



# Introduction: In appreciation of K. Robert Clarke

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## BIOGRAPHY IN BRIEF

### Early years

Professor Kenneth Robert Clarke ('Bob') was born on the 19th of June 1948. He was brought up largely in rural North Dorset in southern England, though his indefatigable love of travel can perhaps be traced to three years of childhood in Malta in the late 1950s, during which he was educated often as the sole English boy in the local schools, his father having taken the family there to head the English department of a newly opened secondary school for the island. Back in England in the 1960s, wise words from his older brother and an inspirational maths teacher at Blandford Grammar School determined Bob's subject choice for life – and the specialised focus of English state education at that time ensured he was taught nothing except mathematics from the age of 16. This led to a first class degree in Mathematics at the University of Leicester in 1969 (which contained no statistics at all, as was the case at the time for both school and university mathematics) and, more importantly that year, marriage (a long and happy one) to Cathy, a Leicester classics graduate. An M.Sc. at the University of Newcastle upon Tyne, under a revered statistician, Robin Plackett, brought Bob into the world of statistical theory (and writing computer code, in the days when 'cut and paste' literally meant taking a pair of scissors and tape to hole-punched paper!). This was followed by a Newcastle Ph.D. in Stereology, a branch of geometric probability and integral equations which infers 3-d properties from 2-d sections and projections, with application in life sciences, metallurgy and other fields. Bob became known on the university seminar

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circuit for provisioning the audience at the tea break by slicing up a cherry cake to derive the cherry density and diameter distribution from the resulting plane sections.

A 6-year stint (1973–1979) as a Lecturer in the Department of Statistics at the University of Glasgow, Scotland – under the tutelage and encouragement of two further giants of statistics, David Silvey and John Aitchison – turned Bob into a lecturer and taught him the trick of keeping just one step ahead of his students. It also showed him how rewarding it could be to work with academics from other departments to bring statistical theory to bear on their problems. He also, arguably, missed his vocation in life when in the mid-1970s a computerised golf game he programmed in machine code for a stand-alone pen plotter – with the correct differential equations for a ball in flight in the wind and on a sloping green with friction – stole the show of the Stats Department's University Open Day offering!

### Plymouth years

A wish to be closer to family brought Bob and Cathy south from Glasgow in 1979 to the warmer climes of Plymouth, Devon, as they started their own family. It is perhaps no surprise that their gifted offspring, Hazel and Ian, between them now have careers in statistics and software development. From 1979 to 2000, Bob worked at the Institute for Marine Environmental Research (IMER), which was renamed Plymouth Marine Laboratory (PML) in 1988. Bob talks about his initial surprise that IMER (a laboratory of the UK's Natural Environment Research Council) would want to appoint someone who professed 'complete ignorance' of any branch of biology, chemistry, hydrodynamics and environmental science, to a laboratory which was populated almost entirely by researchers with Ph.D.s in those disciplines. But the IMER/PML Directors – Roland ('Ro') Glover, and then Brian Bayne, who was a profound source of inspiration for a whole generation of young IMER/PML scientists of that era – were running a highly interdisciplinary laboratory and clearly knew they were missing a

mathematical statistician. Within a very few years, Bob had found his niche, and in addition to writing much of the laboratory's statistical and graphical software, he published papers with a broader range of the laboratory's researchers than any other member of its staff. Although Bob initially began as a 'jobbing statistician' in the role of a Senior Scientific Officer, he stepped readily up through the grades, achieving an Individual Merit Promotion to Unified Grade 6 (professorial equivalent) in 1997. His exceptional organisational skills were soon recognised, and he became a member of IMER Management Committee from 1983 to 1988 and was subsequently a member of the Executive Management Group and Head of PML Scientific Services until 1998.

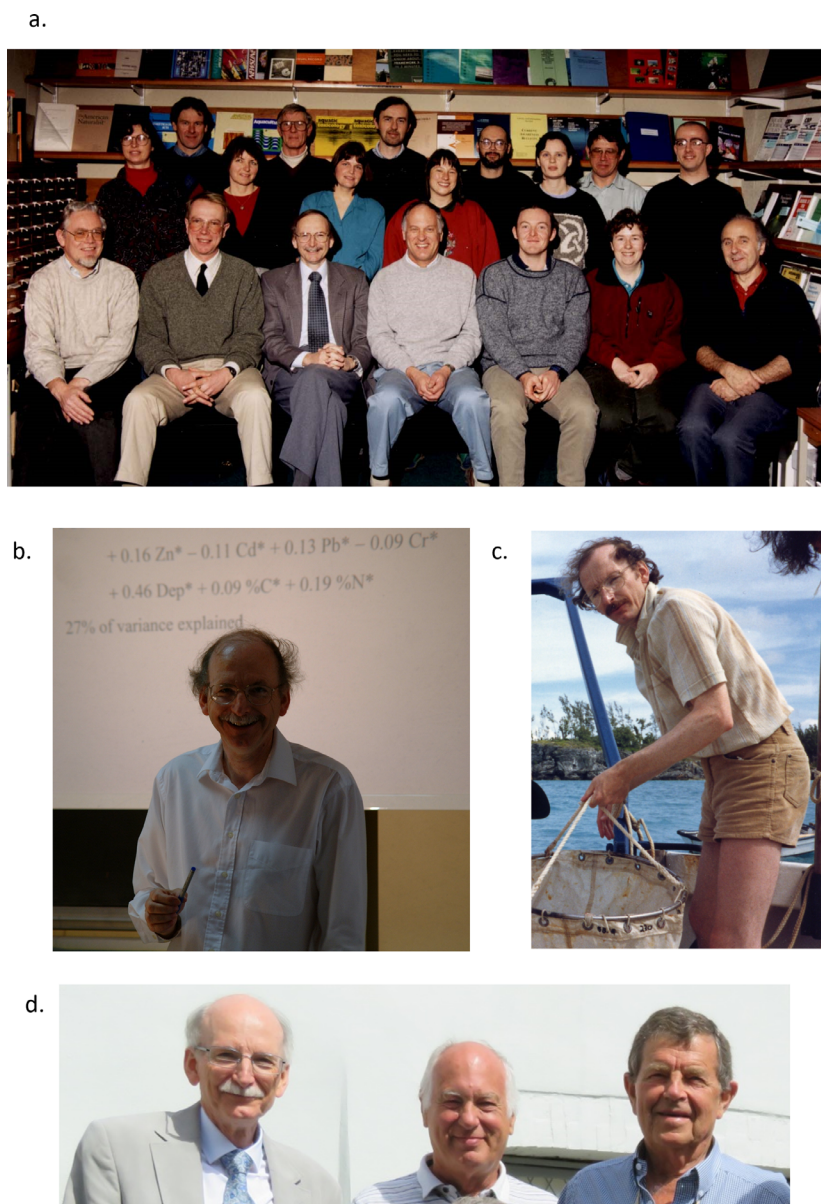
Of Bob's many collaborations at IMER/PML, some did require his mathematical expertise in stereology, such as the work with Mike Moore on mussel tissue-sectioning and, later, with Ian Joint on microbial-level spatial interactions, but the problems which Bob chiefly gravitated towards involved Richard Warwick and his benthic ecology group (Fig. 1a). Bob always had a keen interest in natural history, which was further catalysed by a year's visit in 1981/1982 from Professor John Field (Fig. 1d) on sabbatical from the University of Cape Town. Interaction with John during this visit led to a landmark paper – the proposition of a practical strategy for analysing multispecies distribution patterns (Field *et al.* 1982; Table 1; Fig. 1d) – generally regarded as the precursor to and inspiration for, the initial PRIMER software package and its subsequent development. More specifically, Bob introduced his colleagues to the potential of Kruskal's non-metric multi-dimensional scaling (MDS) for representing the statistically 'awkward' multivariate data of community ecology. It was also clear that an inferential problem existed – specifically structures for hypothesis testing, preferably in a similarly non-parametric context – within what was then seen as a purely descriptive area of statistics, and one which was in any case poorly served for ecological applications by commonly used ordination techniques. Out of this, over the next decade or so, came the non-parametric, permutation-based analysis of similarities (ANOSIM) tests, within a suite of related techniques giving a unified approach to handling biologically defined similarity matrices from community data (Clarke 1993). This, and work in the mid-1990s on definitions of biological diversity utilising taxonomic or phylogenetic relationships among species, was spurred on by the challenging questions posed by Bob's closest collaborators at PML – Richard Warwick and (later) Paul Somerfield (Figs 1a,d,2c). Fortunately for us, Bob's main scientific interests and involvement now lay firmly in the field of ecology, and he became Deputy Project Leader for PML's 'Community Ecology' and 'Marine Biodiversity' research groups (Fig. 1a).

The methodological steps of Bob's first decade or so in Plymouth were coded in the early PRIMER software by Bob, Martin Carr and their students. The meaning of the acronym 'PRIMER' had to be changed from 'Plotting and data Reduction at IMER' to 'Plymouth Routines In Multivariate Ecological Research' on the morphing of IMER into PML in 1988. The software was made available outside the Plymouth laboratory by its transition from mainframe to microcomputer in 1987, leading to the first widely available DOS version (PRIMER v4) from 1993. Particularly in those early years, Bob also made a point of joining in with the fieldwork done in marine ecosystems alongside colleagues at IMER/PML to appreciate the practical problems faced by them in gathering data and designing appropriate sampling strategies (e.g. Fig. 1c). Bob is not only an excellent and patient listener, he is also exceptionally good at explaining quite difficult statistical concepts to non-statisticians (i.e. most biologists!), not only verbally (within a lecture or consultation context), but also in characteristically detailed written missives. A good example is a fax sent in 1988 (before the advent of email) to advise one of us (RMW) on an appropriate sampling design to investigate the effects of disturbance by soldier crabs on meiobenthic infauna that were patchily distributed on a Tasmanian tidal flat (Fig. 3a). The resulting multi-dimensional scaling (MDS) ordination plot arising from this study (Warwick *et al.* 1990) – an example of 2-way crossed ANOSIM (see also Fig. 6.7 of the PRIMER manual; Clarke *et al.* 2014) – closely resembles, rather remarkably, what Bob had drawn *a priori* in his scribbled instructions (*cf.*, Fig. 3b,c)!

### International acclaim

Bob's talents as a brilliant statistician and communicator, and his meticulous organisational abilities, soon became recognised internationally. Much of the early programming development, and Bob's rekindled enthusiasm for teaching, was facilitated by his involvement (encouraged by Brian Bayne and John Gray) in the UNESCO/Intergovernmental Oceanographic Commission's Group of Experts on the Effects of Pollutants (IOC/GEEP), with meetings in Paris, London, Moscow, Bellagio and Oslo, from 1987 to 1994. This led to Bob co-organising major research workshops in Oslo in 1986 and Bermuda in 1988, under the auspices of IOC, to develop international statistically based assessments on the effectiveness of a range of techniques – from biochemical to community-based – for monitoring the impacts of pollution on organisms in the marine environment. He was then guest co-editor for resulting special journal issues (e.g. the blind trials of the 1986 GEEP

**Fig. 1.** (a) The Community Ecology (later Marine Biodiversity) group at Plymouth Marine Laboratory in the mid-1990s. In the front row, third from left is Bob Clarke (Deputy Leader), fourth from left is Richard Warwick (Leader). In the back row, third from left is Ray Gorley, fourth from left is Paul Somerfield; (b) Bob in June 2003, in the middle of presenting a PRIMER workshop in Lecce, Italy; (c) Bob helping with the field work in Hamilton Harbour during a three-week practical workshop on the biological effects of pollutants which was held in Bermuda in September 1988 under the auspices of the Intergovernmental Oceanographic Commission's Group of Experts on the Effects of Pollutants (GEEP); and (d) Bob Clarke (left), Richard Warwick (middle) and John Field (right), the three authors of Field *et al.* (1982), at Ugborough, Devon, in August 2017.



Oslo practical workshop, *Marine Ecology Progress Series* Vol. 46, 1988).

This work also spawned a series of training workshops, initially around the Eastern Mediterranean, on statistical methods for analysing community data, under the MED POL programme, expertly pressed forward by Gabriel Gabrielides of the United Nations Food and Agriculture Organisation (FAO). The first identifiably PRIMER workshop took place for 20 participants from 10 Mediterranean countries, over the week of Bob's 40th birthday in 1988, in Piran, Yugoslavia, using four IBM/XT microcomputers, one pen plotter (the only graphing facility) and an electricity supply which failed several times a day (not many MDS iterations for even the smallest of data sets were possible)! Following this, from 1989

to 2000, Bob (variously supported by colleagues Martin Carr, Richard Warwick, John Gray and/or Paul Somerfield) presented 15 international training workshops in 13 different countries (Greece, Yugoslavia, Norway, Egypt, China, Thailand, Sweden, Denmark, South Africa, Germany, France, Australia and the UK). The focus of these workshops, right from the beginning, was always to connect meaningfully with individual researchers and empower them to see their multivariate ecological data in a new way, through non-parametric (dis)similarity-based tools Bob had championed and further developed for ecological applications. Bob's teaching approach maintained a heavy emphasis on the conceptual framework and appropriate logic required to handle ecological data, making complex statistical material

**Table 1.** List of the top nine peer-reviewed journal articles authored by K. Robert Clarke that have each attracted more than 500 citations (*source*: Web of Science, accessed 7 June 2021)

No. citations	Journal article
8860	Clarke K. R. (1993) Non-parametric multivariate analyses of changes in community structure. <i>Aust. J. Ecol.</i> <b>18</b> , 117–43
1521	Clarke K. R. & Ainsworth M. (1993) A method of linking multivariate community structure to environmental variables. <i>Mar. Ecol. Prog. Ser.</i> <b>92</b> , 205–19
1381	Field J. G., Clarke K. R. & Warwick R. M. (1982) A practical strategy for analysing multispecies distribution patterns. <i>Mar. Ecol. Prog. Ser.</i> <b>8</b> , 37–52
1341	Clarke K. R. & Green R. H. (1988) Statistical design and analysis for a 'biological effects' study. <i>Mar. Ecol. Prog. Ser.</i> <b>46</b> , 213–26
697	Clarke K. R. & Warwick R. M. (1998) A taxonomic distinctness index and its statistical properties. <i>J. Appl. Ecol.</i> <b>35</b> , 523–31
654	Clarke K. R., Somerfield P. J. & Chapman M. G. (2006) On resemblance measures for ecological studies, including taxonomic dissimilarities and a zero-adjusted Bray–Curtis coefficient for denuded assemblages. <i>J. Exp. Mar. Biol. Ecol.</i> <b>330</b> , 55–80
621	Clarke K. R. & Warwick R. M. (2001) A further biodiversity index applicable to species lists: variation in taxonomic distinctness. <i>Mar. Ecol. Prog. Ser.</i> <b>216</b> , 265–78
609	Clarke K. R., Somerfield P. J. & Gorley R. N. (2008) Testing of null hypotheses in exploratory community analyses: similarity profiles and biota–environment linkage. <i>J. Exp. Mar. Biol. Ecol.</i> <b>366</b> , 56–69
566	Warwick R. M. & Clarke K. R. (1995) New 'biodiversity' measures reveal a decrease in taxonomic distinctness with increasing stress. <i>Mar. Ecol. Prog. Ser.</i> <b>129</b> , 301–5

easily accessible and interpretable to his audience, which was comprised (typically, at least initially) of ecological, biological and environmental scientists.

Bob was well recognised in purely academic circles, both statistical and biological. He was a committee member of the Biometric Society and a Fellow of the Royal Statistical Society, and an invited speaker at many international and national statistical conferences, workshops and meetings, for example International Biometric Society (Belgium 1988), RSS General Applications Section (1990), the Rothamsted 150th anniversary meeting (1993), International Environmetrics Society (Canada 1994), SPRUCE

(Mexico 1995), International Centre for Mathematical Science (Edinburgh 1996), Sydney International Statistical Congress (1996), Spanish Biometric Society (Mallorca 1999), to name but a few. He was also a member of the Affiliated Societies Forum of the Institute of Biology and an invited speaker at a number of workshops/conferences on marine or environmental science, for example 'Environmental toxicology' (SETAC Washington 1996, London 1997), 'Groundfish surveys' (Aberdeen 1997), 'Biodiversity' (Sydney 1998), 'Sampling strategies' (Phuket 1998), 'Coral reefs' (Florida 1998) and the MacMillan Lecture on 'Coastal Biodiversity' (Vancouver Island 2000).

Increasing international interest in Bob's work was enhanced by initiatives from Tony Underwood and Gee Chapman of the University of Sydney, Australia. The (then) *Australian Journal of Ecology* published a special issue (Issue 1, Vol. 18, 1993), guest-edited by Tony, which reported proceedings of the International Workshop on Solutions to Environmental Problems which Tony had organised in 1992 at the Institute of Marine Ecology, University of Sydney. In this special issue, Bob detailed the full extent of his advocated non-parametric methods for multivariate analysis in a landmark paper which was ultimately to become a citation classic (Clarke 1993). A later productive spell as a Visiting Professor at Tony & Gee's laboratory (the Centre for Ecological Impacts of Coastal Cities, University of Sydney) was also the seed for papers on dispersion weighting (Clarke *et al.* 2006a), the zero-adjusted Bray–Curtis measure (Clarke *et al.* 2006b) and similarity profile tests (Clarke *et al.* 2008; Somerfield & Clarke 2013), as well as on statistical problems arising in predator 'choice' experiments designed to examine their 'preferences' for differing prey items or habitat (Underwood & Clarke 2005).

## PRIMER-E

From the mid-1990s, regular PRIMER workshops were taking place in Plymouth and elsewhere, though the DOS-based limitations of the PRIMER version 4 implementation were becoming increasingly evident. Moreover, at the end of the 1990s, PML found itself under some financial pressure and staff redundancies loomed. As one of the top-earning scientists, Bob took the brave step at the age of 52 of falling on his sword and took early retirement. However, he was certainly not ready (yet) to turn his full attention towards his pastime passions of watching cricket, visiting fine art galleries, enjoying operas, organising the Clarke family pre-1960 stamp collection, bird watching, photographing nature, solving fiendish killer sudoku puzzles or unravelling cryptic crosswords

**Fig. 2.** (a) Bob and Cathy Clarke in June 2018 (Bob's 70th birthday); (b) Ray Gorley at the top of the DNA Tower in King's Park and Botanic Garden, Perth, Western Australia; (c) the PRIMER-E group at Plymouth, UK in September 2007: (from left to right) Marti Anderson, Ray Gorley, Marg Moroney, Tina Somerfield, Cathy Clarke, Bob Clarke and Paul Somerfield.



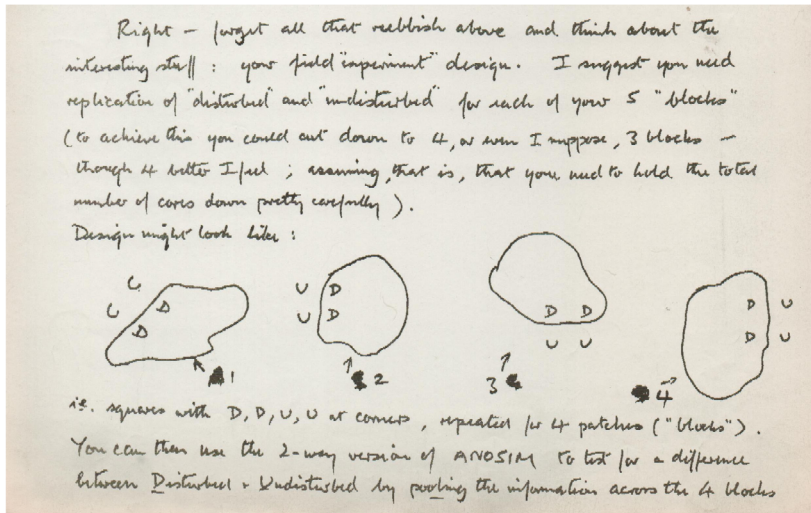
themed after Shakespearean plays (designed by his clever son, Ian). Certainly not!

So, in 2000, Bob, Cathy and an expert and gifted software developer, Ray Gorley (who also left PML, alongside Bob), became the founding co-Directors of a spin-out company from PML called PRIMER-E Limited, UK (Fig. 2a,b). Together, they became an incredibly successful team – with Bob's tireless creativity, entrepreneurship and statistical know-how, Cathy's essential and copacetic communication, organisational and administrative skills (ever-supportive of Bob), and Ray's perfect mathematical genius and splendid programming skills, PRIMER-E went from strength to strength. The company developed new versions of PRIMER software that would operate in a Windows environment: v5 (released in 2001), v6 (in 2006) and v7 (in 2015), each of which greatly increased and enhanced the scope and depth of possible analyses for multivariate data. As the reach of PRIMER grew across the globe, so too did the PRIMER-E business, although it always remained a boutique and personalised enterprise. Ray's partner Marg Moroney (Fig. 2c) joined in to help Cathy with sales and correspondence. Paul Somerfield (of PML, Figs 1a,2c) also began to present PRIMER workshops at a host of international destinations, and Paul's wife Tina (Fig. 2c) took on the burgeoning task of despatching software and manuals.

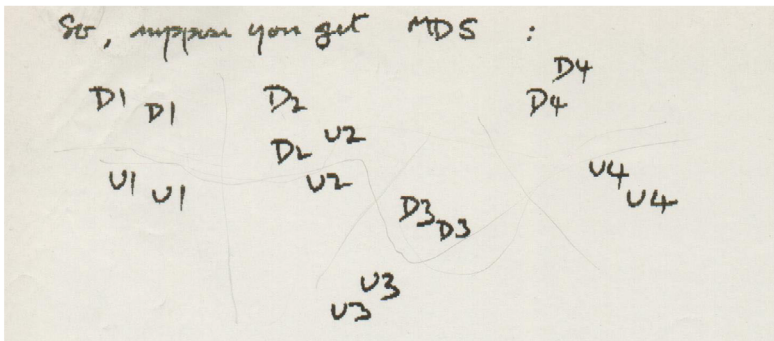
PRIMER software was also subsequently extended through Bob and Ray's collaboration with Marti Anderson (Fig. 2c). In 2008, they together released PERMANOVA+, an add-on package for PRIMER v6 (and, subsequently, v7), which facilitated analyses and inferences for the response of multivariate ecological communities to more complex field studies and experiments (e.g. multi-factorial designs, mixed models, random effects, hierarchical designs etc.), using a dissimilarity-based semi-parametric approach that remained distribution-free (e.g. Anderson 2001, 2017). The idea that PRIMER and PERMANOVA tools could work in tandem was initiated largely through Bob and Marti being invited to present workshops jointly – first at the University of Lecce in 2003 (Fig. 1b; hosted by Antonio Terlizzi and Simonetta Frascchetti), then at the University of Western Australia in 2004 (hosted by Euan Harvey).

With interest in the methods and software expanding apace, Bob accelerated his commitment to teaching workshops globally (and perhaps finally sated his wanderlust?). From 2000 to 2016, Bob presented 107 training workshops in 66 different cities in 27 different countries around the world, showcasing non-parametric multivariate methodology. Importantly, workshops also gave Bob a chance to connect meaningfully with individual researchers. He always met people precisely where they were at, providing

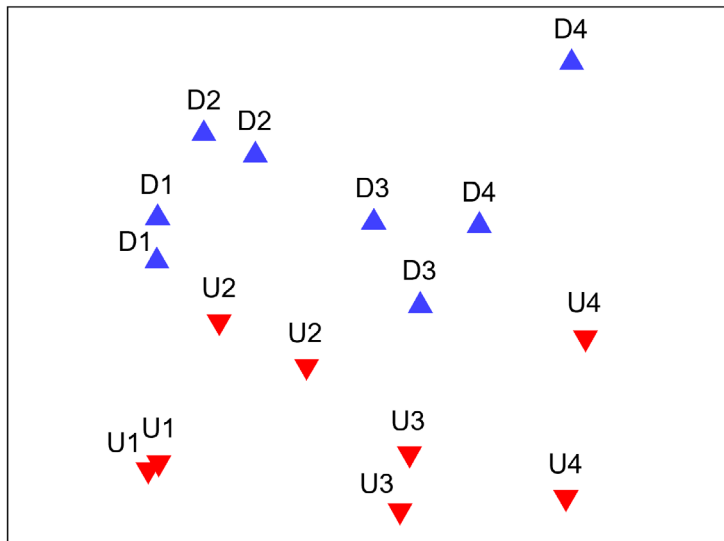
a.



b.



c.



**Fig. 3.** (a) Excerpt from a facsimile sent in 1988 by Bob to Richard Warwick outlining a suitable sampling design to investigate the effects of burrowing by soldier crabs on meiofauna in a sandflat (Eaglehawk Neck) in Tasmania; (b) sketch by Bob, postulating a potential pattern to be expected in the MDS plot of results, in the event that both the (spatial) effects of 'blocks' (1, 2, 3, 4) and the effects of 'disturbance' (U = undisturbed, D = disturbed) were indeed evident; (c) actual non-metric MDS plot (stress = 0.11) of Bray-Curtis resemblances calculated from square-root transformed abundances of 56 species of meiofauna (copepods and nematodes) obtained from 16 cores taken in accordance with the sampling design advocated by Bob (blue = disturbed, red = undisturbed; blocks are numbered 1, 2, 3, 4).

useful and incisive solutions which typically led to unexpected discoveries (plenty of 'aha!' moments) – unveiling new insights that previously had lain hidden

in participants' own high-dimensional data sets. Typically, workshops consisted of 20–35 researchers, and sometimes, they were led in conjunction with Paul

Somerfield, Marti Anderson and Ray Gorley. These would not have been possible without tremendous support from a large number of local organisers, too numerous to list, though it is clear that Bob regards his contacts with such enthusiastic and dedicated researchers and administrators around the world as among the highlights of his professional life. Four major stalwarts must be mentioned (for the sheer number of times they volunteered to host a workshop!), Gerhard Pohle in St Andrews, New Brunswick, Euan Harvey in Perth, Western Australia, Walter Jaap in St Petersburg, FL and Steven Murray in Fullerton, CA. Eventually, PRIMER workshops were also presented in Spanish (by Juan J Cruz-Motta of the University of Puerto Rico and Edlin Guerra Castro of the National Autonomous University of Mexico) and in Portuguese (by Victor Quintino of University of Aveiro). The range of disciplines represented by researchers at workshops, or seeking help by email from Bob, also increased markedly, initially from marine to freshwater, terrestrial, agricultural and forestry contexts and not just from community ecology and environmental science, but also genetics, microbial ecology, ecosystem modelling, geology, palaeontology, archaeology, epidemiology, economics, social science, . . . , even dentistry!

Bob, Cathy and Ray officially retired in August 2016, and PRIMER-E Limited (UK) transferred its business activities to Quest Research Limited (now trading as PRIMER-e) in Auckland, New Zealand, where it continues today, with Marti taking the lead as its new Director. In the years leading up to his retirement, Bob continued to publish new work with his former colleagues from PML and with many other scientists from around the world, including, in particular, Fiona Valesini and other members of Ian Potter's influential group in Biological Sciences at Murdoch University, Western Australia, where Bob held an Adjunct Professorship from 2008 to 2016. Bob remains an Honorary Fellow of PML and also now has plenty of time to devote his limitless energy to a rather long list of hobbies and other interests.

## LEGACY

Bob's contributions have not ended with his 'retirement'. His legacy includes, perhaps most importantly, a host of ambassadors around the world – researchers (many of whom were once workshop participants) who have learned and subsequently passed on their knowledge of Bob's approaches for visualising and analysing multivariate data to their colleagues and students. Generations of researchers continue to make significant scientific advances across an ever-broadening range of fields using the core suite of

non-parametric multivariate methods provided by Bob and his close colleagues.

Bob was listed as an ISI Highly Cited scientist in the category of 'Plant and Animal Science' in February 2004, and this listing was updated in 2011 by Thomson-Reuters also to include the field of 'Ecology and Environment'. According to Web of Science (accessed 7 June 2021), K. Robert Clarke has an *h*-index of 54, having published a total of 122 papers in the primary academic literature that have attracted 24 449 citations in total; 9 of his papers have been cited over 500 times, 34 have been cited over 100 times, and 56 have been cited over 50 times. A full list of Bob's publications is provided in Appendix S1; his most influential papers (i.e. the top 9 most highly cited, accounting for 66% of Bob's total citations) are listed in Table 1.

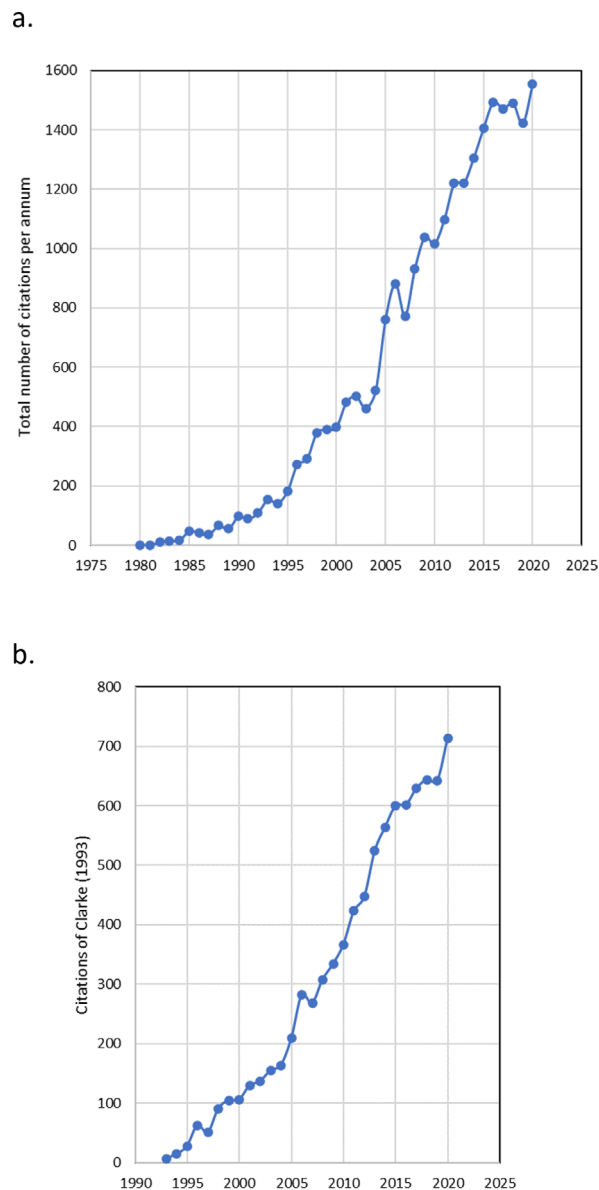
In addition to these clear academic impacts, Bob's (co-authored) manuals for PRIMER software have also attracted a huge number of additional citations. Notably, Google Scholar gives Bob an *h*-index of 73 (being more generous than Web of Science by also including citations from grey literature); it tallies a whopping 75 664 citations for Bob's works in total, with 36 765 of these attributed to citations of the software manuals (Clarke & Gorley 2006; Anderson *et al.* 2008; Clarke *et al.* 2014; Clarke & Gorley 2015). The significance and international reach of Bob's work in the so-called 'grey' literature is not to be underestimated. Such literature here takes the form largely of reports on environmental and ecological research done by government and private consulting agencies, including influential documents that directly inform and advise science-led policy and management decisions across an extraordinary range of applied contexts – from the design and assessment of marine reserves to the effects of off-shore oil drilling.

It would be well-nigh impossible to quantify, let alone adequately to characterise, the full depth and breadth of the impact of Bob's entire body of work on the global research community. We may get an idea, however, by taking a closer look at Bob's most highly cited paper: 'Non-parametric multivariate analyses of changes in community structure' (Clarke 1993). This paper has attracted more citations (both in total, and over the past 3 years) than any other paper that has ever appeared in *Austral Ecology*. According to the Web of Science (accessed 7 June 2021), it has accrued a total of 8781 citations in 1202 journals in 10 different languages by 26 038 different authors working in 104 different research areas (Appendix S2) located in 5139 different research institutions in 153 different countries across the globe! Typically, after a researcher retires, citations of their work also begin to wane. Not so for Bob! In fact, the year 2020 produced the greatest

total number of citations of Bob's work yet (Fig. 4a), and the number of citations of Clarke (1993) alone continues to increase year-on-year, accruing more than 600 additional citations per annum since 2016, the year he retired (Fig. 4b).

Why has this seminal work of Clarke (1993) become a citation classic? It begins with a *pivotal concept* (p. 117):

The pivotal concept has proved to be that of a biologically relevant definition of similarity of two samples, and its utilization mainly in simple rank



**Fig. 4.** (a) Total number of citations per year of the journal articles (up to 122) authored by K. Robert Clarke; and (b) number of citations of Clarke (1993) per year (*source*: Web of Science, accessed 7 June 2021).

form, for example “sample A is more similar to sample B than it is to sample C”.

Indeed, this fundamental concept regarding the utility of (dis)similarity measures, as a means of capturing ecologically relevant information, goes back to some of the earliest work in quantitative field-based community ecology (e.g. Bray & Curtis 1957). A fundamental idea that is very rapidly understood by ecologists and which is directly quantified by ecological measures of resemblance is the extent to which samples *share* or *do not share* species in common. The lack of recognition or appreciation of this fundamental notion is just one of the reasons that classical multivariate statistical methods (such as PCA or MANOVA) and even more sophisticated recent approaches (such as multivariate GLMs to model individual species, with linear latent variables being used to model species' associations) can nevertheless often fail to provide an intuitively useful characterisation of holistic change (or turnover) in communities, particularly in broad-scale biogeographical settings.

The suite of key methods (ANOSIM, MDS, CLUSTER, SIMPER, RELATE, BIO-ENV) advocated and/or developed by Bob drew upon this pivotal concept, the (dis)similarity matrix (among sampling units) acting as a springboard from which a *unified framework* was born, encompassing (p. 117):

- (i) the display of community patterns through clustering and ordination of samples;
- (ii) identification of species principally responsible for determining sample groupings;
- (iii) statistical tests for differences in space and time...; and
- (iv) the linking of community differences to patterns in the physical and chemical environment’.

In Clarke (1993), Bob not only described a unified framework, he also made the underlying statistical concepts both accessible and intuitively appealing from an ecological point of view. This, combined with Bob's tireless energy in expounding the desirable properties and nuances of the techniques in workshops and seminars, along with the key essential provision (through the collaborative genius of Ray Gorley) of user-friendly software in PRIMER (Clarke & Gorley 2006, 2015) has made the framework both practical and available to all. What is more, the immediate translation of the general approach advocated by Bob in this seminal work readily extends its appeal to *other disciplines*, primarily because (p. 117):

Statistical assumptions about the data are ... minimized and the resulting non-parametric techniques will be of very general applicability.



Relying (typically) only on the *ranks* of the (dis) similarities, with *P*-values arising from mathematically pure (and logically intuitive) randomisation arguments for their validity, statistically rigorous inferences in *any* chosen context are effectively ensured. It is thus no wonder that the citations (and, more importantly, the ecological and other scientific insights) continue to grow and flow from this font.

## A SPECIAL ISSUE

We considered it only right and fitting to organise a special issue in the journal *Austral Ecology* to honour Bob, in appreciation of his immense contributions – to this journal, to us personally and professionally and to ecologists everywhere. We are each humbled by having had the opportunity to work with Bob and to witness repeatedly his generosity, through decades of dedicated energy he has invested towards empowering and inspiring a truly international community of ecological researchers.

Most of the contributions to this special issue – entitled ‘Analysing Marine Biodiversity Data’ – focus in some way (to a greater or lesser extent) on statistical methods for ecology, which was Bob’s true and unique forte. Although clearly the breadth of Bob’s contributions (as evidenced above) extends far beyond the marine realm (Fig. 4, Appendix S2), researchers working in marine systems were nevertheless both the earliest and the most direct beneficiaries of Bob’s excellent work. This special issue begins with three articles led by PJS that also include Bob and Ray Gorley as co-authors (Sommerfield *et al.* 2021a,b,c). The first describes a useful generalisation of the ANOSIM statistic to embrace ordered factors. The second and third extend this idea further into two-way and three-way designs, respectively, and also provide key insights to compare and contrast ANOSIM *versus* PERMANOVA approaches for multi-way designs and their associated interpretations. We fully expect that these articles will continue the tradition set by Bob’s other earlier work – of having long legs, broad validity, applicability, accessibility and intuitive appeal. Perhaps these, too, will become citation classics in their own right in the fulness of time.

Next, we have a contribution from Mat Pawley and Brian McArdle on the topic of spatial autocorrelation and its effects (or, rather, in many situations, its *lack* of effects!) on subsequent ecological inferences (Pawley & McArdle 2021). Stanislaw Bevilacqua and colleagues then provide a timely overview of approaches that integrate taxonomic information in multivariate ecological studies; by pointing to present and future methods, this contribution is both retrospective and forward-looking in its scope (Bevilacqua *et al.* 2021). The next two contributions – one led by

Odette Howarth and the other led by Lizzy Myers – deal with precisely the sort of extensions envisaged by the Bevilacqua *et al.* paper. Specifically, they move into the rapidly evolving realm of functional ecology, and they highlight how existing methods (originally designed to incorporate taxonomic/phylogenetic information in multivariate studies) can be adapted and exploited further to gain insights into: (i) broad-scale patterns of functional alpha and beta diversity (Myers *et al.* 2021) and (ii) classifications of species into diet guilds that incorporate relationships among prey (Howarth *et al.* 2021). Finally, Guerra Castro and colleagues provide an exemplary study of highly diverse sessile assemblages that relies on robust non-parametric approaches (including 3-way ANOSIM) to demonstrate connections between observed patterns in assemblage structure at multiple spatial scales and linkages to potential underlying niche *vs* neutral processes (Guerra Castro *et al.* 2021).

All of these contributions underline and acknowledge the importance of Bob’s work, not only as a powerful suite of tools that allow us to achieve novel insights into ecological systems, but also as an exciting platform from which new ideas, techniques and extensions can spring. We anticipate that generations of future researchers, in a similar fashion, will appreciate, celebrate and draw inspiration and new knowledge from Bob’s work, just as we do now.

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## CONFLICT OF INTEREST

MJA is the current director of the research and software development company PRIMER-e.

## AUTHOR CONTRIBUTIONS

**Marti J. Anderson:** Conceptualization (lead); Project administration (lead); Resources (lead); Writing-original draft (lead); Writing-review & editing (lead).  
**Paul J. Somerfield:** Conceptualization (supporting);

Project administration (supporting); Writing-original draft (supporting); Writing-review & editing (supporting). **Richard M. Warwick:** Conceptualization (supporting); Project administration (supporting); Writing-original draft (supporting); Writing-review & editing (supporting).

## DATA AVAILABILITY STATEMENT

Tasmanian meiofauna data are available as an example data set within the PRIMER v7 software package. They are also available by writing directly to the lead author (MJA). Citation data were extracted directly from Clarivate Analytics' Web of Science online on 7 June 2021 and are also available directly from the lead author upon request.

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## SUPPORTING INFORMATION

Additional supporting information may/can be found online in the supporting information tab for this article.

**Appendix S1.** Full list of known published works authored by K. Robert Clarke to date.

**Appendix S2.** List of 104 research areas (according to Web of Science) citing Clarke (1993).