


Image credit: Monroe County and NOAA.

Surveying Nearshore Habitat in the Florida Keys with Bathymetric Structure from Motion Photogrammetry

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Personal Introduction

- Serve in the United States Coast Guard
- Search and Rescue/Law Enforcement Operations Controller
- Stationed in Key West, Florida
- Volunteer with Florida Keys National Marine Sanctuary (FKNMS)
- Assist sanctuary with geospatial needs
    - Mapping
    - Public education/outreach
    - Remote sensing

Image credit: NOAA.

Agenda

Background

Objectives

Methodology

Timeline and Products

Questions

Image credit: NOAA.

The Florida Keys

Background

The Florida Keys

- 220-mile-long archipelago in South Florida
- 1,700 Pleistocene-era limestone islands
- Upper Keys are comprised of ancient reef
- Lower Keys are comprised of sand bars
- Mangroves, lagoons, corals, sponges, and seagrass
- Manatees, sea turtles, whales
- Rich history of piracy, smuggling, and maritime trade

Data credit: USGS.
Image credit: Nature Conservancy.

The Sanctuary

- FKNMS was established in 1990
- Protects approximately 2,900 SQMI of nearshore and ocean habitat
- Extends from Miami to Dry Tortugas
- Prohibits any activity which alters the seafloor or threatens natural resources contained within
- Critical habitats include coral reef, seagrass, and shallow hardbottom habitats
- Includes the only coral barrier reef in the contiguous United States

Image credit: NOAA.

Data credit: USGS and NOAA.

FKNMS Boundaries

Image credit: NOAA and Florida Keys Weekly.

Concerns

Overfishing

Pollution

Disease

Vessel Groundings

Need for Research

"NOAA's requirement for high-resolution bathymetry in the nearshore coastal zone is currently unmet, particularly in remote locations."

Slocum et al. (2019)

"It is critical, therefore, to develop accurate geospatial inventories of benthic systems… an important element of monitoring benthic habitats is the development of accurate maps of species distribution, health, and diversity in relation to seafloor composition."

Hatcher et al. (2020)

Need for Research

- FKNMS is no exception
- High-resolution imagery and bathymetric data is limited
- Existing datasets are outdated
- Resource constraints prohibit quick and easy acquisition of new datasets
- Use cases for data:
  - Benthic mapping in shallow areas
  - Coral barrier reef monitoring
  - Habitat injury assessment
  - Derelict vessel assessment
  - Post-hurricane damage assessment
- Bathymetric Structure from Motion (BSfM) photogrammetry may provide a suitable alternative

Proposal and Objectives

Develop a proof of concept for unmanned aerial vehicle (UAV) based BSfM photogrammetry in the Florida Keys.

- Prepare a concept of operations
- Survey two Sanctuary Preservation Areas (SPAs) using BSfM photogrammetry
- Compare results to existing bathymetric and species composition data
- Generate a standard operating procedure for future surveys by FKNMS staff

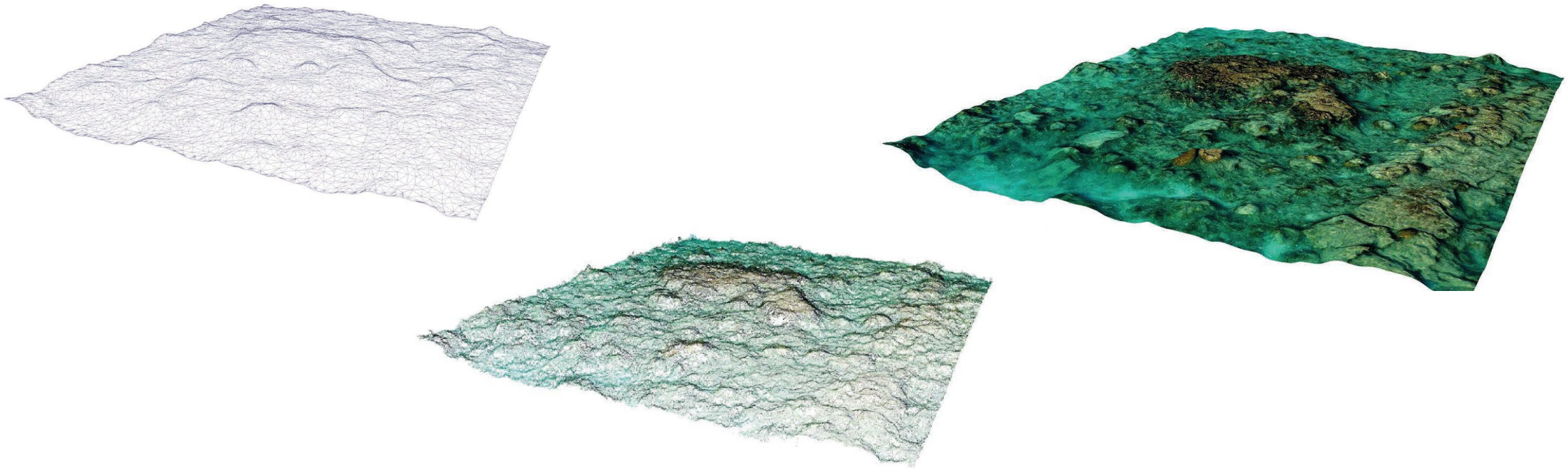


Image credit: Slocum et al. (2019).

UAV-Based BSfM Photogrammetry

Methodology

BSfM Photogrammetry

- Combines traditional photogrammetry and computer vision algorithms
- Generates high-resolution three-dimensional geospatial products
- Deployable from:
  - Unmanned aerial vehicles (UAVs)
  - Unmanned submersible vehicles (USVs)
  - Towed surface vehicles (TSVs)
- Affordable, accessible, and deployable
- Scalable accuracy through commercial-grade or survey-grade systems
- Higher end products do not require ground control points (GCP)
- Products generated include:
  - Digital elevation, surface, and terrain models
  - Orthoimagery
  - Texturized meshes

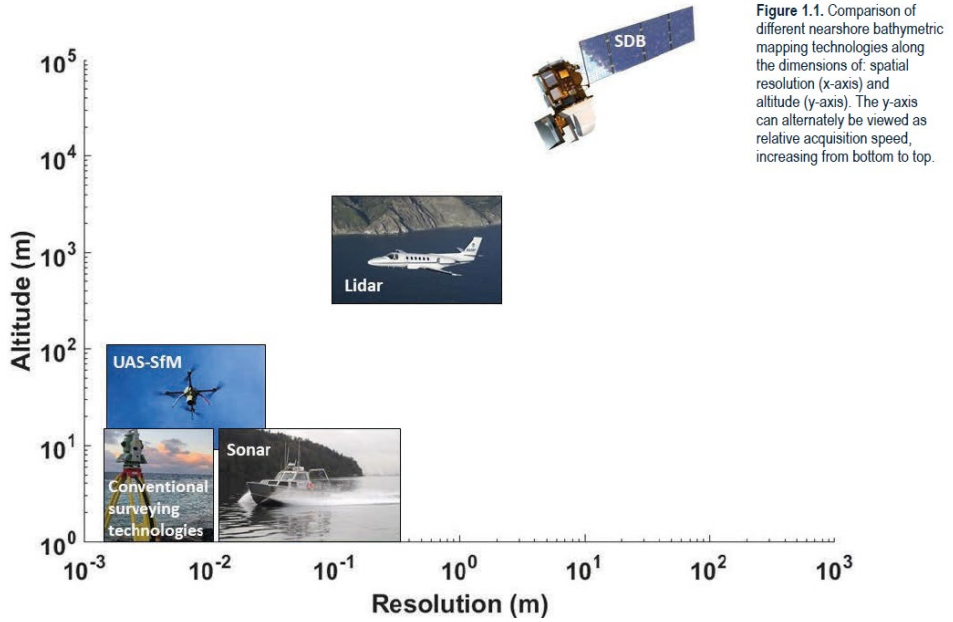


Figure 1.1. Comparison of different nearshore bathymetric mapping technologies along the dimensions of: spatial resolution (x-axis) and altitude (y-axis). The y-axis can alternately be viewed as relative acquisition speed, increasing from bottom to top.

Image credit: Slocum et al. (2019).

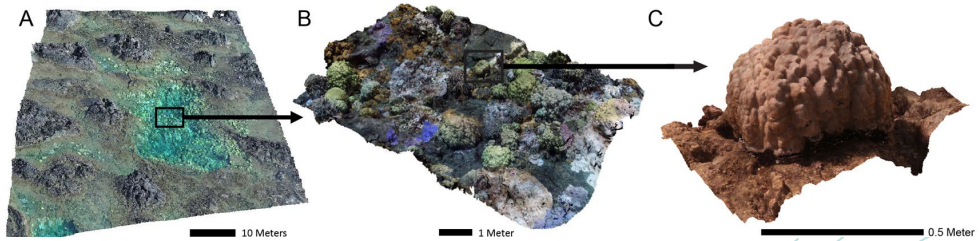


Image credit: NOAA.

Data credit: USGS.

BSfM Photogrammetry Unifies Fields

Traditional Photogrammetry

- Interior/exterior orientation
- Overlap/sidelap
- Ground sampling distance
- Georeferencing
- Image network geometry
- Platform and camera selection

Computer Vision

Algorithms are the core of BSfM:

- Scale-Invariant Feature Transform (SIFT)
- Speeded-Up Robust Features (SURF)
- Multi-View Stereo (MVS)
- Dietrich (AWI)

Algorithms are the core of BSfM – they correct for light refraction thereby permitting accurate measurement.

The Florida Keys Are Optimal For BSfM

Surveys are most effective in areas that have:

- A high degree of water clarity
- Low wave action
- Low tidal amplitude
- Few breaking waves
- High bottom texture

Image credit: Friends of the Pool, Inc. 503 (c)

BSfM Survey Best Practices

- Pre-calibrate camera on land
- > 75% overlap / sidelap
- Image every point from at least three angles
- Fly at higher altitudes to reduce specular glare
- Employ a minimum of one GCP to reduce positional error (particularly for commercial-grade platforms)

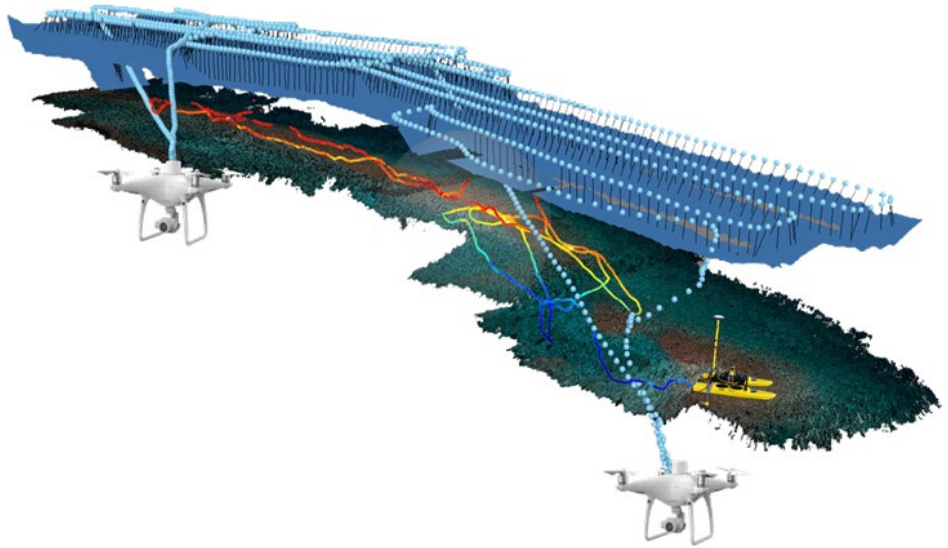


Image credit: Slocum et al. (2019).

Image credit: DJI.

Hardware

DJI Mavic Pro 3

- FKNMS organic resource
- Commercial-grade system
- High resolution imagery
- Decent positional accuracy
- Excellent range/endurance

DJI Matrice 210 RTK

- National Centers for Coastal Ocean Science (NCCOS) resource
- Survey-grade system
- High resolution imagery
- High positional accuracy
- Decent endurance

Software

Basic Software

- ArcGIS Pro
- Mission Planner
- Agisoft Metashape

BSfM-Specific Code

- Dietrich Algorithm via GitHub – computes scalar correction for air-water interface refraction

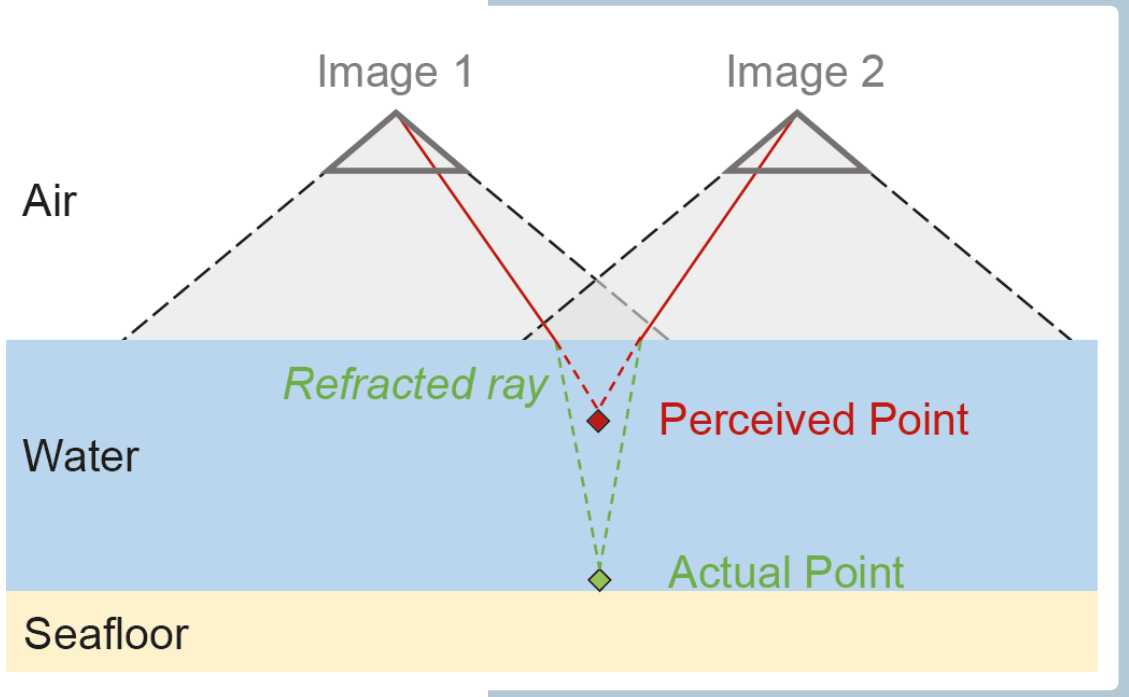
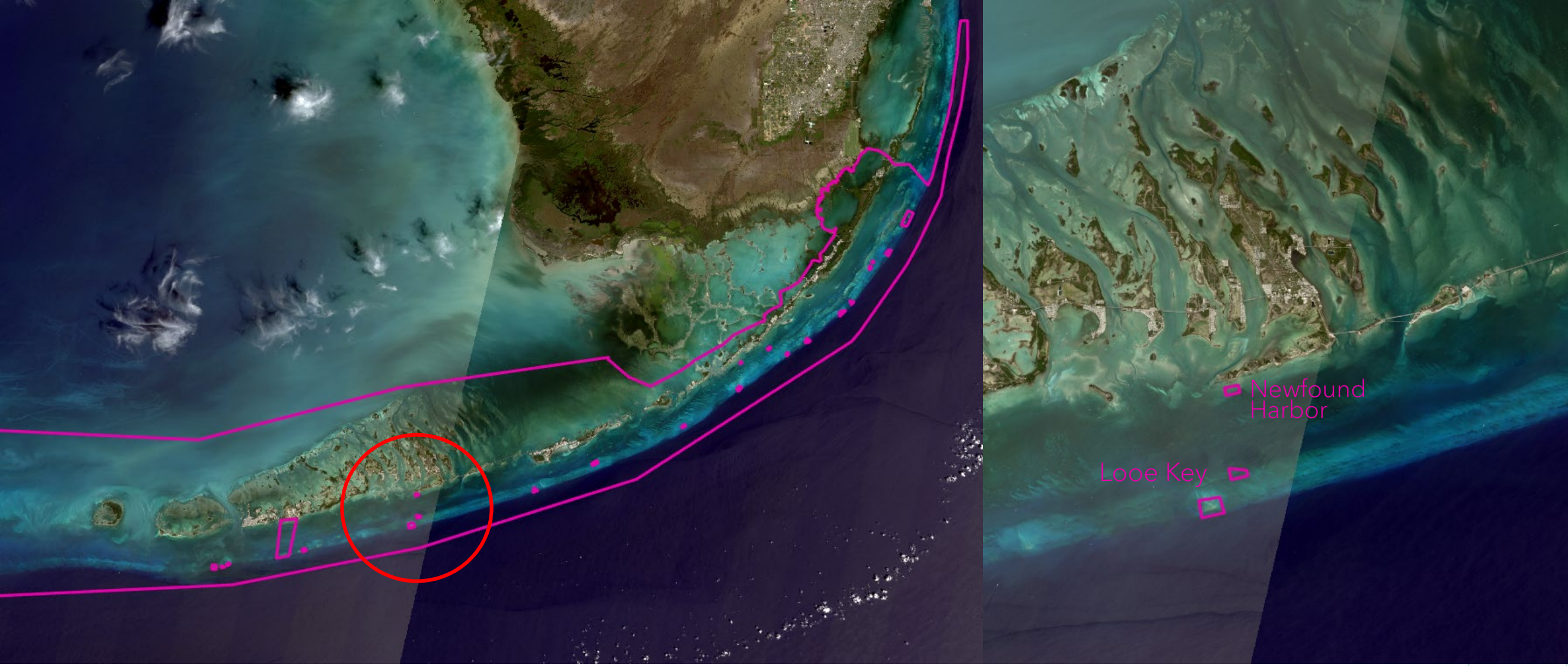


Image credit: Slocum et al. (2019).



Data credit: USGS and NOAA.

Survey Sites

Survey Site #1
Newfound Harbor

- < 1.0 NM offshore Middle Keys
- Unique inshore patch coral reef
- 80 acres (0.5 NM x 0.25 NM)
- Water clarity is variable
- Groundings are common
- Class D airspace

Coral

Hardbottom

Seagrass

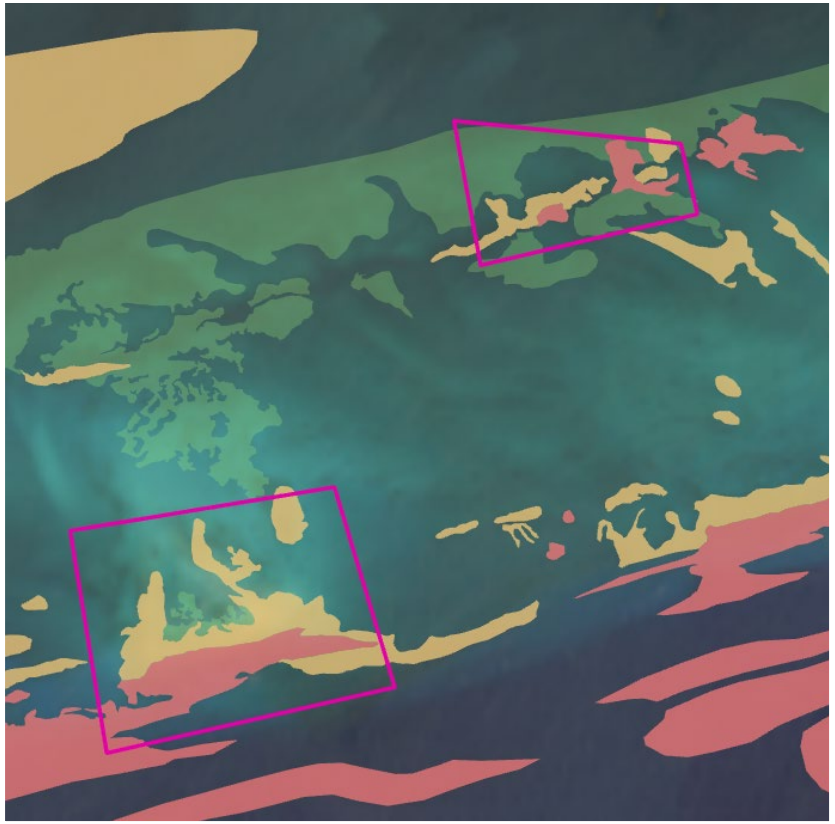
SPA Boundary

Data credit: FWC, NOAA, and USGS.

Survey Site #2
Looe Key

- 5.5 NM offshore Middle Keys
- Shallow coral barrier reef
- 400 acres (1.0 NM x 0.5 NM)
- Class D airspace
- Previously mapped using BSfM using the US Geological Survey's SQUID-5 TSV

Image credit: USGS and NOAA.



Coral

Hardbottom

Seagrass

SPA Boundary

Data credit: FWC, NOAA, and USGS.

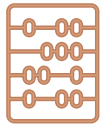
Timeline and Products

Plan of Attack

Research Products

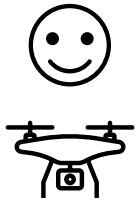
Concept of Operations

Field Data Collection



Comparative Analysis

Standard Operating Procedure



Routine UAV Surveys

Timeline

Concept of Operations &
Mission Planning

Summer 2022

September 2022

Site Survey

Data Analysis

October 2022

November 2022

Delivery of Results and SOP

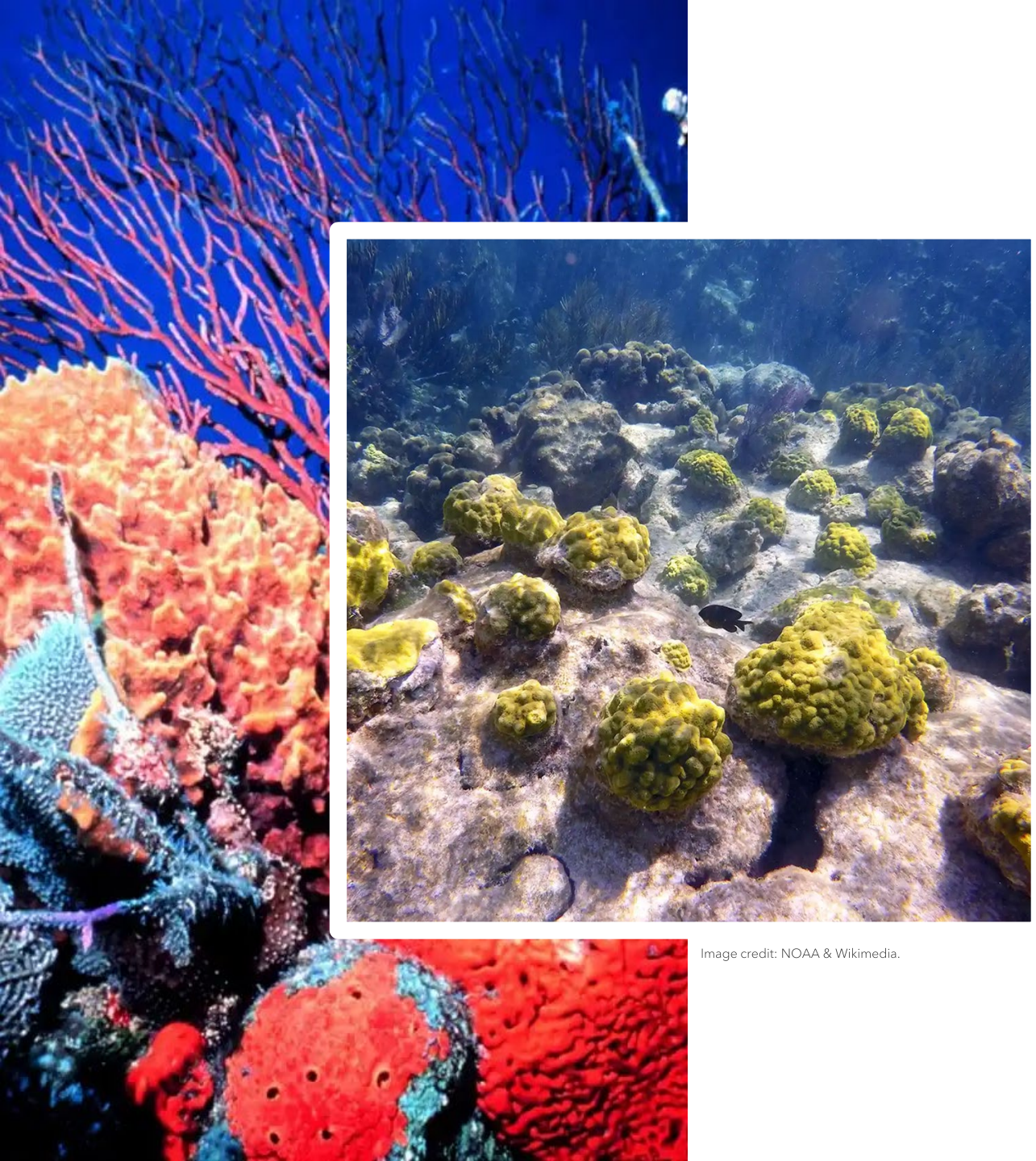


Image credit: NOAA & Wikimedia.

Summary

Persistent gaps in nearshore data complicate natural resource management within FKNMS.

UAV-based BSfM photogrammetry offers one possible solution, providing an innovative means of acquiring the data required to protect resources.

This project will serve as a proof of concept for BSfM photogrammetry, testing its utility within the Florida Keys.

Thank You

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Acknowledgements:

- Dr. Marvin May
- Lisa Symons, FKNMS

Image credit: NOAA.

Acronyms

- FKNMS – Florida Keys National Marine Sanctuary
- FWC – Florida Fish and Wildlife Commission
- GCP – Ground control point
- NCCOS – National Centers for Coastal Ocean Science
- NOAA – National Oceanic and Atmospheric Administration
- SPA – Sanctuary preservation area
- SQUID-5 - Structure from Motion Quantitative Underwater Imaging Device With Five Cameras
- TSVs – Towed surface vehicle
- UAVs – Unmanned aerial vehicle
- USVs – Unmanned submersible vehicle
- USGS – US Geological Survey
- SIFT – Scale-Invariant Feature Transform Algorithm
- SURF – Speeded-Up Robust Features Algorithm
- MVS – Multi-View Stereo Algorithm
- AWI – Air-water interface

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