

Rhodolith structural loss decreases abundance, diversity, and stability of benthic communities at Santa Catalina Island, CA

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Table S1. Three-factor PERMANOVA results on the effect of habitat, site, and time on sediment composition using four sediment size classes (>4.75 mm, 4.75 - 2 mm, 2 - 0.05 mm, <0.05 mm). For each test, habitat and sampling time were considered fixed factors, and site was considered a random factor. All inferences were based on 9999 permutations except for the habitat and sampling time factors, which were evaluated using Monte Carlo tests due to a limited numbers of possible permutable units. Significant ($p < 0.05$) values are in bold type.

Source	df	SS	MS	Pseudo-F	P
Habitat	1	2254.9	2254.90	15.246	0.016
Site	2	375.0	187.51	15.967	0.0001
Time	1	174.3	174.29	1.002	0.447
Time x Habitat	1	296.9	148.44	12.640	0.0001
Time x Site	2	139.2	139.24	1.531	0.298
Habitat x Site	2	349.1	174.54	14.863	0.0001
Habitat x Site x Time	2	182.5	91.262	7.771	0.0001
Residual	77	904.3	11.74		
Total	88	4710.8			

Table S2. Three-way mixed model ANOVA results on the effect of habitat, site, and sampling time on (A) total and (B-E) functional group taxon richness. For each test, habitat and sampling time were considered fixed factors, and site was considered a random factor. Significant ($p < 0.05$) values are in bold type.

A Total						
	Source	df	SS	MS	F	P
	Habitat	1	875.5	875.5	82.594	0.012
	Site	2	173.4	86.7	12.909	< 0.001
	Time	1	105	105	15.639	0.068
	Time x Habitat	1	6	6	0.897	0.350
	Time x Site	2	15.8	7.9	1.176	0.320
	Habitat x Site	2	21.3	10.6	1.585	0.219
	Habitat x Site x Time	2	47.5	23.8	3.540	0.039
	Residual	36	241.7	6.7		
	Total	47	1486.2			
B Macroalgae						
	Source	df	SS	MS	F	P
	Habitat	1	10.08	10.08	6.101	0.279
	Site	2	23.29	11.65	7.046	0.003
	Time	1	6.75	6.75	4.084	0.463
	Time x Habitat	1	1.33	1.33	0.807	0.375
	Time x Site	2	16.62	8.31	5.029	0.012
	Habitat x Site	2	9.29	4.65	2.811	0.073
	Habitat x Site x Time	2	10.79	5.40	3.265	0.050
	Residual	36	59.5	1.65		
	Total	47	137.65			
C Infaunal invertebrates						
	Source	df	SS	MS	F	P
	Habitat	1	4.301	4.301	860.200	0.001
	Site	2	0.182	0.091	1.787	0.182
	Time	1	0.005	0.005	0.106	0.745
	Time x Habitat	1	0.036	0.036	0.717	0.403
	Time x Site	2	0.072	0.036	0.704	0.501
	Habitat x Site	2	0.01	0.005	0.098	0.906
	Habitat x Site x Time	2	0.143	0.072	1.409	0.258
	Residual	36	1.831	0.051		
	Total	47	6.58			
D Epibenthic invertebrates						
	Source	df	SS	MS	F	P
	Habitat	1	54.19	54.19	34.680	0.028
	Site	2	2.79	1.4	0.893	0.418
	Time	1	105.02	105.02	67.213	0.005
	Time x Habitat	1	4.69	4.69	3.000	0.092
	Time x Site	2	1.04	0.52	0.333	0.719
	Habitat x Site	2	3.12	1.56	1.000	0.378
	Habitat x Site x Time	2	15.88	7.94	5.080	0.011
	Residual	36	56.25	1.56		
	Total	47	242.98			
E Fishes						
	Source	df	SS	MS	F	P
	Habitat	1	7.52	7.521	8.267	0.141
	Site	2	18.17	9.083	9.985	< 0.001
	Time	1	4.69	4.688	5.153	0.499
	Time x Habitat	1	4.69	4.687	5.153	0.029
	Time x Site	2	14	7	7.695	0.002
	Habitat x Site	2	2.67	1.333	1.466	0.244
	Habitat x Site x Time	2	0.5	0.25	0.275	0.761
	Residual	36	32.75	0.91		
	Total	47	84.99			

Table S3. Two-way mixed model ANOVA results on the effect of habitat and site on total and functional group taxon richness during the April 2013 and December 2013 sampling times. Taxon richness is divided into total richness (A) and functional group richness (B-E) for the April 2013 and December 2013 sampling times. For each test, habitat was considered a fixed factor and site was considered a random factor. Significant ($p < 0.05$) values are in bold type.

April 2013							December 2013					
A	Total						Total					
	Source	df	SS	MS	F	P	Source	df	SS	MS	F	P
	Habitat	1	368.2	368.2	13.894	0.065	Habitat	1	513.4	513.4	64.987	0.015
	Site	2	94.1	47	4.923	0.020	Site	2	95.1	47.5	12.269	< 0.001
	Habitat x Site	2	53.1	26.5	2.778	0.089	Habitat x Site	2	15.7	7.9	2.032	0.160
	Residual	18	172	9.6			Residual	18	69.8	3.9		
	Total	23	687.4				Total	23	694			
B	Macroalgae						Macroalgae					
	Source	df	SS	MS	F	P	Source	df	SS	MS	F	P
	Habitat	1	2.04	2.042	0.368	0.606	Habitat	1	9.375	9.375	2.083	0.286
	Site	2	31.58	15.792	8.299	0.003	Site	2	8.333	4.167	2.97	0.077
	Habitat x Site	2	11.08	5.542	2.912	0.080	Habitat x Site	2	9	4.5	3.208	0.064
	Residual	18	34.25	1.903			Residual	18	25.25	1.403		
	Total	23	78.95				Total	23	51.958			
C	Infaunal invertebrates						Infaunal invertebrates					
	Source	df	SS	MS	F	P	Source	df	SS	MS	F	P
	Habitat	1	1.7729	1.7729	37.721	0.026	Habitat	1	2.565	2.565	86.364	0.011
	Site	2	0.224	0.112	2.029	0.160	Site	2	0.0295	0.0147	0.317	0.733
	Habitat x Site	2	0.094	0.047	0.851	0.443	Habitat x Site	2	0.0594	0.0297	0.638	0.540
	Residual	18	0.9936	0.0552			Residual	18	0.8376	0.0465		
	Total	23	3.0845				Total	23	3.4915			
D	Epibenthic invertebrates						Epibenthic invertebrates					
	Source	df	SS	MS	F	P	Source	df	SS	MS	F	P
	Habitat	1	45.37	45.37	28.006	0.034	Habitat	1	13.5	13.5	1.714	0.321
	Site	2	3.58	1.79	0.675	0.521	Site	2	0.25	0.125	0.265	0.770
	Habitat x Site	2	3.25	1.62	0.613	0.553	Habitat x Site	2	15.75	7.875	16.676	< 0.001
	Residual	18	47.75	2.65			Residual	18	69.8	3.9		
	Total	23	99.95				Total	23	99.3			
E	Fishes						Fishes					
	Source	df	SS	MS	F	P	Source	df	SS	MS	F	P
	Habitat	1	0.167	0.1667	0.571	0.529	Habitat	1	12.042	12.042	9.320	0.093
	Site	2	1.583	0.7917	0.679	0.520	Site	2	30.583	15.292	23.426	< 0.001
	Habitat x Site	2	0.583	0.2917	0.25	0.781	Habitat x Site	2	2.583	1.292	1.979	0.167
	Residual	18	21	1.1667			Residual	18	11.75	0.653		
	Total	23	23.333				Total	23	56.958			

Table S4. Two-factor PERMANOVA results on the effect of habitat and site on differences in the assemblages of (A) Macroalgae, (B) Infaunal invertebrates, (C) Epibenthic invertebrates, and (D) Fishes during the April 2013 and December 2013 sampling times. For each test, habitat was considered a fixed factor and site a random factor. All inferences were based on 9999 permutations except for the habitat factor, which was evaluated using Monte Carlo tests due to a limited numbers of possible permutable units. Significant ($p < 0.05$) values are in bold type.

April 2013						December 2013					
A Macroalgae						Macroalgae					
Source	df	SS	MS	Pseudo-F	P	Source	df	SS	MS	Pseudo-F	P
Habitat	1	2387.1	2387.1	0.71343	0.592	Habitat	1	15013	15013	9.9117	0.026
Site	2	15542	7771	5.9148	0.0001	Site	2	4464.4	2232.2	2.0391	0.098
Habitat x Site	2	6692	3346	2.5468	0.033	Habitat x Site	2	3029.3	1514.7	1.3836	0.266
Residual	18	23649	1313.8			Residual	18	19705	1094.7		
Total	23	48270				Total	23	42212			
B Infaunal invertebrates						Infaunal invertebrates					
Source	df	SS	MS	Pseudo-F	P	Source	df	SS	MS	Pseudo-F	P
Habitat	1	7382.5	7382.5	6.9963	0.011	Habitat	1	8852.4	8852.4	9.0906	0.015
Site	2	2259.7	1129.9	1.7101	0.070	Site	2	1536.8	768.38	2.4902	0.007
Habitat x Site	2	2110.4	1055.2	1.5971	0.123	Habitat x Site	2	1947.6	973.8	3.156	0.004
Residual	18	11892	660.68			Residual	18	5554	308.56		
Total	23	23645				Total	23	17891			
C Epibenthic invertebrates						Epibenthic invertebrates					
Source	df	SS	MS	Pseudo-F	P	Source	df	SS	MS	Pseudo-F	P
Habitat	1	6716.5	6716.5	2.7063	0.105	Habitat	1	16194	16194	8.2651	0.020
Site	2	4896.2	2448.1	2.4578	0.013	Site	2	4824.1	2412.1	4.8967	0.001
Habitat x Site	2	4963.7	2481.8	2.4917	0.023	Habitat x Site	2	3918.7	1959.3	3.9777	0.002
Residual	18	17929	996.05			Residual	18	8866.6	492.59		
Total	23	34505				Total	23	33803			
D Fishes						Fishes					
Source	df	SS	MS	Pseudo-F	P	Source	df	SS	MS	Pseudo-F	P
Habitat	1	2854.6	2854.6	1.4973	0.301	Habitat	1	447.43	447.43	0.57441	0.631
Site	2	17950	8975.2	17.539	0.0001	Site	2	20267	10134	11.736	0.0001
Habitat x Site	2	3813.1	1906.6	3.7257	0.002	Habitat x Site	2	1557.9	778.93	0.90213	0.487
Residual	18	9211.2	511.73			Residual	18	15542	863.44		
Total	23	33829				Total	23	37815			

Table S5. Results from pair-wise tests from two-factor PERMANOVAs testing the effect of habitat on assemblages of (A) Macroalgae, (B) Infaunal invertebrates, (C) Epibenthic invertebrates, and (D) Fishes, during each sampling time at each site. Due to limited numbers of possible permutable units, inferences were evaluated using Monte Carlo tests. Significant ($p < 0.05$) values are in bold type.

A	Macroalgae	April 2013	December 2013
	Site	p	p
	Cherry	0.044	0.053
	Isthmus	0.531	0.002
	Avalon	0.128	0.057

B	Infaunal invertebrates		
	Site	p	p
	Cherry	0.003	0.004
	Isthmus	0.027	0.001
	Avalon	0.071	0.008

C	Epibenthic invertebrates		
	Site	p	p
	Cherry	0.017	0.005
	Isthmus	0.115	0.000
	Avalon	0.022	0.002

D	Fishes		
	Site	p	p
	Cherry	0.086	0.695
	Isthmus	0.015	0.453
	Avalon	0.116	0.177

Figure S1. Total taxon richness by habitat (n=4 transects, mean \pm SE) during each sampling time at each site. Significant richness differences from t-tests between rhodolith and crushed rhodolith sand are given above bars. Significance denoted as ***p < 0.001; **p < 0.01; *p < 0.05; and blank p > 0.05.

