Title: The Role of Diversity in Science: A Case Study of Women Advancing Female Bird Song Research

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Researchers of different genders and backgrounds contribute greatly to the diversity of questions and approaches in science. Historically bird song was studied primarily as a male trait. However, as researchers in the field of animal behaviour have become more diverse, women have made substantial contributions to the bird song literature including through the study of female song. We investigated the influence of gender on research topic and asked: are research articles on female bird song disproportionately authored by women? We surveyed published "female song" papers within the last twenty years, recording counts of author gender and author position (first, middle, last). We compared these data to a control group of "bird song" papers that were matched by journal and publication date. We found strong associations between research topic and author gender. First authors of female song papers are significantly more likely to be women: women now make up 68% of first authors on female song papers whereas women are only 44% of the first authors on bird song papers. Our case study suggests that women are making a greater contribution to the emerging field of female bird song. This discrepancy demonstrates the importance of diversity in addressing previously understudied areas of science. Increasing diversity in science can lead to new approaches for studying behaviour, ecology, and conservation.

Keywords:

23 Women in STEM; gender diversity; female bird song; research bias; authorship

Research topic bias exists within many areas of scientific research. For example, differences between female and male animals have often been ignored or understudied (e.g., McCarthy et al., 2012). This bias is clearly demonstrated in studies of elaborate colouration and vocal communication. For example, the evolution of male secondary sexual characteristics such as elaborate male plumage and song have been the focus of major research programs since Darwin (e.g., Andersson, 1994). However, female ornamentation and female song have been widely ignored until recently (Langmore, 1998; Amundsen, 2000; Odom et al., 2014). The underrepresentation of female song in the early literature does not accurately reflect the prevalence of this trait in nature: recent studies indicate that approximately two thirds of songbird species have female song (Garamszegi et al., 2006; Odom et al., 2014; Webb et al., 2016).

Scientific researchers from diverse backgrounds can bring different perspectives, providing a range of new approaches, ideas, methods, and outcomes (e.g., (Østergaard et al., 2011; Díaz-García, 2013; Martin, 2014; Galinsky et al., 2015; Nielsen et al., 2017; Page, 2019). Researchers who are women may pose unique questions or propose research methodologies different from researchers who are men (Day, 2002). Therefore, it is important that the pool of researchers across science and within animal behaviour better reflect multiple axes of the diversity in society.

Although the number of women in STEM has risen over the past several decades, underrepresentation still exists. For example, only 19% of STEM full professors in the U.S. are women (Pederson & Minnotte, 2018). However, within STEM, different concentrations of study are more equal based on gender. For example, in 2016, women made up about half (48%) of biological, agricultural, and environmental science occupations (National Science Board, 2016).

In other STEM fields, women compose the majority of practitioners; within medicine, women residents hold the majority of positions in the areas of family medicine (58%), psychiatry (57%), paediatrics (75%), and obstetrics/gynaecology (85%) (Vassar, 2015). 8% of all women in residency programs are part of the obstetrics and gynaecology specialty compared to 1.5% of all men (Jolliff et al., 2012).

We suspected that the study of female bird song has been conducted disproportionately by women scientists due to our impression that many key female bird song papers have been written by women. For example, "Functions of duet and solo songs of female songbirds" is one of the most highly cited papers addressing female song and has been cited over 300 times according to Google Scholar (Langmore, 1998). Additionally, in a recent collaborative paper, "Female song is widespread and ancestral in songbirds", four out of five authors are women; this paper has already been cited over 150 times (Odom et al., 2014).

We hypothesized that gender has an influence on research topic, specifically, women may be more likely to study areas of animal behaviour that involve female behaviour. We investigated the gender of authors of female song papers and comparable bird song papers within the last twenty years in order to ask if female song is more likely to be studied by women or men. We used a binary gender framework for this case study, however we recognize that applying this framework is potentially problematic due to the non-binary nature of gender. We advocate future studies of a similar nature improve upon the methods presented here, taking note of the suggestions that we present in the methods and discussion.

METHODS

We collected all bird song papers from any journal published between 1997 and 2016 that contained the search terms “female song” or “female singing” within the title or abstract using Google Scholar and Web of Science. We encountered several papers in neurobiology and physiology journals that involved manipulating the brains of birds in order to study the effects on song. These papers often aimed at understanding song control systems rather than signal evolution, and were not focused on naturally occurring female song, thus they were not included for this study. We recorded author(s) names and their authorship position (first, middle, last), paper title, journal, website link, type of bird studied, and year published. We recorded names and scored author gender only after recording the other information to limit bias. We created two datasets: 1) a full dataset in which we identified author gender based on name and if necessary, as a last resort, their picture, 2) a verified subset in which we identified author gender based on knowing them personally (e.g., how authors present in person, personal conversations, etc.) or using primary or secondary online sources in which personal pronouns were used (e.g., articles in online newspapers, magazines, science websites, university news sites). Additionally, we calculated correlation values between the full dataset and the smaller verified subset to determine how much of the author gender information matched (R Core Team. 2014, package ‘Hmisc’ (Harrel, 2019)).

We used the verified dataset to assess the accuracy of the full dataset by corroborating if the way we gendered an author in the full dataset matched the way that author presents in person, thereby giving our best assessment of which researchers are women and men. None of the researchers in the verified dataset self-identified as non-binary to the best of our knowledge. Importantly, nowhere do we publicly associate our gender scoring with individual author names.

Our appendix lists all the papers that we used, and we present our total numbers, but we do not indicate the gender associated with any individual authors in our datasets.

We used a paired method to select our control group. For each female song paper, we used the advanced search on Google Scholar and Web of Science to find a "bird song" (i.e., not female song) paper within the same journal that had the closest publication date to the given female song paper. Bird song papers included papers about male song or bird song in general. All matches were found within five years of the female song paper, most within the same year. For these bird song papers, we recorded the same information as for female song papers. In some cases, two or more female song papers matched to the same bird song paper because they were published in the same journal around the same date. If more than one female song paper had the same bird song paper match, we assigned the next chronological bird song paper to whichever female song paper was closer to that date.

Multiple female song papers were published in a special edition of Frontiers in Ecology and Evolution: Behavioral and Evolutionary Ecology between 2015 and 2016. Only four bird song papers were available as matched control points. To ensure unique pairings, we matched the remaining papers by closest date to bird song papers from one of six similar journals: 1) Behavioral Ecology, 2) Animal Behaviour, 3) Behavioral Ecology and Sociobiology, 4) Ethology, 5) Ethology, Ecology and Evolution, or 6) Behaviour. We used a random number generator to choose from which of these six journals a matched paper was chosen.

A total of four female song papers from either Southeastern Naturalist or Journal of Caribbean Ornithology had no potential bird song match published. To create appropriate match controls, we selected the bird song paper closest in publication date to our selected female song paper from a journal of similar audience and impact factor. For Southeastern Naturalist we chose

114 the closest date matched paper from the following journals: 1) The American Naturalist, 2)
115 Northeastern Naturalist, or 3) Southwestern Naturalist. For Journal of Caribbean Ornithology we
116 used: 1) Neotropical Journal of Ornithology, 2) Wilson Journal of Ornithology, or 3) Journal of
117 Field Ornithology.

118 We totalled the counts for female song and bird song papers and used Pearson Chi-
119 Square analyses (vassarstats.net) to test for an association between research topic and author
120 gender in each data set. In addition to this analysis, we also performed the same analysis on
121 female song papers in an earlier twenty-year time span, from 1977-1996, to evaluate consistency
122 of this pattern over time (Appended Methods and Results).

123

124 **RESULTS**

125 Within the more recent twenty-year time span (1997-2016), we found fifty-nine female
126 song papers authored by 166 total authors (Table 1). We were able to corroborate the gender for
127 a large subset of these authors: 80% (133/166) of female song authors and 52% (90/172) of bird
128 song authors whose papers were published (average 66% of authors). In the verified dataset,
129 women authored significantly more female song papers than men. Women made up 56% (75/133
130 authors) of total authors of female song papers, and 40% (36/90 authors) of total authors of
131 general bird song papers ($p = 0.0163$; Table 2). Women held the majority of first author and
132 middle author positions on female song papers (68% and 58%, respectively), but did not for
133 general bird song papers (47% and 42%, respectively) (Table 2).

134 The correlation value between the full dataset and the verified subset is $r = 0.99$; 222/223
135 authors' gender matched between analyses. The verified subset and full dataset show the same
136 percentages for the first author category (e.g., 68% women for both datasets), and all categories

significant in the full dataset were also significant or very close to significant in the verified subset (first authors: full data p = 0.0094, verified p = 0.0509; total authors: full data p = 0.0016, verified p = 0.0163) (see Table 1, Table 2). The verified data support the overall accuracy of the full dataset.

Author Position	FS/Women	FS/Men	BS/Women	BS/Men	P-Value
First Author	40(68%)	19(32%)	26(44%)	33(56%)	0.0094*
Last Author	19(42%)	26(58%)	13(27%)	36(73%)	0.1089
Middle Authors	31(50%)	31(50%)	25(39%)	39(61%)	0.2161
Total Authors	90(54%)	76(46%)	64(37%)	108(63%)	0.0016*

Table 1. Full Dataset: The number of authors based on gender, author position, and paper type from 1997-2016. FS represents female song papers and BS represents bird song papers. P-values reflect significance by author position. Numbers in parenthesis show the percentage of authors of a gender based on paper type. Asterisks denote statistical significance (* p <0.01).

Author Position	FS/Women	FS/Men	BS/Women	BS/Men	P-Value
First Author	38(68%)	18(32%)	16(47%)	18(53%)	0.0509
Last Author	14(38%)	23(62%)	10(31%)	22(69%)	0.5656
Middle Authors	23(58%)	17(42%)	10(42%)	14(58%)	0.2191
Total Authors	75(56%)	58(44%)	36(40%)	54(60%)	0.0163*

Table 2. Verified Dataset: The number of authors based on gender, author position, and paper type from 1997-2016. FS represents female song papers and BS represents bird song papers. P-values reflect significance by author position. Numbers in parenthesis show the percentage of authors of a gender based on paper type. Asterisks denote statistical significance (* p <0.05).

With respect to the full dataset, women comprised 68% (40/59 authors) of first authors on female song papers. In contrast women comprised only 44% of first authors in the general bird song category ($p = 0.0094$; Table 1 & Fig. 1). Women first-authored significantly more female song papers than men (Table 1 & Fig. 2).

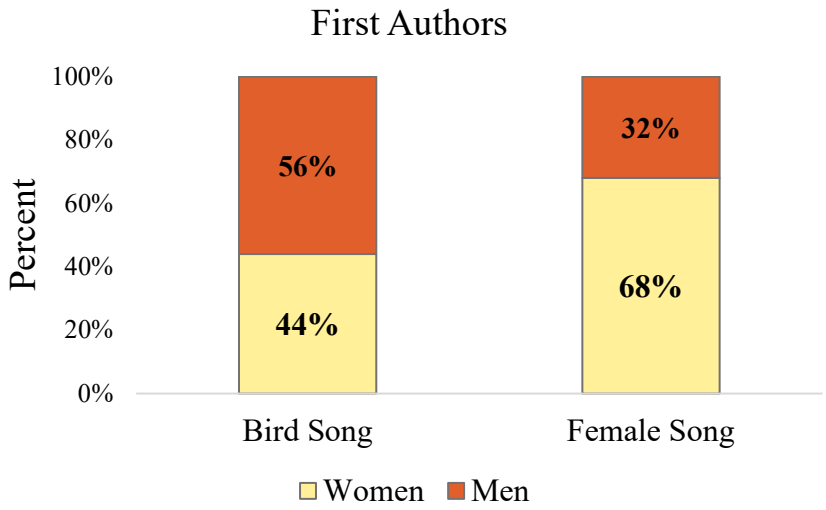

Figure 1. Percentage of women and men first authors for general bird song versus female bird song papers for the full dataset.

In addition, women hold the majority of authorship positions within the total authors category of female song papers. Women represented 54% of total authors on female song publications (90/166 authors) in contrast to 37% (64/172 authors) in the general bird song category ($p = 0.0016$; Table 1 & Fig. 2).

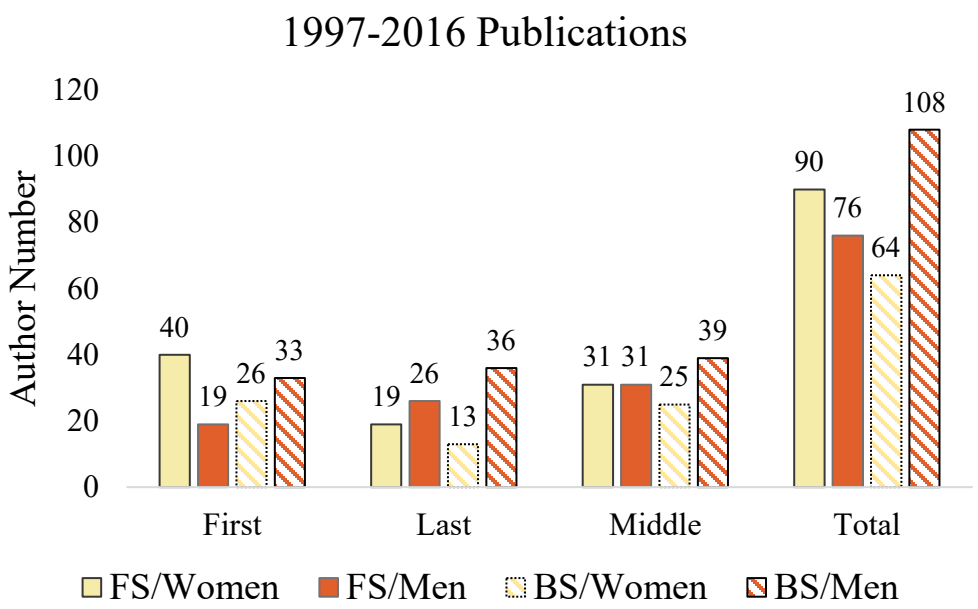

Figure 2. Author count by author gender and author position (full dataset). FS represents a female song paper and BS represents a bird song paper. Yellow indicates women whereas orange indicates men. Solid bars represent female song papers and striped bars represent bird song papers.

There were no significant differences between ratios of women and men for the middle or last author positions between female song and general bird song publications in either the full dataset or the verified dataset (Table 1, Table 2). Men hold the majority of last author positions for both the female song category as well as the general bird song category (full dataset: 58% and 73%, respectively; Table 1; verified dataset: 62% and 69%, respectively; Table 2).

DISCUSSION

Women are significantly more likely to author papers on female bird song. Additionally, women are especially likely to be first authors of female song papers and comprised 68% of first

author positions (both full dataset and verified dataset). Conversely, the majority of first authors on general bird song papers are men (56%, full dataset; 53% verified dataset). These trends have only increased recently compared to data from 1977-1996. The percentage of women authoring female song papers has increased from 29% for 1977-1996 to 68% for 1997-2016 (see appended results). These data suggest that women have made a disproportionate contribution to authoring female song research, particularly in recent years.

The largest discrepancy in author gender lies in the first author position of female song papers (Fig. 1). Interestingly, within the female song paper category, men still hold the majority of last author positions (58% full dataset, 62% verified dataset). However, there exists a smaller difference between the number of female song last authors who are women and last authors who are men compared to the general bird song category within the full dataset. The same trend holds true for middle authors: we found an even split (50/50) between women and men holding middle author positions on female song compared to men holding 61% of middle author positions on bird song papers. Similarly, when looking at total authors, there is a smaller difference between the number of men and women for female song papers compared to bird song papers (full dataset, Fig. 2). These trends indicate that female song research is disproportionately produced by women, especially in early career or women in non-PI positions. In summary, women are especially likely to be first authors on female bird song research compared to bird song research generally. In contrast, there is a smaller difference between the proportion of women and men holding middle, last, and total author positions of female song papers.

Study Limitations:

It is important to address that our case study includes several limitations. First, our data represent gender in a binary framework, which is not reflective of society, potentially resulting in

misgendering authors who are non-binary or gender minorities. Gender minority authors make important contributions to science and are a vital part of increasing diversity. We recommend that more detailed future studies provide opportunities for authors to self-identify their gender to avoid the possibility of misgendering.

Secondly, we acknowledge that primary and/or secondary sources may not use the correct pronouns of an author or that an author may feel uncomfortable revealing their personal gender identity within these sources. Our methods may have misgendered authors who do not identify with the gender commonly associated with their name or how they present. It is often the case that studies use self-reporting as a way to record gender (e.g., Smolen et al., 2018; Grammer et al., 2019). We ultimately chose not to pursue this route given that we were analysing papers going back more than 20 years, and many authors would be unreachable due to death, retirement, name change, moving, etc. It would have been impossible to have a data set that represented the full 20 year period if we used methods that required us to contact authors individually. We corroborated gender for 66% of authors by knowing authors personally or by referencing primary/secondary sources, including online articles and personal web pages. Only in our broader data set did we use names and in rare cases, as a last resort, pictures, to categorize author genders. The methods for our full dataset create the potential to misgender authors who do not identify with the gender associated with their name and/or how they present. Despite the potential misgendering in the full data set, we have included it in the results to fairly represent the literature of the last two decades. Given our research focus in female song, the verified dataset is highly skewed towards authors of female song papers (80% female song authors verified versus 53% general bird song authors verified).

Creating an inclusive gender framework is vital for continued discussions of diversity in science. Therefore, we strongly urge future studies to take a more expansive approach and to improve upon our methods by employing anonymous self-reporting surveys and providing additional gender categories, including a fill-in-the-blank option. Involving social scientists in survey design is also an important consideration for studies gathering demographic or human survey data. Lastly, we encourage scientists to post personal pronouns on professional websites and social media pages and to foster an accepting community for gender minority researchers to feel comfortable sharing their identity.

Study Implications:

Our finding that women are more likely to be first authors on female bird song research may be because more women are starting to contribute to animal behaviour research than in previous generations. We predict that if these data were gathered twenty years from now, we might observe data that reveal an increased percentage of women authoring female song papers, especially for last author position. At that point, researchers who are women and currently students may hold faculty and senior researcher positions, ultimately leading their own research groups and serving as last authors on papers (Borgmann, 2019). Since last authors who are women publish more frequently with women co-authors (Salerno et al., 2019), it is likely that there may be a larger percentage of women in other author positions as well.

Interestingly, evidence suggests that women and men have different preferences not just for research topics but also for different study animals (Bjerke & Østdahl, 2004). Researchers who are women with a preference for certain species may choose those species to study, possibly focusing on animals that have been ignored in the past by researchers who are men. Furthermore, there exists a bias in the sex of animals chosen for research (males used more often than females)

in many biological disciplines (e.g., Zucker & Beery, 2010; Ah-King et al., 2014; Cooper et al., 2019). The findings of this case study suggest that researchers who are women may be more inclined to study female animals, which appear to have been historically ignored (Borgmann, 2019). Therefore, the increased gender diversity of researchers in this field has expanded the scope of research in acoustic signalling beyond male signals, which has led to a broadened perspective that has led to a more balanced and comprehensive understanding of avian vocalizations.

The potential for novel ideas about animal behaviour, ecology and evolution may increase as the diversity of researchers in the field increases. For example, several primatologists who are women helped reverse historical assumptions and dogma based largely on male-focused studies (Small, 1985). Jane Goodall's discoveries of chimpanzee meat-eating, toolmaking, and tool use behaviours lead to a major change to our conception of ape behaviour and led to the demand for complex behavioural study methods in nature (e.g., Goodall, 1964; Quammen, 2010). Furthermore, Sarah Hrdy argued that while researchers who are men had described female primates as timid, modest, and passive, they are actually cunning and cooperative with fellow females (Hrdy, 2009).

Additionally, recent work on female song by several researchers who are women revealed that female song is widespread in modern songbirds and is likely ancestral in songbirds (Odom et al., 2014). These findings contradicted centuries of presumption that birdsong is a primarily male trait and that only a few rare species exhibited female song. In addition, only recently has the idea arisen that elaborate female traits are not simply non-adaptive pleiotropic effects, but that female ornamentation can evolve due to similar or independent selection pressures from those of male traits (Tobias et al., 2012; Price, 2015; Webb et al., 2016).

281 Furthermore, current research suggests that female ornamentation can undergo independent
282 evolutionary transitions, including multiple, independent losses or even re-gains while changes
283 to male ornamentation may be more directional and gradual (Riebel et al., 2005; Price & Eaton,
284 2014; Najar & Benedict, 2015). Early research suggested that male songbirds gained song for the
285 purpose of mate attraction and territory defence (e.g., Marler & Slabbekoorn, 2004). However, it
286 is possible that song may have originally evolved in both sexes for joint territory defence and
287 pair bond maintenance (Tobias et al., 2016; Riebel et al., 2019). In this scenario, it is possible
288 that female birds in temperate migratory species may have lost song as breeding season length
289 and the need to defend long-term territories decreased (Price et al., 2009). That bird song may
290 have first arisen through social selection acting on both sexes rather than sexual selection acting
291 on males represents a potential major paradigm shift in our understanding of the evolution of
292 bird song.

293 The variations in preference for study animal, species, and sex, between researchers of
294 different backgrounds can lead to unique observations and experiments. This diversity allows for
295 increased innovation and useful decision making by expanding complex thinking and
296 information processing (Østergaard et al., 2011; Díaz-García, 2013; Galinsky et al., 2015).
297 Furthermore, diversity expands creativity, which produces more novel concepts and ideas
298 (Bouncken, 2009). Thus, adding new approaches to our field can help expand our knowledge of
299 ecology, evolution and behaviour.

300 Many of the important advances in our understanding of female bird song have clearly
301 been driven or influenced by women. Our study demonstrates the importance of diversity in
302 fostering novel scientific ideas. Many studies have made excellent recommendations for methods
303 to increase diversity in STEM students and faculty (e.g., Blickenstaff, 2006; Glass & Minnotte,

2010; Jackson et al., 2014; Reed et al., 2018). It is critical to continue to study the impact of researcher background and identity to improve the process of science. Future studies of gender diversity would benefit from a broader and more inclusive gender framework, as well as incorporating the intersection of gender with racial and ethnic diversity. Additionally, the continued involvement of women in research and the further increase in diversity of researchers across all genders and backgrounds will help lead to more innovative hypotheses and approaches. Fostering diversity in STEM and other research fields is critical for the formation of novel questions, ideas, and methods. This diversity has the potential to correct current research biases and lead to new discoveries that will better reflect the range of questions relevant to different communities and regions of the world.

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Appendix

Appended Methods

Using the same methods as above, we collected all bird song papers from any journal published between 1977 and 1996 that contained the search terms “female song” or “female singing” within the title or abstract.

Appended Results

In the time frame from 1977-1996, we found that men held the large majority of all authorship positions, with the exception of middle authors on bird song papers (33% men). Due to small sample sizes, we were only able to calculate a chi-squared value for the total authors category of this data set. For first, last, and middle author positions, we used a two-tailed Fisher exact test to calculate significance (see Appended Table 1).

Author Position	FS/Women	FS/Men	BS/Women	BS/Men	P-Value
First Author	6(29%)	15(71%)	5(24%)	16(76%)	1

Last Author	3(27%)	8(72%)	2(14%)	12(86%)	0.6231
Middle Authors	1(17%)	5(83%)	6(67%)	3(33%)	0.1188
Total Authors	10(26%)	28(74%)	13(29%)	31(71%)	0.7401

Appended Table 1. The number of authors based on gender, author position, and paper type from 1977-1996. FS represents female song papers and BS represents bird song papers. P-values reflect significance by author position. Numbers in parenthesis show the percentage of authors of a gender based on paper type. Note: for sample sizes of five or fewer (last author, middle authors) p-values were calculated using a two-tailed Fisher exact test.