Object-oriented Image Classification for Benthic Habitats Using Multispectral Quickbird Data

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Introduction

- Critical need to monitor the conditions of the corals.
- Remote Sensing: an effective tool for mapping coral reef habitats.
- Supervised and unsupervised methods: only per-pixel spectral information is utilized.
- Objective: introduce object-oriented method for benthic habitats classification.

Image classification methods

- Visual interpretation

  Habitats are identified visually by an analyst based on experience, then delineated and labeled manually, labor intensive, inevitable inconsistency, lacks the detail.

- Multispectral classification of image data

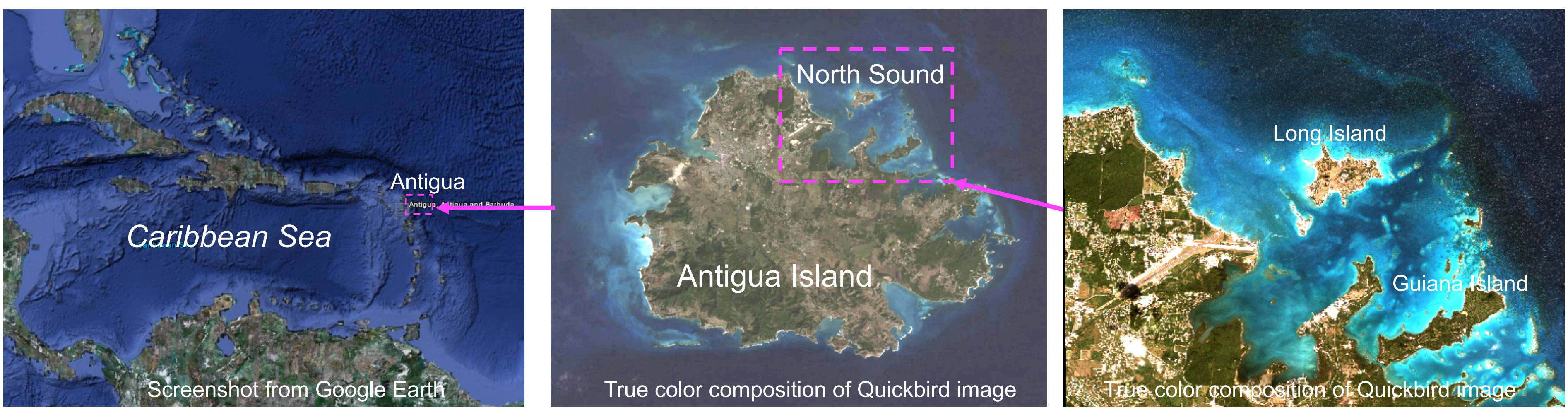
  - Supervised
  - Unsupervised

- Object-Oriented Image segmentation

  Classifies image objects or segments instead of individual pixels

Case Study- North Sound, Antigua

- North Sound of Antigua Island, located in the eastern arc of the Leeward Islands.
- Extensive coral sand beaches with relatively shallow off-shore waters.
- Coral species include Montastrea, Diploria, Cropora, Porites and Acropora.

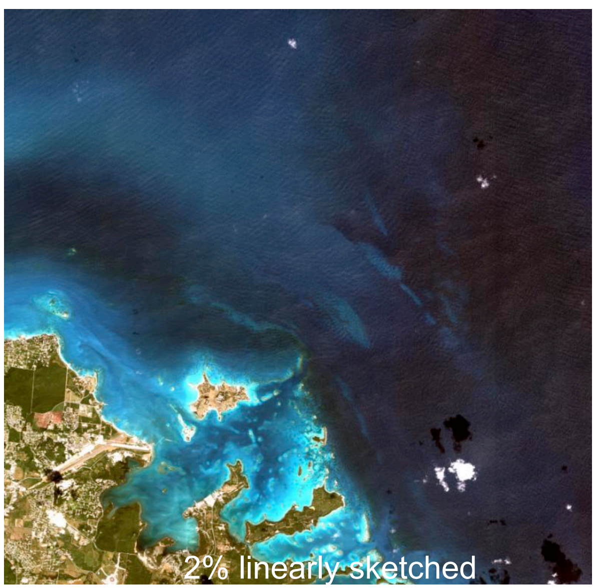


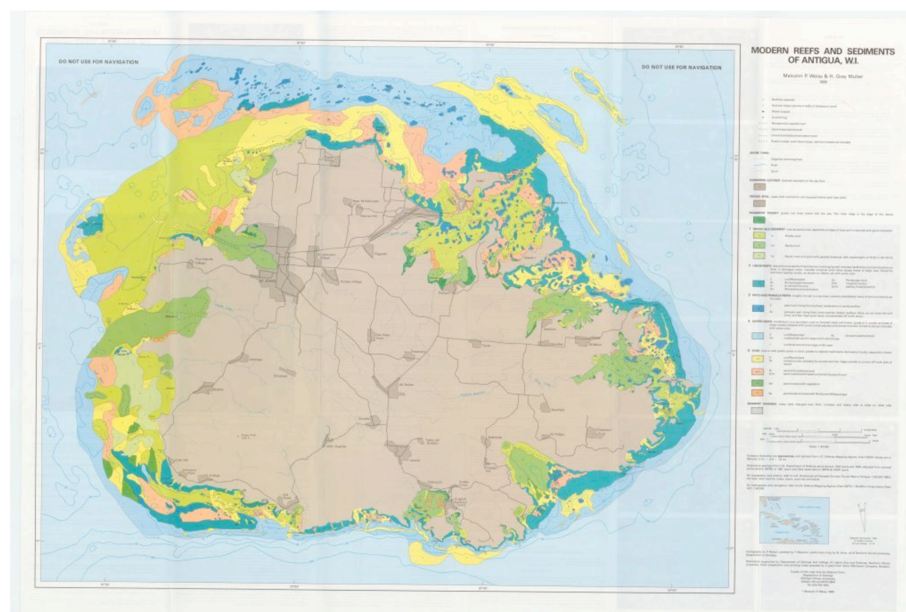
Screenshot from Google Earth
True color composition of Quickbird image
True color composition of Quickbird image

Data

- Quickbird multi-spectral remote sensed imagery acquired on 12/03/2005.
- Weiss M.P. and Multer, H. G., 1988, Map of modern reefs and sediments of Antigua, West Indies, Scale: 1: 40,000.

0.61-meter Black-and-white	**Panchromatic**	**0.45 – 0.90 µm**
2.4-meter Multispectral	**Band 1 (Blue)**	**0.45 – 0.52µm**
	Band 2 (Green)	**0.52 – 0.60µm**
	Band 3 (Red)	**0.63 – 0.69 µm**
	Band 4 (NIR)	**0.76 – 0.90µm**





Data Pre-processing

- **Geometric Corrections**: RPC provided along with the image by Digital Globe, Inc.
- **Land and Cloud Masking**: NIR band
- **Atmospheric Correction**: follows Mishra et al., 2006.

$$L_t(\lambda_i) = L_r(\lambda_i) + L_a(\lambda_i) + T(\lambda_i)L_g(\lambda_i) + t(\lambda_i)L_w(\lambda_i)$$

- **Rayleigh path radiance** $L_r(\lambda_i)$: computed and applied to the image using the algorithm developed by Gordon and Clark (1981).

- **Aerosol scattering** $L_a(\lambda_i)$: derived by subtracting the Rayleigh path radiance from TOA radiance in deep water pixels of the NIR band.

- **Diffuse transmittance** $t(\lambda_i)$: computed as recommended by Gordon *et al*. (1983).

Atmospheric Correction

$$L_t(\lambda_i) = L_r(\lambda_i) + L_a(\lambda_i) + T(\lambda_i)L_g(\lambda_i) + t(\lambda_i)L_w(\lambda_i)$$

Aerosol scattering

Rayleigh scattering

$$L_r(\lambda,\theta) = F_s'(\lambda)P_r(\alpha)\tau_r(\lambda)/4\pi\cos\theta$$

Diffuse transmittance

$$t(\lambda,\theta) = \exp([-\tau_r(\lambda)/2 + \tau_{oz}]\sec\theta)$$

$$F_s' = F_s(\lambda)\exp[-\tau_{oz}(\sec\theta + \sec\theta_s)]$$

$$P_r(\alpha) = \frac{3}{4}(1+\cos\alpha^2)$$

$$\tau_r(\lambda) = \tau_{r0}(P/P_0)$$

Gordon et al. (1981,1983)

$$\tau_{r0} = 0.0089\lambda^{-4}(1 + 0.0113\lambda^{-2} + 0.00013\lambda^{-4})$$

θ : Satellite zenith angle

θ_s : Solar zenith angle

α : Scattering angle relative to the forward direction

τ_{oz} : Optical thickness of the ozone layer

P : Air pressure

P_0 : Standard Surface atmospheric pressure

$F_s(\lambda)$: Solar radiance at the top of atmosphere

λ : Wavelength

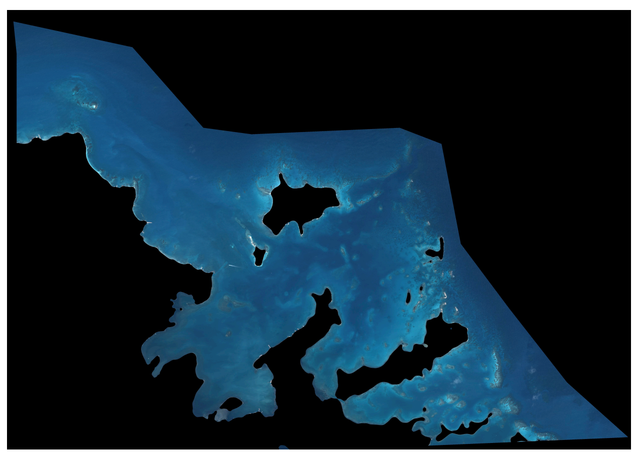
	Rayleigh	Diffuse transmittance
Blue	1.775	0.9235
Green	1.066	0.9608
Red	0.3398	0.9842
NIR	0.2165	0.9994

Atmospheric Correction

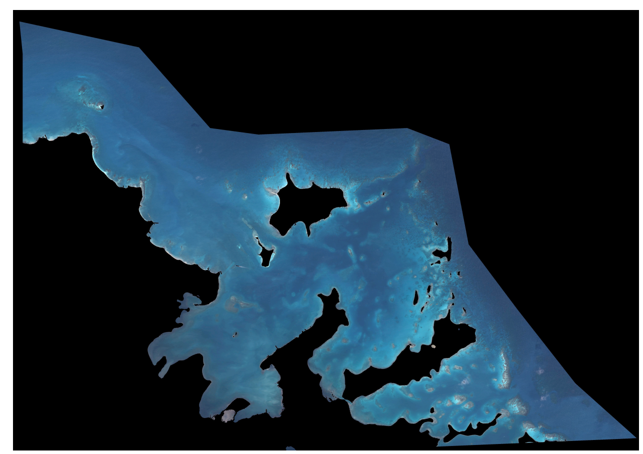
- Trick for extracting TOA radiance in deep water pixels of the NIR band

  Select a group of pixels to represent deep water, calculate the mean and standard deviation of radiance, subtract two standard deviations from the mean to account for sensor noise.

Geometrically corrected image



Land and clouds masked image

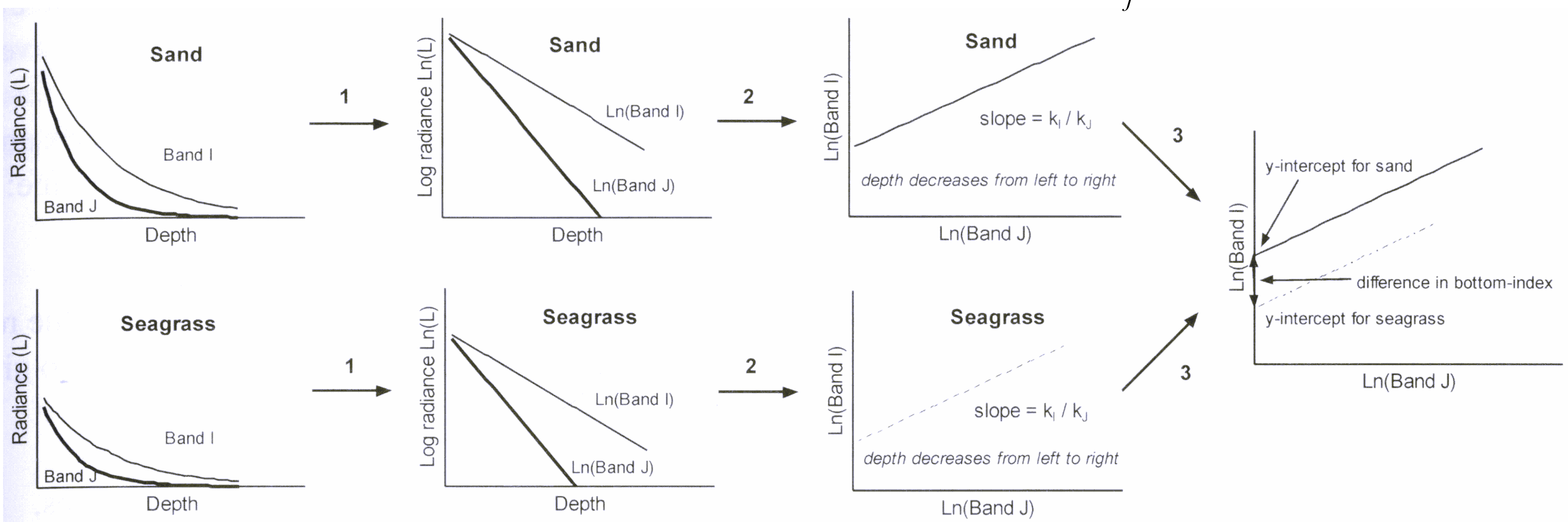


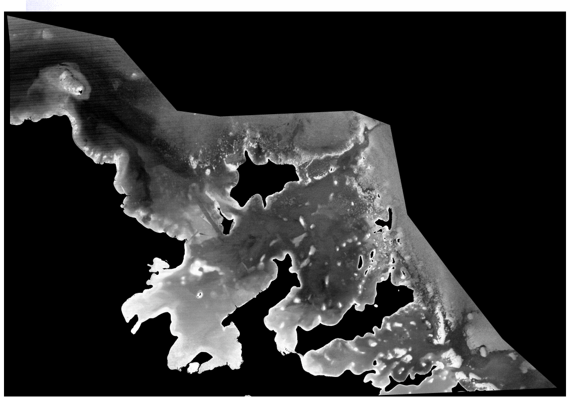
Atmospherically corrected image

All images are linearly stretched

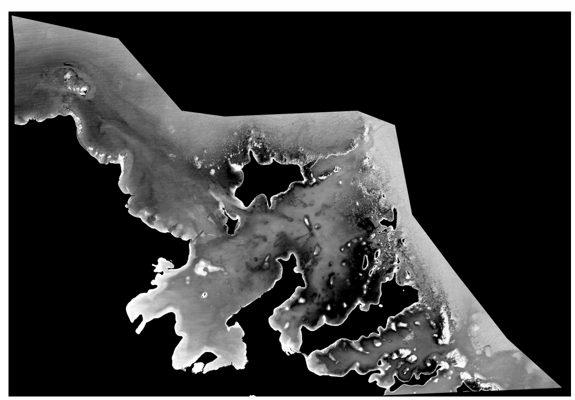
Water Column Correction

Depth-invariant bottom index $x_{ij} = \ln(L_i) - [(\frac{k_i}{k_j}) \cdot \ln(L_j)]$

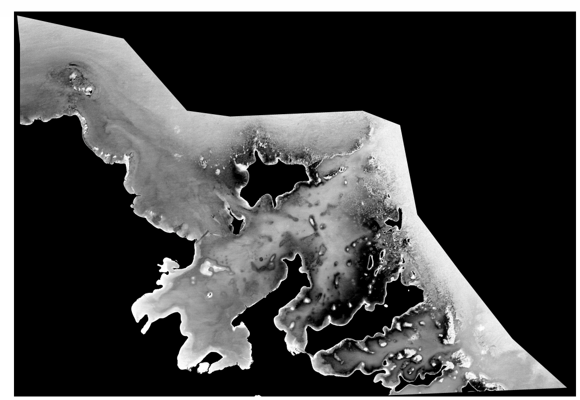




Blue *vs* Green band



Blue *vs* Red band



Green *vs* Red band

Result-
Unsupervised classification

- Software: ENVI, ISODATA functionality
- Combine classes after classification.
- Classes: coral, sand, mixed-coral and sand, sandy mud, muddy sand, mangroves.

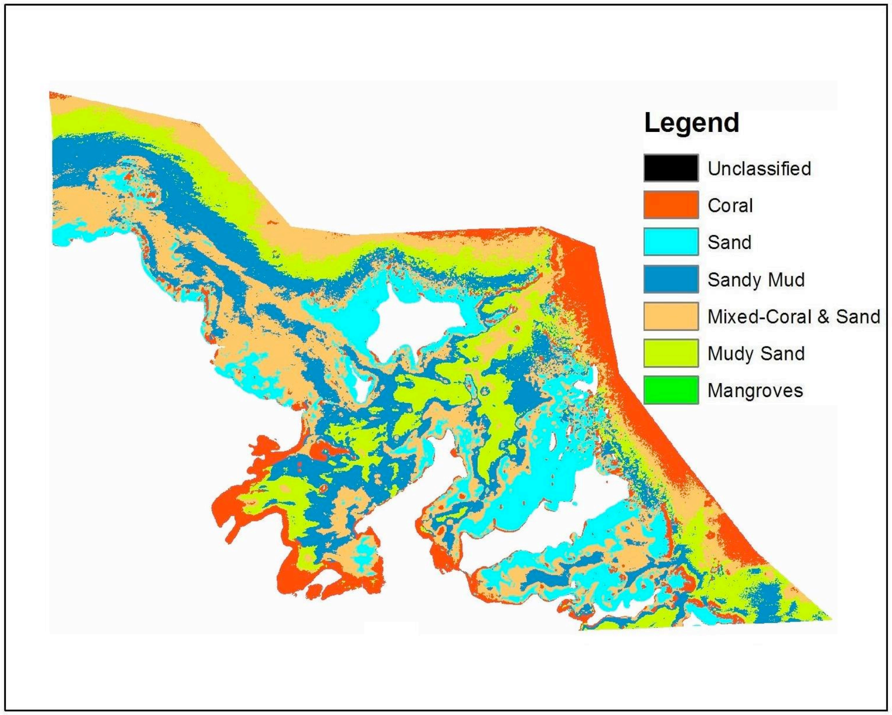
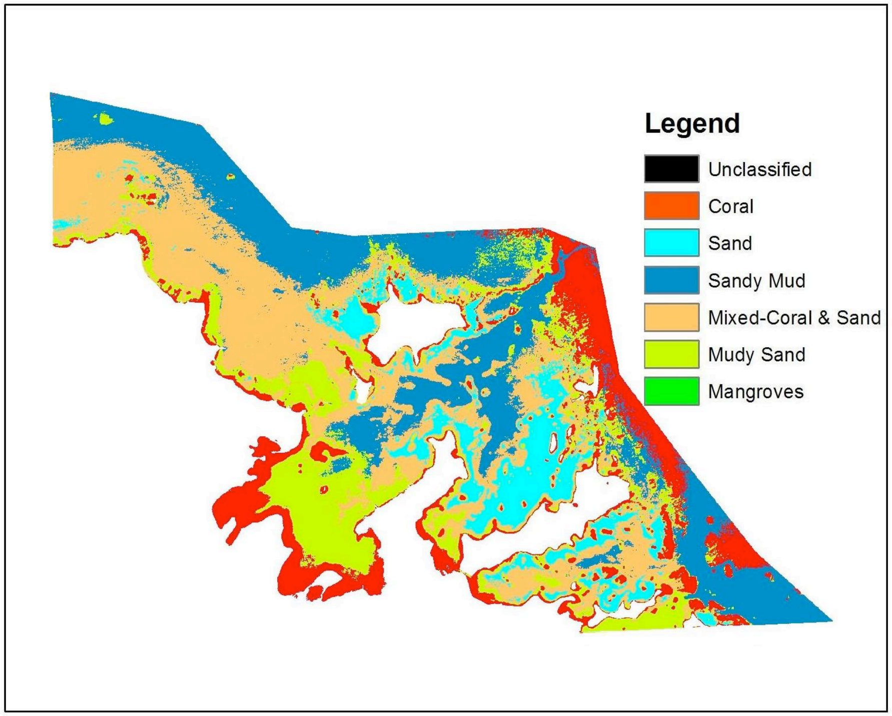


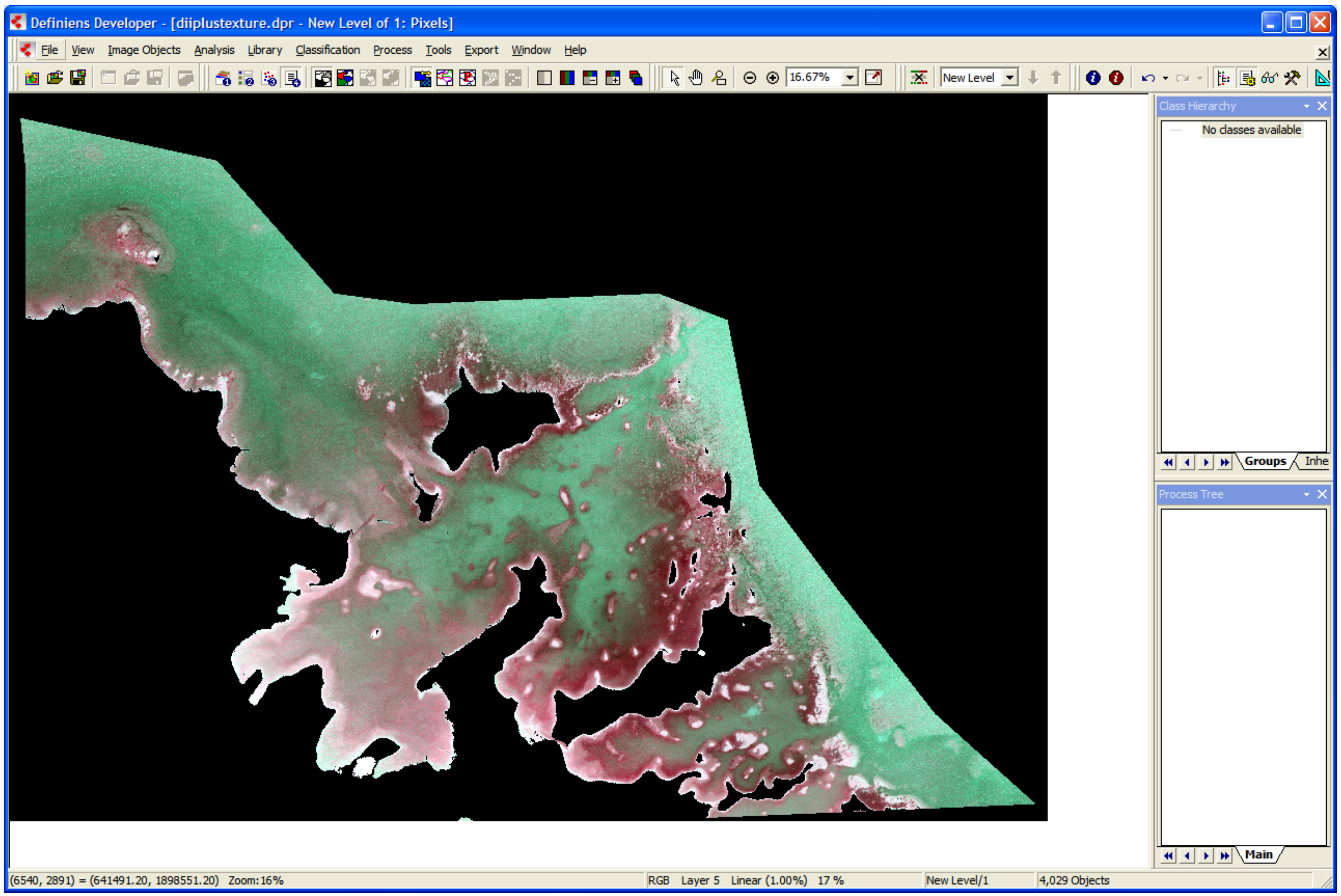
image without water-depth-correction



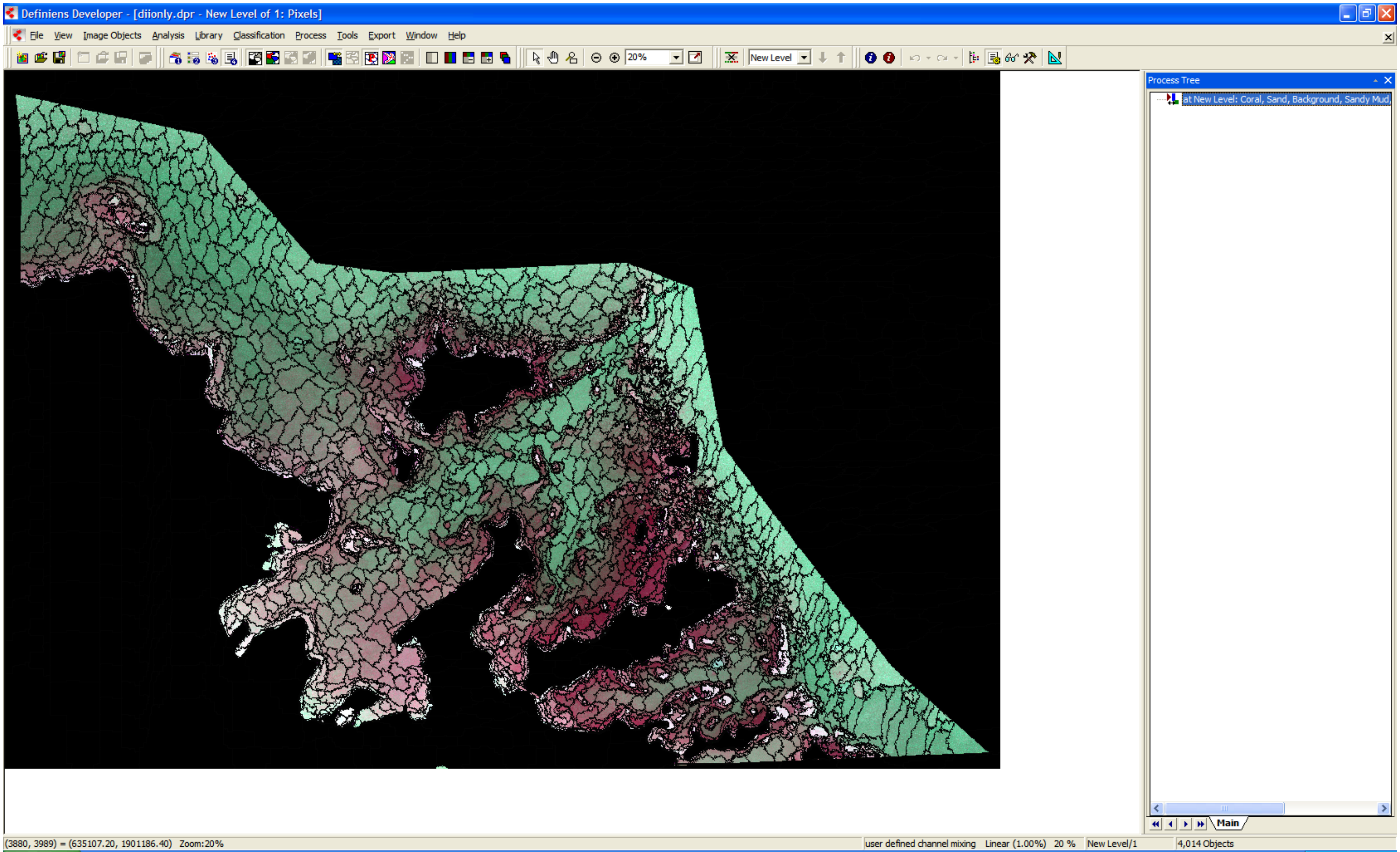
water depth corrected image

Object-oriented classification

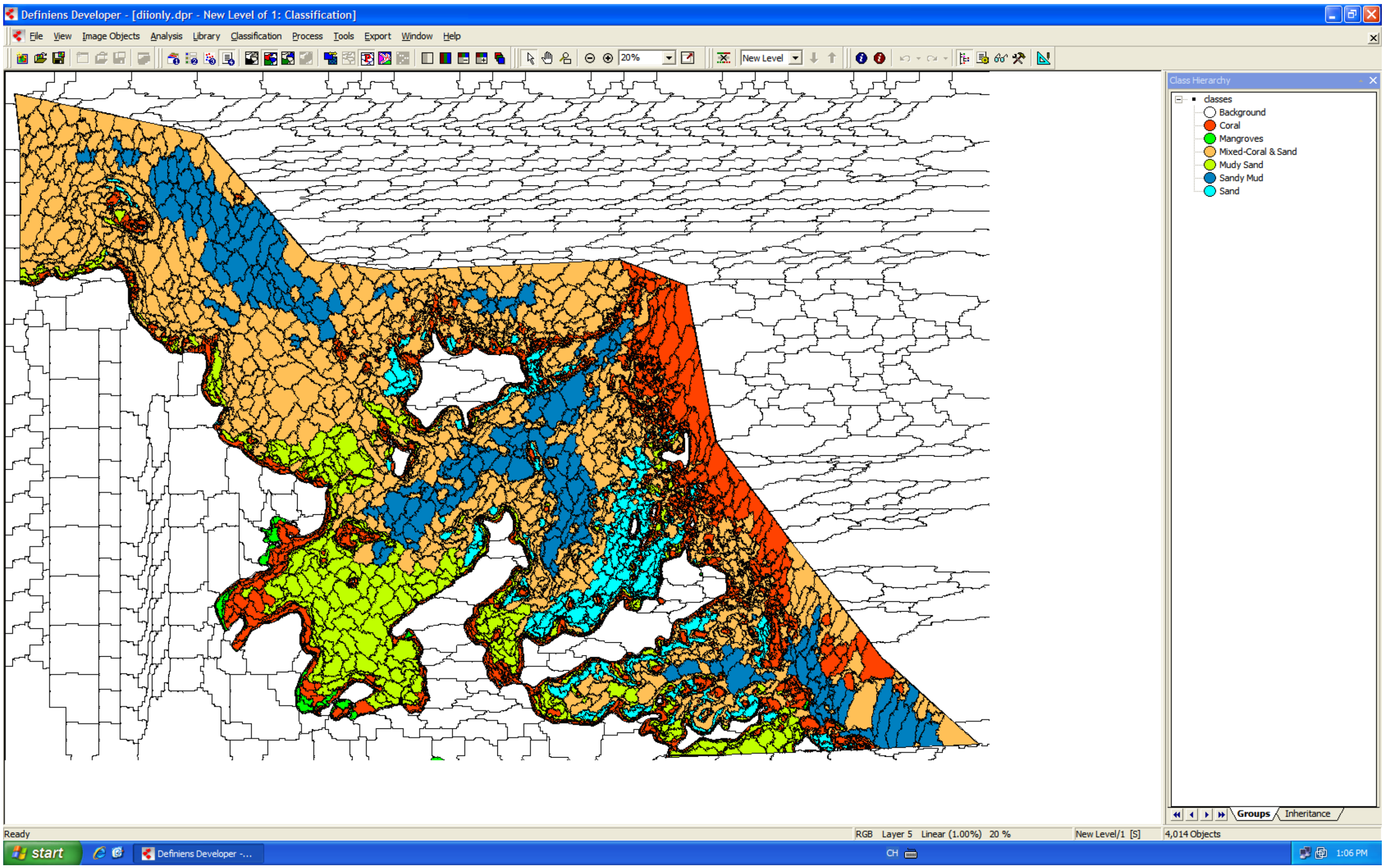
- **Software: Definiens(eCognition)**



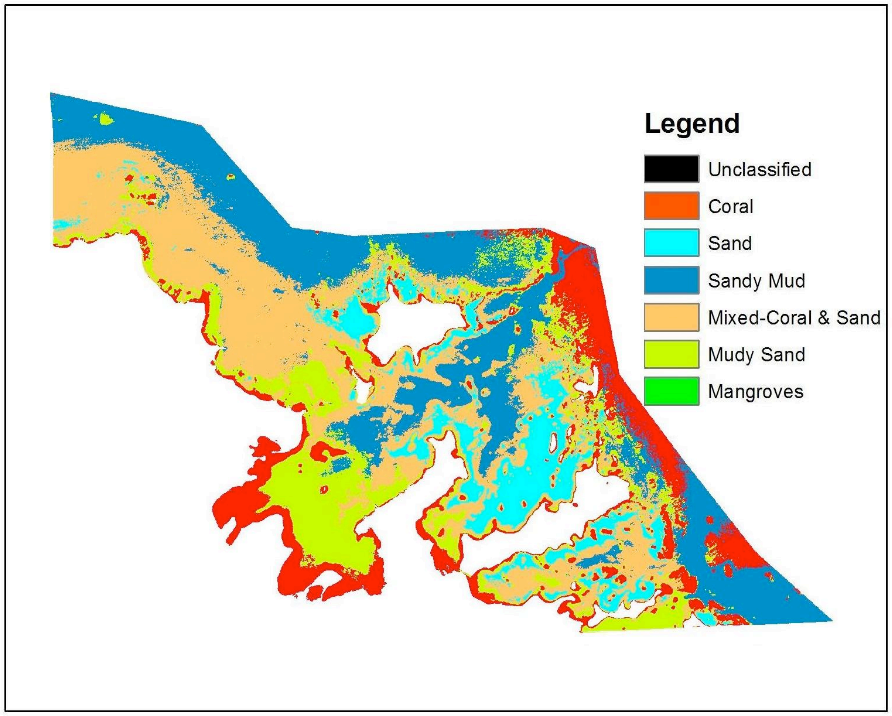
Result- Segment

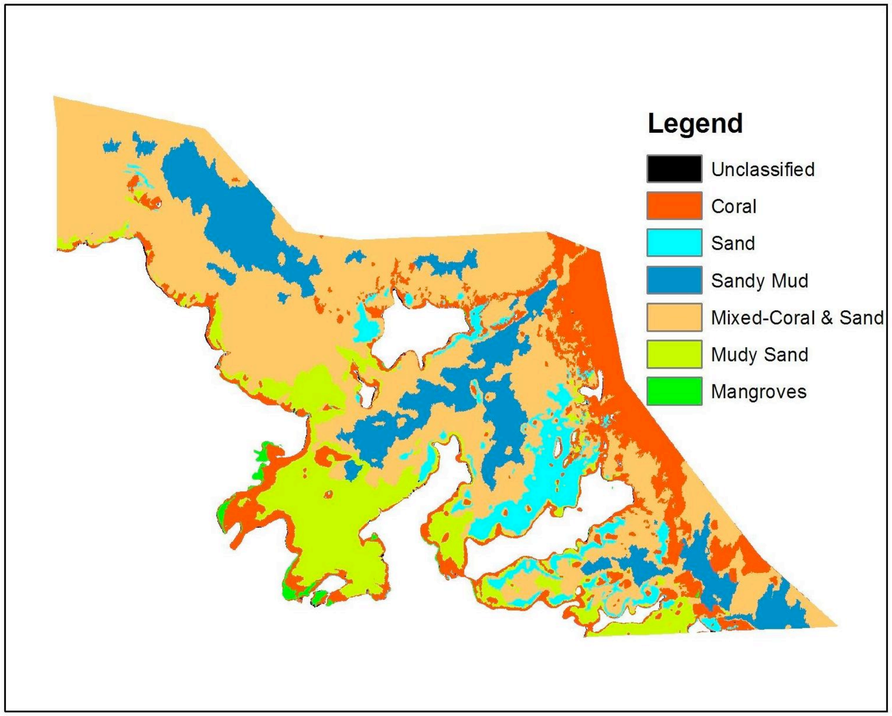


Result-Classification



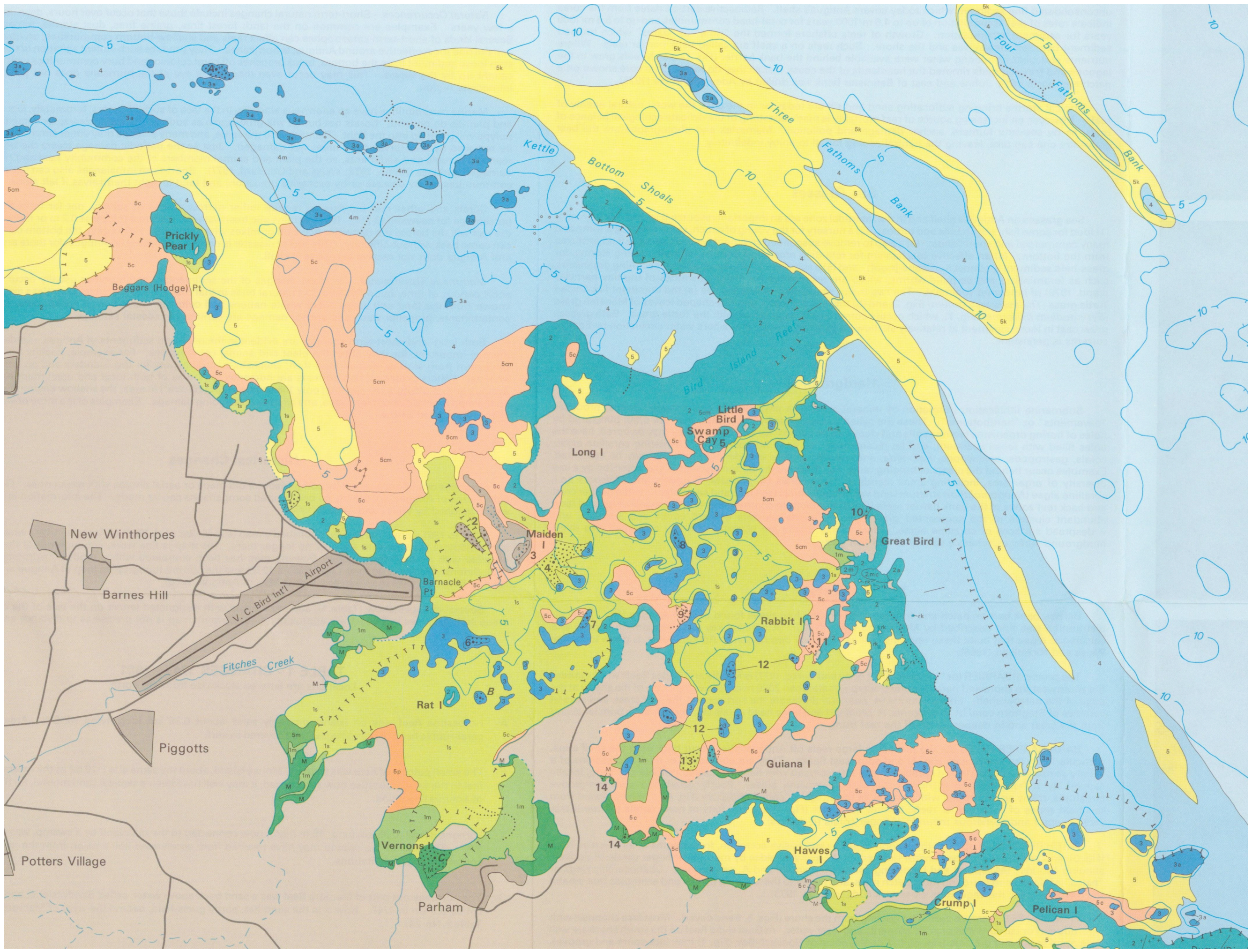
Result-
Unsupervised vs O-O





Unsupervised

Object-Oriented



SUBMARINE OUTCROP: bedrock exposed on the sea floor

OC

DREDGE SPOIL: areas both submarine and exposed where spoil was piled

S

MANGROVE THICKET: grown out from shore into the sea. The inner edge is the edge of the island.

M

1 GRASS-HELD SEDIMENT: may be some coral, especially at edges of tract and in channels with good circulation.

1s	1s	Muddy sand
1m	1m	Sandy mud
1w	1w	Sandy mud and sand with parallel blowouts, with wavelengths of 10-30 m (30-100 ft)

2 LINEAR REEFS: discontinuous bands of bank barrier and fringing reef; includes hardbottom and sand patches on dead or damaged areas. Includes marginal sand halos except those of large area. Zoned by dominant species locally, as shown by letters; all with same color.

2	2	undifferentiated	2p	*Porites* spp. zone
	2a	*Acropora palmata* zone	2mc	mixed 2m and 2c
	2c	*A. cervicornis* zone	2a/2c	patchy, mixed 2a and 2c
	2m	*Montastrea annularis* zone		

3 PATCH AND PINNACLE REEFS: roughly circular in map view, unevenly distributed; halos of sand and debris are included.

3,3a	3	patch reef, rising from bedrock, hardbottom or sandy seafloor
	3a	pinnacle reef, rising from coral-covered, deeper seafloor. Many do not reach the surf zone, and few have sand halos. Concentrated off north shore.

4 DEEPER REEFS: hardbottom and abundant coral on forereef slope and below; grade to 2, usually at break of slope. Locally streaked with sand in small patches and narrow channels. Zoned locally as indicated, with same color.

4	4	undifferentiated	4a	*Acropora palmata* bank
	4m	mottled with sand in large north-central area		
	T	marks terrace at inner edge on SE coast		

5 SAND: bare or with patchy grass or coral; grades to adjacent sediments. Somewhat muddy, especially in bays.

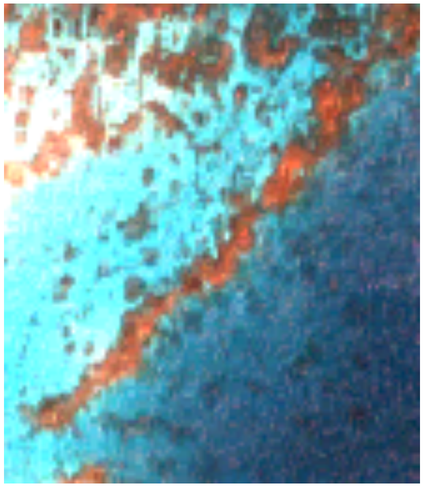
5,5k	5	undifferentiated
	5k	conspicuously streaked by plumes and low ridges parallel to current off north side of island
5c,5cm	5c	sand with scattered coral
	5cm	sand mottled with heads and small clumps of coral
5m	5m	sand mottled with vegetation
5p	5p	sand banks armored with *Porites* and *Millepora* spp.

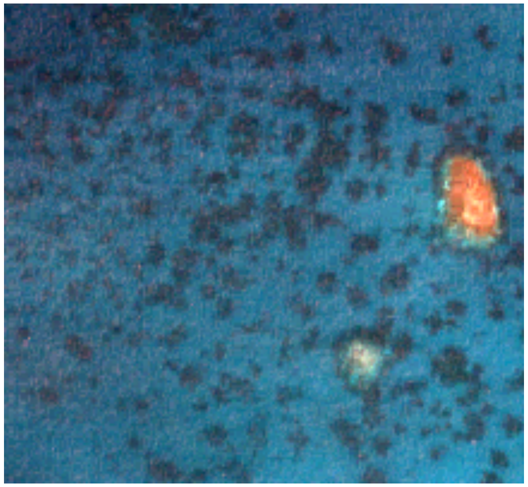
Conclusion

- Atmosphere correction and water depth compensation is critical for benthic habitat classification.
- Objective Oriented method can provides a better way for the classification of benthic habitats by incorporating contexture information.

Further study

- More classes
- Validation
- Incorporate texture information.
- Incorporate shape information: linear reefs *vs* patch and pinnacle reefs.
- Consider the relationship between objects: grouping image objects.





Thank You

Questions