Strategies for Quantitative Research: archaeology by numbers, by Grant S. McCall, Abingdon, Routledge, 2018, xx and 224 pp., Illus. 51, £32.99 (Paperback), ISBN: 978-1-138-63252-3.

McCall's book on quantitative methods in archaeology is the latest addition to the corpus published over the last decade or so including Drennan (*Statistics for Archaeologists: a common sense approach,* 2009), Baxter (*Notes on Quantitative Archaeology and R,* 2015 and *Multivariate Analysis of Archaeometric Data: An Introduction,* 2016), Baxter and Cool (*Basic Statistical Graphics for Archaeology with R: Life Beyond Excel*, 2016) and Carlson (*Quantitative Methods in Archaeology using R,* 2017). It follows a traditional format beginning with data types, graphics and distributions, then looking at univariate, bivariate and finally multivariate methods. Where it departs from that format is in the informal "chatty" style adopted throughout the book (I especially like the tale of whether not to wear a tie when teaching! p. 90), and an attempt to keep mathematical formulae to a minimum. McCall adopts what I have called the "grey-box" approach: you need to know your data, understand what the method is doing, what it needs and how to interpret it but you do not need to understand the ins-and-outs of complex matrix mathematics in order to use these methods. The book is well produced with clear graphics and only a small number of typographic errors and minor slips. It would have been helpful to have provided the data sets used.

The thoughtful introductory and summary chapters are generally excellent and make good discussion pieces. I am particularly in agreement with the comments regarding subjectivity and "fake news" (p. 212). McCall includes descriptions of techniques not normally included in introductory texts including the Kruskal-Wallis analysis of variance, ARIMA time-series analysis, Generalized Linear Modelling, path analysis and partial correlation analysis. These are very welcome. The omission of the F-test for comparing variances is surprising as it is normally seen as a precursor to the *t*-test (Cornillon et al., *R for Statistics* ,2012, pp. 118–24). There are also a few terminological niggles.

The thorny subject of the null-hypothesis significance testing approach (NHST) is introduced in the opening chapter and discussed in context of archaeological theory. The NHST approach is also the subject of controversy within statistics (e.g. Wang, *Sense and Nonsense of Statistical Inference. Controversy, Misuse and Subtlety*, 1993, Chow, *Statistical Significance: Rationale, Validity and Utility*, 1996) and has led to the development of what is called the "New Statistics" with a greater emphasis on confidence intervals rather than a single cut-off level (Cumming and Calin-Jageman, *Introduction to the New Statistics,* 2017). McCall's discussion of the approach is somewhat dispersed and a more consolidated discussion of these issues would be preferable.

McCall's discussion of data types and distributions is generally very good. His concern with the mishandling of count data is extremely useful and the theme recurs throughout the book. To his suggestions for checking for normality, I would add the powerful Q-Q plot. He does not, however, mention the controversial subject of compositional data (i.e. data constrained to a fixed total such as 100%) where conventional statistical methods are often inappropriate.

Chapters 7 and 9 examine various multivariate exploratory data analysis techniques. McCall's discussion of cluster analysis is relatively clear, but I would disagree with some of his assertions. The choice of agglomeration method for hierarchical cluster analysis (HCA) is vital. Single linkage often results in long chains and thus not very useful groups, whereas Ward's method often gives the impression of the existence of small numbers of tight clusters. I have found that average linkage is often the most useful method. For *k*-means clustering, McCall does

not discuss how one might decide on the number of clusters, for example by looking at the within-group sum of squares for a sequence of total numbers of clusters. The vital advantage of *k*-means is that cluster membership does not become fixed at an early stage of the procedure unlike HCA. I find the use of *k*-means for spatial analysis unconvincing and prefer the use of 2D kernel density estimates.

In McCall's description of Linear Discriminant Analysis (LDA) there are a couple of issues. The probabilities of group membership have to be based on some form of validation technique. Resubstitution has been shown to be too optimistic and some form of cross-validation is usually used, preferably the "leave-one-out" method. The data for a LDA need not be normally distributed, although the method does rely on the groups having equal variances (Baxter *Statistics in Archaeology,* 2003, p. 107). The example used by McCall is based on compositional data (see above).

In Chapter 7 McCall discusses Factor Analysis (FA), Principal Components Analysis (PCA) and Correspondence Analysis (CA). McCall argues that FA and PCA are varieties of FA which is an unfortunate retrograde step. Baxter (2003, p. 73) argues convincingly that the terms should be kept separate. Early applications of PCA, sometimes with rotation, were mistakenly called FA and there was considerable confusion between the methods. McCall adds to this confusion when he talks about looking for "latent factors" (a term reserved for FA) in a PCA and does not ever really discuss FA as a separate method. He erroneously states that PCA uses a correlation matrix, whereas the choice of a covariance or a correlation matrix is up to the analyst. The data for a PCA do not need to be normally distributed (Baxter 2003, p. 74). In discussing the interpretation of a PCA, he does not mention the extremely useful h-plot or biplot, or the examination of the fit of data points to the plane created by mapping two components.

McCall asserts that CA is "very conservative" (p. 157), an assertion which I have not seen elsewhere in the literature, nor one that accords with my experience. The graphs derived from a CA should be "maps", i.e., scattergrams where the scale of the x-axis is the same as the y-axis.. Interpretation of the maps should be undertaken in conjunction with the decompositions of inertia, not mentioned by McCall, which give many useful key statistics.

In summary, McCall's book has much to offer someone looking to explore quantitative methods in archaeology, or someone teaching the subject. Chapter 7 is best avoided entirely, for which Baxter (2015) provides a better exposition. The publishers are, however, responsible for the poorest aspect of this volume which wins second prize in the "badly designed cover" category (first prize going to the original 1988 edition of Shennan's *Quantifying Archaeology, 1988*). The word "archaeology" does not appear on the spine at all and on the front cover it is buried in the busy design in a small font.

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