



Using Twitter to communicate conservation science from a professional conference

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Abstract: Scientists are increasingly using Twitter as a tool for communicating science. Twitter can promote scholarly discussion, disseminate research rapidly, and extend and diversify the scope of audiences reached. However, scientists also caution that if Twitter does not accurately convey science due to the inherent brevity of this media, misinformation could cascade quickly through social media. Data on whether Twitter effectively communicates conservation science and the types of user groups receiving these tweets are lacking. To address these knowledge gaps, we examined live tweeting as a means of communicating conservation science at the 2013 International Congress for Conservation Biology (ICCB). We quantified and compared the user groups sending and reading live tweets. We also surveyed presenters to determine their intended audiences, which we compared with the actual audiences reached through live tweeting. We also asked presenters how effectively tweets conveyed their research findings. Twitter reached 14 more professional audience categories relative to those attending and live tweeting at ICCB. However, the groups often reached through live tweeting were not the presenters' intended audiences. Policy makers and government and non-governmental organizations were rarely reached (0%, 4%, and 6% of audience, respectively), despite the intent of the presenters. Plenary talks were tweeted about 6.9 times more than all other oral or poster presentations combined. Over half the presenters believed the tweets about their talks were effective. Ineffective tweets were perceived as vague or missing the presenters' main message. We recommend that presenters who want their science to be communicated accurately and broadly through Twitter should provide Twitter-friendly summaries that incorporate relevant hashtags and usernames. Our results suggest that Twitter can be used to effectively communicate speakers' findings to diverse audiences beyond conference walls.

Keywords: ICCB 2013, live tweeting, science communication, scientific societies, social media, Society for Conservation Biology

El Uso de Twitter como Comunicador de la Ciencia de la Conservación desde una Conferencia Profesional

Resumen: Los científicos cada vez usan más Twitter como una herramienta de comunicación de la ciencia. Twitter puede promover las discusiones académicas, difundir la investigación rápidamente y extender y diversificar la gama de público que se alcanza. Sin embargo, los científicos también advierten que si Twitter no expresa acertadamente a la ciencia debido a la brevedad intrínseca de este medio, la desinformación podría extenderse rápidamente a través de las redes sociales. La información sobre si Twitter comunica efectivamente la ciencia de la conservación y los tipos de grupos de usuarios que reciben estos tuits es escasa. Para dirigirnos a estos vacíos de información, examinamos el tuiteo en vivo como un medio de comunicar la ciencia de la conservación durante el Congreso Internacional de la Biología de la Conservación 2013 (ICCB). Cuantificamos y comparamos los grupos de usuarios que enviaban y leían los tuits en vivo. También sondeamos a los presentadores para determinar su público planeado, el cual comparamos con el público actual que se consiguió por medio del tuiteo en vivo. También les preguntamos a los presentadores cuán efectivamente los tuits expresaron los descubrimientos de sus investigaciones. Twitter alcanzó 14 categorías más profesionales de público en relación con aquellos que estaban presentes y los que tuiteaban en vivo en la ICCB. Sin embargo, los grupos que con frecuencia se conseguían por medio del tuiteo en vivo no

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pertenecían al público planeado de los presentadores. Rara vez se atrajo a quienes elaboran las políticas y a las organizaciones gubernamentales y no-gubernamentales (0%, 4% y 6% del público, respectivamente), a pesar de la intención de los presentadores. Las charlas plenarias se tuitearon aproximadamente 6.9 veces más que todas las demás presentaciones orales o de carteles combinadas. Más de la mitad de los presentadores creyeron que los tuits sobre sus charlas fueron efectivos. Los tuits no efectivos fueron percibidos como vagos o carentes del mensaje principal del presentador. Recomendamos que los presentadores que quieran que su ciencia sea comunicada correctamente y de manera general por medio de Twitter deben proporcionar resúmenes compatibles con Twitter que incorporen hashtags y nombres de usuarios relevantes. Nuestros resultados sugieren que Twitter puede usarse para comunicar efectivamente los hallazgos de los presentadores a un público diverso más allá de los muros de la conferencia.

Palabras Clave: comunicación de la ciencia, ICCB 2013, redes sociales, sociedades científicas, Sociedad para la Biología de la Conservación, tuiteo en vivo

Introduction

Interest in Twitter as a tool for communicating science is gaining momentum globally (Darling et al. 2013; You 2014). As a free platform that is often accessed via mobile devices, Twitter disseminates information rapidly and broadly to diverse audiences, including policy makers, the media, and the general public (e.g., Shiffman 2012; Winkless 2013; Ferguson et al. 2014). As of January 2015, Twitter had over 284 million monthly users, an estimated 77% of whom are outside the United States (Duggan & Smith 2013; Twitter 2014), and was reaching a variety of socio-economic groups and age classes (Duggan & Smith 2013; Twitter 2014). Given Twitter's global reach, a well-constructed tweet has the potential to reach an audience well beyond the scientific community. Twitter could thus overcome the limitations of more traditional means of communicating science, such as journal articles and conference presentations (Shiffman 2012; Ferguson et al. 2014).

Twitter is already being used as a tool to promote scholarly discussion and debate (Darling et al. 2013; Ferguson et al. 2014). Numerous scientists actively use Twitter for public engagement and outreach, most academic universities have their own Twitter account, and most major conferences have their own hashtags (Winkless 2013; Parsons et al. 2014; You 2014). Darling et al. (2013) found that a diverse group of academic, government, and non-governmental organization (NGO) scientists, students, and journalists use Twitter to discuss conservation science topics.

The increasing frequency of Twitter use in the scientific community, however, has raised concerns that Twitter may be an imperfect outlet for science communication. Some scientists worry that 140 characters prohibits the effective communication of complex scientific concepts and that misinterpreted tweets could be particularly detrimental to the time-sensitive and political nature of some conservation issues (Brossard 2013). Other scientists suggest that important individual tweets

often fall short of reaching people in positions to make key conservation decisions. These scientists argue that Twitter remains relatively ineffective in changing conservation policy and practice and is over-popularized by some scientists (Hall 2014; You 2014). Finally, the metric used to evaluate the number of people reached through Twitter is usually based on the total number of followers, rather than the identity of those individuals (Shiffman 2012; Darling et al. 2013; Ferguson et al. 2014). The lack of data on whether Twitter effectively communicates conservation science and the limited information on user groups receiving these tweets inhibits rigorous assessment of whether and how Twitter can help link research and action.

To address these knowledge gaps, we examined live tweeting (Fig. 1) as a means of communicating scientific findings at the 2013 International Congress for Conservation Biology (ICCB) in Baltimore, Maryland (U.S.A.), in July 2013. We quantified and compared the user groups sending and reading live tweets and used surveys to examine presenters' opinions on how effectively tweets conveyed their research and the extent to which tweets reached their intended audiences (refer to Table 1 for a glossary of terms). The goal of ICCB—a biennial international meeting hosted by the Society for Conservation Biology—is to address conservation challenges by presenting new research and developments in conservation science and practice. Participants are predominantly conservation scientists and practitioners from academic institutions, government agencies, and non-governmental organizations.

To determine whether Twitter's potential to communicate conservation science is being met through live tweeting at conferences, we posed the following questions: Which user groups were reached through conference live tweeting? How did these user groups compare with the intended audiences of the presenters? Did presenters at ICCB 2013 believe their research was conveyed effectively through Twitter, and what were the most common reasons for perceived lack of clarity or accuracy?

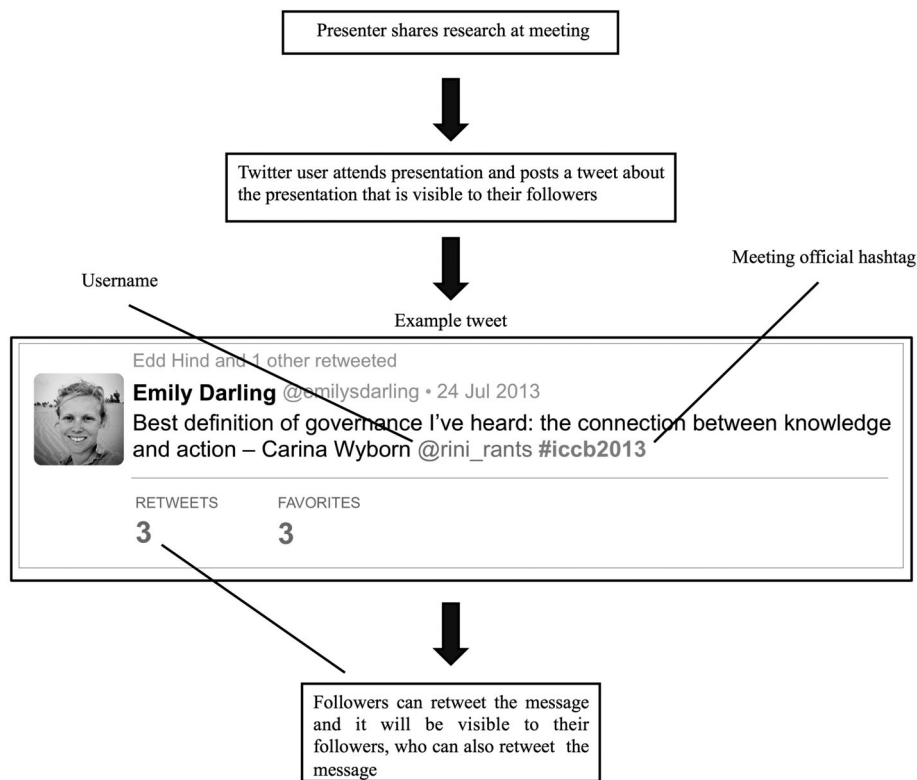


Figure 1. The flow of information from the presenter to the live tweeter to the retweeters to their followers from a tweet about a presentation at the International Congress for Conservation Biology 2013.

Methods

Data Collection

The 2013 ICCB had over 1500 attendees (Parsons et al. 2014). We selected this meeting to address our research questions because the participants and research topics were international in scope, Twitter was widely used by participants (Parsons et al. 2014), and the official conference hashtag (#ICCB2013) was well promoted and is readily searchable with the Twitter search tool.

To identify the audiences being reached by conference live tweeting, we used the search tool in Twitter to compile all tweets that included #ICCB2013. We included all tweets that used this hashtag in our data set except tweets that were not directly relevant to presentations given at the conference (e.g., messages about social gatherings); tweets that could not be clearly assigned to a presentation given at the conference; and messages tweeted by presenters promoting their upcoming talks.

We collected publicly available information related to each tweet and retweet through Twitter user profiles and other internet sources. Specifically, we recorded information on the tweet (full text of tweet, date tweeted, and number of retweets); the tweeters and retweeters (name, professional position or organization type, professional affiliation, location, and number of followers); and the presenters (name, presentation title, presentation type [e.g., plenary, symposium, oral session], professional position or organization type, and professional

affiliation) (Supporting Information). When professional positions and professional affiliations were not explicitly stated in Twitter user profiles, we acquired this information from the most recent internet source related to the individual's professional status (e.g., LinkedIn, professional webpages). We categorized professional positions, professional affiliations, and locations that could not be clearly identified from any source (e.g., users with pseudonyms) as unknown.

Identifying User Groups and Characterizing the Audience

To determine and analyze professional positions or organization types for each Twitter user, we created a list of all potential professional positions and organization types that we could identify in the data set (Supporting Information). We then classified each user into these categories based on the most current position that we could identify using publicly available data from internet searches.

We used the tweet and Twitter user data set to identify and characterize the audience reached through conference live tweeting. We defined the audience as all of the retweeters in our data set. We considered retweeters rather than the total number of followers to represent the Twitter audience because we assumed a retweeter viewed the original tweet in order to pass on the message as a retweet. In contrast, it seems likely that most Twitter followers are not reading every tweet that

Table 1. Glossary of Twitter terms

<i>Term</i>	<i>Definition</i>
Twitter	a free social media platform used to share messages with 140 characters or less
Tweet	a message including up to 140 characters of text that may also contain photos, videos, or links to websites
Live tweeting	when a Twitter user tweets information from an event (e.g., scientific conference) in real time
Retweet	a tweet that is forwarded; often used to pass along tweets of interest through Twitter; always retain original author attribution
Twitter user	a person or organization that uses Twitter and has a username
Tweeter	a Twitter user who creates and sends a tweet
Retweeter	a Twitter user who retweets an original tweet
Username	also known as a Twitter handle; how Twitter users are identified on Twitter; always preceded immediately by the @ symbol (e.g., @charlesdarwin)
Hashtag	a word or phrase immediately preceded by #; a word with a hashtag becomes a keyword or topic that is searchable through the Twitter search tool (e.g., #ICCB2013)
Follower	a Twitter user who has chosen to follow a username and receive tweets from that username in their Twitter feed
Feed	a real-time stream of tweets from followers
Profile	a short bio of a Twitter user (interests, location, etc.) and all tweets they have posted

appears in their Twitter feed. Parsons et al. (2014) found that approximately 90% of the Twitter users that used the hashtag #ICCB2013 did not attend this conference; therefore, we assumed most retweeters were not physically present during the oral presentation that was the subject of their retweets. We used data on tweeters and retweeters to calculate and compare percentages of different professional positions or organization types and tweets per session type (i.e., symposium, workshop, oral session, award speech, speed session, exhibitor booth, poster, and plenary). Because one science-related presentation was given at an exhibitor's booth, we considered the sponsors and exhibitors to be a session in our data collection. Because there was a large disparity in the number of presentations within different session types (e.g., 6 plenary talks vs. 400 oral session presentations), we adjusted the frequency of tweets per session type to account for the total number of presentations in each session type.

During the intended and actual audience classification process, we identified 30 retweeters who were research scientists, program directors, or administrators (hereafter administrators). These individuals worked for

organizations that were also considered audience categories (e.g., NGOs); therefore, they could simultaneously represent 2 different audience categories (e.g., research scientist and NGOs). Due to the nested nature of this classification, we chose post hoc to include in our data set both the research scientists or administrators and the organizations they worked for. We identified organizations for 9 program administrators and 16 research scientists. As a result, the audience-reached categories for academia, NGOs, professional societies, and the private sector were 8%, 2%, 1%, and 1% higher, respectively, than if we had listed the research scientists and administrators independent of the organizations they worked for in our intended audience data set.

Survey Methods

We emailed a survey (Supporting Information), along with a brief definition of Twitter, to each presenter who had his or her research shared via live tweeting and for whom we could obtain contact information. We sent a follow up reminder to all non-respondents within 2 weeks of initially sending the first survey. We sent the survey again to all non-respondents within 4–6 weeks of the initial survey. The survey included their presentation title and a randomly selected tweet about their presentation. We asked the presenters to identify 3 categories of audiences that they wanted to reach with their presentation. The original list of audience categories (Supporting Information) was pooled into the following categories: academia, policy makers, government agencies, NGOs, media, research scientists, resource managers, K-12 education, private sector, and professional societies. Using these pooled categories, we compared the percentage of actual audience types reached through conference live tweeting (obtained from our audience data set) to the percentage of presenters' intended audience choices. We included all three audience choices for each presenter. To assess demographic bias in survey responses, we used a Fisher's exact test to determine whether the responses differed significantly by gender, age, or social media use.

We also asked each presenter to categorize the tweet as very ineffective, moderately ineffective, fair, moderately effective, or very effective. By *effective* we mean how well the tweet conveyed the presenter's intended message. If the presenter chose anything other than very effective, we asked them to describe why it was not very effective. We asked presenters to provide a written response or to select one or more of the following explanations: the tweet included an inaccuracy about my research, the tweet misinterpreted my research, the tweet did not convey the main point of my talk, the tweet did not mention the results of my research, the tweet was too vague, the tweet had spelling or grammatical errors that obscured the message, the tweet did not include a

link to further information about my research. We used these data to calculate and compare the percentage of different responses in each category.

Results

We compiled 774 tweets about ICCB presentations from 96 unique usernames and 1711 retweets from 421 unique usernames. Ninety-two percent of tweets about ICCB presentations came from Twitter users with at least 100 followers. The mean number of followers of tweeters and retweeters was 2404 (SE 1218; median 371) and 1191 (SE 167; median 385), respectively. Nearly 40% of the tweets in our data set were from users with over 10000 Twitter followers. Of that 40%, all but 2 of these tweets were generated by a single, highly active individual. All tweets originated from the conference location; however, retweeters spanned a diverse geographic area. Retweeters were primarily individuals in North America (79%), including users from 34 U.S. states and 5 Canadian provinces, but 40 different countries were represented.

Session Types

Fifty-two percent of retweets were about symposium presentations. The oral sessions and plenary talks were also frequently retweeted (22% and 18%, respectively), and workshops generated about 4% of all retweets. The remaining session types (speed sessions, posters, award speeches, exhibitor booths) each accounted for < 1% of retweets. Some retweets could not be associated with a session type (2%) or pertained to multiple session types (<1%). Plenary talks ($n = 6$) were by far the most influential, each inspiring about 52 retweets/talk on average. Symposiums ($n = 315$) and workshops ($n = 25$) generated an average of 2.8 and 2.5 retweets per session, respectively. In contrast, the mean rates for other session types were all <1 retweet/session (Fig. 2).

User Groups and Affiliations

Individuals in academia were responsible for 67% of the tweets, the majority of which were from graduate students (50%). Research scientists and program administrators were also represented, producing 11% and 9% of total tweets, respectively (Supporting Information). Media sources (i.e., journalists, bloggers, news and media, and websites) were responsible for about 5% of all conference tweets.

Most retweets also came from individuals in academia (44%), a group composed mainly of graduate students (23%) and professors (16%) (Supporting Information). Media sources (19%), research scientists (10%), and program administrators (5%) were also well-represented in retweets. Retweets sent by NGOs, teachers, members

of the general public, and resource managers each accounted for about 2% of all retweets, whereas the private sector comprised 1% (Supporting Information). Other professionals contributed 5% of all retweets, while an additional 2% of retweets were generated by other types of organizations, such as professional societies and scientific journals. We could not reliably assign the remaining 8% of retweets to a particular profession or organization.

Intended and Actual Audiences Reached

Of the 142 presenters that were sent surveys, 59 individuals (42%) completed and returned the survey. Of all respondents, 42% were female, and 58% were male, which was roughly equivalent to the presenters that were contacted (39% female, 61% male). Respondents between the ages of 20–40 comprised 42% of the total, 48% were between the ages of 40–60, and 10% were over the age of 60. Survey respondents reported a range of familiarity with social media. Nineteen percent had never used any form of social media to communicate their research, 81% communicated their research at least once per year on social media platforms, and 31% did so at least once per week. Our tests of whether survey responses varied with self-reported age, gender, and social media use of respondents indicated no significant differences (Fisher's exact test, $p = 0.644$, 0.522 , and 0.946 respectively). Therefore, we pooled survey responses and analyzed them as a group. Six survey respondents did not provide information to link their responses to the original tweet, so we were unable to compare the intended and actual audience groups reached for these presenters.

Survey respondents selected three audience groups they wanted to reach with their presentation (Fig. 3). Academia was listed most frequently (25%), followed by government agencies (22%), policy makers (15%), NGOs (13%), media (8%), research scientists (6%), and members of the public (3%). The groups K-12 education, members of the private sector, professional societies, scientific journals, zoos and aquaria, program administrators, political interest groups, and other professionals were selected least frequently, and each made up <3% of the respondents' choices.

The organizations and individuals that retweeted the live tweets from the conference were notably different from the audience that presenters indicated they would like to reach with their presentation (Fig. 3). Academia was reached almost twice as much as intended and made up 41% of the actual audience reached by the tweets. Government agencies were reached less than one-fourth as much as intended and made up 4% of the audience reached by the tweets. There were no policy makers in the actual audience reached by the tweets. Non-governmental organizations were reached a little more than half as much as they were intended and made up 6% of the actual audience reached. Presenters reached

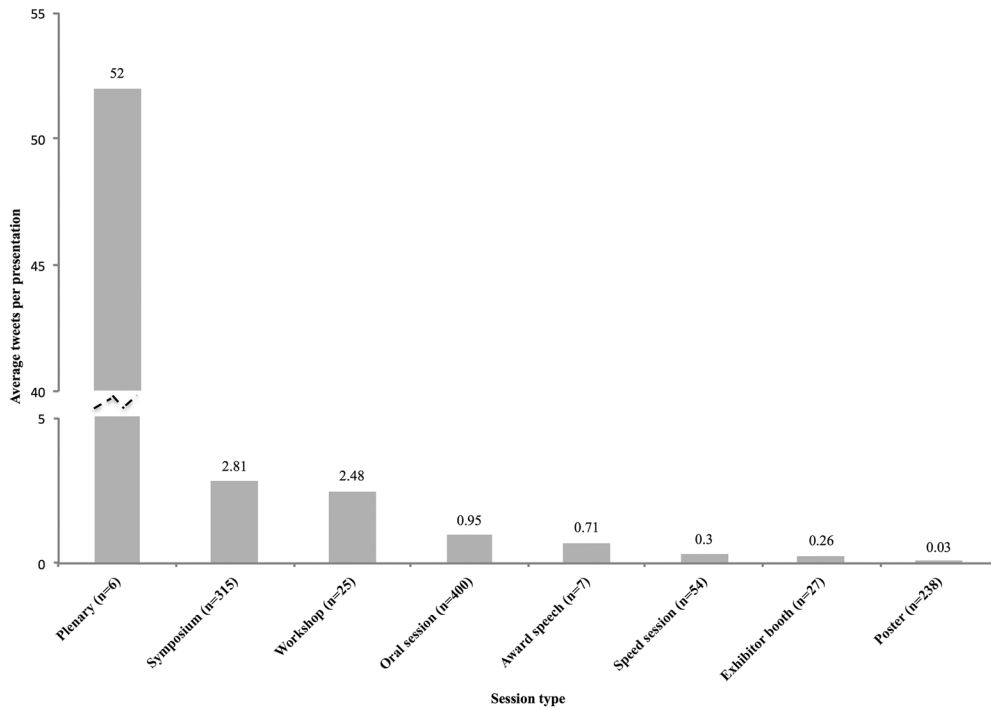


Figure 2. A comparison of live tweeting of session types at the International Congress for Conservation Biology 2013 as measured by the total number of retweets divided by the total number of presentations in a session type. The number of retweets per session type is above each bar and the total number of presentations (n) is below each session type on the x-axis.

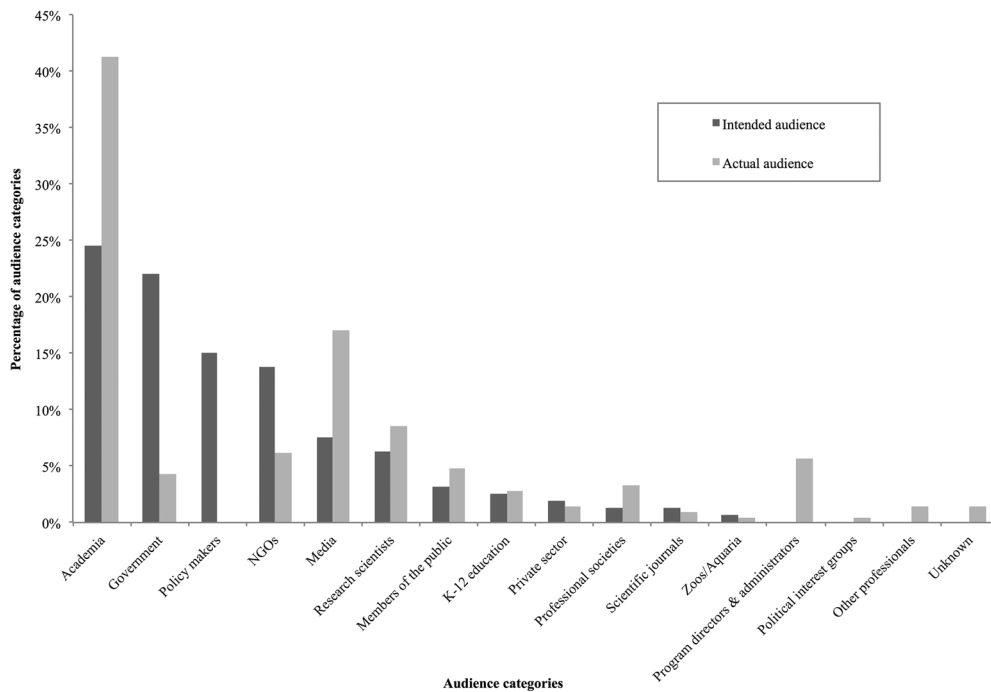


Figure 3. The percentage of audience categories that presenters intended to reach with their research relative to the actual percentage of audience categories reached through live tweeting at the International Congress for Conservation Biology 2013.

members of the media more than twice as frequently as intended; media made up 17% of the actual audience reached. Research scientists were reached slightly more frequently than intended and made up 9% of the actual audience reached. Zoos and aquaria were reached less often than intended and made up 0.5% of the actual audience reached. Members of the public, K-12 education, the private sector, professional societies, scientific journals, program administrators, and political interest groups were reached more frequently than intended, and made up 5%, 3%, 1%, 3%, and 0.5% of the actual audience, respectively.

Tweet Effectiveness

Most tweets were judged favorably by presenters. A majority of respondents (53%) believed the tweet about their presentation was either moderately effective (29%) or very effective (24%) at communicating their intended message. Although 15% of respondents considered the tweet about their presentation to be fair (neither effective nor ineffective), 24% found the tweet to be moderately ineffective, and 9% evaluated the tweet as very ineffective at communicating their intended message.

The most frequent reasons given for ineffectiveness of the tweet were that it did not convey the main point of the talk (40%), was too vague (25%), did not provide a link to another webpage with more information (9%), or did not provide the results of the research (8%) (Fig. 4). Less than 5% of respondents believed the tweet lacked engaging qualities, misinterpreted their research, included an inaccuracy, or had grammatical errors.

Discussion

Our results demonstrated that Twitter effectively conveyed conservation science to a diverse and somewhat unexpected audience beyond the ICCB conference. Although live tweets from ICCB reached a variety of groups, such as the media, educators, and the private sector, tweets rarely reached policy makers, government agencies, or NGOs, despite the intentions of the presenters. Importantly, according to conference presenters, live tweets generally communicated scientific information effectively. As the scientific community discusses how to improve dissemination of science to broad or targeted audiences, our results provide insight into the outcomes of conference live tweeting for conservation practitioners.

The effectiveness of Twitter communication is a major question. Although information can be generated and shared quickly, not all of it is accurate (Aosaki et al. 2010). Additionally, the social nature of Twitter and other online communication tools (e.g., retweets on Twitter or likes on Facebook) has the potential to affect readers' interpretations through social pressure and group

consciousness (Aosaki et al. 2010; Anderson et al. 2014). The ease of access and capability to post unfiltered content also raises concerns about readers' abilities to differentiate between facts and opinions (Brossard 2013). Contrary to these concerns, the majority of our survey respondents (53%) viewed tweets about their conference presentations favorably and described them as moderately or very effective. However, tweets did not always convey messages perfectly; 76% of tweets were categorized as less than very effective. Missing the main point and vagueness were the two most common reasons cited (Fig. 4). These problems may be persistent, perhaps due to the limited number of characters permitted. Conference tweets usually do not occur in isolation, however, and it is possible that the suite of Twitter activity in reference to a particular presentation may help mitigate these shortcomings. Only 3% of presenters said the tweet about their presentation was inaccurate, and only 3% suggested the tweet misinterpreted their research. Presenters may interpret tweets critical of their presentation as inaccurate; however, our data set did not include any tweets that were openly critical. Our findings should help alleviate concerns about whether or not Twitter can accurately convey information about conservation science from a conference. The 44% of tweets that were less than very effective, but not classified as ineffective, may still have value for communicating conservation science messages. These tweets may encourage conversation and debate about conservation topics, increase awareness about current issues, and augment readership of published research (Darling et al. 2013).

An important purported advantage of Twitter is its ability to reach diverse audiences (Twitter 2014). Ideally, the Twitter audiences reached would reflect the intentions of conservation scientists presenting their research, but we found substantial discrepancies between the two (Fig. 3). Members of academia, research scientists, and the media were all reached disproportionately more than intended. Other sought-after audiences such as government agencies, policy makers, and NGOs, were underrepresented. Because many members of these intended audiences have Twitter accounts, there is potential to improve connections with these audiences using Twitter. Many of the well-represented user audiences, such as academia and research scientists, were the same groups doing the majority of the tweeting in our study (Supporting Information). Similarly, underrepresented intended user audiences such as NGOs did not do much live tweeting. These similarities between tweeters and retweeters suggest that Twitter users follow others who share their areas of interest, professions, or opinions. Darling et al. (2013) found comparable results in their analysis of scientists on Twitter, reporting that the majority (55%) of people who follow scientists on Twitter are also scientists. This could explain why we found relatively high levels of

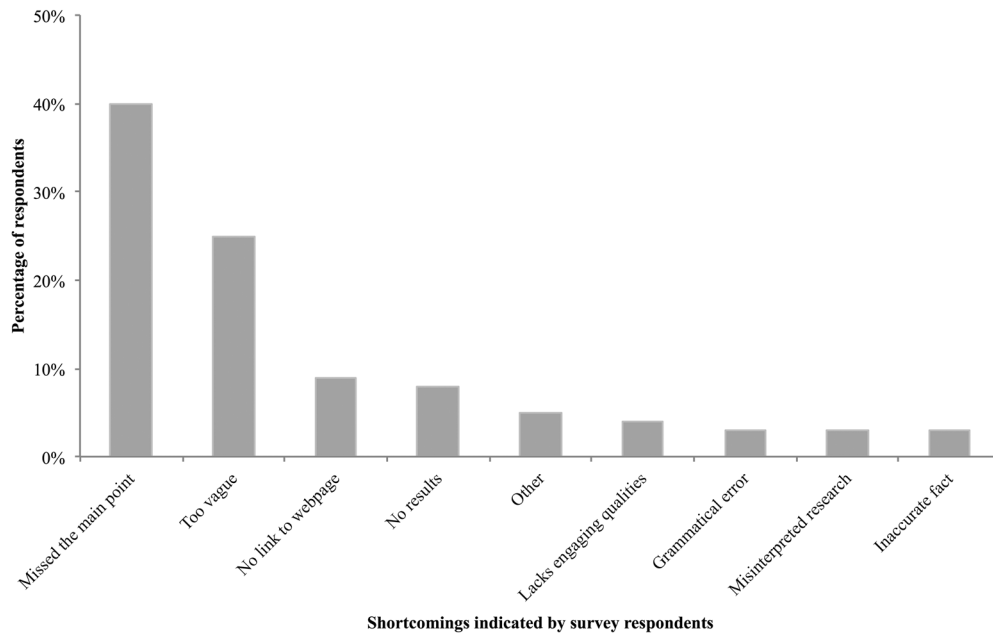


Figure 4. Shortcomings listed by the International Congress for Conservation Biology 2013 presenters that indicated why the randomly selected tweet about their presentation was less than very effective.

similar occupational groups (i.e., academia) retweeting conservation messages (Supporting Information).

One of the strongest advantages of using Twitter in a conference setting is that messages are likely to reach user groups and audiences well beyond the confines of the conference. Our results indicated that the user groups receiving these messages were far more diverse in regard to professional positions relative to those of the original tweeters (Supporting Information). Importantly, the proportion of retweets by news and media affiliates far exceeded the proportion of original tweets from this group. This suggests Twitter is a promising avenue for quickly spreading conservation messages to the public because the media can convey and amplify scientific findings. Other conferences (e.g., 2014 North American Congress for Conservation Biology) have emphasized developing in-person relationships with members of the media to publicize the results of conservation science and to help reporters and writers develop high-quality stories on important topics. Twitter may foster these relationships online and offer an efficient mechanism for connecting remotely. Our results suggest the scientific findings presented at ICCB 2013 were shared far beyond the geographic location of the conference. Twitter users from 40 countries received and retweeted the messages. Over 90% of these messages had the potential to reach at least 100 Twitter users, based on the number of followers. Because most presenters can expect to have only a few dozen people attend their talks (with the exception of plenary talks), live tweeting can reach orders of magnitude more people than those physically present (Shiffman 2012).

Scope of Study

There are several important limitations to our study. During data collection, we were restricted by the public availability of accurate contact information to reach presenters and request participation. However, out of the 155 total presenters who were the subject of tweets, we emailed our survey to 142 (92%) and had a 42% response rate. This response rate is only slightly lower than the average rate for other studies that used surveys to collect data from individuals (Baruch & Holtom 2008). Furthermore, our tweet search strategy included only the official conference hashtag #ICCB2013. Consequently, any relevant tweets or retweets about scientific content at ICCB that lacked the conference hashtag went undetected. Finally, because the rate of tweeting at ICCB conferences has been described as high compared with other academic meetings (Parsons et al. 2014), our results may not be generalizable to other scientific conferences.

Although many followers had the potential to receive conference tweets, we considered a message was read only if it was retweeted. This conservative estimate of the audience ensured high certainty that a follower read a particular tweet. Enthusiastic followers who retweet messages from their favorite users without reading them are an exception. We also acknowledge that many more followers, perhaps from different professional arenas, may have read the message but did not retweet it. Government agencies may only retweet official information relevant to their organization, so our approach may have underestimated how many government agencies were reached. However, we found that research scientists

working for government agencies also rarely retweeted messages (0.06%; Supporting Information), which may indicate that this group was not well-reached overall. Due to cuts in U.S. federal spending, the 2013 ICCB meeting had over 200 fewer federal employees attend than usual (Cigliano 2013), so our results may not be representative of typical government tweet and retweet rates. Last, groups that frequently tweet under pseudonyms would have been categorized as unknown with our approach; thus, tweet and retweet rates of such groups may have been underestimated.

Conferences are just one avenue for communicating science, and disseminating conservation information at a conference may be different from other forms of communication (e.g., scientific journals, webinars). Conference presentations are normally constructed with the audience in mind—they are brief and frequently allow direct interaction with presenters (e.g., during question and answer periods). These unique characteristics of conferences could influence the way live audiences interpret information or share it via Twitter. Moreover, Twitter is one resource in a vast array of social media tools (e.g., Facebook, Reddit, and YouTube) that could be used to communicate conservation science. We predict that there are differences in the effectiveness, composition, and extent of audiences reached by these social media outlets, based on their format requirements and user base. Therefore, we are leery of extrapolating our results and recommendations to all forms of social media. Finally, our study was designed to measure the utility of using Twitter to communicate conservation science beyond those participating in a conference, not whether live tweeting leads to conservation success. Quantifying the extent that Twitter results in conservation action was beyond the scope of this study.

Recommendations

Based on our results and previously published findings, we recommend the following to conservation practitioners who would like to incorporate Twitter in their communication toolbox. First, to overcome the major weaknesses of tweets (vagueness and missed main point) highlighted by presenters, we recommend speakers provide social media statements in footnotes, or as a final slide, during presentations. These stock tweets allow for wide dissemination of a presenter's takeaway message by providing accurate and unambiguous information (Parsons et al. 2014). Presenters and tweeters should remember that well-crafted tweets are concise, use one or two appropriate hashtags, avoid jargon, and provide content beyond the talk title (Parsons et al. 2014). A shortcoming of presenters providing stock tweets is that Twitter is often viewed as a form of self-expression; live tweeters may thus ignore stock tweets that prompt them to communicate specific content under their own username. Second,

we suggest that presenters with Twitter accounts use Twitter tools (e.g., TweetDeck) to schedule automated sharing of their own tweets during their presentation. Third, presenters can facilitate the inclusion of links to websites, if desired, by providing search terms or a simple link that will help the Twitter user locate their work online.

Furthermore, if scientists aim to reach underrepresented groups of Twitter users, they may need to change how they network online. We propose that conservation scientists broaden their following on Twitter by connecting with more diverse groups of people from different disciplines. A direct way to reach out to these groups and extend networks might be to use specific hashtags or incorporate usernames of policy makers or NGOs in stock tweets during presentations. Presenters should also be aware of the most active live tweeters in their field and contact these individuals. Several Twitter users at ICCB 2013 had a large number of followers (>10,000) and were very active (40% of all tweets). Encouraging particularly active tweeters to attend your presentation could expand the reach of your presentation.

Finally, our results also provide several insights for conference organizers. There was a marked disparity in the types of conference sessions that were subject to conference live tweeting. Plenary talks had the most retweets per session (Fig. 2) and, presumably, the most influence beyond the conference. This is not surprising because plenary talks are often scheduled without competing presentations and most conference participants attend these sessions to hear from highly regarded speakers. These data, however, provide conference organizers extra incentive to choose plenary speakers wisely to reflect not only the interests and concerns of the live audience but also the interest and concerns of a more diverse online community. Plenary speakers may want to prepare in advance readily tweetable messages.

Conference organizers should also continue to create and promote official conference hashtags (Parsons et al. 2014) to encourage participation and enhance flow of information. When conference attendees know and use the official hashtag, it makes conference information easily searchable and accessible to all Twitter users (Ferguson et al. 2014). Official hashtags also help organizers disseminate conference updates, publicize new research (Winkless 2013), and promote social networking activities. Using hashtags can help facilitate a sense of community and allow for continued discussion of scientific progress after the conclusion of the conference (Parsons et al. 2014).

Internet-based resources and social media are increasingly prevalent, and people are relying on these sources for scientific information (National Science Board 2012). It has been suggested that science communication will be most successful if it is spread through channels that the public and other target audiences are already utilizing

(Van Eperen & Marincola 2011). Therefore, it is critical to understand the challenges and opportunities associated with communicating science through social media. We measured the first stage of effective communication of conservation science through Twitter. Quantifying the extent that Twitter results in conservation action on the ground is a critical next step. Future research should investigate whether and under what circumstances Twitter contributes to science-based decision making. Due to the time-sensitive nature of environmental issues and the need to engage a diverse group of stakeholders, conservation science may benefit from the ubiquity of Twitter. As Twitter becomes part of more conservation scientists' communication toolboxes, it will be critical to avoid its pitfalls while harnessing its full potential.

Acknowledgments

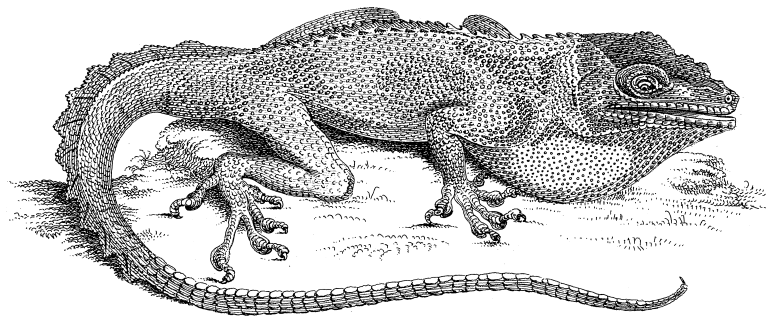
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Supporting Information

The definitions of categories used to organize Twitter users into professional position or organization groups (Appendix S1), the survey sent to presenters (Appendix S2), and professional titles or organization types represented by users that tweeted or retweeted about ICCB 2013 presentations (Appendix S3) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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