

# Supporting Information

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## SI Text

**Further Details of the HURDAT Dataset.** The Atlantic Basin Hurricane Database (HURDAT), available at [http://www.aoml.noaa.gov/hrd/hurdat/Data\\_Storm.html](http://www.aoml.noaa.gov/hrd/hurdat/Data_Storm.html), contains tropical cyclone tracks in the North Atlantic since 1851. Several authors have noted that this record is not spatiotemporally homogeneous: Until 1943, it is based on ship logbooks and landfall observations, with changes over time in the ship tracks affecting the record (1). The ship and landfall record was complemented by aircraft reconnaissance flights from 1944 and satellite observations have been used since they became available in 1966. Various corrections have been proposed to address the storm undercounts which are likely to have occurred before 1944 (1, 2). However,

these corrections are of no use for the purpose of our paper because they aim at correcting the basin-wide yearly numbers of tropical cyclones, whereas our methodology requires the actual tracks. To partially address this issue, following Villarini et al. (3), we only consider HURDAT tracks lasting for more than 2 d. In the figures below, we compare the results obtained by taking all HURDAT tracks versus the results (presented in the main text) which use only tropical cyclones with duration of at least 2 d: There is virtually no change and the same holds for the dispersion of the hurricane tracks. Indeed, only 21 tracks are removed by the 2-d filtering procedure (Fig. S1).

1. Vecchi GA, Knutson TR (2008) On estimates of historical north Atlantic tropical cyclone activity. *J Clim* 21:3580–3600.
2. Landsea CW, Vecchi GA, Bengtsson L, Knutson TR (2010) Impact of duration thresholds on Atlantic tropical cyclone counts. *J Clim* 23:2508–2519.
3. Villarini G, Vecchi GA, Smith JA (2010) Modeling the dependence of tropical storm counts in the north Atlantic basin on climate indices. *Mon Weather Rev* 138:2681–2705.



**Table S1. Contents of individual cells (0.25 m<sup>2</sup>) within the model**

Substratum	Range, cm <sup>2</sup>
Brooding coral 1 (e.g., <i>Porites</i> , <i>Agaricia</i> ) (BC1)	$1 \leq BC1 \leq 2,500$
Brooding coral 2 (e.g., <i>Mycetophyllia</i> ) (BC2)	$1 \leq BC2 \leq 2,500$
Spawning coral 1 (e.g., <i>Montastraea cavernosa</i> , <i>Meandrina</i> ) (SC1)	$1 \leq SC1 \leq 2,500$
Spawning coral 2 (e.g., <i>Montastraea annularis</i> ) (SC2)	$1 \leq SC2 \leq 2,500$
Cropped algae [filamentous, coralline red algae, and short turfs (<5 mm height)], 0–6 mo ( $A_6$ )	$0 \leq A_6 \leq 2,500$
<i>Dictyota pulchella</i> (D)	$0 \leq D \leq 2,500$
<i>Lobophora variegata</i> (L)	$0 \leq L \leq 2,500$
Ungrazeable substratum (e.g., sand), U	$U = 0$ or $U = 2,500$

All substrata represented as area (cm<sup>2</sup>).

**Table S2. Basic parameterization of simulation model for midshelf reefs without significant sediment input and sparismid-dominated grazing**

Parameter	Details
Coral recruitment	Corals recruit to cropped algae, $A_6$ and $A_{12}$ , because algal turfs are not heavily sediment laden. Recruit at size 1 cm <sup>2</sup> . Recruitment rate of brooders and spawners (respectively): 2 and 0.2 per 0.25 m <sup>2</sup> of cropped algae per time interval. Recruitment rate was adjusted for rugosity (ca. 2) and the cover of cropped algae at Glovers Reef (1)
Coral growth	Coral size is quantified as the cross-sectional, basal area of a hemispherical colony (cm <sup>2</sup> ). BC have a lateral extension rate of 0.8 cm y <sup>-1</sup> and SC grow slightly faster at 0.9 cm y <sup>-1</sup> (based on median rates for <i>Porites astreoides</i> , <i>Porites porites</i> , <i>Siderastrea siderea</i> , <i>Montastraea annularis</i> , <i>Colpophyllia natans</i> , and <i>Agaricia agaricites</i> ) (2–6)
Coral reproduction	Excluded, assume constant rate of coral recruitment from outside reef (i.e., no stock-recruitment dynamics)
Colonization of cropped algae	Cropped algae arises (i) when macroalgae is grazed and (ii) after all coral mortality events (7) except those due to macroalgal overgrowth (see coral–algal competition below).
Colonization of macroalgae	Macroalgae have a 70% chance of becoming established if cropped algae are not grazed for 6 mo (mostly <i>Dictyota</i> ) and this increases to 100% probability after 12 mo of no grazing (mostly <i>Lobophora</i> ). Rates acquired from detailed centimeter-resolution observations of algal dynamics with and without grazing (8).
Macroalgal growth over dead coral (cropped algae)	In addition to arising from cropped algae that are not grazed (above), established macroalgae also spread vegetatively over cropped algae (mostly <i>Lobophora</i> because <i>Dictyota</i> spread shows little pattern with grazing). The probability that macroalgae will encroach onto the algal turf within a cell, $P_{A \rightarrow M}$ , is given by $P_{A \rightarrow M} = M_{4 \text{ cells}}$ , where $M_{4 \text{ cells}}$ is the percent cover of macroalgae within the von Neumann (four-cell) neighborhood (9). This is a key method of algal expansion and represents the opportunistic overgrowth of coral that was extirpated by disturbance.
Competition between corals	If corals fill the cell (2,500 cm <sup>2</sup> ), the larger coral overtops smaller corals (chosen at random if more than one smaller coral share the cell). If corals have equal size, the winner is chosen at random (10)
Competition between corals and cropped algae	Corals always overgrow cropped algae (7)
Competition between corals and macroalgae 1: Effect of macroalgae on corals	(i) Growth rate of juvenile corals (area <60 cm <sup>2</sup> ) set to zero if $M_{4 \text{ cells}} > 80\%$ , and reduced by 70% if $60\% < M_{4 \text{ cells}} \leq 80\%$ . Parameters based on both <i>Dictyota</i> and <i>Lobophora</i> (11) (ii) Growth rate of juvenile and adult corals (area $\geq 60$ cm <sup>2</sup> ) reduced by 50% if $M_{4 \text{ cells}} < 60\%$ (7, 12). (iii) Limited direct overgrowth of coral by macroalgae can occur (13, 14). Nugues and Bak (15) found that the upper 95% CL of the mean area of overgrowth ranged from 0–18 cm <sup>2</sup> pa across an approximately 7-cm length of coral edge, with an overall mean of 8 cm <sup>2</sup> pa. This translates to 4 cm <sup>2</sup> in each 6-mo time step of the model. Overgrowth (cm <sup>2</sup> ), $O_{C \rightarrow M}$ , was scaled to entire colonies using $O_{C \rightarrow M} = M_{4 \text{ cells}} \times P_i / 7 \times 4$ , where $M_{4 \text{ cells}}$ is the proportion of macroalgae in the von Neumann four-cell neighborhood and $P_i$ is the perimeter of the coral. Note that Nugues and Bak (15) did not find significant effects of <i>Lobophora</i> on all coral species studied. Although this was the correct interpretation of their data, the published results strongly suggest that an effect does exist and that a larger sample size may well have resulted in significant differences. Other studies have found negative effects of macroalgae on both massive (13) and branching corals (16).
Competition between corals and macroalgae 2: Effect of corals on macroalgae	The vegetative growth rate of macroalgae, $P_{A \rightarrow M}$ , is reduced by 25% when at least 50% of the local von Neumann neighborhood includes coral (7, 17): proportion of coral, $C = \frac{(BC+SC)}{2,500}$ $P_{A \rightarrow M} = 0.75 \times M_{4 \text{ cells}}$ if $C \geq 0.5$ $P_{A \rightarrow M} = M_{4 \text{ cells}}$ if $C < 0.5$
Grazing by fishes and impact of fishing	An unfished community of parrot fishes grazes a maximum of 40% of the seabed per 6-mo time interval. During a given time interval, cells are visited in a random order and all algae consumed until the total grazing impact is reached. All turf and macroalgae are consumed (and converted to $A_6$ ) until the constraint is reached. Fishing can reduce the instantaneous grazing intensity of parrot fish communities by at least sixfold (18) to 5% 6 mo <sup>-1</sup> .

