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

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

* 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.

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 & Harpood 2012); an important first step to ensure better equality is to ensure that

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.

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