

The following supplement accompanies the article

El Niño induced changes to the Bolivar Channel ecosystem (Galapagos): comparing model simulations with historical biomass time series

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Marine Ecology Progress Series 488:7–22 (2012)

Supplement. Additional information used for the construction of the Bolivar Channel ecosystem model. A reference model was modified to an El Niño 1997/98 state model to understand the mechanisms behind the decrease in primary production and increase of water temperature (>7 °C) within this system

Table S1. Input-output parameters of the reference state model (Ruiz & Wolff 2011) and of the El Niño (EN) 1997/98 model of the Bolivar Channel ecosystem. Biomass values in bold correspond to groups that increased in biomass during EN 1997/98

Functional groups / parameter	Trophic level	Trophic level (EN)	B_i (t/km ²)	B_i (t/km ²) (EN)	P_i/B_i (year ⁻¹)	P_i/B_i (year ⁻¹) (EN)	Q_i/B_i (year ⁻¹)	Q_i/B_i (year ⁻¹) (EN)	EE_i	EE_i (EN)	GE_i	GE_i (EN)	Catch (year ⁻¹)	Catch (year ⁻¹) (EN)	F_i	F_i (EN)	$M0_i$	$M0_i$ (EN)	$M2_i$	$M2_i$ (EN)
Phytoplankton	1.00	1.00	31.161	19.822	146.274	144.865	-	-	0.586	0.530	-	-	-	-	-	-	62.122	68.077	84.152	76.788
Macroalgae and others	1.00	1.00	800.475	78.754	15.670	15.511	-	-	0.118	0.932	-	-	-	-	-	-	13.841	1.048	1.829	14.463
Surgeonfishes, chubs and giant damselfish	2.00	2.00	25.172	14.293	0.999	1.367	15.914	15.999	0.684	0.848	0.063	0.085	-	-	-	-	0.325	0.208	0.674	1.159
Sea cucumbers and other	2.00	2.00	11.975	29.131	0.123	0.123	3.382	3.341	0.752	0.523	0.036	0.037	0.432	1.071	0.036	0.299	0.031	0.059	0.055	0.028
Herbivorous zooplankton	2.00	2.00	14.440	8.078	36.335	36.208	147.529	146.786	0.884	0.932	0.246	0.247	-	-	-	-	4.395	2.476	31.940	33.732
Sea turtles and marine iguanas	2.01	2.01	2.109	1.320	0.139	0.141	9.943	10.045	0.210	0.723	0.014	0.014	-	-	-	-	0.110	0.039	0.029	0.102
Small herbivorous gastropods	2.01	2.01	23.992	14.902	2.686	2.703	14.164	14.158	0.761	0.932	0.190	0.191	-	-	-	-	0.672	0.183	2.014	2.520
Sponges and polychaetes	2.01	2.01	37.427	29.312	2.443	2.433	16.450	16.231	0.809	0.538	0.149	0.150	-	-	-	-	0.481	1.123	1.962	1.310

Gorgonians	2.07	2.07	29.209	17.076	2.395	2.402	14.926	14.958	0.643	0.933	0.160	0.161	-	-	-	-	0.914	0.161	1.481	2.241
Parrotfish	2.11	2.11	5.455	4.137	0.499	0.501	16.583	16.378	0.468	0.838	0.030	0.031	-	-	-	-	0.269	0.081	0.230	0.420
Mulletts	2.11	2.11	22.682	7.960	2.869	2.966	10.942	10.954	0.850	0.842	0.262	0.271	18.900	1.448	0.833	0.061	0.458	0.469	1.578	2.315
Benthic omnivorous fish	2.14	2.14	19.795	18.003	2.600	2.681	9.868	9.793	0.678	0.834	0.263	0.274	-	-	-	-	0.856	0.444	1.744	2.237
Anemones and zoanthids	2.14	2.14	37.441	35.108	2.677	2.665	9.881	9.979	0.876	0.934	0.271	0.267	-	-	-	-	0.340	0.177	2.337	2.488
Sea stars and sea urchins	2.28	2.17	81.744	95.094	2.238	2.272	7.851	7.795	0.832	0.864	0.285	0.291	-	-	-	-	0.393	0.309	1.845	1.963
Planktivorous reef fish	2.34	2.34	10.126	8.580	1.522	1.548	15.045	14.993	0.811	0.813	0.101	0.103	-	-	-	-	0.302	0.290	1.220	1.258
Small planktivorous reef fish	2.47	2.46	18.959	7.461	4.661	4.751	17.627	17.663	0.905	0.865	0.264	0.269	25.650	10.225	1.353	0.288	0.469	0.641	2.838	2.739
Lobsters	2.64	2.57	14.487	19.557	0.687	0.693	11.947	11.994	0.885	0.933	0.058	0.058	2.730	5.555	0.188	0.410	0.080	0.047	0.418	0.362
Predatory zooplankton	2.80	2.80	3.481	2.032	31.501	31.487	99.132	98.990	0.892	0.935	0.318	0.318	-	-	-	-	3.549	2.041	27.952	29.446
Big gastropods and other sea stars	2.92	2.88	5.796	2.909	2.811	2.764	9.732	9.819	0.584	0.664	0.289	0.281	-	-	-	-	1.157	0.929	1.654	1.835
Small predatory gastropods	2.96	2.88	17.564	10.321	0.919	0.921	4.006	4.009	0.865	0.933	0.229	0.230	-	-	-	-	0.130	0.062	0.789	0.859
Small benthic predatory fish	3.19	3.16	8.027	6.326	1.206	1.261	5.867	5.745	0.751	0.895	0.206	0.219	-	-	-	-	0.309	0.088	0.897	0.386
Benthic predatory fish	3.36	3.22	19.463	25.158	0.763	0.891	3.857	3.626	0.837	0.955	0.198	0.246	4.500	4.700	0.231	0.210	0.132	0.040	0.400	0.664
Barracudas	3.37	3.49	13.058	14.015	0.611	0.636	3.931	3.613	0.825	0.866	0.155	0.176	-	-	-	-	0.109	0.085	0.502	0.551
Groupers	3.39	3.32	5.197	5.547	0.450	0.459	4.448	4.328	0.736	0.890	0.101	0.106	0.702	0.700	0.135	0.275	0.121	0.051	0.194	0.282
Jacks and mackerels	3.40	3.47	3.902	1.044	0.422	0.421	2.231	2.235	0.805	0.541	0.189	0.188	0.491	0.180	0.126	0.410	0.085	0.193	0.211	0.055
Rays	3.43	3.93	9.570	11.650	0.249	0.253	3.470	3.448	0.807	0.775	0.072	0.073	0.712	0.072	0.074	0.024	0.051	0.057	0.124	0.190
Predatory marine mammals	3.49	3.40	0.979	0.501	0.081	0.082	26.129	25.542	0.776	0.936	0.003	0.003	-	-	-	-	0.019	0.005	0.062	0.077
Seabirds	3.50	3.63	0.050	0.012	5.423	5.364	60.301	60.078	0.000	0.000	0.090	0.089	-	-	-	-	5.423	5.364	0.000	0.000
Sharks	3.89	3.75	2.538	4.201	0.243	0.241	4.816	4.579	0.723	0.671	0.050	0.053	0.187	0.040	0.074	0.040	0.069	0.079	0.101	0.152
Detritus	1.00	1.00	500.000	500.000	-	-	-	-	0.166	0.545	-	-	-	-	-	-	-	-	-	-

B biomass, P_i/B_i production rate, Q_i/B_i consumption rate, EE_i ecotrophic efficiency, GE_i conversion efficiency, F_i fishing mortality, $M0_i$ non-predatory natural mortality, $M2_i$ predation mortality

Table S2. Diet matrix of El Niño 1997/98 steady-state model of the Bolivar Channel ecosystem. Values in parentheses represent the percentages of change in relation to values of the reference steady-state model. The diet matrix was constructed based on general knowledge from the literature, using FishBase (Froese & Pauly 2011) for fish groups and other published models (Opitz 1986, Taylor et al. 2007, 2008, Ruiz & Wolff 2011) for seabirds, marine mammals and invertebrate groups.

Prey/Predator	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
1. Phytoplankton				0.799 (-0.3 %)		0.049		0.637 (-0.5 %)	0.296 (-0.3 %)	0.050		0.496 (-0.6 %)	0.549 (-0.4 %)	0.600 (-0.8 %)		0.152												
2. Macroalgae + others		0.950 (+0.1 %)	0.050	0.939	0.939 (-0.1 %)			0.849		0.701 (-0.3 %)		0.566 (-0.2 %)			0.2 (-48.5 %)		0.151											
3. Surgeonfishes, chubs and giant damselfishes																			0.148 (-1.4 %)	0.025	0.052 (+1.9 %)	0.080			0.190 (+52.1 %)	0.100 (-1.0 %)		
4. Sea cucumbers and other																								0.02				
5. Herbivorous zooplankton				0.010	0.010	0.005	0.050		0.089 (-1.1 %)	0.049	0.050		0.251 (+0.4 %)	0.203 (+2.0 %)		0.796 (-0.1 %)		0.005	0.050									
6. Sea turtles and marine iguanas																											0.007 (+28.6 %)	
7. Small herbivorous gastropods																				0.200 (-0.5 %)	0.301 (+1.0 %)		0.202 (+0.5 %)		0.040			
8. Sponges and polychaetes													0.015 (-553.3 %)			0.100 (+100.0 %)				0.070 (-114.3 %)	0.010 (+100.0 %)							
9. Gorgonians								0.100				0.029 (+3.4 %)					0.163 (+0.6 %)	0.100 (-1.0 %)						0.050 (+100.0 %)				
10. Parrotfish																						0.010 (+100.0 %)			0.030 (-63.3 %)	0.044 (+100.0 %)		
11. Mullets																				0.150 (-132.0 %)	0.072 (-2.8 %)	0.061	0.069 (-278.7 %)	0.200		0.060 (-66.7 %)	0.060 (+18.3 %)	0.020
12. Benthic omnivorous fish																				0.197 (-1.5 %)	0.055 (+27.3 %)	0.250 (+20.0 %)	0.203 (+1.5 %)		0.185 (+100.0 %)	0.361 (+41.9 %)	0.202 (+100.0 %)	0.279 (+46.2 %)
13. Anemones and zoanths												0.098 (+1.0 %)						0.020	0.342 (-0.3 %)									
14. Sea stars and sea urchins															0.401 (-25.4 %)		0.100		0.355 (+57.9 %)	0.492 (+20.7 %)		0.260 (+73.1 %)		0.640 (+5.5 %)		0.002 (+100.1 %)		
15. Planktivorous reef fish																					0.147 (-0.7 %)	0.040	0.152 (+100.0 %)	0.149 (-0.7 %)	0.050	0.050 (+100.0 %)	0.005 (+100.0 %)	
16. Small planktivorous reef fish																				0.050	0.030 (-270.0 %)	0.252 (-98.4 %)	0.089 (-1.1 %)	0.442 (-222.6 %)	0.001	0.442 (-103.8 %)	0.004 (-3675.0 %)	
17. Lobsters																					0.049		0.020	0.050	0.010			
18. Predatory zooplankton						0.005	0.010		0.010	0.050	0.050		0.050	0.146														
19. Big gastropods and other sea stars													0.005 (-100.0 %)												0.040 (-100.0 %)	0.002 (-900.0 %)		
20. Small predatory gastropods																		0.197 (+0.5 %)		0.025		0.040						
21. Small benthic predatory fish																					0.005 (-900.0 %)	0.020	0.030 (-166.7 %)	0.070 (+100.0 %)		0.001 (-1900.0 %)	0.004 (-25.0 %)	
22. Benthic predatory fish																						0.208 (+90.4 %)	0.059	0.145 (+100.0 %)	0.074 (-54.1 %)		0.181 (-11.6 %)	
23. Barracudas																					0.025		0.02			0.04	0.246 (+79.7 %)	0.222 (-12.7 %)
24. Groupers																					0.010					0.030 (+66.7 %)	0.014 (+100.0 %)	
25. Jacks and mackerels																										0.003 (-400.0 %)		
26. Rays																										0.115 (+15.7 %)		
27. Predatory marine mammals																										0.002 (-150.0 %)		
28. Seabirds																												
29. Sharks																										0.05 (+80.0 %)		
30. Detritus	0.050 (-2.0 %)	1.00	0.151 (+1.3 %)	0.051	0.051 (+2.0 %)	0.941	0.303 (+0.1 %)	0.051	0.605 (+0.3 %)	0.150 (+1.3 %)	0.404 (+0.3 %)	0.287 (+30.3 %)	0.150 (+0.7 %)	0.051 (+0.2 %)	0.299 (+33.1 %)	0.052 (+1.9 %)	0.169 (-0.6 %)				0.177 (+44.6 %)				0.250 (+2.0 %)			
SUM	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

LITERATURE CITED

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