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Assessment framework to predict sensitivity of marine calcifiers to ocean alkalinity enhancement – identification of biological thresholds and importance of precautionary principle

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Table S1: Ten representative data points of chemical data for TA:DIC vs pH_T and Ω_{ar} from the experimental OA treatments (see Fig. S2).

TA:DIC	pH_T	Ω_{ar}
1.003	0.77	7.55
1.027	0.85	7.49
1.041	1.18	7.84
1.054	1.63	7.72
1.067	1.92	7.70
1.079	2.32	8.04
1.086	2.25	7.78
1.105	2.49	8.05
1.106	2.95	7.83
1.119	3.04	8.00
1.133	3.21	8.06
1.140	3.21	8.02
1.149	3.25	8.15
1.172	4.28	8.04
1.180	4.52	8.01

Table S2: Inflection points of the quadratic regressions for the parabolic responders. This indicates at what TA:DIC the calcification rate changes slope (i.e. at what TA:DIC the calcification rate starts decreasing with increasing TA:DIC).

Group	Species	Rate unit	Inflection point (TA:DIC)
Algae	*Halimeda macroloba*	mmol/g/hr	1.15
Algae	*Halimeda macroloba*	mmol/hr	1.08
Algae	*Neogoniolithon sp.*	mmol/g/hr	1.09
Algae	*Sporolithon durum*	mmol/m²/hr	1.15
Coccolithophore	*Emiliania huxleyi*	mmol/#/hr	1.23
Coral	*Acropora pulchra*	mmol/m²/hr	1.19
Coral	*Oculina arbuscula*	mmol/g/hr	1.10
Coral	*Pavona cactus*	mmol/m²/hr	1.19
Dinoflagellate	*Thoracosphaera heimii*	mmol/hr	1.13
Echinoderm	*Arbacia punctulata*	mmol/g/hr	1.04
Foraminifera	*Amphistegina lessonii*	%/hr	1.10
Gastropod	*Crepidula fornicata*	mmol/g/hr	1.09
Gastropod	*Nassarius corniculus*	mmol/g/hr	1.06
Pteropod	*Limacina helicina*	µm (shell thickness)	1.07

Table S3: Current calcification rate baselines computed for each species included in this study. Each baseline was computed using a pH of 8.1 and a pCO_2 of 425 ppm, using the average temperature and salinity at which experiments were done per species rate group, $[SiO_2]$ = 50 umol/kg, $[PO_4^{3-}]$ = 0.5 umol/kg). Calculations were carried out with the Python version of CO2SYS (Humphreys et al., 2022) using the stoichiometric dissociation constants for carbonic acid from Sulpis et al. (2020), for sulfuric acid by Dickson et al. (1990) and for total boron from Uppström (1974).

Group	Species	Rate	Average Temperature [°C]	Average Salinity	Baseline
Algae	*Amphiroa tribulus*	mmol/m²/hr	30.98	36.19	1.197
Algae	*Halimeda cylindracea*	mmol/hr	31.00	33.00	1.183
Algae	*Halimeda macroloba*	mmol/g/hr	27.23	36.27	1.176
Algae	*Halimeda macroloba*	mmol/m²/hr	25.22	34.40	1.158
Algae	*Halimeda macroloba*	mmol/hr	31.00	33.00	1.183
Algae	*Halimeda minima*	mmol/g/hr	27.24	36.31	1.176
Algae	*Halimeda opuntia*	mmol/m²/hr	25.22	34.40	1.158
Algae	*Hydrolithon reinboldii*	mmol/g/hr	26.98	36.00	1.173
Algae	*Hydrolithon reinboldii*	mmol/m²/hr	26.50	36.20	1.172
Algae	*Lithophyllum flavescens*	mmol/g/hr	27.23	36.28	1.176
Algae	*Lithophyllum sp.*	mmol/g/hr	28.97	32.20	1.168
Algae	*Lithothamnion sp.*	mmol/m²/hr	30.98	36.19	1.197
Algae	*Neogoniolithon brassica-florida*	mmol/m²/hr	29.99	38.00	1.199
Algae	*Neogoniolithon sp.*	mmol/g/hr	25.00	31.70	1.146
Algae	*Neogoniolithon sp.*	mmol/m²/hr	22.13	35.35	1.146
Algae	*Porolithon onkodes*	mmol/m²/hr	27.26	35.74	1.174
Algae	*Sporolithon durum*	mmol/m²/hr	20.60	35.87	1.140
Annelid	*Hydroides crucigera*	mmol/g/hr	25.01	31.63	1.146
Coccolithophore	*Calcidiscus leptoporus*	mmol/#/hr	19.75	32.25	1.124
Coccolithophore	*Emiliania huxleyi*	mmol/#/hr	17.30	35.12	1.123
Coccolithophore	*Pleurochrysis carterae*	mmol/m³/hr	25.00	35.00	1.159
Coccolithophore	*Pleurochrysis carterae*	mmol/#	16.56	32.10	1.110
Coral	*Acropora millepora*	mmol/m²/hr	25.22	34.40	1.158
Coral	*Acropora pulchra*	mmol/m²/hr	27.30	36.27	1.176
Coral	*Acropora solitaryensis*	mmol/m²/hr	19.83	34.00	1.130
Coral	*Acropora yongei*	mmol/m²/hr	20.60	35.87	1.140
Coral	*Duncanopsammia axifuga*	mmol/m²/hr	27.00	35.00	1.170
Coral	*Goniopora sp.*	mmol/m²/hr	26.50	36.20	1.172
Coral	*Lophelia pertusa*	mmol/g/hr	7.50	34.60	1.082
Coral	*Montastraea cavernosa*	mmol/m²/hr	27.00	35.00	1.170
Coral	*Oculina arbuscula*	mmol/g/hr	25.01	31.61	1.146
Coral	*Pavona cactus*	mmol/m²/hr	27.23	36.28	1.176
Coral	*Plesiastrea versipora*	mmol/m²/hr	20.64	36.30	1.142
Coral	*Pocillopora damicornis*	mmol/g/hr	27.42	35.00	1.172

Group	Species	Rate	Average Temperature [°C]	Average Salinity	Baseline
Coral	*Pocillopora damicornis*	mmol/m²/hr	25.77	35.86	1.166
Coral	*Pocillopora verrucosa*	mmol/m²/hr	27.01	35.61	1.172
Coral	*Porites heronensis*	mmol/m²/hr	19.83	34.00	1.130
Coral	*Porites rus*	mmol/m²/hr	27.23	36.28	1.176
Coral	*Siderastrea radians*	mmol/m²/hr	25.73	37.55	1.173
Coral	*Solenastrea hyades*	mmol/m²/hr	25.43	38.18	1.174
Coral	*Stylophora pistillata*	mmol/m²/hr	25.83	40.00	1.183
Crustacean	*Amphibalanus improvisus*	mmol/g/hr	19.50	17.00	1.074
Crustacean	*Callinectes sapidus*	mmol/g/hr	25.00	31.95	1.147
Crustacean	*Homarus americanus*	mmol/g/hr	25.02	31.96	1.147
Crustacean	*Penaeus plebejus*	mmol/g/hr	25.00	31.95	1.147
Crustacean	*Semibalanus balanoides*	mmol/g/hr	7.41	33.65	1.079
Dinoflagellate	*Alexandrium sp.*	1/hr	18.00	35.00	1.125
Dinoflagellate	*Ceratium lineatum*	#/hr	15.00	30.00	1.098
Dinoflagellate	*Gonyaulax sp.*	1/hr	18.00	35.00	1.125
Dinoflagellate	*Heterocapsa triquetra*	#/hr	15.00	30.00	1.098
Dinoflagellate	*Karenia mikimotoi*	1/hr	25.00	30.00	1.140
Dinoflagellate	*Lingulodinium polyedrum*	1/hr	18.00	35.00	1.125
Dinoflagellate	*Prorocentrum micans*	1/hr	18.00	35.00	1.125
Dinoflagellate	*Prorocentrum minimum*	#/hr	15.00	30.00	1.098
Dinoflagellate	*Symbiodinium sp.*	#/hr	26.00	35.00	1.164
Dinoflagellate	*Thoracosphaera heimii*	mmol/hr	15.00	34.00	1.109
Echinoderm	*Arbacia punctulata*	mmol/g/hr	25.01	31.78	1.147
Echinoderm	*Echinometra viridis*	%	25.53	32.07	1.150
Echinoderm	*Echinometra viridis*	%/hr	25.20	32.07	1.149
Echinoderm	*Eucidaris tribuloides*	mmol/g/hr	25.01	31.78	1.147
Foraminifera	*Ammonia sp.*	mmol/#/hr	26.00	32.75	1.155
Foraminifera	*Amphistegina lessonii*	%/hr	24.18	33.46	1.149
Foraminifera	*Globigerinella siphonifera*	mmol/#/hr	24.56	38.31	1.169
Foraminifera	*Globigerinoides ruber*	mmol/#/hr	24.86	36.08	1.162
Foraminifera	*Marginopora rossi*	%/hr	25.00	35.00	1.159
Foraminifera	*Marginopora vertebralis*	mmol/g/hr	28.50	35.10	1.178
Foraminifera	*Marginopora vertebralis*	mmol/hr	31.00	33.00	1.183
Foraminifera	*Marginopora vertebralis*	%/hr	24.18	33.46	1.149
Foraminifera	*Neogloboquadrina pachyderma*	mmol/#/hr	2.56	34.50	1.064
Foraminifera	*Operculina ammonoides*	mmol/g/hr	25.00	37.00	1.167
Gastropod	*Concholepas concholepas*	mmol/g/hr	17.40	34.58	1.121
Gastropod	*Crepidula fornicata*	mmol/g/hr	15.31	34.33	1.112
Gastropod	*Cyclope neritea*	mmol/g/hr	21.93	38.00	1.154
Gastropod	*Littorina littorea*	mmol/g/hr	24.96	31.80	1.147
Gastropod	*Littorina littorea*	Calc rate (shell thickness) [µm	15.00	35.00	1.112
Gastropod	*Nassarius corniculus*	mmol/g/hr	22.16	38.00	1.156
Gastropod	*Strombus alatus*	mmol/g/hr	24.96	31.80	1.147
Gastropod	*Urosalpinx cinerea*	mmol/g/hr	24.95	31.80	1.147
Mollusks	*Argopecten irradians*	mmol/g/hr	25.04	31.92	1.147
Mollusks	*Argopecten purpuratus*	mmol/g/hr	18.33	34.00	1.124

Group	Species	Rate	Average Temperature [°C]	Average Salinity	Baseline
Mollusks	*Azumapecten farreri*	mmol/g/hr	16.00	28.00	1.096
Mollusks	*Cerastoderma edule*	mmol/g/hr	16.75	34.39	1.118
Mollusks	*Chamelea gallina*	mmol/g/hr	23.09	33.93	1.146
Mollusks	*Crassostrea gigas*	mmol/g/hr	20.00	30.00	1.118
Mollusks	*Crassostrea virginica*	mmol/g/hr	25.07	27.33	1.130
Mollusks	*Mercenaria mercenaria*	mmol/g/hr	25.05	31.92	1.147
Mollusks	*Mya arenaria*	mmol/g/hr	25.06	31.87	1.147
Mollusks	*Mytilus californianus*	mmol/m²/hr	14.42	29.33	1.094
Mollusks	*Mytilus edulis*	mmol/g/hr	23.29	31.24	1.137
Mollusks	*Mytilus galloprovincialis*	mmol/g/hr	18.50	37.98	1.137
Mollusks	*Pecten maximus*	mmol/g/hr	10.61	35.23	1.095
Pteropod	*Cavolinia inflexa*	mm (shell length)	13.00	38.00	1.112
Pteropod	*Limacina helicina*	mmol/g/hr	2.67	34.55	1.065
Pteropod	*Limacina helicina*	mm (shell length)	5.15	34.53	1.073
Pteropod	*Limacina helicina*	µm (shell thickness)	10.50	32.34	1.087
Pteropod	*Limacina retroversa*	mm (shell length)	4.32	34.30	1.070

Table S4: Studies with negative responders (linear and threshold negative, parabolic) with demonstrated TA:DIC thresholds, indicating the amount of Na_2CO_3 needed to halve the current calcification rate (i.e. at the baseline). The value for TA:DIC threshold is used to determine the pH and Ω_{ar} (at average temperature and average salinity per species).

Studies	Group	Species	Temp (°C)	Salinity	Rate unit	Threshold	TA addition	pH at threshold	ΔpH from baseline	Ω_{ar} at threshold	Exposure time
Noisette et al. (2016), Ries et al. (2009)	Gastropod	*Crepidula fornicata*	15.31	34.33	mmol/g/hr	1.14	150	8.20	0.10	4.08	6 months 60 days
Ries et al. (2009)	Algae	*Neogoniolithon sp.*	25.00	31.70	mmol/g/hr	1.16	100	8.16	0.06	4.90	60 days
Ries et al. (2009)	Crustacean	*Homarus americanus*	25.02	31.96	mmol/g/hr	1.19	250	8.23	0.13	5.87	60 days
Ries et al. (2009)	Coral	*Oculina arbuscula*	25.01	31.61	mmol/g/hr	1.20	300	8.25	0.15	6.16	60 days
Prazeres et al. (2015)	Foraminifera	*Amphistegina lessonii*	24.18	33.46	%/hr	1.21	350	8.27	0.17	6.51	30 days
Hansen et al. (2007)	Dinoflagellate	*Ceratium lineatum*	15.00	30.00	#/hr	1.18	500	8.40	0.30	5.89	14 d acclimation to irradiance; 7 days acclimation to experimental conditions; 14 days exposure to irradiance; 22 days stationary growth phase
Sinutok et al. (2011)	Algae	*Halimeda macroloba*	27.23	36.27	mmol/g/hr	1.25	500	8.30	0.20	8.18	2 weeks acclimation, 2 weeks incubation
Comeau et al. (2019)	Algae	*Sporolithon durum*	20.60	35.87	mmol/m²/hr	1.22	500	8.33	0.23	7.06	27 weeks
Van de Waal et al. (2013)	Dinoflagellate	*Thoracosphaera heimii*	15.00	34.00	mmol/hr	1.23	800	8.48	0.38	8.01	21 days acclimation, 8 days experiment = total of >10 generations
Oron et al. (2020)	Foraminifera	*Operculina ammonoides*	25.00	37.00	mmol/g/hr	1.34	1250	8.50	0.40	12.76	65 - 120 hours
Prazeres et al. (2015)	Foraminifera	*Marginopora vertebralis*	24.18	33.46	%/hr	1.34	1400	8.57	0.47	13.58	30 days
Camp et al. (2017), Comeau et al. (2013)	Coral	*Acropora pulchra*	27.30	36.27	mmol/m²/hr	1.38	1600	8.56	0.46	15.63	n/a (natural conditions) 2 weeks acclimation; 2 weeks incubation
Hansen et	Dinofla	*Heterocapsa*	15.00	30.00	#/hr	1.30	1450	8.70	0.60	12.20	14 d acclimation to irradiance; 7 days

al. (2007)	gellate	*triquetra*									acclimation to experimental conditions; 14 days exposure to irradiance; 22 days stationary growth phase
Comeau et al. (2013)	Coral	*Pavona cactus*	27.23	36.28	mmol/m²/hr	1.38	1600	8.56	0.46	15.61	2 weeks acclimation; 2 weeks incubation
Hansen et al. (2007)	Dinoflagellate	*Prorocentrum minimum*	15.00	30.00	#/hr	1.38	2200	8.85	0.75	17.46	14 d acclimation to irradiance; 7 days acclimation to experimental conditions; 14 days exposure to irradiance; 22 days stationary growth phase
*	Coccolithophore	*Emiliania huxleyi*	17.30	35.12	mmol/#/hr	1.46	3100	8.89	0.79	24.16	**
Keul et al. (2013)	Foraminifera	*Ammonia sp.*	26.00	32.75	mmol/#/hr	1.73	10000	9.27	1.17	79.41	59-96 days of culturing

*Barcelos-Ramos et al. (2010), Fiorini et al. (2011), Iglesias-Rodriguez et al. (2008), Richier et al. (2011), Sciandra et al. (2003), Stoll et al. (2012), Gafar et al. (2018), Bach et al. (2011), Sett et al. (2014).

**26hrs, Acclimation for 7 generations, experiment/sampling for 2-3 generations, n/a, 8 days, 16 days, Acclimation for 12 generations, Pre-acclimation for 8-12 generations, 9 generations, Acclimated for at ~7 generations (5-15 days)

Table S5: Temperature and salinity ranges for experimental OA studies per species rate group.

Group	Species	Rate unit	Min. Temp (°C)	Max. Temp (°C)	Temp Range	Min. Sal	Max. Sal	Sal Range
Algae	*Amphiroa tribulus*	mmol/m²/hr	29.98	32.00	2.02	36.19	36.19	0.00
Algae	*Halimeda cylindracea*	mmol/hr	28.00	34.00	6.00	33.00	33.00	0.00
Algae	*Halimeda macroloba*	mmol/g/hr	27.10	27.30	0.20	36.10	36.40	0.30
Algae	*Halimeda macroloba*	mmol/hr	25.00	25.40	0.40	34.40	34.40	0.00
Algae	*Halimeda macroloba*	mmol/m²/hr	28.00	34.00	6.00	33.00	33.00	0.00
Algae	*Halimeda minima*	mmol/g/hr	27.10	27.30	0.20	36.10	36.40	0.30
Algae	*Halimeda opuntia*	mmol/m²/hr	25.00	25.40	0.40	34.40	34.40	0.00
Algae	*Hydrolithon reinboldii*	mmol/m²/hr	26.90	27.10	0.20	36.00	36.00	0.00
Algae	*Hydrolithon reinboldii*	mmol/g/hr	26.50	26.50	0.00	36.20	36.20	0.00
Algae	*Lithophyllum flavescens*	mmol/g/hr	27.10	27.30	0.20	36.10	36.40	0.30
Algae	*Lithophyllum sp.*	mmol/g/hr	28.80	29.20	0.40	32.20	32.20	0.00
Algae	*Lithothamnion sp.*	mmol/m²/hr	29.98	32.00	2.02	36.19	36.19	0.00
Algae	*Neogoniolithon brassica-florida*	mmol/m²/hr	28.22	31.61	3.39	38.00	38.00	0.00
Algae	*Neogoniolithon sp.*	mmol/g/hr	24.90	25.10	0.20	31.50	31.80	0.30
Algae	*Neogoniolithon sp.*	mmol/m²/hr	20.40	32.00	11.60	35.20	36.19	0.99
Algae	*Porolithon onkodes*	mmol/m²/hr	26.90	27.50	0.60	35.30	36.10	0.80
Algae	*Sporolithon durum*	mmol/m²/hr	20.40	20.90	0.50	35.20	36.30	1.10
Annelid	*Hydroides crucigera*	mmol/g/hr	24.90	25.20	0.30	31.50	31.70	0.20
Coccolithophore	*Calcidiscus leptoporus*	mmol/#/hr	19.00	20.00	1.00	32.00	33.00	1.00
Coccolithophore	*Emiliania huxleyi*	mmol/#/hr	10.00	20.00	10.00	32.00	38.20	6.20
Coccolithophore	*Pleurochrysis carterae*	mmol/m³/hr	25.00	25.00	0.00	35.00	35.00	0.00
Coccolithophore	*Pleurochrysis carterae*	mmol/#	25.00	25.00	0.00	35.00	35.00	0.00
Coral	*Acropora millepora*	mmol/m²/hr	25.00	25.40	0.40	34.40	34.40	0.00
Coral	*Acropora pulchra*	mmol/m²/hr	27.10	30.90	3.80	35.40	36.40	1.00
Coral	*Acropora solitaryensis*	mmol/m²/hr	18.00	21.30	3.30	34.00	34.00	0.00
Coral	*Acropora yongei*	mmol/m²/hr	20.40	20.90	0.50	35.20	36.30	1.10
Coral	*Duncanopsammia*	mmol/m²/hr	27.00	27.00	0.00	35.00	35.00	0.00

	axifuga							
Coral	*Goniopora sp.*	mmol/m²/hr	26.50	26.50	0.00	36.20	36.20	0.00
Coral	*Lophelia pertusa*	mmol/g/hr	7.50	7.50	0.00	34.60	34.60	0.00
Coral	*Montastraea cavernosa*	mmol/m²/hr	27.00	27.00	0.00	35.00	35.00	0.00
Coral	*Oculina arbuscula*	mmol/g/hr	24.90	25.20	0.30	31.50	31.70	0.20
Coral	*Pavona cactus*	mmol/m²/hr	27.10	27.30	0.20	36.10	36.40	0.30
Coral	*Plesiastrea versipora*	mmol/m²/hr	20.50	20.90	0.40	36.30	36.30	0.00
Coral	*Pocillopora damicornis*	mmol/g/hr	27.42	27.42	0.00	35.00	35.00	0.00
Coral	*Pocillopora damicornis*	mmol/m²/hr	20.40	29.34	8.94	35.06	36.40	1.34
Coral	*Pocillopora verrucosa*	mmol/m²/hr	26.98	27.04	0.06	35.55	35.66	0.11
Coral	*Porites heronensis*	mmol/m²/hr	18.00	21.30	3.30	34.00	34.00	0.00
Coral	*Porites rus*	mmol/m²/hr	27.10	27.30	0.20	36.10	36.40	0.30
Coral	*Siderastrea radians*	mmol/m²/hr	20.02	30.75	10.73	32.24	47.25	15.00
Coral	*Solenastrea hyades*	mmol/m²/hr	20.02	30.75	10.73	32.24	47.25	15.00
Coral	*Stylophora pistillata*	mmol/m²/hr	23.33	28.33	5.00	40.00	40.00	0.00
Crustacean	*Amphibalanus improvisus*	mmol/g/hr	19.50	19.50	0.00	17.00	17.00	0.00
Crustacean	*Callinectes sapidus*	mmol/g/hr	24.90	25.10	0.20	31.80	32.10	0.30
Crustacean	*Homarus americanus*	mmol/g/hr	24.90	25.10	0.20	31.80	32.10	0.30
Crustacean	*Penaeus plebejus*	mmol/g/hr	24.90	25.10	0.20	31.80	32.10	0.30
Crustacean	*Semibalanus balanoides*	mmol/g/hr	4.92	9.80	4.88	33.50	33.70	0.20
Dinoflagellate	*Alexandrium sp.*	1/hr	18.00	18.00	0.00	35.00	35.00	0.00
Dinoflagellate	*Ceratium lineatum*	#/hr	15.00	15.00	0.00	30.00	30.00	0.00
Dinoflagellate	*Gonyaulax sp.*	1/hr	18.00	18.00	0.00	35.00	35.00	0.00
Dinoflagellate	*Heterocapsa triquetra*	#/hr	15.00	15.00	0.00	30.00	30.00	0.00
Dinoflagellate	*Karenia mikimotoi*	1/hr	25.00	25.00	0.00	30.00	30.00	0.00
Dinoflagellate	*Lingulodinium polyedrum*	1/hr	18.00	18.00	0.00	35.00	35.00	0.00
Dinoflagellate	*Prorocentrum micans*	1/hr	18.00	18.00	0.00	35.00	35.00	0.00
Dinoflagellate	*Prorocentrum minimum*	#/hr	15.00	15.00	0.00	30.00	30.00	0.00
Dinoflagellate	*Symbiodinium sp.*	#/hr	26.00	26.00	0.00	35.00	35.00	0.00
Dinoflagellate	*Thoracosphaera heimii*	mmol/hr	15.00	15.00	0.00	34.00	34.00	0.00
Echinoderm	*Arbacia punctulata*	mmol/g/hr	24.90	25.10	0.20	31.70	31.90	0.20
Echinoderm	*Echinometra viridis*	%	19.70	30.20	10.50	32.00	32.12	0.12
Echinoderm	*Echinometra viridis*	1/hr	20.30	30.00	9.70	32.00	32.12	0.12
Echinoderm	*Eucidaris tribuloides*	mmol/g/hr	24.90	25.10	0.20	31.70	31.90	0.20
Foraminifera	*Ammonia sp.*	mmol/#/hr	26.00	26.00	0.00	32.60	32.80	0.20
Foraminifera	*Amphistegina lessonii*	%/hr	24.10	24.20	0.10	33.46	33.46	0.00
Foraminifera	*Globigerinella siphonifera*	mmol/hr	18.00	31.00	13.00	32.10	44.30	12.20
Foraminifera	*Globigerinoides ruber*	mmol/hr	18.00	30.00	12.00	32.10	44.30	12.20
Foraminifera	*Marginopora rossi*	%/hr	25.00	25.00	0.00	35.00	35.00	0.00
Foraminifera	*Marginopora vertebralis*	%/hr	28.50	28.50	0.00	35.00	35.20	0.20
Foraminifera	*Marginopora vertebralis*	mmol/hr	28.00	34.00	6.00	33.00	33.00	0.00
Foraminifera	*Marginopora vertebralis*	mmol/g/hr	24.10	24.20	0.10	33.46	33.46	0.00
Foraminifera	*Neogloboquadrina pachyderma*	mmol/#/hr	1.05	4.10	3.05	34.50	34.50	0.00

Foraminifera	*Operculina ammonoides*	mmol/g/hr	25.00	25.00	0.00	37.00	37.00	0.00
Gastropod	*Concholepas concholepas*	mmol/g/hr	15.62	19.27	3.65	34.53	34.61	0.08
Gastropod	*Crepidula fornicata*	mmol/g/hr	9.50	25.10	15.60	31.70	34.60	2.90
Gastropod	*Cyclope neritea*	mmol/g/hr	20.00	24.03	4.03	38.00	38.00	0.00
Gastropod	*Littorina littorea*	µm (shell thickness)	24.90	25.10	0.20	31.70	31.90	0.20
Gastropod	*Littorina littorea*	mmol/g/hr	15.00	15.00	0.00	35.00	35.00	0.00
Gastropod	*Nassarius corniculus*	mmol/g/hr	20.00	24.03	4.03	38.00	38.00	0.00
Gastropod	*Strombus alatus*	mmol/g/hr	24.90	25.10	0.20	31.70	31.90	0.20
Gastropod	*Urosalpinx cinerea*	mmol/g/hr	24.90	25.10	0.20	31.70	31.90	0.20
Mollusks	*Argopecten irradians*	mmol/g/hr	25.00	25.10	0.10	31.70	32.10	0.40
Mollusks	*Argopecten purpuratus*	mmol/g/hr	18.29	18.37	0.08	34.00	34.00	0.00
Mollusks	*Azumapecten farreri*	mmol/g/hr	16.00	16.00	0.00	28.00	28.00	0.00
Mollusks	*Cerastoderma edule*	mmol/g/hr	15.71	17.87	2.16	33.86	34.71	0.85
Mollusks	*Chamelea gallina*	mmol/g/hr	23.00	23.10	0.10	33.92	33.93	0.01
Mollusks	*Crassostrea gigas*	mmol/g/hr	20.00	20.00	0.00	30.00	30.00	0.00
Mollusks	*Crassostrea virginica*	mmol/g/hr	20.00	32.00	12.00	16.00	32.10	16.10
Mollusks	*Mercenaria mercenaria*	mmol/g/hr	25.00	25.10	0.10	31.70	32.10	0.40
Mollusks	*Mya arenaria*	mmol/g/hr	25.00	25.10	0.10	31.70	32.10	0.40
Mollusks	*Mytilus californianus*	mmol/m²/hr	11.41	16.56	5.15	27.16	30.22	3.06
Mollusks	*Mytilus edulis*	mmol/g/hr	20.00	25.10	5.10	30.00	32.10	2.10
Mollusks	*Mytilus galloprovincialis*	mmol/g/hr	37.92	38.00	0.08	37.92	38.00	0.08
Mollusks	*Pecten maximus*	mmol/g/hr	8.90	12.40	3.50	34.88	35.64	0.76
Pteropod	*Cavolinia inflexa*	mm (shell length)	13.00	13.00	0.00	38.00	38.00	0.00
Pteropod	*Limacina helicina*	µm (shell thickness)	0.50	5.00	4.50	34.50	34.80	0.30
Pteropod	*Limacina helicina*	mmol/g/hr	2.00	7.80	5.80	34.30	34.70	0.40
Pteropod	*Limacina helicina*	mm (shell length)	9.07	11.52	2.45	31.73	33.13	1.40
Pteropod	*Limacina retroversa*	mm (shell length)	2.00	7.00	5.00	34.30	34.30	0.00

Table S6: Regression analyses with fitted second-order polynomial equation exploring TA:DIC and Ω_{ar} correlation over the 0-50 using various regional datasets and global GLODAP datasets. Shown are the coefficients for the second-order polynomial equation (see also Fig. 1), as well as goodness of fit (R2), significance (p), standard error of regression (ser) and number of observations (#).

Region	b1	b2	b3	b4	rsquared	pvalue	ser	#obs
Arctic	66.84	-206.99	199.39	-58.81	0.96	0	0.094	8991
N-Pacific	346.73	-972.25	896.08	-269.98	0.991	0	0.05	6085
C-Pacific	297.07	-817.72	737.24	-215.9	0.99	0	0.063	13101
N-Atlantic	411.4	-1135.05	1030.06	-305.76	0.993	0	0.044	4914
C-Atlantic	166.02	-500.37	483.06	-148.61	0.968	0	0.109	5466
Indian	189.24	-528.16	479.47	-139.8	0.971	0	0.063	3560
Southern	436.42	-1216.31	1116.76	-336.22	0.997	0	0.022	7052
Global	86.94	-254.47	233.73	-65.8	0.99	0	0.095	56138

Figure S1: The effect of changes in TA and DIC on the properties of seawater (S= 34.68, T=16°C, [SiO_2] = 50 umol/kg, [PO_4^{3-}] = 0.5 umol/kg, TA = 2303 µmol/kg, DIC = 2034 µmol/kg), adapted from Schulz et al. (2023). Orange dots represent GLODAP data for surface waters (0-50m depth). Subfigures show pH_T, aragonite saturation state and pCO_2. Calculations were carried out with the Python version of CO2SYS (Humphreys et al., 2022) using the stoichiometric dissociation constants for carbonic acid from Sulpis et al. (2020), for sulfuric acid by Dickson et al. (1990) and for total boron from Uppström (1974). The solid white line indicates the effect of adding NaOH and the dashed white line indicates the effect of adding Na_2CO_3. This grouping of lines can be translated so that its initial position moves elsewhere on these figures, to visualize different initial conditions.

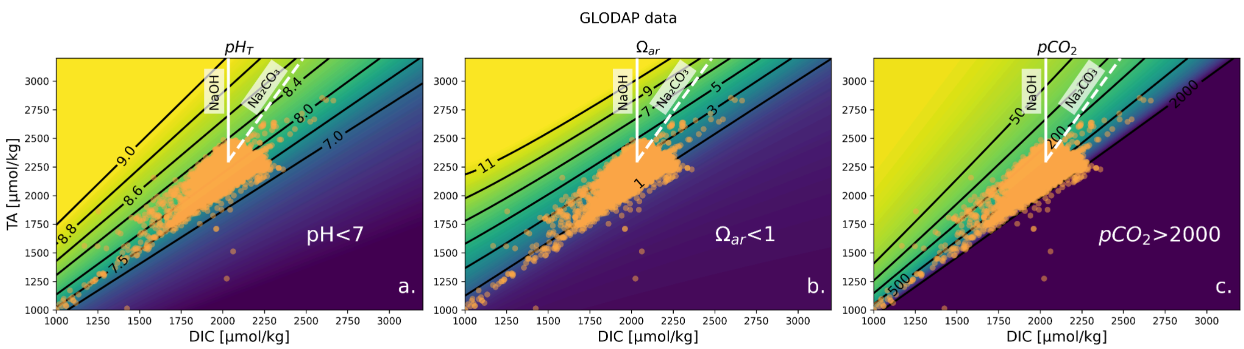


Figure S2: TA:DIC vs pH_T and Ω_{ar} from the chemical data of the experimental OA treatments.

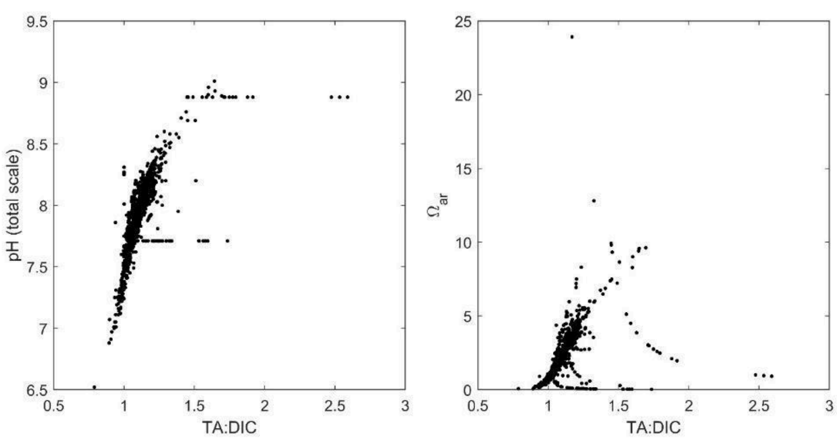


Figure S3: The range of observed pH and DIC and TA values (as represented by the TA:DIC ratio) values and the relationship with the best fitted curve between TA:DIC vs. pH across regional (a-g) and global (h) scales based on the observational GLODAP data set averaged over 0-50 m depth.

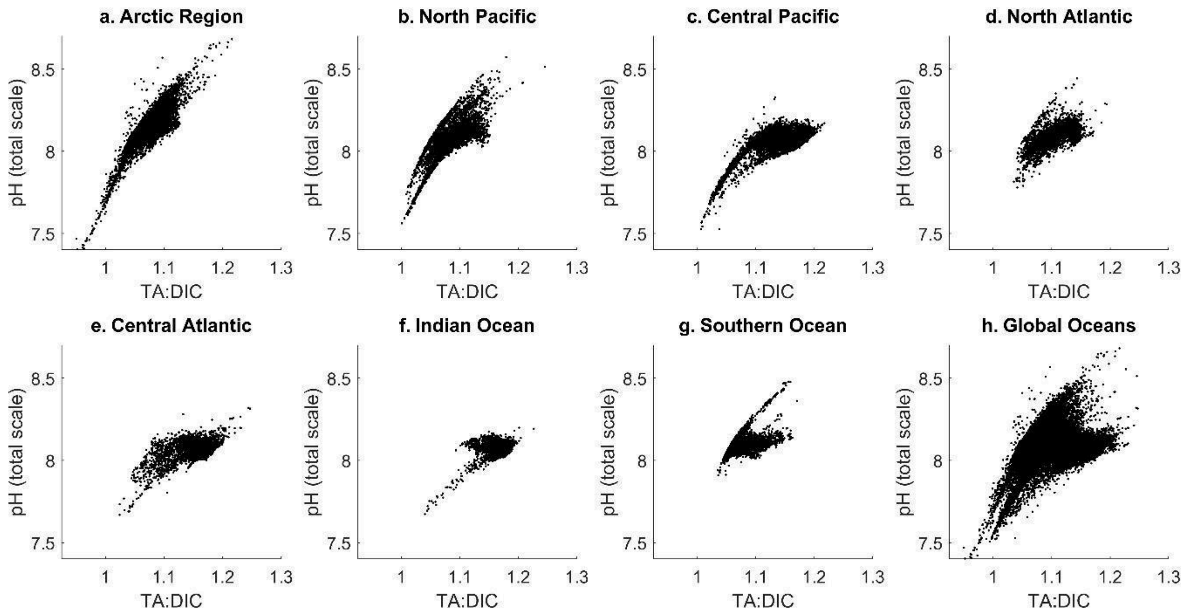
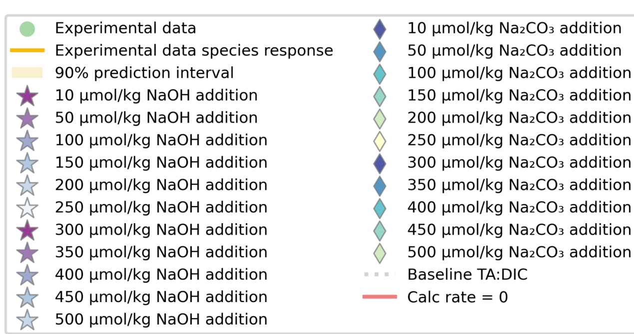
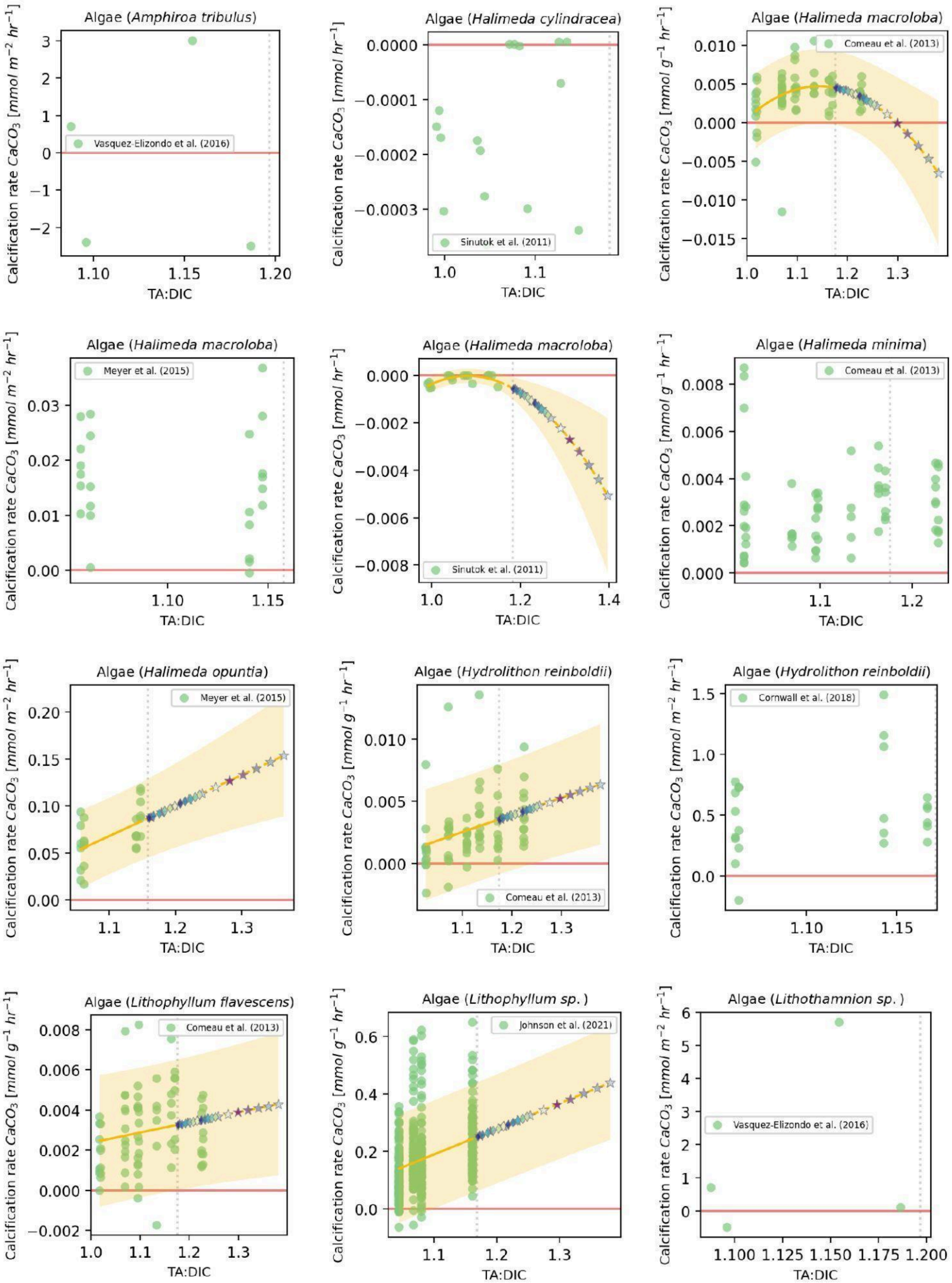
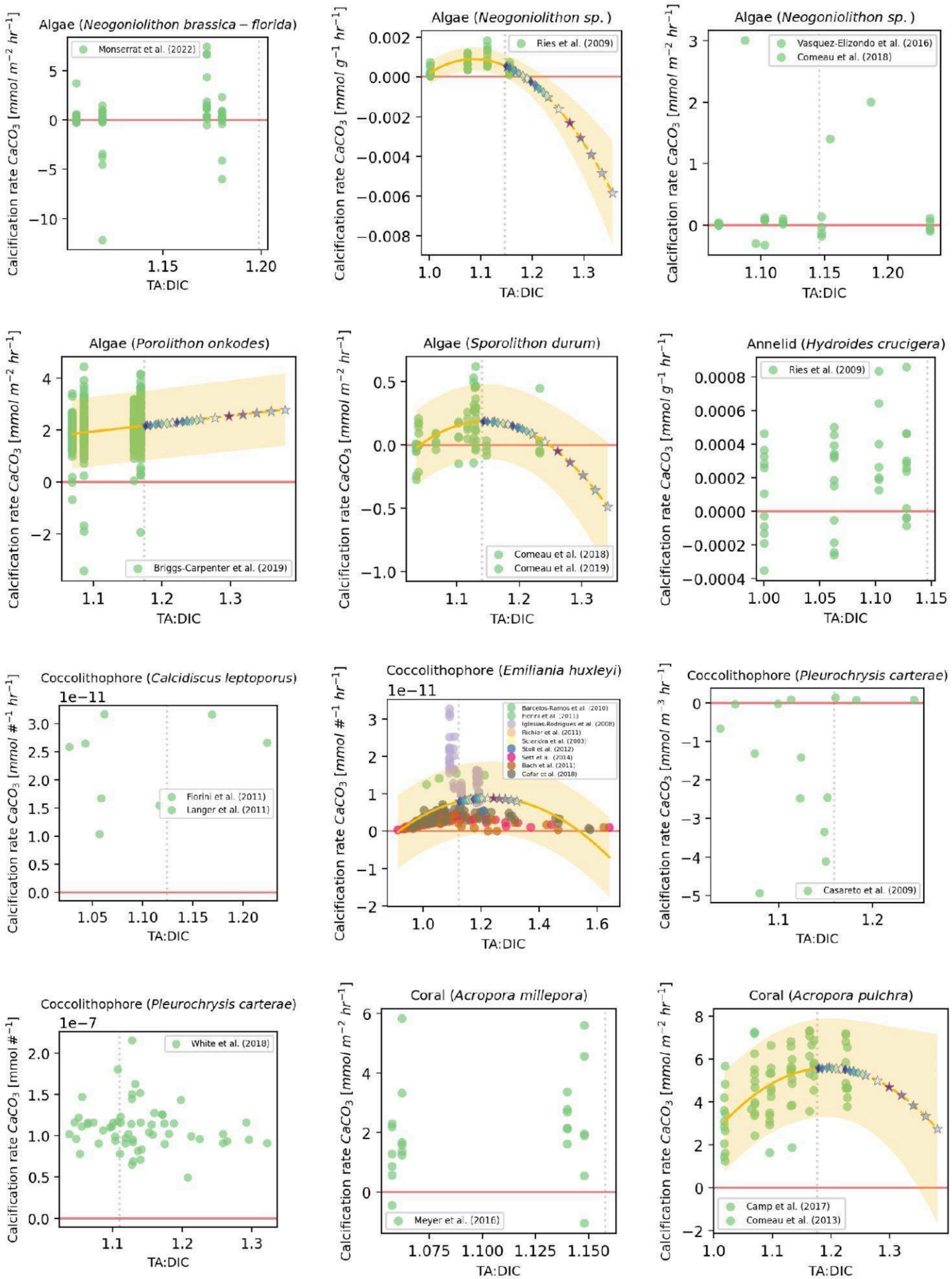


Figure S4: Raw experimental data extracted from the OA studies or databases to which the regression line with prediction error margins was fitted at various additions of alkalinity for the examined species (in alphabetical order). The uncertainty interval indicates a 90 % prediction interval four standard deviations. The vertical gray dotted line represents the baseline and the red line indicates zero net dissolution (calcification rate is equal to 0; dissolution rate = calcification rate).

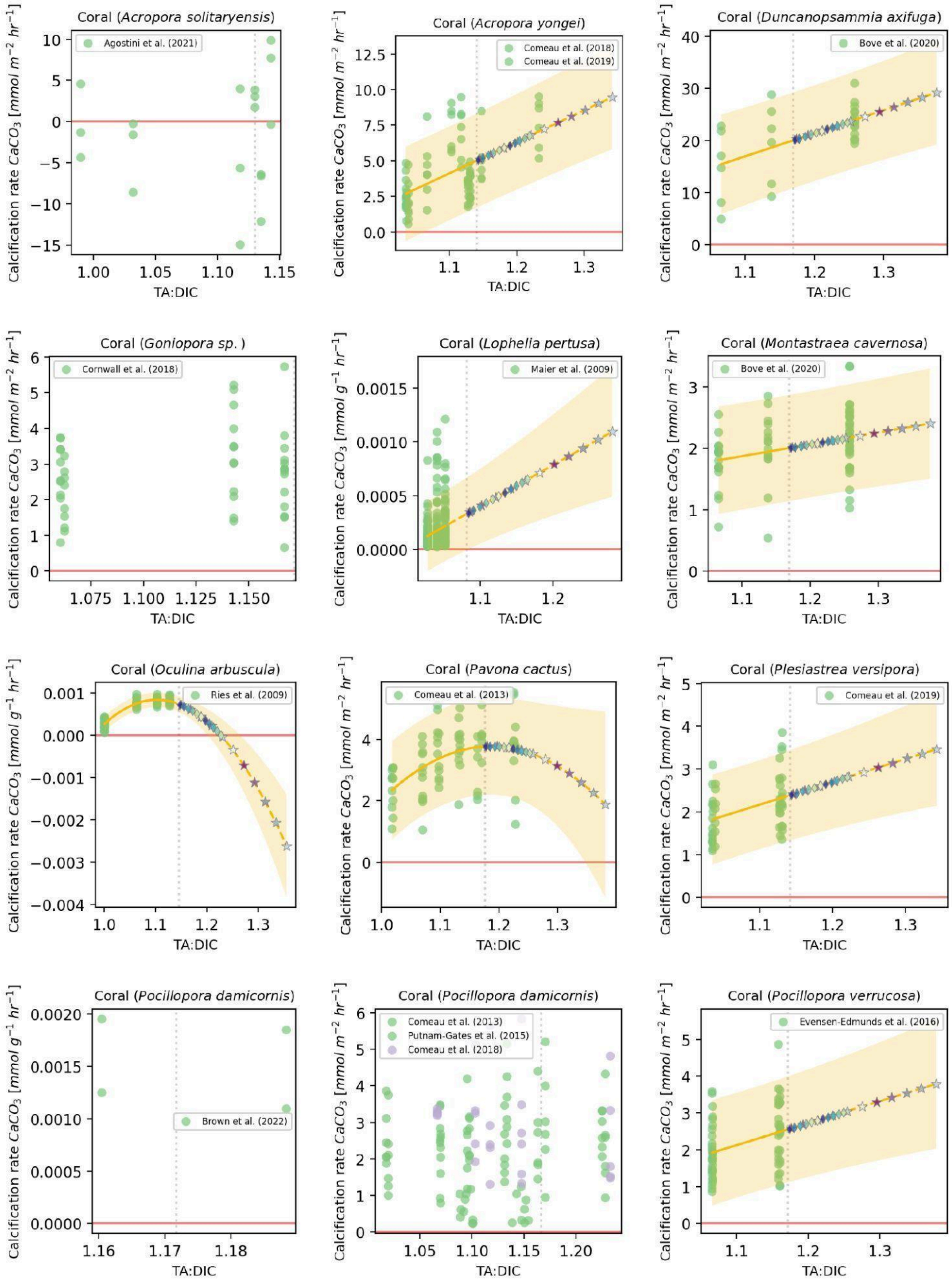


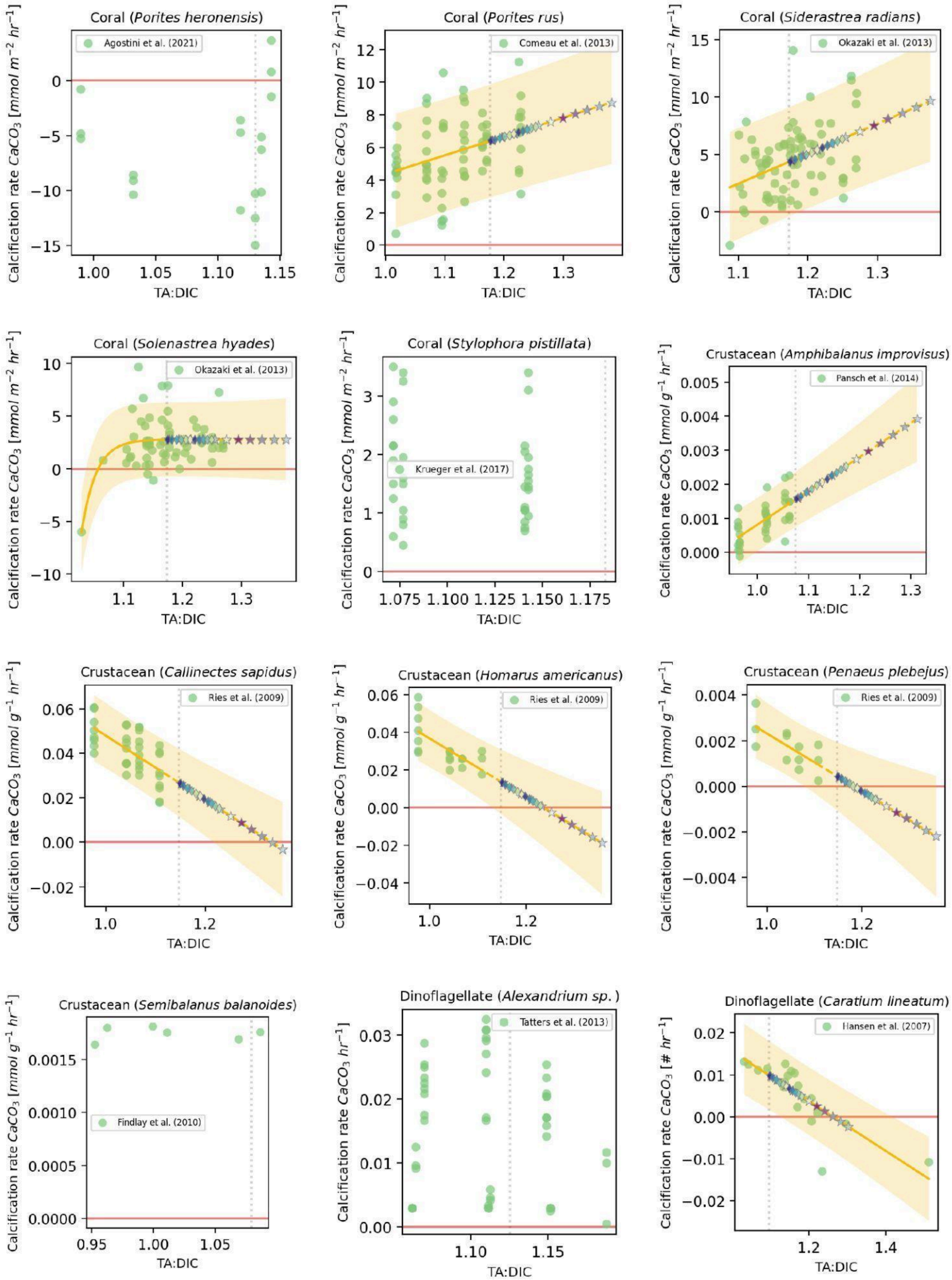


Algae (Amphiroa tribulus)
Calcification rate CaCO3 [mmol m−2 hr−1]
Vasquez-Elizondo et al. (2016)
TA:DIC
Algae (Halimeda cylindracea)
Calcification rate CaCO3 [mmol hr−1]
Sinutok et al. (2011)
TA:DIC
Algae (Halimeda macroloba)
Calcification rate CaCO3 [mmol g−1 hr−1]
Comeau et al. (2013)
TA:DIC
Algae (Halimeda macroloba)
Calcification rate CaCO3 [mmol m−2 hr−1]
Meyer et al. (2015)
TA:DIC
Algae (Halimeda macroloba)
Calcification rate CaCO3 [mmol hr−1]
Sinutok et al. (2011)
TA:DIC
Algae (Halimeda minima)
Calcification rate CaCO3 [mmol g−1 hr−1]
Comeau et al. (2013)
TA:DIC
Algae (Halimeda opuntia)
Calcification rate CaCO3 [mmol m−2 hr−1]
Meyer et al. (2015)
TA:DIC
Algae (Hydrolithon reinboldii)
Calcification rate CaCO3 [mmol g−1 hr−1]
Comeau et al. (2013)
TA:DIC
Algae (Hydrolithon reinboldii)
Calcification rate CaCO3 [mmol m−2 hr−1]
Cornwall et al. (2018)
TA:DIC
Algae (Lithophyllum flavescens)
Calcification rate CaCO3 [mmol g−1 hr−1]
Comeau et al. (2013)
TA:DIC
Algae (Lithophyllum sp.)
Calcification rate CaCO3 [mmol g−1 hr−1]
Johnson et al. (2021)
TA:DIC
Algae (Lithothamnion sp.)
Calcification rate CaCO3 [mmol m−2 hr−1]
Vasquez-Elizondo et al. (2016)
TA:DIC

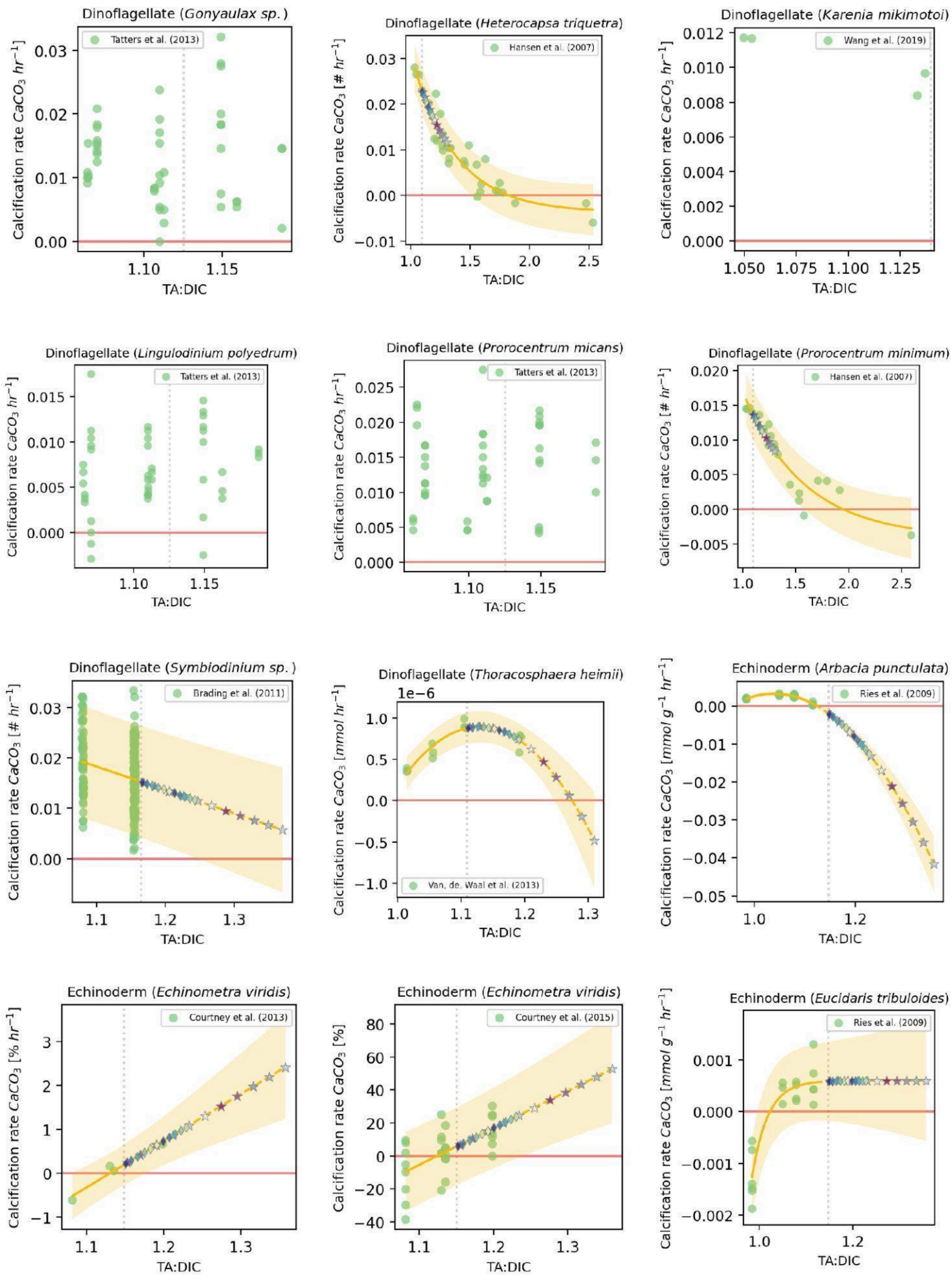


Algae (Neogoniolithon brassica – florida)
Monserrat et al. (2022)
Calcification rate CaCO3 [mmol m−2 hr−1]
TA:DIC
Algae (Neogoniolithon sp.)
Ries et al. (2009)
Calcification rate CaCO3 [mmol g−1 hr−1]
TA:DIC
Algae (Neogoniolithon sp.)
Vasquez-Elizondo et al. (2016)
Comeau et al. (2018)
Calcification rate CaCO3 [mmol m−2 hr−1]
TA:DIC
Algae (Porolithon onkodes)
Briggs-Carpenter et al. (2019)
Calcification rate CaCO3 [mmol m−2 hr−1]
TA:DIC
Algae (Sporolithon durum)
Comeau et al. (2018)
Comeau et al. (2019)
Calcification rate CaCO3 [mmol m−2 hr−1]
TA:DIC
Annelid (Hydroides crucigera)
Ries et al. (2009)
Calcification rate CaCO3 [mmol g−1 hr−1]
TA:DIC
Coccolithophore (Calcidiscus leptoporus)
1e−11
Fiorini et al. (2011)
Langer et al. (2011)
Calcification rate CaCO3 [mmol #−1 hr−1]
TA:DIC
Coccolithophore (Emiliania huxleyi)
1e−11
Barcelos-Ramos et al. (2010)
Fiorini et al. (2011)
Iglesias-Rodrigues et al. (2008)
Richier et al. (2011)
Sciandra et al. (2003)
Stoll et al. (2012)
Sett et al. (2014)
Bach et al. (2011)
Cofar et al. (2018)
Calcification rate CaCO3 [mmol #−1 hr−1]
TA:DIC
Coccolithophore (Pleurochrysis carterae)
Casareto et al. (2009)
Calcification rate CaCO3 [mmol m−3 hr−1]
TA:DIC
Coccolithophore (Pleurochrysis carterae)
1e−7
White et al. (2018)
Calcification rate CaCO3 [mmol #−1]
TA:DIC
Coral (Acropora millepora)
Meyer et al. (2016)
Calcification rate CaCO3 [mmol m−2 hr−1]
TA:DIC
Coral (Acropora pulchra)
Camp et al. (2017)
Comeau et al. (2013)
Calcification rate CaCO3 [mmol m−2 hr−1]
TA:DIC

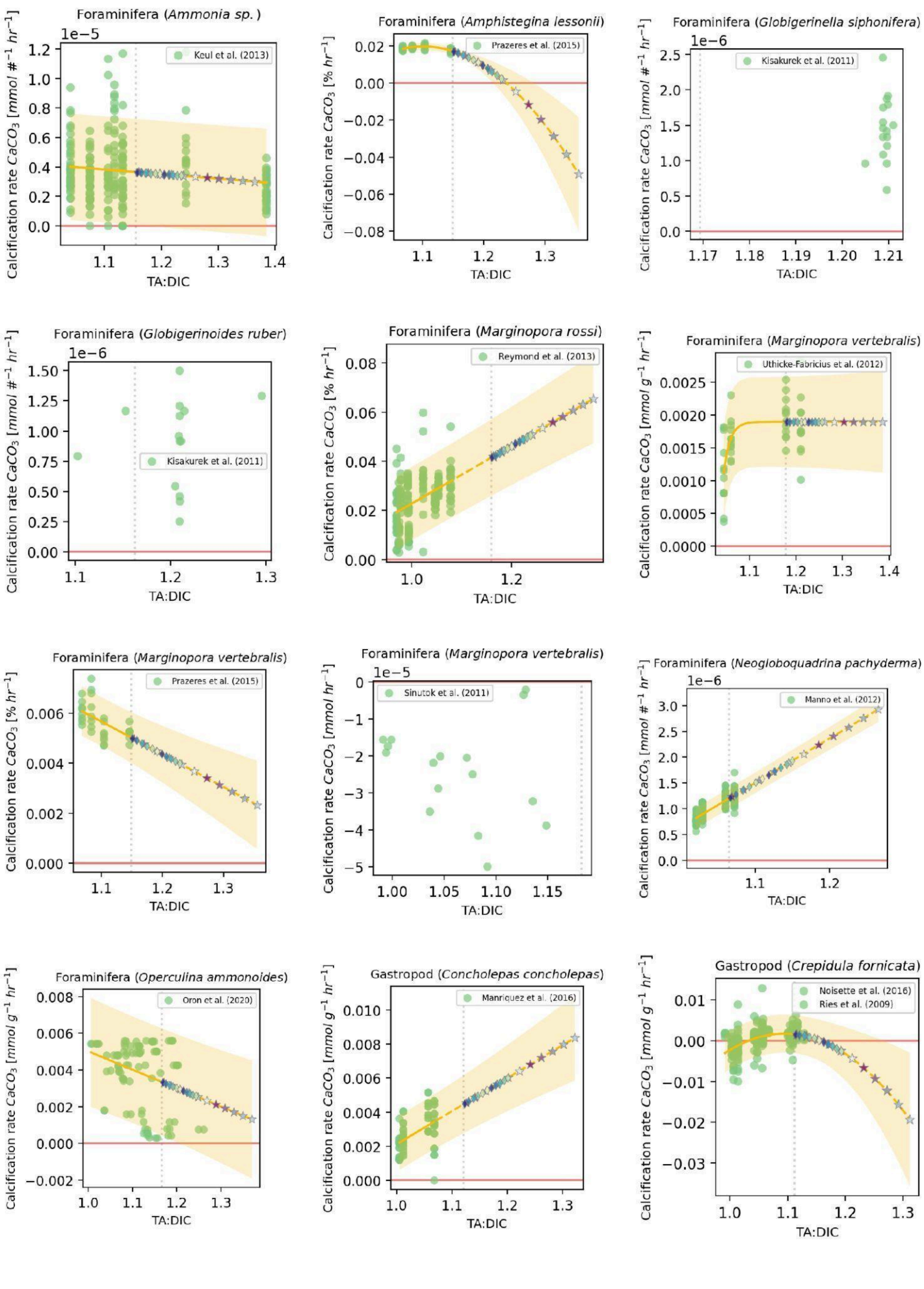

Coral (Acropora solitaryensis)
Agostini et al. (2021)
Coral (Acropora yongei)
Comeau et al. (2018)
Comeau et al. (2019)
Coral (Duncanopsammia axifuga)
Bove et al. (2020)
Coral (Goniopora sp.)
Cornwall et al. (2018)
Coral (Lophelia pertusa)
Maier et al. (2009)
Coral (Montastraea cavernosa)
Bove et al. (2020)
Coral (Oculina arbuscula)
Ries et al. (2009)
Coral (Pavona cactus)
Comeau et al. (2013)
Coral (Plesiastrea versipora)
Comeau et al. (2019)
Coral (Pocillopora damicornis)
Brown et al. (2022)
Coral (Pocillopora damicornis)
Comeau et al. (2013)
Putnam-Gates et al. (2015)
Comeau et al. (2018)
Coral (Pocillopora verrucosa)
Evensen-Edmunds et al. (2016)
Calcification rate $CaCO_3$ [$mmol\ m^{-2}\ hr^{-1}$]
Calcification rate $CaCO_3$ [$mmol\ g^{-1}\ hr^{-1}$]
TA:DIC



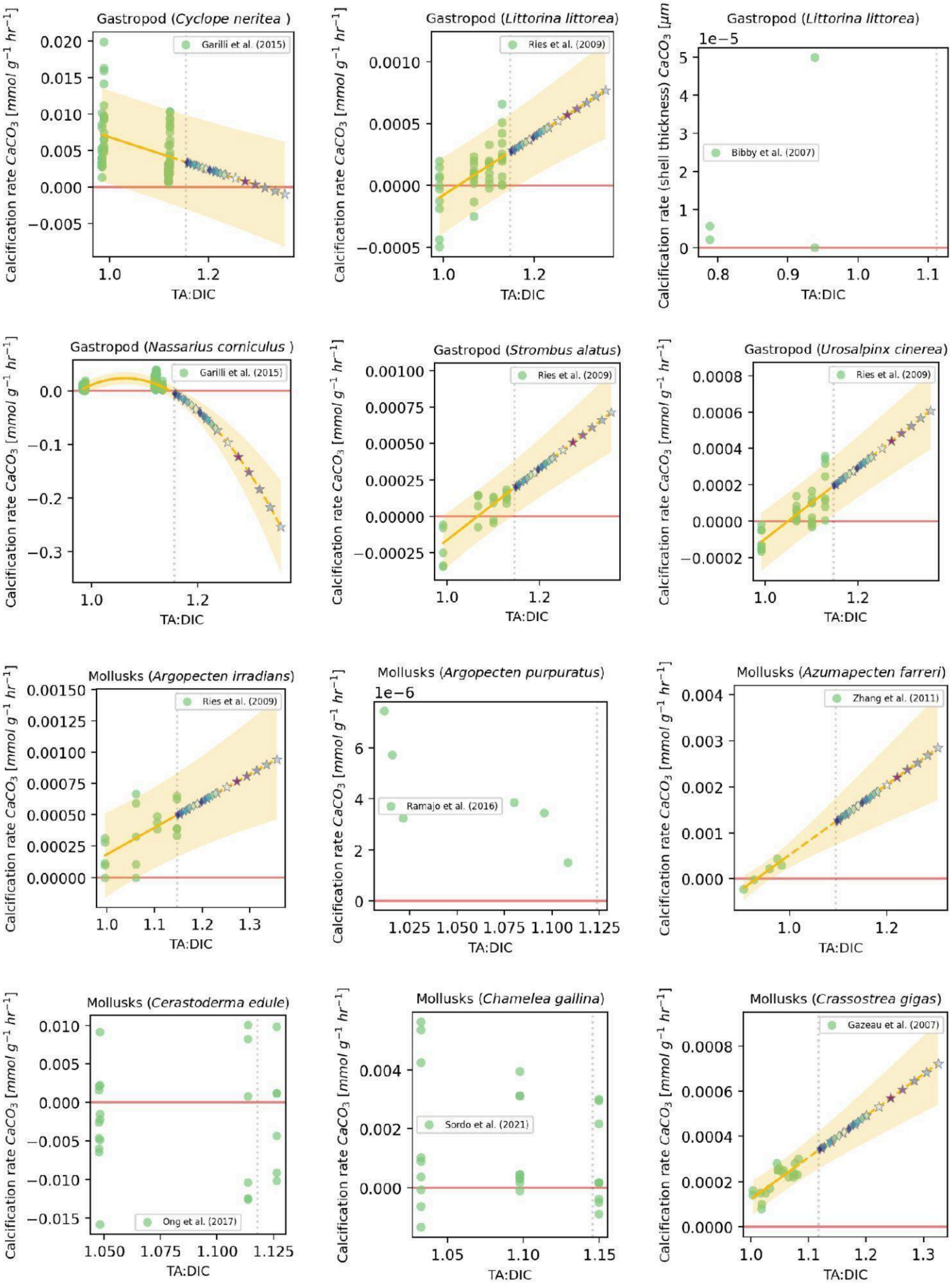
Coral (Porites heronensis)
Agostini et al. (2021)
Coral (Porites rus)
Comeau et al. (2013)
Coral (Siderastrea radians)
Okazaki et al. (2013)
Coral (Solenastrea hyades)
Okazaki et al. (2013)
Coral (Stylophora pistillata)
Krueger et al. (2017)
Crustacean (Amphibalanus improvisus)
Pansch et al. (2014)
Crustacean (Callinectes sapidus)
Ries et al. (2009)
Crustacean (Homarus americanus)
Ries et al. (2009)
Crustacean (Penaeus plebejus)
Ries et al. (2009)
Crustacean (Semibalanus balanoides)
Findlay et al. (2010)
Dinoflagellate (Alexandrium sp.)
Tatters et al. (2013)
Dinoflagellate (Caratium lineatum)
Hansen et al. (2007)
Calcification rate $CaCO_3$ [$mmol\ m^{-2}\ hr^{-1}$]
Calcification rate $CaCO_3$ [$mmol\ g^{-1}\ hr^{-1}$]
Calcification rate $CaCO_3$ [$mmol\ CaCO_3\ hr^{-1}$]
Calcification rate $CaCO_3$ [$\#\ hr^{-1}$]
TA:DIC



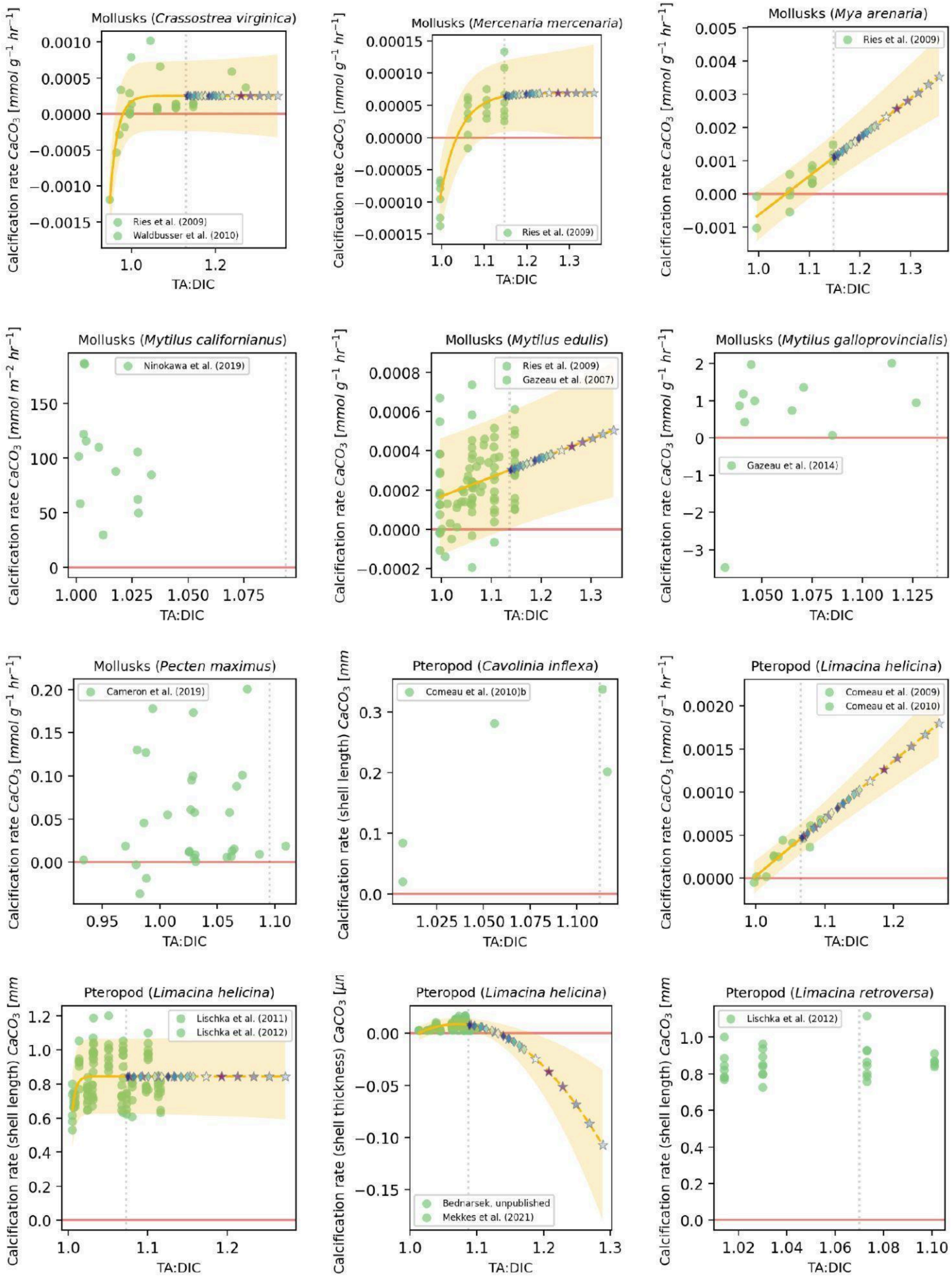
Dinoflagellate (Gonyaulax sp.)
Tatters et al. (2013)
Calcification rate CaCO3 hr−1
TA:DIC
Dinoflagellate (Heterocapsa triquetra)
Hansen et al. (2007)
Calcification rate CaCO3 [# hr−1]
TA:DIC
Dinoflagellate (Karenia mikimotoi)
Wang et al. (2019)
Calcification rate CaCO3 hr−1
TA:DIC
Dinoflagellate (Lingulodinium polyedrum)
Tatters et al. (2013)
Calcification rate CaCO3 hr−1
TA:DIC
Dinoflagellate (Prorocentrum micans)
Tatters et al. (2013)
Calcification rate CaCO3 hr−1
TA:DIC
Dinoflagellate (Prorocentrum minimum)
Hansen et al. (2007)
Calcification rate CaCO3 [# hr−1]
TA:DIC
Dinoflagellate (Symbiodinium sp.)
Brading et al. (2011)
Calcification rate CaCO3 [# hr−1]
TA:DIC
Dinoflagellate (Thoracosphaera heimii)
1e−6
Van. de. Waal et al. (2013)
Calcification rate CaCO3 [mmol hr−1]
TA:DIC
Echinoderm (Arbacia punctulata)
Ries et al. (2009)
Calcification rate CaCO3 [mmol g−1 hr−1]
TA:DIC
Echinoderm (Echinometra viridis)
Courtney et al. (2013)
Calcification rate CaCO3 [% hr−1]
TA:DIC
Echinoderm (Echinometra viridis)
Courtney et al. (2015)
Calcification rate CaCO3 [%]
TA:DIC
Echinoderm (Eucidaris tribuloides)
Ries et al. (2009)
Calcification rate CaCO3 [mmol g−1 hr−1]
TA:DIC



Foraminifera (Ammonia sp.)
Keul et al. (2013)
Foraminifera (Amphistegina lessonii)
Prazeres et al. (2015)
Foraminifera (Globigerinella siphonifera)
Kisakurek et al. (2011)
Foraminifera (Globigerinoides ruber)
Kisakurek et al. (2011)
Foraminifera (Marginopora rossi)
Reymond et al. (2013)
Foraminifera (Marginopora vertebralis)
Uthicke-Fabricius et al. (2012)
Foraminifera (Marginopora vertebralis)
Prazeres et al. (2015)
Foraminifera (Marginopora vertebralis)
Sinutok et al. (2011)
Foraminifera (Neogloboquadrina pachyderma)
Manno et al. (2012)
Foraminifera (Operculina ammonoides)
Oron et al. (2020)
Gastropod (Concholepas concholepas)
Manriquez et al. (2016)
Gastropod (Crepidula fornicata)
Noisette et al. (2016)
Ries et al. (2009)
Calcification rate $CaCO_3$ [$mmol\ \#^{-1}\ hr^{-1}$]
Calcification rate $CaCO_3$ [$\%\ hr^{-1}$]
Calcification rate $CaCO_3$ [$mmol\ g^{-1}\ hr^{-1}$]
Calcification rate $CaCO_3$ [$mmol\ hr^{-1}$]
TA:DIC



Gastropod (Cyclope neritea)
Garilli et al. (2015)
Calcification rate $CaCO_3$ [$mmol\ g^{-1}\ hr^{-1}$]
TA:DIC
Gastropod (Littorina littorea)
Ries et al. (2009)
Gastropod (Littorina littorea)
1e−5
Bibby et al. (2007)
Calcification rate (shell thickness) $CaCO_3$ [μm
Gastropod (Nassarius corniculus)
Garilli et al. (2015)
Gastropod (Strombus alatus)
Ries et al. (2009)
Gastropod (Urosalpinx cinerea)
Ries et al. (2009)
Mollusks (Argopecten irradians)
Ries et al. (2009)
Mollusks (Argopecten purpuratus)
1e−6
Ramajo et al. (2016)
Mollusks (Azumapecten farreri)
Zhang et al. (2011)
Mollusks (Cerastoderma edule)
Ong et al. (2017)
Mollusks (Chamelea gallina)
Sordo et al. (2021)
Mollusks (Crassostrea gigas)
Gazeau et al. (2007)



Mollusks (Crassostrea virginica)
Mollusks (Mercenaria mercenaria)
Mollusks (Mya arenaria)
Mollusks (Mytilus californianus)
Mollusks (Mytilus edulis)
Mollusks (Mytilus galloprovincialis)
Mollusks (Pecten maximus)
Pteropod (Cavolinia inflexa)
Pteropod (Limacina helicina)
Pteropod (Limacina helicina)
Pteropod (Limacina helicina)
Pteropod (Limacina retroversa)
Ries et al. (2009)
Waldbusser et al. (2010)
Ninokawa et al. (2019)
Gazeau et al. (2007)
Gazeau et al. (2014)
Cameron et al. (2019)
Comeau et al. (2010)b
Comeau et al. (2009)
Comeau et al. (2010)
Lischka et al. (2011)
Lischka et al. (2012)
Bednarsek, unpublished
Mekkes et al. (2021)
Calcification rate $CaCO_3$ [mmol g^{-1} hr^{-1}]
Calcification rate $CaCO_3$ [mmol m^{-2} hr^{-1}]
Calcification rate (shell length) $CaCO_3$ [mm
Calcification rate (shell thickness) $CaCO_3$ [μm
TA:DIC

Figure S5: Mechanistic rate equation and parameters (a = 2.31e5, b = 3.55e2 mol/kg, c = 2.19e5 kg/mol, d = 3.76e7 kg/mol) taken from Bach et al. (2015) and calculated using experimental data for '*Calcidiscus leptoporus*' (used data from the studies indicated in legend). No significant correlation (p-value = 0.46) when applying a quadratic regression to this data means a neutral response.

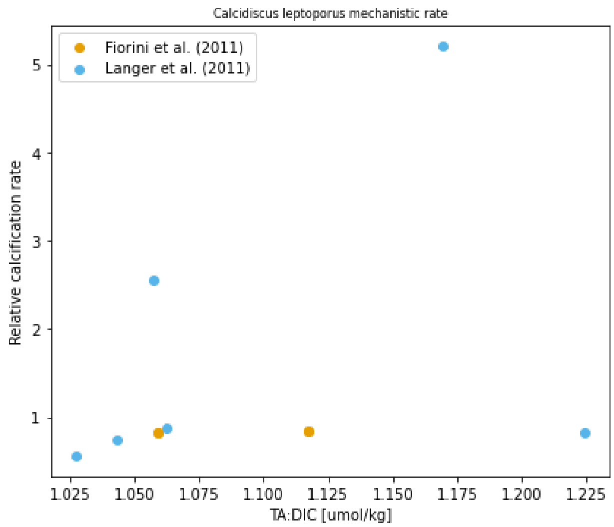
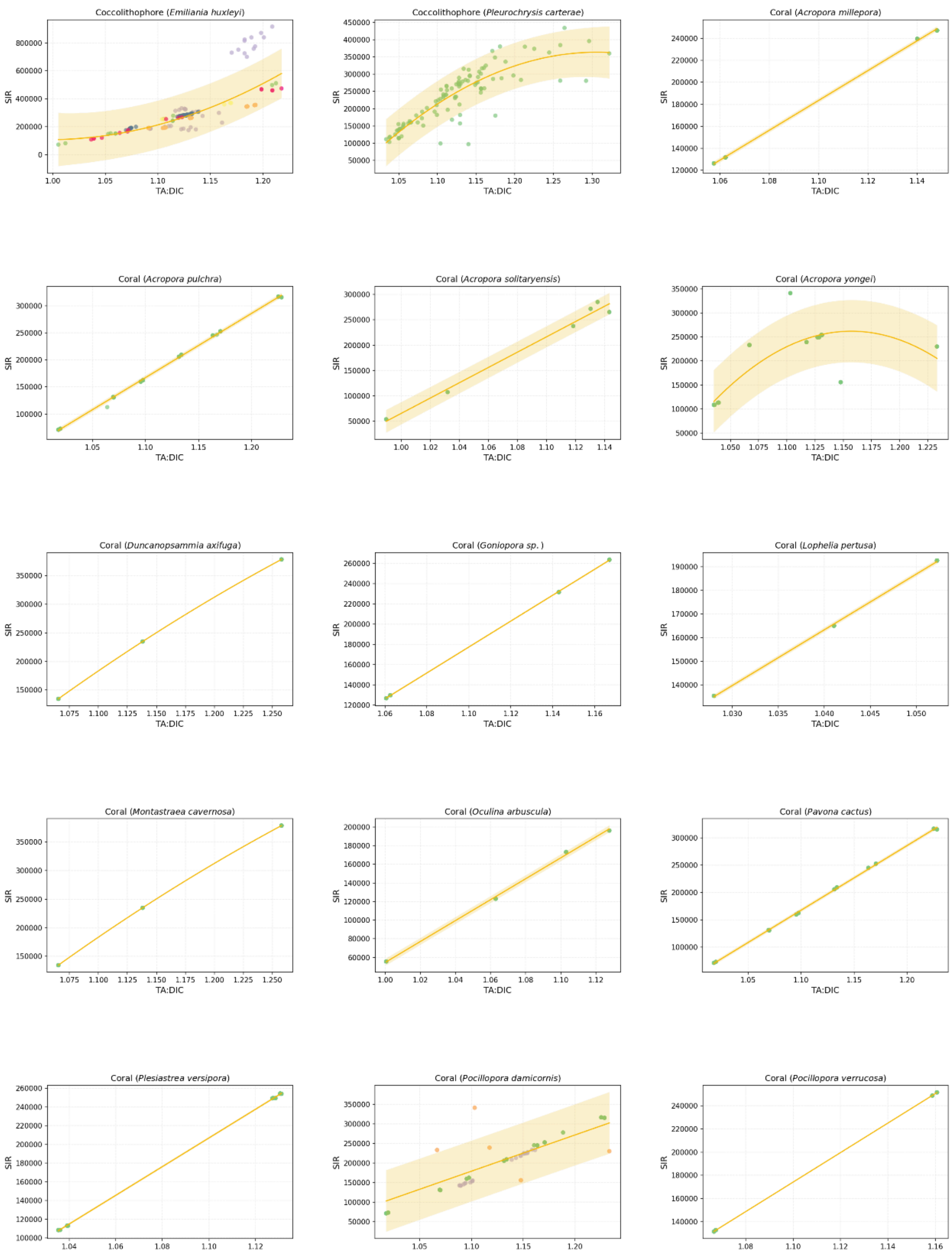
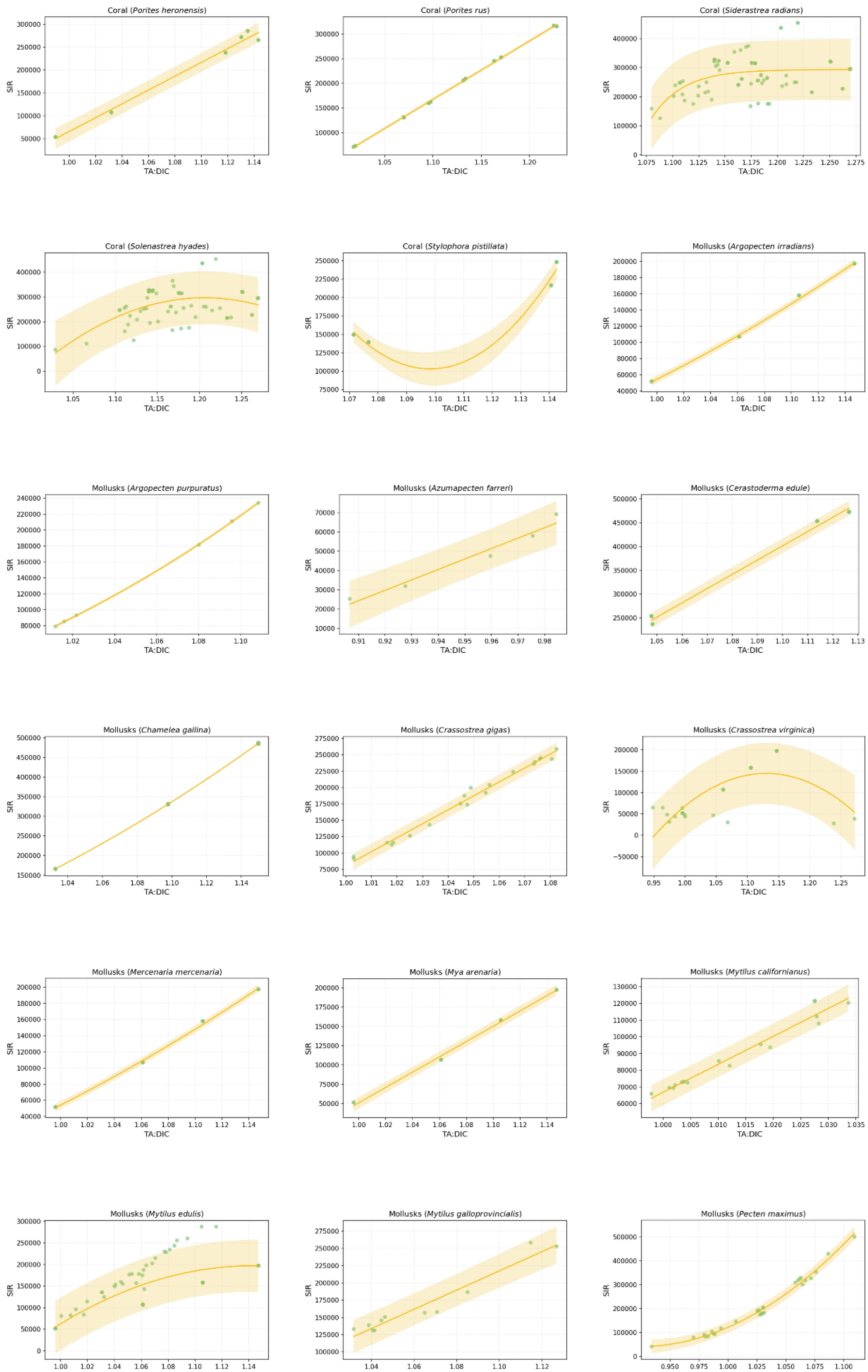


Figure S6: Substrate-to-inhibitor ratio (SIR) (i.e. the bicarbonate ion to hydrogen ion concentration ratio) for coccolithophore, coral and mollusk group experimental data. Bicarbonate ion and hydrogen ion concentration calculated using TA and DIC data.




Coral (Porites heronensis)
Coral (Porites rus)
Coral (Siderastrea radians)
Coral (Solenastrea hyades)
Coral (Stylophora pistillata)
Mollusks (Argopecten irradians)
Mollusks (Argopecten purpuratus)
Mollusks (Azumapecten farreri)
Mollusks (Cerastoderma edule)
Mollusks (Chamelea gallina)
Mollusks (Crassostrea gigas)
Mollusks (Crassostrea virginica)
Mollusks (Mercenaria mercenaria)
Mollusks (Mya arenaria)
Mollusks (Mytilus californianus)
Mollusks (Mytilus edulis)
Mollusks (Mytilus galloprovincialis)
Mollusks (Pecten maximus)
SIR
TA:DIC