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Impact of seawater carbonate chemistry on the calcification of marine bivalves

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Table S1 Meta-analysis of larval calcification responses expressed as % of control shell length and the corresponding carbonate chemistry.

[C_T] (µmol kg^{-1})	pH total scale	[HCO_3^-] (µmol kg^{-1})	pCO$_2$ [µatm]	[CO_3^{2-}] (µmol kg^{-1})	Ωaragonite	[C_T]/[H^+] [mol]/[µmol]	[HCO_3^-]/[H^+] [mol]/[µmol]	shell length % of control	reference	species
1863	7.99	1766	508	78	1.26	0.18	0.174	100	this study	*Mytilus eduli*
2033	7.49	1937	1777	27	0.43	0.06	0.060	79		
848	7.63	811	539	15	0.25	0.04	0.035	79		
3399	7.72	3254	1770	76	1.23	0.18	0.170	99		
2839	8.16	2583	430	240	3.76	0.41	0.372	101	this study	*M. edulis*
2463	8.08	2269	449	177	2.78	0.30	0.275	95		
1996	7.99	1862	460	116	1.83	0.19	0.181	100		
1583	7.91	1488	440	78	1.22	0.13	0.121	101		
1101	7.78	1044	415	41	0.64	0.07	0.063	87		
741	7.59	707	436	18	0.28	0.03	0.028	54		
6283	7.70	5980	2859	193	3.03	0.32	0.300	85		
5525	7.67	5263	2712	158	2.48	0.26	0.245	94		
4589	7.58	4376	2774	107	1.67	0.17	0.166	93		
3553	7.45	3382	2855	62	0.97	0.10	0.096	66		
1490	7.10	1378	2631	11	0.17	0.02	0.017	62		
2271	8.03	2090	468	164	2.56	0.24	0.222	100	Gazeau et al. 2010	*M. edulis*
2408	7.69	2285	1123	82	1.28	0.12	0.111	95		
2253	7.97	2091	537	143	2.22	0.21	0.194	99		
2439	7.46	2320	1930	48	0.75	0.07	0.066	87		
2232	7.90	2076	639	135	2.13	0.18	0.164	97		
1813	8.17	1644	254	159	2.42	0.27	0.243	100	Sunday et al. 2011	*M. trossulus*
1937	7.86	1826	571	87	1.33	0.14	0.133	97		
2021	8.04	1851	399	155	2.40	0.22	0.203	100	Frieder et al. 2014	*M. californian*
2214	7.51	2106	1538	52	0.81	0.07	0.068	91		
2174	7.64	2065	1118	69	1.07	0.09	0.090	94		
2039	8.00	1880	444	144	2.22	0.20	0.188	100		
2082	7.90	1943	578	118	1.83	0.17	0.154	100		
2161	7.68	2050	1012	75	1.16	0.10	0.098	98		
1780	8.02	1645	360	121	1.83	0.19	0.172	100	Kurihara et al. 2009	*M. galloprovinci*
1983	7.31	1873	2104	27	0.41	0.04	0.038	69		
2850	8.10	2574	482	259	3.99	0.36	0.324	100	Vihtakari et al. 2013	*M. gallopovinici*
2859	7.73	2701	1185	116	1.79	0.15	0.145	96		
2061	7.95	1913	507	130	2.02	0.18	0.170	100	Frieder et al. 2014	*M. gallopovinici*
2205	7.54	2098	1430	56	0.86	0.08	0.073	92		
2199	7.56	2091	1361	58	0.90	0.08	0.076	93		
2078	7.91	1937	563	120	1.86	0.17	0.157	100		
2183	7.61	2075	1204	65	1.00	0.09	0.085	95		
2061	7.95	1913	507	130	2.02	0.18	0.170	100		
2189	7.59	2082	1265	62	0.96	0.09	0.081	96		
1703	8.08	1517	314	177	2.80	0.20	0.181	100	Kurihara et al. 2007	*Crassostrea gigas*

1982	7.29	1875	2391	35	0.56	0.04	0.036	93		
1703	8.08	1517	314	177	2.80	0.20	0.181	100		
1982	7.29	1875	2391	35	0.56	0.04	0.036	89		
2207	8.03	2010	450	182	2.84	0.24	0.215	100	Gazeau et al. 2011	*C. gigas*
2339	7.72	2207	1008	98	1.53	0.12	0.116	99		
2443	7.41	2320	2164	51	0.79	0.06	0.060	95		
1030	7.67	974	497	40	0.62	0.05	0.046	90		
6590	7.62	6248	3590	222	3.45	0.27	0.260	100		
3225	8.09	2934	575	271	4.26	0.40	0.362	100	Barros et al. 2013	*C. gigas*
3420	7.76	3233	1355	139	2.20	0.20	0.186	93		
3597	7.37	3413	3514	60	0.94	0.08	0.080	86		
1826	7.99	1684	429	128	2.05	0.18	0.165	100	Timmins-Schiffman et al. 2012	*C. gigas*
1907	7.75	1803	797	78	1.25	0.11	0.101	109		
1931	7.66	1833	998	65	1.04	0.09	0.084	84		
2034	8.07	1841	374	181	2.79	0.24	0.215	100	Parker et al. 2010	*C. gigas*
2120	7.89	1971	606	128	1.97	0.16	0.152	97		
2152	7.81	2018	746	109	1.68	0.14	0.130	93		
2193	7.70	2073	986	87	1.34	0.11	0.104	90		
2000	8.07	1785	371	204	3.19	0.23	0.210	100		
2093	7.89	1929	606	145	2.28	0.16	0.150	96		
2128	7.81	1981	749	124	1.95	0.14	0.128	95		
2172	7.70	2042	994	99	1.56	0.11	0.102	91		
1970	8.06	1735	377	224	3.57	0.23	0.200	100		
2064	7.89	1883	605	164	2.62	0.16	0.146	95		
2103	7.81	1941	750	141	2.25	0.14	0.126	94		
2150	7.70	2009	1000	113	1.81	0.11	0.101	88		
1932	8.06	1674	371	249	4.06	0.22	0.193	100		
2034	7.89	1834	602	185	3.01	0.16	0.143	97		
2075	7.81	1897	748	159	2.59	0.13	0.123	96		
2126	7.70	1973	1003	128	2.09	0.11	0.099	89		
2034	8.07	1841	374	181	2.79	0.24	0.215	100	Parker et al. 2010	*Saccostrea glomarata*
2120	7.89	1971	606	128	1.97	0.16	0.152	90		
2152	7.81	2018	746	109	1.68	0.14	0.130	85		
2193	7.70	2073	986	87	1.34	0.11	0.104	81		
2000	8.07	1785	371	204	3.19	0.23	0.210	100		
2093	7.89	1929	606	145	2.28	0.16	0.150	92		
2128	7.81	1981	749	124	1.95	0.14	0.128	90		
2172	7.70	2042	994	99	1.56	0.11	0.102	88		
1970	8.06	1735	377	224	3.57	0.23	0.200	100		
2064	7.89	1883	605	164	2.62	0.16	0.146	92		
2103	7.81	1941	750	141	2.25	0.14	0.126	87		
2150	7.70	2009	1000	113	1.81	0.11	0.101	83		
1932	8.06	1674	371	249	4.06	0.22	0.193	100		
2034	7.89	1834	602	185	3.01	0.16	0.143	95		
2075	7.81	1897	748	159	2.59	0.13	0.123	90		
2126	7.70	1973	1003	128	2.09	0.11	0.099	86		
1937	7.94	1780	509	142	2.26	0.17	0.154	100.0	Van Colen et al. 2012	*Macoma baltica*
2108	7.40	2001	1987	46	0.73	0.05	0.050	84.9		
2140	7.99	1974	469	149	2.28	0.21	0.194	100.0		
2227	7.78	2100	807	98	1.50	0.14	0.128	95.7	White et al. 2013	*Argopecten irradians*
2278	7.64	2163	1164	72	1.11	0.10	0.094	95.7		

2320	7.51	2207	1599	54	0.83	0.07	0.071	91.3	Andersen et al. 2013
2781	8.00	2604	637	152	2.39	0.28	0.260	100.0	
2914	7.66	2781	1498	73	1.15	0.13	0.126	95.7	
3001	7.42	2853	2640	44	0.69	0.08	0.075	89.5	

Table S2 Meta-analysis of juvenile calcification responses expressed as % of control shell mass growth and the corresponding carbonate chemistry.

[C_T] (µmol kg^{-1})	pH total scale	[HCO_3^-] (µmol kg^{-1})	pCO$_2$ [µatm]	[CO_3^{2-}] (µmol kg^{-1})	Ωaragonite	[C_T]/[H^+] [mol]/[µmol]	[HCO_3^-]/[H^+] [mol]/[µmol]	shell mass growth % of control	reference
1888	8.13	1783	501	82	1.32	0.25	0.24	100	this study
2246	7.16	2035	5214	10	0.16	0.03	0.03	66	
847	7.74	809	564	15	0.24	0.05	0.04	50	
5909	7.57	5616	5649	71	1.14	0.22	0.21	106	
1891	8.01	1797	479	73	1.14	0.19	0.18	100	Thomsen et al. 2010
1984	7.60	1898	1287	30	0.48	0.08	0.08	97	
2126	7.13	1946	3912	11	0.17	0.03	0.03	65	
1891	8.01	1797	479	73	1.14	0.19	0.18	100	
1984	7.60	1898	1287	30	0.48	0.08	0.08	91	
2126	7.13	1946	3912	11	0.17	0.03	0.03	56	
1969	8.02	1874	449	73	1.11	0.21	0.20	100	Thomsen and Melzner 201
2031	7.74	1947	886	40	0.61	0.11	0.11	90	
2124	7.41	2007	1978	19	0.30	0.05	0.05	77	
2214	7.14	2020	3685	10	0.16	0.03	0.03	64	
1882	7.95	1806	508	44	0.72	0.17	0.16	100	Melzner et al. 2011
1952	7.61	1863	1138	21	0.34	0.08	0.08	103	
2033	7.26	1875	2540	10	0.15	0.04	0.03	57	
2097	7.08	1865	3859	6	0.10	0.03	0.02	63	
1775	8.01	1680	460	77	1.29	0.18	0.17	100	Thomsen et al. 2013
1878	7.70	1798	1006	40	0.67	0.09	0.09	76	
1964	7.40	1862	2078	21	0.35	0.05	0.05	75	
2035	7.19	1888	3417	13	0.23	0.03	0.03	58	

Fig. S1. Meta-analysis of the calcification response (measured as shell length) in % of control of bivalve larvae larvae kept under modified carbonate chemistry during the lecitotrophic phase. Calcification response is plotted against seawater (A) pCO2, (B) [HCO3-], (C) [CO_3^{2-}] and (D) pH. Regressions depict an exponential rise to maximum: f=y0+a*(1-exp(-b*x)).

Fig. S2. Delay of shell formation in M. edulis larvae two days after fertilization.
Carbonate chemistry corresponds to the treatments (pCO2/[CO_3^{2-}]) given in Table 1: (A) 390/78, B) 2400/20, C) 390/20, D) 2400/78.

Fig. S1

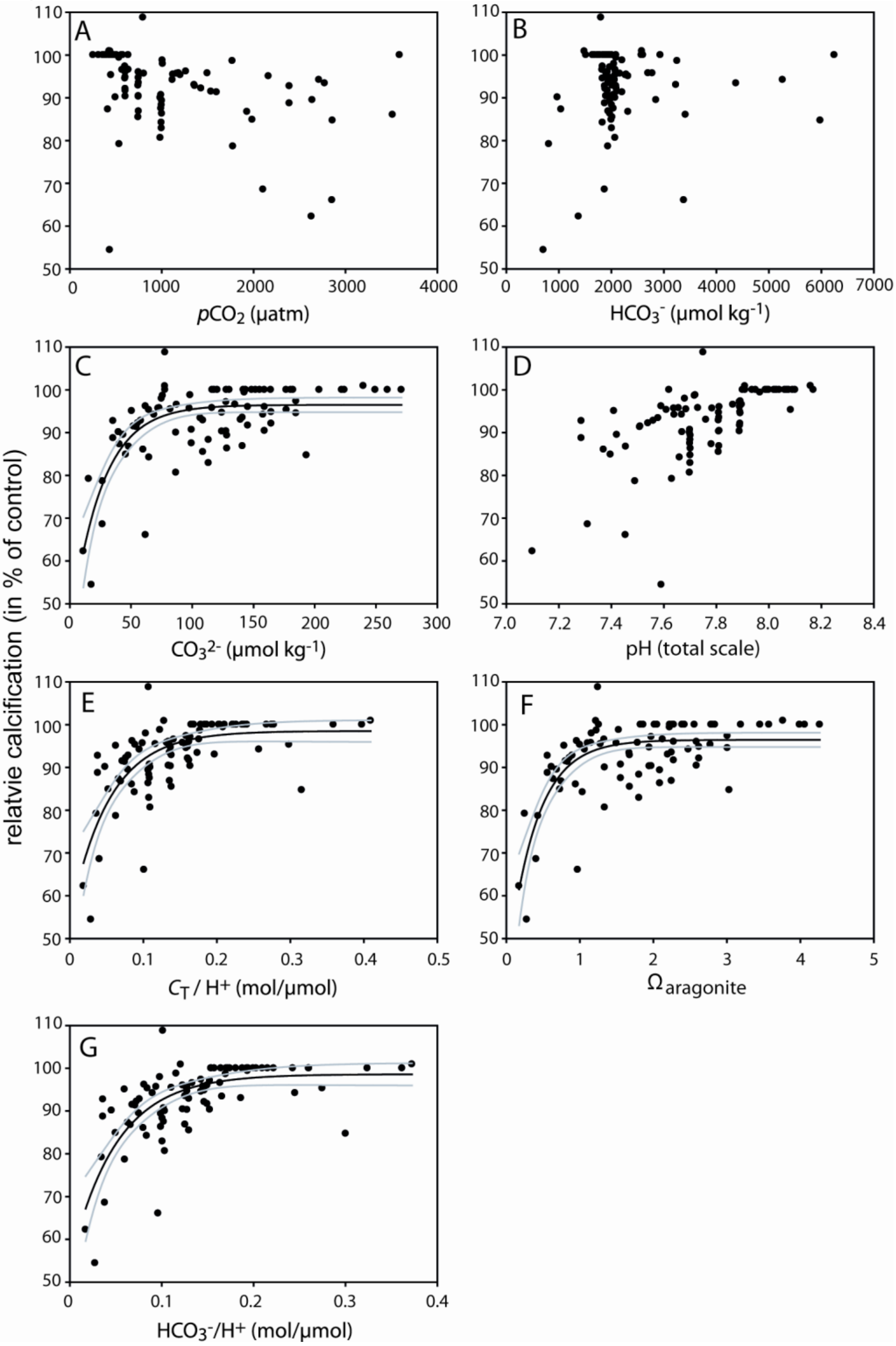
relatvie calcification (in % of control)
A
110
100
90
80
70
60
50
0
1000
2000
3000
4000
pCO$_2$ (µatm)
B
0
1000
2000
3000
4000
5000
6000
7000
HCO$_3^-$ (µmol kg^{-1})
C
0
50
100
150
200
250
300
CO$_3^{2-}$ (µmol kg^{-1})
D
7.0
7.2
7.4
7.6
7.8
8.0
8.2
8.4
pH (total scale)
E
0
0.1
0.2
0.3
0.4
0.5
C_T / H$^+$ (mol/µmol)
F
0
1
2
3
4
5
Ω$_{aragonite}$
G
0
0.1
0.2
0.3
0.4
HCO$_3^-$/H$^+$ (mol/µmol)

Fig. S2