PNAS
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Supplementary Information for

Isotopes from fossil coronulid barnacle shells record evidence of migration in multiple Pleistocene whale populations

Larry Taylor, Department of Integrative Biology, University of California, Berkeley.

Aaron O'Dea, Smithsonian Tropical Research Institute.

Timothy Bralower, Department of Geosciences, Pennsylvania State University.

Seth Finnegan, Department of Integrative Biology, University of California, Berkeley.

Corresponding author: Larry Taylor
Email: larry.taylor@berkeley.edu

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www.pnas.org/cgi/doi/10.1073/pnas.1808759116

Fig. S1. Three views of Coronula diadema fossil UCMP 221030. The cavity seen in (a) and (b) would hold the body of the animal in life, and would be covered by a membranous sheath. The multiple chambers seen in (c) anchor the shell to the host by enclosing a prongs of whale skin which extend from the shell's base to its apex.

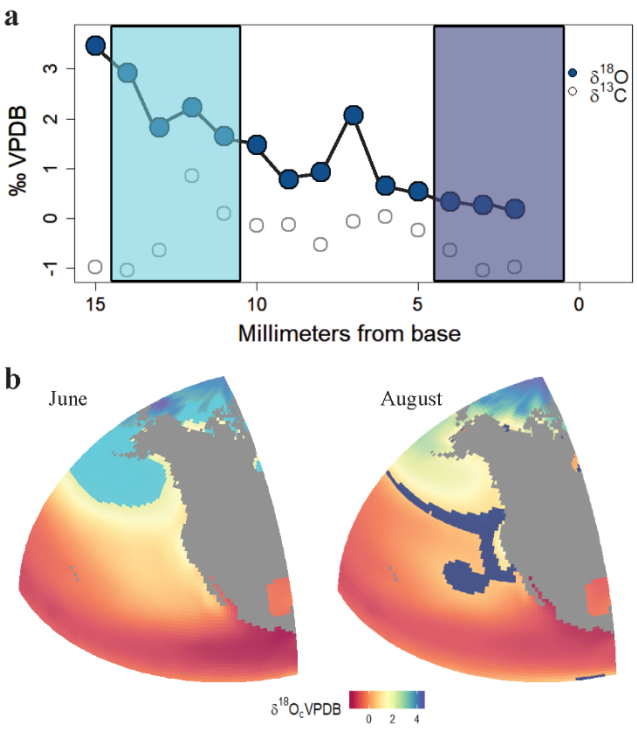

Fig. S2. δ18O profile of CAS MAM 21149, a Cryptolepas rhachianecti collected from a gray whale that washed ashore in late August in northern California. Colored regions of the δ18O profile (a) correspond with the colored regions of plausability for the whale's location (b) during the feeding season and the final weeks before its discovery. The δ18O profile is consistent with the whale having traveled south from the Bering Sea, where many gray whales feed in the summer.

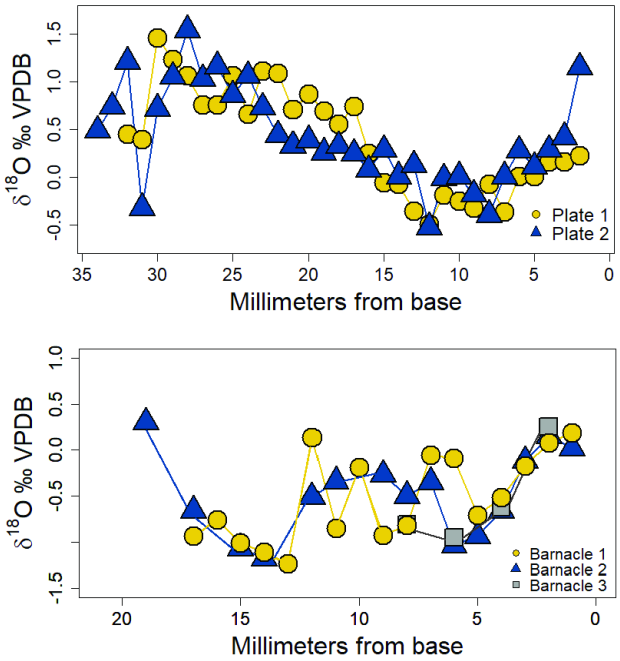

Fig S3. δ18O profiles of two separate plates of UCMP 221031, a modern Coronula diadema (a). δ18O profiles from UCMP 221032, 221033, and 221034, three modern Coronula collected from a single humpback whale (b). In (b) two barnacles were much larger than the other, and thus older. All three profiles were aligned such that each shell was taken to have ceased growing at the same time.

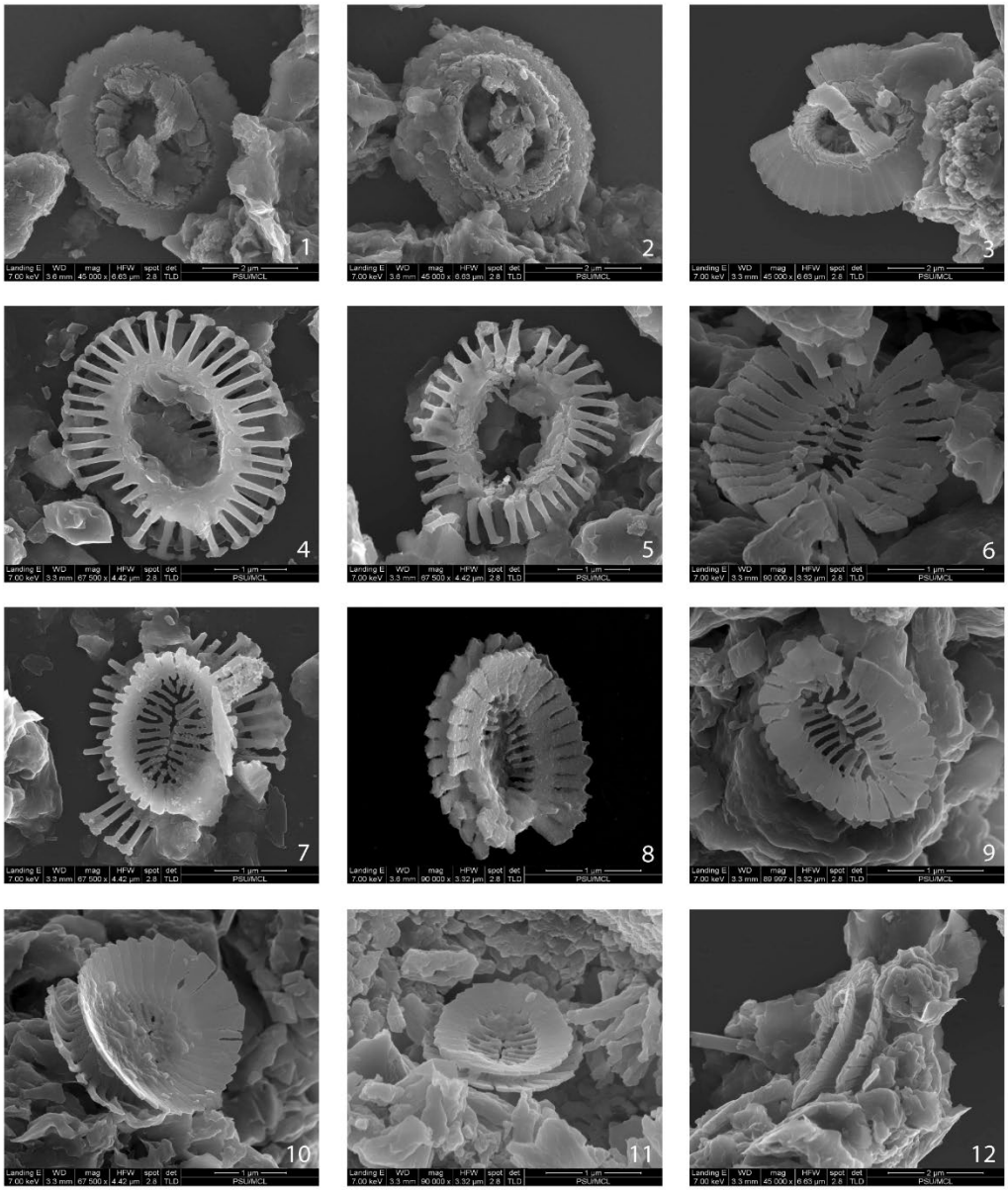

Fig. S4. Scanning electron micrographs of nannoplankton from Burica Peninsula sediments. The presence of Emiliania huxleyi indicates these sediments are of Pleistocene age, and younger than ~270 kyr. Previously these sediments were reported as being of Pliocene age. 1: Gephyrocapsa sp. distal view, Sample 12-5. 2: Gephyrocapsa sp., proximal view, Sample 12-5. 3: Gephyrocapsa sp., distal view, Sample 167. 4-6, 7, 9, 10-12: Emiliania huxleyi, Sample 167; 4, 5: distal view; 6, 7, 9: proximal view; 10-12: side view. 8. Emiliania huxleyi, proximal view, sample 12-5. Scale bars for 1-3, 12 are 2 µm, remainder of plates scale bars are 1 µm. Emiliania huxleyi shows considerable variation in degree of preservation.

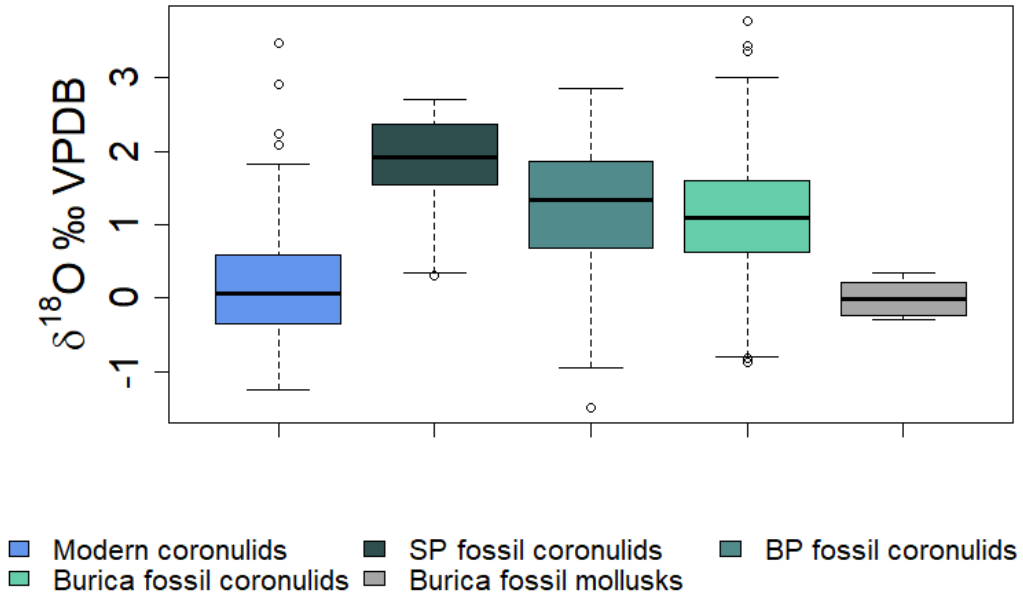

Fig. S5. Summary of δ18O ranges recovered from modern coronulids, San Pedro fossil coronulids, Bay Point fossil coronulids, Burica fossil coronulids, and fossil mollusks collected from the same beds as the Burica coronulids, adjacent to UCMP 221028.

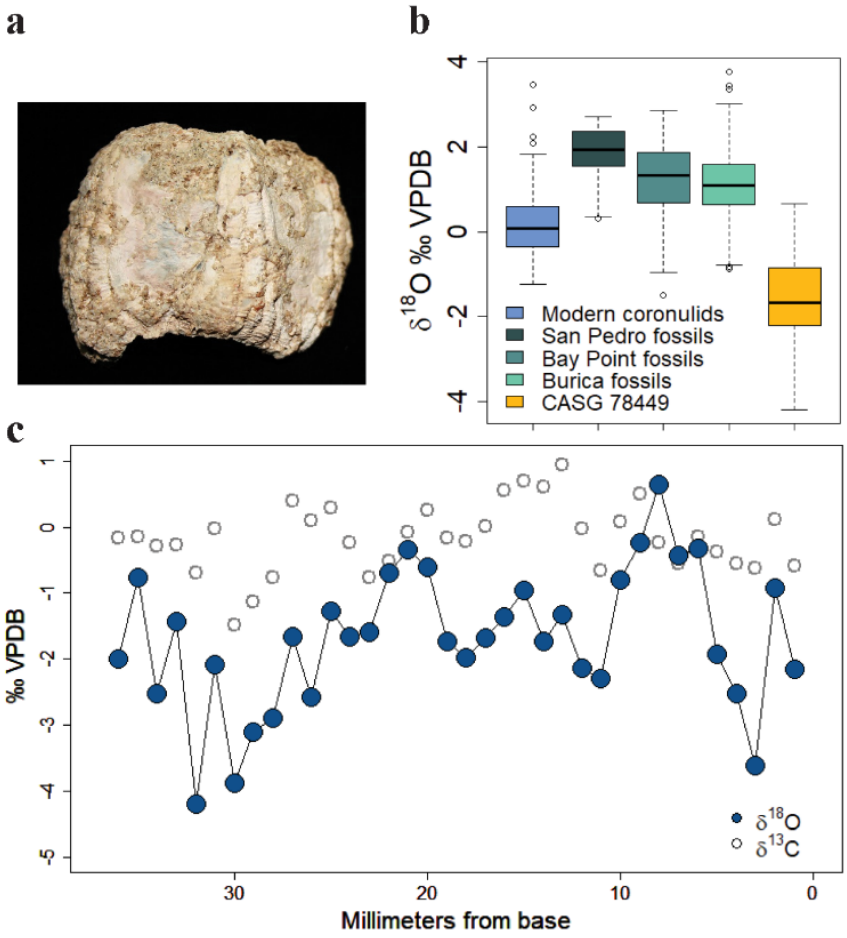

Fig. S6. CASG 78449 (a). The specimen displayed texture and color abnormalities indicative of alteration. The δ18O profile yields values that are substantially depleted compared to all other modern and fossil specimens analyzed (b). δ18O and δ13C profile recovered from CASG 78449 (c).

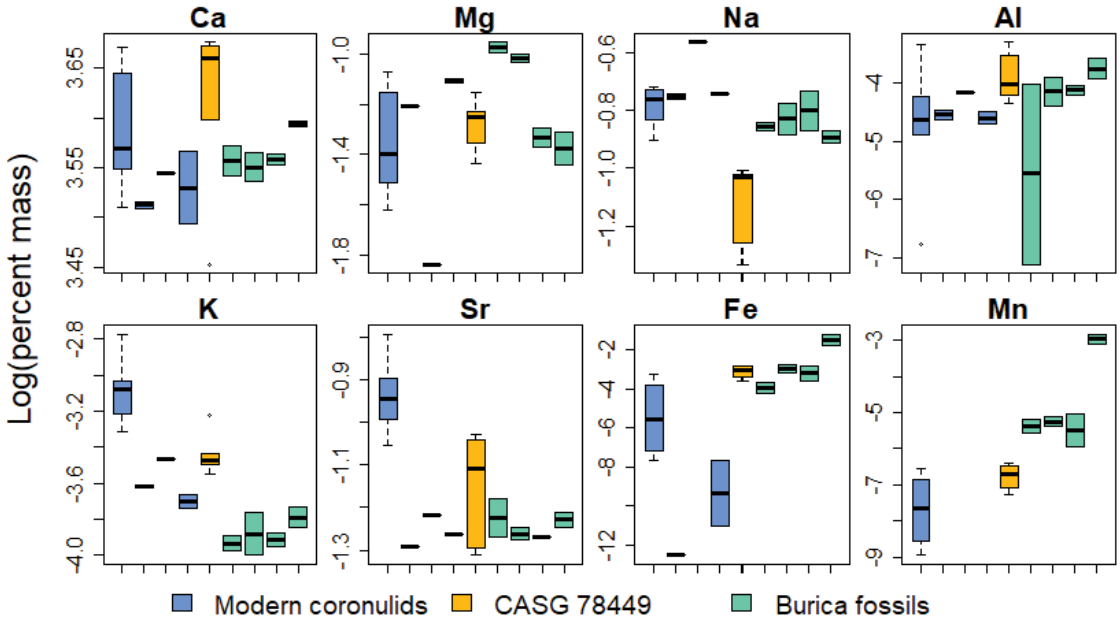

Fig. S7. Element concentrations from four modern coronulids, fossil CASG 78449, and the four Burica fossils, as revealed by ICP-OES. Modern specimens are (in order) UCMP 221031, 221032, 221033, and 221034. Burica fossils are (in order) UCMP 221029, 221022, 221028, and 220130.

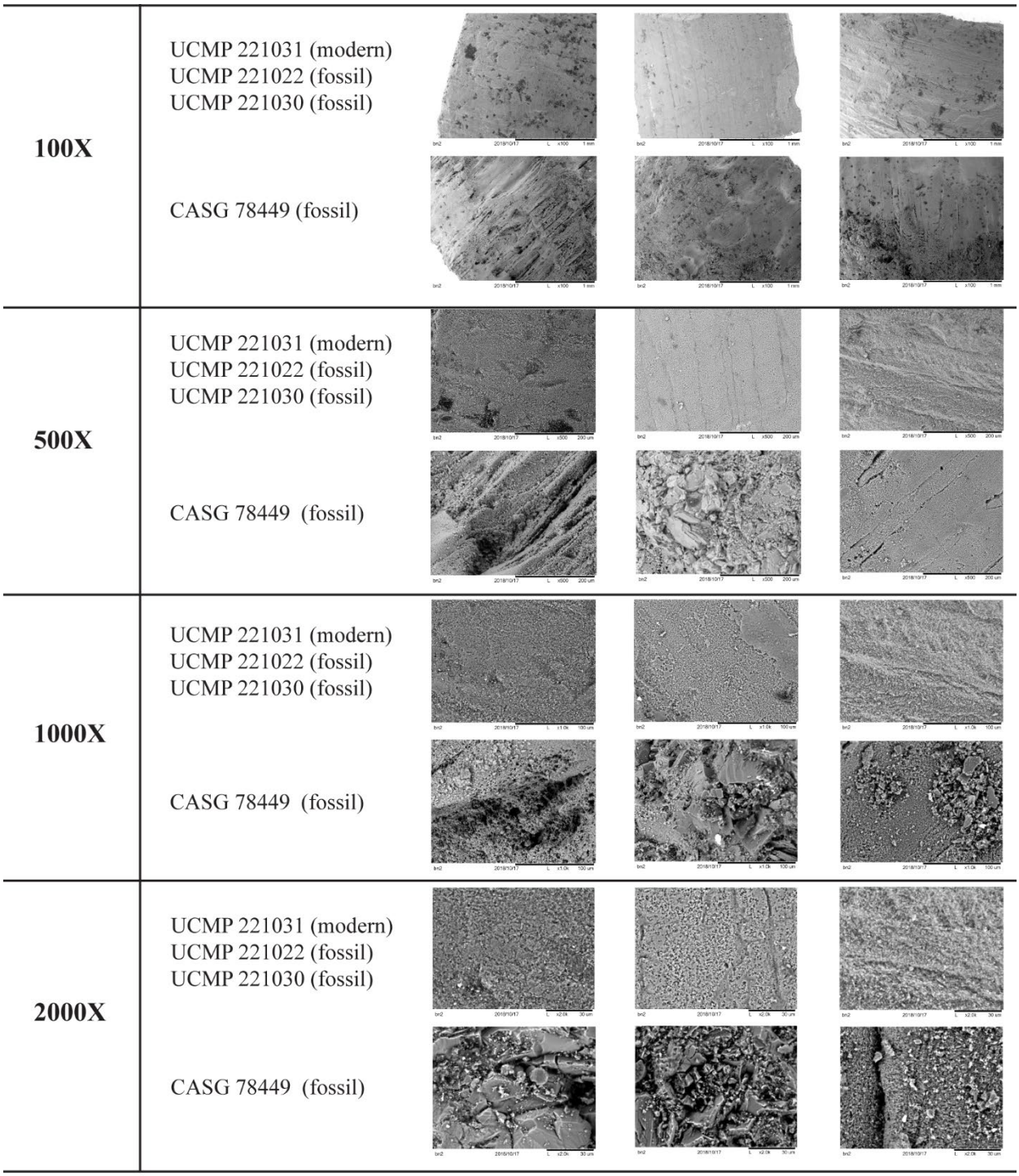

Fig. S8. Scanning electron micrographs of a modern coronulid, two Burica fossil coronulids, and CASG 78449. Modern and Burica samples were relatively homogeneous, while CASG 78449 displays a variety of morphologies, including evidence of pitting, dissolution, and crystalline overgrowth.

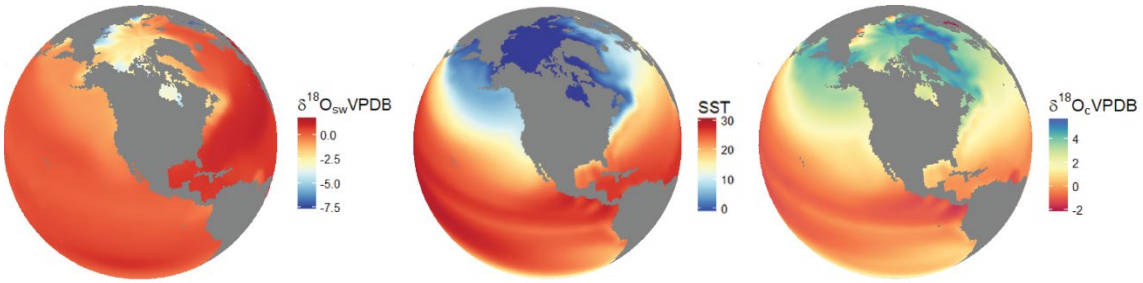

Fig. S9. Creation of expectations against which to compare modern coronulid δ18O profiles is done by downloading sea surface δ18O data (a) and monthly temperature data (b), merging them in R, then coercing R to use the barnacle-specific paleotemperature equation to calculate the expected δ18O of coronulid calcite being produced in each unit of the map grid during the selected time interval (c).

Table S1: Summary of coronulids analyzed in this study

Specimen	Genus	Location	$\delta^{18}O$ max	$\delta^{18}O$ min	$\delta^{18}O$ range
UCMP 221031	*Coronula*	California, USA (modern)	1.46	-0.49	1.95
CAS MAM 21691	*Coronula*	Alaska, USA (modern)	1.47	-0.72	2.19
CAS MAM 21149	*Cryptolepas*	California, USA (modern)	3.47	0.19	3.28
UCMP 221032	*Coronula*	California, USA (modern)	0.40	-1.18	1.58
UCMP 221033	*Coronula*	California, USA (modern)	0.51	-1.24	1.75
UCMP 221034	*Coronula*	California, USA (modern)	0.53	-0.95	1.48
UCMP 221029	*Coronula*	Burica Peninsula, Panama	1.44	-0.88	2.32
UCMP 221028	*Coronula*	Burica Peninsula, Panama	3.77	-0.02	3.79
UCMP 221022	*Coronula*	Burica Peninsula, Panama	3.00	-0.79	3.79
UCMP 221030	*Coronula*	Burica Peninsula, Panama	1.82	0.45	1.37
SDSNH 111656	*Coronula*	Bay Point Fm, CA, USA	2.36	-0.15	2.51
SDSNH 114317	*Coronula*	Bay Point Fm, CA, USA	1.93	-0.29	2.22
SDSNH 102564	*Coronula*	Bay Point Fm, CA, USA	2.85	0.59	2.26
SDSNH 134747	*Cryptolepas*	Bay Point Fm, CA, USA	1.99	-1.49	3.48
SDSNH 30462	*Cryptolepas*	San Pedro Fm, CA, USA	2.00	0.31	1.69
SDSNH 50195	*Coronula*	San Pedro Fm, CA, USA	2.70	0.91	1.79
CASG 78449	*Coronula*	Unknown site, Mexico	0.65	-4.20	4.85

Table S2: Raw data from modern coronulids

UCMP 221031		UCMP 221031		CAS MAM 21691		UCMP 221032		UCMP 221033		UCMP 221034		CAS MAM 21149	
$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{18}O$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$
0.23	1.18	1.15	1.27	0.01	0.44	0.40	-0.43	0.51	-0.78	0.53	-1.03	0.19	-0.98
0.16	1.09	0.42	1.11	0.81	-0.19	0.02	-0.6	0.19	-0.56			0.28	-1.04
0.16	1.13	0.29	1.18	0.25	0.83	0.15	-0.45	0.08	-0.62	0.25	-0.29	0.34	-0.64
0.01	1.01	0.11	1.32	0.74	0.37	-0.12	-0.51	-0.17	-0.73			0.54	-0.25
0.01	1.11	0.28	1.38	0.55	-0.17	-0.66	-0.62	-0.52	-0.46	-0.62	0.048	0.66	0.03
-0.36	0.88	0.01	1.17	0.62	-0.22	-0.94	-0.77	-0.71	-0.83			2.08	-0.06
-0.07	1.05	-0.39	0.99	0.71	-0.26	-1.04	-0.85	-0.09	-1.23	-0.95	-0.06	0.93	-0.53
-0.32	0.99	-0.18	1.01	-0.72	0.60	-0.35	-0.77	-0.06	-0.93			0.78	-0.13
-0.25	0.92	0.01	1.13	-0.18	-0.52	-0.50	-0.39	-0.82	-1.2	-0.81	0.00	1.48	-0.15
-0.18	1.05	-0.01	1.02	0.04	-0.18	-0.27	-0.20	-0.93	-1.32			1.66	0.10
-0.49	0.84	-0.52	0.81	-0.11	-0.38			-0.19	-0.73			2.24	0.85
-0.35	0.76	0.13	0.90	0.24	-0.08	-0.34	-0.03	-0.85	-0.85			1.83	-0.64
-0.07	0.80	0.01	1.08	0.27	0.15	-0.51	-0.22	0.14	-1.61			2.92	-1.04
-0.05	0.79	0.29	1.02	0.02	0.19			-1.24	-1.26			3.47	-0.98
0.25	0.83	0.08	0.92	-0.21	0.74	-1.18	-0.79	-1.11	-1.16				
0.74	-0.06	0.25	0.92	-0.29	1.16	-1.07	-0.79	-1.01	-1.65				
0.56	0.56	0.33	0.56	-0.24	1.54			-0.76	-1.49				
0.69	0.45	0.26	0.51	-0.67	1.45	-0.66	-0.59	-0.94	-1.52				
0.87	0.01	0.39	-0.19	-0.65	1.21								
0.71	0.14	0.33	0.14	-0.33	1.39	0.30	-0.01						
1.09	-0.17	0.44	0.23	0.10	1.25								
1.11	-0.44	0.73	0.08	-0.24	0.86								
0.66	-0.02	1.06	0.18	-0.25	0.63								
1.06	0.21	0.86	0.09	-0.46	-0.23								
0.76	0.20	1.16	0.01	-0.44	-0.43								
0.76	-0.05	1.03	0.02	-0.33	-0.50								
1.06	0.09	1.54	0.00	0.17	-0.08								
1.23	-0.26	1.05	-0.02	-0.20	-0.87								
1.46	0.00	0.72	-0.16	0.09	-0.92								
0.40	-1.85	-0.32	-0.58	0.19	-1.16								
0.45	-0.04	1.21	0.09	0.07	-1.21								
		0.74	0.37	0.45	-1.11								
		0.49	0.70	0.51	-1.25								
				0.42	-1.49								
				0.79	-1.35								
				1.32	-1.21								
				1.14	-1.13								
				1.32	-0.99								
				1.47	-0.88								
				-0.22	1.07								
				0.16	0.84								
				-0.19	0.64								
				-0.56	0.68								
				-0.45	-0.48								

Table S3: Raw data from SDSNH and CAS fossil coronulids

SDSNH 50195		SDSNH 102564		SDSNH 30462		SDSNH 111656		SDSNH 134747		SDSNH 114317		CASG 78449	
$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$
1.61	-1.24	1.41	-1.71	0.35	-0.94	-0.15	-3.05	1.95	-3.38	-0.29	-1.69	-2.00	-0.17
0.91	-0.92	0.62	-1.08	1.26	-1.63	1.41	-2.10	0.90	-2.61	1.04	-0.85	-0.76	-0.15
2.37	-0.77	0.59	-1.51	0.31	-1.62	1.80	-2.36	1.99	-2.29	1.93	-1.12	-2.53	-0.29
1.88	-0.78	0.66	-1.27	1.55	-2.07	1.64	-2.19	0.66	-1.23	1.16	-1.73	-1.44	-0.27
2.67	-1.05	2.33	-0.85	1.69	-2.20	2.10	-2.28	-0.13	-1.99	0.74	-2.76	-4.20	-0.69
2.18	0.22	2.85	-1.79	1.66	-1.72	1.75	-1.93	-1.49	-2.18	1.52	-1.78	-2.08	-0.02
2.70	-0.32	2.37	-1.97	2.00	-2.05	2.36	-2.33	-0.95	-2.35	1.42	-0.96	-3.88	-1.48
2.42	-0.28	1.16	-1.91							1.41	-1.03	-3.11	-1.14
2.59	-0.41	1.25	-1.20							0.91	-1.91	-2.90	-0.77
2.32	-0.47									0.69	-1.62	-1.67	0.39
1.97	-0.40											-2.58	0.10
												-1.27	0.29
												-1.67	-0.24
												-1.59	-0.77
												-0.70	-0.52
												-0.35	-0.07
												-0.60	0.26
												-1.73	-0.17
												-1.98	-0.21
												-1.68	0.01
												-1.36	0.56
												-0.95	0.70
												-1.73	0.61
												-1.33	0.95
												-2.14	-0.03
												-2.29	-0.66
												-0.80	0.08
												-0.23	0.50
												0.65	-0.24
												-0.43	-0.55
												-0.33	-0.15
												-1.92	-0.38
												-2.52	-0.56
												-3.62	-0.62
												-0.92	0.11
												-2.15	-0.58

Table S4: Raw data from Panama fossil coronulids							
UCMP 221029		UCMP 221028		UCMP 221022		UCMP 221030	
$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$
1.10	0.87	0.52	0.45	1.92	-0.03	1.42	0.32
0.91	0.49	0.68	0.51	1.52	-0.14	1.82	-0.15
0.83	-0.42	0.34	0.47	2.80	-0.18	1.08	-0.49
1.09	-0.38	0.5	0.52	2.71	-1.52	1.30	0.02
0.65	-1.09	0.84	0.44	1.71	-0.37	0.79	0.21
1.32	-0.96	0.99	0.50			0.83	0.58
1.44	-0.86	0.4	0.19	1.15	0.00	0.61	0.81
0.98	-1.08	0.54	0.7	1.38	1.06	0.45	0.38
0.71	-0.97	0.97	0.69	0.7	-0.32	0.90	0.28
1.20	-1.22	1.01	1.24			0.59	-0.10
0.26	-0.36	1.31	1.03	1.59	-0.28	1.04	-0.06
-0.47	0.42	2.67	1.36	2.07	-1.18	1.00	-0.24
-0.88	0.26	2.28	1.07	1.72	-0.36	1.13	-0.41
-0.82	0.68	0.14	0.79	1.02	-0.69	1.37	-0.19
-0.46	0.78	1.05	0.58	2.29	-0.26	1.06	-0.36
-0.53	0.74	-0.02	-1.48			1.29	-0.37
-0.45	0.73	1.44	0.49	2.10	-0.47	1.15	-0.45
-0.62	0.61	0.75	0.77	1.39	0.40	1.15	-0.34
-0.37	0.74	1.76	0.66	1.66	-0.85	0.96	-0.58
-0.42	0.59	0.76	0.68	1.53	0.23	1.22	-0.51
-0.31	0.54	1.07	0.65	3.00	-0.58	1.19	-0.56
-0.62	0.18	1.50	0.87			1.46	-0.68
0.01	0.06	2.44	0.44	2.15	-0.60	1.32	-0.73
		1.59	0.46	2.68	0.06	1.37	-0.76
		3.36	0.88	0.87	0.43		
		2.57	0.99	1.75	0.23		
		3.77	1.27	-0.02	0.81		
		2.62	1.03	-0.12	0.75		
		3.43	1.02	-0.79	0.94		
		1.87	0.34				
		2.17	0.82				

Table S5: Raw data from Panama fossil bivalves associated with UCMP 221028			
Specimen 1		Specimen 2	
$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$
-0.29	1.59	-0.02	1.43
0.00	2.05	0.18	1.37
-0.23	2.24	0.35	1.59
0.21	2.15	-0.23	2.03
-0.01	1.96		
0.26	2.24		