

Three-dimensional analysis of reef fish spawning aggregation sites in Belize and the Cayman Islands



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Fish spawning aggregation (FSA)

- A group of conspecific fish gathered for the purpose of spawning with fish densities or numbers significantly higher than those found in the area of aggregation during non-reproductive periods (Domeier & Colin 1997).
- → Resident Spawning Aggregations
- → Transient Spawning Aggregations

Transient spawning aggregations

- Relatively large body size
- Migrate relatively long distance
- 3x abundance
- Specific time of year
 - One/two weeks of a year (2-3 consecutive months. depend on species)
 - Lunar cycle
- Same places
- (maybe) only the known reproductive chance for the species
- Highly predictable

FSAs (Video)

QuickTime™ and a
decompressor
are needed to see this picture.

Table 1. Species reported in interviews and in published and gray literature that spawn in aggregations as determined on the basis of direct or indirect criteria for spawning (see text for definitions), including number of records and countries noted for each species.*

Family and genus and species	Records	Countries	Family and genus and species	Records	Countries
Acanthuridae			<i>Hipposcarus longiceps</i>	2	1
<i>Acanthurus babianus</i>	1	1	<i>Scarus iserti</i>	2	2
<i>A. coeruleus</i>	2	2	<i>S. prasignathos</i>	1	1
<i>A. guttatus</i>	3	1	<i>Sparisoma rubripinne</i>	1	1
<i>A. triostegus</i>	1	1	Serranidae		
<i>A. lineatus</i>	2	2	<i>Epinephelus adscensionis</i>	1	1
<i>Chromocentrus stellatus</i>	2	2	<i>E. guttatus</i>	1	1

Florida, Caribbean, Bahamas

Lujanidae

	Record	Countries
<i>Lutjanus analis</i>	18	4
<i>L. Cyanopterus</i>	13	2
<i>L. Griseus</i>		10 2
<i>L. Jocu</i>	6	3
<i>L. Synagris</i>	15	2

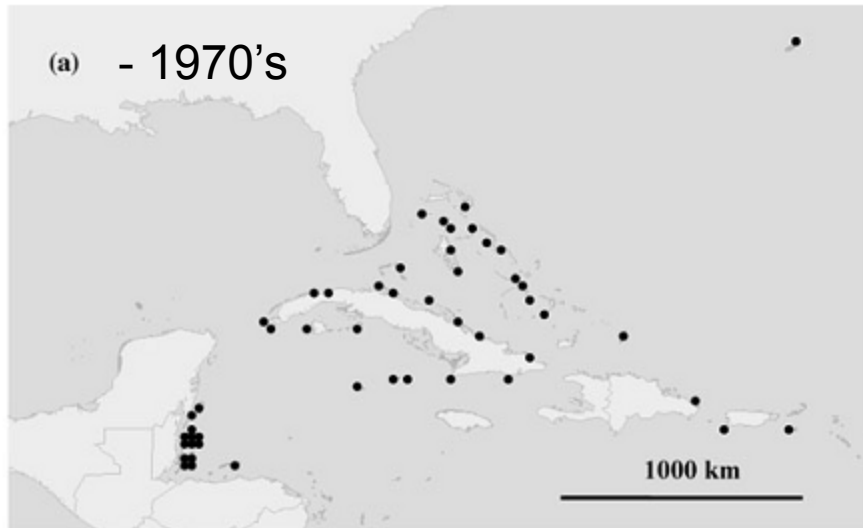
Serranidae

<i>Epinephelis guttatus</i>	4	3
<i>E. itajara</i>		3 1
<i>E. striatus</i>	47	8
<i>Mycteroperca bonaci</i>	12	5
<i>M. tigris</i>	5	5
<i>M. venenosa</i>	12	5

Cayman Islands, Cuba, Egypt, Fiji, Indonesia, Jamaica, Japan, Kiribati, Malaysia, Maldives, Marshall Islands, Mexico, Micronesia (Kosrae, Pohnpei, Chuuk), New Caledonia, Palau, Papua New Guinea, Puerto Rico, Seychelles, Solomon Islands, Turks and Caicos Islands, and United States including Virgin Islands.

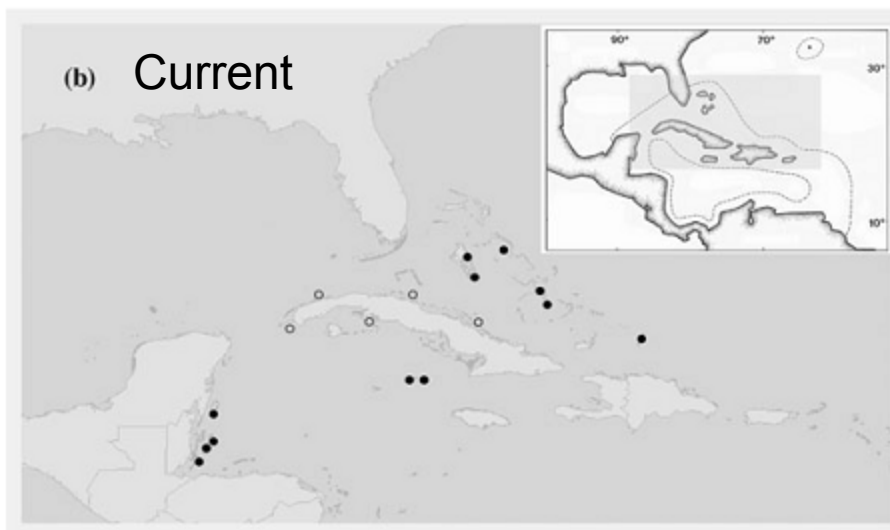
Sadovy et al. 2008

FSA sites in the Caribbean



Many sites are gone.

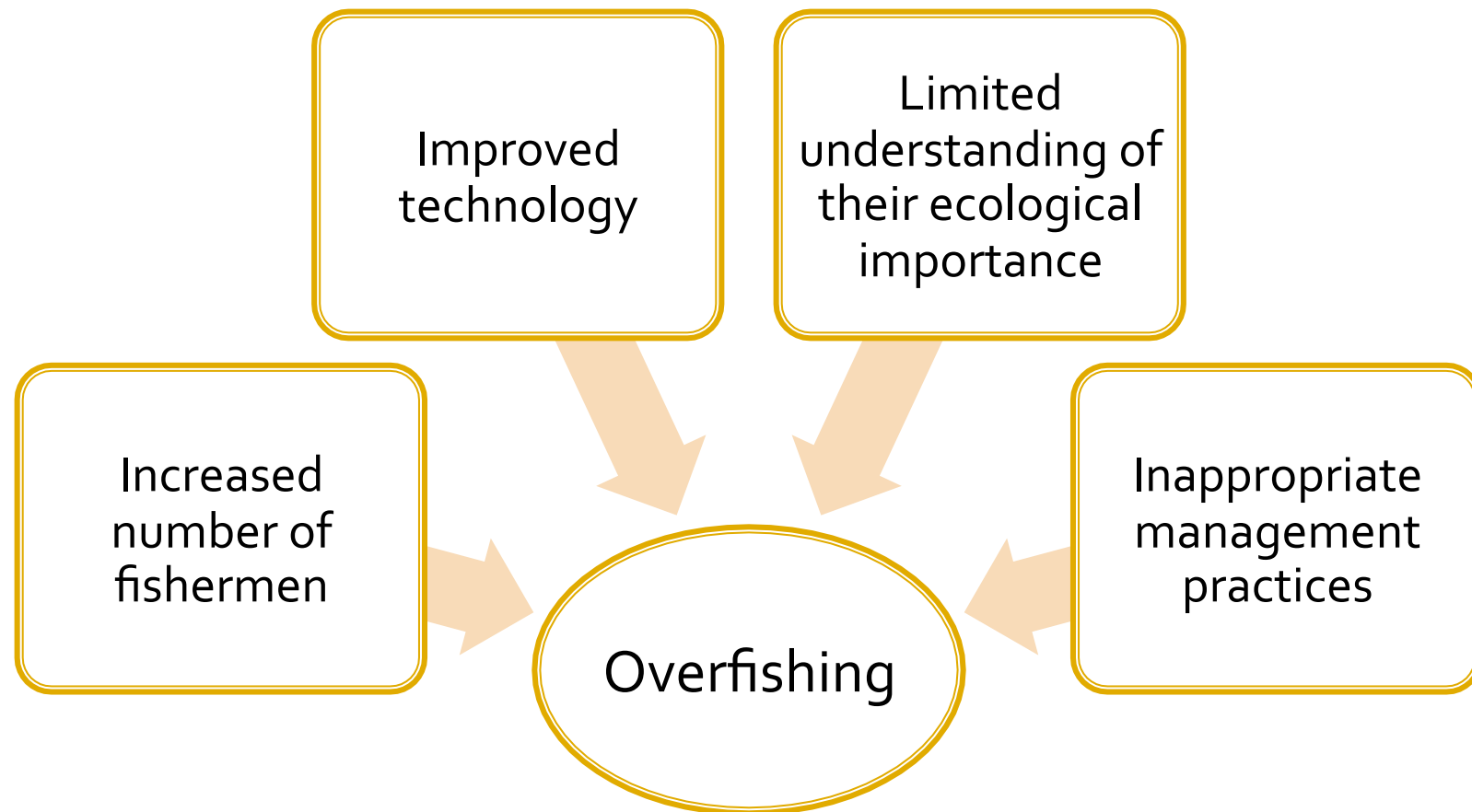
Belize and the Cayman Islands still have active spawning aggregation sites



Based on distribution of grouper & snapper, South America could have spawning aggregation sites.

Sadovy *et al.* 2008

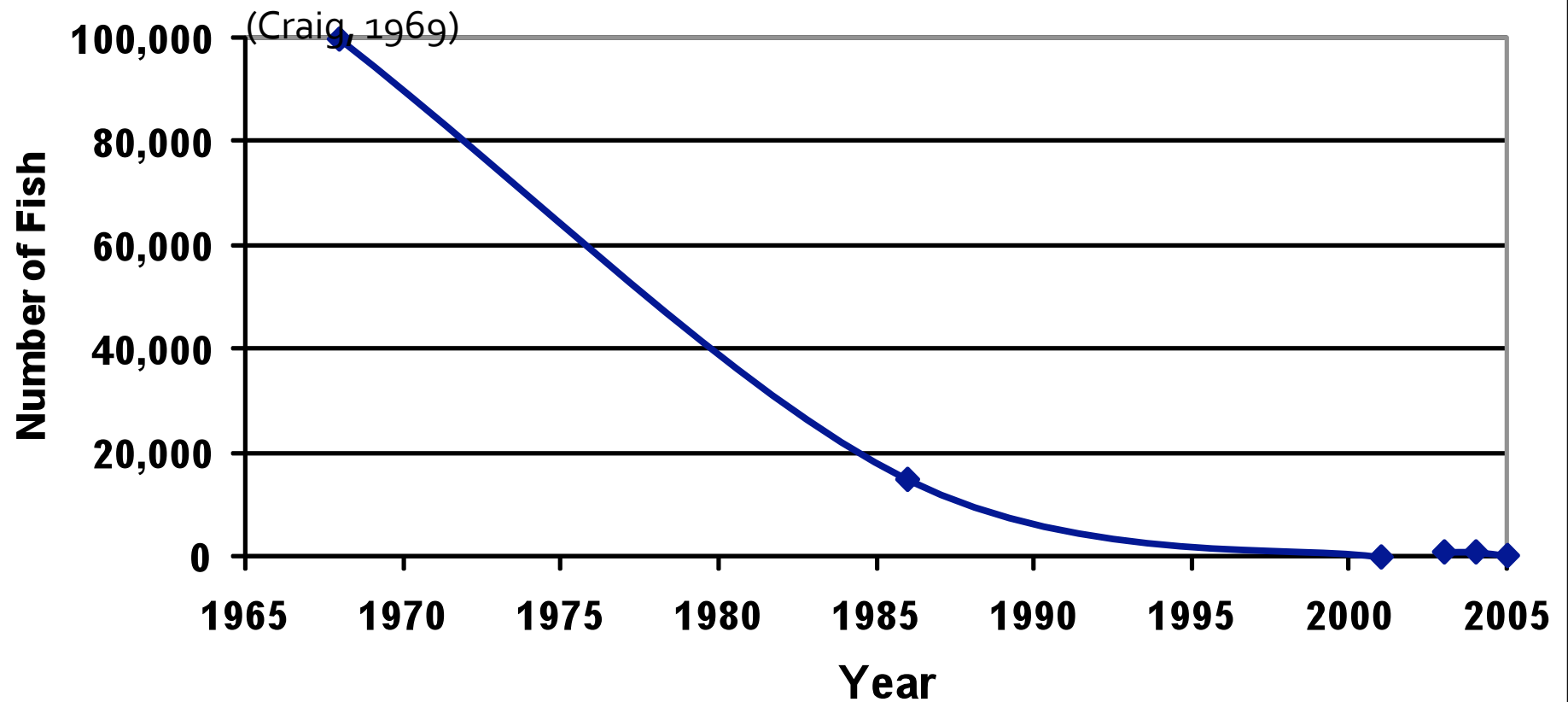
Vulnerable to fishing



- Endangered species
- Many sites are gone.

Example

Nassau Grouper at Caye Glory Belize

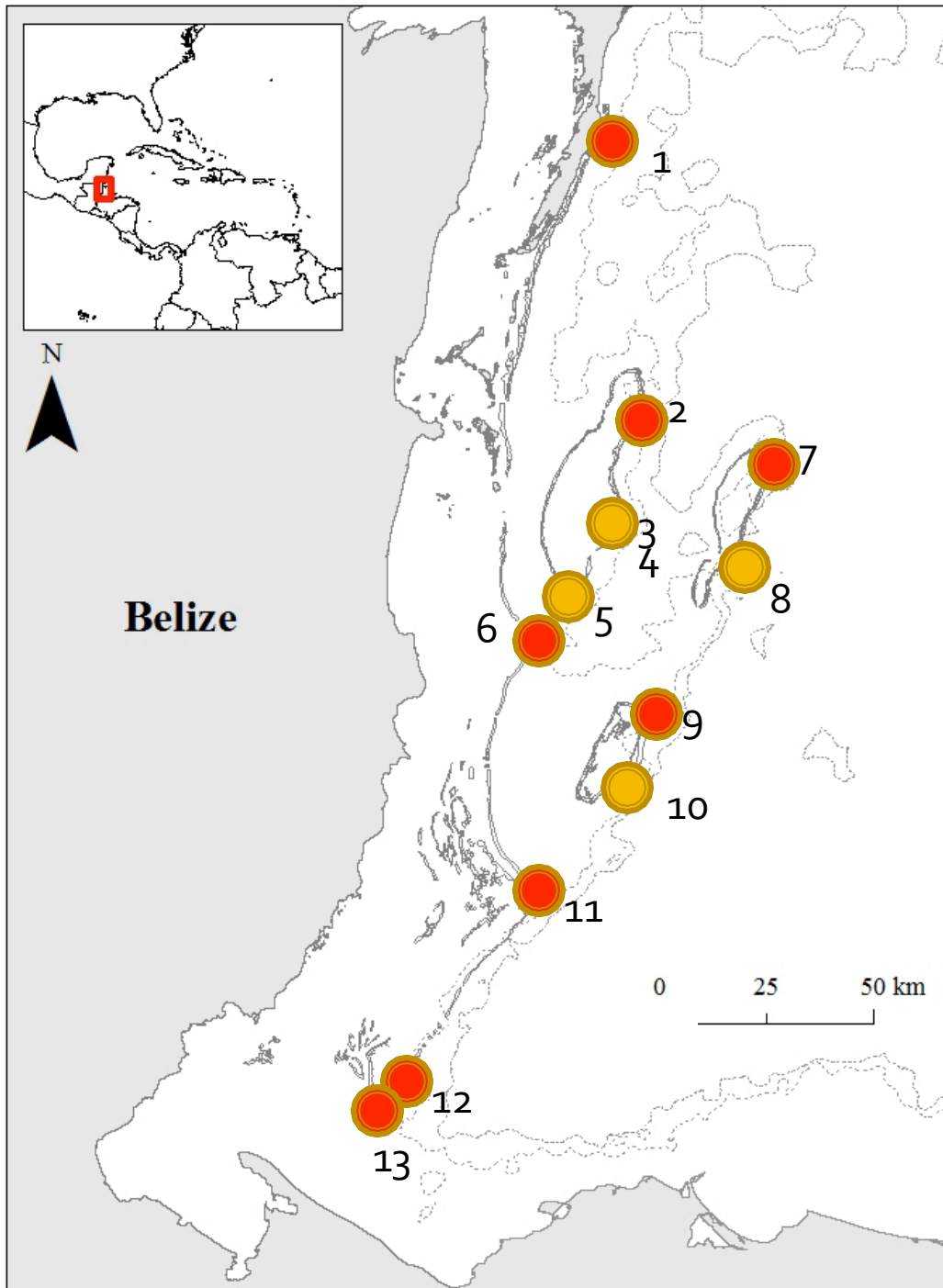



Heyman *et al.*

Question

**Why
these
places?**

**Any specific
characteristics
?**



- 
- Specific place – there is something intrinsically advantageous about the site.
 - Focus on the reef structure.
 - The well-studied FSA species, *Epinephelus striatus* (Nassau grouper) are known to share their sites with other grouper, snapper and jacks.

Possible reef structure

- Four reef structures encompass almost all possible reef structures (Claydon 2004):
 - (1) Channels and passages
 - (2) Walls
 - (3) Reef slopes
 - (4) **Promontories/shelf-edges**
- But all of the terminology is subjective and dependent on scale (Claydon 2004).
- There are no fine-scale topography data
 - **No quantitative comparison among FSA sites.**

To Understand geomorphology of historically known sites

Belize
&
Cayman Islands

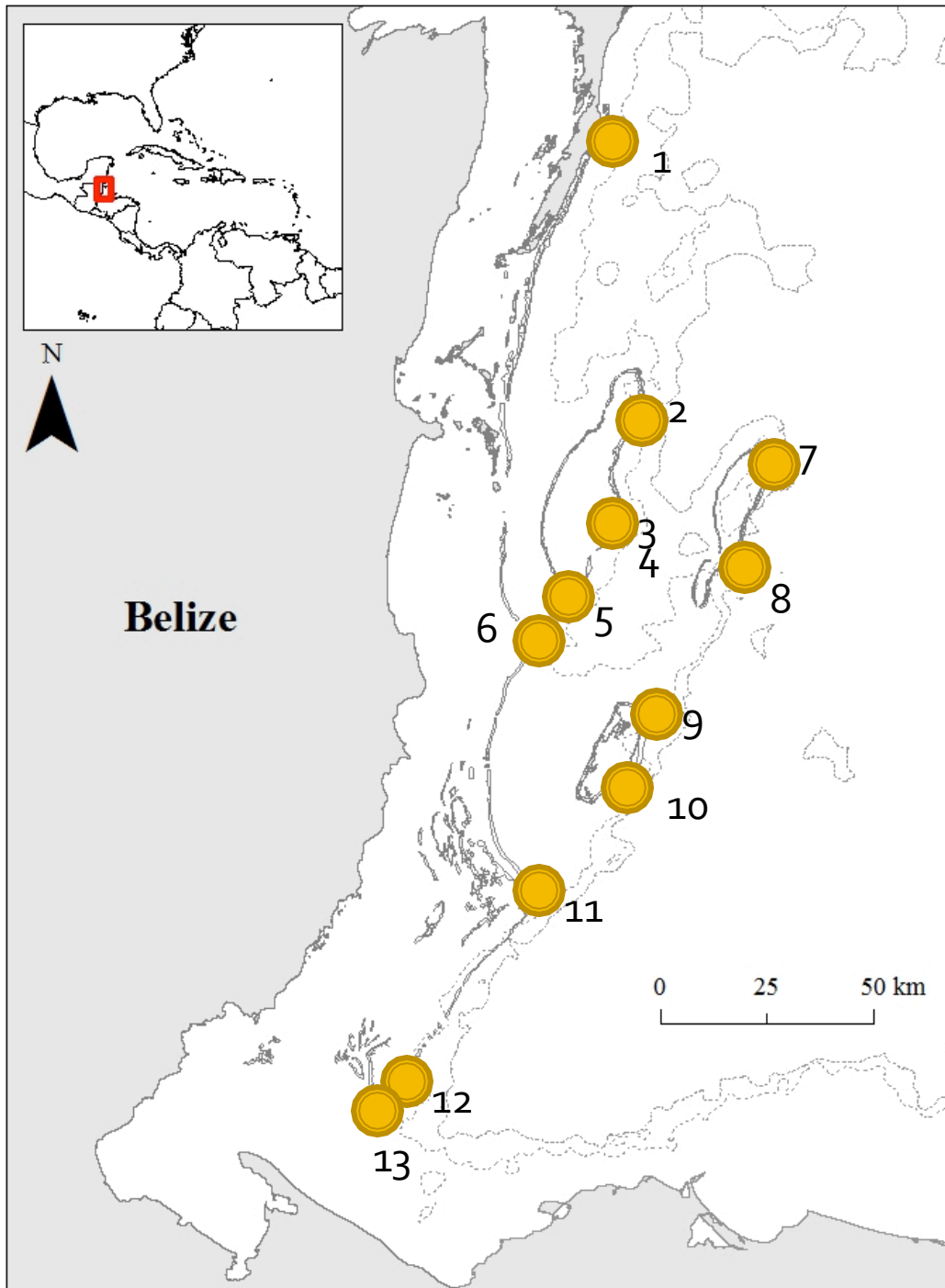
- Known FSA sites
- Geospatial analysis
- Describe FSA sites quantitatively. (Similarities/difference)

Los Roques,
Venezuela

- Reef promontory theory
- Previously no FSA info.
- Potential FSA sites

Methodology

1. Identify sites

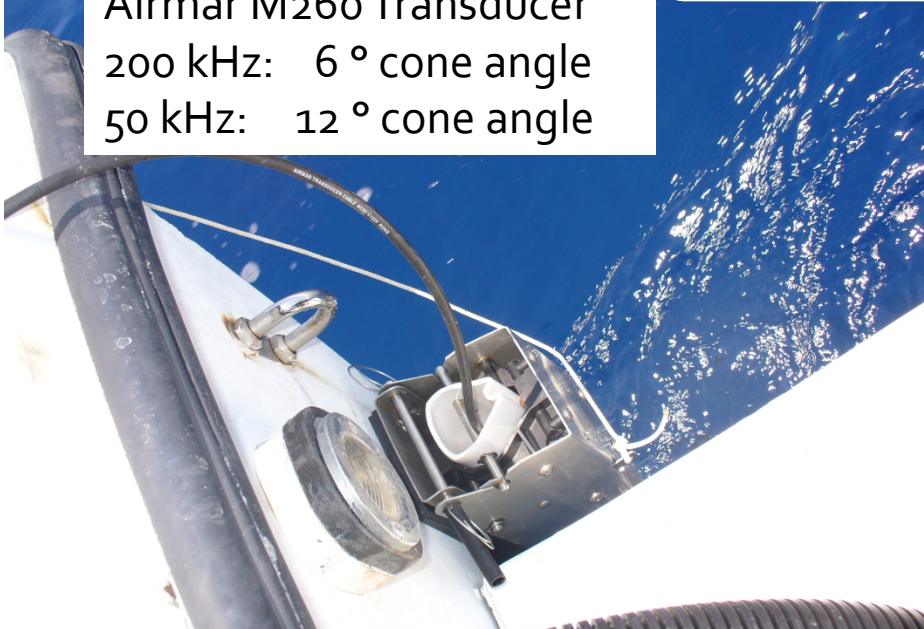


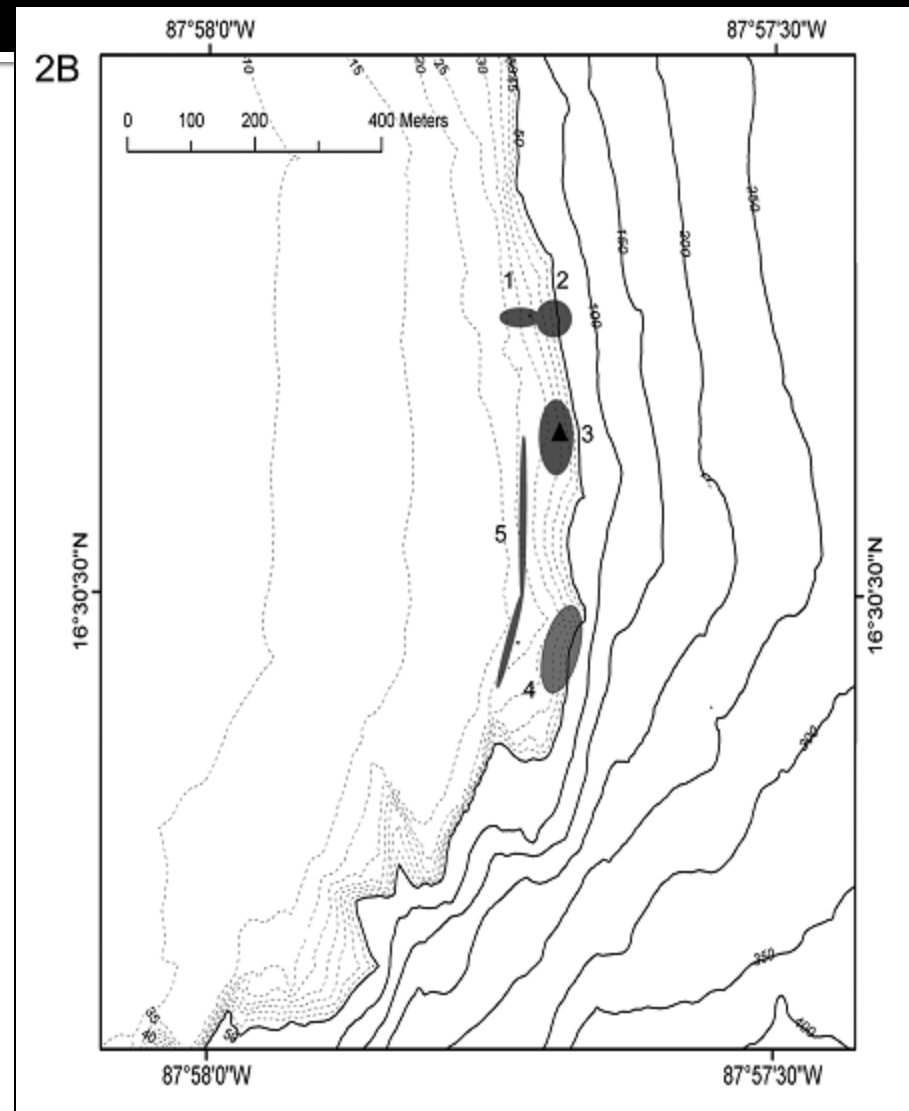
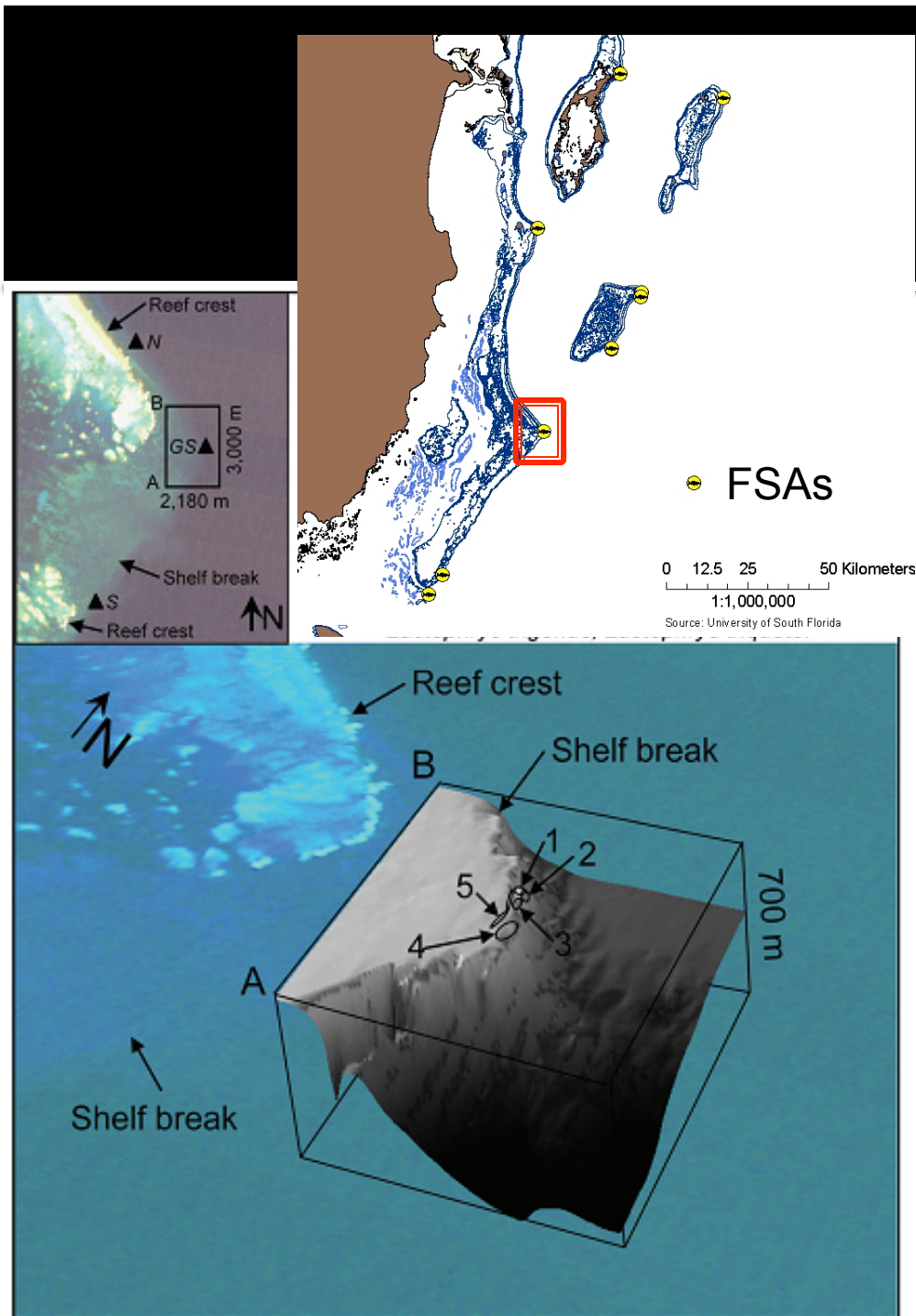
1. Rocky Point
2. Dog Flea Caye
3. Soldier
4. Calabash
5. Cay Bokel
6. Emily
7. Sandbore
8. Half moon Caye
9. Glovers – Northeast
10. Middle Caye
11. Gladden Spit
12. Nicholas Caye
13. Rise and Fall Bank



Methodology

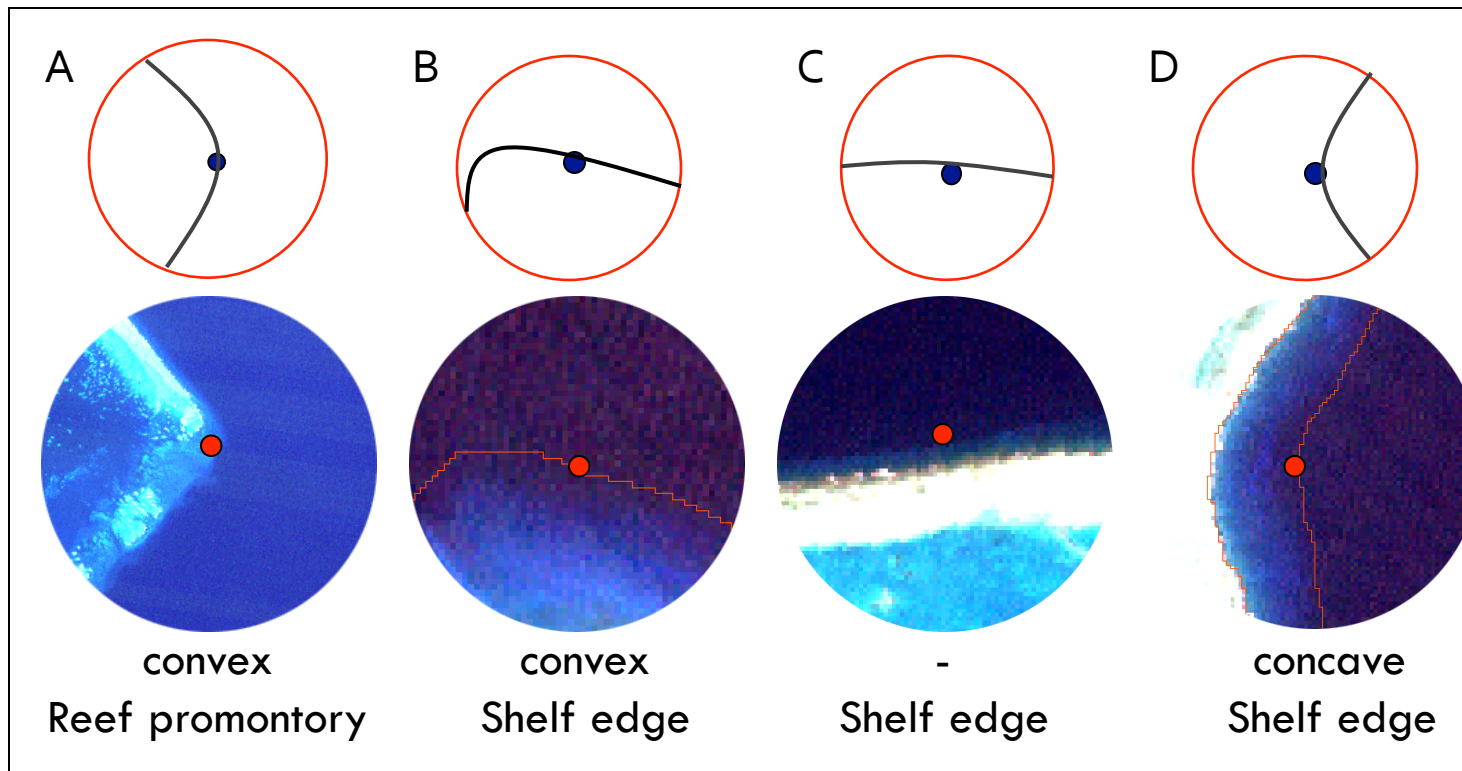
Airmar M260 Transducer
200 kHz: 6 ° cone angle
50 kHz: 12 ° cone angle



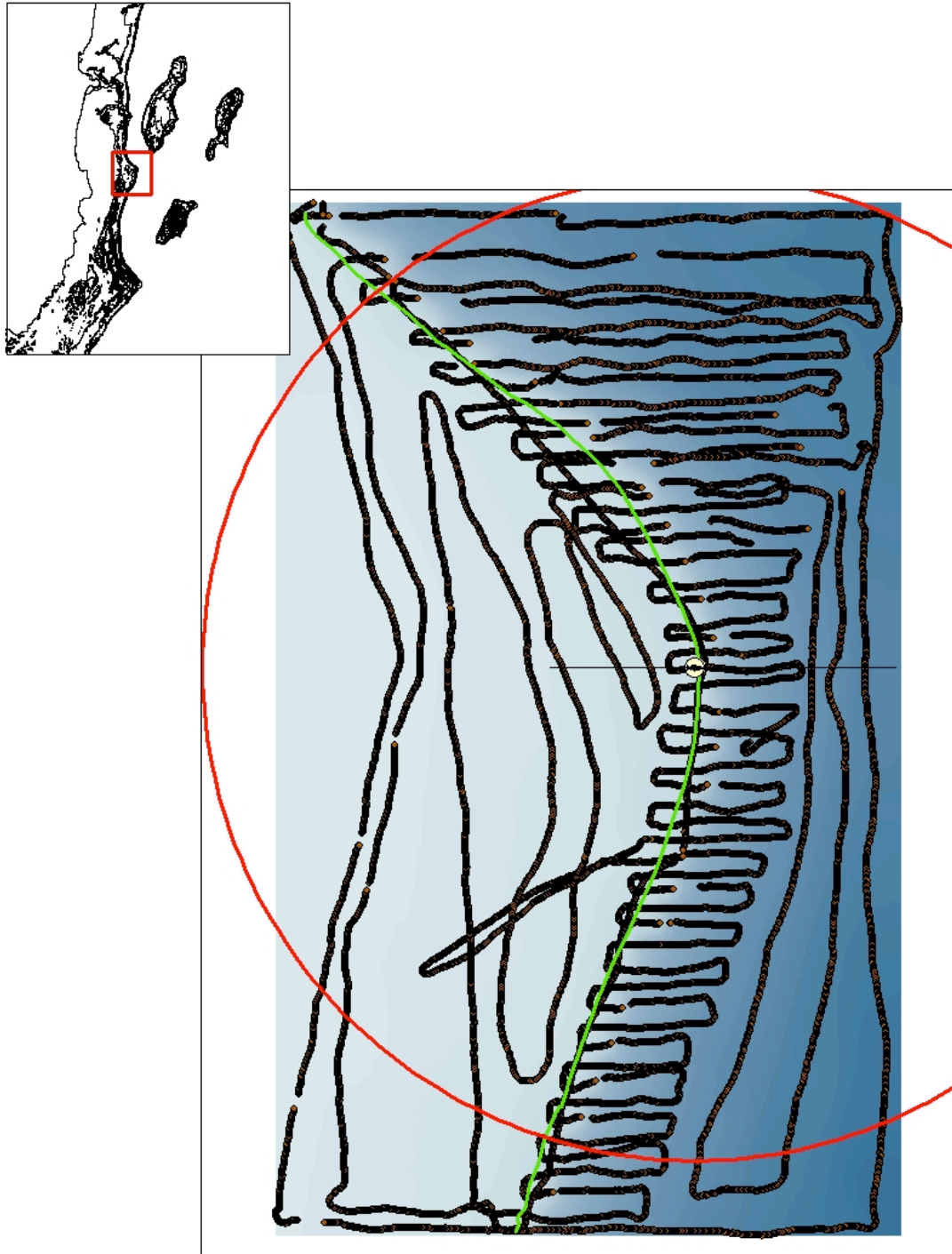


Heyman and Kjerfve 2008

Shape

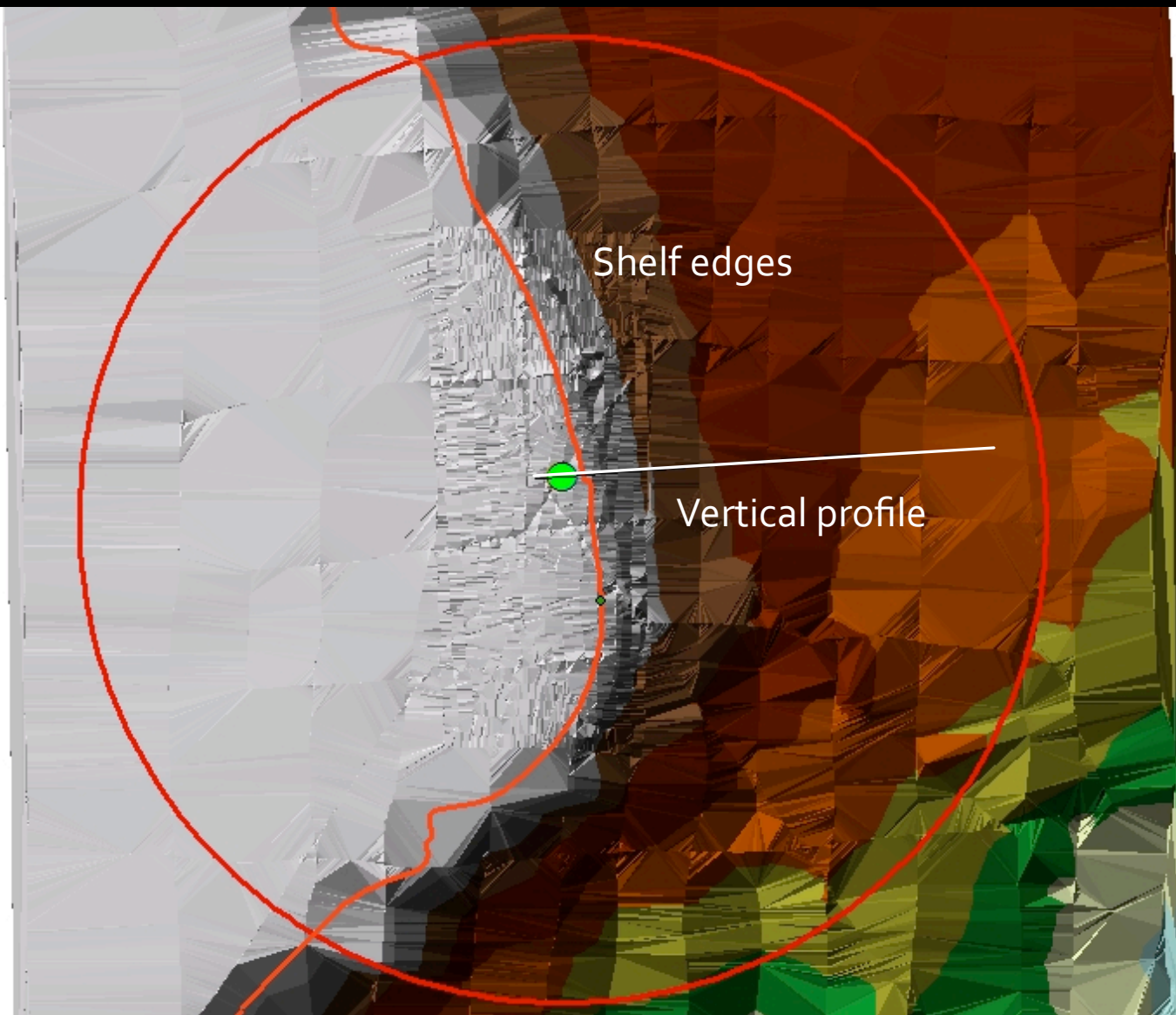


1km buffer circle
from spawning
aggregation sites



Methodology (Cont')

- Spawning aggregation sites
- 1km buffer circle from spawning aggregation sites (red line)
- Shelf edge line (more than 20 degree slope) (green line)
- Vertical profiles across the spawning aggregation sites
- Distances from shelf edges and from inflection points.
- Shapes



Depth and Distances

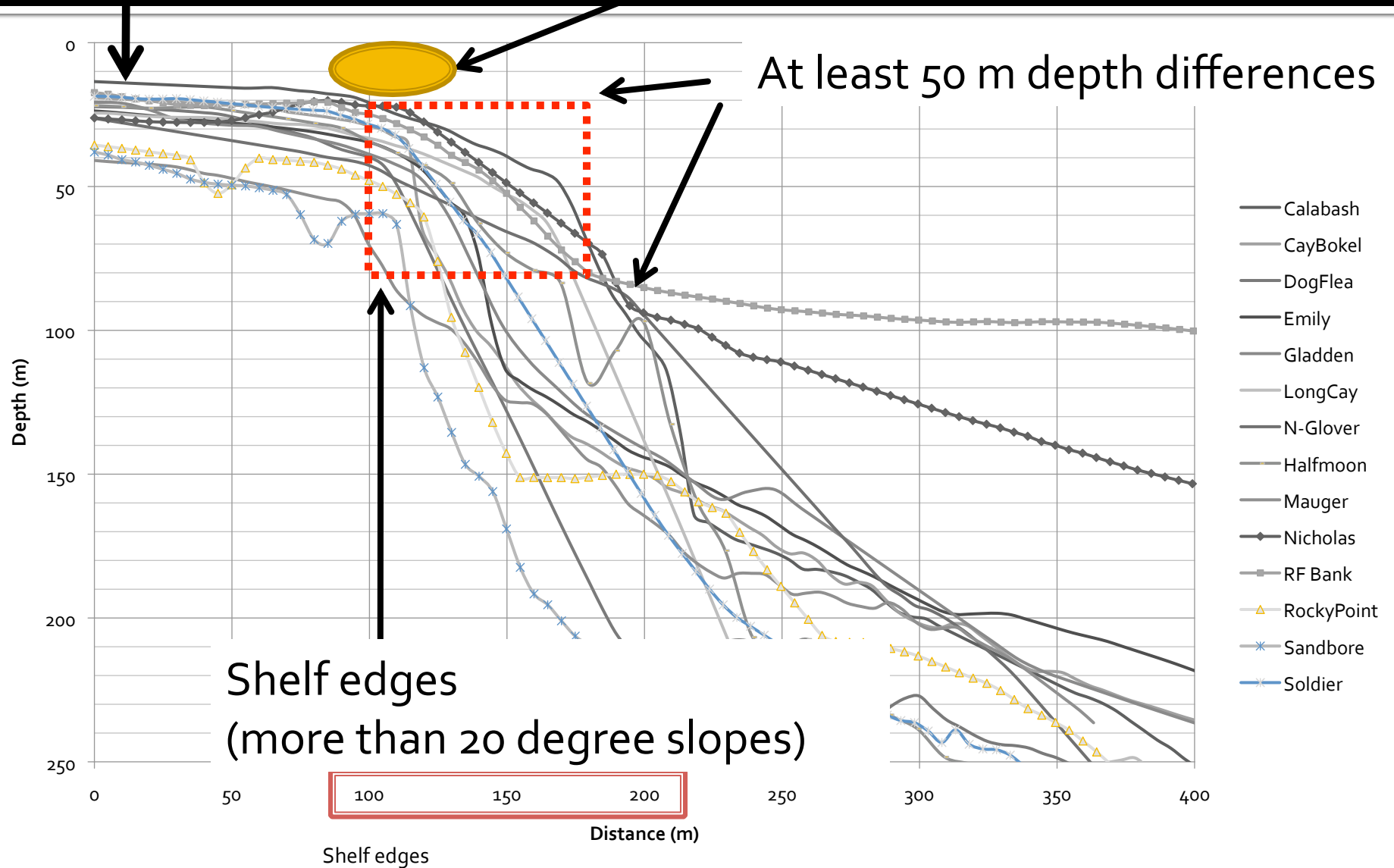
Location	Reef types	Shape	Orientation	Depth (m)		Distance to (m)	
				FSA	shelfedge	shelfedge	inf. pts
Rocky Point	Fringing	convex	windward	80	48	28	290
Dog Flea Caye	Atoll	convex	windward	23	39	67	170
Soldier Caye	Atoll	convex	windward	26	30	5	167
Calabash Caye	Atoll	convex	windward	20	22	6	98
Caye Bokel	Atoll	convex	windward	83	29	31	31
Sandbore	Atoll	convex	windward	50	53	5	40
Halfmoon Caye	Atoll	convex	windward	30	35	15	245
Northern Glovers	Atoll	convex	windward	60	47	45	45
Glovers LongCaye	Atoll	convex	windward	45	33	25	40
Caye Glory	Barrier	convex	windward	33	35	5	5
Gladden Spit	Barrier	convex	windward	31	38	40	270
Nicholas Caye	Barrier	convex	windward	25	22	15	150
Rise and Fall Bank	Bank	convex	windward	20	24	24	465
Mean				40	35	24	155
SD				22	10	19	134

Vertical Profiles





Less than 5 degree slopes

FSAs

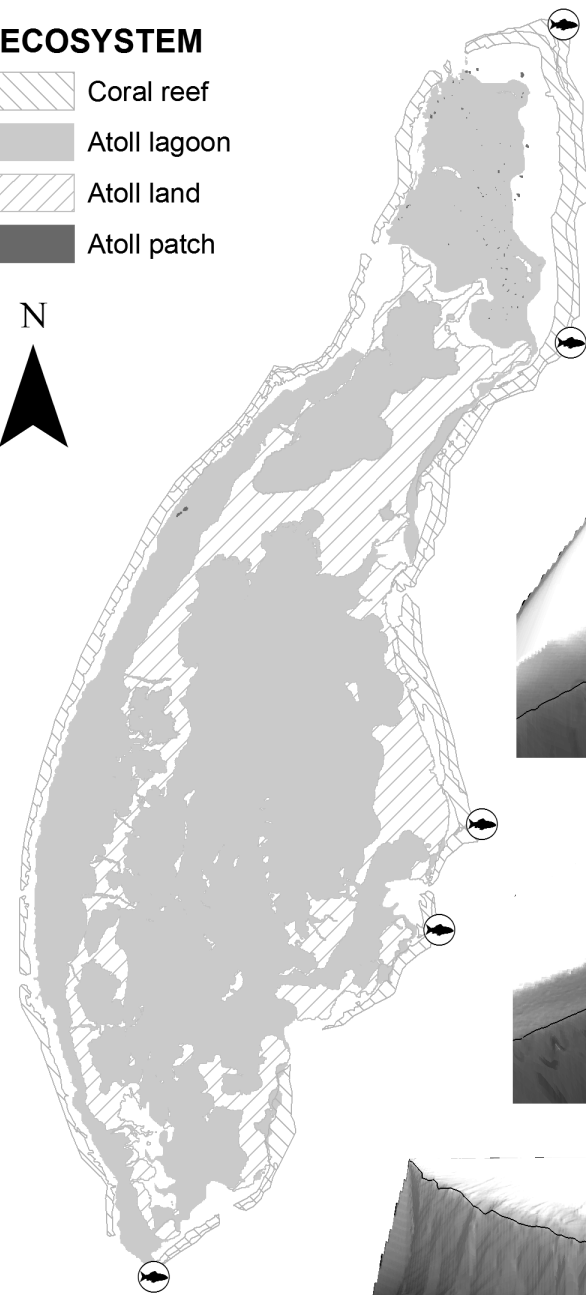
at least 20 m depth



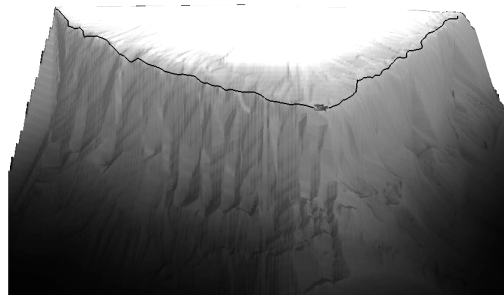
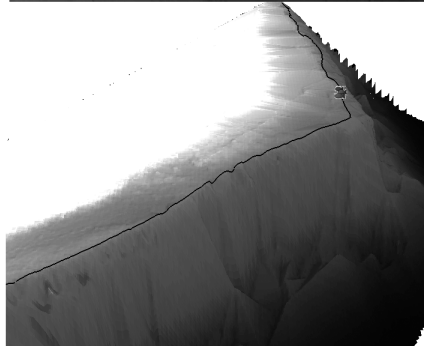
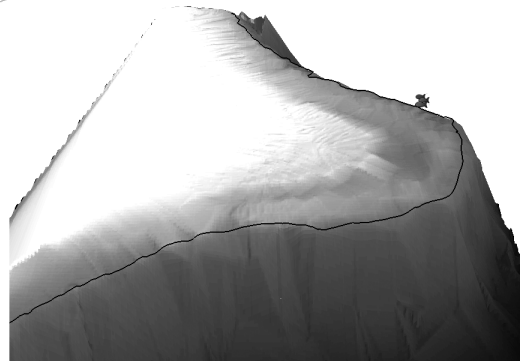
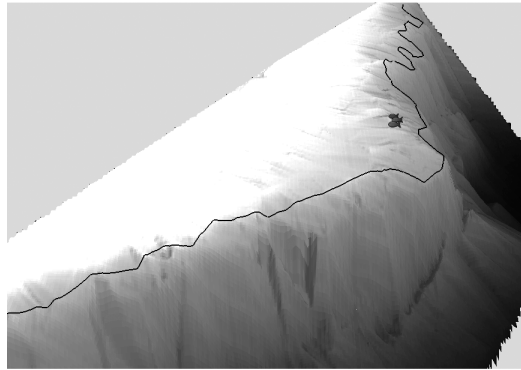
ECOSYSTEM

-  Coral reef
-  Atoll lagoon
-  Atoll land
-  Atoll patch

N

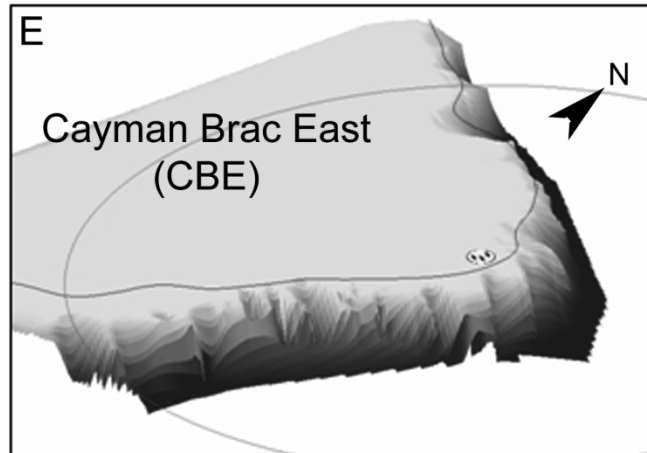
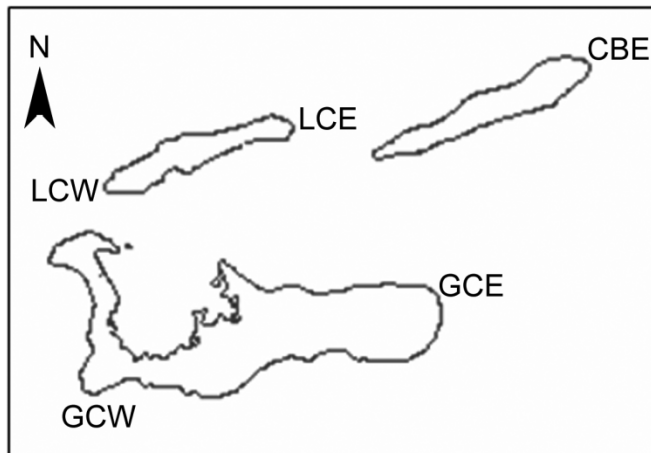
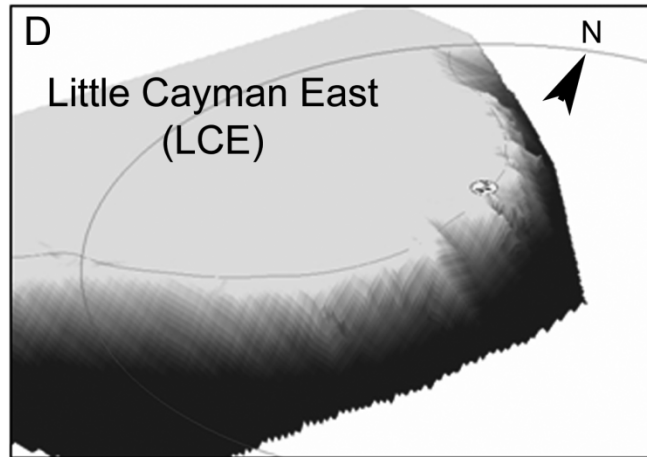
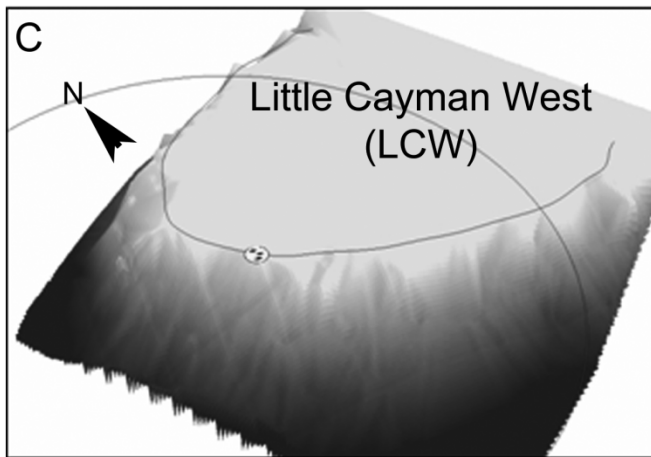
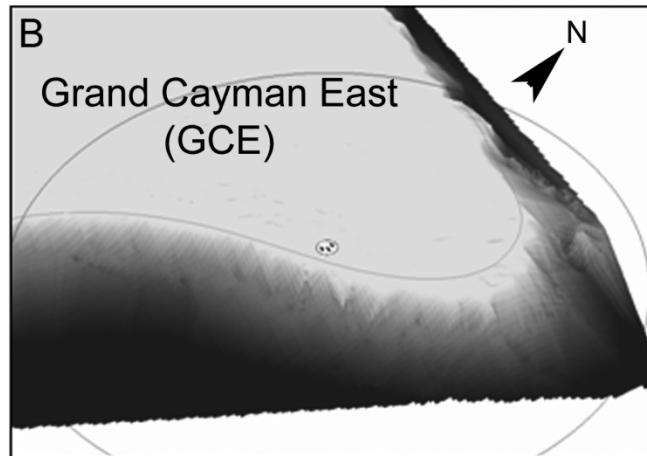
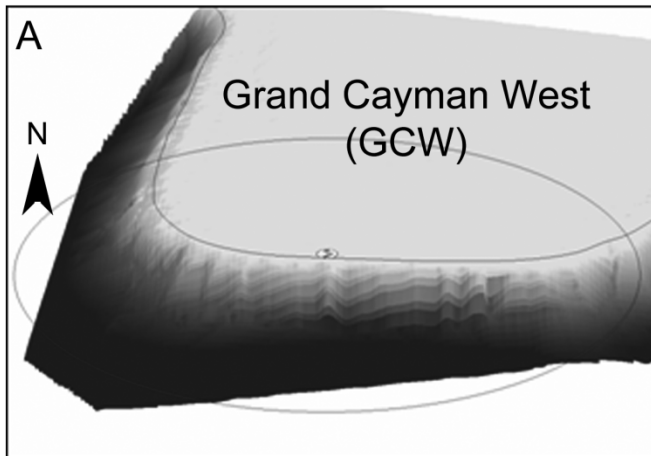


0 5 10 km



Turneffe Reef Atoll

The Cayman Islands



Kobara and Heyman 2008

Belize and Cayman Islands

- All spawning aggregation sites were located
 - convex-shaped seaward extending reefs
 - Reef Promontories
 - At least 20 m depth
 - Steep drop-off
 - Proximity to deep water

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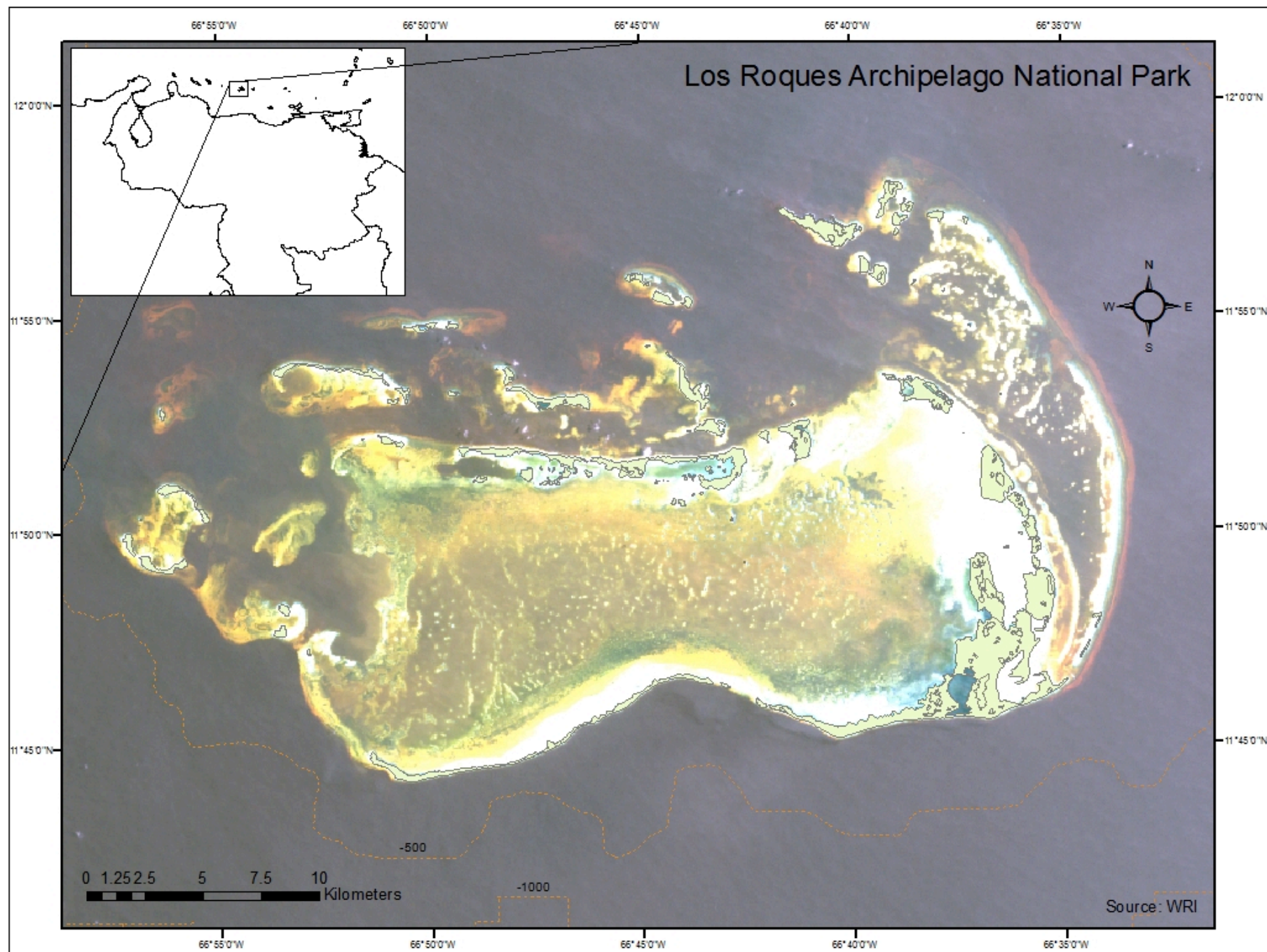
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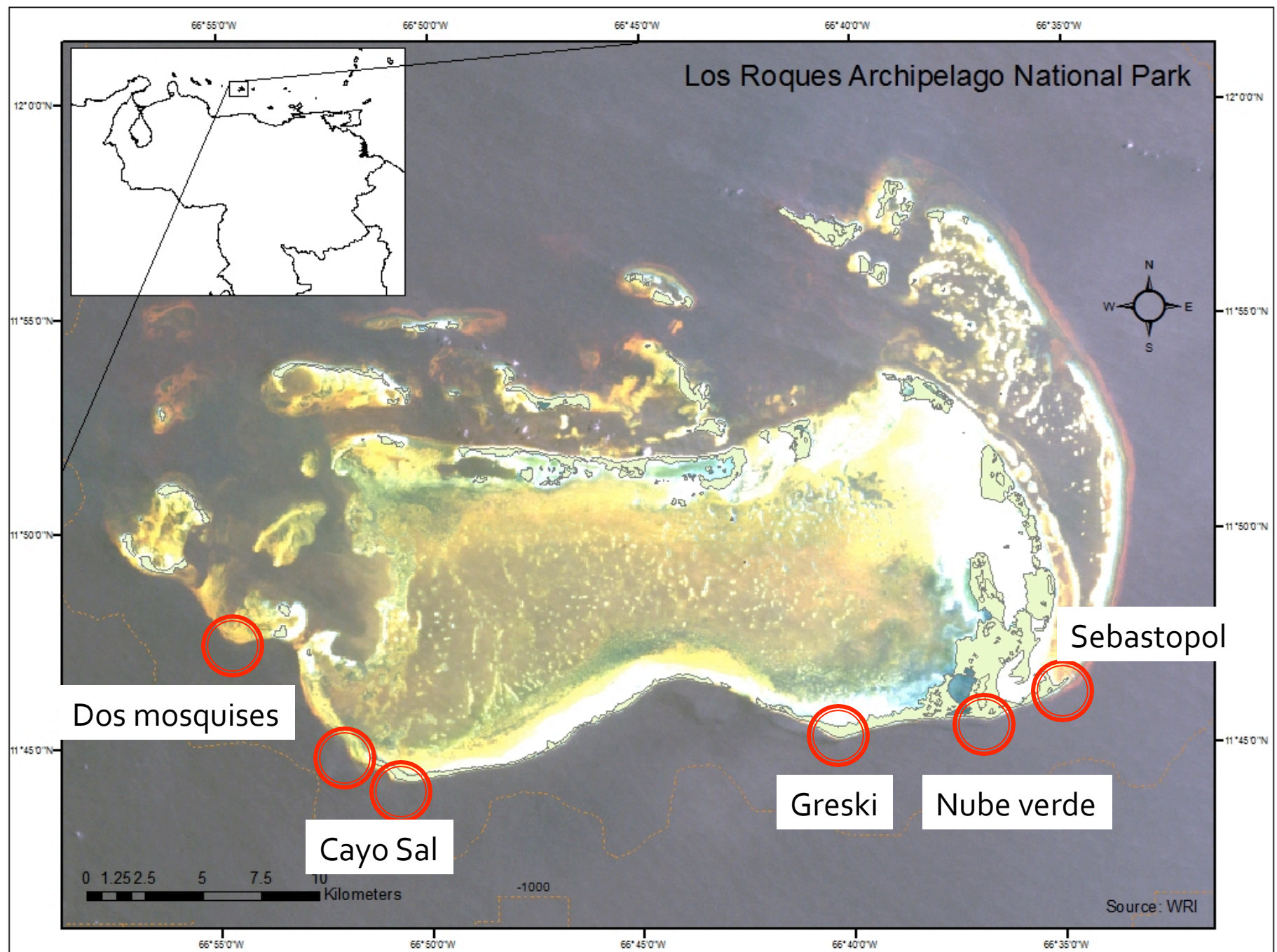
Predicting potential FSA sites

- The six widely scattered grouper aggregation sites in Belize are all reef promontories (Carter *et al.* 1994)
- Nearly all reef promontories are visible in Aerial photo/Landsat imagery (Carter *et al.* 1994, Heyman and Requena 2002).
- Based on two-dimensional shape information and satellite imagery for Los Roques, Venezuela, we predicted the occurrence of spawning aggregation sites at reef promontories within the archipelago.

Why Los Roques, Venezuela?

- The Venezuelan government declared the area a national park in 1972.
- *Cervigón (1993) described aggregation of Mutton snapper (*Lutjanus analis*) and Nassau grouper fishing*
- Large groups of schoolmaster snapper (*Lutjanus apodus*) displaying possible reproductive behaviors near Cayo Sal in September 2005

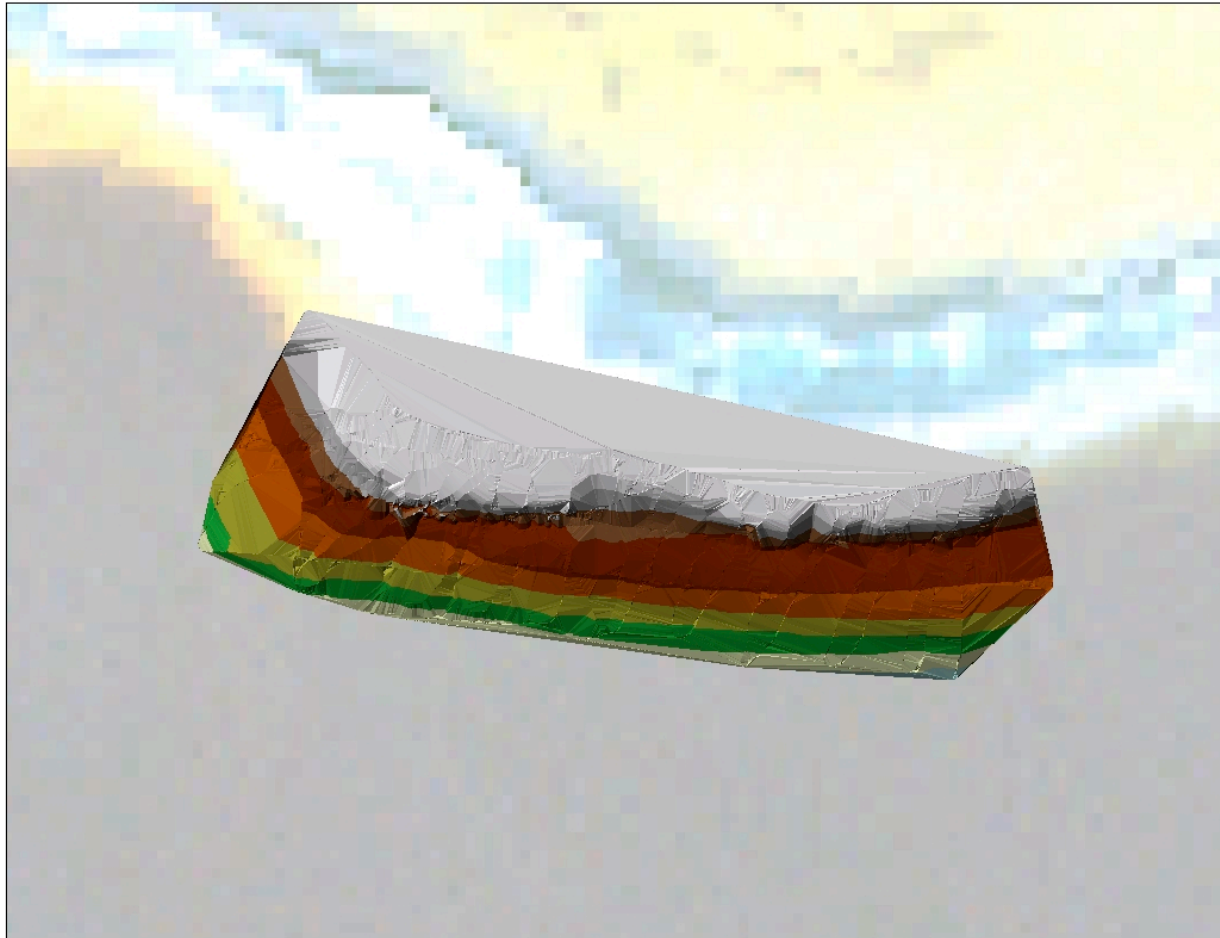




Universidad Simón Bolívar

- 30 interviews with experienced local fishermen and divers described Groupers (*Epinephelus spp.* and *Mycteroperca spp.*) as uncommon (except *E. guttatus*).
- Interviews identified probable spawning aggregations of *Lutjanus analis* at Cayo Sal in May.

Cayo Sal



Visual Survey was conducted by Universidad Simon Bolivar
Feb – Aug 2007

Results – Los Roques, Venezuela

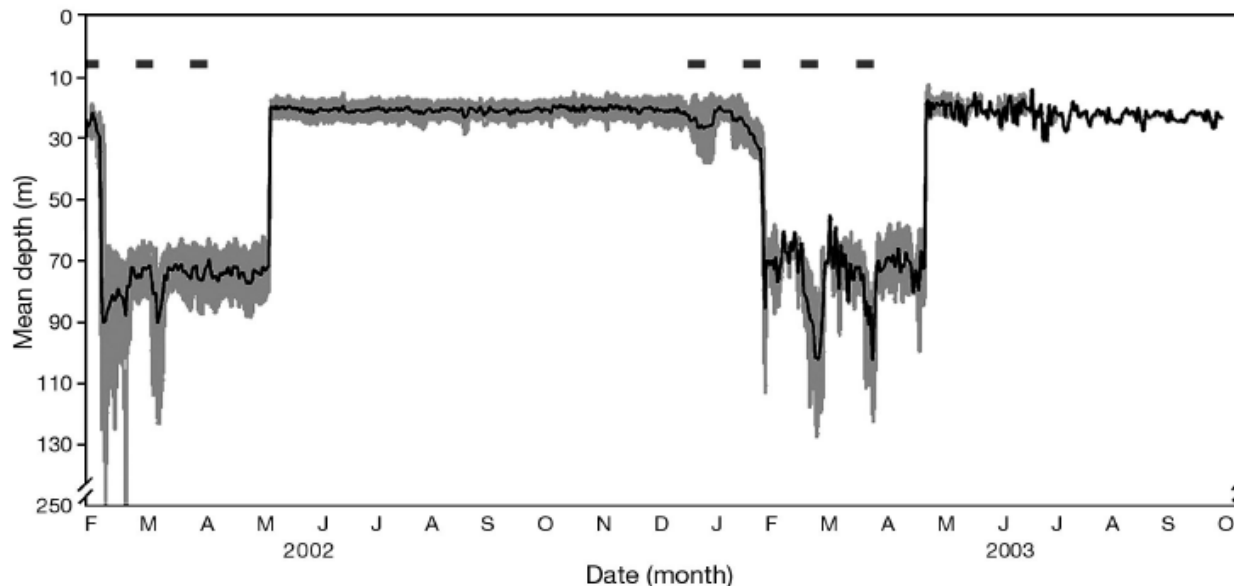
- Increases in density of *Lutjanus apodus* (Schoolmaster), *L. analis* (Mutton snapper), *L. griseus* (Gray snapper), and *Caranx latus* (Horse-eye jack) were observed in certain months although spawning events were not observed (Boomhower *et al.* in review).

Geomorphological features of Los Roques were different from those of Belize and Cayman.

- Visual survey sites in Los Roques generally occurred on **shallower** shelf edges (7m, Cayo Sal) than sites in Belize and the Cayman Islands.
- The site was generally **not steep wall and proximal to deep waters**.
- These differences may have influenced the non-occurrence of spawning aggregations for large groupers and snappers at these sites.

Conclusion – 2D → 3D!

- Spawning aggregation sites (Belize, Cayman) are reef promontories, deeper than 20 m depth, more than 20 degree slopes of shelf edge and adjacent to deep water.



Nassau grouper
Movement in depth

Tagged fish w/ depth
sensors

Starr et al. 2007

Fig. 4. *Epinephelus striatus*. Depth profiles of tagged Nassau groupers at Glover's Reef. The line represents average depth, and shading depicts range of minimum to maximum recorded depths. Each letter on the x-axis represents the first day of the month. Dashed lines at the top indicate the times when groupers were aggregating at the spawning site



Thank you