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Bronx, New York, USA

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Clark Labs and the Wildlife Conservation Society

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ACRS, Coffs Harbour, Australia
September 11-13, 2010

Object Based Analysis Of High Spatial Resolution Imagery for Mapping Large Coral Reef Systems to Estimate Fish Resources in Kubulau, Fiji

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2) Wildlife Conservation Society, Fiji

3) Canada Centre for Remote Sensing, Ottawa, Canada

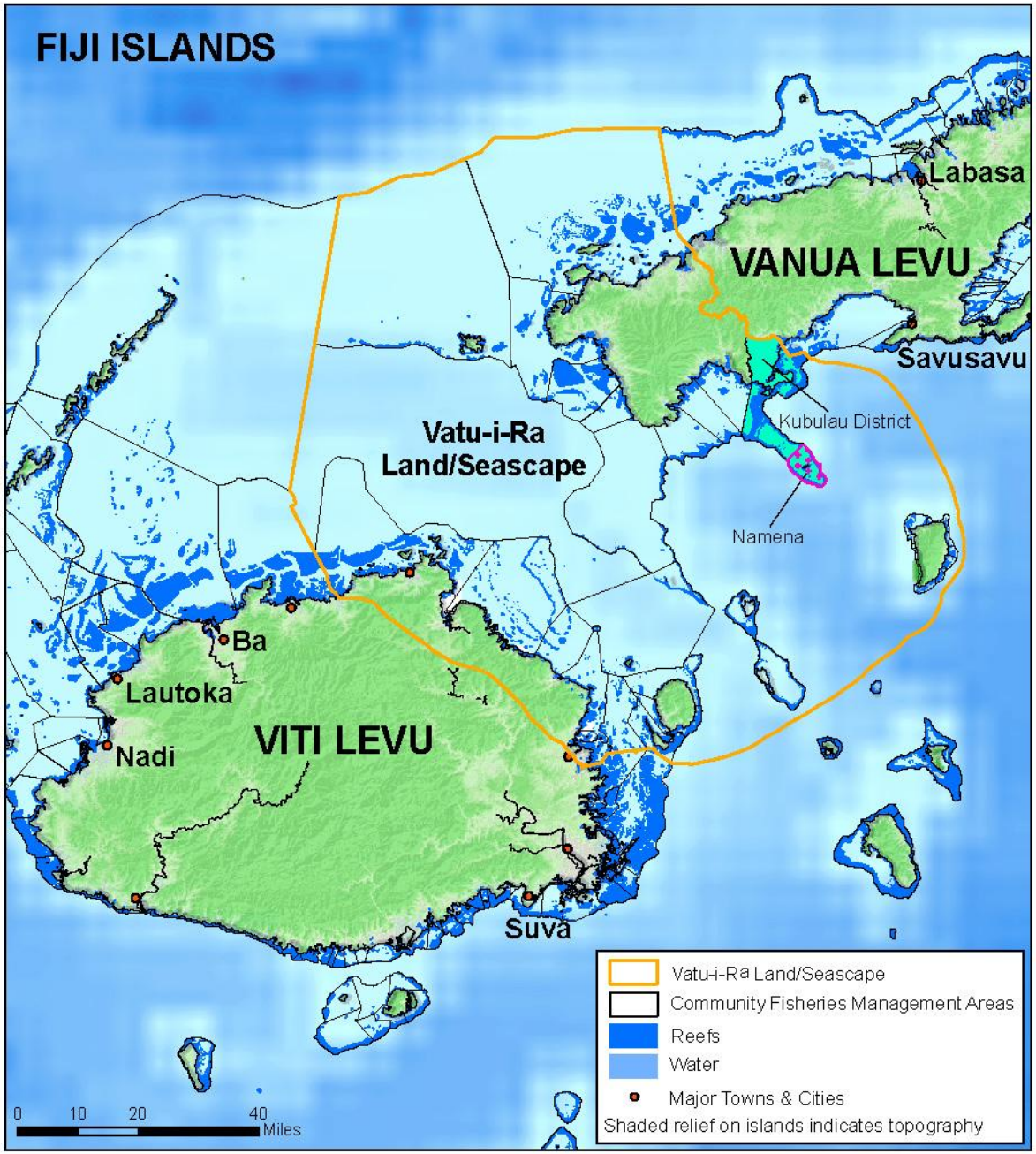
Aims

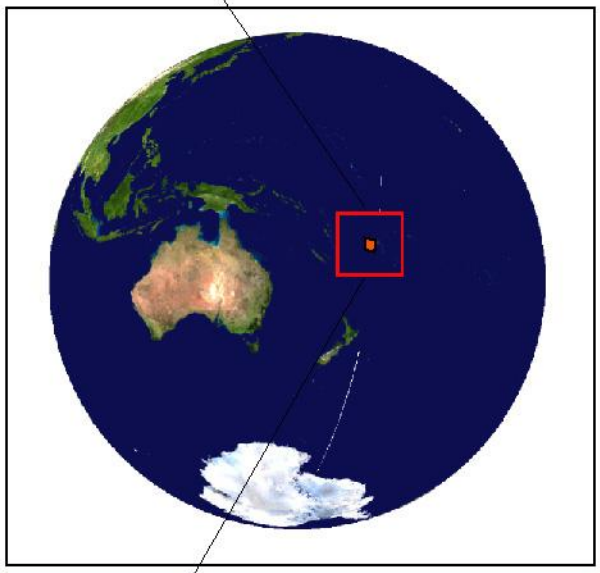
RESEARCH: Demonstrate the application of object based satellite image analysis for coral reef habitat mapping at various spatial scales to help predict spatially explicit fish community variables

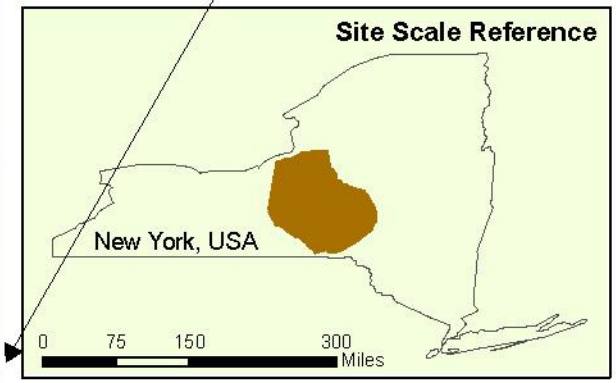
CONSERVATION: Use pixel-based measures of fish biomass and relative species diversity as inputs to decision support tools to develop options for MPA network configuration

Outline

- Introduction
  - Coral Reefs and MPAs of Kubulau
- Methods and Results
  - Field data collection & analysis
  - Object Based Image Classification
  - Bathymetry
  - Predicting fish community variables
- Summary

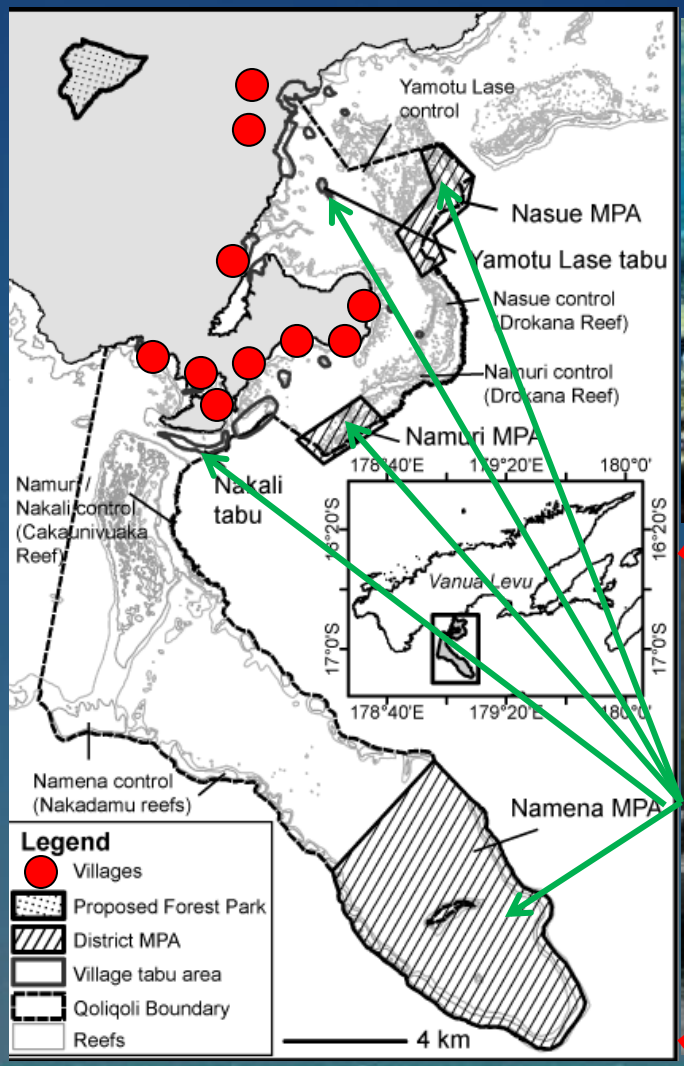

FIJI ISLANDS
Labasa
VANUA LEVU
Savusavu
Kubulau District
Vatu-i-Ra
Land/Seascape
Namena
Ba
Lautoka
Nadi
VITI LEVU
Suva
0 10 20 40
Miles
Vatu-i-Ra Land/Seascape
Community Fisheries Management Areas
Reefs
Water
Major Towns & Cities
Shaded relief on islands indicates topography




Site Scale Reference
New York, USA
0 75 150 300
Miles

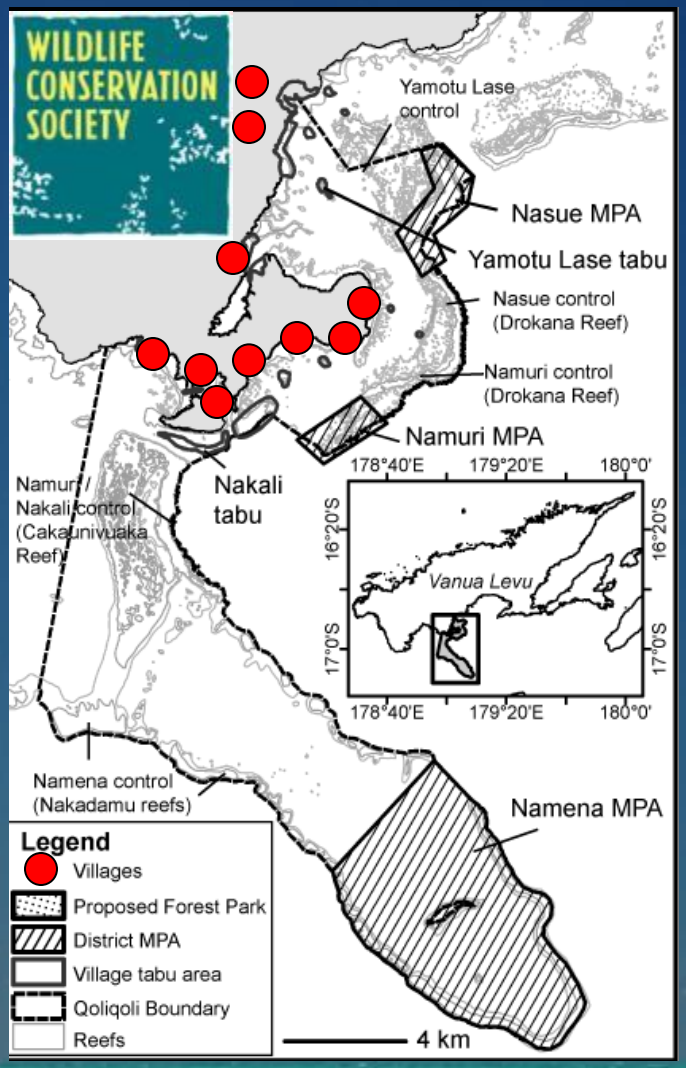
Introduction: Coral Reefs of Kubulau Fiji

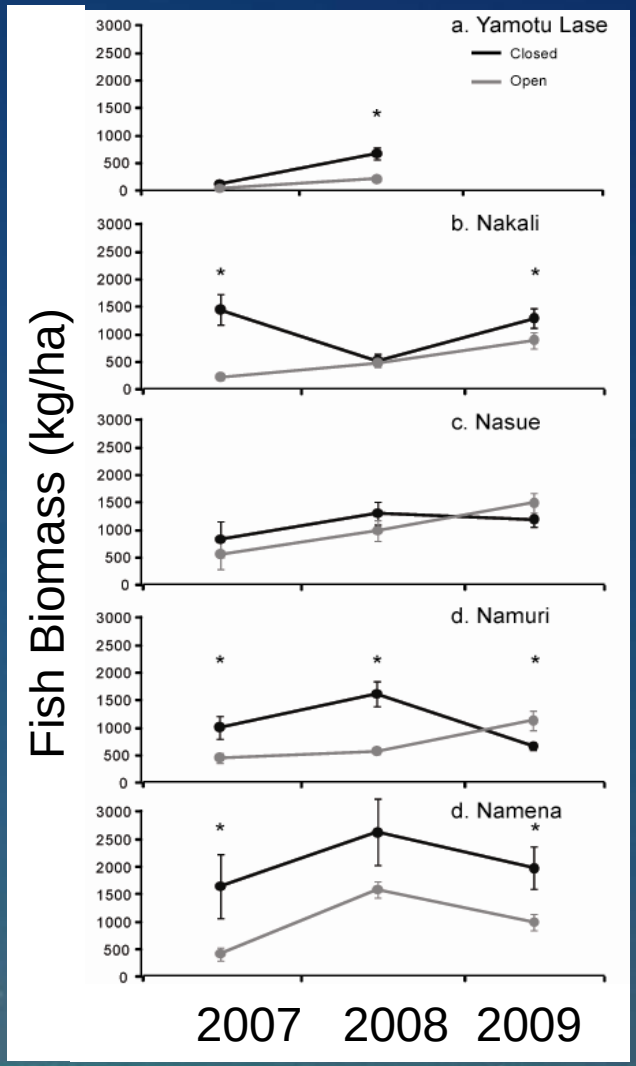
Kubulau reef(400 km^2) is important resource for local people



MPA Effectiveness for Kubulau (Jupiter & Egli in press)

MPA Effectiveness has been very variable to a number of factors including:





Poaching from nearby districts

Poaching by Kubulau residents when made aware of where there were a lot of fish

Lack of awareness of MPA boundaries

Conflict over resource user rights

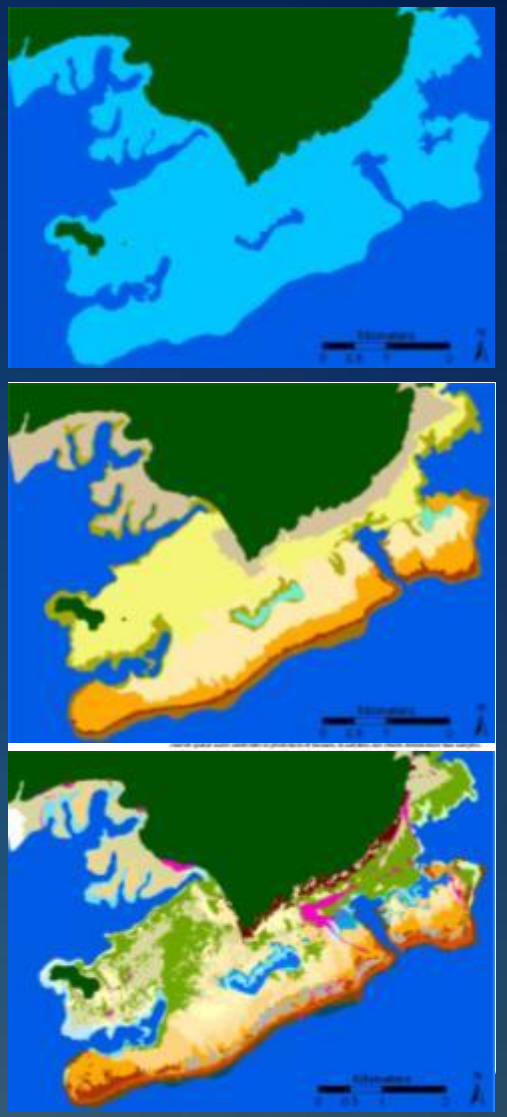
Alternative MPA location should be considered

Introduction: Redesign MPA of Kubulau

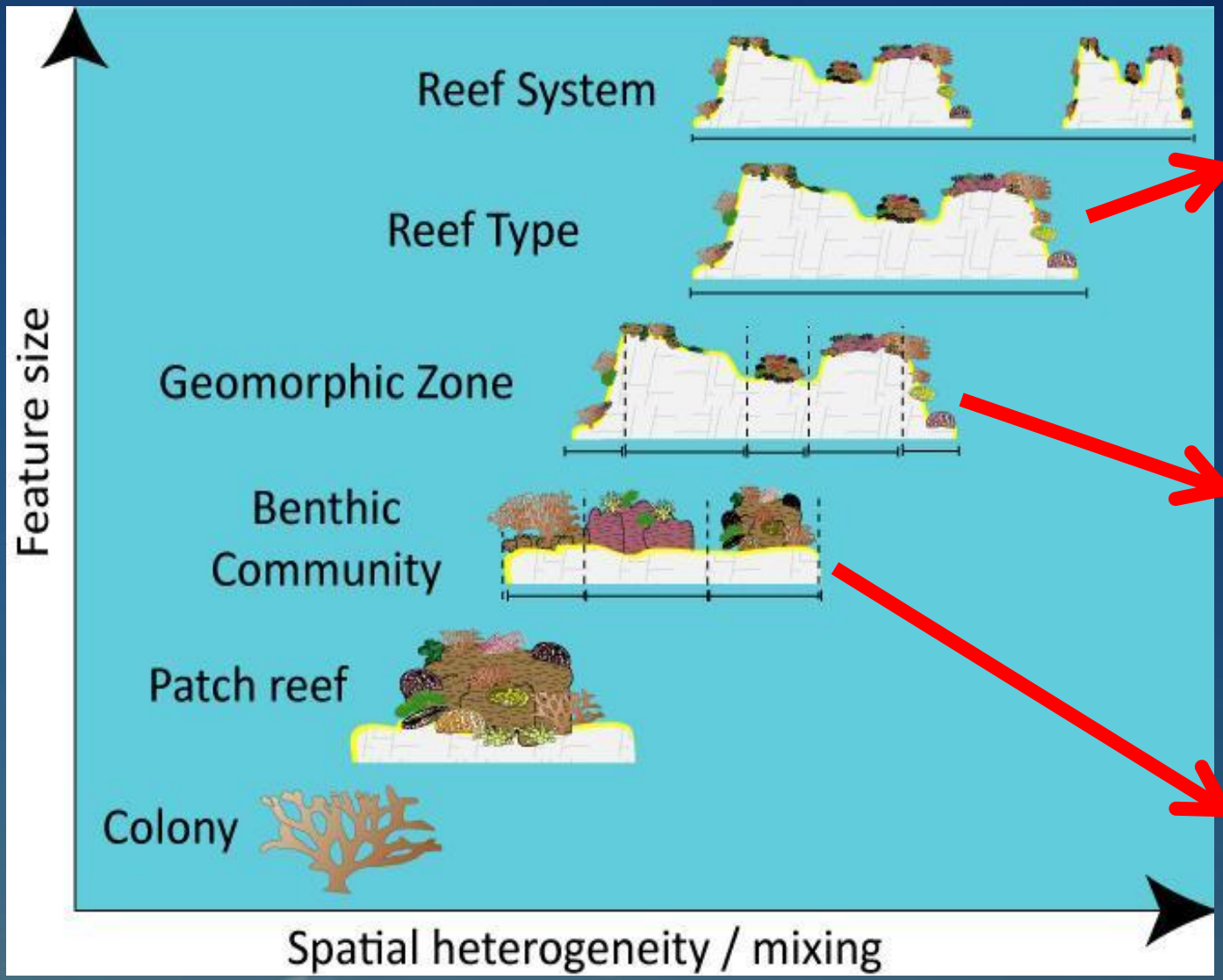
Original MPA network design based on:
- fish species, biomass & diversity field data
- extent of reefs from coarse Lands Dept. shapefiles
- “not” reef composition & depth

Previous research (Knudby et al 2010) :
- single small reef (5 km^2) in Tanzania
- successfully used predictive spatial modeling of fish assemblage characteristics based on detailed habitat maps

Inputs required for MPAs reconfiguration:
- Socio-economic data (“opportunity costs”
- Predictive spatial modeling (400 km^2)
- Geomorphic, benthic & bathymetry maps

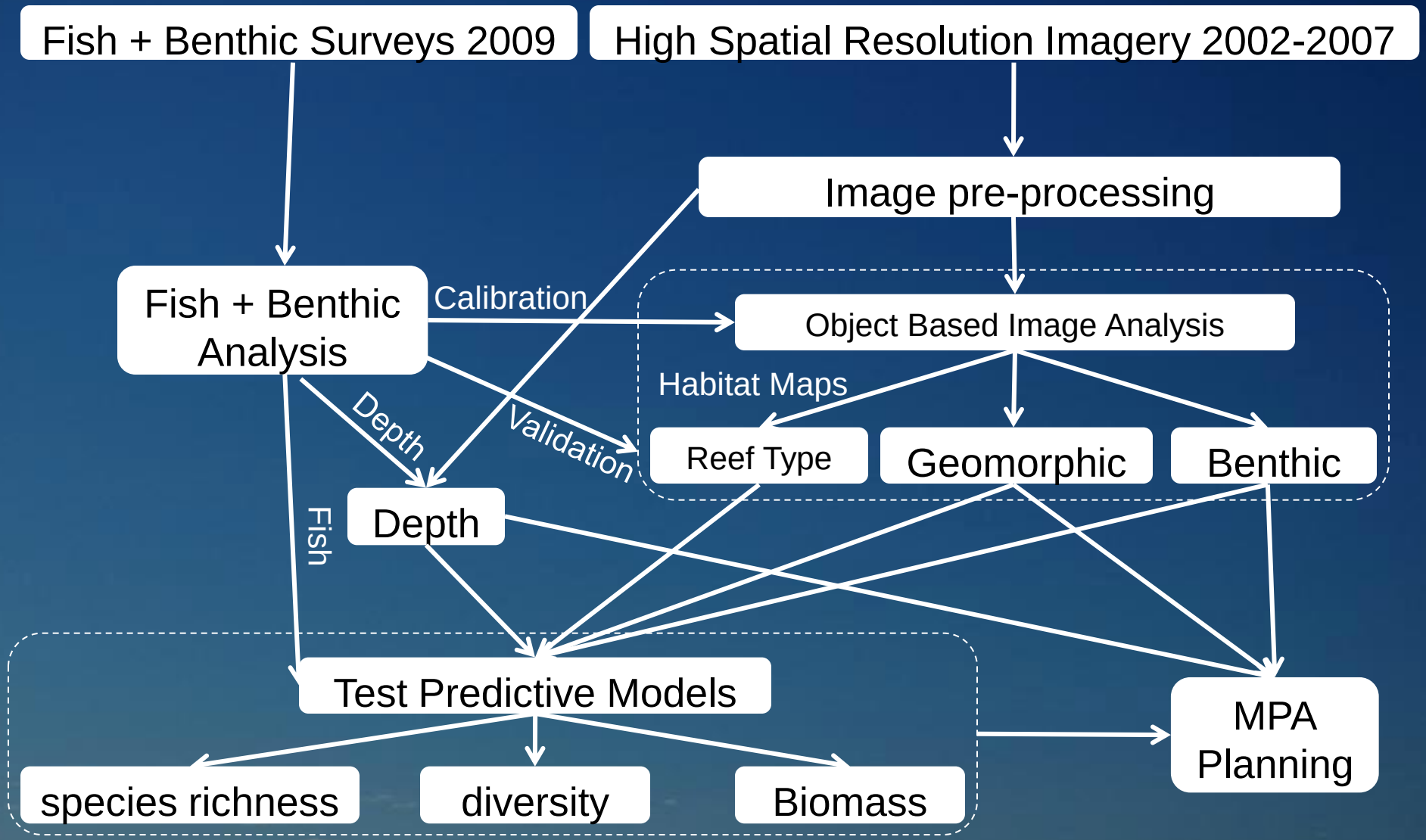


Introduction: Habitat Maps for Conservation



Different habitat map extent, scales & categories can be provided by object based image analysis

Flowchart


Fish + Benthic Surveys 2009
High Spatial Resolution Imagery 2002-2007
Image pre-processing
Fish + Benthic Analysis
Calibration
Object Based Image Analysis
Habitat Maps
Depth
Validation
Reef Type
Geomorphic
Benthic
Fish
Depth
Test Predictive Models
MPA Planning
species richness
diversity
Biomass

Methods: High Spatial Resolution Imagery 2002-2007

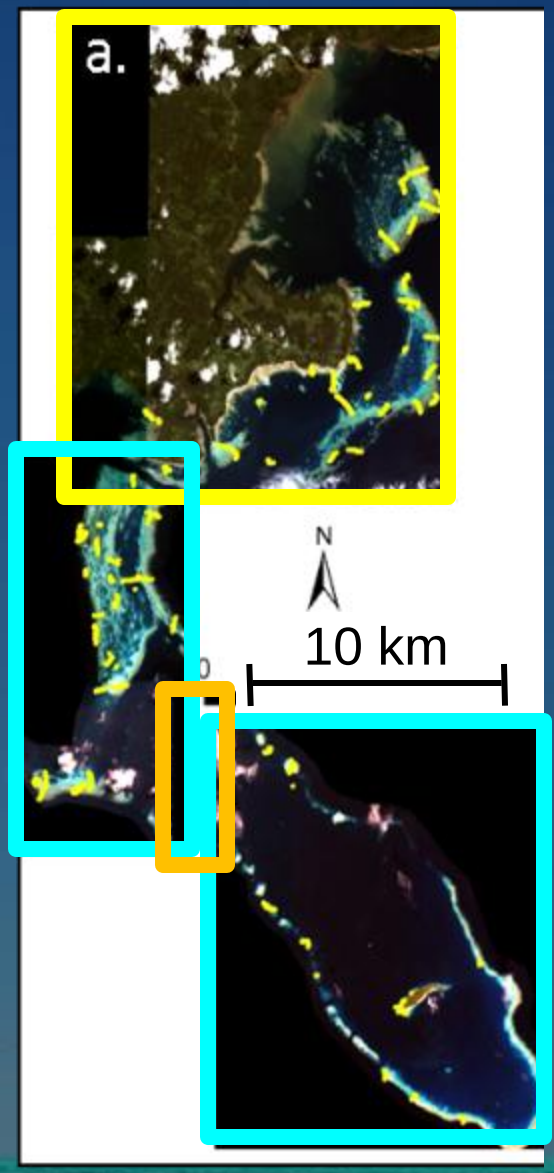
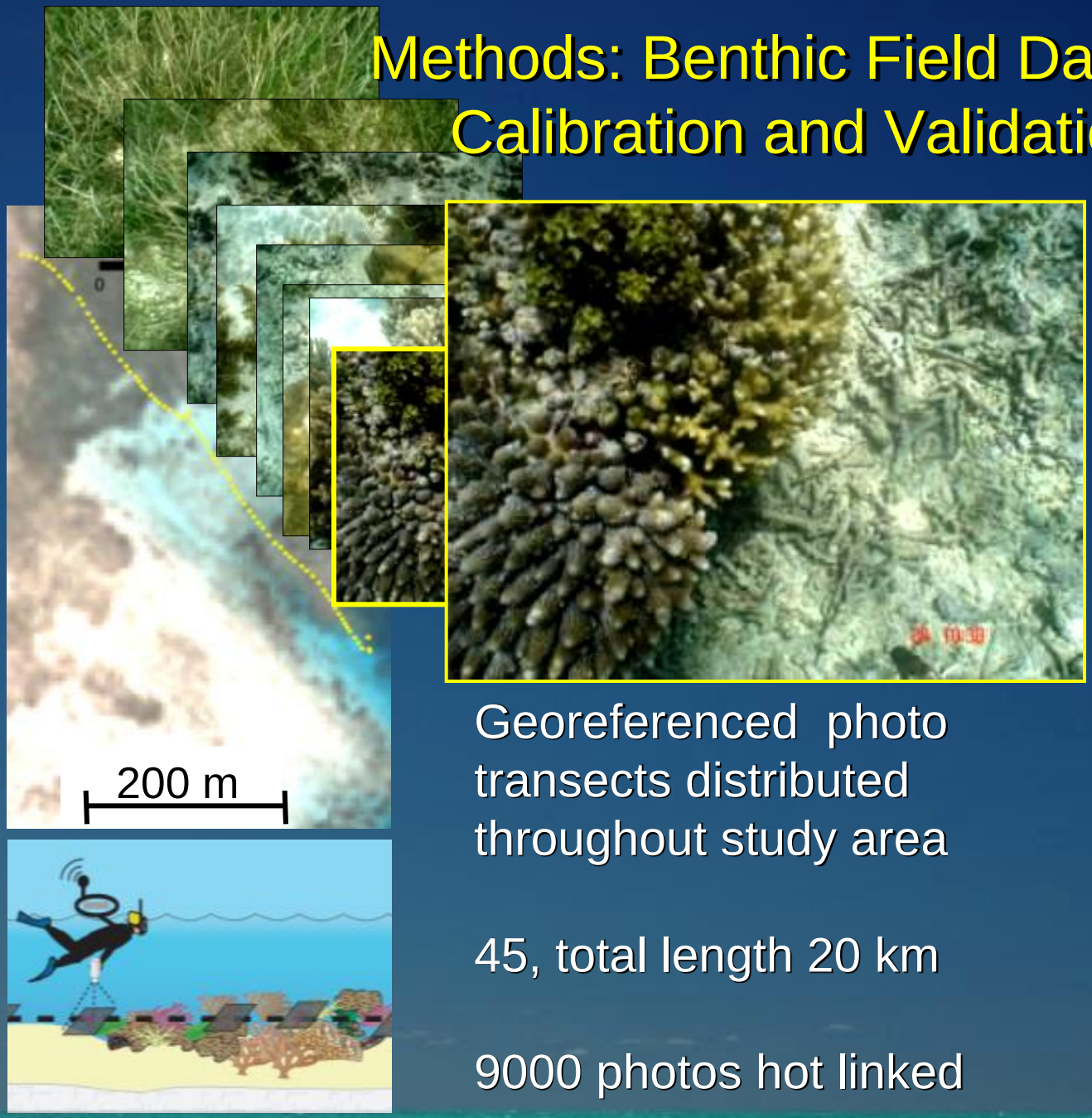


Image	Ikonos	Quickbird	Landsat
Pixel	4 m	2.5 m	30 m
Spectral	Multi	Multi	Multi
Date	2006/2007	2006/2007	2002

All archived imagery.

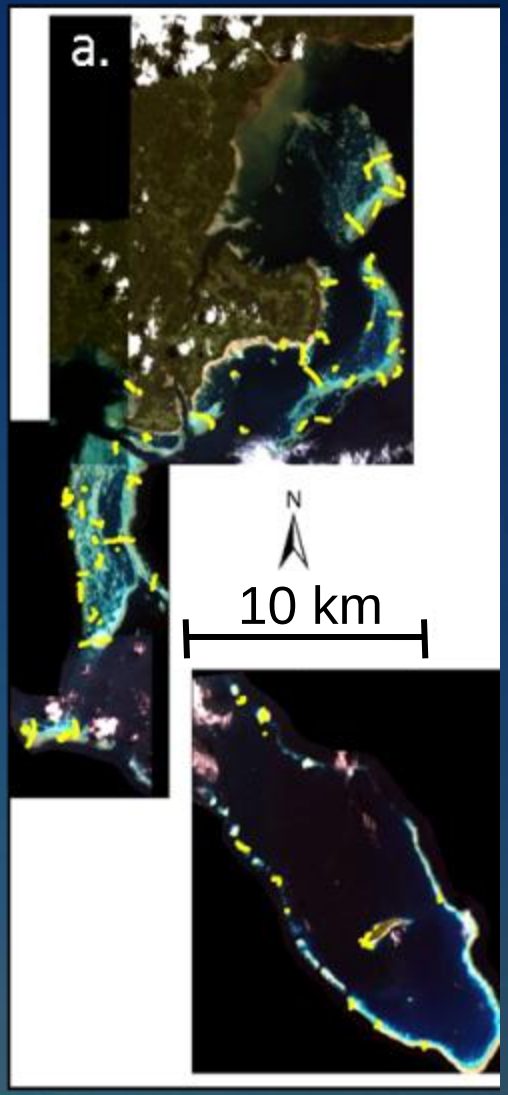
Methods: Benthic Field Data for Calibration and Validation



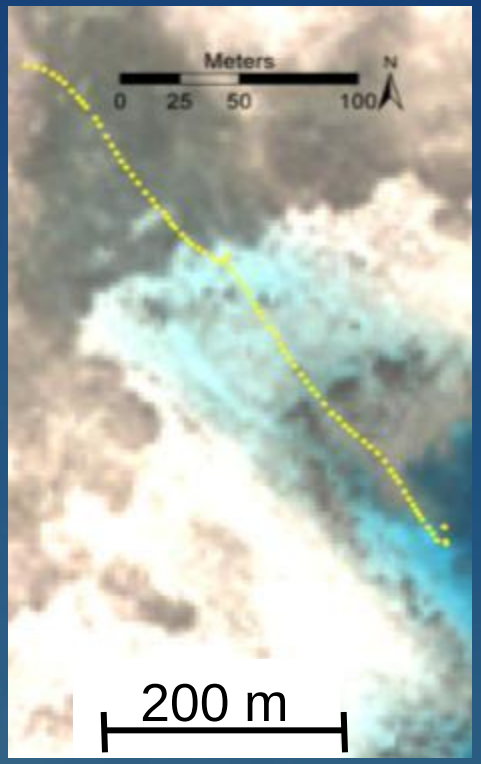
Georeferenced photo transects distributed throughout study area

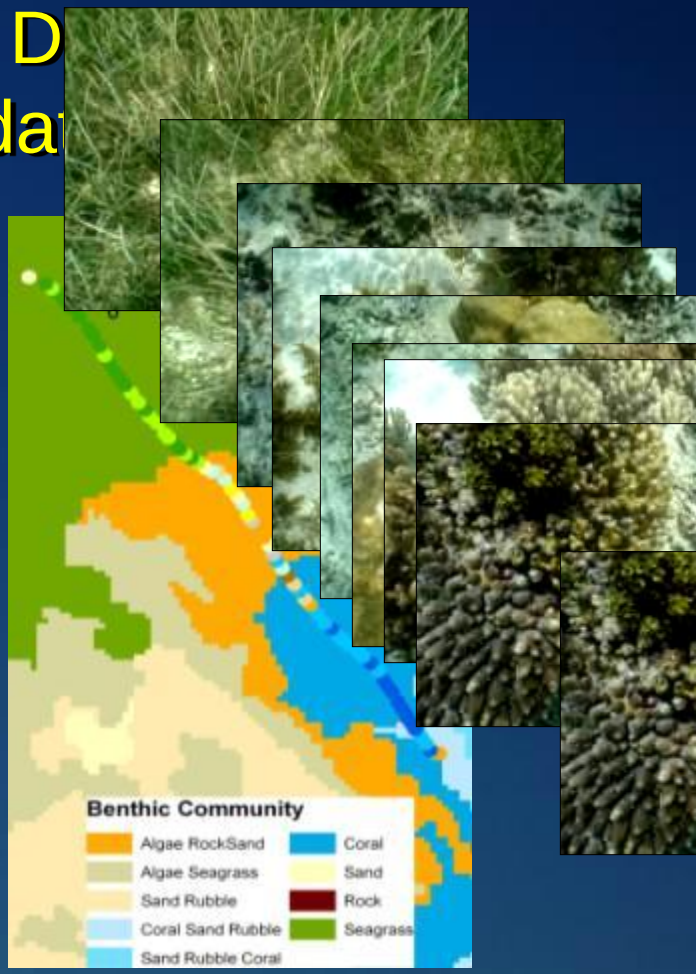
45, total length 20 km

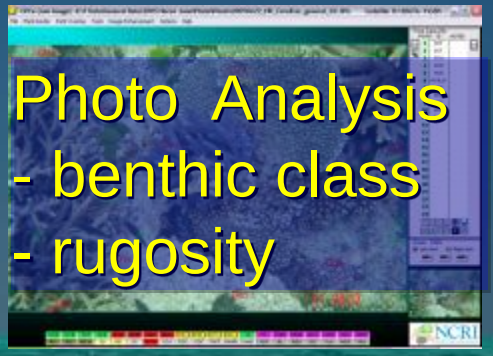
9000 photos hot linked



Methods: Benthic Field D
Calibration and Validat





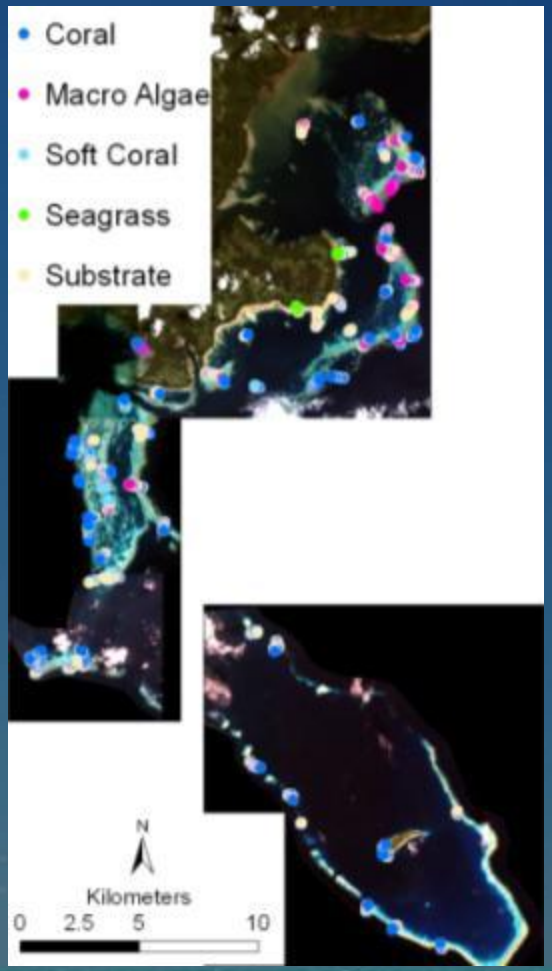


Photos+data:
- Calibrate
- Validate

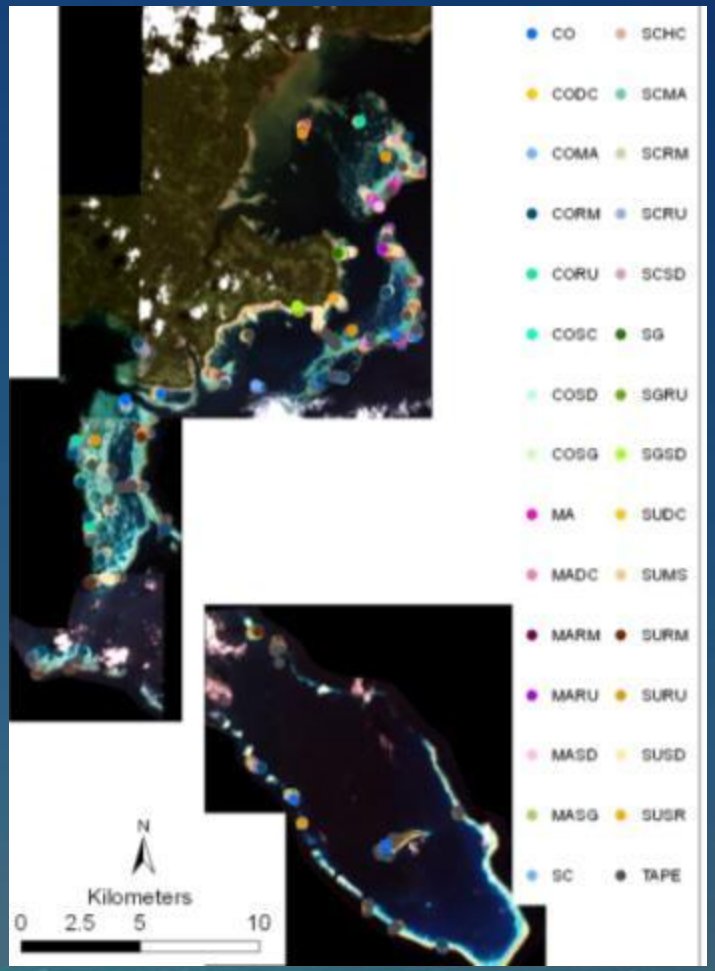
Results: Benthic Photo Analysis

Benthic photos resulted in detailed calibration & validation data.

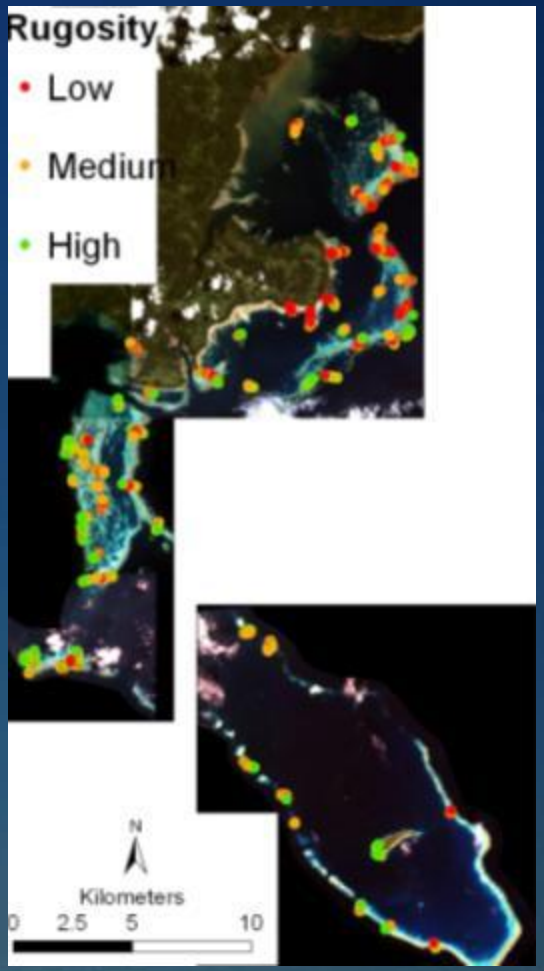
Major Categories



Sub Categories



Rugosity



Methods: Detail Benthos & Fish Surveys (S. Jupiter)

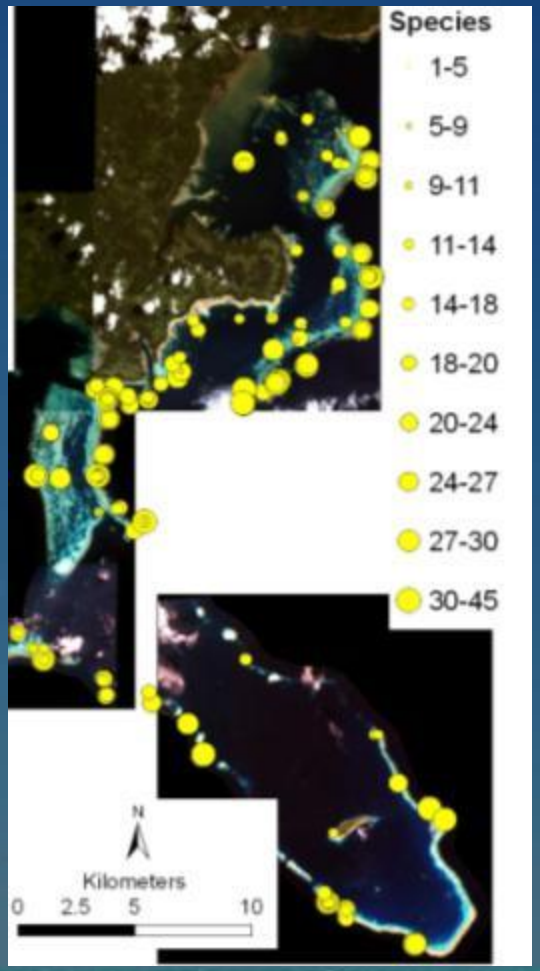
- Underwater Visual Census Surveys
- Transects at each site
  - 3-5 replicate transects
  - between 1 – 10 m Depth
  - Georeferenced

- Fish (5 x 50 m belt transects)
  - Abundance
  - size of major fish families
- Benthos (measured every 0.5 m):
  - Life form
  - micro-complexity

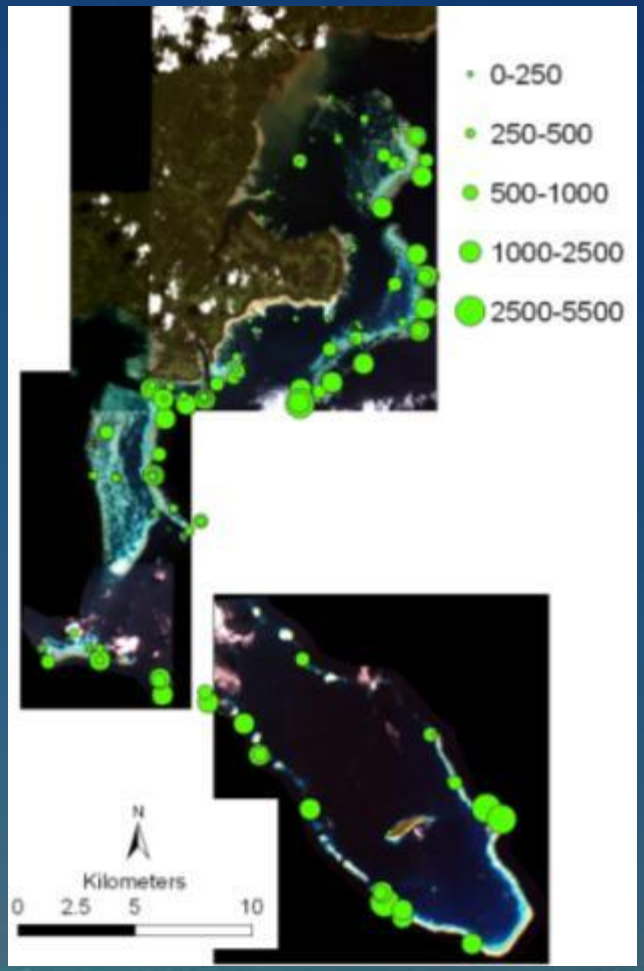
Results: Fish Survey Data

Fish field data to help calibrate predictive models

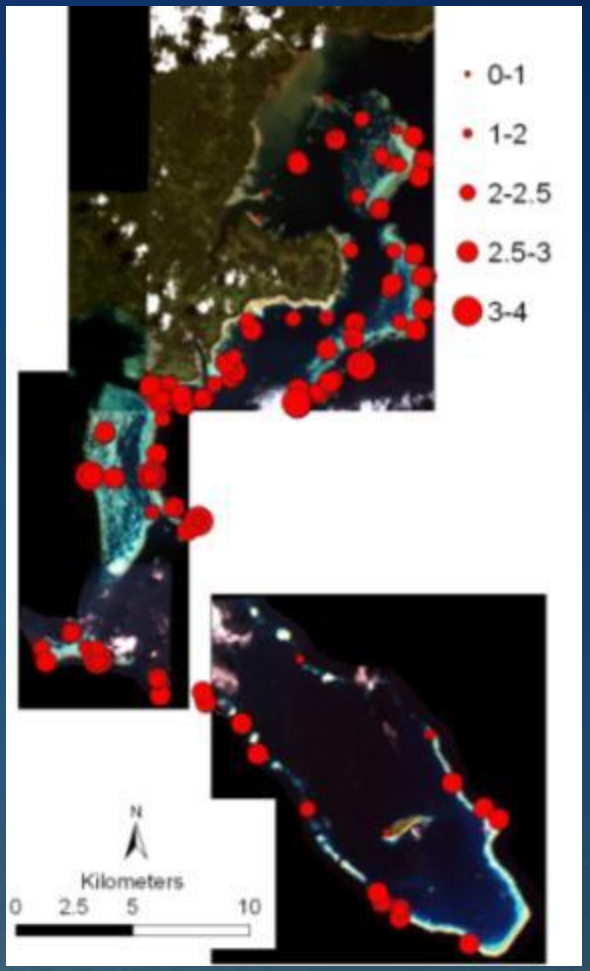
Species Richness



Biomass (kg/ha)



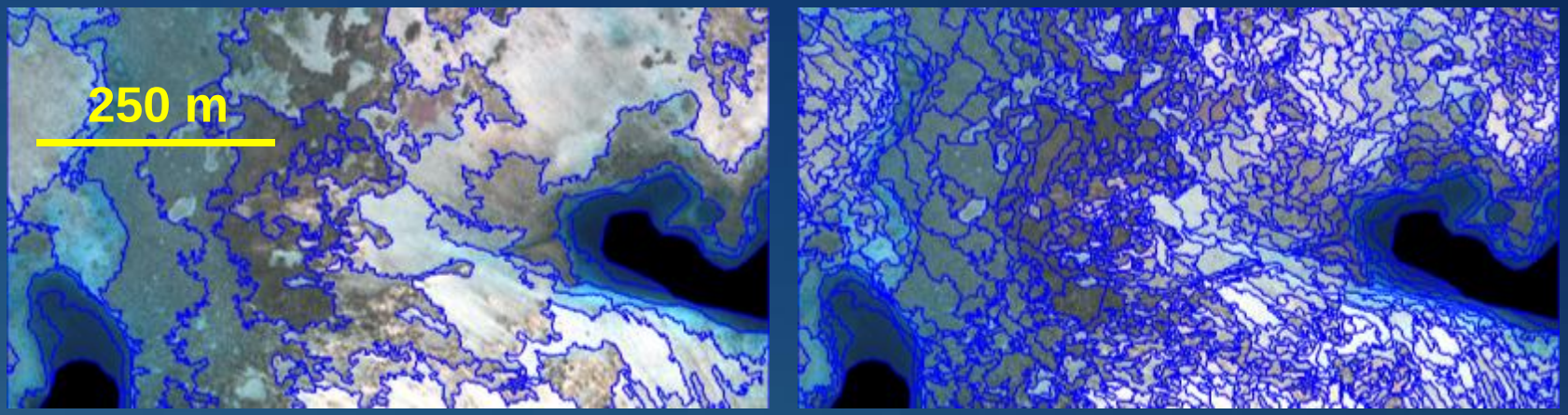
Species Diversity



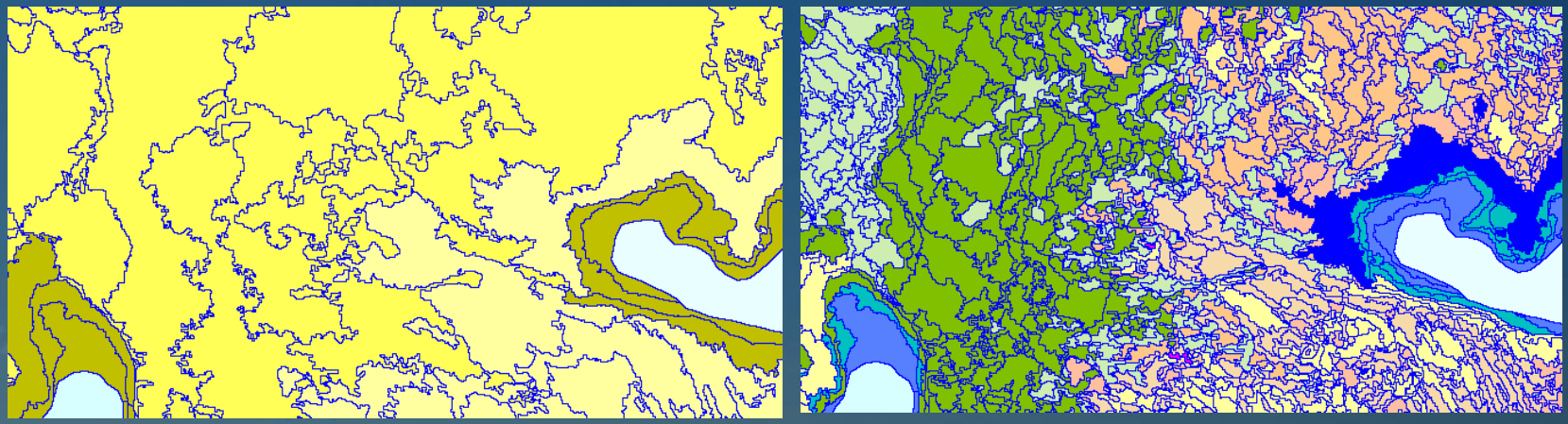
Object Based Image Analysis

Applies manually developed rules sets to automatically segment an satelite image and then label each segment (object).

Image segmentation based on colour + texture + scale of groups of pixels

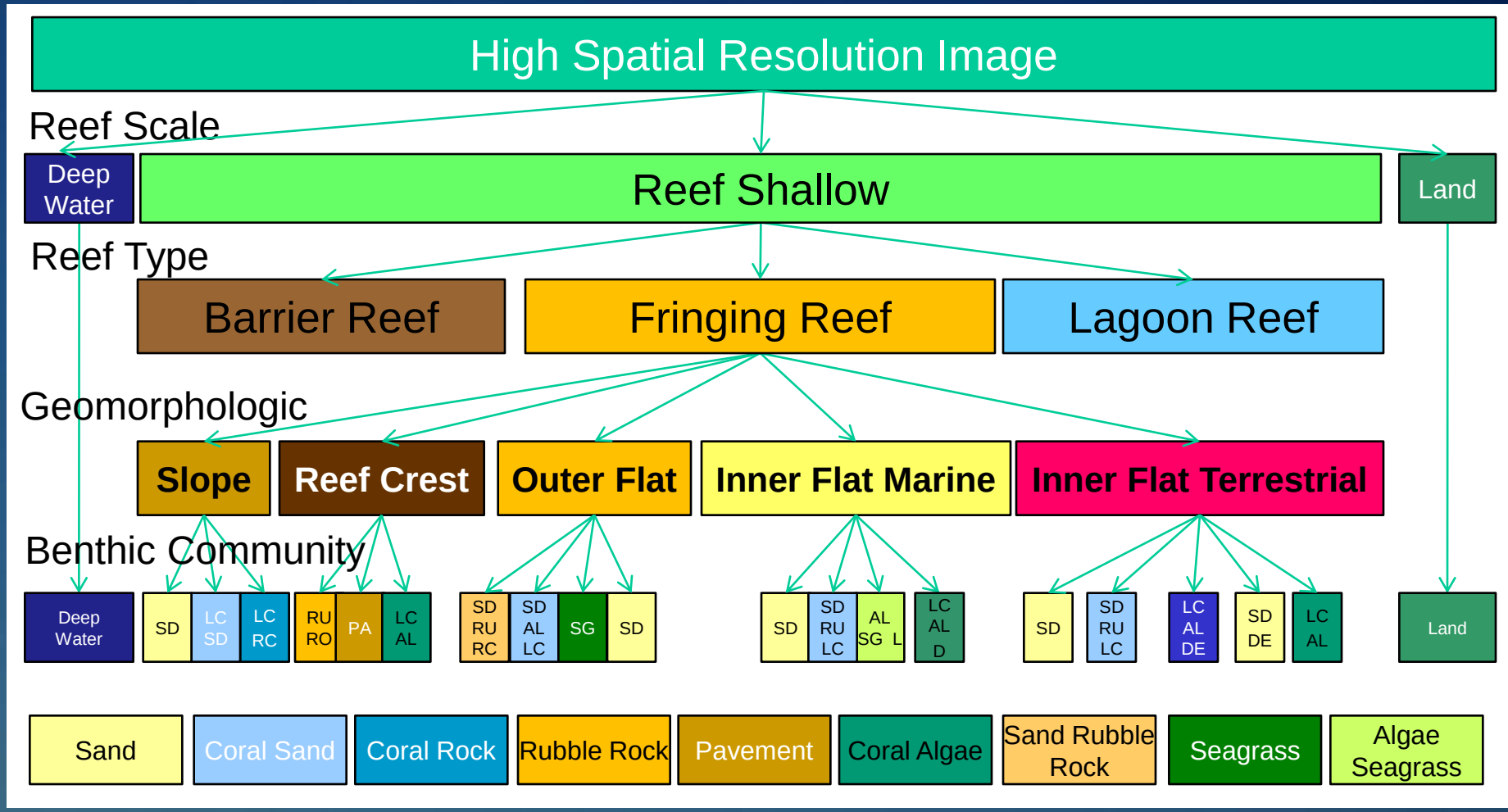


Labelling segments : Membership rules (colour, texture, location + biophysical)



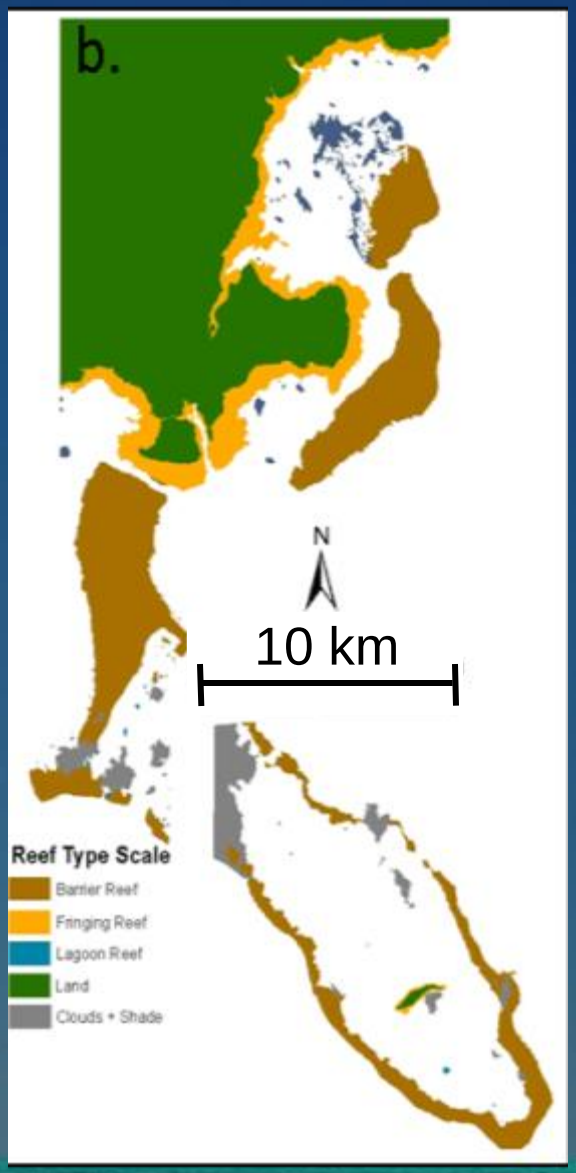
Most per-pixel mapping is based on the colour of pixels

Methods: Hierarchical Object Based Classification

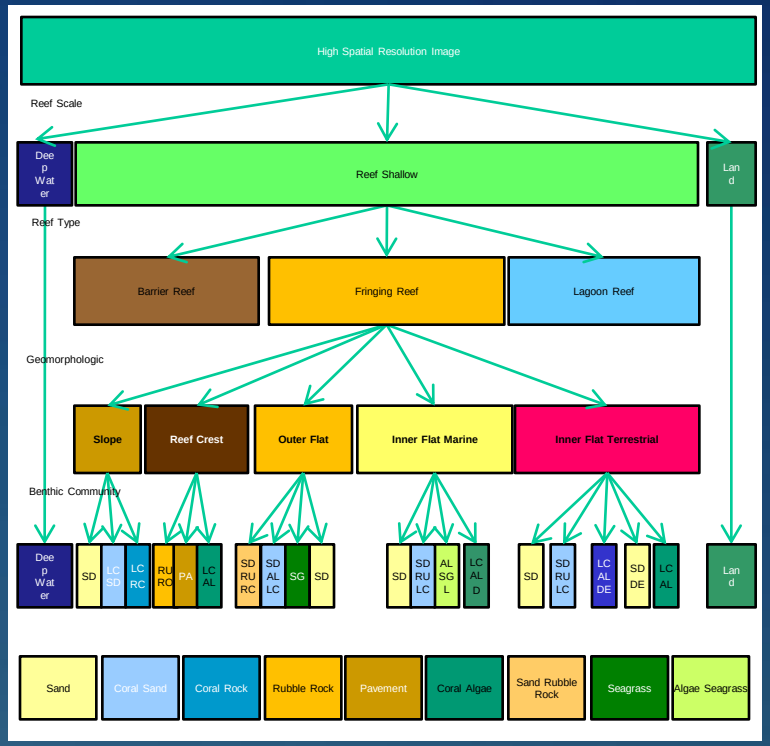


Hierarchical application of segmentation and assignment of map category through membership rules

Results: Multi Scale Habitat Maps- Reef Type

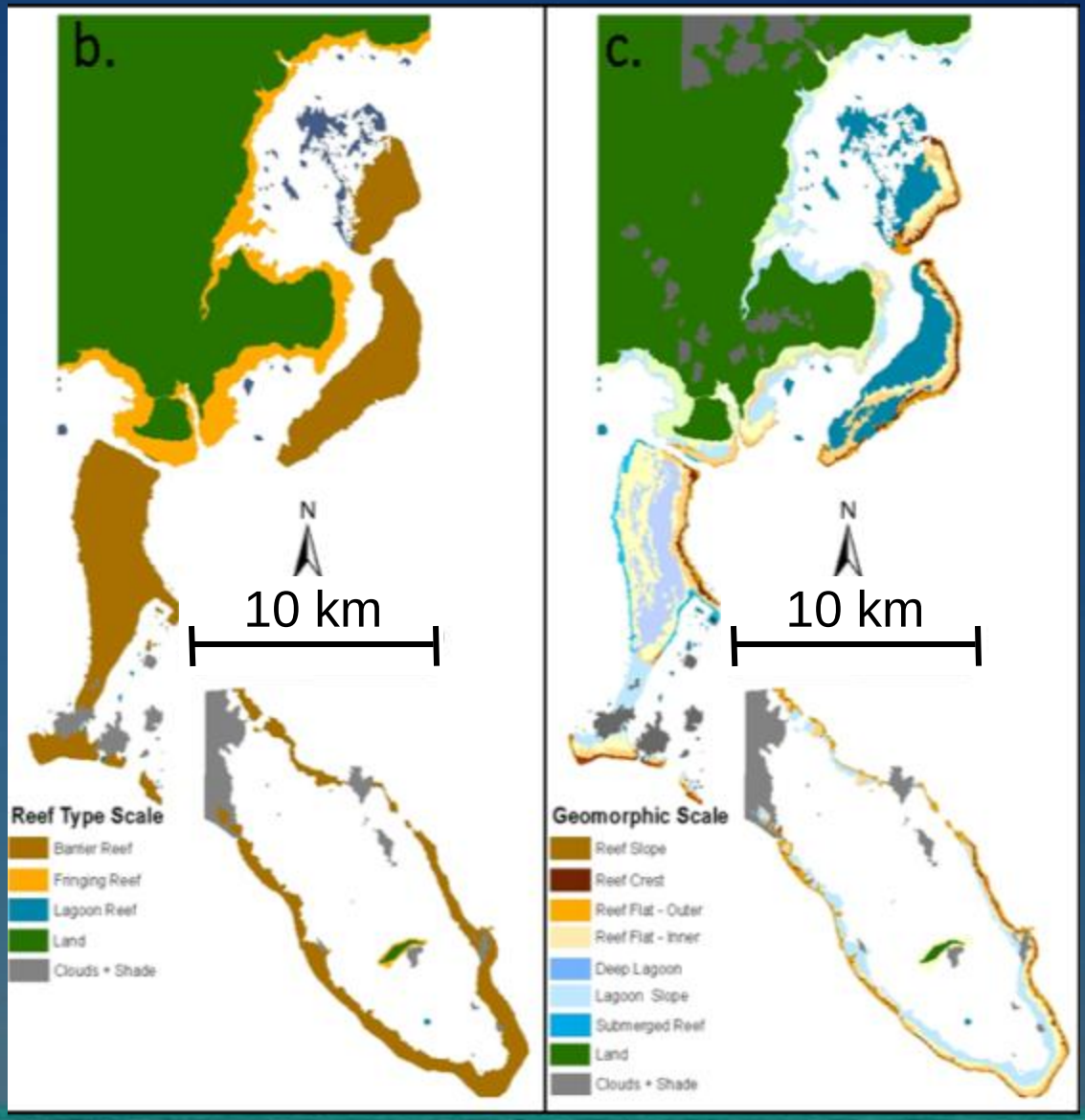


Hierarchical scales

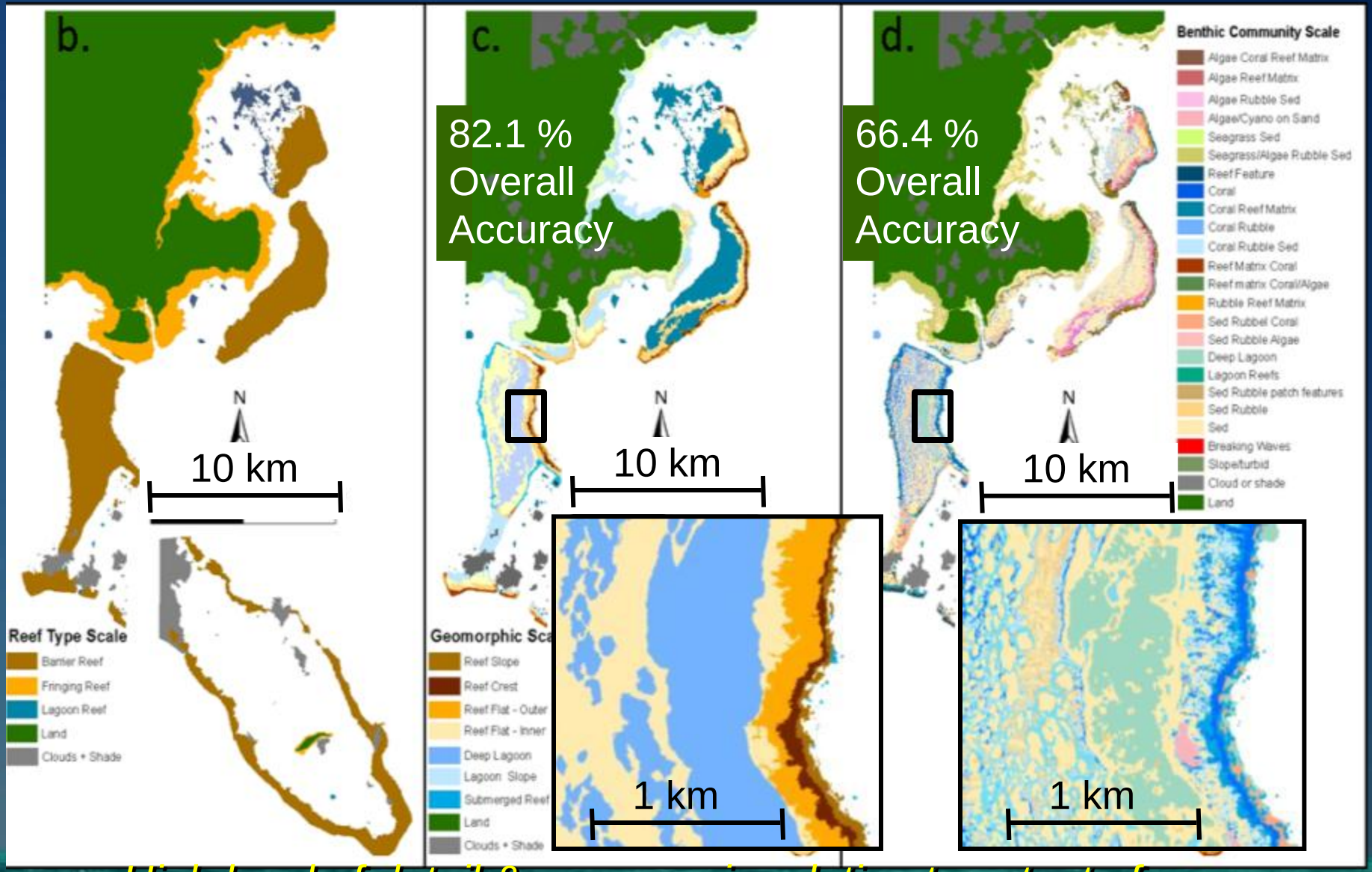


- Image
- Reef
- Reef Type
- Geomorphic
- Benthic Community

Results: Multi Scale Habitat Maps- Reef Type and Geomorphic

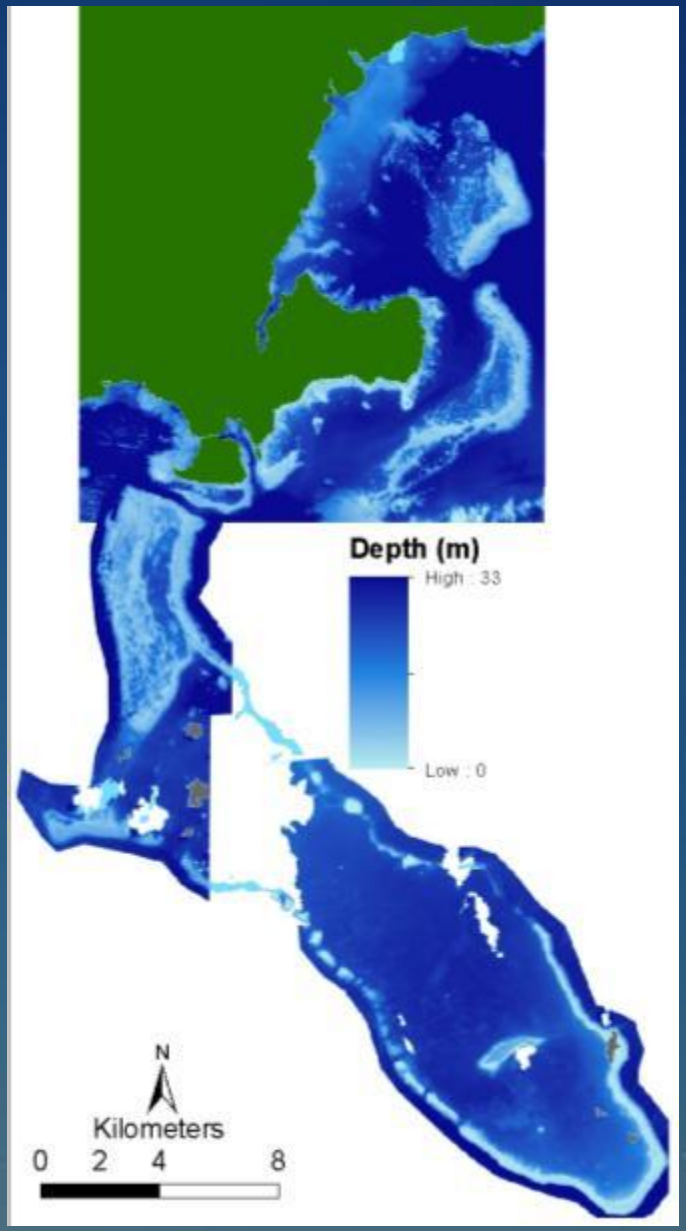


Results: Multi Scale Habitat Maps- Reef Type, Geomorphic and Benthic Community



High level of detail & accuracy in relation to extent of area

Results: Bathymetry (M. Lyons)



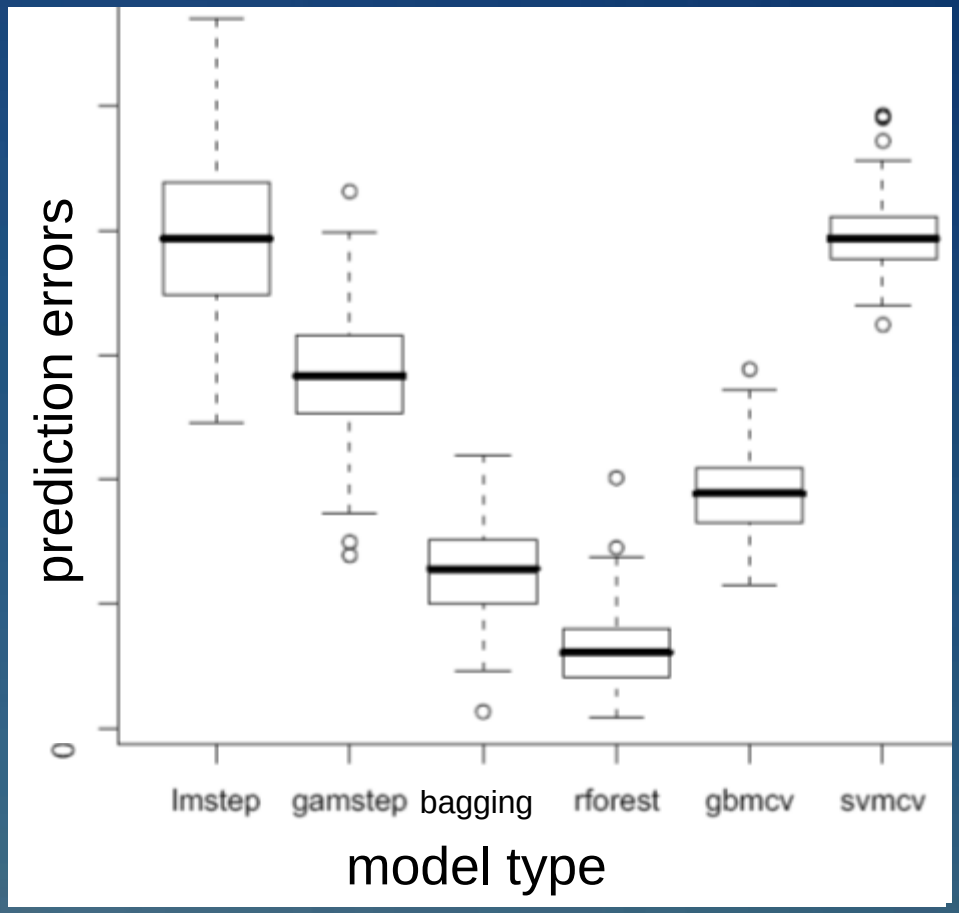
Bathymetric layer

- empirical approach (Lyzenga (1978)

- field data and imagery

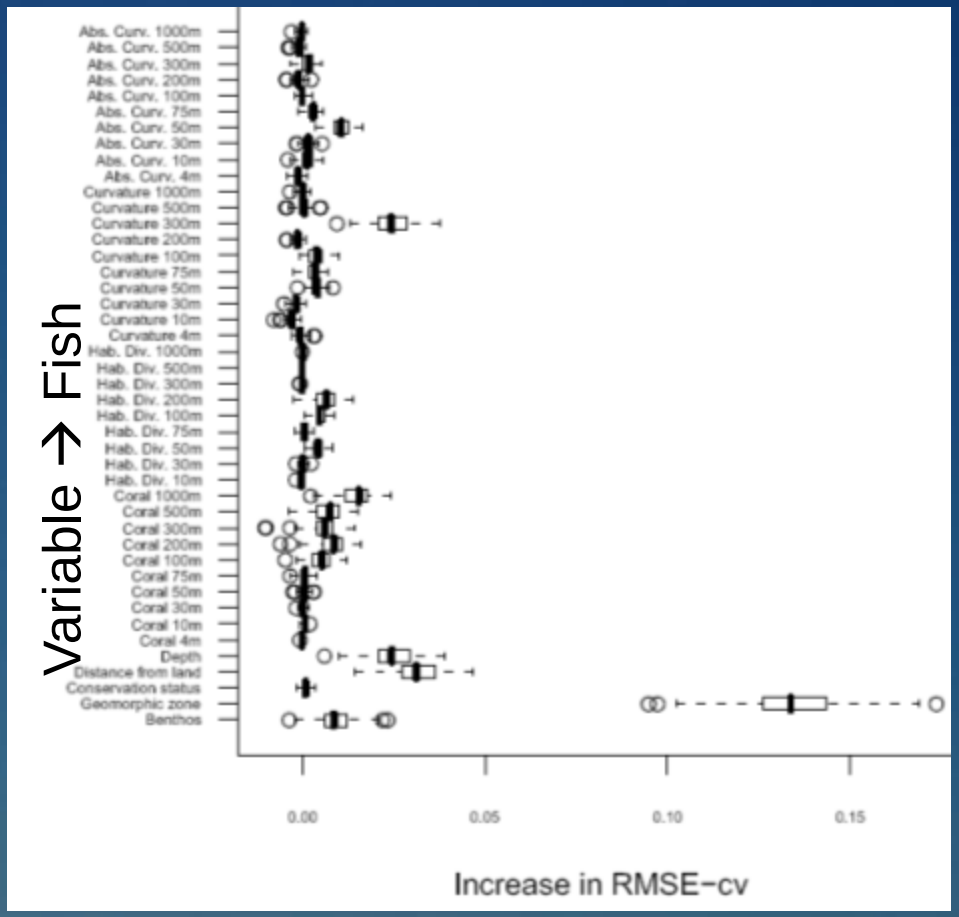
- trained over high albedo (sand)

Predictive Models Test
(A.Knudby)



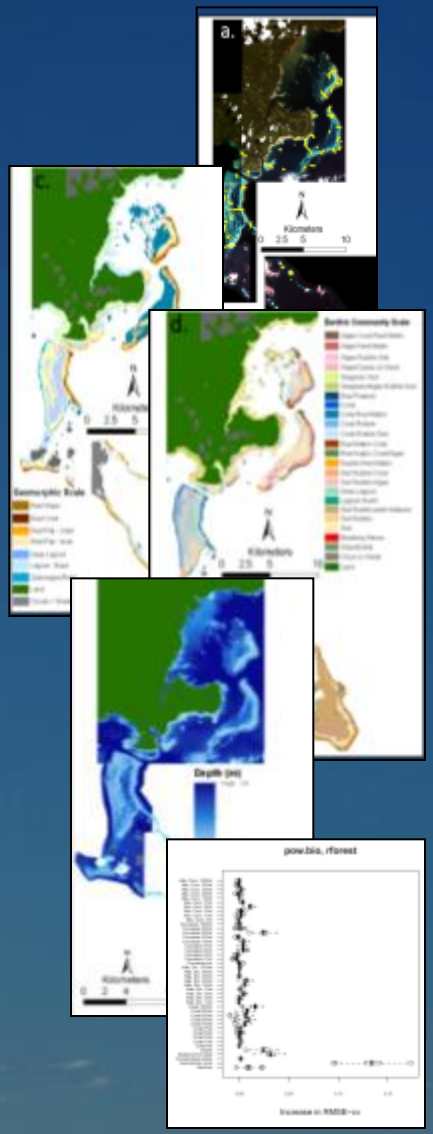
- Multiple models were tested to assess performance of relating satellite derived habitat variables to field fish data
- Boxplots to left show observed distributions of prediction errors for each total fish biomass per model type
- Random forest regression trees performed best for all fish variables tested (species richness, diversity, total fish biomass, food fish biomass)

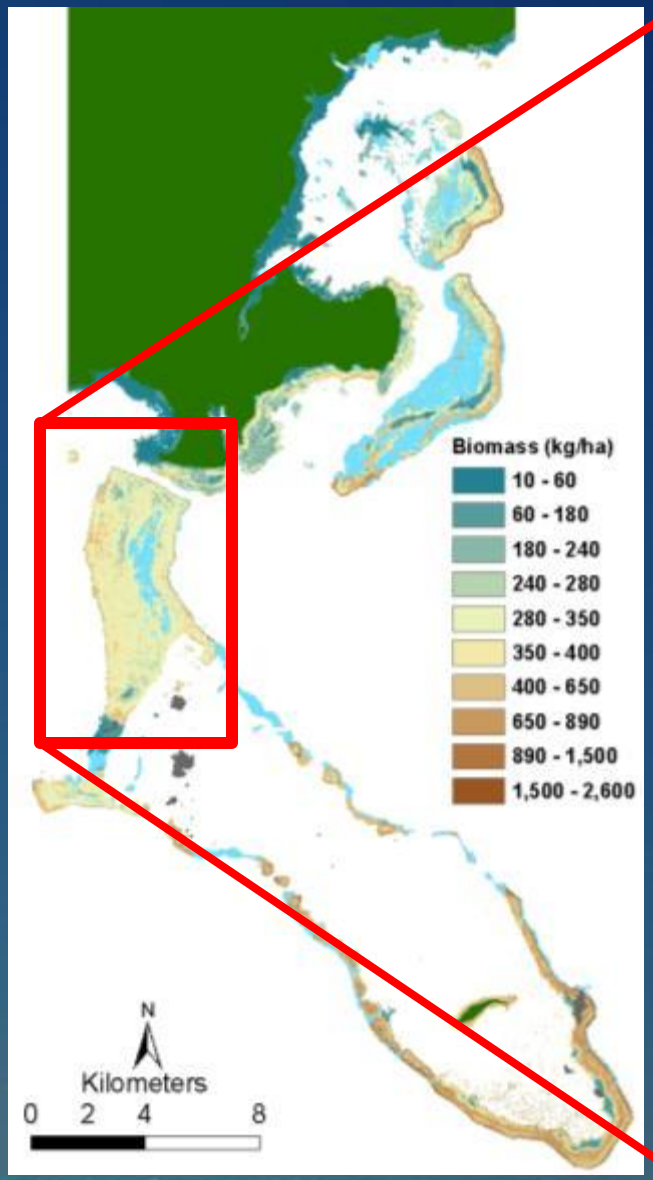
Variables of Importance for predicting fish variables
(A. Knudby)

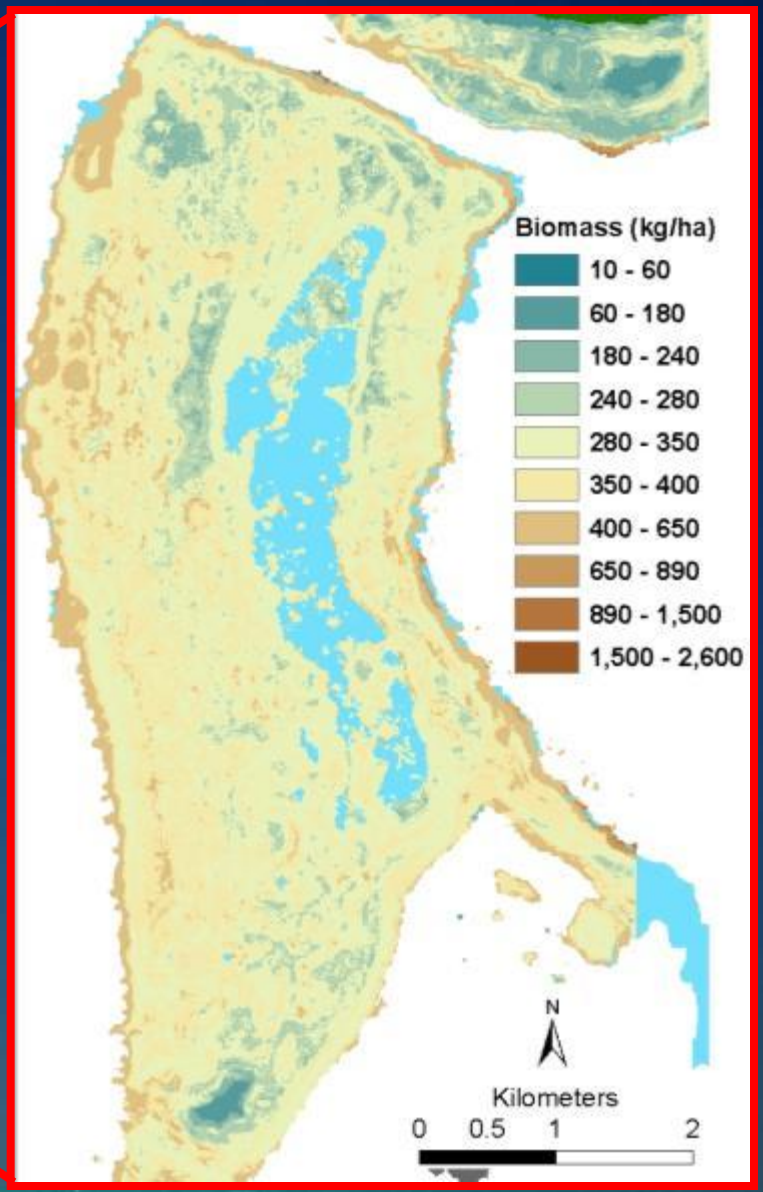


- Geomorphic zone was the most important variable for all fish variables
- Other important variables:
  - depth,
  - benthic community
  - rugosity (larger scales)
- Distance from land important for predicting fish biomass, likely indicates fishing pressure
- Conservation status not important due to variable effectiveness of MPAs in 2009

Predicting Fish Biomass
(A.Knudby)

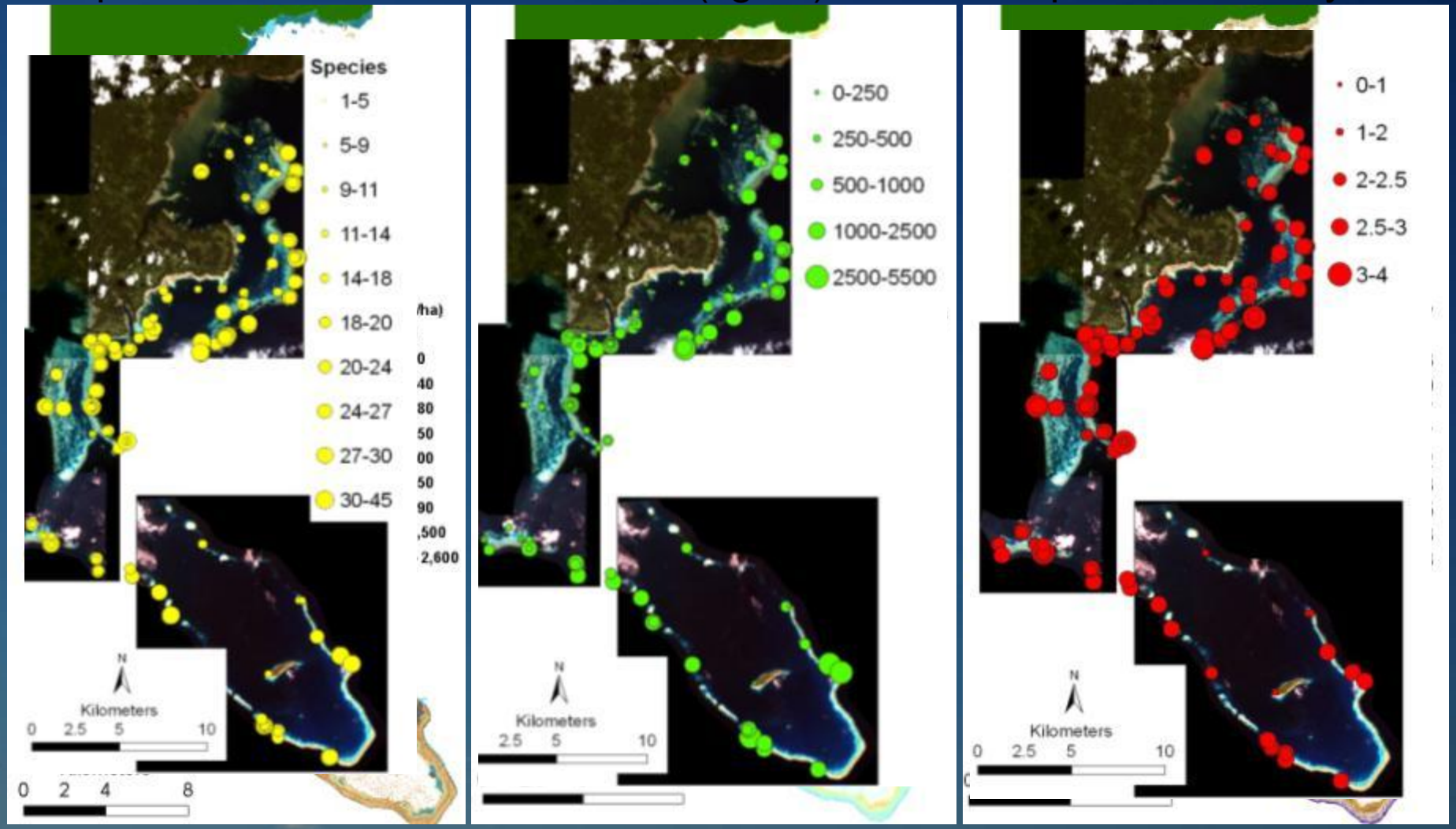






Predicted Fish Biomass, Species + Diversity
(A.Knudby)

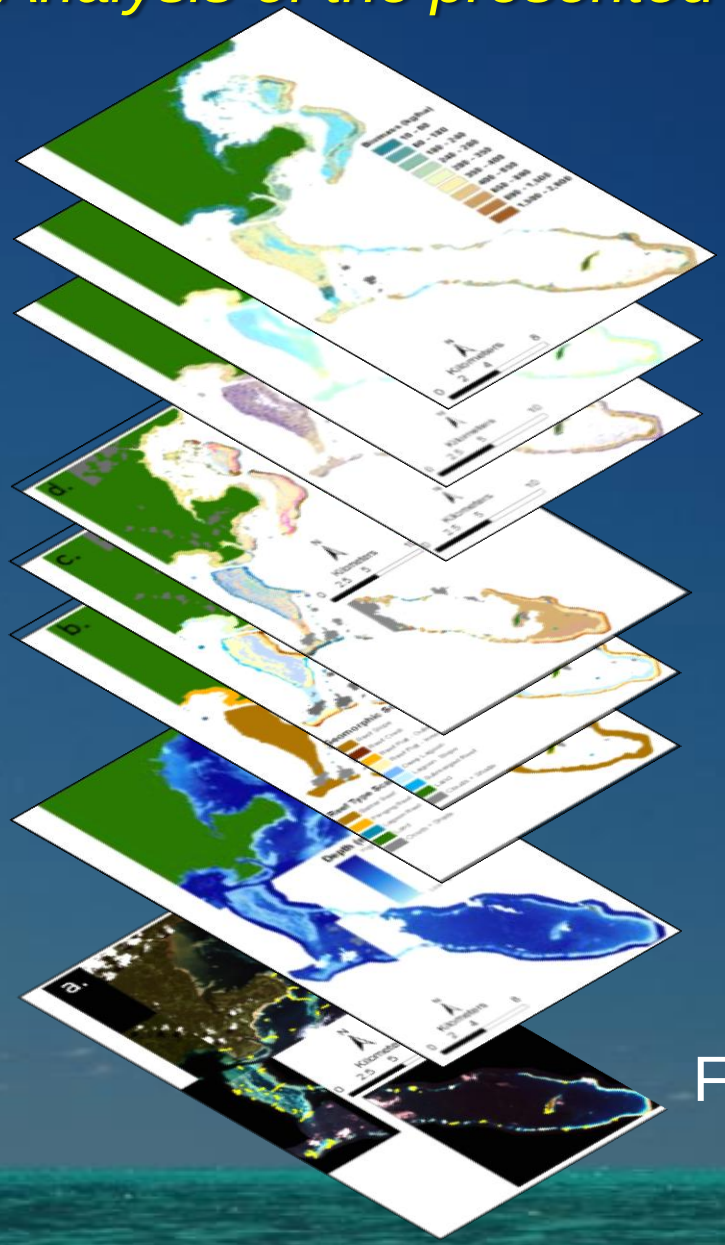
Species Richness | Biomass (kg/ha) | Species Diversity



From point field data to spatial explicit data

Next Step

Analysis of the presented spatial data sets & socio-economic data



Fish abundance

Fish Biomass

Fish diversity

Benthic Community

Geomorphic

Reef Type

Bathymetry

Field data + Satellite imagery

Conclusions

Georeferenced photo transects + object based analysis of high spatial resolution images, resulted in: reef type, geomorphic & benthic community maps for Kubulau reef system.

Geomorphic, benthic community & bathymetry maps and random forest tree models resulted in spatially explicit predictions of fish community variables (species, biomass & diversity).

Future work
Analyse of the findings from the predictive modelling in combination with socio economic studies to redesign MPA

Knudby, Jupiter, Roelfsema *et al* in preparation

Acknowledgements

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