

Supplementary Materials for

**Subsurface pH and carbonate saturation state of aragonite on the
Chinese side of the North Yellow Sea: Seasonal variations and controls**

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The supplementary materials include:

Table S1. Field-measured temperature, salinity, TAlk, DIC, pH (at 25°C), DO, and calculated pH (in situ), $f\text{CO}_2$ and Ω_{arag} in bottom waters.

Figure S1. Distribution of red tides and dominant organism species in Bohai Sea and the North Yellow Sea in 2011.

Table S1. Field-measured temperature, salinity, TAlk, DIC, pH (at 25°C), DO, and calculated pH (in situ), $f\text{CO}_2$ and Ω_{arag} in bottom waters.

Sample#	Latitude (°N)	Longitude (°E)	Water depth (m)	Temperature (°C)	Salinity	TAlk ($\mu\text{mol kg}^{-1}$)	DIC ($\mu\text{mol kg}^{-1}$)	pH _T (at 25°C)	DO ($\mu\text{mol kg}^{-1}$)	pH _T (in situ)	$f\text{CO}_2$ (μatm)	Ω_{arag}
Surveying period: 10-17 May 2011												
1	38.7551	121.7500	55	4.32	31.78	2283	2120	7.79	No data	8.13	323	1.83
2	38.5841	121.2507	74	5.91	31.74	2278	2097	7.86	No data	8.15	306	2.00
3	38.2495	121.2497	36	5.50	31.58	2312	2132	7.84	No data	8.15	310	2.02
4	37.9113	121.2501	20	7.46	31.54	2306	2103	7.89	No data	8.17	293	2.25
5	37.5837	121.7501	18	10.21	31.47	2346	2140	7.88	No data	8.13	333	2.33
6	37.5841	122.2480	25	9.23	31.59	2314	2118	7.88	No data	8.13	331	2.21
7	37.5836	122.7493	30	8.01	31.57	2340	2141	7.85	No data	8.15	316	2.23
8	37.5833	123.2507	67	6.65	32.22	2304	2134	7.80	No data	8.10	350	1.91
9	37.2509	123.2491	75	6.28	32.20	2298	2137	7.78	No data	8.09	361	1.83
10	37.2511	123.5743	73	6.60	32.31	2302	2134	7.79	No data	8.09	355	1.89
11	37.5841	123.5850	71	6.59	32.26	2303	2135	7.79	No data	8.10	353	1.89
12	38.2500	123.5843	71	5.65	32.12	2307	2124	7.81	No data	8.14	311	2.01
13	38.2498	123.2521	63	4.83	32.12	2306	2150	7.77	No data	8.10	353	1.78
14	38.2509	122.7504	52	5.62	32.06	2317	2162	7.73	No data	8.08	370	1.78
15	38.2504	122.2508	52	3.55	31.97	2321	2163	7.75	No data	8.12	332	1.79
16	38.2499	121.7502	50	3.99	31.90	2310	2154	7.74	No data	8.11	341	1.77
17	38.7500	122.2485	52	3.44	32.04	2321	2176	7.69	No data	8.09	361	1.68
18	38.7502	122.7512	52	3.62	32.12	2322	2183	7.68	No data	8.07	381	1.62
19	38.7501	123.2500	56	4.50	32.05	2288	2126	7.79	No data	8.12	332	1.81
20	38.7494	123.5835	52	6.04	32.15	2286	2125	7.82	No data	8.09	355	1.82
21	39.2498	123.8278	37	6.49	31.36	2255	2079	7.84	No data	8.14	315	1.97
22	39.6598	123.6613	13	8.39	29.38	2161	2011	7.84	No data	8.08	358	1.74
23	39.5330	123.4994	20	5.73	30.33	2207	2028	7.88	No data	8.17	280	1.99

Sample#	Latitude (°N)	Longitude (°E)	Water depth (m)	Temperature (°C)	Salinity	TAlk ($\mu\text{mol kg}^{-1}$)	DIC ($\mu\text{mol kg}^{-1}$)	pH _T (at 25°C)	DO ($\mu\text{mol kg}^{-1}$)	pH _T (in situ)	fCO ₂ (μatm)	Ω_{arag}
24	39.2495	123.4169	39	5.15	31.66	2267	2105	7.83	No data	8.12	330	1.83
25	39.2378	123.0003	35	5.69	31.24	2249	2083	7.82	No data	8.13	321	1.88
26	39.0445	122.5006	35	6.61	31.29	2251	2091	7.83	No data	8.09	352	1.81
Surveying period: 22-24 June 2011												
27	37.8947	123.0598	61	6.42	32.14	2297	2156	7.74	273	8.03	415	1.65
28	38.4317	123.4783	66	7.09	32.15	2299	2128	7.82	301	8.10	353	1.92
29	38.9748	123.9076	56	9.74	31.93	2281	2093	7.88	306	8.10	350	2.10
30	39.2084	124.0863	41	10.91	31.65	2271	2083	7.89	303	8.09	362	2.12
31	39.2215	123.6356	49	8.68	31.84	2281	2102	7.85	297	8.10	353	2.01
32	38.7412	123.3595	57	7.28	32.13	2295	2123	7.84	305	8.10	351	1.94
33	38.7479	122.4999	55	3.94	32.03	2304	2180	7.70	289	8.02	422	1.49
34	38.1577	122.4834	51	4.85	31.89	2298	2169	7.73	278	8.03	418	1.54
35	37.7701	122.4809	35	6.82	31.66	2305	2164	7.77	274	8.03	420	1.67
36	37.5956	122.4742	25	14.15	31.47	2342	2164	7.86	224	8.01	462	2.10
37	37.7002	121.9915	22	9.37	31.60	2322	2152	7.84	289	8.06	394	1.96
38	38.1987	121.9979	56	3.84	32.02	2298	2177	7.71	285	8.02	428	1.46
39	38.6956	122.0063	53	4.60	31.91	2298	2162	7.74	294	8.05	394	1.60
40	38.6668	121.6252	61	5.62	31.81	2287	2138	7.78	292	8.07	373	1.72
41	38.4034	121.3270	50	6.27	31.75	2278	2129	7.79	291	8.06	383	1.72
42	38.1072	121.2174	32	11.28	31.39	2309	2127	7.87	281	8.07	391	2.09
43	37.9113	121.1586	22	12.09	31.47	2315	2120	7.91	300	8.08	374	2.24
Surveying period: 24-31 July 2011												
44	38.7503	121.7503	53	7.37	31.89	No data	2146	7.76	No data	No data	No data	No data
45	38.5826	121.2493	71	6.52	31.78	No data	2160	7.73	No data	No data	No data	No data
46	38.2502	121.2502	34	13.91	31.01	No data	No data	7.81	No data	No data	No data	No data
47	37.9114	121.2510	20	15.84	31.07	2305	2135	7.81	No data	7.98	501	2.04

Sample#	Latitude (°N)	Longitude (°E)	Water depth (m)	Temperature (°C)	Salinity	TAlk ($\mu\text{mol kg}^{-1}$)	DIC ($\mu\text{mol kg}^{-1}$)	pH _T (at 25°C)	DO ($\mu\text{mol kg}^{-1}$)	pH _T (in situ)	fCO ₂ (μatm)	Ω_{arag}
48	37.5853	121.7508	18	14.95	31.11	2294	2127	7.79	No data	7.98	489	1.99
49	37.5838	122.2471	24	14.85	31.16	2302	2149	7.75	No data	7.95	537	1.86
50	37.5844	122.7477	30	12.04	31.20	2265	2117	7.76	No data	7.98	481	1.77
51	37.5842	123.2493	67	5.91	32.06	2301	2166	7.70	No data	8.02	426	1.59
52	37.2503	123.2496	71	5.66	31.92	2306	2176	7.67	No data	8.02	433	1.55
53	37.5828	123.5838	68	6.74	32.05	2292	2159	7.73	No data	8.01	443	1.58
54	38.2501	123.5833	68	9.67	31.88	2287	2125	7.78	No data	8.04	412	1.85
55	38.2494	123.2519	63	8.89	31.99	2287	2130	7.78	No data	8.04	412	1.81
56	38.2492	122.7512	51	5.42	32.10	2299	2170	7.71	No data	8.02	433	1.54
57	38.2500	122.2579	52	4.21	31.98	2299	2190	7.68	No data	7.98	470	1.37
58	38.2498	121.7495	48	6.07	31.81	2293	2196	7.69	No data	7.92	559	1.27
59	38.7494	122.2498	50	6.72	32.09	2293	2162	7.76	No data	8.00	448	1.57
60	38.7505	122.7488	50	9.75	31.98	2288	2124	7.80	No data	8.04	407	1.89
61	38.7488	123.2462	55	11.17	31.90	2285	2119	7.82	No data	8.03	425	1.92
62	38.7495	123.5812	53	11.89	31.80	2278	2115	7.84	No data	8.01	445	1.89
63	39.2491	123.8265	35	11.89	31.80	2273	2079	7.89	No data	8.09	365	2.19
64	39.6662	123.8318	17	19.03	30.45	2213	2008	7.91	No data	8.03	423	2.40
65	39.5339	123.4995	22	17.15	31.09	2247	2060	7.88	No data	8.00	453	2.20
66	39.2490	123.4172	39	13.27	31.75	2278	2085	7.85	No data	8.06	391	2.19
67	39.0440	122.4998	35	14.37	31.29	2253	2082	7.82	No data	8.00	455	1.99
Surveying period: 20-22 August 2011												
68	38.6591	122.0018	50	9.37	31.89	No data	No data	7.77	245	No data	No data	No data
69	38.1928	122.0008	50	7.46	31.84	2295	2179	7.67	253	7.95	513	1.45
70	38.1619	122.4832	47	5.08	32.02	2303	2202	7.64	264	7.94	520	1.31
71	38.7480	122.4975	51	11.94	31.83	2287	2139	7.78	239	7.97	495	1.76
72	38.7416	123.3656	56	14.64	31.18	2238	2093	7.78	215	7.94	532	1.75

Sample#	Latitude (°N)	Longitude (°E)	Water depth (m)	Temperature (°C)	Salinity	TAlk ($\mu\text{mol kg}^{-1}$)	DIC ($\mu\text{mol kg}^{-1}$)	pH _T (at 25°C)	DO ($\mu\text{mol kg}^{-1}$)	pH _T (in situ)	fCO ₂ (μatm)	Ω_{arag}
73	39.2212	123.6358	49	19.10	31.04	2232	2044	7.90	219	7.98	482	2.22
74	39.2089	124.0864	41	19.57	30.52	2194	2002	7.94	222	7.99	460	2.26
75	38.9714	123.9066	55	17.88	30.31	2184	2029	7.85	216	7.93	537	1.87
76	38.4324	123.4782	65	12.11	31.68	2261	2127	7.76	229	7.94	534	1.62
77	37.8962	123.0594	62	9.61	31.89	2282	2163	7.71	236	7.93	546	1.48
78	37.7696	122.4828	35	17.44	30.87	2266	2124	7.77	188	7.89	618	1.78
79	37.5971	122.4782	24	20.58	30.83	2296	2162	7.74	156	7.82	755	1.75
80	37.7001	121.9917	20	19.43	30.86	2297	2164	7.73	166	7.83	726	1.73
81	37.9032	121.1597	21	20.06	30.80	2280	2112	7.83	192	7.91	587	2.06
82	38.1054	121.2142	29	18.55	30.83	2282	2128	7.78	182	7.90	604	1.91
83	38.4004	121.3261	50	10.46	31.78	2283	2137	7.74	244	7.99	469	1.73
Surveying period: 18-23 October 2011												
84	38.7551	121.7500	56	11.15	31.62	2273	2165	No data	No data	7.88	619	1.41
85	38.5841	121.2507	73	12.34	31.40	2260	2150	7.66	No data	7.87	633	1.43
86	38.2495	121.2497	35	16.86	30.73	2229	2071	7.80	No data	7.94	527	1.91
87	37.9113	121.2501	20	18.00	30.50	2224	2018	7.97	217	8.04	406	2.39
88	37.5841	122.2480	23	18.37	30.56	2222	2044	7.86	211	7.98	487	2.12
89	37.5836	122.7493	32	17.74	30.73	2250	2055	7.89	234	8.02	442	2.28
90	37.5833	123.2507	65	7.79	31.97	2285	2194	7.62	No data	7.87	627	1.24
91	37.2509	123.2491	68	7.26	32.23	2286	2206	7.59	188	7.85	665	1.16
92	37.2511	123.5743	68	7.11	32.13	2296	2199	7.61	198	7.90	586	1.29
93	37.5841	123.5850	68	7.07	32.02	2286	2208	7.63	No data	7.84	671	1.14
94	38.2500	123.5843	68	9.87	31.87	2278	2158	7.64	181	7.93	543	1.50
95	38.2498	123.2521	63	9.22	31.88	2286	No data	7.60	176	No data	No data	No data
96	38.2509	122.7504	50	11.10	31.68	2279	2192	7.56	No data	7.82	729	1.24
97	38.2504	122.2508	50	11.91	31.52	2270	2177	7.59	No data	7.83	713	1.29

Sample#	Latitude (°N)	Longitude (°E)	Water depth (m)	Temperature (°C)	Salinity	TAlk ($\mu\text{mol kg}^{-1}$)	DIC ($\mu\text{mol kg}^{-1}$)	pH _T (at 25°C)	DO ($\mu\text{mol kg}^{-1}$)	pH _T (in situ)	fCO ₂ (μatm)	Ω_{arag}
98	38.2499	121.7502	49	9.15	31.77	2289	2214	7.53	No data	7.81	748	1.13
99	38.7500	122.2485	48	11.61	31.65	2256	2167	7.61	168	7.82	724	1.24
100	38.7502	122.7512	49	11.36	31.71	2273	2156	7.59	166	7.90	592	1.48
101	38.7501	123.2500	49	12.11	31.72	2258	2153	7.63	153	7.86	657	1.38
102	38.7494	123.5835	51	13.15	31.66	2247	2144	7.66	161	7.84	687	1.37
103	39.2498	123.8278	32	16.51	30.81	2204	2039	7.81	No data	7.97	488	1.96
104	39.6598	123.6613	16	16.80	28.24	2076	1864	7.97	237	8.13	308	2.42
105	39.5330	123.4994	21	17.21	29.63	2159	1943	7.94	230	8.10	342	2.48
106	39.2495	123.4169	38	16.38	30.86	2209	2092	7.68	157	7.85	674	1.52
107	39.2378	123.0003	27	16.69	30.39	2187	2000	7.89	239	8.03	417	2.17
108	39.0445	122.5006	33	15.44	31.06	2221	2100	7.68	138	7.87	641	1.55
Surveying period: 22-25 November 2011												
109	37.4826	123.4927	73	7.82	32.25	2286	2186	7.62	192	7.90	587	1.30
110	37.6908	123.2690	68	8.04	32.13	2283	2181	7.63	196	7.90	581	1.32
111	37.8949	123.0621	61	9.01	32.03	2278	2155	7.66	194	7.95	519	1.50
112	38.1382	123.2468	64	8.65	31.93	2280	2177	7.63	192	7.90	590	1.33
113	38.4322	123.4784	65	10.45	31.85	2269	2141	7.70	216	7.94	524	1.56
114	38.7418	123.7189	58	12.09	31.69	2244	2098	7.77	244	7.97	487	1.72
115	38.9742	123.9093	56	13.19	31.42	2224	2079	7.79	247	7.96	499	1.73
116	39.2281	124.1036	31	13.67	30.39	2174	2008	7.87	255	8.02	418	1.92
117	39.2222	123.6034	40	13.43	31.29	2214	2083	7.77	218	7.92	551	1.61
118	38.7342	123.3686	58	11.33	31.78	2253	2146	7.69	203	7.88	622	1.39
119	38.7448	123.0077	54	10.36	31.84	2264	2188	7.58	160	7.79	766	1.13
120	38.7477	122.4992	54	12.02	31.63	2244	2163	7.58	137	7.79	776	1.18
121	38.1628	122.4878	50	11.93	31.55	2244	2139	7.69	181	7.86	641	1.38
122	37.5945	122.4719	26	12.76	30.81	2264	2090	7.88	261	8.04	413	2.03

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123	37.7842	121.9927	24	12.14	30.97	2267	2102	7.84	265	8.02	432	1.93
124	38.1991	121.9932	55	12.67	31.06	2219	2062	7.85	243	8.00	447	1.83
125	38.6675	122.0038	50	12.40	31.32	2237	2131	7.70	168	7.86	641	1.39
126	38.6675	121.6258	60	12.52	31.04	2216	2075	7.79	220	7.96	495	1.68
127	38.6351	121.4084	71	12.72	30.98	2220	2064	7.81	230	8.00	451	1.82
128	38.2660	121.2670	42	12.99	30.97	2227	2070	7.83	248	8.00	455	1.84
129	37.9105	121.1599	22	12.34	30.92	2278	2103	7.85	263	8.04	411	2.03
Surveying period: 09-13 January 2012												
130	39.6304	123.7999	17	-0.86	25.14	No data	No data	7.94	380	No data	No data	No data
131	39.2501	123.8262	38	5.63	31.04	2205	2067 ^{a)}	7.78	308	8.06 ^{a)}	374 ^{a)}	1.60 ^{a)}
132	38.7484	123.5749	57	6.47	31.92	2243	2121 ^{a)}	7.72	301	7.99 ^{a)}	457 ^{a)}	1.46 ^{a)}
133	37.5771	122.2619	25	3.27	31.16	No data	No data	7.75	331	No data	No data	No data
134	37.5816	123.2568	63	6.74	31.98	2249	2143 ^{a)}	7.68	286	7.94 ^{a)}	522 ^{a)}	1.33 ^{a)}
135	38.2555	123.5783	65	6.24	32.09	2251	2148 ^{a)}	7.67	301	7.94 ^{a)}	521 ^{a)}	1.31 ^{a)}
136	38.2502	122.7508	49	5.76	31.83	2243	2141 ^{a)}	7.67	305	7.94 ^{a)}	511 ^{a)}	1.30 ^{a)}
137	38.7452	122.7481	47	5.14	31.60	2229	2107 ^{a)}	7.73	311	8.01 ^{a)}	423 ^{a)}	1.46 ^{a)}
Surveying period: 13-15 May 2012												
138	37.3899	123.3669	72	7.51	32.52	2286	2100	No data	No data	8.12	327	2.05
139	37.3895	123.1604	69	7.35	32.36	2285	2108	No data	No data	8.10	343	1.96
140	37.3919	122.9346	32	7.81	31.56	2300	2129	No data	No data	8.09	360	1.95
141	37.8942	123.0589	61	7.02	32.24	2284	2137	No data	No data	8.04	408	1.70
142	38.1356	123.2485	63	5.20	31.97	2289	2155	No data	No data	8.03	412	1.57
143	38.4270	123.4757	65	5.32	32.02	2285	2138	No data	No data	8.07	377	1.69
144	38.7400	123.7171	58	6.32	32.10	2288	2101	No data	No data	8.15	305	2.07
145	38.9722	123.9044	54	6.56	32.01	2280	2079	No data	No data	8.18	283	2.19
146	39.2251	124.1026	28	6.41	31.05	2237	2051	No data	No data	8.17	289	2.06

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147	39.2236	123.6062	38	6.07	31.40	2256	2068	No data	No data	8.17	288	2.07
148	38.7432	123.3643	57	4.97	31.91	2279	2091	No data	No data	8.17	284	2.05
149	38.7463	123.0006	53	3.92	31.84	2287	2137	No data	No data	8.10	344	1.72
150	38.5022	122.8788	57	4.31	31.99	2290	2178	No data	No data	7.99	462	1.38
151	38.2240	122.7370	53	4.49	31.77	2291	2145	No data	No data	8.08	365	1.69
152	38.2240	122.7370	53	4.50	31.80	2307	2143	No data	No data	8.12	328	1.85
153	37.9701	122.6129	51	4.95	31.71	2291	2133	No data	No data	8.11	342	1.80
154	37.6994	122.4916	29	8.75	31.13	2310	2125	No data	No data	8.12	340	2.11
155	37.7008	121.9927	22	8.64	31.15	2311	2115	No data	No data	8.14	318	2.21
156	38.1993	121.9973	54	4.00	31.68	2285	2132	No data	No data	8.11	338	1.74
157	38.7424	122.0050	51	4.23	31.54	2264	2103	No data	No data	8.13	320	1.80
158	38.6663	121.6240	61	4.39	31.40	2247	2086	No data	No data	8.13	314	1.81
159	38.2665	121.2676	41	5.87	31.39	2288	2138	No data	No data	8.07	373	1.73
160	37.9104	121.1583	21	9.44	31.26	2299	2136	No data	No data	8.06	400	1.90

a) Calculated from measured pH_T (at 25°C) and TAlk.

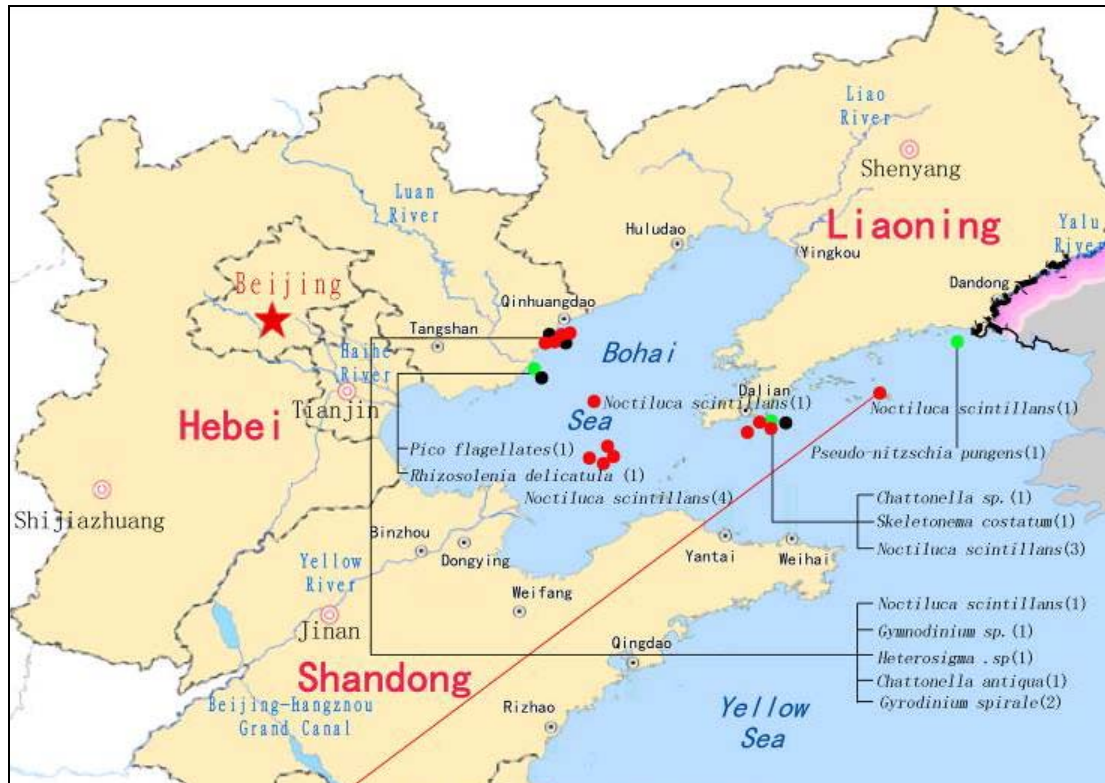


Fig. S1. Distribution of red tides and dominant organism species in Bohai Sea and the North Yellow Sea (NYS) in 2011, based on the Bulletin of Marine Environmental Status of China for 2011, which is released by State Oceanic Administration of China in June 2012. In 2011, seven cases of red tide were recorded in the northern part of the NYS. Among them, four red-tides were caused by *Noctiluca scintillans*, while the other 3 red tides were induced by *Skeletonema costatum*, *Pseudo-nitzschia pungens*, and *Chattonella* sp. The Chinese version of this figure is available at http://www.soa.gov.cn/zwgk/hygb/zghyhjzlg/hyhjzlgbm/2011ml/201212/t20121206_21275.html.