Supplementary Material

Unifying framework for assessing sensitivity of marine calcifiers to ocean alkalinity enhancement identifies potential winners, losers and biological thresholds - importance of precautionary principle

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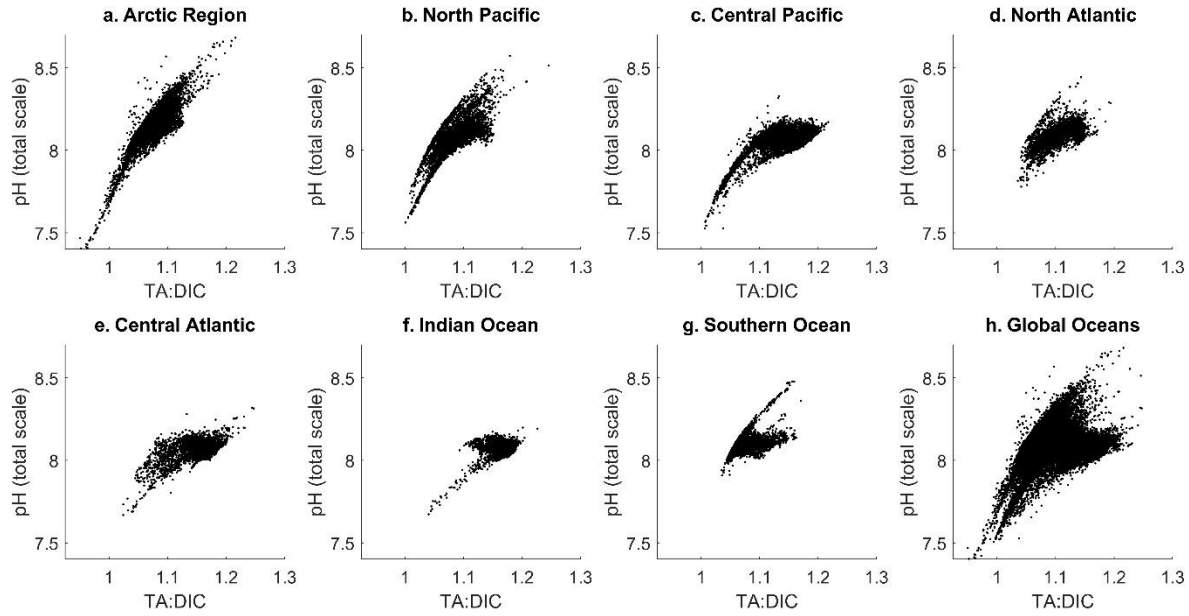
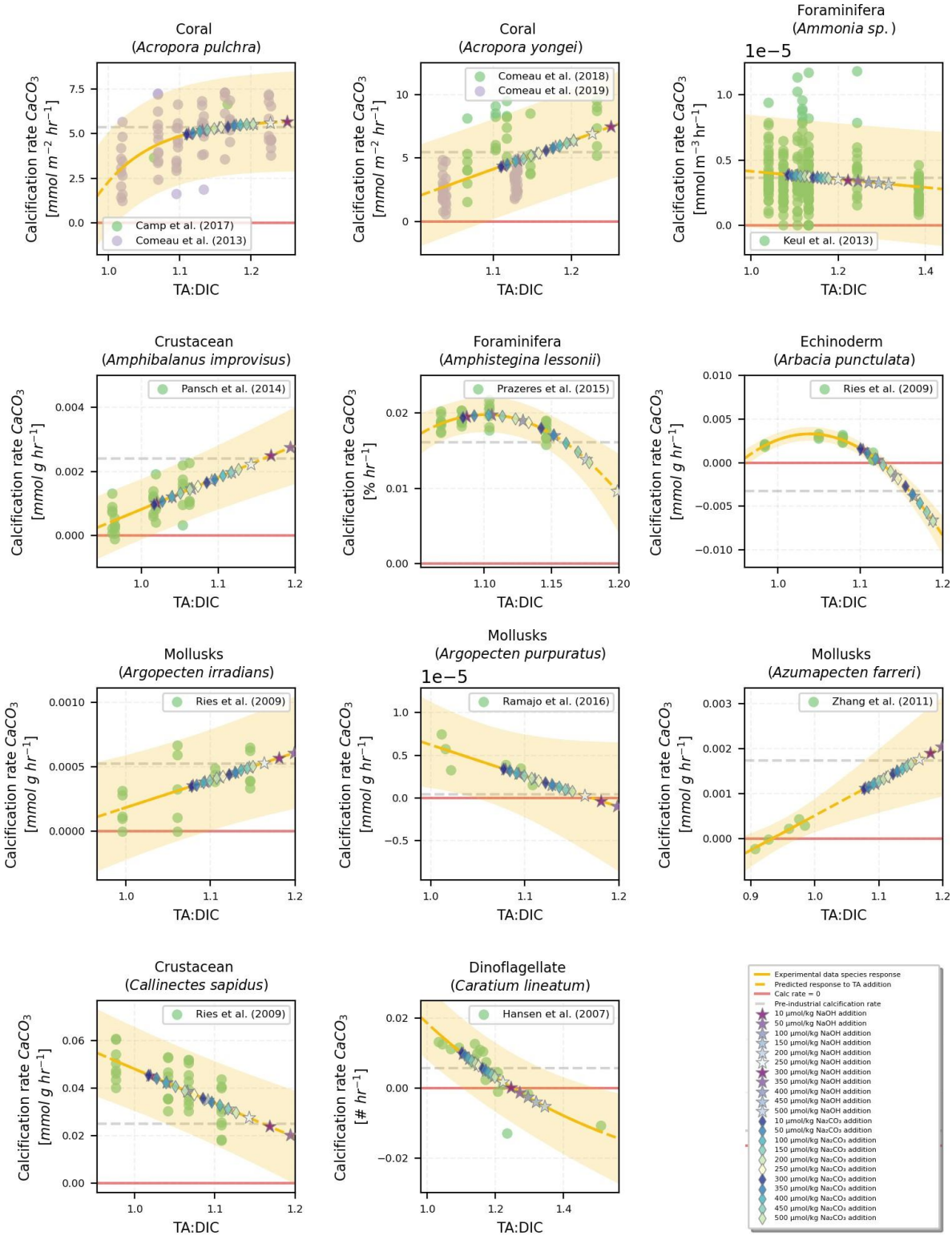
Supplementary Table 1: *Regression analyses with fitted second-order polynomial equation exploring TA:DIC and Ω_{ar} correlation over the 0-50 using various regional datasets and global GLODAP datasets. Shown are the coefficients for the second-order polynomial equation (see also Fig. 1), as well as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

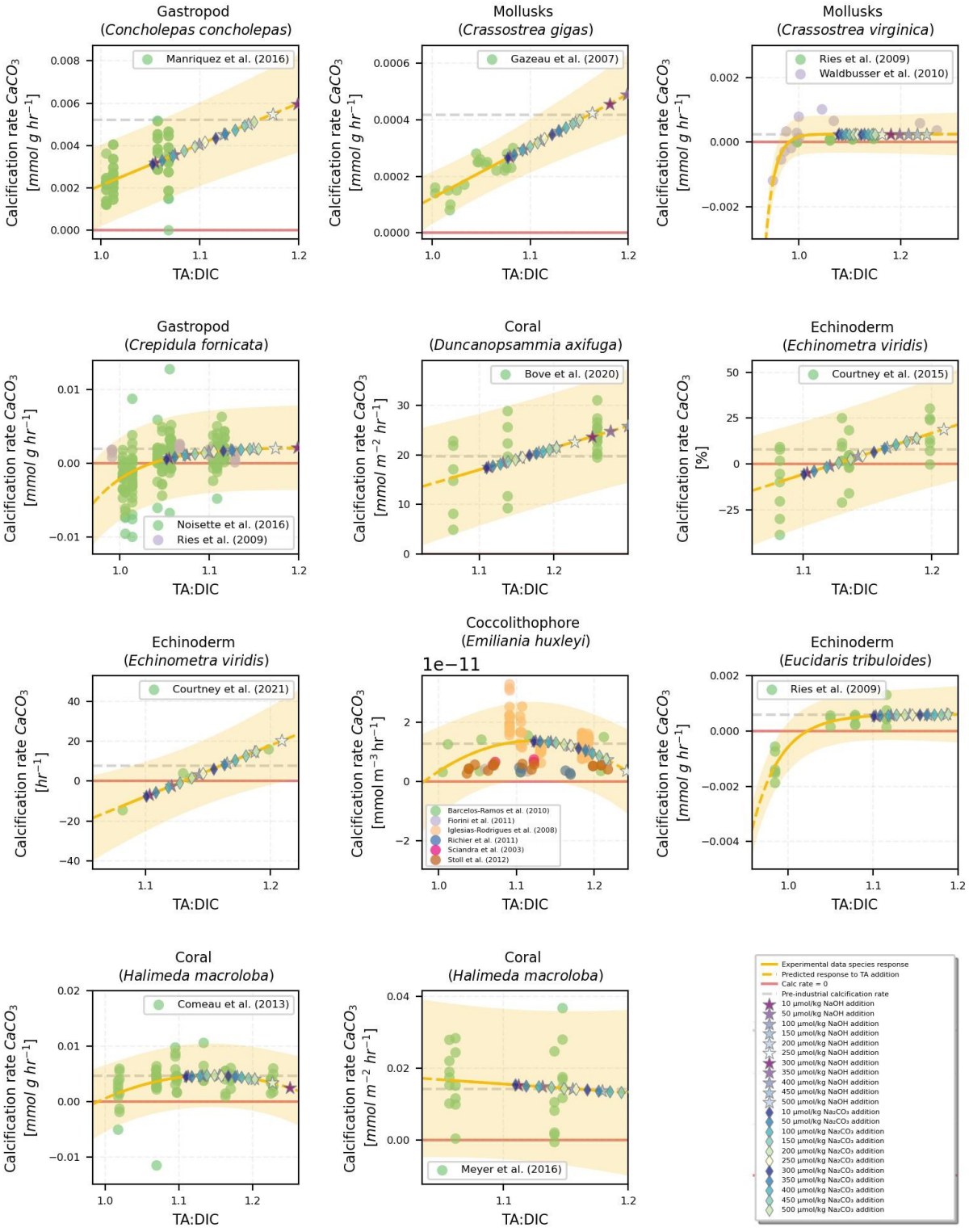
Region	b1	b2	b3	b4	rsquared	pvalue	ser	# obs
Arctic	66.84	-206.99	199.39	-58.81	0.96	0	0.094	8991
N-Pacific	346.73	-972.25	896.08	-269.98	0.991	0	0.05	6085
C-Pacific	297.07	-817.72	737.24	-215.9	0.99	0	0.063	13101
N-Atlantic	411.4	-1135.05	1030.06	-305.76	0.993	0	0.044	4914
C-Atlantic	166.02	-500.37	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

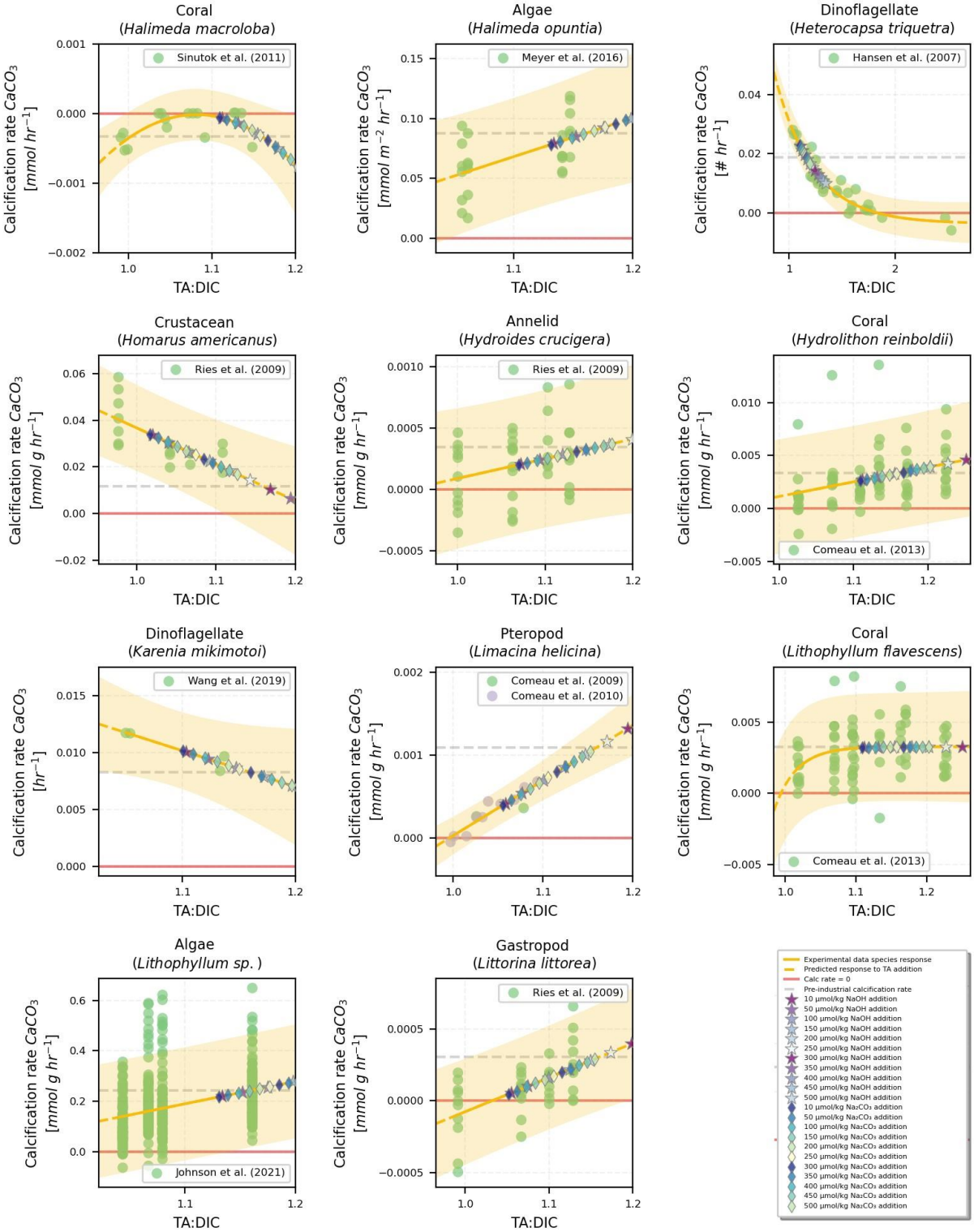
Supplementary Figure 1: *The range of observed pH and DIC and TA values (as represented by the TA:DIC ratio) values and the relationship with the best fitted curve between TA:DIC vs. pH across regional (a-g) and global (h) scales based on the observational GLODAP data set averaged over 0-50 m depth.*

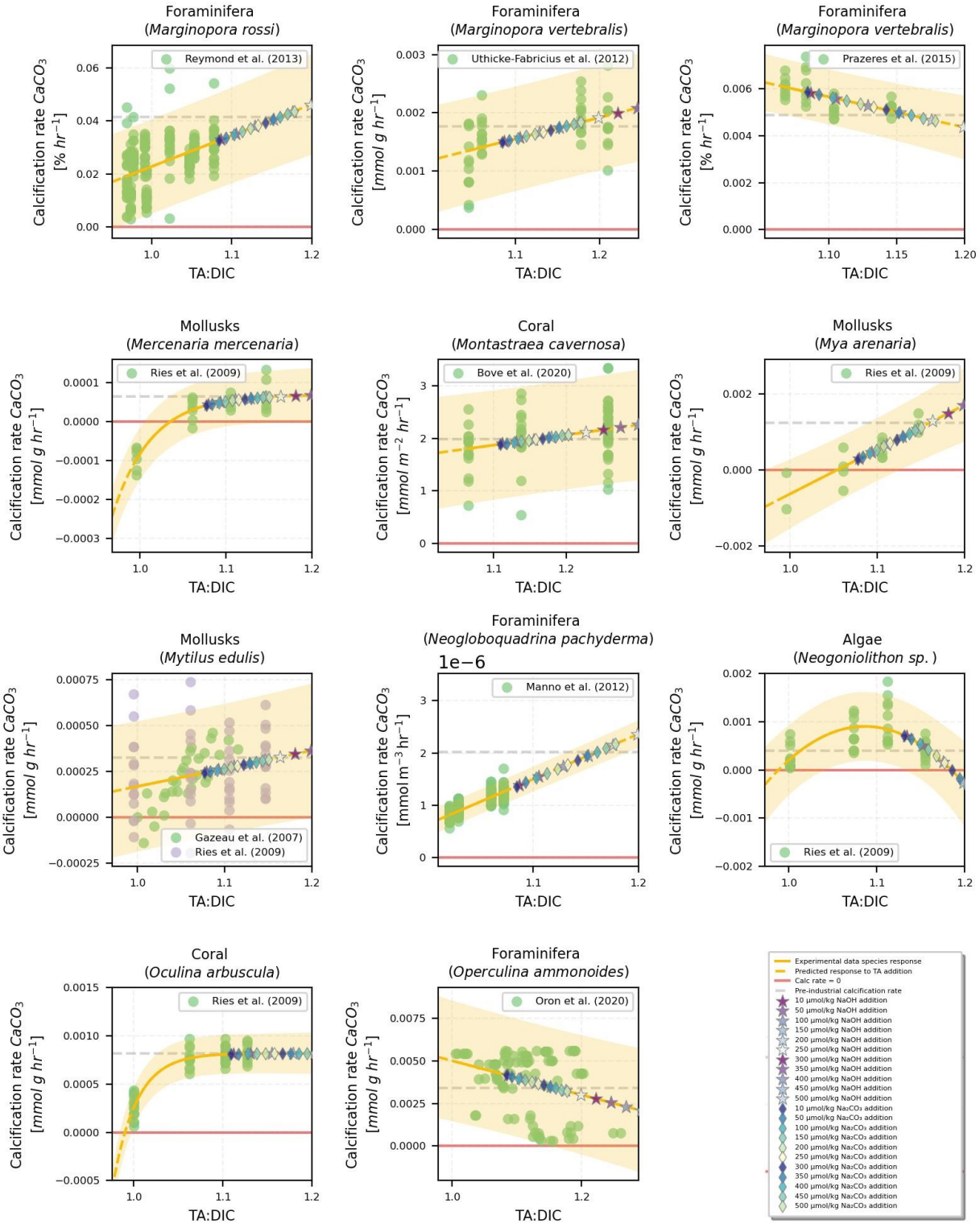


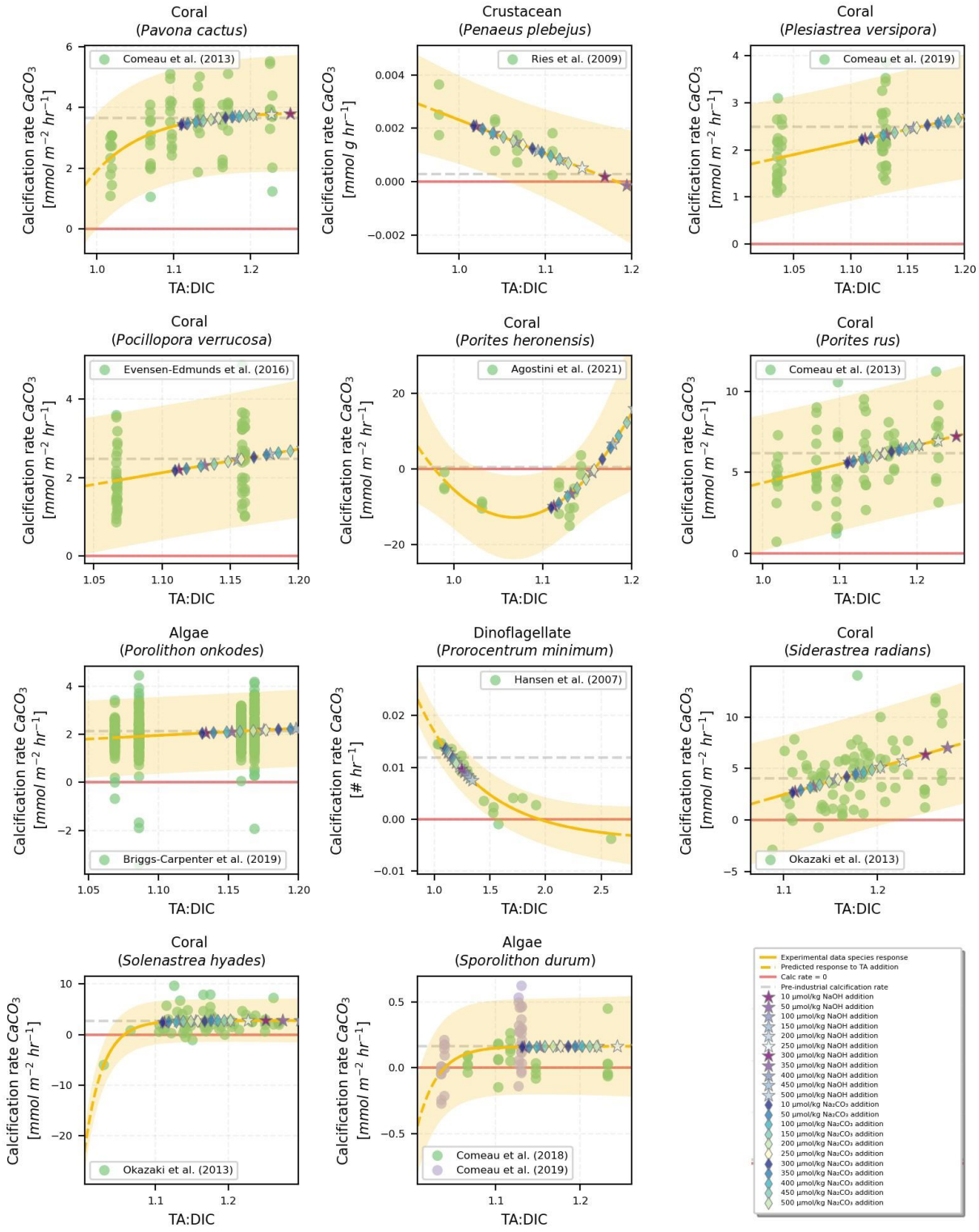
Supplementary Figure 2: *Raw experimental data extracted from the OA studies or data bases to which the regression line with prediction error margins was fitted at various additions of alkalinity for the examined species (in alphabetical order). The uncertainty interval indicates four standard deviations. Blue horizontal dotted line indicates reduction of the half of the calcification rate, the red line indicates zero net dissolution (calcification rate is equal to 0; dissolution rate = calcification rate).*


Coral
(Acropora pulchra)
Calcification rate CaCO3
[mmol m−2 hr−1]
Camp et al. (2017)
Comeau et al. (2013)
TA:DIC
Coral
(Acropora yongei)
Comeau et al. (2018)
Comeau et al. (2019)
TA:DIC
Foraminifera
(Ammonia sp.)
1e−5
Calcification rate CaCO3
[mmol m−3 hr−1]
Keul et al. (2013)
TA:DIC
Crustacean
(Amphibalanus improvisus)
Calcification rate CaCO3
[mmol g hr−1]
Pansch et al. (2014)
TA:DIC
Foraminifera
(Amphistegina lessonii)
Calcification rate CaCO3
[% hr−1]
Prazeres et al. (2015)
TA:DIC
Echinoderm
(Arbacia punctulata)
Calcification rate CaCO3
[mmol g hr−1]
Ries et al. (2009)
TA:DIC
Mollusks
(Argopecten irradians)
Calcification rate CaCO3
[mmol g hr−1]
Ries et al. (2009)
TA:DIC
Mollusks
(Argopecten purpuratus)
1e−5
Calcification rate CaCO3
[mmol g hr−1]
Ramajo et al. (2016)
TA:DIC
Mollusks
(Azumapecten farreri)
Calcification rate CaCO3
[mmol g hr−1]
Zhang et al. (2011)
TA:DIC
Crustacean
(Callinectes sapidus)
Calcification rate CaCO3
[mmol g hr−1]
Ries et al. (2009)
TA:DIC
Dinoflagellate
(Caratium lineatum)
Calcification rate CaCO3
[# hr−1]
Hansen et al. (2007)
TA:DIC
Experimental data species response
Predicted response to TA addition
Calc rate = 0
Pre-industrial calcification rate
10 µmol/kg NaOH addition
50 µmol/kg NaOH addition
100 µmol/kg NaOH addition
150 µmol/kg NaOH addition
200 µmol/kg NaOH addition
250 µmol/kg NaOH addition
300 µmol/kg NaOH addition
350 µmol/kg NaOH addition
400 µmol/kg NaOH addition
450 µmol/kg NaOH addition
500 µmol/kg NaOH addition
10 µmol/kg Na2CO3 addition
50 µmol/kg Na2CO3 addition
100 µmol/kg Na2CO3 addition
150 µmol/kg Na2CO3 addition
200 µmol/kg Na2CO3 addition
250 µmol/kg Na2CO3 addition
300 µmol/kg Na2CO3 addition
350 µmol/kg Na2CO3 addition
400 µmol/kg Na2CO3 addition
450 µmol/kg Na2CO3 addition
500 µmol/kg Na2CO3 addition


Gastropod
(Concholepas concholepas)
Manriquez et al. (2016)
Mollusks
(Crassostrea gigas)
Gazeau et al. (2007)
Mollusks
(Crassostrea virginica)
Ries et al. (2009)
Waldbusser et al. (2010)
Gastropod
(Crepidula fornicata)
Noisette et al. (2016)
Ries et al. (2009)
Coral
(Duncanopsammia axifuga)
Bove et al. (2020)
Echinoderm
(Echinometra viridis)
Courtney et al. (2015)
Echinoderm
(Echinometra viridis)
Courtney et al. (2021)
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)
Echinoderm
(Eucidaris tribuloides)
Ries et al. (2009)
Coral
(Halimeda macroloba)
Comeau et al. (2013)
Coral
(Halimeda macroloba)
Meyer et al. (2016)
Calcification rate CaCO3 [mmol g hr−1]
Calcification rate CaCO3 [mmol m−2 hr−1]
Calcification rate CaCO3 [hr−1]
Calcification rate CaCO3 [mmol m−3 hr−1]
Calcification rate CaCO3 [%]
TA:DIC
Experimental data species response
Predicted response to TA addition
Calc rate = 0
Pre-industrial calcification rate
10 µmol/kg NaOH addition
50 µmol/kg NaOH addition
100 µmol/kg NaOH addition
150 µmol/kg NaOH addition
200 µmol/kg NaOH addition
250 µmol/kg NaOH addition
300 µmol/kg NaOH addition
350 µmol/kg NaOH addition
400 µmol/kg NaOH addition
450 µmol/kg NaOH addition
500 µmol/kg NaOH addition
10 µmol/kg Na2CO3 addition
50 µmol/kg Na2CO3 addition
100 µmol/kg Na2CO3 addition
150 µmol/kg Na2CO3 addition
200 µmol/kg Na2CO3 addition
250 µmol/kg Na2CO3 addition
300 µmol/kg Na2CO3 addition
350 µmol/kg Na2CO3 addition
400 µmol/kg Na2CO3 addition
450 µmol/kg Na2CO3 addition
500 µmol/kg Na2CO3 addition


Coral
(Halimeda macroloba)
Sinutok et al. (2011)
Algae
(Halimeda opuntia)
Meyer et al. (2016)
Dinoflagellate
(Heterocapsa triquetra)
Hansen et al. (2007)
Crustacean
(Homarus americanus)
Ries et al. (2009)
Annelid
(Hydroides crucigera)
Ries et al. (2009)
Coral
(Hydrolithon reinboldii)
Comeau et al. (2013)
Dinoflagellate
(Karenia mikimotoi)
Wang et al. (2019)
Pteropod
(Limacina helicina)
Comeau et al. (2009)
Comeau et al. (2010)
Coral
(Lithophyllum flavescens)
Comeau et al. (2013)
Algae
(Lithophyllum sp.)
Johnson et al. (2021)
Gastropod
(Littorina littorea)
Ries et al. (2009)
Calcification rate CaCO3 [mmol hr−1]
Calcification rate CaCO3 [mmol m−2 hr−1]
Calcification rate CaCO3 [# hr−1]
Calcification rate CaCO3 [mmol g hr−1]
Calcification rate CaCO3 [hr−1]
TA:DIC
Experimental data species response
Predicted response to TA addition
Calc rate = 0
Pre-industrial calcification rate
10 µmol/kg NaOH addition
50 µmol/kg NaOH addition
100 µmol/kg NaOH addition
150 µmol/kg NaOH addition
200 µmol/kg NaOH addition
250 µmol/kg NaOH addition
300 µmol/kg NaOH addition
350 µmol/kg NaOH addition
400 µmol/kg NaOH addition
450 µmol/kg NaOH addition
500 µmol/kg NaOH addition
10 µmol/kg Na2CO3 addition
50 µmol/kg Na2CO3 addition
100 µmol/kg Na2CO3 addition
150 µmol/kg Na2CO3 addition
200 µmol/kg Na2CO3 addition
250 µmol/kg Na2CO3 addition
300 µmol/kg Na2CO3 addition
350 µmol/kg Na2CO3 addition
400 µmol/kg Na2CO3 addition
450 µmol/kg Na2CO3 addition
500 µmol/kg Na2CO3 addition


Foraminifera
(Marginopora rossi)
Reymond et al. (2013)
Calcification rate CaCO3
[% hr−1]
TA:DIC
Foraminifera
(Marginopora vertebralis)
Uthicke-Fabricius et al. (2012)
[mmol g hr−1]
Foraminifera
(Marginopora vertebralis)
Prazeres et al. (2015)
Mollusks
(Mercenaria mercenaria)
Ries et al. (2009)
Coral
(Montastraea cavernosa)
Bove et al. (2020)
[mmol m−2 hr−1]
Mollusks
(Mya arenaria)
Mollusks
(Mytilus edulis)
Gazeau et al. (2007)
Ries et al. (2009)
Foraminifera
(Neogloboquadrina pachyderma)
1e−6
Manno et al. (2012)
[mmol m−3 hr−1]
Algae
(Neogoniolithon sp.)
Coral
(Oculina arbuscula)
Foraminifera
(Operculina ammonoides)
Oron et al. (2020)
Experimental data species response
Predicted response to TA addition
Calc rate = 0
Pre-industrial calcification rate
10 µmol/kg NaOH addition
50 µmol/kg NaOH addition
100 µmol/kg NaOH addition
150 µmol/kg NaOH addition
200 µmol/kg NaOH addition
250 µmol/kg NaOH addition
300 µmol/kg NaOH addition
350 µmol/kg NaOH addition
400 µmol/kg NaOH addition
450 µmol/kg NaOH addition
500 µmol/kg NaOH addition
10 µmol/kg Na2CO3 addition
50 µmol/kg Na2CO3 addition
100 µmol/kg Na2CO3 addition
150 µmol/kg Na2CO3 addition
200 µmol/kg Na2CO3 addition
250 µmol/kg Na2CO3 addition
300 µmol/kg Na2CO3 addition
350 µmol/kg Na2CO3 addition
400 µmol/kg Na2CO3 addition
450 µmol/kg Na2CO3 addition
500 µmol/kg Na2CO3 addition


Coral
(Pavona cactus)
Comeau et al. (2013)
Crustacean
(Penaeus plebejus)
Ries et al. (2009)
Coral
(Plesiastrea versipora)
Comeau et al. (2019)
Coral
(Pocillopora verrucosa)
Evensen-Edmunds et al. (2016)
Coral
(Porites heronensis)
Agostini et al. (2021)
Coral
(Porites rus)
Comeau et al. (2013)
Algae
(Porolithon onkodes)
Briggs-Carpenter et al. (2019)
Dinoflagellate
(Prorocentrum minimum)
Hansen et al. (2007)
Coral
(Siderastrea radians)
Okazaki et al. (2013)
Coral
(Solenastrea hyades)
Okazaki et al. (2013)
Algae
(Sporolithon durum)
Comeau et al. (2018)
Comeau et al. (2019)
Calcification rate $CaCO_3$ [$mmol\ m^{-2}\ hr^{-1}$]
Calcification rate $CaCO_3$ [$mmol\ g\ hr^{-1}$]
Calcification rate $CaCO_3$ [$\#\ hr^{-1}$]
TA:DIC
Experimental data species response
Predicted response to TA addition
Calc rate = 0
Pre-industrial calcification rate
10 µmol/kg NaOH addition
50 µmol/kg NaOH addition
100 µmol/kg NaOH addition
150 µmol/kg NaOH addition
200 µmol/kg NaOH addition
250 µmol/kg NaOH addition
300 µmol/kg NaOH addition
350 µmol/kg NaOH addition
400 µmol/kg NaOH addition
450 µmol/kg NaOH addition
500 µmol/kg NaOH addition
10 µmol/kg Na2CO3 addition
50 µmol/kg Na2CO3 addition
100 µmol/kg Na2CO3 addition
150 µmol/kg Na2CO3 addition
200 µmol/kg Na2CO3 addition
250 µmol/kg Na2CO3 addition
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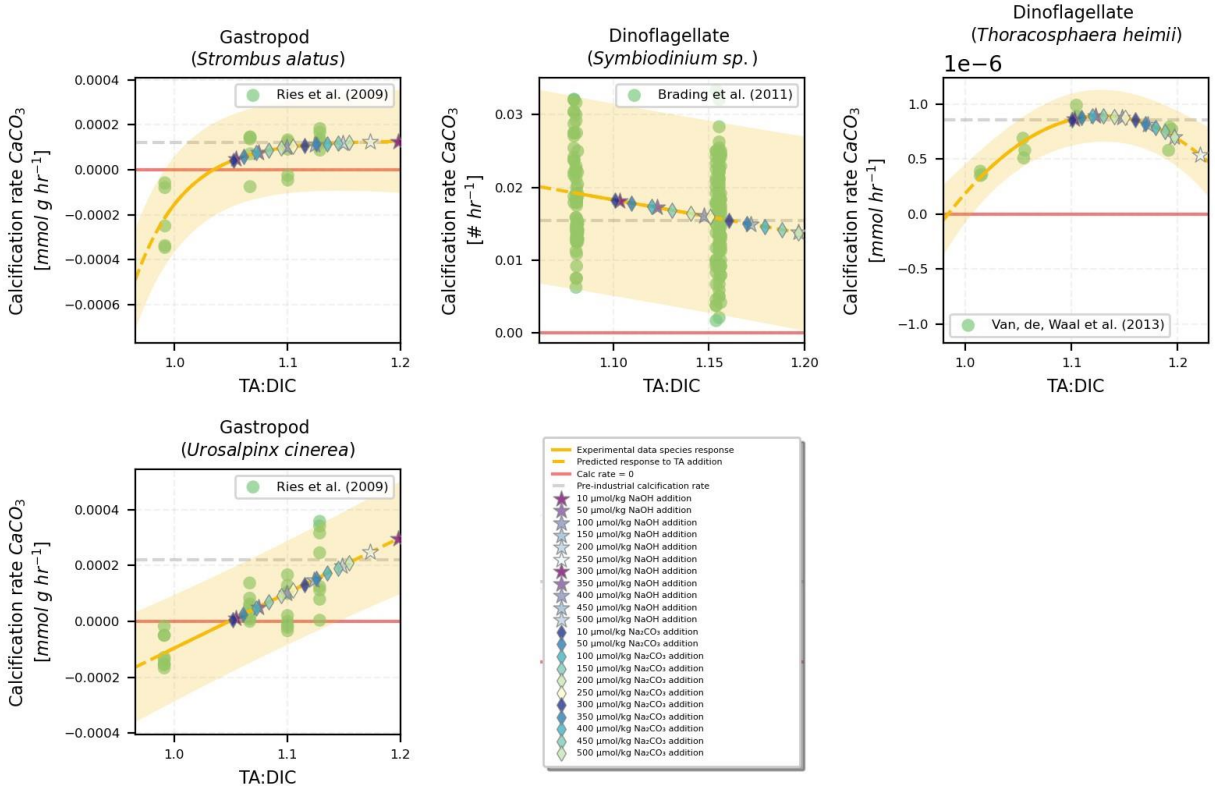
450 µmol/kg Na2CO3 addition
500 µmol/kg Na2CO3 addition


Gastropod
(Strombus alatus)
Ries et al. (2009)
Calcification rate $CaCO_3$ [$mmol\ g\ hr^{-1}$]
TA:DIC
Dinoflagellate
(Symbiodinium sp.)
Brading et al. (2011)
Calcification rate $CaCO_3$ [$\#\ hr^{-1}$]
TA:DIC
Dinoflagellate
(Thoracosphaera heimii)
1e−6
Van, de, Waal et al. (2013)
Calcification rate $CaCO_3$ [$mmol\ hr^{-1}$]
TA:DIC
Gastropod
(Urosalpinx cinerea)
Ries et al. (2009)
Calcification rate $CaCO_3$ [$mmol\ g\ hr^{-1}$]
TA:DIC
Experimental data species response
Predicted response to TA addition
Calc rate = 0
Pre-industrial calcification rate
10 µmol/kg NaOH addition
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100 µmol/kg NaOH addition
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250 µmol/kg NaOH addition
300 µmol/kg NaOH addition
350 µmol/kg NaOH addition
400 µmol/kg NaOH addition
450 µmol/kg NaOH addition
500 µmol/kg NaOH addition
10 µmol/kg Na₂CO₃ addition
50 µmol/kg Na₂CO₃ addition
100 µmol/kg Na₂CO₃ addition
150 µmol/kg Na₂CO₃ addition
200 µmol/kg Na₂CO₃ addition
250 µmol/kg Na₂CO₃ addition
300 µmol/kg Na₂CO₃ addition
350 µmol/kg Na₂CO₃ addition
400 µmol/kg Na₂CO₃ addition
450 µmol/kg Na₂CO₃ addition
500 µmol/kg Na₂CO₃ addition