**Supplementary table 1: Summary of the impacts of ocean acidification on marine calcifiers**

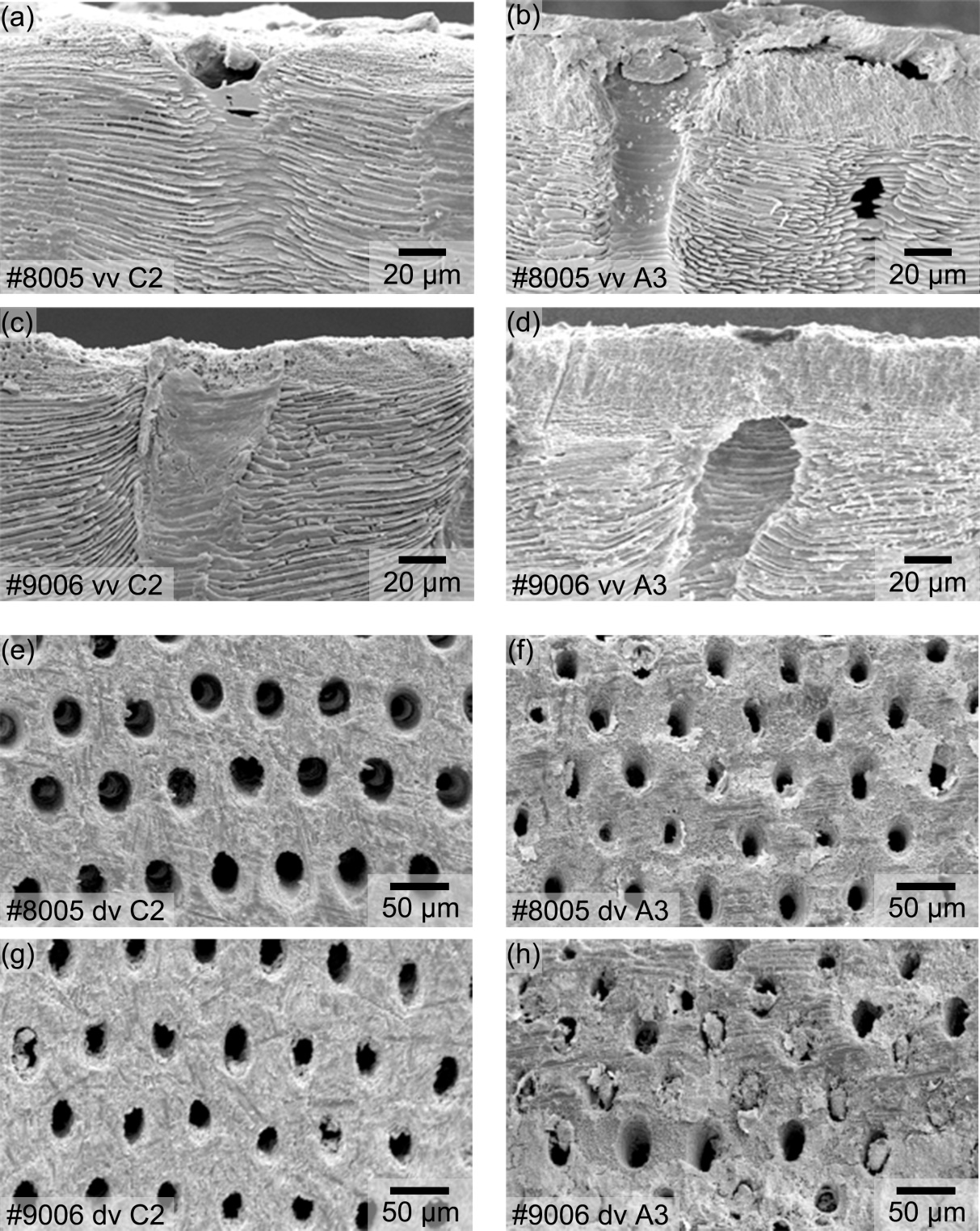
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| --- | --- | --- | --- | --- | --- | --- |
| Species  *n*(number of sample) | Growth Parameters | Shell repair/Microstructure/Oxygen consumption/Dissolution of shell/Microstructure | Method & Material | Environment/conditions  T=Temperature (℃)  S=Salinity (PSU)  *p*CO2 (μatm)/(ppm)/(kPa)/(Pa) | Duration of experiment | Source |
| Brachiopod *Calloria inconspicua* (Sowerby, 1846)  *n* = 123 | 1) ＞3 mm in length undamaged individuals were not affected  by lower pH;  2) ＜3 mm in length undamaged individuals grew faster at pH 7.62 than the control conditions | Shell growth rates and shell repair frequencies were not affected by low pH(＞80% of all damaged individuals repair after 12 weeks) | Culture experiment | (μatm)  a) pH 8.16, T 16.5, S 33.9, *p*CO2 465, Ωcalcite 3.5  b) pH 7.79, T 16.9, S 33.9, *p*CO2 1130, Ωcalcite 1.6  c) pH 7.62, T 16.6, S 33.9, *p*CO2 1536, Ωcalcite 1.3 | 12 weeks | Cross et al., 2016 |
| Brachiopod *Calloria inconspicua* (Sowerby, 1846)  *n*adult = 389 for shell morphology analyses\* |  | Punctae width decreased by 8.26%, shell density increased by 3.43%, no change in shell morphology, punctae density, shell thickness, and shell elemental composition (Ca, Mg, Na, Sr and P)  No changes were found in shell dissolution over the last 120 years. | Collected every decade from one site | (μatm)  Last two decades pH reduced 0.1 unit  Temperature varied from 10.7 – 13.0 ℃  *p*CO2 varied from 320 – 400  Salinity and Ωcalcite not provided | 120-year record | Cross et al., 2018 |
| Brachiopod *Liothyrella uva* (Broderip, 1833)  *n*= 156 | Not affected by lower pH and temperature | Shell repair frequencies were not affected by low pH and temperature (＞83% of individuals repair after 7 months) | Culture experiment | (μatm)  a) pH 7.98, T -0.3, S 35, *p*CO2 417, Ωcalcite 1.20  b) pH 8.05, T 1.7, S 35, *p*CO2 365, Ωcalcite 1.49  c) pH 7.75, T 1.9, S 35, *p*CO2 725, Ωcalcite 0.78  d) pH 7.54, T 2.2, S 35, *p*CO2 1221, Ωcalcite 0.50 | 7 months | Cross et al., 2015 |
| Brachiopod *Liothyrella uva* (Broderip, 1833)  Bivalve *Laternula elliptica* (King, 1832), *Yoldia eightsi* (Jay, 1839)  Gastropod *Nacella concinna* (Strebel, 1908)  *n*post-mortem = 25 |  | Significantly higher dissolution in gastropods and brachiopods at lower pH after 14 days. For the bivalves, the difference became significant after 28 days in *L. elliptica* and 35 days in *Y. eightsi* | Empty shells exposed to different treatment conditions | a) pH 7.4, T 4, S 35, Ωcalcite 0.74  b) pH 8.2, T 4, S 35, Ωcalcite 4.22  *p*CO2 Not provided | 14 to 63 days | McClintock et al., 2009 |
| Bivalves *Arctica islandica* (Linnaeus, 1767), *Mytilus edulis* (Linnaeus, 1758)  *n*young = 960 | Only marginal effects after *p*CO2 treatment on both species |  | Culture experiment | (μatm)  7.5, 10, 16, 20 and 25 °C for *M. edulis*;  7.5, 10 and 16 °C for *A. islandica*  15 different condition containers:  Five different temperature (7.5, 10, 16, 20, 25)  Three different *p*CO2 level (Low: 308.2 – 737.9; Medium: 768.6 – 1093.3; High: 1147.9 – 1654.5)  and three different pH conditions (High: 7.85 – 8.01; Medium: 7.76 – 7.86; Low: 7.63 – 7.73)  S: 16.4  Ωcalcite varied 0.5 – 2.1 | 13 weeks | Hiebenthal et al., 2013 |
| Bivalve *Arctica islandica* (Linnaeus, 1767)  *n*adult = 225 | No effect on shell growth | No effect on crystal microstructure | Culture experiment | (μatm)  a) pH 8.07, T 10.6, S 30.9, *p*CO2 524, Ωaragonite 1.68  b) pH 7.90, T 9.5, S 30.9, *p*CO2 800, Ωaragonite 1.14  c) pH 7.75, T 9.3, S 30.9, *p*CO2 1140, Ωaragonite 0.83 | 90 days | Stemmer et al., 2013 |
| Bivalve *Argopecten irradians* (Lamarck, 1819), *Crassostrea virginica* (Gmelin, 1791), *Mercenaria mercenaria* (Linnaeus, 1758)  *n* larva = 48 beakers with larvae  *n* juvenile = 120 | All species have lowest growth rates for individuals grown at 750 ppm CO2 and 28℃  *M. mercenaria* and *A. irradians* larvae reduce growth at higher *p*CO2  *C. virginica* and *A. irradians* juveniles reduce growth at higher *p*CO2, while *M. mercenaria* does not |  | Culture experiment | (ppm)  Larvae experiments for *M. mercenaria*, and *A. irradians* (12 different conditions)  Pre-industrial CO2: pH 8.2, T 24/28, S 28, *p*CO2 220 – 247, Ωcalcite 2.86 – 3.48  Ambient, present day CO2: pH 8.08 T 24/28, S 28, *p*CO2 374 – 387, Ωcalcite 2.66 – 3.17  Elevated CO2: pH 7.8 T 24/28, S 28, *p*CO2 756 – 795, Ωcalcite 1.51 – 1.78  Juveniles experiments (4 different conditions)  b1) pH 8.091, T 24, S 28, *p*CO2 400, Ωcalcite 2.99  b2) pH 7.620, T 24, S 28, *p*CO2 1665, Ωcalcite 1.42  b3) pH 8.092, T 28, S 28, *p*CO2 399.5, Ωcalcite 3.38  b4) pH 7.617, T 28, S 28, *p*CO2 1737, Ωcalcite 1.64 | 45 days | Talmage and Gobler, 2011 |
| Bivalves *Argopecten irradians* (Lamarck, 1819), *Mercenaria mercenaria* (Linnaeus, 1758)  *n*larva = 28 beakers with larvae  *n*juvenile = 480 | Larval stages: growth rates decrease at low pH  Later stages (juveniles) are not affected when hypoxia or acidification are applied separately; but growth rates decrease when juveniles are exposed to both conditions simultaneously |  | Culture experiment | (ppm)  a) larvae and first year juveniles, normal and low pH/low dissolved oxygen conditions via the delivery of varying mixtures of gas and air  (12 different conditions)  Control: pH 7.904 – 7.985, T 22, S 31 – 32, *p*CO2 448 – 590, Ωcalcite 2.87-3.06;  Low oxygen: pH 7.849 – 8.03, T 22, S 31 – 32, *p*CO2 417 – 534, Ωcalcite 2.92 – 3.37;  Low pH: pH 7.388 – 7.52, T 22, S 31 – 32, *p*CO2 1418 – 1970, Ωcalcite 1.10 – 1.30;  Low oxygen, Low pH: pH 7.365 – 7.55, T 22, S 31 – 32, *p*CO2 1428 – 1959, Ωcalcite 108 – 1.18;  b) larval stages, low pH and low dissolved oxygen obtained from a hypoxic and acidified ecosystem (3 different conditions)  b1) pH 7.365, T 24, S 25.3, *p*CO2 2620, Ωcalcite 0.377  b2) pH 7.934, T 24, S 25.3, *p*CO2 464, Ωcalcite 2.45  b3) pH 7.905, T 24, S 25.3, *p*CO2 520, Ωcalcite 2.97 | 30–40 days | Gobler et al., 2014 |
| Bivalve *Cerastoderma edule* (Linnaeus, 1758)  *n* = 15 | Growth is reduced in acidified conditions | Neither microstructure nor shell hardness were affected by different *p*CO2  Higher *p*CO2 could induce a severe dissolution of ontogenetically younger portions of the shell | Culture experiment | (μatm)  a) pH 7.8, T 6.2, S 17.6, *p*CO2 923.7, Ωaragonite 0.5  b) pH 7.4, T 6.2, S 17.7, *p*CO2 1461.9, Ωaragonite 0.3  c) pH 7.4, T 6.4, S 17.8, *p*CO2 2882.5, Ωaragonite 0.2  d) pH 7.0, T 6.3, S 17.8, *p*CO2 6630.1, Ωaragonite 0.1  e) pH 6.7, T 6.3, S 17.8, *p*CO2 12783.5, Ωaragonite 0.04  f) pH 6.4, T 6.3, S 17.8, *p*CO2 24381.1, Ωaragonite 0.02 | About 2 months | Milano et al., 2016 |
| Bivalve *Chlamys farreri*  *n*adult = 18-30 |  | Calcification and respiration decline under decreasing pH | Culture experiment | a) pH 8.08, T 16, S 28.1  b) pH 7.87, T 16, S 28.1  c) pH 7.58, T 16, S 28.1  d) pH 7.28, T 16, S 28.1  e) pH 6.96, T 16, S 28.1  *p*CO2 and Ωcalcite not provided | One week for acclimatation and 2 hours for culturing | Mingliang et al., 2011 |
| Bivalve *Chlamys nobilis* (Sowerby II, 1842), *Perna viridis* (Linnaeus, 1758), *Pinctada fucata* (Gould, 1850)  *n*adult = 180 |  | Little effect on the respiration rate of *P. viridis* and *P. fucata*, significantly reduced respiration at pH 7.4 on *C. nobilis* | Culture experiment | a) pH 8.1, T 25, S 32  b) pH 7.7, T 25, S 32  c) pH 7.3, T 25, S 32  *p*CO2 and Ωcalcite not provided | 5 days | Liu and He, 2012 |
| Bivalve *Crassostrea gigas* (Thunberg, 1793)  *n*control = 11  *n*CO2 = 37 |  | At the temperature of 15 °C, they have similar metabolism at different pH conditions (8.07 and 7.68). However, at higher temperatures, standard metabolism rates increase in both groups, but stronger increase at low pH condition | Culture experiment | (kPa)  a) pH 8.07, S 32.1, *p*CO2 0.059, Ωcalcite 3.59  b) pH 7.68, S 31.3, *p*CO2 0.15, Ωcalcite 1.36  temperature varied from 15 – 25 ℃ | up to 55 days | Lannig et al., 2010 |
| Bivalve *Crassostrea gigas* (Thunberg, 1793), *Saccostrea glomerata* (Gould, 1850)  *n* = 12 water baths with sperm and eggs |  | Elevated *p*CO2 reduces fertilization of gametes, reduces development, increases abnormality of D-veliger larvae and reduces growth of larvae and spat  *S. glomerata* has greater sensitivity than *C. gigas* | Culture experiment | (μatm)  pH varied from 7.82 – 8.21  Four different *p*CO2 (375, 600, 750, 1,000)  Four different temperature (18, 22, 26, 30℃)  S 35  Ωcalcite Not provided | 4 to 28 days | Parker et al., 2010 |
| Bivalve *Crassostrea virginica* (Gmelin, 1791)  *n*juvenile = ~600  *n*adult = 60 | High CO2 levels reduced both shell and soft-parts growth | High CO2 levels caused mortality rates increases in juveniles  High CO2 levels caused thickening of the calcite laths within the hypostracum and reduced hardness and fracture toughness of the shells  High CO2 levels can induce a doubling of standard metabolic rate in juveniles and ca 15% increase in adults | Culture experiment | (μatm)  a) pH 7.5, T 20, S 30.0, *p*CO2 3523.3, Ωcalcite 1.42  b) pH 8.3, T 20, S 30.1, *p*CO2 385.4, Ωcalcite 8.4 | 20 weeks for juveniles and 2 weeks for adults | Beniash et al., 2010 |
| Bivalve *Crassostrea virginica* *(*Gmelin, 1791)  *n*juvenile = 200 |  | Generally, no effect on the metabolic rate, the only exception is lower salinity of 15 combined elevated *p*CO2 condition can reduced acetate content levels of tissues | Culture experiment | (μatm)  a) pH 8.11, T 22.6, S 15.1, *p*CO2 470.4, Ωcalcite 1.94  b) pH 7.97, T 22.2, S 15.2, *p*CO2 676.5, Ωcalcite 1.56  c) pH 8.36, T 21.4, S 30.1, *p*CO2 392.1, Ωcalcite 9.09  d) pH 8.1, T 21.4, S 30.0, *p*CO2 802.3, Ωcalcite 5.58 | 11 weeks | Dickinson et al., 2012 |
| Bivalve *Laternula elliptica* (P. P. King, 1832)  *n*adult = 24 |  | Significantly higher rates in Oxygen consumption under lower pH conditions | Culture experiment | (ppm)  a) pH 8.316, T -1.76, S 34.1, *p*CO2 186.5, Ωaragonite 2.178  b) pH 7.993, T -1.76, S 34.1, *p*CO2 429.5, Ωaragonite 1.133  c) pH 7.775, T -1.76, S 34.1, *p*CO2 734.6, Ωaragonite 0.710 | 120 days | Cummings et al., 2011 |
| Bivalve *Mytilus chilensis* (Hupé, 1854)  *n*juvenile= 375 | Scope for growth negatively affected by elevated *p*CO2 | Oxygen uptake decreased at lower pH conditions | Culture experiment | (ppm)  a) pH 7.90, T 16.05, S 33.55, *p*CO2 405.22, Ωcalcite 3.70  b) pH 7.84, T 15.59, S 33.45, *p*CO2 676.23, Ωcalcite 2.36  c) pH 7.70, T 15.39, S 33.61, *p*CO2 981.92, Ωcalcite 1.76 | 70 days | Navarro et al., 2013 |
| Bivalve *Mytilus edulis* (Linnaeus, 1758)  *n*adult = 84 | Significant shell growth reductions at 550 and 750 μatm *p*CO2 | Uniform structural orientation at 380 μatm *p*CO2 condition; disorientation at higher *p*CO2 conditions | Culture experiment | (μatm)  a) pH 7.7, T 9.4, S 33, *p*CO2 376, Ωcalcite 0.29  b) pH 7.7, T 11.58, S 36, *p*CO2 376, Ωcalcite 0.39  c) pH 7.7, T 10.01, S 33, *p*CO2 554, Ωcalcite 0.47  d) pH 7.5, T 10.28, S 28, *p*CO2 769, Ωcalcite 0.21  e) pH 7.4, T 12.34, S 37, *p*CO2 769 Ωcalcite 0.21  f) pH 7.3, T 10.23, S 34, *p*CO2 1133 Ωcalcite 0.13  g) pH 7.2, T 12.04, S 37, *p*CO2 1133 Ωcalcite 0.13 | 6 months | Fitzer et al., 2014a |
| Bivalve *Mytilus edulis* (Linnaeus, 1758)  *n*Juvenile not provided |  | Juvenile shells at 1000 μatm *p*CO2 grow only calcite, others comprise both calcite and aragonite  At 380, 550 μatm *p*CO2 treatments,theyproduce uniform crystals of similar size and shape in calcite prismatic layers, at 750 and 1000 μatm *p*CO2 conditions, they produce less organised, thinner and disorientated calcite crystals  Nacreous tablets grow more rounded edges and are less well packed at 550 and 750 μatm *p*CO2 conditions | Culture experiment | (μatm)  a) T 9.4, S 32.78, *p*CO2 375.62, Ωcalcite 0.29  b) T 10.01, S 32.74, *p*CO2 553.59, Ωcalcite 0.47  c) T 10.28, S 28.42, *p*CO2 768.74, Ωcalcite 0.21  d) T 10.23, S 34.18, *p*CO2 1132.53, Ωcalcite 0.13  pH not provided | 6 months | Fitzer et al., 2014b |
| Bivalve *Mytilus edulis* (Linnaeus, 1758)  *n* = 500 | Growth may be affected by the pH levels. Within the pH range 7.4-8.1, growth of bivalves is not affected, but at pH 7.1 and pH 6.7, the growth rates of the shell are significantly lower (both in small and large size specimens) |  | Culture experiment | Five different pH conditions (~ pH 6.7, ~ pH 7.1, ~ pH 7.4, pH 7.6, pH 8.1)  S varied from 21.4 to 28.3  T varied from 16 to 24  *p*CO2 Not provided  Ωcalcite varied from 1.40 to 2.36 | 44 days | Berge et al., 2006 |
| Bivalve *Mytilus edulis* (Linnaeus, 1758)  *n*adult = 208 | Shell growth decreased but somatic growth not changed under lower pH conditions | Oxygen consumption rates increased when elevated *p*CO2 | Culture experiment | (pa)  a) pH 8.03, T 8, S 18.1, *p*CO2 47.8, Ωcalcite 1.86  b) pH 7.70, T 8, S 18.1, *p*CO2 92.2, Ωcalcite 1.02  c) pH 7.38, T 8, S 18.1, *p*CO2 204.3, Ωcalcite 0.50  d) pH 7.14, T 8, S 18.1, *p*CO2 377.8, Ωcalcite 0.27 | 2 months | Thomsen and Melzner, 2010 |
| Bivalve *Mytilus edulis* (Linnaeus, 1758)  *n* = 128 | higher *p*CO2 values decreased shell growth |  | Culture experiment | (μatm)  a) pH 8.01, T 4.8, S 16, *p*CO2 523.11, Ωcalcite 1.23  b) pH 7.69, T 4.7, S 16, *p*CO2 1174.53, Ωcalcite 0.58  c) pH 7.35, T 4.8, S 16, *p*CO2 2585.94, Ωcalcite 0.26  d) pH 7.15, T 4.9, S 16, *p*CO2 3908.52, Ωcalcite 0.17  e) pH 8.01, T 5.4, S 16, *p*CO2 542.85, Ωcalcite 1.26  f) pH 7.70, T 5.1, S 16, *p*CO2 1121.76, Ωcalcite 0.61  g) pH 7.40, T 5.0, S 16, *p*CO2 2309.58, Ωcalcite 0.30  h) pH 7.19, T 4.9, S 16, *p*CO2 3957.87, Ωcalcite 0.17 | About 7 weeks | Melzner et al., 2011 |
| Bivalve *Mytilus edulis* (Linnaeus, 1758)  *n*adult = 640 |  | There is a δ13C decreasing trend of ca 10‰ from pH 8.0 to pH 7.2 conditions | Culture experiment | (μatm)  a) pH 8.03, T 11.8, S 15.7, *p*CO2 612, Ωcalcite 1.47  b) pH 7.73, T 11.6, S 15.7, *p*CO2 1254, Ωcalcite 0.76  c) pH 7.46, T 11.6, S 15.7, *p*CO2 2360, Ωcalcite 0.42  d) pH 7.21, T 11.7, S 15.7, *p*CO2 4237, Ωcalcite 0.24 | 6–12 months | Hahn et al., 2014 |
| Bivalve *Mytilus edulis* (Linnaeus, 1758)  Field *n*young = 50  Culture *n*= 72 +32 | No effect on growth at moderately elevated *p*CO2 (1400 μatm) | No effect on metabolic at moderately elevated *p*CO2 (1400 μatm) | Field study and Culture experiment | (μatm)  Field: pH varied from 7.49 – 8.23  Temperature varied from 3.3 – 18.7 ℃  Salinity varied from 14.5 – 21.5  *p*CO2 varied from 385 – 2309  Ωcalcite varied from 0.35 – 0.96  Culture:  Experiment 1  Six *p*CO2 treatments (464, 661, 789, 1046, 1480, 4254) (μatm)  pH varied from 7.08 – 8.05, T 12.5, S 11.8  Ωcalcite varied from 0.22 – 1.77  Experiment 2  Three pH treatments *p*CO2 (493, 1332, 3898)  (μatm)  Ωcalcite varied from 0.28 – 1.94 pH varied from 7.26 – 8.13, T 13.8, S 15 | Field study 12 months  Culture experiment 2 weeks + 8 weeks | Thomsen et al., 2010 |
| Bivalve *Mytilus galloprovincialis* (Lamarck, 1819)  *n*adult = 200  *n*juvenile = 200 | Lower rate of shell growth at elevated *p*CO2 | Oxygen consumption decrease in lower pH condition | Culture experiment | *p*CO2 (Hg)  a) pH 8.05, T 18, S 32, *p*CO2 0.82  b) pH 7.3, T 18, S 32, *p*CO2 3.82  Ωcalcite not provided | 90 days | Michaelidis et al., 2005 |
| Bivalve *Mytilus galloprovincialis* (Lamarck, 1819)  *n*juvenile = 235 |  | There is no significant difference between different pH treatments | Culture experiment | (μatm)  a) pH 8.03, T 17.73, S 28.79, *p*CO2 963, Ωcalcite 5.53  b) pH 7.74, T 17.73, S 28.79, *p*CO2 1989, Ωcalcite 3.03  c) pH 7.48, T 17.73, S 28.79, *p*CO2 3790, Ωcalcite 1.72 | 78 days | Fernández-Reiriz et al., 2012 |
| Bivalve *Mytilus galloprovincialis* (Lamarck, 1819)  *n*juvenile = 1800 | Increased shell growth before 61 days at pH 7.3, reduced shell growth before 20 days at pH 7.6, after 84 days they are similar in shell growth among different pH conditions |  | Culture experiment | (μatm)  a) pH 7.88, T 16.5 – 17.73, S 28.79 – 28.87, *p*CO2 963 – 977, Ωcalcite 5.53 – 5.73  b) pH 7.59, T 16.5 – 17.73, S 28.79 – 28.87, *p*CO2 1989 – 2051, Ωcalcite 3.03  c) pH 7.30 – 7.33, T 16.5 – 17.73, S 28.79 – 28.87, *p*CO2 3790 – 4193, Ωcalcite 1.61 – 1.72 | 84 days | Range et al., 2012 |
| Bivalve *Mytilus galloprovincialis* (Lamarck, 1819)  *n*adult = Several |  | The calcite layer of the control specimen is well ordered, while that from acidified conditions is unordered  Calcite shell layer is thinner; nacreous shell layer is not formed in acidified condition | Field study | (μatm)  Control site:  pH 8.07, T 21, *p*CO2 474, Ωcalcite 5.42  Experimental site:  pH 7.25, T 20.7, *p*CO2 5494, Ωcalcite 1.37  Salinity not provided | 68 days | Hahn et al., 2012 |
| Bivalve *Ruditapes decussatus* (Linnaeus,  1758)  *n*juvenile = 900 |  | Significantly reduced the respiration rate after exposure to lower pH | Culture experiment | (μatm)  a) pH 8.13 – 8.16, T 21.6 – 22.97, S 30.59 – 31.36, *p*CO2 730 – 805, Ωcalcite 7.86 – 8.61  b) pH 7.82 – 7.84, T 21.6 – 22.97, S 30.59 – 31.36, *p*CO2 1698 – 1813, Ωcalcite 4.27 – 4.44  c) pH 7.46 – 7.53, T 21.6 – 22.97, S 30.59 – 31.36, *p*CO2 3702 – 4345, Ωcalcite 1.91 – 2.41 | 87 days | Fernández-Reiriz et al., 2011 |
| Bivalve *Ruditapes decussatus* (Linnaeus,  1758)  *n*juvenile = 900 | No effect on the shell growth |  | Culture experiment | (μatm)  a) pH 8.13 – 8.16, T 21.6 – 22.97, S 30.59 – 31.36, *p*CO2 730 – 805, Ωcalcite 7.86 – 8.61  b) pH 7.82 – 7.84, T 21.6 – 22.97, S 30.59 – 31.36, *p*CO2 1698 – 1813, Ωcalcite 4.27 – 4.44  c) pH 7.46 – 7.53, T 21.6 – 22.97, S 30.59 – 31.36, *p*CO2 3702 – 4345, Ωcalcite 1.91 – 2.41 | 75 days | Range et al., 2011 |
| Bivalve *Saccostrea glomerata* (Gould, 1850)  *n*adult = 25  *n* = 1000 | Shell growth reduced in both wild and bred population in higher *p*CO2 |  | Culture experiment | (ppm)  a) pH 8.2, T 25, S 35, *p*CO2 375, Ωcalcite 5.42  b) pH 7.84, T 25, S 35, *p*CO2 1000, Ωcalcite 1.80  c) pH 8.2, T 25, S 35, *p*CO2 375, Ωcalcite 5.38  d) pH 7.84, T 25, S 35, *p*CO2 1000, Ωcalcite 2.72 | 4 days | Parker et al., 2011 |
| Bivalve *Saccostrea glomerata* (Gould, 1850)  *n*adult = 600  *n*larva = 24×106 embryos | Reduced growth in larvae | Increased metabolic in adult | Culture experiment | (μatm)  Adults  a) pH 8.2, T 24, S 34.6, *p*CO2 380, Ωcalcite 5.2  b) pH 7.9, T 24, S 34.6, *p*CO2 856, Ωcalcite 2.9  Larvae  c) pH 8.2, T 24, S 34.6, *p*CO2 380, Ωcalcite 5.2  d) pH 7.9, T 24, S 34.6, *p*CO2 856, Ωcalcite 2.9 | Larvae 19 days  Adults 5 weeks | Parker et al., 2012 |
| Bivalve *Saccostrea glomerata* (Gould, 1850)  *n*6-month age = 480 | Growth rates were strongly influenced by exposure to acid sulfate soils runoff |  | Observation outside | 8 localities:  a) pH 6.41 – 6.80, T 14.6-24.0, S 27.8-31.4,  b) pH 6.15 – 6.64, T 14.8-24.5, S 28.5-30.9,  c) pH 7.94 – 8.01, T 15.7-23.8, S 29.1-32.5,  d) pH 7.77 – 7.95, T 15.6-24.2, S 28.8-32.0,  e) pH 6.73 – 6.93, T 15.7-23.0, S 30.4-36.3,  g) pH 6.50 – 6.83, T 15.9-22.5, S 29.8-36.6,  h) pH 7.85 – 7.95, T 15.5-24.9, S 31.6-37.1,  i) pH 7.71 – 7.91, T 16.2-22.7, S 29.5-36.8,  *p*CO2 Not provided  Ωcalcite Not provided | 20 weeks | Amaral et al., 2012 |
| Gastropod *Austrocochlea porcata* (A. Adams, 1853)and *Subninella undulata* (Lightfoot, 1786)  *n*adult = 140 |  | At low pH condition, *A. porcata* shows lower shell repair rate  *S. undulata* was not affected | Culture experiment | (ppm)  Three different pH conditions (pH 7.7, pH 7.9, pH 8.1)  Three different *p*CO2 (380, 560, 840)  pH 7.71 – 7.91, T 16.2 – 22.7, S 29.5 – 36.8,  T 20℃  S ‰ 35 to 37  Ωcalcite Not provided | From 25 to 95 days | Coleman et al., 2014 |
| Gastropod *Littorina littorea* (Linnaeus, 1758)  *n* not provided |  | Reduced metabolic rate | Culture experiment | Natural: pH 7.97  Culture: pH 6.63, T 15, S 35  *p*CO2 and Ωcalcite not provided | 15 days | Bibby et al., 2007 |
| Gastropod *Nucella lamellosa* (Gmelin, 1791)  *n* = 100 |  | Shell weight growth decreased trend in live was paralleled by shell weight loss in empty shells when increasing *p*CO2, thismay due to increased dissolution of existing shell | Culture experiment | (ppm)  a) pH 7.98, T 9, S 35, *p*CO2 385  b) pH 7.80, T 9, S 35, *p*CO2 785  c) pH 7.54, T 9, S 35, *p*CO2 1585  Ωcalcite not provided | 6 days | Nienhuis et al., 2010 |
| Gastropod *Patella vulgate* (Linnaeus 1758)  *n*adult = 20 |  | There is no effect in metabolism | Culture experiment | (μatm)  a) pH 8.24, T 13.8, S 35, *p*CO2 418, Ωcalcite 5.48  b) pH 7.53, T 13.8, S 35, *p*CO2 2803, Ωcalcite 1.4 | 5 days | Marchant et al., 2010 |
| Gastropod *Strombus luhuanus* (Linnaeus, 1758)  Echinoid *Hemicentrotus pulcherrimus* (A. Agassiz, 1864)  Echinoid *Echinometra*  *Mathaei* (Blainville, 1825)  *n*juvenile = 180 | Reduced growth rates in both echinoid and gastropod, and echinoid were more sensitive than gastropod |  | Culture experiment | Control: pH 7.936 – 7.945  Low pH: pH 7.897 – 7.902  temperature varied from 20 – 25.5 ℃  Salinity, *p*CO2 and Ωcalcite not provided | 6 months | Shirayama and Thornton, 2005 |
| Ophiuroid *Amphiura filiformis* (O.F. Müller, 1776)  *n*adult = 80 |  | Metabolic rate were significantly higher at low pH conditions | Culture experiment | Four pH treatments (8.0, 7.7, 7.3 and 6.8)  Temperature, salinity, *p*CO2 and Ωcalcite not provided | 40 days | Wood et al., 2008 |
| Echinoid *Sterechinus neumayeri* (Meissner, 1900)  *n*adult = 288 | No somatic growth in the adults over the 2 years experiment | Oxygen consumption at the start of the experiment (0 months) was higher under acidified conditions (7.7 and 7.5), but no other difference among treatments was observed in the longer term | Culture experiment | (μatm)  a) pH 7.98, T -0.3, S 34, *p*CO2 392, Ωcalcite 1.10  b) pH 7.99, T 1.8, S 35, *p*CO2 437, Ωcalcite 1.5  c) pH 7.70, T 2.1, S 35, *p*CO2 928, Ωcalcite 0.75  d) pH 7.53, T 2.4, S 35, *p*CO2 1405, Ωcalcite 0.54 | 2 years | Suckling et al., 2015 |
| Coral *Porites sp.* *Stylophora pistillata*  *n* = 20 fragments | Skeletal growth decreases under high *p*CO2 | δ18O enrichment and δ11B depletion under high *p*CO2, whereas δ13C results imply species-specific response to high *p*CO2 conditions | Culture experiment | (μatm)  a) pH 8.09, T 25, S 40.7, *p*CO2 387, Ωaragonite 3.99  b) pH 7.49, T 25, S 40.7, *p*CO2 1908, Ωaragonite 1.25  c) pH 7.19, T 25, S 40.7, *p*CO2 3976, Ωaragonite 0.65 | 6–14 months | Krief et al., 2010 |
| Echinoid *Paracentrotus lividus* (Lamarck, 1816) and *Arbacia lixula* (Linnaeus, 1758)  *n* = 670 |  | Not effect on the distribution of *A. lixula*, much reduced the density of *P. lividus*. Skeletal degradation an increase in skeletal manganese levels in both specis | Natural CO2 seeps and reference sites in the Sea. | (μatm)  C) pH 8.11, T 21.1, S 39.4, *p*CO2 615, Ωcalcite 5.54  V0) pH 7.48, T 20.6, S 39.2, *p*CO2 2700, Ωcalcite 2.89  V1) pH 7.75, T 20.6, S 39.3, *p*CO2 1398, Ωcalcite 3.40  V2) pH 7.50, T 20.5, S 39.3, *p*CO2 2541, Ωcalcite 3.19 | May and September 2012 | Bray et al., 2014 |
| Echinoid *Heliocidaris erythrogramma* (Valenciennes, 1846)  *n*juvenile = 2400 |  | Spine development was negatively affected increased temperature and acidification | Culture experiment | (μatm)  Four different pH treatments: pH8.1 (*p*CO2 396.8-404.3, Ωcalcite 4.7-5.2), pH7.8 (*p*CO2 1064.0-1099.5, Ωcalcite 2.3-2.6), pH7.6 (*p*CO2 1753.6-1820.4, Ωcalcite 1.5-1.7), pH7.4 (*p*CO2 2850.2-2909.0, Ωcalcite1.0-1.1);  Three different temperature treatments: 21, 23, 25; | 2 weeks | Wolfe et al., 2013 |

\*A subsample of 40 brachiopods (2-5 specimens per decade over the last 120 years) were used for further shell analysis on shell density, punctal width, punctal density, shell dissolution, shell thickness and shell elemental composition.

**Supplementary table 2: *t*-tests of the isotope data of *Magellania venosa* from different pH treatments. *n* = number of measurement. Population standard deviation (σ) was calculated using the Excel STDEV.P function. Significant values (*p*–value ≤ 0.05) are marked in bold. vv: ventral valve, dv: dorsal valve, for the position of zones (BC: before-culturing, DC: during-culturing) see Figure 10.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| δ¹³C (‰V-PDB) | *n* | Mean | σ | Min | Max | *P*-values |
| 9006vv BC | 13 | -2.76 | 1.67 | -8.05 | -1.36 | 9006vv BC vs DC: **≤0.001**  9006dv BC vs DC: **≤0.001**  8005vv BC vs DC: 0.086  8005dv BC vs DC: 0.083  9004vv BC vs DC: **0.001**  8004vv BC vs DC: 0.073  9005vv BC vs DC: 0.078  9006vv BC vs 8005vv BC: **0.001**  9006vv DC vs 8005vv DC: **≤0.001**  9006dv BC vs 8005dv BC: **0.004**  9006dv DC vs 8005dv DC: **0.004**  9004vv DC vs 8004vv DC: **≤0.001**  9005vv DC vs 8004vv DC: **0.002**  9004vv DC vs 9005vv DC: 0.893  9004vv DC vs 9006vv DC: 0.944  9006vv DC vs 9005vv DC: 0.830  8005vv DC vs 8004vv DC: **0.029** |
| 9006vv DC | 4 | -20.46 | 0.40 | -20.86 | -19.98 |
| 9006dv BC | 8 | -1.63 | 1.01 | -3.65 | -0.53 |
| 9006dv DC | 4 | -19.47 | 1.69 | -21.82 | -17.05 |
| 8005vv BC | 10 | -0.46 | 0.75 | -2.02 | 0.45 |
| 8005vv DC | 2 | -1.58 | 0.24 | -1.82 | -1.34 |
| 8005dv BC | 10 | -0.31 | 0.52 | -1.54 | 0.33 |
| 8005dv DC | 1 | -1.42 |  |  |  |
| 9004vv BC | 3 | -5.90 | 3.47 | -9.24 | -1.12 |
| 9004vv DC | 12 | -20.66 | 5.40 | -27.09 | -9.69 |
| 8004vv BC | 1 | -0.89 |  |  |  |
| 8004vv DC | 4 | -5.07 | 1.19 | -6.80 | -3.53 |
| 9005vv BC | 1 | -3.91 |  |  |  |
| 9005vv DC | 4 | -21.11 | 5.05 | -25.91 | -12.67 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| δ¹8O (‰V-PDB) | *n* | Mean | σ | Min | Max | *P*-values |
| 9006vv BC | 13 | -0.90 | 0.79 | -2.89 | -0.03 | 9006vv BC vs DC: **≤0.001**  9006dv BC vs DC: **≤0.001**  8005vv BC vs DC: **≤0.001**  8005dv BC vs DC: **≤0.001**  9004vv BC vs DC: 0.109  8004vv BC vs DC: **0.023**  9005vv BC vs DC: **0.007**  9006vv BC vs 8005vv BC: 0.294  9006vv DC vs 8005vv DC: 0.789  9006dv BC vs 8005dv BC: 0.709  9006dv DC vs 8005dv DC: 0.635  9004vv DC vs 8004vv DC: 0.645  9005vv DC vs 8004vv DC: 0.376  9004vv DC vs 9005vv DC: 0.282  9004vv DC vs 9006vv DC: 0.139  9006vv DC vs 9005vv DC: 0.775  8005vv DC vs 8004vv DC: 0.341 |
| 9006vv DC | 4 | -5.87 | 0.38 | -6.33 | -5.32 |
| 9006dv BC | 8 | -0.57 | 0.71 | -2.26 | 0.05 |
| 9006dv DC | 4 | -5.44 | 0.14 | -5.63 | -5.29 |
| 8005vv BC | 10 | -0.59 | 0.45 | -1.46 | 0.14 |
| 8005vv DC | 2 | -5.77 | 0.08 | -5.85 | -5.70 |
| 8005dv BC | 10 | -0.43 | 0.77 | -2.68 | 0.21 |
| 8005dv DC | 1 | -5.53 |  |  |  |
| 9004vv BC | 3 | -2.84 | 1.79 | -4.92 | -0.55 |
| 9004vv DC | 12 | -6.31 | 0.47 | -6.97 | -5.37 |
| 8004vv BC | 1 | -2.39 |  |  |  |
| 8004vv DC | 4 | -6.47 | 0.74 | -7.39 | -5.38 |
| 9005vv BC | 1 | -1.67 |  |  |  |
| 9005vv DC | 4 | -5.98 | 0.49 | -6.56 | -5.20 |



**Supplementary figure 1: microstructure of brachiopod shell under different pH treatments. (a)-(d): primary layer, (e)-(h): endopunctae.**

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