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Using data from online social networks in conservation science: which species engage people the most on Twitter?

Jean-Michel Roberge

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Abstract Knowledge about the level of public attention toward different species is crucial to successful conservation. The evolution of online social networks offers new possibilities for collecting data about public interest. Building on an analysis of text messages on Twitter, this study aimed to quantify the level of public attention toward different mammal and bird species listed (at the full species or subspecies/population level) under the United States' Endangered Species Act (ESA). Once a month during 1 year, I searched recently posted messages ('tweets') for the common names of every listed species. The polar bear (*Ursus maritimus*) was by far the most tweeted species. The other most tweeted mammals were the American bison (*Bison bison*), brown bear (*U. arctos*), cougar (*Puma concolor*), killer whale (*Orcinus orca*), black bear (*U. americanus*) and West Indian manatee (*Trichechus manatus*), respectively. The three most frequently tweeted birds were the sandhill crane (*Grus canadensis*), whooping crane (*G. americana*) and spotted owl (*Strix occidentalis*). Some species, such as the manatee, right whale (*Eubalaena glacialis*), and gray wolf (*Canis lupus*) ranked higher when restricting the search to conservation contexts. The results suggest that Twitter users interact about a biased sample of ESA-listed species: mammals were better represented than birds among the most tweeted species and larger-sized species received more tweets. The findings can be used for prioritizing conservation education and marketing campaigns aiming to raise the profile of lesser-known listed species. Data from online social networks open the door for a range of novel applications in conservation science.

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J.-M. Roberge (✉)
Department of Wildlife, Fish and Environmental Studies, Swedish University of Agricultural Sciences (SLU), 90183 Umeå, Sweden
e-mail: jean-michel.roberge@slu.se

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Introduction

Much of the conservation work worldwide is oriented toward securing species populations, as exemplified by the development of lists of species at risk and their use in environmental policy and management (Rodrigues et al. 2006). In this context, knowledge about the level of public attention toward different listed species is important, as it improves our understanding of people's perceptions of conservation issues and helps identifying potential biases in public interest relative to conservation needs. This type of knowledge is crucial for successful conservation, as public interest largely drives public policy (Czech et al. 1998).

A number of recent studies have shed light on the kinds of species that most commonly appear in printed media and on internet websites (Stokes 2007; Clucas et al. 2008; Ballouard et al. 2011), providing valuable knowledge about the types of species that people are exposed to in various settings. From a public attention perspective, one would also want to know which species receive interest from members of the public. Here, the evolution of the internet opens the door for new approaches. First, it is possible to collect data about the types of internet contents that people search for. As a recent example of application to conservation science, McCallum and Bury (2013) analyzed trends in internet searches during the last decade and found a decrease in public interest for a range of environmental issues. Another possible approach is to take advantage of the rapidly increasing trend whereby internet users contribute actively to online contents, as opposed to passive viewing of websites. This phenomenon—known as 'Web 2.0'—has involved the development of virtual communities where users interact online, often through social networking services (e.g. Twitter, Facebook, Sina Weibo). In the present context, data extracted from online social networks could add to past studies of printed media and website contents by providing information on the actual numbers of social interactions about different species. This would provide a direct behavioral basis for measuring actual public engagement, as opposed to metrics based on e.g. stated personal preference. Moreover, analyses of online social network contents would provide data which are not subject to possible self-reporting errors and non-response bias, unlike most traditional methods such as telephone polls and written questionnaires (Gavin et al. 2010).

One of the globally dominating online social networks is Twitter. It is a so-called microblog enabling users to post short (max 140 characters) text messages called 'Tweets' and to read other people's messages. Twitter can be accessed through its own website or third-party applications using a variety of desktop or mobile devices including telephones. This service is growing rapidly and it had, as of March 2012, 140 million active users worldwide producing on average more than 1 billion tweets every 3 days (Twitter 2012a). Twitter users, commonly called 'tweeters', are mostly individuals but also include media, businesses, governmental agencies and non-governmental organizations (NGOs). Several recent studies in medicine (e.g. Scanfeld et al. 2010; McNeil et al. 2012) and the social sciences (e.g. Golbeck et al. 2010; Gonçalves et al. 2011) have revealed a high potential for using Twitter as a data source in scientific research. For example, analyses of Twitter contents have proven useful for tracking the level of public attention and behavioral responses toward the H1N1 influenza virus outbreak in 2009 (e.g. Chew and Eysenbach

2010; Signorini et al. 2011). The increased availability of data about online communications has even led to the emergence of a new and rapidly growing discipline known as 'infodemiology' (Eysenbach 2002).

It becomes apparent from the examples above that online social networks may also provide a wealth of data for conservation research. This study capitalizes on this opportunity by providing the first analysis of a social networking service's contents in the area of biodiversity conservation. Building on an analysis of Twitter traffic, it aims to quantify the level of public attention directed at different mammal and bird species listed under the United States' Endangered Species Act (ESA). To provide an example of how data from online social networks can be used to explore general patterns about public attention toward different species, I relate tweeting frequency to a key biological trait: body mass. A number of other traits could have been of interest here (e.g. diet, range size, degree of similarity to humans), but I focus on body mass as an example because past studies have shown that it is one of the most important traits influencing public conservation interest in several contexts (Kellert 1996; Metrick and Weitzman 1996; Knegtering et al. 2002), and because many other traits of interest are strongly correlated with body mass. Finally, I discuss the general potential of data from online social networks in conservation research.

Materials and methods

Taxonomic and geographical scope

This study focuses on mammals and birds. Data collection was restricted to species listed as threatened or endangered under the U.S. Endangered Species Act, as well as species having at least one subpopulation or population listed as such (as of 28 May 2011). Only species occurring on mainland United States and in marine environments along the U.S. coast were included (i.e. species restricted to Hawaii or offshore territories were excluded). This yielded a total of 61 mammals and 35 birds (Online Resource 1). For coherence, nomenclature and systematics follow those used in the ESA.

Data collection on Twitter

To quantify the level of public attention directed at the listed species, I used Twitter Search (http://search.twitter.com), an online search engine that can be used to search for tweets containing specific words. Posted tweets are publicly visible to anyone by default, even though there is a possibility for tweeters to limit message access to their so-called followers. Only publicly available tweets—which represent about 88 % of all tweets (Beevolve 2012)—were included in this study. Note that according to Twitter, some material that jeopardizes search quality (e.g. spam) may be removed by Twitter Search (Twitter 2012b). For each species, I performed one Twitter search every month over the period of 1 year (August 2011–July 2012), on any day between the 12th and 19th of the month. Repeating the search twelve times over a whole year allowed minimizing seasonal biases linked to the species' biology (e.g. migration, hibernation) and the potential influence of news or special events on species-related Twitter traffic. I performed all searches during daytime, each individual search being performed at a point in time not earlier than 12 a.m. and not later than 6 p.m. Eastern U.S. time.

For each species I searched for all of the most widespread species-specific English common names (on the basis of prior searches in the printed and online literature),

separated by the Boolean operator 'OR', in order to capture tweets including any of these names (Online Resource 1). Both singular and plural forms were included. Even though some species are only listed at the subspecies level, I focused on the use of the full species names because non-biologists often do not specify subspecies names in casual conversations. However, for species listed at the subspecies level I also added the subspecies name if it was not an extension of the species name. For example, I did not search specifically for 'northern spotted owl' or 'Mexican spotted owl' (subspecies of the spotted owl) in addition to 'spotted owl', but I did search for 'Key deer' (a subspecies of the white-tailed deer) in addition to 'white-tailed deer'. Hence, no matter if the ESA listing concerned species, subspecies or individual populations, the common names of the full species were included in every search to ensure that all searches encompassed the common taxonomic level of species. Only English-language tweets were counted.

Due to the possibility of obtaining unmanageable volumes of data, time restrictions were placed on the searches. At the time of each species-specific search, I only computed tweets published in the previous 60 min (i.e. data collection extended 1 h into the past) for mammals, and the previous 7 days for birds. I scrutinized all individual tweets to exclude those which did not refer directly to the animal (e.g. sports teams, trademarks or product names, artist or character names, metaphors, place names) and those which referred to other species with similar names. Every month, I performed the 96 species-specific searches one after the other, by systematically following a species list. However, using the same ordering every month may introduce bias as Twitter activity may vary according to weekday and time. Therefore, I randomized the order of the species list every month so that the searches were performed on alternating weekdays and times (within the frames stated above) during the course of the 12 months.

The search described above (hereafter 'general search') provided a general index of the rate at which people mention a particular species in the text messages they publish on the microblog. The identified tweets addressed a wide variety of species-related subjects and, in the case of ESA listing at taxonomic levels below that of species, they did not necessarily address the particular subspecies or populations which are actually considered at risk. To obtain a more refined picture focusing on conservation contents, I conducted an additional monthly search combining the species names with three conservation-related keywords (also separated by 'OR'): 'endangered', 'threatened' and 'save'. Several additional conservation-related keywords could have been relevant, but I restricted the number of keywords to three because of technical limitations with the Twitter search engine. This search was performed to obtain an index (hereafter called the 'ETS tweet index', *cf.* the first letters of the three keywords 'endangered', 'threatened' and 'save') of how often people write about the species specifically in a conservation context. The time frame of that second search (hereafter 'conservation-focused search') was extended to include all tweets published in the previous 7 days for both mammals and birds. Here, all tweets were individually examined to exclude those where the words 'endangered', 'threatened' or 'save' were used outside of a conservation context. This keyword-restricted search was not intended to capture all posted conservation-related tweets, but rather to provide an index of the magnitude of the conservation discussion about the different species.

The amount of attention directed toward a given species in social networks tells little about the actual attitudes conveyed. In particular, negative attitudes may pose special challenges to conservation. Hence, at every search and for each species, I examined the latest 10 tweets (or all available tweets if <10) and categorized each of them as conveying either a negative or positive/neutral/unknown opinion about the species. Typical examples of negative tweets are: "That species is a public nuisance", "That species is threatening

our jobs" or "This is an ugly creature". Here, the aim was not to perform an in-depth analysis of public attitudes toward the listed species, but rather to provide a preliminary check of whether negative tweets were preponderant in the Twitter traffic for any of the studied species. For this exploratory analysis I focused on species with a median tweeting rate $\geq$1 tweet h^{-1} in the general search because other species had too few total numbers of tweets across the year to allow reliable estimates of the prevalence of negative tweets.

For some species there is a theoretical risk that some extremely active individual tweeters would have an unduly large influence on the results. This risk is probably negligible for popular species engaging large numbers of people, but perhaps not for some lesser-known species. To provide a coarse assessment of the prevalence of that potential issue, I recorded the identity of the tweeters for the latest 5 species-relevant tweets (or all available tweets if <5) for each of the species. For the general search this was done during all 12 monthly searches, whereas for ETS-tweets this data was collected during the last 5 monthly searches only. From that material, I then computed the mean ratio of the number of individual tweeters to the number of tweets to get an index of the influence of individual tweeters on the data. Here, a ratio close to one means that nearly all of the most recent tweets were posted by different individuals, whereas a ratio close to zero would indicate that some individual tweeters were dominating the traffic.

Statistical analyses

Due to the strong non-normality of the data and in order to minimize the influence of outliers, I used median values across the 12 monthly searches when comparing tweeting rates among species. I used Kruskal–Wallis rank sum tests followed by post hoc multiple comparison tests to explore the relationship between body mass and tweet numbers. I extracted body mass data from Smith et al. (2003) for mammals and Lilsevand et al. (2007) for birds. Prior to analysis, I categorized body mass data into intervals according to a common logarithmic scale to account for the wide range of observed values. To perform the Kruskal–Wallis tests I used the "kruskal.test" and "kruskal" (*agricolae* package) functions in R (R Core Team 2013).

Results

The vast majority of species were characterized by relatively low tweeting rates: only 33 % of the mammals (20 species) and 9 % of the birds (3 species) had median tweeting rates $\geq$1 tweet h^{-1} (Fig. 1). The polar bear (*Ursus maritimus*) was by far the most tweeted species, with a median of 118.5 tweets h^{-1}. The other most tweeted species that followed were the American bison (*Bison bison*; median of 31.5 tweets h^{-1}), brown bear (*U. arctos*; 21), cougar (*Puma concolor*; 17.5), killer whale (*Orcinus orca*; 17), black bear (*U. americanus*; 15.5) and West Indian manatee (*Trichechus manatus*; 14), respectively. The only three bird species having medians of at least 1 tweet h^{-1} were the sandhill crane (*Grus canadensis*), whooping crane (*G. americana*) and spotted owl (*Strix occidentalis*), all three having a median equal to 1 tweet h^{-1} (Fig. 1). Only for a small minority of tweets was the tone negative: the mean percentage of negative tweets was 2 % and varied from 0 % (several species) to 8 % (red squirrel *Tamiasciurus hudsonicus*).

The conservation-focused search also showed a strong dominance of the polar bear, with a median ETS tweet index of 291.5 (Fig. 2). Apart from that species, however, the ordering of the most tweeted species was largely reshuffled compared to the general search

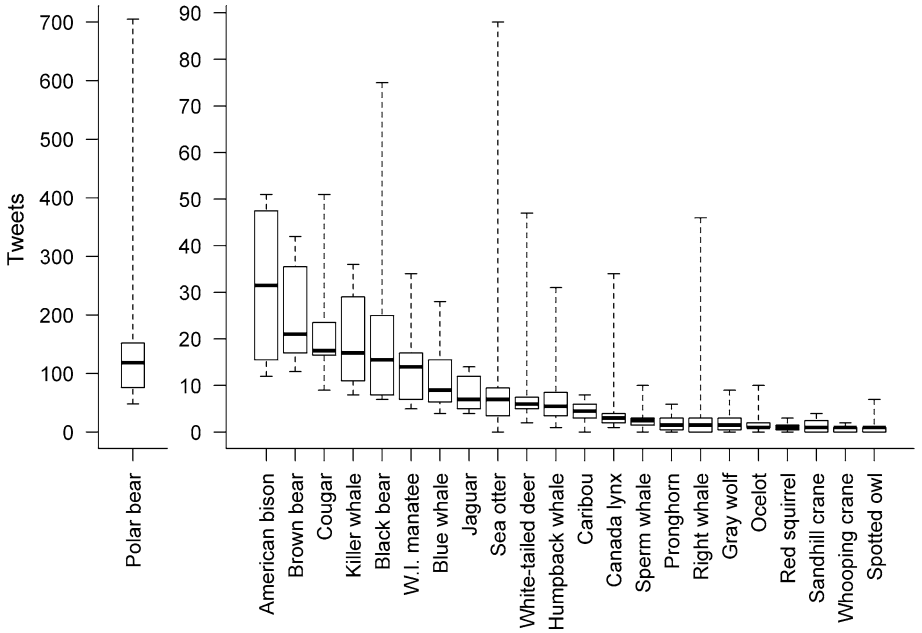

Fig. 1 *Boxplots* for the numbers of posted Twitter messages containing the common names of ESA-listed species of mammals and birds, on the basis of 12 monthly searches covering 60 min each. The *horizontal segments* show the medians, the *boxes* depict the *lower* and *upper* quartiles and the *whiskers* extend to the *minimum* and *maximum* values. Species are ordered from *left* to *right* in decreasing order of median values. Only species with a median $\geq$ 1 tweet h^{-1} are shown. For visual clarity, data for the polar bear are presented in a separate frame with a different vertical scale

(compare Figs. 1, 2). For example, the American bison, which was second only to the polar bear in the general search, ranked 12th in the conservation-focused search (median ETS = 8). Other examples of species which were relatively less prevalent in the conservation-focused search include the black bear (median ETS = 2.5; 6th place in the general search compared to 20th in the conservation-focused search) and white-tailed deer (*Odocoileus virginanius*) (median ETS = 1.5; 11th–27th place). In contrast, the cougar retained relatively high positions in both searches (median ETS = 25; 4th to 3rd place). The conservation-focused search revealed some species which placed relatively better in a conservation context than in the general search, particularly the West Indian manatee (median ETS = 35; 7th to 2nd place), right whale (*Eubalaena glacialis*; median ETS = 16.5; 16th to 5th place), gray wolf (*Canis lupus*; median ETS = 15; 16th to 6th place), and whooping crane (median ETS = 12, 19th to 9th place). Among birds, other examples of species tweeted relatively often in a conservation context were the spotted owl (median ETS = 7.5) and California condor (*Gymnogyps californianus*; median ETS = 4.5).

Tweeting frequency varied strongly according to body mass both in mammals ($\chi^2 = 32.65$, df = 6, $p < 0.001$) and birds ($\chi^2 = 12.08$, df = 3, $p = 0.007$). Mammal species with a body mass >10 kg were tweeted more frequently than smaller species (Fig. 3). In birds, species >1 kg were tweeted most frequently, while species <10 g had the lowest tweeting frequency (Fig. 4).

The ratio of the number of tweeters to the number of tweets was generally close to 1, indicating that individual tweeters probably did not have a major influence on the results.

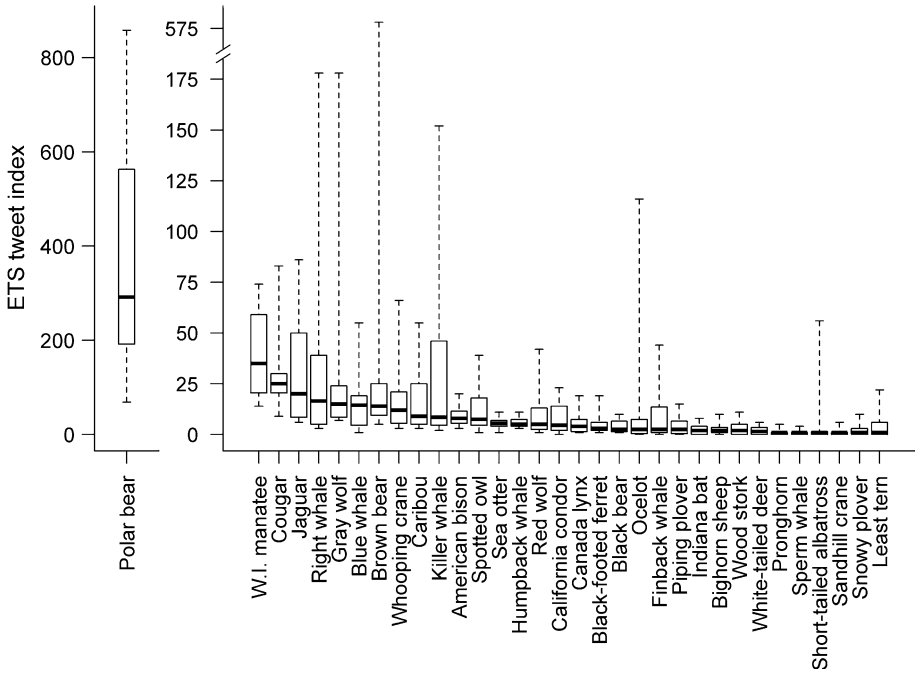

Fig. 2 *Boxplots* for the ETS tweet index obtained from the conservation-focused search (see "Materials and methods" section) for different ESA-listed species of mammals and birds, on the basis of 12 monthly searches covering 7 days each. Only species with a median ETS tweet index ≥1 are shown. Note the axis break. See Fig. 1 for explanations

For the 23 species with a median ≥1 tweets h^{-1} (*cf.* Fig. 1), the mean ratio across species was 0.98 (range 0.90—1.00). As regards the conservation-focused search, species with a median ETS tweet index ≥1 (*cf.* Fig. 2) had a mean ratio of 0.95 (range 0.66–1.00) and all species in the top 10 had ratios ≥0.88.

Discussion

Level of public attention toward listed species

This study provided a quantitative assessment of the level of attention directed at ESA-listed mammal and bird species by the users of Twitter, one of the globally dominating social networking services. The results showed that, for ESA-listed species, mammals were much better represented than birds among the most tweeted species. Several past studies have highlighted the presence of a taxonomic bias in conservation attention and shown that birds and mammals generally benefit from more attention or support than other taxonomic groups (e.g. Metrick and Weitzman 1996; Clark and May 2002; Knegtering et al. 2002; Clucas et al. 2008). However, past studies are not consistent as to which of these two groups attracts the most attention. For example, using a nationwide mail survey in the United States, Czech et al. (1998) showed that mammals were generally ranked higher than birds in terms of conservation importance by the public. However, birds were represented by more NGOs than mammals and involved higher mean expenditures. In the Netherlands,

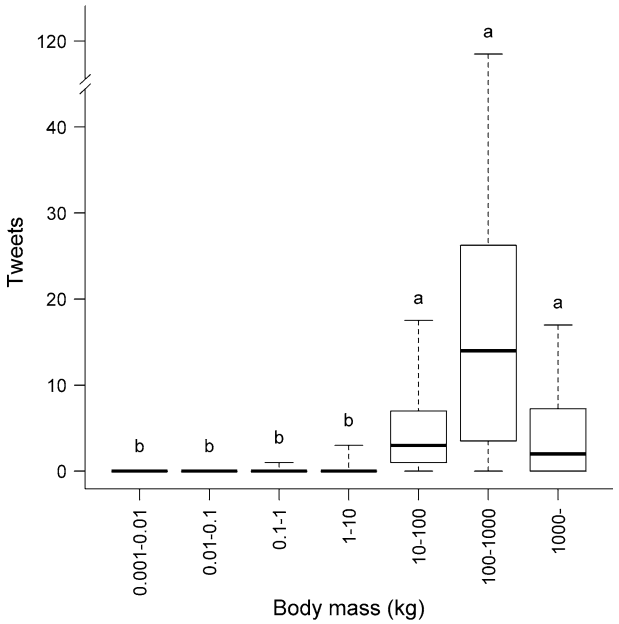

Fig. 3 *Boxplots* for the median number of tweets for mammal species belonging to different body mass categories, on the basis of searches covering 60 min (note the axis break). *Different letters* depict groups with significantly different tweeting rates ($p < 0.05$)

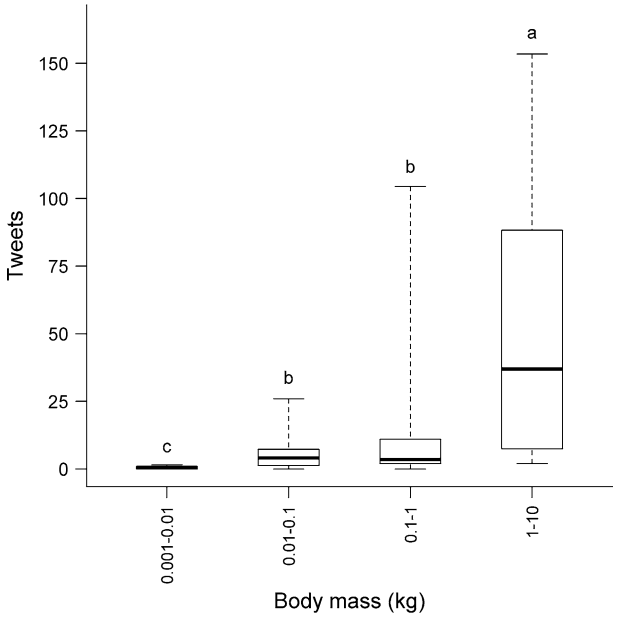

Fig. 4 *Boxplots* for the median number of tweets for bird species belonging to different body mass categories, on the basis of searches covering 7 days. See Fig. 3 for explanations

Knegtering et al. (2002) found that NGOs' levels of concern and support was higher for birds than mammals. Clucas et al. (2008), however, showed that mammals appeared more often on the cover of U.S. conservation and nature magazines than birds. With regards to conservation research, Clark and May (2002) found that mammals were more overrepresented (relative to their species richness) than birds in the scientific literature. The present study also showed a clear relationship between tweeting frequency and body size, in accordance with previous studies suggesting that large-sized animals attract more public interest and conservation support (Kellert 1996; Metrick and Weitzman 1996; Knegtering et al. 2002; Walpole and Leader-Williams 2002; Clucas et al. 2008). The uneven level of attention directed at listed mammals compared to birds, as well as at species of different body sizes, suggests that online social network users interact about a highly biased sample of species conservation issues, and that many stakeholders may be basing their opinions and decisions on such biased information. The results of this study can be used to prioritize future conservation education and marketing campaigns aiming to raise the profile of listed species currently attracting less attention (see also Kellert 1985; Smith et al. 2010; Veríssimo et al. 2011), such as small-sized birds (e.g. insectivorous passerines) and mammals (e.g. rodents, bats). Indeed, it is probable that many of these are 'Cinderella species', i.e. potentially appealing but currently overlooked species (Smith et al. 2012). Future consideration should also be given to taxonomic groups not included in the present study, such as reptiles, amphibians, fish, invertebrates, plants and fungi.

The conservation-focused search involved some reshuffling of the identities of the most tweeted species compared to the general search. Some species such as the American bison, black bear and white-tailed deer received a lot of attention in the general search but much less in a conservation context, as measured by the ETS tweet index. This suggests that a large proportion of the Twitter traffic about those species addresses other topics than their conservation. The bison is an iconic species in American culture and is farmed for meat production, two factors probably contributing to its high frequency of occurrence in the Twitter traffic. The black bear and white-tailed deer are relatively abundant in large parts of the United States but are listed at the subspecies level under the ESA (Online Resource 1). The strong interest in those species is probably due to their commonness—which increases the frequency of interactions with humans—and their status as hunted game. In contrast, some species placed better in a conservation context than in the general search, for example the West Indian manatee, right whale, gray wolf and whooping crane. Hence, much of the public attention toward these species seems to be due to people's awareness about their conservation status.

The polar bear stood out as the most frequently tweeted species, both generally and in a conservation context. This is consistent with the observation that the polar bear has become a flagship species for climate change (Smith et al. 2010; Veríssimo et al. 2012). More generally, it can be observed that most of the species included in this study which have previously been recognized as flagship species (see Kalland 1993; Clucas et al. 2008; Caro 2010; Barua et al. 2011) benefited from high tweeting rates. For example, in their study of animals on the covers of U.S. conservation and nature magazines, Clucas et al. (2008) found that the wolf, brown bear, polar bear and cougar were the most commonly featured flagship species. In the present study, these figured amongst the most tweeted species in the conservation-focused search. Moreover, in addition to large carnivores, the present study showed that people also engage intensely in the conservation of manatees and whales. In a meta-analysis of willingness to pay for the conservation of species of conservation concern, Richardson and Loomis (2009) found that marine mammals, together with birds and fish, were associated with a higher willingness to pay than other types of species.

The results also suggest that although negative attitudes did occur, they did not constitute the core of the Twitter traffic for any of the high-profile species identified in the study. The aim of this preliminary analysis was simply to check whether negative attitudes were dominating for any of the species, which may have implications for their conservation. Although detailed analyses of attitudes toward different species or conservation actions were beyond the scope of this study, microblogs and other social networking services offer much potential for such future studies, which should be based on refined categorization schemes (e.g. Chew and Eysenbach 2010; McNeil et al. 2012) and analytical methods developed in the social sciences (Heberlein 2012).

Limitations of online social network data

Notwithstanding their potential, data extracted from online social network contents also present a number of limitations. First, while more traditional methods such as written questionnaires allow collecting detailed demographic data on each of the respondents (e.g. Czech et al. 1998), this information is usually not readily available for online social networks. This may be a concern because online social network users are not representative of society as a whole. For example, among Twitter users in the United States there are slightly more women than men (55 vs. 45 %), 45 % of users are between 18 and 34 years old, 58 % have a household income >$60,000, and about one-half have college education or higher (Viralblog 2012). Still, results from studies of online social network contents can be expected to have significant value for applications within settings involving specific sections of the human population. For example, knowledge about the level of attention toward various species on Twitter could be useful for designing conservation campaigns for online social networks or other internet platforms.

As with other studies based on internet content, there are limitations linked to geography and language. Retrieving information about the location of the individual social network user can be difficult, especially in the case of large-volume searches, and was not possible in this study. It is estimated that 51 % of the tweeters are in the United States (Beevolve 2012). Hence, not all of the English-language tweets about species occurring in the United States necessarily originate from this country.

Another challenge is the selection of appropriate keywords for the searches. In the present study, for example, some species had rather complex common names which may be less likely to be used in full in everyday communication. Nevertheless, I had to use the full species-specific names in the searches to distinguish the species from other related species. One example is the black bear, which is often simply called “bear” in informal conversations. However, using only “bear” for the Twitter search would not have allowed distinguishing contents about the black bear from those about the brown and polar bears. An alternative would have been to perform the searches at a more general level using common names encompassing several related species (e.g. “bear”, “whale”), but the problem here is that these generic names may represent widely differing taxonomic levels, resulting in taxonomically unbalanced comparisons. For example, the three North American bears are congeneric, whereas the whales include representatives from different families.

Moreover, it should be kept in mind that the present study pertains to the use of the common names of full species. Hence, in the case of species listed at the subspecies or population level, the results may include tweets which do not specifically concern the listed subspecies/population(s) of the focal species. A possibility would have been to search solely for the common names of the different listed subspecies or populations (i.e. without

including the name of the full species) whenever listing concerned such lower taxonomic levels. However, subspecies common names are often cumbersome extensions of the species name and hence less likely to be used in casual tweets, and listed population segments do not usually have specific common names. Moreover, this again would have led to taxonomically unbalanced comparisons of tweeting rates. The conservation-focused search allowed alleviating this issue to a large extent, as all tweets identified in that search addressed conservation topics. Therefore, they can be assumed to pertain mostly to the taxonomic entity(-ies) (species, subspecies, or population(s)) which is/are of conservation concern.

Online networking services and the future of conservation research

Online networking services play an increasing role in research. To date, much of the discussion has revolved around their usefulness for facilitating interactions among researchers, keeping up with research developments, and communicating scientific results to the general public (Bik and Goldstein 2013). The present study illustrates the potential of online social networks as a data source for conservation research. In this context, a wide variety of applications can be conceived. For example, data from microblogs and other online social networks could be used to study the attitudes of people toward proposed conservation or restoration actions, the occurrence of specific behaviors having positive or negative impacts on the environment, the strategies used by governmental agencies and NGOs in public conservation education and promotion of citizen science, and the spreading of false information. Such studies will be facilitated by the recent development of tools for automated data retrieval from online social networks (e.g. package 'twitteR' in the statistical software R; R Core Team 2013). The recognition that human values and actions constitute a central element in biodiversity conservation (Kareiva and Marvier 2012) calls for making better use of these newly available types of data in conservation science.

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