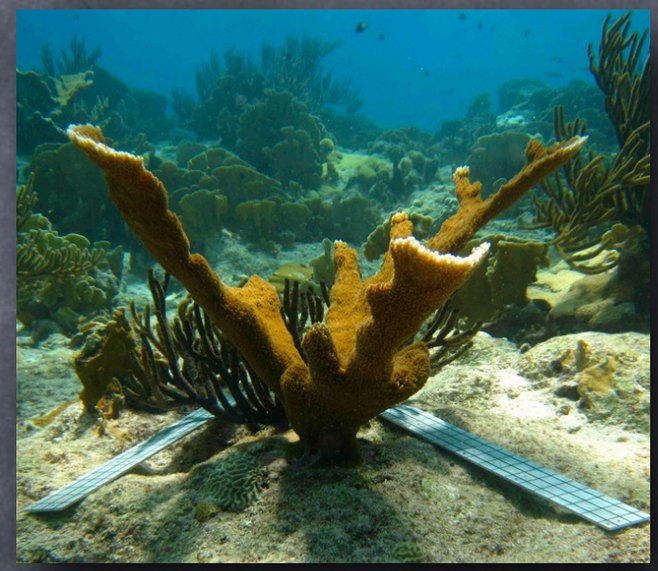
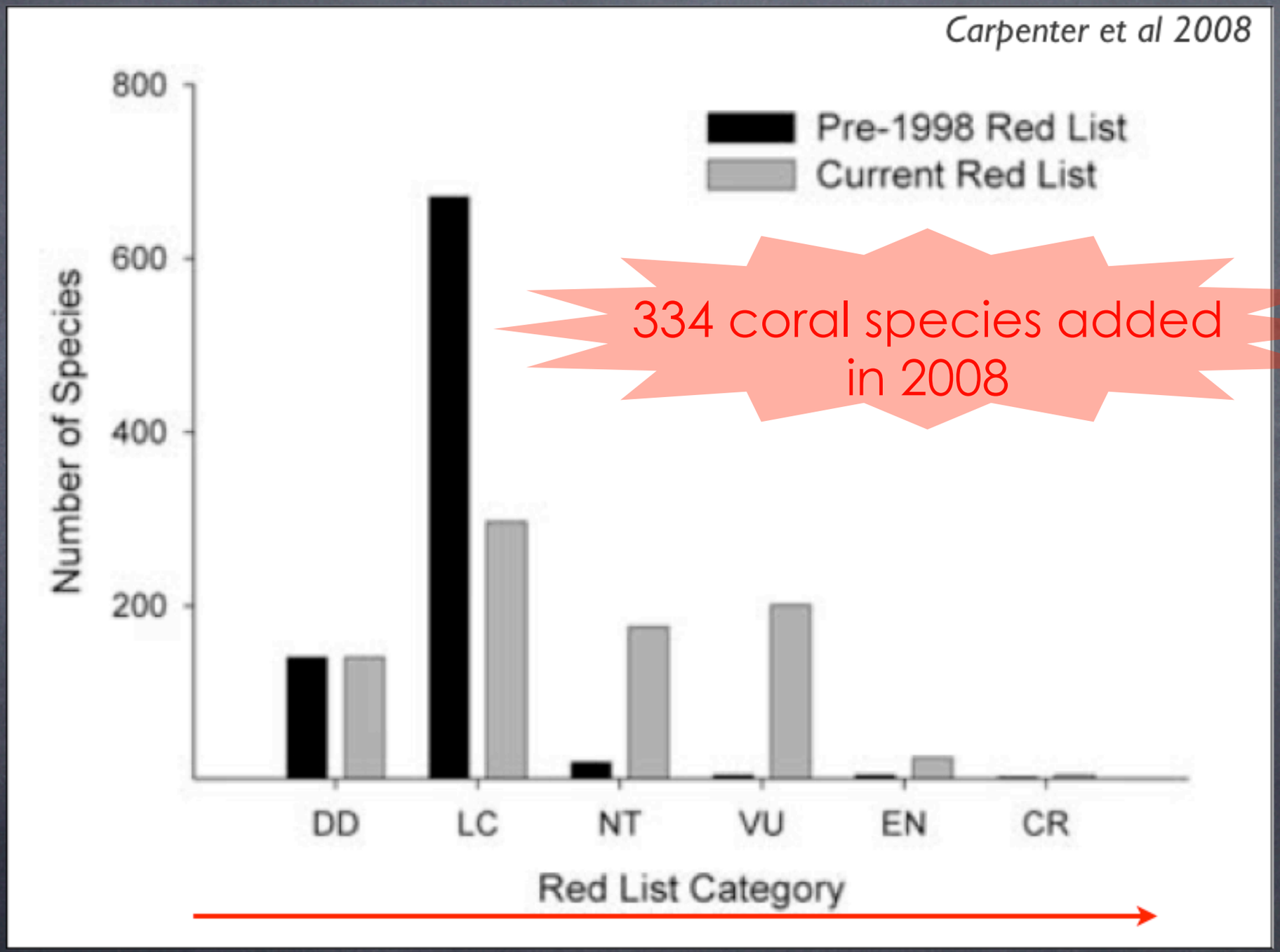
Elkhorn Coral Population Dynamics and Predictions for Recovery



Knauss Fellows Lecture Series

Tali Vardi, Ph.D.

Corals as Threatened Species



Corals as Threatened Species

NOAA Technical Memorandum NMFS-PIFSC-27

September 2011

Status Review Report of 82 Candidate Coral Species Petitioned Under the U.S. Endangered Species Act

Russell E. Brainard, Charles Birkeland, C. Mark Eakin, Paul McElhany, Margaret W. Miller, Matt Patterson, and Gregory A. Piniak

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

What is a coral?

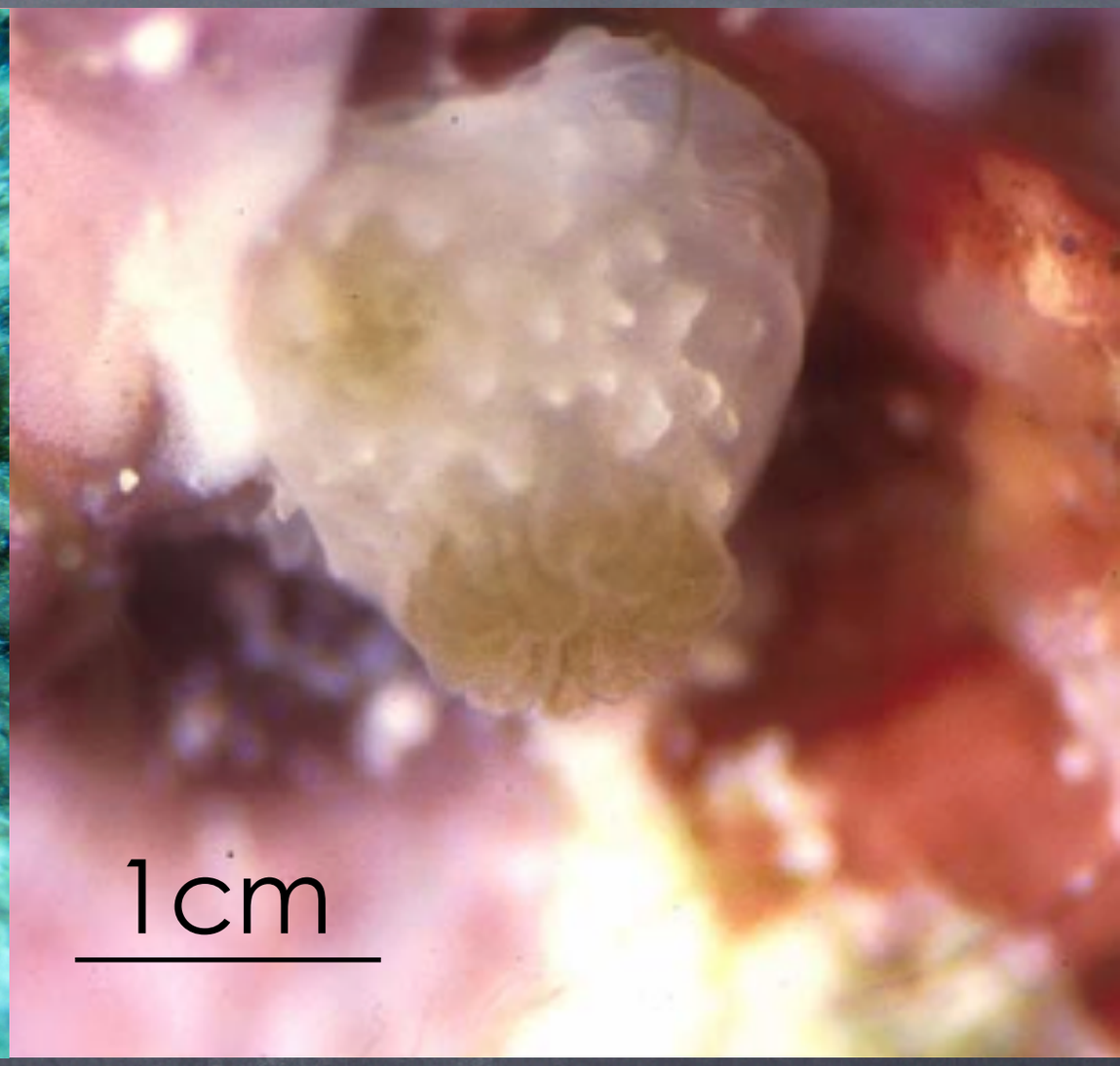
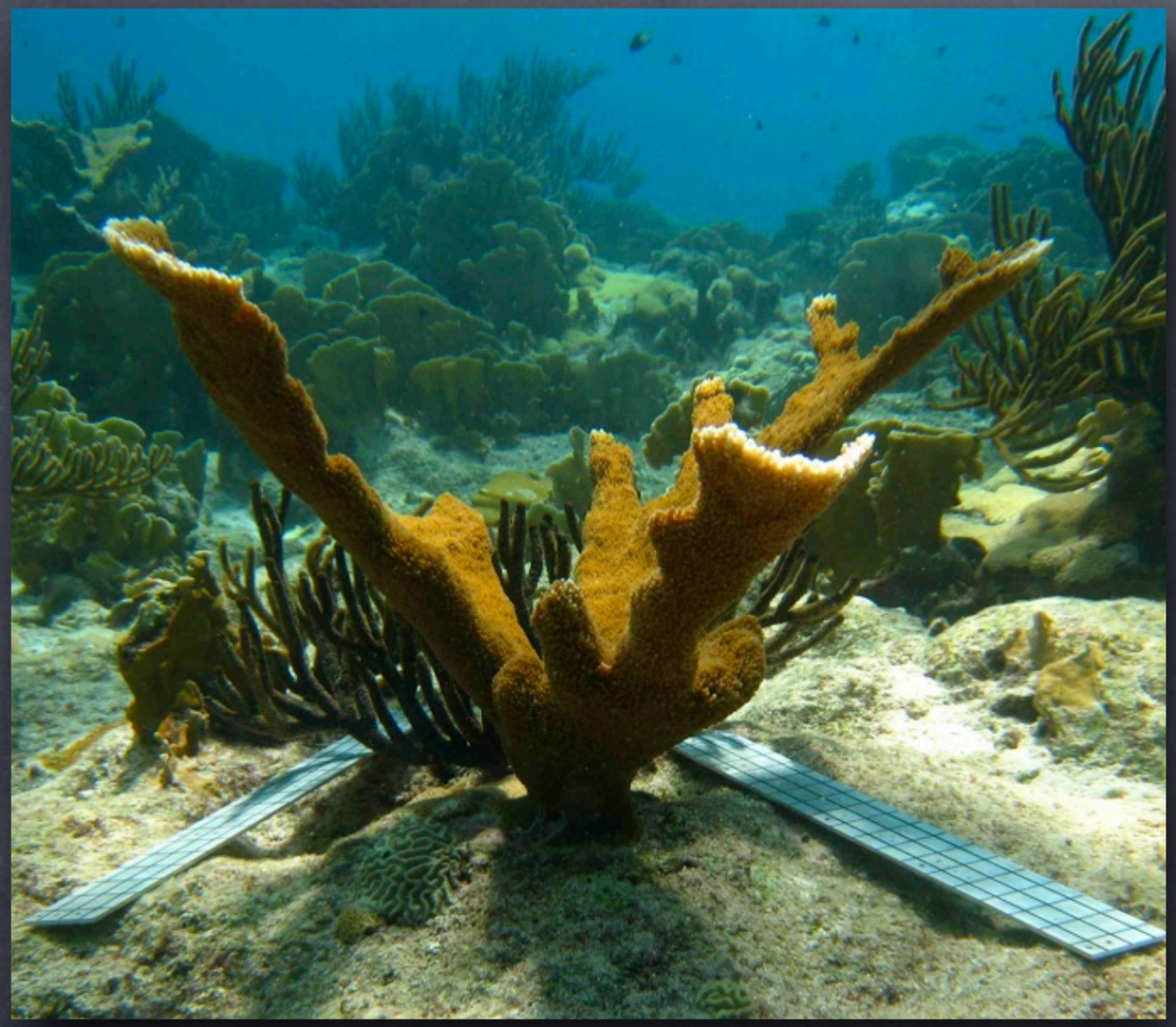


Photo credit A. Szmant

A. palmata - growth and reproduction



- fast grower (10 cm/yr)
- reproduces primarily through fragmentation

Acropora palmata

East Point Curaçao, Photo credit Stuart Sandin

- complex three-dimensional structure
- fish and invertebrate habitat

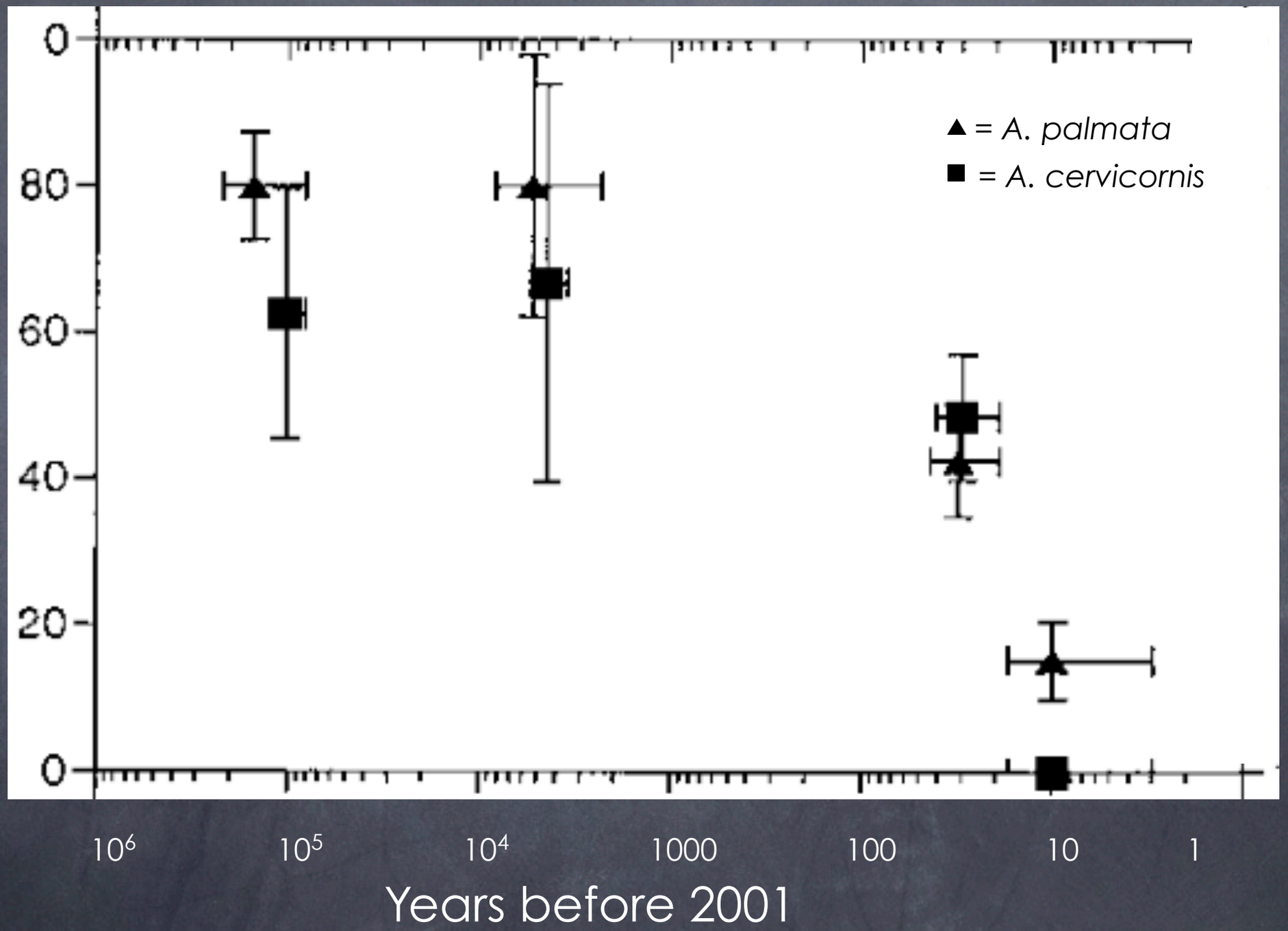
Reef structure

Bahamas, Photo credit C. Kendall

Greer et al. 2009

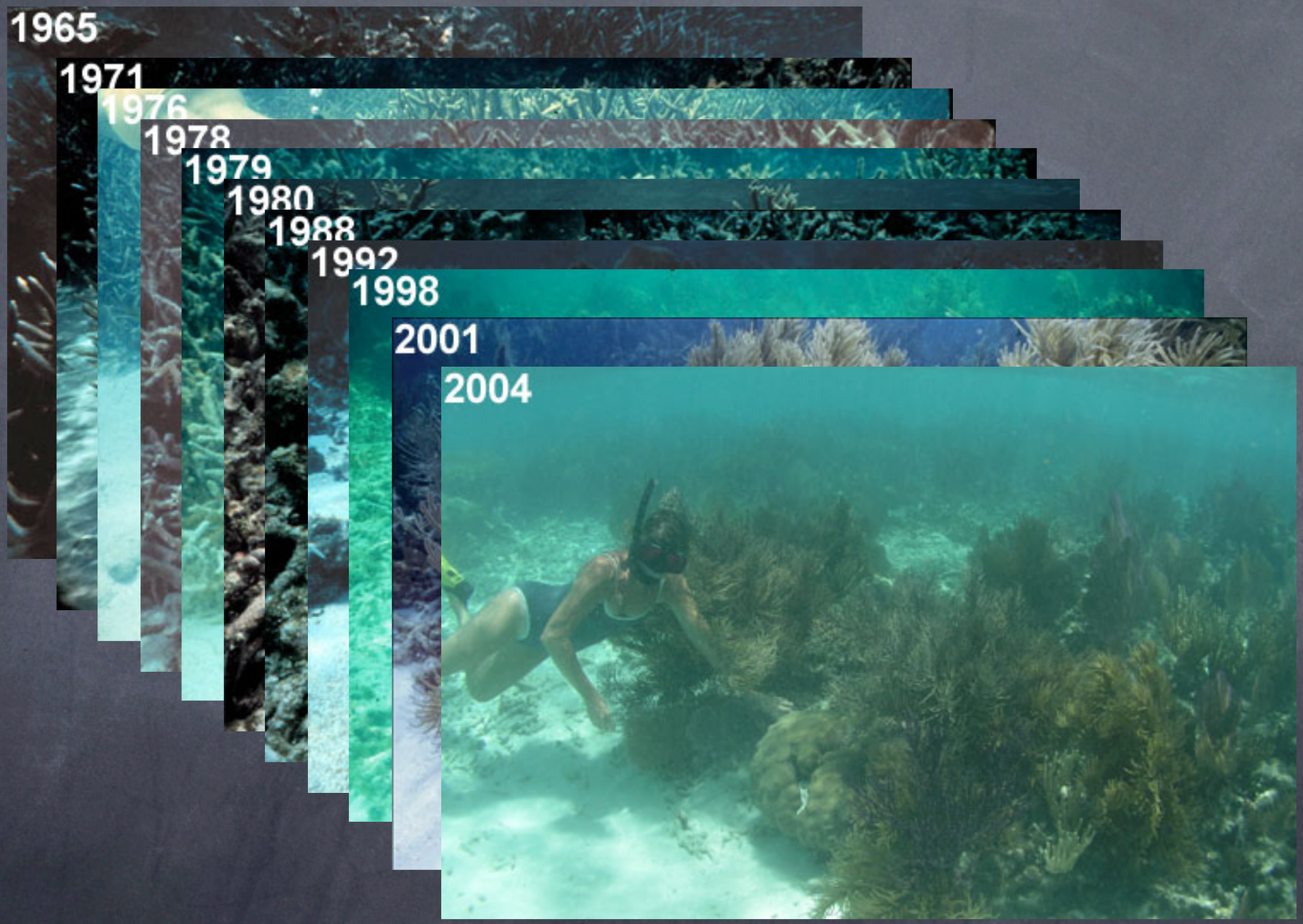
Dominated Caribbean reefs

Percent of localities with *Acropora* dominant



(Jackson et al. 2001)

The human footprint



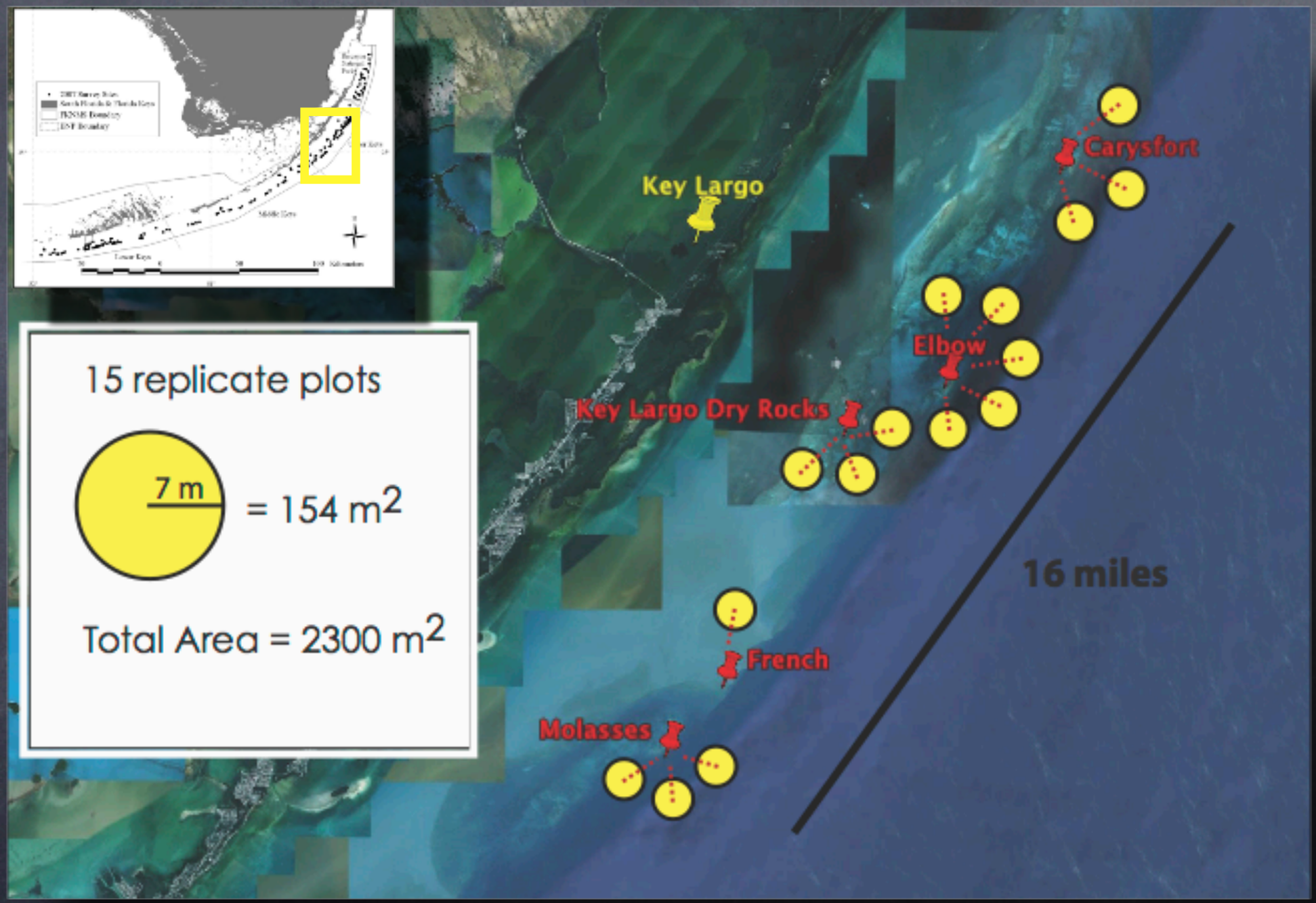
Florida, Gene Shinn

NOAA SEFSC

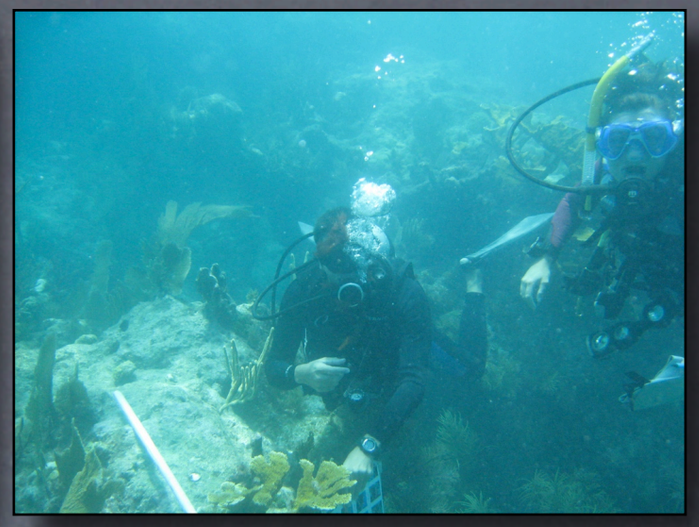
Florida *A. palmata* population

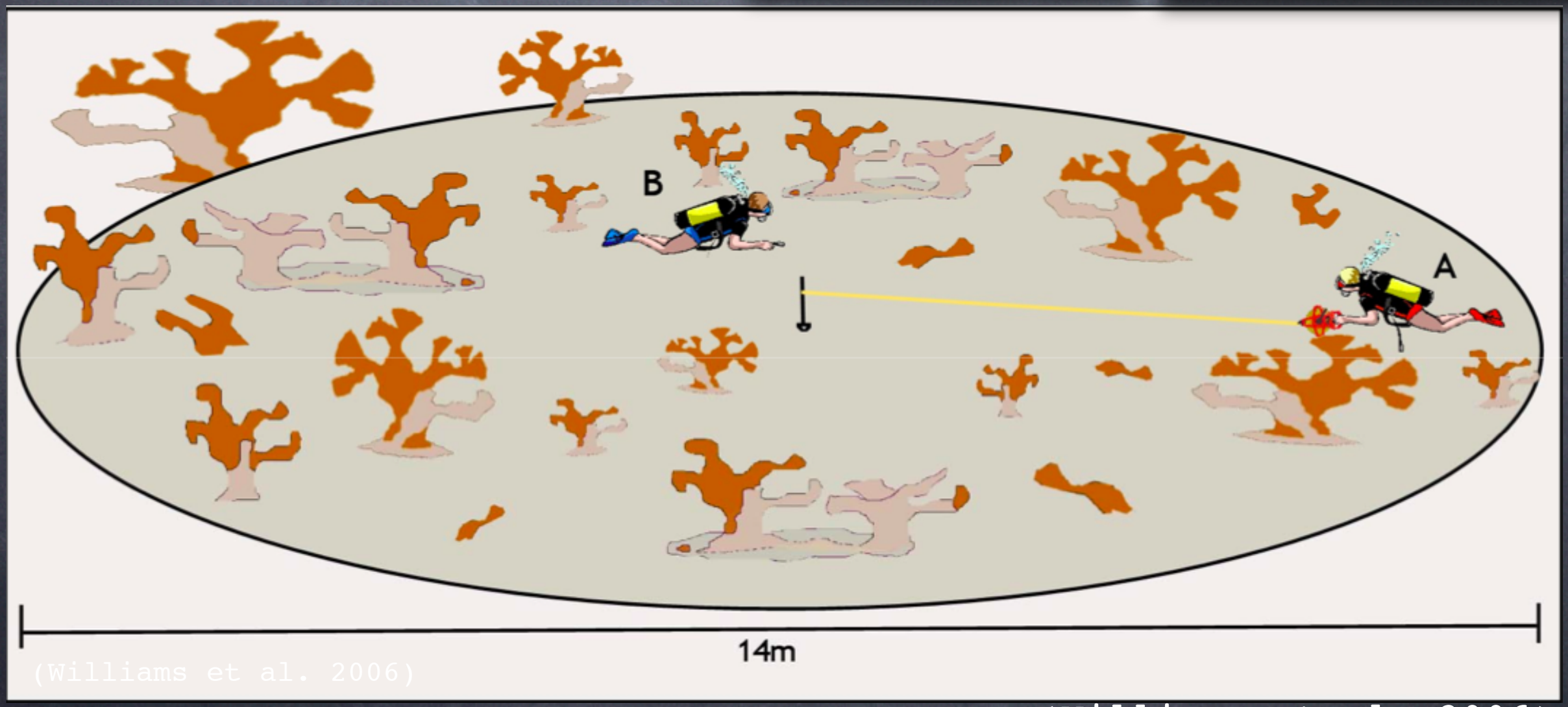
- Is the population expanding or depleting further? What is affecting this rate of change?
- What will population abundance, percent cover, and size structure be in 20 years? 50 years?

Study area


Key Largo
Carysfort
Elbow
Key Largo Dry Rocks
16 miles
French
Molasses
15 replicate plots
7 m
= 154 m2
Total Area = 2300 m2

Monitoring

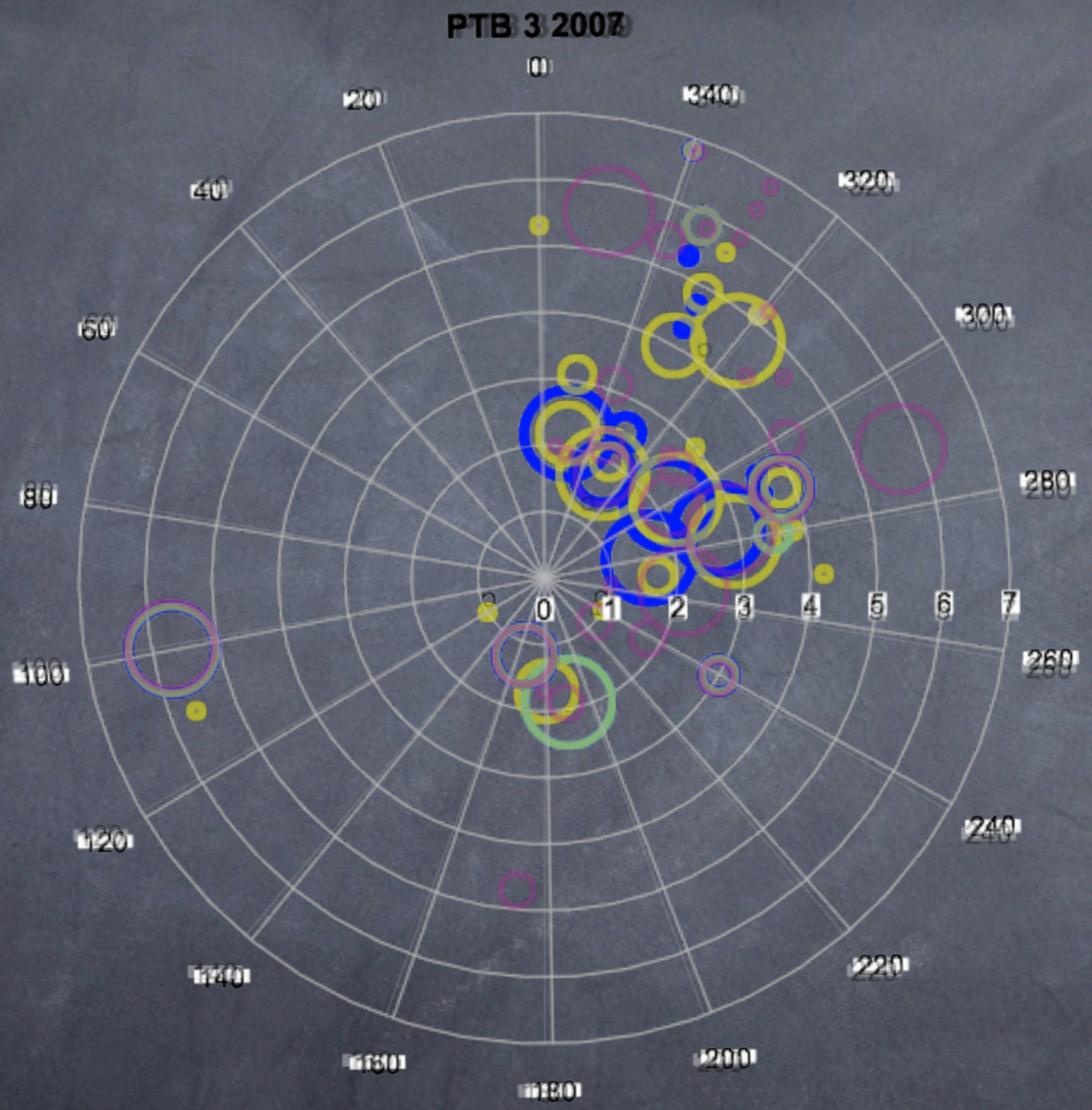




(Williams et al. 2006)

(Williams et al. 2006)

Population dynamics



Vital Rates

- growth
- stasis
- shrinking
- fragmenting
- mortality

Population matrix

Age class	1	2	3	4
1	0	0	1	1
2	0.7	0	0	0
3	0	0.9	0	0
4	0	0	0.8	0

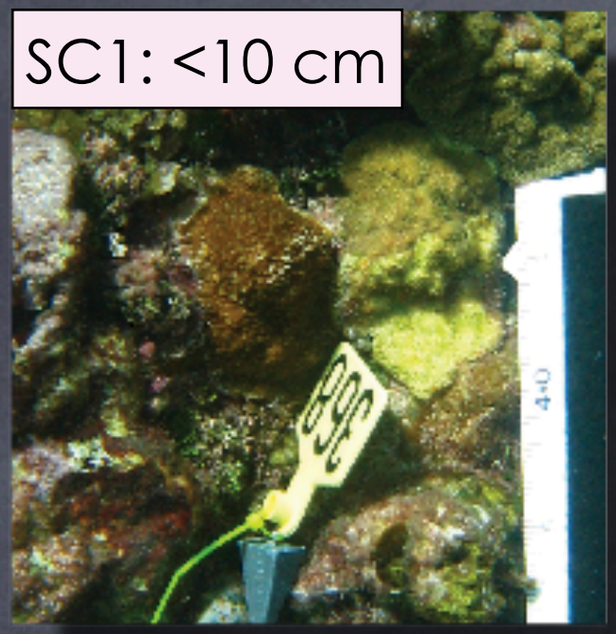
$$n_{t2} = \mathbf{A} \cdot n_{t1}$$

Coral Population Matrix

$$\mathbf{A} = \mathbf{T} + \mathbf{F} = \begin{bmatrix} \ell & s & s+f & s+f \\ g & \ell & s+f & s+f \\ g & g & \ell & s+f \\ g & g & g & \ell \end{bmatrix}$$

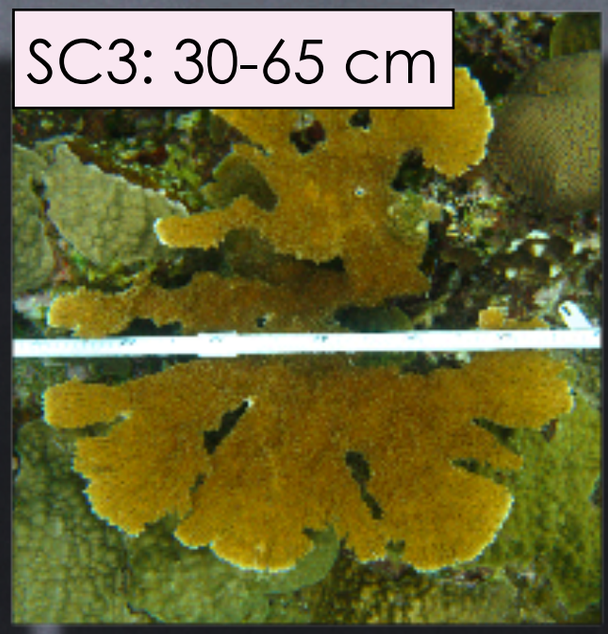
Size class designations

SC1: <10 cm



SC2: 10-30 cm

SC3: 30-65 cm



SC4: >65 cm

Population matrices

(a) **2004–5** [a,b]

	1	2	3	4
1	.60	.07	0 +.06	0 +.28
2	.15	.69	.10 +.06	.06 +.30
3	.01	.11	.74	.11 +.23
4	0	0	.11	.83
Survivorship	.75	.87	.94	1

(b) **2005–6** [b]

	1	2	3	4
1	.44	.14	.08 +.03	0 +.19
2	0	.37	.19 +.03	0 +.16
3	0	.02	.43	.13 +0
4	0	0	0	.71
Survivorship	.44	.53	.70	.84

(c) **2006–7** [c]

	1	2	3	4
1	.60	.12	0 +.01	0 +.05
2	.13	.61	.11 +.02	0 +.11
3	0	.12	.79	.04 +0
4	0	0	.0	.96
Survivorship	.72	.85	.98	1

(d) **2007–8**

	1	2	3	4
1	.56	.12	0 +.04	0 +.22
2	.24	.67	.07 +.04	0 +.20
3	.01	.06	.70	.07 +.04
4	0	0	.21	.93
Survivorship	.81	.85	.99	1

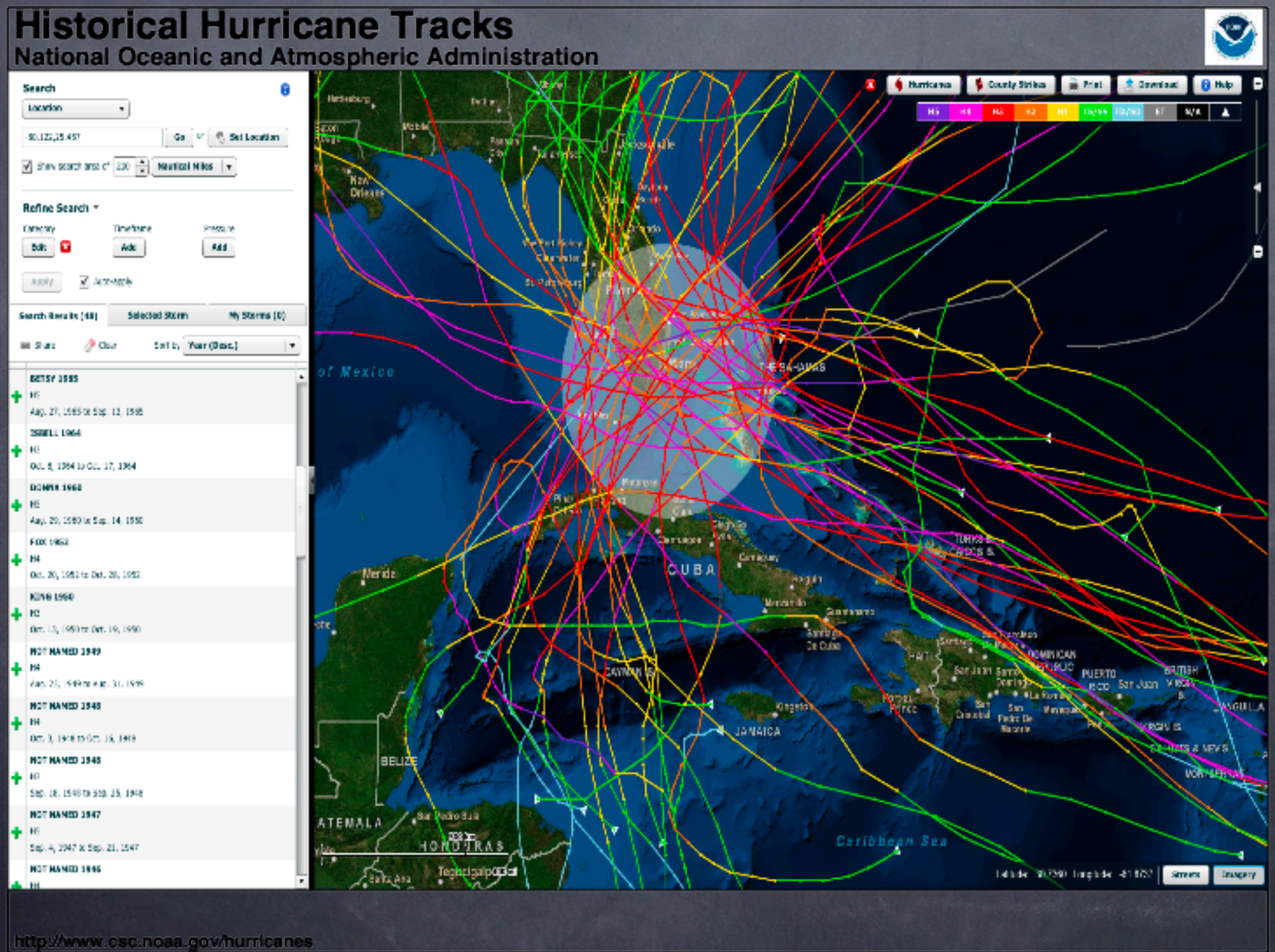
(e) **2008–9**

	1	2	3	4
1	.64	.11	.03 +.09	0 +.41
2	.12	.57	.22 +.06	0 +.31
3	0	.11	.53	.08 +.03
4	0	0	.07	.92
Survivorship	.76	.80	.85	1

(f) **2009–10**

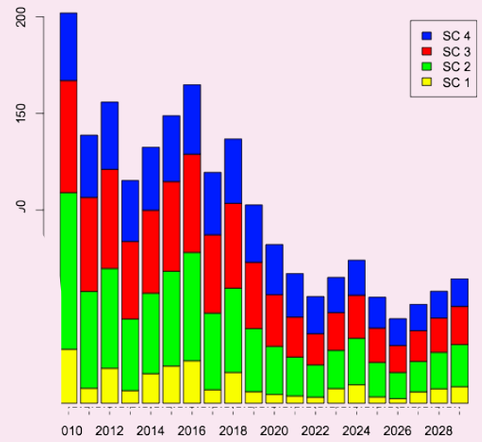
	1	2	3	4
1	.43	.11	.02 +.03	0 +.15
2	.21	.57	.16 +.02	0 +.12
3	0	.08	.54	.09 +.05
4	0	0	.2	.91
Survivorship	.63	.76	.96	1

Frequency of hurricanes - Florida Keys

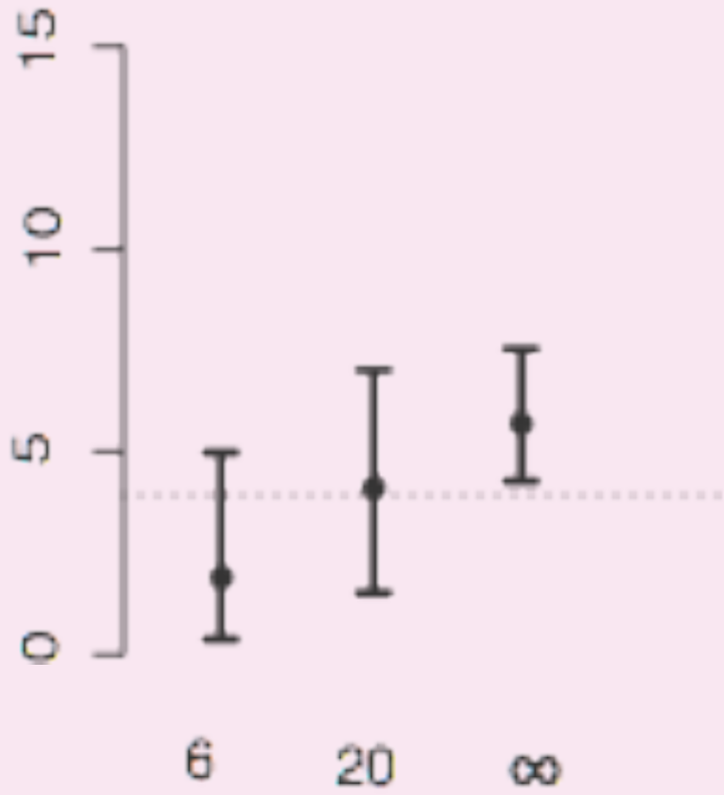


http://www.csc.noaa.gov/hurricanes

Hurricane scenarios



2030

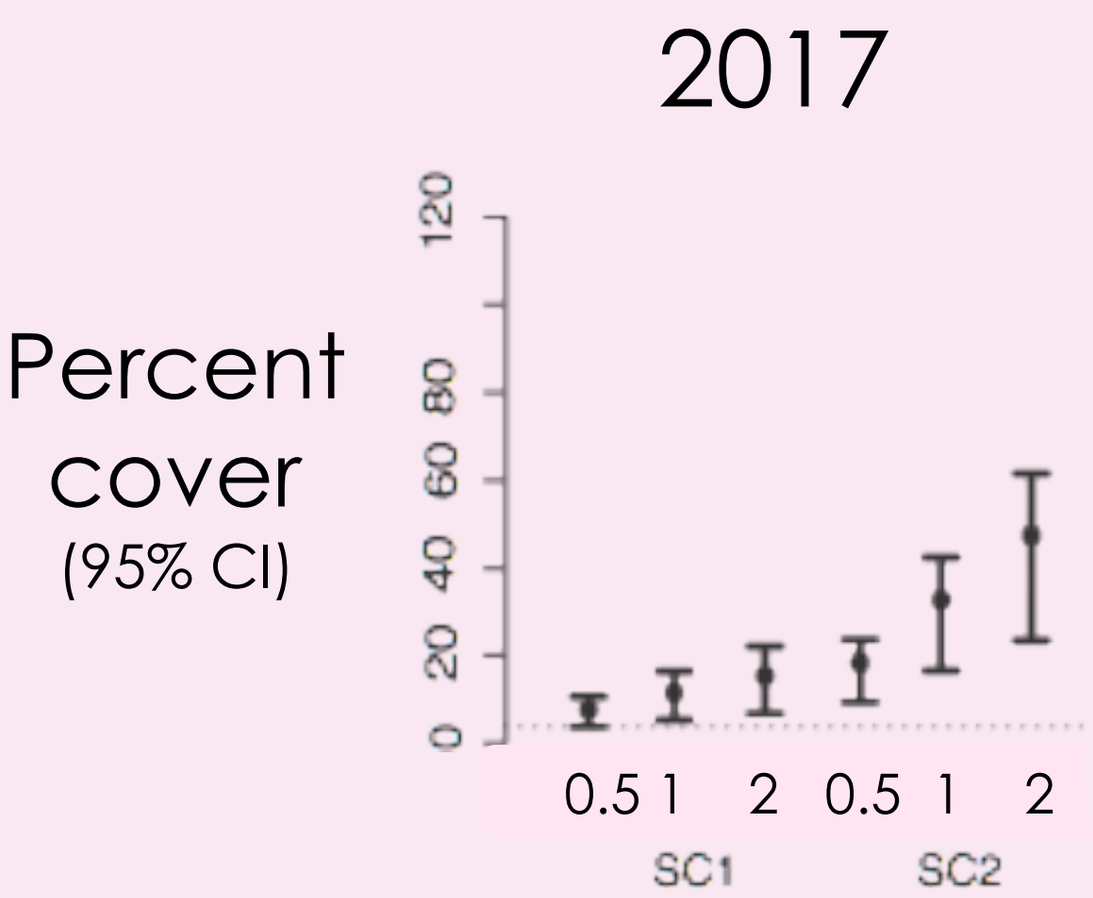


Outplanting

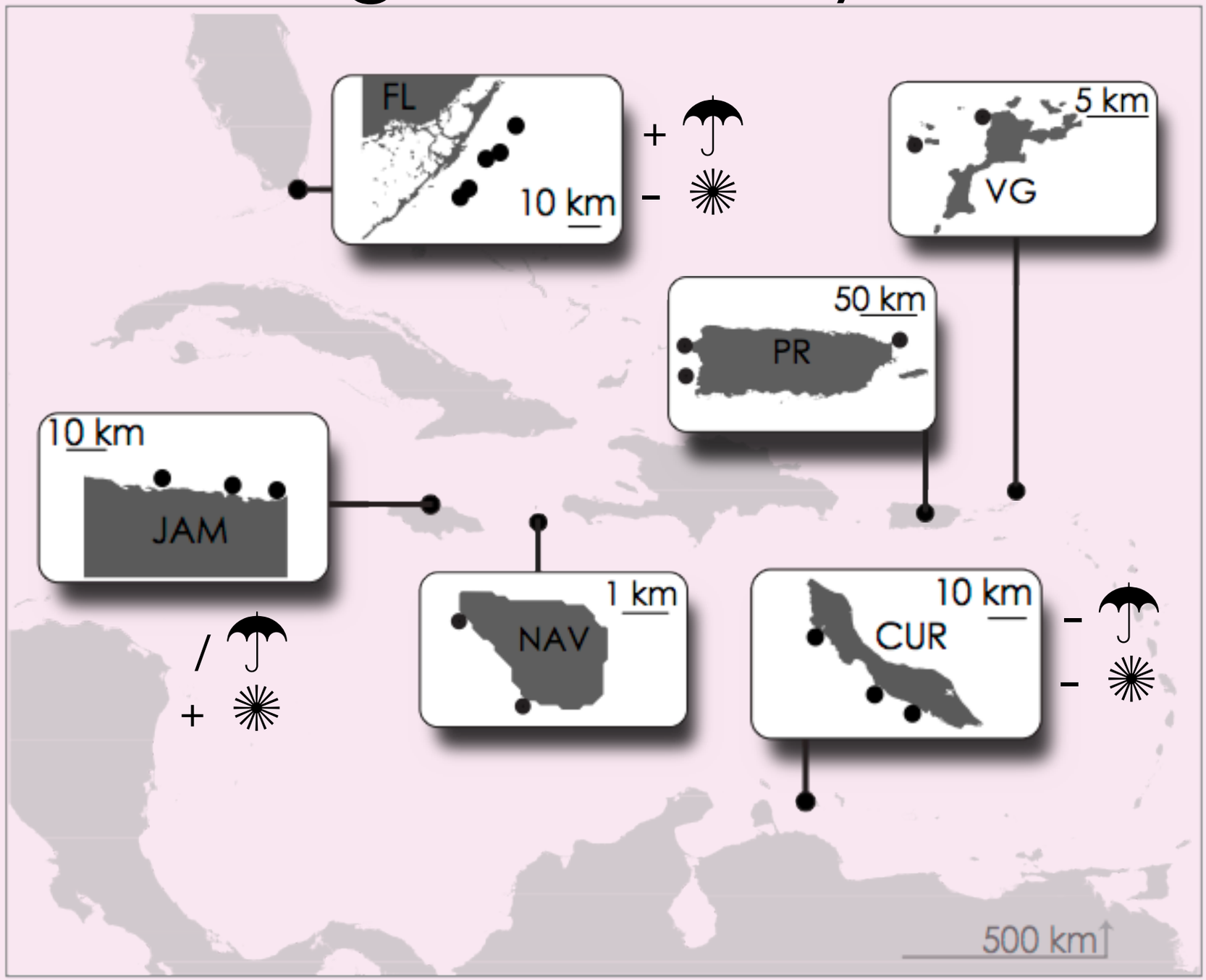
Photo credit: NOAA Restoration Center)

- grow small colonies
- transplant onto the reef

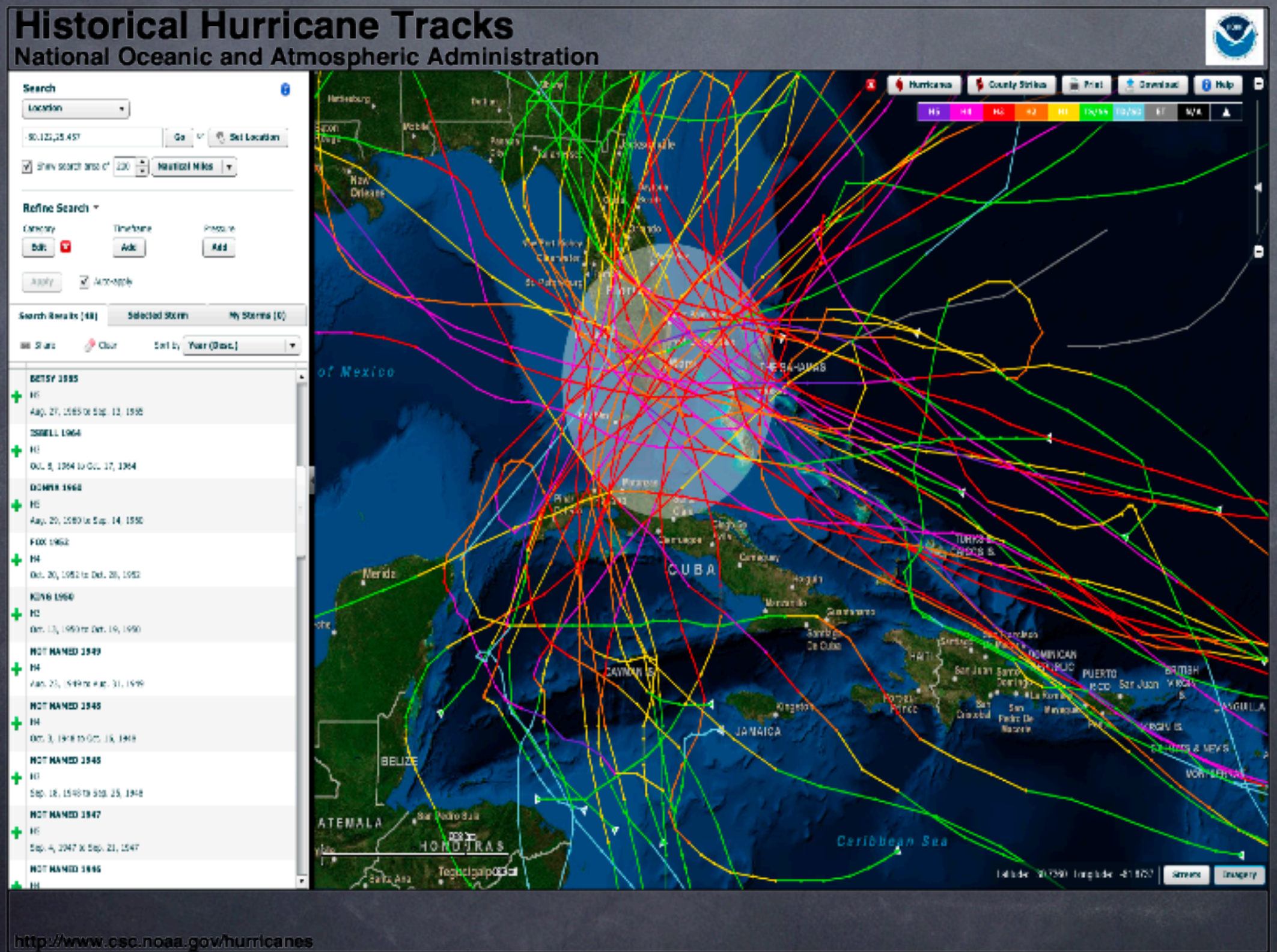
Outplanting Scenarios



Regional Analysis

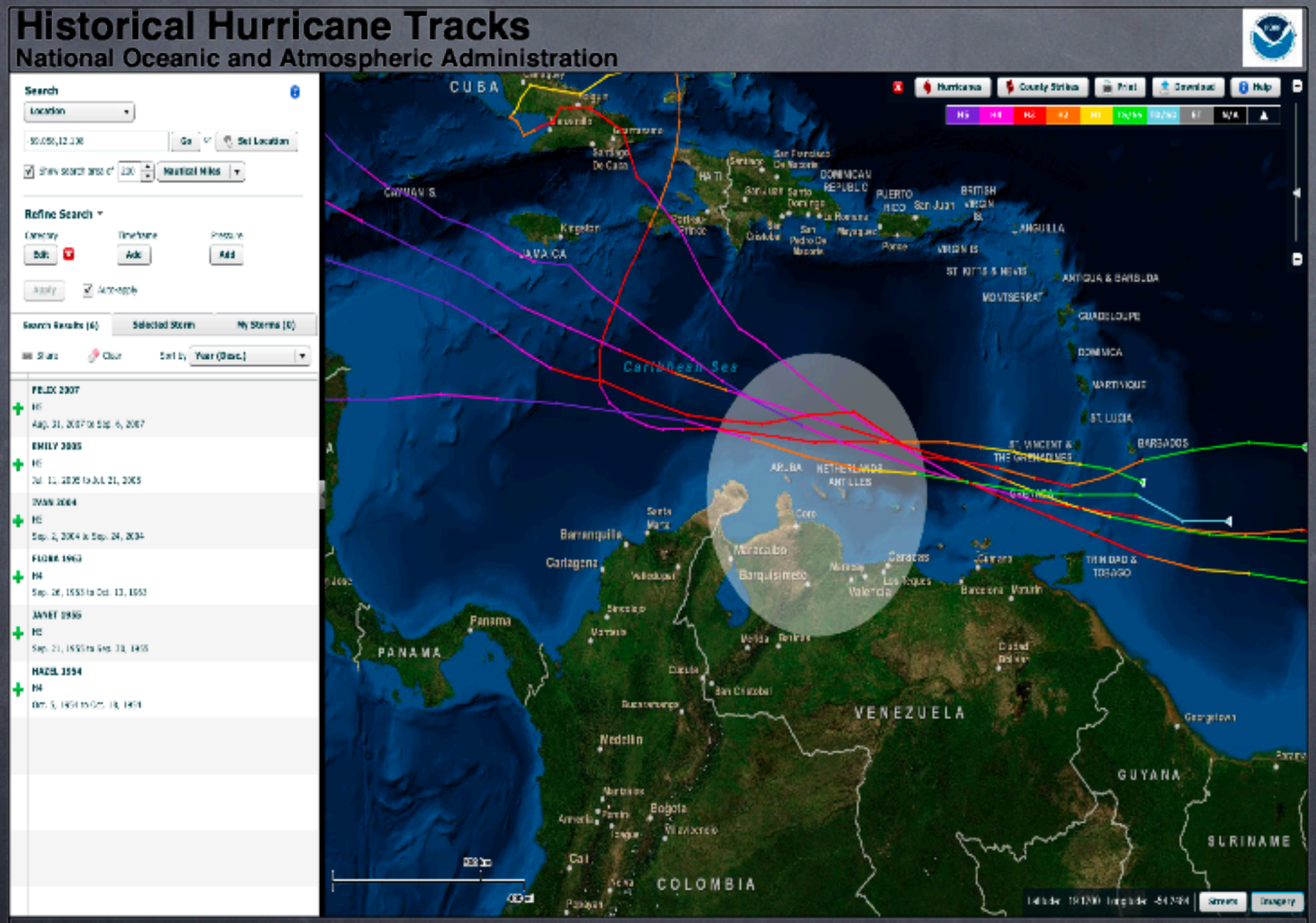


Frequency of hurricanes - Florida Keys



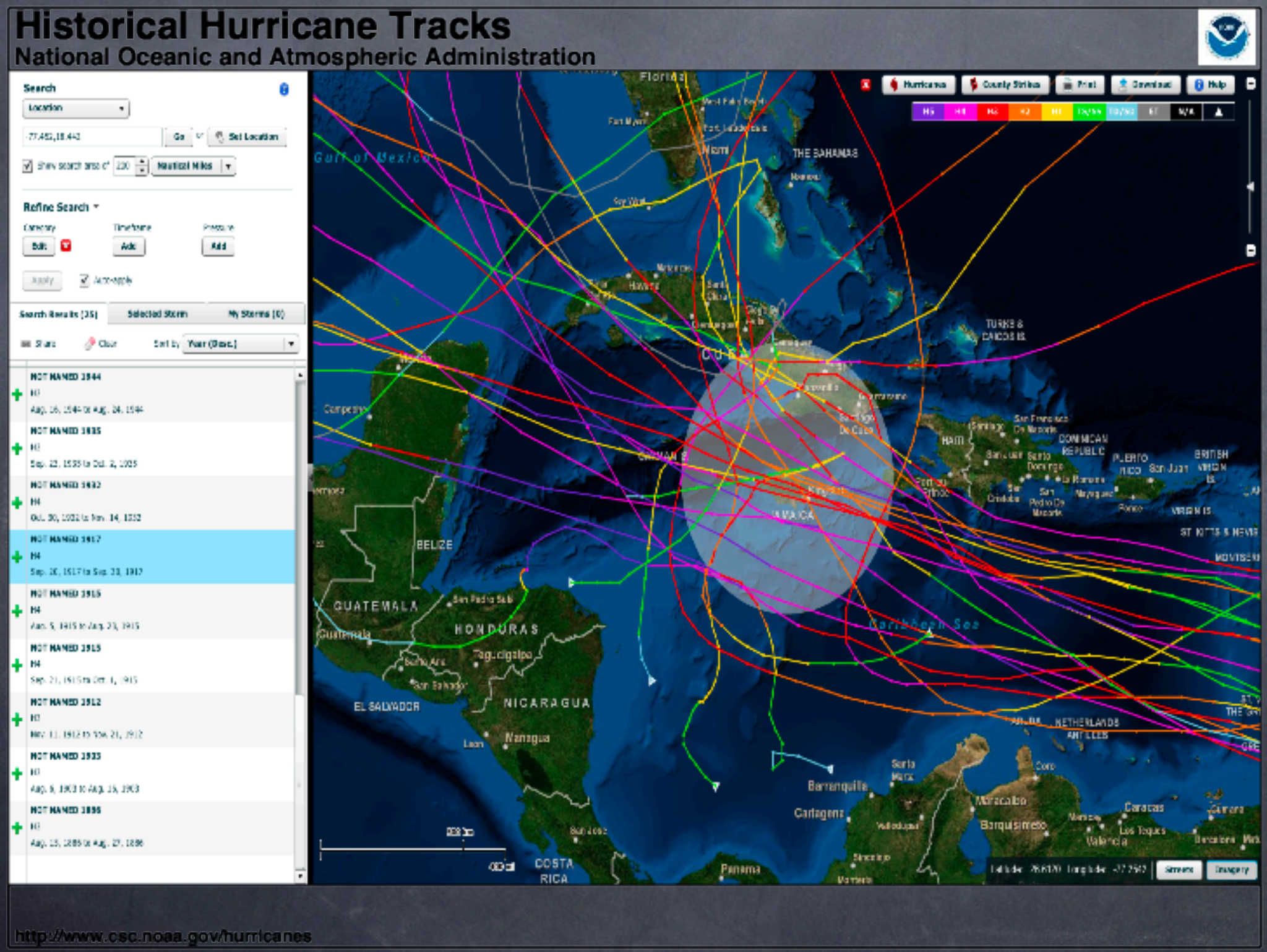
http://www.csc.noaa.gov/hurricanes

Frequency of hurricanes - Curaçao



http://www.csc.noaa.gov/hurricanes

Frequency of hurricanes - Jamaica



http://www.csc.noaa.gov/hurricanes

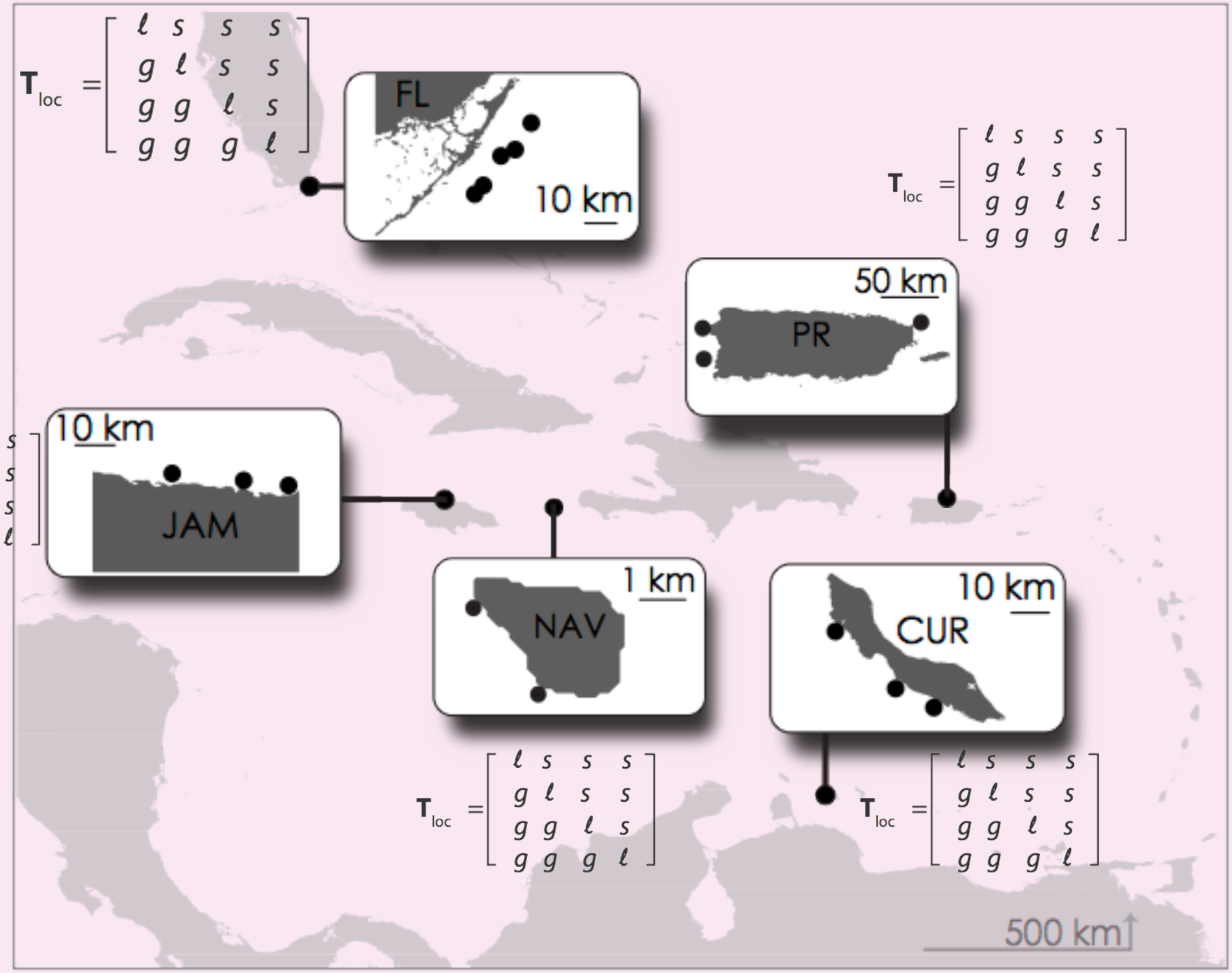
Density of urchins

Location	Mean # of *D. antillarum*/m^2 (±SE)	
Curaçao	0.03 ± 0.03	
Florida	0.00 ± 0.00	
Jamaica	3.51 ± 0.59	
Navassa	0.16 ± 0.02	(Miller et al. 2008)
Puerto Rico	0.00 ± 0.00	(Ruiz-Ramos et al. 2011)
Virgin Gorda	0.53 ± 0.33	

Regional analysis

- Is there a difference in dynamics among locations?
- Do predicted size distributions and rates of change in population size, (λ), corroborate hypotheses?
  - Jamaica: dominance by small individuals, λ >1
  - Curaçao: dominance by large individuals, λ =1

Regional analysis of **T**



Spatial scale of regional differences

* model including fate-location:

$$\log m = u + u_S + u_F + u_L + u_{SF} + u_{SL} + u_{FL} + u_{FSL}$$

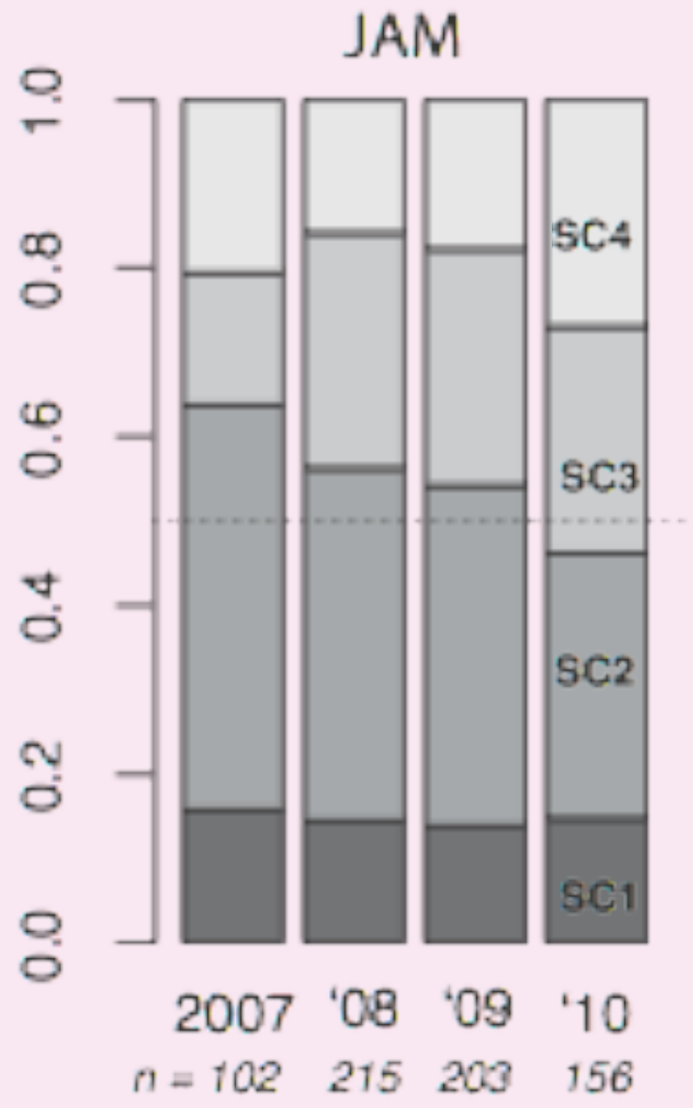
P = 0.000000000001195488

model excluding fate-location:

$$\log m = u + u_S + u_F + u_L + u_{SF} + u_{SL}$$

Jamaica

Proportion of individuals in each size class

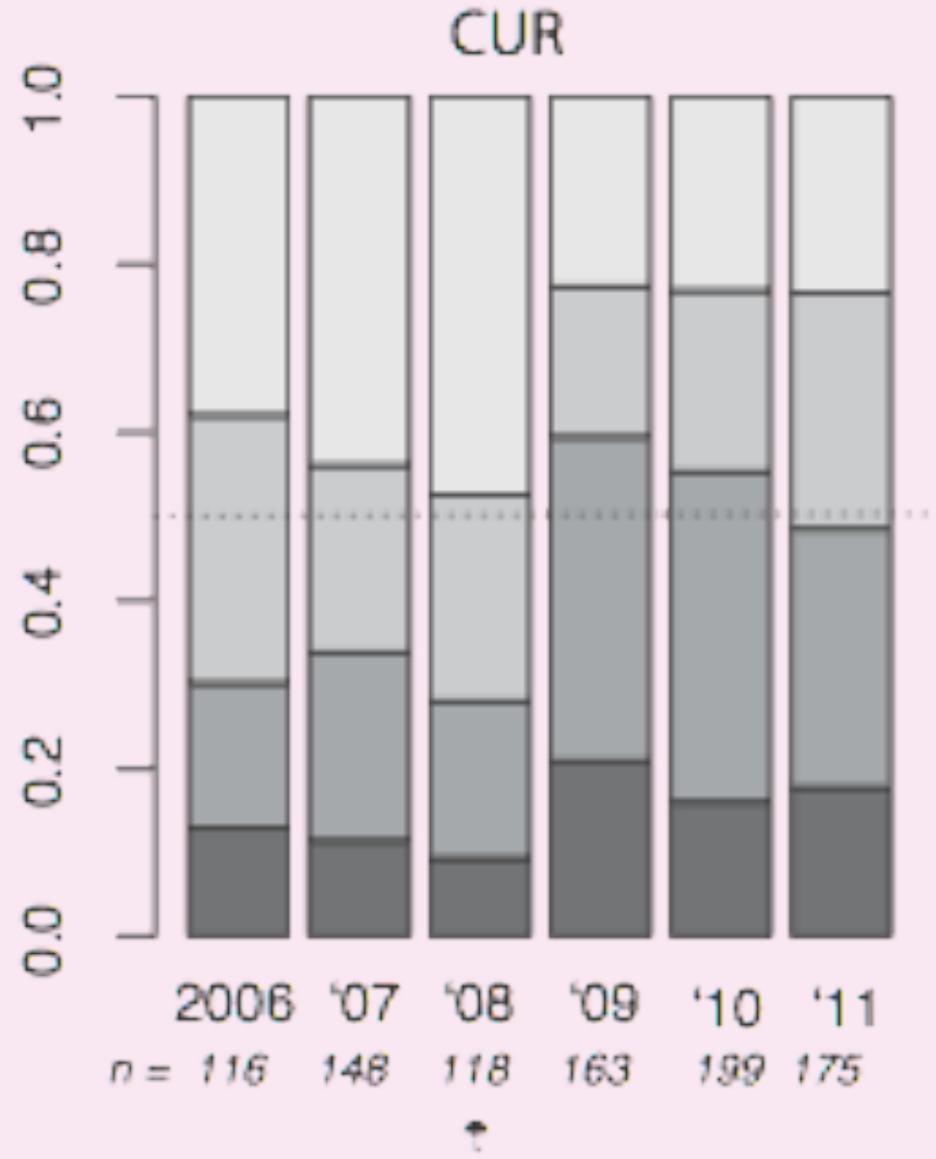


year

abundance

Curaçao

Proportion of individuals in each size class



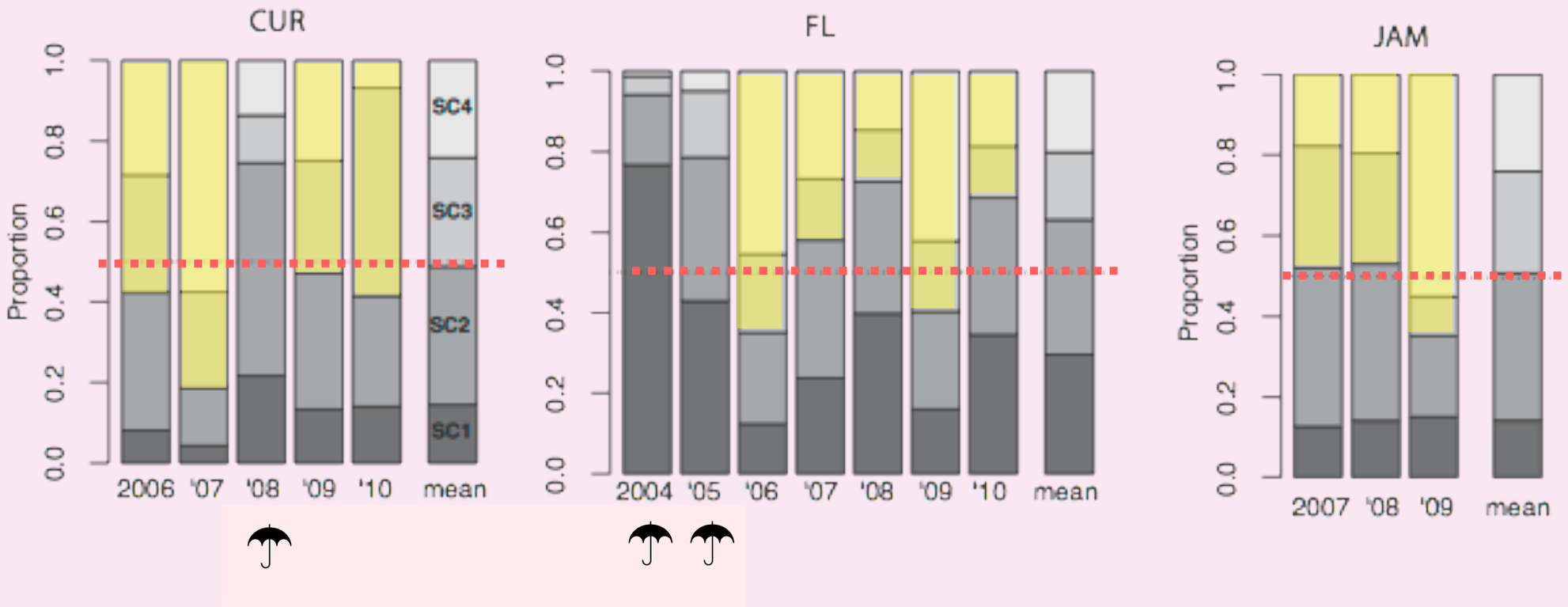
year

abundance

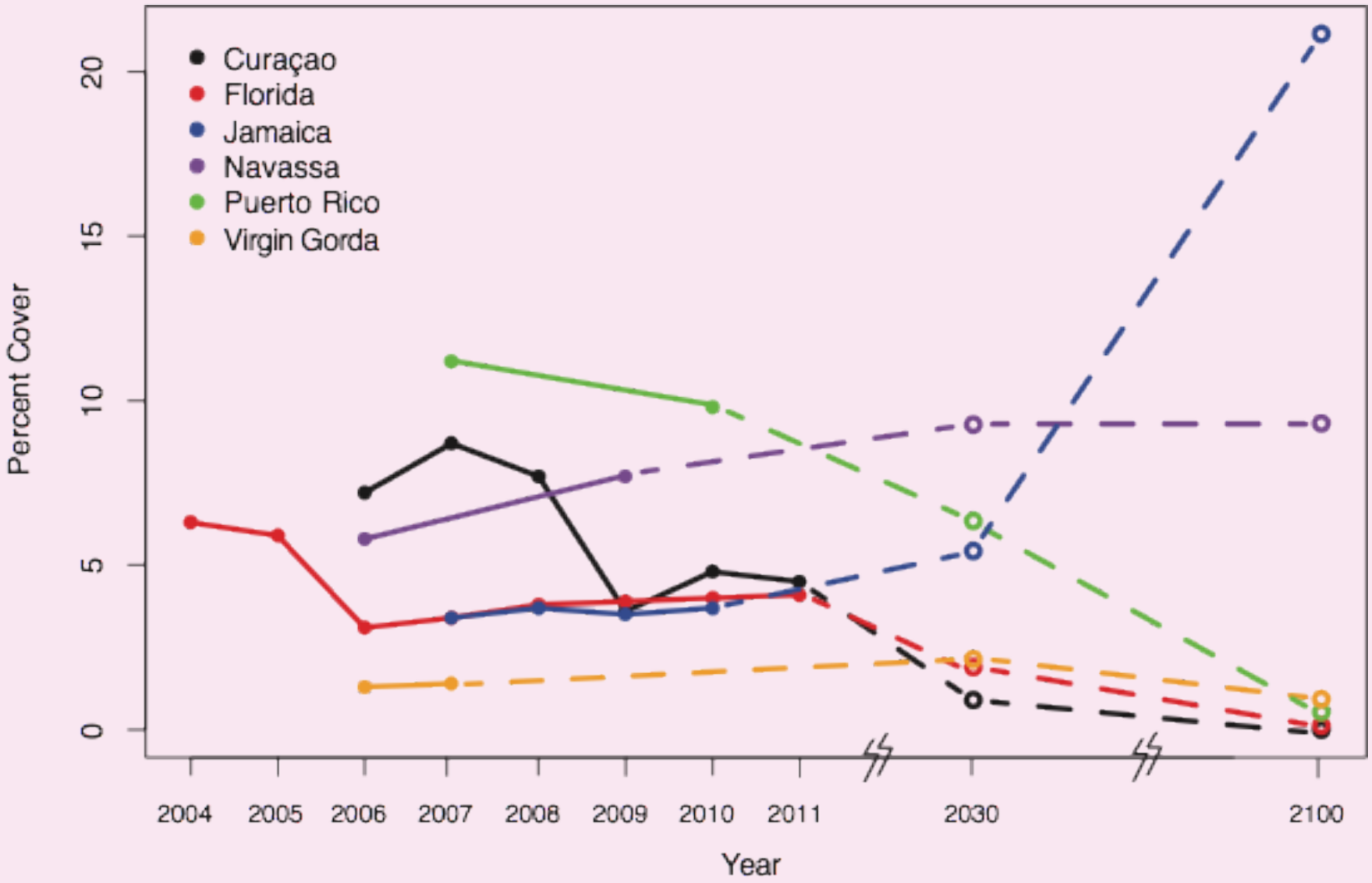
Rate of change in population size

Location	n	Deterministic λ_A	One Time Step λ_A	One Time Step lci	One Time Step uci	2030 λ_A	2030 lci	2030 uci	2100 λ_A	2100 lci	2100 uci
FL	7	0.961	0.983	0.928	1.039	0.965	0.949	0.979	0.957	0.929	0.975
CUR	5	0.910	0.896	0.806	0.989	0.905	0.860	0.939	0.895	0.837	0.940
JAM	3	1.020	1.051	0.949	1.154	1.022	1.003	1.038	1.020	1.013	1.026
PR	1	0.966	0.975	0.946	1.003	0.967	0.950	0.983	0.962	0.932	0.978
NAV	1	1.000	1.026	0.989	1.064	1.017	1.009	1.024	1.005	1.003	1.006

Predicted size distribution



Percent cover over time



Summary

- Population size continues to decline throughout the Caribbean, though different islands exhibit different transition rates
- FL population doomed to functional extinction w/o intervention, though outplanting offers positive population growth and percent cover
- Witnessed signatures of resilience (Curaçao) and apparent recovery (Jamaica)

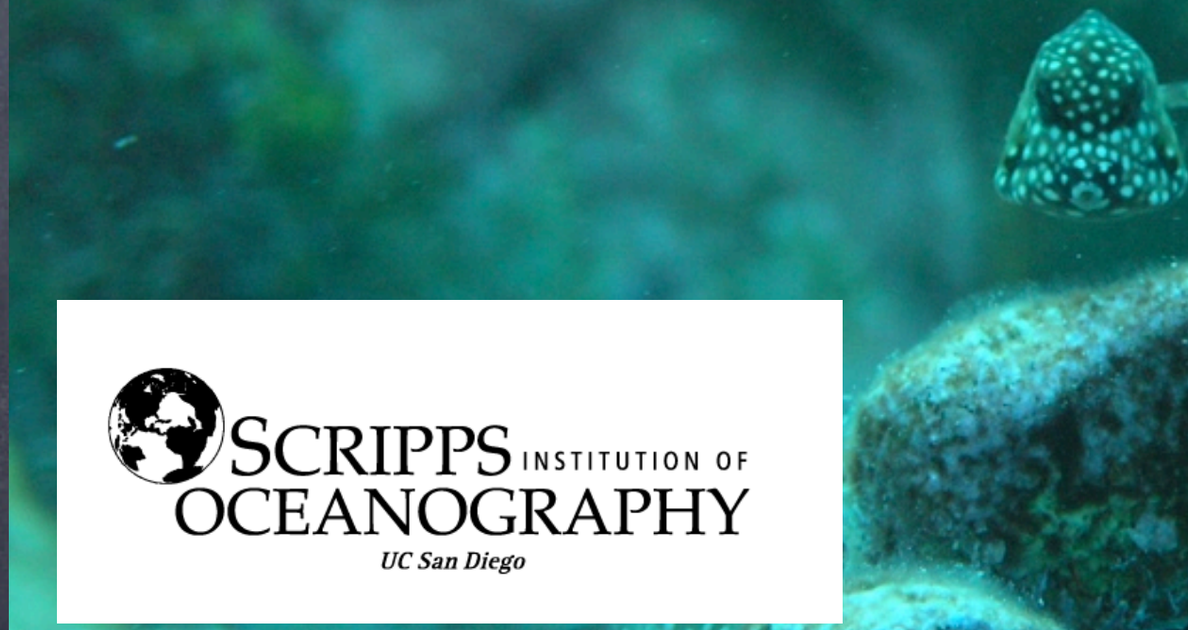
Policy considerations

- Potential listing of 82 species
- None of which have this much data
- Opportunity for true ecosystem based management

Acknowledgements

PhD Committee – Stuart Sandin, Jeremy Jackson, Nancy Knowlton, George Sugihara, and Theodore Groves

Collaborators – Jennifer Moore (NOAA SERO),
– Margaret Miller and Dana Williams (NOAA SEFSC
– Discovery Bay Marine Lab



Questions?

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