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Engaging for a Good Cause: Sophia's Story and Why #BugsR4Girls

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Abstract

Scientists, particularly those involved with nonapplied or "basic" science, are often asked to justify the broader impacts of their work, or more acutely, how they and their work contribute to society. Although it may be difficult to articulate the immediate importance of providing names for new flies, the inherent value of knowledge is undeniable. At times, however, the positive impact scientists have on society, or even on a single individual, can burst into reality in real-time. Here we examine one such example: a tweet and hashtag that circled the globe in support of a young girl being bullied for her entomological passion. We explore the responses to the tweet, within Twitter and in the larger media landscape, and what they mean for entomology, scientific societies using social media, and the promotion of women in science, and provide recommendations for increasing engagement on social media to improve representation of science.

Key words: Twitter, entomology, social media, outreach, women in science

On August 25, 2016, the Entomological Society of Canada (ESC) received an e-mail from Nicole Spencer explaining that her 7-yr-old daughter, Sophia (junior author of this paper), was passionate about insects and entomology but that her peers routinely teased her for that passion. Ms. Spencer wished to encourage Sophia's interests, and was looking for educational resources and contact information for a professional entomologist who could answer some of Sophia's questions about insects and entomology. Ms. Spencer's anonymized e-mail was forwarded to the lead author of this paper to try and find entomologists via the ESC's Twitter account (@canentomologist) who might be willing to correspond with Sophia. At the time, @canentomologist was followed by an estimated 1,600 users, placing it in the top 13% of scientific Twitter accounts based on following (Collins et al. 2016) and allowing for a much wider potential audience than a mass e-mail to the ESC's roughly 350 official members.

Twitter (twitter.com) is a social networking site that asks its users, "What's happening?" and provides them a means to share short text messages, pictures, videos, and other media with their peers and followers in response. Tweets, as the individual, modular messages are called, are limited to 140 characters, including any text, usernames, hashtags, or URL links the author wishes to share (photos, videos, and other media uploaded directly through the Twitter client are now handled separately, and do not contribute to the 140 character limit), and are publicly published (as compared to other social networking sites like Facebook, where post visibility are often restricted to mutually approved "friends"). Twitter users can address or "tag" other users in their tweets by including unique usernames preceded by the at sign, '@', to notify others that they are being talked to or about. Users can also create hashtags of any length or complexity by placing a string of letters or numerals without punctuation or spaces after a '#' (the number sign, pound, or hash mark). These hashtags are recognized by Twitter and serve as automated search functions, allowing individuals or groups to publish their tweets into a shared conversation connected by the hashtag. Twitter has been adopted by many scientists as a means for sharing their work with their peers (Priem and Costello 2010), communicating emerging research presented at scientific conferences (Shiffman 2012), engaging with undergraduate students outside of the classroom (Soluk and Buddle 2015), recognizing and tracking biodiversity (Daume 2015, Daume and Galaz 2016, Jackson et al. 2017), and to engage with the public about their work and global issues (Smith 2015).

The Entomological Society of Canada, one of North America's oldest professional societies (Timms 2009), joined Twitter (@canentomologist) in 2012 as a means to fulfill its goal to "raise awareness and promote education about insects and entomological issues for the general public" and to "serve as a hub for communication about entomological issues among amateur and professional entomologists, and the general public," while also living up to the society's Vision Statement: "The Entomological Society of Canada/La Société

d'entomologie du Canada (ESC/SEC) will be recognized as the preeminent organization in Canada for promoting and facilitating entomological research and collaboration, and for disseminating entomological knowledge in Canada and the rest of the world for the benefit of society" (Entomological Society of Canada—Vision Statement 2017). The ESC primarily uses the account to share member news, society publications including peer-reviewed papers, conference information, and outreach materials related to Canadian entomology, while also advocating for public, professional, and political support of entomology. Ms. Spencer's request broadly aligned with the mission of the ESC and its Twitter account, and a tweet was constructed and published at 1:06 PM EDT (17:06 UTC) on August 25, 2016, with the following objectives: find an entomologist willing to communicate directly with Sophia; normalize and increase visibility of women in entomology; and create a resource to encourage girls and women to embrace their entomological interests. We here report on the unusually strong response to this tweet, both within Twitter and more broadly in the media, assess whether the objectives of the initial tweet were met, and provide recommendations for using Twitter for advocacy and to engage scientists and the broader public.

Anatomy of a Tweet

Crafting a 140-character tweet that resonates with other users and encourages them to engage with the author or the subject can be difficult, and requires greater consideration than perhaps may be expected. The structure of the tweet (Fig. 1) and how this structure may have led to its considerable success are discussed.

One of the key aspects of the tweet was the inclusion of the anonymized text of Ms. Spencer's initial e-mail to help readers empathize with her daughter and request. Just as the e-mail may have been forwarded among ESC society members directly, the inclusion of the text of the e-mail was judged to be imperative for informing potential correspondents on Sophia's situation. However, at more than 1,300 characters in its original form, it would be impossible to include the full e-mail within the body of the tweet. In order to get around character limits, Ms. Spencer's e-mail was copied into Microsoft Word, lightly edited for grammar and to maintain focus on her daughter's predicament, and then a screen capture of the text was uploaded as an image attachment to the tweet (Fig. 1D). Using this method allows more text to be shared directly with followers. Additionally, tweets that include media such as photos or other images are more likely to be retweeted (Bruni et al. 2012), and can receive 313% more engagement than tweets with only text (Steyck 2015). The e-mail was kept in its original first-person style rather than rewritten as a third-person synopsis in order to maintain the emotional significance of a mother asking for help on behalf of her daughter.

With the photo added as an attachment, 117 characters remained with which to convey a message from the society (URL links included in tweets are automatically shortened by Twitter to 23 characters; at the time of this tweet, links to photo attachments were not yet "free" in terms of characters). This message was constructed to briefly summarize Ms. Spencer's e-mail, catch the attention of users as they scrolled through Twitter, and also elicit an emotional response to increase engagement (Dobele et al. 2007). For example, "bullied" was used despite not appearing in Ms. Spencer's original e-mail because it is concise, is almost universally familiar, and can act as a strong emotional trigger for those who have experienced bullying. In order to protect Sophia's privacy, direct contact details were withheld, and people interested in reaching out were asked to send @canentomologist a Direct Message (DM) with their e-mail address and correspondence, which would then be passed along to Sophia's family. Direct messages allow Twitter users to correspond and share information privately. Normally the receiving user must be following the sender in order for the message to be delivered, but Twitter recently provided users the option to allow Direct Messages from anyone, regardless of follow status. Direct Messages were left "open" until the rate of new contact appeared to dissipate (closed September 2, 2016) to allow anyone on Twitter to send @canentomologist their contact information and a message for Sophia and her mother; those messages were then organized into a Microsoft Word document to be passed to the family all at once.

Finally, in an attempt to expand the reach of Sophia's story, and inspire further dialogue about girl's and women's participation in entomology, the hashtag #BugsR4Girls (Fig. 1C) was created. As is common for Twitter hashtags, grammar and taxonomic accuracy were sacrificed for brevity and conciseness, and the hashtag was searched prior to publishing to ensure it was original and not already in use by other organizations or users. While contributing to a preexisting hashtag can allow for messages to coopt existing communities (e.g., #WomenInSTEM is a commonly used hashtag that would broadly match the audience goals of this tweet), the tweet was designed to stand apart, and not become lost in a greater conversation already occurring to provide an easy way for Ms. Spencer to show Sophia the public responses to her story.

Analysis of Engagement and Responses

There are several means by which engagement with the initial tweet can be assessed, including responses and engagement made within Twitter via direct engagement with the tweet, response to the call to action (Direct Messages), and contributions to the #BugsR4Girls hashtag, as well as examining engagement with the tweet outside of Twitter.

Ethical Considerations for Social Media Research

Social network sites such as Twitter provide a new means to study how people interact with each other and greater societal issues, but care must be taken that this research is done respectively and ethically. The present study is solely concerned with observing information made publically available via Twitter under the terms and conditions of Twitter's service agreement (https://twitter.com/tos) and which does not involve direct interaction with users (Moreno et al. 2013). Additionally, while all information discussed herein is publically available and easily searched on Twitter, no individuals are directly quoted or identified, meeting the guidelines for ethical research using social media put forth by Markham and Buchanan (2012).

Direct Engagement

As part of its service, Twitter tracks how users interact with individual tweets and then provides this data to the user for their tweets. While there are many statistics available (see Supplemental Material), the most relevant measures for engagement are presented in Table 1, with each of the engagement methods linked back to where a user clicked within the Tweet (Fig. 1A–G). *Impressions* are the number of times a tweet was served to another user within Twitter, and are used as a proxy for the number of views a tweet receives within Twitter. *Engagement Rate* is the quotient of total

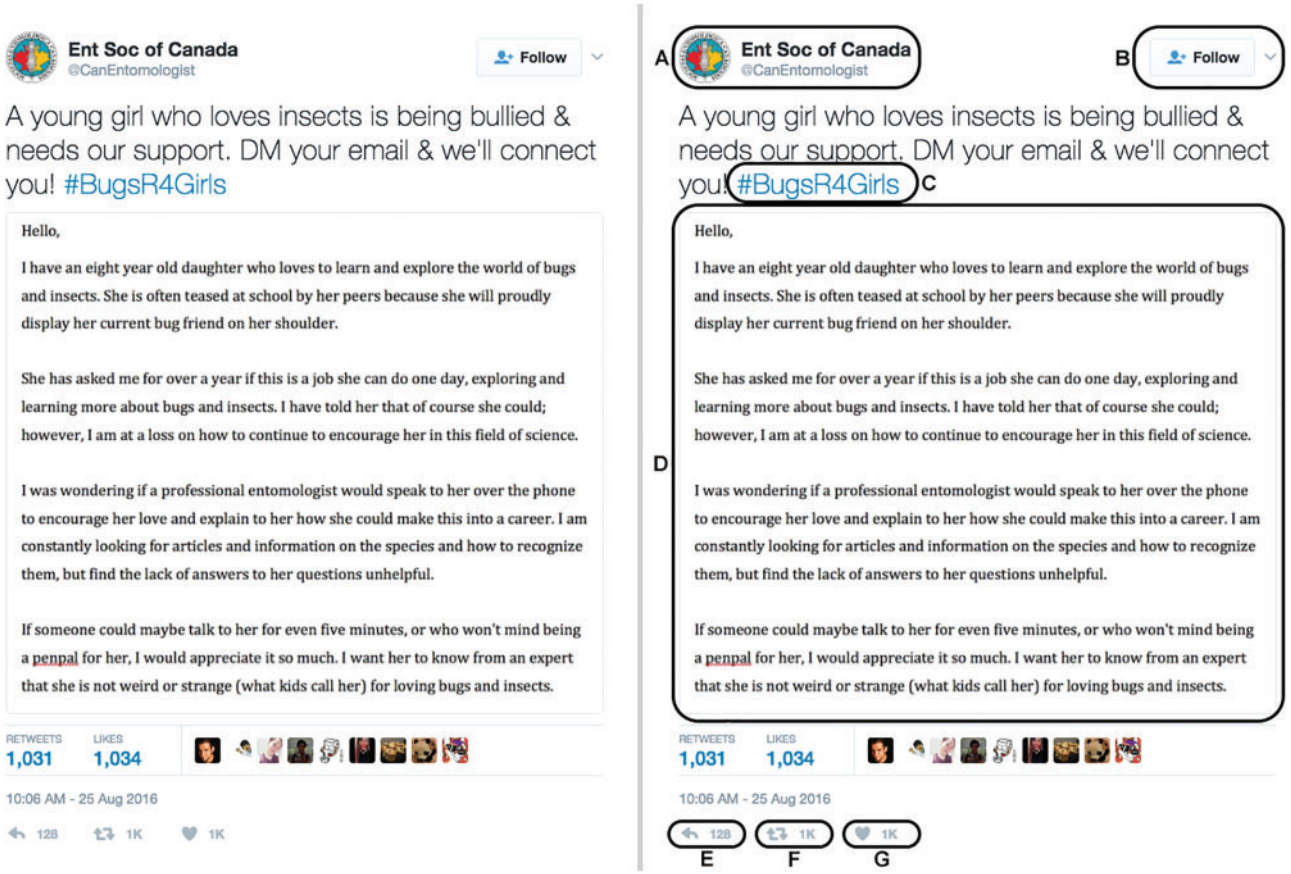

Fig. 1. Screen capture taken January 23, 2016 of the initial #BugsR4Girls tweet by @canentomologist, as it appears using the desktop web browser client for Twitter and annotated to denote the different locations where a user's interaction with the tweet are recorded by Twitter.

Table 1. Tweet-level analytical data for @canentomologist obtained from twitter.com on January 2, 2017.

	No. of tweets	Impressions	Engagement rate	Profile clicks	Follows	Hashtag clicks	Media views	Replies	Retweets	Likes
May 2016	4	6,142	0.011	2	0	0	20	3	8	12
June 2016	4	4,120	0.007	1	0	1	0[a]	4	7	4
July 2016	1	2,507	0.011	1	0	1	0[a]	0	6	4
Aug. 1–24 2016	1	2,741	0.005	1	0	0[b]	0[a]	0	4	1
Initial #BugsR4Girls Tweet	1	175,742	0.085	467	52	170	6,149	128	1,033	1,034
Aug. 25–31 2016	15	107,636	0.013	171	1	18	4	17	103	260
Sept. 2016	23	28,285	0.013	25	1	42	0[a]	7	81	79
Oct. 2016	7	8,167	0.034	22	0	3	0[a]	1	18	22
Nov. 2016	1	2,968	0.038	0	0	0[b]	38	0	14	14
Dec. 2016	5	5,576	0.016	2	0	0[b]	0[a]	1	23	9

Data are cumulative for periods involving more than one tweet.
[a]No images, videos, or other media were tweeted.
[b]No hashtags were tweeted.

engagements (including engagement statistics not presented here; see Supplementary Material) and Impressions. *Profile Clicks* represent the number of times users clicked on the embedded profile picture or user name (Fig. 1A) to view the @canentomologist profile page. *Follows* represent the number of times users followed @canentomologist directly from the tweet using the embedded button (Fig. 1B). *Hashtag Clicks* represent the number of times users clicked on a hashtag included in the tweet (Fig. 1C), which automatically searches Twitter and returns all other tweets containing that hashtag. *Media Views* represent the number of times users clicked on the embedded image (Fig. 1D). *Replies* represent the number of times users replied to a tweet with a public tweet of their own (Fig. 1E). *Retweets* represent the number of times users shared the tweet in its entirety with their followers (Fig. 1F). *Likes* represent the number of times users "liked" a tweet (Fig. 1G); this function is often used as a bookmark or an

acknowledgement of approval, however individual usage varies widely.

In comparison to other tweets from @canentomologist over an 8-mo period (May–December, 2016), the initial #BugsR4Girls tweet was shared and engaged with dramatically more than any other tweet, and surpassed the combined impressions and engagement for all other tweets in the 8-mo period, even when accounting for abnormally strong engagement statistics associated with follow-up tweets regarding #BugsR4Girls from late August to early September, and tweets relating to the International Congress of Entomology in late September. Focusing on Engagement Rate, a frequently used metric of the "success" of content and accounts on social media (Drula 2012, Saxton et al. 2015), particularly for social advocacy organizations (Saxton and Waters 2014), the initial #BugsR4Girls tweet was engaged with by 8.5% of those who were served it, dramatically more than the 1.5% average for the remainder of @canentomologist tweets in the examined 8-mo period. While there is little published data on Twitter Engagement Rates, and specifically what a "good" Engagement Rate is, large, international Environmental and Wildlife/Animal Welfare nonprofit organizations reported 1.6% and 2.2% average engagement rates respectively in 2015 (Benchmarks X: Online metrics for nonprofits 2017).

The initial tweet was eventually delivered to >175,000 Twitter users (Table 1: *Impressions*), in large part due to its unusually high Engagement Rate. This high degree of engagement helped propagate the message and call for action further, but also helped instigate multiuser discussions about Sophia, the importance of women in entomology, and shared appreciations for insects from broad audiences in reply to the original tweet. Many of these conversations were anchored by the #BugsR4Girls hashtag, creating a community of users discussing insects, women in entomology, and Sophia's story in a way that can be easily searched and contributed to by any Twitter user, and read by all internet users, regardless of whether they have a Twitter account.

Contributions to #BugsR4Girls

Between August 25 and December 28, 2016, 1,094 tweets were published by 754 unique Twitter users that included the hashtag #BugsR4Girls. While contributions to the hashtag continued for >4 mo, 96% of tweets containing #BugsR4Girls were published within 1 mo of the original tweet. Contributors also used an additional 306 hashtags in conjunction with #BugsR4Girls, spreading the message to potentially hundreds of new communities. Hamed and Wu (2014) demonstrated that connected hashtag networks on Twitter make the world a smaller place, halving the "six degrees of separation" made famous by Travers and Milgram (1969). The ongoing conversations using the #BugsR4Girls hashtag not only helped build or reinforce a community inherently interested in the themes and outcomes of Sophia's story, but also helped connect communities, furthering the profile of the initial tweet while broadly communicating the ideas and values of that community to users who may have little exposure to these issues normally.

Objective-based hashtags like #BugsR4Girls run the risk of contributor's usage misaligning with the goals of the hashtag's creators. Bravo and Hoffman-Goetz (2016) found that only 0.6% of assessed tweets contributed to the 2013 #Movember campaign's goal of spreading awareness of prostate or testicular cancers in Canada, with the vast majority of users instead sharing facial hair grooming information and community news. Of the 1094 tweets containing #BugsR4Girls, 643 (59%) were considered to be "on message" (i.e. illustrating or discussing women in entomology, providing encouragement to girls/women in entomology, or women sharing personal observations or experiences involving insects), and, perhaps surprisingly, there were no examples of trolling or maliciousness recognized. Of the tweets considered "on message," 298 (27% of all #BugsR4Girls tweets) included photos, videos, or illustrations relating to entomology: 187 tweets included media depicting girls or women holding insects or entomology paraphernalia (books, collecting equipment, toys, etc.), 75 tweets were contributed by female users and included media depicting insects, and 36 tweets were contributed by nonfemale users (males, organizations, etc.) and included media depicting insects. It is clear that visible representation of women in science not only positively influences girls' self-perception of their ability to do science (Smith and Erb 1986), but also mitigates stereotypes in both men and women regarding the masculinity or femininity of science (Young et al. 2013), while exposing girls to illustrations of women in the role of scientist can increase comprehension (Good et al. 2010). The large number of Twitter users who shared photos of themselves, their daughters, nieces, sisters, mothers, aunts, cousins, or friends exploring the natural world through entomology provided visible role models that may encourage other girls and women to embrace their interests in insects and entomology, while also helping to normalize the role of women in entomology, mitigating gendered stereotypes.

Response to the Call to Action

In response to the call for entomologists to privately share their contact information with Sophia, @canentomologist received Direct Messages via Twitter from 135 unique users, 73% of whom were women. The first Direct Message was received 7 min after publishing the initial #BugsR4Girls tweet, and 64% of correspondents made first contact within 24 h, while all respondents made first contact within 1 wk (Fig. 2). No users contacted @canentomologist wishing to send a Direct Message after the inbox was "closed" on September 2, 2016. While most correspondents identified themselves as professional entomologists or entomologists in training (59%), remaining correspondents identified a present or past interest with insects, were professional scientists in fields other than entomology, or just wanted to personally voice their support of Sophia and her interests. The strong, rapid response to the initial tweet via Direct Message is likely due to the built-in private messaging system of Twitter. This feature, which is easily accessed via large buttons on every user's profile page, allows for individuals to immediately send a Direct Message with only 2 clicks within the Twitter environment. Had users been asked to e-mail Sophia or @canentomologist, thus requiring additional clicks and applications, it's likely the response rate would have atrophied. While it's impossible to track how many of the 467 *Profile Clicks* recorded from the initial tweet (Table 1) translated to Direct Messages, it seems reasonable to assume that the ability to send messages quickly within the app while still emotionally engaged was an important contributor to the response.

In addition to measuring the numbers of Direct Messages, it is also worth examining the emotional tone of the messages received. The majority of Direct Messages received (93%) included a personal message or story to be passed to Sophia in addition to the user's contact information. All Direct Messages that included more than contact information had a positive, inspirational, or encouraging tone (Fig. 3), and together, Direct Messages resulted in a 6,000-word, 25-page document when collated.

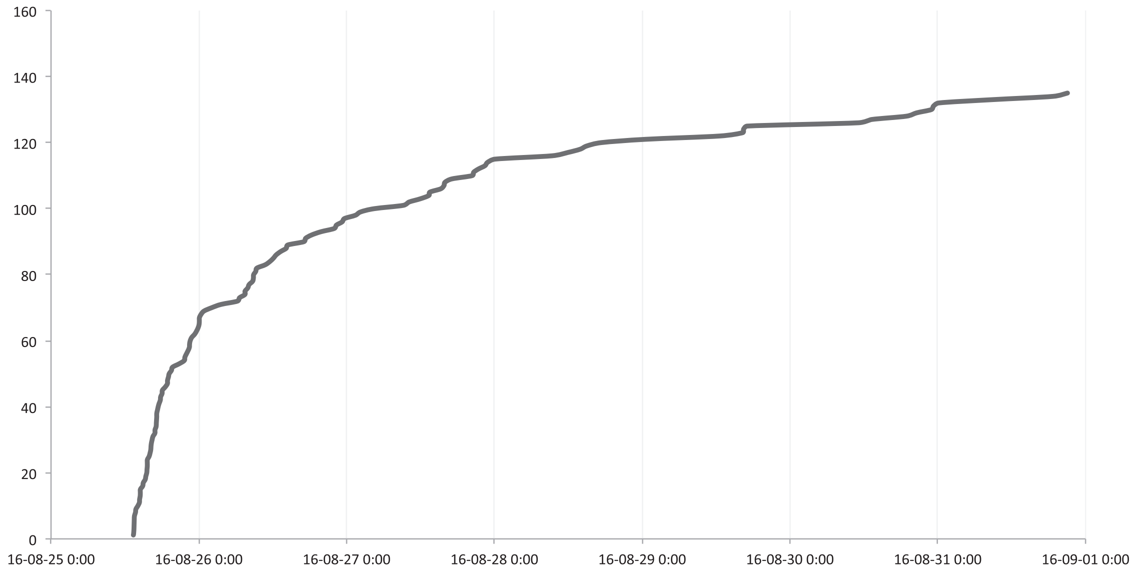

Fig. 2. Accumulation curve of Twitter users sending Direct Messages to @canentomologist in response to initial #BugsR4Girls tweet. Times are EDT (UTC -4).

Fig. 3. Word cloud of 150 most frequently used words in Direct Messages to @canentomologist in response to initial #BugsR4Girls tweet, created with wordle.net. Word size is proportional to occurrence frequency; maximum occurrences = 63 (1 word, "love"), minimum occurrences = 3 (56 words, including "species"; not all displayed). All identifying information was removed prior to analysis, and common English words, "e-mail," and "Hi" were excluded.

Engagement Outside of Twitter

While the initial #BugsR4Girls tweet was widely shared and engaged with within Twitter, less than one quarter of adult internet users have an active Twitter account (Greenwood et al. 2016). This means any given tweet will only ever be seen by a small fraction of the population. However, Twitter content that draws unusually high engagement is often featured in other media, introducing the hashtag or tweet to unconnected communities, an important factor in predicting how widespread or viral a message will become on social media (Weng et al. 2013). In the case of the initial #BugsR4Girls tweet, not only were individuals inspired to publish personal replies to Sophia's story (Thomas 2016), reporters for major digital and print publications also picked up the story: Buzzfeed covered the story the day after the initial #BugsR4Girls tweet was published (Daro 2016), while the London Free Press (Van Brenk 2016a), National Post (Van Brenk 2016b), UpWorthy (Hirschlag 2016), The Mary Sue (Lachenal 2016), Metro UK (Lynch 2016), The Today Show (Peters 2016), Daily Mail (Siebert 2016), The Toronto Star (Vendeville 2016) and several other outlets published stories online, with both the London Free Press and The Toronto Star also publishing their stories on the front page of their daily print editions. This exposure outside of Twitter subsequently resulted in 266 tweets with the hashtag #BugsR4Girls (24% of all #BugsR4Girls tweets) being shared expressly to promote articles about Sophia, in addition to hundreds of shares and likes on Facebook and other social media networks. The news organizations that reported on Sophia's story share a digital audience of >250 million monthly unique users combined (Supplementary data), while the two newspapers that printed stories about Sophia have a combined weekday circulation of >350,000 copies (Newspapers Canada 2015). Taken in full, it's not unreasonable to conclude the Entomological Society of Canada's initial tweet, the #BugsR4Girls hashtag, and Sophia's story reached upwards of a million people in some form or another through these outside sources.

Outcomes and Benefits of High-Engagement Tweets

While social media engagement and other analytics are easily cited, the real-world implications of these statistics are more difficult to contextualize, particularly for a scientific society. How does a tweet and hashtag with unusually high engagement benefit the membership of that society, either directly or indirectly?

The most commonly cited benefit of social media use by scientific societies is with respect to conferences. Many scientific conferences now promote unique hashtags to help members and attendees contribute to a common conversation about the conference. "Live-tweeting" of a conference (where attendees share short synopses or anecdotes from presentations or posters) can expand the audience for any given presentation well beyond the conference room, providing a megaphone for attendees, who are presumably also members of the hosting society. Shiffman (2012) found that even a single prolific Twitter user in attendance could dramatically increase the digital audience of a conference, helping create greater conversations about the data and information being presented. These conversations are not limited to those in attendance either; Parsons et al. (2014) report that tweets about the Society for Conservation Biology Marine Section conference were overwhelmingly from people not physically attending the meeting, but rather participating from afar via social media. These remote interactions can be likened to the backchannel discussions that occur in hallways or over coffee at conferences, and can allow society members unable to attend in person to still engage with their peers over new research, with the additional benefit of these conversations being publically available and citable. However, scientific conferences are finite events, usually taking place over a matter of days. Scientific societies can better serve their membership by engaging throughout the year with social media, helping to build a platform that can be capitalized on for member promotion during flagship events such as conferences. While regular postings and community engagement are important for day-to-day maintenance of scientific society social media accounts, high engagement content that leads to increased followers (Table 2) can provide added exposure and outreach potential for members attending hosted conferences.

Social media influence and engagement is also being found to affect peer-reviewed publication metrics and citations. Liang et al. (2014) found academics who interacted with journalists and were mentioned frequently on Twitter had higher *h*-indexes, while Eysenbach (2011) found the number of tweets linking to journal articles could predict citation rates, although Peoples et al. (2016) concluded that while tweeting about ecology papers was less influential to their citation rate than the journal's impact factor, papers published in less impactful journals could become more highly cited when tweeted about. Could we expect to see similar effects on citation rates and impact factor for journals associated with Twitter-savvy scientific societies? More research is necessary, but if bibliometrics at the journal level are as influenced by social media as they are at the individual paper level, scientific societies can better serve their members through improved social media usage, including investing in the creation and propagation of highly engaging content.

Finally, social media content that is strongly engaged with has the potential to bring scientists and other members of the public together via social movements driven in part by social media hashtags. Recent examples include #dresslikeawoman, a response to sexist remarks made by President Donald Trump regarding his thoughts on how female White House staffers should dress (Nathoo 2017), and #actuallivingscientist, where scientists introduced themselves to other social media users with the goal of increasing the proportion of adults who can name a living scientist (Becker 2017). Like #BugsR4Girls, contributions by scientists to hashtags help make scientists relatable, and more reliable in the eyes of the public (Matheson 2017). At a time when public distrust of science, including over entomologically relevant topics such as the safety of pesticide use in food crops, can result in opinion trumping fact (Funk et al. 2015), demonstrating that scientists are caring, compassionate humans can help mend these divisions (Fiske and Dupree 2014). At least 70 tweets contributed to #BugsR4Girls, as well as many replies to the original tweet that lacked the hashtag, included some form of positive emotion regarding the entomological community's support of Sophia. People were inspired by the support from scientists, thanked @canentomologist and others for their kindness, and expressed feeling positive emotions regarding the hashtag and tweets it collected. Meanwhile, headlines spoke of "Cool scientists" (Hirschlag 2016), and informed the world that not only do "Entomologists swoop in on the wings of empathy" (Vendeville 2016), but that "Insect experts swarm to bullied bug girl's defence" (Van Brenk 2016a). While politicians were riding waves of bad press and anti-science divisiveness into positions of political leadership, entomologists were lauded for their positivity, inclusiveness, and passion for community, science, and equality. These cultural benefits may seem less acutely applicable to the membership of a scientific society, but members of the Entomological Society of Canada should feel pride in their society's involvement with this story, and given time and continuing outreach from entomological and other scientific societies, perhaps will find themselves within a public and political environment where science and those who undertake it are more greatly valued, funded, and consulted.

Table 2. Account-level analytical data for @canentomologist obtained from twitter.com on January 2, 2017

Month	Tweets	Profile visits	Mentions	New followers
May 2016	4	273	40	0
June 2016	4	157	25	0
July 2016	1	222	20	38
Aug. 2016	17	8,916	362	301
Sept. 2016	23	2,967	91	106
Oct. 2016	7	538	38	47
Nov. 2016	1	259	8	23
Dec. 2016	5	438	14	47

Outcomes and Benefits for Sophia, in Her Own Words

My favorite bugs are snails, slugs, and caterpillars, but my favorite one of all is grasshoppers. Last year in the fall I had a best bug friend and his name was Hoppers. When I first found Hoppers, I was kind of scared because that was the first time I held a grasshopper. When I grabbed him, he peed on me, and I thought he had bit me and that was my blood, so I flinged him and he landed somewhere on the stairs, but I found him and I was still a little bit scared, but I realized the he still liked me, like that was just a way to see if I was going to hurt him! I'd find him on the porch, or on the roof of my bug cage, or the side and it'd be really funny. And then I'd give him a little drop of water, which was really cool. I really like being a bug expert, but a lot of kids at school, they're killing grasshoppers, especially the big kids at my old school.

After my mom sent the message and showed me all the responses, I was happy. I felt like I was famous. Because I was! It felt good to have so many people support me, and it was cool to see other girls and grown-ups studying bugs. It made me feel like I could do it too, and I definitely, definitely, definitely want to study bugs when I grow up, probably grasshoppers. Not a lot of kids believe I have pen-pals and that I have friends and they're in different parts of the world, I know they don't believe that, and I don't think they believe me that I was famous, but I was, and I made friends with a lot of people! My mom says I'm back to being my funny old self with

my confidence after seeing all the girls who like bugs. And now I have a microscope somebody sent to me, and when I bring it to school, the kids in my school, whenever they find a bug they come and tell me and say "Sophia, Sophia, we found a bug!" After I was famous, sometimes people in my town would come up and say "Hi, you're Sophia the Bug Girl!" and it makes me feel good, even if I'm not supposed to talk to them because they're strangers. My grandpa saved all of the articles about me too, and said he was proud.

If somebody said bugs weren't for girls, I would be really mad at them, but I wouldn't do anything, I would just not talk to them. I think anything can be for anybody, including bugs. Plus, not a lot of kids at school like bugs, but they think they're a little cool. I told my best friend and her sister about bugs, and now they think they're cool, and her sister will pick up any bug! I think other girls who saw my story would like to study bugs too.

Did the Outcomes Satisfy the Objectives?

The initial #BugsR4Girls tweet was created with three objectives in mind: find an entomologist willing to communicate directly with Sophia; normalize and increase visibility of women in entomology; and create a resource to encourage girls and women to embrace their entomological interests. With 135 private messages and offers to talk to Sophia about insects and entomology from a wide spectrum of entomologists and insect enthusiasts, an overwhelmingly high number of which were from women, it's clear that the first objective was met. Assessing the status of the remaining objectives is more difficult, but we feel confident that the response to the initial tweet and subsequent coverage of it by media outlets represents a positive outcome for the visibility of women in entomology, and served as a positive influence for encouraging girls' and women's interest in entomology. Contributors to the #BugsR4Girls hashtag were predominantly women, and the majority of contributions to the hashtag were in support of women in entomology. Additionally, media outlets covering Sophia's story and #BugsR4Girls more frequently quoted female entomologists (either directly or via their tweets) than male scientists, further increasing the visibility and influence of women entomologists.

The importance of this visibility and support for women in entomology, and science more broadly, is paramount. Women are proportionately underrepresented in positions of authority in academia, with women representing only 25% of tenured professors and 43% of tenure track professors in biological and life sciences (NSF 2013), with similarly skewed ratios on editorial boards of biological science journals (Cho et al. 2014), and as authors of the articles therein (Martin 2012). This despite the fact that in 2014, 59% of life science Bachelor's degrees (NSF 2015a), 57% of Master's degrees (NSF 2015b), and 53% of Doctorate degrees (NSF 2015c) were awarded to women in the USA. This imbalance in gender ratios within academia may continue to exacerbate inequality as the importance of female role models and mentors throughout a female student's education is repeatedly shown to increase interest in science as a viable career (Baker and Leary 1995, Buck et al. 2002, Gunter 2013, Dennehy and Dasgupta 2017). Interestingly, social media may represent an opportunity for female scientists to serve as defacto, digital role models for girls and women interested in science: Ke et al. (2017) found women scientists are better represented on Twitter than they are as authors in the scientific literature (albeit still outnumbered nearly two to one by male scientists on Twitter), and with a quarter of internet using women maintaining Twitter accounts, and an even larger proportion of women aged 18-29 (Greenwood et al. 2016), the opportunity for female scientists to reach and influence other women directly via social media may represent a novel and revolutionary opportunity to inspire future generations of women to pursue a career in science. However, the barriers women in science continue to face and which they are forced to overcome to simply remain in science, never mind succeed, are more numerous and complicated than a lack of role models (Clancy et al. 2014, Smith et al. 2015, Howe-Walsh and Turnbull 2016), and the entomological and broader scientific communities must continue to work toward dismantling these barriers quickly and entirely. Social media has and will hopefully continue to play an important role in this progress in at least some small part thanks to social movements that succeed in engaging scientists, their societies, and the broader public.

Increasing Engagement on Twitter

While very few tweets will result in thousands, or even hundreds, of retweets and likes, regularly creating content that encourages engagement will help any Twitter user, whether an individual researcher, an institution, or a scientific society, find and connect with an audience online. Bik and Goldstein (2013), Bik et al. (2015), and Wolf (2017) provide broad advice for science communication via social media, while Guo and Saxton (2014) discuss the use of social media by nonprofit organizations for advocacy that can be adapted by scientific societies. Here we present five additional recommendations for maximizing engagement with scientific content on Twitter, informed by the #BugsR4Girls experience:

1. *Be the engagement you wish to see* may sound like a poor take on a common idiom, but it is also a sound strategy for increasing engagement with your content. Interacting with other users will help you find and build communities who will in turn engage with you; retweet and promote others' ideas and work, while regularly striking up conversation with your followers. #BugsR4Girls was wholly dependent on a mutually engaged community that would engage with the tweet and its objectives. A Twitter feed that only features one voice endlessly shouting out links or information about themselves isn't something many people will want to follow, but a feed that incorporates diverse voices from others within the community will attract users and engagement like a moth to a mercury vapor lamp.

2. *Give your audience something they can use*, but make sure it's what they expect from you. Followers of science museums engage more with educational tweets than marketing tweets (Baker 2016), while followers of public health organizations engage more with personal health advice than organizational news (Park et al. 2016). Tweets that could serve as icebreakers at a cocktail party are more likely to be engaged with by your followers, and will help build your reputation on Twitter as the place to go for interesting information about your expertise. It may be as specific as fly taxonomy, or as broad as agricultural pest management, but learning to package interesting or useful information about your expertise into small, tweet-sized snippets will get other users talking about you.

3. *Experiment* with how you package your information, and don't be afraid to try out new tricks. Hashtags, memes, internet slang (used correctly or ironically, but never incorrectly), GIFs and emoji can all help bring greater attention and engagement to your content. Describe your research using only emoji (Murphy 2017), or start a game of #BestCarcass (Klein 2017) with your followers and see what happens; if it doesn't work and no one seems interested, tweak your materials and methods until they give you the results you're looking for.

4. *Collaborate* with your peers, and encourage them to join you. Tag other users who you have a Twitter relationship with and who have a slightly larger audience than you (i.e., don't tag Neil DeGrasse Tyson and expect to be noticed among his 6.7 million followers), and invite them to join in your hashtag, or ask for help amplifying a particular message you feel is important. #BugsR4Girls relied on this step-up amplification in the beginning, with several followers (including the lead author) using their personal accounts with larger follower numbers to share the initial tweet and hashtag several times during the first day. Likewise, if another user tags you to join in their campaign, use the opportunity to pay back the favor. Unsurprisingly, Axelrod's Tit for Tat stratagem (Axelrod 1984) remains good advice when it comes to collaborative social media: be nice, be provocable, don't be envious, and don't be too clever.

5. *Invest* in your content's success, both by regularly practicing your ability to create engaging content, and by committing to content that your audience engages with. The first hashtag or campaign you attempt on Twitter is not likely to become a social media phenomenon, but by honing your skills through practice, you'll be more likely to catch the attention of a wider audience. However, when you do catch it, be prepared to invest time in maintaining that audience. During the events detailed in this paper, several hours were spent cultivating engagement through strategic retweeting and user engagement until the tweet and hashtag became self-sustaining, in addition to several days spent collating and responding to direct messages for Sophia and corresponding with journalists. Most investment of this kind will only be needed for a few days as conversations and attention spans move on, but these small bursts of dedicated time can help you accomplish your goals when presented with an opportunity.

In conclusion, rarely are entomologists provided a stage with an audience of a million people, yet when offered one, it's clear they can use it to make a positive impact. By encouraging a young girl's love for insects and entomology through an outpouring of community support made possible via social media, entomologists and insect enthusiasts not only made a difference in the life of that one girl, but spread their influence and enthusiasm across the globe and into the homes of hundreds of people who may have felt similarly alone or ostracized. It's impossible to know or predict the long-term effects this tweet, the hashtag, or the resulting network of social media-mobilized insect enthusiasts will have on entomology, but in the present, we can appreciate and take pride in the fact that when asked what was happening, we responded as one to engage with the world about our love for insects.

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