Can High Resolution Mapping Help Protect The Great Barrier Reef?

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Remote Sensing Research Centre

Australian Government
Great Barrier Reef Marine Park Authority

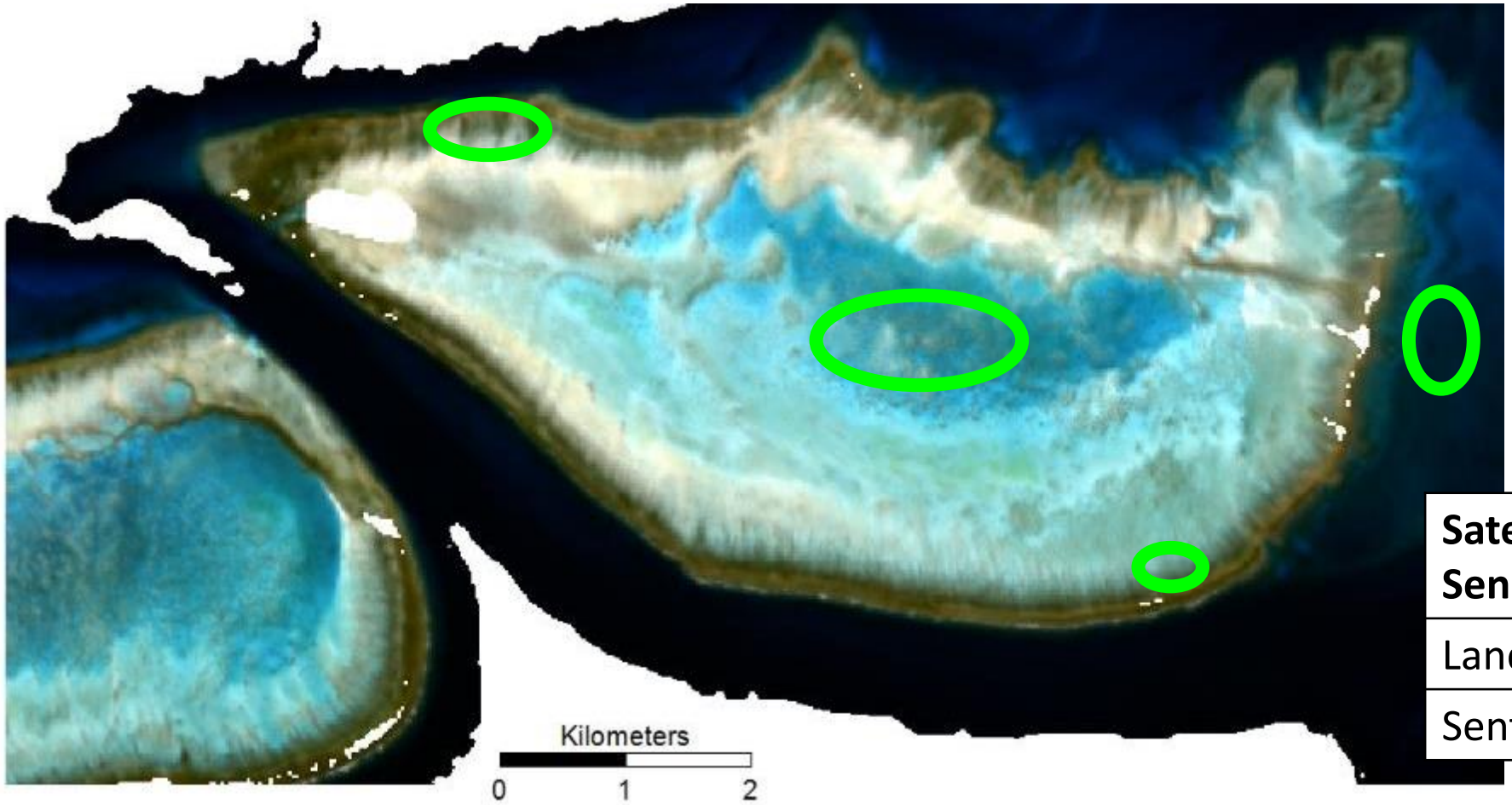
EOMAP

Australian Institute of Marine Science

Great Barrier Reef Foundation

Coral habitats require various factors, such as suitable: light , temperature, water chemistry, hard bottom, and wave action

For every GBR Reef you have a complete coverage by satellite imagery providing qualitative visual assessment.

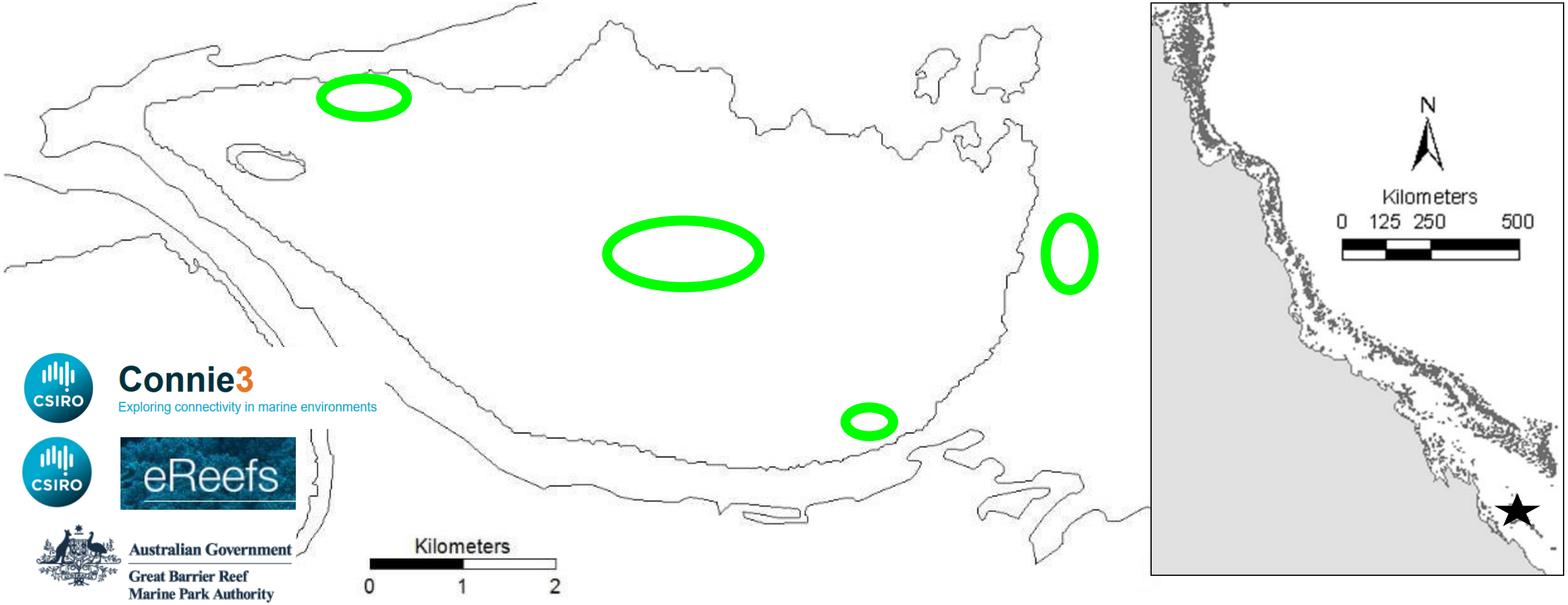


Satellite Sensor(s)	Pixel (m)	Revisit (days)	Cost
Landsat OLI	30	16	Free
Sentinel 2a+b	10	5	Free

Could you decide from this "Satellite Image" :
where best to sent a COTS boat, where to conduct restoration, etc, etc?

The highest level of habitat detail currently available for every single GBR reef is its outline/extent.

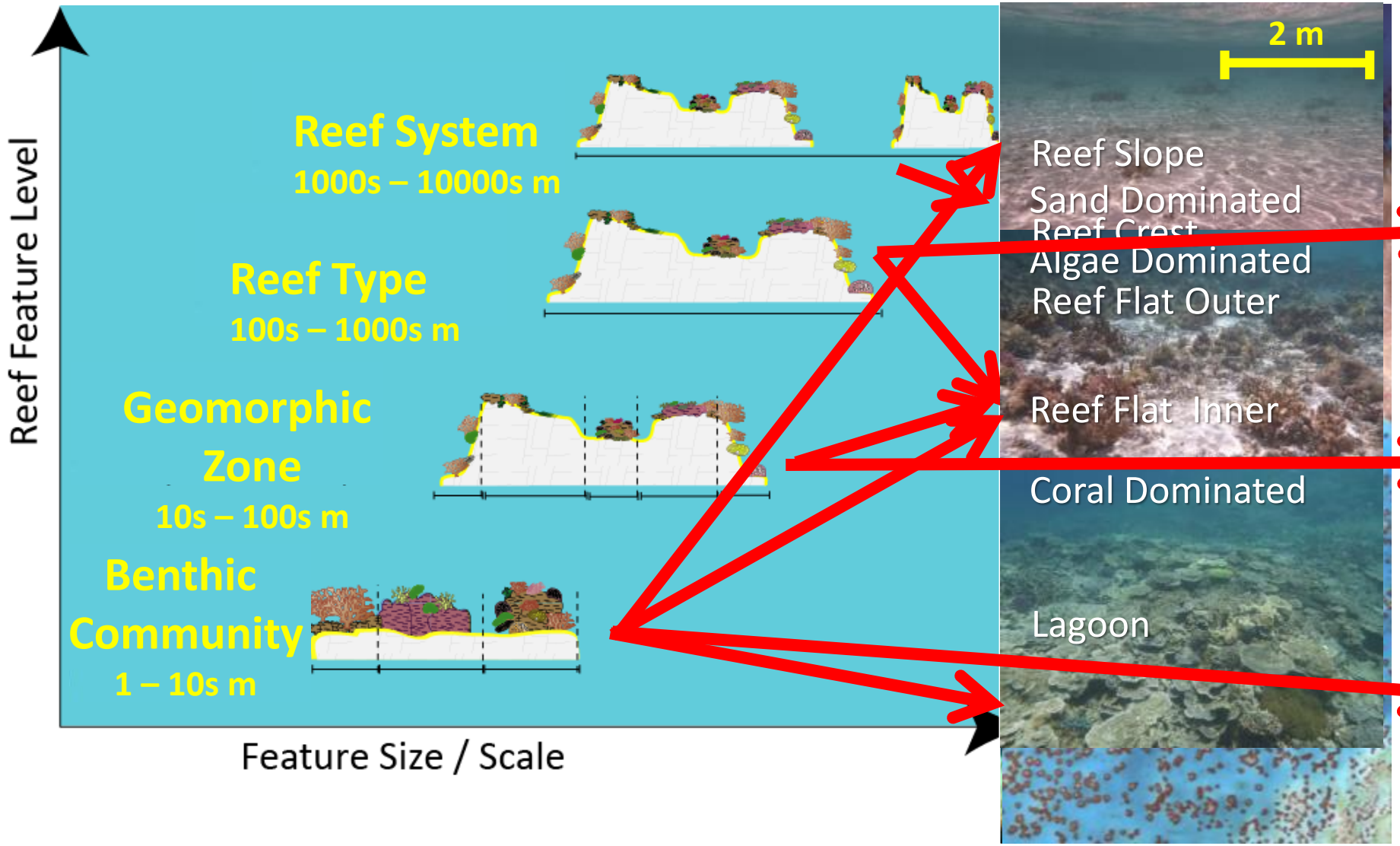
Outline is used as surrogate for coral area (e.g. connectivity, interventions, resilience, management)

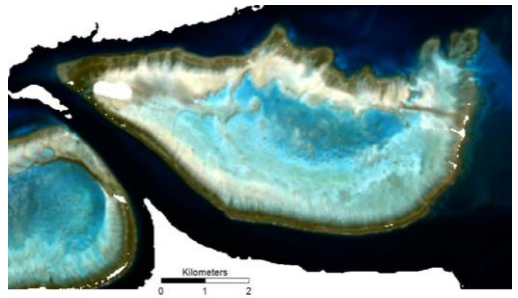


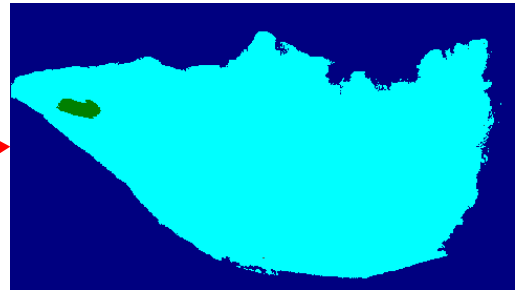
Could you decide from this "Habitat Map" :
where best to sent a COTS boat, where to conduct restoration, etc, etc?

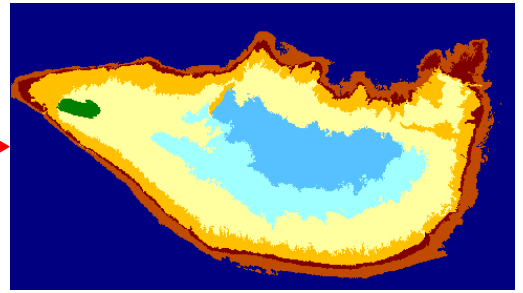
Appropriate Spatial And Information Scales

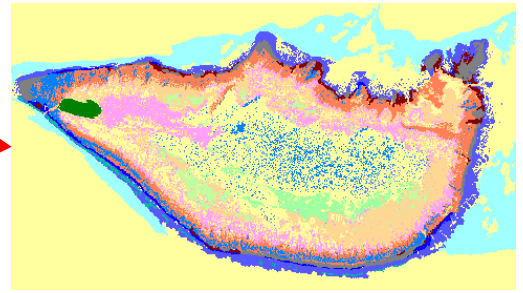
inline with Queensland Intertidal and Subtidal Classification scheme





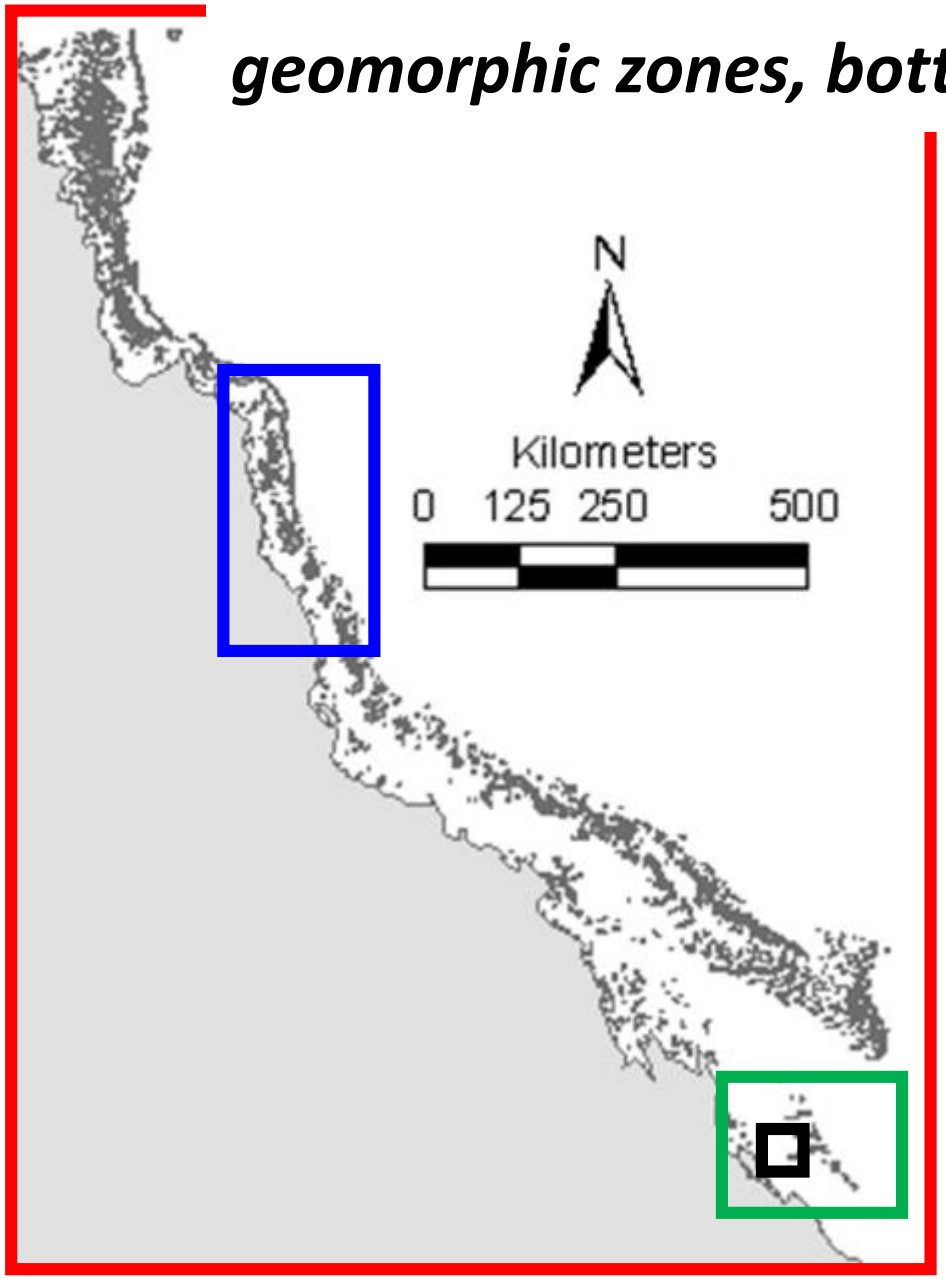


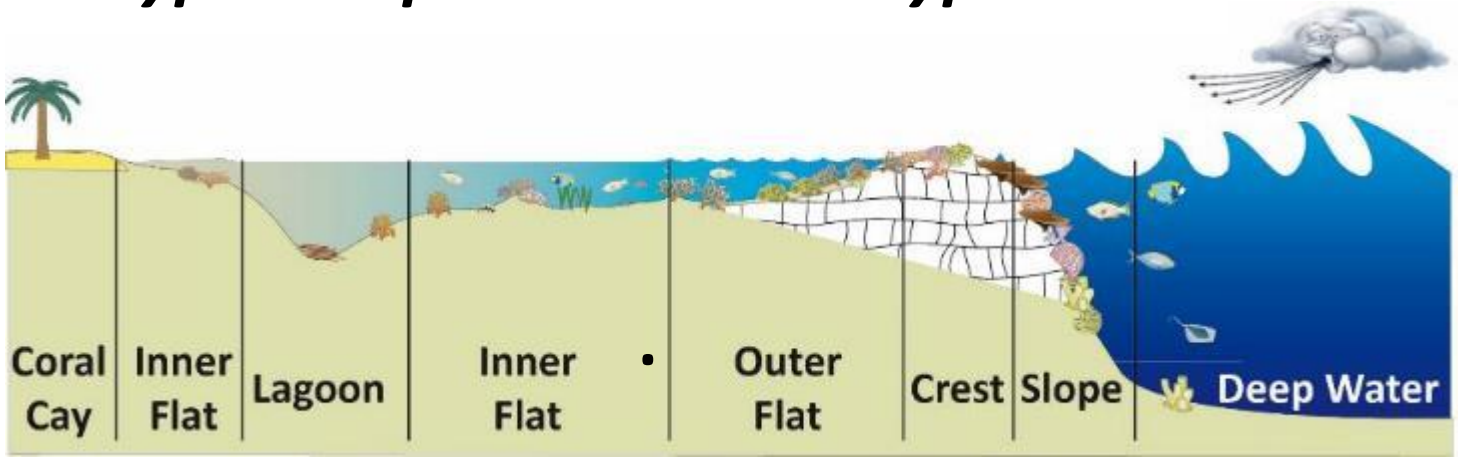




Mapping through clues in the **airborne & satellite Imagery** *such as texture, colour but also physical attributes such as depth, slope, waves, or neighbourhood relations.*

Each shallow offshore reef on the Great Barrier Reef will be mapped by 2021 geomorphic zones, bottom type and predicted coral type habitat





History

1 Reef, annual - Heron Reef 2000-2018

20 reefs, Capricorn Bu 2016

237 reefs, Ca gion 2017

3000 reef R 2019-2021

See Eva Kovacs Talk

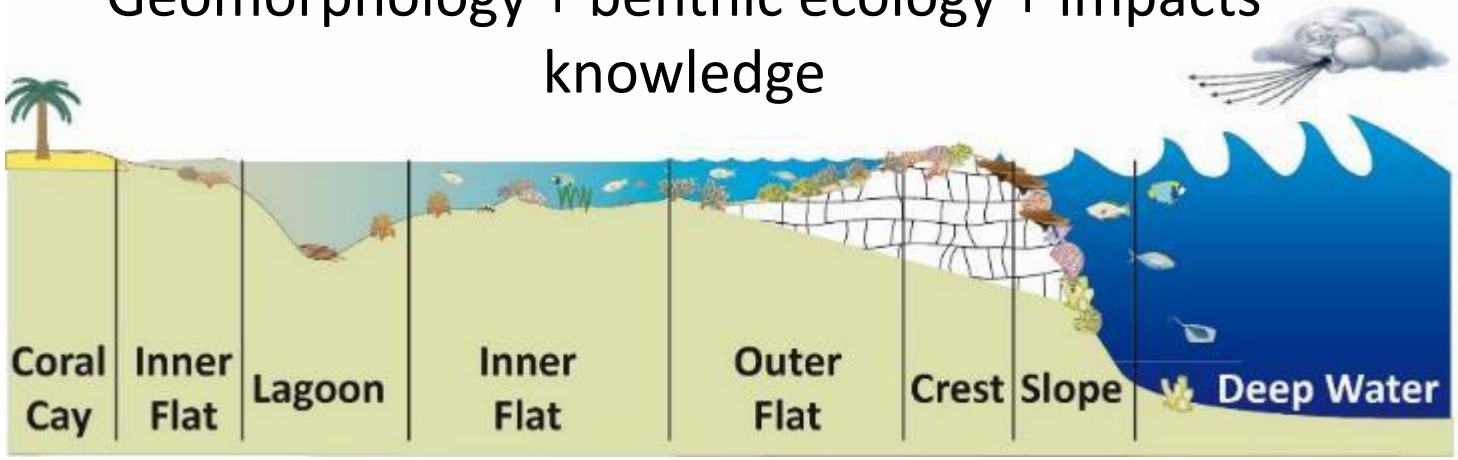
Great Barrier Reef Foundation

Australian Government
Great Barrier Reef Marine Park Authority

Mapping Approach for 3000 individual GBR reefs

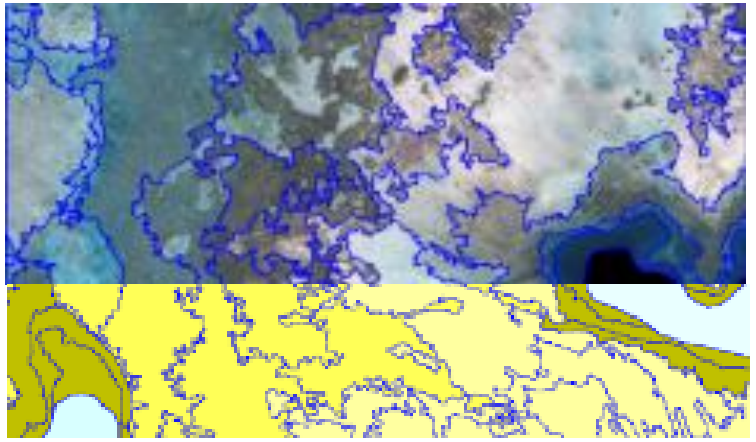
Satellite imagery

Geomorphology + benthic ecology + impacts knowledge



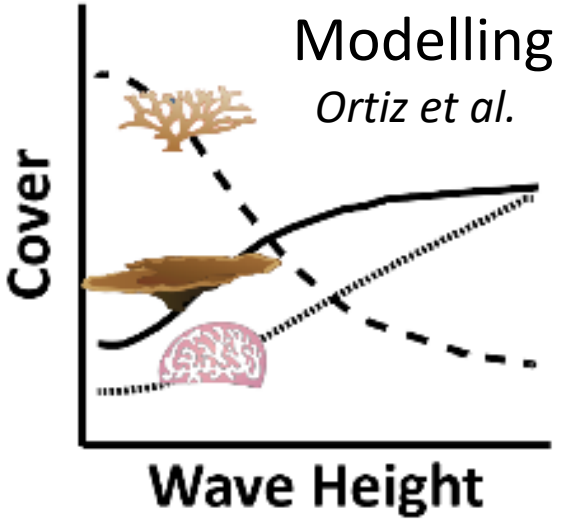
Geo-located benthic photos

Object Based Analysis



Modelling

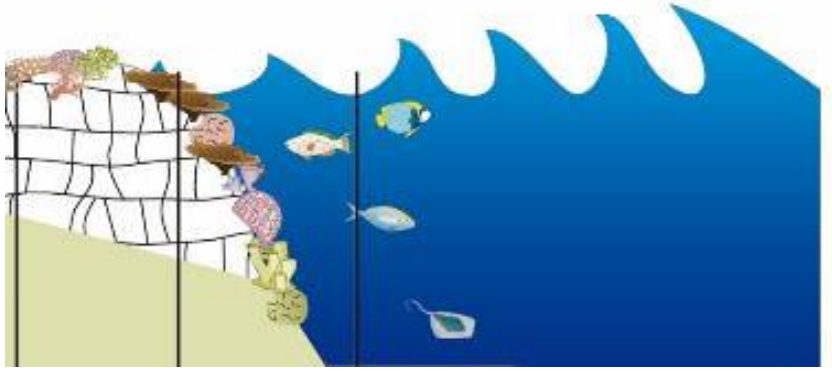
Ortiz et al.



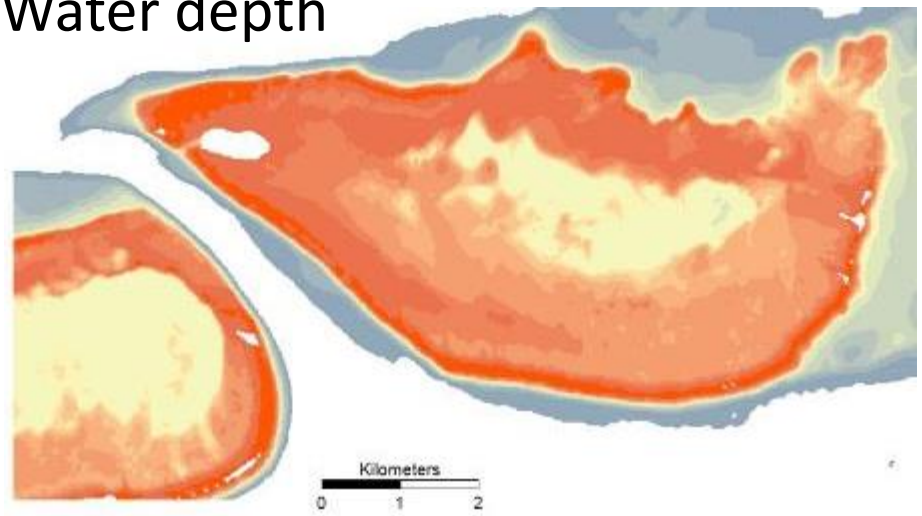
Predicting waves from wind and water depth

Satellite imagery

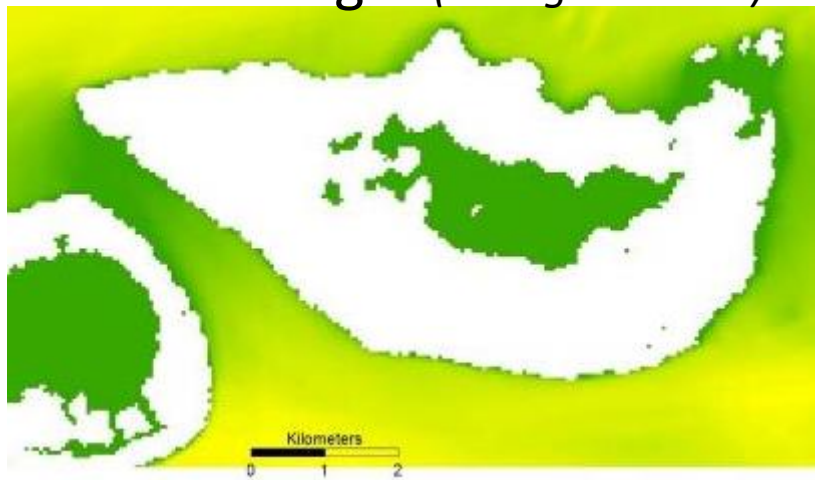
Waves = depth + wind



Water depth

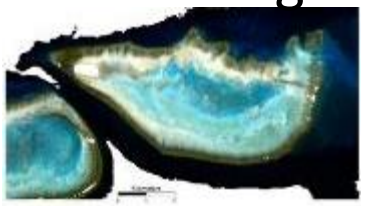


Wave height *(Callaghan et al.)*



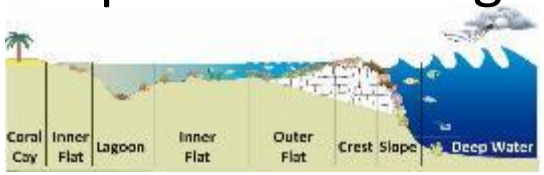
INPUT DATA

Satellite imagery

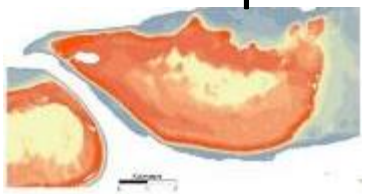


Field data

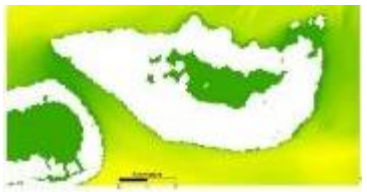
Geomorphic + benthos +impacts knowledge



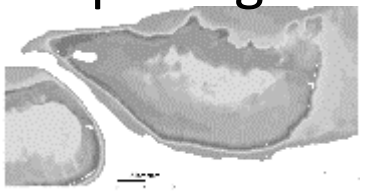
Water depth



Wave climate

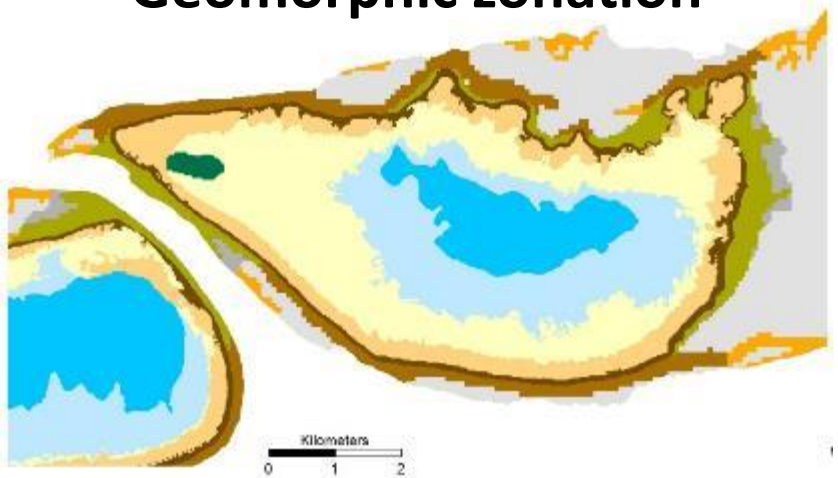


Slope angle



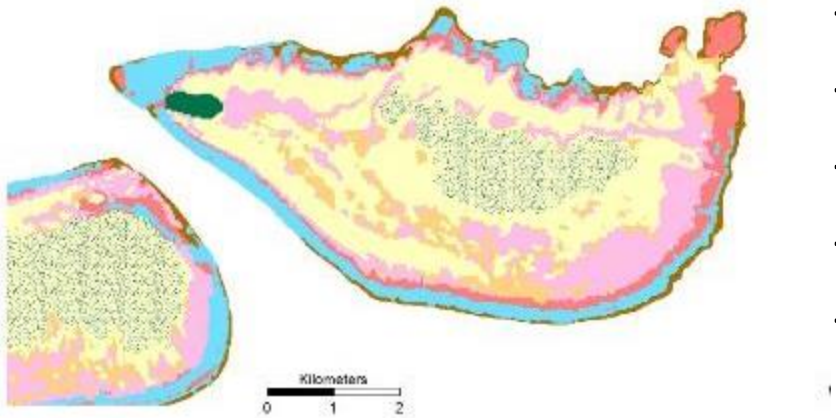
Object Based Mapping

Geomorphic zonation



Reef Slope, Crest, flat, lagoon

Bottom Type



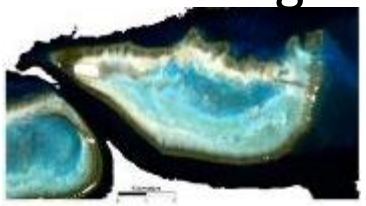
Coral/Algae, Rock, Rubble, Sand

e.g. Rules to map reef crest:

- Consolidated (Darker objects)
- Shallowest (Depth)
- Horizontal plane (slope angle)
- Windward (wave height)
- Next to slope (neighbourhood)

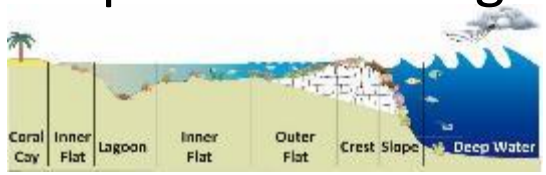
INPUT DATA

Satellite imagery

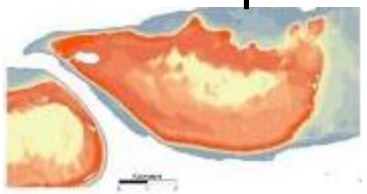


Field data

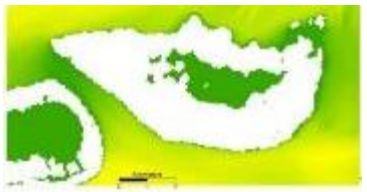
Geomorphic + benthos +impacts knowledge



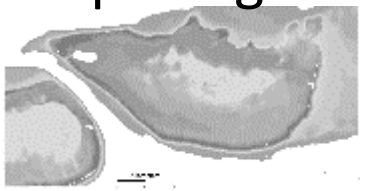
Water depth

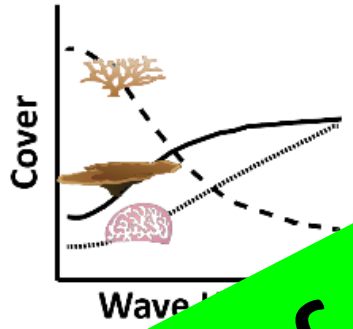


Wave climate



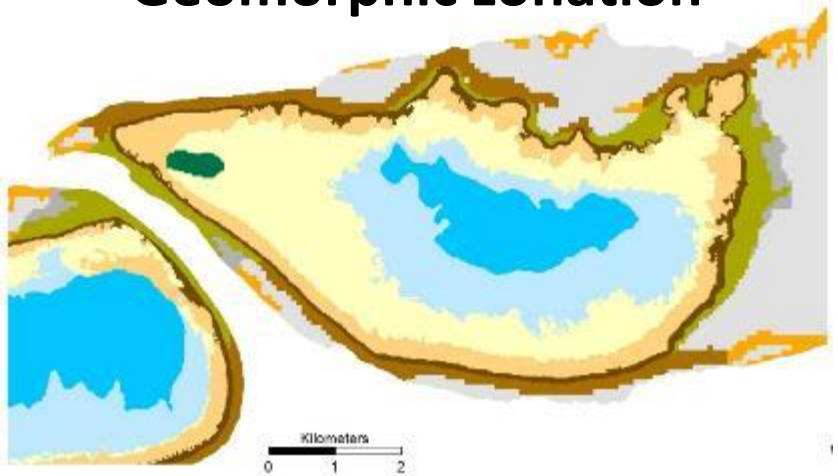
Slope angle





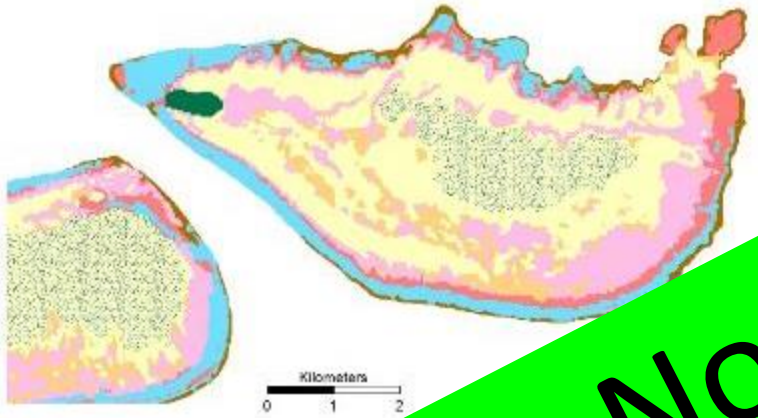
Mapping and Modelling

Geomorphic zonation



Reef Slope, Crest, flat, lagoon

Bottom Type



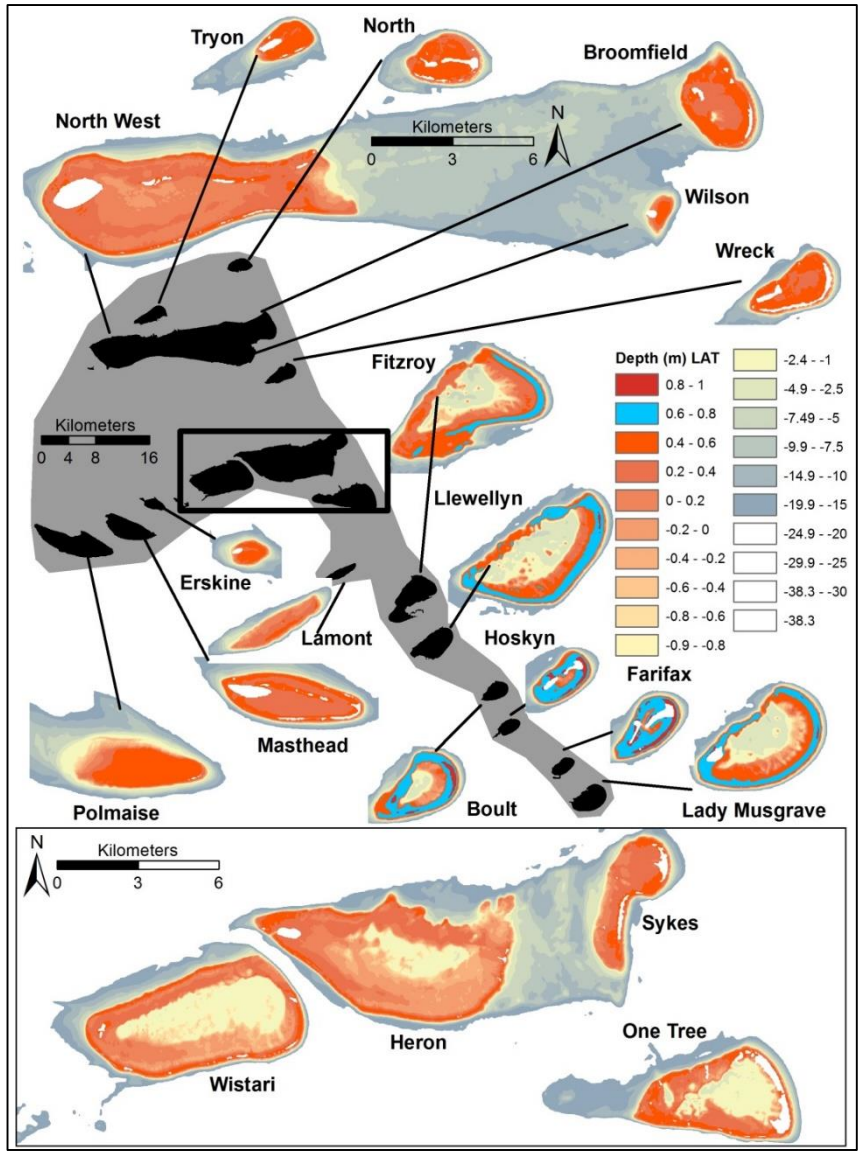
Coral/Algae, Roc

Predicted Coral typ

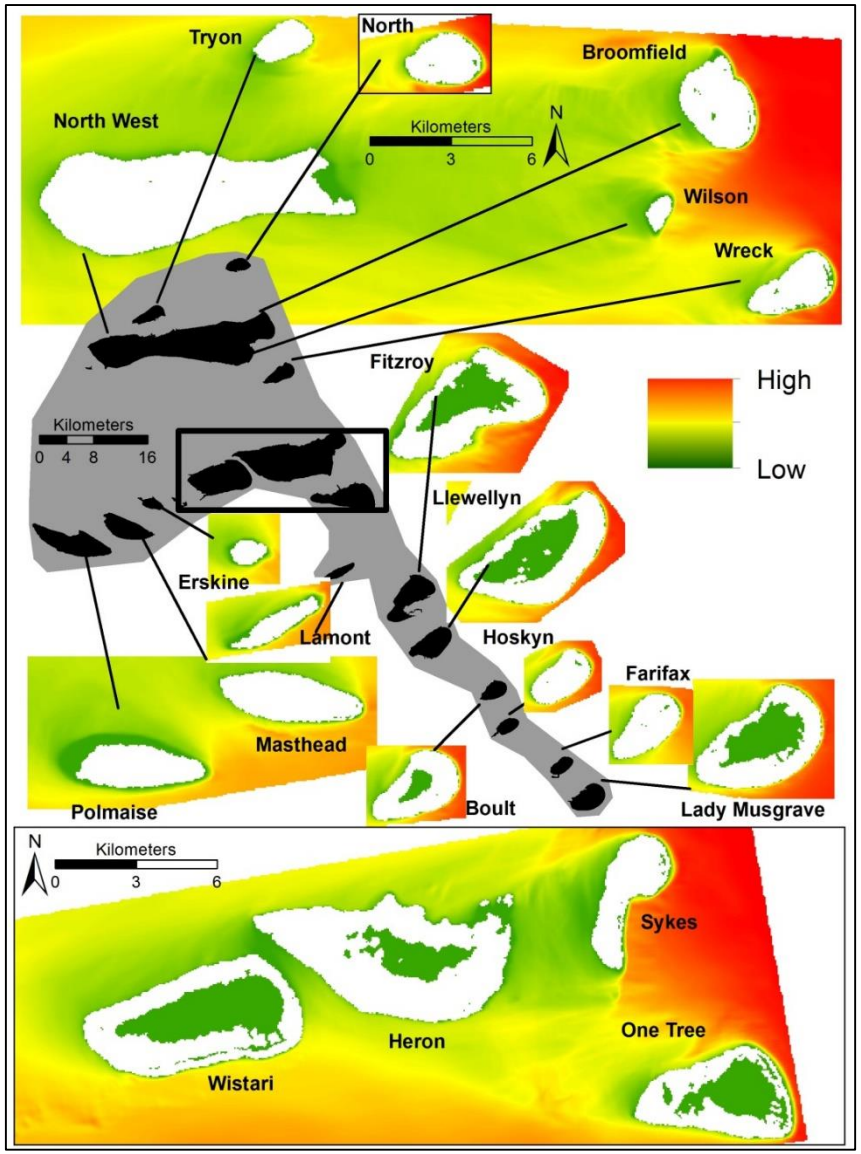
Massive, Branching, Plate

Not only for 1 reef

Example for 20 reefs in the Capricorn (2016) *published in Roelfsema et al 2018*

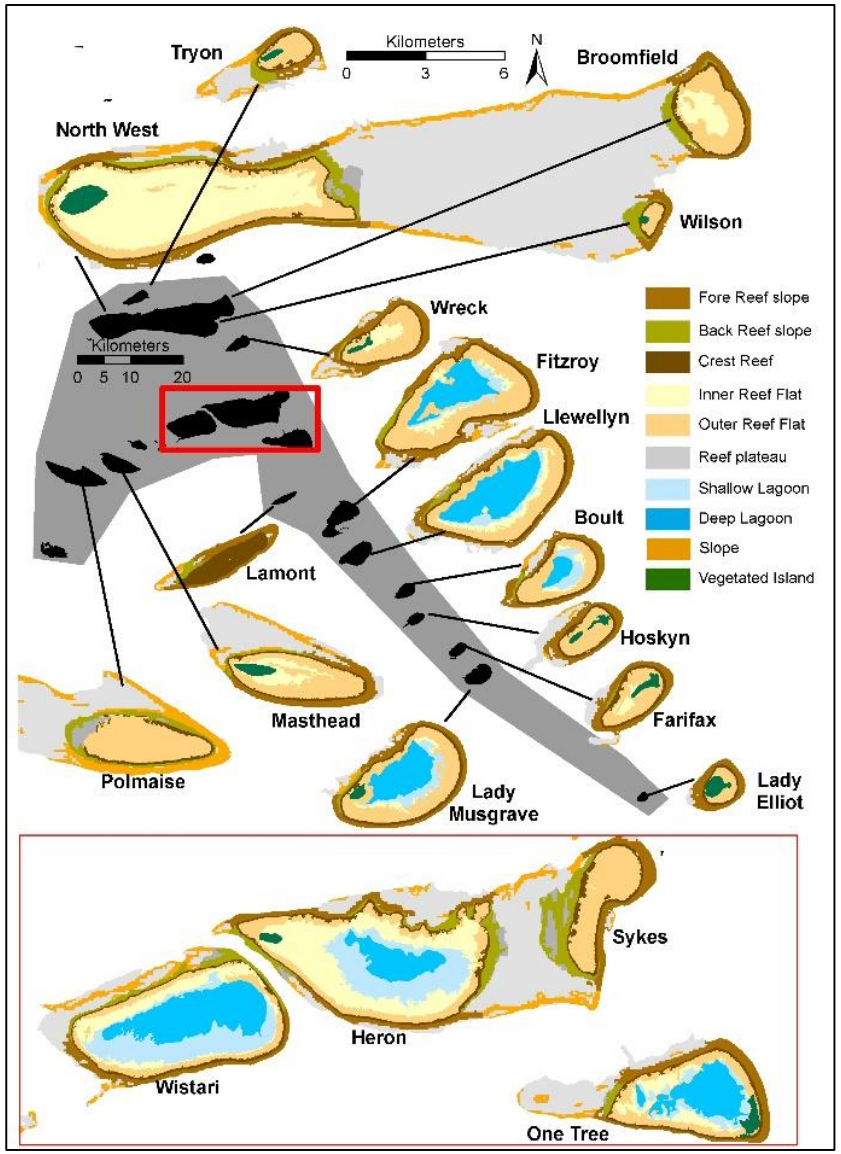


Depth

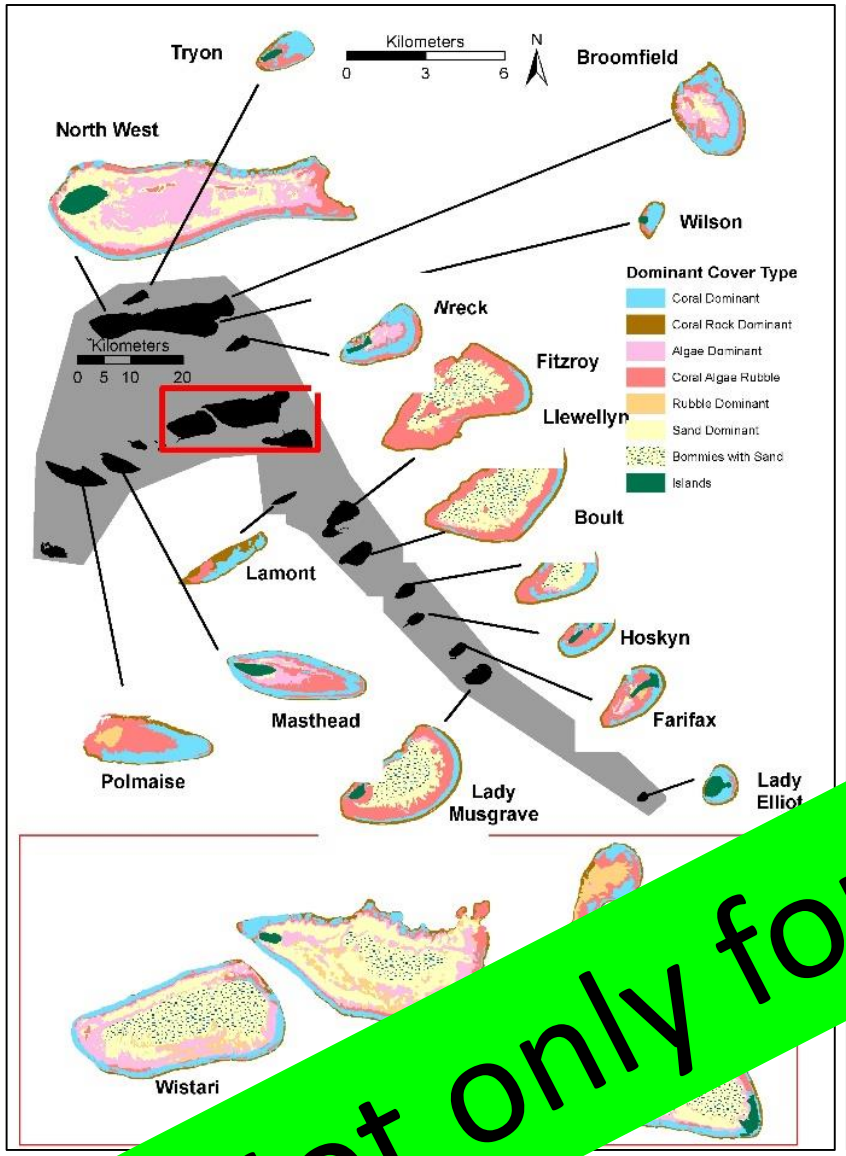


Significant Wave Height
(1 out 19 parameters)

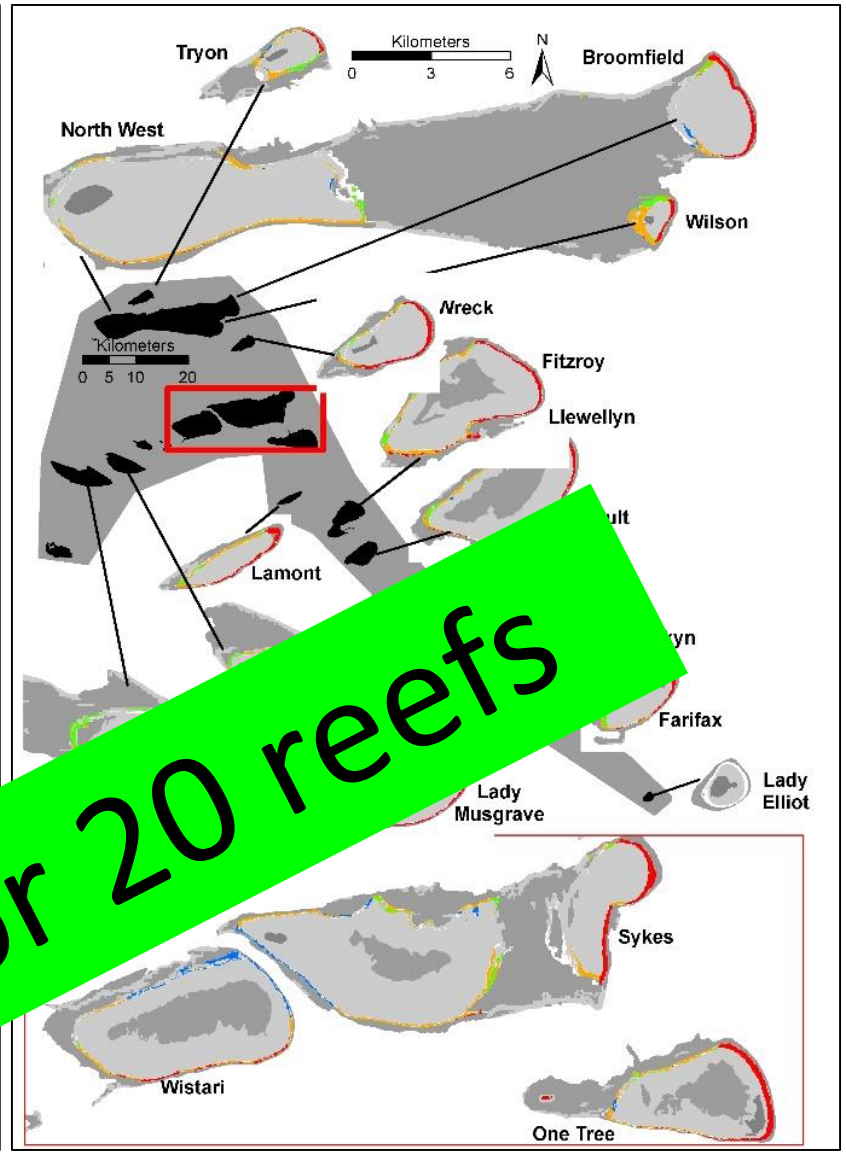
Example for 20 reefs in the Capricorn (2016) *published in Roelfsema et al 2018*



Geomorphic zonation



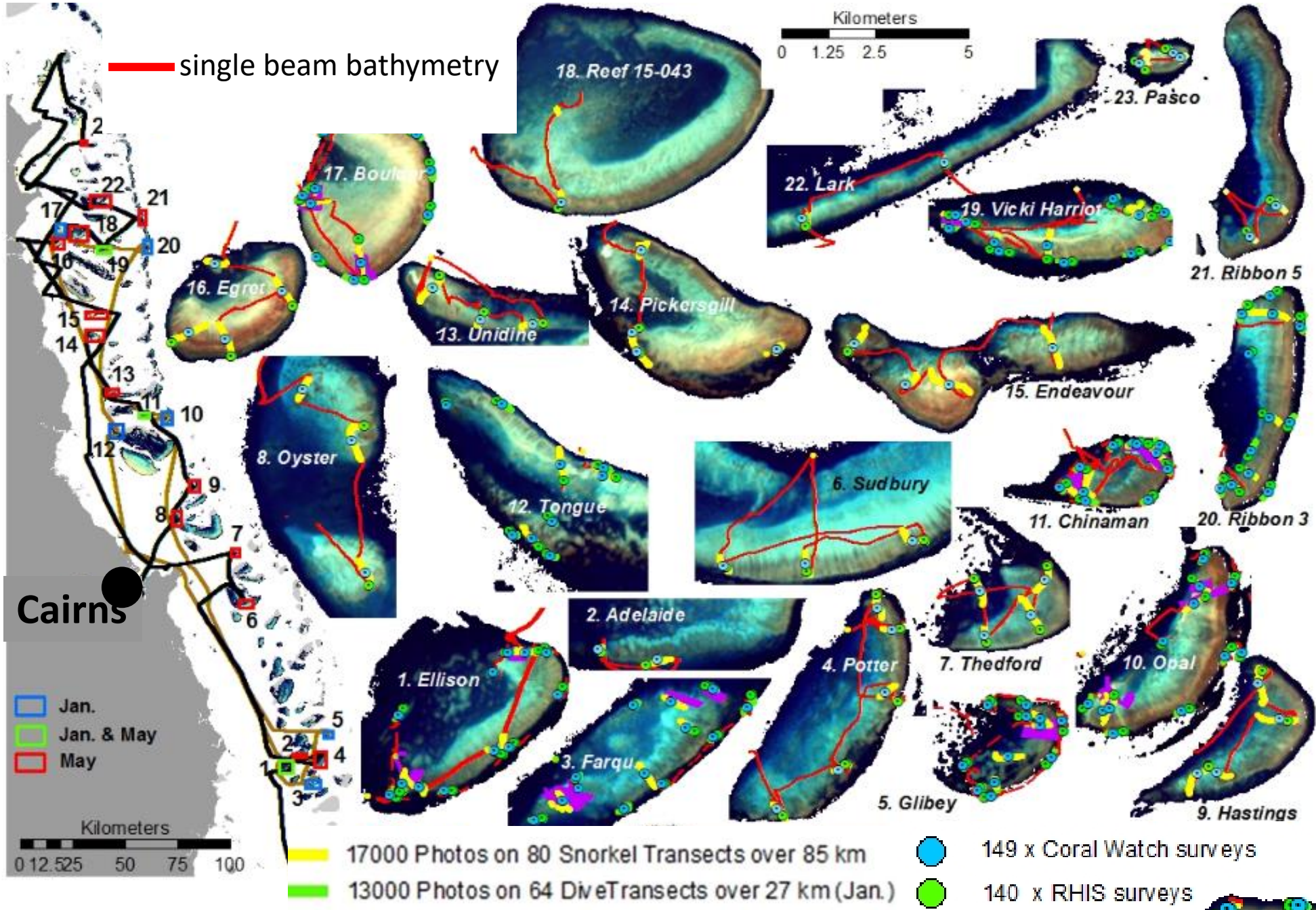
Type



Predicted Coral type habitat

Not only for 20 reefs

We surveyed 23 reefs out of 237 reefs

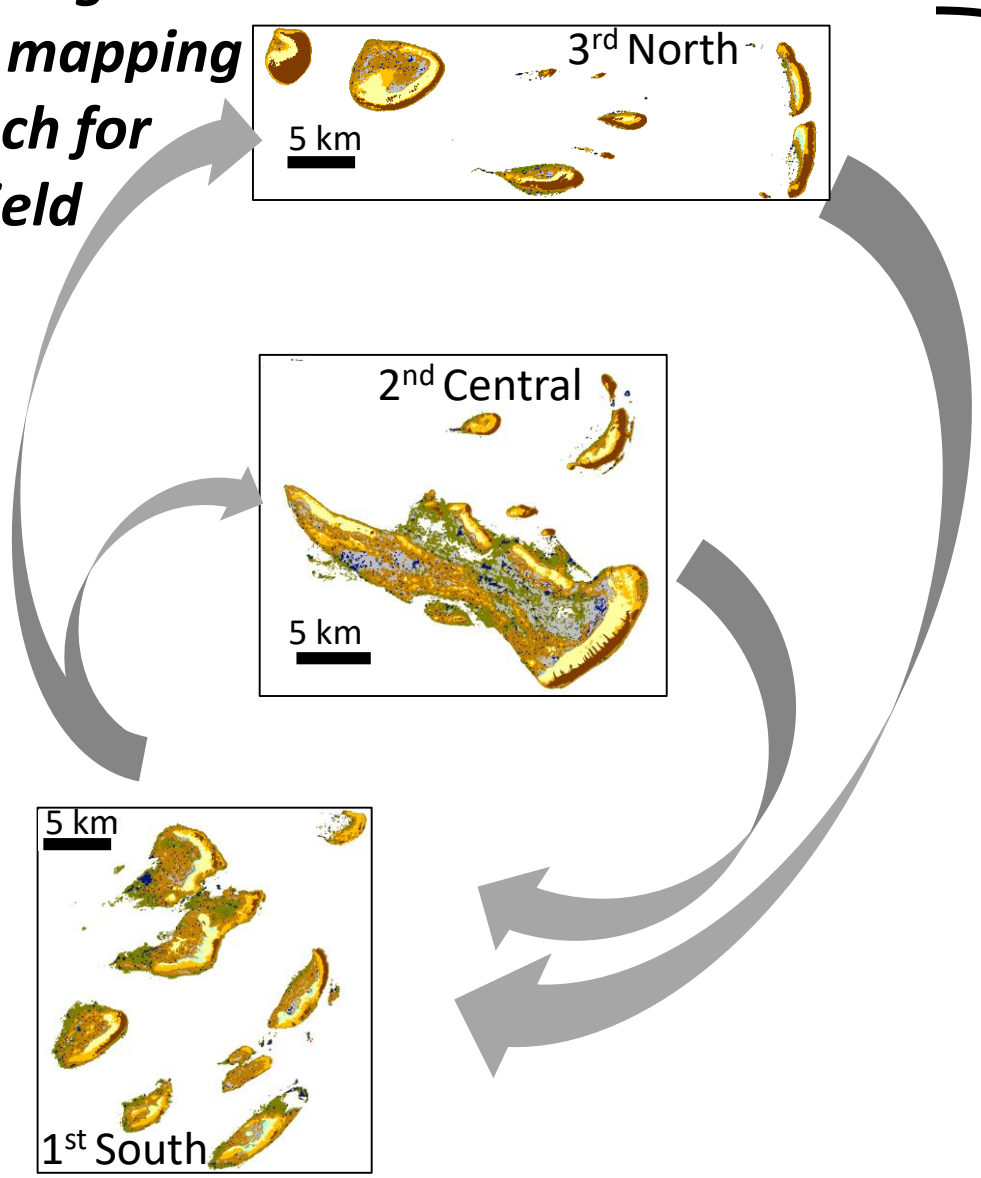


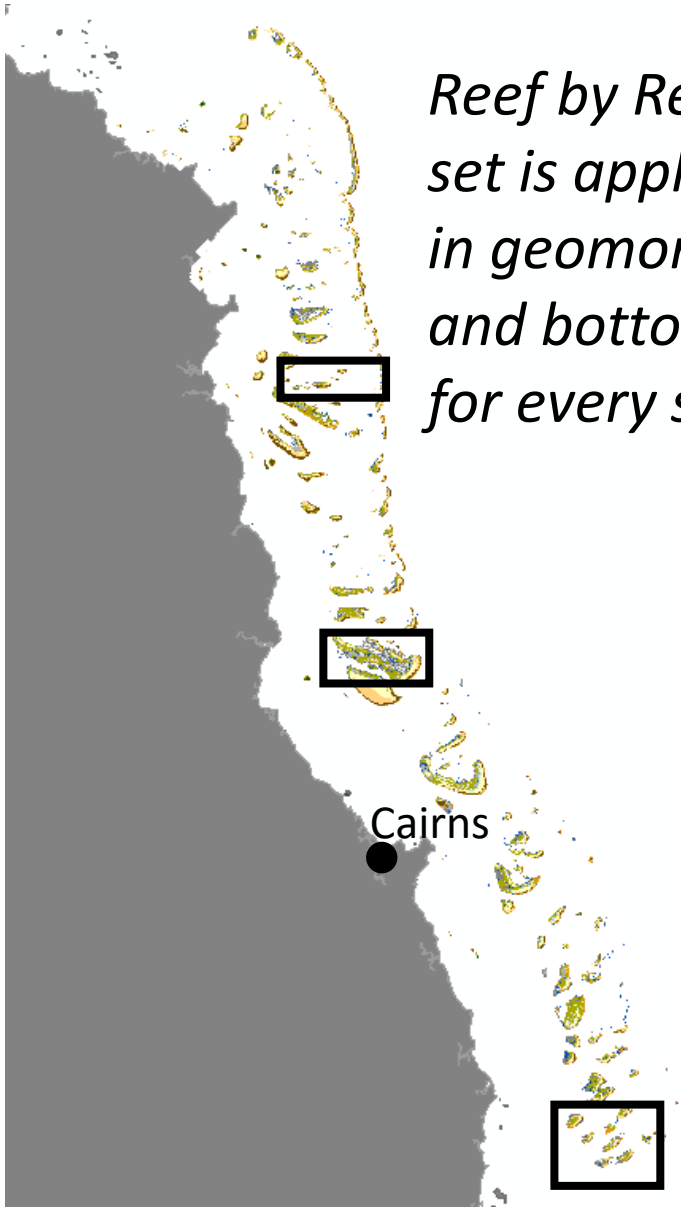
Mv Kalinda 9 days

Mv Fleur Du Passion
Swiss Research Vessel
21 days

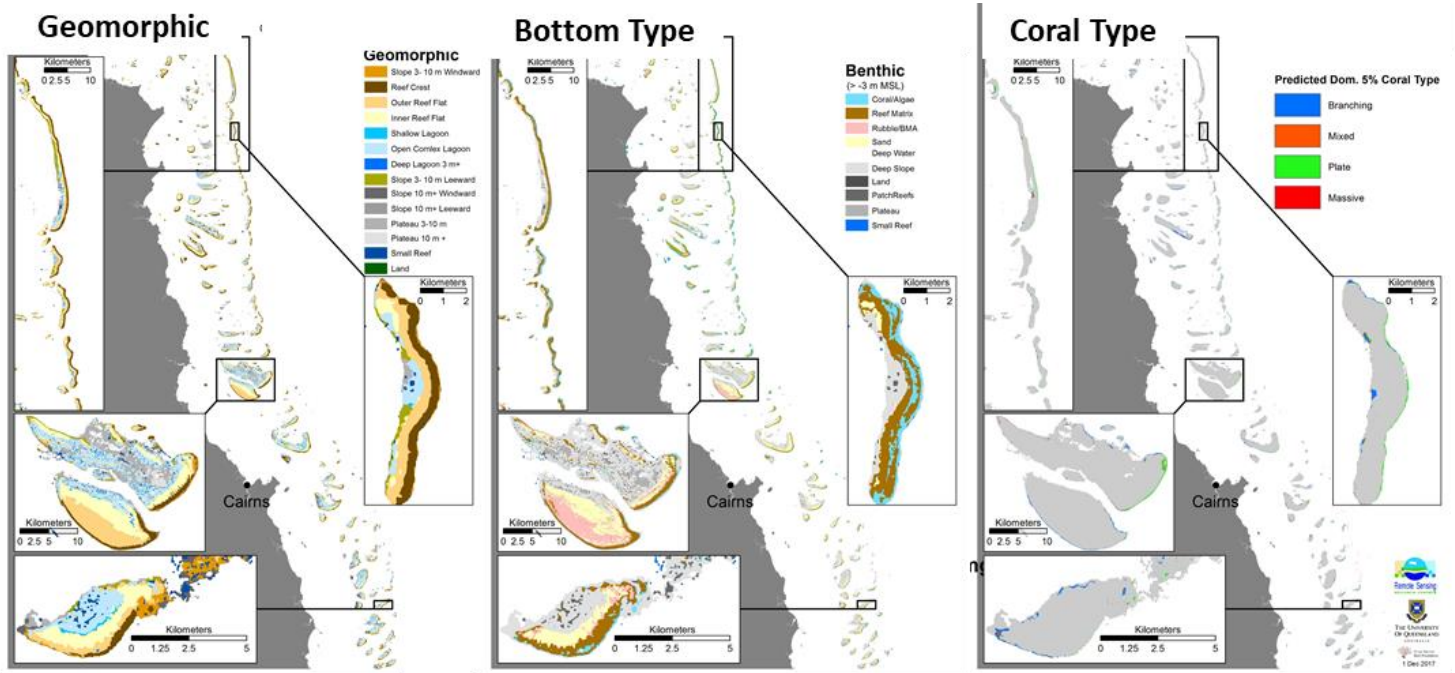
Using the field data + knowledge of 23 reefs to map 237 reefs

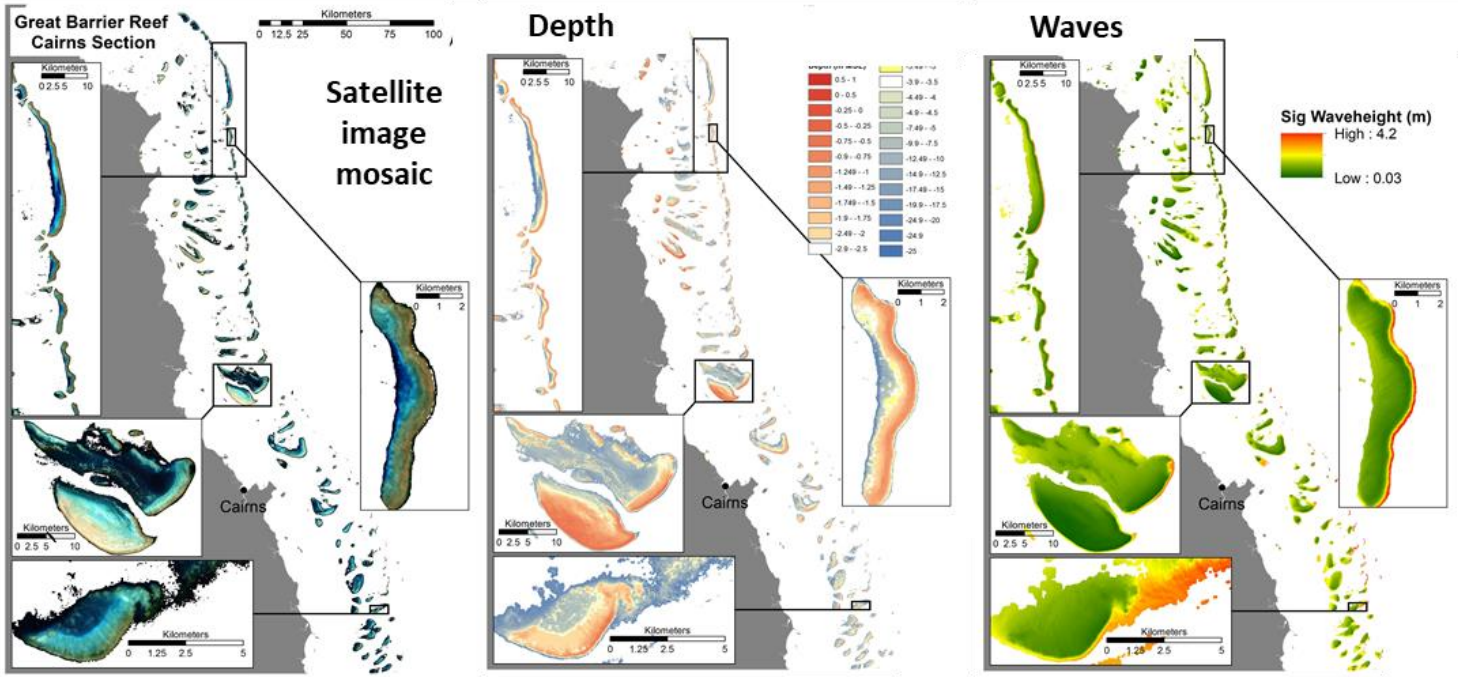
Developing and testing mapping approach for three field areas.





Reef by Reef, the rule set is applied, resulting in geomorphic map and bottom type map for every single reef.





Composition of reefs (e.g. 237 Cairns Reefs)

Habitat

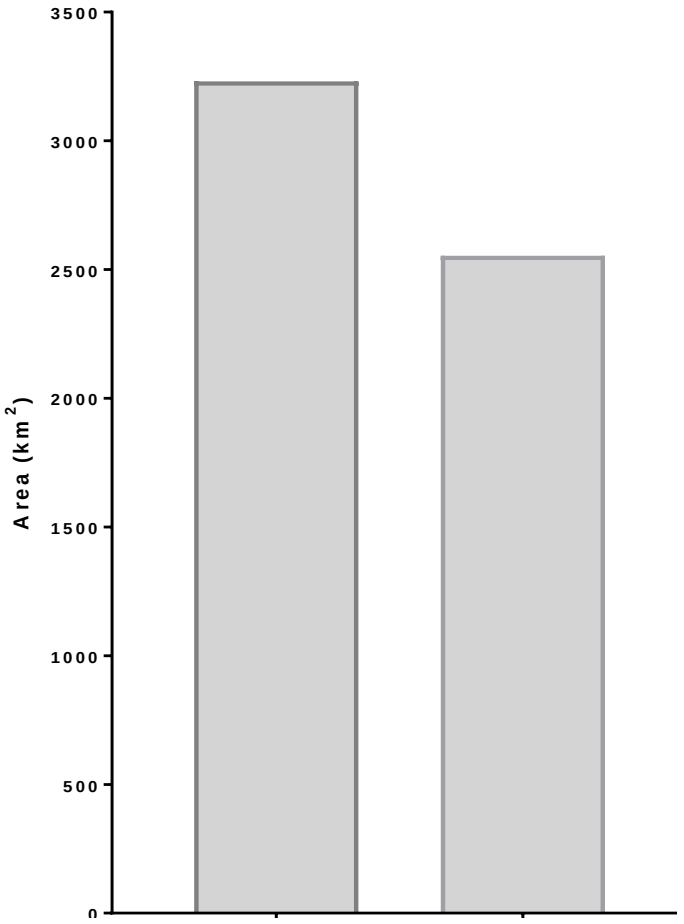
- Geomorphic zonation (0-20 m)
- Bottom type habitat (0-3 m)
- Predicted coral type habitat (3-10 m)

Physical attributes

- Depth
- Slope
- Waves (19 parameters)

What do these maps tell us more? (e.g. 237 Cairns Reefs)

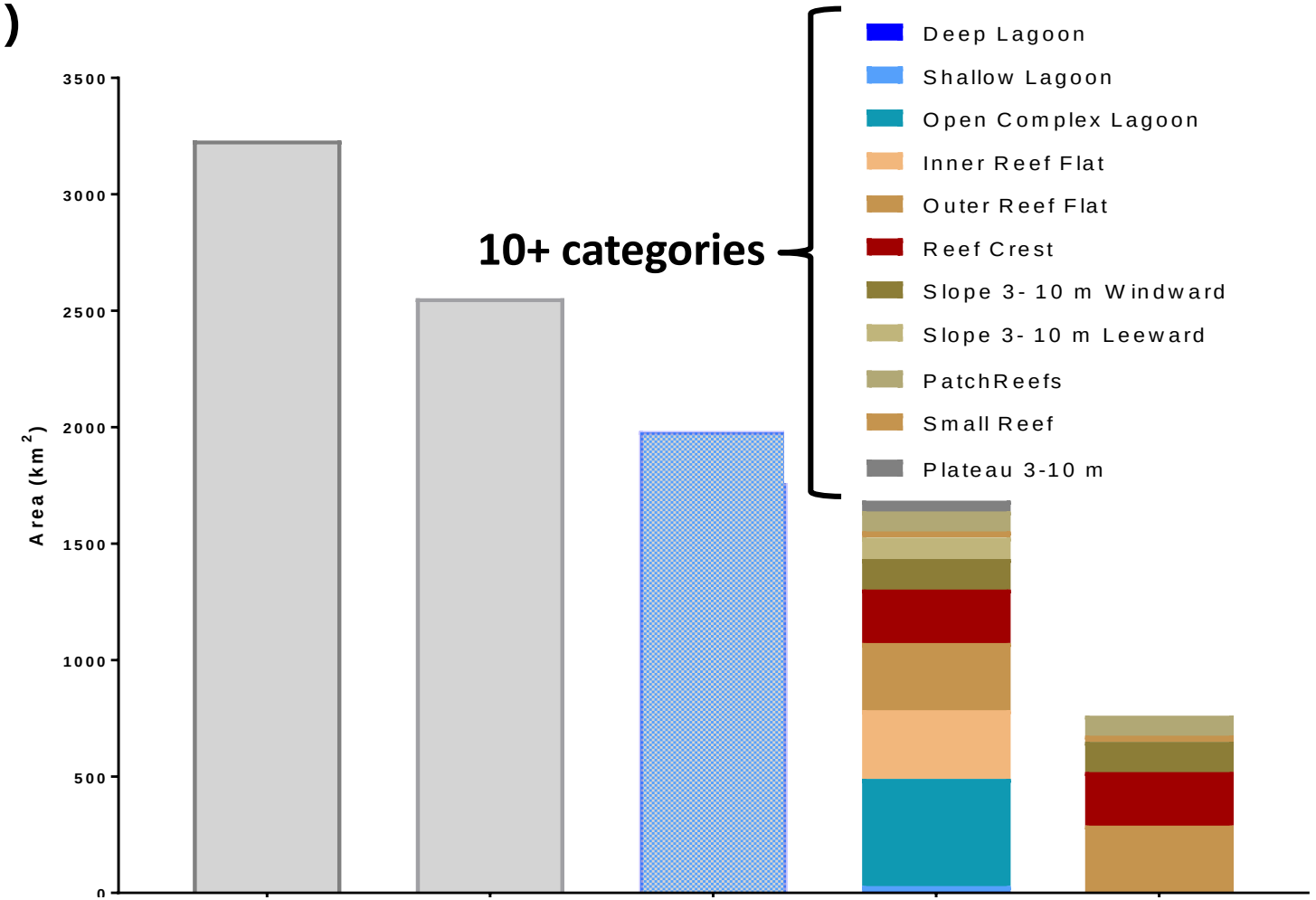
(a)



Existing Spatial Data

What do these maps tell us more?(e.g. 237 Cairns Reefs)

(a)



Reef Outline Lewis et al.

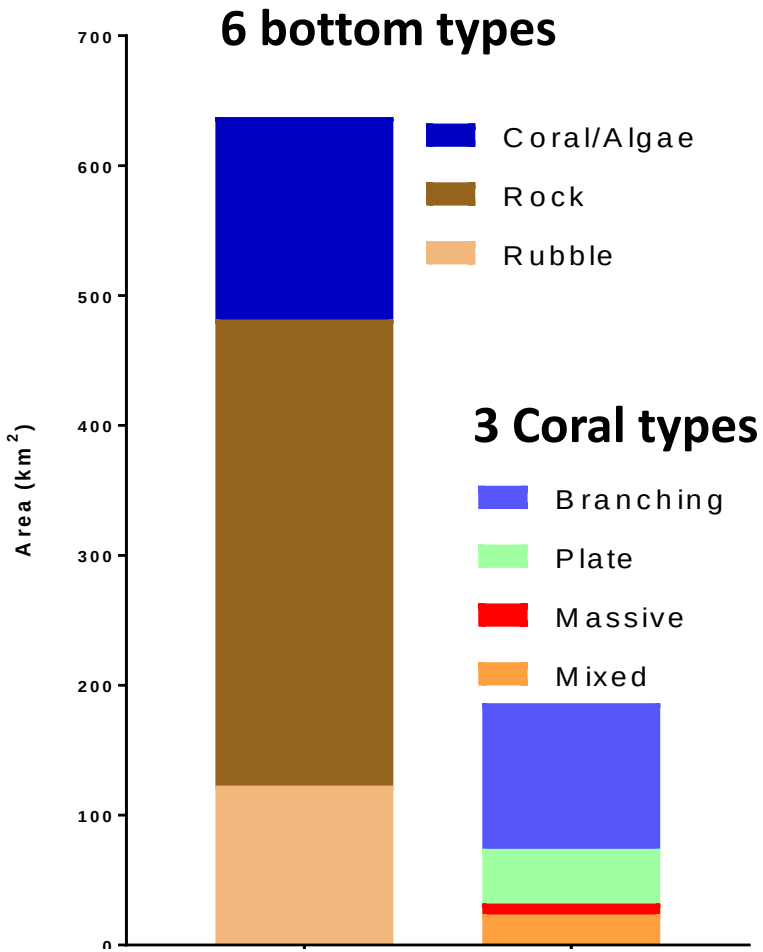
Geomorphic reef type Hopley et al

Reef area 0-20m)

Geo. Zones 0-10m

Geo. (hard) Zones 0-10m

(b)

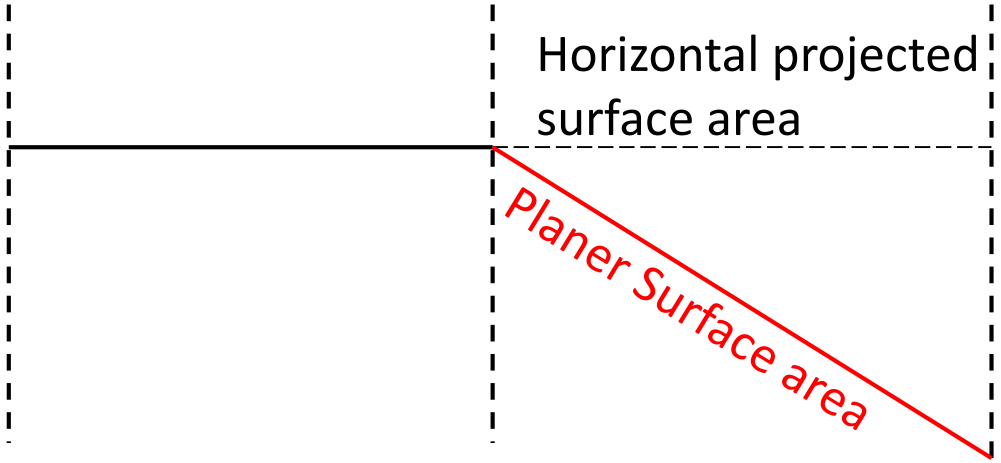


Potential coral Habitat 0- 3 m

Predicted Coral Type Habitat 3-10m

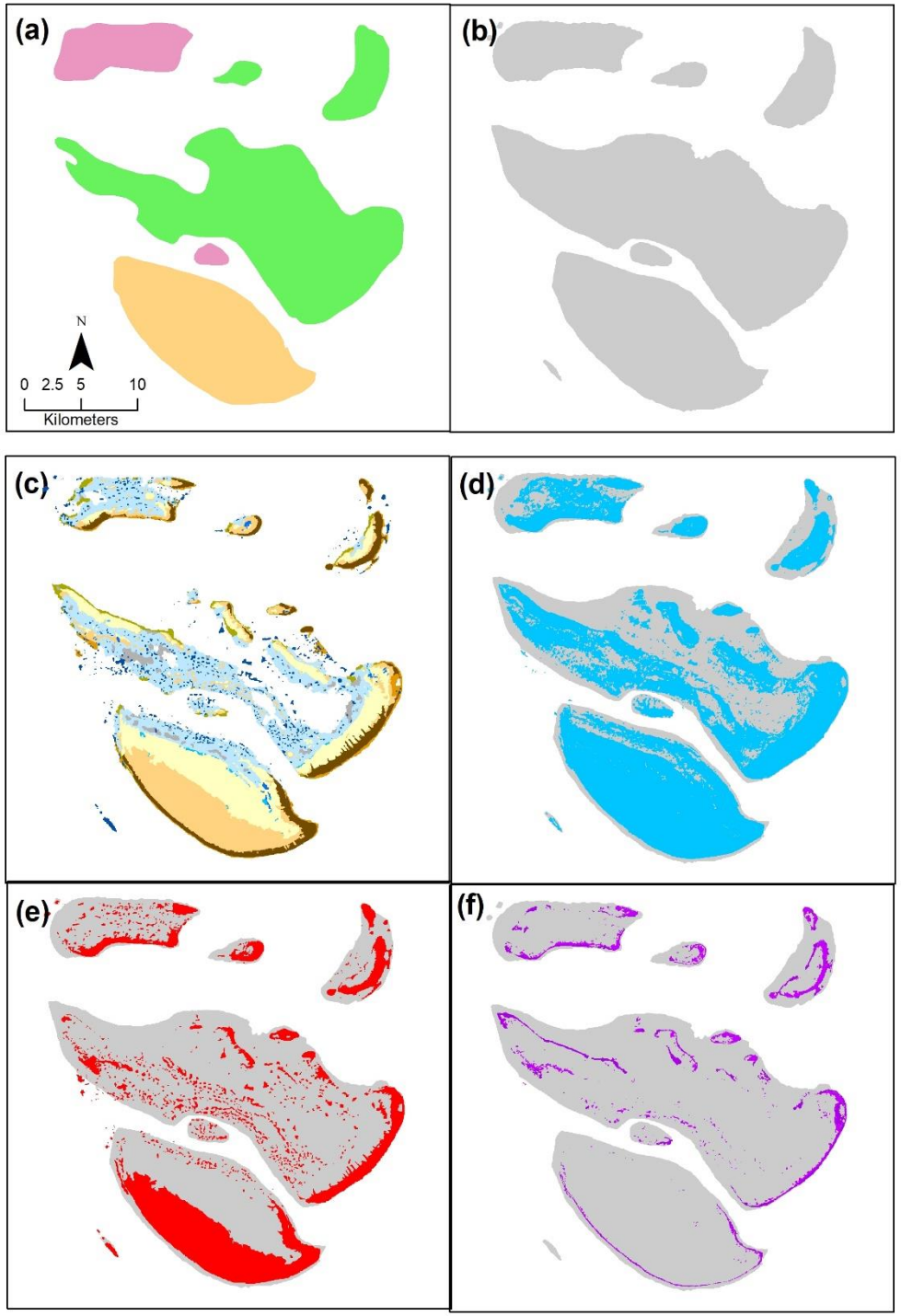
What do these maps tell us more?

3D habitat map as we know depth and slope e.g. 237 Cairns Reefs



You need depth to make it 3D

	Horizontal projected surface area (km^2)
Exposed Slope 10-20 m	62
Exposed Slope 3- 10 m	131
Sheltered Slope 3- 10 m no lagoon	93
Sheltered Slope 10-20 m	217
total	503



What do these maps tell us more?

Existing data

a) Geomorphic reef type (Hopley et al. 2008)

b) Reef Outline (Lewis et al. 2003)

Unknown + variable max depth and 1 category per reef

New layers

c) Geomorphic zones (0-15 m)

d) Reef area (0 - 10 m)

e) Geomorphic zones dominated by hard substrate (

f) Potential coral habitat (0 - 10 m)

Known fixed max depth

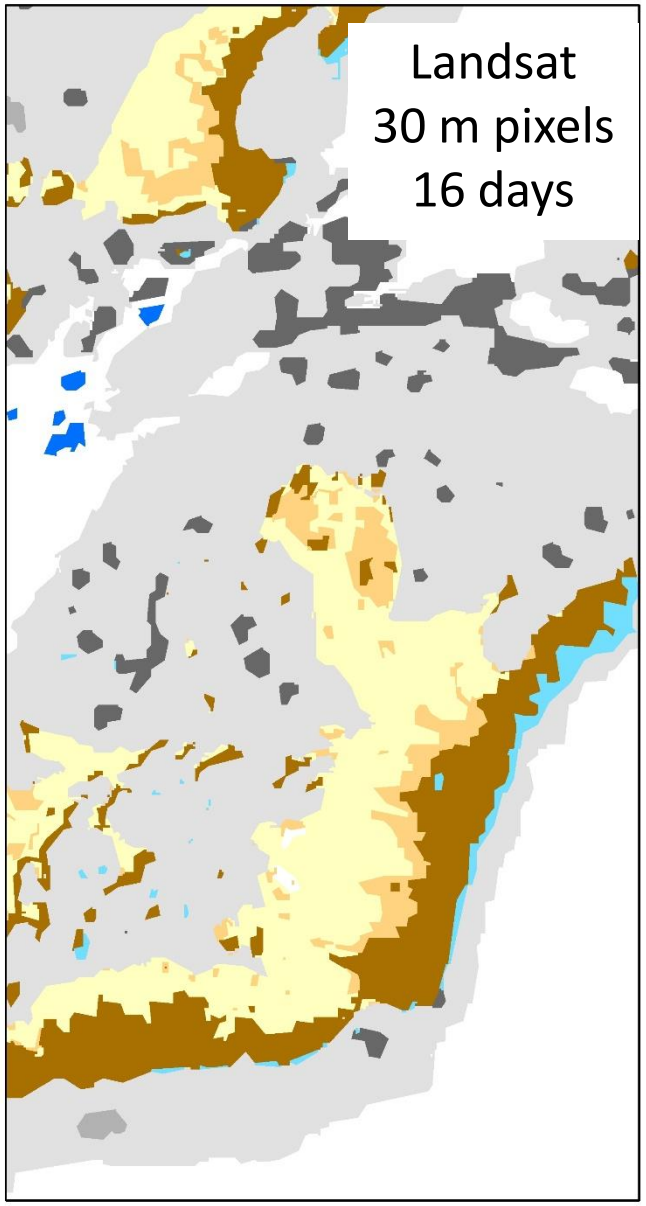
Categories per reef:

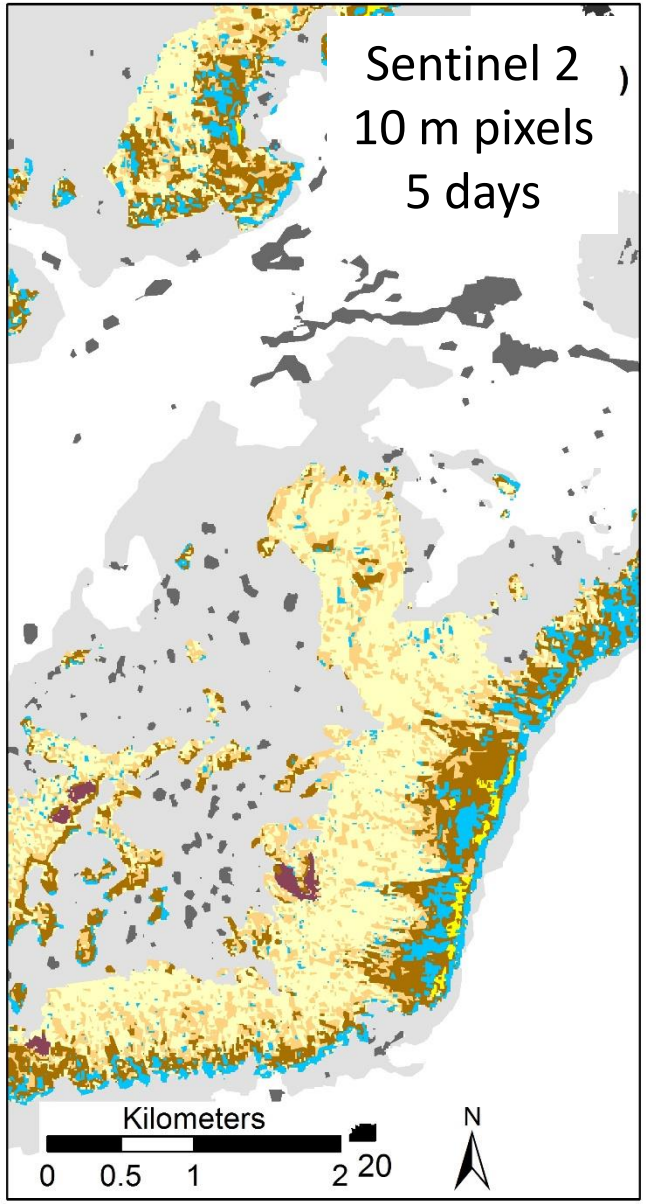
10+ for Geom

6+ bott

Imagine 3000 reefs

Using High Spatial and Temporal Resolution Sentinel 2 for whole GBR





Benthic (Reef Top) Draft

- Bleached
- Coral/Algae
- Rock
- Rubble
- Sand
- Deep Slope
- Small Reefs
- DeepWater-Nodata

Sentinel 2:

- 10 m pixels,
- 5 days revisit
- Scenes 2018- 2019

EOMAP

The University of Queensland
AUSTRALIA

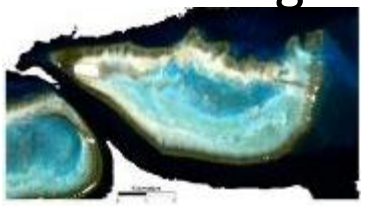
Australian Institute of Marine Science

To derive:

- Surface reflectance mosaic
- Water depth
- Geomorphic
- Bottom type
- Coral type (Ortiz et al)

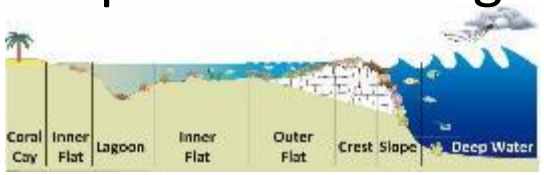
INPUT DATA

Satellite imagery

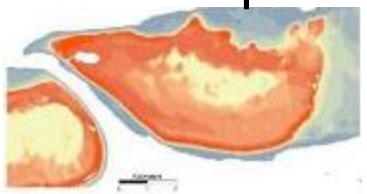


Field data

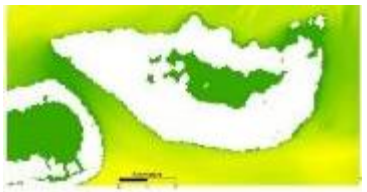
Geomorphic + benthos +impacts knowledge



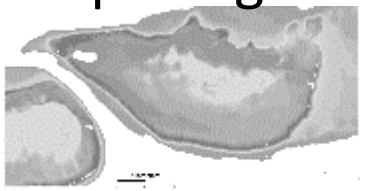
Water depth



Wave climate

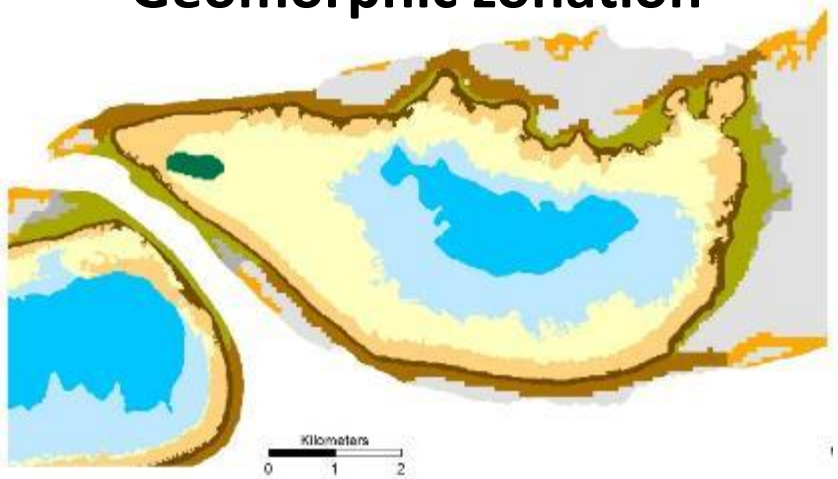


Slope angle



Object Based Mapping

Geomorphic zonation



Reef Slope, Crest, flat, lagoon

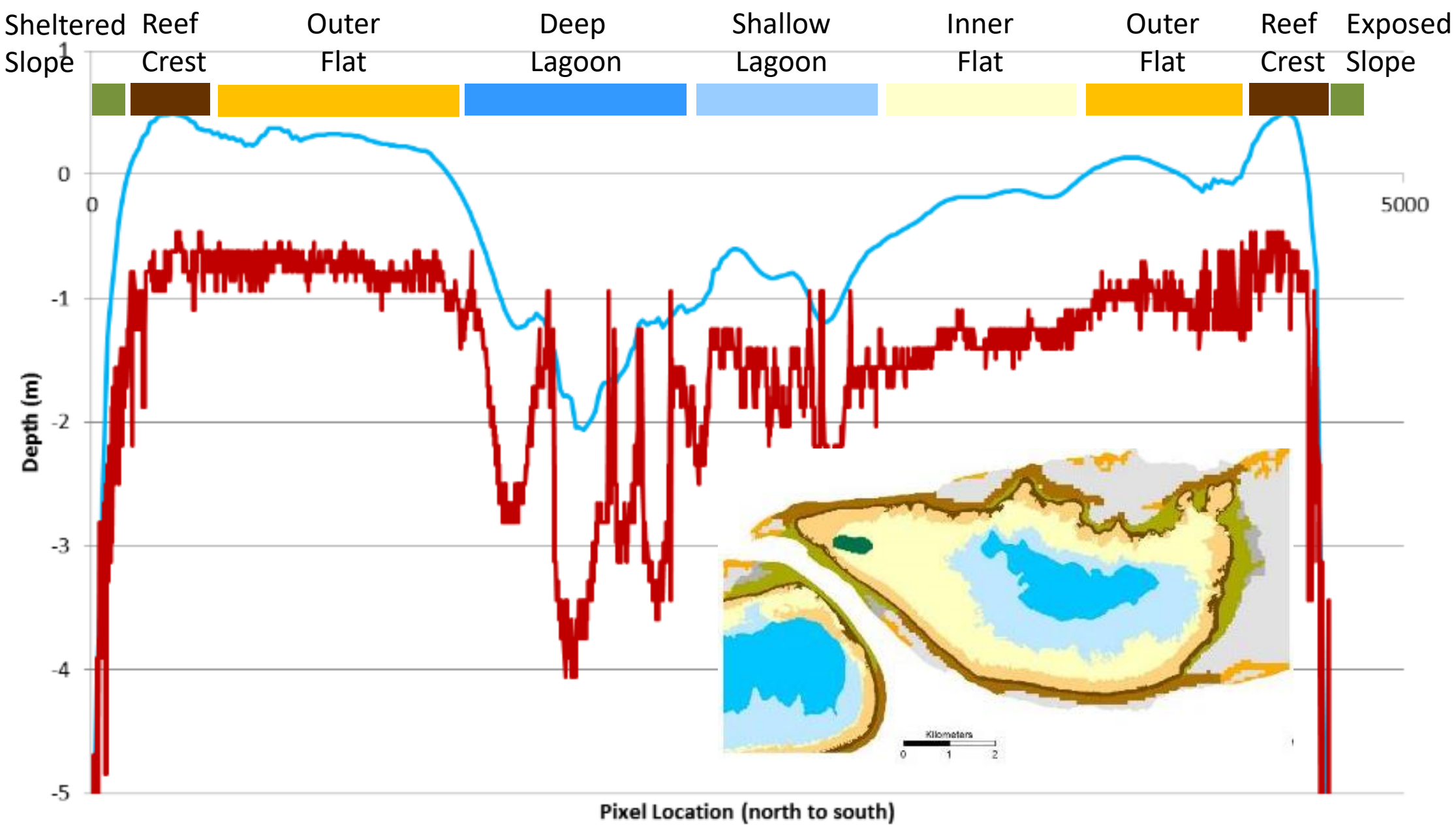
e.g. Rules to map reef crest:

- Consolidated (Darker objects)
- Shallowest (Depth)
- Horizontal plane (slope angle)
- Windward (wave height)
- Next to slope (neighbourhood)

Object Based Analysis Driven by Physical Attributes

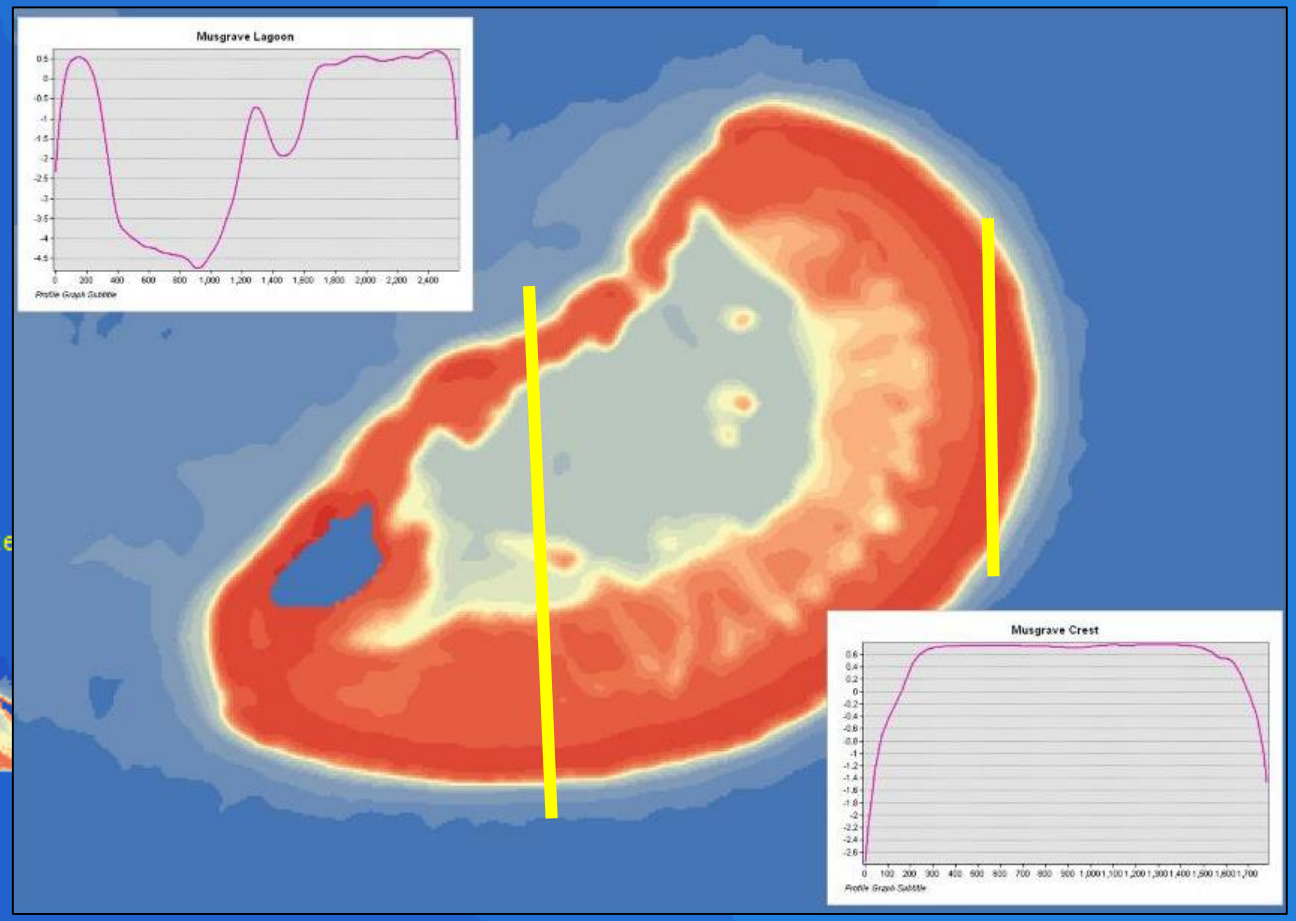
Object Based Analysis Driven by Physical Attributes

Geomorphic Zone Type	Intertidal	Subtidal	Depth (m)									Slope (degrees)				Wave Height		Consolidation				
			0	< 1	1-1.5	1.5-3	< 3	>3	<10	10-20	>20	0-5	0-10	5-70	70-90	High	Low	Hard	Soft	Hard over soft	Soft over hard	Soft vs Hard
Slope-Exposed Deep		✓								✓				✓		✓		✓				
Slope-Exposed shallow		✓							✓					✓		✓		✓				
Wall-Exposed		✓									✓				✓	✓		✓				
Reef Rim	✓			✓									✓			✓		✓				
Outer Reef Flat	✓				✓							✓					✓			✓		
Inner Reef Flat	✓					✓						✓					✓				✓	
Inner Terrestrial Flat	✓						✓					✓					✓		✓			
Reef Flat (on its own)	✓						✓					✓					✓			✓		
Deep Lagoon Enclosed		✓						✓									✓		✓			
Shallow Lagoon Enclosed		✓				✓							✓				✓		✓			
Open Complex Lagoon		✓						✓									✓		✓			
Open Shallow Lagoon		✓				✓						✓					✓		✓			
Slope-Sheltered deep		✓								✓				✓			✓					✓
Slope-Sheltered shallow		✓							✓					✓			✓					✓
Wall - Sheltered		✓									✓				✓		✓					✓


Sheltered Slope
Reef Crest
Outer Flat
Deep Lagoon
Shallow Lagoon
Inner Flat
Outer Flat
Reef Crest
Exposed Slope
1
0
-1
-2
-3
-4
-5
0
5000
Depth (m)
Pixel Location (north to south)
Kilometers
0
1
2

Integrated Water Depth

Capricorn Bunker Groups:
Southern Great Barrier Reef, Australia



Tyron Reef
Broomfield Reef
Northwest Reef
Wilson Island
Wreck Reef
Heron Reef
Wistari Reef
Erskine Reef
Masthead Reef
Polmaise Reef
Lamont Reef
Fitzroy Reef
Liewellyn Reef
Boult Reef

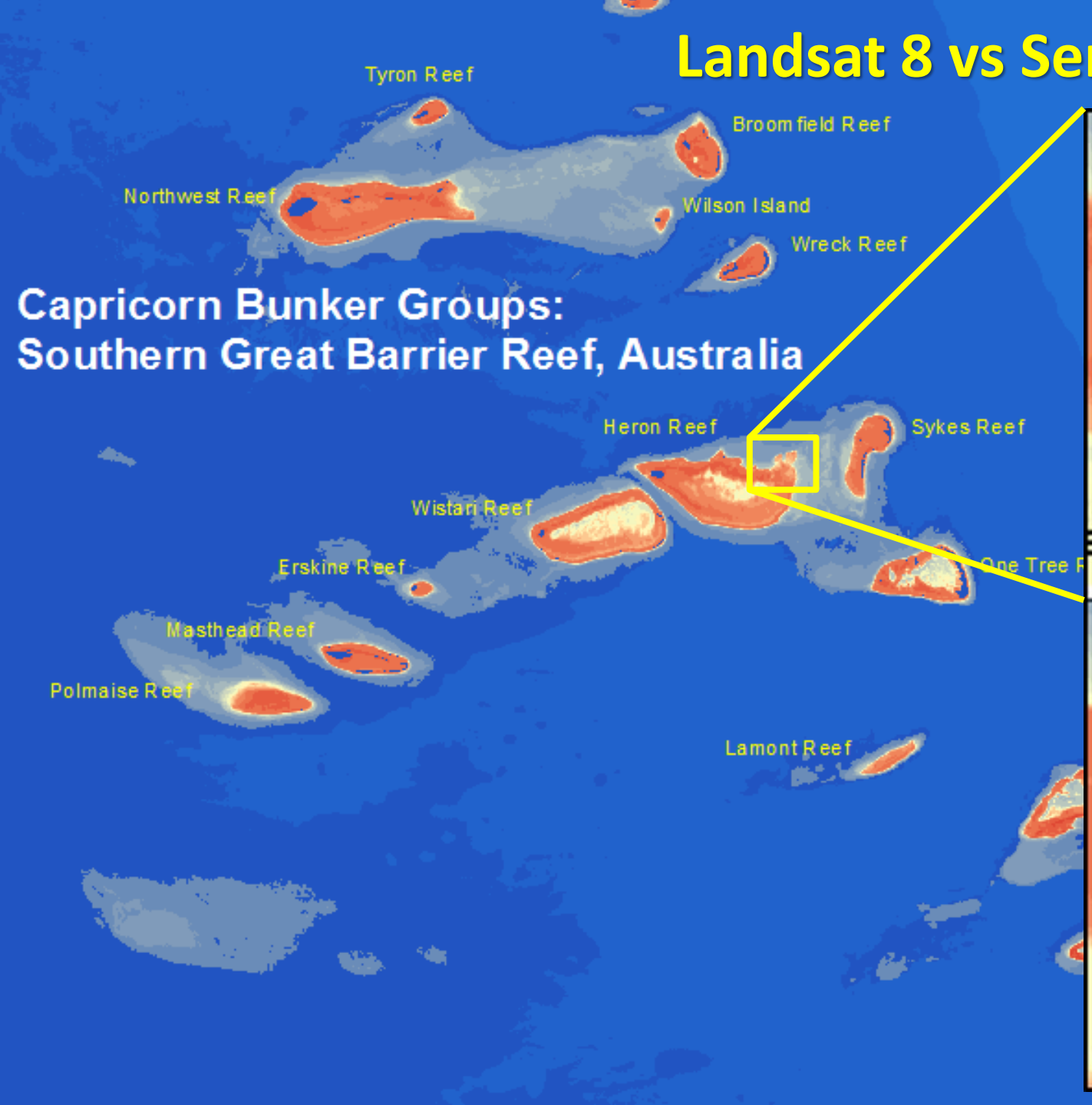
Deep Area > 20 m: 30 m grid Beaman et al.

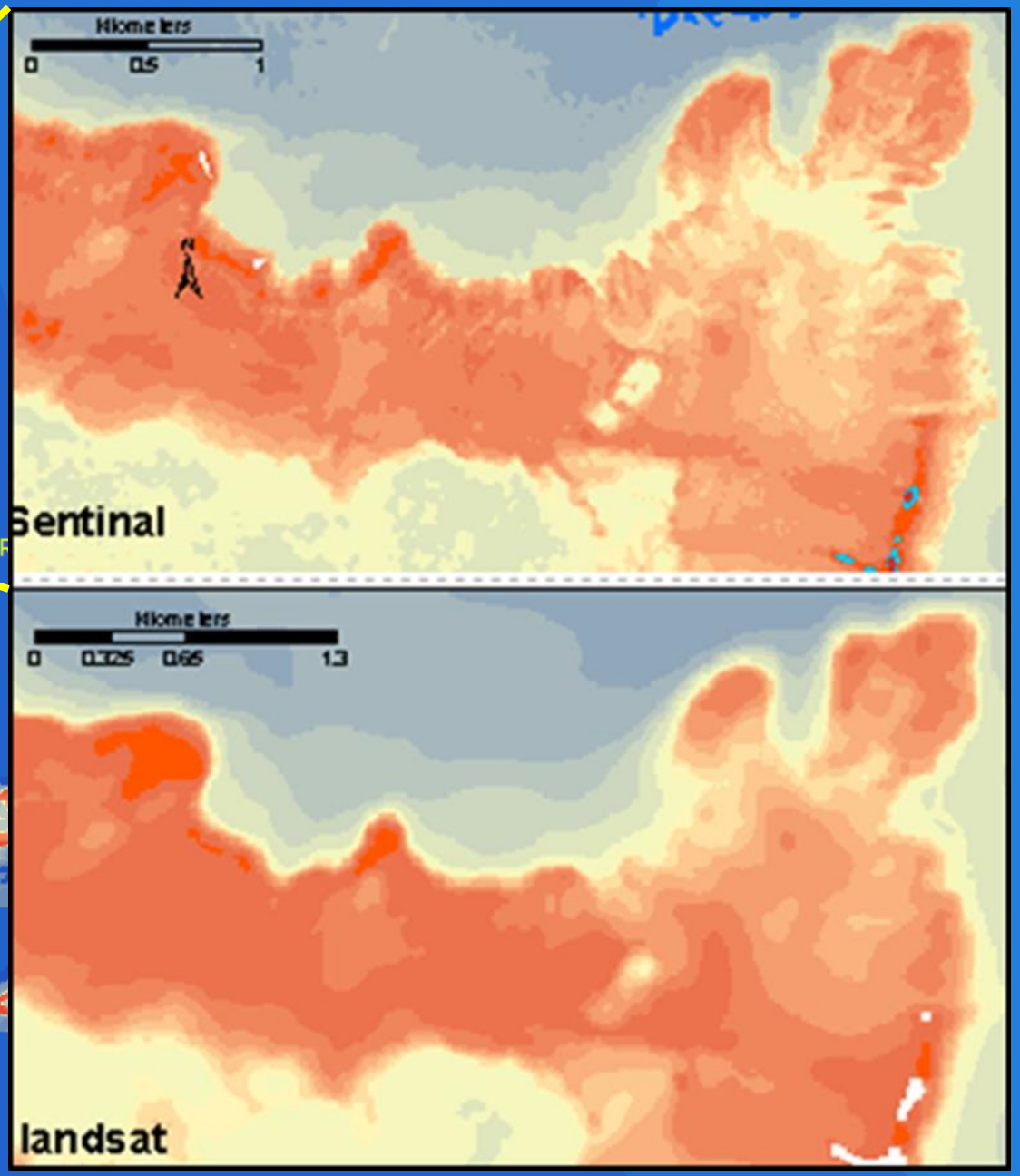
www.deepreef.org

Shallow reefs 0-20m: 15 m grid Landsat 8

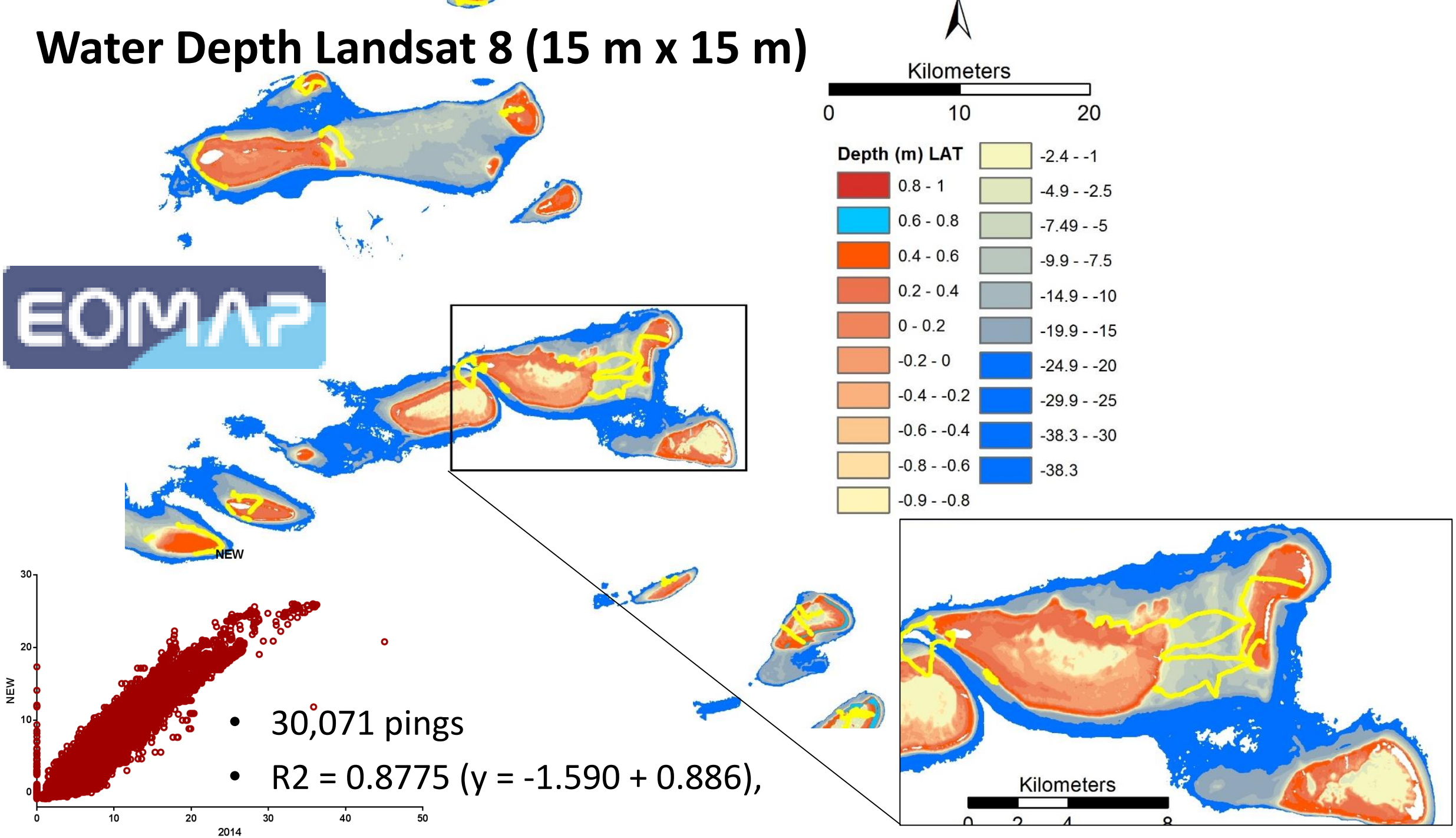
www.eomap.com

Landsat 8 vs Sentinel 2



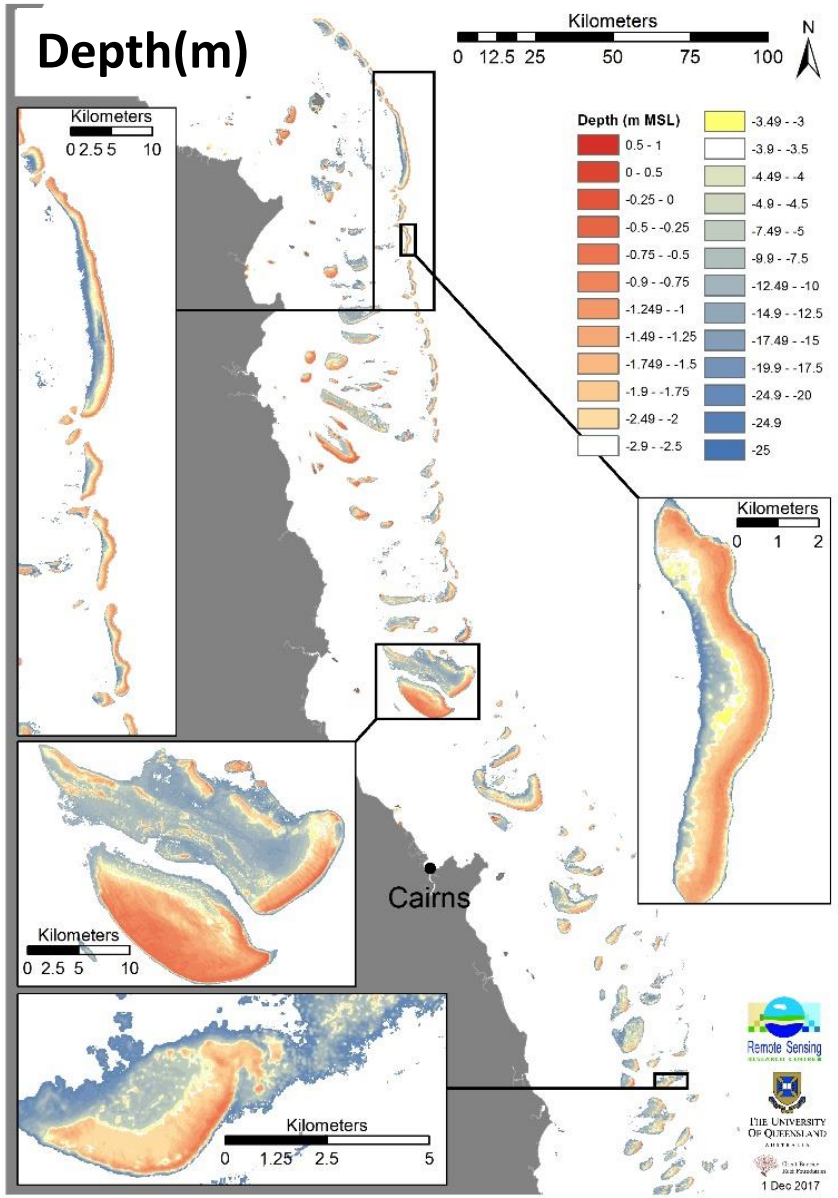


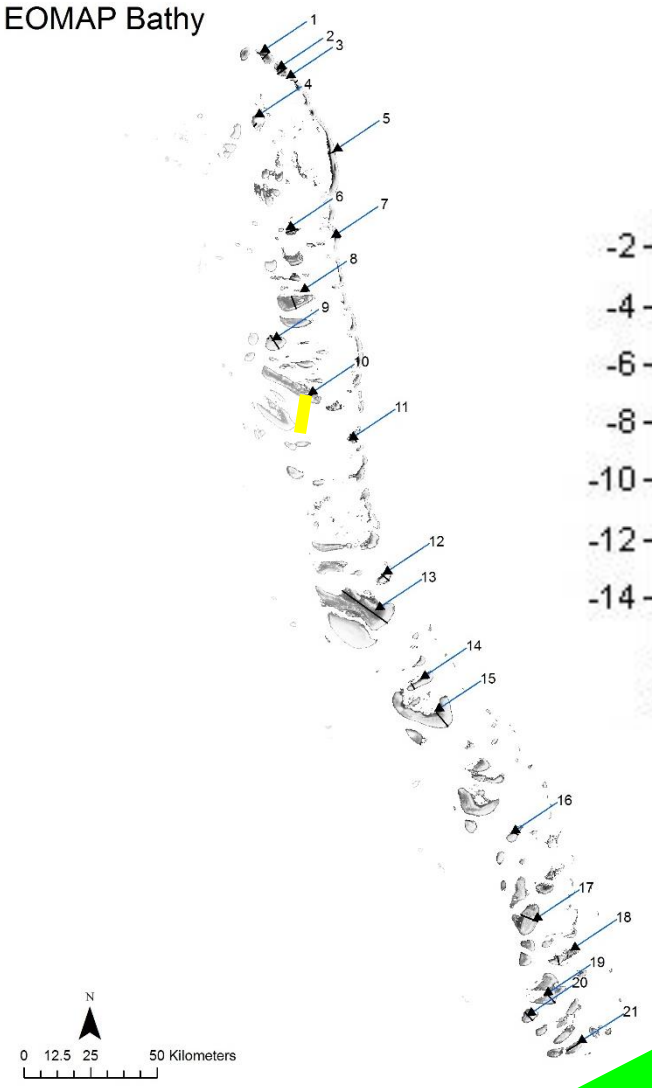
Water Depth Landsat 8 (15 m x 15 m)

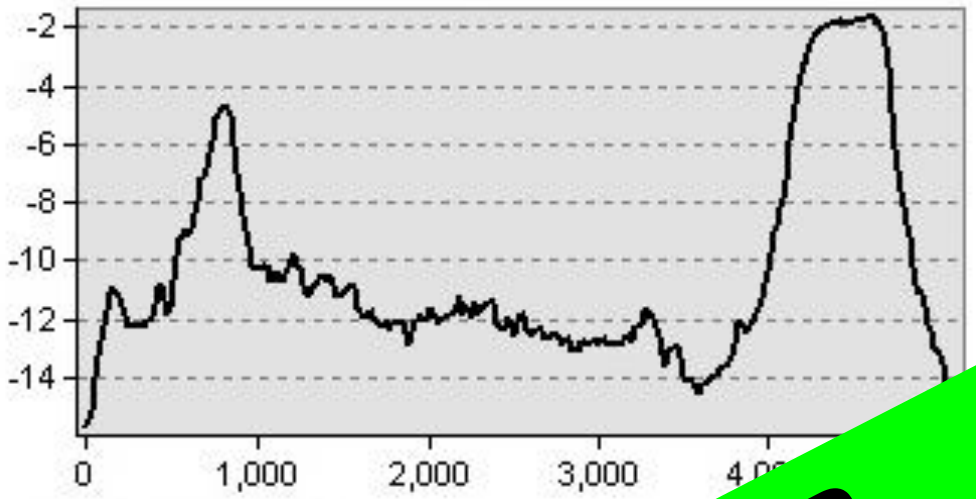


- 30,071 pings
- R2 = 0.8775 (y = -1.590 + 0.886),

Water Depth Landsat 8 (15 m x 15 m)





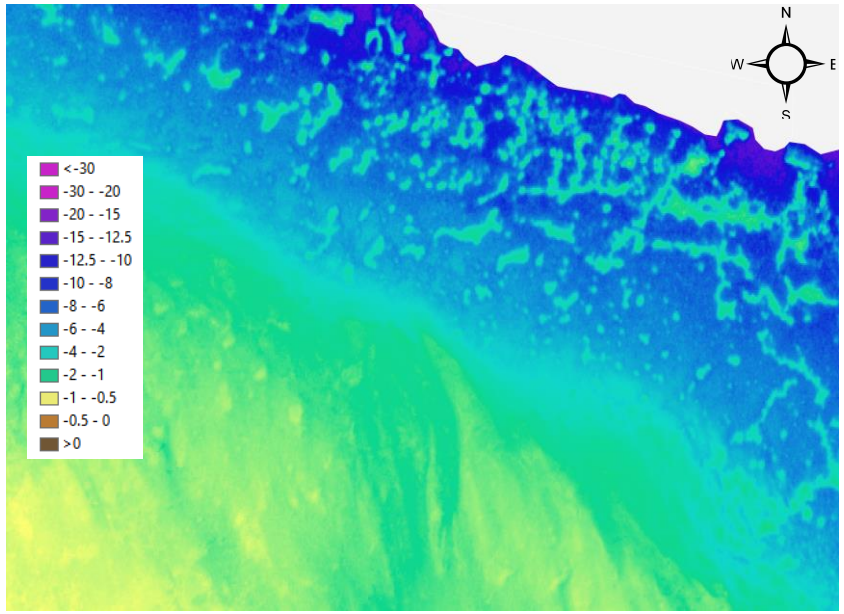


Imagine whole GBR-MP

EOMAP

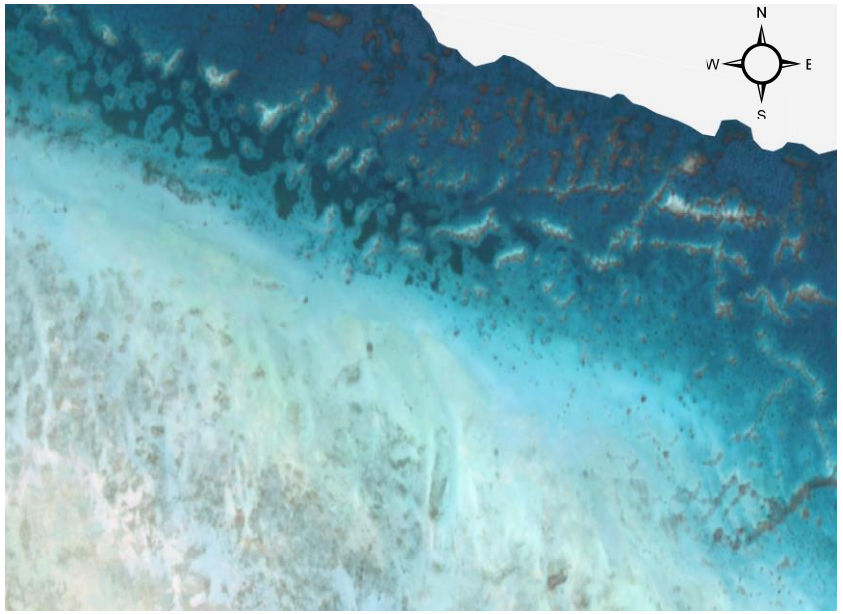
Sentinel 2 (10 m x 10 m)

Depth



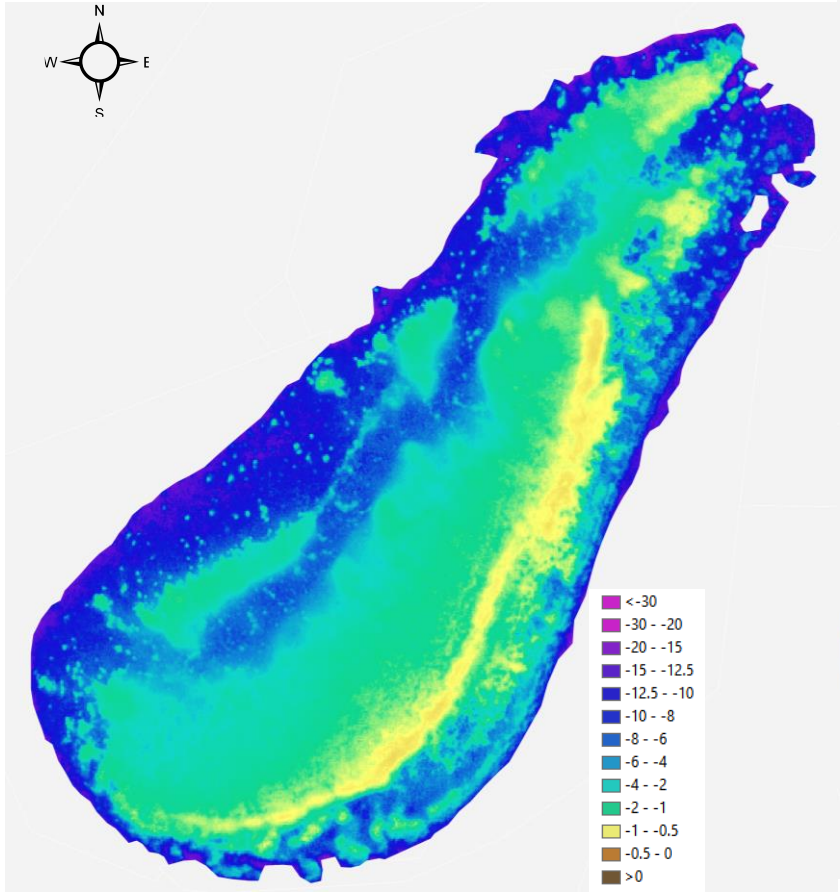
Sea Surface Reflectance

Sea Floor Reflectance

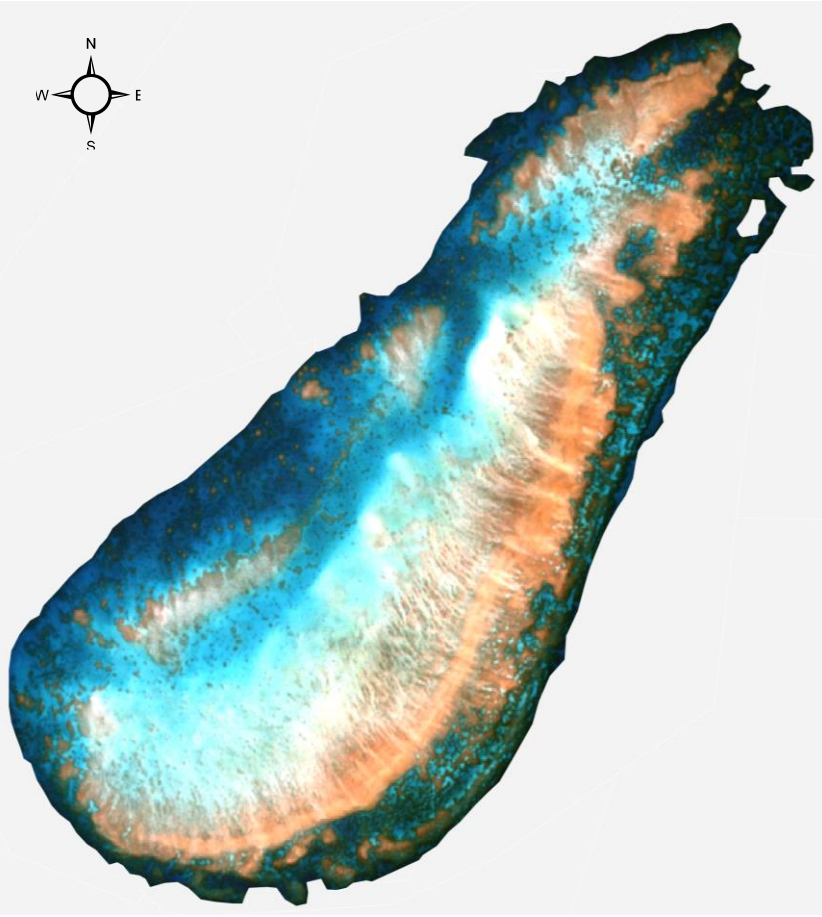


Sentinel 2 (10 m x 10 m)

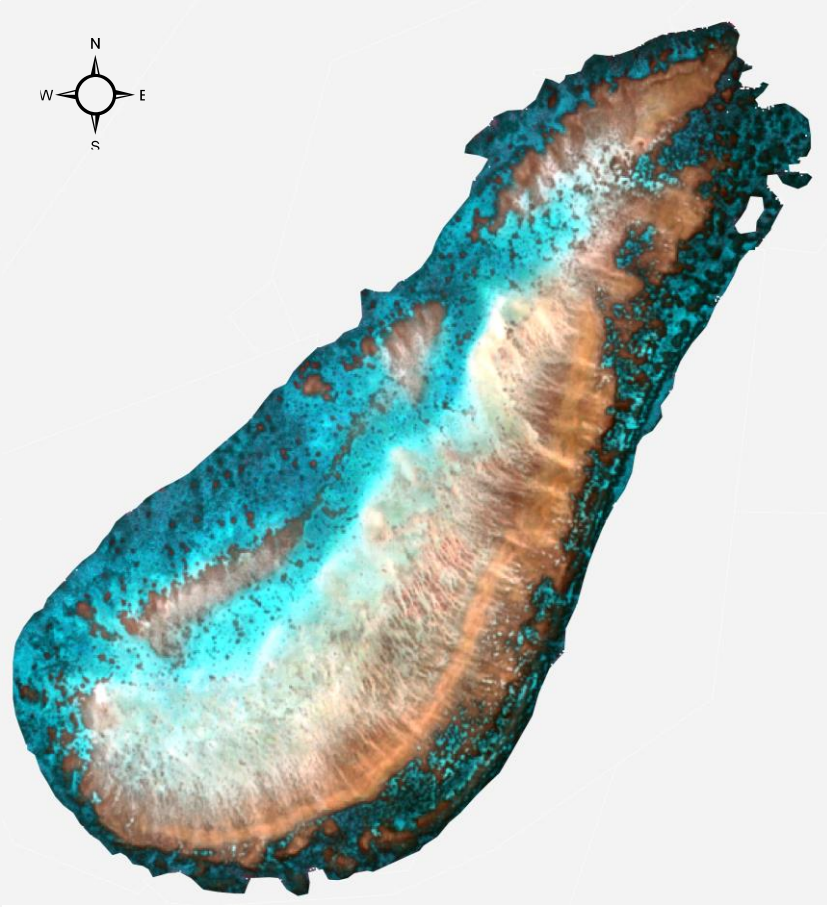
Depth



Sea Surface Reflectance

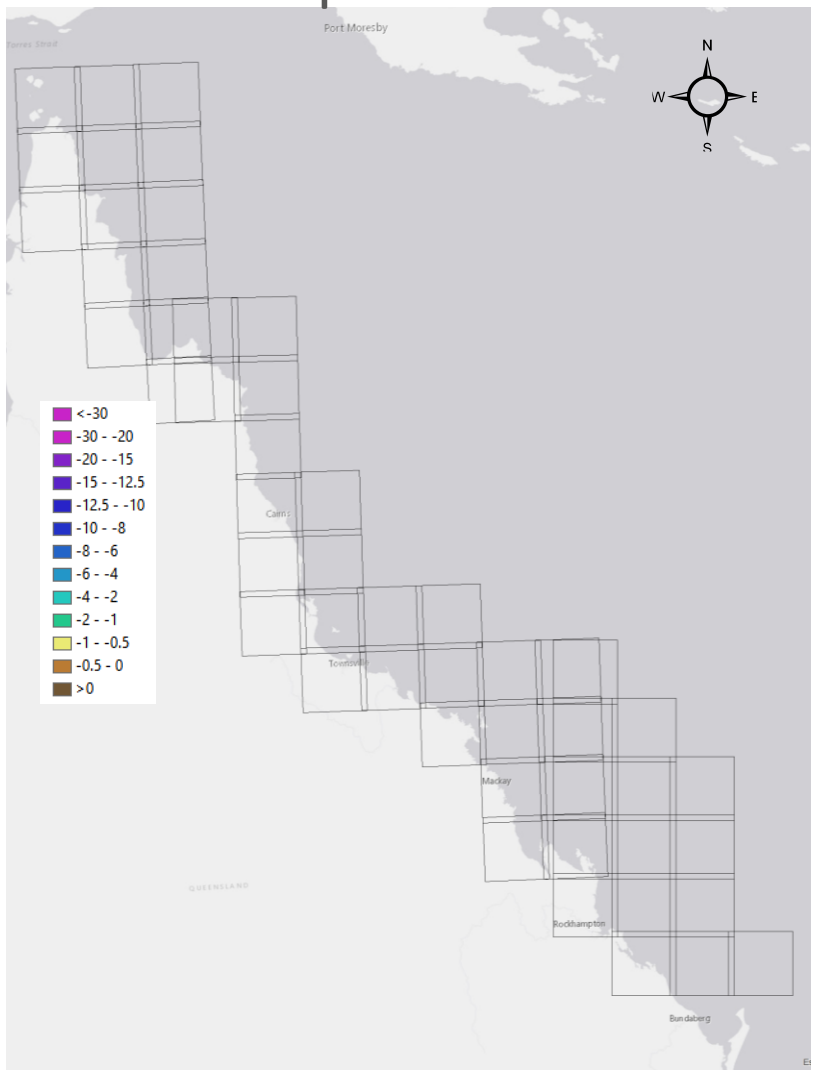


Sea Floor Reflectance

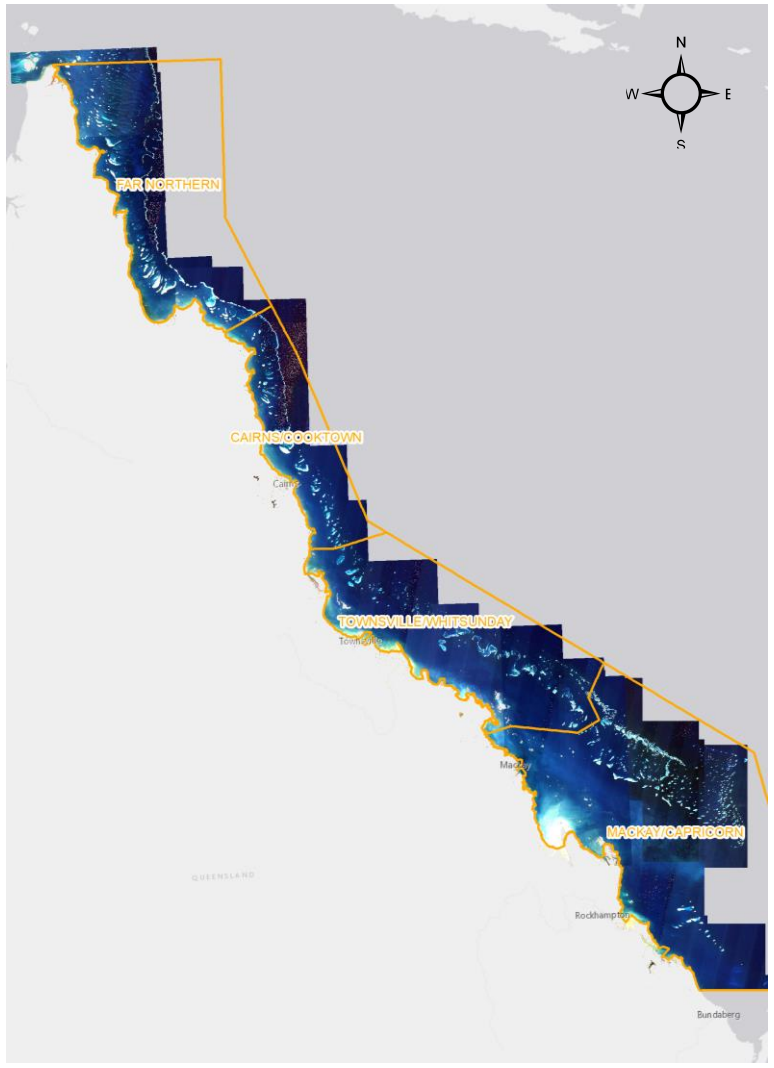


Sentinel 2 (10 m x 10 m)

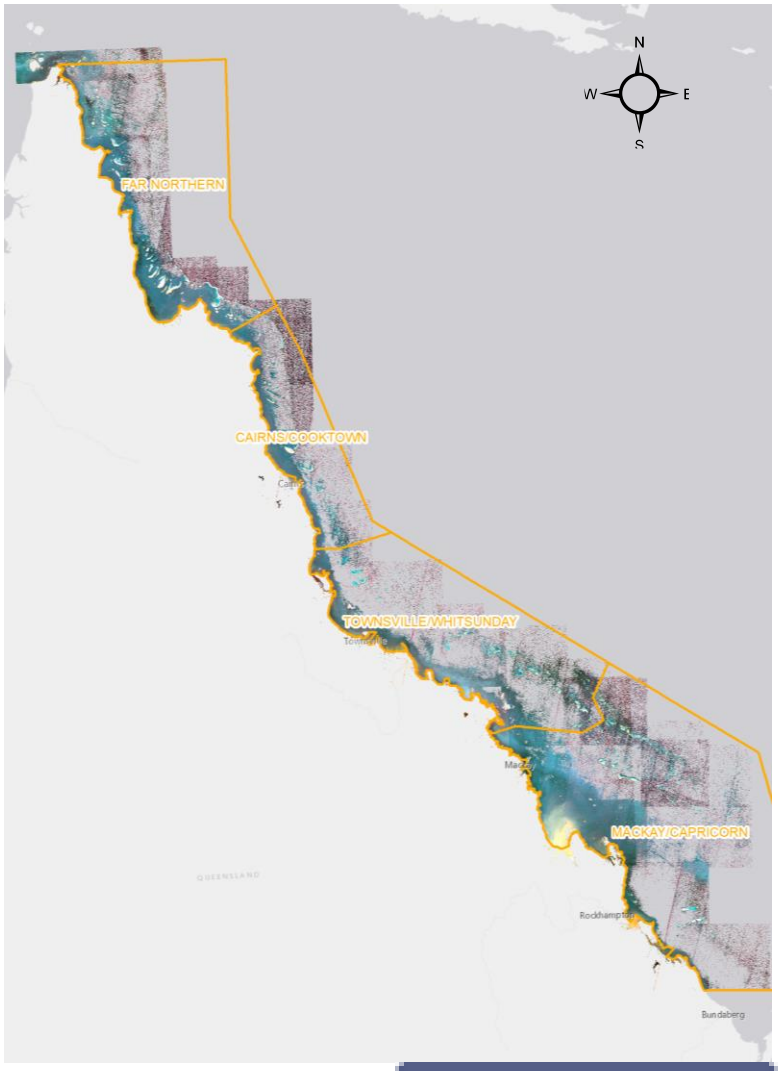
Depth



Sea Surface Reflectance



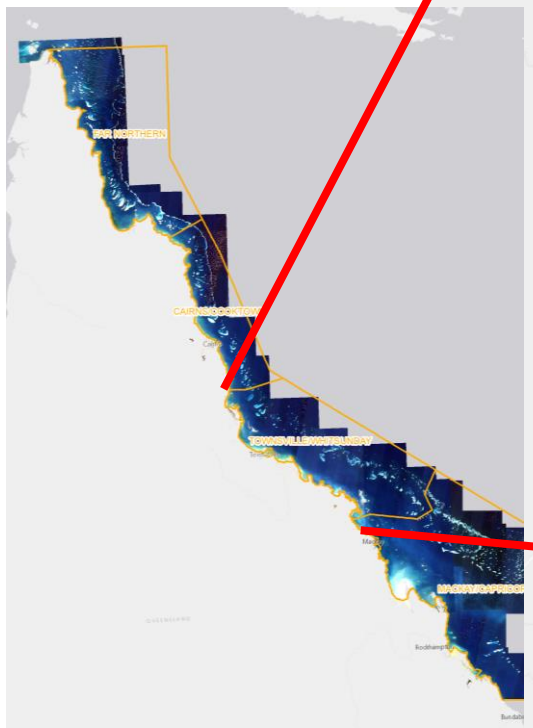
Sea Floor Reflectance

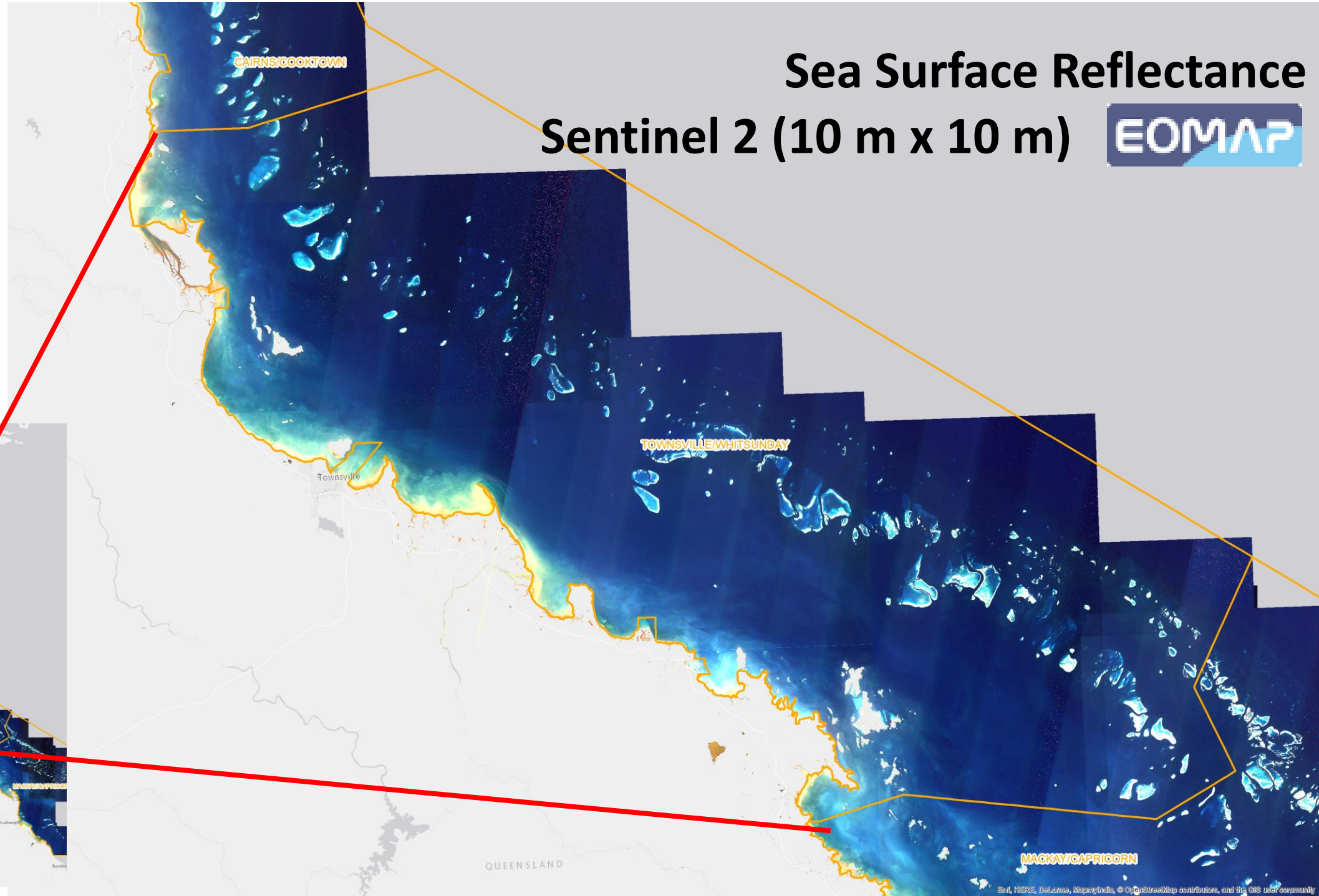


EOMAP

Sea Surface Reflectance

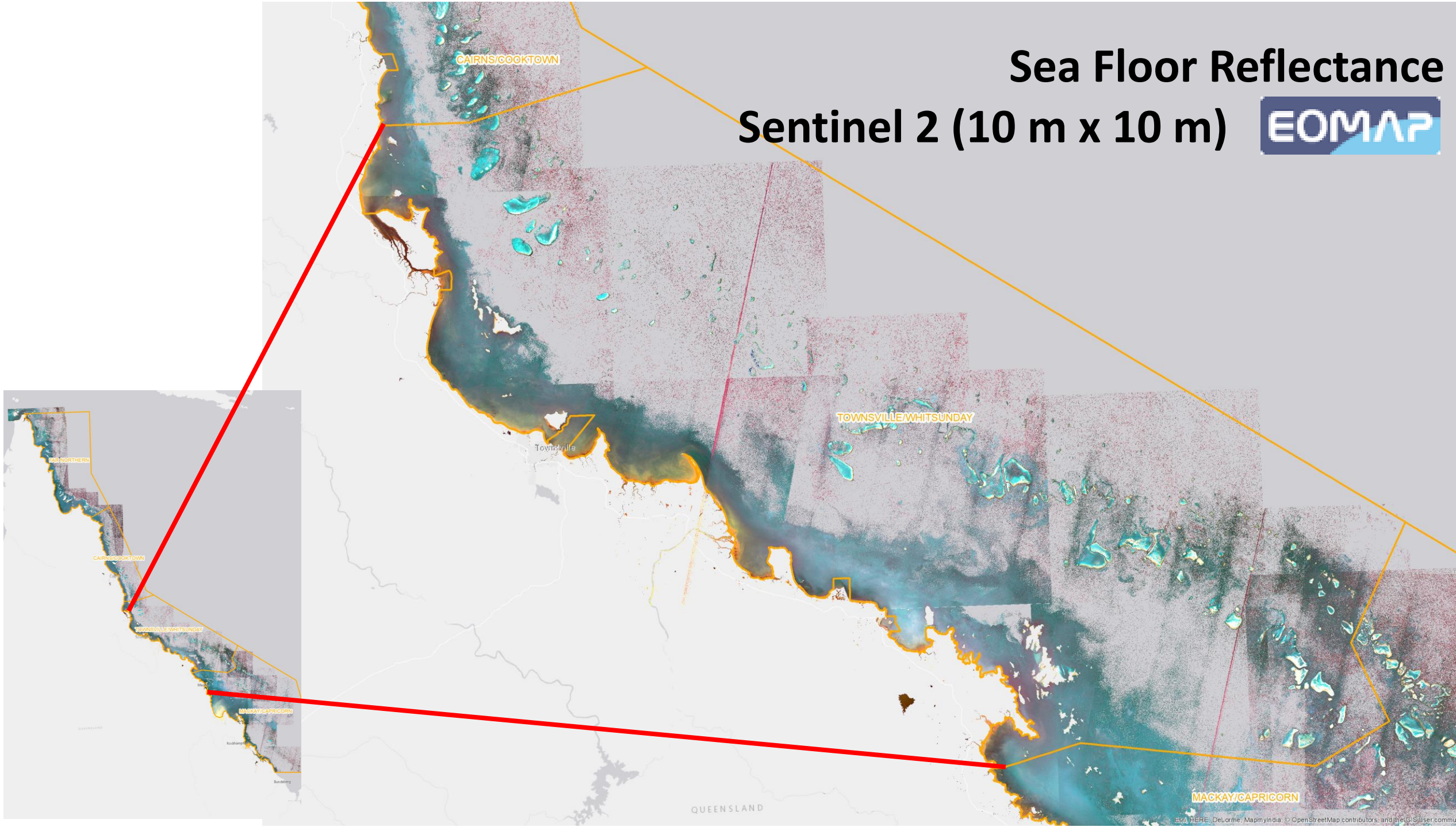
Sentinel 2 (10 m x 10 m)





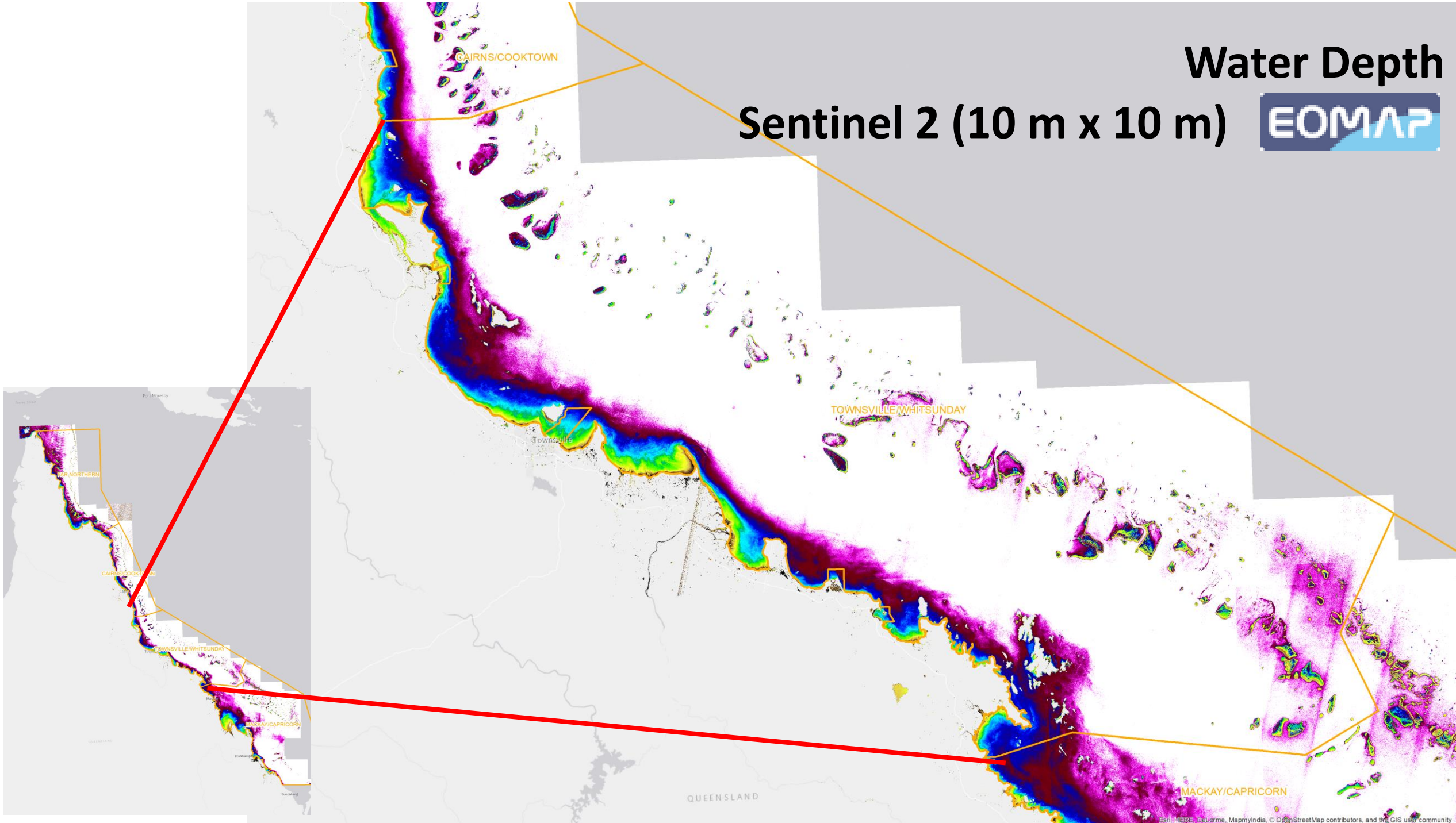
Sea Floor Reflectance

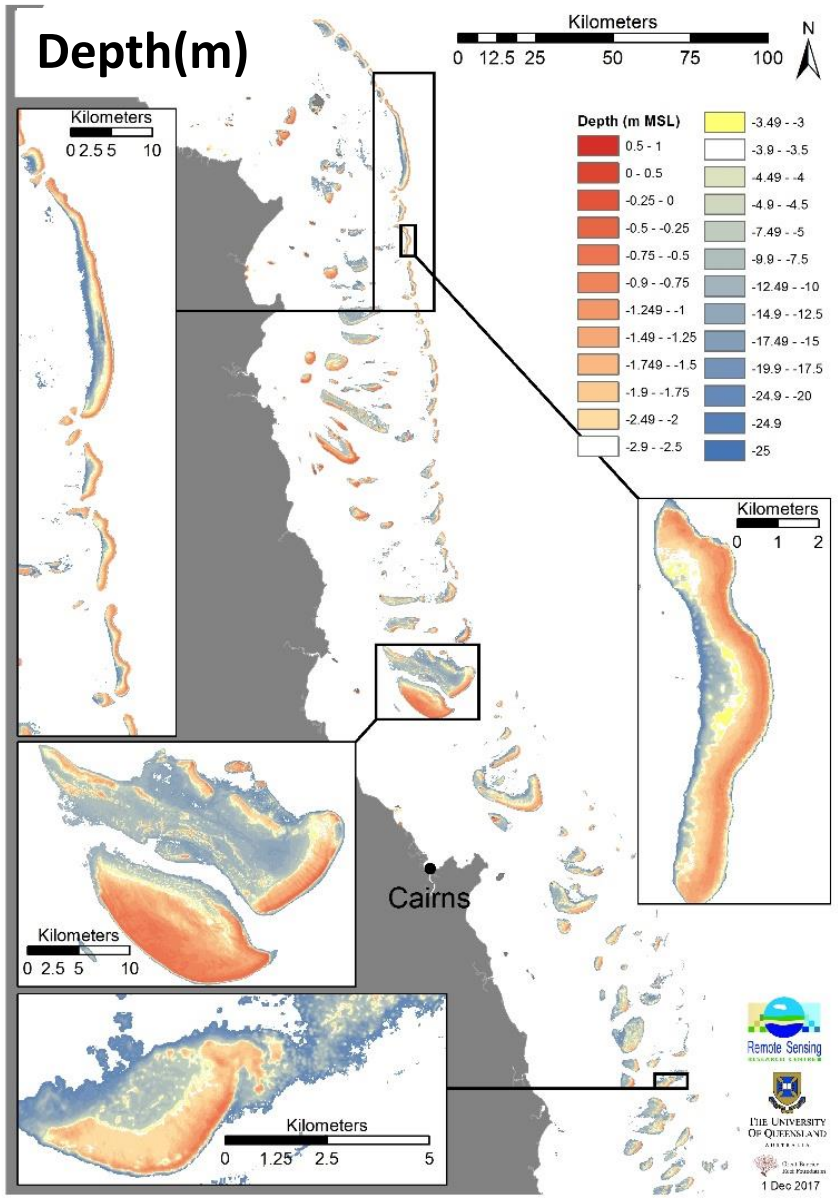
Sentinel 2 (10 m x 10 m)

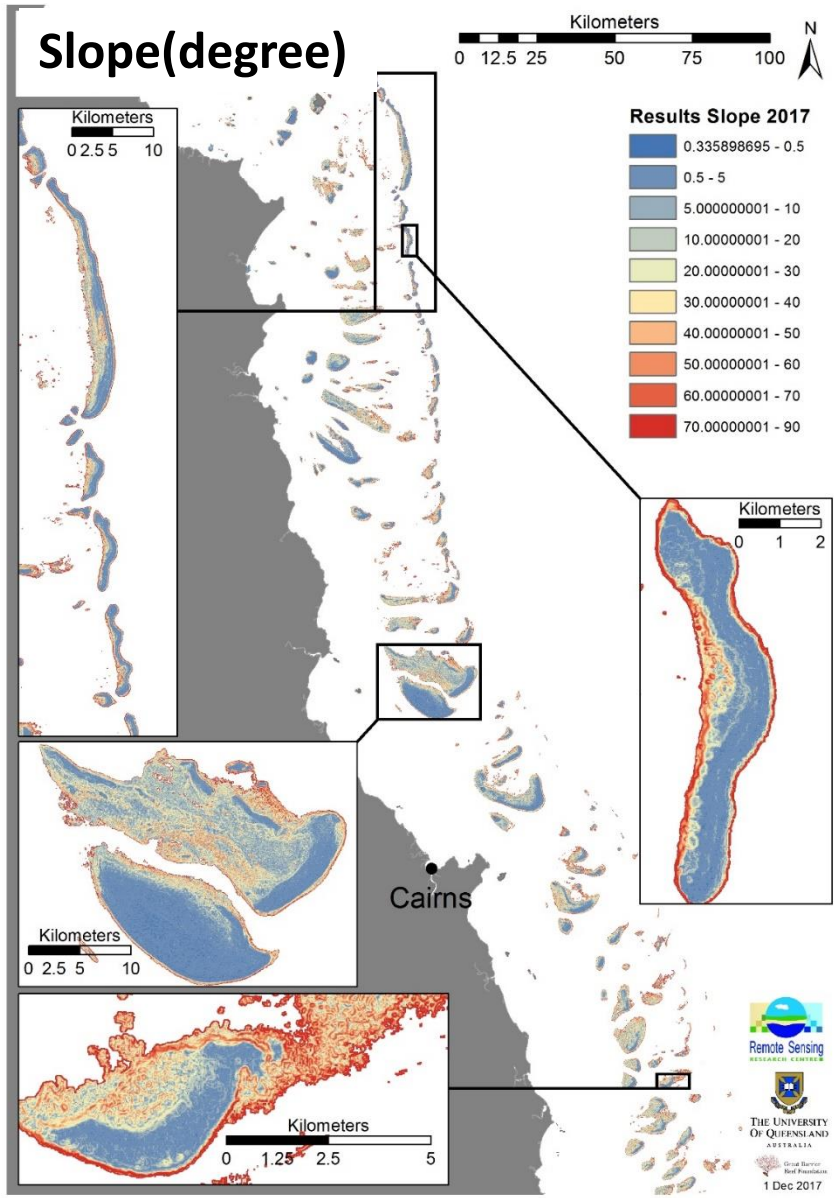


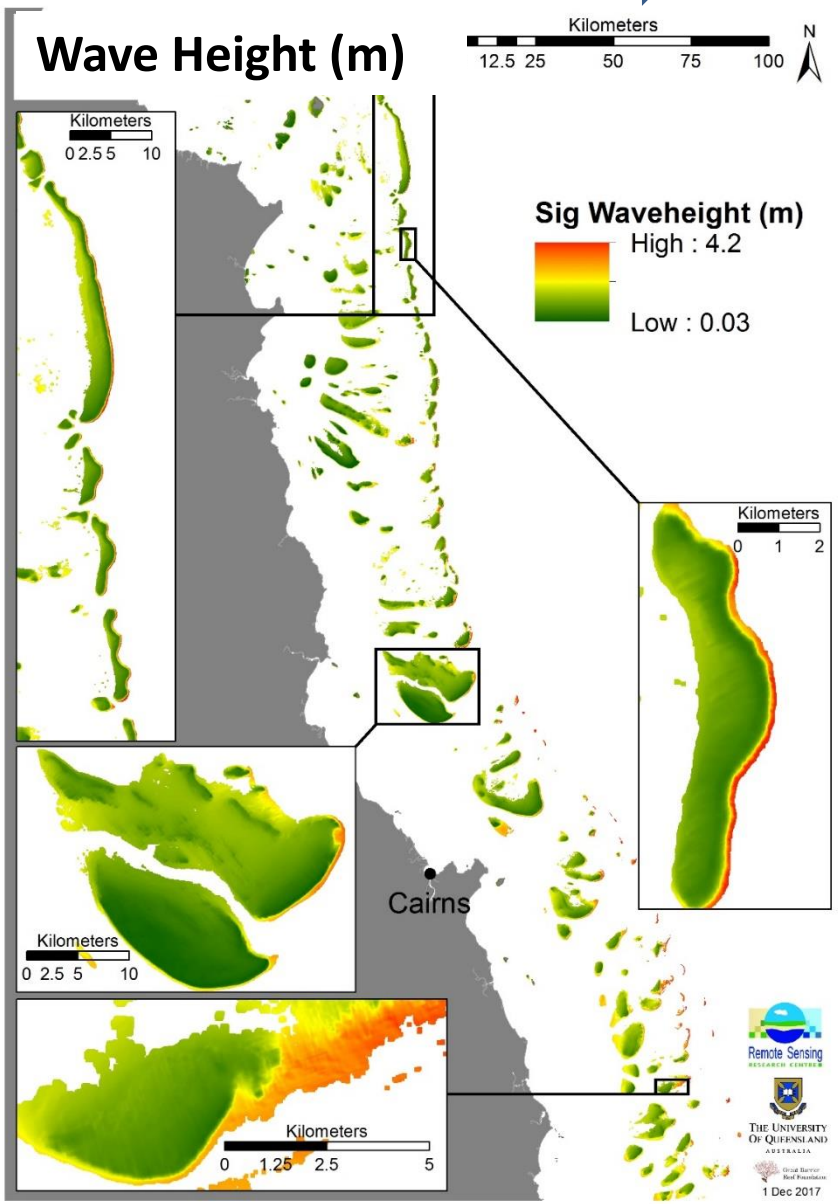
Water Depth

Sentinel 2 (10 m x 10 m)

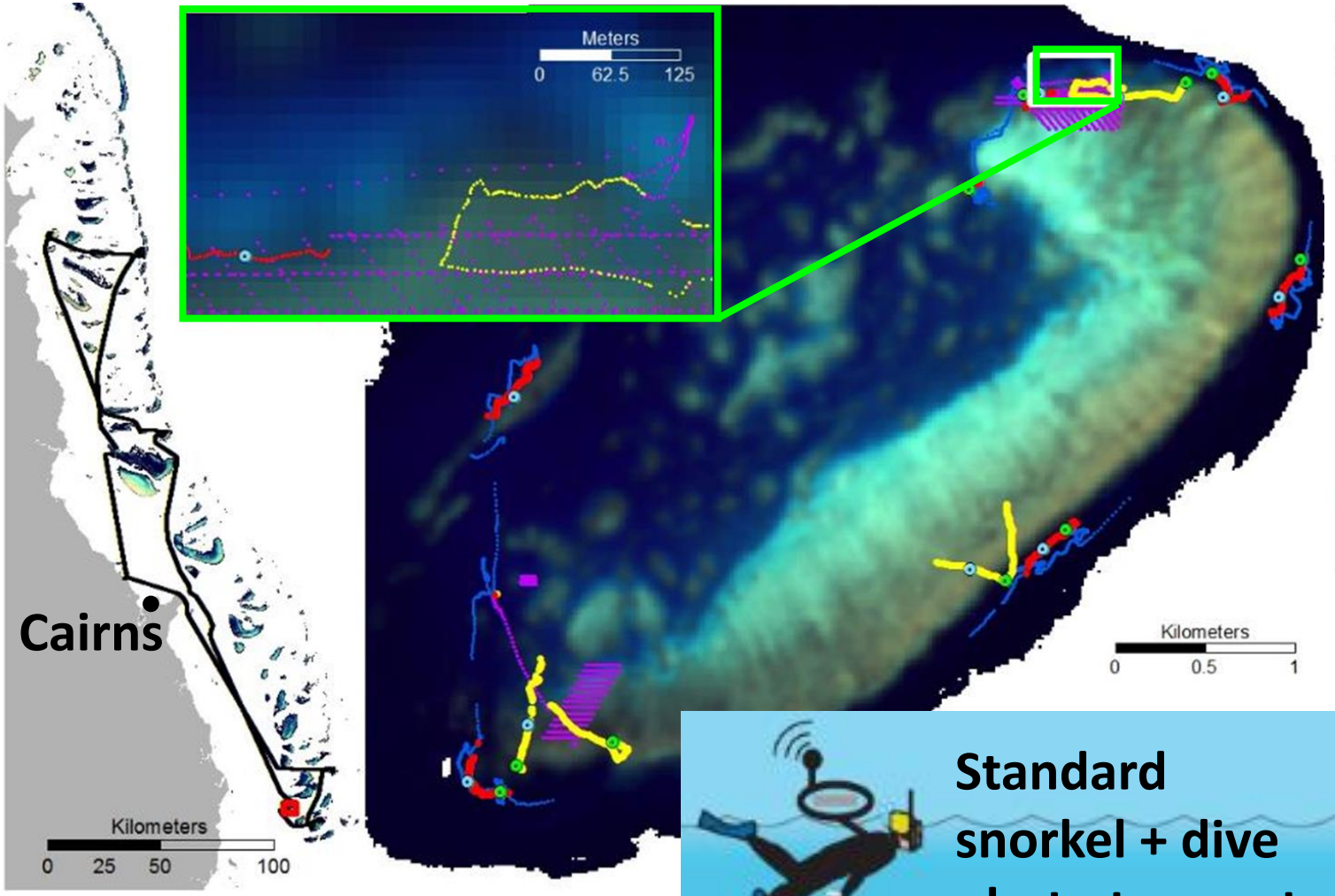


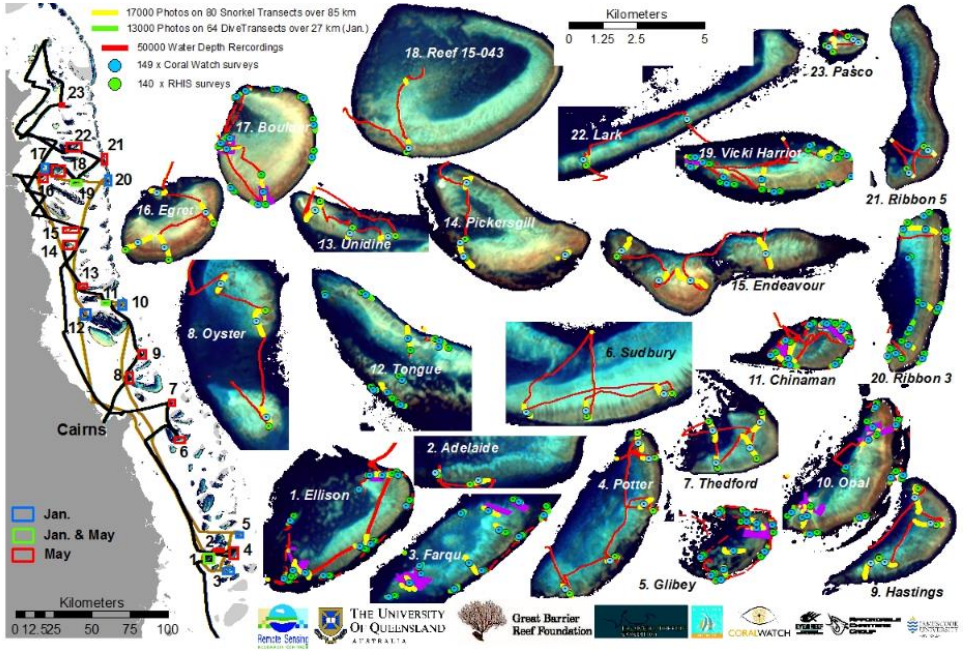

Depth(m)
Kilometers
0 12.5 25 50 75 100
N
Depth (m MSL)
0.5 - 1
0 - 0.5
-0.25 - 0
-0.5 - -0.25
-0.75 - -0.5
-0.9 - -0.75
-1.249 - -1
-1.49 - -1.25
-1.749 - -1.5
-1.9 - -1.75
-2.49 - -2
-2.9 - -2.5
-3.49 - -3
-3.9 - -3.5
-4.49 - -4
-4.9 - -4.5
-7.49 - -5
-9.9 - -7.5
-12.49 - -10
-14.9 - -12.5
-17.49 - -15
-19.9 - -17.5
-24.9 - -20
-24.9
-25
Kilometers
0 2.5 5 10
Kilometers
0 1 2
Kilometers
0 2.5 5 10
Cairns
Kilometers
0 1.25 2.5 5
Remote Sensing
The University Of Queensland
1 Dec 2017


Slope(degree)
Kilometers
0 12.5 25 50 75 100
N
Results Slope 2017
0.335898695 - 0.5
0.5 - 5
5.000000001 - 10
10.00000001 - 20
20.00000001 - 30
30.00000001 - 40
40.00000001 - 50
50.00000001 - 60
60.00000001 - 70
70.00000001 - 90
Kilometers
0 2.5 5 10
Kilometers
0 1 2
Kilometers
0 2.5 5 10
Cairns
Kilometers
0 1.25 2.5 5
Remote Sensing
The University Of Queensland
1 Dec 2017


Wave Height (m)
Kilometers
12.5 25 50 75 100
N
Sig Waveheight (m)
High : 4.2
Low : 0.03
Kilometers
0 2.5 5 10
Kilometers
0 1 2
Kilometers
0 2.5 5 10
Cairns
Kilometers
0 1.25 2.5 5
Remote Sensing
The University Of Queensland
1 Dec 2017

Benthic Field Data Collection For Calibration and Validation





e,g 23 reefs visited for Cairns section resulting 30000 geolocated photo quadrates (all online)

CORALNET ALPHA
A WEB SOLUTION FOR CORAL REEF ANALYSIS

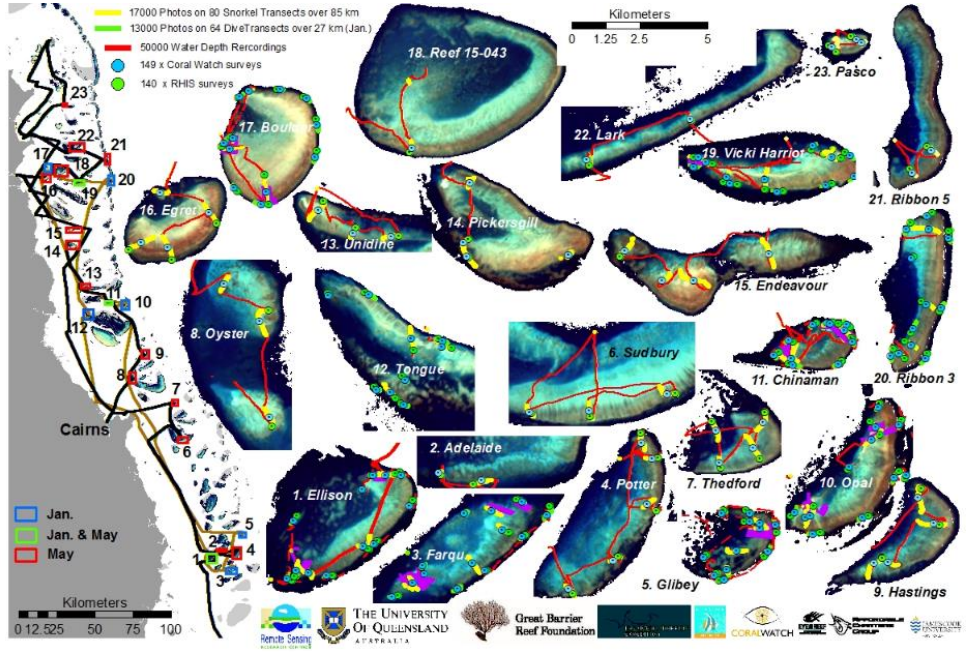
Benthic Composition Data (all online) derived via machine learning of 97%, after training 3% of photo quadrates.

Benthic Field Data Collection Existing & New From Various Sources

Australian Government
Great Barrier Reef Marine Park Authority

EYE ON THE REEF
A Great Barrier Reef Marine Park Authority Initiative

AUSTRALIAN INSTITUTE OF MARINE SCIENCE



2017 Cairns Section Data
2018 Far North GBR Legacy data
2019 Citizen science
2019 AIMS, RHIS, COTS surveys

CORALWATCH
CORAL HEALTH CHART

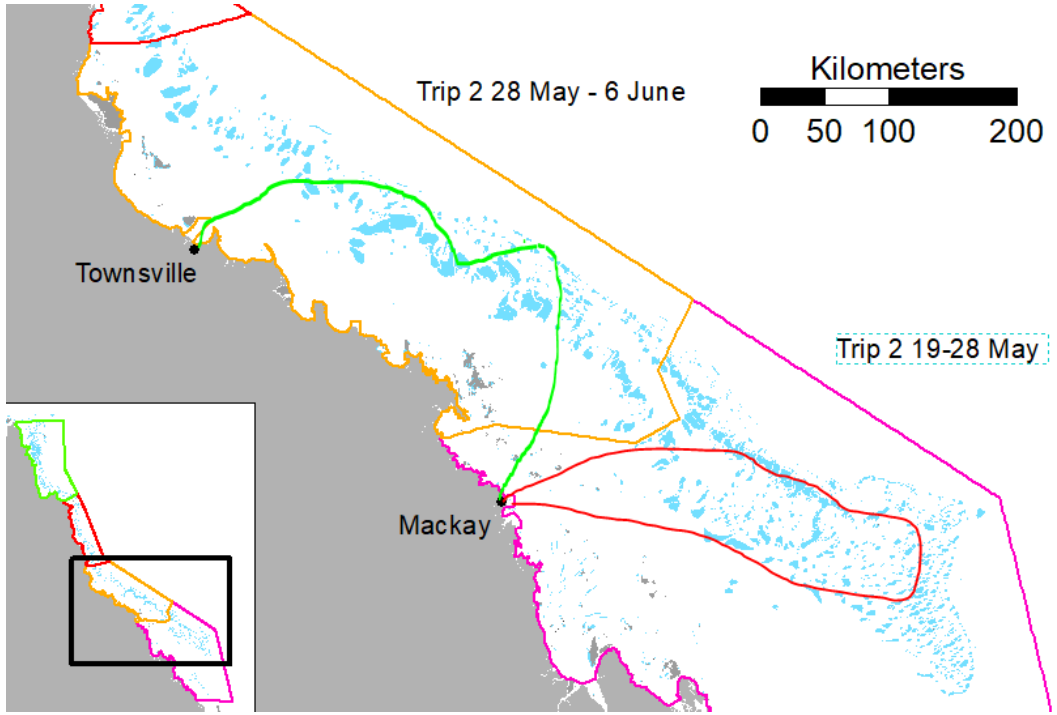
VIRTUALREEFDIVER

REEF CHECK AUSTRALIA
EMPOWERING PEOPLE TO SAVE OUR REEFS & OCEANS

Additional Field Data Collection 2019

Mv Kalinda 3 x 8 Days

- May Swains-Mackay
- June Mackay Townsville
- Dec Far North

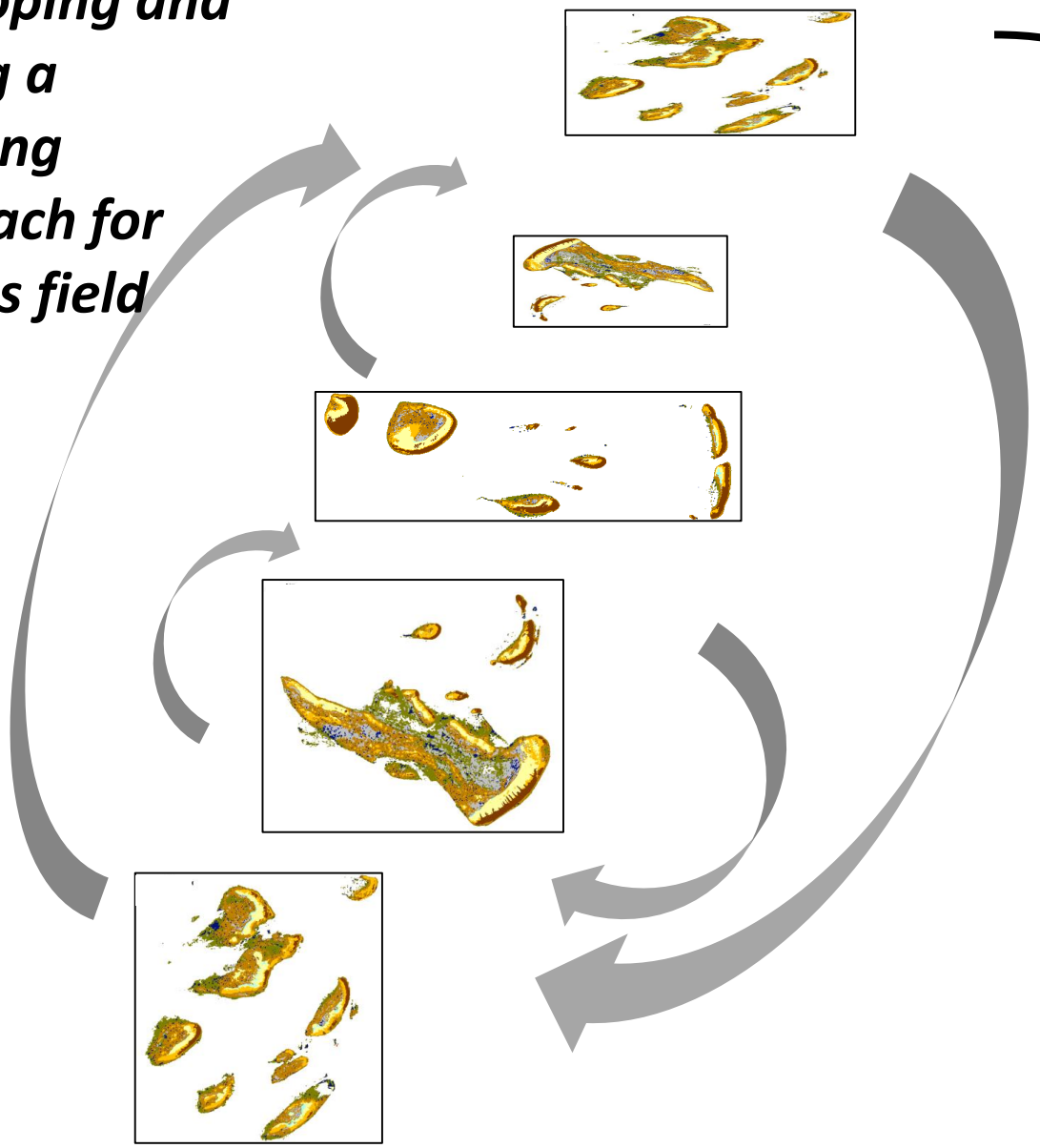


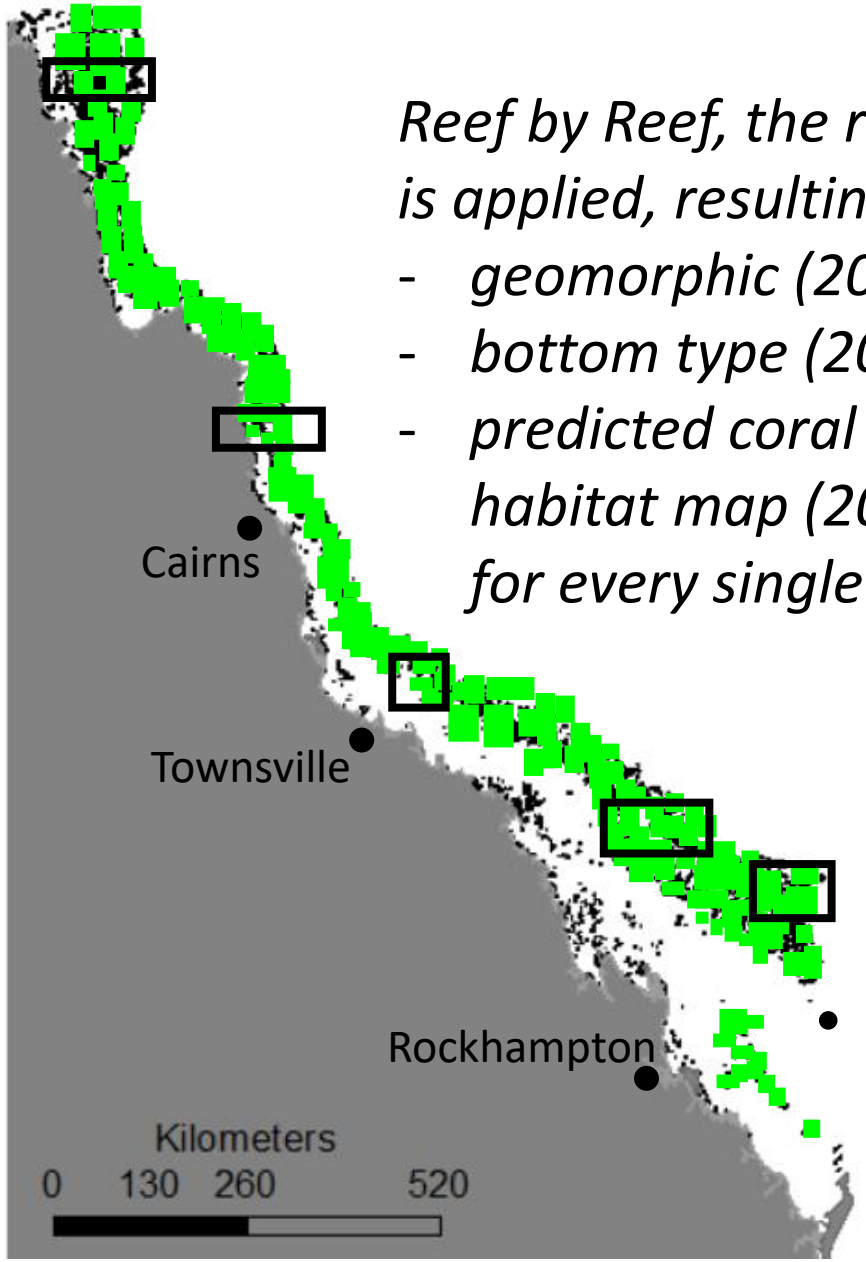
Additional but optional

- Rugosity (Markey, Gomez)
- Depth surveys (UQ)
- COTS surveys (GBRMPA)

By 2021 the 3000 GBR shallow offshore GBR reefs mapped.

Developing and testing a mapping approach for various field areas.





Reef by Reef, the rule set is applied, resulting in:

- *geomorphic (2019),*
- *bottom type (2020)*
- *predicted coral type habitat map (2021) for every single reef.*

Can we improve predictions of the future of The GBR?

- Connectivity
  - Larvae Coral, COTS *(Cairns section, UQ, CSIRO)*
  - Fish – groupers *(Cairns section, Exceter)*
- Fortunate Reefs *(Cairns section, GBRMPA)*
- Water quality model *(Cairns section, eReefs, CSIRO)*
- Marine park planning *(Cairns Section, UQ RSRC PhD study)*
- Up scaling using habitat maps of for example
  - Fish species, biomass *(Cairns section, QUT)*
  - % cover *(GBR, UQ RSRC*
  - Rugosity *(GBR, UQ*
  - CCA, Turf *(GB*
- Carbon production *UQ, Exceter, QUT)*
- Restoration site selection *(GBR, UQ, SCU, GBRF)*
- Geomorphic structure juvenile and mature reefs *(GBR, UQ RSRC PhD study)*
- *Etc etc*

Collectively we are working on it

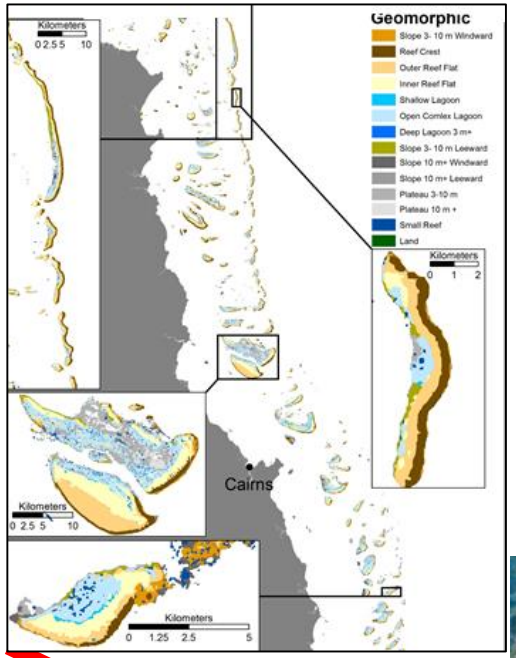
Summary

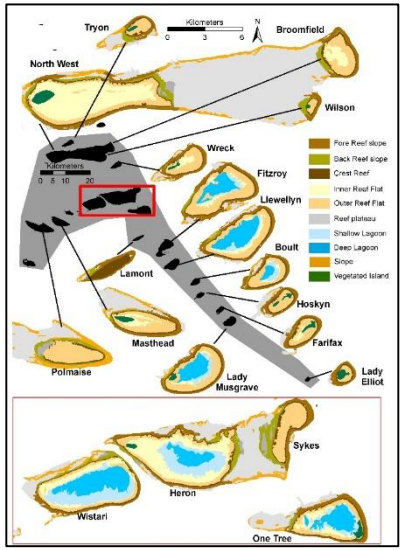
Semi automated approach: satellite imagery + field data + object based analysis + physical attributes + geo-ecological modelling

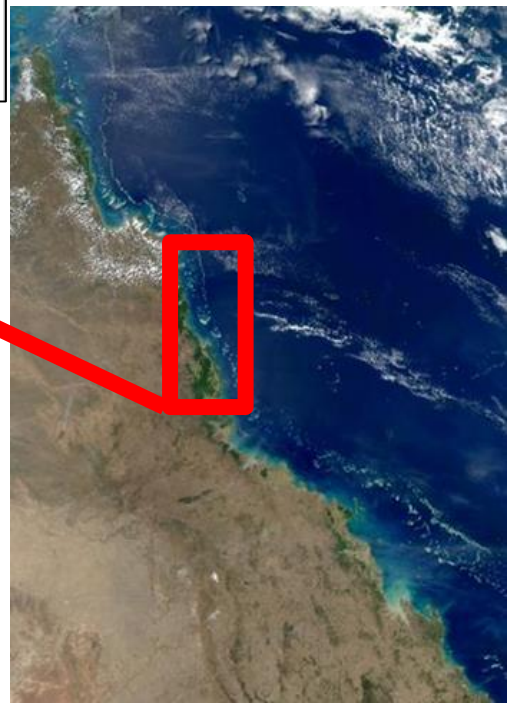
Depth is crucial physical attribute and slope + wave height are derived from it.

3000 Reefs: geomorphic (2019) and benthic (2021) funded and accessible through GBRMPA

Creating new & unique, publically accessible large data sets to improve predictions of the future of the GBR.







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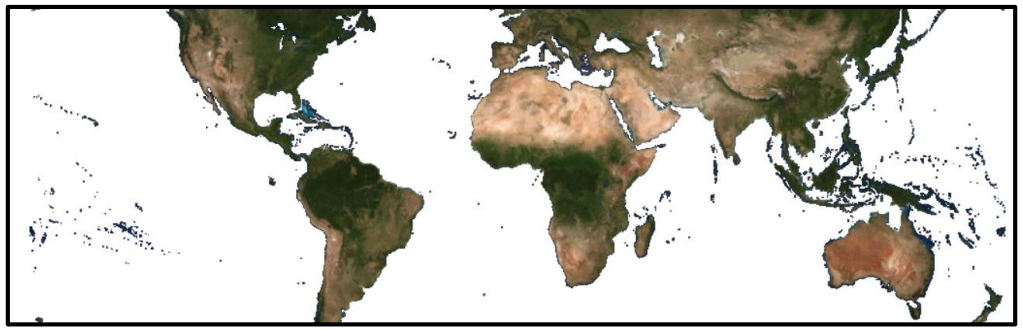
Creating new & unique, publically accessible large data sets to improve predictions of the future of the GBR.

GBR mapping methods form basis for the Allen Coral Atlas, a Global Reef Mapping Project



Acknowledgements & Contacts

- Funding :

Australian Government
Great Barrier Reef Marine Park Authority

Great Barrier Reef Foundation

- Funding for field data and image data collection and analysis: University of Wollongong, Heron Island Research Station; Mv Kalinda, Mv Fleur de Passion, Mv Flying Fish, Ocean Mapping Expedition, Digital Globe, Coral Watch & Reef Check Australia Volunteers, Coral Reef Airborne Laboratory, Trimble eCognition.

- Dr. Megan Saunders, Dr. John Hedley, Douglas Stetner, Josh Passenger, Stephano Freguia, Peran Bray, Monique Grol, Breanne Vincent, Diana Kleine, and many others SEES general staff

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The University of Queensland
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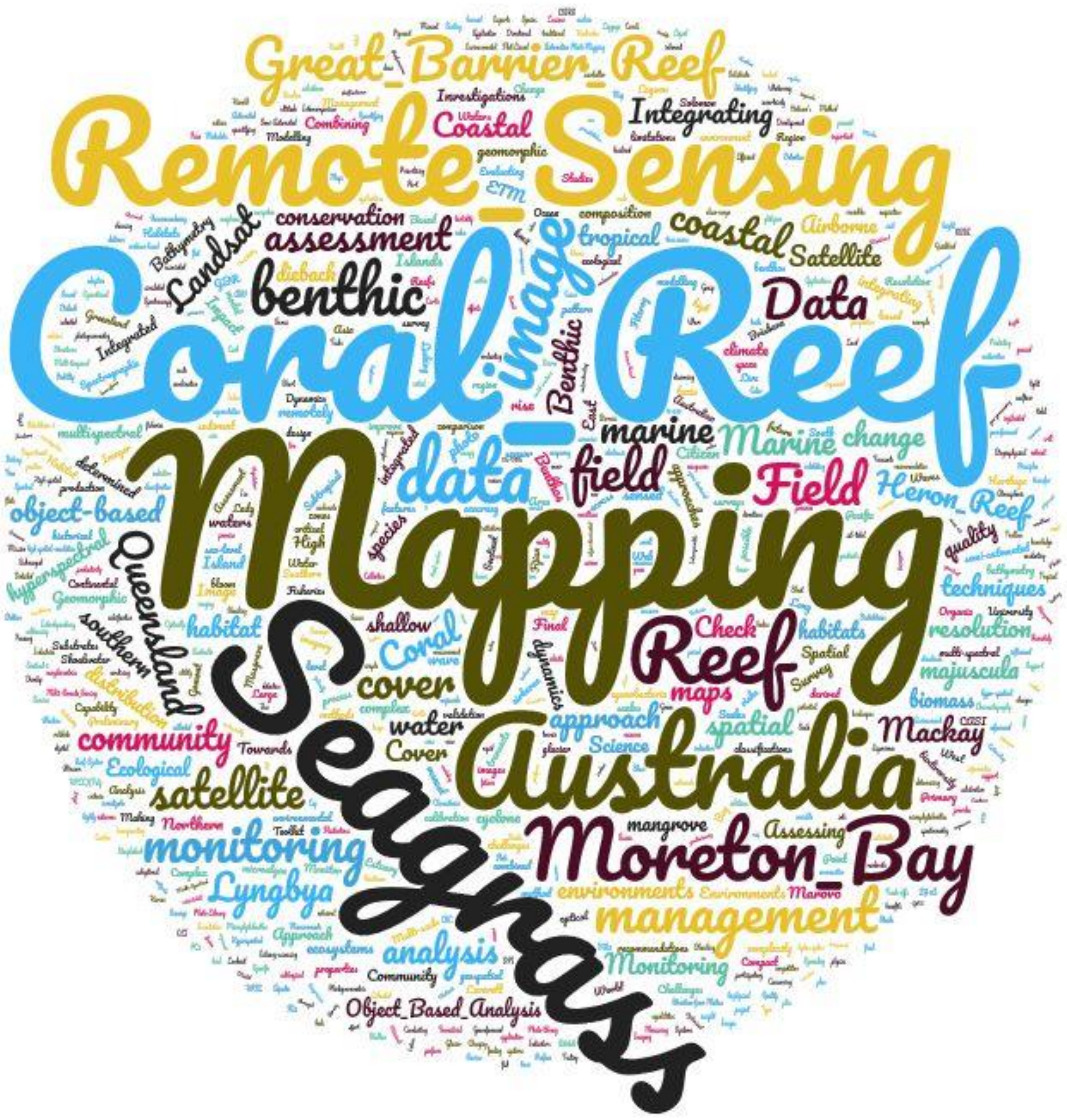
twitter @chris.roelfsema @RSRC_UQ

Remote Sensing RESEARCH CENTRE

THE UNIVERSITY OF QUEENSLAND AUSTRALIA


Coral_Reef
Mapping
Seagrass
Remote_Sensing
Australia
Great_Barrier_Reef
Moreton_Bay
Reef
image
data
benthic
Data
field
Field
Marine
marine
coastal
Coastal
assessment
conservation
Landsat
Integrating
Heron_Reef
monitoring
management
satellite
community
cover
Queensland
Lyngbya
object-based
hyperspectral
habitat
habitats
Coral
analysis
Monitoring
Object_Based_Analysis
environments
mangrove
Mackay
spatial
approach
techniques
resolution
majuscula
biomass
tropical
Satellite
Airborne
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Ecological
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Science
Check
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