

Temporal variation in macroalgal removal: insights from an impacted equatorial coral reef system

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Supplementary Material

Table S1: Total abundances and biomass (kg 300 m⁻²) of nominally herbivorous fish species from Kusu Island, Pulau Satumu and Terumbu Pempang Tengah, a combined total for each species pooled across sites, and then expressed as a percentage of all herbivorous fishes.

Species	Kusu Island		Pulau Satumu		Terumbu Pempang Tengah		Combined		% of combined total	
	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass
<i>Pomacanthus sexstriatus</i>	0	0	4	2.12	4	2.00	8	4.13	0.24	0.60
<i>Scarus ghobban</i>	28	14.82	135	67.02	2	0.73	165	82.57	4.94	11.91
<i>Scarus rivulatus</i>	503	118.76	587	142.06	142	42.30	1232	303.11	36.91	43.71
<i>Siganus canaliculatus</i>	122	18.35	158	20.71	52	9.14	332	48.19	9.95	6.95
<i>Siganus guttatus</i>	29	7.58	49	13.62	2	0.52	80	21.72	2.40	3.13
<i>Siganus javus</i>	131	20.14	131	30.69	115	20.58	377	71.40	11.29	10.30
<i>Siganus punctatus</i>	14	4.24	3	1.28	10	3.47	27	8.99	0.81	1.30
<i>Siganus virgatus</i>	340	46.34	611	81.57	150	21.51	1101	149.42	32.98	21.55
<i>Siganus vulpinus</i>	0	0	10	2.74	6	1.23	16	3.96	0.48	0.57
Total	1167	230.22	1688	361.80	483	101.48	3338	693.50	100	100

Table S2: Mean initial weight (g) of macroalgal assays deployed at Kusu Island, Pulau Satumu, and Terumbu Pempang Tengah.

Month	Kusu Island	Pualu Satumu	Terumbu Pempang Tengah
July	37.70 ± 1.38	37.26 ± 1.27	40.12 ± 0.54
August	43.47 ± 0.74	42.03 ± 0.96	41.88 ± 1.12
September	51.97 ± 1.65	51.04 ± 1.47	52.04 ± 1.88
October	61.86 ± 1.02	62.58 ± 0.69	61.92 ± 1.34
November	67.13 ± 0.93	66.89 ± 0.92	66.44 ± 1.04
December	81.43 ± 0.93	81.19 ± 0.92	81.00 ± 0.95
January	87.53 ± 0.93	87.30 ± 1.05	87.50 ± 0.98
February	71.79 ± 0.89	71.54 ± 1.13	70.32 ± 1.14
March	47.11 ± 0.93	46.90 ± 1.80	48.20 ± 0.58
April	29.65 ± 1.00	28.14 ± 1.38	30.82 ± 0.65
May	28.36 ± 0.97	27.39 ± 1.15	29.92 ± 0.65
June	31.26 ± 0.97	30.29 ± 1.15	32.60 ± 0.65

Table S3: Monthly average ($\pm$ SE) abundances and biomass (kg 300 m⁻²) of herbivorous fishes from Kusu Island, Pulau Satumu and Terumbu Pempang Tengah and a combined monthly average pooled across sites.

	Kusu Island		Pulau Satumu		Terumbu Pempang Tengah		Combined	
Month	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass	Abundance	Biomass
July	17.00 $\pm$ 3.51	4.25 $\pm$ 0.33	44.33 $\pm$ 10.20	9.97 $\pm$ 2.75	7.67 $\pm$ 0.88	2.12 $\pm$ 0.31	23.00 $\pm$ 6.33	5.45 $\pm$ 1.42
August	22.33 $\pm$ 7.31	5.16 $\pm$ 1.54	40.67 $\pm$ 15.07	8.28 $\pm$ 2.94	12.67 $\pm$ 3.18	3.03 $\pm$ 0.87	25.22 $\pm$ 6.41	5.49 $\pm$ 1.25
September	30.00 $\pm$ 2.00	5.94 $\pm$ 0.62	59.67 $\pm$ 5.49	11.81 $\pm$ 1.55	6.67 $\pm$ 2.60	1.26 $\pm$ 0.40	32.11 $\pm$ 7.89	6.33 $\pm$ 1.60
October	25.33 $\pm$ 4.06	5.41 $\pm$ 1.26	41.33 $\pm$ 4.81	9.22 $\pm$ 1.38	22.00 $\pm$ 3.06	4.10 $\pm$ 0.70	29.56 $\pm$ 3.60	6.25 $\pm$ 0.96
November	40.33 $\pm$ 7.88	7.47 $\pm$ 0.64	43.67 $\pm$ 3.33	8.23 $\pm$ 1.06	27.00 $\pm$ 2.52	4.82 $\pm$ 0.85	37.00 $\pm$ 3.62	6.84 $\pm$ 0.67
December	36.33 $\pm$ 7.45	5.72 $\pm$ 1.00	55.00 $\pm$ 9.50	11.14 $\pm$ 1.88	14.33 $\pm$ 4.91	3.17 $\pm$ 1.29	35.22 $\pm$ 6.98	6.68 $\pm$ 1.38
January	41.33 $\pm$ 11.84	7.48 $\pm$ 1.81	56.33 $\pm$ 6.17	12.33 $\pm$ 1.37	16.00 $\pm$ 3.61	3.28 $\pm$ 0.94	37.89 $\pm$ 7.11	7.70 $\pm$ 1.49
February	38.00 $\pm$ 3.51	7.45 $\pm$ 1.10	45.00 $\pm$ 8.08	10.01 $\pm$ 1.26	13.00 $\pm$ 1.53	2.78 $\pm$ 0.13	32.00 $\pm$ 5.50	6.74 $\pm$ 1.16
March	41.33 $\pm$ 4.91	8.25 $\pm$ 1.23	45.33 $\pm$ 7.42	10.86 $\pm$ 1.41	13.67 $\pm$ 2.19	3.22 $\pm$ 0.88	33.44 $\pm$ 5.64	7.44 $\pm$ 1.27
April	43.33 $\pm$ 8.45	8.17 $\pm$ 1.51	51.33 $\pm$ 7.62	12.45 $\pm$ 1.18	6.00 $\pm$ 1.53	1.69 $\pm$ 0.23	33.56 $\pm$ 7.73	7.44 $\pm$ 1.66
May	31.00 $\pm$ 3.51	6.57 $\pm$ 0.76	42.33 $\pm$ 6.06	9.06 $\pm$ 1.67	6.33 $\pm$ 0.33	1.15 $\pm$ 0.12	26.56 $\pm$ 5.69	5.59 $\pm$ 1.28
June	22.67 $\pm$ 5.90	4.86 $\pm$ 1.46	37.67 $\pm$ 4.48	7.25 $\pm$ 1.14	15.67 $\pm$ 0.88	3.20 $\pm$ 0.49	25.33 $\pm$ 3.89	5.11 $\pm$ 0.81
Total	32.42 $\pm$ 4.23	6.40 $\pm$ 0.72	46.89 $\pm$ 4.42	10.05 $\pm$ 1.00	13.42 $\pm$ 2.42	2.82 $\pm$ 0.49	30.91 $\pm$ 1.71	6.42 $\pm$ 0.36

Table S4: Table of results of Analysis of Variance F or chi-square test for fixed effect term (month) in LME and GLMM models, marginal and conditional R^2 values.

Response variable	Model used	F or χ^2	p value	R^2 marginal	R^2 conditional
Herbivorous fish abundance	LME	1.33	0.27	0.0538	0.7882
Herbivorous fish biomass (kg 300 m ⁻²)	LME	1.07	0.42	0.0361	0.7718
Macroalgal removal rate (% 4 h ⁻¹)	LME	48.77	<0.01	0.4248	0.8375
Mass-standardised bite rates (3.5 h ⁻¹)	GLMM	654.33	<0.01	0.8881	0.9997

Table S5: Mean monthly absolute biomass loss ($\text{g } 4 \text{ h}^{-1}$) and biomass removal rate ($\% 4 \text{ h}^{-1}$) of *Si. ilicifolium* assays at Kusu Island, Palau Satumu, and Terumbu Pempang Tengah, and across sites.

	Kusu Island		Pulau Satumu		Terumbu Pempang Tengah		Combined	
Month	Absolute	Percentage	Absolute	Percentage	Absolute	Percentage	Absolute	Percentage
July	3.15 $\pm$ 0.47	8.51 $\pm$ 1.41	7.02 $\pm$ 1.09	18.77 $\pm$ 2.75	1.51 $\pm$ 0.34	3.79 $\pm$ 0.90	3.92 $\pm$ 0.62	10.43 $\pm$ 1.65
August	5.39 $\pm$ 0.96	12.57 $\pm$ 2.26	9.64 $\pm$ 0.99	23.13 $\pm$ 2.44	2.18 $\pm$ 0.47	5.19 $\pm$ 1.17	5.74 $\pm$ 0.76	13.63 $\pm$ 1.83
September	9.03 $\pm$ 1.09	17.47 $\pm$ 2.13	15.15 $\pm$ 1.84	29.58 $\pm$ 3.48	4.71 $\pm$ 0.81	8.90 $\pm$ 1.45	9.61 $\pm$ 1.12	18.60 $\pm$ 2.18
October	10.52 $\pm$ 1.78	16.89 $\pm$ 2.66	24.45 $\pm$ 2.70	39.03 $\pm$ 4.21	5.00 $\pm$ 0.64	8.07 $\pm$ 1.00	13.44 $\pm$ 2.07	21.52 $\pm$ 3.27
November	12.93 $\pm$ 1.57	19.28 $\pm$ 2.34	24.80 $\pm$ 1.38	37.26 $\pm$ 2.31	11.57 $\pm$ 1.19	17.37 $\pm$ 1.71	16.62 $\pm$ 1.43	24.92 $\pm$ 2.17
December	25.38 $\pm$ 1.78	31.19 $\pm$ 2.19	46.93 $\pm$ 2.66	58.07 $\pm$ 3.72	11.99 $\pm$ 1.60	14.71 $\pm$ 1.93	28.10 $\pm$ 3.05	34.66 $\pm$ 3.82
January	23.29 $\pm$ 1.90	26.65 $\pm$ 2.22	42.04 $\pm$ 3.99	48.45 $\pm$ 4.92	15.31 $\pm$ 2.18	17.42 $\pm$ 2.41	26.74 $\pm$ 2.72	30.67 $\pm$ 3.19
February	12.94 $\pm$ 2.29	17.90 $\pm$ 3.00	27.73 $\pm$ 2.49	38.54 $\pm$ 3.17	8.91 $\pm$ 1.47	12.57 $\pm$ 1.99	16.53 $\pm$ 1.98	23.00 $\pm$ 2.68
March	5.31 $\pm$ 0.90	11.16 $\pm$ 1.79	9.13 $\pm$ 1.84	19.02 $\pm$ 3.63	3.04 $\pm$ 0.56	6.23 $\pm$ 1.10	5.41 $\pm$ 0.76	11.28 $\pm$ 1.54
April	1.42 $\pm$ 0.26	4.94 $\pm$ 1.03	3.33 $\pm$ 0.25	11.87 $\pm$ 0.78	0.49 $\pm$ 0.18	1.62 $\pm$ 0.58	1.68 $\pm$ 0.28	5.90 $\pm$ 1.00
May	0.65 $\pm$ 0.16	2.41 $\pm$ 0.63	1.66 $\pm$ 0.31	6.22 $\pm$ 1.11	0.20 $\pm$ 0.08	0.65 $\pm$ 0.27	0.86 $\pm$ 0.17	3.19 $\pm$ 0.63
June	1.30 $\pm$ 0.27	4.18 $\pm$ 0.88	2.94 $\pm$ 0.50	10.01 $\pm$ 1.88	0.55 $\pm$ 0.27	1.72 $\pm$ 0.82	1.64 $\pm$ 0.28	5.44 $\pm$ 1.01
Total	9.38 $\pm$ 0.87	14.53 $\pm$ 1.01	18.18 $\pm$ 1.58	28.62 $\pm$ 1.79	5.46 $\pm$ 0.57	8.20 $\pm$ 0.69	10.97 $\pm$ 0.69	17.05 $\pm$ 0.87

Table S6: Mean monthly total bites and mass-standardised bites taken from *Si. ilicifolium* assays in 3.5 h⁻¹ at Kusu Island, Palau Satumu, and Terumbu Pempang Tengah, and across sites.

	Kusu Island		Pulau Satumu		Terumbu Pempang Tengah		Combined	
Month	Total bites	Mass-standardised bites	Total bites	Mass-standardised bites	Total bites	Mass-standardised bites	Total bites	Mass-standardised bites
July	141.00 ± 12.10	26.22 ± 0.96	285.67 ± 75.06	60.29 ± 17.53	109.33 ± 28.81	17.77 ± 5.32	178.67 ± 35.88	34.76 ± 8.38
August	130.67 ± 43.00	22.59 ± 6.29	284.67 ± 26.77	65.85 ± 3.97	118.00 ± 24.91	18.79 ± 4.66	177.78 ± 31.35	35.74 ± 7.96
September	291.00 ± 16.82	69.61 ± 10.14	469.67 ± 22.88	127.05 ± 4.57	170.33 ± 61.24	33.16 ± 11.70	310.33 ± 47.64	76.61 ± 14.44
October	370.33 ± 42.06	99.59 ± 13.84	605.33 ± 40.83	162.54 ± 7.81	251.33 ± 19.19	68.26 ± 4.58	409.00 ± 54.97	110.13 ± 14.66
November	422.67 ± 42.79	112.99 ± 14.93	562.00 ± 72.15	153.03 ± 20.82	411.50 ± 86.50	110.56 ± 22.56	472.12 ± 41.43	127.40 ± 12.04
December	736.33 ± 55.21	214.31 ± 16.10	1007.33 ± 127.89	296.84 ± 38.63	429.33 ± 98.46	113.58 ± 24.90	724.33 ± 96.92	208.24 ± 29.99
January	721.00 ± 67.26	207.52 ± 18.21	852.00 ± 230.00	255.09 ± 70.33	595.50 ± 101.50	169.31 ± 26.40	722.57 ± 72.27	210.19 ± 22.19
February	407.67 ± 71.52	117.61 ± 20.45	635.00 ± 68.25	190.61 ± 21.29	259.00 ± 32.04	78.81 ± 9.20	433.89 ± 62.36	129.01 ± 18.66
March	173.00 ± 24.64	50.83 ± 8.45	226.33 ± 36.93	78.24 ± 10.84	119.67 ± 28.85	32.57 ± 7.84	173.00 ± 21.69	53.88 ± 8.06
April	38.33 ± 13.22	11.75 ± 3.11	92.33 ± 5.36	31.15 ± 1.64	35.67 ± 25.44	10.38 ± 6.82	55.44 ± 12.49	17.76 ± 4.02
May	13.00 ± 5.03	4.19 ± 1.55	58.00 ± 8.96	21.45 ± 2.93	10.33 ± 7.84	2.99 ± 2.08	27.11 ± 8.59	9.55 ± 3.19
June	48.00 ± 12.10	12.74 ± 3.26	109.00 ± 19.97	23.88 ± 4.92	42.33 ± 20.12	7.11 ± 3.13	66.44 ± 13.89	14.58 ± 3.13
Total	291.0833 ± 41.46	79.16250 ± 12.21	420.2857 ± 52.42	118.37143 ± 15.52	195.5882 ± 30.64	50.29412 ± 8.69	303.23 ± 25.97	82.88 ± 7.66

Table S7: Sum of total and mass-standardised bites taken by nominally herbivorous fish species from Kusu Island, Pulau Satumu and Terumbu Pempang Tengah, a combined total for each species pooled across sites, and then expressed as a percentage of all herbivorous fishes.

Species	Kusu Island		Pulau Satumu		Terumbu Pempang Tengah		Combined		% of Combined Total	
	Total	Mass-standardised bites	Total	Mass-standardised bites	Total	Mass-standardised bites	Total	Mass-standardised bites	Total	Mass-standardised bites
<i>Kyphosus vaigiensis</i>	321	142.82	524	241.42	0	0.00	845	384.24	2.65	4.42
<i>Pomacanthus sexstriatus</i>	0	0.00	0	0.00	2	0.76	2	0.76	0.01	0.01
<i>Scarus ghobban</i>	0	0.00	116	75.74	0	0.00	116	75.74	0.36	0.87
<i>Scarus rivulatus</i>	684	216.46	1199	434.85	531	185.38	2414	836.69	7.58	9.61
<i>Siganus canaliculatus</i>	219	58.93	265	71.63	41	11.15	525	141.72	1.65	1.63
<i>Siganus corallinus</i>	6	1.53	2	0.51	33	9.67	41	11.71	0.13	0.13
<i>Siganus javus</i>	452	91.11	298	58.09	743	140.05	1493	289.25	4.69	3.32
<i>Siganus punctatus</i>	0	0.00	0	0.00	13	3.22	13	3.22	0.04	0.04
<i>Siganus virgatus</i>	8797	2339.00	12306	3260.78	5287	1359.78	26390	6959.56	82.89	79.97
Total	10479	2849.85	14710	4143.02	6650	1710.02	31839	8702.89	100	100