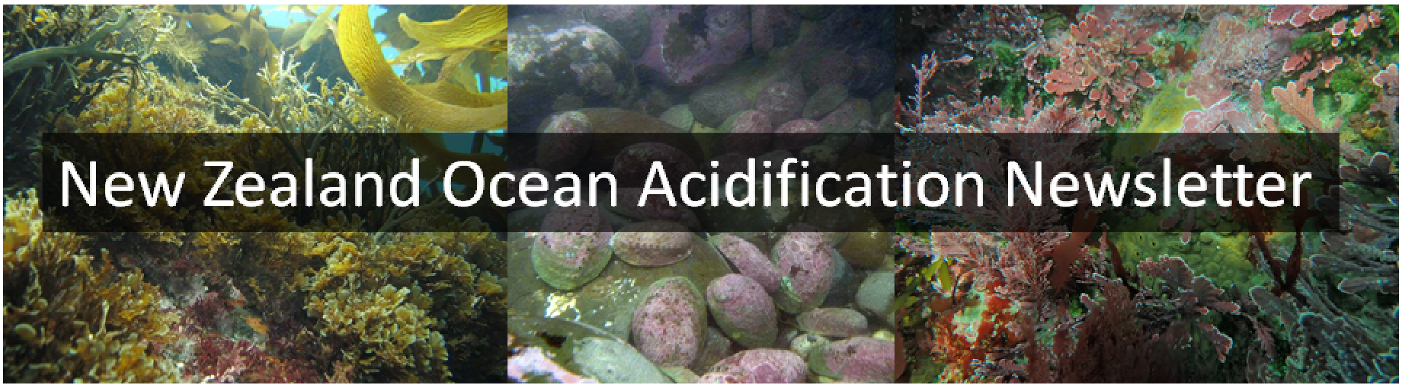
#60 – September-October 2019 (http://nzoac.nz/)



Local News

Reminder - 2020 New Zealand Ocean Acidification Conference

17–18th February, 2020
Victoria University of Wellington

The 2020 New Zealand Ocean Acidification Conference will be held in Wellington on the 17th to 18th of February at Victoria University. Abstract submissions and registration are now open. Please see previous version of the newsletter for details on registration or contact Christopher.cornwall@vuw.ac.nz

Reminder - NZOAC post-conference workshop:

19 February, 2020
9:30 – 4:00
Victoria University of Wellington

How will biota respond to a changing ocean?
A best practice guide for multiple drivers research

Christina M. McGraw (University of Otago, Department of Chemistry) and Christopher Cornwall (Victoria University, School of Biological Sciences)

Spaces are limited in this free workshop. To register, e-mail christina.mcgraw@otago.ac.nz by January 31st.

International News and jobs

Job opportunity: ocean acidification project at Universita Di' Bologna, Italy

Project title: Anthropogenic impacts on calcification of Mediterranean benthic invertebrates as bio-indicators of marine ecosystem health: consequences of ocean acidification
Project description: The research project aims to investigate the effects of seawater acidification in calcifying marine organisms along a natural pH gradient, created by constant carbon dioxide emissions from the underwater crater of Panarea (Eolian Island). This site in the Mediterranean Sea is an ideal natural laboratory for studying acidification because there are acidity levels predicted for the current century by the IPCC. In particular, this project wants to study the effects of acidification on calcification (skeletal density, porosity, linear extension, calcification rates) and skeletal properties (structure and morphology of crystal domains, mineral phase, mechanical properties) of benthic invertebrates like corals, gastropods, bivalves and vermetides. Moreover, during the project the environmental characterization of the site will be carry out with measurements of the environmental parameters along the pCO2 gradient (temperature, pH, alkalinity, nutrients concentrations).
Application deadline: 28/10/2019

More information.

Accelerating actions to address ocean acidification in the Pacific

The Pacific Ocean is home to 25% of the world's coral reefs. Coral reefs hold particular significance in terms of food security, cultural value and as tourist attractions in the Pacific region.

Ocean Acidification (OA), which is being labelled as the "evil twin" of climate change, has had a severe impact on these coral reefs, as well as on food security and community livelihoods. It was identified as a priority issue at the Fourth and Fifth meetings of the Pacific Meteorological Council.

The work that is being carried out in the Pacific to address this issue was highlighted at a side event during the second day of the Secretariat of the Pacific Regional Environment Programme (SPREP)'s 29th Meeting of Officials taking place in Apia, Samoa.

Amongst those highlighted were work of the New Zealand-Pacific Partnership on Ocean Acidification (NZPPOA) project in Fiji and Tokelau, Samoa's joint initiative on OA monitoring with the Republic of Korea, and the recently published "Mainstreaming Ocean Acidification into National Policies" handbook on OA for the Pacific.

The NZPPOA project is a collaborative effort between the University of the South Pacific, the Pacific Community and SPREP, with funding support from the Ministry of Foreign Affairs of New Zealand and the Government of the Principality of Monaco. It aims to build resilience of Pacific island communities to OA and was developed in response to needs identified during the Third United Nations Small Islands States Conference in Apia in 2014.

Its focus is on research and monitoring, capacity and awareness building, and practical adaptation actions. The pilot sites for the practical adaptation actions were Fiji, Kiribati and Tokelau, two of which were present at the side event this afternoon and presented on the progress of the work being done in their countries.

Ms Bridget Kennedy of Conservation International, Fiji, presented on the implementation of the PPOA project on Taveuni island, specifically in Cakudrove Province. Temporal restrictions on fishing have been put in place, as well as mangrove or coastal vegetation enhancement to locally buffer pH and to curb coastal erosion while improving the habitat of fish.

Ms Jewel Toloa of Tokelau identified some of the challenges in raising awareness on OA in Tokelau's three atolls of Atafu, Fakaofo and Atafu, the main one being trying to translate technical terminologies and scientific language into the local language for Tokelauans to understand.

The NZPPOA Project has enabled the translation of materials into Tokelauan, which have been distributed to schools and used as lesson materials for students to gain a better understanding of what OA is.

In Samoa, the joint initiative between the Government of Samoa and the Republic of Korea, a project titled "Ocean Acidification Monitoring in Samoa" has established the infrastructure and networks to monitor OA.

OA monitoring buoys have been set up and deployed successfully in Palau, and will soon be set up in Samoa, and staff of the Ministry of Natural Resources and Environment in Samoa will have the responsibility to operate and maintain these buoy systems.

Finally, a new handbook on OA for the Pacific region was recently published by the PPOA project, titled "Mainstreaming Ocean Acidification into National Policies."

This publication was a collaborative effort between SPREP and the International Ocean Acidification Alliance, which is based in Washington D.C. The handbook draws upon the framework of the OA Alliance, and highlights some of the ways in which OA can be brought into national policies.

The Secretariat of the Pacific Regional Environment Programme, 4 September 2019. Article.

Selection of recent papers

Effect of reduced pH on physiology and shell integrity of juvenile *Haliotis iris* (pāua) from New Zealand
The New Zealand pāua or black footed abalone, *Haliotis iris*, is one of many mollusc species at potential risk from ocean acidification and warming. To investigate possible impacts, juvenile pāua (~24 mm shell length) were grown for 4 months in seawater pH/pCO2 conditions projected for 2100. End of century seawater projections (pHT 7.66/pCO2 ~1,000 µatm) were contrasted with local ambient conditions (pHT 8.00/pCO2 ~400 µatm) at two typical temperatures (13 and 15 °C). We used a combination of methods (morphometric, scanning electron microscopy, X-ray diffraction) to investigate effects on juvenile survival and growth, as well as shell mineralogy and integrity.

Lowered pH did not affect survival, growth rate or condition, but animals grew significantly faster at the higher temperature. Juvenile pāua were able to biomineralise their inner nacreous aragonite layer and their outer prismatic calcite layer under end-of-century pH conditions, at both temperatures, and carbonate composition was not affected. There was some thickening of the nacre layer in the newly deposited shell with reduced pH and also at the higher temperature. Most obvious was post-depositional alteration of the shell under lowered pH: the prismatic calcite layer was thinner, and there was greater etching of the external shell surface; this dissolution was greater at the higher temperature. These results demonstrate the importance of even a small (2 °C) difference in temperature on growth and shell characteristics, and on modifying the effects at lowered pH. Projected CO2-related changes may affect shell quality of this iconic New Zealand mollusc through etching (dissolution) and thinning, with potential implications for resilience to physical stresses such as predation and wave action.

Cummings V. J., Smith A. M., Marriott P. M., Peebles B. A. & Halliday N. J., in press. Effect of reduced pH on physiology and shell integrity of juvenile *Haliotis iris* (pāua) from New Zealand. *PeerJ* 7: e7670. doi: 10.7717/peerj.7670. Article.

The dynamics and impact of ocean acidification and hypoxia: insights from sustained investigations in the Northern California Current Large Marine Ecosystem Coastal upwelling ecosystems around the world are defined by wind-generated currents that bring deep, nutrient-rich waters to the surface ocean where they fuel exceptionally productive food webs. These ecosystems are also now understood to share a common vulnerability to ocean acidification and hypoxia (OAH). In the California Current Large Marine Ecosystem (CCLME), reports of marine life die-offs by fishers and resource managers triggered research that led to an understanding of the risks posed by hypoxia. Similarly, unprecedented losses from shellfish hatcheries led to novel insights into the coastal expression of ocean acidification. Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) scientists and other researchers in the CCLME responded to the rise of OAH with new ocean observations and experiments. This work revealed insights into the expression of OAH as coupled environmental stressors, their temporal and spatial variability, and impacts on species, ecological communities, and fisheries. Sustained investigations also deepened the understanding of connections between climate change and the intensification of hypoxia, and are beginning to inform the ecological and eco-evolutionary processes that can structure responses to the progression of ocean acidification and other pathways of global change. Moreover, because the severity of the die-offs and hatchery failures and the subsequent scientific understanding combined to galvanize public attention, these scientific advances have fostered policy advances. Across the CCLME, policymakers are now translating the evolving scientific understanding of OAH into new management actions.

Chan F., Barth J. A., Kroeker K. J., Lubchenco J. & Menge B. A., 2019. The dynamics and impact of ocean acidification and hypoxia: insights from sustained investigations in the Northern California Current Large Marine Ecosystem. *Oceanography* 32 (3): 62-71. Article.

Changes in the metabolic potential of the sponge microbiome under ocean acidification. Anthropogenic CO_2 emissions are causing ocean acidification, which can affect the physiology of marine organisms. Here we assess the possible effects of ocean acidification on the metabolic potential of sponge symbionts, inferred by metagenomic analyses of the microbiomes of two sponge species sampled at a shallow volcanic CO_2 seep and a nearby control reef. When comparing microbial functions between the seep and control sites, the microbiome of the sponge *Stylissa flabelliformis* (which is more abundant at the control site) exhibits at the seep reduced potential for uptake of exogenous carbohydrates and amino acids, and for degradation of host-derived creatine, creatinine and taurine. The microbiome of *Coelocarteria singaporensis* (which is more abundant at the seep) exhibits reduced potential for carbohydrate import at the seep, but greater capacity for archaeal carbon fixation via the 3-hydroxypropionate/4-hydroxybutyrate pathway, as well as archaeal and bacterial urea production and ammonia assimilation from arginine and creatine catabolism. Together these metabolic features might contribute to enhanced tolerance of the sponge symbionts, and possibly their host, to ocean acidification.

Botté E. S., Nielsen S., Wahab M. A. A., Webster J., Robbins S., Thomas T. & Webster N. S., 2019. Changes in the metabolic potential of the sponge microbiome under ocean acidification. *Nature Communications* 10: 4134. Article.

Variation in the effects of ocean acidification on shell growth and strength in two intertidal gastropods. Many marine organisms rely on calcified hard parts to resist predation, and ocean acidification (OA) affects calcification negatively. However, calcification-related consequences may manifest in variable and/or cryptic ways across species. For example, shell strength is a primary defense for resisting shell-crushing predation, yet the consequences of OA on such biomechanical properties cannot be assessed visually. We exposed 2 species of intertidal gastropods common to the west coast of North America (the black turban snail *Tegula funebralis* and the striped dogwhelk *Nucella ostrina*) to OA (pH decreased by ~0.5 units) and predation cues for 6 mo, then measured both shell growth and strength. Shell growth in *T. funebralis* was significantly depressed under OA and in the presence of predation cues (declines of 83 and 63%, respectively). Shells produced by OA-exposed *T. funebralis* were also 50% weaker. In contrast, shell growth of *N. ostrina* was unaffected by OA, yet its shells were still 10% weaker. These findings highlight the potential for both different and easily overlooked responses of organisms to seawater acidification. Moreover, such results raise the possibility of ensuing shifts in consumption rates and rankings of prey items by shell-crushing predators, leading to shifts in the balance of species interactions in temperate shoreline communities.

Barclay K. M., Gaylord B., Jellison B. M., Shukla P., Sanford E. & Leighton L. R., 2019. Variation in the effects of ocean acidification on shell growth and strength in two intertidal gastropods. *Marine Ecology Progress Series* 626:109-121. Article (subscription required).

Flow-driven micro-scale pH variability affects the physiology of corals and coralline algae under ocean acidification Natural variability in pH in the diffusive boundary layer (DBL), the discrete layer of seawater between bulk seawater and the outer surface of organisms, could be an important factor determining the response of corals and coralline algae to ocean acidification (OA). Here, two corals with different morphologies and one coralline alga were maintained under two different regimes of flow velocities, pH, and light intensities in a 12 flumes experimental system for a period of 27 weeks. We used a combination of geochemical proxies, physiological and micro-probe measurements to assess how these treatments affected the conditions in the DBL and the response of organisms to OA. Overall, low flow velocity did not ameliorate the negative effect of low pH and therefore did not provide a refugia from OA. Flow velocity had species-specific effects with positive effects on calcification for two species. pH in the calcifying fluid (pHcf) was reduced by low flow in both corals at low light only. pHcf was significantly impacted by pH in the DBL for the two species capable of significantly modifying pH in the DBL. The dissolved inorganic carbon in the calcifying fluid (DICcf) was highest under low pH for the corals and low flow for the coralline, while the saturation state in the calcifying fluid and its proxy (FWHM) were generally not affected by the treatments. This study therefore demonstrates that the effects of OA will manifest most severely in a combination of lower light and lower flow habitats for sub-tropical coralline algae. These effects will also be greatest in lower flow habitats for some corals. Together with existing literature, these findings reinforce that the effects of OA are highly context dependent, and will differ greatly between habitats, and depending on species composition.

Comeau S., Cornwall C. E., Pupier C. A., DeCarlo T. M., Alessi C., Trehern R. & McCulloch M. T., 2019. Flow-driven micro-scale pH variability affects the physiology of corals and coralline algae under ocean acidification. *Scientific Reports* 9: 12829. doi: 10.1038/s41598-019-49044-w. Article.

Little evidence of adaptation potential to ocean acidification in sea urchins living in "future ocean" conditions at a CO2 vent Ocean acidification (OA) can be detrimental to calcifying marine organisms, with stunting of invertebrate larval development one of the most consistent responses. Effects are usually measured by short-term, within-generation exposure, an approach that does not consider the potential for adaptation. We examined the genetic response to OA of larvae of the tropical sea urchin Echinometra sp. C. raised on coral reefs that were either influenced by CO2 vents (pH ~ 7.9, future OA condition) or nonvent control reefs (pH 8.2). We assembled a high quality de novo transcriptome of Echinometra embryos (8 hr) and pluteus larvae (48 hr) and identified 68,056 SNPs. We tested for outlier SNPs and functional enrichment in embryos and larvae raised from adults from the control or vent sites. Generally, highest FST values in embryos were observed between sites (intrinsic adaptation, most representative of the gene pool in the spawned populations). This comparison also had the highest number of outlier loci (40). In the other comparisons, classical adaptation (comparing larvae with adults from the control transplanted to either the control or vent conditions) and reverse adaptation (larvae from the vent site returned to the vent or explanted at the control), we only observed modest numbers of outlier SNPs (6–19) and only enrichment in two functional pathways. Most of the outliers detected were silent substitutions without adaptive potential. We conclude that there is little evidence of realized adaptation potential during early development, while some potential (albeit relatively low) exists in the intrinsic gene pool after more than one generation of exposure.

Uthicke S., Deshpande N. P., Liddy M., Patel F., Lamare M. & Wilkins M. R., in press. Little evidence of adaptation potential to ocean acidification in sea urchins living in "future ocean" conditions at a CO2 vent. *Ecology and Evolution*. Article.

Ocean acidification and coastal marine invertebrates: tracking CO2 effects from seawater to the cell. In the last few decades, numerous studies have investigated the impacts of simulated ocean acidification on marine species and communities, particularly those inhabiting dynamic coastal systems. Despite these research efforts, there are many gaps in our understanding, particularly with respect to physiological mechanisms that lead to pathologies. In this review, we trace how carbonate system disturbances propagate from the coastal environment into marine invertebrates and highlight mechanistic links between these disturbances and organism function. We also point toward several processes related to basic invertebrate biology that are severely understudied and prevent an accurate understanding of how carbonate system dynamics influence organismic homeostasis and fitness-related traits. We recommend that significant research effort be directed to studying cellular phenotypes of invertebrates acclimated or adapted to elevated seawater pCO2 using biochemical and physiological methods.

Melzner F., Mark F. C., Seibel B. A. & Tomanek L., 2019. Ocean acidification and coastal marine invertebrates: tracking CO2 effects from seawater to the cell. *Annual Review of Marine Science* 12: 12.1-12.25. Article (subscription required).

Ocean acidification during prefertilization chemical communication affects sperm success Ocean acidification (OA) poses a major threat to marine organisms, particularly during reproduction when externally shed gametes are vulnerable to changes in seawater pH. Accordingly, several studies on OA have focused on how changes in seawater pH influence sperm behavior and/or rates of in vitro fertilization. By contrast, few studies have examined how pH influences prefertilization gamete interactions, which are crucial during natural spawning events in most externally fertilizing taxa. One mechanism of gamete interaction that forms an important component of fertilization in most taxa is communication between sperm and egg-derived chemicals. These chemical signals, along with the physiological responses in sperm they elicit, are likely to be highly sensitive to changes in seawater chemistry. In this study, we experimentally tested this possibility using the blue mussel, Mytilus galloprovincialis, a species in which females have been shown to use egg-derived chemicals to promote the success of sperm from genetically compatible males. We conducted trials in which sperm were allowed to swim in gradients of egg-derived chemicals under different seawater CO2 (and therefore pH) treatments. We found that sperm had elevated fertilization rates after swimming in the presence of egg-derived chemicals in low pH (pH 7.6) compared with ambient (pH 8.0) seawater. This observed effect could have important implications for the reproductive fitness of external fertilizers, where gamete compatibility plays a critical role in modulating reproduction in many species. For example, elevated sperm fertilization rates might disrupt the eggs' capacity to avoid fertilizations by genetically incompatible sperm. Our findings highlight the need to understand how OA affects the multiple stages of sperm-egg interactions and to develop approaches that disentangle the implications of OA for female, male, and population fitness.

Lymbery R. A., Kennington W. J., Cornwall C. E. & Evans J. P., in press. Ocean acidification during prefertilization chemical communication affects sperm success. *Ecology and Evolution*. Article.

Sensitivities to global change drivers may correlate positively or negatively in a foundational marine macroalga Ecological impact of global change is generated by multiple synchronous or asynchronous drivers which interact with each other and with intraspecific variability of sensitivities. In three near-natural experiments, we explored response correlations of full-sibling germling families of the seaweed Fucus vesiculosus towards four global change drivers: elevated CO2 (ocean acidification, OA), ocean warming (OW), combined OA and warming (OAW), nutrient enrichment and hypoxic upwelling. Among families, performance responses to OA and OW as well as to OAW and nutrient enrichment correlated positively whereas performance responses to OAW and hypoxia anti-correlated. This indicates (i) that families robust to one of the three drivers (OA, OW, nutrients) will also not suffer from the two other shifts, and vice versa and (ii) families benefitting from OAW will more easily succumb to hypoxia. Our results may imply that selection under either OA, OW or eutrophication would enhance performance under the other two drivers but simultaneously render the population more susceptible to hypoxia. We conclude that intraspecific response correlations have a high potential to boost or hinder adaptation to multifactorial global change scenarios.

Al-Janabi B., Wahl M., Karsten U., Graiff A. & Kruse I., 2019. Sensitivities to global change drivers may correlate positively or negatively in a foundational marine macroalga. *Scientific Reports* 9: 14653. doi: 10.1038/s41598-019-51099-8. Article.