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Working groups, gender and publication impact of Canada's ecology and evolution faculty

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SOCIOLOGY

Executive summary

A critical part of science is the extraction of general principles by synthesizing results from many different studies or disciplines. In the fields of ecology and evolution, a popular method to conduct synthesis science is in working groups – that is, research collaborations based around intensive week-long meetings.

We present in this report an analysis of the impact of working group participation and gender on the publication impact of ecology and evolution faculty at Canadian universities who were research active over the last three decades (N=1408). Women are underrepresented in this group relative to the general population and even the Canadian faculty population.

Participation in working groups not only benefits science, but also benefits the researchers involved by accelerating the temporal increase in their H-index. However, this benefit is particularly associated with senior researchers and male researchers. The effect is weaker for female researchers and even negative for researchers just out of their PhD. Gender does not affect current participation rates in working groups, nor reported indirect benefits – such as future collaborations, funding and data resources.

The results of this study suggest that working groups can act as career catalysts for researchers, but that – as in many areas of science – there are challenging issues of equity that require action. Because the H-index is a cumulative measure, gender inequities from before the turn of the millennium may still be distorting the perceived publication impact of today's research-active faculty.

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Authorship. Qian Wei, Francois Lachapelle, Sylvia Fuller, Catherine Corrigall-Brown and Diane S. Srivastava. This is a joint report by the Canadian Institute of Ecology and Evolution and Dept. of Sociology, University of British Columbia. The Canadian Institute of Ecology and Evolution is Canada's national synthesis centre for ecology and evolution, and since 2008 has funded working groups involving >350 researchers.

An extended version of this report, including technical details of the methods and results, can be downloaded from bioRxiv (*Working groups, gender and publication impact of Canada's ecology and evolution faculty,* doi 10.1101/2020.05.12.092247).

1. Purpose of the study

We investigate how synthesis science, especially as undertaken in working groups, affects the academic impact of researchers, and if this is moderated by gender. Our focal population is past and current research faculty in ecology and evolution at Canadian universities.

What is synthesis science? Progress in science depends on our ability to draw out general principles from large amounts of heterogeneous data. While the grist of science is empirical observations and experimental manipulations - that is, primary research - the full strength of individual studies is only realized when they are synthesized, either statistically, mathematically or conceptually. Rapid development of computational tools to analyse large datasets, combined with the increasing availability of data through public repositories, has allowed scientists to harness the power of large-scale analyses of previously published results (Hampton et al. 2013). Such "synthesis science" allows researchers to determine which processes are truly general (by comparing multiple studies) and develop new paradigms (by exploring the interface between disciplines).

What are working groups? Much synthesis science is formally organized and funded through synthesis centers (Baron et al. 2017). These centres primarily fund working groups: a small network of researchers - typically 5 to 15 people - that meet to work intensively on a critical problem that requires the synthesis of large amounts of information, ideas or disciplines.

Why is it important to know the career impacts of synthesis science and working groups? While it is apparent that scientific synthesis and working groups benefit science, the benefits to individual scientists are less clear. If Canada wants to support its researchers in achieving global impacts, we need to know how high impact research approaches affect scholars' publication impact and careers - and whether this differs by gender and career stage. This information can then inform discussions of how the Canadian funding landscape might best support the careers of Canadian researchers to optimize impact and equity.

How might the career impact of synthesis science and working groups depend on gender? Women remain disadvantaged in multiple areas of science, for example in terms of grants (Urquhart-Cronish and Otto 2019, Witteman et al. 2019), citations (Huang et al. 2020) and hiring (Rivera 2017). Working groups and other collaborative networks that are more diverse in gender are more productive (Bear and Woolley 2011, Hampton and Parker 2011). However, this need not mean that there is gender equity in either the roles or recognition of the participants. For example, analyses of authorship contribution statements reveal that women are overrepresented in data collection roles and men in authorship roles (Macaluso et al. 2016). The "Matilda effect" (Rossiter 1993) refers to the systematic discounting of the quality or importance of contribution made by women scientists, as revealed in randomized experiments with scientific abstracts (Knobloch-Westerwick et al. 2013) or job applications (Moss-Racusin et al. 2012). Finally, women may participate less in working groups because of gendered childcare responsibilities – known generally to reduce women's participation in international research collaborations (Uhly et al. 2017). All of the above may result in gender-specific impacts of working groups on careers.

2. Ecology and Evolution Research Faculty in Canada

To understand the ecology and evolution (EE) research faculty population at Canadian universities, we utilize multiple sources of information – an online survey we conducted and a researcher database we built (see Condensed Methods, at end of report), as well as data drawn from Statistics Canada. We defined our study population as all researchers who held at least one NSERC Discovery Grant in the Evolution and Ecology committee between 1991and 2018 (N=1,408). We realize that some researchers, who otherwise consider themselves ecologists and evolutionary biologists, hold Discovery Grants at other committees, and that it is also possible to have a successful research career while never holding a Discovery Grant. Nonetheless, this is a simple and unambiguous criterion for defining the population of study.

Gender inequality still exists in the university faculty population in Canada. Overall, female researchers are underrepresented among university faculty (40.6% of all faculty): Figure 1). Women are even more underrepresented amongst EE faculty, as revealed both in our survey (33.1%) and researcher database (22.8%) (Figure 1). The difference in the proportion of female researchers between the survey and database reflects differences in the population sampled by each method: the survey was only completed by researchers with functional and public email addresses, generally younger (and therefore more likely to be female) researchers.

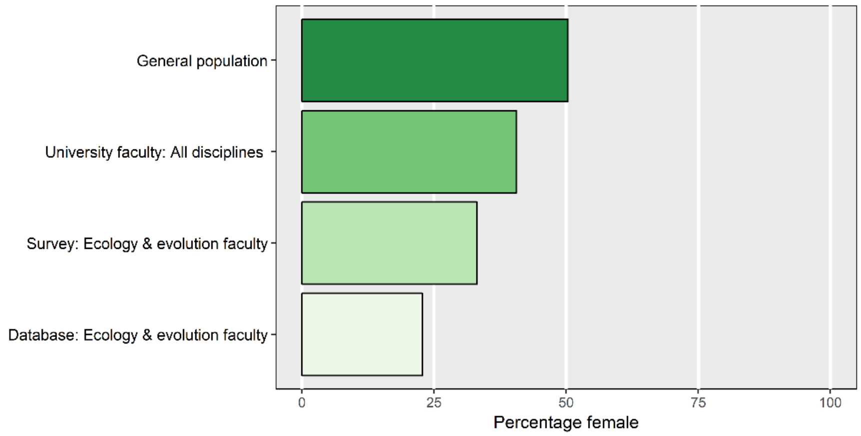

Figure 1. *Female researchers are underrepresented, compared to the general population, among university faculty in general and ecology and evolution faculty. Source for general population and university faculty all disciplines: Statistics Canada. Source for ecology and evolution faculty: Researcher Survey and Researcher Database (see "How we did this study")*

The percentage of female EE faculty varies between academic ranks, declining from Assistant Professor to Associate Professor to Full Professor. This pattern mirrors similar patterns in the general faculty population (Figure 2).

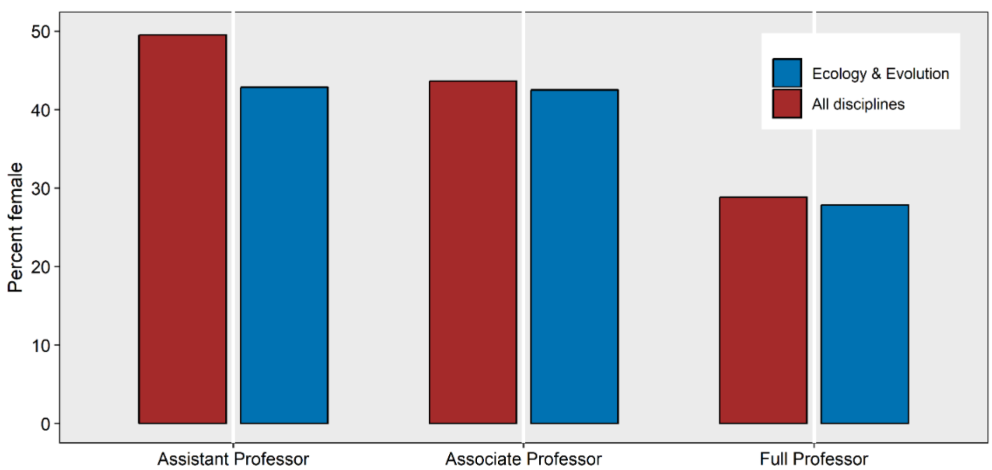

Figure 2. *The percentage of faculty that are female declines from junior to senior academic ranks in both the EE and general faculty population. Source: Researcher database*

Universities have increased the share of women amongst EE faculty hires. This can be visualized by examining cohorts of faculty who received their PhD in the same year: more recent cohorts are increasingly female ($p < 10^{-232}$). For example, 28 researchers received their PhD degree in the year 1997, and13 of them are female, so the percentage of female professors is 46% for the 1997 cohort.

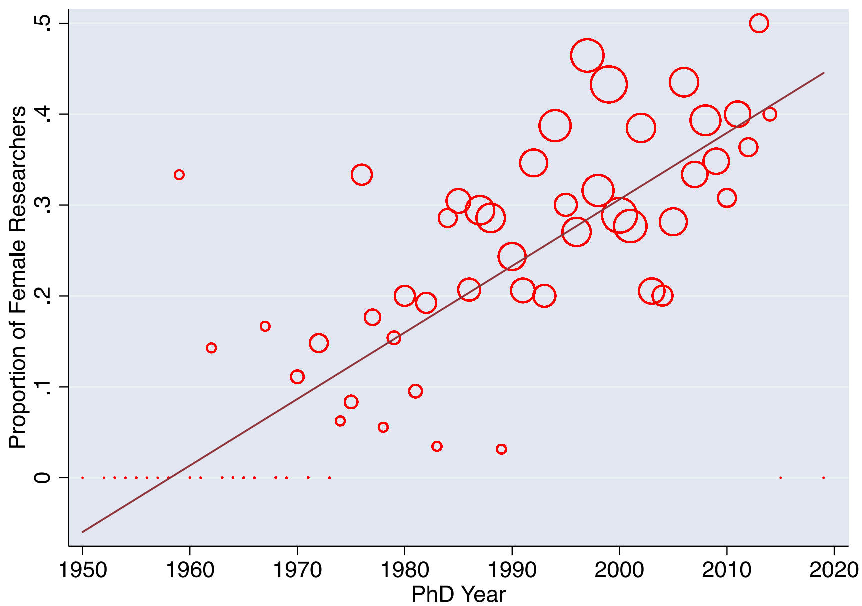

Figure 3. Female representation increases in cohorts of EE faculty (binned by PhD year) who received their PhD more recently. The size of the circle is the number of female faculty in the cohort. Source: Researcher database

In addition to gender, our survey also collected information about ethnicity of EE faculty (Figure 4). Indigenous researchers are dramatically underrepresented both in the overall faculty population and among EE faculty (1.2%). Visible minorities are also markedly underrepresented among ecology and evolution faculty (6.1%), compared not only to the general population but also to other disciplines in Canadian universities. The EE faculty population in Canada remains highly homogeneous in ethnicity.

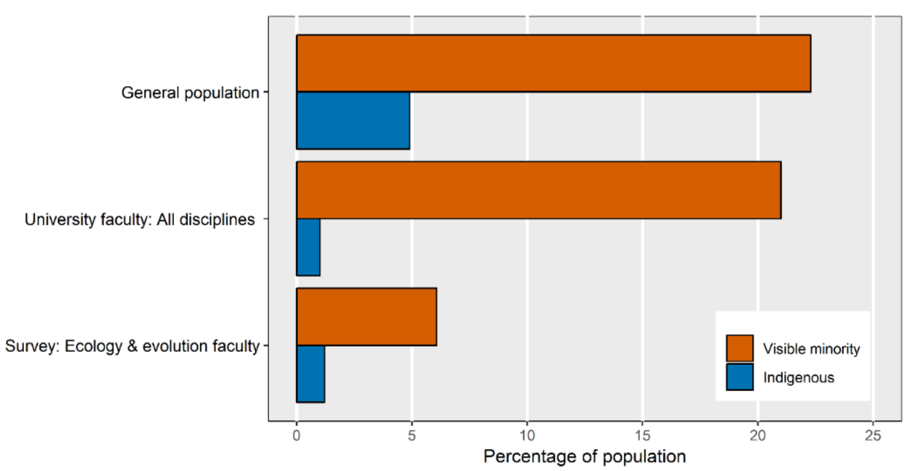

Figure 4. Visible minority and Indigenous researchers, compared to the general population, are underrepresented among EE faculty. Source: Researcher Survey (169 respondents).

3. Participation in Working Groups and Barriers to Inclusivity

The majority of the 169 faculty who took part in our survey had participated in at least one working group (Figure 5): 54% of female researchers, and 64% of male researchers (a non-significant difference: χ^2 = 1.2, p =0.27).

Our survey data provide more specific information regarding whether researchers have declined to participate in working groups and, if so, why (Figure 5). A similar proportion of female (36%) and male (38%) researchers declined at least one invitation to take part in a working group. However, the reasons for declining the invitation vary. Both genders list "work-related duties" as the main reason for declining an invitation, but the second-most common reason for female researchers is "family-related duties" whereas men are at least as likely to give other reasons, such as not being interested in the topic or not liking the working group method.

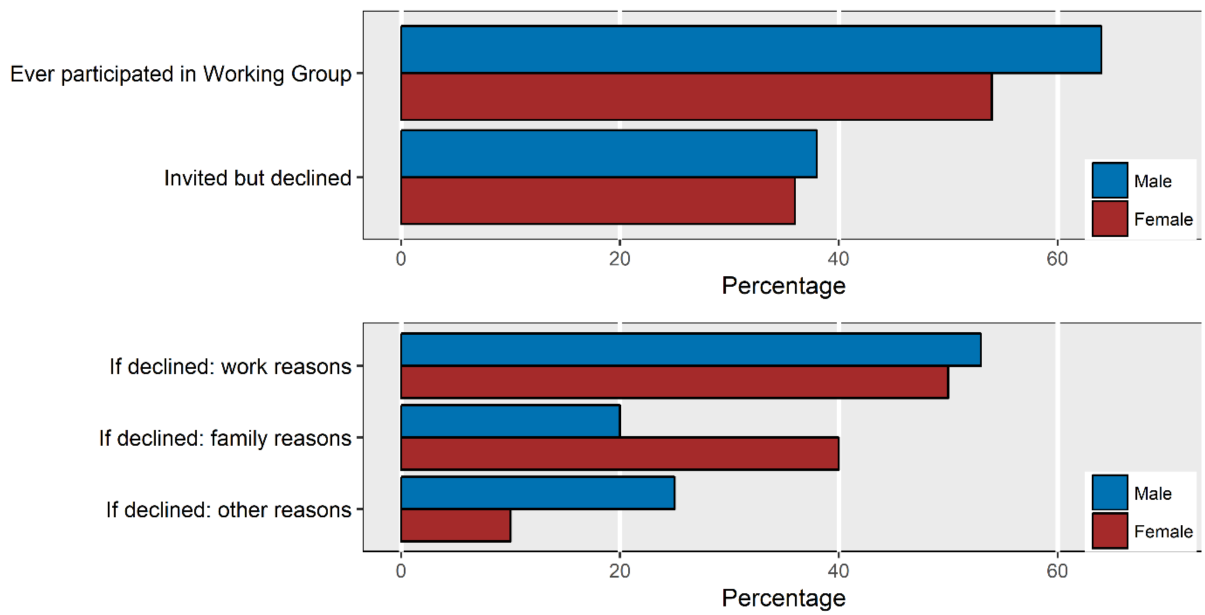

Figure 5. *The percentage of faculty who have ever participated in a working group or have ever declined an invitation to participate are similar between male and female respondents (top panel, N = 169). The reasons for declining a working group invitation show more difference between male and female respondents (bottom panel, N = 63). Source: Researcher Survey*

4. Publication Impact of Working Group Participation

The first synthesis science centre, NCEAS (National Center for Ecological Analysis and Synthesis) was established in 1995 (Hampton and Parker 2011). Since then, working groups have become an innovative and productive research approach used by more and more scientists. Canadian researchers have participated in working groups around the world, including those organised by the Canadian Institute of Ecology and Evolution (founded 2008). Among Canadian researchers, working group publications were evident soon after NCEAS was established in 1995 (Figure 6), although for most researchers such working group publications account for a minority of publications each year (Figure 6). Using a fixed effects model, we find that there is no significant difference between male and female researchers in the proportion of their overall publications originating from working groups (interaction (gender * year): p = 0.47). This result supports our earlier conclusion from the survey that male and female researchers have similar rates of participation in working groups.

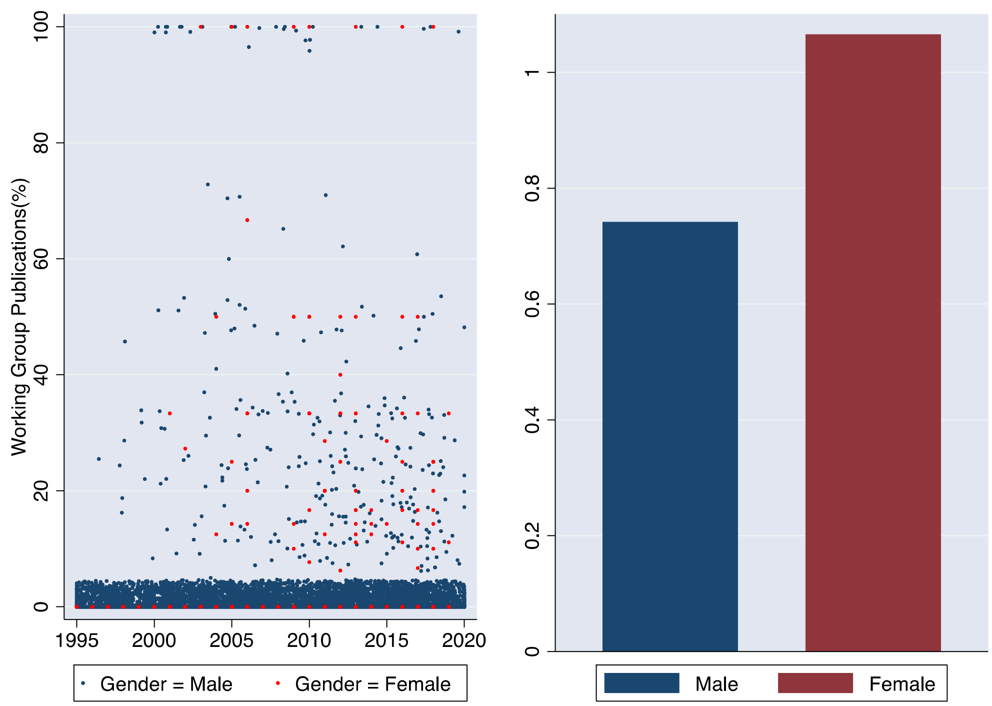

Figure 6. *The percentage of working group publications of total publications in a particular year for both female and male researchers from 1995 to 2019, displayed either for all researchers (left panel) or as mean over both time and individuals within a gender (right panel). Note that the vertical scale on left and right panel differs, although the response variable is identical. Source: Researcher database*

We quantified the publication impact of researchers by their H-index, a metric that is widely used in decision-making for academic hiring, university advancement, research awards and funding decisions. An H-index of *n* simply means that the researcher has published *n* papers that have been cited *n* times. The H-index is a cumulative measure, so can only increase with time, as shown for each of the 1247 faculty in our longitudinal database (Fig. 7). Although these trajectories appear almost linear, this is because overall citation rates have increased in recent decades. If we factor out the effects of calendar year, the H-index trajectories actually increase more slowly over time (i.e. H-index ~ $year^{0.6}$).

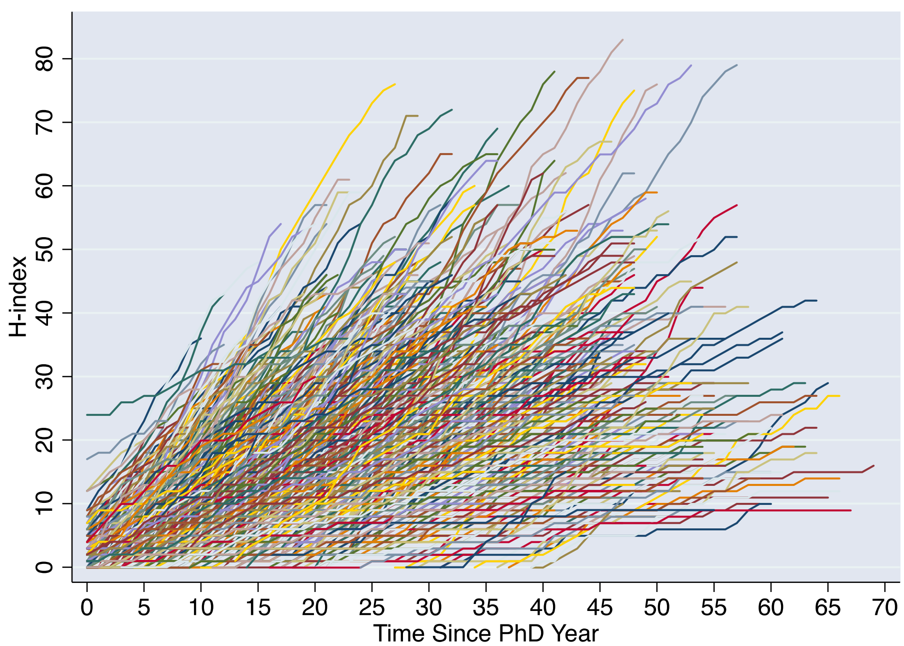

Figure 7. *The H-index of each individual researcher (different coloured lines) increases with years since PhD. Source: Researcher Database*

Our model explores the association of working group participation and gender on the trajectory of H-indices over time. It should be noted that this is a longitudinal analysis, such that each researcher acts as their own control: the model compares the trajectory of their H-index before participating in a working group with that after the working group (although note that many researchers in our database never participated in a working group during our study period). Even so, we caution that it is difficult to unambiguously ascribe causality in observational data.

The first question we addressed was whether participating in working groups has a positive association with researchers' H-indices. Based on our models, the answer is yes, but only later in the career (Figure 8; time: $p = 10^{-26}$; working group experience: $p = 0.00018$; working group x time interaction: $p = 10^{-9}$). For those who are fourteen or more years out from their PhD, a first working group publication is associated with a higher H-index. However, in the first 4-13 years post-PhD, H-indexes increase at a statistically indistinguishable rate before and after participation in a working group, and for researchers who obtained their PhDs within the last 4 years, H-indexes increase faster prior to working-group experience (Figure 8). Since publications typically follow several years after the actual meeting of the working group, such faculty would likely have participated in working groups as graduate students, postdoctoral fellows or recent faculty hires.

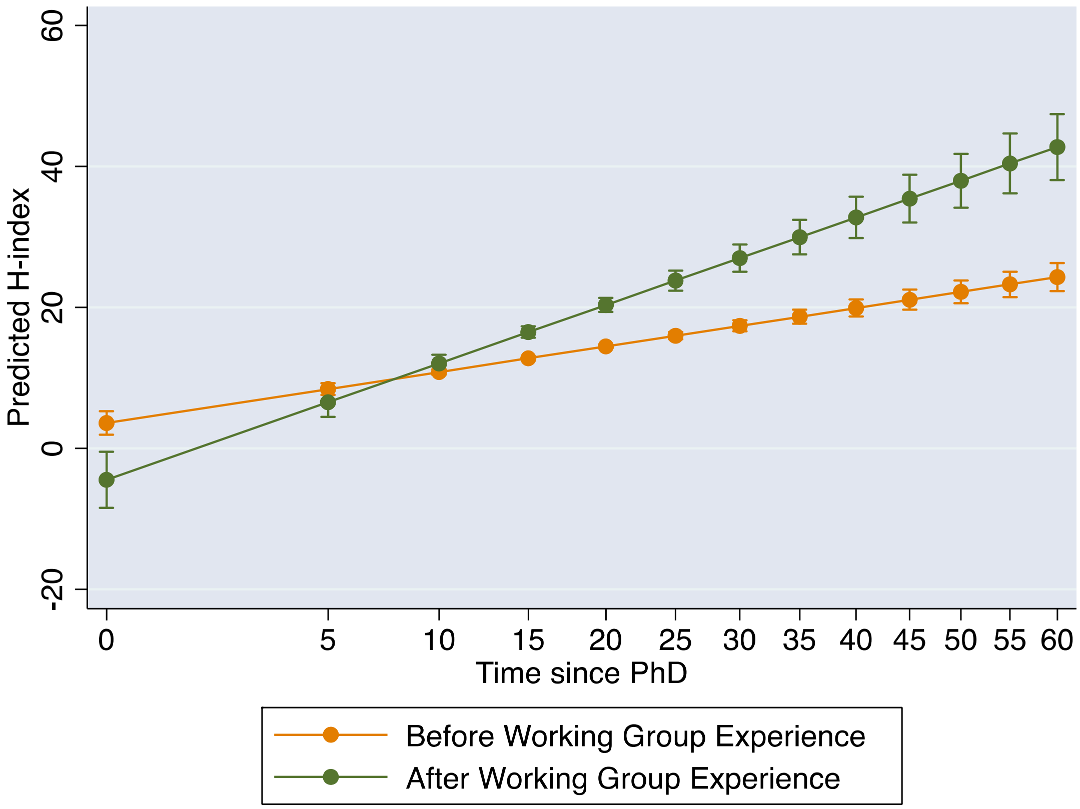

Figure 8. *The predicted effects of working group experience on H-index are influenced by researcher gender and years since PhD. Error bars are 95% confidence intervals on predictions and the horizontal axis has a non-linear (year$^{0.6}$) scale. Source: Researcher Database*

Does this positive effect of working groups differ for male and female researchers? According to our findings, the answer is yes: in terms of advancing their H-index, male researchers benefit more from the experience of working groups than do female researchers. As we can see from Figure 9, male researchers with working group experience are predicted – apart from just after their PhD – to have higher H-indices than the other three categories of researchers, including female researchers with working group experience.

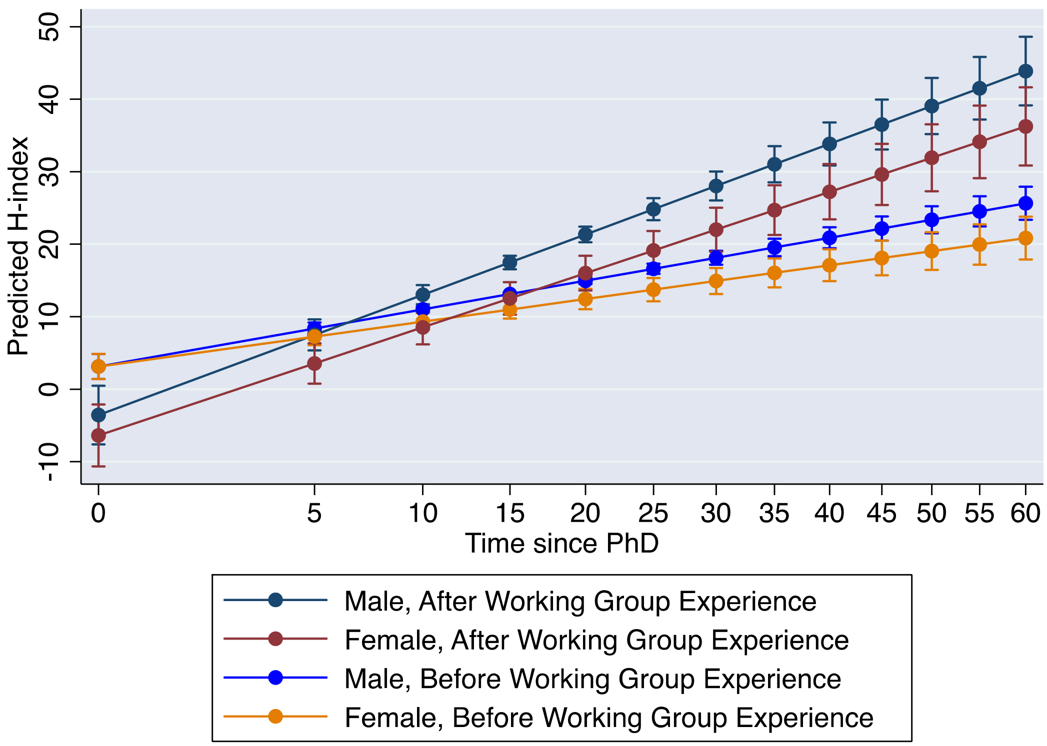

Figure 9. *Predicted effects of working groups and gender on H-index. Error bars are 95% confidence intervals on predictions and the horizontal axis has a non-linear (year$^{0.6}$) scale. Source: Researcher Database*

To facilitate visualizing the gender gap, we can examine the predictions separately for researchers with and without working group experience (right vs. left panels, Figure 10). Regardless of working group experience, the gender gap - the difference between the H-index predictions for male and female researchers in each of these panels – is significant (gender x time: $p = 0.0046$), but this gap widens with working group experience (working group x gender: $p = 0.027$).

It is important to note that this gender gap in working group benefits is associated with cohorts of senior researchers. If we restrict our analysis to researchers who obtained their PhDs after 2000, the gender gap persists but is not exacerbated by working group participation. However, this younger cohort of researchers is still competing for grants against more senior cohorts of researchers. If we consider currently research-active faculty, defined as all faculty who have won a NSERC Discovery grant during the past five years, from 2015 to 2019, the findings remain substantially the same as the full dataset: working group experience is associated with higher H-indices and this difference is gendered. In practical terms, this means that the legacy of gender inequities from before the turn of the millennium may still be distorting the H-indices of today's grant winners.

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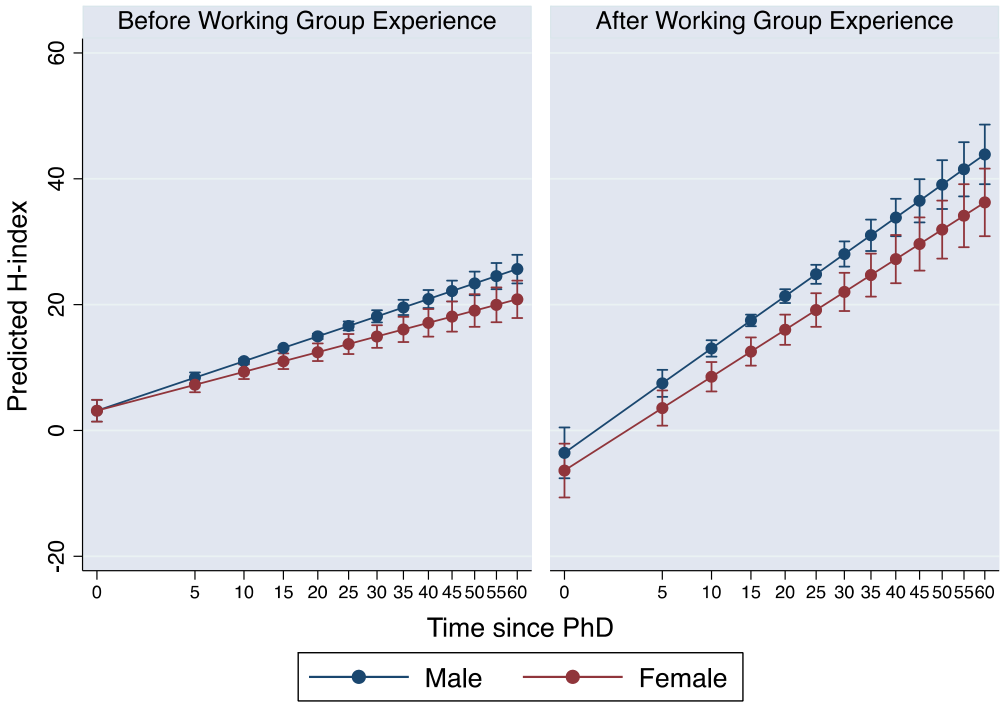

Figure 10. The gender gap in H-index increases with time regardless of working group experience, but is narrower for researchers without working group experience (left panel) than those without (right panel). Error bars are 95% confidence intervals on predictions and the horizontal axis has a non-linear (year$^{0.6}$) scale. Source: Researcher Database

5. Potential mechanisms

Working groups may accelerate the H-indices of researchers in two different ways. First, if working group publications are more often cited than non-working group publications, participation in a working group could directly increase the number of highly-cited publications, the basis of the H-index. This could occur both because of the type of publication created by working groups - synthetic publications are cited more than primary research (Miranda and Garcia-Carpintero 2018) - and because of the collaborative nature of working groups - publications from collaborations are cited more (Leimu and Koricheva 2005, Larivière et al. 2015). Second, working groups could provide future benefits to researchers, such as the development of collaborations after the working group, enhanced access to future funding opportunities, or re-use of databases developed by the working group in another project. For example, previous analyses of a U.S. synthesis centre found that its participants were more collaborative after participating in a working group (Hampton and Parker 2011). We found evidence for each of these effects in our study.

Working groups produce, overwhelmingly (>98%), synthesis science publications. Synthesis science publications, by themselves, are more cited than primary research publications (Figure 11; $\chi 2 = 33.7$, $p = 10^{-9}$). Synthesis science publications can be divided into three types: mathematical (e.g. theoretical or simulation models), conceptual (e.g. literature reviews, framework papers) and statistical (e.g meta-analyses, species distribution models). All three types are cited more than primary research, but this is especially true of statistical syntheses (Figure 11; research type: $\chi^2 = 177.5$, $p = 10^{-16}$). Independent of the type of synthesis research, publications from working groups are cited more than publications based on other, more traditional, methods (Figure 11; working groups: $\chi^2 = 65.8$, $p = 10^{-16}$; working group x research type interaction, $\chi^2 = 2.7$, $p = 0.44$).

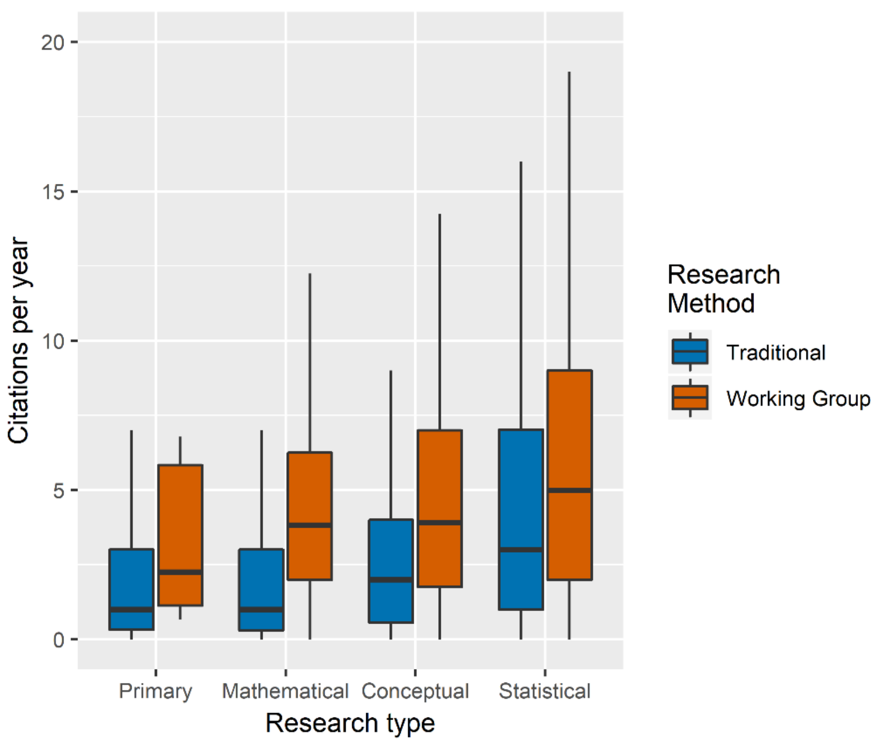

Figure 11. *Publications vary in the average number of citations per year according to research type (primary research or synthesis research, with the latter comprising mathematical synthesis, conceptual synthesis and statistical synthesis) and research method (working group, or non-working group, her denoted "traditional"). Source: Publication database*

Working groups also provide future benefits. In our survey, we asked the 102 researchers who had participated in a working group about indirect benefits of their most recent working group (Figure 12). The majority of respondents reported that they developed new collaborations in their working group which carried forward into new projects. Roughly a quarter of respondents reported that their participation in a working group led to new funding opportunities or the ability to reuse a database developed in a working group for a new purpose. Importantly, there was no gender difference in these proportions, suggesting that male and female researchers have similar future benefits, at least for their most recent working groups.

We plan further analyses of our dataset to partition the working group effect on H-indices into the direct effect of publications and the indirect future benefits.

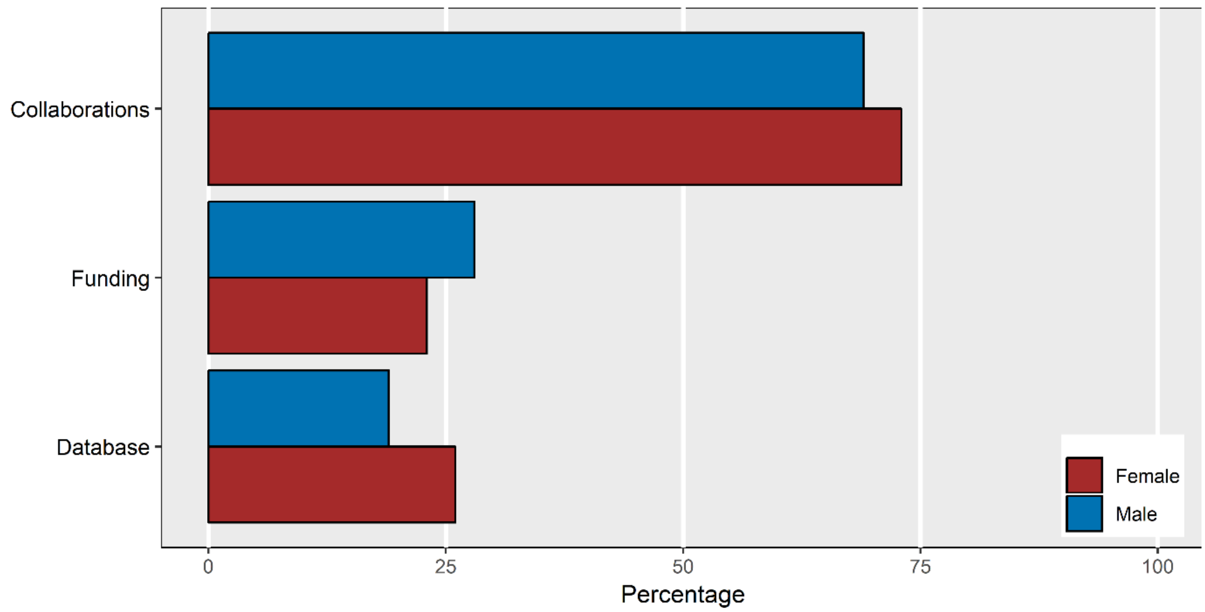

Figure 13. *Percentage of researchers (N = 102) who received future benefits from their most recent working group in terms of subsequent collaboration with working group participants in other contexts ("collaborations"), funding opportunities ("funding"), and reuse of a database constructed within the working group for other projects ("database"). Source: Researcher database.*

Our analysis also discovered that academic age and gender moderated the effects of working group experience on H-indices. There are several potential mechanisms here.

First, this may represent real differences between working group participants in the costs born and the benefits reaped. The publications produced by working groups are the result of many different activities, such as: collating of large amounts of published data into databases, qualitative summaries of the literature, advanced statistical analyses or mathematical modelling, creation of figures, and writing and editing of manuscripts. These activities may not be shared equitably. When graduate students and postdoctoral fellows are relied upon to do the more time-consuming and routine tasks (often collating data and surveying literature), they may have less time to invest in primary research. Previous studies suggest that scientific labour in research collaborations is gendered, with women more likely to collect data and men more likely to make conceptual, material, statistical and editorial contributions (Macaluso et al. 2016). The benefits may not also be shared equally. Because publications tend to increase the reputation of first authors or last authors more than other co-authors, if such authorship positions are disproportionately claimed by older and/or male researchers (West et al. 2013) then less benefit from publications will accrue to other researchers.

Second, there is a historical dimension to patterns in researchers' H-indices. The H-index is a cumulative measure of publication impact, and so it preserves - over the entire career of a researcher - any historical inequities in the distribution of publications or citations in the researcher community. Since the citation rate of papers increases with time since publication, the H-index may in fact magnify such historic patterns. Further analyses of our dataset will enable us to more fully characterize how the impact of academic age, gender and working group participation may have changed through time.

Many synthesis centers have enacted policies to ensure that the participant composition is gender-balanced and represents a range of academic career stages and backgrounds. Such policies probably explain why male and female researchers in our survey reported similar rates of participation in working groups. The challenge is to now go beyond these current policies to ensure that the career benefits of participating in working groups are equitably shared amongst participants.

6. How we did this study

We have constructed three databases to explore the impact of working groups on career advancement and gender equality in the EE faculty community in Canada: a Researcher Database, a Publication Database, and a Researcher Survey. The study population includes all Canadian university faculty who received an NSERC Discovery grant through the Evolution and Ecology evaluation committee from 1991 to 2019 (N=1,409). **Full details of methods can be found in our preprint: *Working groups, gender and publication impact of Canada's ecology and evolution faculty,* (**bioRxiv doi 10.1101/2020.05.12.092247).

Researcher Database: For these researchers, we manually collected information in May-July 2019 from publicly available sources on gender, year of PhD, name format on publications, and current and previous institutions. For our longitudinal analysis of H-indices we restricted our analysis to researchers for whom we could locate information on their PhD year (N= 1247). Once we had constructed the Publication Database, described next, we could also reconstruct the H-index of the researcher through time as well as the annual number of working group publications through time.

Publication database: For each researcher, we downloaded all publications from Web of Science with the same last name and first initial. We then filtered these publications using publication titles from online cvs (only available for 5% of researchers), and the researcher's known name format on publications and known institutional affiliations (both from Researcher Database). Because an author may list multiple institutions on a single publication, this process revealed other institutional affiliations that we had not discovered in constructing the Researcher database, and which we could then add to our filtering routine. For each publication, we used a combination of methods to establish if it originated from a working group: we matched titles with publication lists provided by nine synthesis centres around the world, we searched funding and acknowledgement fields for names and acronyms of 15 synthesis centres including those that comprise the International Synthesis Consortium as well as for phrases often used to describe working groups ("working group", "synthesis group", "synthesis working group", "synthesis committee", "synthesis workshop", "catalysis group"). The last approach allows us to capture publications from working groups that were not funded through formal synthesis centres. All 323 working group publications were manually validated, and categorized as one of: statistical synthesis (involving the statistical analysis of previously published or archived data collected by multiple different researchers and/or studies), conceptual synthesis (qualitative review of the literature or proposal of new frameworks for scientific concepts or investigation), or mathematical synthesis (theoretical mathematical models or specific application of general models for the purpose of prediction). We used keywords approach to categorize a subset (N = 2133) of non-working group publications into similar types of synthesis research or primary research. Once we had established the publication record for each researcher, we then generated the retrospective h-index using the open-source Python package "hindex". We also tabulated, for each researcher, the number of working group publications for each year and a dummy variable that represented working group experience (0 before first working group publication, 1 for the year of first working group publication and thereafter).

Researcher Survey. We recruited participants for our survey from the 1151 researchers in the Researcher Database with valid email addresses. Email invitations were sent to all 1,151 scholars containing a link to an online questionnaire with a consent cover letter in July-September 2019. Eventually, 169 usable responses were received, amounting to a response rate of 14.7%. In addition to questions such as academic progression and ethnicity, our survey data also provide nuanced information including whether researchers have declined working groups and why, number of children and parental leave

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