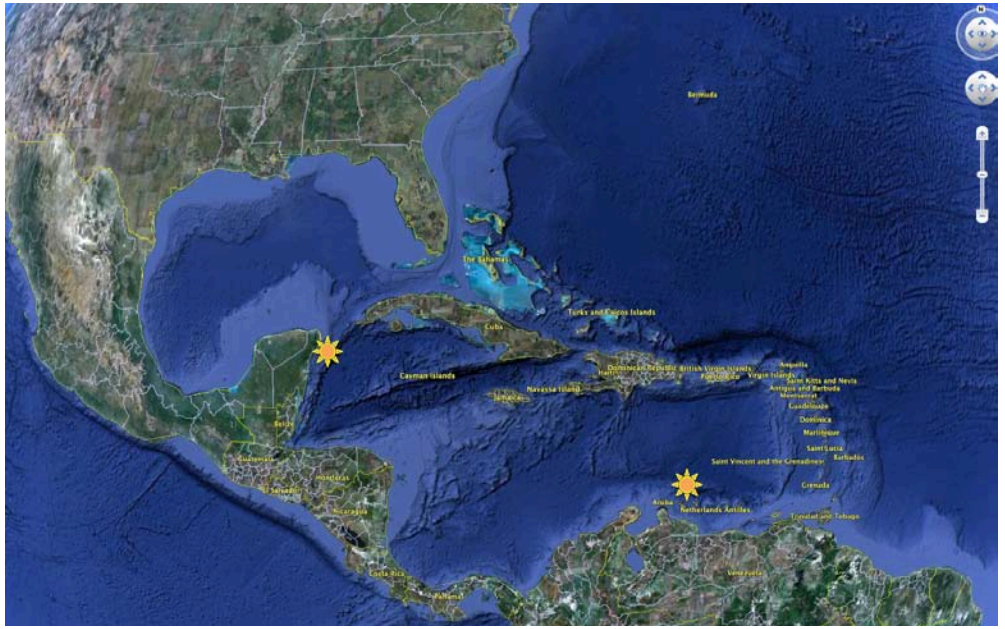
A Spatial Analysis of Coastal Development in Cozumel, Mexico and Curaçao, N.A.

Carl Nim
2010 Knauss Fellow
Coral Reef Watch (CRW)

Outline

- Experience
- Academic projects
- Examples of coastal management analyses
  - Cozumel, Mexico
  - Curaçao, Netherlands Antilles



Experience With Coastal Management Projects

MIAMI UNIVERSITY

Degree Areas

- Geography, M.A.
  - Nature-Society interactions in the Caribbean.
- Environmental Science, M.En.
  - Coastal management and seascape ecology

Content Areas

- Qualitative Methods:
  - Interviews
  - Surveys
- Spatial Analysis Tools:
  - GIS and GPS
  - Remote sensing
    - ERDAS Imagine
- Marine Ecology
  - Tropical marine ecology
  - Coral reef ecology

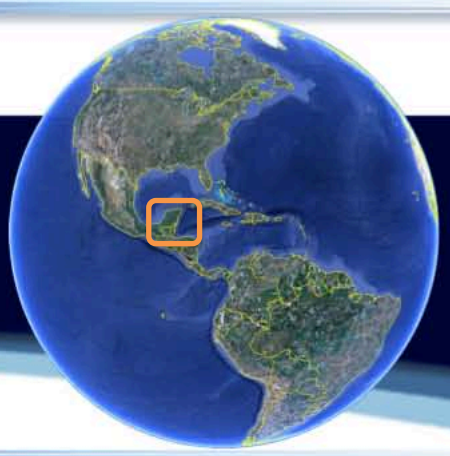
Academic Projects

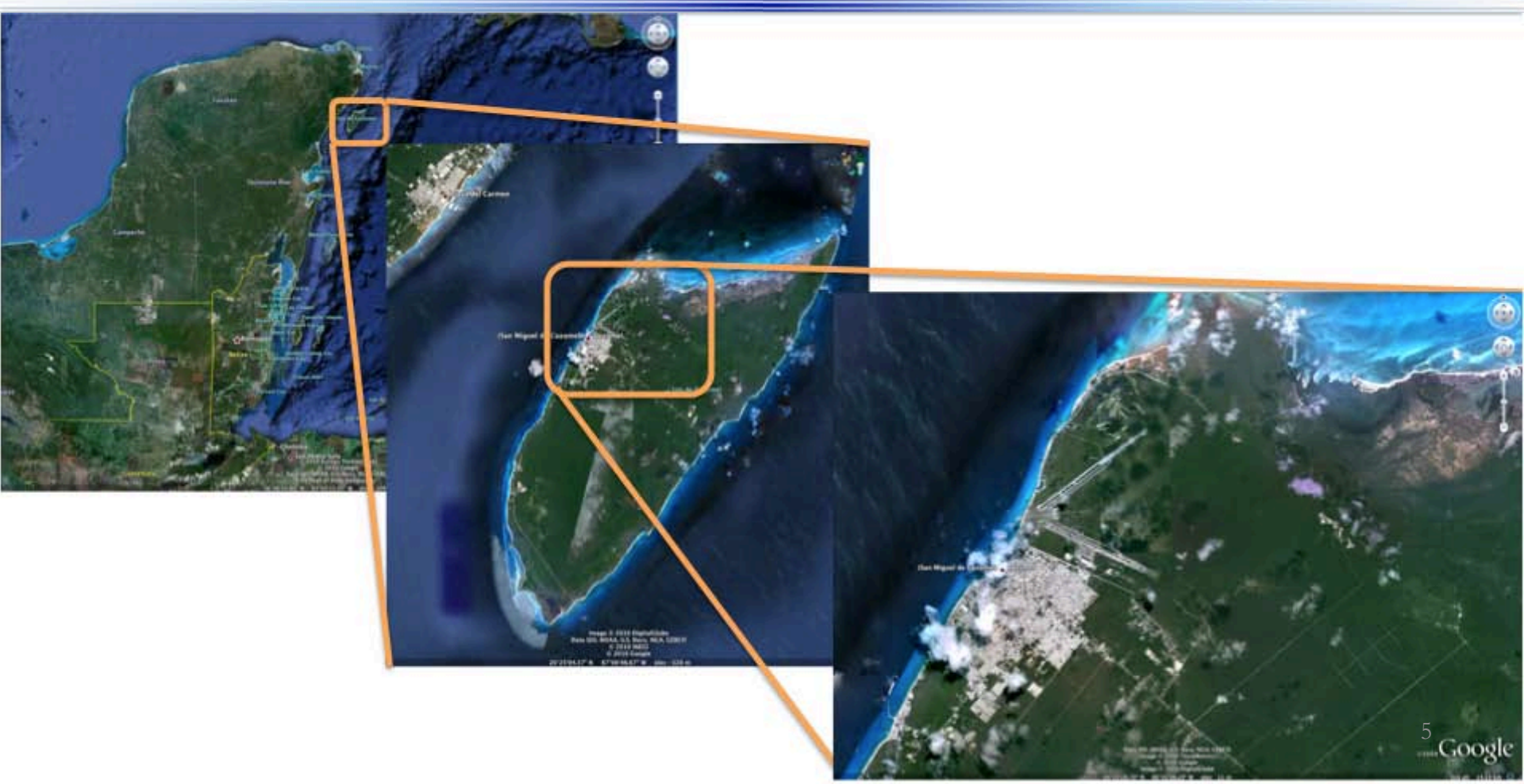
- M.A. Thesis – Cozumel

  "The Political Ecology of Environmental Change and Tourist Development in Cozumel, Mexico"

- M.En. Course Projects - Curaçao
  - Coral Reef Ecology
  - GIS in Landscape Ecology

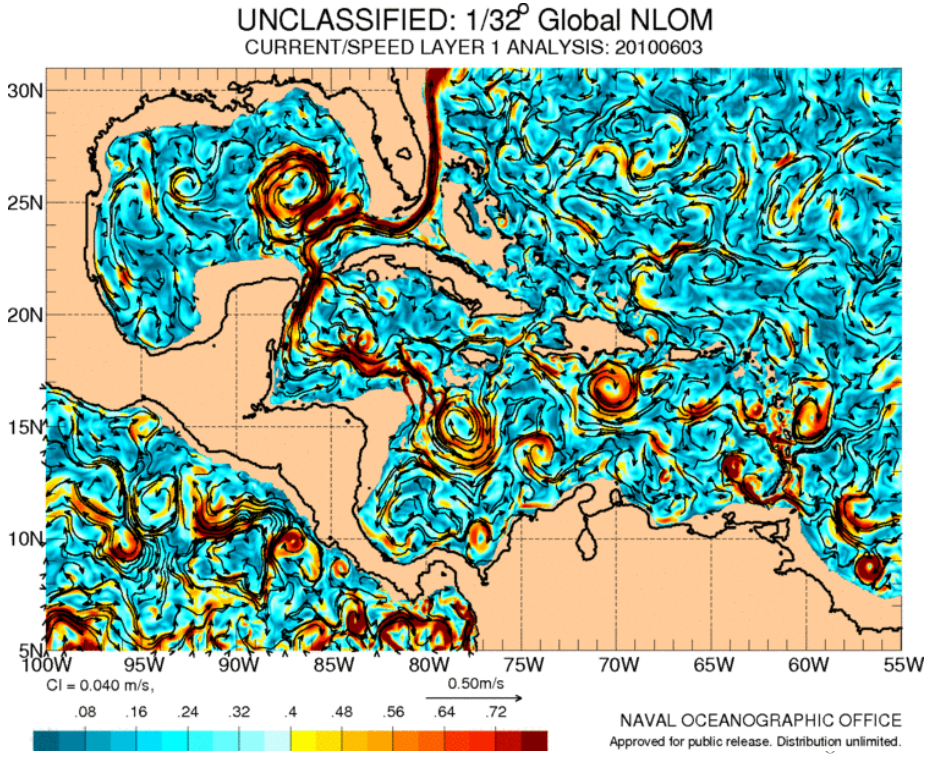
Cozumel, Mexico





Why Cozumel?

- What do these have in common?



Biological Significance of Cozumel

- In this region, the island of Cozumel represents a key ecological reserve because of the high species richness and the complexity of the ecosystem (Jordán- Dahlgren and Rodríguez-Martínez 2003; Fig. 1).

- Within the Gulf of Mexico and the Mexican Caribbean "Species richness suggests that the highest coral biodiversity is located around Cozumel on the Caribbean with 33 species."

Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008
Session number 14

INDIRECT EVIDENCES ON THE CONNECTIVITY OF CORAL REEFS OF THE GULF OF MEXICO AND THE MEXICAN CARIBBEAN

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Abstract. Coral reef connectivity results from the export and import of species or reproductive product between localities. Possible exchange pathways between the reef ecosystems in the country are not known; such knowledge about coral reef connectivity could contribute to its management and conservation. The connectivity between reefs of the Gulf of Mexico and Mexican Caribbean was evaluated based on patterns of similarity. Information for 48 stony coral species in 19 localities was compiled from different sources. Species richness suggests that the highest coral biodiversity is located around Cozumel on the Caribbean with 33 species. Cluster analysis based on biological similarity between localities shows that the Veracruz Reef System (VRS) is more similar to the reefs of the Mexican Caribbean than those on the Campeche Bank. Correlation (Mantel test) of biological similarity with geographical distance, days of transport by currents and environment variables, was negative and highly significant, corroborating that biological similarity decreases with increasing distances. The hypothesis that the reefs of the VRS and the Caribbean are more similar because these areas are less affected by hurricanes is proposed. This environmental stability would lead to an accumulation of Caribbean coral species that makes VRS more similar to the Caribbean than to those reefs in the Northern Veracruz or those in the Yucatan shelf.

Key words: Connectivity, Dispersion, Coral reefs, Similarity

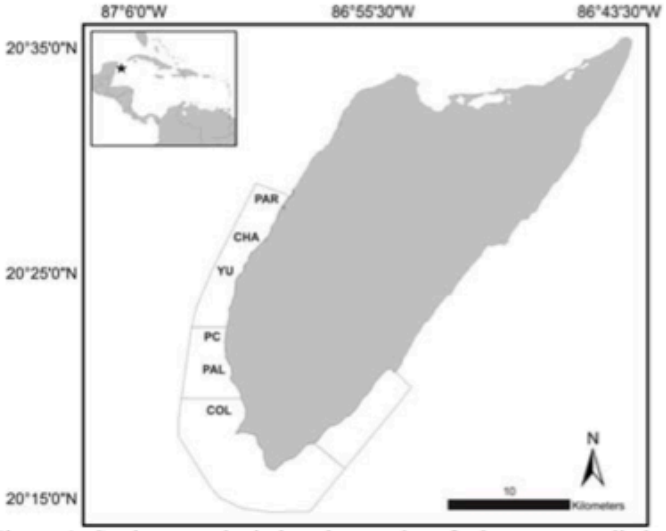
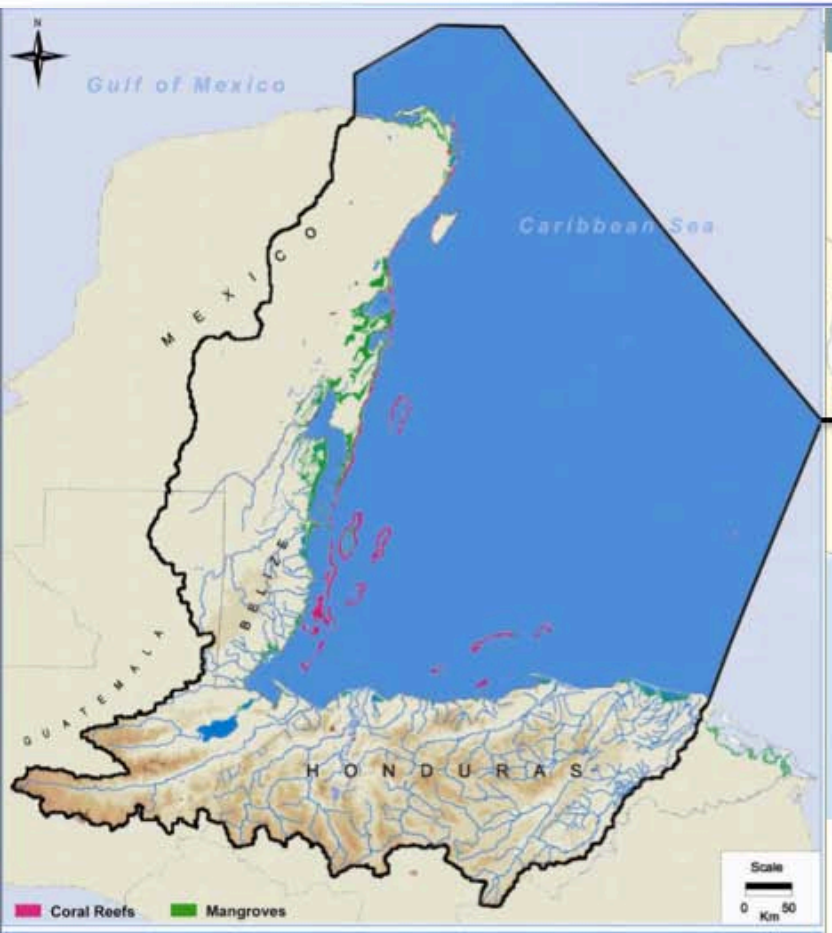


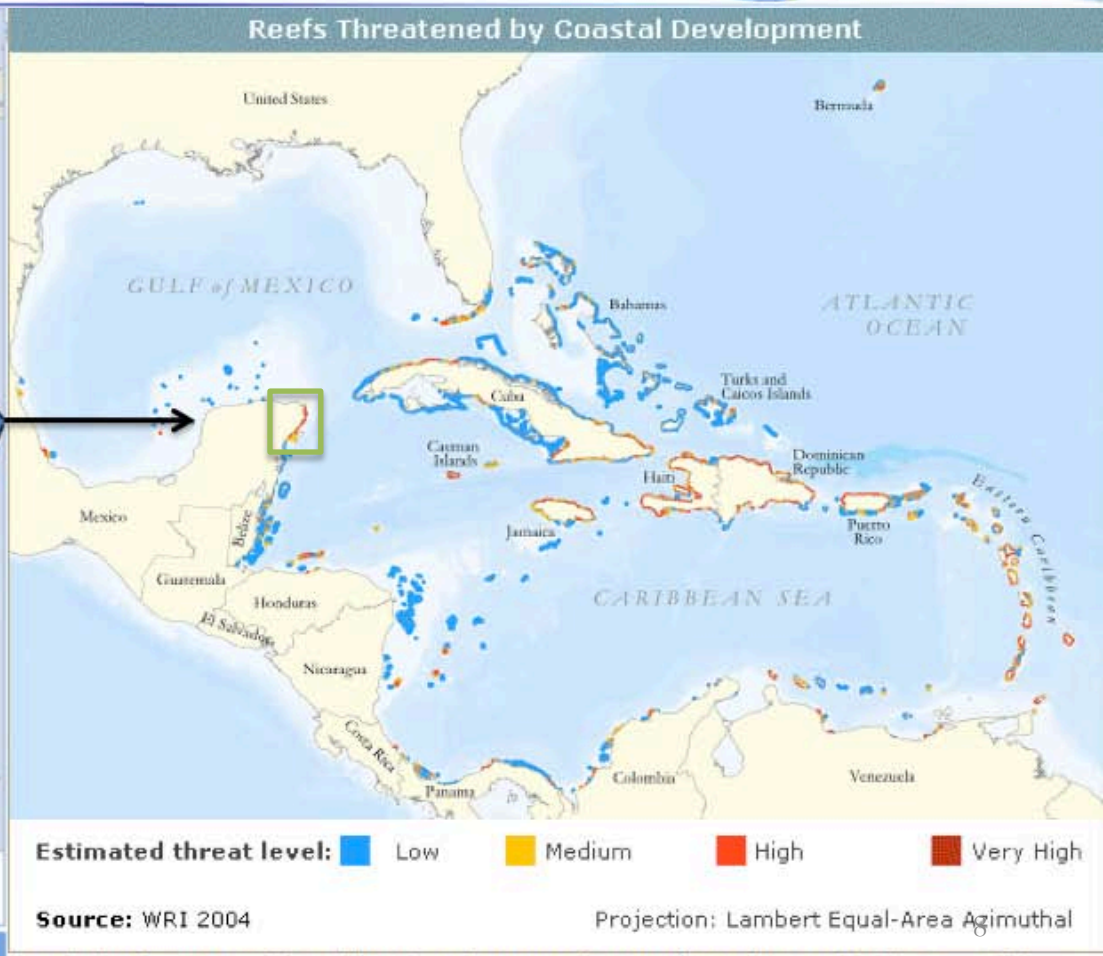
Figure 1: Study area, depicting the coral reefs that were studied at Cozumel Island. PA= Paraiso, CHA= Chanlana´ab, YU= Yucab, PC= Paso del Cedral, PAL= Palancar, COL= Colombia. Continuous line delimits the polygon of the Parque Nacional Arrecifes de Cozumel.

Cozumel's Conflicted Space

The Riviera Maya



MESOAMERICAN REEF ECOREGION



Dudenhoefer 2004 and http://earthtrends.wri.org/features/view_feature.php?theme=3&fid=55

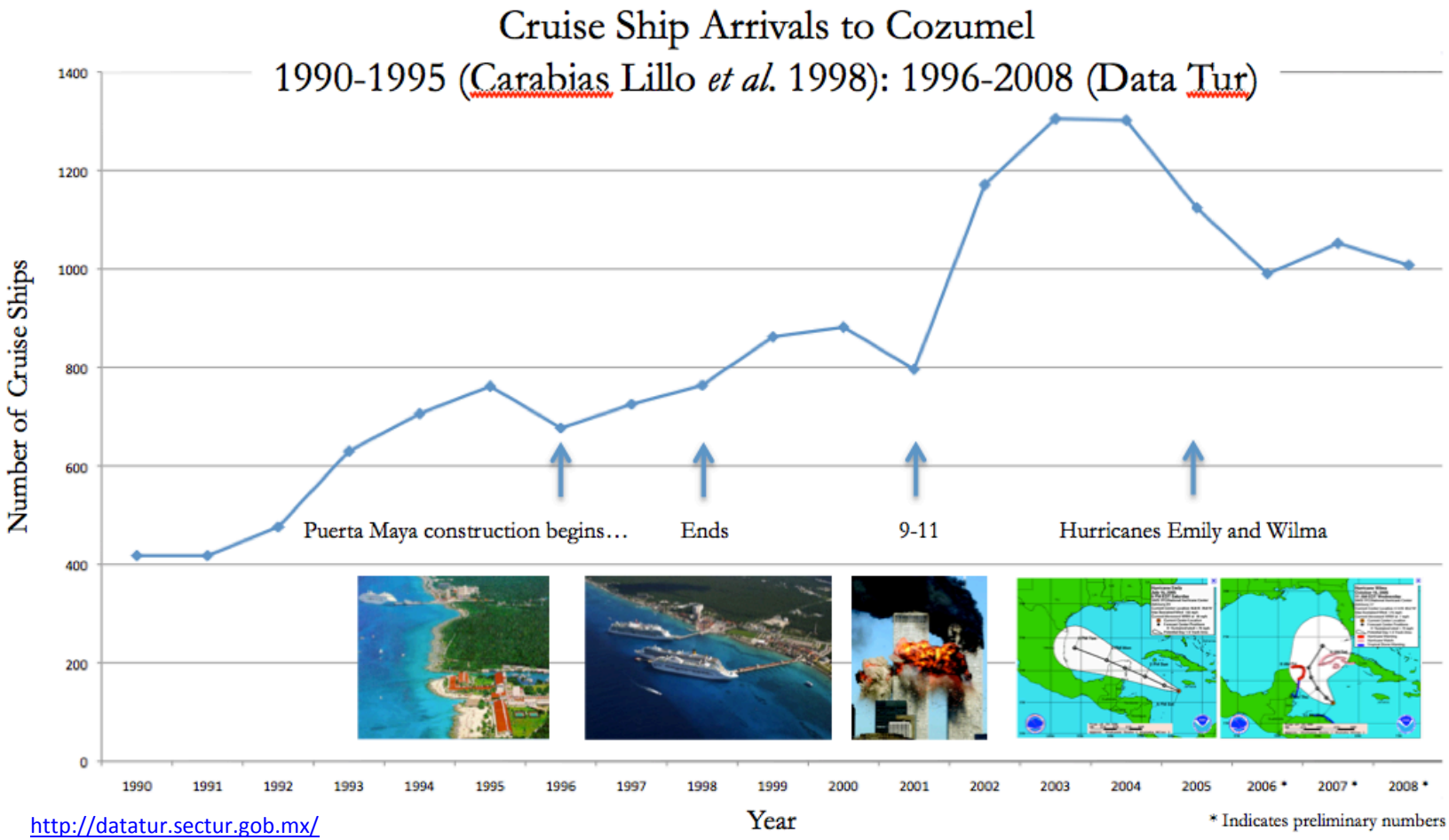
Developmental Context

- Significant pre-colonial Maya civilization with numerous archeological sites
  - San Gervasio, Tulum, Chichen Itza
- US air base during WWII
- 1960 Jacque Cousteau visits Cozumel
- 1970's to present, "Gringolandia"

(Torres and Momsen, 2005)

Cozumel's Economic Niche

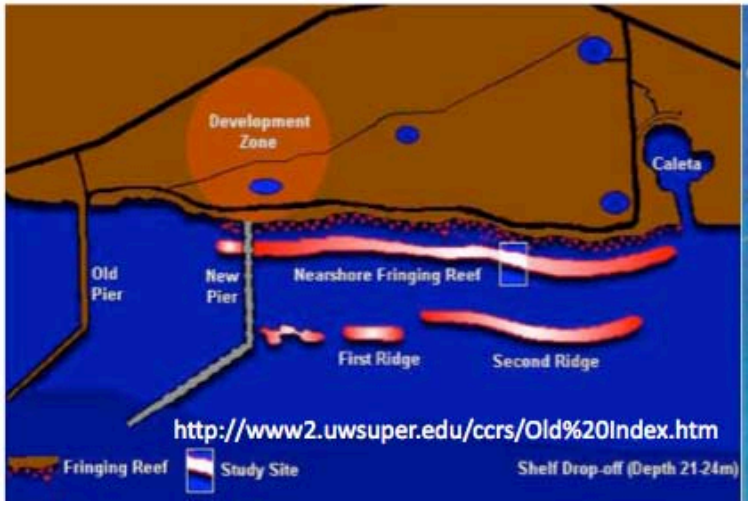
Cruise Ship Trend



http://datatur.sectur.gob.mx/

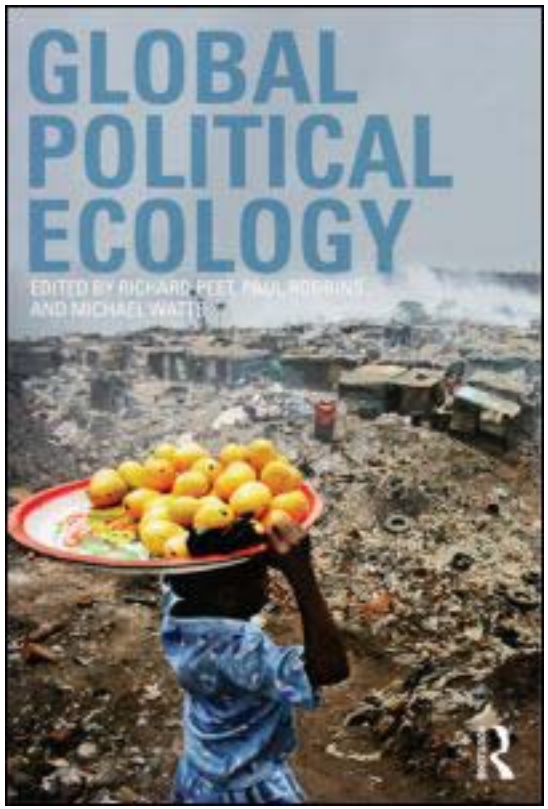
Cruise Ship Pier Development

- Construction of additional cruise ship pier (Puerta Maya) over Paradise Reef (3 cruise ship piers total)
- Public opposition to location of construction.
- Multiple interpretations of possible violations (e.g. EIS).
- For more see Vera-Morales 1996 and Preston 1996.



Methodologies

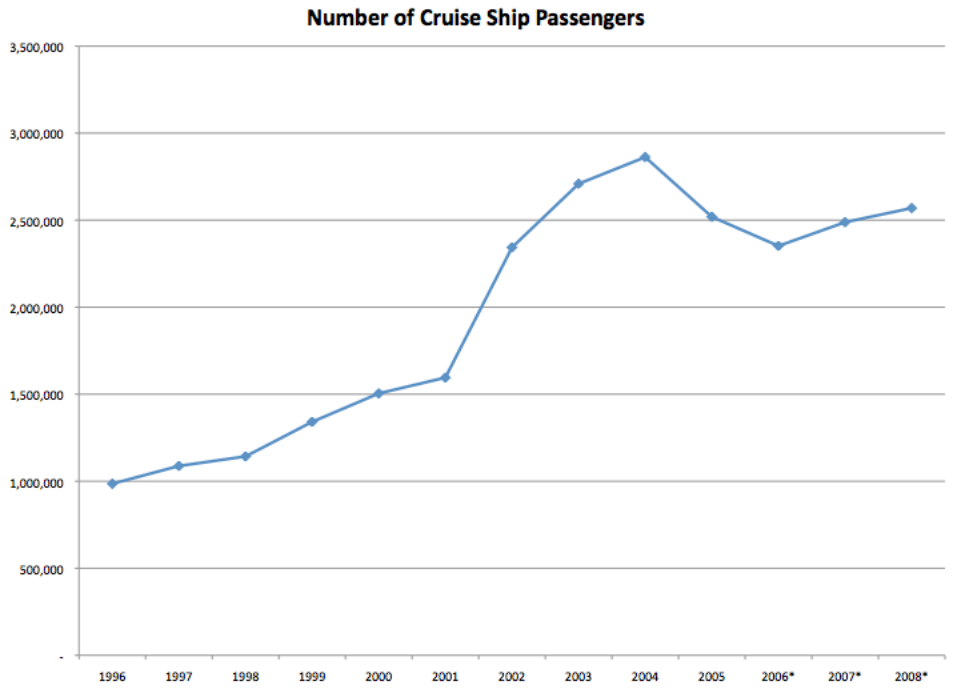
- Political Ecology theoretical framework.
- Qualitative
  - Semi-structured interviews with 21 participants in July of 2005.
- Quantitative
  - LULC 1998-2001



Interview Results

- Perception of residents indicated:
  - Politicians disregarded local request / referendum to move the pier to another location.
  - Cruise ship visitation stresses local resources (e.g. water supply, sanitation)

    Cozumel population estimates
    2005: *75,000*
    2010: *90,000*
    http://www.travelyucatan.com/cozumel_mexico.php
  - Concern for coastal water quality due to dolphin enclosures, ship discharges and inadequate sewage treatment at some tourist locations.
  - Limited economic "trickle down" to residents.
    - For more on the political economy of cruise ships see Clancy (2008) and Wood (2000)



http://www.globalcoral.org/What%20Should%20the%20Policy%20of%20the%20Municipality%20of%20Cozumel.htm

Land-Cover
Land-Use Change (LCLUC)

Landsat TM: 13 April 1988
Path 18 – Row 46

Landsat ETM: 17 April 2001
Path 18 – Row 46

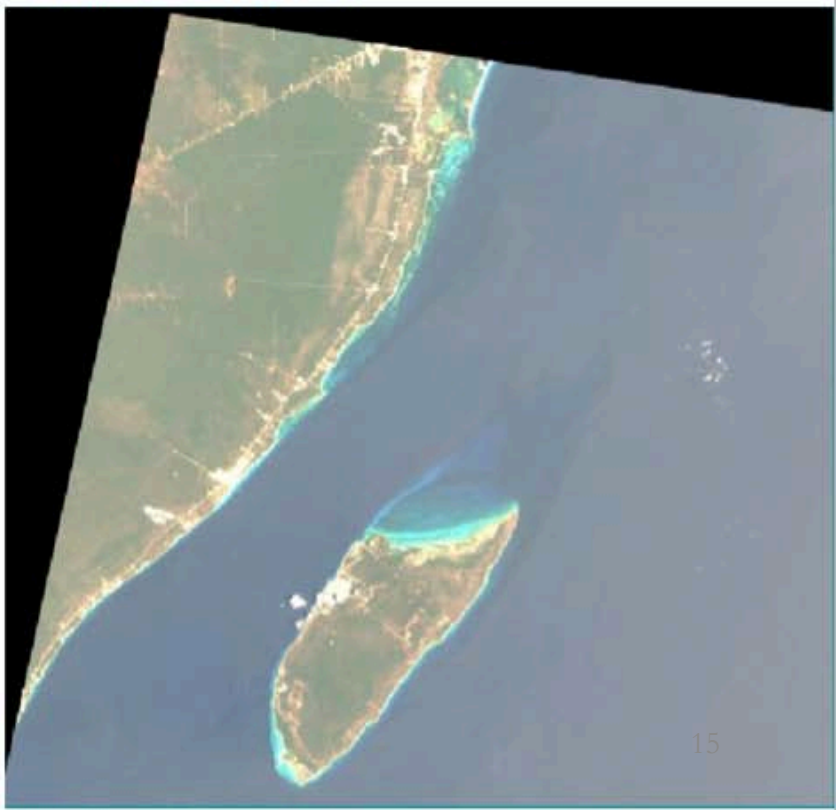


Image Processing

Conversion of Landsat TM Digital Numbers (DN) to ETM DNs.

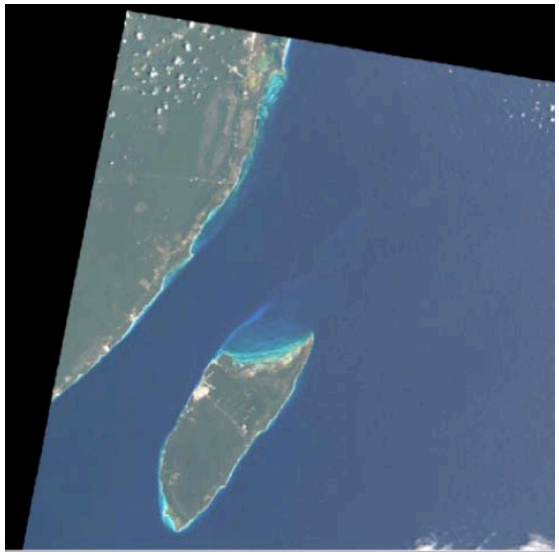
Created AOI of Cozumel Island

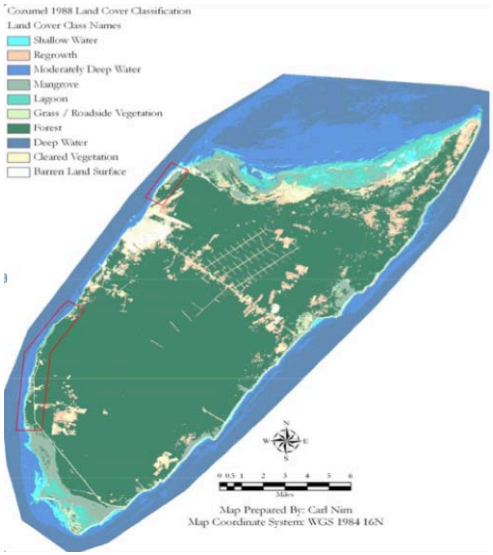
Dark object subtraction for atmospheric correction.

Subset of bands 5,3,1 for vegetation comparison.

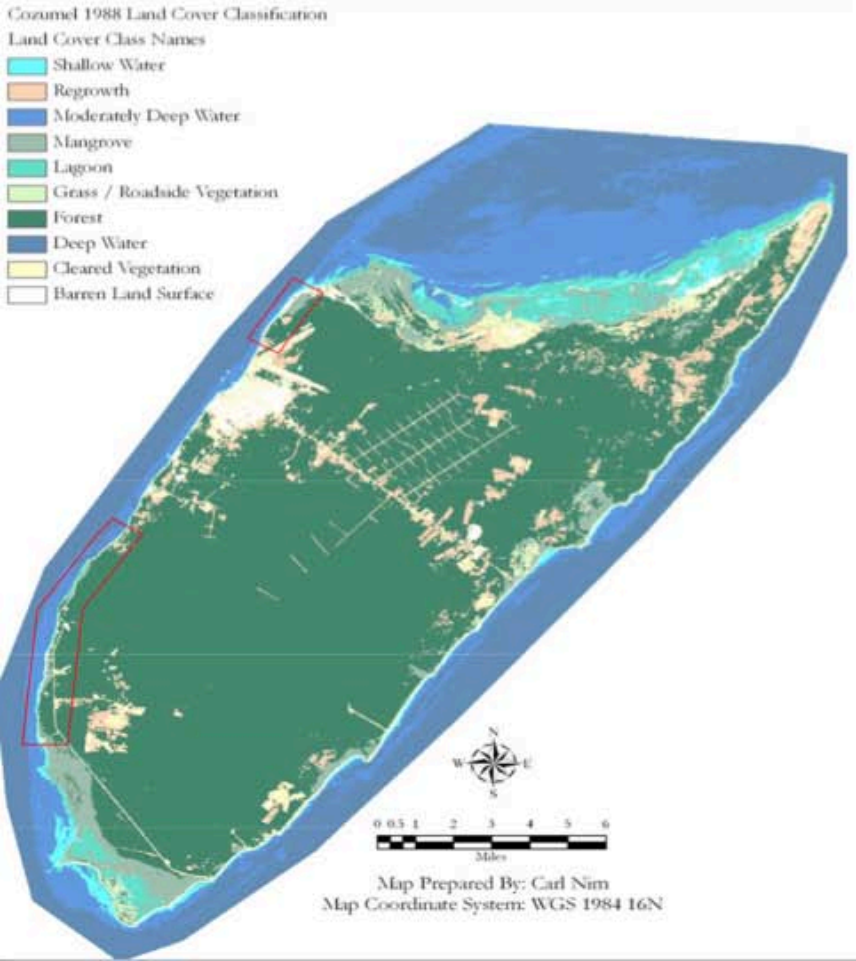
Unsupervised classification of 20 classes.

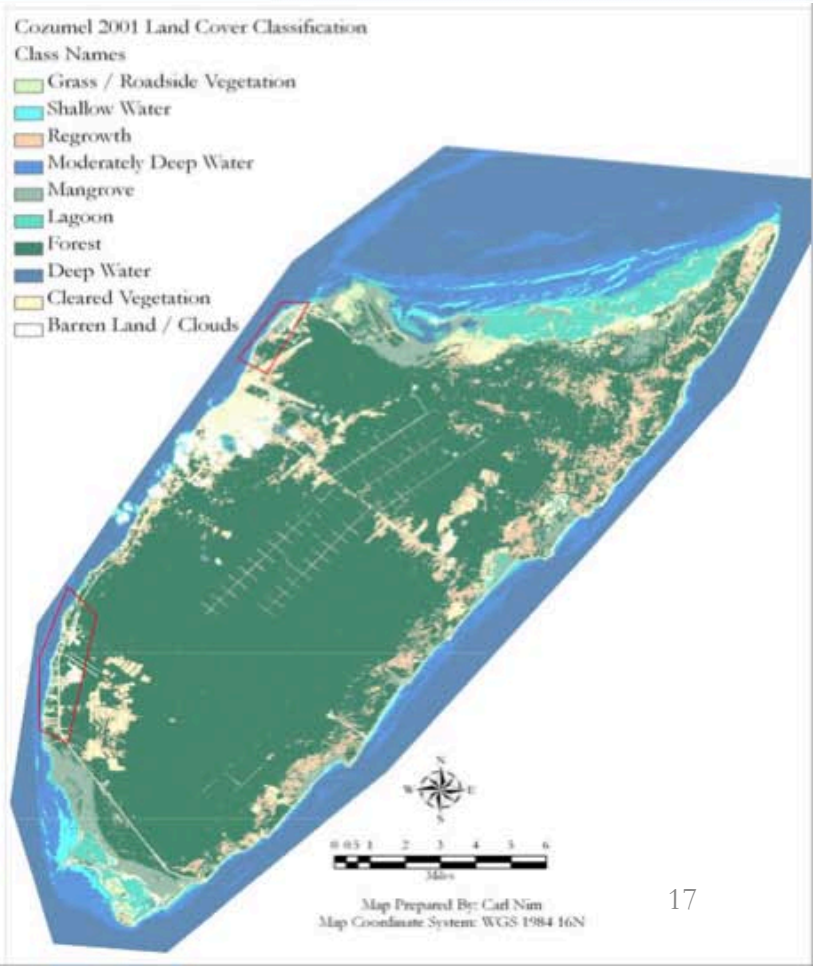
Using ground reference points, I merged the 20 classes to 10.





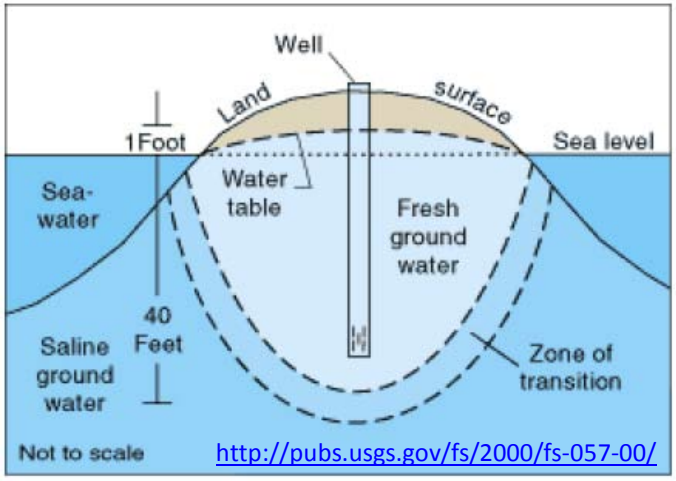
LCLUC 1988 - 2001





LCLUC Implications

- Additional Cruise Ship Piers
  - 1-3 Piers: Sediment from concrete mixing, Paraiso reef damage.
- Increased Urban Areas
  - Change in San Miguel's urban area from 2.09 miles^2 to 3.25 miles^2.
- Increased Coastal Construction
  - Sediment from concrete mixing, removal of mangroves, sewage runoff.
- Increased Water Well Pipelines
  - Aquifer reduction and potential for salt water intrusion



Hurricanes Emily / Wilma (2005)

21 DEC 2003

Punta Langosta Pier

International Pier

Puerta Maya Pier

5 JUN 2006

Biological effects of Hurricanes Emily and Wilma

- Wilma 4 times more damaging than Emily.
- Coral cover 24% to 10% and back to 16% in May 2007.

Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008
Session number 18

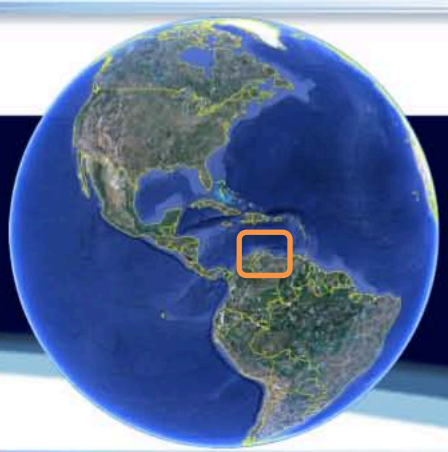
Cozumel Island, México: A disturbance history

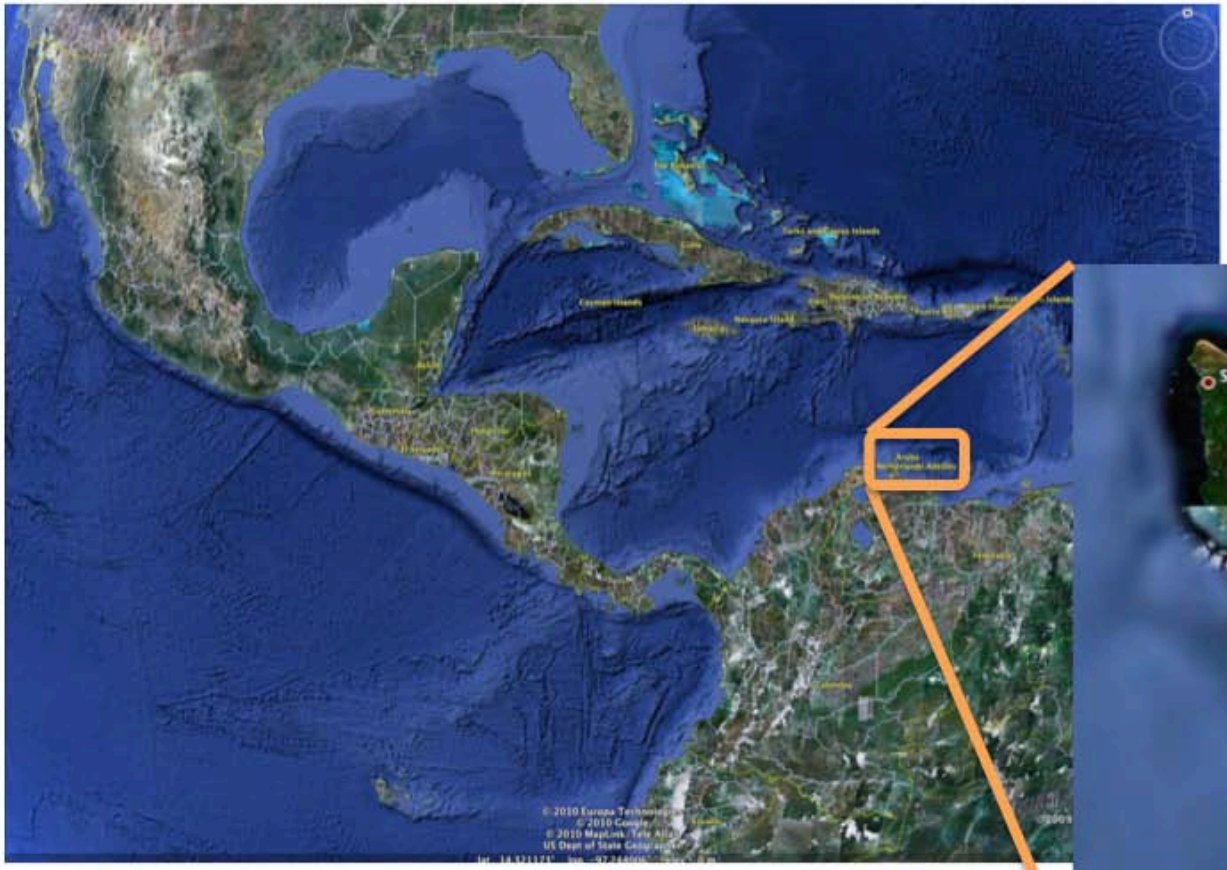
P.A. Álvarez del Castillo-Cárdenas[1*], H. Reyes-Bonilla[1], L. Álvarez-Filip[2], M. Millet-Encalada[3], L.E. Escobosa-González[1]

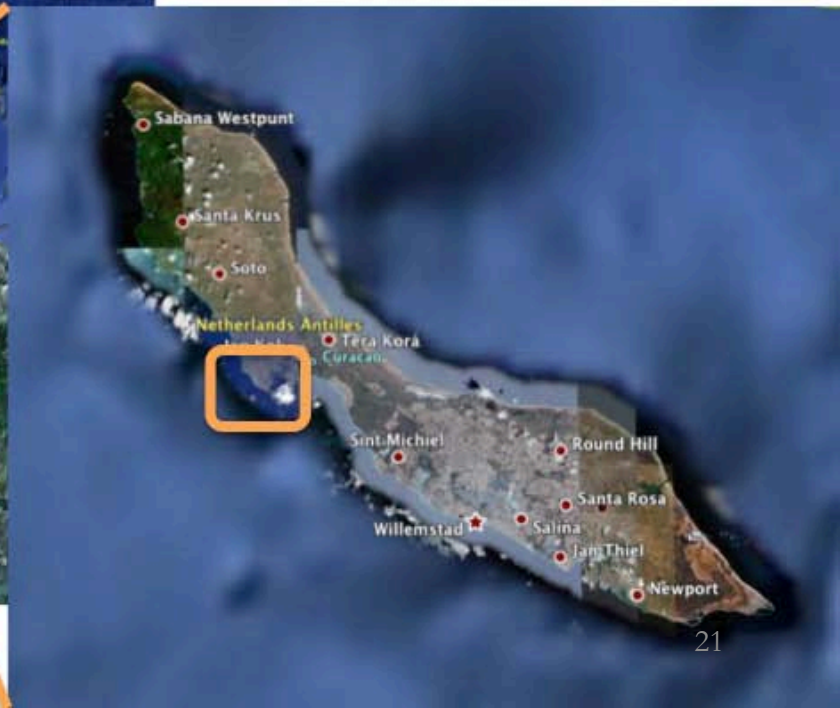
1) Departamento de Biología Marina. UABCS. Carretera al Sur km 5.5, CP 23080. La Paz, BCS, México. *strellada@gmail.com
2) Centre for Ecology, Evolution and Conservation. University of East Anglia. Norwich, NR4 7TJ. United Kingdom.
3) Departamento de Monitoreo y Vinculación Científica. Parque Nacional Arrecifes de Cozumel. Oficinas de la CONANP. Altos Plaza Sol S/N. Col. Centro. C.P. 77600 tel. (987)-8724689. Cozumel Quintana Roo, México.

Abstract. This study aims to determine the damage caused by the 2005 hurricanes "Emily" and "Wilma" on the landscape structure of the Parque Nacional Arrecifes de Cozumel (PNAC), México. We conducted samplings at six reefs located in the PNAC during May 2005 and May 2007. At each reef, six 30-m point-intercept transects were run parallel to the coast. The bottom elements that were quantified were coral, sponges, macro algae, coral with recent death, rock and sand. Landscape structure was quantified with the Pielou´s evenness index (J´), and changes were evaluated with non-metric multi-dimensional scaling (NMDS) and the Bray-Curtis similarity coefficient. The results show a significant decrease in the percentage of live cover, and an increase in the percentage of sand and rock. Corals were the most affected group decreasing from 24% to 10% in cover after the two hurricanes; fortunately, cover has increased to 16% by May 2007. Significant differences were found in the landscape evenness, being lower in July 2005($F_{5,210^{\infty}} = 14.94$, $P=0.00$),; the high similarity of J´ between May 2005 and May 2007 indicates a clear trend of recovery in the reefs. The NMDS show that the two hurricanes affected Cozumel reefs with varying intensity, with "Wilma" having an impact four times higher than "Emily".

Curaçao N.A.






Sabana Westpunt
Santa Krus
Soto
Netherlands Antilles
Tera Kora
Curacao
Sint Michiel
Round Hill
Santa Rosa
Willemstad
Salina
Jan Thiel
Newport

Curaçao Reefs

Coral Reefs (2005) 24: 475–479
DOI 10.1007/s00338-005-0009-1

REPORT

Rolf P. M. Bak · Gerard Nieuwland · Erik H. Meesters

Coral reef crisis in deep and shallow reefs: 30 years of constancy and change in reefs of Curacao and Bonaire

Received: 17 June 2004 / Accepted: 16 June 2005 / Published online: 9 November 2005

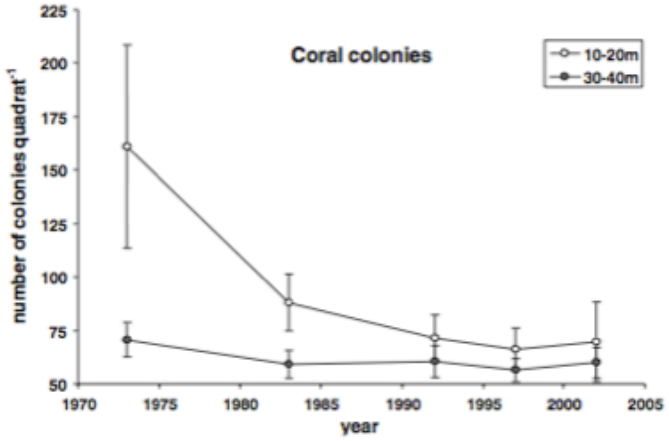


Fig. 1 Number of coral colonies (mean ± 1SE) from 1973 to 2003 at two depths, 10–20 and 30–40 m

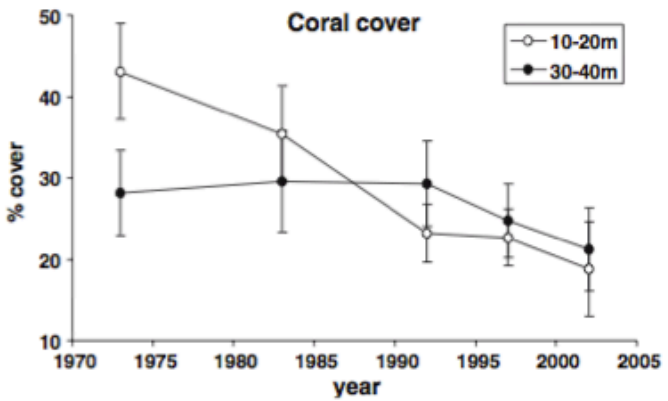


Fig. 2 Coral cover (mean ± 1SE) from 1973 to 2003 at two depths, 10–20 and 30–40 m

Mapping Methods

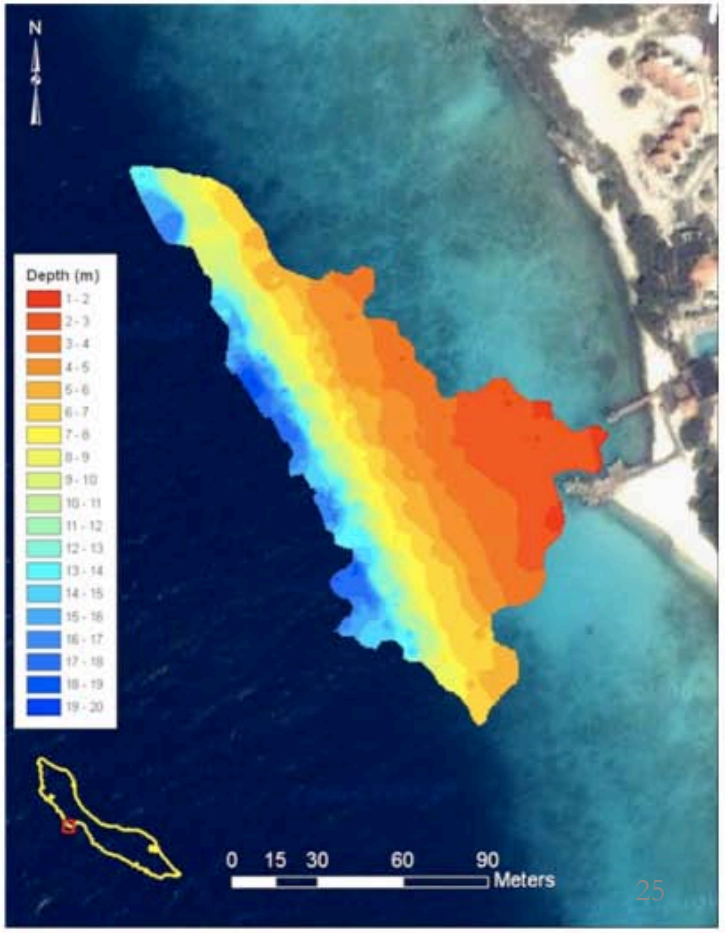
- Create Bathymetric Map of Study Site
  - Using Depth Data Loggers, GPS and ArcGIS

- Create Benthic Classification Map of Study Site
  - Using Remote Sensing Data

Transect Data Collection

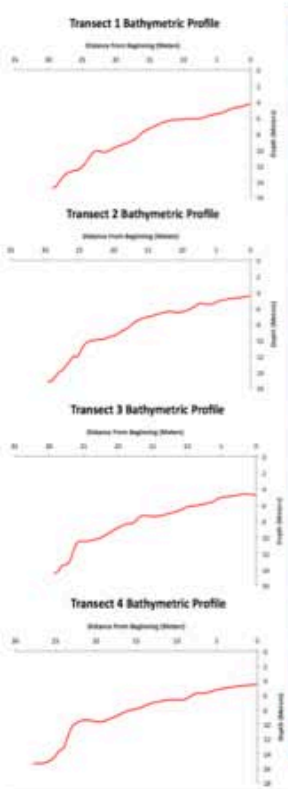
Benthic Mapping

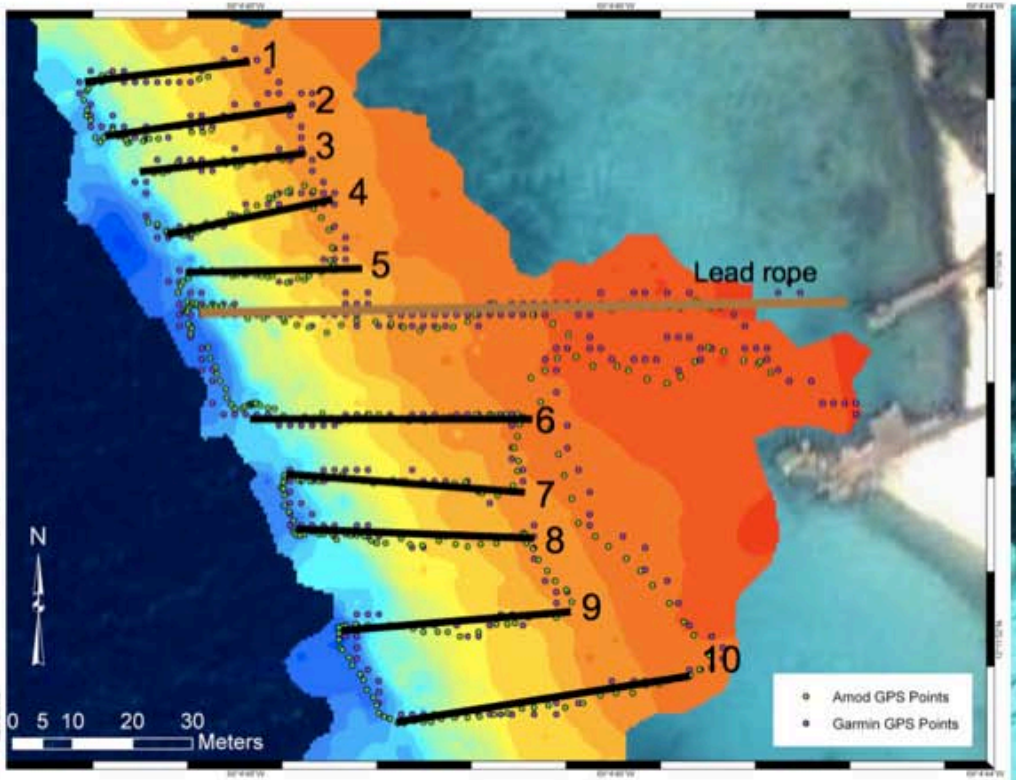
- 10, 50 meter transects at varied intervals; started at a depth of 50 feet.
- Used Triangular Irregular Networks (TIN) Creation Tool in ArcGIS 3D Analyst to make map.



Transect Video

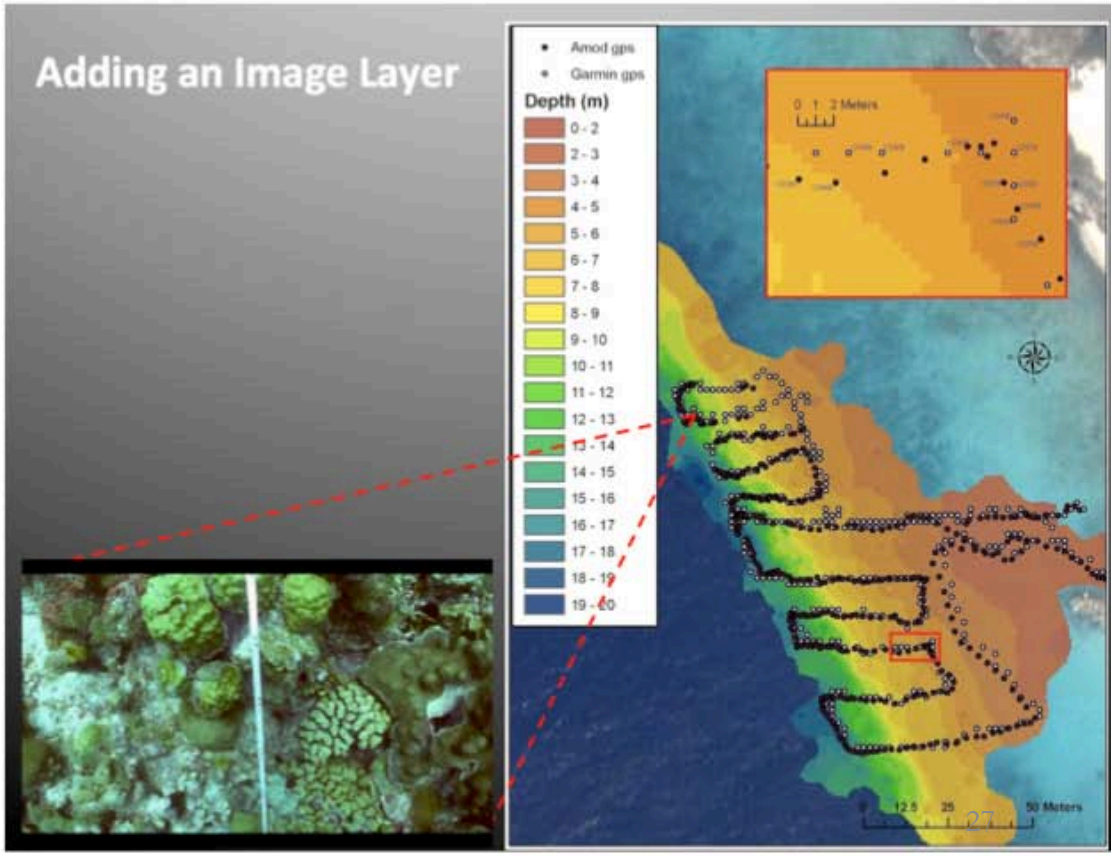
- HD Video of all Transects to be analyzed later





Incorporating Coral Cover with Habitat Maps

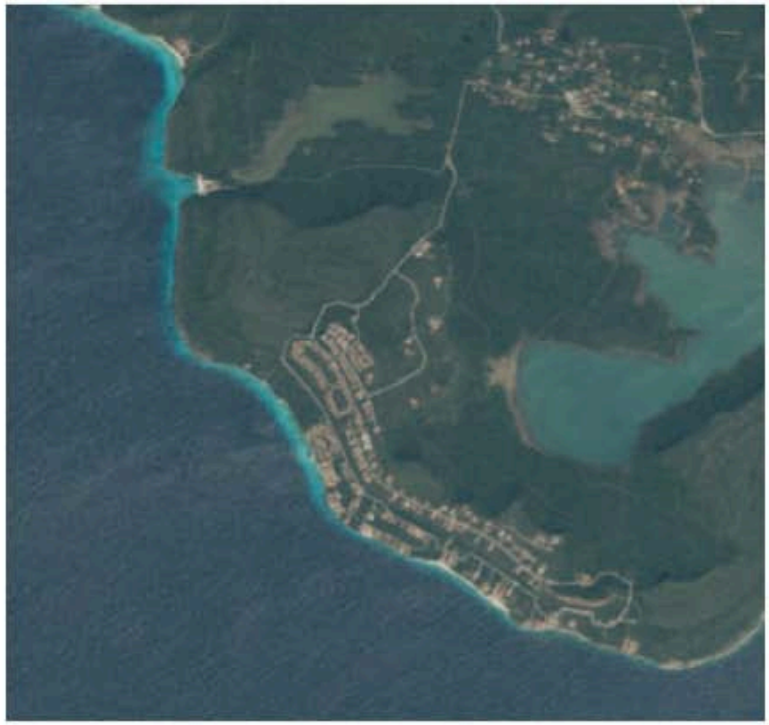
- Provides baseline
- Monitors trends
- Still frames and coral cover quantification (and other data) from video can be placed in DB for GPS points in ArcGIS.



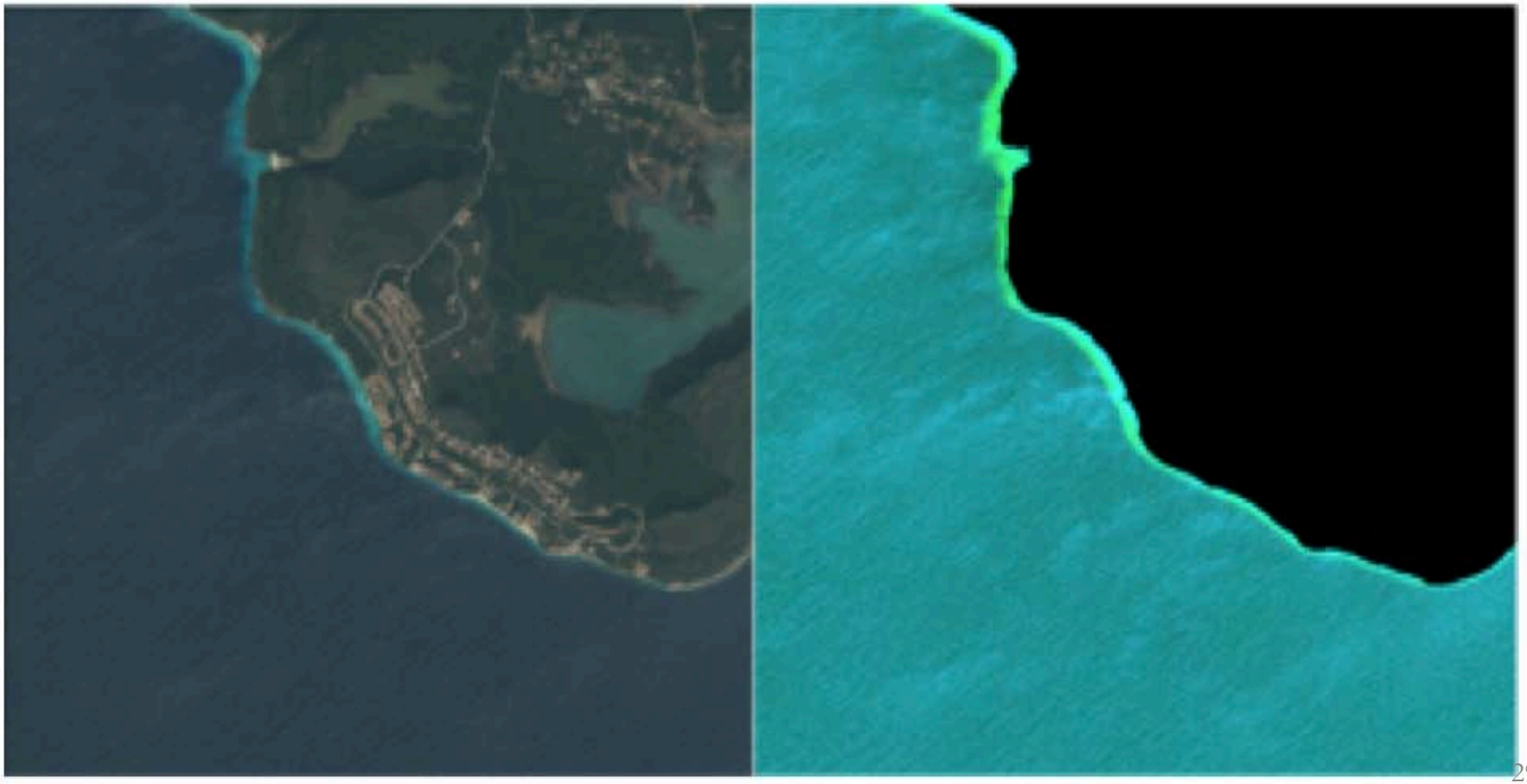
Benthic Classification

Learning Experience (Course Project: Landscape Ecology)

- QuickBird 2.4 meter pixel from 28 December 2008.
- Mask
- Deglinting
- Supervised Classification
- Atmospheric Correction
- Water Column Correction

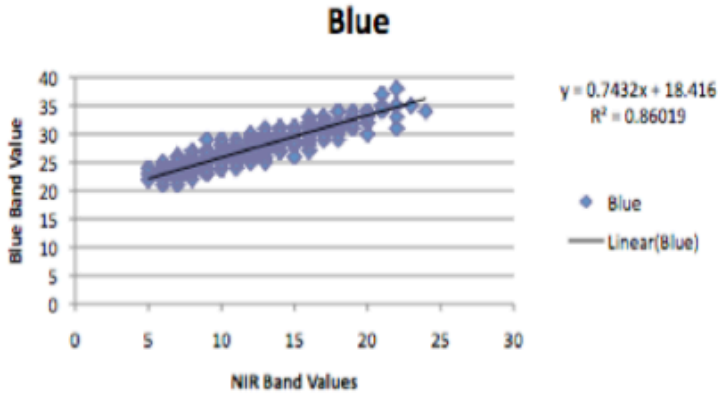


Land Mask



Deglinting

$$R_i' = R_i - b_i(R_{NIR} - Min_{NIR})$$

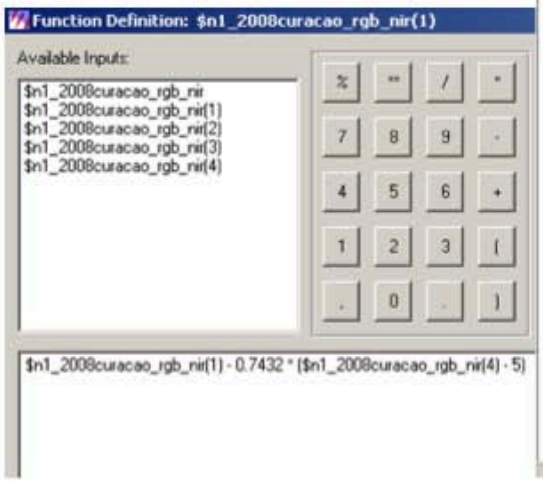


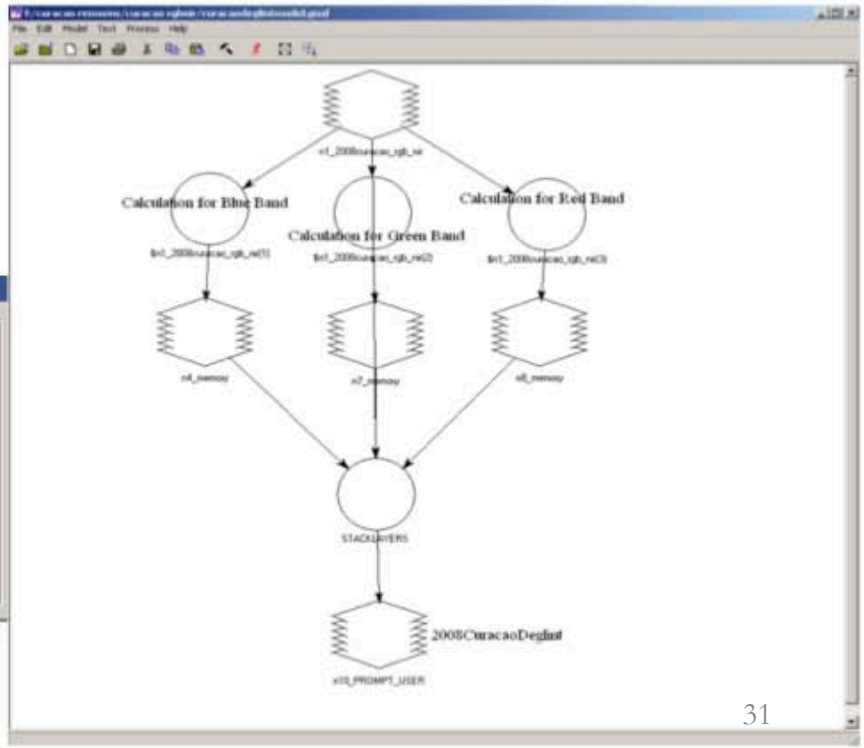
Hedley, J.D., Harborne, A.R., and Mumby, P.J. 2005. Simple and robust removal of sun glint for mapping shallow-water benthos. *International Journal of Remote Sensing* 26(10): 2107-2112.

- Select AOI of open water at varying degrees of reflectance.
- Convert pixel to ASCII
- Plot R,G, B bands against NIR band.
- R'_i =Deglinted Band
- R_i = Band to be corrected
- b_i = slope of band plotted against NIR band
- R_{NIR} = NIR band
- Min_{NIR} = lowest NIR pixel value from sample.

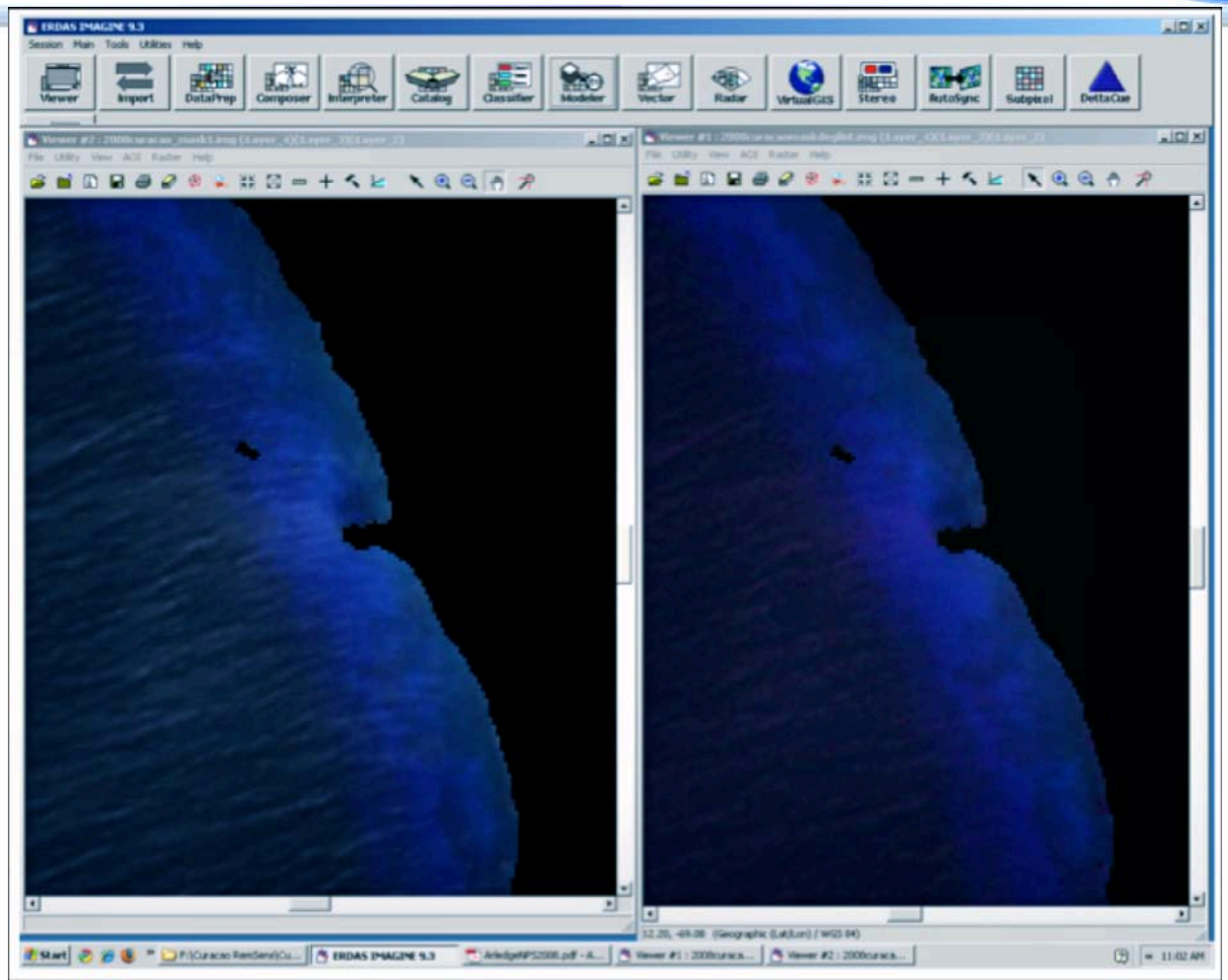
Deglinting Equations and Model

ERDAS Imagine





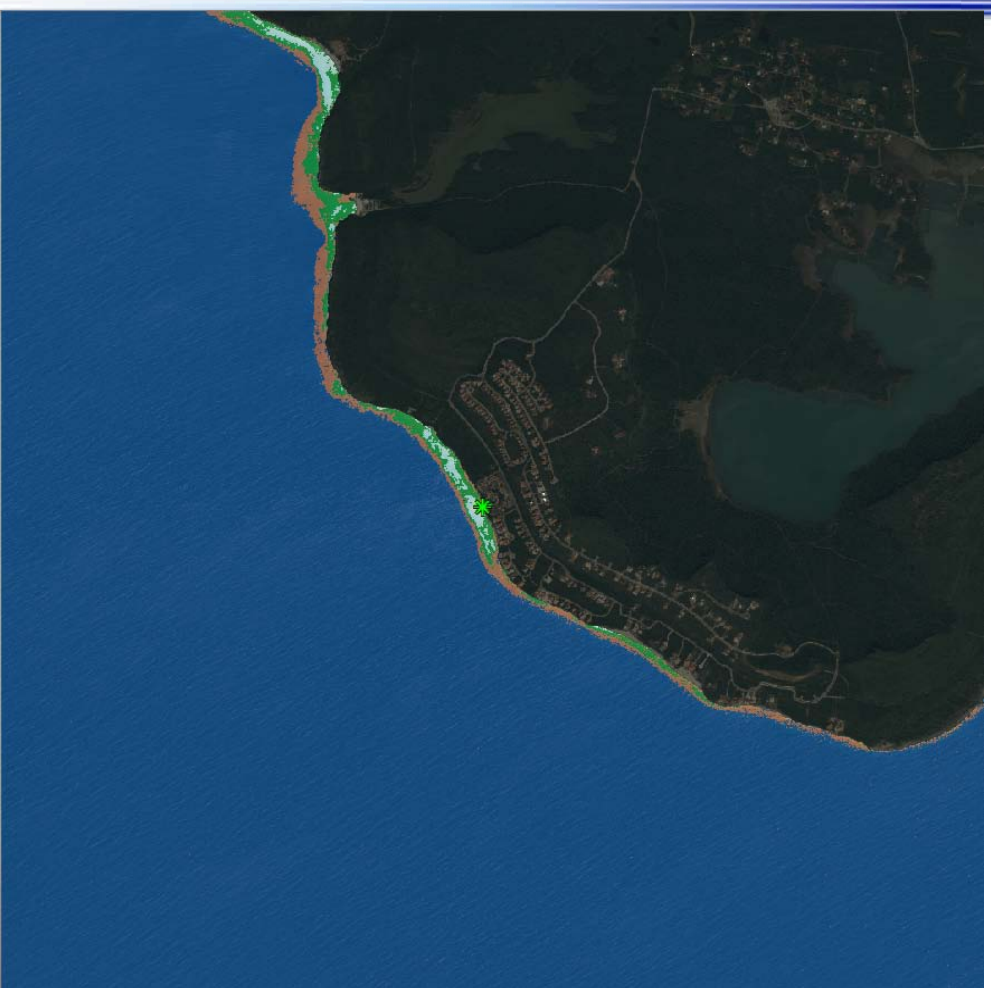
Deglinting Results



Benthic Classification

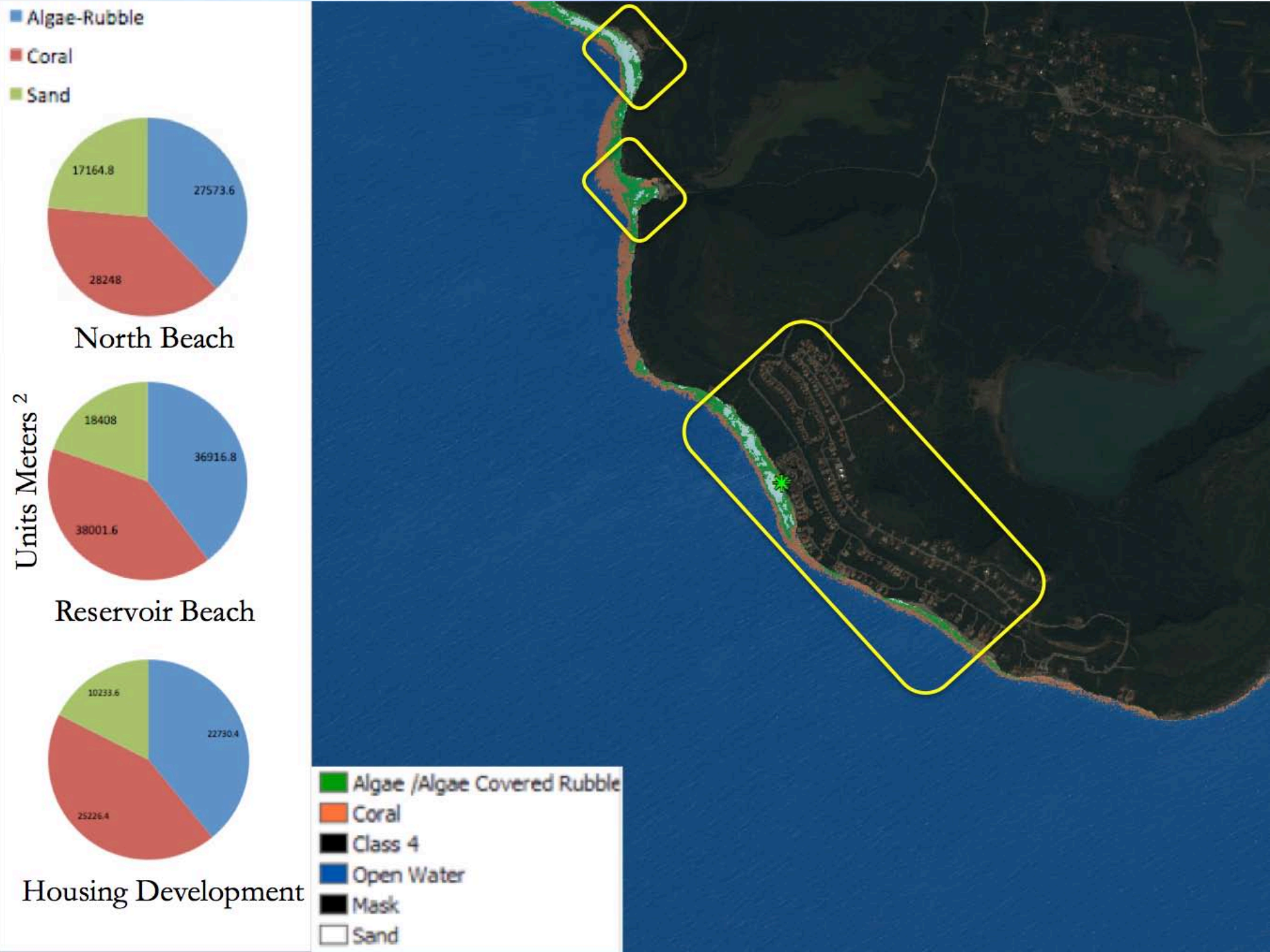
- Unsupervised Classification (20 classes)
- Supervised Classification (3 classes)
  - Coral
  - Algae / Algae covered rubble
  - Sand

Spatial Survey of Benthic/Terrestrial Relationships



Question:

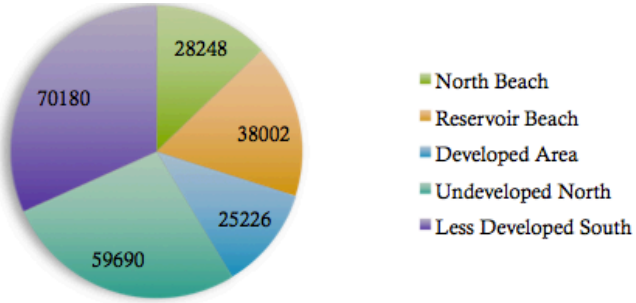
Based on the classification, what is the composition of benthic cover types adjacent to different land use types?


Algae-Rubble
Coral
Sand
17164.8
27573.6
28248
North Beach
Units Meters 2
18408
36916.8
38001.6
Reservoir Beach
10233.6
22730.4
25226.4
Housing Development
Algae /Algae Covered Rubble
Coral
Class 4
Open Water
Mask
Sand

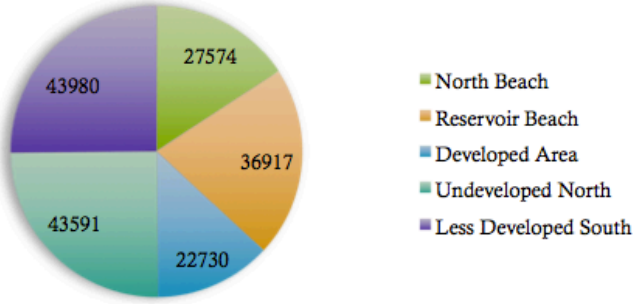

Algae-Rubble
Coral
Sand
Units Meters 2
18636
43591.2
59690.4
Undeveloped
18643.2
43980
70180.8
Less Developed
Algae /Algae Covered Rubble
Coral
Class 4
Open Water
Mask
Sand

Benthic Composition by Location (Meters^2)

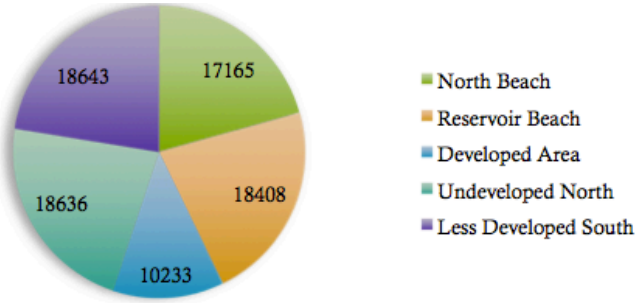
Coral

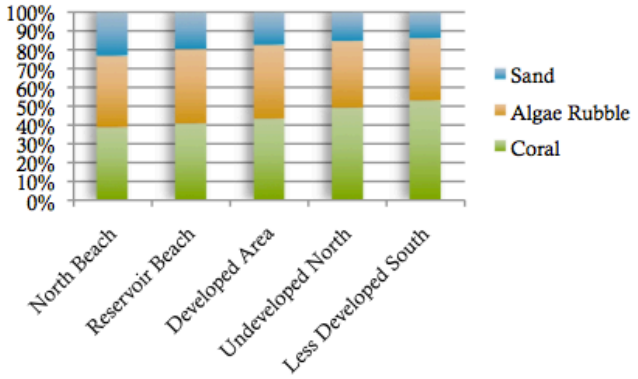


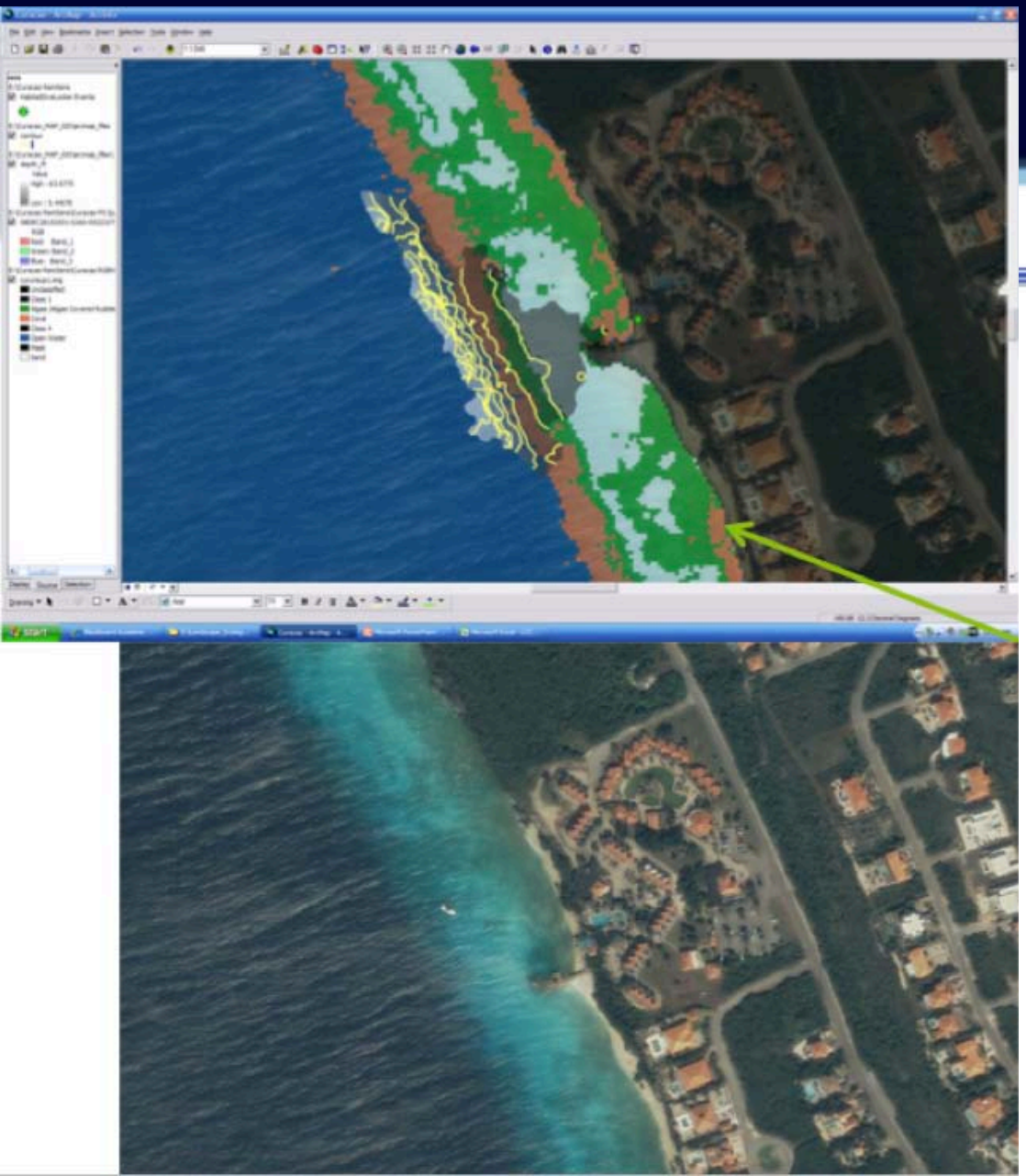
Algae Rubble



Sand







Discussion

- Additional preprocessing procedures would enhance classification by minimizing the similarities in the spectral reflectance signatures.
- Some classification errors
- Important to understand limits of tools, coral reef areas that look like they have less coral may just be oriented differently, and sensors can't observe coral deeper than 24'.
- Further research needed to see if development is influencing reef composition.

Things I would have done differently…

… if I had more time!

- Atmospheric correction
- Water column correction

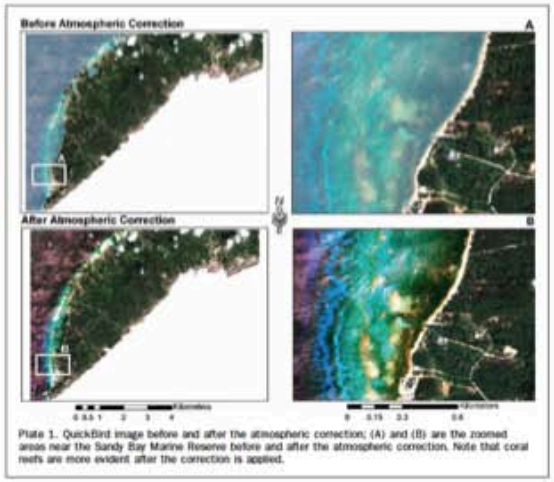


Plate 1. QuickBird image before and after the atmospheric correction; (A) and (B) are the zoomed areas near the Sandy Bay Marine Reserve before and after the atmospheric correction. Note that coral reefs are more evident after the correction is applied.

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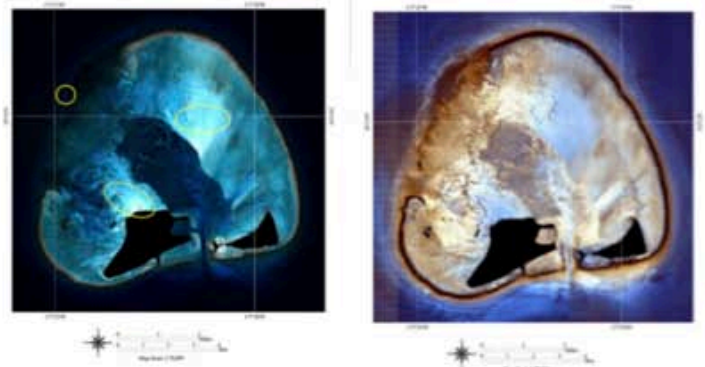

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Summary

- A variety of useful spatial tools are available for coastal development studies
- Some technical issues still restrict possibilities
- Planning and stakeholder involvement during coastal development is crucial
- The cruise industry exerts a disproportionate amount of power over the political economy of destinations
- Well defined statutes are important to avoid multiple interpretations of the law.

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