**Supplemental material**

Projecting ocean acidification impacts for the Gulf of Maine to 2050: New tools and expectations

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**Figure S2. Trends at WB7 for temperature and salinity**

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**Figure S3. Model evaluation at CML and Buoy D for Ωarag**

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**Figure S4. Model acidification annual metrics at Buoy D**

Boxplots (top) of the surface modeled average (left), acidification intensity (center), and duration (right) annual metrics for the grid cell nearest Buoy D. Each box was generated as an ensemble of the model outputs for each of the conditions (present, 2050\_RCP8.5, and 2050\_slug). Yellow shaded region demarks Ωarag<1.5 while red shading denotes values <1.0.

**Figure S5. Total alkalinity (**µ**mol/kg) seasonal CTRL for the ROMS model with empirical biogeochemistry**

Seasonal maps of the surface (top) and bottom (bottom) for the control (CTRL) conditions in the GOM. Seasons are broken up into December -February (DJF), March-May (MAM), June-August (JJA), and September - November (SON).

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**Table S1. Responses of six commercially important species of the Gulf of Maine to increased ocean and coastal acidification (OCA) conditions1**

**Table S2. Studies on organismal response of species from the Gulf of Maine to ocean acidification (OA) conditions1**

**Table S3.** **GOM regional OA observing capacity description of observations plotted in Figure 2**

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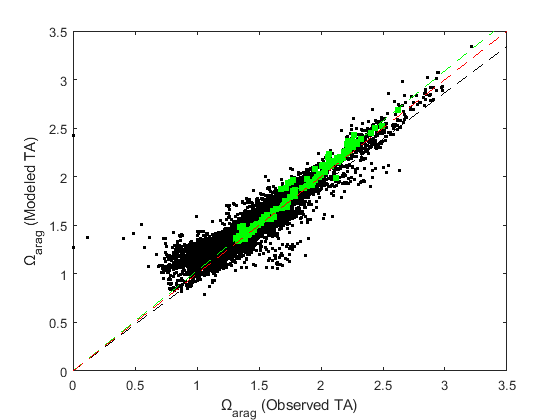
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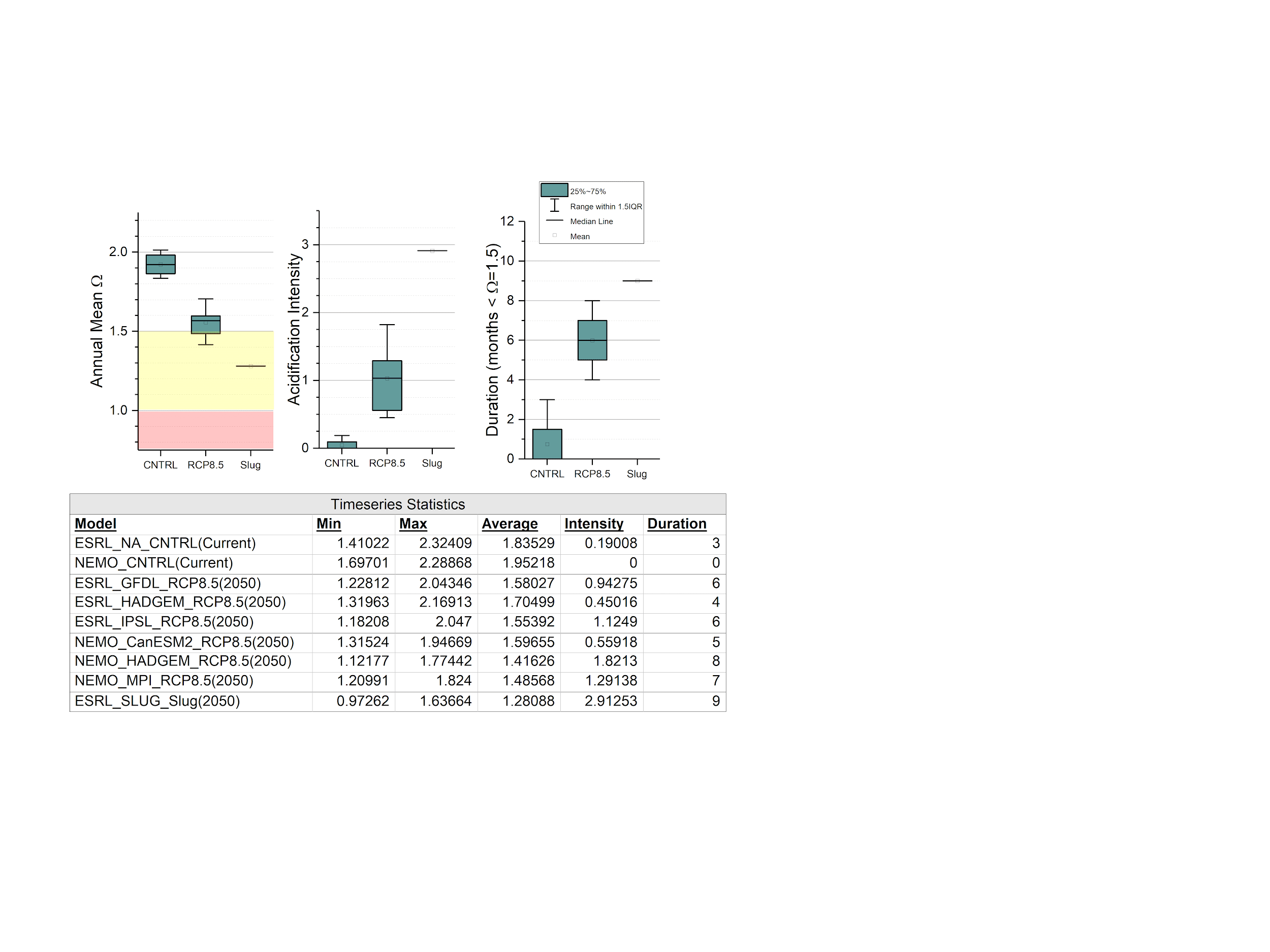
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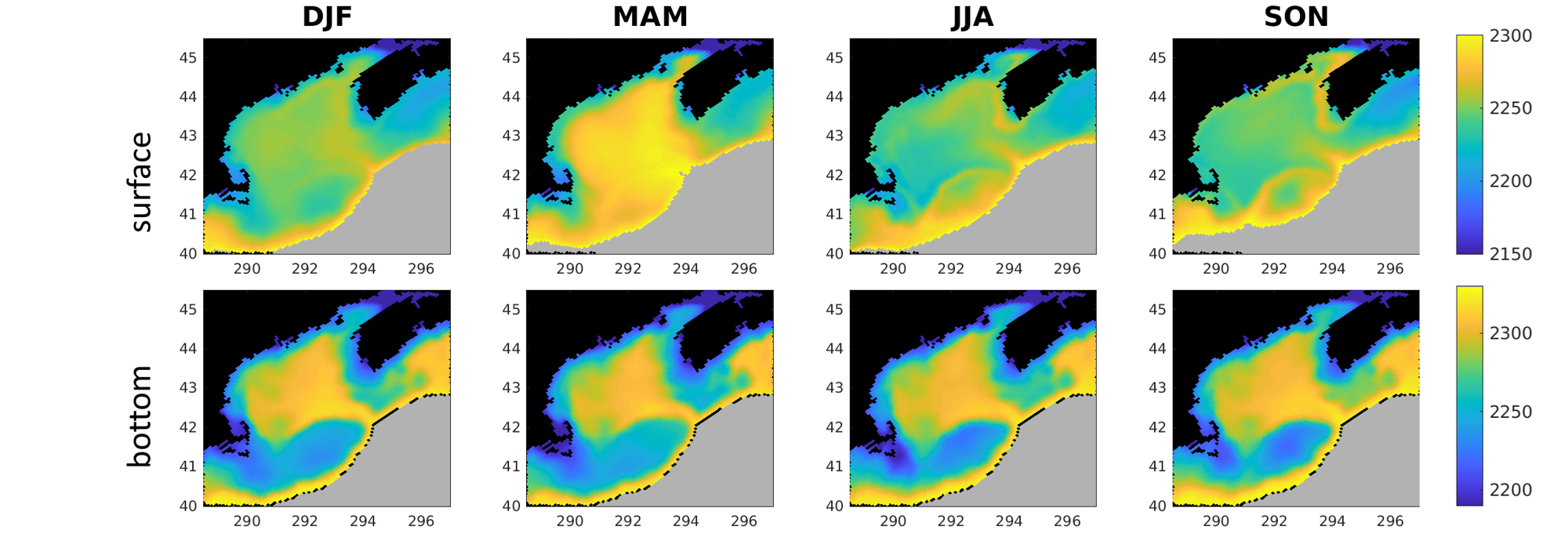
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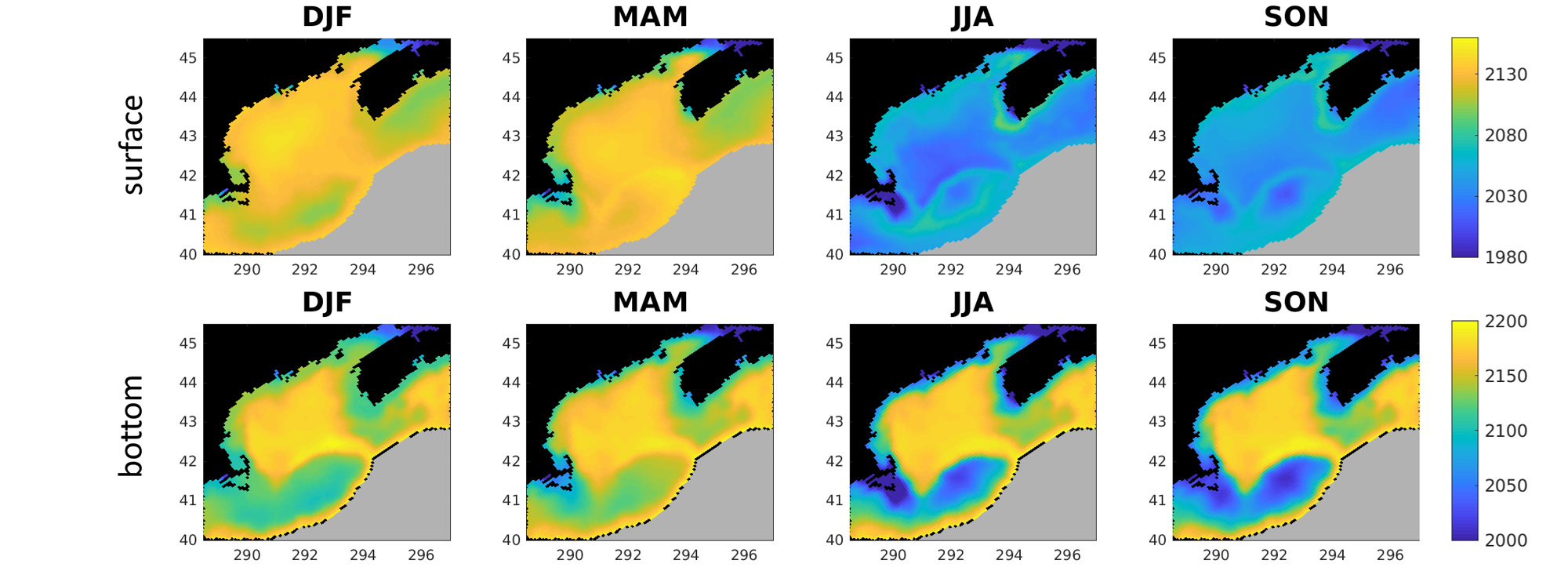
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**Table S1. Responses of six commercially important species of the Gulf of Maine to increased ocean and coastal acidification (OCA) conditions1**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Reference** | **pCO2 (ppm), T (°C)** | **pH** | Ωarag, Ωcalcite**a** | **Exposure period** | **Life stage** | **Resultsb** |
| American lobster *Homarus americanus* | | | | | | |
| Harrington and Hamlin, 2019 | 486 | 7.95 | Ωarag: 1.25 | 60 days | Juveniles: 50–65 mm carapace length, sub adult females | ↔hemolymph total protein |
| 850 | 7.6 | Ωarag:0.63 | ↔hemolymph calcium |
| ↔hemolymph ecdysterone (20E) |
| ↓L-lactate concentration |
| ↓Total Hemocyte Counts |
| ↓Cardiac performance |
| McLean et al., 2018 | 400 (year 2014) | 7.92 | Ωcalcite:3.15 | 90–120 days | Juveniles: 4–6 mo post hatch | ↓ growth |
| 400 (year 2015) | 8.02 | Ωcalcite:2.66 | ↑ 1st intermolt time period |
| 1000 (year 2014) | 7.68 | Ωcalcite:1.57 | ↑ 2nd and 3rd intermolt time period at medium CO2 level |
| 1000 (year 2015) | 7.64 | Ωcalcite:1.48 | ↑shell disease |
| 2000 (year 2014) | 7.40 | Ωcalcite:0.86 |
| 2000 (year 2015) | 7.40 | Ωcalcite:0.89 |
| Waller et al., 2017 | 380, 16 | 8.066 | Ωarag:2.14 | 25 up to 32 days | Larvae: stage I–IV | ↔ with CO2 alone; |
| 380, 19 | 8.091 | Ωarag:2.65 | with CO2 and T increases: |
| 750, 16 | 7.886 | Ωarag:1.62 | ↑feeding rates, swimming speeds, carapace lengths, dry mass |
| 750, 19 | 7.836 | Ωarag:1.67 | ↓survival |
| Menu-Courey et al., 2019 | 400 | 7.97 | Ωarag 2.03 | 40 days | Larvae: stage IV–V | ↓ survival and slower development |
| 600 | 7.89 | Ωarag:1.76 | ↑aerobic capacity |
| 800 | 7.80 | Ωarag:1.47 |
| 1000 | 7.73 | Ωarag:1.27 |
| 1200 | 7.67 | Ωarag:1.12 |
| 2000 | 7.39 | Ωarag:0.61 |
| 3000 | 7.17 | Ωarag:0.38 |
| Niemisto et al., 2020 | 400, 16 | 7.94 | Ωarag:1.45 | 15 to 31 days | Larvae: stage I–IV; collected as postlarvae | ↓ down-regulation of cuticle proteins and a calcification-associated peptide at elevated T. ↑ upregulated chitinase and cuticle proteins associated with calcium binding under elevated CO2. Heat shock proteins: ↓ downregulated under elevated T alone; ↑ upregulated at elevated pCO2 and at elevated pCO2/T |
|  | 1200, 16 | 7.56 | Ωarag:0.72 |
|  | 400, 19 | 7.89 | Ωarag:1.52 |
|  | 1200, 19 | 7.63 | Ωarag:0.88 |
| Eastern oyster *Crassostrea virginica* | | | | | | |
| Clements et al., 2017 | - | 7 | - | 21 - 35 days in lab; 50 days in field | Adults: 45–90 mm in length | ↔ Shell length, width or weight |
| - | 7.5 | - | ↓ parasite *Polydora websteri* |
| - | 8 | - |
| Clements et al., 2018 | 1000 | 7.64 | Ωarag: 0.60 | 10 days | Adults: 64.1–82.4-mm shell height | ↔gaping |
| 1500 | 7.44 | Ωarag:0.38 |
| 2500 | 7.30 | Ωarag:0.28 |
| 5500 | 6.91 | Ωarag:0.12 |
| 8000 | 6.79 | Ωarag:0.09 |
| Young and Gobler, 2018 | 400 | 7.98 | Ωarag: 1.91 | 14 days | Juveniles: 2.45 and 24.92 mm | ↓ Shell growth rates |
| 1700 | 7.39 | Ωarag:0.59 | ↓ Tissue growth rates; adding Ulva: ↑ bivalve performance |
| Richards, 2017 | 400 | 8.47 | - | 6 days | Larvae: early stages | ↓ mean shell length, ↓ survival |
| 1000 | 8.32 | - | ↓↑ in expression levels of four calcium binding protein genes. |
| Sea Scallop *Placopecten magellanicus* | | | | | | |
| Rheuban et al., 2018c | RCP 4.5 | - | - | - | Adults | ↓ biomass, 13% by 2100 |
| RCP 8.5 | - | - | - | ↓ biomass >50% by 2100 |
| Cooley et al., 2015 c | RCP8.5 MA | S: 8.05-7.91 | Ωcalcite: 3.35-2.65 | 40 years | Various: Model assumes less recruitment and growth due to OA, and more growth due to warming | ↓ harvests by 2050 under RCP 8.5 CO2 emissions and current harvest rules |
| RCP8.5 GB | S: 8.08- 7.94 | Ωcalcite: 3.23- 2.51 | Projected pH for surface (S) and deep waters (D); larger pH is initial condition; MA = Mid- Atlantic; GB = Georges Bank |
| RCP8.5 MA | D: 8.05- 7.85 | Ωcalcite: 2.64- 1.99 |
| RCP8.5 GB | D: 8.05-7.89 | Ωcalcite: 2.80- 2.11 |
| Surfclam *Spisula solidissima* | | | | | | |
| Pousse et al., in press | 566 | 7.80 | Ωarag: 1.16 | 15 weeks | Juveniles | ↓ Scope for growth, ↓Assimilation ↓ clearance rate, ↑ excretion, Ո selection efficiency and respiration |
|  | 1380 | 7.46 | Ωarag: 0.57 |
|  | 2164 | 7.28 | Ωarag: 0.37 |
| Meseck et al., in press | 344 | 7.97 | Ωarag: 2.18 | 28 days | Larvae | Ո growth rates, % metamorphosis, shell height  ↔ on survival |
| 820 | 7.63 | Ωarag: 1.09 |
| 1243 | 7.46 | Ωarag: 0.77 |
| Soft-shell clam *Mya aenaria* | | | | | | |
| Lesser et al., 2019 | 380,10-12C | 8.076 | Ωarag: 2.298 | 13 days | Juveniles: 1.5–2.4 cm Shell Length | ↑Steamerd expression at low pH |
| 380,16-18 C | 8.055 | Ωarag: 2.455 |
| 560,10-12 C | 7.93 | Ωarag: 1.822 |
| 560,16-18 C | 7.948 | Ωarag: 2.202 |
| Clements et al., 2016 | - | 6.94 lab sediment | - | 20 minutes up to 7 days | Juveniles | ↓burrowing, ↓dispersal pattern |
| - | 6.82 field sediment | - |
| Glaspie et al., 2017e | 1284 | 7.8 | Ωcalcite: 3.88 | 30 days | Juveniles: 28 mm | ↓shell weight, ↓responsiveness to predators |
| 6464 | 7.2 | Ωcalcite: 1.18 |
| Clements and Hunt, 2018f | - | - | - | - | Juveniles: < 6mm in length | ↓Mean clam abundance with ↓sediment pH and ↓sediment grain size |
| Meseck et al., 2018 f | - | 6.18 to 8.34 in porewater | Ωarag: 0.30 to 3.52 | - | Juveniles< 4mm in length | pH and phosphate explained 44% of bivalve abundance. *Mya arenaria* and *Nucula* spp. are >80% |
| Atlantic sea herring *Clupea harengus* | | | | | | |
| Leo et al., 2018 | 415, 6 C | 8.15 | - | 27 days | Larvae: measured at hatch, from exposed eggs | At higher T: ↑energy demand; at higher T and CO2: ↑ larval malformations |
| 1101, 6 C | 7.77 | - | 27 days |
| 408, 10 C | 8.17 | - | 16 days |
| 1050, 10C | 7.79 | - | 16 days |
| 403, 14C | 8.18 | - | 11 days |
| 1050, 14C | 7.78 | - | 11 days |
| Maneja et al., 2015 | 370 | 8.08 | - | 34 days | Larvae: 34 days post hatch | ↔ Swim behavior, ↓ larval growth |
| 1800 | 7.44 | - |
| 4200 | 7.08 | - |
| Sswat et al., 2018ae | 380 | - | - | 113 days | Larvae: measured at hatch, from exposed eggs | ↑ survival 19% |
| 760 | - | - |
| Sswat et al., 2018b | 400, 10 C | 8.11 | - | 32 days | Larvae: Post hatch until stage 2c | At higher T: ↑ swimming activity, ↓survival and growth rate; at higher CO2: ↔ Larval size, growth rate and swimming activity; at higher CO2 and lower T: ↓ larval weight |
| 400, 12 C | - | - |
| 900, 10 C | 7.81 | - |
| 900, 12 C | - | - |

1 This Table only includes studies for species from the Gulf of Maine region since the review by Gledhill et al. (2015)

a Saturation state for aragonite (Ωarag) or for calcite (Ωcalcite)

b Significant increase (↑), significant decrease (↓), no significant response (↔) or hormetic response (Ո) in variable to increased pCO2

c Modeling study

d Steamer is a retrotrasposon likely involved in disseminated neoplasia or hemocyte leukemia in the clam

e Mesocosm experiment

f Field study

**Table S2. Studies on organismal response of species from the Gulf of Maine to ocean acidification (OA) conditions1**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **# of studies** | | **Life Stage** | | | **Response to acidification** | | |  |
| **Common Name** | **Scientific name** | **OA** | **Multi-stressor** | **Egg/Larvae** | **Juvenile** | **Adult** | **↑a** | **↓b** | **↔c** | **Reference** |
| Crustaceans | | | | | | | | | | |
| Blue crab | *Callinectes sapidus* | 1 | - | - | - | 1 | - | - | 1 | Glaspie et al.,, 2017 |
| Green crab | *Carcinus maenas* | 1 | - | - | - | 1 | - | - | 1 | Spangenberg, 2018 |
| Artic copepod | *Calanus glacialis* | 1 |  | 1 | - | - | - | - | 1 | Bailey et al., 2016 |
| Copepod | *Calanus finmarchicus* | - | 1 | 1 | - | - | - | - | 1 | Preziosi et al., 2017 |
| Copepod | *Acartia tonsa* | 1 | - | 1 | 1 | 1 | - | 1 | - | (Cripps et al.,, 2014) |
| Mollusks | | | | | | | | | | |
| Blue mussel | *Mytilus edulis* | 6 | 3 | 2 | 2 | 5 | 1 | 7 | 1 | Broszeit et al., 2016; Dickey et al., 2018; Fitzer et al., 2014a; 2014b; 2015; Lesser, 2016; Ramesh et al., 2017; Ventura et al., 2016; Young and Gobler, 2018 |
| Hard clam | *Mercenaria mercenaria* | - | 4 | 2 | 1 | 1 | 1 | 5 | - | Clements and Hunt, 2017; Clements et al., 2016; Griffith and Gobler, 2017; Miller and Waldbusser, 2016; Young and Gobler, 2018 |
| Nut clam | *Nucula* spp. | - | 1 | - | - | 1 | - | 1 | - | Meseck et al., 2018 |
| Pteropod | *Limacina retroversa* | 2 | 1 | 1 | - | 2 | - | 3 | - | Bergan et al., 2017; Thabet et al., 2015 |
| Bay scallops | *Argopecten irradians* | - | 2 | - | 1 | 1 | 1 | 1 | - | Griffith and Gobler, 2017; Young and Gobler, 2018 |
| Fish | | | | | | | | | | |
| Little skate | *Leucoraja erinacea* | - | 3 | 2 | 1 | - | - | 3 | - | Di Santo, 2015; 2016; 2019 |
| Skate | *Rostroraja eglanteria* | - | 1 | - | - | 1 | - | 1 | - | Schwieterman et al., 2019 |
| Thorny Skate | *Amblyraja radiata* | - | 1 | - | - | 1 | - | 1 | - | Schwieterman et al., 2019 |
| Inland Silverside | *Menidia beryllina* | - | 1 | 1 | - | - | - | 1 | - | Gobler et al, 2018 |
| Sheepshead minnow | *Cyprinodon variegatus* | - | 1 | 1 | - | - | - | 1 | - | Gobler et al., 2018 |
| Smooth dogfish | *Mustelus canis* | 1 | - | - | - | 1 | - | 1 | - | Dixson et al., 2015 |
| Scup | *Stenotomus chrysops* | 1 | - | - | 1 | - | - | - | 1 | Perry et al., 2015 |
| Echinoderms | | | | | | | | | | |
| Seastar | *Asterias rubens* | 1 | - | - | - | 1 | - | - | 1 | McCarthy et al., 2020 |
| Polychaetes | | | | | | | | | | |
| Worms | *Hediste diversicolor* | 1 | 1 | - | - | 2 | - | 2 | - | Freitas et al., 2016; 2017; |
| Worm | *Alitta virens* | - | 1 | - | - | - | - | - | 1 | Nielson et al., 2019 |
| Worm | *Hydroides elegans* | 1 | 1 | - | - | 2 | 1 | 1 | - | Li et al., 2016; Meng et al., 2019 |
| Macroalgae | | | | | | | | | | |
| Sea lettuce | *Ulva* spp. | - | 2 | - | - | - | 2 | - | - | Young and Gobler, 2016; 2018 |
| Sea lettuce | *Ulva lactuca* | 1 | - | - | - | - | 1 | - | - | Chen et al., 2019 |
| Sea lettuce | *Gracilaria tikvahiae* | - | 1 | - | - | - | 1 | - | - | Young and Gobler, 2016 |
| Sea lettuce | *Pyropia leucosticta* | 1 | - | - | - | - | 1 | - | - | Chen et al., 2019 |
| Rhodophyta | *Lithothamnion glaciale* | 2 | - | - | - | 2 | - | 2 | - | Ragazzola et al., 2012; 2016 |
| Rhodophyta | *Lithothamnion corallioides* | - | 2 | - | - | 2 | - | 2 | - | Legrand et al., 2017; 2019 |
| Protists | | | | | | | | | | |
| Foraminifera | *Globobulimia turgida* | - | 1 | - | - | - | - | - | 1 | Wit et al., 2016 |
| Phytoplankton | | | | | | | | | | |
| Coccolithophore | *Emiliania huxleyi* | 1 | 1 | - | - | - | 2 | - | - | Jin et al., 2015; Schlüter, 2016 |
| Dinoflagellates | *Alexandrium catenella* | - | 1 | - | - | - | - | 1 | - | Seto et al. 2019 |
| Dinoflagellates | *Scrippsiella* sp. | - | 1 | - | - | - | 1 | - | - | Seto et al., 2019 |
| Dinoflagellates | *Karenia mikimotoi* | - | 2 | - | - | - | - | - | 2 | Seto et al., 2019; Wang et al., 2019 |
| Mesocosms | | | | | | | | | | |
| Phytoplankton | - | - | 1 | - | - | - | 1 | 1 | - | Schulz et al., 2017 |
| Copepod | - | - | 1 | - | - | - | - | 1 | - | Vehmaa et al., 2016 |
| Marine Ecosystem Models | | | | | | | | | | |
| Fish, Sharks, protected species, invertebrates, plankton | - | 1 | - | - | - | - | - | 1 | - | Fay et al., 2017 |
| Lobster, snow crabs, shrimp, scallops, clams, mussels, oysters | - | 1 | - | - | - | - | - | 1 | - | Wilson et al., 2020 |
| Harmful Algal Bloom | - | - | 1 | - | - | - | 1 | - | - | Glibert, 2020; Raven et al., 2020; Tester et al., 2020 |
| Evolutionary/Adaptive experiments | | | | | | | | | | |
| Blue mussel | *Mytilus edulis* | 2 | - | 2 | - | - | 1 | 1 | - | Kong et al., 2019; Thomsen et al., 2017 |
| Worm | *Hydroides elegans* | 1 | - | - | - | 1 | - | - | 1 | Lane et al., , 2015 |
| Copepod | *Acartia tonsa* | 2 | - | - | 2 | - | - | 1 | 1 | Aguilera et al., 2016; Langer et al., 2019 |
| Seastar | *Asterias rubens* | - | 1 | - | - | 1 | - | 1 | - | Hu et al., 2018 |

1 This is a review of biological studies for species from the Gulf of Maine region since the review by Gledhill et al. (2015)

a ↑ is a significant positive response to increased pCO2;

b↓ is a significant negative response to increased pCO2

c ↔ is no significant response to increased pCO2

**Table S3.** **GOM regional OA observing capacity description of observations plotted in Figure 2**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Project Name** | **Category** | **Parameter(s) measured** | **Discrete or continuous monitoring?** | **Frequency of sampling** | **Sampling depth** |
| ***LISICOS Western Long Island Sound*** | buoy | pH, pCO2 | continuous | every 15 mins throughout the year | bottom |
| ***LISICOS ARTG*** | buoy | pH | continuous | every 15 mins throughout the year | bottom |
| ***Portland Harbor carbon monitoring station (EPA)*** | monitoring station | pH, pCO2 | continual | every hour throughout the year | surface |
| ***Friends of Casco Bay*** | monitoring station | pCO2, pH | hourly | every hour throughout the year | surface |
| ***Halifax station (DFO)*** | buoy | pCO2 and pH | continuous | every hour throughout the year | surface |
| ***NERACOOS Gulf of Maine UNH Coastal Marine Lab Field Station*** | monitoring station | pCO2 | hourly | every hour throughout the year | surface |
| ***UNH Great Bay*** | buoy | pCO2, pH | continuous | every hour May-Nov | surface |
| ***Coastal Western Gulf of Maine mooring (NOAA, UNH)*** | buoy | pH, pCO2 | continual | every 3 hours throughout the year | surface |
| ***Bedford Basin*** | monitoring station | pH, pCO2, DIC, and TA | discrete (bottom mooring with pCO2 sensor) | pCO2 hourly/pH, pCO2, DIC, TA weekly | full column |
| ***Halifax station (DFO)*** | monitoring station | DIC, TA, pCO2 | discrete | weekly to monthly during the ice free season | full column |
| ***NERACOOS Gulf of Maine UNH Coastal Marine Lab Field Station*** | monitoring station | TA, pH, DIC | discrete | monthly-to-quarterly | surface |
| ***Wilkinson Basin transect (NOAA OAP)*** | cruise | pCO2 | continual | 4–7 times per year | surface |
| ***Wilkinson Basin transect (NOAA OAP)*** | sampling locations | TA, pH, DIC | discrete | 4-7 times per year | full column |
| ***R/V Bigelow (Global Carbon Group NOAA AOML), SOOP*** | cruise | pCO2 | continual | cruises run March–Nov, between 4–6 times in this timeframe, cruises last anywhere from 2–10 weeks | surface flow through |
| ***R/V Gunter (Ocean Chemistry and Ecosystems Division NOAA AOML), SOOP*** | cruise | pCO2 | continual | May–Nov deployments, 7 in 2019, 4 in northeast region | surface flow through |
| ***NSF NES-LTER*** | cruise | pCO2 | continous | 4 cruises per year | surface flow through |
| ***NSF NES-LTER*** | sampling locations | DIC and TA | discrete | 4 times per year | full column |
| ***Eco-Mon (NOAA NEFSC)*** | sampling locations | DIC, pH, TA, nutrients | discrete | 2–3 times per year | full column |
| ***OOI Maintanance/Deployment cruise (WHOI)*** | cruise | pH, DIC, TA, pCO2 | discrete | twice per year | full column |
| ***OOI Pioneer Array*** | buoy | pCO2 | continous | twice per year | surface |
| ***AZMP Halifax line*** | cruise | pCO2 | continuous | twice per year | surface flow through |
| ***AZMP Browns Bank line*** | cruise | pCO2 | continuous | twice per year | surface flow through |
| ***AZMP Yarmouth Line*** | cruise | pCO2 | continuous | twice per year | surface flow through |
| ***AZMP PL line*** | cruise | pCO2 | continuous | twice per year | surface flow through |
| ***AZMP PS line*** | cruise | pCO2 | continuous | twice per year | surface flow through |
| ***AZMP HL stations*** | monitoring stations | pH, pCO2, DIC and TA | discrete | twice per year | full column |
| ***AZMP BBL stations*** | monitoring stations | pH, pCO2, DIC and TA | discrete | twice per year | full column |
| ***AZMP YL stations*** | monitoring stations | pH, pCO2, DIC and TA | discrete | twice per year | full column |
| ***AZMP PL stations*** | monitoring stations | pH, pCO2, DIC and TA | discrete | twice per year | full column |
| ***AZMP PS stations*** | monitoring stations | pH, pCO2, DIC and TA | discrete | twice per year | full column |
| ***ECOA (NOAA OAP)*** | cruise | pCO2, DIC, pH, CO2atm | continual | once every 4 years | surface flow through |
| ***ECOA (NOAA OAP)*** | sampling locations | pH, DIC, pCO2, TA, nutrients (nitrate, nitrite, phosphate, orthosilicic acid) | discrete | once every 4 years | full column |
| ***Shell Day*** | monitoring locations | TA, salinity, some pH | discrete | single monitoring blitz August 2019 | surface |

**References:**

Aguilera, VM, Vargas, CA, Lardies, MA, Poupin, MJ. 2016. Adaptive variability to low‐pH river discharges in *Acartia tonsa* and stress responses to high pCO2 conditions. *Mar Ecol* **37**(1): 215–226. DOI: https://doi.org/10.1111/maec.12282

Bailey, A, Thor, P, Browman, HI, Fields, DM, Runge, J., Vermont, A., Bjelland, R, Thompson, C, Shema, S, Durif, CMF, Hop, H. 2016. Early life stages of the Arctic copepod *Calanus glacialis* are unaffected by increased seawater pCO2. *ICES J Mar Sci,* **74**(4): 996-1004. DOI: <https://doi.org/10.1093/icesjms/fsw066>

Bednaršek, N, Ohman MD. 2015. Changes in pteropod distributions and shell dissolution across a frontal system in the California Current System. *Mar Ecol Prog Ser* **523**: 93–103. DOI: https://doi.org/10.3354/meps11199

Bednaršek, N, Feely, RA, Beck, MW, Alin, SR, Siedlecki, SA, Calosi, P, Norton, EL, Saenger, C, Štrus, J, Greeley, D, Nezlin, NP, Roether, M, Spicer, JI. 2020. Exoskeleton dissolution with mechanoreceptor damage in larval Dungeness crab related to severity of present-day ocean acidification vertical gradients. *Sci Total Environ* **716**: 136610. [DOI: https://doi.org/10.1016/j.scitotenv.2020.136610](DOI:%20https://doi.org/10.1016/j.scitotenv.2020.136610)

Bergan, AJ, Lawson, GL, Maas, AE, Wang, ZA. 2017. The effect of elevated carbon dioxide on the sinking and swimming of the shelled pteropod *Limacina retroversa*. *ICES J Mar Sci* **74**(7): 1893–1905. DOI: https://doi.org/10.1093/icesjms/fsx008

Broszeit, S, Hattam, C, Beaumont, N. 2016. Bioremediation of waste under ocean acidification: Reviewing the role of *Mytilus edulis*. *Mar Pollut Bull* **103**(1): 5–14. DOI: <https://doi.org/10.1016/j.marpolbul.2015.12.040>

Fisheries and Oceans Canada. 2018. Canada’s Fish and Seafood Trade. Retrieved from <https://www.dfo-mpo.gc.ca/ea-ae/economic-analysis/CANADAS_FISH_SEAFOOD_TRADE_OVERVIEW.pdf>

Chavez, FP, Pennington, JT, Michisaki, RP, Blum, M, Chavez, GM, Friederich, J, Jones, B, Herlien, R, Kieft, B, Hobson, B, Ren, AS, Ryan, J, Sevadjian, JC, Wahl, C, Walz, KR, Yamahara, K, Friederich, GE, Messié, M. 2017. Climate variability and change: Response of a coastal ocean ecosystem. *Oceanography* **30**(4): 128–145. DOI: <https://doi.org/10.5670/oceanog.2017.429>

Chen, B, Lin, L, Ma, Z, Zhang, T, Chen, W, Zou, D. 2019. Carbon and nitrogen accumulation and interspecific competition in two algae species, *Pyropia haitanensis* and *Ulva lactuca*, under ocean acidification conditions. *Aquacult Int* **27**(3): 721–733. DOI: <https://doi.org/10.1007/s10499-019-00360-y>

Clements, JC, Woodard, KD, Hunt, HL. 2016. Porewater acidification alters the burrowing behavior and post-settlement dispersal of juvenile soft-shell clams (*Mya arenaria*). *J Exp Mar Biol Ecol* **477**: 103–111. DOI: https://doi.org/10.1016/j.jembe.2016.01.013

Coastal Enterprises, Inc. 2018. Opportunities for Aquaculture on the Massachusetts South Coast: A Sector Analysis. 65 pp. <https://www.ceimaine.org/wp-content/uploads/2018/04/MA-South-Coast-Aquaculture-Analysis.2018.pdf>

Cripps, G, Lindeque, P, Flynn, KJ. 2014. Have we been underestimating the effects of ocean acidification in zooplankton? *Glob Change Biol* **20**(11): 3377–3385. DOI: https://doi.org/10.1111/gcb.12582

Di Santo, V. 2015. Ocean acidification exacerbates the impacts of global warming on embryonic little skate, *Leucoraja erinacea* (Mitchill). *J Exp Mar Biol Ecol* **463**: 72–78. DOI: <https://doi.org/10.1016/j.jembe.2014.11.006>

Di Santo, V. 2016. Intraspecific variation in physiological performance of a benthic elasmobranch challenged by ocean acidification and warming. *J Exp Biol* **219**(11): 1725–1733. DOI: https://doi.org/10.1242/jeb.139204

Di Santo, V. 2019. Ocean acidification and warming affect skeletal mineralization in a marine fish. *P Roy Soc B-Biol Sci* **286**(1894). DOI: https://doi.org/10.1098/rspb.2018.2187.

Fennel, K, Wilkin, J, Levin, J, Moisan, J, O'Reilly, J, Haidvogel, D. 2006. Nitrogen cycling

in the Middle Atlantic Bight: Results from a three‐dimensional model and implications for the North Atlantic nitrogen budget, *Global Biogeochem Cy* **20**: GB3007, DOI: https://doi.org/[10.1029/2005GB002456](https://doi.org/10.1029/2005GB002456).

Fisheries and Oceans Canada. 2019. Farmed Salmon. <http://www.dfo-mpo.gc.ca/aquaculture/sector-secteur/species-especes/salmon-saumon-eng.htm> (Accessed 7 October 2019).

Fitzer, SC, Cusack, M, Phoenix, VR, Kamenos, NA. 2014a. Ocean acidification reduces the

crystallographic control in juvenile mussel shells. *J Struct Biol* **188**(1): 39–45. DOI: <https://doi.org/10.1016/j.jsb.2014.08.007>

Fitzer, SC, Phoenix, VR, Cusack, M, Kamenos, NA. 2014b. Ocean acidification impacts mussel

control on biomineralisation. *Sci Rep* **4**(1): 6218. DOI: https://doi.org/10.1038/srep06218

Fitzer, SC, Zhu, W, Tanner, KE, Phoenix, VR, Kamenos, NA, Cusack, M. 2015. Ocean acidification alters the material properties of *Mytilus edulis* shells. *J R Soc Interface* **12**(103): 20141227. DOI: https://doi.org/10.1098/rsif.2014.1227

Freitas, R, de Marchi, L, Moreira, A, Pestana, JLT, Wrona, FJ, Figueira, E, Soares, AMVM. 2017. Physiological and biochemical impacts induced by mercury pollution and seawater acidification in *Hediste diversicolor*. *Sci Total Environ* **595**: 691–701. DOI: <https://doi.org/10.1016/j.scitotenv.2017.04.005>

Freitas, R, Pires, A, Moreira, A, Wrona, FJ, Figueira, E, Soares, AMVM. 2016. Biochemical alterations induced in *Hediste diversicolor* under seawater acidification conditions. *Mar Environ Res* **117**: 75–84. DOI: <https://doi.org/10.1016/j.marenvres.2016.04.003>

Gentry, RR, Froelich, HE, Grimm, D, Karelva, P, Parke, M, Rust, M, Gaines, SD, Halpern, BS. 2017.

Mapping the global potential for marine aquaculture. *Nature Ecology and Evolution* **1**: 1317–1324. DOI: https://doi.org/[10.1038/s41559-017-0257-9](https://doi.org/10.1038/s41559-017-0257-9)

Glaspie, CN, Longmire, K, Seitz, RD. 2017. Acidification alters predator-prey interactions of blue

crab *Callinectes sapidus* and soft-shell clam *Mya arenaria*. *J Exp Mar Biol Ecol* **489**: 58–65. DOI: <https://doi.org/10.1016/j.jembe.2016.11.010>

Glibert, PM. 2020. Harmful algae at the complex nexus of eutrophication and climate change. *Harmful*

*Algae* **91**: 101583. DOI: <https://doi.org/10.1016/j.hal.2019.03.001>

Gobler, CJ, Merlo, LR, Morrell, BK, Griffith, AW. 2018. Temperature, acidification, and food

supply interact to negatively affect the growth and survival of the forage fish, *Menidia beryllina* (Inland Silverside), and *Cyprinodon variegatus* (Sheepshead Minnow). *Frontiers in Marine Science* **5**: 86. DOI: https://doi.org/10.3389/fmars.2018.00086

Gulf of Maine Council on the Marine Environment. 2010. Ecosystem indicator partnership. 3 pp.

<http://www.gulfofmaine.org/esip/ESIPFactSheetAquacultureversion3.pdf>

Hale Group, LTD. 2016. Maine farmed shellfish market analysis. Gulf of Maine Research Institute. 65 pp. <https://gmri.org/sites/default/files/resource/gmri_farmed_shellfish_final_with_cover_10.13.16.pdf>

Hu, MY, Lein, E, Bleich, M, Melzner, F, Stumpp, M. 2018. Trans-life cycle acclimation to experimental ocean acidification affects gastric pH homeostasis and larval recruitment in the sea star *Asterias rubens*. *Acta Physiol* **224**(2): e13075. DOI: <https://doi.org/10.1111/apha.13075>

Johnson, TR, Beard, K, Brady, DC, Byron, CJ, Cleaver, C, Duffy, K, Keeney, N, Kimble, M,

Miller, M, Moeykens, S, Teisl, M, van Walsum, GP, Yuan, J. 2019. A social-ecological systems framework to guide marine aquaculture research. *Sustainability* **11**: 2522. DOI: https://doi.org/10.3390/su11092522

Jokiel, PL. 2016. Predicting the impact of ocean acidification on coral reefs: evaluating the

assumptions involved. *ICES J Mar Sci* **73(**3): 550–557. DOI: <https://doi.org/10.1093/icesjms/fsv091>

Kelly, RP, Caldwell, MR. 2013. Ten Ways States Can Combat Ocean Acidification (and Why They Should). *Harvard Environmental Law Review* **37**(1): 57–103. Retrieved from <https://digitalcommons.law.uw.edu/wjelp/vol6/iss2/5>

Kong, H, Jiang, X, Clements, JC, Wang, T, Huang, X, Shang, Y, Chen, J, Hu, M, Wang, Y. 2019.

Transgenerational effects of short-term exposure to acidification and hypoxia on early developmental traits of the mussel *Mytilus edulis*. *Mar Environ Res* **145**: 73–80. DOI: <https://doi.org/10.1016/j.marenvres.2019.02.011>

Lane, A, Campanati, C, Dupont, S, Thiyagarajan, V. 2015. Trans-generational responses to low pH

depend on parental gender in a calcifying tubeworm. *Sci Rep* **5**(1): 1–7. DOI: https://doi.org/10.1038/srep10847

Langer, JA, Meunier, CL, Ecker, U, Horn, HG, Schwenk, K, Boersma, M. 2019. Acclimation and adaptation of the coastal calanoid copepod *Acartia tonsa* to ocean acidification: a long-term laboratory investigation. *Mar Ecol Prog Ser* **619**: 35–51. DOI: <https://doi.org/10.3354/meps12950>

Legrand, E, Riera, P, Lutier, M, Coudret, J, Grall, J, Martin, S. 2017. Species interactions can shift the response of a maerl bed community to ocean acidification and warming. *Biogeosciences* **14**(23): 5359–5376. DOI: https://doi.org/10.5194/bg-14-5359-2017

Legrand, E, Riera, P, Lutier, M, Coudret, J, Grall, J, Martin, S. 2019. Grazers increase the sensitivity of coralline algae to ocean acidification and warming. *J Sea Res* **148–149**: 1–7. DOI: <https://doi.org/10.1016/j.seares.2019.03.001>

Lesser, MP. 2016. Climate change stressors cause metabolic depression in the blue mussel, *Mytilus*

*edulis*, from the Gulf of Maine. *Limnol Oceanogr* **61**(5): 1705–1717. DOI: https://doi.org/10.1002/lno.10326

Lesser, MP, Thompson, MM, Walker, CW. 2019. Effects of thermal stress and ocean acidification on the expression of the retrotransposon *steamer* in the Softshell *Mya arenaria*. *J Shellfish Res* **38**(3): 535–541. DOI: <https://doi.org/10.2983/035.038.0304>

Li, C, Meng, Y, He, C, Chan, VB, Yao, H, Thiyagarajan, V. 2016. Mechanical robustness of the calcareous tubeworm *Hydroides elegans*: warming mitigates the adverse effects of ocean acidification. *Biofouling* **32**(2): 191–204. DOI: <https://doi.org/10.1080/08927014.2015.1129532>

Love, E. 2016. Shellfish and seaweed aquaculture as a mechanism for economic diversification in Maine

island and coastal communities. Casco Bay Estuary Partnership & the Island Institute. 31 pp. <https://www.cascobayestuary.org/wp-content/uploads/2016/11/Shellfish-and-seaweedaquaculture-as-a-mechanism-for-diversification-2016-1.pdf>

McCarthy, ID, Whiteley, NM, Fernandez, WS, Ragagnin, MN, Cornwell, TO, Suckling, CC, Turra, A. 2020. Elevated pCO2 does not impair performance in autotomised individuals of the intertidal predatory starfish *Asterias rubens* (Linnaeus, 1758). *Mar Environ Res* **153**: 104841. DOI: <https://doi.org/10.1016/j.marenvres.2019.104841>

Meng, Y, Li, C, Li, H, Shih, K, He, C, Yao, H, Thiyagarajan, V. 2019. Recoverable impacts of ocean acidification on the tubeworm, *Hydroides elegans*: implication for biofouling in future coastal oceans. *Biofouling* **35**(8): 945–957. DOI: https://doi.org/10.1080/08927014.2019.1673376.

Mizuta, DD, Wikfors, GH. 2019a. Depth selection and in situ validation for offshore mussel aquaculture in Northeast United States federal waters. *Journal of Marine Science and Engineering* **7**(9): 293. DOI: https://doi.org/10.3390/jmse7090293

Mizuta, DD, Dixon, MS, Maney, EJ, Fregeau, M, Wikfors, GH. 2019b. Offshore mussel aquaculture: strategies for farming in the changing environment of the Northeast US shelf EEZ. *Bull Jap Fish Res Edu Agen* **49**: 119. <http://www.fra.affrc.go.jp/bulletin/bull/bull49/49-0513.pdf>

Nielson, C, Hird, C, Lewis, C. 2019. Ocean acidification buffers the physiological responses of the

king ragworm *Alitta virens* to the common pollutant copper. *Aquat Toxicol* **212**: 120–127. DOI: <https://doi.org/10.1016/j.aquatox.2019.05.003>

Niemisto M, Fields DM, Clark KF, Waller JD, Greenwood SJ, Wahle RA. American lobster postlarvae alter gene regulation in response to ocean warming and acidification. *Ecol Evol*. 2021;11(2):806-819. doi:10.1002/ece3.7083

Perry, DM, Redman, DH, Widman, JC, Meseck, S, King, A, Pereira, JJ. 2015. Effect of ocean acidification on growth and otolith condition of juvenile scup, *Stenotomus chrysops*. *Ecol Evol* **5**(18): 4187-4196. DOI: <https://doi.org/10.1002/ece3.1678>

Pousse E, Poach ME, Redman DH, Sennefelder G, White LE, Lindsay JM, Munroe D, Hart D, Hennen D, Dixon MS, Li Y, Wikfors, GH, Meseck, SL. 2020. Energetic response of Atlantic surfclam *Spisula solidissima* to ocean acidification. *Mar Pollut Bull* **161**:111740. DOI: https://doi.org/10.1016/j.marpolbul.2020.111740

Preziosi, BM, Runge, JA, Christensen, JP, Jones, RJ. 2017. Effects of pH and temperature on egg hatching success of the marine planktonic copepod, *Calanus finmarchicus*. *Marine Biology* **164**(11): 218. DOI: https://doi.org/10.1007/s00227-017-3243-5

Ragazzola, F, Foster, LC, Form, A, Anderson, PS, Hansteen, TH, Fietzke, J. 2012. Ocean acidification weakens the structural integrity of coralline algae. *Glob Change Biol* **18**(9): 2804-2812. DOI: https://doi.org/10.1111/j.1365-2486.2012.02756.x

Ragazzola, F, Foster, LC, Jones, CJ, Scott, TB, Fietzke, J, Kilburn, MR, Schmidt, DN. 2016. Impact of high CO2 on the geochemistry of the coralline algae *Lithothamnion glaciale*. *Sci Rep* **6**(1): 20572. DOI: https://doi.org/10.1038/srep20572

Ramesh, K, Hu, MY, Thomsen, J, Bleich, M, Melzner, F. 2017. Mussel larvae modify calcifying

fluid carbonate chemistry to promote calcification. *Nat Commun* **8**(1): 1709. DOI: <https://doi.org/10.1038/s41467-017-01806-8>

Schlüter, L. 2016. Long-term adaptation of the coccolithophore *Emiliania huxleyi* to ocean acidification

and global warming. (Doctoral dissertation) Christian-Albrechts-Universität: Kiel.

Schwieterman, GD, Crear, DP, Anderson, BN, Lavoie, DR, Sulikowski, JA, Bushnell, PG, Brill, RW. 2019. Combined effects of acute temperature change and elevated pCO2 on the metabolic rates and hypoxia tolerances of clearnose skate (*Rostaraja eglanteria*), summer flounder (*Paralichthys dentatus*), and thorny skate (*Amblyraja radiata*). *Biology,* **8**(3): 56. DOI: https://doi.org/10.3390/biology8030056

Seto, DS, Karp-Boss, L, Wells, ML. 2019. Effects of increasing temperature and acidification on the growth and competitive success of *Alexandrium catenella* from the Gulf of Maine. *Harmful Algae* **89**: 101670. DOI: <https://doi.org/10.1016/j.hal.2019.101670>

Snyder, J, Boss, E, Weatherbee, R, Thomas, A, Brady, DC, Newell, C. 2017. Oyster aquaculture

site selection using Landsat 8-derived sea surface temperature, turbidity, and chlorophyll a. *Frontiers in Marine Science* **4**(190): 1–11. DOI: https://doi.org/10.3389/fmars.2017.00190

Spangenberg, CM. 2018. *Construction of an accessible ocean-acidification simulator to investigate physiological responses of the green crab, Carcinus maenas, to acidified conditions.* (Degree with Honors). University of Maine, Orono. Available at <https://digitalcommons.library.umaine.edu/honors/353>

Tlusty, MF, Wikgren, B, Lagueux, K, Kite-Powell, H, Jin, D, Hoagland, P, Kenney, RD, Kraus, SD. 2018. Co-occurrence mapping of disparate data sets to assess potential aquaculture sites in the Gulf of Maine. *Reviews in Fisheries Science & Aquaculture* **26**(1): 70–85. DOI: https://doi.org/10.1080/23308249.2017.1343798

Thabet, AA, Maas, AE, Lawson, GL, Tarrant, AM. 2015. Life cycle and early development of

the thecosomatous pteropod *Limacina retroversa* in the Gulf of Maine, including the effect of elevated CO2 levels. *Marine Biology* **162**(11): 2235–2249. DOI: https://doi.org/10.1007/s00227-015-2754-1

Thomsen, J, Stapp, LS, Haynert, K, Schade, H, Danelli, M, Lannig, G, Wegner, KM, Melzner, F. 2017.

Naturally acidified habitat selects for ocean acidification-tolerant mussels. *Science Advances* **3**(4): e1602411. DOI: https://doi.org/10.1126/sciadv.1602411

Townsend, DW, Thomas, AC, Mayer, LM, Thomas, MA, Quinlan, JA. 2006. Oceanography of the Northwest Atlantic Continental Shelf, in AR Robinson, KH Brink eds, *The Sea: The Global Coastal Ocean: Interdisciplinary Regional Studies and Syntheses*. Cambridge, Mass: Harvard Univ Press: 119–168.

United Nations, Department of Economic and Social Affairs, Population Division. 2015. World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.241. 66 pp.

Waldbusser, GG, Hales, B, Langdon, CJ, Haley, BA, Schrader, P, Brunner, EL, Gray, MW, Miller, CA, Gimenez, I, Hutchinson, G. 2015b. Ocean acidification has multiple modes of action on bivalve larvae. *PLOS One* **10**(6): e0128376. DOI: https://doi.org/10.1371/journal.pone.0128376

Wang, X, Feng, X, Zhuang, Y, Lu, J, Wang, Y, Gonçalves, RJ, Li, X, Lou, Y, Guan, W. 2019. Effects of

ocean acidification and solar ultraviolet radiation on physiology and toxicity of dinoflagellate *Karenia mikimotoi*. *Harmful Algae* **81**: 1–9. DOI: <https://doi.org/10.1016/j.hal.2018.11.013>

Wit, JC, Davis, MM, Mccorkle, DC, Bernhard, JM. 2016. A short-term survival experiment assessing impacts of ocean acidification and hypoxia on the benthic foraminifer *Globobulimina turgida. J Foramin Res* **46**(1): 25–33. DOI: https://doi.org/10.2113/gsjfr.46.1.25

Young, CS, Gobler, CJ. 2016. Ocean acidification accelerates the growth of two bloom-forming macroalgae. *PLOS One* **11**(5). DOI: https://doi.org/10.1371/journal.pone.0155152

Zakroff, C, Mooney, TA, Berumen, ML. 2019. Dose-dependence and small-scale variability in responses to ocean acidification during squid, *Doryteuthis pealeii*, development. *Marine Biology,* **166**(5): 62. DOI: https://doi.org/10.1007/s00227-019-3510-8

Zakroff, C, Mooney, TA, Wirth, C. 2018. Ocean acidification responses in paralarval squid swimming behavior using a novel 3D tracking system. *Hydrobiologia* **808**(1): 83–106. DOI: https://doi.org/10.007/s10750-017-3342-9