AWIS Conference paper

Maternity, metrics and morale: Addressing the continued attrition of women from science

Elissa Z. Cameron[1]*, Angela M. White[2], Meeghan Gray[3]
[1]School of Biological Sciences, University of Tasmania Private Bag 49, Hobart, Australia
[2]US Department of Agriculture Forest Service, 1731 Research Park, Davis, California, USA
[3]Truckee Meadows Community College, 7000 Dandini Boulevard, Reno, Nevada, USA

Women continue to be under-represented in science careers globally, despite decades of awareness of gender issues in STEM[§] (Shen 2013, Larivière *et al.* 2013). While in some fields, women are under-represented at all career stages, in other fields (particularly biological sciences) an increasing number of women are attracted into undergraduate programmes (O'Brien & Hapgood 2012, Moss-Racusin *et al.* 2012). However, even in fields in which women outnumber men in undergraduate programmes (like ecology, Martin 2012), women are increasingly under-represented with advancing career stage, suggesting either a glass ceiling preventing career advancement (e.g. Dobele *et al.* 2014), or a leaky pipeline effect, whereby more women than men leave science without career advancement (e.g. Pell 1996). These factors suggest a very different experience of the science career environment by men and women.

A variety of factors contribute to the attrition of women from sciences. We recently suggested that the differences in the experience of science between men and women result in key sex differences in publishing behaviour, mediated through these societal influences (Cameron *et al.* 2013, Figure 1). Even before entering science careers and during undergraduate study, societal influences suggest that science is a masculine pursuit (Barres 2006). This is reinforced in textbook examples and role models, almost exclusively male despite contributions of female scientists (Damschen *et al.* 2005). Lack of competence is reinforced by implicit bias, with females judged less competent, and males judged worthy of a higher starting salary with identical qualifications (Moss-Racusin *et al.* 2012). Consequently, women have less confidence in their scientific abilities even before their careers begin. Nonetheless, the representation of women in undergraduate and postgraduate study continues to

*Correspondence: elissa.cameron@utas.edu.au

[§]STEM: Science, Technology, Engineering and Mathematics.

Elissa Cameron works on the ecology, behaviour and conservation of mammals, occasionally including humans! She did her undergraduate and masters degrees at the University of Canterbury, and PhD at Massey University.

Elissa then did postdocs overseas, in Australia and then South Africa. Her first faculty position was at the University of Nevada, Reno, before she returned to South Africa as the Director of the Mammal Research Institute.

Since 2010 she has been Professor of Wildlife Ecology at the University of Tasmania, Australia.

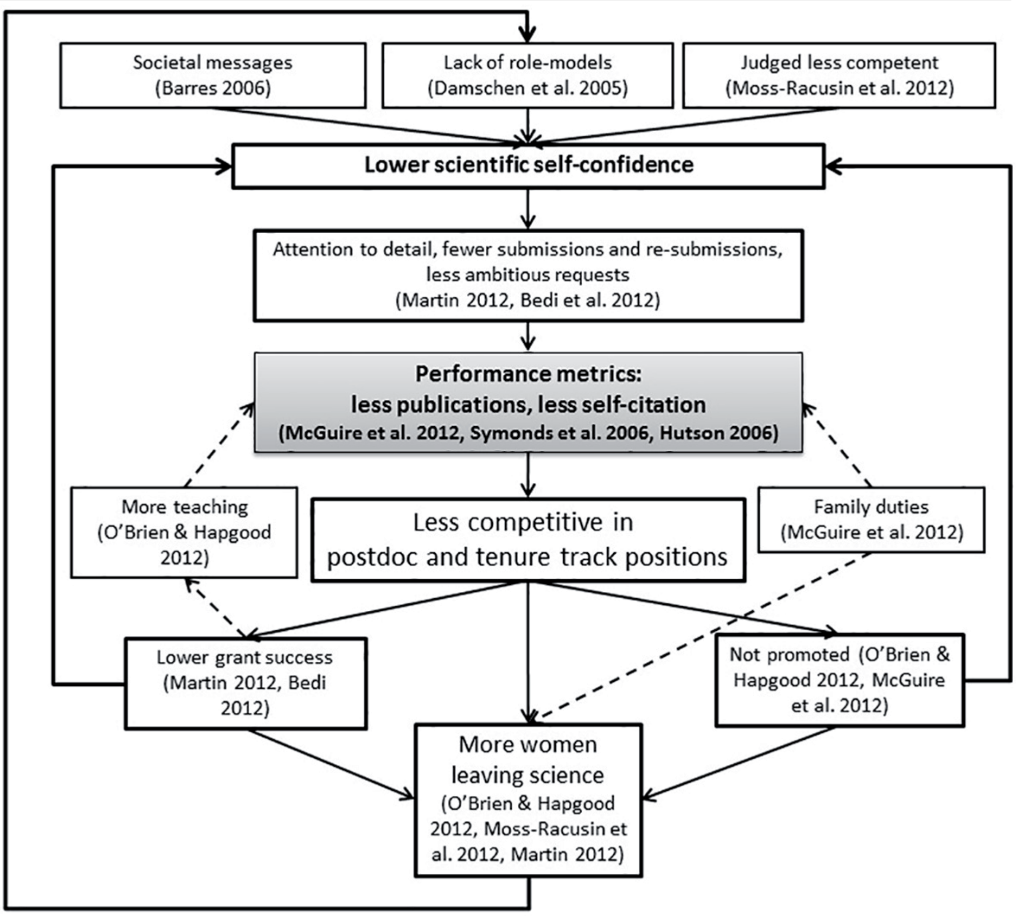
Angela White is a research ecologist with US Department of Agriculture Forest Service, Davis, California. Her interests lie in understanding how temporal and spatial environmental heterogeneity impact species' distribution, abundance and reproductive success. The focus of Angela's work is integrating her research with management-based questions.

Her undergraduate degree was taken at the University of California, San Diego, and her masters degree at San Diego State University. Her PhD in ecology, evolution and conservation biology was taken at the University of Nevada, Reno.

Meeghan Gray is college instructor in the Biology Department of Truckee Meadows Community College, Reno, Nevada.

She received her BS in Animal Science from California State Polytechnic University, Pomona, in 2001 and her PhD in ecology, evolution and conservation biology with respect to feral horse contraception at the University of Nevada, Reno.

Figure 1. Diagrammatic representation of the relationships between the experience of science, low scientific self-confidence, and the attrition of women from science. (Adapted from Cameron *et al.* 2013.)



grow, suggesting that these factors do not prevent women from initially considering science as a career.

During the early post-PhD career, small advantages can disproportionately influence future success ('Matthew Effect', Petersen *et al.* 2011, DiPrete & Eirich 2006). If women already have a lower scientific self-confidence, an increased attention to detail results in fewer journal submissions (Martin 2012) and less ambitious funding requests (Bedi *et al.* 2012). Implicit bias contributes, as women are cited less often (Davenport & Snyder 1995), compounded by women citing their own work less often than do men (Hutson 2006, Cameron *et al.* in review), resulting in lower h-indices for women than men (Cameron *et al.* in review). Thus, for both commonly used performance metrics (publication rate and impact), women score lower than men (Cameron *et al.* in review).

Performance metrics impact all aspects of the later career. Lower scores on performance metrics result in less grant success (Martin 2012), compounded by more moderate requests for funding (Bedi *et al.* 2012). This can lead to higher teaching loads (O'Brien & Hapgood 2012), and lack of promotion (O'Brien & Hapgood 2012, McGuire *et al.* 2012). These sexually dimorphic patterns are compounded if women take time out from their careers for family duties (McGuire *et al.* 2012), which can coincide with the period of intense competition associated with gaining a faculty position (Adamo 2013), all resulting in less time spent active in research. Importantly, women leave science at all stages from early to late career (O'Brien & Hapgood 2012, Moss-Racusin *et al.* 2012, Martin 2012), reinforcing the lack of role-models in science, and beginning the cycle again.

Many of the factors influencing the attrition of women from science are difficult to change quickly. For example, implicit or unconscious bias is difficult to change quickly, especially amongst scientists who consider themselves unbiased. Indeed, perceiving oneself as objective has been shown to be associated with greater gender bias (Uhlmann & Cohen 2005). The bias also increases with the prestige of an organisation (Sheltzer & Smith 2014). Therefore, unbiased performance metrics should increase the representation of women in STEM fields. If, however, metrics are biased against women, these metrics could contribute to the attrition of women from science. Here, we demonstrate the effect of removing self-citations on the evaluation of women faculty members in ecology, a field dominated by women in undergraduate and postgraduate levels, but still under-represented among employed faculty (O'Brien & Hapgood 2012).

We identified ecology-related faculty members in universities in New Zealand, Australia and South Africa from website profiles. We used only those who published their first paper between 1980 and 2007, thereby minimising both historical effects and early career variation, and who were still actively publishing (at least 1 paper in the last 5 years). The resulting sample was 85 women and 105 men. We then used Scopus to document their publication career, recording year of first publication, total publications, H-index (Hirsch 2005) and total citations. We then excluded the citations of the author themselves (i.e. still including co-author citations), resulting in an H-index excluding self-citations, which we called H(ns), and total citations excluding self-citations. These enabled us to calculate the percentage of an author's citations that were by themselves, and the difference this made to their H-index.

There was no significant difference in year of first publication between the males and females ($t_{188}=1.59$, $p=0.11$). Men published significantly more than women across their career (men 60 papers, women 42, $t_{188} = 3.69, p = 0.0003$), confirming other studies (e.g. Symonds *et al.* 2006), although some studies have shown the pattern to be decreasing among early-career researchers (e.g. van Arensbergen *et al.* 2012). Women tended to have more citations per paper (men 19, women 26), as seen in previous studies (e.g. Addessi *et al.* 2012) but the differences were not significant ($t_{188} = 1.55, p = 0.12$). This provides limited support for the suggestion that, in ecological terms, women follow a relatively more K-selected strategy*, investing more in each individual manuscript, while men invest more in productivity, a more r-selected strategy (Cameron *et al.* 2013). Nonetheless, men had higher H-index scores (Figure 2, $t_{188} = 2.4, p = 0.02$). However, there was no difference in the H-index if self-citations were excluded (Figure 2, $t_{188} = 1.54, p = 0.14$), since men self-cited more than women (Figure 3, $t_{188} = 3.11, p = 0.002$), which made a significant difference to their H-index (Figure 3, $t_{188} = 2.75, p = 0.007$). The extent of H-index inflation by self-citation ranged from 0 to 4 in women, but 0 to 9 in men. Almost half the women (49%) had no change to their H-index when self-citations were excluded, compared to 17% of men. Conversely, almost half the men (48%) had an H-index that was higher by 2 or more points when self-citations were included, compared with only 19% of women. Consequently, including self-citations in the H-index (the most common practice), advantaged men more than women, in some cases by significant amounts.

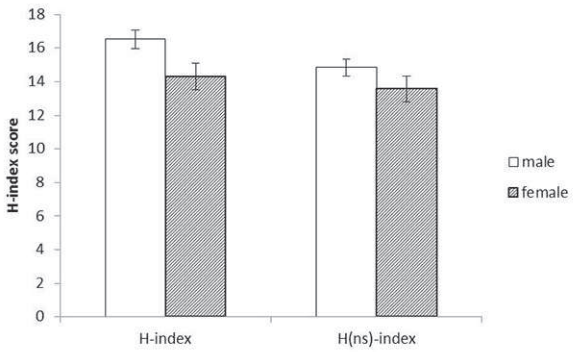


Figure 2. H-indexes for men and women, without and with self-citations included.

The average rate of self-citation was consistent with previous studies (around 10%, Leblond 2012, Wallace *et al.* 2012, Slyder *et al.* 2011), but the variation between sexes calls into question the conclusion that strategic self-citation has only a short-term effect (Engqvist & Frommen 2008, but see Purvis 2006). Some H-indices were dramatically affected by self-citation, and there was a significant gender impact, consistent with other studies (Hutson 2006, Cameron *et al.* in review). Simply excluding self-citations makes the H-index a more equitable measure. Furthermore, self-citation indicates little about the impact of research such that its exclusion should not disadvantage any researchers.

In conclusion, many issues remain to be addressed (e.g. education about implicit bias, Jackson *et al.* 2014; making workplaces more flexible, O'Brien & Hapgood 2012); an important first step to ensure better equality is to ensure that

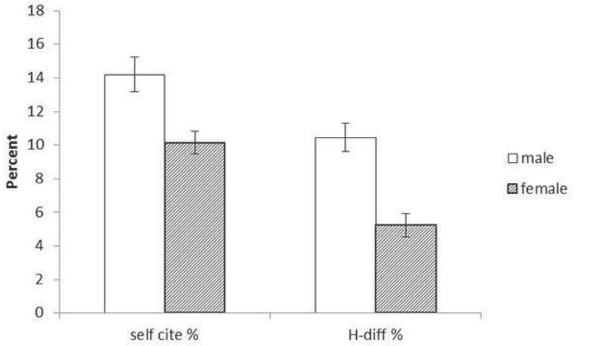


Figure 3. Self-citation rates for men and women and their effect on the H-index.

presumed objective measures of scientific achievement are not biased. Several other authors have advocated for the importance of equitable measures of research performance (e.g. McNutt 2013, Shen 2013, Cameron *et al.* 2013, Symonds *et al.* 2006). The use of equitable measures may be particularly important during the early career, when small advantages can influence the career trajectory (Petersen *et al.* 2011). Here we show that a simple adjustment (excluding the authors own self-citations) would promote gender equity, and be more equitable generally.

* Analogous to the ecological evolutionary 'strategies', K-selection, for those species that produce few 'expensive' offspring and live in stable environments, and r-selection, for those species that produce many 'cheap' offspring and live in unstable environments.

Acknowledgments

We thank the many people that we have discussed these ideas with over the years, who contributed to the development of ideas. Copyright permission for reproducing Figure 1 was given by the publishers of *Trends in Ecology & Evolution.*

References

Adamo, S.A. 2013. Attrition of women in the biological sciences: workload, motherhood, and other explanations revisited. *Bioscience 63*: 43–48.

Addessi, E.; Borgi, M.; Palagi, E. 2012. Is primatology an equal-opportunity discipline? *PLoS One* 7: e30458.

Barres, B.A. 2006. Does gender matter? *Nature 442*: 133–136.

Bedi, G.; Van Dam, N.T.; Munafo, M. 2012. Gender inequality in awarded research grants. *Lancet 380*: 474.

Cameron, E.Z.; Gray, M.E.; White, A.M. 2013. Is publication rate an equal opportunity metric? *Trends in Ecology & Evolution 28*: 7–8.

Ceci, S.J.; Williams, W.M. 2011. Understanding current causes of women's underrepresentation in science. *Proceedings of the National Academy of Sciences 108*: 3157–3162.

Damschen, E.I.; Rosenfeld, K.M.; Wyer, M.; Murphy-Medley, D.; Wentworth, T.R.; Haddad, N.M. 2005. Visibility matters: increasing knowledge of women's contribution to ecology. *Frontiers in Ecology and the Environment 3*: 212–219.

Davenport, E.; Snyder, H. 1995. Who cites women? Whom do women cite? An exploration of gender and scholarly citation in sociology. *Journal of Documentation 51(4)*: 404–410.

DiPrete, T.A.; Eirich, G.M. 2006. Cumulative advantage as a mechanism for inequality: A review of theoretical and empirical developments. *Annual Review of Sociology 32*: 271–297.

Dobele, A.R.; Rundle-Theile, S.; Kopandidis, F. 2014. The cracked glass ceiling: equal work but unequal status. *Higher Education Research and Development 33*: 456–468.

Engqvist, L.; Frommen, J.G. 2008. The h-index and self-citations. *Trends in Ecology & Evolution 23*: 250–252.

Hirsch, J.E. 2005. An index to quantify an individual's scientific output. *Proceedings of the National Academy of Sciences 102*: 16569–16572.

Hutson, S.R. 2006. Self-citation in archaeology: age, gender, prestige, and the self. *Journal of Archaeological Method and Theory 13*: 1–18.

Jackson, S.M.; Hillard, A.L.; Schneider, T.R. 2014. Using implicit bias training to improve attitudes toward women in STEM. *Social Psychology of Education 17*: 419–438.

Larivière, V.; Ni, C.; Gingras, Y.; Cronin, B.; Sugimoto, C.R. 2013. Bibliometrics: Global gender disparities in science. *Nature 504*: 211–213.

Leblond, M. 2012. Author self-citations in the field of ecology. *Scientometrics 91*: 943-953.

Martin, L.J. 2012. Where are the women in ecology? *Frontiers In Ecology and the Environment 10*: 177–178.

McGuire, K.L.; Primack, R.B.; Losos, E.C. 2012. Dramatic improvements and persistent challenges for women ecologists. *Bioscience 62*: 189–196.

McNutt, M. 2013. Leveling the playing field. *Science 341*: 317.

Moss-Racusin, C.A.; Davidio, J.F.; Brescoll, V.L.; Graham, M.J.; Handelsman, J. 2012. Science faculty's subtle gender biases favor male students. *Proceedings of the National Academy of Sciences 109*: 16474–16479.

O'Brien, K.R.; Hapgood, K.P. 2012. The academic jungle: Ecosystem modelling reveals why women are driven out of research. *Oikos 121*: 999–1004.

Pell, A.N. 1996: Fixing the leaky pipeline: Women scientists in academia. *Journal of Animal Science 74*: 2843–2848.

Petersen, A.M.; Jung, W.S.; Yang, J.S.; Stanley, H.E. 2011. Quantitative and empirical demonstration of the Matthew effect in a study of career longevity. *Proceedings of the National Academy of Sciences 108*: 18–23.

Purvis, A. 2006. The h-index: playing the numbers game. *Trends in Ecology & Evolution 21*: 422.

Shen, H. 2013. Mind the gender gap. *Nature 495*: 22–24.

Sheltzer, J.M.; Smith, J.C. 2014. Elite male faculty in the life sciences employ fewer women. *Proceedings of the National Academy of Sciences 111*: 10107–10112.

Slyder, J.B.; Stein, B.R.; Sams, B.S.; Walker, D.M.; Beale, B.J.; Feldhaus, B.J.; Copenheaver, C.A. 2011. Citation pattern and lifespan: a comparison of discipline, institution, and individual. *Scientometrics 89*: 955–966.

Symonds, M.R.E.; Gemmell, N.J.; Braisher, T.L.; Gorringe, K.L.; Elgar, M.A. 2006. Gender differences in publication output: towards an unbiased metric of research performance. *PLoS One* 1: e127.

Uhlmann, E.L.; Cohen, G.L. 2005. Constructed criteria: redefining merit to justify discrimination. *Psychological Review 16*: 474–480.

van Arensbergen, P.; van der Weijden, I.; van den Besselaar, P. 2012. Gender differences in scientific productivity: a persisting phenomenon? *Scientometrics 93*: 857–868.

Wallace, M.L.; Lariviere, V.; Gingras, Y. 2012. A small world of citations? The influence of collaboration networks on citation practices. *PLoS One* 7: e33339.