# #43 – Dec 2017/Jan 2018 (http://nzoac.nz/) Upcoming meetings The 11th New Zealand Ocean Acidification Workshop, 13-14th February 2018 – University of Waikato

Draft program

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| Day/Time | Speaker | Title |
| Tuesday 13th Feb 08:45 |  | Welcome and Introductions |
| 09:00 | John Zeldis | Contrasting catchment loading and net ecosystem metabolism in four New Zealand bays: implications for coastal management |
| 09:15 | Graham Rickard | Biogeochemical ROMS modelling of NZ Shelves for present day and future states |
| 09:30 | Qingshan Luan | Changes in phytoplankton community and particle size distribution during a mesocosm study on OA and warming – results from a FlowCam measurement |
| 09:45 | Cliff Law | Will ocean acidification and warming alter phytoplankton feedbacks in climate? |
| 10:00 | Morgan Myers | Copepod Grazing and selectivity on natural prey communities during a high-temperature, low-pH mesocosm experiment |
| 10:15 | Miles Lamare | Potential effects of OA on the settlement and metamorphosis of marine larvae: a review with reference to CARIM experiments |
| 10:30 |  | Morning Tea |
| 11:00 | Anna Kluibenschedl | NZ crustose coralline algae communities in a future ocean: biological and ecological responses under elevated pCO2 |
| 11:15 | Vonda Cummings | Larval paua in a high CO2 world: does nature or nurture matter most? |
| 11:30 | Nadjejda Espinel | Effects of OA on larval settlement on Z Abalone (Haliotis iris) |
| 11:45 | Jenn Jury | The influence of genetics and elevated pCO2 upon acute thermo-tolerance of green-lipped mussel *Perna canaliculus* spat |
| 12:00 | Norman Ragg | Prolonged exposure of adult mussels (*Perna canaliculus*) to elevated pCO2 influences offspring performance |
| 12:15 | Zoe Hilton | Bioenergetic impacts of exposure to chronic future OA scenarios on adult Greenshell mussels, *Perna canaliculus* |
| 12:30 |  | Lunch |
| 13:30 | Oliver Knebel | Putting the Pacific Ocean to the Litmus test: resolving the multi-millennial record of ocean pH from corals with boron isotopes |
| 13:45 | Helen Bostock | Boron isotopes: a proxy for past pH changes in the ocean |
| 14:00 | Jessica Wilkes | Diatom and coccolithophore assemblages from “time capsule” sediment trap records; distinctions north and south of Chatham Rise. |
| 14:15 | Ro Allen | Bacterioplankton resistance to acidification and warming in the oligotrophic ocean |
| 14:30 | Kim Currie | Drivers of pH variability in NZ coastal regions |
| 14:45 | Liz Sikes | Carbonate weather in the US Atlantic seaboard estuarine/coastal systems in a regime of carbonate climate change |
| 15:00 |  | Afternoon tea |
| 15:30 | Steph Mangan | The cost of living in coastal environments: physiological responses of blue mussels (*Mytilus edulis*) to variable compared to static seawater pH |
| 15:45 | Emily Frost | Impact of long-term near-future OA on the physiology, molecular biology and buffering capacity of adult *Evechinus chloroticus* |
| 16:00 | Craig Norrie | Trace metal incorporation into bivalve shell in an acidified ocean |
| 16:15 | Kay Vopel | Effects of excess CO2 on benthic primary production and inorganic nitrogen fluxes in 2 coastal sediments |
| 16:30 | Bonnie Laverock | Microscale coastal sediment responses to OA |
| 16:45 | Shelly Brandt | The effects of OA on microbial nutrient cycling and productivity in coastal marine sediments |

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| Day/Time | Speaker | Title |
| 08:45 |  | Housekeeping/intro |
| 09:00 | Linn Hoffmann | Unwanted additional stressors in mesocosm experiments |
| 09:15 | Abby Smith | Effect of sample preparation and storage on biomineral carbonate on measurements of mineralogy and stable isotopes |
| 09:30 | Wayne Dillon | Development of an optical figure based omega probe for calcium carbonate |
| 09:45 | Christina McGraw | Changing Ocean Biological Systems (COBS): How will biota respond to a changing ocean? |
| 10:00 | Melissa Foley | Identifying and accounting for local drivers in OA in coastal waters |
| 10:15 | Victoria Metcalf | Telling the OA story |
| 10:30 |  | Morning Tea |
| 11:00 | Jenn Philipps | Keynote: science to policy |
| 12:00 |  | Lunch |
| 13:00 | Jessie Turner | Science to policy – via video link |
| 13:30 | Lily Hurley | Science to policy – via video link |
| 14:00 |  | Discussion |
| 15:00 |  | Afternoon tea |
| 15:30 |  | Discussion |
| 16:00 |  | Workshop close |

If you would like to attend the workshop then please get in touch with [conrad.pilditch@waikato.ac.nz](mailto:conrad.pilditch@waikato.ac.nz) a.s.a.p. There is no registration fee for the workshop. Morning teas will be provided, but not lunch.

## News

**NZOAC committee**

The committee recently met on the 22nd January 2018 – below is a brief summary of the discussions.

Initial discussion have started around the Ocean Acidification Alliance and NZ action plan. A subcommittee of the NZOAC have formed including Christina McGraw, Nikki, Linn Hoffmann, Norman Ragg, Mary Sewell and Tim. Tim will have to step back from leading this initiative as he has been instructed that the NZ government will be pulling back from OA, but will be focussing on climate change more broadly. The OA alliance and NZ action plan will be discussed in the policy session at the conference.

The NZOAC Council will hold a brief discussion session at the workshop. Several members of the committee have stepped down in the last year and we are looking for nominations for new members of the council (with a particular goal of recruiting policy makers). The session will also include a discussion of a potential ‘terms of reference’ for the NZOAC.

If you cannot make the workshop but are interested in being involved in the NZOAC council (which meets on average 3-4 times a year) then please get in touch with [Christina.McGraw@otago.ac.nz](mailto:Christina.McGraw@otago.ac.nz).

**2 recent reports from NZ and Australian region  
Auckland Region climate change projections and impacts**

Auckland Council and Council Controlled Organisations commissioned NIWA to analyse projected climate changes for the Auckland region and potential impacts of climate change on some of Auckland’s environments and sectors. This report addresses expected changes for 21 different climate variables out to 2120, and draws heavily on climate model simulations from the [Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report](https://www.ipcc.ch/report/ar5). Potential climate change impacts on important environments and sectors in the Auckland region are discussed. Chapter 8 addresses ocean acidification.

Pearce P., Bell R., Bostock H., Carey-Smith T., Collins D., Fedaeff N., Kachhara A., Macara G., Mullan B., Paulik R., Somervell E., Sood A., Tait A., Wadhwa S. & Woolley J.-M., 2017. 357 p. National Institute of Water and Atmospheric Research. [Report](http://www.knowledgeauckland.org.nz/publication/?mid=1747).

**Oceans: science and solutions for Australia,**

**Chapter – The Oceans and our climate** - Church J., Cai W., Wang G. & Lenton A., 2017. [Report](http://www.publish.csiro.au/ebook/download/pdf/7724).

* Ocean acidification is an inevitable consequence of rising atmospheric carbon dioxide.
* Ocean warming and acidification have significant negative implications for marine environments and ecosystem services.

***Chapter - Ocean changes to come*** Matear R., Hobday A. & Chamberlain M., 2017.  [Report](http://www.publish.csiro.au/ebook/download/pdf/7724).

* Oceans are key to the climate system’s carbon, heat and freshwater cycles.
* Oceans are changing, and further physical, chemical and biological changes are projected for Australian waters this century.
* Ocean warming, acidification, deoxygenation and sea-level rise have important implications for marine ecosystems and the ocean services on which humans depend.
* Climate models are essential tools for exploring mitigation options and integrating climate predictions with human systems such as agriculture and fisheries.

Selection of reports, theses and recent papers from the SW Pacific

**Individual and interactive effects of warming and CO2 on Pseudo-nitzschia subcurvata and Phaeocystis antarctica, two dominant phytoplankton from the Ross Sea, Antarctica.** We investigated the effects of temperature and CO2 variation on the growth and elemental composition of cultures of the diatom *Pseudo-nitzschia subcurvata* and the prymnesiophyte *Phaeocystis antarctica*, two ecologically dominant phytoplankton species isolated from the Ross Sea, Antarctica. To obtain thermal functional response curves, cultures were grown across a range of temperatures from 0 to 14 °C. In addition, a co-culturing experiment examined the relative abundance of both species at 0 and 6 °C. CO2 functional response curves were conducted from 100 to 1730 ppm at 2 and 8 °C to test for interactive effects between the two variables. The growth of both phytoplankton was significantly affected by temperature increase, but with different trends. Growth rates of *P. subcurvata* increased with temperature from 0 °C to maximum levels at 8 °C, while the growth rates of *P. antarctica* only increased from 0 to 2 °C. The maximum thermal limits of *P. subcurvata* and *P. antarctica* where growth stopped completely were 14 and 10 °C, respectively. Although *P. subcurvata* outgrew *P. antarctica* at both temperatures in the co-incubation experiment, this happened much faster at 6 than at 0 °C. For *P. subcurvata*, there was a significant interactive effect in which the warmer temperature decreased the CO2 half-saturation constant for growth, but this was not the case for *P. antarctica*. The growth rates of both species increased with CO2 increases up to 425 ppm, and in contrast to significant effects of temperature, the effects of CO2 increase on their elemental composition were minimal. Our results suggest that future warming may be more favorable to the diatom than to the prymnesiophyte, while CO2 increases may not be a major factor in future competitive interactions between *Pseudo-nitzschia subcurvata* and *Phaeocystis antarctica* in the Ross Sea. Zhu Z., et al., 2017.  Biogeosciences 14 (23): 5281-5295. [Article](https://doi.org/10.5194/bg-14-5281-2017).

**Coral calcification mechanisms facilitate adaptive responses to ocean acidification.**Ocean acidification (OA) is a pressing threat to reef-building corals, but it remains poorly understood how coral calcification is inhibited by OA and whether corals could acclimatize and/or adapt to OA. Using a novel geochemical approach, we reconstructed the carbonate chemistry of the calcifying fluid in two coral species using both a pH and dissolved inorganic carbon (DIC) proxy (δ11B and B/Ca, respectively). To address the potential for adaptive responses, both species were collected from two sites spanning a natural gradient in seawater pH and temperature, and then subjected to three pHT levels (8.04, 7.88, 7.71) crossed by two temperatures (control, +1.5°C) for 14 weeks. Corals from the site with naturally lower seawater pH calcified faster and maintained growth better under simulated OA than corals from the higher-pH site. This ability was consistently linked to higher pH yet lower DIC values in the calcifying fluid, suggesting that these differences are the result of long-term acclimatization and/or local adaptation to naturally lower seawater pH. Nevertheless, all corals elevated both pH and DIC significantly over seawater values, even under OA. This implies that high pH upregulation combined with moderate levels of DIC upregulation promote resistance and adaptive responses of coral calcification to OA. Schoepf V., et al., Proceedings of the Royal Society B. [Article](https://doi.org/10.1098/rspb.2017.2117) (subscription required).

**Past and future evolution of the carbonate system in a coastal zone of the Northern Antarctic Peninsula.** In this study, we have reconstructed the carbonate system in the Gerlache Strait, a coastal zone of the Northern Antarctic Peninsula. We also analyzed the impact of ocean acidification by calculating the tipping points of the calcium carbonate saturation states and pH (i.e., when saturation state and pH goes below one and 7, respectively). Hydrographic and carbonate data from three distinct data sets (GOAL – 2013 to 2016, FRUELA – 1996, and World Ocean Database – 1965 to 2004) have been joined and used to reconstruct the carbonate system from the past 50 years. Temporal annual mean trends were determined depending on the water column depth-layer. The northern Gerlache Strait showed a significant increasing trend of CT concentrations (1.0024 ± 0.34 µmol kg–1) and related pH decreasing trend (–0.0026 ± 0.0009 sws) in the surface mixed layer (> 60 m). The properties variability is relatively different (magnitudes and signs) between the northern and southern sectors of the Gerlache Strait, which indicate that adjacent regions to the Gerlache Strait to the southwest and north, respectively, may major influence the regional carbonate dynamics. Results also show that episodic under-saturation conditions, in relation to aragonite within the surface mixed layer, may already occur, especially in regions close to large glaciers. Lencina-Avila J. M., et al.,  Deep Sea Research Part II: Topical Studies in Oceanography. [Article](https://doi.org/10.1016/j.dsr2.2017.10.018) (subscription required).

**Low and variable ecosystem calcification in a coral reef lagoon under natural acidification.** Laboratory-based CO2 experiments and studies of naturally low pH coral reef ecosystems reveal negative impacts of ocean acidification on the calcifying communities that build coral reefs. Conversely, in Palau’s low pH lagoons, coral cover is high, coral communities are diverse, and calcification rates of two reef-building corals exhibit no apparent sensitivity to the strong natural gradient in pH and aragonite saturation state (Ωar). We developed two methods to quantify rates of Net Ecosystem Calcification (NEC), the ecosystem-level balance between calcification and dissolution, in Risong Lagoon, where average daily pH is ∼ 7.9 and Ωar ∼ 2.7. While coral cover in the lagoon is within the range of other Pacific reefs (∼ 26%), NEC rates were among the lowest measured, averaging 25.9 ± 13.7 mmol m−2 d−1 over two 4 d study periods. NEC rates were highly variable, ranging from a low of 13.7 mmol m−2 d−1 in March 2012 to a high of 40.3 mmol m−2 d−1 in November 2013, despite no significant changes in temperature, salinity, inorganic nutrients, Ωar, or pH. Our results indicate that the coral reef community of Risong Lagoon produces just enough calcium carbonate to maintain net positive calcification but comes dangerously close to net zero or negative NEC (net dissolution). Identifying the factors responsible for low NEC rates as well as the drivers of NEC variability in naturally low pH reef systems are key to predicting their futures under 21st century climate change. Shamberger K. E. F., et al. Limnology & Oceanography. [Article](https://doi.org/10.1002/lno.10662).

**Sensitivity to ocean acidification differs between populations of the Sydney rock oyster: role of filtration and ion-regulatory capacities.** Understanding mechanisms of intraspecific variation in resilience to environmental drivers is key to predict species’ adaptive potential. Recent studies show a higher CO2 resilience of Sydney rock oysters selectively bred for increased growth and disease resistance (‘selected oysters’) compared to the wild population. We tested whether the higher resilience of selected oysters correlates with an increased ability to compensate for CO2-induced acid-base disturbances. After 7 weeks of exposure to elevated seawater PCO2 (1100 μatm), wild oysters had a lower extracellular pH (pHe = 7.54 ± 0.02 (control) vs. 7.40 ± 0.03 (elevated PCO2)) and increased hemolymph PCO2 whereas extracellular acid-base status of selected oysters remained unaffected. However, differing pHe values between oyster types were not linked to altered metabolic costs of major ion regulators (Na+/K+-ATPase, H+-ATPase and Na+/H+-exchanger) in gill and mantle tissues. Our findings suggest that selected oysters possess an increased systemic capacity to eliminate metabolic CO2, possibly through higher and energetically more efficient filtration rates and associated gas exchange. Thus, effective filtration and CO2 resilience might be positively correlated traits in oysters. Stapp L. S., et al.,  Marine Environmental Research. [Article](https://doi.org/10.1016/j.marenvres.2017.12.017) (subscription required).

**An interplay between plasticity and parental phenotype determines impacts of ocean acidification on a reef fish.**The impacts of ocean acidification will depend on the ability of marine organisms to tolerate, acclimate and eventually adapt to changes in ocean chemistry. Here, we use a unique transgenerational experiment to determine the molecular response of a coral reef fish to short-term, developmental and transgenerational exposure to elevated CO2, and to test how these responses are influenced by variations in tolerance to elevated CO2 exhibited by the parents. Within-generation responses in gene expression to end-of-century predicted CO2 levels indicate that a self-amplifying cycle in GABAergic neurotransmission is triggered, explaining previously reported neurological and behavioural impairments. Furthermore, epigenetic regulator genes exhibited a within-generation specific response, but with some divergence due to parental phenotype. Importantly, we find that altered gene expression for the majority of within-generation responses returns to baseline levels following parental exposure to elevated CO2 conditions. Our results show that both parental variation in tolerance and cross-generation exposure to elevated CO2 are crucial factors in determining the response of reef fish to changing ocean chemistry. Schunter C., et al., 2017. Nature Ecology & Evolution. [Article](https://doi.org/10.1038/s41559-017-0428-8) (subscription required).

**Distribution of planktonic biogenic carbonate organisms in the Southern Ocean south of Australia: a baseline for ocean acidification impact assessment.** The Southern Ocean provides a vital service by absorbing about one-sixth of humankind’s annual emissions of CO2. This comes with a cost – an increase in ocean acidity that is expected to have negative impacts on ocean ecosystems. The reduced ability of phytoplankton and zooplankton to precipitate carbonate shells is a clearly identified risk. The impact depends on the significance of these organisms in Southern Ocean ecosystems, but there is very little information on their abundance or distribution. To quantify their presence, we used coulometric measurement of particulate inorganic carbonate (PIC) on particles filtered from surface seawater into two size fractions: 50–1000 µm to capture foraminifera (the most important biogenic carbonate-forming zooplankton) and 1–50 µm to capture coccolithophores (the most important biogenic carbonate-forming phytoplankton). Ancillary measurements of biogenic silica (BSi) and particulate organic carbon (POC) provided context, as estimates of the biomass of diatoms (the highest biomass phytoplankton in polar waters) and total microbial biomass, respectively. Results for nine transects from Australia to Antarctica in 2008–2015 showed low levels of PIC compared to Northern Hemisphere polar waters. Coccolithophores slightly exceeded the biomass of diatoms in subantarctic waters, but their abundance decreased more than 30-fold poleward, while diatom abundances increased, so that on a molar basis PIC was only 1 % of BSi in Antarctic waters. This limited importance of coccolithophores in the Southern Ocean is further emphasized in terms of their associated POC, representing less than 1 % of total POC in Antarctic waters and less than 10 % in subantarctic waters. NASA satellite ocean-colour-based PIC estimates were in reasonable agreement with the shipboard results in subantarctic waters but greatly overestimated PIC in Antarctic waters. Contrastingly, the NASA Ocean Biogeochemical Model (NOBM) shows coccolithophores as overly restricted to subtropical and northern subantarctic waters. The cause of the strong southward decrease in PIC abundance in the Southern Ocean is not yet clear. The poleward decrease in pH is small, and while calcite saturation decreases strongly southward, it remains well above saturation ( > 2). Nitrate and phosphate variations would predict a poleward increase. Temperature and competition with diatoms for limiting iron appear likely to be important. While the future trajectory of coccolithophore distributions remains uncertain, their current low abundances suggest small impacts on overall Southern Ocean pelagic ecology. Trull T. W., et al., 2018. Biogeosciences 15: 31-49. [Article](https://doi.org/10.5194/bg-15-31-2018).

**Assessing carbon dioxide removal through global and regional ocean alkalization under high and low emission pathways.** Atmospheric CO2 levels continue to rise, increasing the risk of severe impacts on the Earth system, and on the ecosystem services that it provides. Artificial Ocean Alkalization (AOA) is capable of reducing atmospheric CO2 concentrations, surface warming and addressing ocean acidification. Here we simulate global and regional responses to alkalinity addition (0.25 PmolAlk/year) using the CSIRO-Mk3L-COAL Earth System Model in the period 2020–2100, under high (RCP8.5) and low (RCP2.6) emissions. While regionally there are large changes associated with locations of AOA, globally we see only a very weak dependence on where and when AOA is applied. We see that under RCP2.6, while the carbon uptake associated with AOA is only ~ 60 % of the total under RCP8.5, the relative changes in temperature are larger, as are the changes in pH (1.4×) and aragonite saturation (1.7×). The results of this modelling study are significant as they demonstrate that AOA is more effective under lower emissions, and the higher the emissions the more AOA required to achieve the same reduction in global warming and ocean acidification. Finally, our simulations show AOA in the period 2020–2100 is capable of offsetting global warming and ameliorating ocean acidification increases due to low emissions, but regionally the response is more variable. Lenton A., et al., 2017. Earth System Dynamics. doi: 10.5194/esd-2017-92. [Article](https://doi.org/10.5194/esd-2017-92).

**Taking the metabolic pulse of the world’s coral reefs.** Worldwide, coral reef ecosystems are experiencing increasing pressure from a variety of anthropogenic perturbations including ocean warming and acidification, increased sedimentation, eutrophication, and overfishing, which could shift reefs to a condition of net calcium carbonate (CaCO3) dissolution and erosion. Herein, we determine the net calcification potential and the relative balance of net organic carbon metabolism (net community production; NCP) and net inorganic carbon metabolism (net community calcification; NCC) within 23 coral reef locations across the globe. In light of these results, we consider the suitability of using these two metrics developed from total alkalinity (TA) and dissolved inorganic carbon (DIC) measurements collected on different spatiotemporal scales to monitor coral reef biogeochemistry under anthropogenic change. All reefs in this study were net calcifying for the majority of observations as inferred from alkalinity depletion relative to offshore, although occasional observations of net dissolution occurred at most locations. However, reefs with lower net calcification potential (i.e., lower TA depletion) could shift towards net dissolution sooner than reefs with a higher potential. The percent influence of organic carbon fluxes on total changes in dissolved inorganic carbon (DIC) (i.e., NCP compared to the sum of NCP and NCC) ranged from 32% to 88% and reflected inherent biogeochemical differences between reefs. Reefs with the largest relative percentage of NCP experienced the largest variability in seawater pH for a given change in DIC, which is directly related to the reefs ability to elevate or suppress local pH relative to the open ocean. This work highlights the value of measuring coral reef carbonate chemistry when evaluating their susceptibility to ongoing global environmental change and offers a baseline from which to guide future conservation efforts aimed at preserving these valuable ecosystems. Cyronak T., et al., PLoS ONE 13(1): e0190872. doi:10.1371/journal.pone.0190872. [Article](https://doi.org/10.1371/journal.pone.0190872).

**Climate change could drive marine food web collapse through altered trophic flows and cyanobacterial proliferation.** Global warming and ocean acidification are forecast to exert significant impacts on marine ecosystems worldwide. However, most of these projections are based on ecological proxies or experiments on single species or simplified food webs. How energy fluxes are likely to change in marine food webs in response to future climates remains unclear, hampering forecasts of ecosystem functioning. Using a sophisticated mesocosm experiment, we model energy flows through a species-rich multilevel food web, with live habitats, natural abiotic variability, and the potential for intra- and intergenerational adaptation. We show experimentally that the combined stress of acidification and warming reduced energy flows from the first trophic level (primary producers and detritus) to the second (herbivores), and from the second to the third trophic level (carnivores). Warming in isolation also reduced the energy flow from herbivores to carnivores, the efficiency of energy transfer from primary producers and detritus to herbivores and detritivores, and the living biomass of detritivores, herbivores, and carnivores. Whilst warming and acidification jointly boosted primary producer biomass through an expansion of cyanobacteria, this biomass was converted to detritus rather than to biomass at higher trophic levels—i.e., production was constrained to the base of the food web. In contrast, ocean acidification affected the food web positively by enhancing trophic flow from detritus and primary producers to herbivores, and by increasing the biomass of carnivores. Our results show how future climate change can potentially weaken marine food webs through reduced energy flow to higher trophic levels and a shift towards a more detritus-based system, leading to food web simplification and altered producer–consumer dynamics, both of which have important implications for the structuring of benthic communities. Ullah H., et al., 2018. PLoS Biology 16(1): e2003446. doi: 10.1371/journal.pbio.2003446. [Article](https://doi.org/10.1371/journal.pbio.2003446).

**Ocean acidification of a coastal Antarctic marine microbial community reveals a critical threshold for CO2 tolerance in phytoplankton productivity.** High-latitude oceans are anticipated to be some of the first regions affected by ocean acidification. Despite this, the effect of ocean acidification on natural communities of Antarctic marine microbes is still not well understood. In this study we exposed an early spring, coastal marine microbial community in Prydz Bay to CO2 levels ranging from ambient (343 µatm) to 1641 µatm in six 650 L minicosms. Productivity assays were performed to identify whether a CO2 threshold existed that led to a change in primary productivity, bacterial productivity, and the accumulation of chlorophyll *a* (Chl *a*) and particulate organic matter (POM) in the minicosms. In addition, photophysiological measurements were performed to identify possible mechanisms driving changes in the phytoplankton community. A critical threshold for tolerance to ocean acidification was identified in the phytoplankton community between 953 and 1140 µatm. CO2 levels  ≥ 1140 µatm negatively affected photosynthetic performance and Chl *a*-normalised primary productivity (csGPP14C), causing significant reductions in gross primary production (GPP14C), Chl *a* accumulation, nutrient uptake, and POM production. However, there was no effect of CO2 on C : N ratios. Over time, the phytoplankton community acclimated to high CO2 conditions, showing a down-regulation of carbon concentrating mechanisms (CCMs) and likely adjusting other intracellular processes. Bacterial abundance initially increased in CO2 treatments  ≥ 953 µatm (days 3–5), yet gross bacterial production (GBP14C) remained unchanged and cell-specific bacterial productivity (csBP14C) was reduced. Towards the end of the experiment, GBP14C and csBP14C markedly increased across all treatments regardless of CO2 availability. This coincided with increased organic matter availability (POC and PON) combined with improved efficiency of carbon uptake. Changes in phytoplankton community production could have negative effects on the Antarctic food web and the biological pump, resulting in negative feedbacks on anthropogenic CO2 uptake. Increases in bacterial abundance under high CO2 conditions may also increase the efficiency of the microbial loop, resulting in increased organic matter remineralisation and further declines in carbon sequestration. Deppeler S. et al., 2018. Biogeosciences 15: 209-231. [Article](https://doi.org/10.5194/bg-15-209-2018).

**Biophysical feedbacks mediate carbonate chemistry in coastal ecosystems across spatiotemporal gradients.** Ocean acidification (OA) projections are primarily based on open ocean environments, despite the ecological importance of coastal systems in which carbonate dynamics are fundamentally different. Using temperate tide pools as a natural laboratory, we quantified the relative contribution of community composition, ecosystem metabolism, and physical attributes to spatiotemporal variability in carbonate chemistry. We found that biological processes were the primary drivers of local pH conditions. Specifically, non-encrusting producer-dominated systems had the highest and most variable pH environments and the highest production rates, patterns that were consistent across sites spanning 11° of latitude and encompassing multiple gradients of natural variability. Furthermore, we demonstrated a biophysical feedback loop in which net community production increased pH, leading to higher net ecosystem calcification. Extreme spatiotemporal variability in pH is, thus, both impacting and driven by biological processes, indicating that shifts in community composition and ecosystem metabolism are poised to locally buffer or intensify the effects of OA. Silbiger N. J. & Sorte C. J. B., 2018. Scientific Reports 8: 796. doi:10.1038/s41598-017-18736-6. [Article](https://doi.org/10.1038/s41598-017-18736-6).

**Antarctic emerald rockcod have the capacity to compensate for warming when uncoupled from CO2-acidification.** Increases in atmospheric CO2 levels and associated ocean changes are expected to have dramatic impacts on marine ecosystems. Although the Southern Ocean is experiencing some of the fastest rates of change, few studies have explored how Antarctic fishes may be affected by co-occurring ocean changes, and even fewer have examined early life stages. To date, no studies have characterized potential trade-offs in physiology and behavior in response to projected multiple climate change stressors (ocean acidification and warming) on Antarctic fishes. We exposed juvenile emerald rockcod Trematomus bernacchii to three PCO2 treatments (~450, ~850, and ~1,200 μatm PCO2) at two temperatures (−1 or 2°C). After 2, 7, 14, and 28 days, metrics of physiological performance including cardiorespiratory function (heart rate [fH] and ventilation rate [fV]), metabolic rate (M˙O2), and cellular enzyme activity were measured. Behavioral responses, including scototaxis, activity, exploration, and escape response were assessed after 7 and 14 days. Elevated PCO2 independently had little impact on either physiology or behavior in juvenile rockcod, whereas warming resulted in significant changes across acclimation time. After 14 days, fH, fV and M˙O2 significantly increased with warming, but not with elevated PCO2. Increased physiological costs were accompanied by behavioral alterations including increased dark zone preference up to 14%, reduced activity by 12%, as well as reduced escape time suggesting potential trade-offs in energetics. After 28 days, juvenile rockcod demonstrated a degree of temperature compensation as fV, M˙O2, and cellular metabolism significantly decreased following the peak at 14 days; however, temperature compensation was only evident in the absence of elevated PCO2. Sustained increases in fV and M˙O2 after 28 days exposure to elevated PCO2 indicate additive (fV) and synergistic (M˙O2) interactions occurred in combination with warming. Stressor-induced energetic trade-offs in physiology and behavior may be an important mechanism leading to vulnerability of Antarctic fishes to future ocean change. Davis B. E., et al.,  Global Change Biology. [Article](http://onlinelibrary.wiley.com/doi/10.1111/gcb.13987/full) (subscription required).

**Pteropods counter mechanical damage and dissolution through extensive shell repair.** The dissolution of the delicate shells of sea butterflies, or pteropods, has epitomised discussions regarding ecosystem vulnerability to ocean acidification over the last decade. However, a recent demonstration that the organic coating of the shell, the periostracum, is effective in inhibiting dissolution suggests that pteropod shells may not be as susceptible to ocean acidification as previously thought. Here we use micro-CT technology to show how, despite losing the entire thickness of the original shell in localised areas, specimens of polar species *Limacina helicina* maintain shell integrity by thickening the inner shell wall. One specimen collected within Fram Strait with a history of mechanical and dissolution damage generated four times the thickness of the original shell in repair material. The ability of pteropods to repair and maintain their shells, despite progressive loss, demonstrates a further resilience of these organisms to ocean acidification but at a likely metabolic cost. Peck V. L., et al., 2018. Nature Communications 9: 264. doi:10.1038/s41467-017-02692-w. [Article](https://doi.org/10.1038/s41467-017-02692-w).

**Effects of CO2 enrichment on benthic primary production and inorganic nitrogen fluxes in two coastal sediments.** Ocean acidification may alter the cycling of nitrogen in coastal sediment and so the sediment–seawater nitrogen flux, an important driver of pelagic productivity. To investigate how this perturbation affects the fluxes of NOX− (nitrite/nitrate), NH4+ and O2, we incubated estuarine sand and subtidal silt in recirculating seawater with a CO2-adjusted pH of 8.1 and 7.9. During a 41-day incubation, the seawater kept at pH 8.1 lost 97% of its NOX− content but the seawater kept at pH 7.9 lost only 18%. Excess CO2 increased benthic photosynthesis. In the silt, this was accompanied by a reversal of the initial NOX− efflux into influx. The estuarine sand sustained its initial NOX− influx but, by the end of the incubation, released more NH4+ at pH 7.9 than at pH 8.1. We hypothesise that these effects share a common cause; excess CO2 increased the growth of benthic microalgae and so nutrient competition with ammonia oxidising bacteria (AOB). In the silt, diatoms likely outcompeted AOB for NH4+ and photosynthesis increased the dark/light fluctuations in the pore water oxygenation inhibiting nitrification and coupled nitrification/denitrification. If this is correct, then excess CO2 may lead to retention of inorganic nitrogen adding to the pressures of increasing coastal eutrophication. Vopel K., et al. 2018. Scientific Reports 8: 1035. doi:10.1038/s41598-017-19051-w. [Article](https://doi.org/10.1038/s41598-017-19051-w).

**Diverging seasonal extremes for ocean acidification during the twenty-first century.** How ocean acidification will affect marine organisms depends on changes in both the long-term mean and the short-term temporal variability of carbonate chemistry. Although the decadal-to-centennial response to atmospheric CO2 and climate change is constrained by observations and models, little is known about corresponding changes in seasonality, particularly for pH. Here we assess the latter by analysing nine earth system models (ESMs) forced with a business-as-usual emissions scenario. During the twenty-first century, the seasonal cycle of surface-ocean pH was attenuated by 16 ± 7%, on average, whereas that for hydrogen ion concentration [H+] was amplified by 81 ± 16%. Simultaneously, the seasonal amplitude of the aragonite saturation state (*Ω*arag) was attenuated except in the subtropics, where it was amplified. These contrasting changes derive from regionally varying sensitivities of these variables to atmospheric CO2 and climate change and to diverging trends in seasonal extremes in the primary controlling variables (temperature, dissolved inorganic carbon and alkalinity). Projected seasonality changes will tend to exacerbate the impacts of increasing [H+] on marine organisms during the summer and ameliorate the impacts during the winter, although the opposite holds in the high latitudes. Similarly, over most of the ocean, impacts from declining *Ω*arag are likely to be intensified during the summer and dampened during the winter. Kwiatkowski L. & Orr J. C., in press. *Nature Climate Change.* [Article](https://doi.org/10.1038/s41558-017-0054-0) (subscription required).

**Ocean acidification affects coral growth by reducing skeletal density.** Ocean acidification (OA) is considered an important threat to coral reef ecosystems, because it reduces the availability of carbonate ions that reef-building corals need to produce their skeletons. However, while theory predicts that coral calcification rates decline as carbonate ion concentrations decrease, this prediction is not consistently borne out in laboratory manipulation experiments or in studies of corals inhabiting naturally low-pH reefs today. The skeletal growth of corals consists of two distinct processes: extension (upward growth) and densification (lateral thickening). Here, we show that skeletal density is directly sensitive to changes in seawater carbonate ion concentration and thus, to OA, whereas extension is not. We present a numerical model of Porites skeletal growth that links skeletal density with the external seawater environment via its influence on the chemistry of coral calcifying fluid. We validate the model using existing coral skeletal datasets from six Porites species collected across five reef sites and use this framework to project the impact of 21st century OA on Porites skeletal density across the global tropics. Our model predicts that OA alone will drive up to 20.3 ± 5.4% decline in the skeletal density of reef-building Porites corals. Mollica N. R., et al.  Proceedings of the National Academy of Sciences of the United Sciences of America. [Article](https://doi.org/10.1073/pnas.1712806115) (subscription required).

**Strengthening seasonal marine CO2 variations due to increasing atmospheric CO2.**The increase of atmospheric CO2 (ref. [1](https://www.nature.com/articles/s41558-017-0057-x#ref-CR1)) has been predicted to impact the seasonal cycle of inorganic carbon in the global ocean[2](https://www.nature.com/articles/s41558-017-0057-x#ref-CR2),[3](https://www.nature.com/articles/s41558-017-0057-x#ref-CR3), yet the observational evidence to verify this prediction has been missing. Here, using an observation-based product of the oceanic partial pressure of CO2 (*p*CO2) covering the past 34 years, we find that the winter-to-summer difference of the *p*CO2 has increased on average by 2.2 ± 0.4 μatm per decade from 1982 to 2015 poleward of 10° latitude. This is largely in agreement with the trend expected from thermodynamic considerations. Most of the increase stems from the seasonality of the drivers acting on an increasing oceanic *p*CO2 caused by the uptake of anthropogenic CO2 from the atmosphere. In the high latitudes, the concurrent ocean-acidification-induced changes in the buffer capacity of the ocean enhance this effect. This strengthening of the seasonal winter-to-summer difference pushes the global ocean towards critical thresholds earlier, inducing stress to ocean ecosystems and fisheries[4](https://www.nature.com/articles/s41558-017-0057-x#ref-CR4). Our study provides observational evidence for this strengthening seasonal difference in the oceanic carbon cycle on a global scale, illustrating the inevitable consequences of anthropogenic CO2 emissions. Landschutzer P., et al., Nature Climate Change. [Article](https://doi.org/10.1038/s41558-017-0057-x) (subscription required).

**Environmental controls on the elemental composition of a Southern Hemisphere strain of the coccolithophore *Emiliania huxleyi*.**A series of semi-continuous incubation experiments were conducted with the coccolithophore *Emiliania huxleyi* strain NIWA1108 (Southern Ocean isolate) to examine the effects of five environmental drivers (nitrate and phosphate concentrations, irradiance, temperature, and partial pressure of CO2 (*p*CO2)) on both the physiological rates and elemental composition of the coccolithophore. Here, we report the alteration of the elemental composition of *E. huxleyi* in response to the changes in these environmental drivers. A series of dose–response curves for the cellular elemental composition of *E. huxleyi* were fitted for each of the five drivers across an environmentally representative gradient. The importance of each driver in regulating the elemental composition of *E. huxleyi* was ranked using a semi-quantitative approach. The percentage variations in elemental composition arising from the change in each driver between present-day and model-projected conditions for the year 2100 were calculated. Temperature was the most important driver controlling both cellular particulate organic and inorganic carbon content, whereas nutrient concentrations were the most important regulator of cellular particulate nitrogen and phosphorus of *E. huxleyi*. In contrast, elevated *p*CO2 had the greatest influence on cellular particulate inorganic carbon to organic carbon ratio, resulting in a decrease in the ratio. Our results indicate that the different environmental drivers play specific roles in regulating the elemental composition of *E. huxleyi* with wide-reaching implications for coccolithophore-related marine biogeochemical cycles, as a consequence of the regulation of *E. huxleyi* physiological processes. Feng Y., et al., 2018. Biogeosciences 15 (2): 581-595. [Article](https://doi.org/10.5194/bg-15-581-2018).

## International Workshops, Courses and Conferences

Summer Graduate Course at Friday Harbor Laboratories (College of the Environment, University of Washington), July 16 – August 17, 2018

This graduate level course introduces students to the theory, methods, and techniques needed to conduct successful experiments on the biological effects of ocean acidification. Through a combination of lectures, laboratory exercises, and field work we will prepare students to perform ocean acidification research at their home institutions and in other settings. Students will learn standard protocols for measuring carbonate chemistry variables in the laboratory, gain an understanding of the underlying chemical theory, and learn how these influence the design and performance of biological experiments. The course will cover key developing issues in ocean acidification research and the broader field of global ocean change. Applications are currently being accepted. Review begins Jan 1, 2018.Students are encouraged to apply as early as possible. Late applications will be accepted if space is available. Enrollment is limited to 15 students.

For online application instructions, see <https://fhl.uw.edu/courses/applying-for-an-fhl-course/>