Genetic variability and fine-scale population structure in the threatened species *Acropora palmata* and *Acropora cervicornis* around Puerto Rico

by
Joselyd Garcia Reyes
University of Puerto Rico- Mayagüez

Acropora palmata

- Found along the reef crest where wave energy is high
- Known as elkhorn coral
- Light tan to brown coloration
- Found at depths ranging from 0-15 m
- The skeleton extension growth rate from 5-9.5 cm/yr
- Spawn three to six nights after the full moon of August and/or September

Acropora cervicornis

- Found mostly in patch and barrier reefs
- Known as staghorn coral for its thin, fragile branches
- Found at depths ranging from 3-30 meters
- Provides habitat for many different organisms among its branches
- Has one of the fastest growing rates among corals, 12 cm/yr
- Spawn three to six nights after the full moon of August and/or September

The Decline

- Have declined 95% since the 1970s due mostly to white band disease
- Northern localities of Puerto Rico showed a 68% decline of *A. palmata* in the last 20 years (Weil et al. 2003)
- Eastern localities showed a decrease of 53% in the last 20 years (Weil et al 2003)
- *A. cervicornis* declined 99% in both northern and eastern localities (Weil et al 2003)
- Both *A. palmata* and *A. cervicornis* were listed as threatened under the Endangered Species Act in 2006

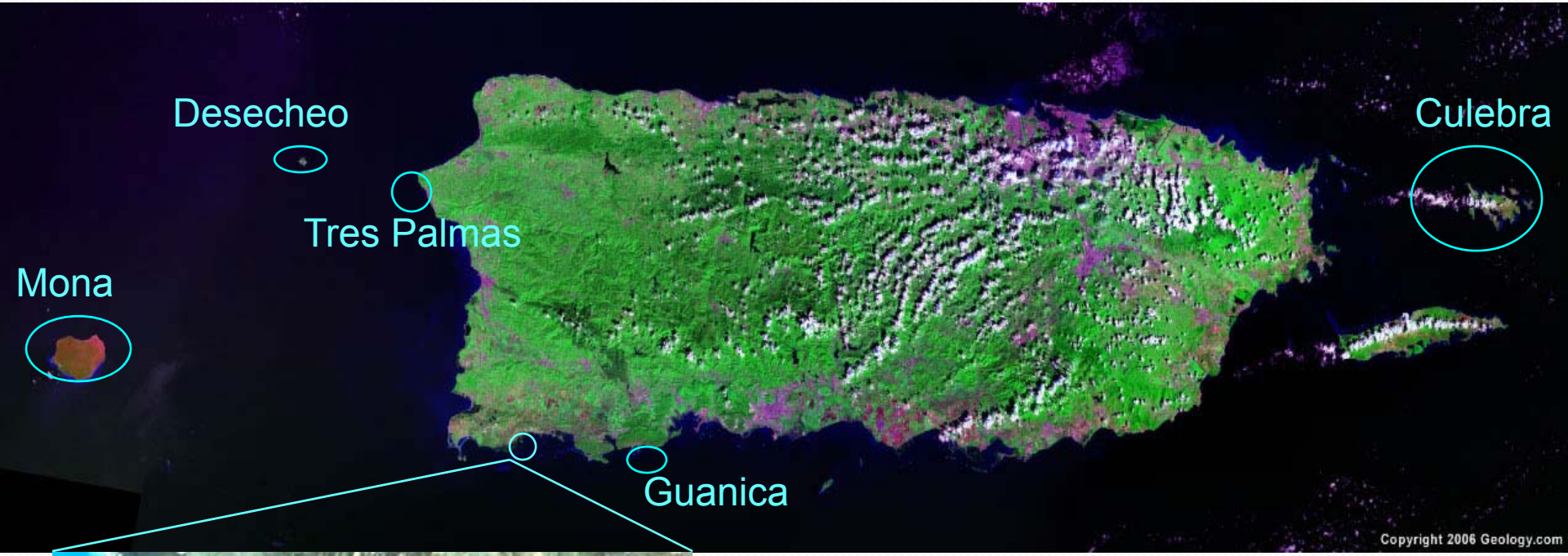
Previous Studies

- Baums et al (2005b) five microsatellite markers showed 18-25 distinct alleles per loci at six areas in Puerto Rico
- Baums et al (2006) found that sexual recruitment is more prevalent in eastern Caribbean; Puerto Rico has more affinity to the western Caribbean
- Vollmer and Palumbi (2007) four genes in *A. cervicornis* exhibited significant genetic structure across the Caribbean

Objectives

- Determine the genetic variation and population structure around Puerto Rico in *Acropora palmata* and *Acropora cervicornis*
- Understand level of connectivity between reefs around La Parguera, PR and around Puerto Rico

Sampling around Puerto Rico



Methods

- 220 *Acropora palmata* and 124 *Acropora cervicornis* colonies were sampled from 26 reefs from 6 localities in Puerto Rico and 3 reefs from Lee Stocking Island, Bahamas
- Collected using concentric circle design (Baums et al. 2005) and haphazardly at least 5m apart around each reef
- Performed AMOVA to test for population structure, DnaSP to estimate the genetic diversity indices and TCS to construct haplotype networks

Results:
Genetic diversity

mtDNA Results

Acropora palmata

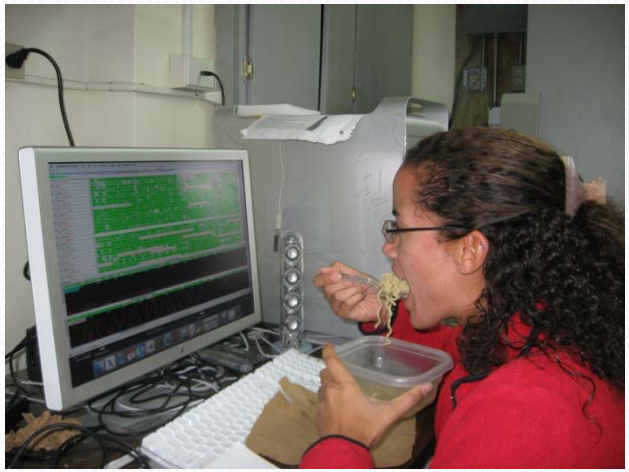
- 25 haplotypes for *A. palmata* in Puerto Rico (2 in the Bahamas)
- 200 colonies from Puerto Rico resulted in:
  - h_d= 0.333
  - π= 0.00075

mtDNA Results

Acropora cervicornis

- 24 haplotypes for *A. cervicornis* identified around Puerto Rico (4 in the Bahamas), twice as many as previously identified

- 117 colonies from Puerto Rico resulted in:
  - h_d= 0.853, slightly higher haplotype diversity
  - π= 0.0050, and slightly lower nucleotide diversity than those reported



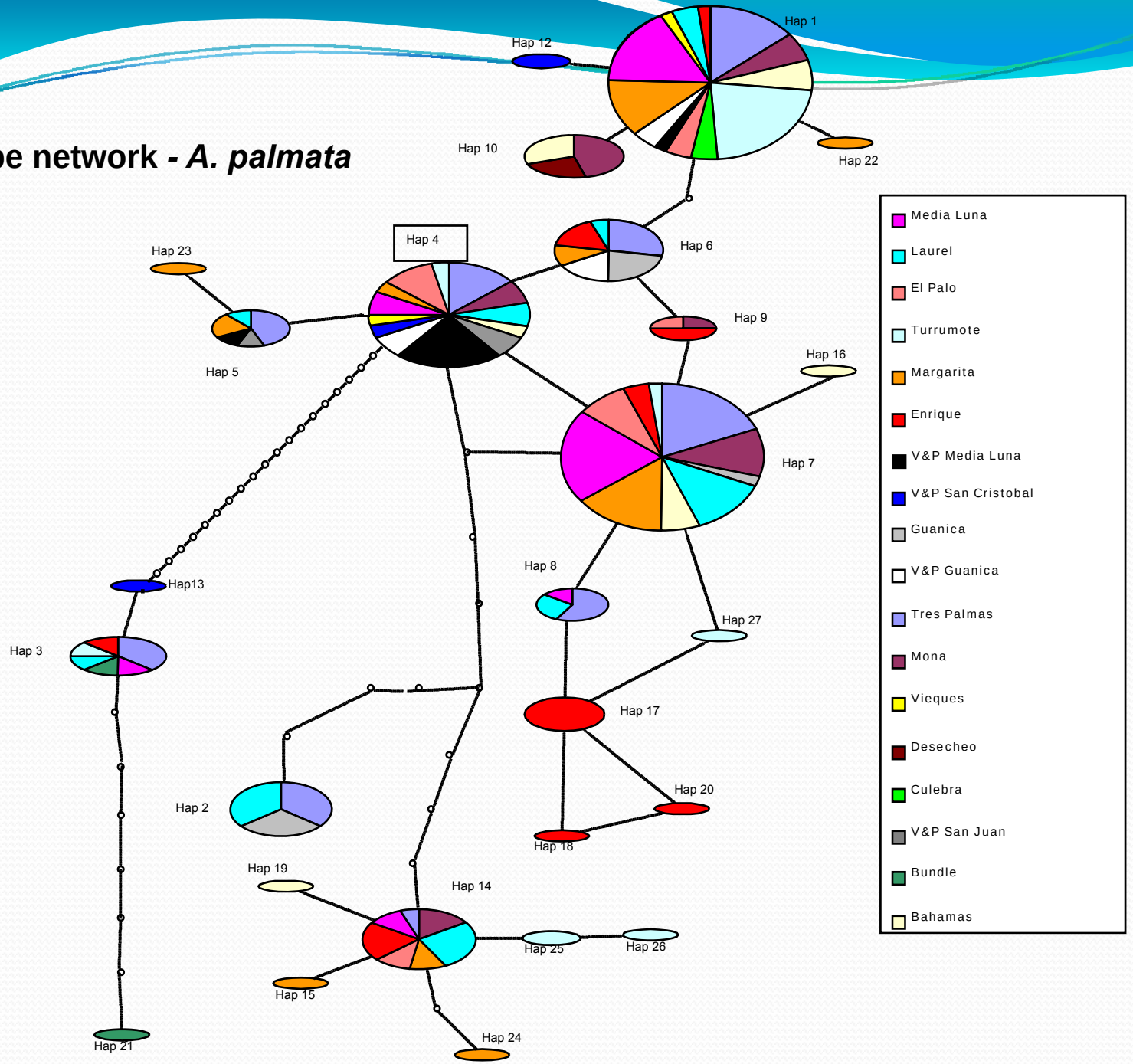
DNA summary statistics - *A. palmata*.

Location	# of colonies	S	h	π	θ
All Tres Palmas	41	3	9	0.00075	0.00075
All Laurel	18	3	9	0.00048	0.00096
All Margarita	26	3	10	0.0006	0.00085
All Turrumote	17	3	6	0.00064	0.00095
All Enrique	23	3	9	0.00089	0.00087
All Media Luna	24	2	6	0.00055	0.00057
El Palo haphazard	13	1	5	0.0004	0.00036
All La Parguera	121	6	20	0.00071	0.00118
Guánica	9	1	3	0.00012	0.0005
Mona	16	2	6	0.00096	0.00064
Desecheo	4	1	2	0.00053	0.00057
Bahamas	13	4	6	0.00124	0.00136
All V & P	22	1	2	0.00018	0.00029
V & P_Media Luna	8	1	2	0.00026	0.00041
V & P Guanica	7	0	1	0	0
V & P San Cristobal	4	0	1	0	0

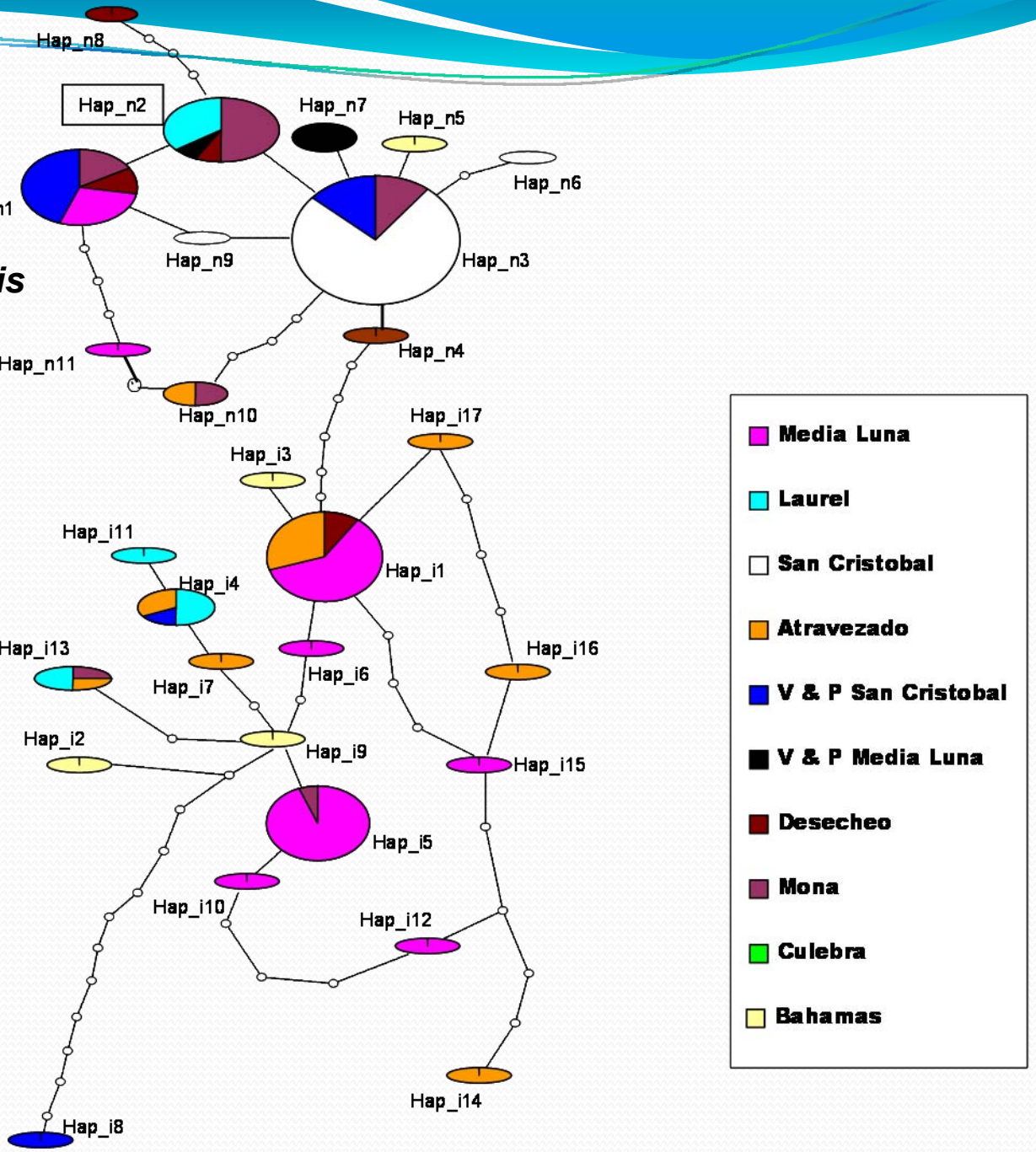
DNA summary statistics *A. cervicornis*

Location	# of colonies	S	h	π	θ
All San Cristobal	30	1	3	0.00006	0.00024
All Media Luna	38	15	8	0.00468	0.00339
All Laurel	10	11	4	0.00574	0.00369
Atravesado circles	12	11	6	0.00391	0.00346
All La Parguera	89	18	19	0.00512	0.00337
Mona	17	14	6	0.00281	0.00393
Desecheo	7	8	5	0.0038	0.0031
Bahamas	6	10	4	0.00373	0.00415
All V & P	19	13	6	0.0029	0.00353
V & P Media Luna	4	2	2	0.00095	0.00104
V & P San Cristobal	15	12	4	0.00303	0.0035

Haplotype network - *A. palmata*



Haplotype network A. cervicornis



Results:
Structure around La Parguera

A. palmata						
	Laurel	Turrumote	Enrique	Media Luna	Margarita	El Palo
Laurel		**0.7717****	**0.3285****	-0.1331	0.1202	N/A
Turrumote	**0.3749***		**0.6795****	**0.4272****	**0.2774***	N/A
Enrique	**0.365***	**0.2867***		**0.3530****	**0.425****	N/A
Media Luna	0.1828	**0.2792****	-0.1139		-0.0146	N/A
Margarita	0.0677	**0.3027****	-0.0549	-0.0902		N/A
El Palo	**0.3437***	0.2432	-0.1965	-0.0302	0.027	

Pairwise differences between reefs in La Parguera, PR. The upper values reflect the concentric circle collection method while the bottom values reflect the haphazard collection method. Permutations of 1000. Using Kimura 2-P model. * significant at $p<0.05$; **significant at $p<0.001$, N/A = location not sampled

A. cervicornis				
	Media Luna	San Cristobal	Atravesado	Laurel
Media Luna		**0.5302****	0.0950	N/A
San Cristobal	**0.9278****		**0.8055****	N/A
Atravesado	**0.5114****	**0.6831****		N/A
Laurel	**0.7381****	**0.3076****	**0.4580****	

Pairwise differences in the mtDNA between reefs in La Parguera, Puerto Rico in *A. cervicornis*. The upper values reflect the concentric circle collection method and the bottom reflect the haphazard collection method.

* significant at the $p<0.05$; ** significant at $p<0.001$

Results:
Structure around Puerto Rico

Analysis of Molecular Variance (AMOVA) - *A. palmata*

Between reefs in Puerto Rico (All La Parguera vs. Mona Island vs. Desecheo Island vs. Guanica vs. Tres Palmas)					
	df	Sums of Squares	Variance Components	% variation	F_{ST}
Among populations	4	5.332	0.03650	8.63	**0.0863****
Within populations	186	71.906	0.38659	91.37	
Total	190	77.238	0.4231		

A. palmata				
	Mona	Desecheo	All La Parguera	Tres Palmas
Mona				
Desecheo	0.1404			
La Parguera	**0.1166***	**0.4832****		
Tres Palmas	**0.0976***	**0.4519****	0.0007	
Guanica	0.0108	**0.7234***	-0.0254	-0.0751

Pairwise differences between reefs around Puerto Rico. All La Parguera includes samples collected using both collection methods. Permutations of 1000. Using Kimura 2-P model.* significant at $p<0.05$ ** significant at $p<0.001$

Analysis of Molecular Variance (AMOVA) - *A. cervicornis*

Between reefs in Puerto Rico (All La Parguera vs. Mona Island vs. Desecheo Island)					
	df	Sums of Squares	Variance components	% variation	F_{ST}
Among populations	2	19.179	0.35461	12.37	**0.1237***
Within populations	110	276.42	2.51291	87.63	
Total	112	295.599	2.86752		

A. cervicornis			
	Mona	Desecheo	La Parguera
Mona			
Desecheo	0.0067		
La Parguera	**0.1598***	0.0389	

Pairwise differences between reefs around Puerto Rico. All La Parguera includes samples collected using both collection methods. * significant at the $p<0.05$.

Discussion

Discussion

Genetic Diversity:

- Low genetic diversity could be in part due to past organelle bottleneck events which decrease the effective population size (N_e)
  - Reef accretion ceased at the continental shelf 7,000 years ago and an apparent shift from a *A. palmata*- to *M. annularis*-dominant reefs
  - 1963 - Hurricane Edith devastated windward outer reef zones in La Parguera
  - 1980s - White Band Disease epizootic event
  - 2005 - Bleaching Event La Parguera
  - 2007 - Hurricane Dean
- However, we do not know the population and genetic history of the species before the die-offs

Discussion

Structure around reefs in La Parguera, PR

- The island mass effect, described by Hamner (1981) considers many variables that cause the water flow around islands and reefs to vary:
  - differences in current speed (e.g. back vs. fore reef)
  - tidal flow
  - size of islands or reefs (e.g. Margarita vs. San Cristobal)
  - depth
  - Substrate (e.g. rubble vs. sand)

- Differences in water motion between reefs in La Parguera have been reported (McGehee 1994)

- A geographic model proposed by Baums et al (2006) and Galindo and Palumbi (2006) with reproductive timing, larval traits, and oceanographic features together could inhibit the dispersal of *A. palmata* and *A. cervicornis* larva between the western and eastern Caribbean

Summary

- Significant population structure found among different reefs in Puerto Rico suggests that gene flow is restricted between closely spaced reefs
- Locally, larval dispersal may be greatly influenced by the local oceanographic conditions, the shape and topology of the reef
- Larval dispersal could be limited over long distances restricting larval replenishment of reef systems from other regions

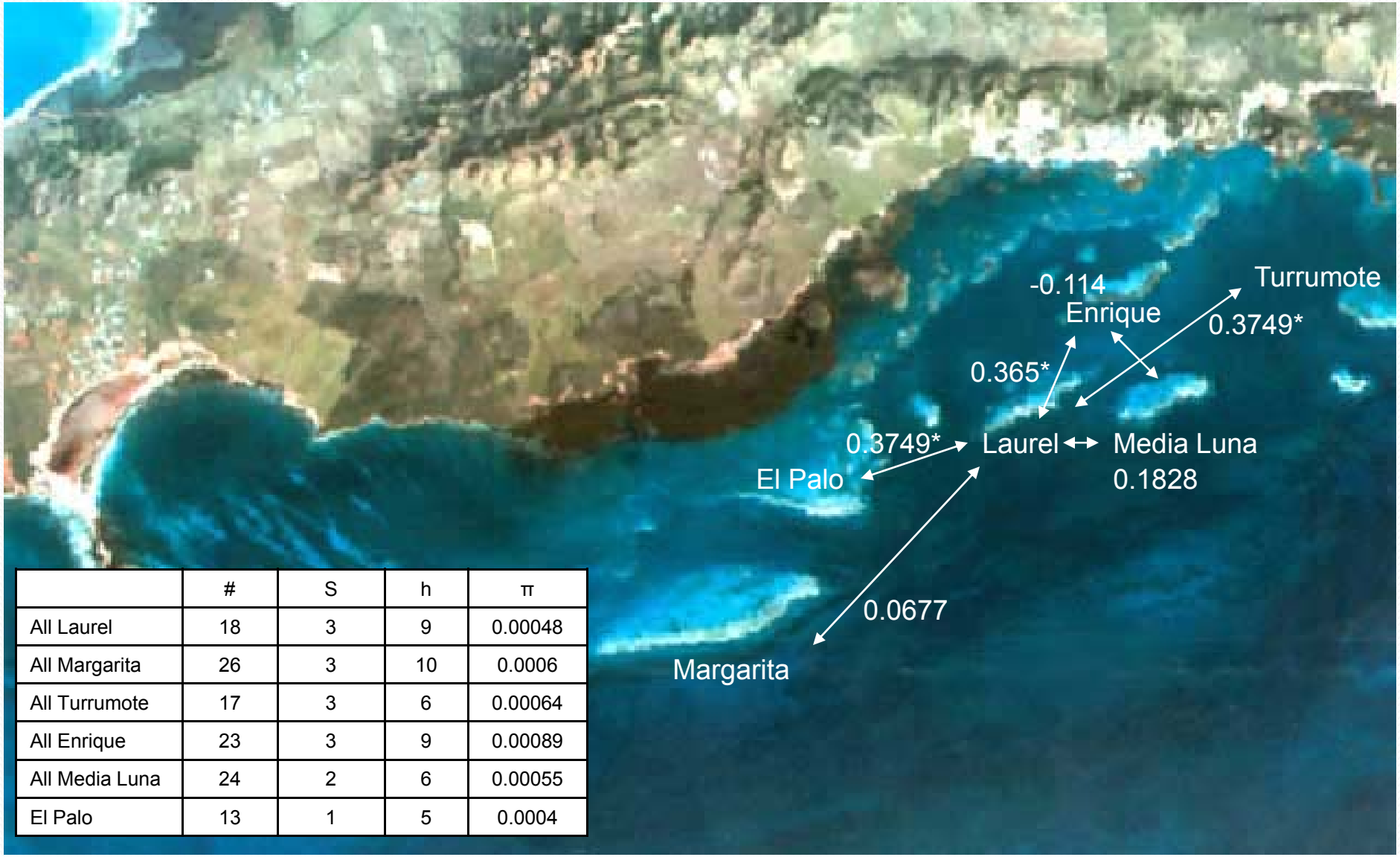
Summary

- Even though this study displayed several mitochondrial haplotypes, reefs are susceptible to environmental stresses that could prevent their recovery or long term survival (e.g. San Cristobal)

- Local water flow patterns in conjunction with direct observations of newly settled planulae and indirect methods of population connectivity (through genetic data) might provide a better indication of the natural processes governing the coral distribution

So What?

Hypothetical Marine Reserve



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El Palo	13	1	5	0.0004

Marine Mammal Commission

www.mmc.gov

- **Independent science-based over-sight agency created by the Marine Mammal Protection Act**

- **Duties of the Commission:**
  - review and study of US activities pursuant to existing laws and international conventions relating to marine mammals
  - recommend to the Secretary and other Federal officials such steps as it deems necessary or desirable for the protection and conservation of marine mammals
  - recommend to the Secretary, other appropriate Federal officials, and Congress such additional measures as it deems necessary or desirable to further the policies of this Act, including provisions for the protection of the Indians, Eskimos, and Aleuts whose livelihood may be adversely affected by actions taken pursuant to this Act

Who is part of the MMC:

- 3 Commissioners
- 9 Scientific Advisors
- 12 Staff
- 1 Advisor on Native Affairs
- 1 Knauss Fellow
- 1 National Research Council Post-Doc

- **My experiences:**
  - Annual Report of 2007 (coming soon!)
    - Unusual mortality events
    - International Species of Concern
  - Arctic Report Card (http://www.arctic.noaa.gov/reportcard/)
  - PIT tag report (Could it be used for right whale detection?)
  - JSOST Inter-agency meetings
  - Seminars, forums, meetings on multitude of issues
  - Global disease spreadsheet/database (currently)

Questions??