Florida Keys
National Marine Sanctuary

Population Assessments of Benthic Coral Reef Organisms In the Florida Keys: 1999 – 2009

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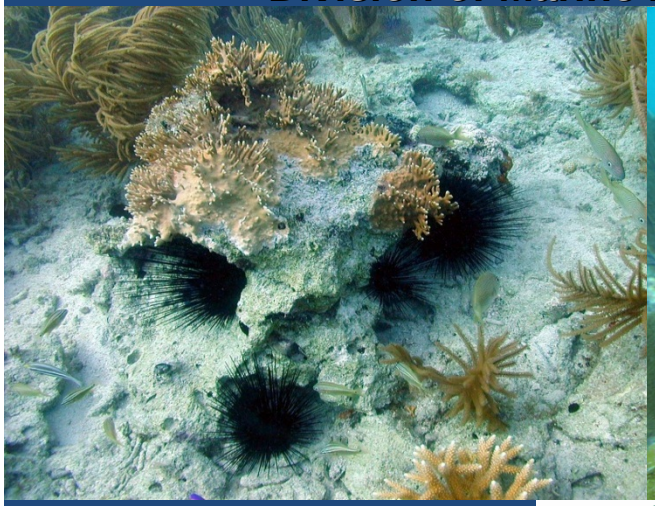
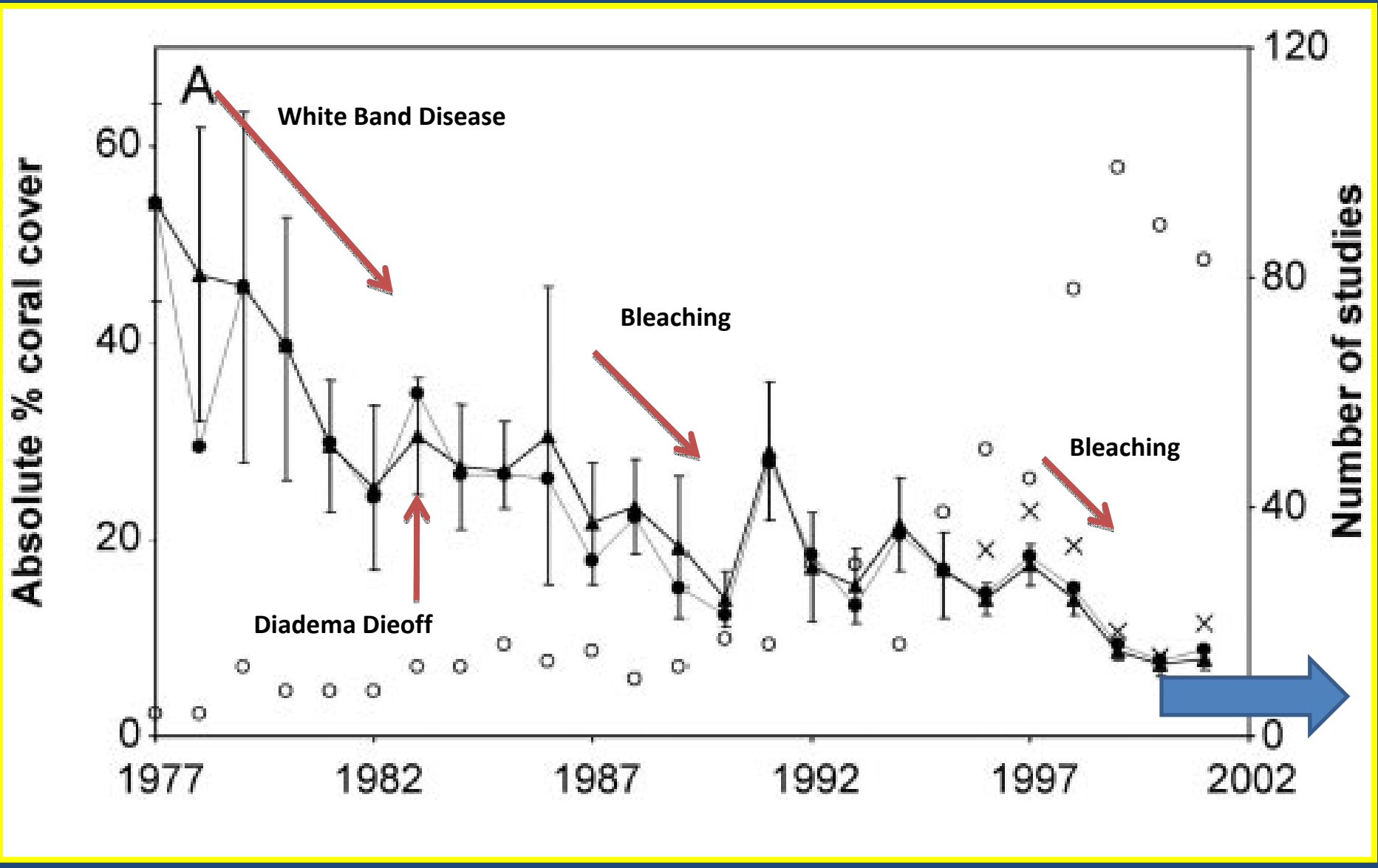


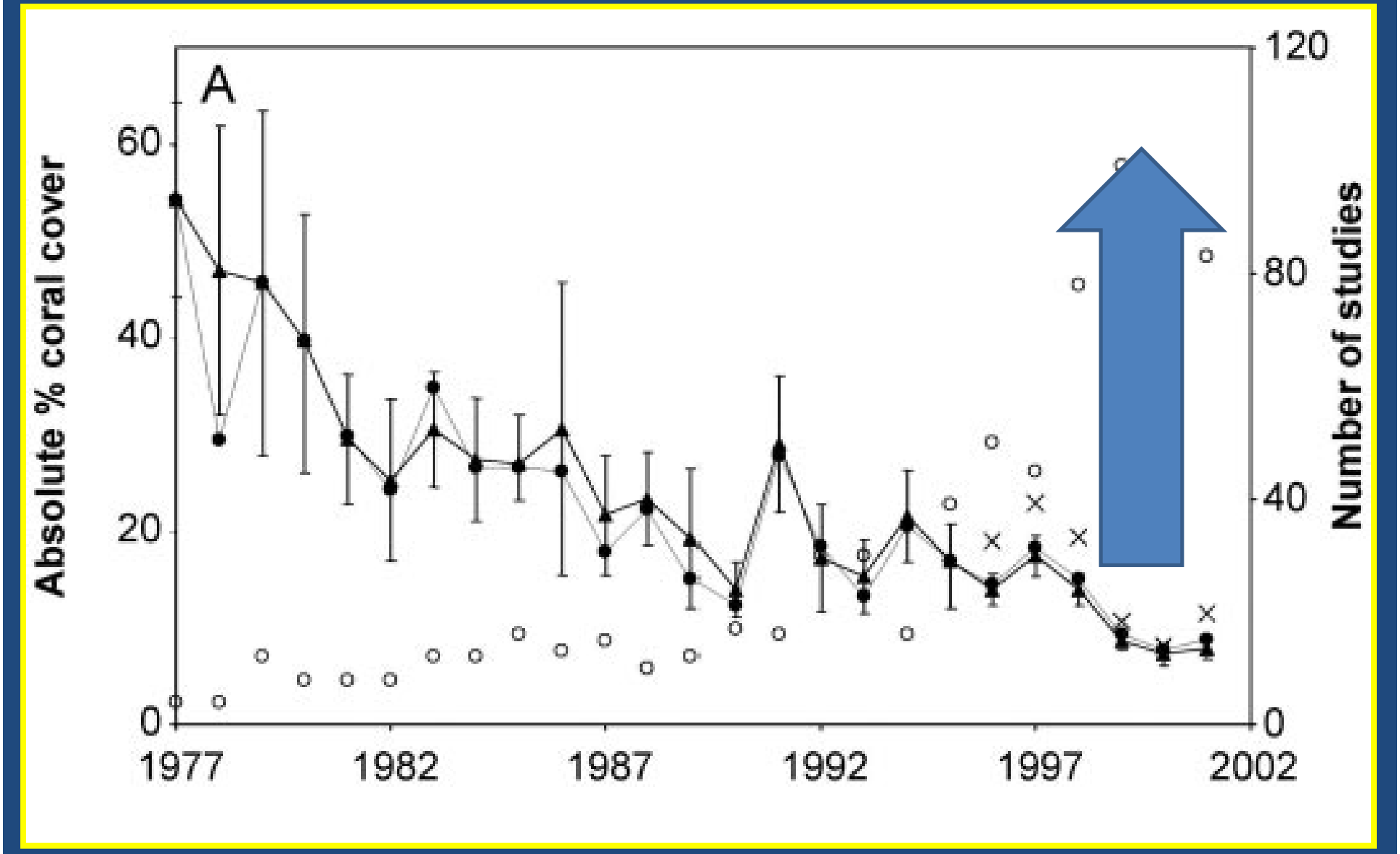
UNCW

NOAA

NOAA CORAL REEF CONSERVATION PROGRAM



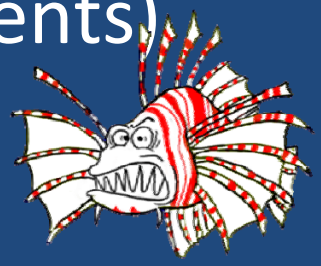
Gardner et al. 2003



Gardner et al. 2003

Factors Affecting Coral Reefs in Florida

- Geography (winter cold fronts)
- Hurricanes
- Disease
- Bleaching
- Loss of herbivores (over-fishing, urchin die-off)
- Pollution (especially nutrients)
- Ocean Acidification
- Marine Zoning



What we measure

- **15-m transects for benthic cover**
  - point-intercept
  - photo archives for general site descriptions
- **15-m x 0.5-m belt transects**
  - Species richness (coral, sponge, gorgonian)
  - Gorgonian abundance and height (8m x 1m)
  - Juvenile coral abundance and size (10 x 0.312 m^2)
  - Adult coral abundance, size and condition (10m x 1m)
  - Urchin density and size
  - Marine ornamental species density
  - Substratum topography (vertical relief, slope, depth)
  - Density, length and impacts of fishing gear (15m x 4m)

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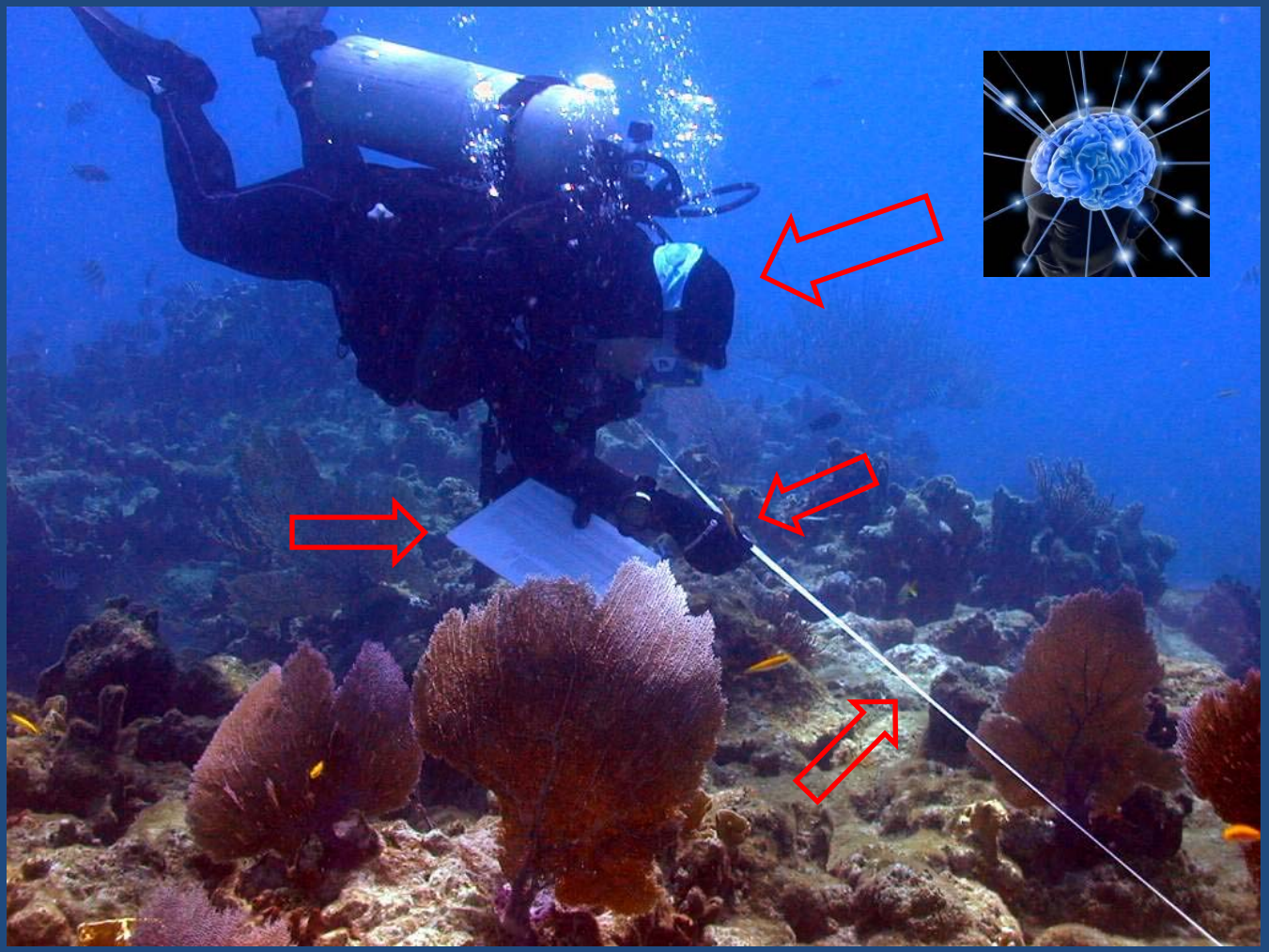
Rapid Assessment Methods



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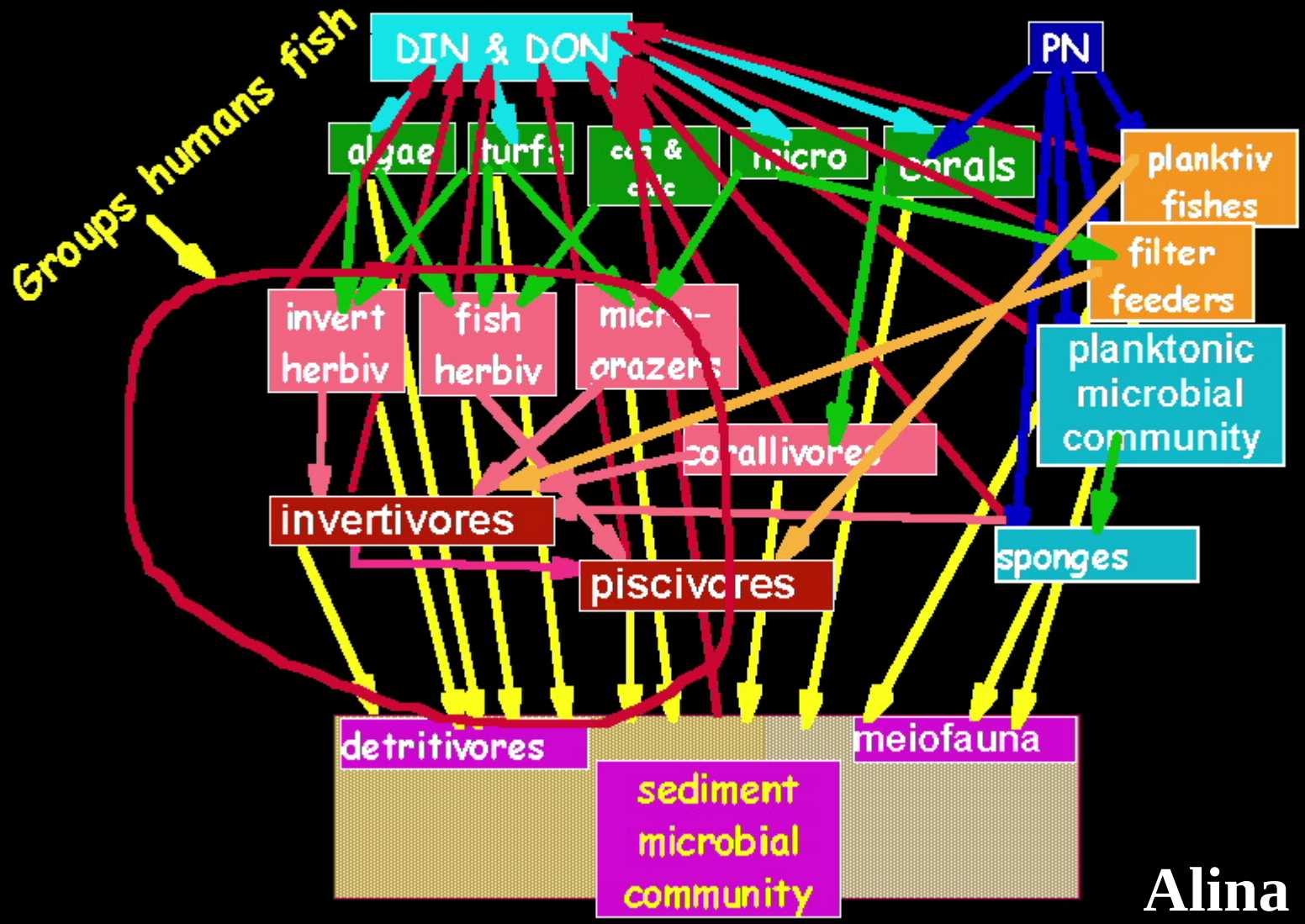
Management Relevance

- No Take Zone status and trends (performance)
- Program establishes baselines (5Ws + HM)
- Monitor status and trends of iconic species
- Debris surveys evaluate compliance
- Sample design statistics to estimate population abundances = stock assessment

UNDISTURBED CORAL REEF ECOSYSTEM: COMPLEX FOOD WEB; HIGH PREDATOR PRESSURE



Alina Szmant

Program Design

1. A two-stage stratified random sampling design is used to allocate effort according to habitat type and depth, along-shelf position, geography and management zone

2. Sample Design Statistics – what's important in not how intensely we sample individual sites, but how many sites we can sample while achieving CVs that are acceptable. From density numbers we calculate abundances at the population level.

Sample Design Statistics

Symbol	Definition	Computational Formula
h	Stratum subscript	
i	Primary sample unit subscript	
j	Second-stage sample unit subscript	
T_{hij}	Area of *j*th second-stage unit in primary unit *i* in stratum *h*	
M_{hi}	Total possible number of second-stage units in primary unit *i* in stratum *h*	
a_{hi}	Area of *i*th primary unit in stratum *h*	$a_{hi} = \sum_{j=1}^{M_{hi}} T_{hij}$
N_h	Total possible number of primary units in stratum *h*	
A_h	Area of stratum *h*	$A_h = \sum_{i=1}^{N_h} a_{hi}$
A	Area of entire survey domain	$A = \sum_h A_h$
$N_h M_h$	Total possible number of second-stage units in stratum *h*	
w_h	Stratum *h* weighting factor	$w_h = \frac{N_h M_h}{\sum_h N_h M_h}$
C_{hij}	Number of individuals (coral colonies) observed in second-stage unit *j* in primary unit *i* in stratum *h*	
D_{hij}	Density (individuals m^{-2}) in second-stage unit *j* in primary unit *i* in stratum *h*	$D_{hij} = \frac{C_{hij}}{T_{hij}}$
m_{hi}	Number of second-stage units sampled in primary unit *i* in stratum *h*	
$\overline{D}_{hi}$	Mean density in primary unit *i* in stratum *h*	$\overline{D}_{hi} = \frac{1}{m_{hi}} \sum_j D_{hij}$
n_h	Number of primary units sampled in stratum *h*	
$\overline{\overline{D}}_h$	Mean density in stratum *h*	$\overline{\overline{D}}_h = \frac{1}{n_h} \sum_i \overline{D}_{hi}$
s_{1h}^2	Sample variance among primary units *i* in stratum *h*	$s_{1h}^2 = \frac{\sum_i \left(\overline{D}_{hi} - \overline{\overline{D}}_h\right)^2}{n_h - 1}$
s_{2h}^2	Sample variance among second-stage units *j* in stratum *h*	$s_{2h}^2 = \frac{1}{n_h} \sum_i \left[\frac{\sum_j (D_{hij} - \overline{D}_{hi})^2}{m_{hi} - 1} \right]$
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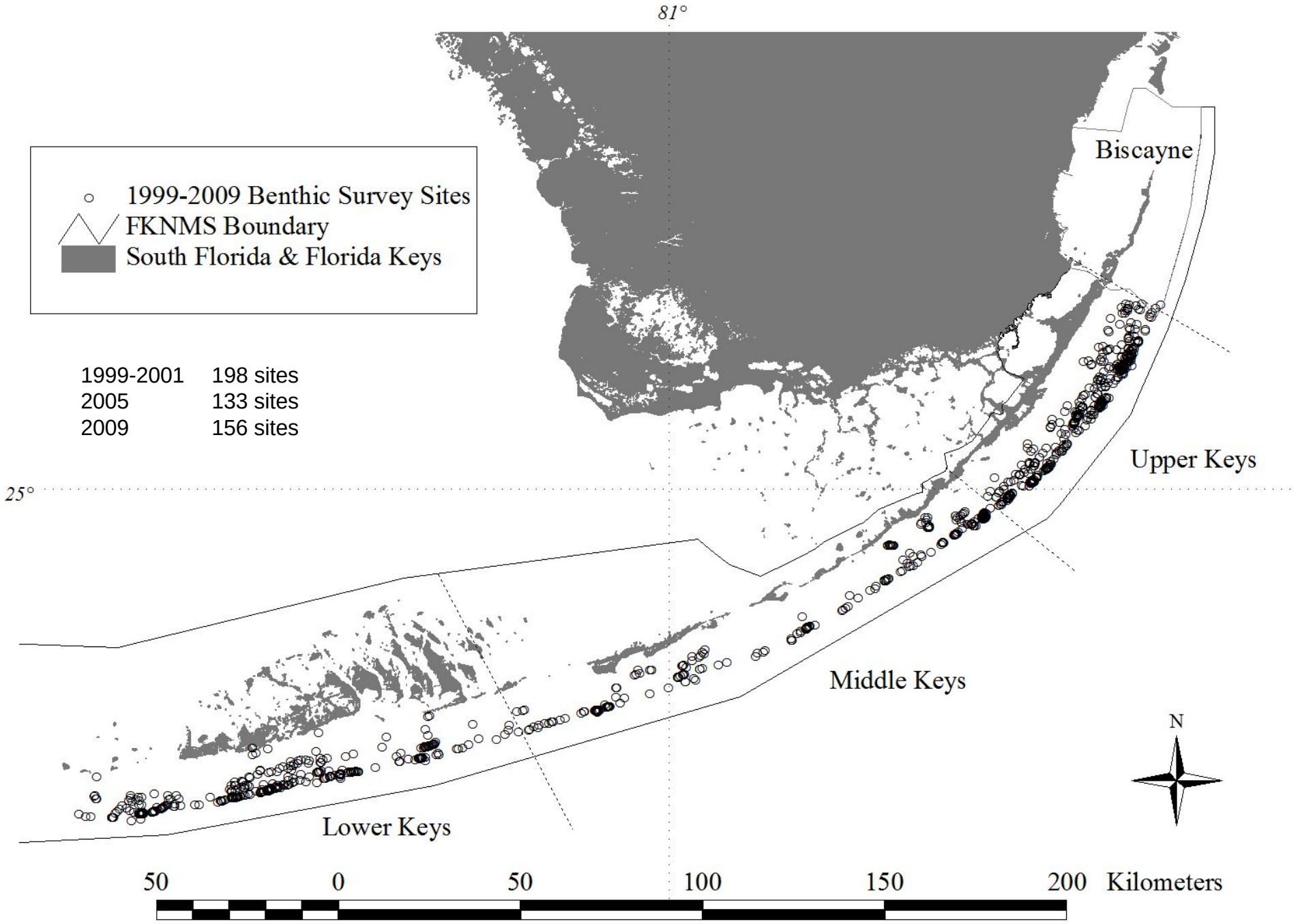
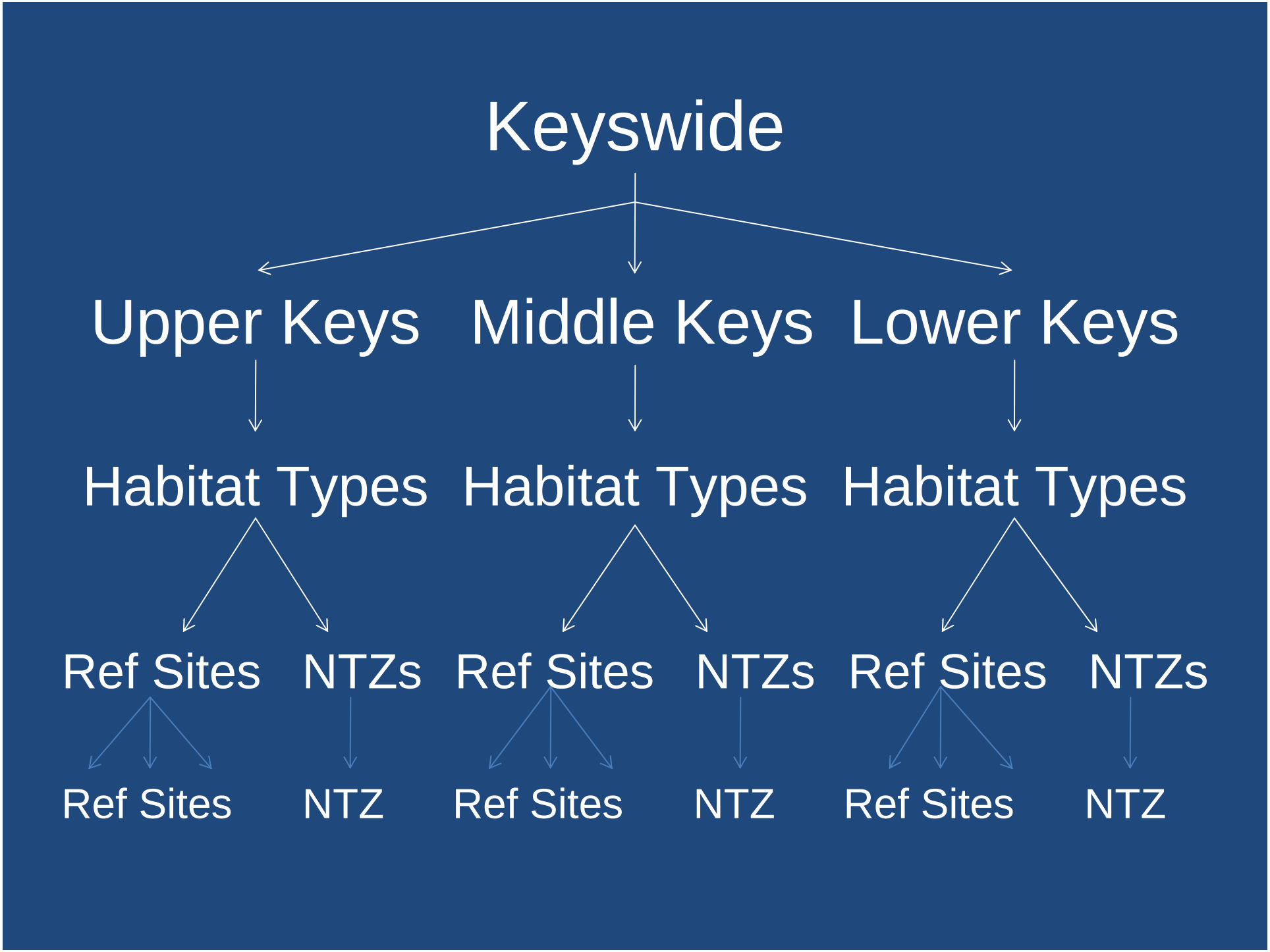
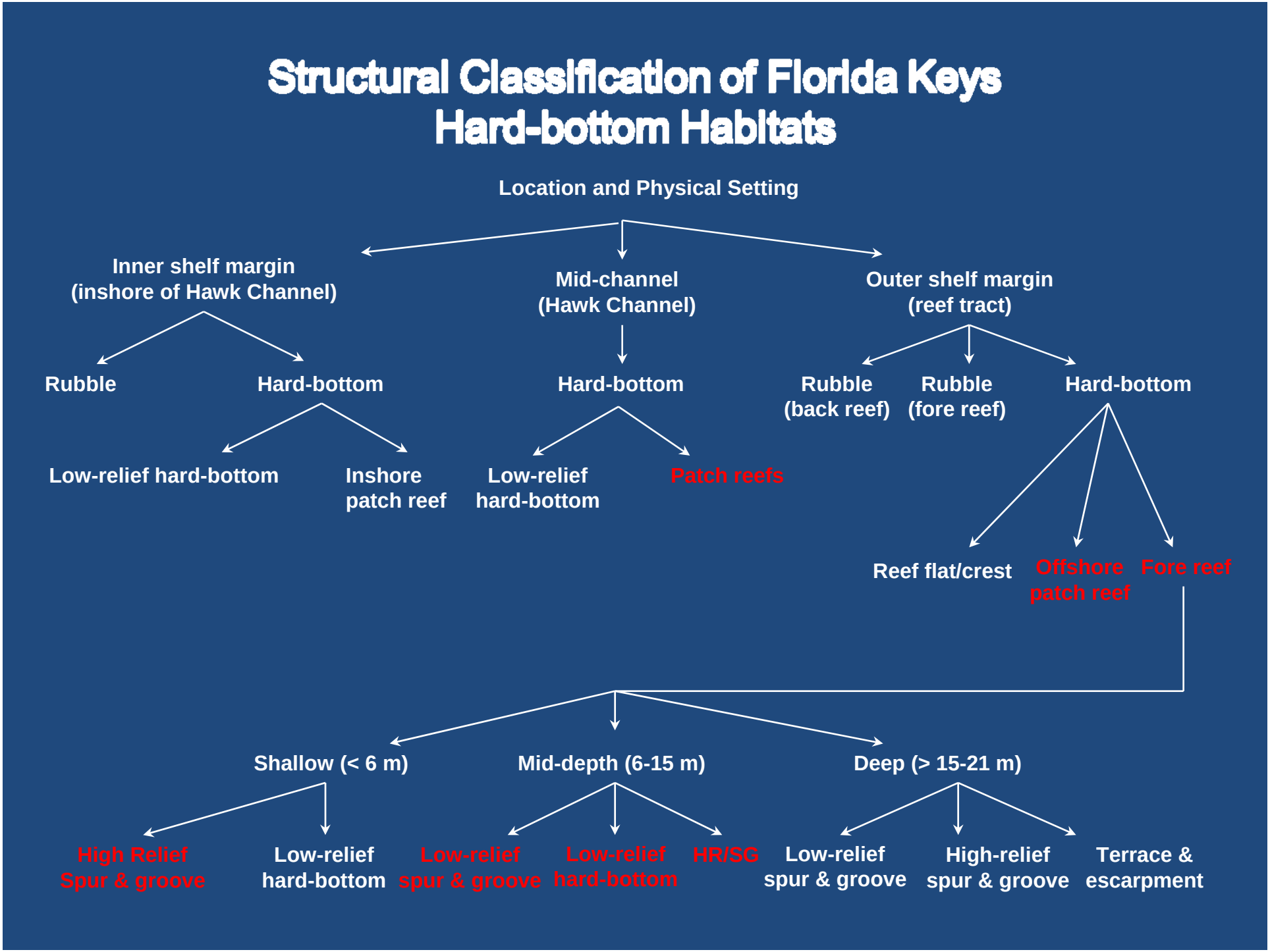
$\overline{m}_h$	Average number of second-stage units sampled per primary unit in stratum *h*	$\overline{m}_h = \frac{1}{n_h} \sum_i m_{hi}$

m^*_h	Optimum number of second-stage unit samples per primary unit in stratum *h*	$m^*_h = \frac{\sqrt{s_{2h}^2}}{s_{uh}}$
$V\left[\overline{\overline{D}}_{st}\right]$	Target variance for domain-wide mean density	$V\left[\overline{\overline{D}}_{st}\right] = \left(CV\left[\overline{\overline{D}}_{st}\right] \cdot \overline{\overline{D}}_{st}\right)^2$
n^*	Number of primary unit samples required to achieve a specified variance	$n^* = \frac{\sum_h w_h s_{uh} \left(\sum_h w_h s_{uh} + \sum_h \frac{w_h^2 s_{2h}^2}{m^*_h w_h s} \right)}{V\left[\overline{\overline{D}}_{st}\right] + \sum_h \frac{w_h^2 s_{1h}^2}{N_h}}$
n^*_h	Optimal allocation of primary units among strata	$n^*_h = n^* \left(\frac{w_h s_{uh}}{\sum_h w_h s_{uh}} \right)$


81°
25°
1999-2009 Benthic Survey Sites
FKNMS Boundary
South Florida & Florida Keys
1999-2001 198 sites
2005 133 sites
2009 156 sites
Biscayne
Upper Keys
Middle Keys
Lower Keys
N
50 0 50 100 150 200 Kilometers

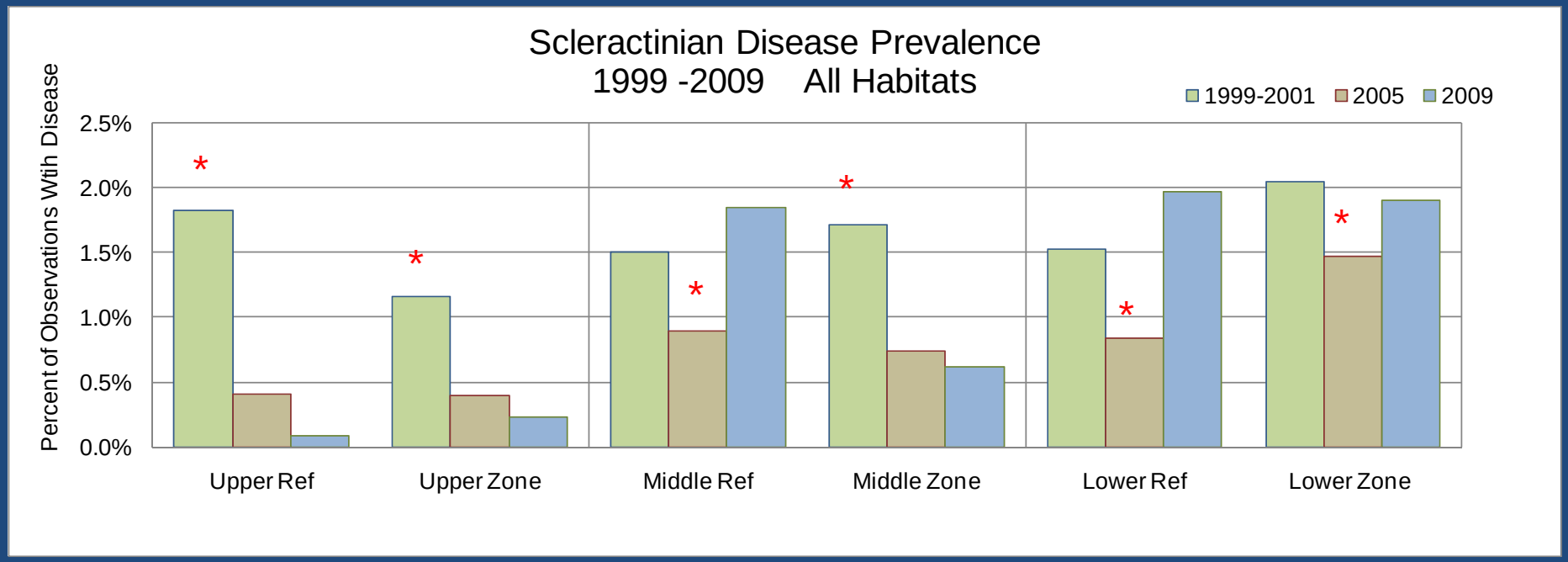

Keyswide
Upper Keys
Middle Keys
Lower Keys
Habitat Types
Habitat Types
Habitat Types
Ref Sites
NTZs
Ref Sites
NTZs
Ref Sites
NTZs
Ref Sites
NTZ
Ref Sites
NTZ
Ref Sites
NTZ

Structural Classification of Florida Keys Hard-bottom Habitats



Coral Diseases Keys-wide

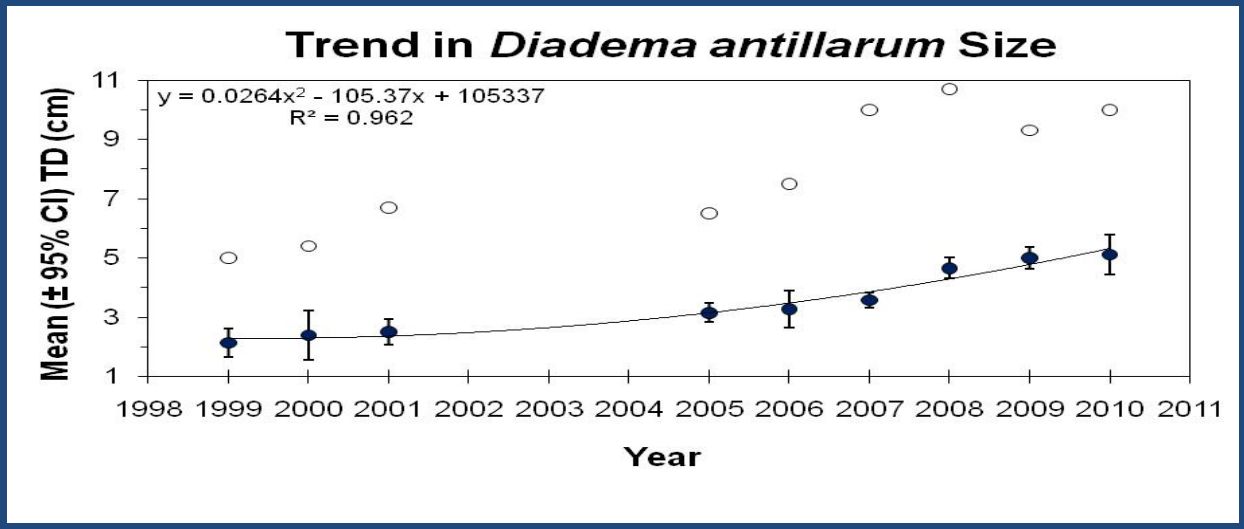
- White plague
- Black band disease
- White band disease
- Yellow blotch
- Dark spot

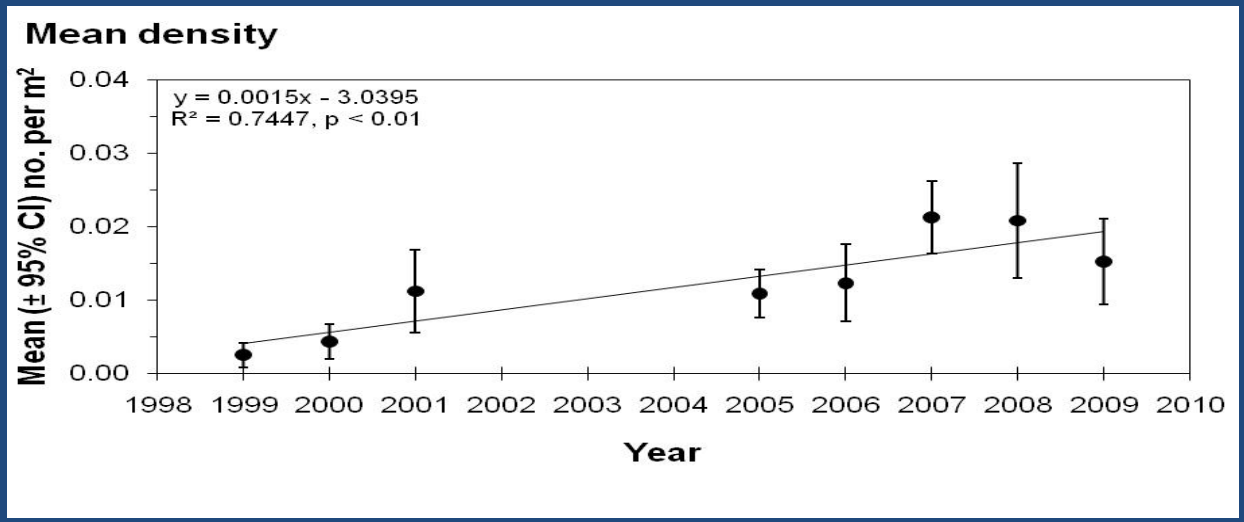

Scleractinian Disease Prevalence
1999 -2009 All Habitats
1999-2001
2005
2009
Percent of Observations With Disease
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
*
Upper Ref
Upper Zone
Middle Ref
Middle Zone
Lower Ref
Lower Zone

Human Disease Prevalence Statistics

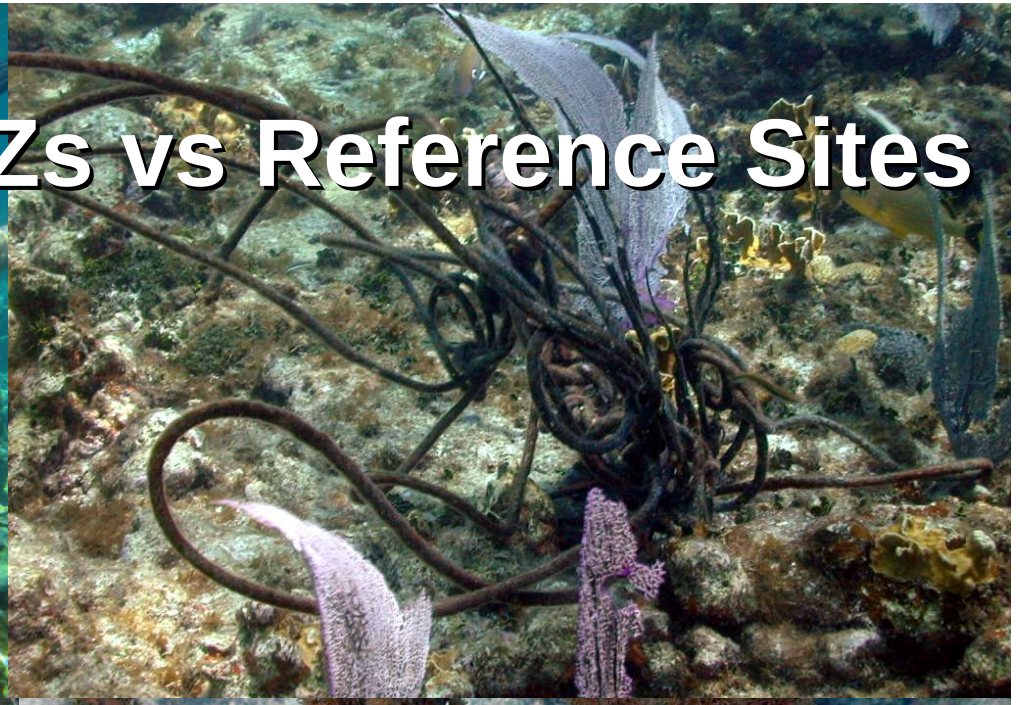
- Corals in the Keys: 0.2 - 1.9%
  - AIDS in North America: 0.45% (2006)
  - Breast Cancer: 0.8% (2007) [12% will be diagnosed lifetime]
  - Prostate Cancer: 0.8% (45-64) [16% will be diagnosed lifetime]
  - Heart Disease: 6.5% woman, 8.2% men (2005)
  - Bubonic Plague (Black Death): 1/3 of Europe's population killed (25 million deaths) 1347-1352

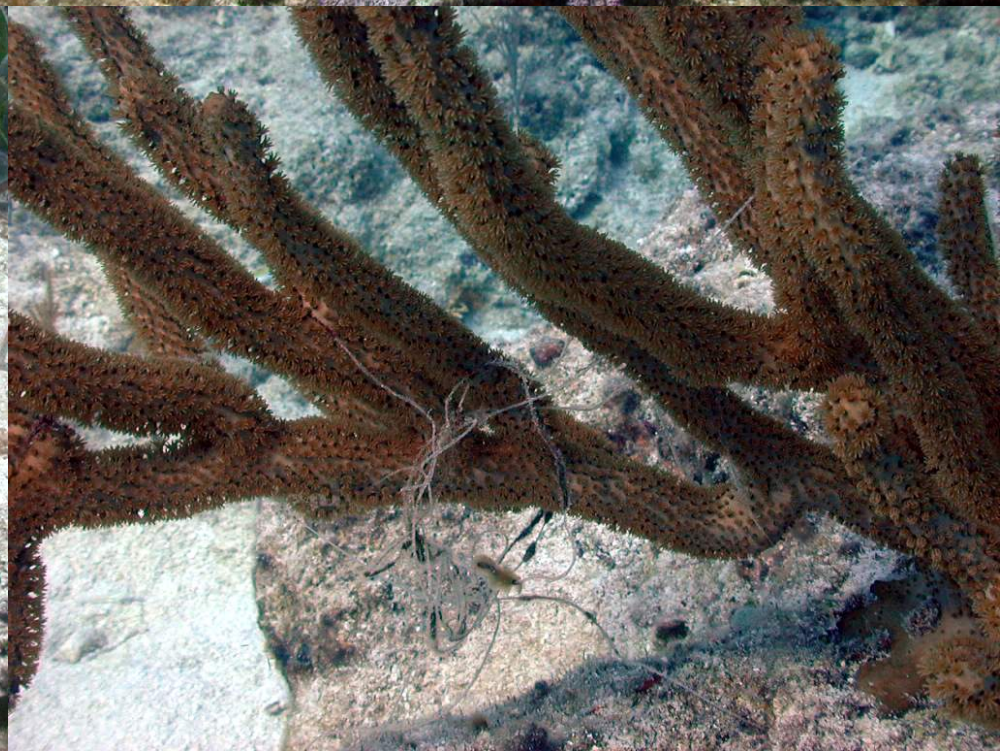
Diadema Size and Density





Marine Debris: NTZs vs Reference Sites





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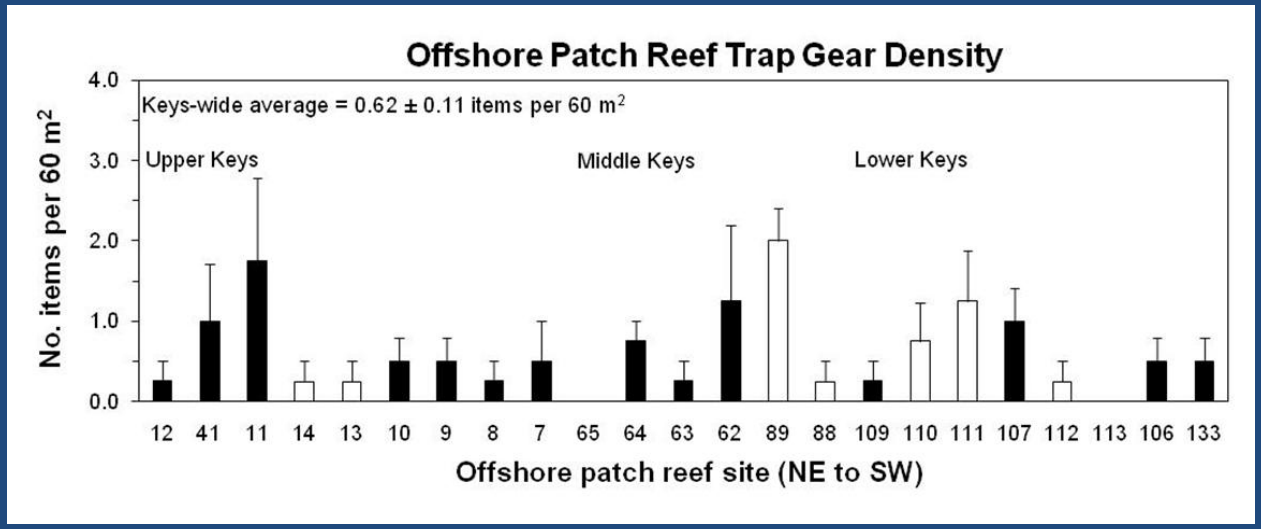
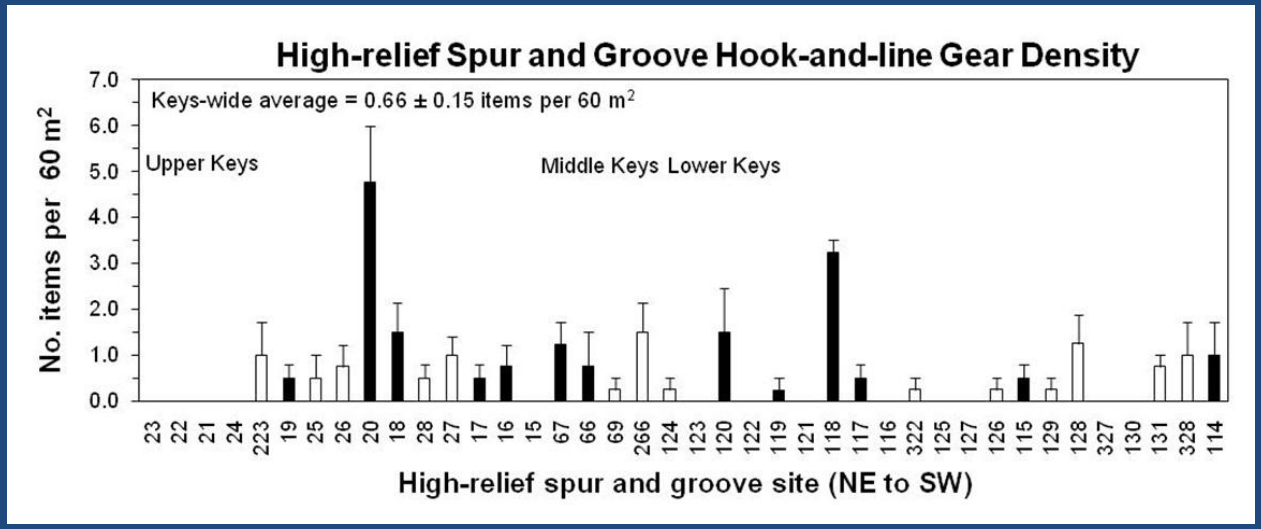
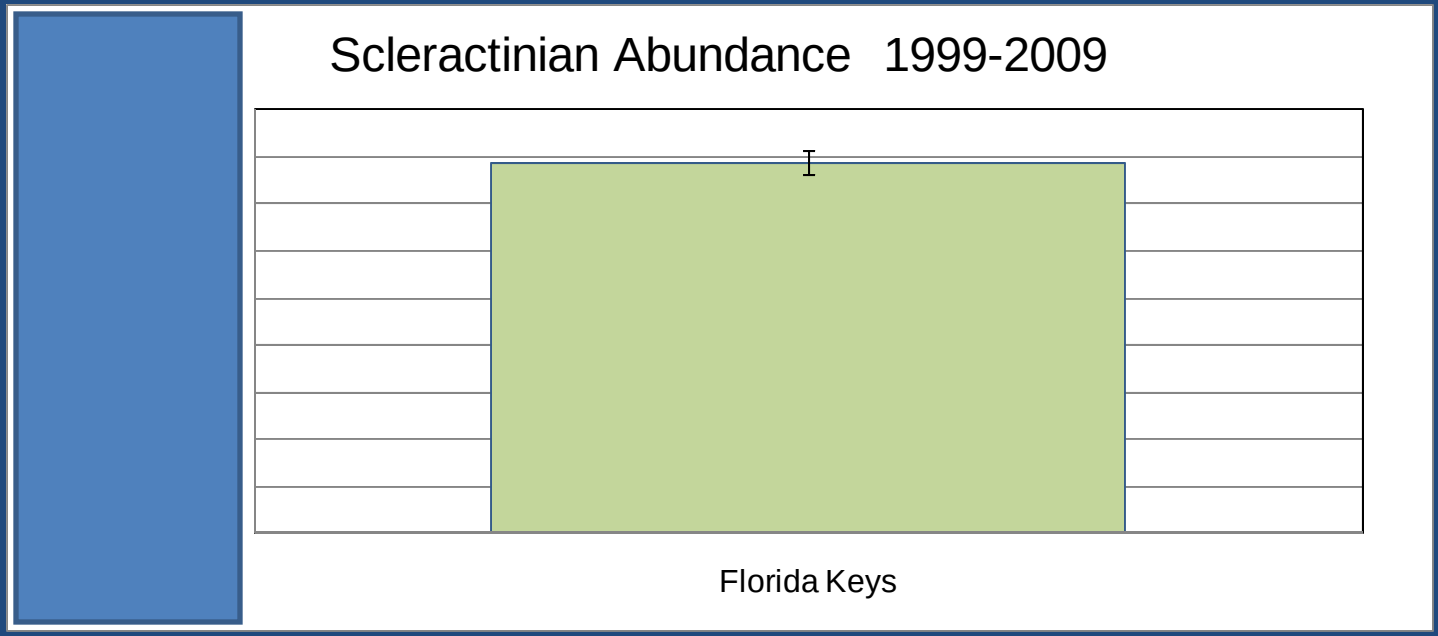
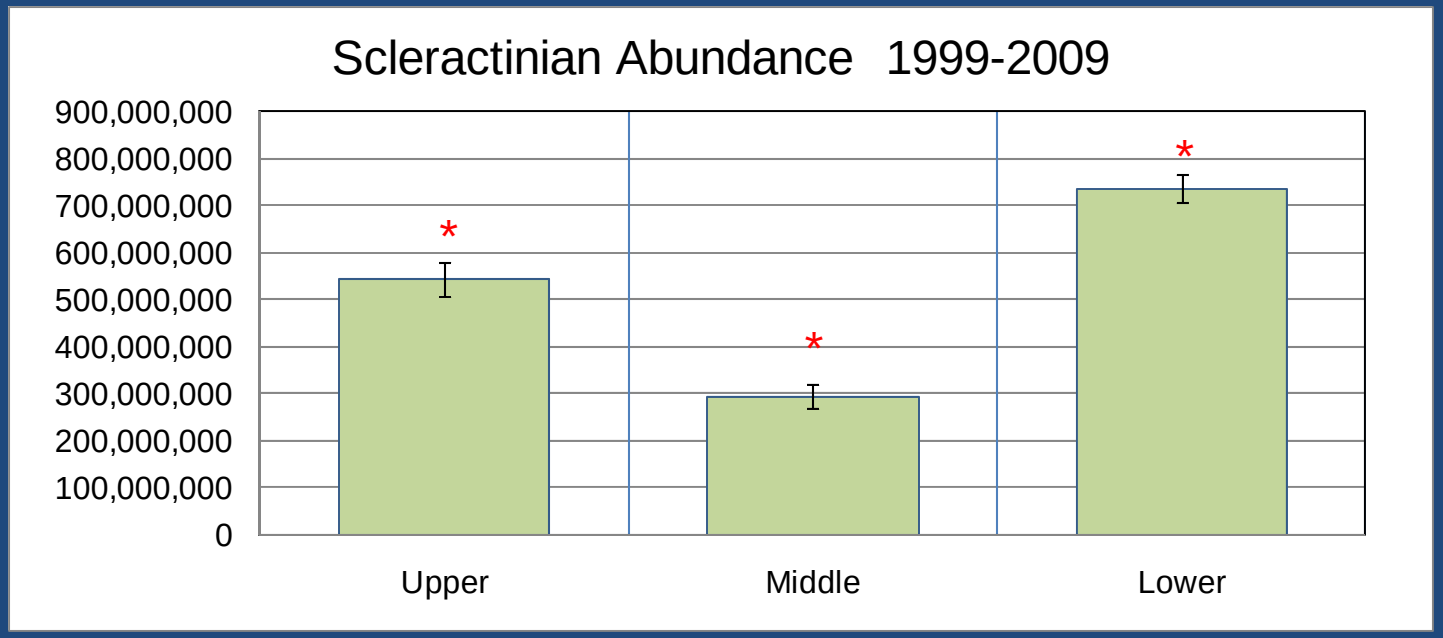
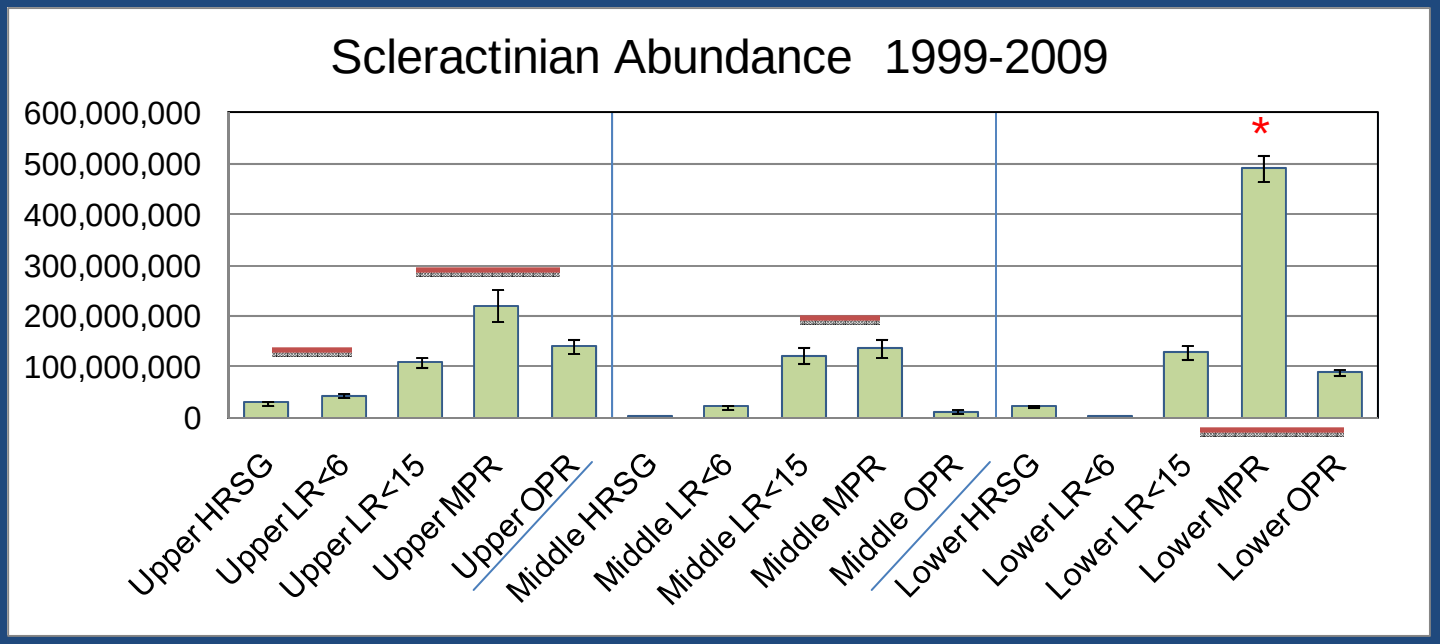




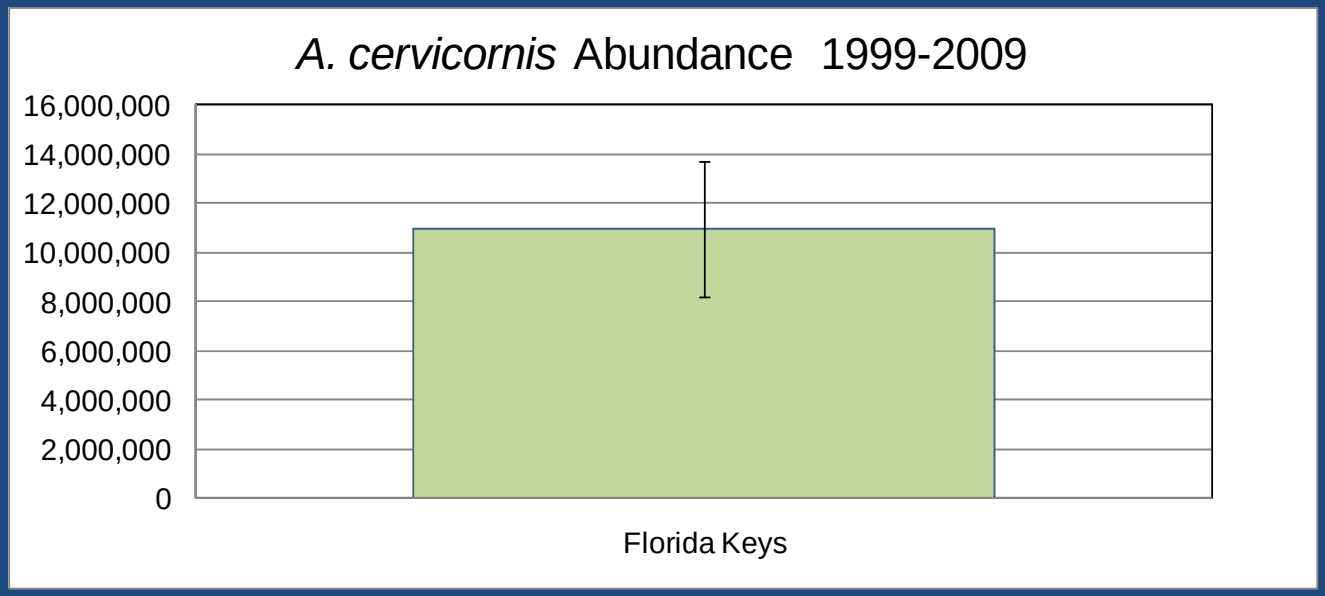
Keys-wide Coral Population

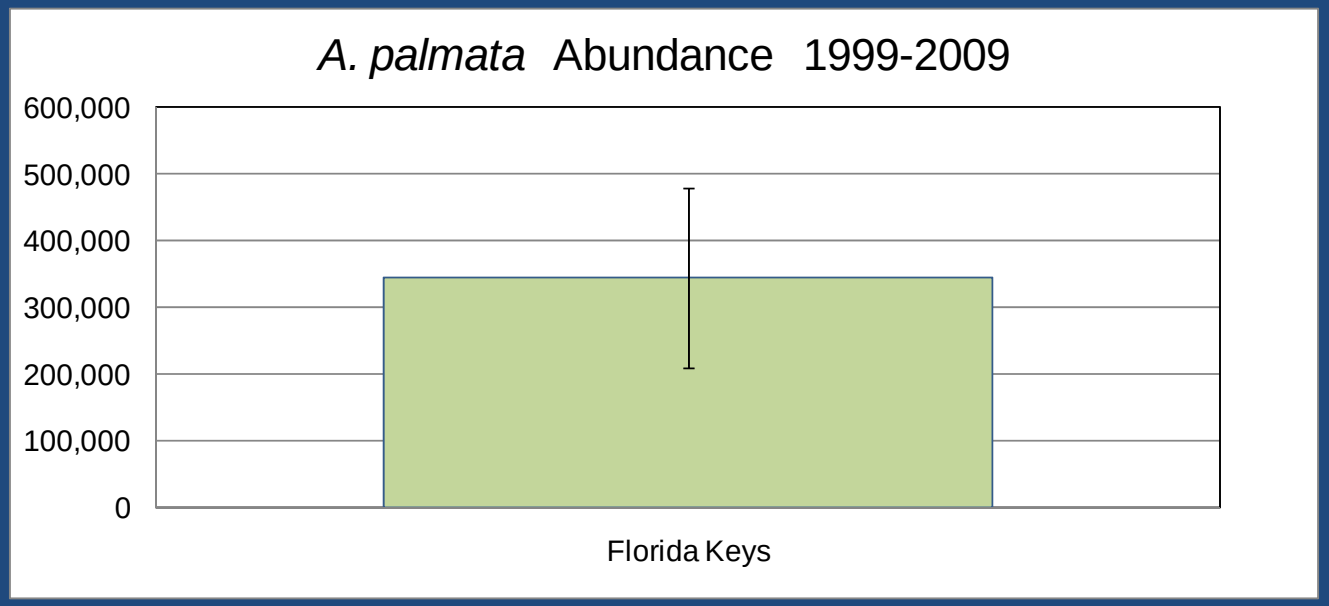



Scleractinian Abundance 1999-2009
900,000,000
800,000,000
700,000,000
600,000,000
500,000,000
400,000,000
300,000,000
200,000,000
100,000,000
0
*
*
*
Upper
Middle
Lower

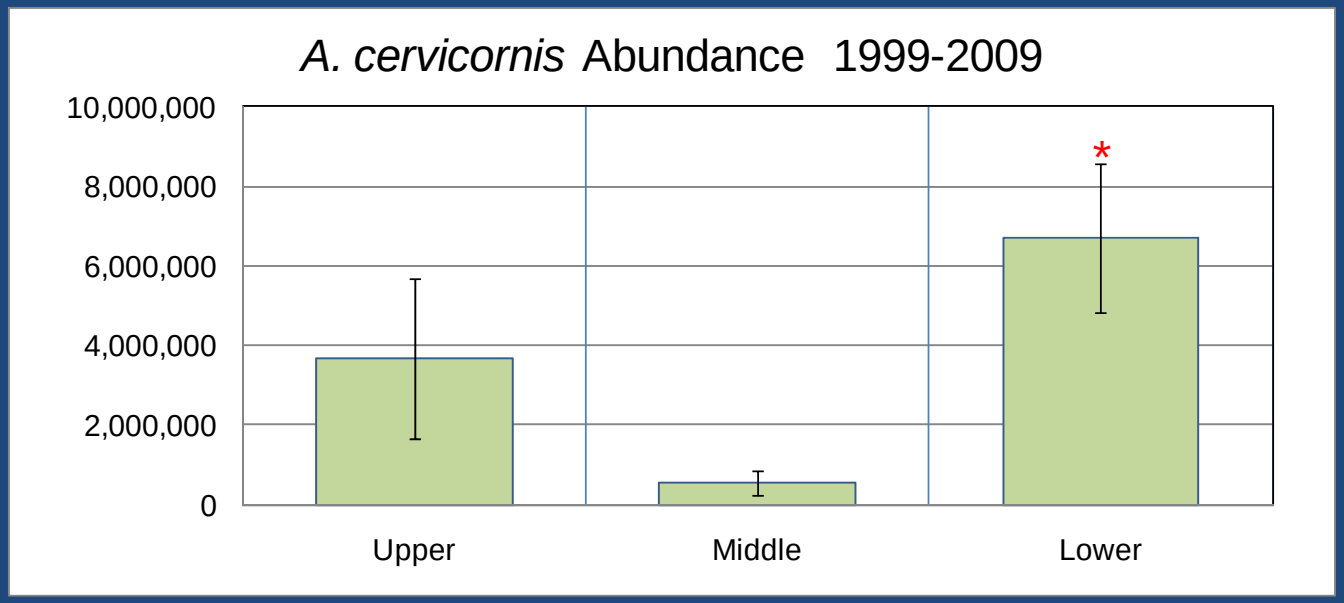

Scleractinian Abundance 1999-2009
600,000,000
500,000,000
400,000,000
300,000,000
200,000,000
100,000,000
0
*
Upper HRSG
Upper LR<6
Upper LR<15
Upper MPR
Upper OPR
Middle HRSG
Middle LR<6
Middle LR<15
Middle MPR
Middle OPR
Lower HRSG
Lower LR<6
Lower LR<15
Lower MPR
Lower OPR

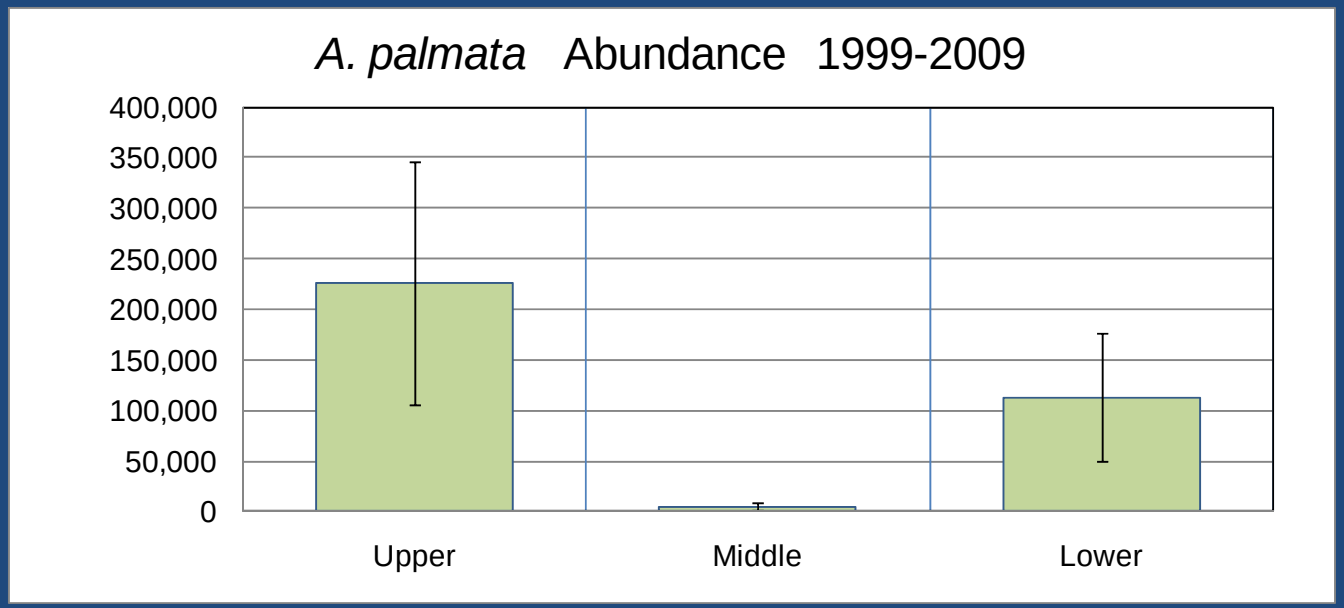
Keys-wide Acroporid Populations



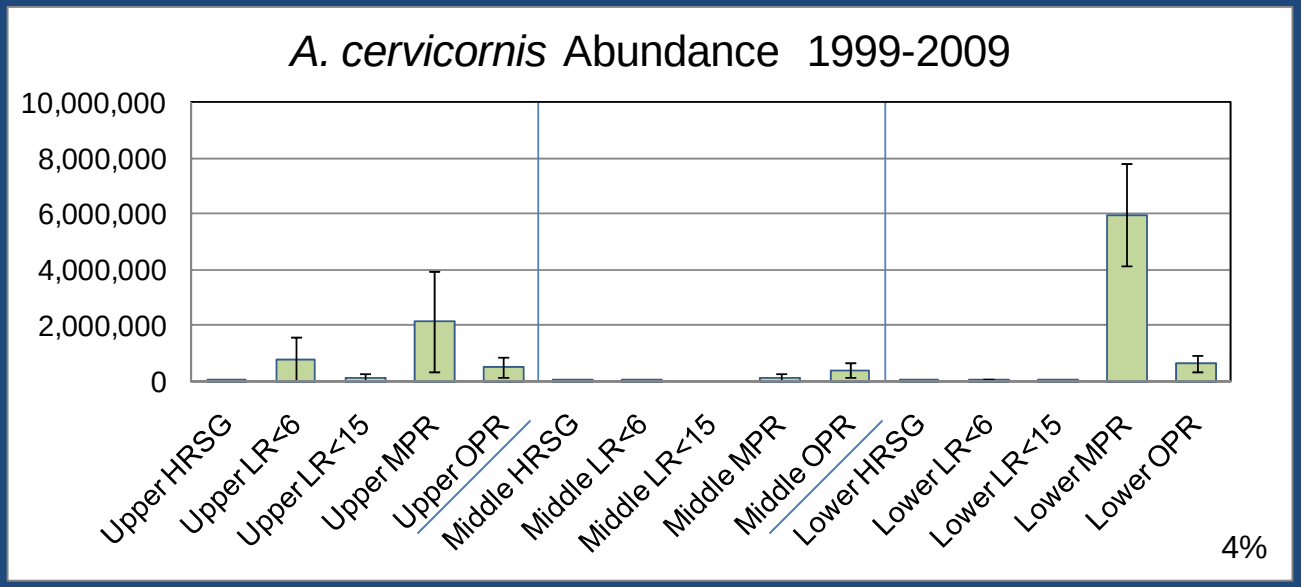


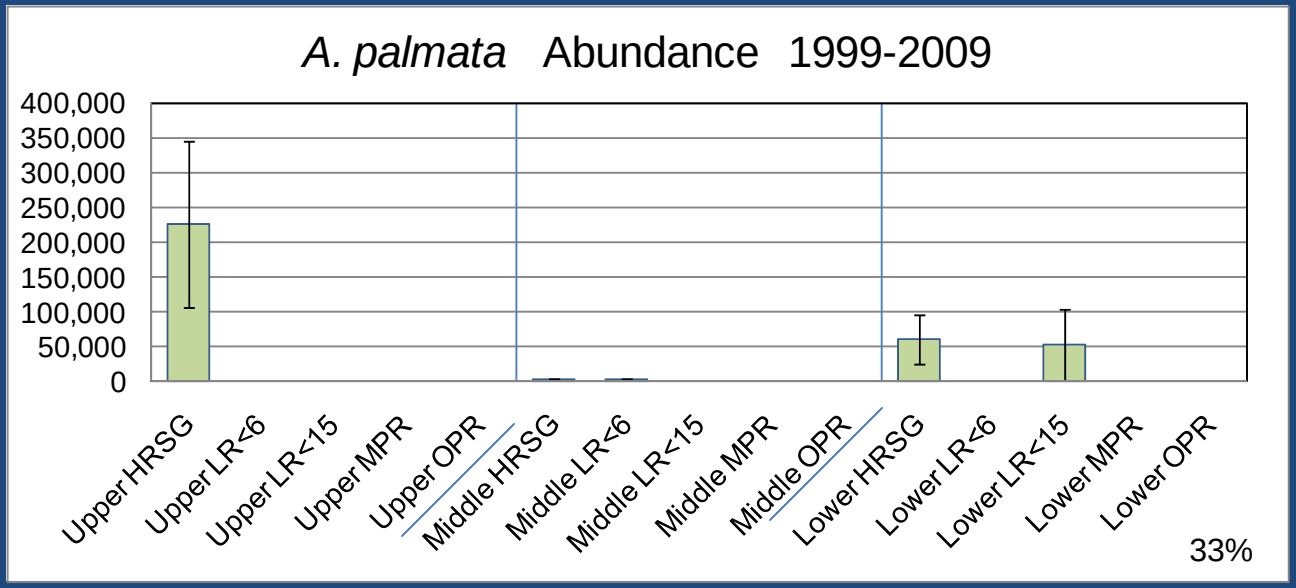
Acroporid Population by Region

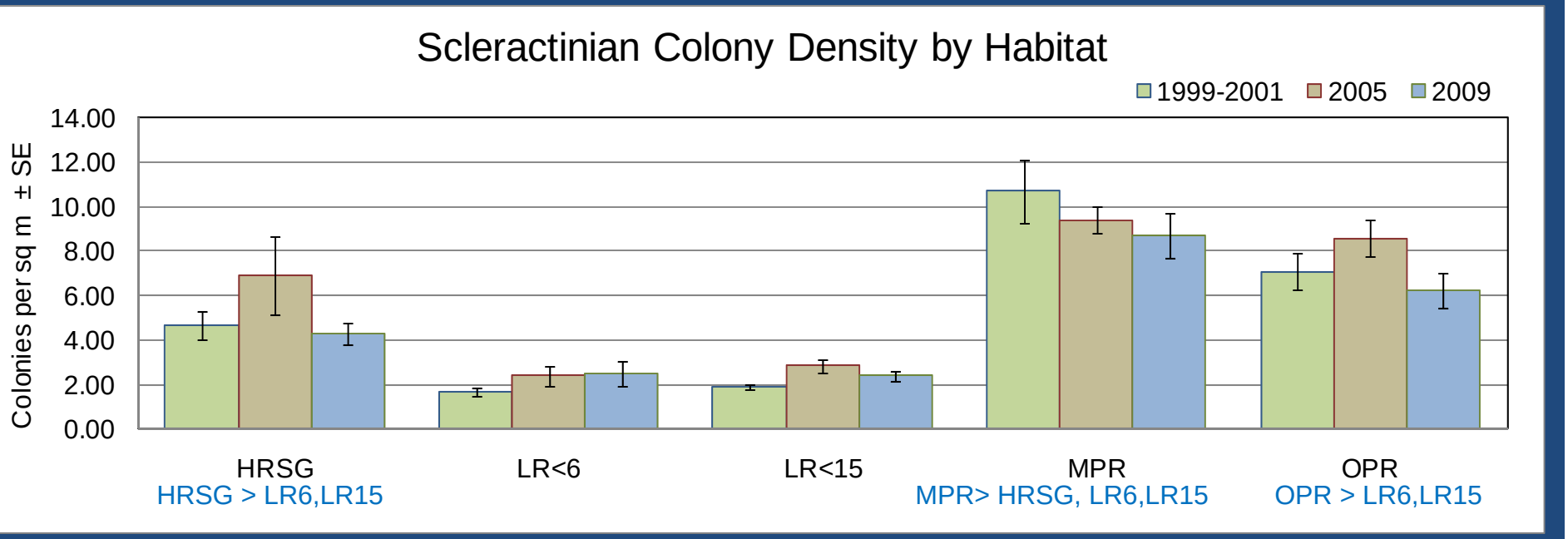


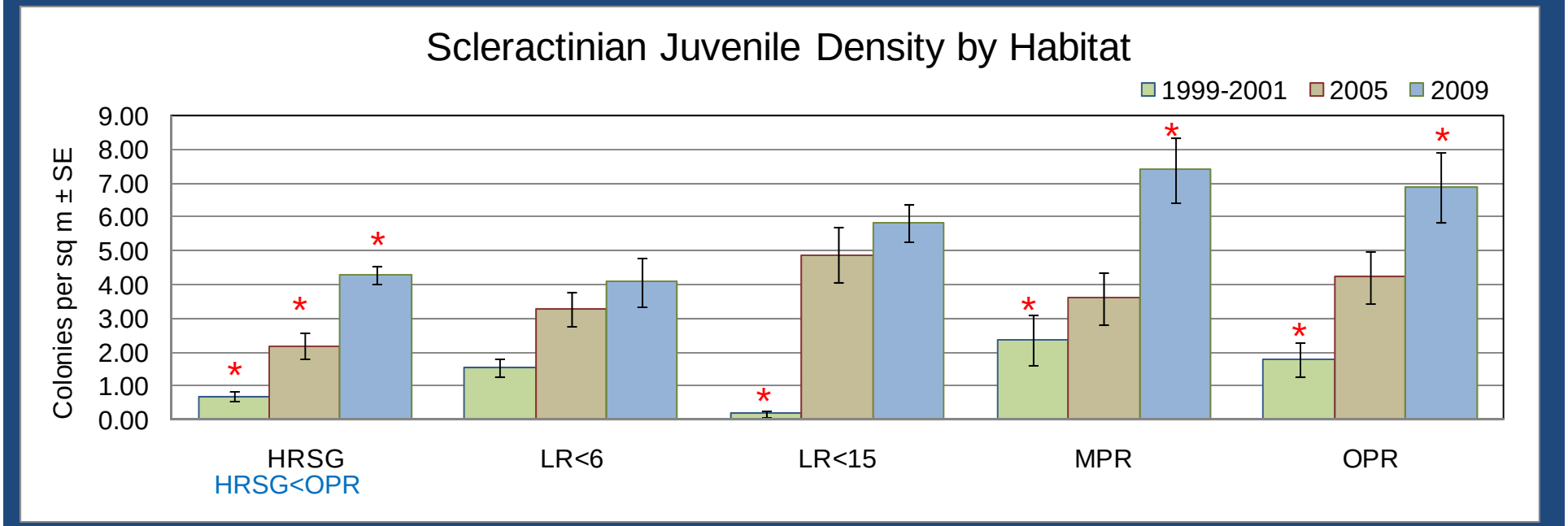


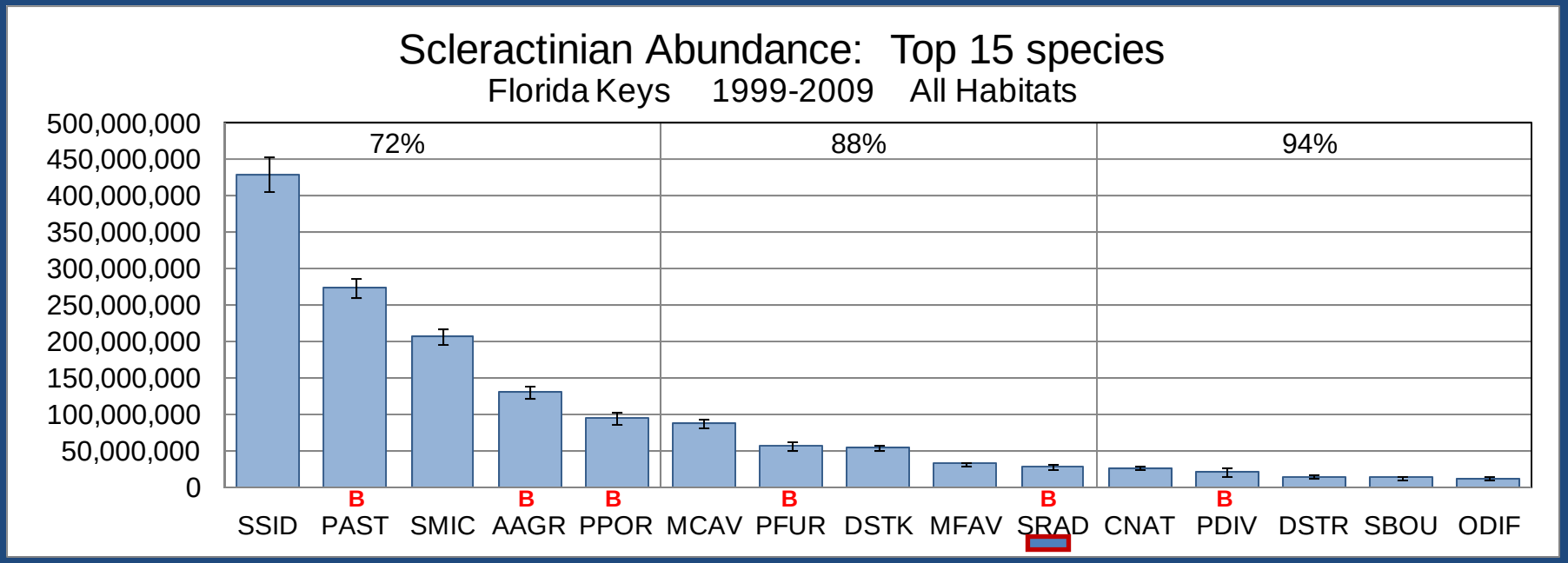
Acroporid Population by Region and Habitat Type

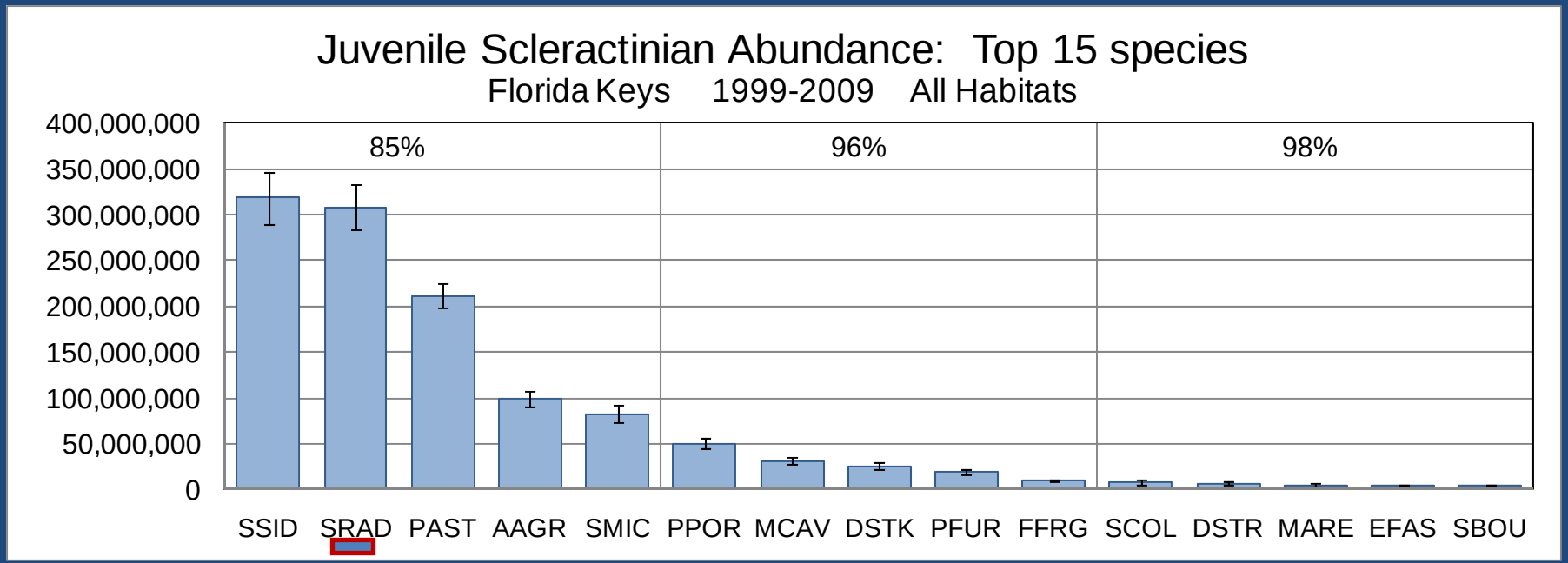




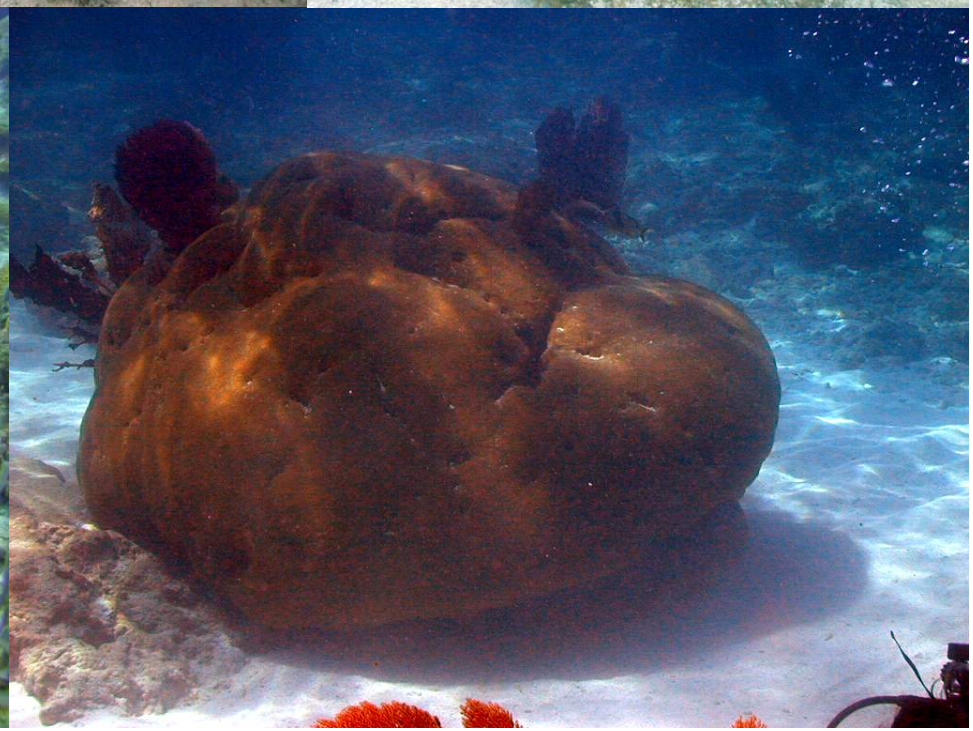

Scleractinian Colony Density by Habitat
1999-2001
2005
2009
Colonies per sq m ± SE
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
HRSG
LR<6
LR<15
MPR
OPR
HRSG > LR6,LR15
MPR> HRSG, LR6,LR15
OPR > LR6,LR15

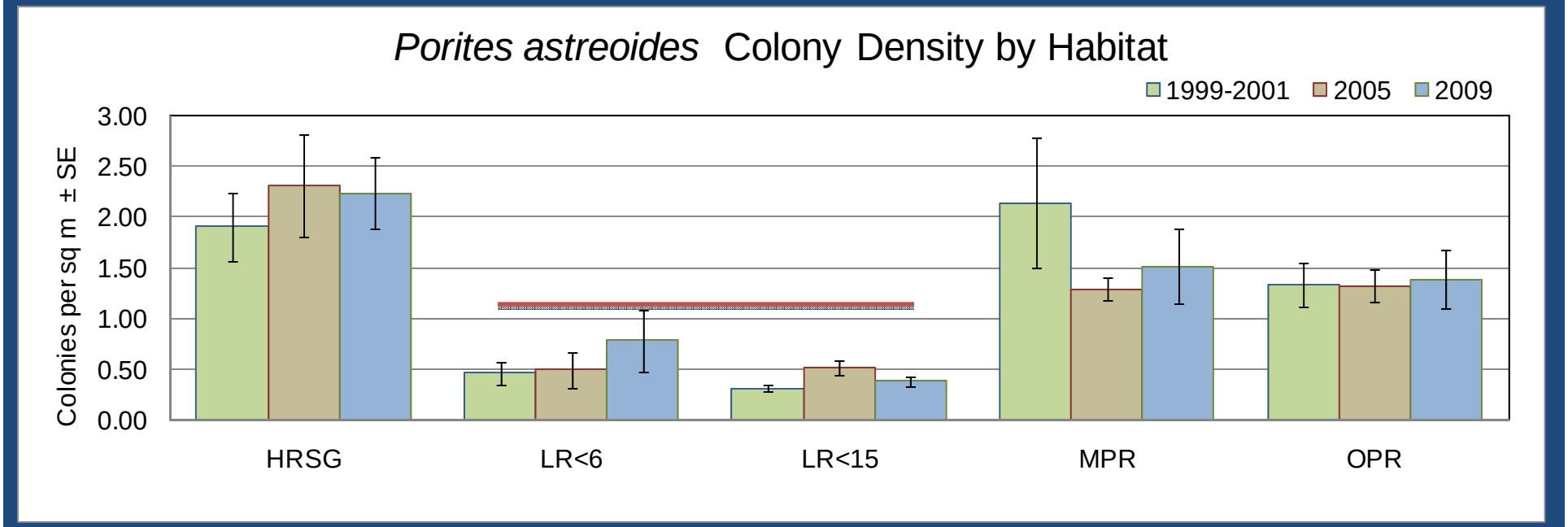

Scleractinian Juvenile Density by Habitat
1999-2001
2005
2009
Colonies per sq m ± SE
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
HRSG
LR<6
LR<15
MPR
OPR
HRSG<OPR

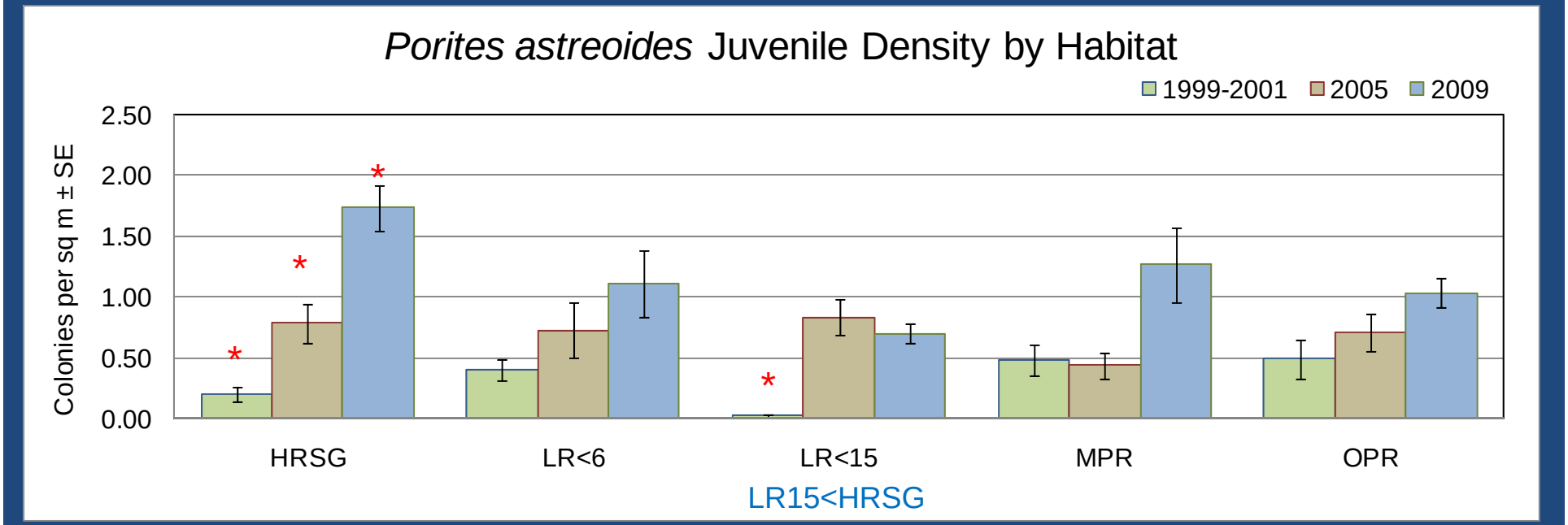

Scleractinian Abundance: Top 15 species
Florida Keys 1999-2009 All Habitats
500,000,000
450,000,000
400,000,000
350,000,000
300,000,000
250,000,000
200,000,000
150,000,000
100,000,000
50,000,000
0
72%
88%
94%
B
B
B
B
B
B
SSID PAST SMIC AAGR PPOR MCAV PFUR DSTK MFAV SRAD CNAT PDIV DSTR SBOU ODIF

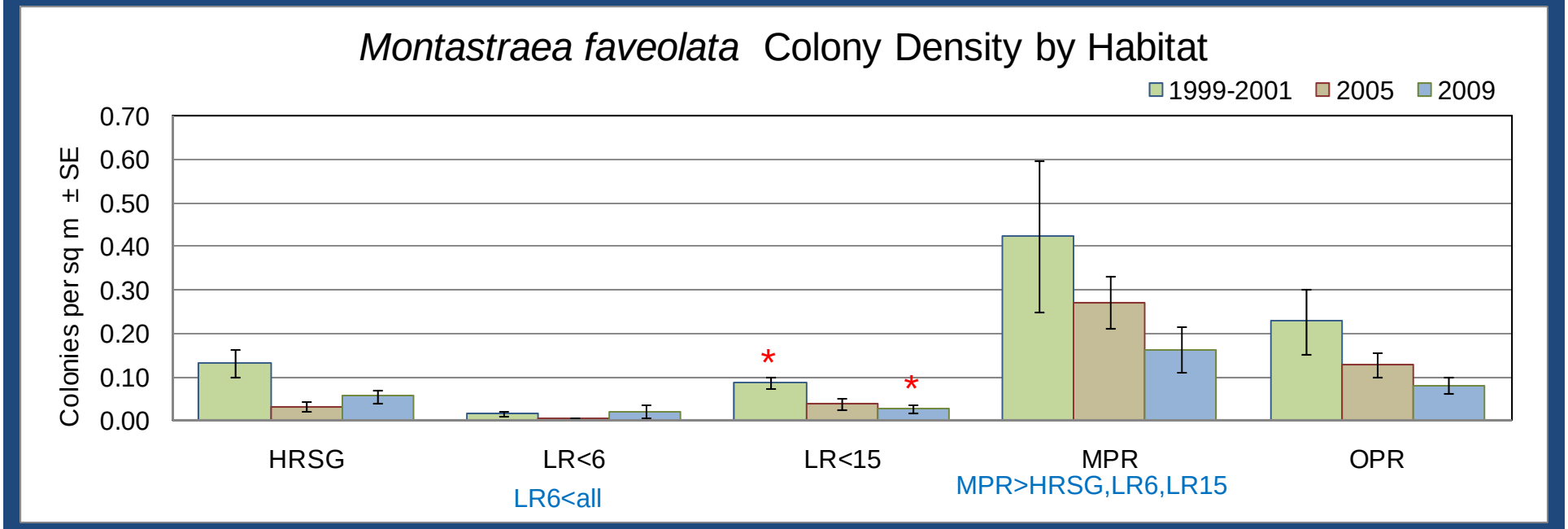

Juvenile Scleractinian Abundance: Top 15 species
Florida Keys 1999-2009 All Habitats
400,000,000
350,000,000
300,000,000
250,000,000
200,000,000
150,000,000
100,000,000
50,000,000
0
85%
96%
98%
SSID SRAD PAST AAGR SMIC PPOR MCAV DSTK PFUR FFRG SCOL DSTR MARE EFAS SBOU

What will reefs in the Florida Keys look like in the future?

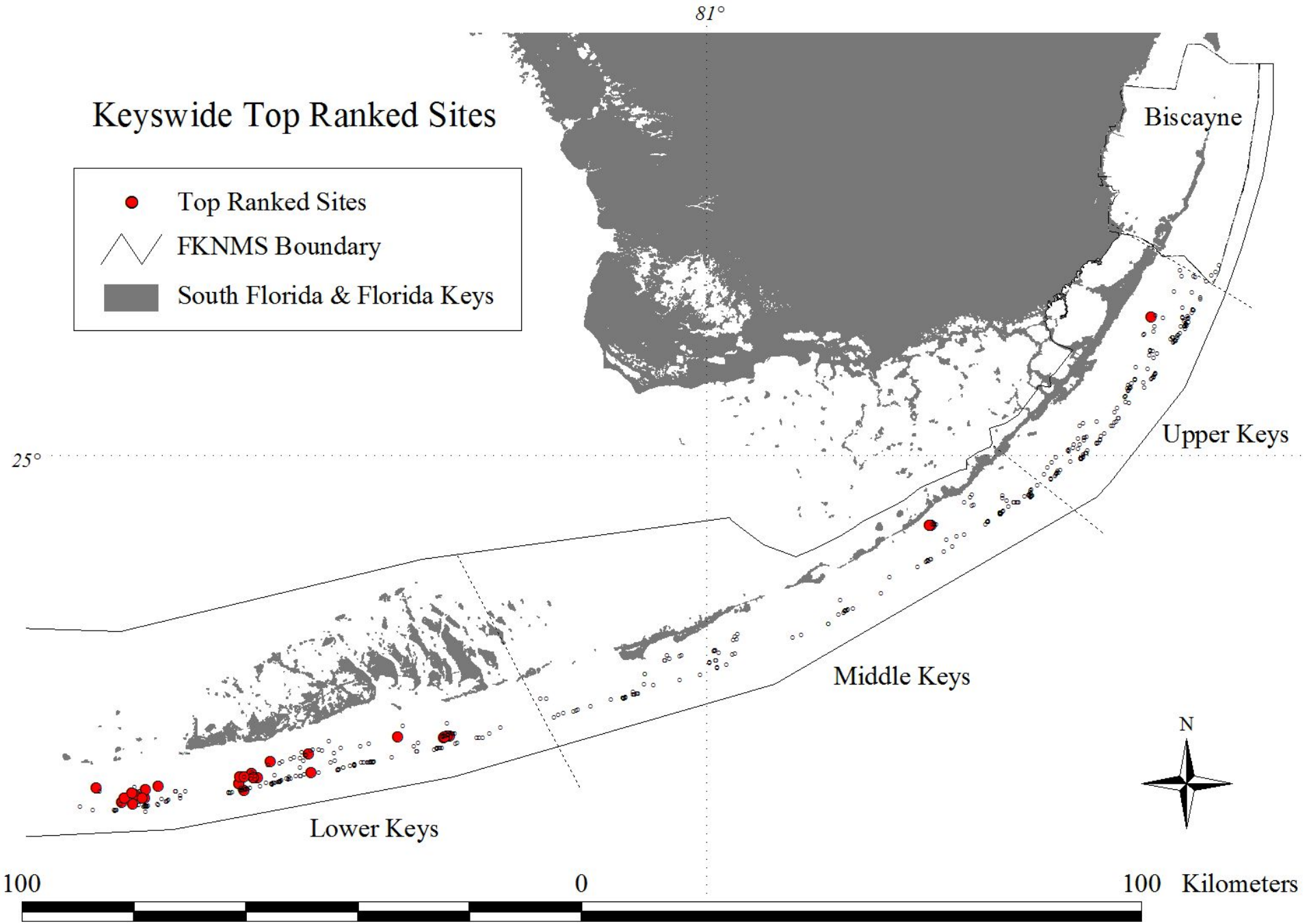


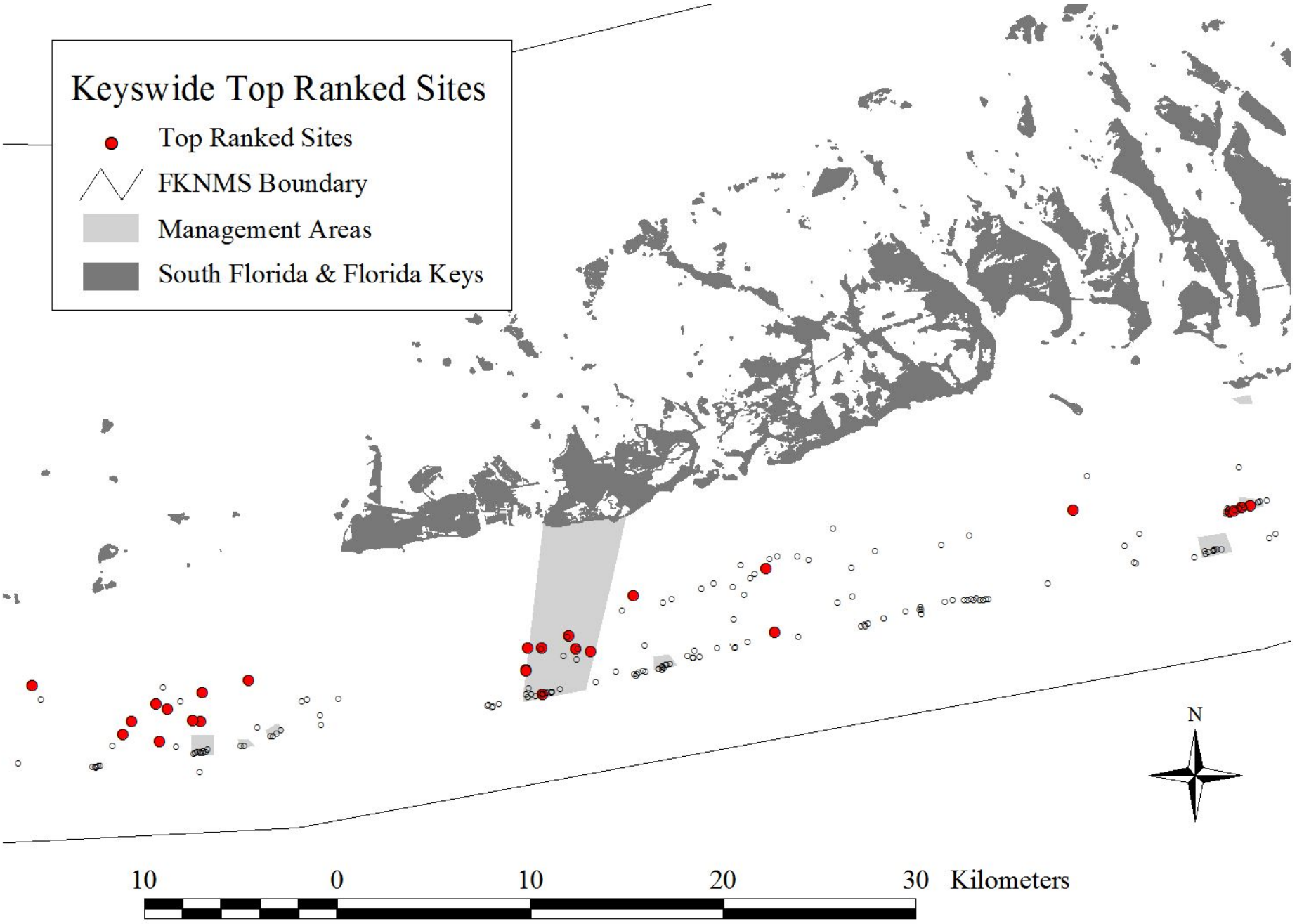

Porites astreoides Colony Density by Habitat
1999-2001
2005
2009
Colonies per sq m ± SE
3.00
2.50
2.00
1.50
1.00
0.50
0.00
HRSG
LR<6
LR<15
MPR
OPR


Porites astreoides Juvenile Density by Habitat
1999-2001
2005
2009
Colonies per sq m ± SE
2.50
2.00
1.50
1.00
0.50
0.00
*
*
*
HRSG
LR<6
LR<15
MPR
OPR
LR15<HRSG

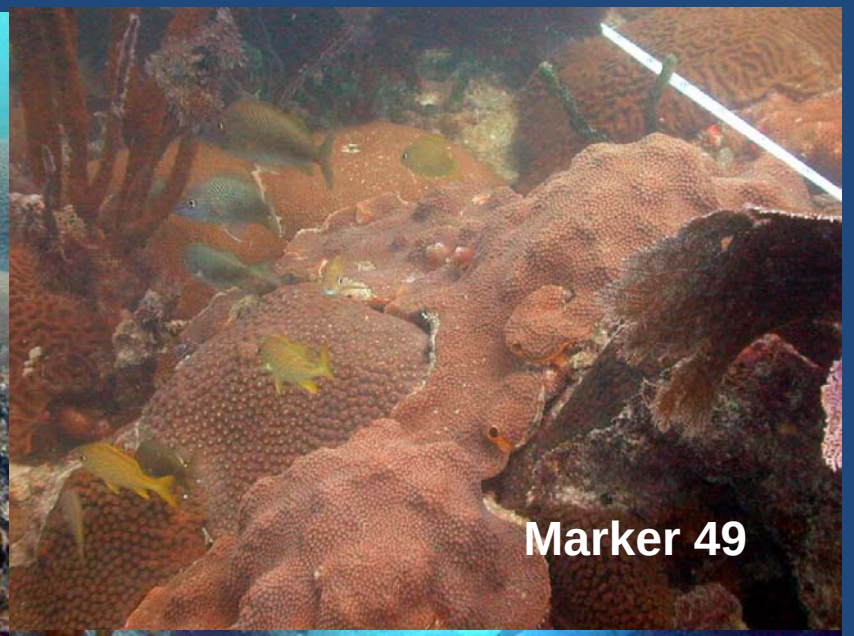


No Juvenile Observations for *M faveolata*


Keyswide Top Ranked Sites
Top Ranked Sites
FKNMS Boundary
South Florida & Florida Keys
81°
25°
Biscayne
Upper Keys
Middle Keys
Lower Keys
N
100
0
100 Kilometers


Keyswide Top Ranked Sites
Top Ranked Sites
FKNMS Boundary
Management Areas
South Florida & Florida Keys
N
10
0
10
20
30
Kilometers

Mid-channel Patch Reefs

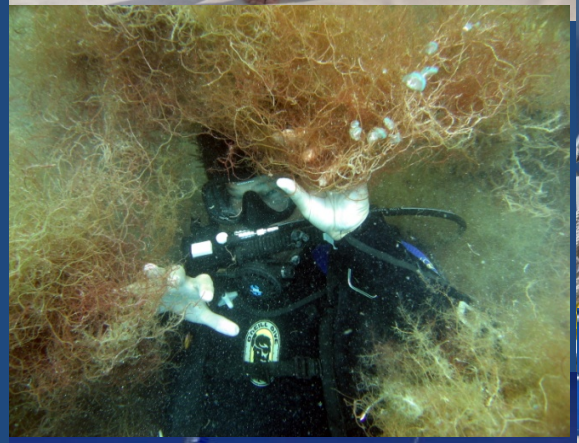


Future Plans

- Keyswide Acropora sampling in 2011 concurrent with same in USVI and PR
- Data analyses and publication
- Data rescue for an unpublished 1970s NSF-funded coral reef assessment program (presentation)


1960


Today




Oak Leaf