Habitat, fishing and biodiversity controls on coral reef grazing function

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Supplementary Methods

Region details

In Seychelles, 21 reefs were surveyed in 2008, 2014, and 2017 on two inhabited islands (Mahe, Praslin). Surveys were conducted on the reef slope at 9-12 m depth, and stratified to include carbonate fringing reefs, granitic rocky reefs with coral growth, and patch reef habitats on a sand, rubble, or rock base (Fig. S1B). Surveys were repeated for either 8 (2008) or 16 (2011, 2014, 2017) replicates at each reef, which were located at least 15 m away from each other. To ensure that survey effort was comparable among Seychelles reefs, we only considered surveys from the first 8 replicates (per site per survey year). Overall, the surveys covered up to 0.5 km of reef front and 2,500 m2 of reef habitat, including 672 point counts over 4 surveyed years. Reefs were categorised by their exploitation status, with 9 sites in small protected areas and 12 sites supporting artisanal fisheries.

In the Chagos archipelago, 25 reefs were surveyed on four uninhabited atolls in 2010 (Fig. S1B). Surveys were stratified to include sheltered (9) and exposed (9) habitats, and four replicate transects were conducted at each site, resulting in 100 total transects. All reefs were categorised as remote.

In Maldives, 11 reefs were surveyed on one atoll (Huvadhoo) in 2013 (Fig. S1B). Surveys were conducted on the reef slope for 4 replicates per reef, resulting in 44 total transects. All reefs were categorised as fished.

In Australia, five reefs were surveyed on the central Great Barrier Reef in 2010 and 2011 (Wheeler, Davies, Rib, Trunk, John Brewer) (Graham et al. 2014) (Fig. S1B). Reefs were stratified to include 3 wave exposed and 3 wave sheltered locations (6 per reef), which were further divided into reef slope (7-9 m depth), reef crest (2-3 m depth), and reef flat (100 m distance from crest). Each location and habitat type was surveyed with four replicate transects. We used data for surveys conducted on the reef slope, which produced a dataset of 24 transects per reef and 120 transects in total. Davies, Rib, Trunk and John Brewer were categorised as fished, and Wheeler was categorised as protected (no-take zone).

Benthic categories

Across all reefs, we detected four benthic regimes characterised by 1) hard coral dominance, 2) macroalgal dominance, 3) high availability of bare substrate, and 4) rubble reefs (Fig. S1B). Coral dominance was the most common regime, detected at 41 reefs across all four regions, whereas bare substrate regimes were only present in Seychelles (9) and Chagos (6).

Macroalgal dominance was detected on five Seychelles reefs and nine GBR reefs, while rubble reefs were only present in Seychelles (6 reefs).

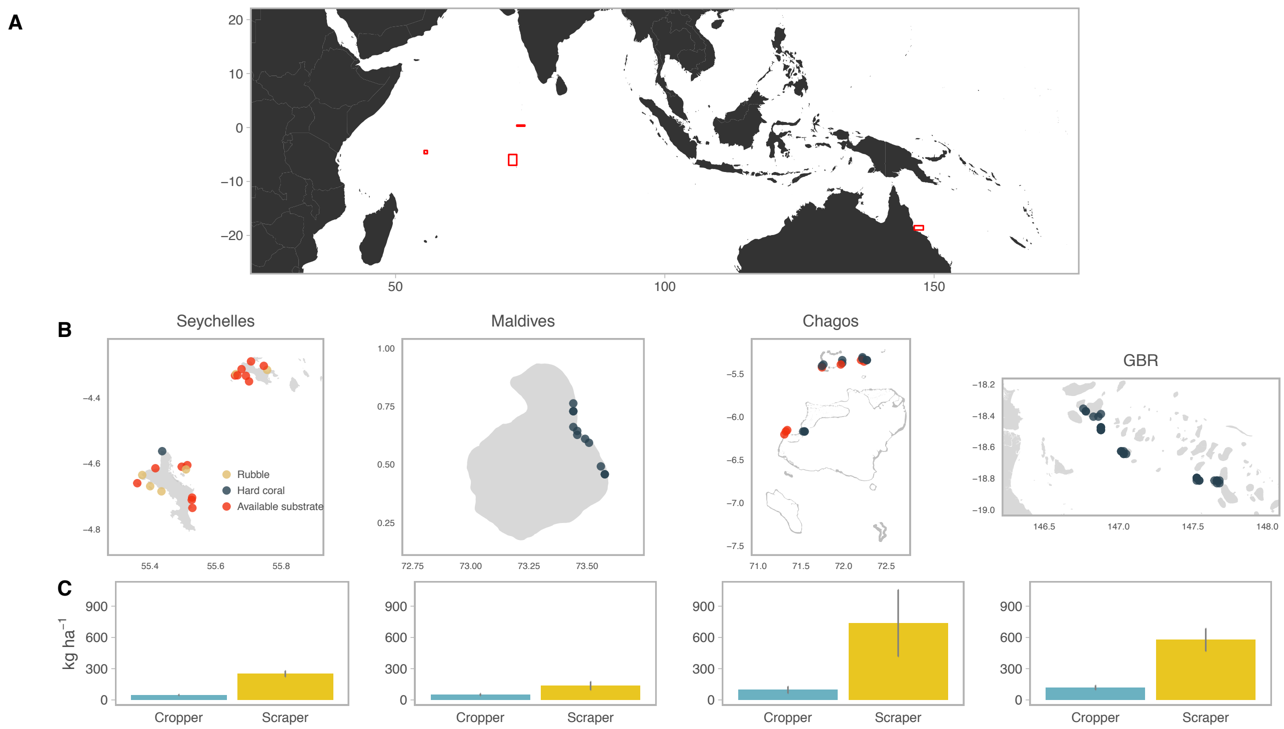

Figure S1 | Map of study sites with benthic habitat regimes (B) and herbivore biomass levels (C). Survey sites are coloured by regimes identified in k-cluster analysis (rubble = yellow, macroalgae = green, substrate = blue, coral = red), and bar plots show mean grazing biomass (± 2 standard errors) for croppers and scrapers.

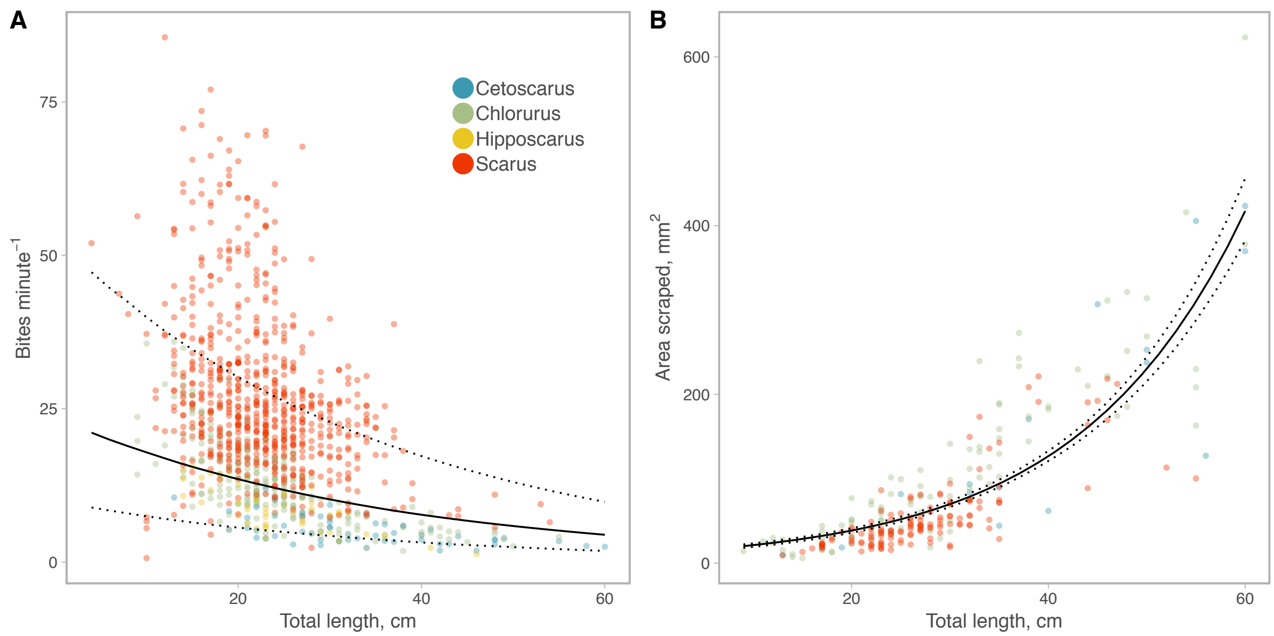

Figure S2 | Size effects on scraper bite rates (A) and bite area (B). Lines indicate median posterior predictions with 95% certainty intervals, excluding species and genera effects, across the range of observed body sizes (total length, cm). Points are observed bite rates or bite areas coloured by genera.

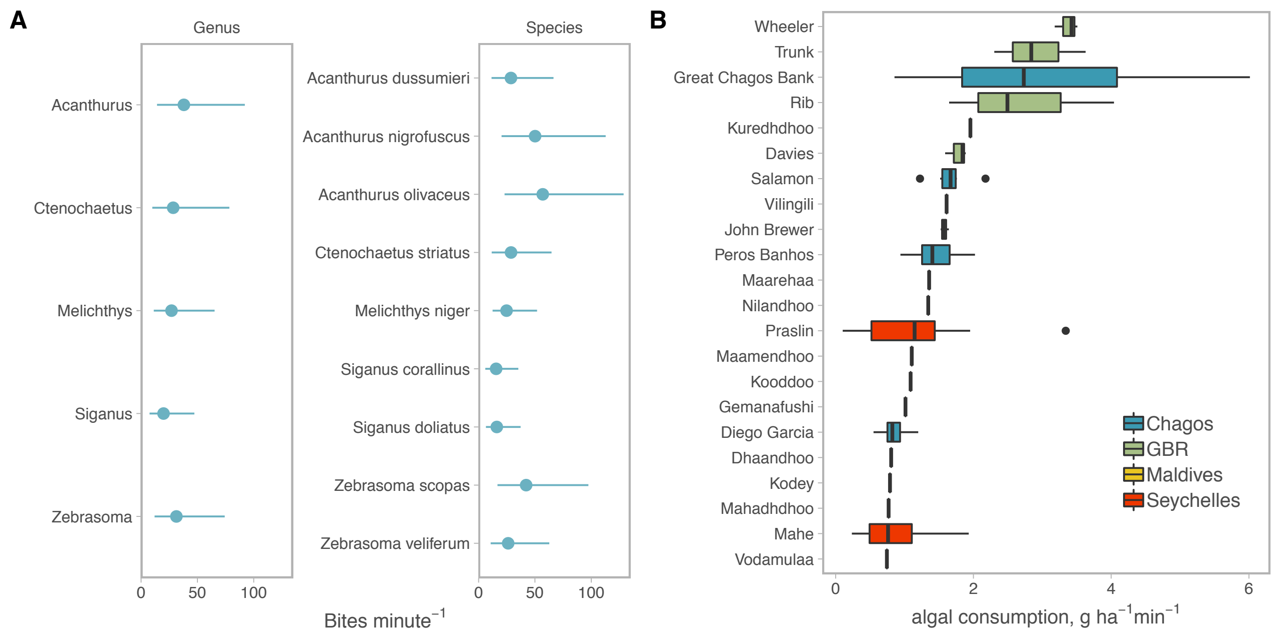

Figure S3 | Cropper bite rate predictions (A) and observed cropper function in UVC (B) Predicted bite rates are median posterior predictions with 95% certainty intervals (A), and boxplots are site-level observed cropping function for each reef, coloured by UVC region.

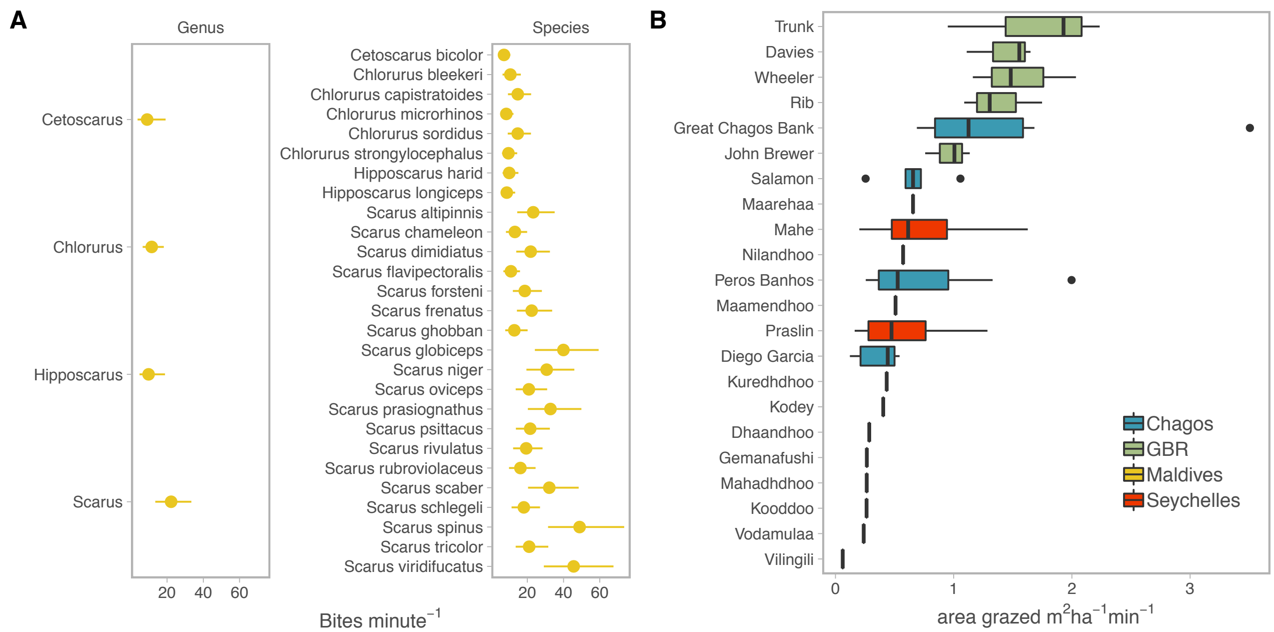

Figure S4 | Scraper bite rate predictions (A) and observed scraping function in UVC (B) Predicted bite rates are median posterior predictions with 95% certainty intervals (A), and boxplots are site-level observed scraping function for each reef, coloured by UVC region.

Croppers	*Acanthurus auranticavus, Acanthurus blochii,* ***Acanthurus dussumieri****, Acanthurus leucocheilus, Acanthurus leucosternon, Acanthurus lineatus, Acanthurus nigricans, Acanthurus nigricauda,* ***Acanthurus nigrofuscus****, Acanthurus nigroris,* ***Acanthurus olivaceus****, Acanthurus tennenti, Acanthurus tennentii, Acanthurus triostegus, Acanthurus tristis, Centropyge bicolor, Centropyge bispinosa, Centropyge vrolikii, Chrysiptera biocellata, Ctenochaetus binotatus,* ***Ctenochaetus striatus****, Ctenochaetus truncatus, Dischistodus melanotus, Dischistodus perspicillatus, Dischistodus prosopotaenia, Dischistodus pseudochrysopoecilus,* ***Melichthys niger****, Plectroglyphidodon lacrymatus, Plectroglyphidodon leucozonus, Plectroglyphidodon phoenixensis, Pomacentrus amboinensis, Pomacentrus bankanensis, Pomacentrus indicus, Pomacentrus nagasakiensis, Pomacentrus trilineatus, Pomacentrus wardi,* ***Siganus corallinus****,* ***Siganus doliatus****, Siganus puelloides, Siganus puellus, Siganus punctatus, Siganus spinus, Siganus stellatus, Siganus vulpinus, Stegastes apicalis, Stegastes fasciolatus, Stegastes lividus, Stegastes nigricans, Zebrasoma desjardinii,* ***Zebrasoma scopas****,* ***Zebrasoma veliferum***
Scrapers	***Cetoscarus bicolor****, Chlorurus atrilunula,* ***Chlorurus bleekeri****,* ***Chlorurus capistratoides****, Chlorurus enneacanthus,* ***Chlorurus microrhinos****,* ***Chlorurus sordidus****, Chlorurus stronglycephalus,* ***Hipposcarus harid****,* ***Hipposcarus longiceps****,* ***Scarus altipinnis****, Scarus capistratoides, Scarus caudofasciatus,* ***Scarus chameleon****,* ***Scarus dimidiatus****, Scarus falcipinnis,* ***Scarus flavipectoralis****,* ***Scarus forsteni****,* ***Scarus frenatus****,* ***Scarus ghobban****,* ***Scarus globiceps****,* ***Scarus niger****,* ***Scarus oviceps****, Scarus prasiognathos,* ***Scarus psittacus****,* ***Scarus rivulatus****,* ***Scarus rubroviolaceus****,* ***Scarus scaber****,* ***Scarus schlegeli****,* ***Scarus spinus****,* ***Scarus tricolor****,* ***Scarus viridifucatus***

Table S1 | Nominal cropping and scraping herbivores surveyed in UVC. Species with feeding observations are indicated in bold.

	Parameter	Prior	Mean	Lower 89%	Upper 89%	Effective samples	$\hat{R}$
Cropping bite rate	X	N(3.43, 10)	3.346	2.655	4.080	357	1.00
	θ	Exp(2)	4.937	4.546	5.239	1500	1.00
	species	$N(0, \sigma_s)$	0.414	0.172	0.622	486	1.00
	genus	$N(0, \sigma_G)$	0.453	0.004	0.839	188	1.03
	region	$N(0, \sigma_d)$	0.372	0.004	0.753	356	1.00
	$\sigma_s, \sigma_G, \sigma_d$	$Cauchy$(0, 1)					
Scraping bite rate	A	N(3.10, 10)	3.161	2.491	3.794	718	1.00
	B	N(0, 5)	-0.028	-0.031	-0.025	3500	1.00
	θ	Exp(1)	1.624	1.512	1.733	2708	1.00
	species	$N(0, \sigma_s)$	0.408	0.302	0.501	1872	1.00
	genus	$N(0, \sigma_G)$	0.650	0.184	1.085	830	1.00
	region	$N(0, \sigma_d)$	0.282	0.049	0.532	737	1.00
	$\sigma_s, \sigma_G, \sigma_d$	$Cauchy$(0, 1)					
Scraping bite area	A	N(4.45, 5)	2.459	2.354	2.568	1182	1.00
	B	N(0, 2)	0.060	0.057	0.062	1052	1.00

Table S2 | Bayesian priors and model convergence indicators for feeding rate models (Eqs 1,2, 4-7). Priors are weakly informative, except for intercept priors which were set at the mean bite rate or bite area (on a log scale). Parameter symbols are defined in Eqs. 4 – 7, and θ is the scale parameter for the Gamma distribution. N(0, 10) is a normal distribution with mean = 0 and standard deviation = 10, $Cauchy$(0, 1) is a Cauchy distribution with location = 0 and scale = 1. Estimates for random effect variances not shown.