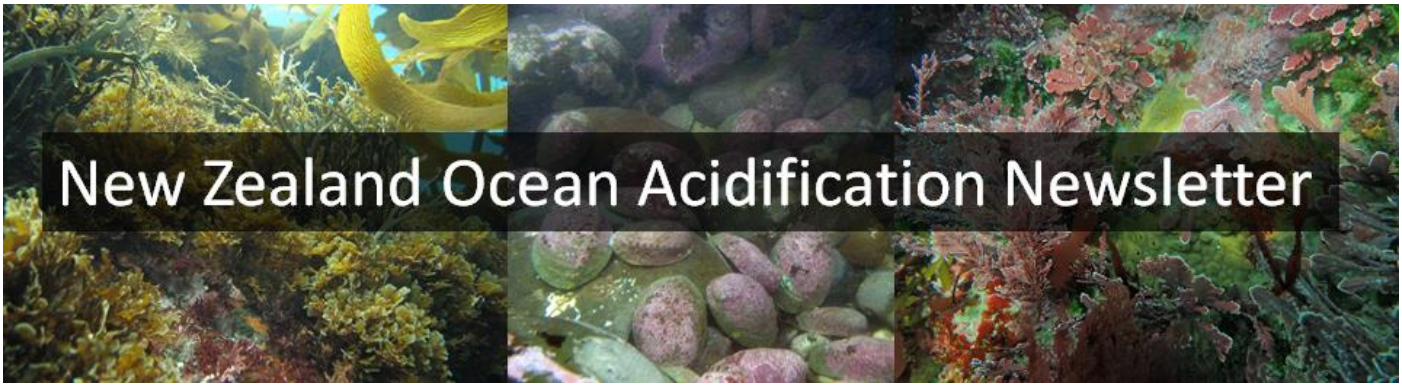
**#63 – March 2020 (http://nzoac.nz/)**




## Local News

### Successful CARIM and MEDDLE workshops and NZOAC conference

Both the Coastal Acidification – Rates, Impacts and Management (CARIM), and the multi-driver experimental design groups had successful had successful workshops on Feb 19th. The 2020 New Zealand Ocean Acidification Conference was held in Wellington on the 17th to 18th of February at Victoria University, and we had a range of excellent speakers. Thanks to all who attended any of these conferences/workshops, and hopefully see you again next year at the conference, which the University of Otago agreed to host.

## Selection of recent papers

**Changes in fish communities due to benthic habitat shifts under ocean acidification conditions** Ocean acidification will likely change the structure and function of coastal marine ecosystems over coming decades. Volcanic carbon dioxide seeps generate dissolved CO2 and pH gradients that provide realistic insights into the direction and magnitude of these changes. Here, we used fish and benthic community surveys to assess the spatio-temporal dynamics of fish community properties off CO2 seeps in Japan. Adding to previous evidence from ocean acidification ecosystem studies conducted elsewhere, our findings documented shifts from calcified to non-calcified habitats with reduced benthic complexity. In addition, we found that such habitat transition led to decreased diversity of associated fish and to selection of those fish species better adapted to simplified ecosystems dominated by algae. Our data suggest that near-future projected ocean acidification levels will oppose the ongoing range expansion of coral reef-associated fish due to global warming.

Cattano C., Agostini S., Harvey B. P., Wada S., Quattrocchi F., Turco G., Inaba K., Hall-Spencer J. M. & Milazzo M., in press. Changes in fish communities due to benthic habitat shifts under ocean acidification conditions. *Science of The Total Environment*. Article (subscription required).

**Near-future ocean warming and acidification alter foraging behaviour, locomotion, and metabolic rate in a keystone marine mollusc** Environmentally-induced changes in fitness are mediated by direct effects on physiology and behaviour, which are tightly linked. We investigated how predicted ocean warming (OW) and acidification (OA) affect key ecological behaviours (locomotion speed and foraging success) and metabolic rate of a keystone marine mollusc, the sea hare Stylocheilus striatus, a specialist grazer of the toxic cyanobacterium Lyngbya majuscula. We acclimated sea hares to OW and/or OA across three developmental stages (metamorphic, juvenile, and adult) or as adults only, and compare these to sea hares maintained under current-day conditions. Generally, locomotion speed and time to locate food were reduced ~1.5- to 2-fold when the stressors (OW or OA) were experienced in isolation, but reduced ~3-fold when combined. Decision-making was also severely altered, with correct foraging choice nearly 40% lower under combined stressors. Metabolic rate appeared to acclimate to the stressors in isolation, but was significantly elevated under combined stressors. Overall, sea hares that developed under OW and/or OA exhibited a less severe impact, indicating beneficial phenotypic plasticity. Reduced foraging success coupled with increased metabolic demands may impact fitness in this species and highlight potentially large

ecological consequences under unabated OW and OA, namely in regulating toxic cyanobacteria blooms on coral reefs.

Horwitz R., Norin T., Watson S.-A., Pistevos J. C. A., Beldade R., Hacquart S., Gattuso J.-P., Rodolfo-Metalpa R., Vidal-Dupiol J., Killen S. S. & Mills S. C., 2020. Near-future ocean warming and acidification alter foraging behaviour, locomotion, and metabolic rate in a keystone marine mollusc. *Scientific Reports* 10: 5461. doi: 10.1038/s41598-020-62304-4. Article.

**Diel-cycling seawater acidification and hypoxia impair the physiological and growth performance of marine mussels** Ocean acidification and hypoxia are concurrent in some coastal waters due to anthropogenic activities in the past decades. In the natural environment, pH and dissolved oxygen (DO) may fluctuate and follow diel-cycling patterns, but such effects on marine animals have not been comprehensively studied compared to their constant effects. In order to study the effects of diel-cycling seawater acidification and hypoxia on the fitness of marine bivalves, the thick shell mussels Mytilus coruscus were exposed to two constant levels of dissolved oxygen (2 mg/L, 8 mg/L) under two pH treatments (7.3, 8.1), as well as single diel fluctuating pH or DO, and the combined diel fluctuating of pH and DO for three weeks. The experimental results showed that constant acidification and hypoxia significantly reduced the extracellular pH (pHe) and condition index (CI) of mussels, and significantly increased HCO3−, pCO2 and standard metabolic rate (SMR). Diel fluctuating hypoxia and acidification also significantly reduced the pHe and CI, and significantly increased pCO2 and SMR, but had no significant effects on HCO3−. However, the diel-cycling acidification and hypoxia resulted in a higher CI compared to continuous exposure. In general, continuous and intermittent stress negatively impact the hemolymph and growth performance of mussels. However, mussels possess a little stronger resistance to diel-cycling seawater acidification and hypoxia than sustained stress.

Shang Y., Wang X., Deng Y., Wang S., Gu H., Wang T., Xu G., Kong H., Feng Y., Hu M. & Wang Y., 2020. Diel-cycling seawater acidification and hypoxia impair the physiological and growth performance of marine mussels. *Science of The Total Environment* 722: 138001. doi: 10.1016/j.scitotenv.2020.138001. Article (subscription required).

**NZOA-ON: the New Zealand Ocean Acidification Observing Network** A national observing network has been operating over the past 4 years to inform the scientific and economic challenges of ocean acidification (OA) facing New Zealand. The New Zealand Ocean Acidification Observing Network (NZOA-ON) consists of 12 sites across varied coastal ecosystems. These ecosystems range from oligotrophic ocean-dominated systems to eutrophic river-dominated systems, with sites that are pristine or affected by agriculture and urbanisation. Fortnightly measurements of total alkalinity and dissolved inorganic carbon provide the baseline of carbonate chemistry in these varied ecosystems and will facilitate detection of future changes, as well as providing a present-day baseline. The National Institute of Water and Atmospheric Research and the University of Otago have developed a 'grass-roots' sampling program, providing training and equipment that enable sampling partners to collect field samples for analyses at a central laboratory. NZOA-ON leverages existing infrastructure and partnerships to maximise data captured for understanding the drivers of chemical changes associated with OA and ecological responses. NZOA-ON coordinates with and contributes to global initiatives to understand and mitigate the broader impacts of OA. A description of NZOA-ON is presented with preliminary analyses and comparison of data from different sites after the first 4 years of the network.

Vance J. M., Currie K. I., Law C. S., A D , Murdoch J. & Zeldis J., 2019. NZOA-ON: the New Zealand Ocean Acidification Observing Network. *Marine and Freshwater Research* 71 (3): 281-299. Article (subscription required).

**Responses of sea urchin larvae to field and laboratory acidification** Understanding the extent to which laboratory findings of low pH on marine organisms can be extrapolated to the natural environment is key towards making better projections on the impacts of global change on marine ecosystems. We simultaneously exposed larvae of the sea urchin Arbacia lixula to ocean acidification in laboratory and natural CO2 vents and assessed the arm growth response as a proxy of net calcification. Populations of embryos were simultaneously placed at both control and volcanic CO2 vent sites in Ischia (Italy), with a parallel group maintained in the laboratory in control and low pH treatments corresponding to the mean pH levels of the field sites. As expected, larvae grown at constant low pH (pHT 7.8) in the laboratory exhibited reduced arm growth, but counter to expectations, the larvae that developed at the low pH vent site (pHT 7.33–7.99) had the longest arms. The larvae at the control field site (pHT 7.87–7.99) grew at a similar rate to laboratory controls. Salinity, temperature, oxygen and flow regimes were comparable between control and vent sites; however, chlorophyll a levels and particulate organic carbon were higher at the vent site than at the control field site. Thus, increased food availability may have modulated the effects of low pH, creating an opposite calcification response in the laboratory and the field. Divergent responses of the same larval populations developing in laboratory and field environments show the importance of considering larval phenotypic plasticity and complex interactions between decreased pH, food availability and larval responses.

Foo S. A., Koweek D. A., Munari M., Gambi M. C., Byrne M. & Caldeira K., in press. Responses of sea urchin larvae to field and laboratory acidification. *Science of The Total Environment*. Article.

**Cascading effects of climate change on plankton community structure** Plankton communities account for at least half of global primary production and play a key role in the global carbon cycle. Warming and acidification may alter the interaction chains in these communities from the bottom and top of the food web. Yet, the relative importance of these potentially complex interactions has not yet been quantified. Here, we examine the isolated and combined effects of warming, acidification, and reductions in phytoplankton and predator abundances in a series of factorial experiments. We find that warming directly impacts the top of the food web, but that the intermediate trophic groups are more strongly influenced by indirect effects mediated by altered top-down interactions. Direct manipulations of predator and phytoplankton abundance reveal similar strong top-down interactions following top predator decline. A meta-analysis of published experiments further supports the conclusion that warming has stronger direct impacts on the top and bottom of the food web rather than the intermediate trophic groups, with important differences between freshwater and marine plankton communities. Our results reveal that the trophic effect of warming cascading down from the top of the plankton food web is a powerful agent of global change.

Murphy G. E. P., Romanuk T. N. & Worm B., in press. Cascading effects of climate change on plankton community structure. *Ecology and Evolution*. Article.

**A unique temperate rocky coastal hydrothermal vent system (Whakaari–White Island, Bay of Plenty, New Zealand): constraints for ocean acidification studies** In situ effects of ocean acidification are increasingly studied at submarine CO2 vents. Here we present a preliminary investigation into the water chemistry and biology of cool temperate CO2 vents near Whakaari–White Island, New Zealand. Water samples were collected inside three vent shafts, within vents at a distance of 2 m from the shaft and at control sites. Vent samples contained both seawater pH on the total scale (pHT) and carbonate saturation states that were severely reduced, creating conditions as predicted for beyond the year 2100. Vent samples showed lower salinities, higher temperatures and greater nutrient concentrations. Sulfide levels were elevated and mercury levels were at concentrations considered toxic at all vent and control sites, but stable organic and inorganic ligands were present, as deduced from Cu speciation data, potentially mediating harmful effects on local organisms. The biological investigations focused on phytoplankton, zooplankton and macroalgae. Interestingly, we found lower abundances but higher diversity of phytoplankton and zooplankton at sites in the direct vicinity of Whakaari. Follow-up studies will need a combination of methods and approaches to attribute observations to specific drivers. The Whakaari vents represent a unique ecosystem with considerable biogeochemical complexity, which, like many other vent systems globally, require care in their use as a model of 'future oceans'.

Zitoun R., Connell S. D., Cornwall C. E., Currie K. I., Fabricius K., Hoffmann L. J., Lamare M. D., Murdoch J., Noonan S., Sander S. G., Sewell M. A., Shears N. T., K , van den Berg C. M. G. & Smith A. M., 2019. A unique temperate rocky coastal hydrothermal vent system (Whakaari–White Island, Bay of Plenty, New Zealand): constraints for ocean acidification studies. *Marine and Freshwater research*. Article.

**Regulation of calcification site pH is a polyphyletic but not always governing response to ocean acidification** The response of marine-calcifying organisms to ocean acidification (OA) is highly variable, although the mechanisms behind this variability are not well understood. Here, we use the boron isotopic composition (δ11B) of biogenic calcium carbonate to investigate the extent to which organisms' ability to regulate pH at their site of calcification (pHCF) determines their calcification responses to OA. We report comparative δ11B analyses of 10 species with divergent calcification responses (positive, parabolic, threshold, and negative) to OA. Although the pHCF is closely coupled to calcification responses only in 3 of the 10 species, all 10 species elevate pHCF above pHsw under elevated pCO2. This result suggests that these species may expend additional energy regulating pHCF under future OA. This strategy of elevating pHCF above pHsw appears to be a polyphyletic, if not universal, response to OA among marine calcifiers—although not always the principal factor governing a species' response to OA.

Liu Y.-W., Sutton J. N., Ries J. B. & Eagle R. A., 2020. Regulation of calcification site pH is a polyphyletic but not always governing response to ocean acidification. *Science Advances* 6 (5): eaax1314. doi: 10.1126/sciadv.aax1314. Article (subscription required).

**A review of transgenerational effects of ocean acidification on marine bivalves and their implications for sclerochronology** Ocean acidification can negatively impact marine bivalves, especially their shell mineralization processes. Consequently, whether marine bivalves can rapidly acclimate and eventually adapt in an acidifying ocean is now increasingly receiving considerable attention. Projecting the fate of this vulnerable taxonomic group is also pivotal for the science of sclerochronology – the study which seeks to deduce records of past environmental changes and organismal life-history traits from various geochemical properties of periodically layered hard tissues (bivalve shells, corals, fish otoliths, etc.). In this review, we provide a concise overview of the long-term and transgenerational responses of marine bivalves to elevated pCO2 manifested at different levels of biological organization, with a specific focus on responses of geochemical properties (stable carbon and oxygen isotopes, minor and trace elements and microstructures) of their shells. Without exception, positive transgenerational responses to

an elevated pCO2 scenario projected for the year 2100 have been found in all five bivalve species hitherto studied, under the umbrella of two non-genetic mechanisms (increased maternal provisioning and epigenetic inheritance), suggesting that marine bivalves have remarkable transgenerational phenotypic plasticity which allows them to respond plastically and acclimate rapidly in an acidifying ocean. Rapid transgenerational acclimation, especially in terms of physiological processes, however, hinders a reliable interpretation of proxy records. Transgenerationally acclimated bivalves can actively modify the calcification physiology in response to elevated pCO2, which in turn affects the processes of almost all geochemical proxies preserved in their shells. In particular, stable carbon isotopes, metabolically regulated elements (Na, K, Cu, Zn, Fe, etc.), and shell microstructures can be highly biased. In this context, we propose a number of challenges and opportunities the field of sclerochronology may face.

Zhao L., Shirai K., Tanaka K., Milano S., Higuchi T., Murakami-Sugihara N., Walliser E. O., Yang F., Deng Y. & Schöne B. R., in press. A review of transgenerational effects of ocean acidification on marine bivalves and their implications for sclerochronology. *Estuarine, Coastal and Shelf Science*. Article (subscription required).

**Keith Hunter's legacy to Marine Science in New Zealand** On 24 October 2018, Keith Hunter sadly passed away. In his passing, the marine science world lost one of its most distinguished environmental chemists of his generation. Keith left a large scientific legacy in his research outputs including 162 research items with over 10 000 citations in the field of trace metal and carbonate chemistry, and his research has been supported by many research grants awarded by the New Zealand Marsden Fund and the Foundation for Research, Science and Technology. These metrics convey his incredible intellect and ability, but another equally important legacy is the postgraduate students he supervised, and the 40 years he spent in the
field of Marine Science. This research front in Marine and Freshwater Research is dedicated to Keith Hunter. He was a strong supporter of this journal where he served as co-Editor between 2008 and 2011. The articles published in this research front cover a small range of Keith's research interests and include articles on marine chemistry with specific emphasis on the marine carbonate system, ocean acidification, trace metal biogeochemistry and
trace metal speciation (Cornwall and Hurd 2020; Ellwood et al. 2020; Frew et al. 2020; Hassler et al. 2020; Hurd et al. 2020; Mosley and Liss 2020; Vance et al. 2020; Zitoun et al. 2020).

Michael J. Ellwood, Philip W. Boyd, Christopher E. Cornwall, Peter Croot, Kim I. Currie, , Russell D. Frew, Catriona L. Hurd, Cliff Law, Peter S. Liss, Christina M. McGraw, Luke M. Mosley, Sylvia G. Sander, Claudine Stirling and Rebecca Zitoun. https://www.publish.csiro.au/MF/pdf/MFv71n3_ED