# #41 – Oct 2017 (http://nzoac.nz/)

## News

Earlier this year NZOAC joined the Ocean Acidification Alliance (<https://www.oaalliance.org/>) as an affiliate member. At the same time the Ministry for the Environment made a recommendation that the New Zealand Government join the OA Alliance as a government member. After some delays, the Honourable Dr Nick Smith agreed that New Zealand should join the Alliance, and this was formally announced at the “Our Oceans” Conference in Malta on the 6th of October. As a government member, the New Zealand Government is eager to work with NZOAC to produce an OA action plan for New Zealand, to ensure we develop useful, practical, and effective approaches to responding to the challenges of OA. The Government and the NZOAC will look to progress this in the following months, but would welcome your thoughts and input. Any questions or suggestions, please contact Tim Riding ([tim.riding@mfe.govt.nz](mailto:tim.riding@mfe.govt.nz)).

**The 11th New Zealand Ocean Acidification Workshop, 13-14th February 2018**

**Location:** University of Waikato

Scientists, policy makers and stakeholders are all welcome. The workshop this year will include plenary speakers (to be confirmed) short talks, updates from OA projects, and discussion sessions on OA Alliance and research coordination, directions and value to management, mitigation and adaptation. Please submit formatted abstracts **(see instructions at the end of the Newsletter) by December 15th 2017.** Any enquiries please contact: [conrad.pilditch@waikato.ac.nz](mailto:conrad.pilditch@waikato.ac.nz).

**OA Workshops in the South Pacific**

The Secretariat of the Pacific Regional Environment Programme (S.P.R.E.P) and The Ocean Foundation (T.O.F) have signed a Memorandum Of Understanding to commit to co-host three workshops on ocean acidification to benefit 10 Pacific Islands. The signing took place at the “Our Ocean Conference” in Malta. The three workshops focus on Ocean acidification capacity building, a two week workshop for science capacity building including peer-to-peer training and full participation in the Global Ocean Acidification Observing Network (G.O.A-O.N) as well as training on Technology transfer on the G.O.A-ON in a box lab and field study kits.

The Ocean Foundation announced a EUR 1.05 million (USD 1.25 million) initiative for the ocean acidification capacity building for 2017 and 2018, particularly for developing nations, which will include workshops for policy and science capacity building as well as technology transfer for African, Pacific island, Central American and Caribbean nations.

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

**Ocean acidification in New Zealand waters: trends and impacts.**The threat posed by ocean acidification (OA) to the diversity and productivity of New Zealand marine ecosystems is assessed in a synthesis of published trends and impacts. A 20-year time series in Subantarctic water, and a national coastal monitoring programme, provide insight into pH variability, and context for experimental design, modelling and projections. A review of the potential impact of changes in the carbonate system on the major phyla in New Zealand waters confirms international observations that calcifying organisms, and particularly their early life-history stages, are vulnerable. The synthesis considers ecosystem and socio-economic impacts, and identifies current knowledge gaps and future research directions, including mechanistic studies of OA sensitivity. Advanced ecosystem models of OA, that incorporate the indirect effects of OA and interactions with other climate stressors, are required for robust projection of the future status of New Zealand marine ecosystems. Law C. S., et al., 2017. New Zealand Journal of Marine and Freshwater Research. [Article](http://dx.doi.org/10.1080/00288330.2017.1374983).

**Combined effects of ocean acidification with morphology, water flow, and algal acclimation on metabolic rates of tropical coralline algae*.*** Coral reefs are currently facing multiple stressors that threaten their health and function, including ocean acidification (OA). OA has been shown to negatively affect many reef calcifiers, such as coralline algae that provide many critical contributions to reef systems. Past studies have focused on how OA independently influences coralline algae, but more research is necessary as it is expected that the effects of OA on coralline algae will vary depending on many other factors. To better understand how algal morphology, water flow, and algal acclimation interact with OA to affect coralline algae, three studies were conducted in Moorea, French Polynesia, from June 2015 to July 2016. In January 2016, I tested the hypothesis that algal individuals with higher morphological complexity would exhibit faster metabolic rates under ambient pCO2 conditions, but would also demonstrate higher sensitivity to OA conditions. For three species of crustose coralline algae, *Lithophyllum kotschyanum, Neogoniolithon frutescens*, and *Hydrolithon reinboldii*, algal individuals with more complex morphologies demonstrated faster rates of calcification, photosynthesis, and respiration in the ambient pCO2 treatment than individuals with simpler morphological forms. There also appeared to be a relationship between morphology and sensitivity to OA conditions, with calcification rates negatively correlated with higher morphological complexity. In the summers of 2015 and 2016, I conducted three experiments examining the effects of water flow and OA on different morphologies of coralline algae to test the hypotheses that increased flow would enhance metabolic rates and mitigate the effects of OA, and that algae with more complex morphologies would be more responsive to increased water flow and more sensitive to OA conditions. A field experiment investigating the effects of water flow on *Amphiroa fragilissima, L. kotschyanum, N. frutescens*, and *H. reinboldii* detected enhanced rates of calcification, photosynthesis, and respiration with increased flow, and this relationship appeared to be the strongest for the crustose algal species with the highest structural complexity. A flume manipulation examining the combined effects of water flow and OA on *A. fragilissima, L. kotschyanum, N. frutescens, H. reinboldii,* and *Porolithon onkodes* suggested that coralline algal species with high structural complexity were the most sensitive to OA conditions. Finally, *A. fragilissima* and *L. kotschyanum* were maintained in different pCO2 and water flow conditions in a long-term mesocosm experiment, which indicated that flow was unable to mitigate the effects of OA on coralline algae. In the summer of 2016, I investigated the acclimation potential of *A. fragilissima* and *L. kotschyanum* to OA, and predicted that the original treatment conditions would induce phenotypic modifications that would influence algal responses to the end treatment. There were negative effects of long-term exposure of coralline algae to elevated pCO2 conditions on calcification and photosynthesis, though partial acclimation in calcification to OA was observed. The instantaneous exposure of elevated pCO2 had negative impacts on algal calcification, but had a nominal effect on photosynthesis. No effects of long-term or instantaneous exposure to elevated pCO2 were observed for respiration. The results of these studies indicate that the coralline algal response to OA conditions will likely be complex and depend on numerous factors including water flow, morphology, and acclimation potential. Therefore, it is critical that future studies further investigate the effects of these factors; specifically examining the mechanisms that underlie these responses in order to better predict the future of coralline algae and thus coral reef ecosystems in a more acidic ocean. Merolla S., 2017. MSc Thesis, California State University, Northridge, 118 p. [Thesis](http://scholarworks.csun.edu/handle/10211.3/196697) (limited access).

**Impacts of near-future ocean acidification and warming on the shell mechanical and geochemical properties of gastropods from intertidal to subtidal zones.** Many marine organisms produce calcareous shells as the key structure for defence, but the functionality of shells may be compromised by ocean acidification and warming. Nevertheless, calcifying organisms may adaptively modify their shell properties in response to these impacts. Here, we examined how reduced pH and elevated temperature affect shell mechanical and geochemical properties of common grazing gastropods from intertidal to subtidal zones. Given the greater environmental fluctuations in the intertidal zone, we hypothesized that intertidal gastropods would exhibit more plastic responses in shell properties than subtidal gastropods. Overall, three out of five subtidal gastropods produced softer shells at elevated temperature, while intertidal gastropods maintained their shell hardness at both elevated *p*CO2 (i.e. reduced pH) and temperature. Regardless of pH and temperature, degree of crystallization was maintained (except one subtidal gastropod) and carbonate polymorph remained unchanged in all tested species. One intertidal gastropod produced less soluble shells (e.g. higher calcite/aragonite) in response to reduced pH. In contrast, subtidal gastropods only produced aragonite which has higher solubility than calcite. Overall, subtidal gastropods are expected to be more susceptible than intertidal gastropods to shell dissolution and physical damage under future seawater conditions. The increased vulnerability to shell dissolution and predation could have serious repercussions for their survival and ecological contributions in the future subtidal environment. Leung J. Y. S., et al., 2017. Environmental Science & Technology. [Article](https://doi.org/10.1021/acs.est.7b02359) (subscription required).

**Exposure to elevated pCO2 does not exacerbate reproductive suppression of Aurelia aurita jellyfish polyps in low oxygen environments.**  Eutrophication-induced hypoxia is one of the primary anthropogenic threats to coastal ecosystems. Under hypoxic conditions, a deficit of O2 and a surplus of CO2 will concurrently decrease pH, yet studies of hypoxia have seldom considered the potential interactions with elevated *p*CO2 (reduced pH). Previous studies on gelatinous organisms concluded that they are fairly robust to low oxygen and reduced pH conditions individually, yet the combination of stressors has only been examined for ephyrae. The goals of this study were to determine the individual and interactive effects of hypoxia and elevated *p*CO2 on the asexual reproduction and aerobic respiration rates of polyps of the scyphozoan *Aurelia aurita* during a manipulative experiment that ran for 36 d. *p*CO2 and *p*O2 were varied on a diel basis to closely mimic the diel conditions observed in the field. Exposure to low dissolved oxygen (DO) reduced asexual budding of polyps by ~50% relative to control conditions. Under hypoxic conditions, rates of respiration were elevated during an initial acclimation period (until Day 8), but respiration rates did not differ between DO levels under prolonged exposure. There was no significant effect of increased *p*CO2 on either asexual reproduction or aerobic respiration, suggesting that elevated *p*CO2 (reduced pH) did not exacerbate the negative reproductive effects of hypoxia on *A. aurita* polyps. Treible L. M., et al.,. Marine Ecology Progress Series. [Article](https://doi.org/10.3354/meps12298).

**Ocean warming and acidification alter Antarctic macroalgal biochemical composition but not amphipod grazer feeding preferences.** Increased anthropogenic atmospheric CO2 concentrations have resulted in ocean warming and alterations in ocean carbonate chemistry, decreasing seawater pH (ocean acidification). The combination of ocean warming and acidification (OWA) may alter trophic interactions in marine benthic communities along the western Antarctic Peninsula (WAP). Abundant and diverse macroalgae–grazer assemblages, dominated by macroalgae (e.g. chemically defended *Desmarestia anceps* and *D. menziesii*) and gammarid amphipods (e.g. *Gondogeneia antarctica*), occur on the nearshore benthos along the WAP. In the present study, the amphipod *G. antarctica* and macroalgae *D. anceps* and *D. menziesii* were exposed for 39 and 79 d, respectively, to combinations of current and predicted near-future temperature (1.5 and 3.5°C, respectively) and pH (8.0 and 7.6, respectively). Protein and lipid levels of macroalgal tissues were quantified, and 5-way choice amphipod feeding assays were performed with lyophilized macroalgal tissues collected at time zero and following exposure to the 4 temperature-pH treatments. For *D. anceps,* we found a significant interactive temperature-pH effect on lipid levels and significantly lower protein levels at reduced pH. In contrast, tissues of *D. menziesii* exhibited significantly greater lipid levels after exposure to reduced pH, but there was no temperature effect on lipid or protein levels. Despite shifts in macroalgal biochemical composition, there were no changes in amphipod feeding preferences. Our results indicate that despite altered macroalgal nutritional quality under OWA, both macroalgae retained their ability to deter amphipod feeding. This deterrent capacity could become an important contributor to net community resistance of macroalgae-mesograzer assemblages of the WAP to predicted OWA. Schram J. B., et al., 2017. Marine Ecology Progress Series 581:45-56. [Article](https://doi.org/10.3354/meps12308).

**Maximum thermal limits of coral reef damselfishes are size-dependent and resilient to near-future ocean acidification.**  Theoretical models predict that ocean acidification, caused by increased dissolved CO2, will reduce the maximum thermal limits of fishes, thereby increasing their vulnerability to rising ocean temperatures and transient heatwaves. Here, we test this prediction in three species of damselfishes on the Great Barrier Reef, Australia. Maximum thermal limits were quantified using critical thermal maxima (CTmax) tests following acclimation to either present-day or end-of-century levels of CO2 for coral reef environments (∼500 or ∼1,000 µatm, respectively). While species differed significantly in their thermal limits, whereby Dischistodus perspicillatus exhibited greater CTmax (37.88±0.03oC; N=47) than Dascyllus aruanus (37.68±0.02oC; N=85) and Acanthochromis polyacanthus (36.58±0.02oC; N=63), end-of-century CO2 had no effect (D. aruanus) or a slightly positive effect (increase in CTmax of 0.16oC in D. perspicillatus and 0.21oC in A. polyacanthus) on CTmax. Contrary to expectations, smaller individuals were equally as resilient to CO2 as larger conspecifics, and CTmax was higher at smaller body sizes in two species. These findings suggest that ocean acidification will not impair the maximum thermal limits of reef fishes, and they highlight the critical role of experimental biology in testing predictions of theoretical models forecasting the consequences of environmental change. Clark T. D., et al., 2017. *Journal of Experimental Biology.* [Article](https://doi.org/10.1242/jeb.162529) (subscription required).

**Ocean life breaking rules by building shells in acidic extremes.**  Rising levels of carbon dioxide (CO2) from fossil fuel combustion is acidifying our oceans [1,2] . This acidification is expected to have negative effects on calcifying animals because it affects their ability to build shells [3,4]. However, the effects of ocean acidification in natural environments, subject to ecological and evolutionary processes (such as predation, competition, and adaptation), is uncertain [5,6]. These processes may buffer, or even reverse, the direct, short-term effects principally measured in laboratory experiments (for example, [6] ). Here we describe the discovery of marine snails living at a shallow-water CO2 vent in the southwest Pacific, an environment 30 times more acidic than normal seawater (Figure 1). By measuring the chemical fingerprints locked within the shell material, we show that these snails have a restricted range of movement, which suggests that they live under these conditions for their entire lives. The existence of these snails demonstrates that calcifying animals can build their shells under the acidic and corrosive conditions caused by extreme CO2 enrichment. This unforeseen capacity, whether driven by ecological or adaptive processes, is key to understanding whether calcifying life may survive a high-CO2 future. Doubleday Z. A., et al., 2017. Current Biology 27 (20): R1104–R1106. [Article](http://dx.doi.org/10.1016/j.cub.2017.08.057) (subscription required).

**Coccolithophore growth and calcification in a changing ocean.**  Coccolithophores are the most abundant calcifying phytoplankton in the ocean. These tiny primary producers have an important role in the global carbon cycle, substantially contributing to global ocean calcification, ballasting organic matter to the deep sea, forming part of the marine food web base, and influencing ocean-atmosphere CO2 exchange. Despite these important impacts, coccolithophores are not explicitly simulated in most marine ecosystem models and, therefore, their impacts on carbon cycling are not represented in most Earth system models. Here, we compile field and laboratory data to synthesize overarching, across-species relationships between environmental conditions and coccolithophore growth rates and relative calcification (reported as a ratio of particulate inorganic carbon to particulate organic carbon in coccolithophore biomass, PIC/POC). We apply our relationships in a generalized coccolithophore model, estimating current surface ocean coccolithophore growth rates and relative calcification, and projecting how these may change over the 21st century using output from the Community Earth System Model large ensemble. We find that average increases in sea surface temperature of ∼2-3 °C leads to faster coccolithophore growth rates globally ( >10% increase) and increased calcification at high latitudes. Roughly an ubiquitous doubling of surface ocean pCO2 by the end of the century has the potential to moderately stimulate coccolithophore growth rates, but leads to reduced calcification ( ∼25% decrease). Decreasing nutrient availability (from warming-induced increases in stratification) produces increases in relative calcification, but leads to ∼25% slower growth rates. With all drivers combined, we observe decreases in calcification and growth in most low and mid latitude regions, with possible increases in both of these responses in most high latitude regions. Major limitations of our coccolithophore model stem from a lack of conclusive physiological responses to changes in irradiance (we do not include light limitation in our model), and a lack of physiological data for major coccolithophore species. Species within the Umbellosphaera genus, for example, are dominant in mid to low latitude regions where we predict some of the largest decreases in coccolithophore growth rate and calcification. Krumhardt K. M., et al., 2017. Progress in Oceanography. [Article](https://doi.org/10.1016/j.pocean.2017.10.007) (subscription required).

**Transcriptomic response of the Antarctic pteropod Limacina helicina antarctica to ocean acidification.**  In order to better characterize the response of a polar calcifier to conditions of OA, we assessed differential gene expression in the Antarctic pteropod, Limacina helicina antarctica. Experimental levels of pCO2 were chosen to create both contemporary pH conditions, and to mimic future pH expected in OA scenarios. Significant changes in the transcriptome were observed when juvenile L. h. antarctica were acclimated for 21 days to low-pH (7.71), mid-pH (7.9) or high-pH (8.13) conditions. Differential gene expression analysis of individuals maintained in the low-pH treatment identified down-regulation of genes involved in cytoskeletal structure, lipid transport, and metabolism. High pH exposure led to increased expression and enrichment for genes involved in shell formation, calcium ion binding, and DNA binding. Significant differential gene expression was observed in four major cellular and physiological processes: shell formation, the cellular stress response, metabolism, and neural function. Across these functional groups, exposure to conditions that mimic ocean acidification led to rapid suppression of gene expression.  
Results of this study demonstrated that the transcriptome of the juvenile pteropod, L. h. antarctica, was dynamic and changed in response to different levels of pCO2. In a global change context, exposure of L. h. antarctica to the low pH, high pCO2 OA conditions resulted in a suppression of transcripts for genes involved in key physiological processes: calcification, metabolism, and the cellular stress response. The transcriptomic response at both acute and longer-term acclimation time frames indicated that contemporary L. h. antarctica may not have the physiological plasticity necessary for adaptation to OA conditions expected in future decades. Lastly, the differential gene expression results further support the role of shelled pteropods such as L. h. antarctica as sentinel organisms for the impacts of ocean acidification. Johnson K. M. & Hofmann G. E., 2017. BMC Genomics 18: 812. doi: 10.1186/s12864-017-4161-0. [Article](https://doi.org/10.1186/s12864-017-4161-0).

**Potential influence of ocean acidification on deep-sea Fe–Mn nodules: results from leaching experiments.** With the continuous rise in CO2 emissions, the pH of seawater may decrease extensively in the coming centuries. Deep-sea environments are more vulnerable to decreasing pH since sediments in deep oceans below the carbonate compensation depth (CCD) are often completely devoid of carbonate particles. In order to assess the potential risk of heavy metal release from deep-sea deposits, the mobility of elements from ferromanganese (Fe–Mn) nodules and pelagic clays was examined by means of leaching experiments using phosphate buffer solutions ranging in pH from 7.1 to 8.6 (NBS scale). With decreasing pH, the results showed an enhanced leaching of elements such as Li, B, Mg, Si, Sc, Sr, Ba, Tl, and U, but a reduced leaching of V, Cu, Mo, Cd, and W. Elements in leachates originate mainly from exchangeable fractions, and tend to be affected by sorption–desorption processes. Concentrations of most elements did not exceed widely used international water quality criteria, indicating that changes in pH caused by future ocean acidification may not increase the risk of heavy metal release during deep-sea nodule mining operations. Wang Q., et al., 2017. Aquatic Geochemistry 23 (4): 233-246. [Article](https://rd.springer.com/article/10.1007/s10498-017-9320-z) (subscription required).

**Oyster reproduction is compromised by acidification experienced seasonally in coastal regions.**  Atmospheric carbon dioxide concentrations have been rising during the past century, leading to ocean acidification (OA). Coastal and estuarine habitats experience annual pH variability that vastly exceeds the magnitude of long-term projections in open ocean regions. Eastern oyster (Crassostrea virginica) reproduction season coincides with periods of low pH occurrence in estuaries, thus we investigated effects of moderate (pH 7.5, pCO2 2260 µatm) and severe OA (pH 7.1, pCO2 5584 µatm; and 6.7, pCO2 18480 µatm) on oyster gametogenesis, fertilization, and early larval development successes. Exposure at severe OA during gametogenesis caused disruption in oyster reproduction. Oogenesis appeared to be more sensitive compared to spermatogenesis. However, Eastern oyster reproduction was resilient to moderate OA projected for the near-future. In the context of projected climate change exacerbating seasonal acidification, OA of coastal habitats could represent a significant bottleneck for oyster reproduction which may have profound negative implications for coastal ecosystems reliant on this keystone species. Boulais M., et al., 2017. Scientific Reports 7: 13276. doi:10.1038/s41598-017-13480-3. [Article](https://doi.org/10.1038/s41598-017-13480-3).

**Effects of ocean acidification and UV radiation on marine photosynthetic carbon fixation. In: Kumar M. & Ralph P. (Eds),**  The oceans absorb anthropogenically released CO2 at a rate of more than one million tons per hour, which causes a pH decrease of seawater and results in ocean acidification (OA). The effect of OA and absorption of CO2 via the biological carbon pump driven by marine photosynthesis has drawn increasing attentions. As a consequence, there are numerous studies on influences of OA on primary producers, and the effects on photosynthetic carbon fixation are still under debate. OA can promote the growth of diatoms at low PAR irradiances and inhibit it at high PAR. Besides, OA may influence metabolic pathways of phytoplankton, upregulating β-oxidation, and the tricarboxylic acid cycle, resulting in increased accumulation of toxic phenolic compounds. In parallel, phytoplankton cells in the upper mixed layer are affected by intense PAR and UV radiation (UVR). The calcareous layers of calcified algae, which have been shown to shield the organisms from UVR, are thinned due to OA, exposing the cells to increased UVR and further inhibiting the calcification. Therefore, effects of OA and UV on marine photosynthetic carbon fixation could be compounded. While the photosynthetic carbon fixation is controlled by other environmental stressors in addition to OA and UV, such as nutrients limitation and warming, combined effects of OA and UV have been less considered. In this review, we synthesize and analyze recent advances on effects of OA and UV and their combined effects, implying that future studies should pay special attentions to ecological and physiological effects of OA in the presence of solar UV irradiance to reflect more realistic implications. The ecophysiological effects of OA and/or UV and their mechanisms in complex environments should be further explored. Gao K. & Häder D.-P., in press. Systems biology of marine ecosystems, pp 235-250. Springer, Cham. [Chapter](https://link.springer.com/chapter/10.1007/978-3-319-62094-7_12) (subscription required).

## Upcoming meetings

**11th NZOA Workshop – 13-14th February 2018 - Abstracts due Dec 15 2017**

Abstract instructions

* **Paper title:** Calibri 11 point, bold, sentence case, leave one blank line below the title.
* **Authors' names:** Calibri 11 point. First name or initials should come before the family name for each author. Highlight the **presenting author** in bold. Use superscript numbers to indicate different affiliations and list below.
* **Authors affiliation:** Calibri 11 point, sentence case**.**
* Use “**Calibri**” 11 point with single line spacing for all text including headings. Left align all text.
* **250 words maximum.**
* Margins should be set at 2 cm all round.

**Email your abstract as a Microsoft word document to:** [**conrad.pilditch@waikato.ac.nz**](mailto:conrad.pilditch@waikato.ac.nz)

## PhD opportunities

**(1) PhD opportunity: ”Effect of ocean acidification on nitrogen fixation in the South Pacific”, University of Otago, New Zealand** Marine nitrogen fixation plays a major role in the biogeochemical cycling of C and N. Climate change related stressors such as ocean acidification and ocean warming have shown to significantly affect marine nitrogen fixation rates however, it seems that iron availability plays an overpowering role. Most research on nitrogen fixation has been performed in laboratory experiments or in the northern parts of the Atlantic and Pacific Ocean but very little is known about the South Pacific where primary production is low due to limiting nutrient concentrations. Changes in nitrogen fixation rates would therefore have significant implications for the ecosystem here. This PhD project will investigate the distribution and activity of diazotrophs in the South Pacific and quantify their contribution to primary production. In detailed incubation experiments the PhD student would further investigate the effect of ocean acidification, ocean warming, and iron availability on nitrogen fixation in this region.

The PhD student will receive training in all aspects of this project from participating in research cruises and performing incubation experiments on board, using especially designed incubators with precise pH control, metagenomics, and metatranscriptomics.

**(2) PhD opportunity: ”Effect of ocean acidification on phytoplankton – bacteria interactions in Southern Ocean waters”, University of Otago, New Zealand**  Marine phytoplankton live in close contact with a variety of bacteria and interact in form of chemical signalling. Interactions between marine phytoplankton and bacteria can thereby be mutualistic, parasitic or even pathogenic and therefore have a major impact on primary production and carbon export. Climate change related stressors such as ocean acidification and ocean warming will expose marine phytoplankton to enormous changes in their environment and potentially also affect phytoplankton – bacteria interactions. This PhD project will investigate the effect of ocean acidification on phytoplankton – bacteria interactions in natural Southern Ocean phytoplankton communities as well as in laboratory experiments.

The PhD student will receive training in all aspects of this project from participating in collection of seawater samples on board the Otago research vessel Polaris, using especially designed incubators with precise pH control, and measuring phytoplankton and bacteria community composition and activity using a combination of different methods including: microscopy, flow cytometry, FRRF, metagenomics, and metatranscriptomics.

The successful applicants would be expected to be eligible for and to apply for a University of Otago PhD scholarship. More information about scholarships at Otago can be found here: <http://www.otago.ac.nz/study/scholarships/database/otago014687.html> For more information about the project please contact: Dr. Linn Hoffmann Department of Botany University of Otago New Zealand <http://www.otago.ac.nz/botany/staff/linnhoffmann.html> e-mail: [linn.hoffmann@otago.ac.nz](mailto:linn.hoffmann@otago.ac.nz) or Dr. Tina Summerfield Department of Botany University of Otago New Zealand <http://www.otago.ac.nz/botany/staff/tinasummerfield.html> e-mail: tina.summerfield(at)otago.ac.nz