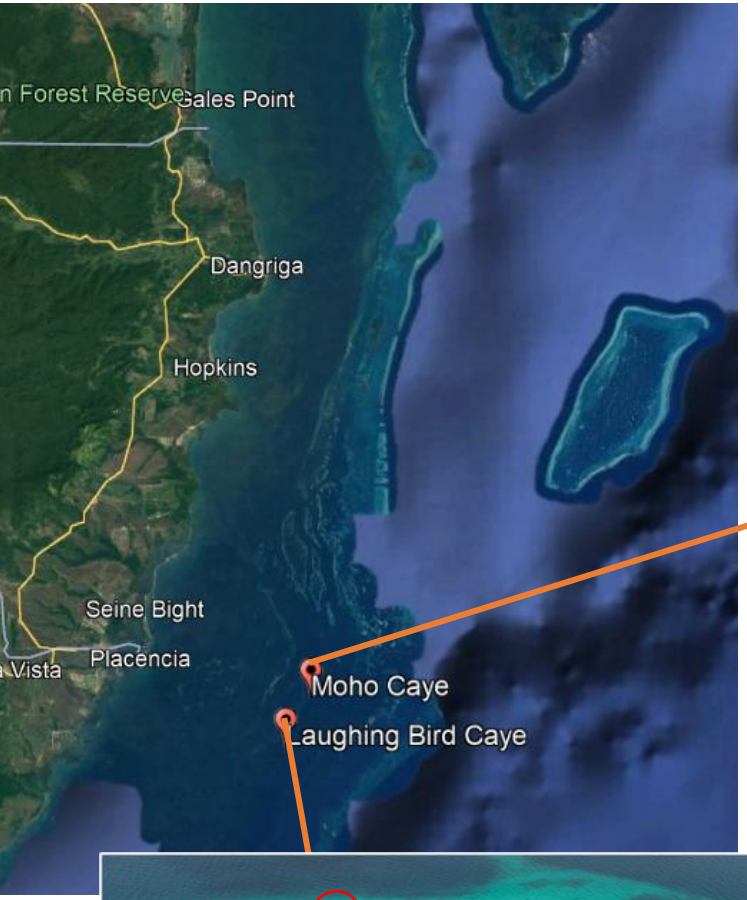

FRAGMENTS of HOPE
Site 23: 2014
Video 5


Site 24: 2014
Video 6

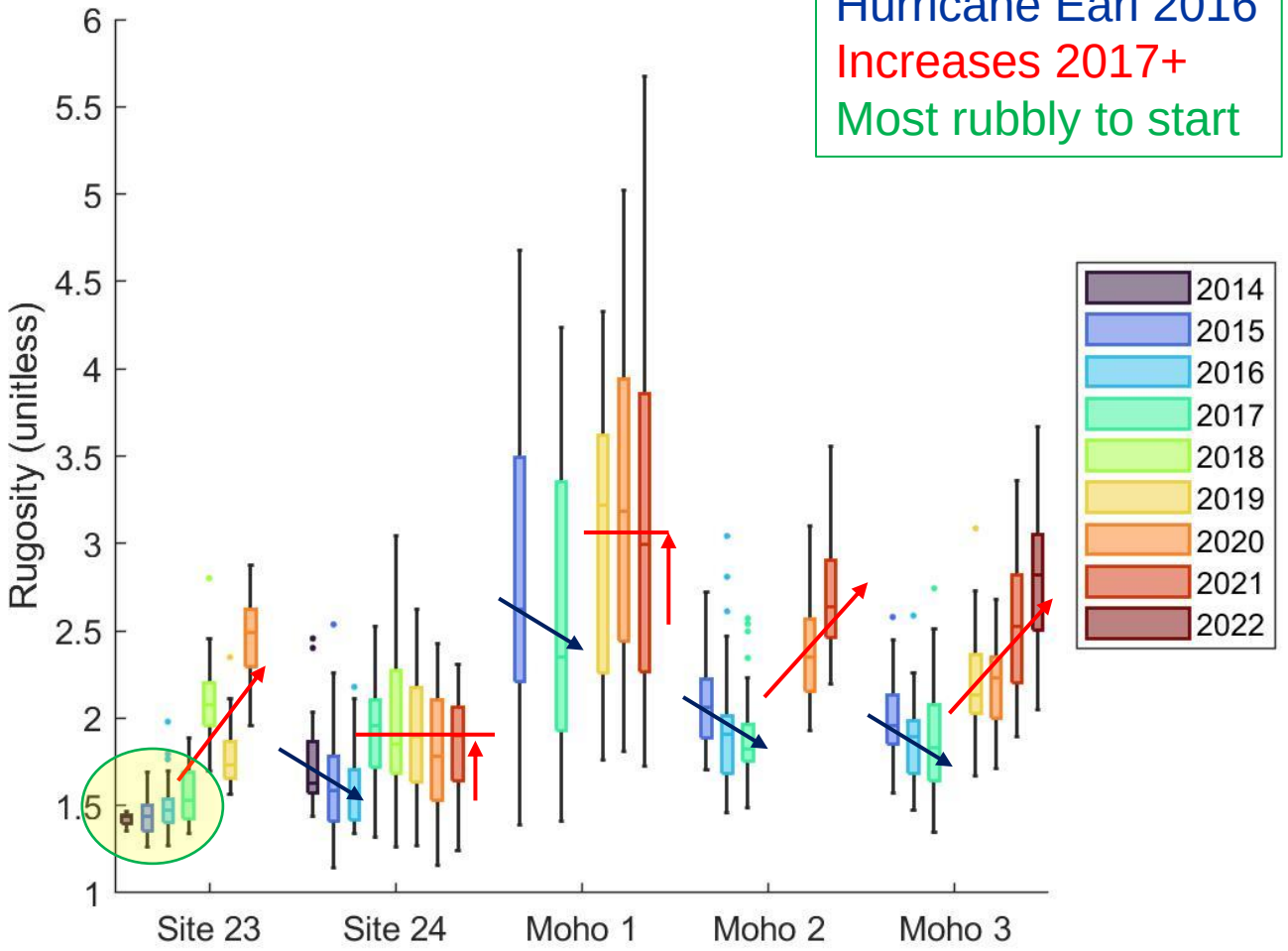

Rugosity (unitless)
4
3.5
3
2.5
2
1.5
1
Site 23
Site 24

5 plots in Belize

Laughing Bird Caye = protected
Moho = unprotected
These 5 sites have pre-outplanting imagery
No control sites

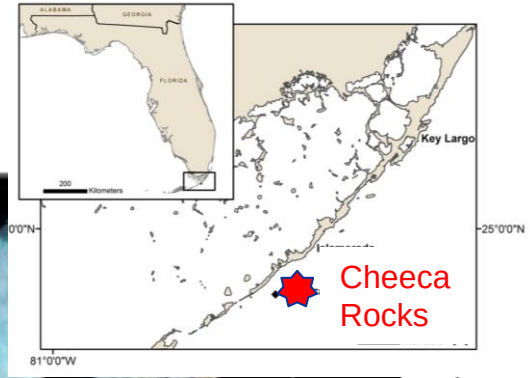


Hurricane Earl 2016
Increases 2017+
Most rubbly to start



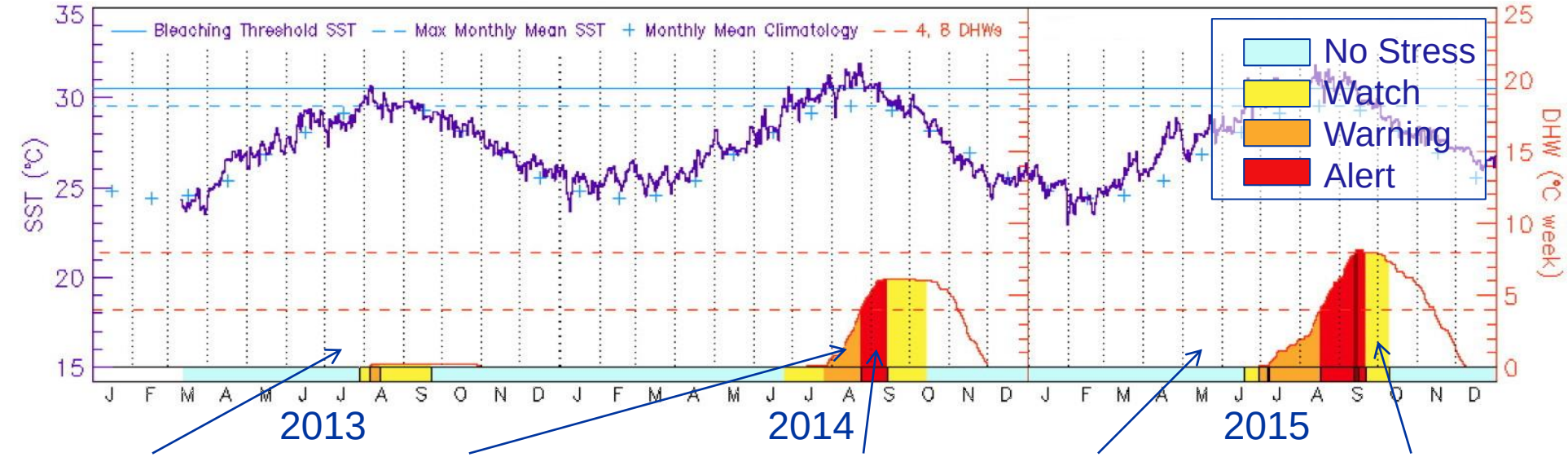
Cheeca Rocks, FL

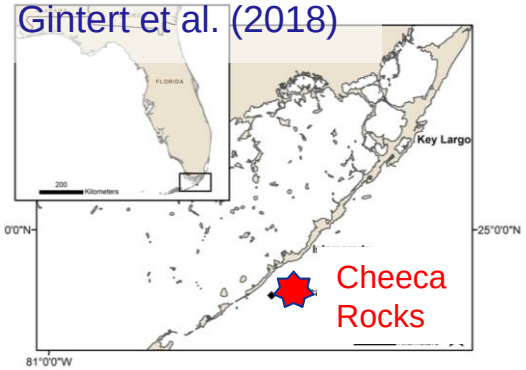
Gintert et al. (2018)
http://web2.physics.miami.edu/~agleason/cheeca.html

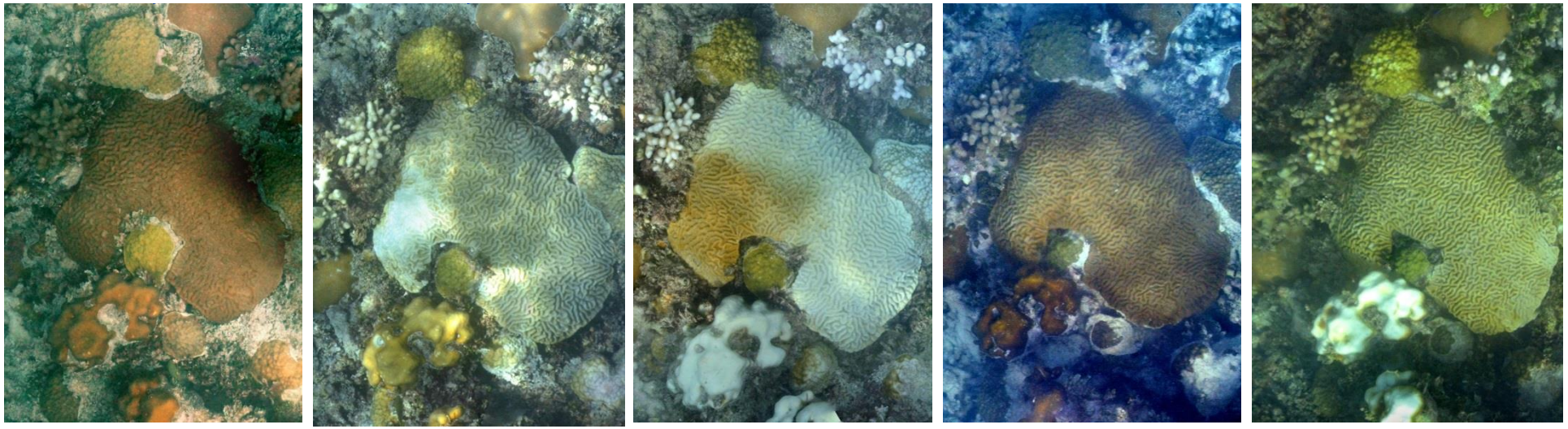


Video 7

Sync







- "Virtual tagging" with mosaics permits fate tracking: **4,234 colonies over 6 years**
- Repeat visits = higher power to detect change than random transects
- Also allows you to take past history into account when looking at coral dynamics
- **Corals at Cheeca Rocks seem to have become more resistant following multiple successive bleaching events**

SCTLD at Cheeca Rocks

Kolodziej et al. 2021

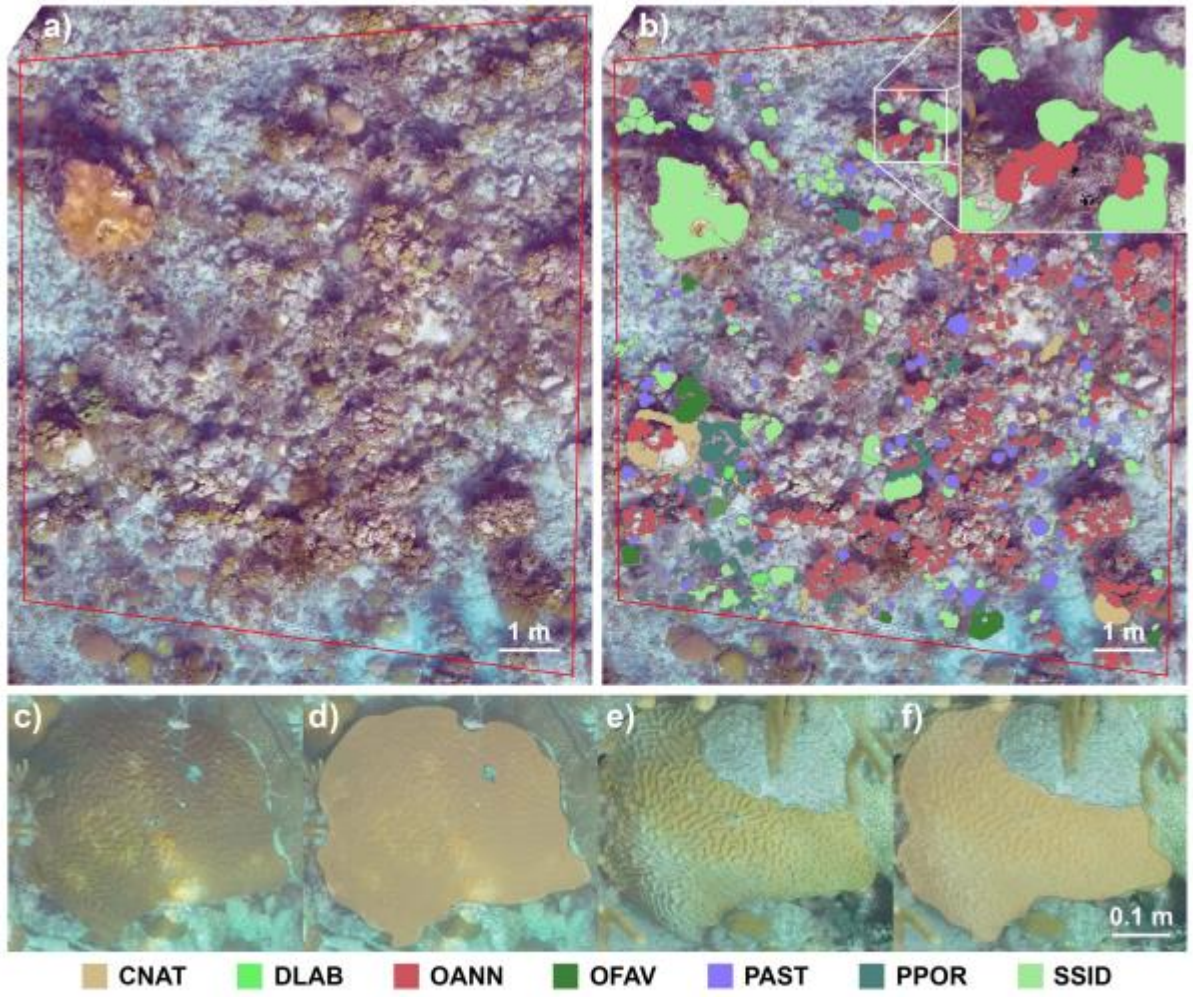


FIGURE 2 | (a) Orthomosaic of one of the six plots analyzed in this study. The red boundary was defined by permanent markers at the site, and all scleractinian coral colonies within this area were included in the analysis. **(b)** The same orthomosaic with superimposed polygons representing the boundaries of individual coral colonies. A fate-tracked *Colpophyllia natans* colony in **(c)** November 2017, **(d)** with resulting analysis polygon, **(e)** and the same colony showing partial mortality in September 2019, **(f)** with its resulting edited polygon. CNAT, *Colpophyllia natans*; DLAB, *Diploria labyrinthiformis*; OANN, *Orbicella annularis*; OFAV, *Orbicella faveolata*; PAST, *Porites astreoides*; PPOR, *Porites porites*; SSID, *Siderastrea siderea*.

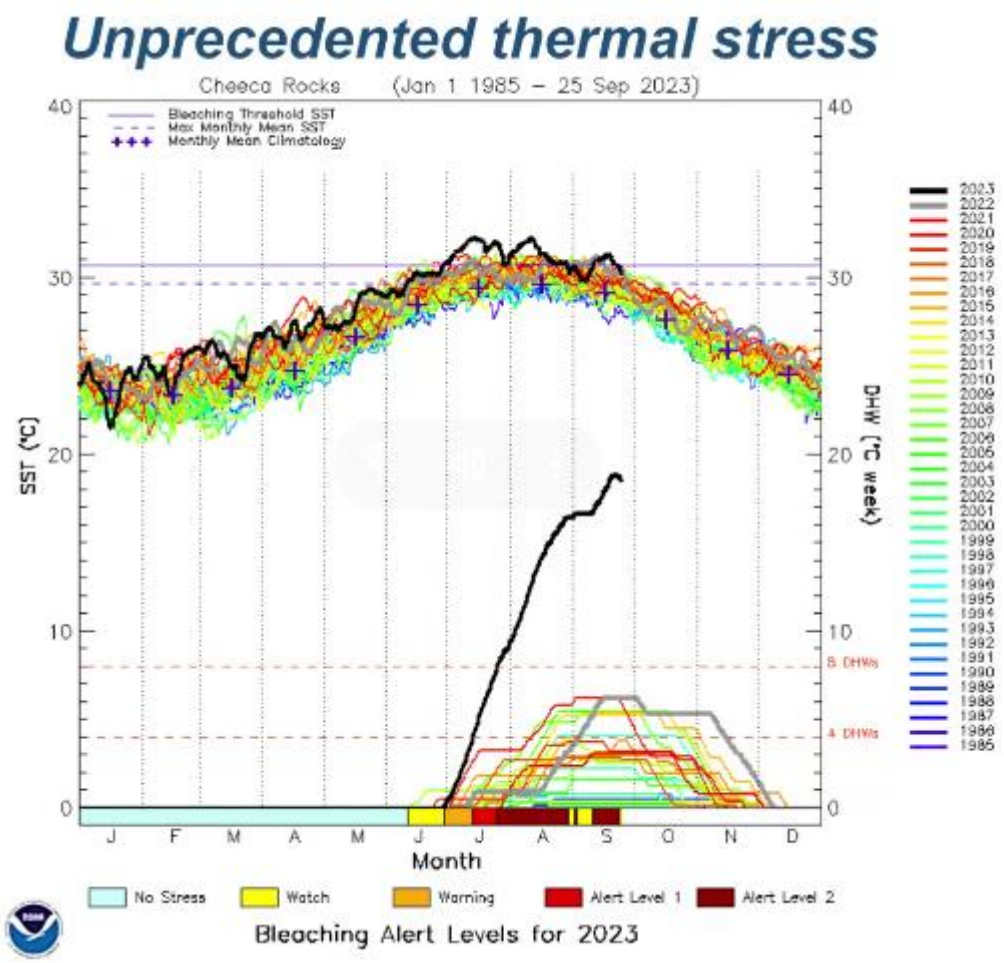
Minimal (1.6%) loss of coral cover from 2017 to 2019 following stony coral tissue loss disease (SCTLD).

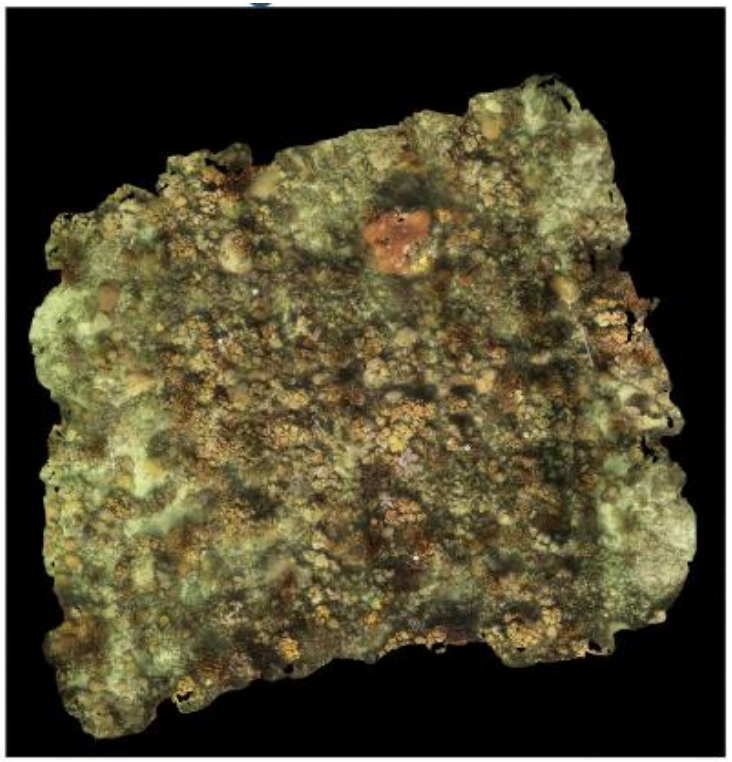
Impacts less severe at Cheeca Rocks relative to other areas of Florida's coral reef tract.

Why? Not really known but possibly increased nutrient concentrations, turbidity, chlorophyll, and temperature variability conveys increased coral fitness? This is a good dataset to check that.

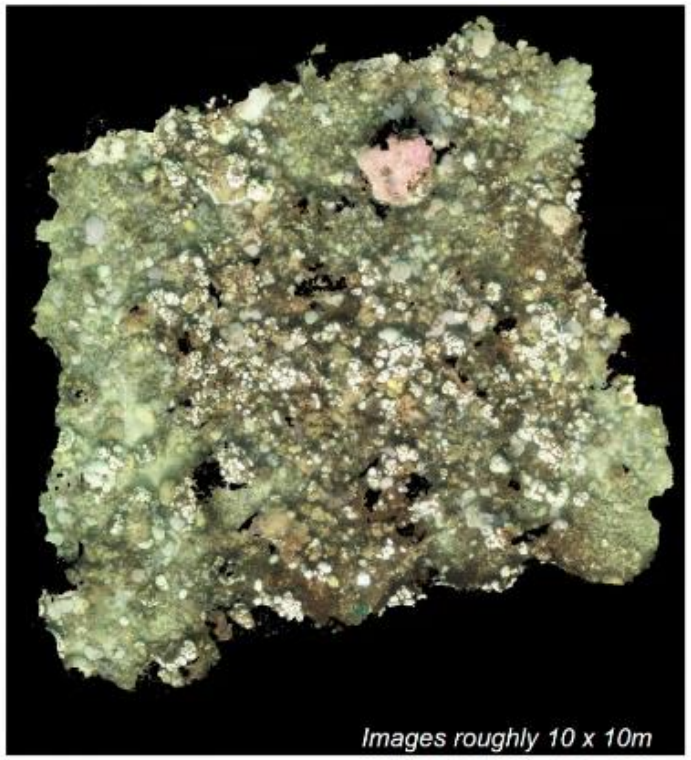
2023 Bleaching

Enochs unpublished data





June 30

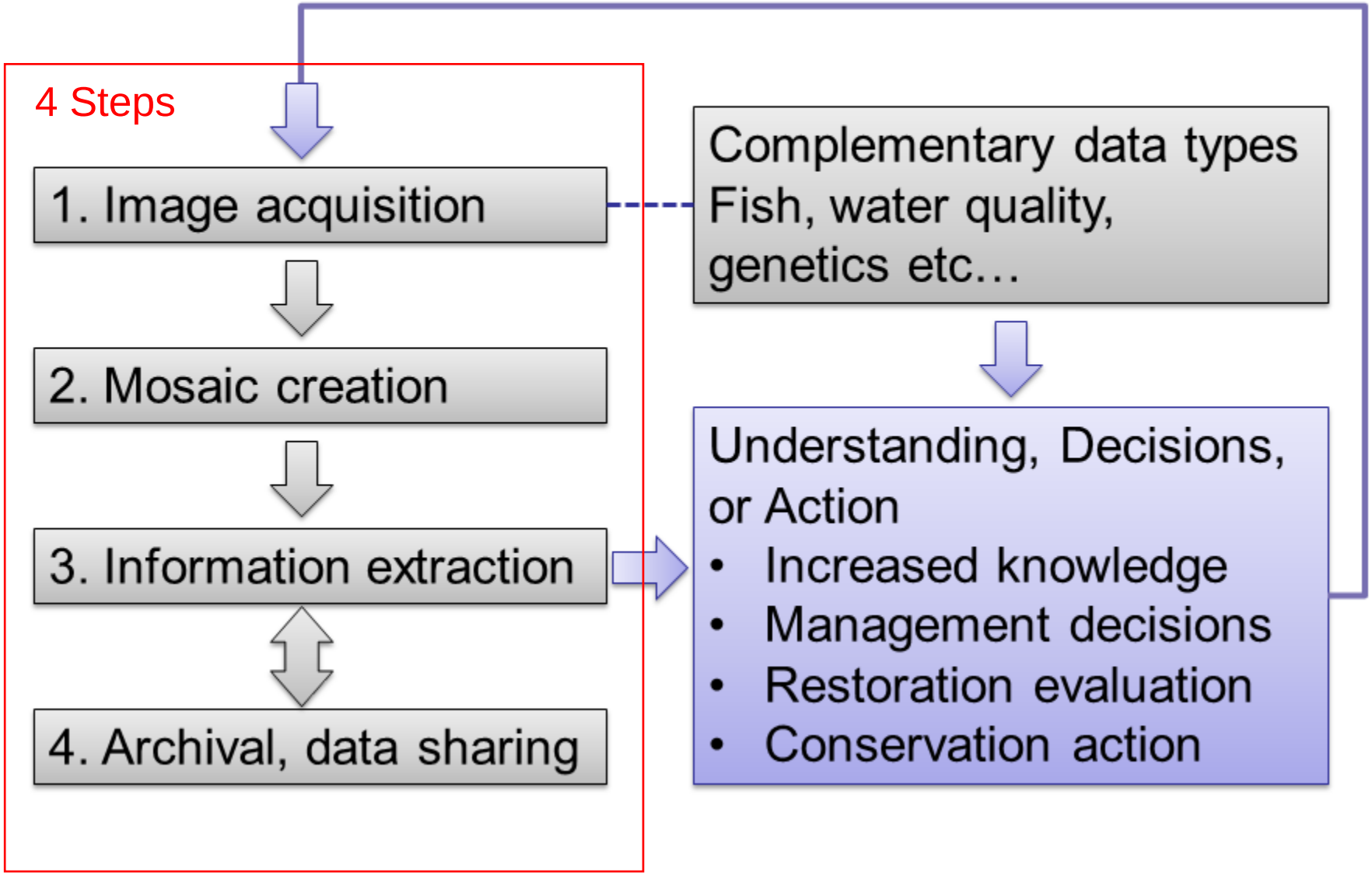


July 24

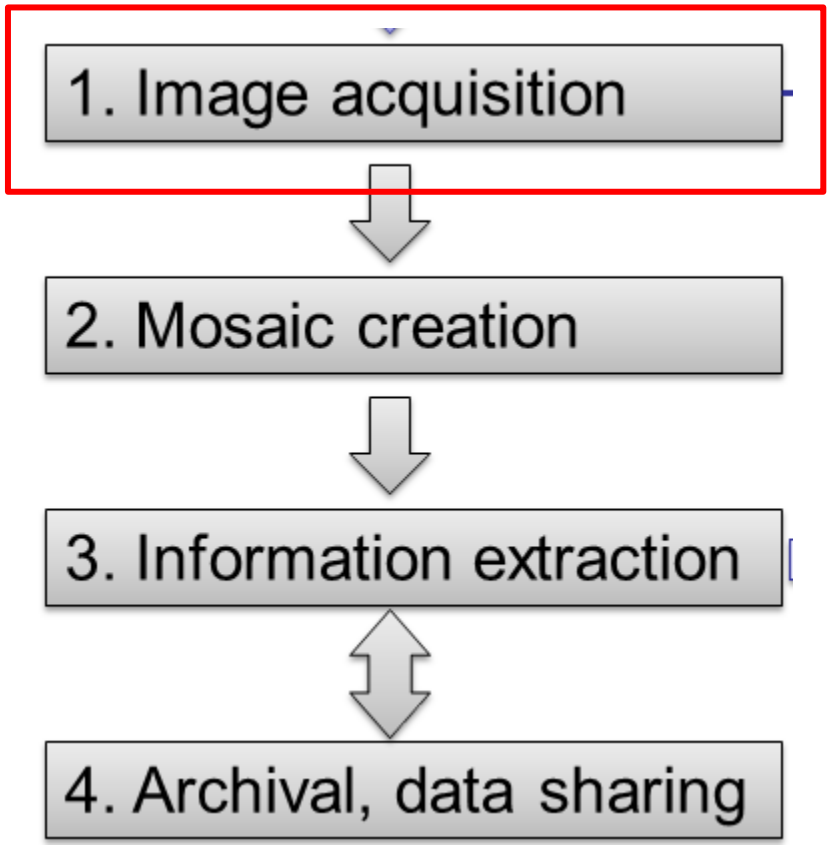
Strategic sampling times to capture this event.
Recovery to be determined (have not seen latest imagery)

The LAI “pipeline”

Success with this technology involves much more than just stitching photos.



What camera do I need?



Must haves:

- Sharp images (in focus, blur-free)
- Intervalometer (careful, not usually = “time lapse”)
- Many images over site
- High overlap

Preferred

- Long battery life (for multiple surveys / day)
- Multiple cameras (for high resolution and backup)
- Large sensor (for low light)

What are people currently using?

- GoPro
- Sony a6400
- Nikon D7500 or D780
- Combinations of the above
- Many others, actually, but these seem to be common

I personally use (but don’t recommend to everyone)

- Dual Canon SL-3

Everyone wants a SOP

1. Image acquisition
2. Mosaic creation
3. Information extraction
4. Archival, data sharing

Guidelines for handheld image acquisition

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CORAL RESTORATION FOUNDATION™

WHITE PAPER
NOVEMBER 9, 2020

Coral Restoration Foundation™ Photomosaic Manual
Second Edition - November 2020

USGS
science for a changing world

Processing Coastal Imagery With Agisoft Metashape Professional Edition, Version 1.6

PIMS forthcoming?

Multiple protocol documents.
Focus on the common elements, **not** the differences

Good data are fundamental

1. Image acquisition
2. Mosaic creation
3. Information extraction
4. Archival, data sharing

- Step 2 is easy now if you have good data, but hard if not
- Class mostly about what is good data, e.g. compare sequences:

Processing help

1. Image acquisition
2. Mosaic creation
3. Information extraction
4. Archival, data sharing

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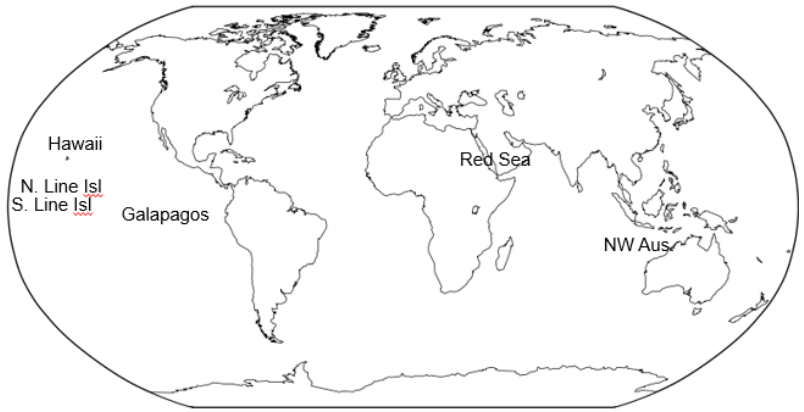

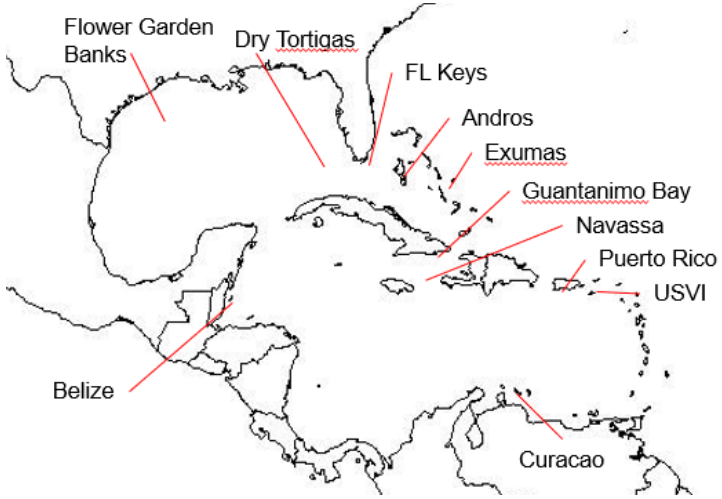

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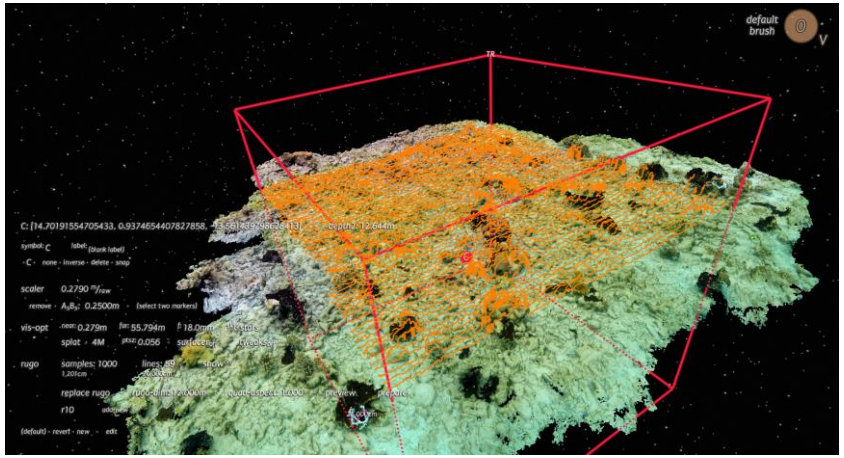
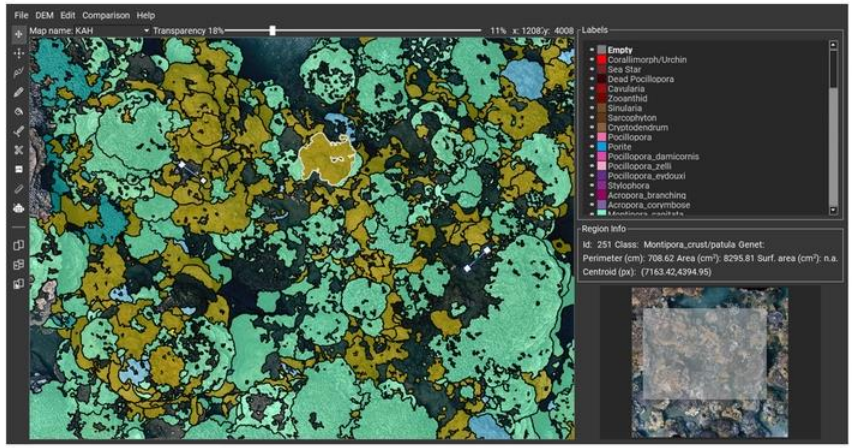
Analysis tools

1. Image acquisition
2. Mosaic creation
3. Information extraction
4. Archival, data sharing



Viscore: point cloud analysis
- Point counting
- Rugosity
- Multitemporal registration



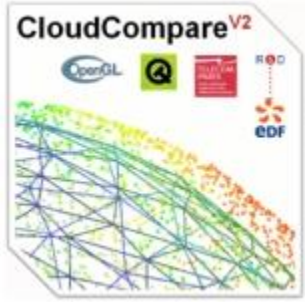
TagLab: 2-D segmentation
- Machine assisted
- "Plays well" with Viscore

Modern Machine Learning Tools:
- Not all support LAI (yet)

ReefCloud

CORALNET
A WEB SOLUTION FOR CORAL REEF ANALYSIS

CERULEAN AI
BY CORAL RESTORATION FOUNDATION™



CloudCompare:
- View/align point clouds
- Not coral specific

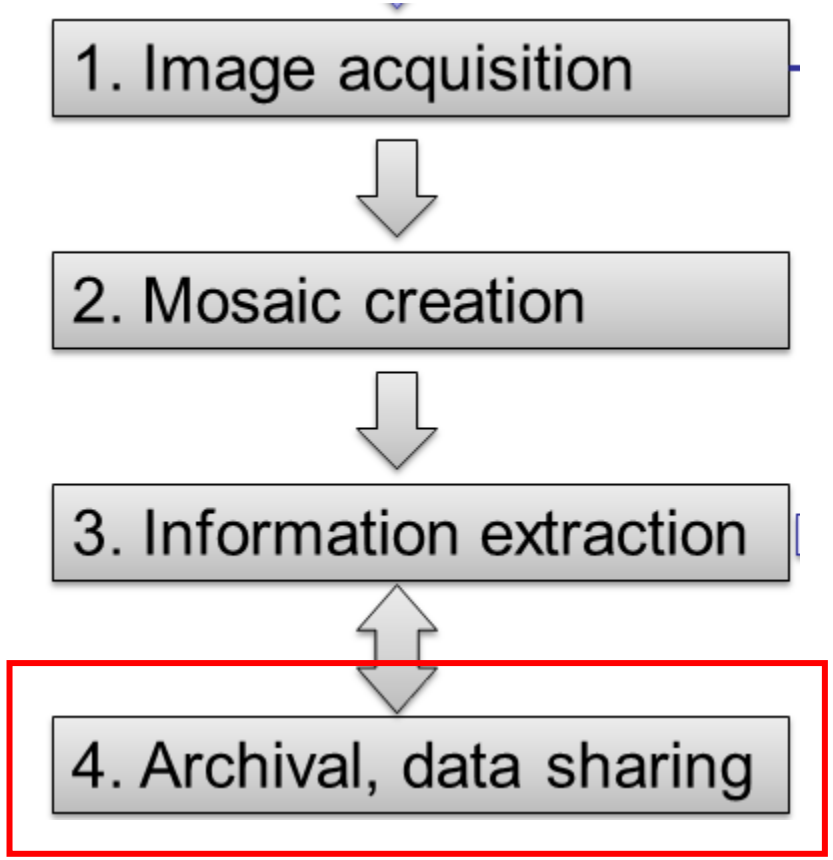
ArcGIS

Ps

CPCe
Coral Point Count with Excel extensions

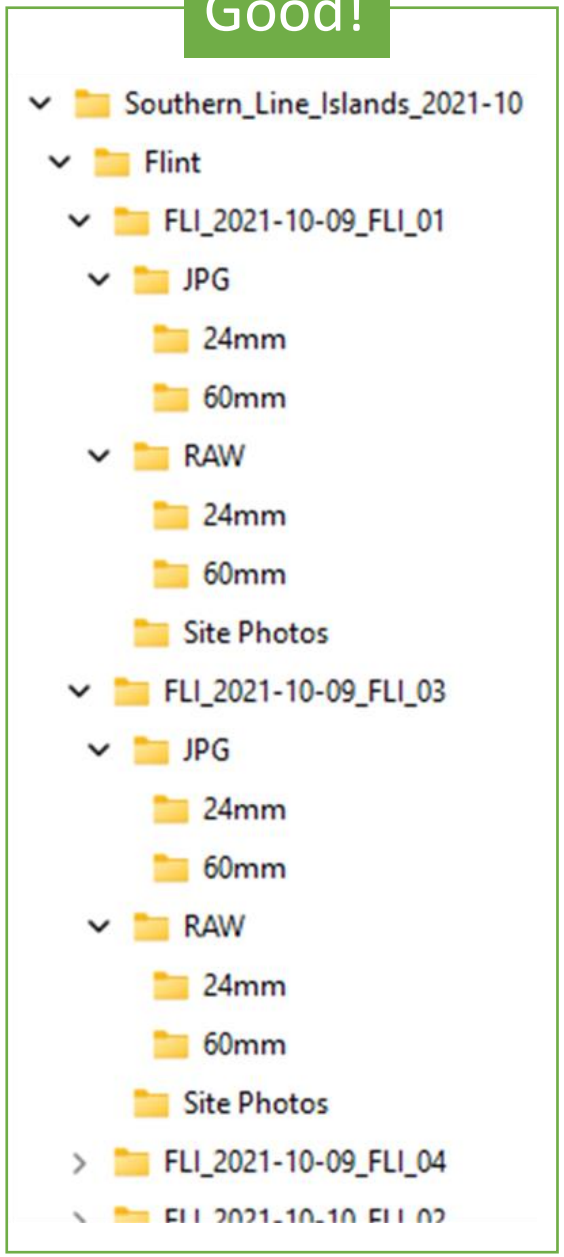
Legacy methods:
- Still viable, still a lot of work

Data archival

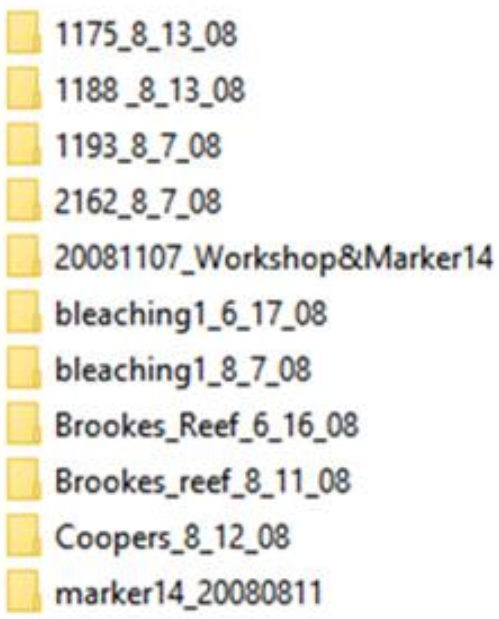


Could an archaeologist decipher your data?

Good!



Bad!



Key tips:

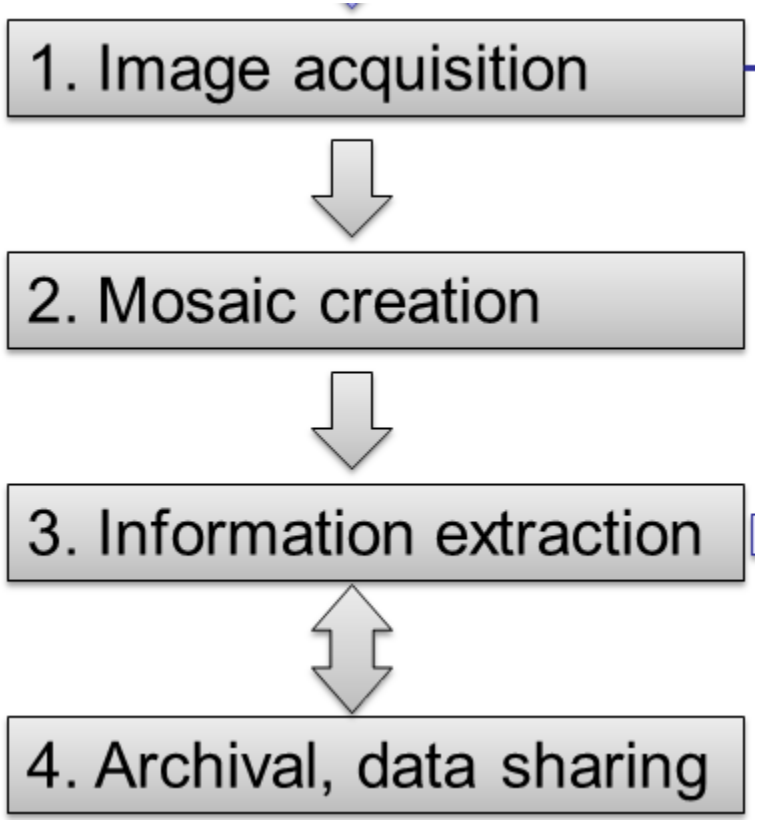
- Digital metadata (not paper)
- Quality control of inputs (e.g. GPS)
- Consistent naming
- Useful naming (dates, sites in names)
- Multiple backups
- Snail mail viable if internet is slow

Data archival and sharing

1. Image acquisition
2. Mosaic creation
3. Information extraction
4. Archival, data sharing

Video 8

Costs



Equipment budget:

• Camera(s), housing(s), batteries, cards	$500 - $5,000
• Stitching software	$700 - $5,000
• Stitching computer	$3,500
• Storage: big HDD + backup	$1,000
• Scale bars	$0 - $100

Field costs

- ~1 hr dive time per site (100-200m^2)
- Permanently marking site

Analysis costs

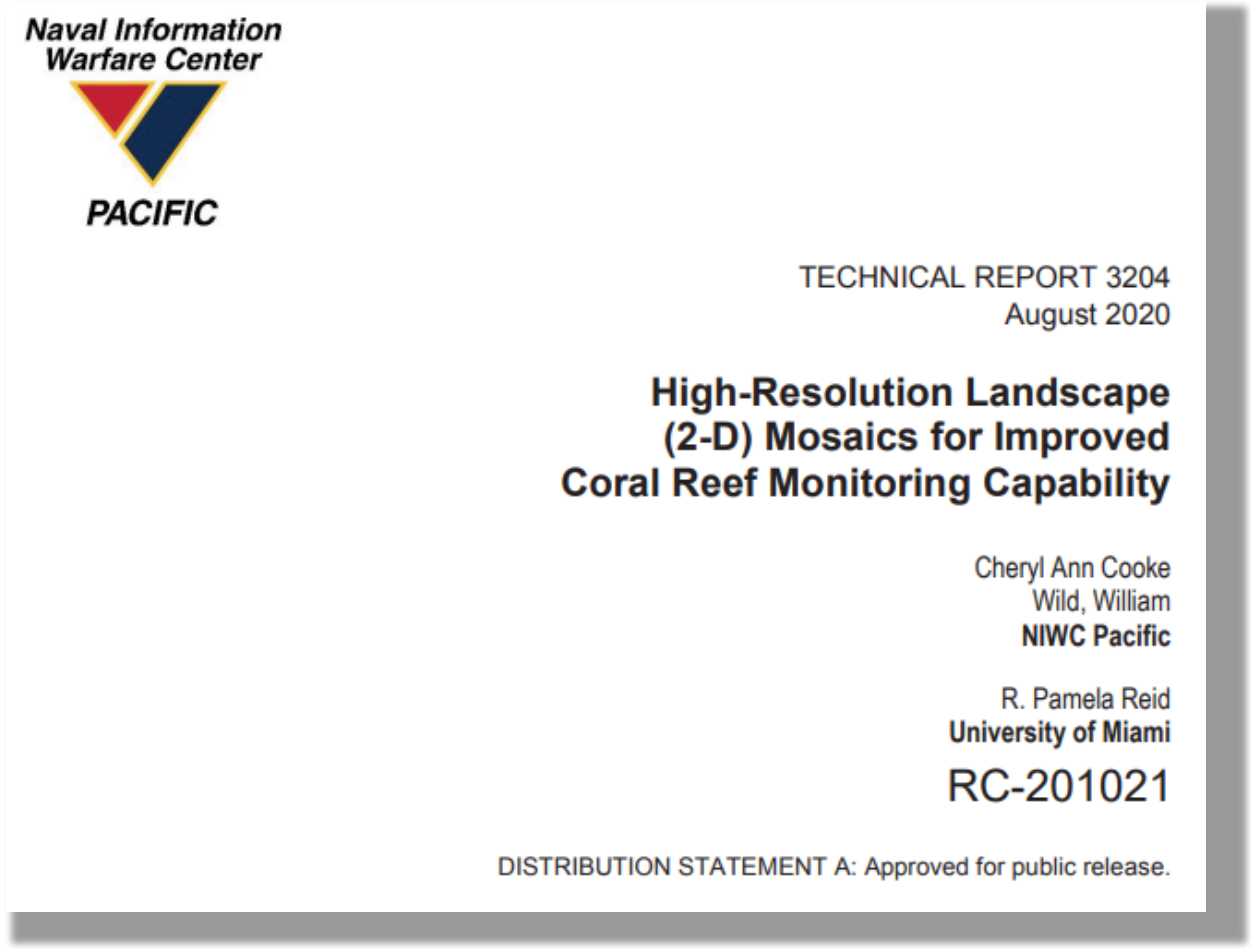
- Highly variable, depending on information to extract
- Highly variable, depending on salary of analyst
- Software from $0 - $many K (e.g. for ArcMap)

Costs for different types of measurements varied over at least 2 orders of magnitude, which was much greater than the range of costs associated with different methods or different divers performing the same type of measurement.

As for any technology, it makes no sense to ask “what is the cost of the mosaic technology?”
The correct question is “what is the cost of the mosaic technology to do X ?”

Pros and Cons

	Traditional: Diver Survey
Strengths of the diver transect	
Percent cover of benthic organisms	excellent
Diversity indices	excellent
Disease / Bleaching / Partial Mortality	excellent
Coral colony size	excellent
Juvenile coral density	excellent
Limitations of the diver transect	
Permanent record for reanalysis	weak
Landscape view (map large features)	weak
Repeatability (monitor without tagging)	weak
Spatial accuracy	weak
Long dive times	weak
Scientific diver required	weak



Naval Information Warfare Center
PACIFIC

TECHNICAL REPORT 3204
August 2020

High-Resolution Landscape (2-D) Mosaics for Improved Coral Reef Monitoring Capability

Cheryl Ann Cooke
Wild, William
NIWC Pacific

R. Pamela Reid
University of Miami

RC-201021

Field experiments with Navy: Can mosaics address limitations of the diver transect?

Pros and Cons

	Traditional: Diver Survey		Mosaics relative to traditional
Strengths of the diver transect			
Percent cover of benthic organisms	excellent		see comments
Diversity indices	excellent		excellent
Disease / Bleaching / Partial Mortality	excellent		excellent
Coral colony size	excellent		excellent
Juvenile coral density	excellent		fair
Limitations of the diver transect			
Permanent record for reanalysis	weak		excellent
Landscape view (map large features)	weak		excellent
Repeatability (monitor without tagging)	weak		excellent
Spatial accuracy	weak		excellent
Long dive times	weak		excellent
Scientific diver required	weak		excellent

% cover complications:

- Resolution
- Specifics of diver technique

Juvenile density limitations

- Resolution
- Obscuration

- Mosaics do address limitations of the diver transect.
- Mosaics generally retain strengths of the diver transect.

Pros and Cons

	Traditional: Diver Survey		Mosaics relative to traditional
Strengths of the diver transect			
Percent cover of benthic organisms	excellent		see comments
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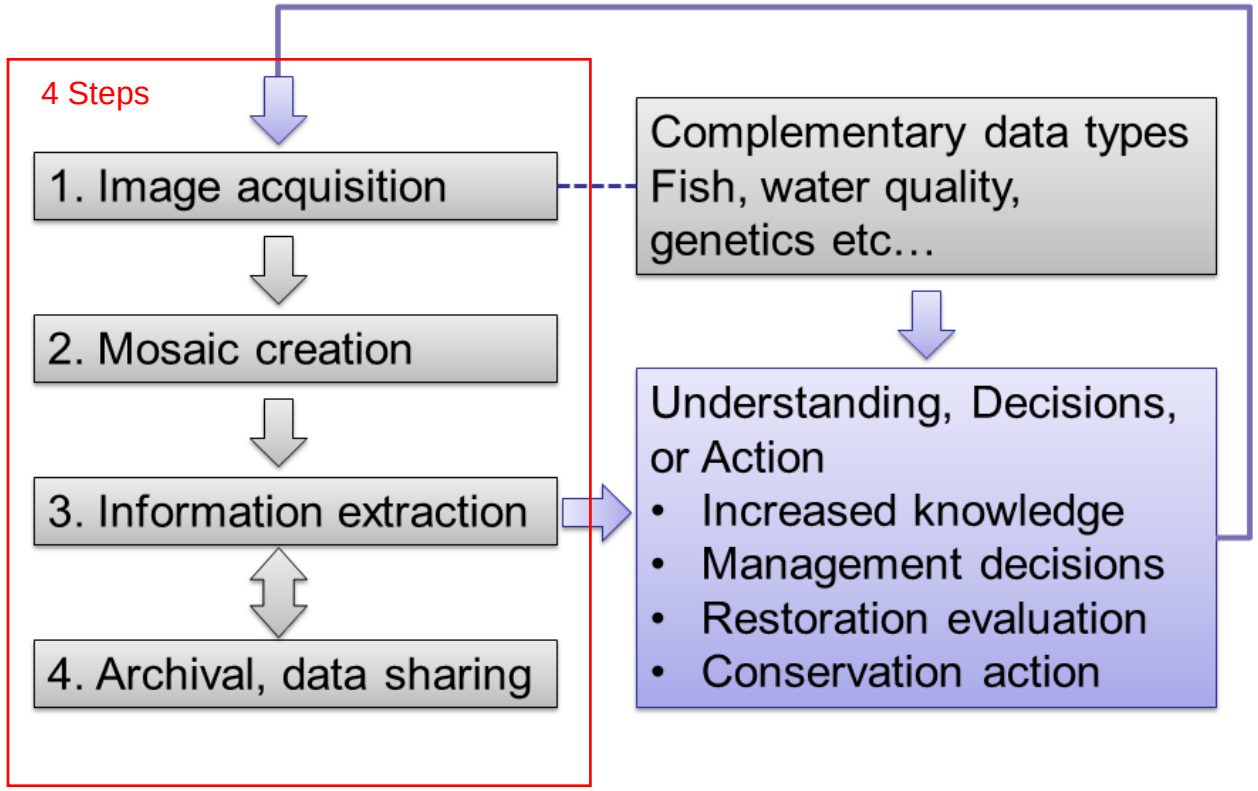
Spatial accuracy	weak		excellent
Long dive times	weak		excellent
Scientific diver required	weak		excellent

Mosaics are not a replacement for traditional diver transects in all situations.
Where / when to use them?

- When dive or field time is relatively expensive (use cost model to estimate)
- For measuring sizes, distances, or areas
- For measuring multiple variables, or when you are not sure what to measure
- For low impact monitoring studies (no tags)
- To leverage availability of non-biologist divers
- To communicate results visually

Conclusions



- Large-area imaging is a process, not just data or an algorithm.
- Possible now due to software, camera, batteries, storage and computing 2000-2010
- Step 1 is the only part of the pipeline that can't improve over time with reprocessing.
- Step 2 in this process is pretty well figured out if you do step 1 well.
- Step 3 may always be evolving due to different needs.
- Step 4 has transformative potential if we work together as a community

Conclusions

Basic message:

- If you would like help, please let me know.
- Do not let analysis fears paralyze you: get started with good data collection

Enable community-wide cooperation:

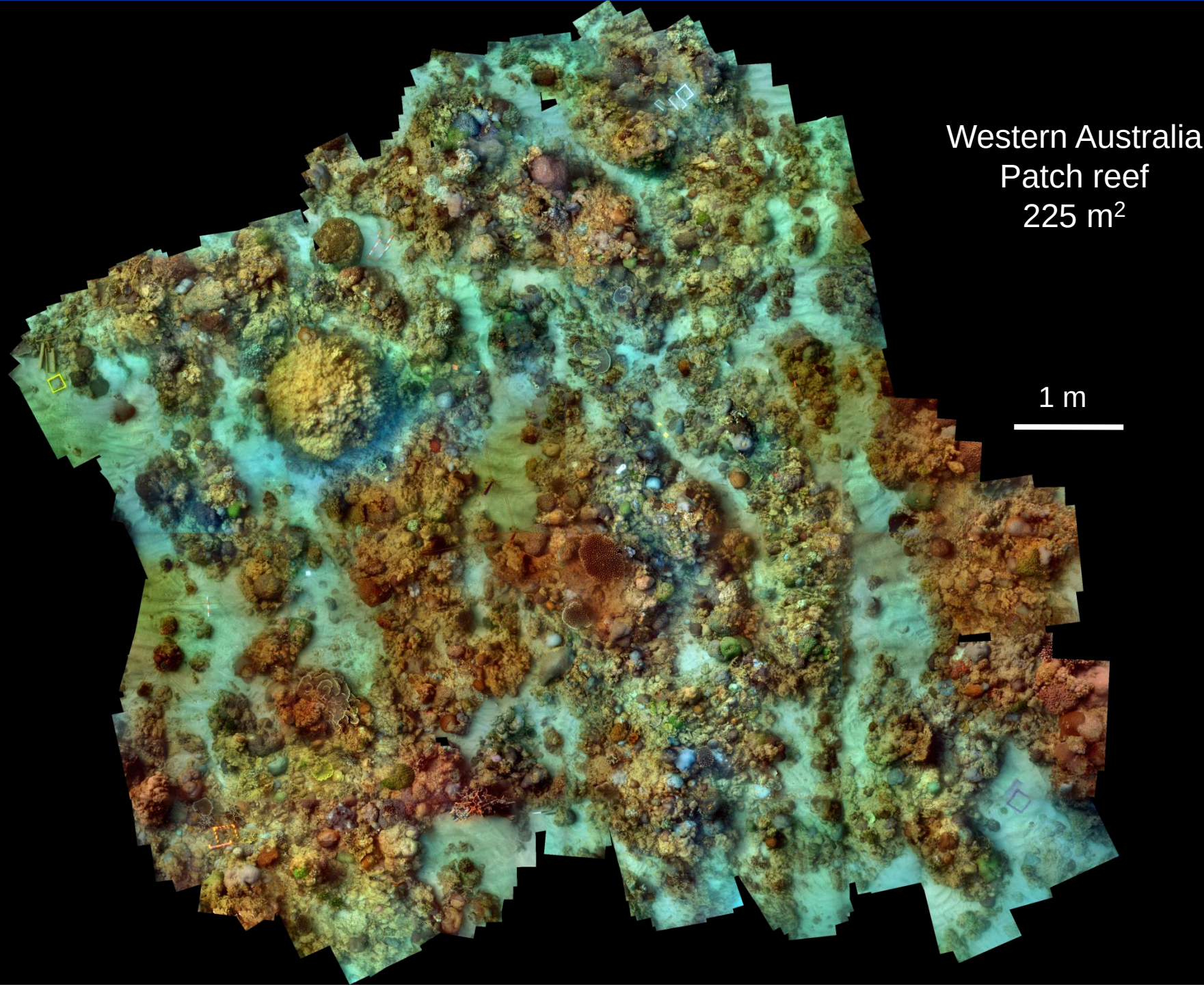
- Let us please avoid methodological wars (at a minimum).
- Let us advance as a community with shared data (ideally).

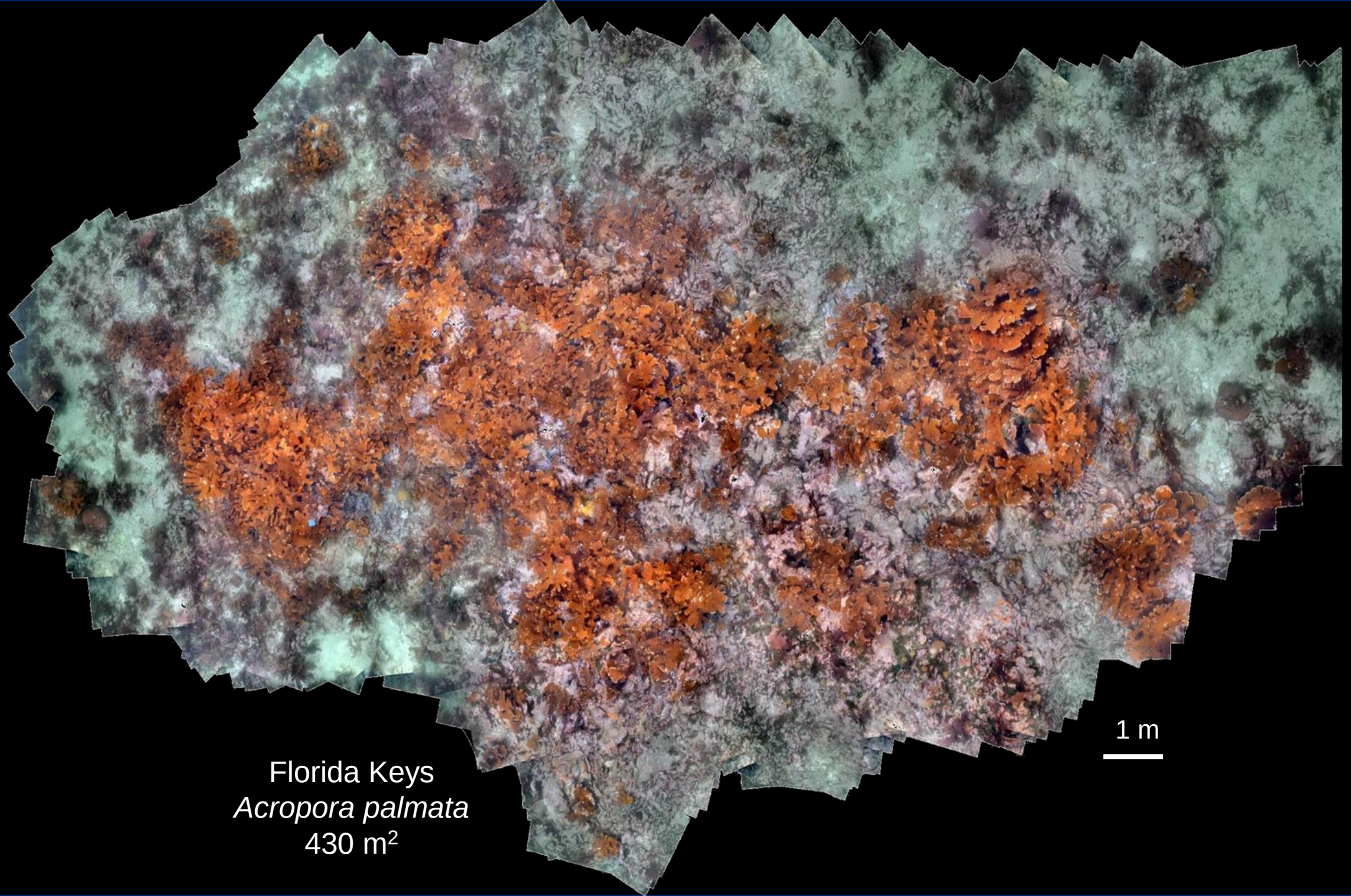
Acknowledgements

The Pew Fellows Program in Marine Conservation at The Pew Charitable Trusts

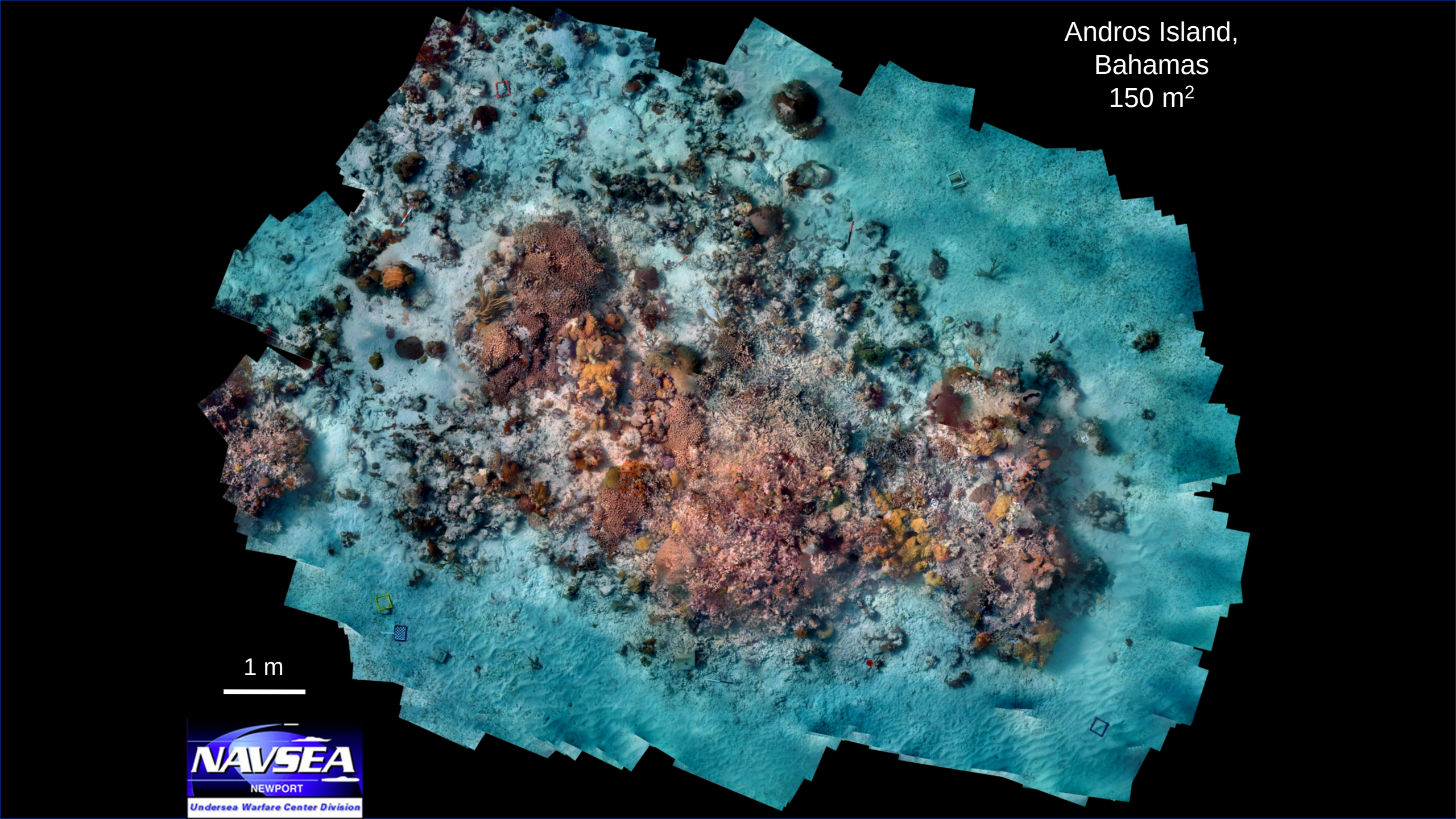
Stuart Sandin, Clint Edwards, Nicole Pedersen, Vid Petrovic, Alex Neufeld, Shay Viehman

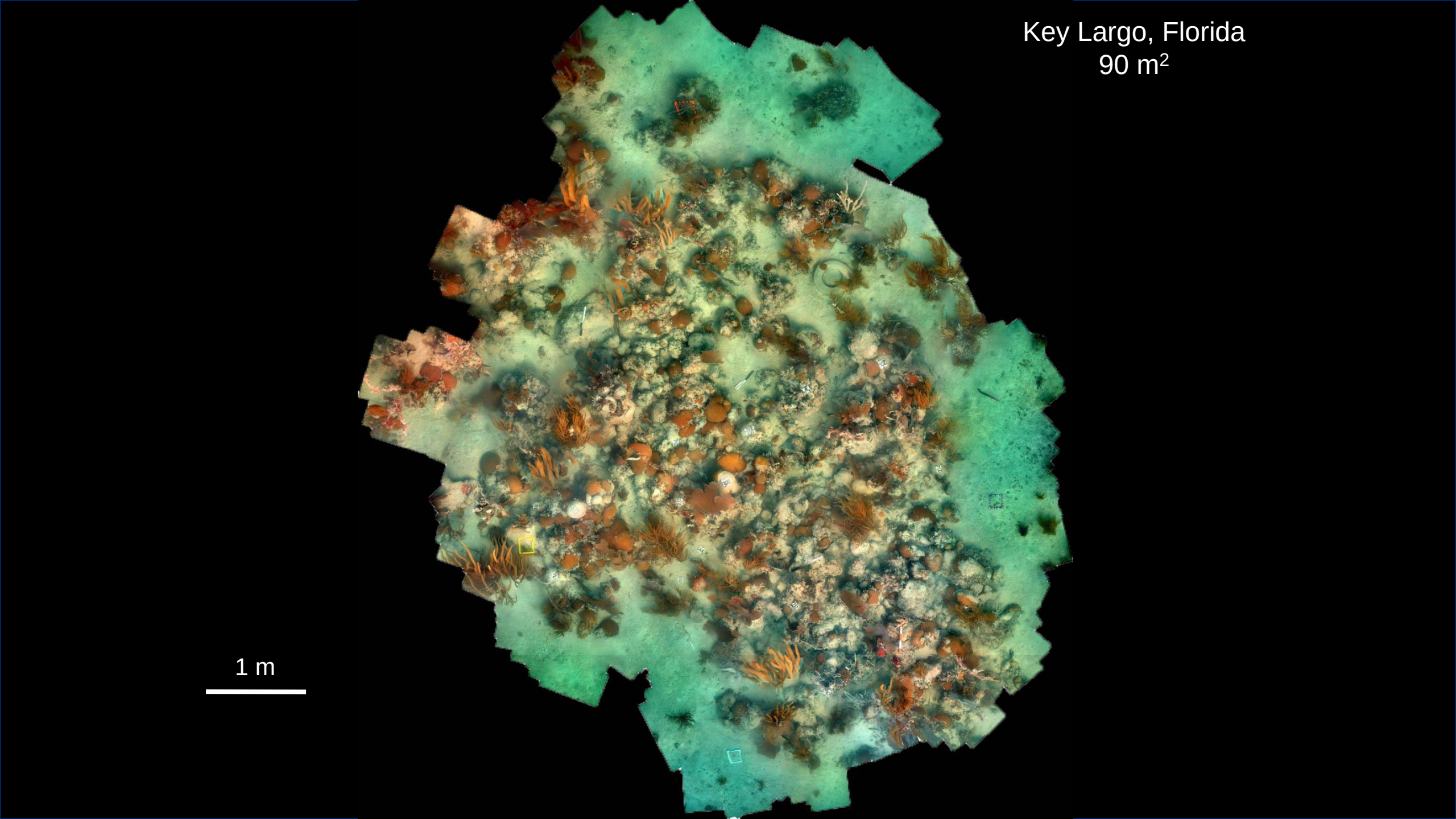
Groups that have contributed imagery to the Mission: Iconic Reefs archive:
Florida Keys National Marine Sanctuary
NOAA Southeast Fisheries Science Center
NOAA Atlantic Oceanographic and Meteorological Laboratory
NOAA National Centers for Coastal Ocean Science
Mote Marine Labs
USGS
Coral Restoration Foundation
Reef Renewal USA
University of Miami
Scripps Institution of Oceanography

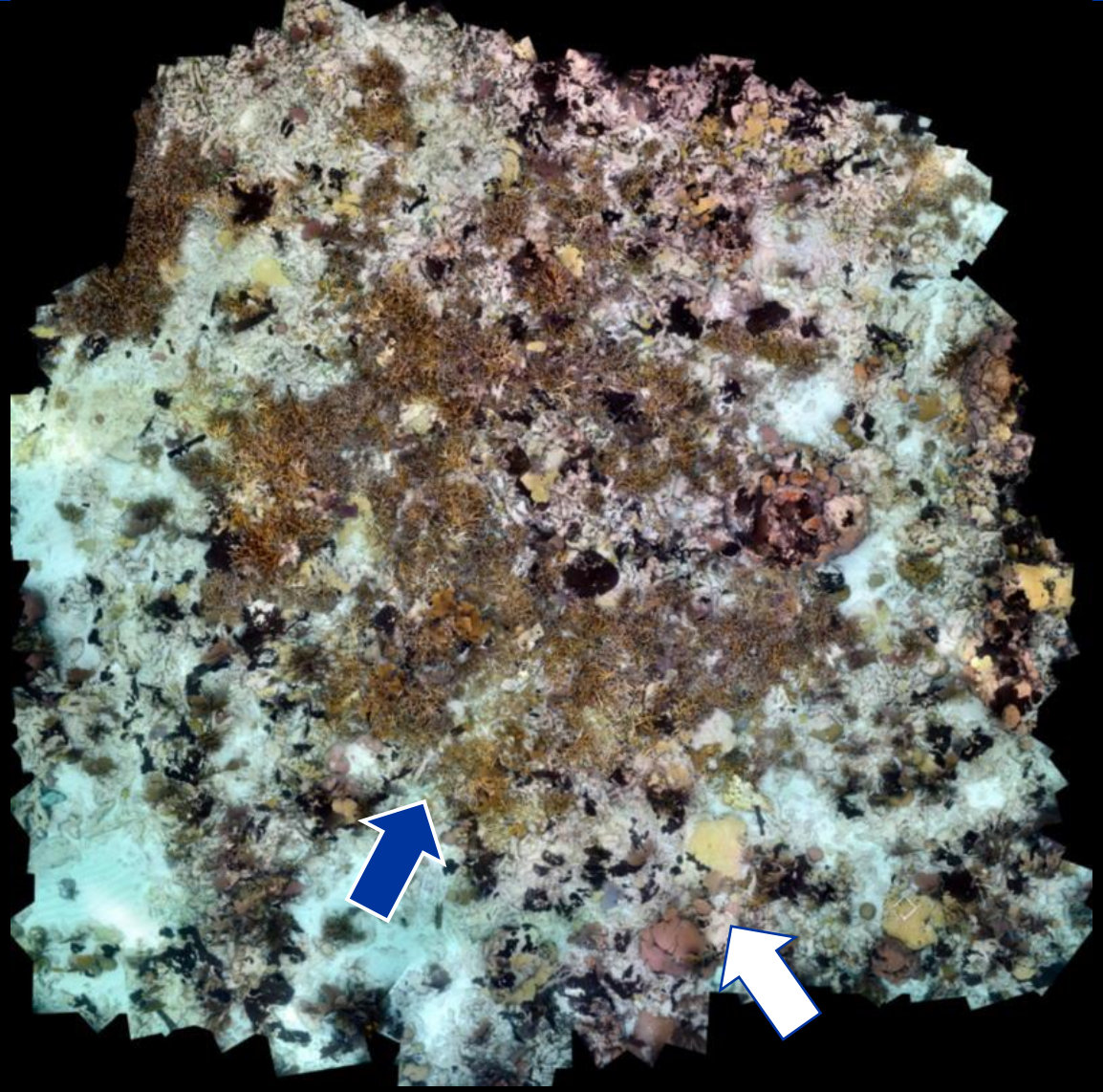

Western Australia
Patch reef
225 m²
1 m

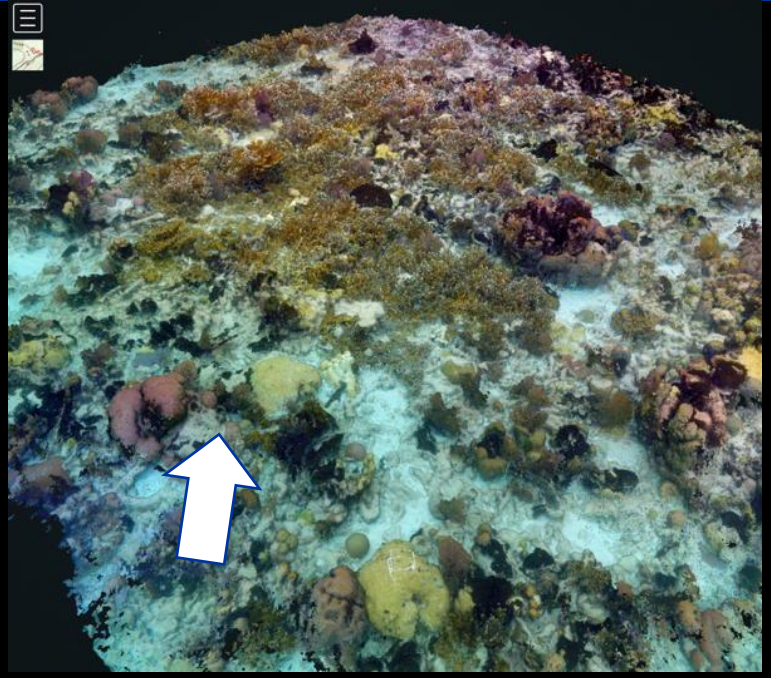


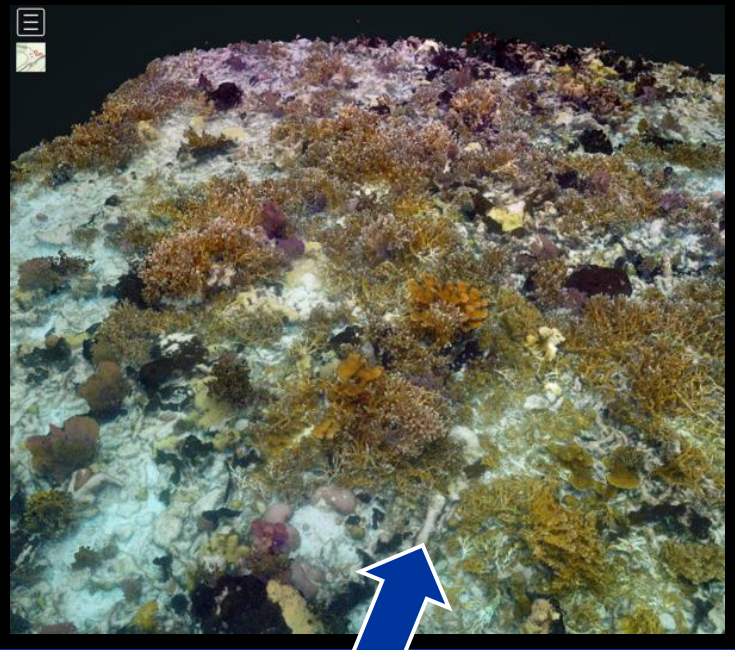
Florida Keys
Acropora palmata
430 m^2


Andros Island,
Bahamas
150 m2
1 m
NAVSEA
NEWPORT
Undersea Warfare Center Division


Key Largo, Florida
90 m2
1 m







Laughing Bird Caye, Belize 125 m^2