Reported Individual Costs and Benefits of Sharing Open Data among Canadian Academic Faculty in Ecology and Evolution

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Open data facilitate reproducibility and accelerate scientific discovery but are hindered by perceptions that researchers bear costs and gain few benefits from publicly sharing their data, with limited empirical evidence to the contrary. We surveyed 140 faculty members working in ecology and evolution across Canada's top 20 ranked universities and found that more researchers report benefits (47.9%) and neutral outcomes (43.6%) than costs (21.4%) from openly sharing data. The benefits were independent of career stage and gender, but men and early career researchers were more likely to report costs. We outline mechanisms proposed by the study participants to reduce the individual costs and increase the benefits of open data for faculty members.

Keywords: data sharing, FAIR data, open science, public data archiving, reproducibility, transparency

Open and FAIR (for *findable*, *accessible*, *interoperable*, and *reusable*) data are a cornerstone of transparent, reproducible, and reusable scientific research. Therefore, many funding bodies and scientific journals are adopting policies mandating open data as a condition of funding or publication (Costello 2009, Whitlock 2011, Houtkoop et al. 2018, Sholler et al. 2019, Culina et al. 2020). In ecology and evolution, the first journal began requiring open data in 1999 (Moore et al. 2010), and the number of journals with a mandatory open data policy currently exceeds 60. Despite broad support for data sharing by funders, publishers, and policymakers, many academics resist making their research data publicly available (Piwowar 2011, Milia et al. 2012, Fecher et al. 2015, Houtkoop et al. 2018, Campbell et al. 2019). One reason might be that, although the collective benefits of open data are broadly acknowledged (Vision 2010, Piwowar et al. 2011, Reichman et al. 2011, Whitlock 2011, Wicherts and Bakker 2012), there is less evidence that publicly sharing research data benefits individuals (Piwowar and Vision 2013, Roche et al. 2014, Chawinga and Zinn 2019, Hunt 2019, Popkin 2019, Colavizza et al. 2020).

Open data practices also remain controversial among academics because of perceived individual costs in today's hypercompetitive research environment (Mills et al. 2015, Longo and Drazen 2016, Edwards and Siddhartha 2017, Abele-Brehm et al. 2019, Miyakawa 2020). Many researchers feel a sense of ownership over their data and fear that potential individual benefits do not make up for future publications lost by relinquishing priority of access to the data they collected—the fear of being scooped (Costello 2009, Moore et al. 2010, Reichman et al. 2011, Gewin 2016). Researchers have also voiced concerns that sharing their data could result in misinterpretations or misuses by third parties (Chawinga and Zinn 2019) as well as public shaming if errors are identified in their work (Costello 2009, Houtkoop et al. 2018). Currently, apprehensive authors can avoid publishing in journals that mandate open data (Roche et al. 2014), ignore funder or journal policies altogether (Couture et al. 2018), or share their data in ways that make them difficult or impossible to reuse (Roche et al. 2015, Hardwicke et al. 2018, Towse et al. 2020), undermining efforts to promote reproducibility. Understanding and addressing the real or perceived costs of data sharing is essential to bolster researcher's engagement in open and FAIR data practices (Costello 2009).

Research to date has centered on understanding the opinions of researchers in order to identify motivations and enablers or fears and barriers to data sharing (Piwowar 2011, Tenopir et al. 2011, Tenopir et al. 2015, Schmidt et al.

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2016, Van den Eynden et al. 2016, Houtkoop et al. 2018, Abele-Brehm et al. 2019, Chawinga and Zinn 2019). A recent systematic review of researcher's attitudes toward open data identified five elements that strongly influence data sharing: seniority, age, a lack of time, the loss of control over one's data, and data misappropriation (Chawinga and Zinn 2019). Although the losses of control and data misappropriation are frequently cited by researchers as reasons for not sharing (Digital Science and Figshare 2020), it is unclear whether these fears are perceptions or legitimate concerns.

We contacted 351 principal investigators (PIs) self-described as working in the fields of ecology and evolution at the 20 highest-ranked Canadian universities to investigate positive and negative outcomes of sharing open data: 140 PIs completed our questionnaire, including 54 women, 84 men, and 2 nonbinary people (refer to the supplementary material for the methods). They were all academic faculty members at these institutions.

A large majority of the survey respondents reported always or occasionally sharing open data alongside their published papers (84.3%), believing that open data are beneficial to society (88.6%), and supporting mandatory open data policies (77.9%; table 1, figure 1a). Support for mandatory policies was similar among genders ($\chi^2(2) = 3.54$, $p = .17$) and career stages ($\chi^2(2) = 3.65$, $p = .16$). These views and practices by the PIs in ecology and evolution align with recent reports of growing support for open data initiatives by scientists across disciplines (Digital Science and Figshare 2020).

Almost half of the respondents (47.9%) reported positive outcomes from sharing open data (table 1), without notable differences between genders (odds ratio = 0.77, $z = -1.5$, $p = .134$) and career stages (odds ratio = 1.0, $z = 0.32$, $p = .747$; figure 2a). The most common benefit was a personal sense of satisfaction from openly sharing one's data, but many of the PIs also reported benefits in terms of productivity and career advancement (figure 1b). 43.6% of the PIs reported experiencing neither costs nor benefits.

Approximately one-fifth of the PIs (21.4%) reported having previously experienced some form of negative outcome from sharing open data (table 1). The probability of experiencing negative outcomes was greater for men than women (odds ratio = 5.85, $z = 2.21$, $p = .027$) and tended to be higher for researchers at an early career stage (odds ratio = 1.04, $z = 1.93$, $p = .054$; figure 2b). The effect of career stage was independent of gender ($z = -1.28$, $p = .200$). Why men experience costs more frequently than women is unclear. One possible explanation is that costs are more readily perceived by men than women, which translates into higher self-reported costs among the male respondents. Psychology research has consistently shown that men tend to be more competitive than women (Niederle and Vesterlund 2011). For example, men in our study might have perceived that their data were "misused" more often than women if they considered the reuser to be a competitor. In contrast, our finding that early career researchers tend to experience more costs than their senior colleagues aligns with concerns expressed by others (Gewin 2016). The few studies in which the effects of age and seniority on data sharing attitudes were examined reported that, whereas younger researchers think more favorably about data sharing and reuse (Tenopir et al. 2011, Tenopir et al. 2015), early career researchers tend to be more fearful and reluctant to share their data than senior researchers are (Tenopir et al. 2011, Tenopir et al. 2015, Abele-Brehm et al. 2019, Chawinga and Zinn 2019, but see Campbell et al. 2019). The most commonly reported costs experienced by the PIs of all genders and career stages were related to data misuse or misinterpretation; only one respondent reported experiencing reputational damage from errors being identified in their work (figure 1c).

One in three of our respondents felt that mandatory open data requirements by journals or funders imposed excessive time demands on researchers (table 1). This was echoed in several free-form comments by the PIs, arguing that publicly sharing data in a reusable format can be "extremely time consuming" and felt little value in doing so given a "sense that they [the data] are very rarely used." Indeed, although the societal benefits of sharing big data are frequently acknowledged (Hampton et al. 2013, May 2014), we lack empirical evidence that long-tail research data (data from small, independent research projects) are frequently reused, at least presently (Evans 2016). Similarly, several researchers expressed support for open data but felt that time demands to clean and annotate data (and sometimes the associated code or script) were "not excessive but nontrivial," "definitely significant," or "huge," depending on the type and amount of data to be shared. Some of the PIs expressed that data sharing expectations promote the adoption of good data curation early on, ultimately reducing time demands for data management and research more generally. This sentiment was reflected in the fact that nearly half (47.5%) of the PIs who had previously published open data reported a reduction in the time and effort needed to share their data. The absence of time gains among the other respondents (52.5%) could result from several of the PIs having shared few data sets (47.8% shared data with less than 50% of their papers; figure 1a) and observations by the PIs that frequent differences among studies and data sets mean that "each data submission is *de novo*." A recurring comment was that research groups seldom have qualified personnel to assist with research data management and that funders and universities must dedicate resources and build capacity to help researchers comply with new research data management and open data policies.

In Canada, the Natural Sciences and Engineering Research Council of Canada (NSERC) funds most of the academic research in ecology and evolution through Discovery Grants, which have annual success rates above 60% (NSERC 2020). Whereas the US National Science Foundation began mandating plans for depositing data

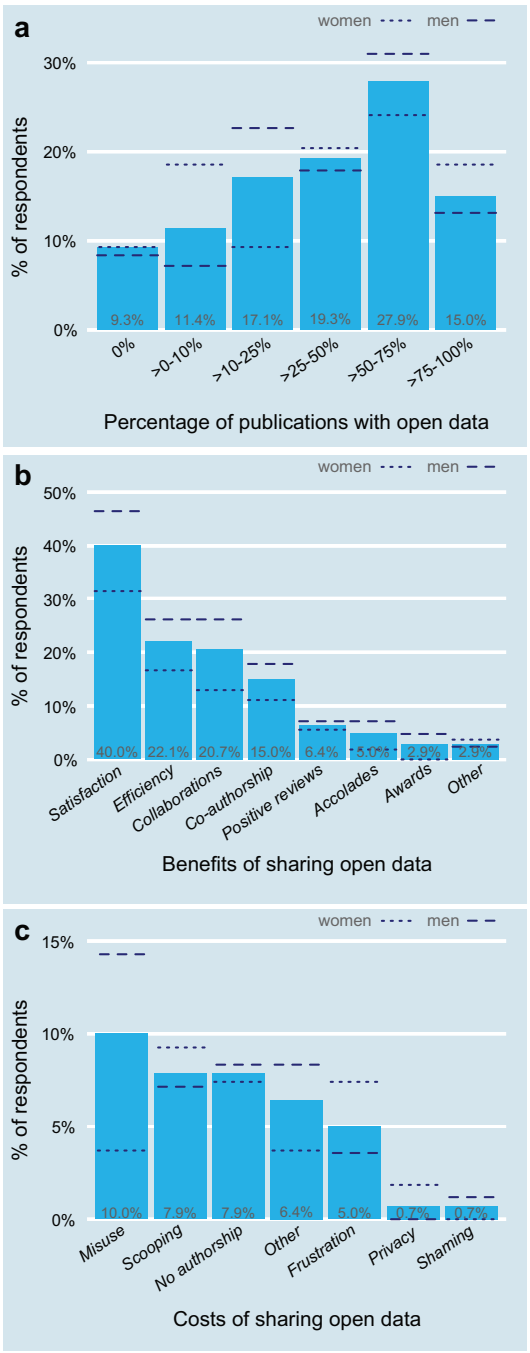

Figure 1. The costs and benefits of sharing open data in ecology and evolution. The percentage of the respondents (N = 140: 54 women, 84 men, 2 nonbinary) having (a) published empirical studies with associated open data between 2015 and 2020, (b) experienced benefits from open data, and (c) experienced costs from open data. Dashed and dotted lines indicate the percentage of men and women having selected each category, respectively. The bars (and lines) do not add up to 100% in panels (b) and (c) because the respondents could select more than one category. The benefits of open data include a personal sense of satisfaction from having published a research product other than a scientific paper, greater efficiency from adopting better data management practices, new collaborations (whether to reuse the open data or not), offers of co-authorship from researchers having reused the data, positive reviews on applications for grants, fellowships or manuscripts, accolades from peers, awards or promotions and other benefits. The costs of open data include data misuse or misinterpretation by a third party, being scooped on a paper, lack of warranted co-authorship on a study reusing open data, other costs, frustration from having to share data that researchers would have preferred to keep private, putting humans or other species at risk of privacy infringement or disturbance or exploitation, and public shaming or reputational damage from errors being identified in a researcher's work.

Table 1. The opinions and experiences of PIs in ecology and evolution regarding open data.

	Positive		Neutral		Negative	
Question	Percentage	95% confidence interval (CI)	Percentage	95% CI	Percentage	95% CI
Do you share open data?[a]	37.9	29.8–45.9	46.4	38.2–54.7	15.7	9.7–21.7
Do you support mandatory open data?[b]	77.9	71.0–84.7	10.7	5.6–15.8	11.4	6.2–16.7
Are open data beneficial to society?[c]	88.6	83.3–93.8	–	–	11.4	6.2–16.7
Does data sharing require excessive time?	34.3	26.4–42.1	–	–	65.7	57.9–73.6
Have time requirements decreased for you?	40.0	31.9–48.1	–	–	60.0	51.9–68.1
Have you benefited from sharing open data?	47.9	39.6–56.1	–	–	52.1	43.9–60.4
Have you incurred costs from sharing open data?	21.4	14.6–28.2	–	–	78.6	71.8–85.4

Note: The questions in the table are paraphrased. 35.0% of the respondents reported experiencing only benefits from sharing open data, 12.9% experienced both costs and benefits, and 8.6% experienced only costs. $N = 140$. [a]Positive, *always*; neutral, *occasionally*; negative, *never*. [b]Positive, *yes*; neutral, *indifferent*; negative, *no*. [c]Positive, *yes*; negative, *no*.

in an appropriate repository in 2011 (NSF 2020), NSERC and other Canadian federal funding agencies have no such requirements. Therefore, Canadian PIs who share open data do so either voluntarily or to comply with journal editorial policies. In 2021, Canada's Tri-Council Agencies (including NSERC) will start requiring that universities develop institutional research data management strategies and encourage researchers to submit a data management plan alongside grant applications (Government of Canada 2018). However, this new policy does not mandate open data, nor does it specify mechanisms to facilitate or incentivize FAIR data.

When asked what initiatives by journals, funding agencies, and universities would increase their participation in open data, the PIs formulated extensive and specific recommendations that we identified as centering on three themes. The questionnaire and a comprehensive list of anonymous comments by the PIs are provided as supplemental material.

Better guidelines, standards, and training for data sharing

Editorial open data policies are often unclear (Weber et al. 2010, Sholler et al. 2019), resulting in what one respondent characterized as "clunky and uncertain processes, especially around sensitive data." The respondents emphasized the need for clearer guidelines on what, where, and how data should be shared. Compounding this issue is a lack of well-established, domain-specific standards to facilitate sharing (and reusing) data in many subdisciplines of ecology and evolution (Poisot et al. 2019). The need for adequate training to familiarize students and PIs with good data management and curation practices was repeatedly highlighted as crucial.

Greater support for research data management and equity in sharing practices

Two leading concerns of the PIs with open data were financial and time requirements, resulting in what several of the PIs described as inequitable requirements on labs with different levels of funding and personnel. Some of the PIs suggested small grants to organize data files for public access; however, many insisted that a sustainable approach to open data requires funding agencies to mandate, check, and provide adequate financial and technical resources to support data sharing.

Better incentives for sharing and better protection from potential negative outcomes

The PIs clearly communicated that a greater adoption of data sharing practices requires greater recognition of open data in research funding and career advancement decisions. A popular suggestion was that funders and universities ask applicants to list open data sets and consider these in their evaluation of researchers as is currently done for student or personnel training and, increasingly, for contributions to equity, diversity, and inclusion. In parallel, one suggestion was that journals reduce page, color figure or open access fees to incentivize data sharing. Beyond increasing benefits, the PIs also stressed the need to formalize mechanisms for avoiding negative outcomes, such as agreed-on best practices for reusing open data and attributing much needed credit to the data collectors.

Overall, most comments by the PIs were highly constructive, with very few stating they would never make their data open (e.g., "when hell freezes over"). Some recommendations by the PIs were impractical for advancing open data (e.g., data should be available on request and

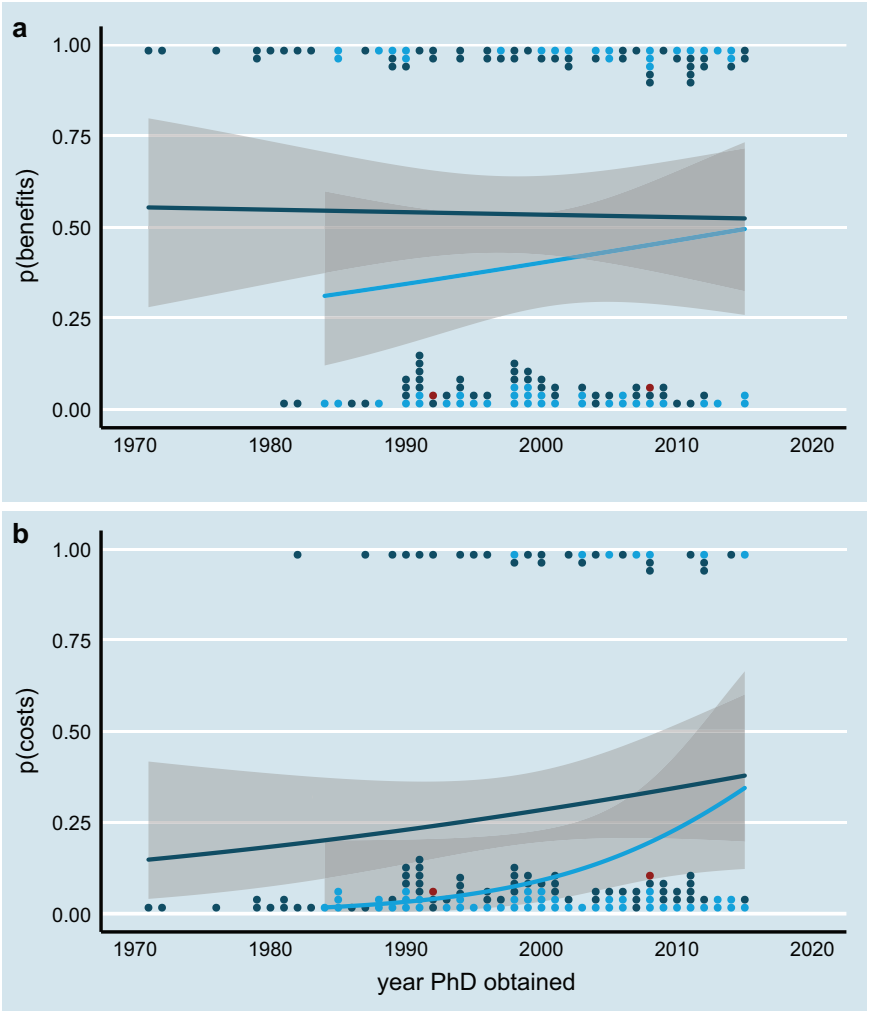

Figure 2. The influence of gender and career stage on the probability of researchers in ecology and evolution experiencing (a) benefits and (b) costs from sharing open data. Men (n = 84) are shown as dark blue dots, women (n = 54) as light blue dots, and nonbinary people (n = 2) as red dots. The predictions from binomial generalized linear models are indicated as dark blue (men) and light blue (women) lines, and the error bars represent 95% confidence intervals.

contingent on sharing a research proposal), and some pointed to developing mechanisms that already exist—for example, trusted repositories (Lin 2017), embargo options (Roche et al. 2014), citable DOIs for data sets (Silvello 2018), and access control for sensitive data (Lennox et al. 2020). The latter highlights a lack of familiarity with current open data practices among some of the PIs, which is not surprising because open data are a relatively new expectation in most subdisciplines of ecology and evolution. Importantly, many of the respondents' recommendations for addressing reported individual costs of open data mirror calls for improvements made by researchers in psychology (Towse et al. 2020), biomedicine (Rouleau 2017), biology (Hipsley and Sherratt 2019), and other disciplines (Tenopir et al. 2015) internationally. Considering these researcher-driven recommendations is crucial because recent evidence points to low compliance rates with existing mandatory open data policies put in place by funders (Jones et al. 2018, Hipsley and Sherratt 2019) and journals (Sholler et al. 2019, Christian et al. 2020, Miyakawa 2020).

In conclusion, our findings indicate strong support for mandatory open data policies among the PIs in ecology and evolution, a general willingness to publicly share research data, and an appetite for greater incentives to share. Although our study was focused on Canadian academic faculty, the findings are likely to be representative of the broader population of PIs in ecology and evolution, given Canada's diverse institutions, as well as the high degree of PI mobility in today's globalized academic landscape. Therefore, the practical recommendations highlighted in the present article should be broadly considered by funders, universities, and journals in Canada and elsewhere to incentivize participation in data sharing and reduce potential costs to researchers.

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Supplemental material

Supplemental data are available at *BIOSCI* online.

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