#24 – March 2016 (http://nzoac.nz/)

News

NZOAC

NZOAC website http://nzoac.nz/%20-%20new-zealand-ocean-acidification-community/ . We hope you have all had a chance to have a look at this and bookmarked it for future. The facebook page has also been very popular with a few new postings. https://www.facebook.com/NewZealandOceanAcidificationCommunity/

Please can researchers, students and professionals fill out the expertise database: If you head to the Research tab, and scroll down you will see a button tab that says NZOAC Research Expertise Database: https://docs.google.com/spreadsheets/d/1foA0D9bqj41HYnEFRT9I_veRhJES1U9AEaYCBRpQPnc/edit?usp=sharing

Note that there are two spreadsheets within this doc. The first is: a space for everyone to add their expertise. The second is: a space for people to add their outreach/media activities

The next NZOAC committee meeting will be at the upcoming 4th International Symposium on the Ocean in a High-CO2 World.

CARIM

The Ministry for Business Innovation and Employment (MBIE) funded CARIM (Coastal Acidification: Rate, Impacts and Management) project is now underway. A general article about the project can be found at https://www.niwa.co.nz/news/investigating-ocean-acidification.

A new website has been launched and pages will appear soon: http://www.carim.nz/. There is also a Facebook page: www.facebook.com/CoastalAcidificationNZ, Twitter account: @CARIM_NZ https://twitter.com/CARIM_NZ and Instagram: carimnz https://www.instagram.com/carimnz/. We hope people will use these to share their activities with the community, so keep an eye out for the latest stuff going on in this exciting new project.

Upcoming events

9th Annual NZOA workshop

The 9th Annual New Zealand Ocean Acidification workshop will be held on Friday 8th July at Victoria University Wellington, following the AMSA/NZMSS conference. Scientists, policy makers and stakeholders are all welcome. The workshop this year includes a plenary speaker, short talks, updates from OA projects, and short discussion sessions on OA research coordination, directions and value to management, mitigation and adaptation. Please submit abstracts for talks and posters by the 16th May (template available from Helen.Bostock@niwa.co.nz). We also encourage people to present talks at the OA session at the NZMSS on the 7th July.

NZMSS- AMSA joint conference - Sharing Ocean Resources Now and in the Future

New Zealand Marine Sciences Society (NZMSS) and Australian Marine Sciences Association (AMSA) joint 2016 Conference – 4-7th July 2016, Victoria University, Wellington
https://innovators.eventsair.com/QuickEventWebsitePortal/nzmss-amsa-2016/home

Deadline for abstracts is 7th April. We encourage NZOA members to attend and present their Ocean Acidification studies in Session 3.4 (see description below). This session will be held on the last day of the conference.

Session 3.4: Preparing for climate change: it is one thing to understand what changes are taking place in the ocean in response to climate change but marine decision-makers continue to be daunted by what can be done to mitigate and prepare for changes in their own EEZ. Scope of presentations sought: Effects of climate change on resource management; the positives and negatives of climate change and ocean acidification on marine industry and other sector interests and obligations. Biosecurity in a changing ocean environment.

Gordon Research Conference – Ocean Global Change Biology

https://www.grc.org/programs.aspx?id=15856 July 17-22nd 2016 Waterville Valley, New Hampshire

The term Ocean Global Change Biology encapsulates climate-change mediated shifts in a wide range of oceanic conditions, the rate and magnitude of which will likely lead to altered physiological performance and changes in ecosystem status for biota in all oceanic regions. Nine thematic sessions will build a comprehensive picture of the progress made to date and the challenges that lie ahead. This GRC will develop the map needed to enable this research community to prioritize mid-term foci needed to meet longer term scientific goals. Chaired by Phil Boyd and Gretchen Hofmann. Deadline for applications is 19th June 2016, but apply early as there are limited places.

Program summary and list of speakers

- Advances in Ocean Global Change Biology Research (David Hutchins / Andrew Barton / Thorsten Reusch / Jean-Pierre Gattuso)
- Multi-Stressors in the Coastal Ocean (Gretchen Hofmann / Frank Melzner / Francis Chan / Madeleine van Oppen)
- Lessons in Studying Multi-Stressors from Other Disciplines: Ecotoxicology and Freshwater Research (Denise Breitburg / David Costantini / Craig Williamson / David Secor)
- The Quest for Unifying Concepts in Ocean Global Change Studies: Energetics, Biophysics and Trait-Based Research (Brian Helmuth / Inna Sokolova / Mark Denny / Becca Kordas)
- Adaptation, Microevolution, and Evolutionary Rescue (Sinead Collins / Andrew Hendry / Josianne Lachapelle / Gabriel Yvon-Durocher)
- Multi-Stressors Across Foodwebs: Effects of Differential Vulnerability and the Role of Species Interactions (Cathy Pfister / Sophie McCoy / Sean Connell/Doug Rasher)
- The Importance of Experimental Design in Ocean Global Change Studies (Jean-Pierre Gattuso / Christopher Cornwall / Ulf Riebesell / Jonathan Havenhand)
- Modeling of Multiple Stressors – From Physiology to Biogeochemistry (Scott Doney / Kevin Flynn / Kenneth Denman / Charles Stock)
- Communicating Multi-Stressor Issues to Policymakers and Managers (Philip Williamson / Lucia Fanning / Skyli McAfee / Libby Jewett)

Further information and application.

Gordon Research Seminar series for Early Career Researchers

Abstract submissions are still being accepted for the **Gordon Research Seminar** associated with the Global Ocean Change Biology Gordon Research Conference. The seminar will be held on July 16-17 in Waterville Valley, NH and is open to graduate students, post-docs and early career scientists.

The focus of this seminar series is to bring together our understanding about how the environmental history of a population or individual influences tolerance or vulnerability to future environmental change and thus the ability for marine species to cope with the multi-stressor scenario of global ocean change. Organizers are interested in studies that span a wide range of time scales (from carryover effects within an individual's lifetime to transgenerational plasticity to population level timescales to pale oceanographic time scales), and are also looking to highlight interdisciplinary tools for linking environmental exposure to organismal performance.

The seminar series will feature approximately 10 talks and 2 poster sessions. Please note: Although applications for the Gordon Research Conference are generally accepted by 18 June 2016, any applicants who wish to be considered for an oral presentation should submit their application by 16 April 2016.

International News

Ocean Acidification Report

News from the front lines of ocean acidification research, legislation, resources, and profiles from the waterfront around the world. The March 2016 edition covers topics such as lobsters and ocean acidification, chasing ocean acidification resilience in red abalone, the first ocean acidification African experiment, new Maine legislation on ocean acidification and many more.
http://globaloceanhealth.cmail20.com/t/ViewEmail/d/534BD3191C7B62F8/B2CA1C676579649AD9767B6002735221

Invitation to survey: GOA-ON biology observations and map updates

The Global Ocean Acidification Observing Network (GOA-ON) seeks community input guiding its development and, specifically, to inform the 3rd GOA-ON workshop in Hobart during May (www.goa-on.org). We value your feedback via a short survey on two topics: 1) biological observations that can be used to monitor the impact from OA and 2) updates to the GOA-ON map (www.goa-on.org/Map/), an interactive representation of OA platforms and observing activities. The survey link is: http://goo.gl/forms/qAu5bYBSsJ.

Selection of recent papers from the SW Pacific and beyond

Light levels affect carbon utilisation in tropical seagrass under ocean acidification. Under future ocean acidification (OA), increased availability of dissolved inorganic carbon (DIC) in seawater may enhance seagrass productivity. However, the ability to utilise additional DIC could be regulated by light availability, often reduced through land runoff. To test this, two tropical seagrass species, *Cymodocea serrulata* and *Halodule uninervis* were exposed to two DIC concentrations (447 µatm and 1077 µatm pCO2), and three light treatments (35, 100, 380 µmol m-2 s-1) for two weeks. DIC uptake mechanisms were separately examined by measuring net photosynthetic rates while subjecting *C. serrulata* and *H. uninervis* to changes in light and addition of bicarbonate (HCO3-) use inhibitors (carbonic anhydrase inhibitor, acetazolamide) and TRIS buffer (pH 8.0). We observed a strong dependence on energy driven H+-HCO3- co-transport (TRIS, which disrupts H+ extrusion) in *C. serrulata* under all light levels, indicating greater CO2 dependence in low light. This was confirmed when, after two weeks exposure, DIC enrichment stimulated maximum photosynthetic rates (Pmax) and efficiency (α) more in *C. serrulata* grown under lower light levels (36–60% increase) than for those in high light (4% increase). However, *C. serrulata* growth increased with both DIC enrichment and light levels. Growth, NPP and photosynthetic responses in *H. uninervis* increased with higher light treatments and were independent of DIC availability. Furthermore, *H. uninervis* was found to be more flexible in HCO3- uptake pathways. Here, light availability influenced productivity responses to DIC enrichment, via both carbon fixation and acquisition processes, highlighting the role of water quality in future responses to OA. Ow Y. X., et al., 2016. *PLoS ONE* 11(3): e0150352. Article (subscription required).

Will ocean acidification affect the early ontogeny of a tropical oviparous elasmobranch (*Hemiscyllium ocellatum*)? Atmospheric CO2 is increasing due to anthropogenic causes. Approximately 30% of this CO2 is being absorbed by the oceans and is causing ocean acidification (OA). The effects of OA on calcifying organisms are starting to be understood, but less is known about the effects on non-calcifying organisms, notably elasmobranchs. One of the few elasmobranch species that has been studied with respect to OA is the epaulette shark, *Hemiscyllium ocellatum*. Mature epaulette sharks can physiologically and behaviourally tolerate prolonged exposure to elevated CO2, and this is thought to be because they are routinely exposed to diurnal decreases in O2 and probably concomitant increases in CO2 in their coral reef habitats. It follows that *H. ocellatum* embryos, while developing in ovo on the reefs, would have to be equally if not more tolerant than adults because they would not be able to escape such conditions. Epaulette shark eggs were exposed to either present-day control conditions (420 µatm) or elevated CO2 (945 µatm) and observed every 3 days from 10 days post-fertilization until 30 days post-hatching. Growth (in square centimetres per day), yolk usage (as a percentage), tail oscillations (per minute), gill movements (per minute) and survival were not significantly different in embryos reared in control conditions when compared with those reared in elevated CO2 conditions. Overall, these findings emphasize the importance of investigating early life-history stages, as the consequences are expected to transfer not only to the success of an individual but also to populations and their distribution patterns. Johnson M. S., et al., 2016. *Conservation Physiology* 4(1):cow003. Article.

Effects of reduced pH on the early larval development of hatchery-reared Donkey's ear abalone, *Haliotis asinina* (Linnaeus 1758). Declining pH levels caused by absorption of accumulating atmospheric CO2 in the ocean threaten the normal development of early life stages and particularly impair the ability of calcifying organisms to construct their shells. An experiment was conducted to determine the direct effects of reduced pH on % hatching of fertilized eggs, survival and developmental stages of trochophore larvae of the Donkey's ear abalone, *Haliotis asinina*. The ambient pH (7.97 ± 0.02) of experimental seawater was reduced by bubbling food-grade CO2 to obtain the desired pH levels of 7.78 ± 0.03, 7.60 ± 0.03 and 7.40 ± 0.02 as treatments. There were increasing negative impacts of reduced pH on the mean % hatched trochophores (97.6 at ambient pH conditions, 83.9 at pH 7.78, 24.1 at pH 7.60, and 1.4 at pH 7.40). Significant impacts of reduced pH were also observed on mean % survival of trochophores (98.3 at ambient pH conditions, 84.9 at pH 7.78, 24.1 at pH 7.60, and 1.4 at pH 7.40). Of the surviving trochophores, 23.2 ± 3.2% (mean ± sd) of those exposed to pH 7.60 were morphologically deformed but in much lower pH treatment (pH 7.40), all the trochophores were deformed. At pH 7.78, only 63.3 ± 3.7% of the surviving trochophores developed normally compared to 96.7 ± 1.6% normal trochophores at ambient pH conditions. Normal trochophores have prototrochal cells and girdle fully developed and developing shell tissue. Malformed trochophores showed highly undefined morphological characters and cleavage failed to progress to further developmental stages. In conclusion, the early larval development of *H. asinina* was found to be highly sensitive to reduced pH levels projected for the end of the present century. Therefore, future rise in CO2 concentration in tropical marine waters will likely pose a significant threat to the natural population densities of this species. Tahil A. S. & Dy D. T., in press. *Aquaculture.* Article (subscription required).

Silent oceans: ocean acidification impoverishes natural soundscapes by altering sound production of the world's noisiest marine invertebrate. Soundscapes are multidimensional spaces that carry meaningful information for many species about the location and quality of nearby and distant resources. Because soundscapes are the sum of the acoustic signals produced by individual organisms and their interactions, they can be used as a proxy for the condition of whole ecosystems and their occupants. Ocean acidification resulting from anthropogenic CO2 emissions is known to have profound effects on marine life. However, despite the increasingly recognized ecological importance of soundscapes, there is no empirical test of whether ocean acidification can affect biological sound production. Using field recordings obtained from three geographically separated natural CO2 vents, we show that forecasted end-of-century ocean acidification conditions can profoundly reduce the biological sound level and frequency of snapping shrimp snaps. Snapping shrimp were among the noisiest marine organisms and the suppression of their sound production at vents was responsible for the vast majority of the soundscape alteration observed. To assess mechanisms that could account for these observations, we tested whether long-term exposure (two to three months) to elevated CO2 induced a similar reduction in the snapping behaviour (loudness and frequency) of snapping shrimp. The results indicated that the soniferous behaviour of these animals was substantially reduced in both frequency (snaps per minute) and sound level of snaps produced. As coastal marine soundscapes are dominated by biological sounds produced by snapping shrimp, the observed suppression of this component of soundscapes could have important and possibly pervasive ecological consequences for organisms that use soundscapes as a source of information. This trend towards silence could be of particular importance for those species whose larval stages use sound for orientation towards settlement habitats. Rossi T., et al., 2016. *Proceedings of the Royal Society B: Biological Sciences* 283(1826). Article (subscription required).

Modelling climate change impacts on marine fish populations: process-based integration of ocean warming, acidification and other environmental drivers. Global climate change affects marine fish through drivers such as ocean warming, acidification and oxygen depletion, causing changes in marine ecosystems and socioeconomic impacts.

While experimental and observational results can inform about anticipated effects of different drivers, linking between these results and ecosystem-level changes requires quantitative integration of physiological and ecological processes into models to advance research and inform management. We give an overview of important physiological and ecological processes affected by environmental drivers. We then provide a review of available modelling approaches for marine fish, analysing their capacities for process-based integration of environmental drivers. Building on this, we propose approaches to advance important research questions. Examples of integration of environmental drivers exist for each model class. Recent extensions of modelling frameworks increase the potential for including detailed mechanisms and improving model projections. Experimental results on energy allocation, behaviour and physiological limitations will advance the understanding of organism-level trade-offs and thresholds in response to multiple drivers. More explicit representation of life cycles and biological traits can improve description of population dynamics and adaptation, and data on food web topology and feeding interactions help to detail the conditions for possible regime shifts. Identification of relevant processes will also benefit the coupling of different models to investigate spatial–temporal changes in stock productivity and integrated responses of social–ecological systems. Thus, a more process-informed foundation for models will promote the integration of experimental and observational results and increase the potential for model-based extrapolations into a future under changing environmental conditions. Koenigstein S., et al., in press. *Fish and Fisheries.* Article (subscription required).

Flow and coral morphology control coral surface pH: implications for the effects of ocean acidification. The future impact of ocean acidification (OA) on corals is disputed in part because mathematical models used to predict these impacts do not seem to capture, or offer a framework to adequately explain, the substantial variability in acidification effects observed in empirical studies. The build-up of a diffusive boundary layer (DBL), wherein solute transport is controlled by diffusion, can lead to pronounced differences between the bulk seawater pH, and the actual pH experienced by the organism, a factor rarely considered in mathematical modeling of ocean acidification effects on corals. In the present study, we developed a simple diffusion-reaction-uptake model that was experimentally parameterized based on direct microsensor measurements of coral tissue pH and O2 within the DBL of a branching and a massive coral. The model accurately predicts tissue surface pH for different coral morphologies and under different flow velocities as a function of ambient pH. We show that, for all cases, tissue surface pH is elevated at lower flows, and thus thicker DBLs. The relative effects of OA on coral surface pH was controlled by flow and we show that under low flow velocities tissue surface pH under OA conditions (pHSWS = 7.8) can be equal to the pH under normal conditions (pHSWS = 8.2). We conclude that OA effects on corals in nature will be complex as the degree to which they are controlled by flow appears to be species specific. Chan N. C. S., et al., 2016. *Frontiers in Marine Science* 3:10. Article.

Skeletal mineralogy of coral recruits under high temperature and pCO2. Aragonite, which is the polymorph of CaCO3 precipitated by modern corals during skeletal formation, has a higher solubility than the more stable polymorph calcite. This higher solubility may leave animals that produce aragonitic skeletons more vulnerable to anthropogenic ocean acidification. It is therefore important to determine whether scleractinian corals have the plasticity to adapt and produce calcite in their skeletons in response to changing environmental conditions. Both high pCO2 and lower Mg ⁄ Ca ratios in seawater are thought to have driven changes in the skeletal mineralogy of major marine calcifiers in the past ∼ 540 Ma. Experimentally reduced Mg ⁄ Ca ratios in ambient seawater have been shown to induce some calcite precipitation in both adult and newly settled modern corals; however, the impact of high pCO2 on the mineralogy of recruits is unknown. Here we determined the skeletal mineralogy of 1-month-old *Acropora spicifera* coral recruits grown under high temperature (+3 °C) and pCO2 (∼ 900 µatm) conditions, using X-ray diffraction and Raman spectroscopy. We found that newly settled coral recruits produced entirely aragonitic skeletons regardless of the treatment. Our results show that elevated pCO2 alone is unlikely to drive changes in the skeletal mineralogy of young corals. Not having an ability to switch from aragonite to calcite precipitation may leave corals and ultimately coral reef ecosystems more susceptible to predicted ocean acidification. An important area for prospective research would be the investigation of the combined impact of high pCO2 and reduced Mg ⁄ Ca ratio on coral skeletal mineralogy. Foster T. & Clode P. L., 2016. *Biogeosciences* 13:1717-1722. Article.

Historical reconstruction of ocean acidification in the Australian region. The ocean has become more acidic over the last 200 years in response increasing atmospheric carbon dioxide (CO2) levels. Documenting how the ocean has changed is critical for assessing how these changes impact marine ecosystems and for the management of marine resources. Here we use present-day ocean carbon observations, from shelf and offshore waters around Australia, combined with neural network mapping of CO2, sea surface temperature, and salinity to estimate the current seasonal and regional distributions of carbonate chemistry (pH and aragonite saturation state). The observed changes in atmospheric CO2 and sea surface temperature (SST) and climatological salinity are then used to reconstruct pH and aragonite saturation state changes over the last 140 years (1870–2013). The comparison with data collected at

Integrated Marine Observing System National Reference Station sites located on the shelf around Australia shows that both the mean state and seasonality in the present day are well represented, with the exception of sites such as the Great Barrier Reef. Our reconstruction predicts that since 1870 decrease in aragonite saturation state of 0.48 and of 0.09 in pH has occurred in response to increasing oceanic uptake of atmospheric CO_2. Large seasonal variability in pH and aragonite saturation state occur in southwestern Australia driven by ocean dynamics (mixing) and in the Tasman Sea by seasonal warming (in the case of the aragonite saturation state). The seasonal and historical changes in aragonite saturation state and pH have different spatial patterns and suggest that the biological responses to ocean acidification are likely to be non-uniform depending on the relative sensitivity of organisms to shifts in pH and saturation state. This new historical reconstruction provides an important link to biological observations that will help to elucidate the consequences of ocean acidification. Lenton A., et al., 2016. *Biogeosciences* 13:1753-1765. Article.

Nitrate fertilisation does not enhance CO_2 responses in two tropical seagrass species. Seagrasses are often considered "winners" of ocean acidification (OA); however, seagrass productivity responses to OA could be limited by nitrogen availability, since nitrogen-derived metabolites are required for carbon assimilation. We tested nitrogen uptake and assimilation, photosynthesis, growth, and carbon allocation responses of the tropical seagrasses *Halodule uninervis* and *Thalassia hemprichii* to OA scenarios (428, 734 and 1213 µatm pCO_2) under two nutrients levels (0.3 and 1.9 µM NO_3^-). Net primary production (measured as oxygen production) and growth in *H. uninervis* increased with pCO_2 enrichment, but were not affected by nitrate enrichment. However, nitrate enrichment reduced whole plant respiration in *H. uninervis*. Net primary production and growth did not show significant changes with pCO_2 or nitrate by the end of the experiment (24 d) in *T. hemprichii*. However, nitrate incorporation in *T. hemprichii* was higher with nitrate enrichment. There was no evidence that nitrogen demand increased with pCO_2 enrichment in either species. Contrary to our initial hypothesis, nutrient increases to levels approximating present day flood plumes only had small effects on metabolism. This study highlights that the paradigm of increased productivity of seagrasses under ocean acidification may not be valid for all species under all environmental conditions. Ow Y. X., et al., 2016. *Scientific Reports* 6:23093. Article.

Optimising reef-scale CO_2 removal by seaweed to buffer ocean acidification. The equilibration of rising atmospheric CO_2 with the ocean is lowering pH in tropical waters by about 0.01 every decade. Coral reefs and the ecosystems they support are regarded as one of the most vulnerable ecosystems to ocean acidification, threatening their long-term viability. In response to this threat, different strategies for buffering the impact of ocean acidification have been proposed. As the pH experienced by individual corals on a natural reef system depends on many processes over different time scales, the efficacy of these buffering strategies remains largely unknown. Here we assess the feasibility and potential efficacy of a reef-scale (a few kilometers) carbon removal strategy, through the addition of seaweed (fleshy multicellular algae) farms within the Great Barrier Reef at the Heron Island reef. First, using diagnostic time-dependent age tracers in a hydrodynamic model, we determine the optimal location and size of the seaweed farm. Secondly, we analytically calculate the optimal density of the seaweed and harvesting strategy, finding, for the seaweed growth parameters used, a biomass of 42 g N m^{-2} with a harvesting rate of up 3.2 g N m^{-2} d^{-1} maximises the carbon sequestration and removal. Numerical experiments show that an optimally located 1.9 km^2 farm and optimally harvested seaweed (removing biomass above 42 g N m^{-2} every 7 d) increased aragonite saturation by 0.1 over 24 km^2 of the Heron Island reef. Thus, the most effective seaweed farm can only delay the impacts of global ocean acidification at the reef scale by 7–21 years, depending on future global carbon emissions. Our results highlight that only a kilometer-scale farm can partially mitigate global ocean acidification for a particular reef. Mongin M., et al., 2016. *Environmental Research Letters* 11(3):34023-34032(10). Article (subscription required).

Marine projections of warming and ocean acidification in the Australasian region. In response to increasing carbon dioxide emissions the oceans have become warmer and more acidic. In this paper, the ability of Earth System Models to simulate observed temperature and ocean acidification around Australia is as-sessed. The model results are also compared with observations collected at sta-tions around Australia over recent years to assess how representative the model results are of the coastal domain; and are found to adequately simulate the mean state at most sites. Simulations from the Coupled Model Intercomparison Project 5 (CMIP5) under low, medium and high emissions scenarios (RCPs 2.6, 4.5 and 8.5 respectively) are then used to project how ocean acidification and sea surface temperature will change. Under each of these emissions scenarios the oceans around Australia exhibit warming and continued acidification. However, these changes are quite heterogeneous, with increases of up to +6 K (under RCP 8.5) above the pre-industrial value, projected in areas such as the Tasman Sea. We conclude that the projected changes in SST, aragonite saturation state and pH are likely to profoundly impact marine ecosystems, and the ecosystem services that they provide in the Australasian region. Lenton A., et al., 2016. *Australian Meteorological and Oceanographic Journal* 65(1):S1-S28. Article.