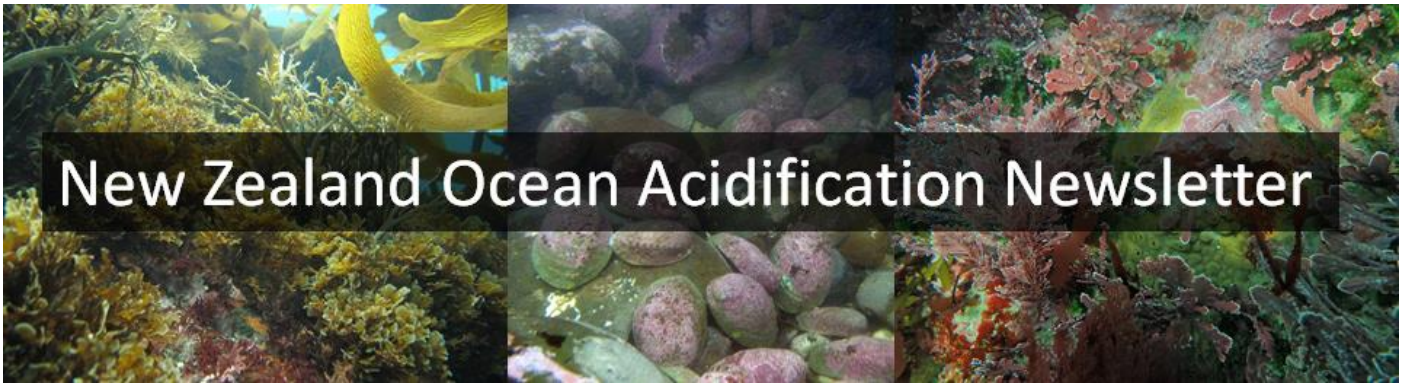
#54 – Feb 2019 (http://nzoac.nz/)



Local News

12th Annual NZOA workshop 20–21st February 2019

The 12th Annual NZOAC Workshop was held at the Otago Museum in Dunedin from February 20 – 21st. This was the largest workshop yet, with 65 attendees from 9 countries. The 34 talks included a plenary lecture from Christopher Harley (University of British Columbia) and sessions on ecosystem responses, national and international coordination, and the CARIM project. The last session of Day 1 was a special session in honour of Keith Hunter and included both projects he was involved in and those related to work he was passionate about.

The next workshop will be held in Wellington and co-organised by Christopher Cornwall (Victoria University of Wellington) and Monique Ladds (Department of Conservation).

Commonwealth Ocean Acidification Action Group Workshop 17–19th February 2019

The Commonwealth Ocean Acidification Action Group Workshop was held in Dunedin from 17 – 19 February. This technical workshop included government officials and international experts on ocean acidification science and policy from 17 Commonwealth countries – Antigua and Barbuda, Australia, Cook Islands, Fiji, Ghana, Kenya, Mauritius, Mozambique, New Zealand, Samoa, Seychelles, Solomon Islands, South Africa, Tonga, Tuvalu, UK, and Vanuatu. This workshop was the first step to bringing Commonwealth Countries together to share knowledge to better understand and address the impacts of ocean acidification.

International News, courses, Scholarships

Call for applications: OA-ICC/SCOR training course on best practices for ocean acidification experiments in multi-stressor scenarios, 24-28 June 2019, Monaco

Location/Dates: IAEA Environment Laboratories in Monaco, 24-28 June 2019
Organizers: The International Atomic Energy Agency (IAEA) Ocean Acidification International Coordination Centre (OA-ICC) and the Scientific Committee on Oceanic Research (SCOR)
Purpose:
The objectives of this training course are to become familiar with the modes of learning available in the new SCOR WG149 web-based best practice guide (to become available in April 2019). This best practice guide will provide a valuable platform to test methods and best practices for ocean acidification studies within a multi-stressor context that were developed at an IAEA Technical Meeting held in Monaco in June 2017.

Expected Outputs:
– Competency in the use of the new web-based best practices guide that can be passed on to others;
– New tools and best practices to study ocean acidification in conjunction with other stressors tested and adapted as necessary;
– Increased capacity by participants to study ocean acidification in a multi-stressor context; and
– New science collaborations among scientists attending the event.

Scope and Nature:
The ocean is subject to a multitude of human-caused pressures, such as ocean warming, acidification, eutrophication and oxygen depletion, acting simultaneously in complex ways. A major challenge for scientists today is to determine the cumulative effects of such interactive stressors on marine organisms, communities and ecosystems. Most studies on ocean change to date have investigated the response of acclimated single species/strains under the influence of a single driver. However, the assessment of impacts on ecosystems, necessary to inform science-based policy advice, requires information on responses to multiple drivers at the ecosystem level. There is an urgent need to develop a new generation of studies based on methodology that will allow studies to progress from single to multiple drivers, from organisms to ecosystems, and from acclimation to adaptation responses.
The trans-disciplinary of the Scientific Committee on Oceanic Research (SCOR) is working to design a framework of experiments, observations, and conceptual/mathematical models to address this need. These include a series of guidelines to perform multi-stressor studies, including a web-based decision support tool for researchers to assist with the design of their experiments; a virtual marine scientist laboratory application called MEDDLE (Multiple Environmental Driver Design Lab for Experiments) to test experimental set-ups; and a series of video tutorials on a range of topics made by experts in each field. These resources will go live in April 2019 and will provide a platform for the next generation of scientists to conduct rigorous interrelated research and to further refine this approach as new technologies emerge.
The IAEA promotes international collaboration and coordination to address ocean acidification. Among its many activities, the OA-ICC facilitates the development of standardized protocols, methods and tools for ocean acidification research to ensure the quality and comparability of results. To that end, it also promotes the use and development of guidelines and protocols, including those developed by SCOR Working Group 149, for both newcomers and established scientists working in the field, as well as training using these tools.

This training will be based on the web-based decision support tool and other tools developed by the SCOR Working Group 149, and include both lectures and discussions in plenary sessions and hands-on laboratory sessions in smaller groups to support the online tools. Subjects to be covered include: introduction to multiple-driver studies and to a newly developed online best practices guide for multi-stressor experiments, including a decision support tool, and the MEDDLE (Multiple Environmental Driver Design Lab for Experiments) simulator.

Participants and qualifications:
This course is open to 20 participants from IAEA Member States. Financial support is limited to participants from Member States eligible to receive technical assistance under the IAEA's Technical Cooperation Programme. Participants should have a university degree in marine biology, oceanography or a related scientific field, and should be currently involved in ocean acidification studies, ideally within a multi-stressor context. Priority will be given to early- to mid-career scientists and/or technicians, working in the ocean acidification/ocean change field.

Nomination procedure:
All persons wishing to participate in the event have to be designated by an IAEA Member State or should be members of organizations that have been invited to attend. In order to be designated by an IAEA Member State, participants are requested to send the Participation Form (Form A) to their competent national authority (e.g. Ministry of Foreign Affairs, Permanent Mission to the IAEA or National Atomic Energy Authority) for onward transmission to the IAEA by 5 April 2019. Selected participants will be informed in due course on the procedures to be followed with regard to administrative and financial matters.

Grants:
The IAEA is generally not in a position to bear the travel and other costs of participants in the event. The IAEA has, however, limited funds at its disposal to help meet the cost of attendance of certain participants. Upon specific request, such assistance may be offered to normally one participant per country, provided that, in the IAEA's view, the participant will make an important contribution to the event. The application for

financial support should be made using the Grant Application Form (Form C) which has to be stamped, signed and submitted by the competent national authority to the IAEA together with the Participation Form (Form A) by 5 April 2019.

For more information or any questions, please contact Lina Hansson, L.Hansson@iaea.org

PhD student project: Understanding the role of changes in means and variability in multiple stressors over single and multiple lifetimes in coralline algae

Here this project would use coralline algae as a model species to determine how multiple drivers of climate change interact to influence the fitness of coralline algae. The PhD work will examine whether populations and species which have evolved in more variable pH environments can gain tolerance to different drivers, and how variability in these drivers influence species responses. This work will use state-of-the-art geochemical and genetic techniques, in-depth physiological assessments, and multi-generational laboratory experiments to determine exactly how physiological and environmental controls impart tolerance to ocean acidification in multiple coralline algal species.

For more information contact Christopher.cornwall@vuw.ac.nz or see project description: https://www.findaphd.com/phds/project/understanding-the-role-of-changes-in-means-and-variability-in-multiple-stressors-over-single-and-multiple-lifetimes-in-coralline-algae/?p107178

Selection of recent papers

Biogenic habitat shifts under long-term ocean acidification show nonlinear community responses and unbalanced functions of associated invertebrates. Experiments have shown that increasing dissolved CO_2 concentrations (i.e. Ocean Acidification, OA) in marine ecosystems may act as nutrient for primary producers (e.g. fleshy algae) or a stressor for calcifying species (e.g., coralline algae, corals, molluscs). For the first time, rapid habitat dominance shifts and altered competitive replacement from a reef-forming to a non-reef-forming biogenic habitat were documented over one-year exposure to low pH/high CO_2 through a transplant experiment off Vulcano Island CO_2 seeps (NE Sicily, Italy). Ocean acidification decreased vermetid reefs complexity via a reduction in the reef-building species density, boosted canopy macroalgae and led to changes in composition, structure and functional diversity of the associated benthic assemblages. OA effects on invertebrate richness and abundance were nonlinear, being maximal at intermediate complexity levels of vermetid reefs and canopy forming algae. Abundance of higher order consumers (e.g. carnivores, suspension feeders) decreased under elevated CO_2 levels. Herbivores were non-linearly related to OA conditions, with increasing competitive release only of minor intertidal grazers (e.g. amphipods) under elevated CO_2 levels. Our results support the dual role of CO_2 (as a stressor and as a resource) in disrupting the state of rocky shore communities, and raise specific concerns about the future of intertidal reef ecosystem under increasing CO_2 emissions. We contribute to inform predictions of the complex and nonlinear community effects of OA on biogenic habitats, but at the same time encourage the use of multiple natural CO_2 gradients in providing quantitative data on changing community responses to long-term CO_2 exposure.

Milazzo M., Alessi C., Quattrocchi F., Chemello R., D'Agostaro R., Gil J., Vaccaro A. M., Mirto S., Gristina M. & Badalamenti F., 2019. *Science of The Total Environment* 667: 41-48. https://doi.org/10.1016/j.scitotenv.2019.02.391

Global aquaculture productivity, environmental sustainability, and climate change adaptability. To meet the demand for food from a growing global population, aquaculture production is under great pressure

to increase as capture fisheries have stagnated. However, aquaculture has raised a range of environmental concerns, and further increases in aquaculture production will face widespread environmental challenges. The effects of climate change will pose a further threat to global aquaculture production. Aquaculture is often at risk from a combination of climatic variables, including cyclone, drought, flood, global warming, ocean acidification, rainfall variation, salinity, and sea level rise. For aquaculture growth to be sustainable its environmental impacts must reduce significantly. Adaptation to climate change is also needed to produce more fish without environmental impacts. Some adaptation strategies including integrated aquaculture, recirculating aquaculture systems (RAS), and the expansion of seafood farming could increase aquaculture productivity, environmental sustainability, and climate change adaptability.

Ahmed N., Thompson S. & Glaser M., 2019. *Environmental Management* 63 (2): 159-172. https://doi.org/10.1007/s00267-018-1117-3

A comparison of species specific sensitivities to changing light and carbonate chemistry in calcifying marine phytoplankton. Coccolithophores are unicellular marine phytoplankton and important contributors to global carbon cycling. Most work on coccolithophore sensitivity to climate change has been on the small, abundant bloom-forming species *Emiliania huxleyi* and *Gephyrocapsa oceanica*. However, large coccolithophore species can be major contributors to coccolithophore community production even in low abundances. Here we fit an analytical equation, accounting for simultaneous changes in CO2 and light intensity, to rates of photosynthesis, calcification and growth in *Scyphosphaera apsteinii*. Comparison of responses to *G. oceanica* and *E. huxleyi* revealed *S. apsteinii* is a low-light adapted species and, in contrast, becomes more sensitive to changing environmental conditions when exposed to unfavourable CO2 or light. Additionally, all three species decreased their light requirement for optimal growth as CO2 levels increased. Our analysis suggests that this is driven by a drop in maximum rates and, in *G. oceanica*, increased substrate uptake efficiency. Increasing light intensity resulted in a higher proportion of muroliths (plate-shaped) to lopadoliths (vase shaped) and liths became richer in calcium carbonate as calcification rates increased. Light and CO2 driven changes in response sensitivity and maximum rates are likely to considerably alter coccolithophore community structure and productivity under future climate conditions.

Gafar N. A., Eyre B. D. & Schulz K. G., 2019. *Scientific Reports* 9: 2486. doi: 10.1038/s41598-019-38661-0. https://doi.org/10.1038/s41598-019-38661-0

Acid–base physiology over tidal periods in the mussel *Mytilus edulis*: size and temperature are more influential than seawater pH. Ocean acidification (OA) studies to date have typically used stable open-ocean pH and CO2 values to predict the physiological responses of intertidal species to future climate scenarios, with few studies accounting for natural fluctuations of abiotic conditions or the alternating periods of emersion and immersion routinely experienced during tidal cycles. Here, we determine seawater carbonate chemistry and the corresponding in situ haemolymph acid–base responses over real time for two populations of mussel (Mytilus edulis) during tidal cycles, demonstrating that intertidal mussels experience daily acidosis during emersion. Using these field data to parameterize experimental work we demonstrate that air temperature and mussel size strongly influence this acidosis, with larger mussels at higher temperatures experiencing greater acidosis. There was a small interactive effect of prior immersion in OA conditions (pHNBS 7.7/pCO2 930 µatm) such that the haemolymph pH measured at the start of emersion was lower in large mussels exposed to OA. Critically, the acidosis induced in mussels during emersion in situ was greater (ΔpH approximately 0.8 units) than that induced by experimental OA (ΔpH approximately 0.1 units). Understanding how environmental fluctuations influence physiology under current scenarios is critical to our ability to predict the responses of key marine biota to future environmental changes.

Mangan S., Wilson R. W., Findlay H. S. & Lewis C., 2019. *Proceedings of the Royal Society B* 286: 20182863. doi: 10.1098/rspb.2018.2863. https://doi.org/10.1098/rspb.2018.2863

The impact of ocean acidification on the gonads of three key Antarctic benthic macroinvertebrates. CO_2 atmospheric pressure is increasing since industrial revolution, leading to a lowering of the ocean surface water pH, a phenomenon known as ocean acidification, with several reported effects on individual species and cascading effects on marine ecosystems. Despite the great amount of literature on ocean acidification effects on calcifying organisms, the response of their reproductive system still remains poorly known. In the present study, we investigated the histopathological effects of low pH on the gonads of three key macroinvertebrates of the Terra Nova Bay (Ross Sea) littoral area: the sea urchin *Sterechinus neumayeri*, the sea star *Odontaster validus* and the scallop *Adamussium colbecki*. After 1 month of exposure at control (8.12) and reduced (7.8 and 7.6) pH levels, we dissected the gonads and performed histological analyses to detect potential differences among treatments. Results showed significant effects on reproductive conditions of *A. colbecki* and *S. neumayeri*, while *O. validus* did not show any kind of alteration. Present results reinforce the need to focus on ocean acidification effects on soft tissues, particularly the gonads, whose damage may exert large effects on the individual fitness, with cascading effects on the population dynamic of the species.

Dell'Acqua, O., Ferrando, S., Chiantore, M., Asnaghi, V. 2019. *Aquatic Toxicology* 210. Pages 19-29 https://www.sciencedirect.com/science/article/pii/S0166445X18308038

Ocean acidification affects somatic and otolith growth relationship in fish: evidence from an *in situ* study. Ocean acidification (OA) may have varied effects on fish eco-physiological responses. Most OA studies have been carried out in laboratory conditions without considering the in situ pCO_2/pH variability documented for many marine coastal ecosystems. Using a standard otolith ageing technique, we assessed how in situ ocean acidification (ambient, versus end-of-century CO_2 levels) can affect somatic and otolith growth, and their relationship in a coastal fish. Somatic and otolith growth rates of juveniles of the ocellated wrasse *Symphodus ocellatus* living off a Mediterranean CO_2 seep increased at the high-pCO2 site. Also, we detected that slower-growing individuals living at ambient pCO_2 levels tend to have larger otoliths at the same somatic length (i.e. higher relative size of otoliths to fish body length) than faster-growing conspecifics living under high pCO_2 conditions, with this being attributable to the so-called 'growth effect'. Our findings suggest the possibility of contrasting OA effects on fish fitness, with higher somatic growth rate and possibly higher survival associated with smaller relative size of otoliths that could impair fish auditory and vestibular sensitivity.

Di Franco A., Calò A., Sdiri K., Cattano C., Milazzo M. & Guidetti P., 2019. *Biology Letters* 15: 20180662. doi: 10.1098/rsbl.2018.0662. Article.

Effects of light and darkness on pH regulation in three coral species exposed to seawater acidification. The resilience of corals to ocean acidification has been proposed to rely on regulation of extracellular calcifying medium pH (pHECM), but few studies have compared the capacity of coral species to control this parameter at elevated pCO_2. Furthermore, exposure to light and darkness influences both pH regulation and calcification in corals, but little is known about its effect under conditions of seawater acidification. Here we investigated the effect of acidification in light and darkness on pHECM, calcifying cell intracellular pH (pHI), calcification, photosynthesis and respiration in three coral species: *Stylophora pistillata*, *Pocillopora damicornis* and *Acropora hyacinthus*. We show that *S. pistillata* was able to maintain pHECM under acidification in light and darkness, but pHECM decreased in *P. damicornis* and *A. hyacinthus* to a much greater extent in darkness than in the light. Acidification depressed calcifying cell pHI in all three species, but we identified an unexpected positive effect of light on pHI. Calcification rate and pHECM decreased together under acidification, but there are inconsistencies in their relationship indicating that other physiological parameters are likely to shape how coral calcification responds to acidification. Overall our

study reveals interspecies differences in coral regulation of pHECM and pHI when exposed to acidification, influenced by exposure to light and darkness.

Venn A. A., Tambutté E., Caminiti-Segonds N., Techer N., Allemand D. & Tambutté S., 2019. *Scientific Reports* 9: 2201. doi: 10.1038/s41598-018-38168-0. https://doi.org/10.1038/s41598-018-38168-0

Seagrass can mitigate negative ocean acidification effects on calcifying algae. The ultimate effect that ocean acidification (OA) and warming will have on the physiology of calcifying algae is still largely uncertain. Responses depend on the complex interactions between seawater chemistry, global/local stressors and species-specific physiologies. There is a significant gap regarding the effect that metabolic interactions between coexisting species may have on local seawater chemistry and the concurrent effect of OA. Here, we manipulated CO_2 and temperature to evaluate the physiological responses of two common photoautotrophs from shallow tropical marine coastal ecosystems in Brazil: the calcifying alga *Halimeda cuneata*, and the seagrass *Halodule wrightii*. We tested whether or not seagrass presence can influence the calcification rate of a widespread and abundant species of *Halimeda* under OA and warming. Our results demonstrate that under elevated CO_2, the high photosynthetic rates of *H. wrightii* contribute to raise *H. cuneata*calcification more than two-fold and thus we suggest that *H. cuneata*populations coexisting with *H. wrightii* may have a higher resilience to OA conditions. This conclusion supports the more general hypothesis that, in coastal and shallow reef environments, the metabolic interactions between calcifying and non-calcifying organisms are instrumental in providing refuge against OA effects and increasing the resilience of the more OA-susceptible species.

Bergstrom, E., Silva, J., Martins, C. & Horta, P. 2019 *Scientific Reports* 9, Article number: 1932. https://www.nature.com/articles/s41598-018-35670-3

***In-situ* behavioural and physiological responses of Antarctic microphytobenthos to ocean acidification.** Ocean acidification (OA) is predicted to alter benthic marine community structure and function, however, there is a paucity of field experiments in benthic soft sediment communities and ecosystems. Benthic diatoms are important components of Antarctic coastal ecosystems, however very little is known of how they will respond to ocean acidification. Ocean acidification conditions were maintained by incremental computer controlled addition of high fCO_2 seawater representing OA conditions predicted for the year 2100. Respiration chambers and PAM fluorescence techniques were used to investigate acute behavioural, photosynthetic and net production responses of benthic microalgae communities to OA in *in-situ* field experiments. We demonstrate how OA can modify behavioural ecology, which changes photo-physiology and net production of benthic microalgae. Ocean acidification treatments significantly altered behavioural ecology, which in turn altered photo-physiology. The ecological trends presented here have the potential to manifest into significant ecological change over longer time periods.

Black, J.G. et al. 2019. Scientific Reports 9, Article number: 1890. https://www.nature.com/articles/s41598-018-36233-2

Diel CO2 cycles and parental effects have similar benefits to growth of a coral reef fish under ocean acidification. Parental effects have been shown to buffer the negative effects of within-generation exposure to ocean acidification (OA) conditions on the offspring of shallow water marine organisms. However, it remains unknown if parental effects will be impacted by the presence of diel CO_2 cycles that are prevalent in many shallow water marine habitats. Here, we examined the effects that parental exposure to stable elevated (1000 µatm) and diel-cycling elevated (1000 ± 300 µatm) CO2 had on the survival and growth of juvenile coral reef anemonefish, *Amphiprion melanopus*. Juvenile survival was unaffected by within-generation

exposure to either elevated CO_2 treatment but was significantly increased (8%) by parental exposure to diel-cycling elevated CO_2. Within-generation exposure to stable elevated CO_2 caused a significant reduction in juvenile growth (10.7–18.5%); however, there was no effect of elevated CO_2 on growth when diel CO_2 cycles were present. Parental exposure to stable elevated CO_2 also ameliorated the negative effects of elevated CO2 on juvenile growth, and parental exposure to diel CO_2 cycles did not alter the effects of diel CO_2 cycles on juveniles. Our results demonstrate that within-generation exposure to diel-cycling elevated CO_2 and parental exposure to stable elevated CO_2 had similar outcomes on juvenile condition. This study illustrates the importance of considering natural CO_2 cycles when predicting the long-term impacts of OA on marine ecosystems.

Jarrold M. D. & Munday P. L., 2019. *Biology Letters* 15: 20180724. doi: 10.1098/rsbl.2018.0724. https://doi.org/10.1098/rsbl.2018.0724

Variation in brachiopod microstructure and isotope geochemistry under low-pH–ocean acidification conditions. In the last few decades and in the near future CO_2-induced ocean acidification is potentially a big threat to marine calcite-shelled animals (e.g. brachiopods, bivalves, corals and gastropods). Despite the great number of studies focusing on the effects of acidification on shell growth, metabolism, shell dissolution and shell repair, the consequences for biomineral formation remain poorly understood. Only a few studies have addressed the impact of ocean acidification on shell microstructure and geochemistry. In this study, a detailed microstructure and stable isotope geochemistry investigation was performed on nine adult brachiopod specimens of *Magellania venosa* (Dixon, 1789). These were grown in the natural environment as well as in controlled culturing experiments under different pH conditions (ranging from 7.35 to 8.15±0.05) over different time intervals (214 to 335 days). Details of shell microstructural features, such as thickness of the primary layer, density and size of endopunctae and morphology of the basic structural unit of the secondary layer were analysed using scanning electron microscopy. Stable isotope compositions (δ13C and δ18O) were tested from the secondary shell layer along shell ontogenetic increments in both dorsal and ventral valves. Based on our comprehensive dataset, we observed that, under low-pH conditions, *M. venosa* produced a more organic-rich shell with higher density of and larger endopunctae, and smaller secondary layer fibres. Also, increasingly negative $\delta^{13}C$ and $\delta^{18}O$ values are recorded by the shell produced during culturing and are related to the CO_2 source in the culture set-up. Both the microstructural changes and the stable isotope results are similar to observations on brachiopods from the fossil record and strongly support the value of brachiopods as robust archives of proxies for studying ocean acidification events in the geologic past.

Ye F., Jurikova H., Angiolini L., Brand U., Crippa G., Henke D., Laudien J., Hiebentha C. & Šmajgl D., 2019. *Biogeosciences*16: 617-642. https://doi.org/10.5194/bg-16-617-2019