Science Advances
AAAS

advances.sciencemag.org/cgi/content/full/6/17/eaax9395/DC1

Supplementary Materials for

Widespread loss of Caribbean acroporid corals was underway before coral bleaching and disease outbreaks

Katie L. Cramer*, Jeremy B. C. Jackson, Mary K. Donovan, Benjamin J. Greenstein, Chelsea A. Korpanty, Geoffrey M. Cook, John M. Pandolfi

*Corresponding author. Email: katie.cramer@gmail.com

Published 22 April 2020, *Sci. Adv.* **6**, eaax9395 (2020)
DOI: 10.1126/sciadv.aax9395

The PDF file includes:

Other Supplementary Material for this manuscript includes the following:

(available at advances.sciencemag.org/cgi/content/full/6/17/eaax9395/DC1)

Supplementary Materials

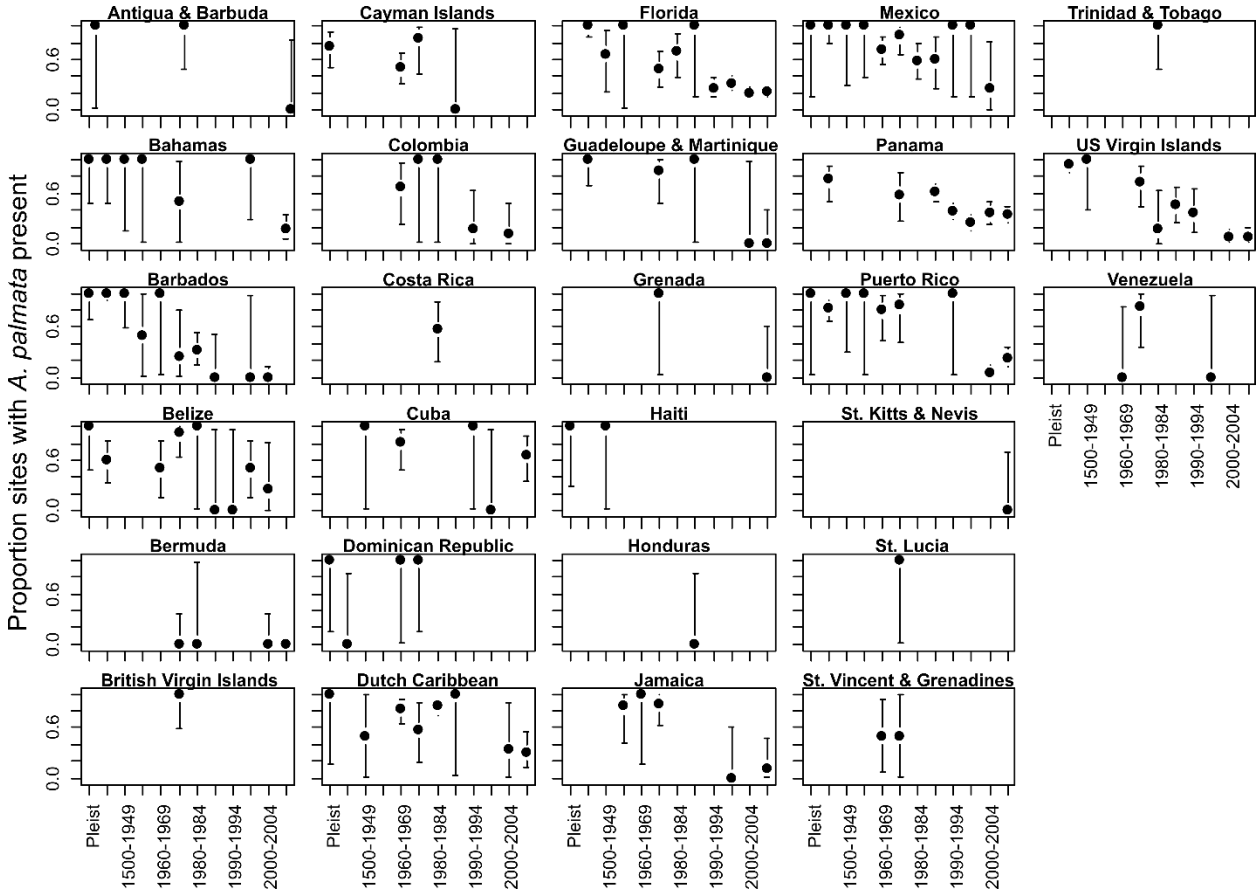

Fig. S1. Proportion of reef sites with *A. palmata* present in reef crest zone, by country. Bars are binomial confidence intervals.

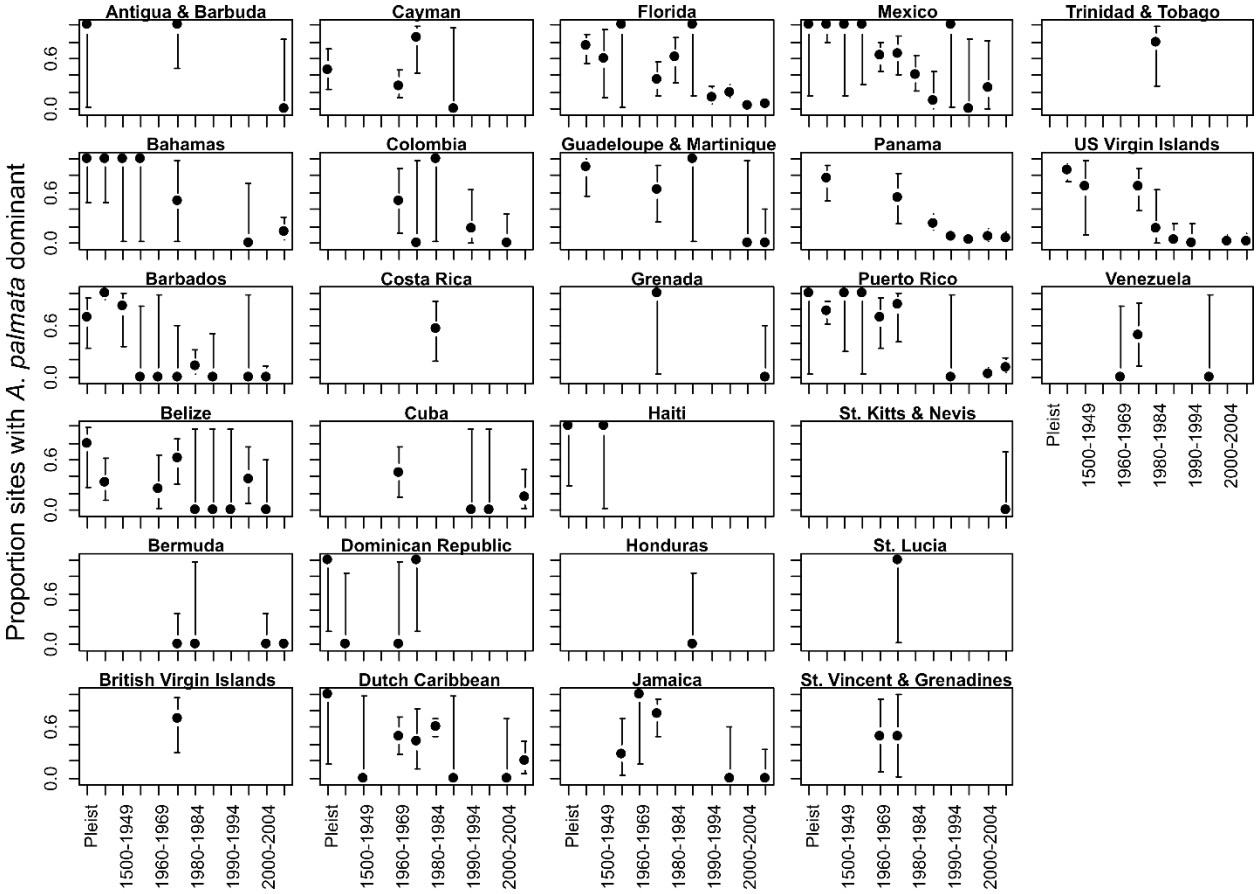

Fig. S2. Proportion of reef sites with *A. palmata* dominant in reef crest zone, by country. Bars are binomial confidence intervals.

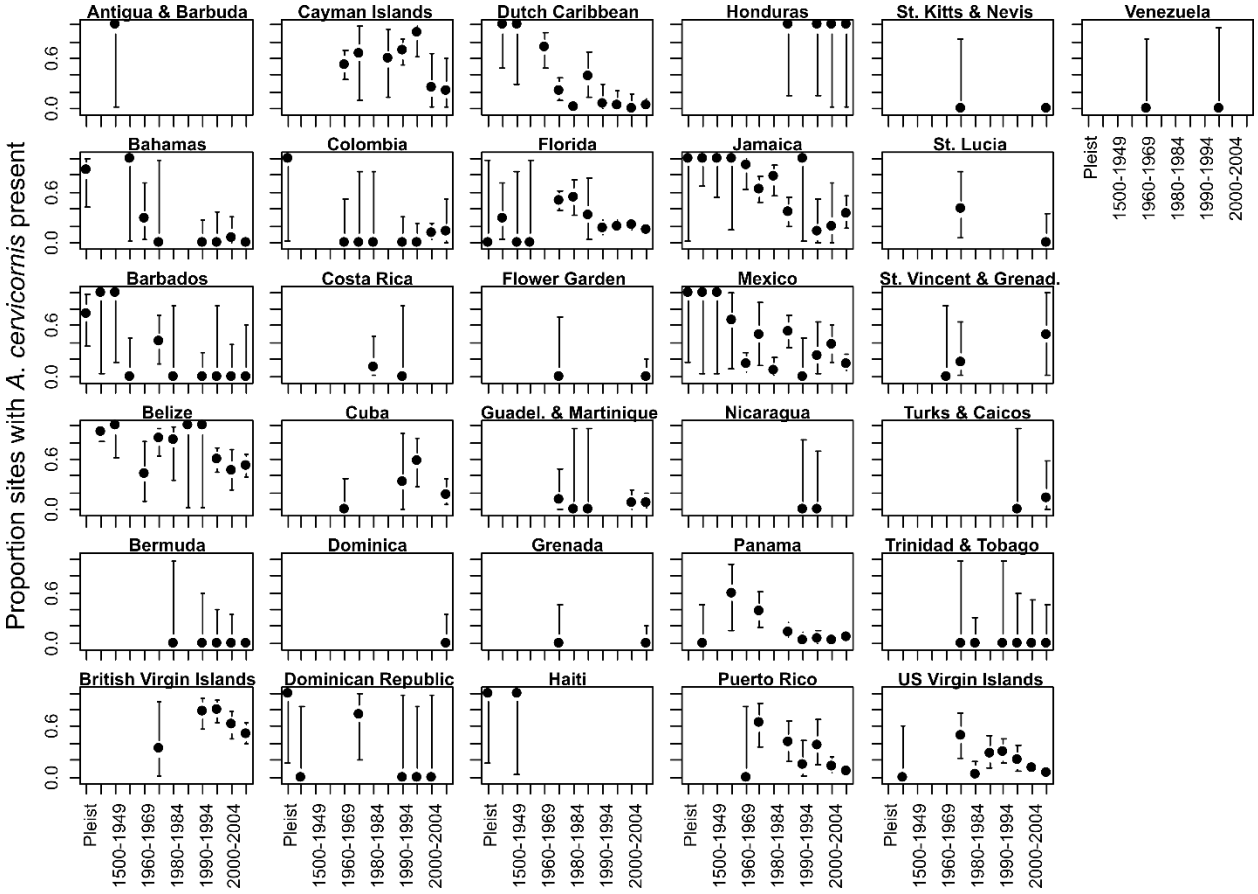

Fig. S3. Proportion of reef sites with *A. cervicornis* present in midslope zone, by country. Bars are binomial confidence intervals.

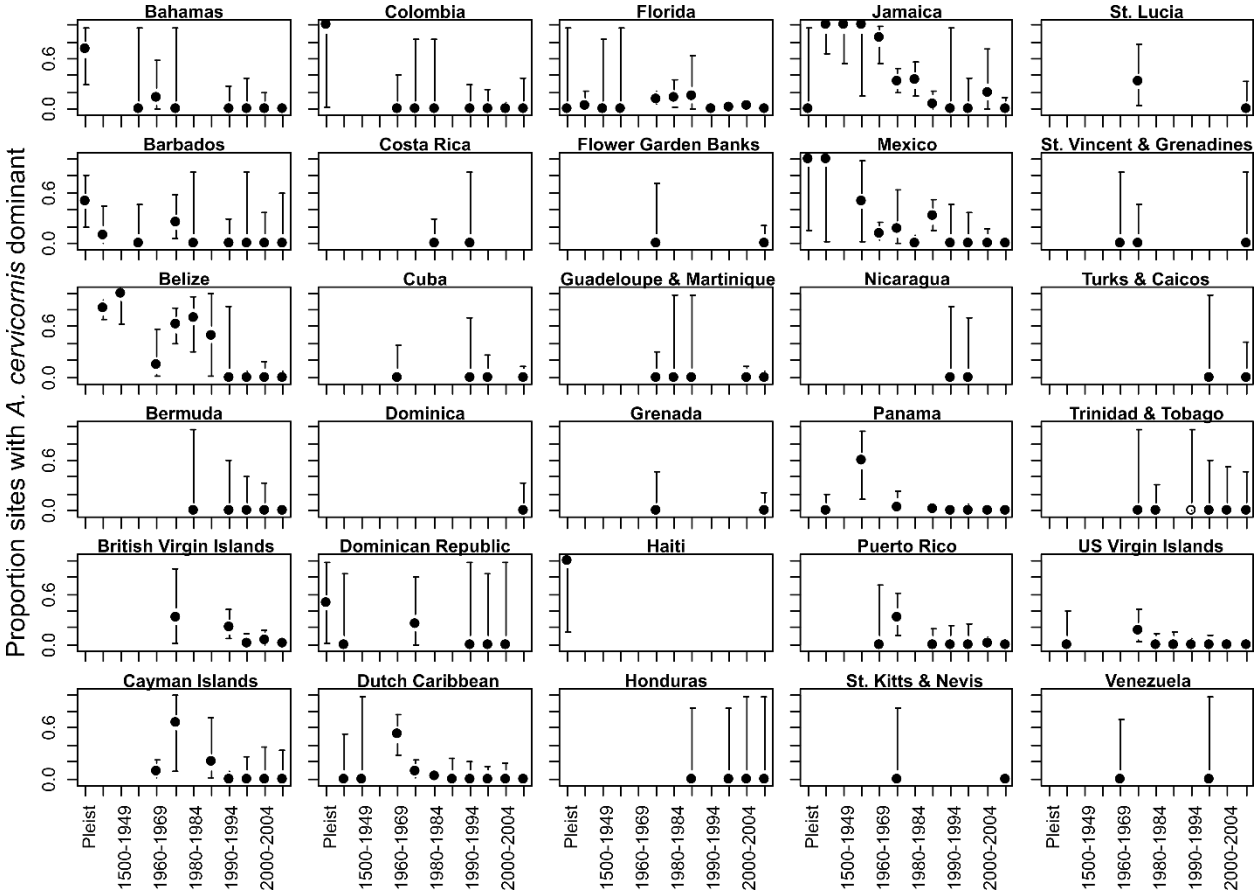

Fig. S4. Proportion of reef sites with *A. cervicornis* dominant in midslope zone, by country. Bars are binomial confidence intervals.

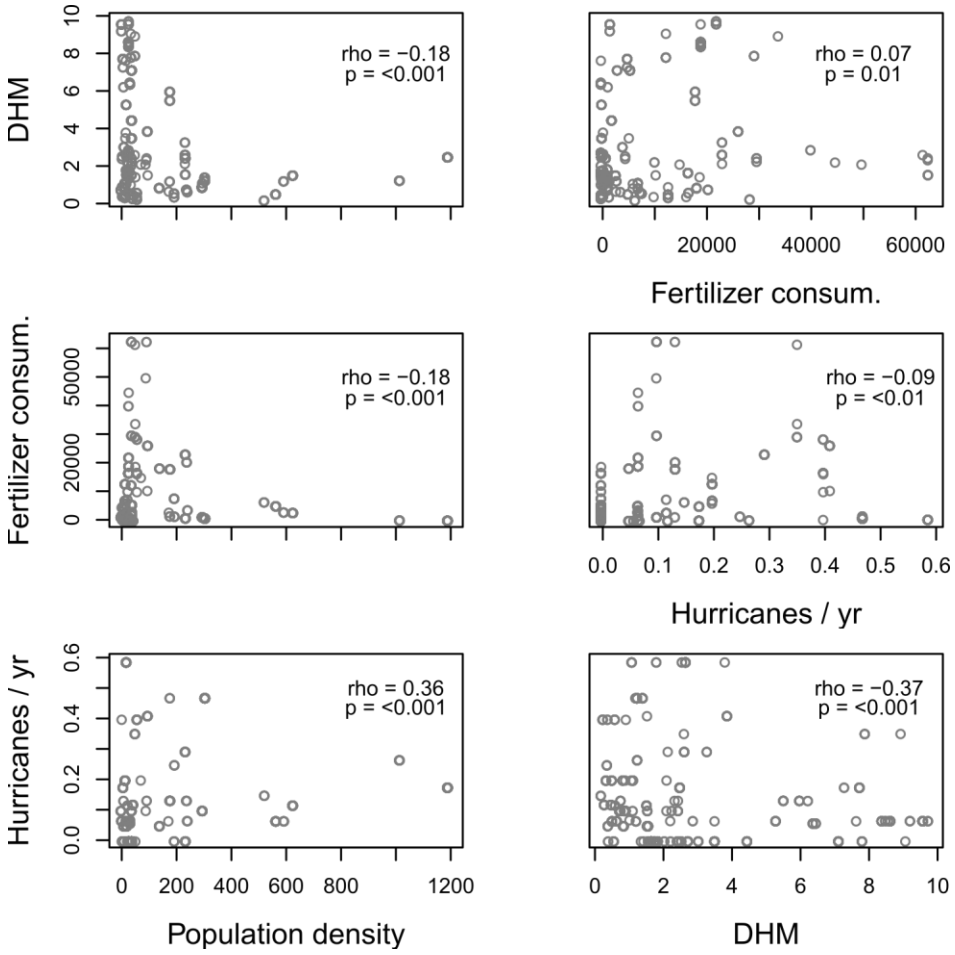

Fig. S5. Relationship between potential drivers of decline in dominance of *A. palmata* at reef crest zone. All comparisons are significant. Spearman rank sum test statistic (rho) and p-values indicated within each biplot.

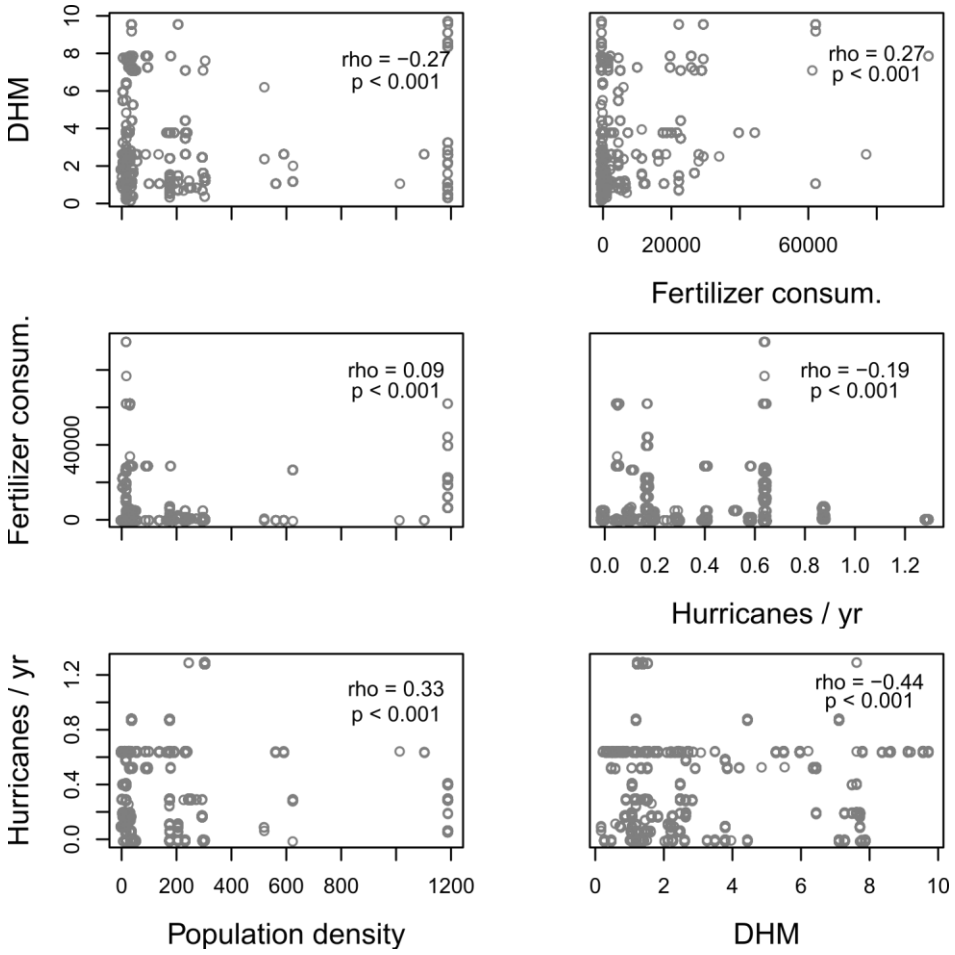

Fig. S6. Relationship between potential drivers of decline in dominance of *A. cervicornis* at midslope reef zone. All comparisons are significant. Spearman rank sum test statistic (rho) and p-values indicated within each biplot.

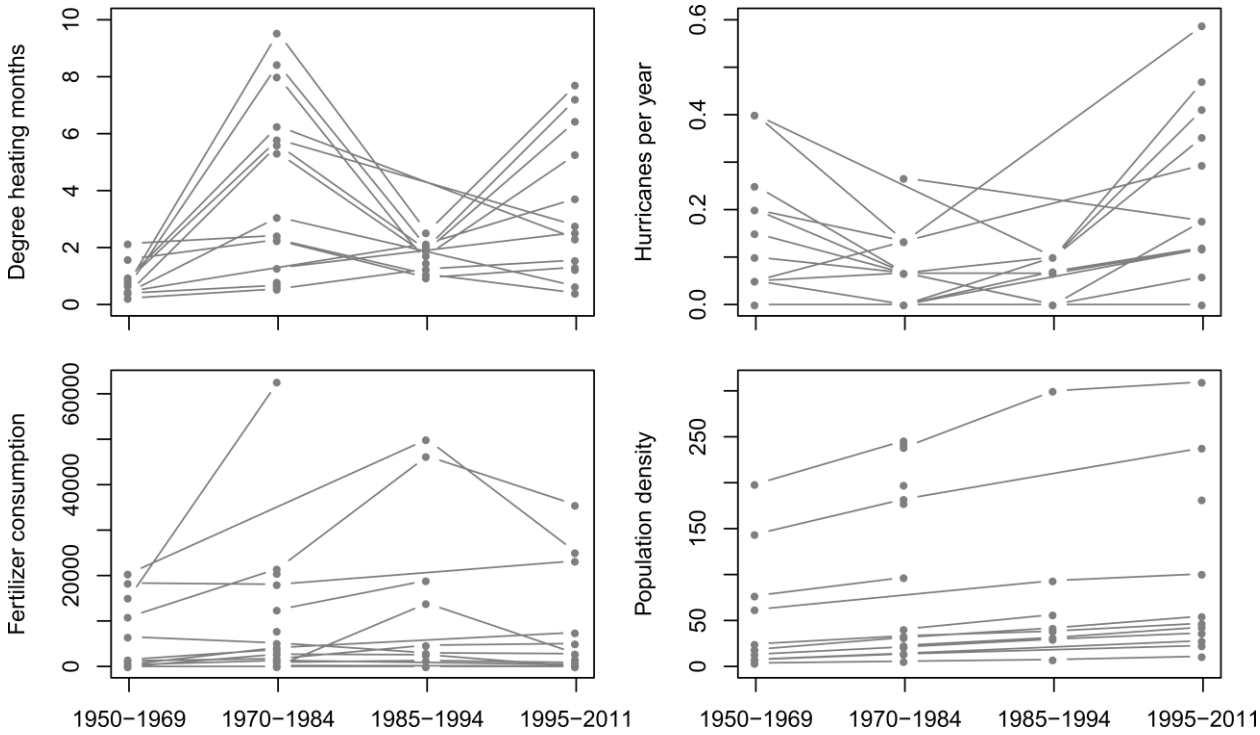

Fig. S7. Trends in potential drivers of decline in dominance of *A. palmata* at reef crest zone. Dots are mean values; trends plotted separately for each country.

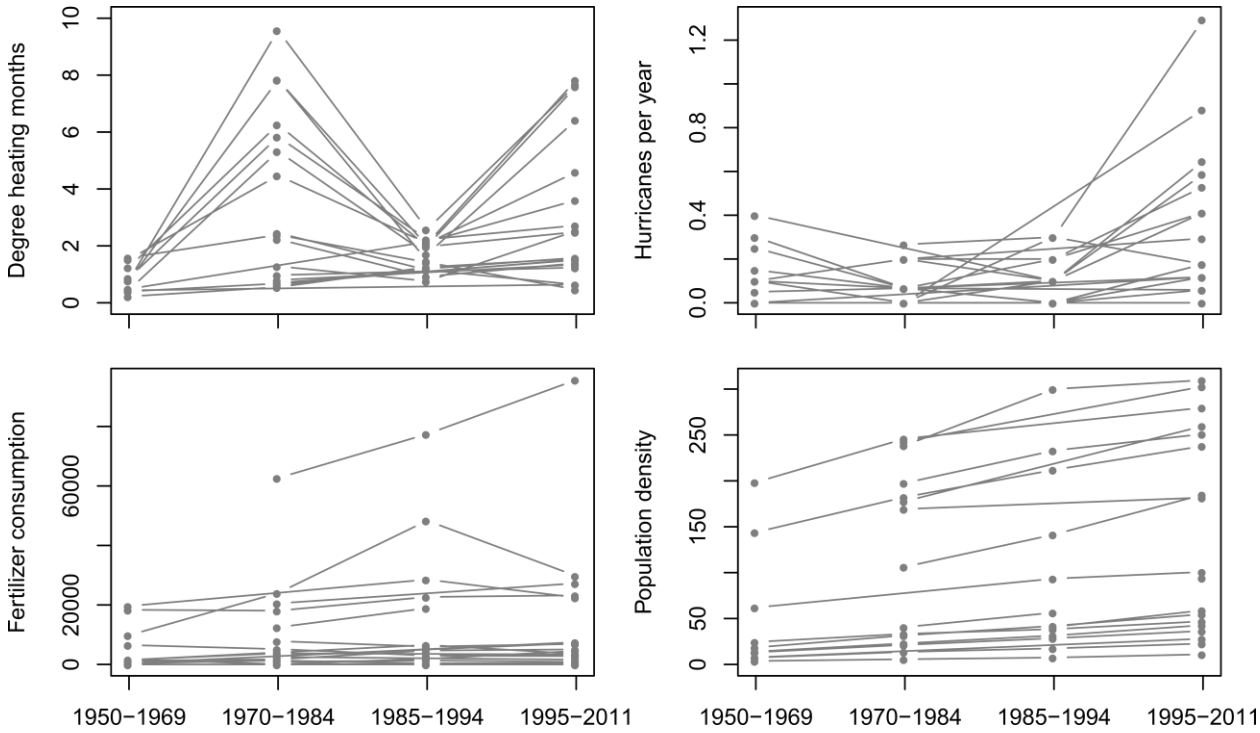

Fig. S8. Temporal trends for potential drivers of decline in dominance of *A. cervicornis* at midslope reef zone. Dots are mean values.

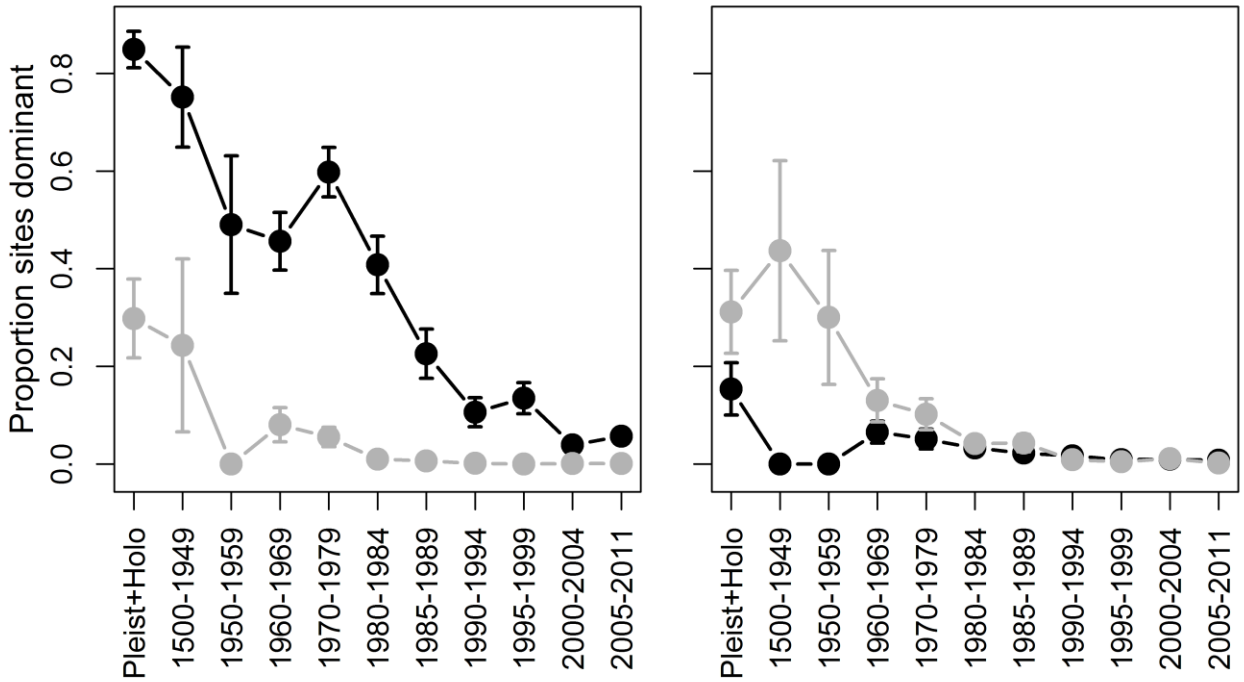

Fig. S9. *Acropora* dominance through time, with Pleistocene and Holocene time periods combined. GLMM results of *A. palmata* dominance (left) and *A. cervicornis* dominance (right) at reef crest (black line) and midslope zone (gray line). Error bars are standard error of the mean fitted values.

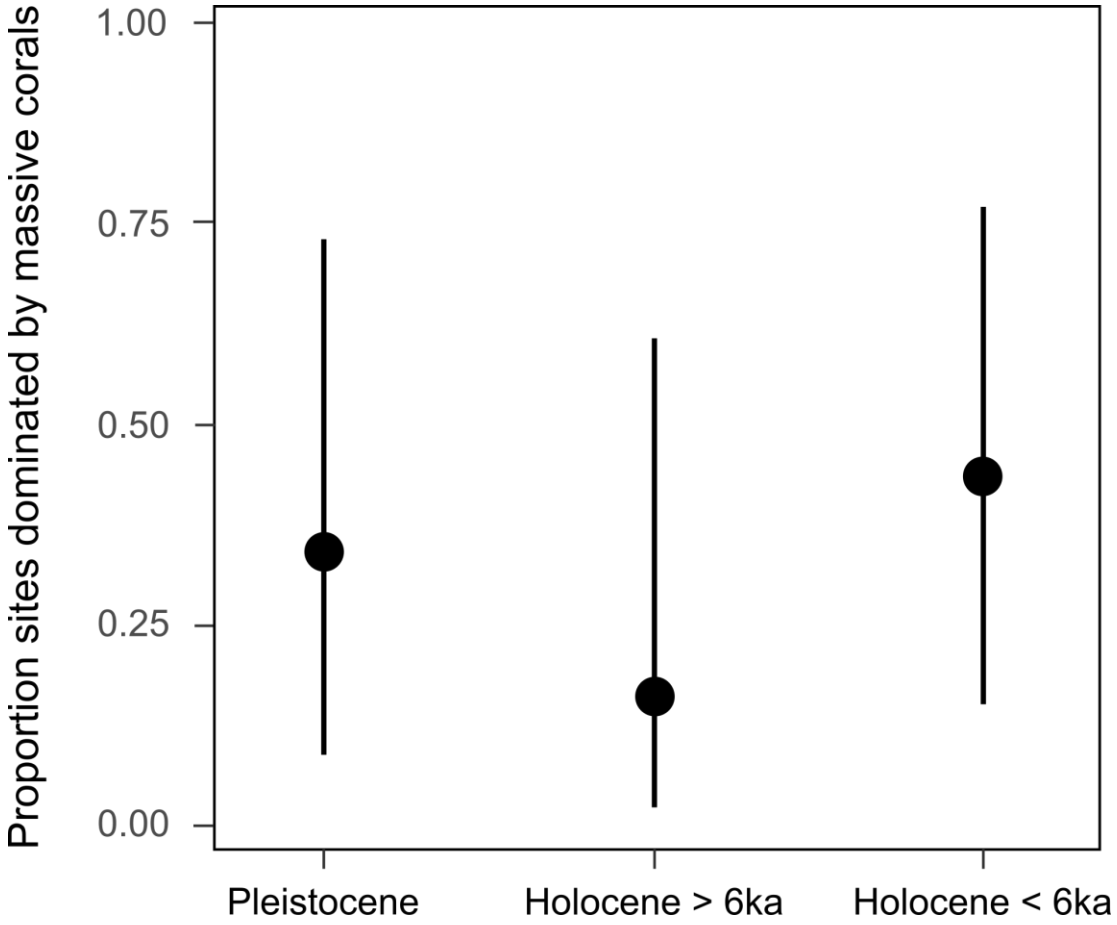

Fig. S10. Dominance of slow-growing corals with a massive colony form during a period of fluctuating sea level (Pleistocene), sea level rise (Holocene > 6ka) and relative stasis in sea level (Holocene < 6ka). Dots are mean fitted values determined from a binomial generalized linear mixed effects model that included time bin as fixed effect and country as random effect. Vertical bars are standard errors of mean fitted values.

Table S2. **Number of reef sites with dominance data for *A. palmata* at reef crest zone.** Countries with * were not included in analyses of potential drivers of change because of insufficient data for one or more drivers.

Country	Pleist	Holo	1500-1949	1950-1959	1960-1969	1970-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2011
Antigua & Barbuda *	1					5						2
Bahamas	5	5	1	1		2				3		30
Barbados	10	44	6	2	1	4	25	5		1	27	
Belize	5	15			8	13	1	1	1	8	4	
Bermuda						8	1				8	69
British Virgin Islands *						7						
Cayman *	17				32	7		1				
Colombia					6	1	1		6		9	
Costa Rica							7					
Cuba					11				1	1		12
Dominican Republic	2	2			1	2						
Dutch Caribbean	2		1		20	7	80	1			3	20
Florida *		28	5	1		23	13	2	54	110	185	276
Guadel. & Martinique		10				8		1			1	7
Grenada *						1						4
Haiti *	3		1									
Honduras								2				
Jamaica				7	2	17				4		9
Mexico	2	17	2	3	33	18	22	10	1	2	4	
Panama		17				11		93	101	96	56	89
Puerto Rico *	1	38	3	1	10	7			1		48	57
St. Kitts & Nevis												3
St. Lucia						1						
St. Vincent & Grenadines					4	2						
Trinidad & Tobago							5					
US Virgin Islands		51	3			15	6	22	14		58	51
Venezuela					2	6				1		
Total	47	227	22	15	130	165	161	138	179	226	403	629

Table S3. **Number of reef sites with dominance data for *A. cervicornis* at midslope zone.** Countries with * were not included in analyses of potential drivers of change because of insufficient data on *A. cervicornis* dominance and/or insufficient data for one or more drivers.

Country	Pleist	Holo	1500-1949	1950-1959	1960-1969	1970-1979	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2011
Bahamas	7			1	7	1			12	8	16	541
Barbados	10	10		6		12	2		11	2	8	4
Belize		51	8		7	24	7	2	2	55	19	53
Bermuda							1		4	7	9	105
British Virgin Islands *						3			24	40	40	64
Cayman Islands *					37	3		5	40	12	8	9
Colombia	1				7	2	2		11	14	46	8
Costa Rica							11		2			
Cuba					8				3	12		28
Dominica												9
Dominican Republic	2	2				4			1	2	1	
Dutch Caribbean		5	1		19	38	96	13	17	23	19	83
Florida *	1	23	2	1		87	22	6	78	186	235	521
Flower Garden *						3						16
Guadel. & Martinique						10	1	1			27	48
Grenada *						6						15
Haiti *	2											
Honduras								2		2	1	1
Jamaica	1	9	6	2	13	48	23	31	1	8	5	26
Mexico	2	1		2	45	6	34	28	6	8	19	66
Nicaragua *									2	3		
Panama		16		5		22		72	53	44	119	132
Puerto Rico *					3	15		17	14	13	56	181
St. Kitts & Nevis						2						188
St. Lucia						6						9
St. Vincent & Grenadines					2	6						2
Turks & Caicos *										1		7
Trinidad & Tobago						1	10		1	4	5	6
US Virgin Islands		7				18	27	23	45	30	194	346
Venezuela					3					1		
Total	26	124	17	17	151	317	236	200	327	475	827	2468

Table S4. Structure of generalized linear mixed effect models used for time series analyses. * signifies random effect.

Time period	Reef zone	Coral species	Response variable	Predictor variables
Pleistocene - 2011	Crest	*A. palmata*	Proportion sites w/ species present	~ Time Bin + Country*
			Proportion sites w/ species dominant	~ Time Bin + Country*
		A. cervicornis	Proportion sites w/ species present	~ Time Bin + Country*
			Proportion sites w/ species dominant	~ Time Bin + Country*
Pleistocene - 2011	Midslope	*A. palmata*	Proportion sites w/ species present	~ Time Bin + Country*
			Proportion sites w/ species dominant	~ Time Bin + Country*
		A. cervicornis	Proportion sites w/ species present	~ Time Bin + Country*
			Proportion sites w/ species dominant	~ Time Bin + Country*

Table S5. Structure of generalized linear mixed effect models used for drivers analyses. Random effects indicated by *. All four possible fixed effects included in initial model; non-significant fixed effects (in parentheses) dropped in final model. For *A. cervicornis* in the midslope zone, none of the fixed effects were significant.

Time period	Reef zone	Coral species	Response variable	Predictor variables
1950-2011	Crest	*A. palmata*	Proportion sites w/ species dominant	~ Time Bin* + Country* + (DHM) + (FertCons) + (HurrPerYr) + PopDens
1950-2011	Midslope	*A. cervicornis*	Proportion sites w/ species dominant	~ Time Bin* + Country* + (DHM) + (FertCons) + (HurrPerYr) + (PopDens)

Table S6. **Model-fitted presence and dominance of *A. palmata* at reef crest zone, from Pleistocene Epoch to 2011.**

Reef zone	Species	Abundance measure	Time bin	Percent sites	Effect	*Z*	p-level
Crest	*A. palmata*	Presence	Pleistocene	94%	--	--	--
			Holocene	92%	-0.33	-0.56	0.58
			1500-1949	91%	-0.51	-0.62	0.54
			1950-1959	86%	-0.92	-0.97	0.33
			1960-1969	65%	-2.17	-3.82	0.00
			1970-1979	74%	-1.75	-3.03	0.00
			1980-1984	59%	-2.40	-4.11	0.00
			1985-1989	50%	-2.79	-4.75	0.00
			1990-1994	29%	-3.69	-6.29	0.00
			1995-1999	24%	-3.93	-6.76	0.00
			2000-2004	16%	-4.43	-7.71	0.00
			2005-2011	19%	-4.25	-7.48	0.00
		Dominance	Pleistocene	78%	--	--	--
			Holocene	85%	0.44	1.10	0.27
			1500-1949	78%	-0.02	-0.05	0.96
			1950-1959	49%	-1.3	-1.99	0.05
			1960-1969	45%	-1.4	-3.69	0.00
			1970-1979	60%	-0.87	-2.21	0.02
			1980-1984	41%	-1.62	-3.93	0.00
			1985-1989	23%	-2.5	-5.67	0.00
			1990-1994	11%	-3.41	-7.37	0.00
			1995-1999	13%	-3.14	-7.25	0.00
			2000-2004	4%	-4.45	-9.79	0.00
			2005-2011	6%	-4.06	-9.84	0.00

Table S7. Model-fitted presence and dominance of *A. cervicornis* at reef crest zone, from Pleistocene Epoch to 2011.

Reef zone	Species	Abundance measure	Time bin	Percent sites	Effect	*Z*	p-level
Crest	*A. cervicornis*	Presence	Pleistocene	73%	--	--	--
			Holocene	45%	-1.18	-2.28	0.03
			1500-1949	72%	-0.03	-0.04	0.97
			1950-1959	33%	-1.70	-2.08	0.04
			1960-1969	13%	-2.92	-6.13	0.00
			1970-1979	22%	-2.28	-4.74	0.00
			1980-1984	9%	-3.31	-6.46	0.00
			1985-1989	19%	-2.42	-4.71	0.00
			1990-1994	12%	-2.96	-5.80	0.00
			1995-1999	12%	-2.95	-5.97	0.00
			2000-2004	6%	-3.78	-7.73	0.00
			2005-2011	6%	-3.74	-7.86	0.00
		Dominance	Pleistocene	18%	--	--	--
			Holocene	12%	-0.413	-0.74	0.46
			1500-1949	0%	-16.99	0.00	1.00
			1950-1959	0%	-16.97	-0.01	1.00
			1960-1969	7%	-1.11	-2.00	0.05
			1970-1979	5%	-1.37	-2.32	0.02
			1980-1984	3%	-1.83	-2.97	0.00
			1985-1989	2%	-2.23	-3.10	0.00
			1990-1994	2%	-2.51	-3.51	0.00
			1995-1999	1%	-3.16	-3.84	0.00
			2000-2004	1%	-3.05	-4.68	0.00
			2005-2011	1%	-3.28	-5.35	0.00

Table S8. Model-fitted presence and dominance of *A. cervicornis* at midslope reef zone, from Pleistocene Epoch to 2011.

Reef zone	Species	Abundance measure	Time bin	Percent sites	Effect	*Z*	p-level
Midslope	*A. cervicornis*	Presence	Pleistocene	92%	--	--	--
			Holocene	39%	-2.92	-4.23	0.00
			1500-1949	83%	-0.95	-0.94	0.34
			1950-1959	45%	-2.71	-3.39	0.00
			1960-1969	16%	-4.18	-6.31	0.00
			1970-1979	30%	-3.37	-5.27	0.00
			1980-1984	92-11%	-4.59	-6.98	0.00
			1985-1989	92-20%	-3.87	-5.92	0.00
			1990-1994	92-12%	-4.52	-7.02	0.00
			1995-1999	92-11%	-4.59	-7.18	0.00
			2000-2004	92-8%	-4.88	-7.66	0.00
			2005-2011	92-6%	-5.28	-8.38	0.00
		Dominance	Pleistocene	63%	--	--	--
			Holocene	17%	-2.11	-3.77	0.00
			1500-1949	43%	-0.83	-0.97	0.33
			1950-1959	35%	-1.19	-1.64	0.10
			1960-1969	12%	-2.52	-4.43	0.00
			1970-1979	9%	-2.86	-5.29	0.00
			1980-1984	4%	-3.75	-6.41	0.00
			1985-1989	4%	-3.67	-6.14	0.00
			1990-1994	1%	-5.27	-7.62	0.00
			1995-1999	0%	-5.96	-9.12	0.00
			2000-2004	1%	-5.04	-8.64	0.00
			2005-2011	0%	-6.69	-11.00	0.00

Table S9. Model-fitted presence and dominance of *A. palmata* at midslope reef zone, from Pleistocene Epoch to 2011.

Reef zone	Species	Abundance measure	Time bin	Percent sites	Effect	*Z*	p-level
Midslope	*A. palmata*	Presence	Pleistocene	46%	--	--	--
			Holocene	6%	-0.44	-0.85	0.39
			1500-1949	0%	-14.52	-0.67	0.50
			1950-1959	23%	-1.09	-1.48	0.13
			1960-1969	10%	-2.12	-4.04	0.00
			1970-1979	20%	-1.28	-2.72	0.01
			1980-1984	6%	-2.58	-4.82	0.00
			1985-1989	15%	-1.64	-3.24	0.00
			1990-1994	6%	-2.57	-5.11	0.00
			1995-1999	2%	-3.89	-6.63	0.00
			2000-2004	3%	-3.35	-6.79	0.00
			2005-2011	2%	-3.80	-8.14	0.00
		Dominance	Pleistocene	4%	--	--	--
			Holocene	14%	1.28	1.74	0.08
			1500-1949	0%	-16.76	0.00	0.99
			1950-1959	0%	-18.33	0.00	0.99
			1960-1969	8%	0.63	0.79	0.43
			1970-1979	6%	0.32	0.44	0.66
			1980-1984	1%	-1.10	-1.25	0.21
			1985-1989	1%	-1.69	-1.66	0.10
			1990-1994	0%	-3.08	-2.51	0.01
			1995-1999	0%	-17.60	-0.01	0.99
			2000-2004	0%	-3.45	-3.43	0.00
			2005-2011	0%	-3.45	-4.21	0.00

Table S10. Generalized linear mixed model results of temporal changes in percent of reef sites with *Acropora* present or dominant, using values from historical period (1500-1949 AD) as baseline. Proportion of sites modeled as a function of time bin treated as a fixed effect and country treated as a random effect.

Reef zone	Species	Abundance measure	Earliest change relative to Pleistocene	Change	AIC	*Z*	p-level	total sites
Crest	*A. palmata*	presence	1960-1969	91-65%	2237	-3.0	0.01	2087
		dominance	1950-1959	78-49%	1504	-1.9	0.05	2068
Midslope	*A. cervicornis*	presence	1950-1959	83-45%	3615	-1.9	0.05	4491
		dominance	1950-1959	43-35%	1084	-4.4	0.001	5035