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Editorial

Keith Hunter's legacy to Marine Science in New Zealand

Michael J. Ellwood[A], *Philip W. Boyd*[B], *Christopher E. Cornwall*[C], *Peter Croot*[D], *Kim I. Currie*[E], *Russell D. Frew*[F], *Catriona L. Hurd*[B], *Cliff Law*[G,H], *Peter S. Liss*[I], *Christina M. McGraw*[E,F], *Luke M. Mosley*[J], *Sylvia G. Sander*[K], *Claudine Stirling*[F,L] *and Rebecca Zitoun*[F]

[A]Research School of Earth Sciences, Australian National University, Canberra, ACT 2601, Australia.
[B]Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tas. 7004, Australia.
[C]School of Biological Sciences, Victoria University Wellington, Wellington, New Zealand.
[D]School of Natural Sciences, National University of Ireland, Galway, Ireland.
[E]National Institute for Water and Atmospheric Research (NIWA) Centre of Chemical and Physical Oceanography, University of Otago, Dunedin, New Zealand.
[F]Department of Chemistry, University of Otago, Dunedin, New Zealand.
[G]NIWA, Wellington, New Zealand.
[H]Department of Marine Sciences, University of Otago, Dunedin, New Zealand.
[I]School of Environmental Sciences, University of East Anglia, UK.
[J]Ecology and Evolutionary Biology, University of Adelaide, South Australia, Australia.
[K]Marine Environmental Studies Laboratory, International Atomic Energy Agency, Monaco, Monaco.
[L]Centre for Trace Element Analysis, University of Otago, Dunedin, 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).

Keith Hunter's legacy

In 1974, Keith was the first recipient of the Rutherford Scholarship, allowing him to study for his Ph.D. with Peter Liss in the School of Environmental Sciences at the University of East Anglia (UEA). Keith had trained as a traditional chemist at the University of Auckland, but, during his time at UEA, he very successfully transitioned from pure chemistry to environmental and marine chemistry. This transition led Keith to evaluate the importance of surface charge for the behaviour of marine particulates, the role of trace metals in the sea surface microlayer and the role of organic material in the enrichment of dissolved trace metals in the microlayer.

After completing his Ph.D., Keith spent a year at the French Atomic Energy Commission followed by a second year at UEA. In 1979, he returned to New Zealand to join the Department of Chemistry at the University of Otago as a lecturer to help establish a new research direction in marine chemistry.

On his return to New Zealand, Keith set about making the first trace-metal measurements in the marine environment around New Zealand. To make these measurements down to the picomolar level required a dust-free environment, so he established a cleanroom laboratory; the first of its kind in New Zealand and one of the first in the Southern Hemisphere. Through the application and development of clean sampling and handling techniques, Keith and his group made the first reliable measurements of lead, cadmium, zinc and iron for New Zealand and Southern Ocean waters. Indeed, Keith and his student Russell Frew were the first to highlight the influence of the Southern Ocean on the coupling between cadmium and phosphate in the global ocean.

Keith benefited early on through links with the international SEAREX program, particularly with regard to collecting the first trace metal clean samples in the Tasman Sea using trace metal clean GO-FLO bottles in collaboration with Clare

Keith Hunter (centre front) and Otago University Ocean Acidifciation team *c*. 2011. Christopher Cornwall, Kim Currie, Catriona Hurd, Chris Hepburn, and Philip Boyd – missing Christina McGraw.

Patterson's group from the California Institute of Technology. SEAREX also spurred Keith into making aerosol and rainwater measurements. Through this work, long-term collaborations and friendships were developed with colleagues in the USA and elsewhere, most notably Bill Fitzgerald, Bob Duce and Tom Church. This network was to prove extremely helpful to his graduate students as they branched out across the globe.

In the late 1980s, while on sabbatical at the Department of Oceanography at the University of Washington in Seattle, Keith became interested in CO_2 and the marine-carbonate system, long before climate change seriously hit the scientific agenda. To understand the role CO_2 has on the marine system, Keith and his students developed new methods to monitor the marine-carbonate system, he wrote programs for calculating seawater parameters associated with the carbon cycle (SWCO2) and he instigated the Munida Time-Series Transect. The Munida transit is 65 km long, extending from neritic waters off the Otago coast to subantarctic surface waters originating in the Southern Ocean. This transit was designed to understand seasonal, annual and long-term variability of the marine-carbonate system, and is one of only several such transects worldwide. Today, the Munida Time-Series Transect forms a key part of the New Zealand Ocean Acidification Observing Network (NZOA-ON) and is the Southern Hemisphere's longest-running record of pH measurements.

One of Keith's great strengths was the ability to work with people from different disciplines. This was manifest in his leading role in the development of the field of ocean acidification both in New Zealand and internationally: he led a team of chemists, chemical engineers, biologists and geologists to develop new methods for manipulating and monitoring the seawater-carbonate system in ways that mimic future ocean acidification, and also addressed the requirements of biologists for independent replication of experimental units. He was also pivotal in recognising the role of marine life, particularly primary producers, in modifying seawater chemistry and generating pH fluctuations in coastal waters.

By the mid-1990s, it was becoming apparent that chemical speciation of trace metals was fundamental to understanding their biogeochemical cycling in marine and freshwater environments. Keith realised this early on and set about making some of the first measurements for the speciation of iron, zinc and copper in marine and freshwater systems. He then related these data to metal bioavailability and toxicity. Keith and his students also made several significant research breakthroughs on estuarine geochemistry, including measurement of the forces and kinetics of colloid aggregation, elucidating trace-metal behaviour, and new methods for measurement and modelling of pH.

In 1996, Keith helped establish the joint National Institute for Water and Atmospheric Research (NIWA)–University of Otago Centre of Excellence for Physical and Chemical Oceanography. Through this centre, natural collaborations between NIWA and university staff were established leading to many high-profile publications.

During the late 1990s, Keith co-chaired the UN Scientific Committee on Oceanic Research (SCOR) Working Group 109 with David Turner, which was tasked with evaluating the evidence for iron limitation of primary production in High Nutrient-Low Chlorophyll (HNLC) areas of the ocean. This

was particularly relevant with several high-profile ocean-iron fertilisation experiments occurring at the time. Keith was also involved in the Scientific Aspects of Marine Environmental Protection (GESAMP) Working Group 38: tasked with understanding the 'The Atmospheric Input of Chemicals to the Ocean', and was the New Zealand delegate to the UN Scientific Committee on Oceanic Research (SCOR).

In the late 2000s, Keith championed the establishment of the Centre for Trace Element Analysis at the University of Otago. This centre is dedicated to measuring trace elements and their isotope systems to understand biogeochemical processes across a wide range of disciplines including earth, environmental, climate, planetary, archaeological, nutrition and biomedical sciences.

Awards and service

In 1997, Keith was elected Fellow of the Royal Society of New Zealand for his contribution to New Zealand and international science. In 2007, he was awarded the University of Otago Distinguished Research Medal. In 2011, 15 years after the establishment of the joint NIWA–University of Otago Centre of Excellence, Keith and collaborators were awarded the New Zealand Prime Minister's Science Prize for their high-impact research, and 1 year later, the University of Otago Distinguished Research Group Award. In 2014, Keith received the Marsden Medal from the Royal Society of New Zealand, the highest research distinction in New Zealand, for his leadership and innovative mind in environmental and chemical oceanography.

Outside of research, Keith also served as the President of the New Zealand Institute of Chemistry and Head-of-Department for the Department of Chemistry at the University of Otago between 2005 and 2009. Subsequently, he became the Pro Vice-Chancellor of Sciences at the University of Otago from 2009 until his retirement in 2017.

When considering Keith's contribution, it is not just the papers, grants and prizes that constitute his scientific legacy, but also the people he helped, guided and mentored. Keith co-supervised 37 Ph.D. and 30 M.Sc. students over his career as was renowed for kind and considered approach to his mentees. In his roles as head-of-department and then Pro Vice-Chancellor of Sciences, Keith was renowned for the enthusiastic support and guidance he provided, especially for younger staff and the next generation of scientists. He also played a critical role for New Zealand science, paving the way for high-profile research fields such as trace-metal chemistry and ocean acidification in New Zealand, as was recognised by him receiving the Marsden Medal. Keith Hunter was a visionary and a world-class scientist who had a strong sense of community and an immense passion and knowledge of Marine Science and complex environmental challenges, such as global climate change. Keith Hunter will be greatly missed as a person and as a scientist.

If the worth of a life is measured by the people we influence, then Keith Hunter's was a life well lived!

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