LETTER

Investigating public biodiversity conservation awareness based on the propagation of wildlife-related incidents on the Sina Weibo social media platform

Yinglin Wu1,5, Ling Xie, Zengwei Yuan2,5, Songyan Jiang3, Wenhua Liu1 and Hu Sheng2

1 School of Life Science and Technology, Lingnan Normal University, Zhanjiang, Guangdong 524048, People’s Republic of China
2 State Key Laboratory of Pollution Control and Resource Reuse, School of the Environment, Nanjing University, Nanjing 210023, People’s Republic of China
3 School of Management Science and Engineering, Nanjing University of Information Science & Technology, Nanjing 210044, People’s Republic of China
4 Marine Biotechnology Key Laboratory of Guangdong Province, Marine Biology Institute, Shantou University, Shantou, Guangdong 515063, People’s Republic of China
5 Author to whom any correspondence should be addressed
E-mail: wuyinglin18@163.com and yuanzw@nju.edu.cn

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Abstract
The use of social media platforms (e.g. Twitter and Facebook) to raise public awareness towards wildlife conservation is an emerging discussion. However, little is currently known about the propagation pattern of wildlife-related information on social media. In this study, a quantitative model was developed based on 230 independent cetacean stranding incidents (2008–2018) across mainland China from a popular Chinese social media platform (Sina Weibo). This model enabled analysis of the post formation process, identification of the key factors influencing the popularity of the posts and wildlife-related incidents, and allowed investigation of public opinions. The results showed that central media users can increase the overall possibility of elevating incident popularity by ~75 times, an attractive species or incident by ~5 times, and a negative social ethics incident by ~3 times. Traditional media users and celebrity influencers performed key roles in affecting the level of re-posting. Online audiences of highly popular posts predominantly encompassed both users from relatively developed regions and female users. It was observed that posts which became popular within ~12 h retained their influence for ~3 d. Post popularity was closely related to comment counts rather than forwarding in the first day of posting and the whole status retention time. Public opinion generally expressed a supportive attitude towards wildlife conservation, but lacked in-depth thinking, and individual responsibility was expressed through revival incidents. In order to raise public awareness towards biodiversity conservation, social media–based wildlife information dissemination should balance the content of attractive and non-charismatic species or incidents and include more positive emotions. Posts via traditional users (especially central media users) and opinion leaders (celebrities) can attract a highly educated audience and females, and thus evoke increased comment numbers during the first day of posting. This will help to popularise conservation knowledge and legislation with continuous efforts.

1. Introduction
Using publicity and education to raise public awareness of wildlife conservation is a strategic target of biodiversity conservation [1]. The past efforts of conventional media-based methods (e.g. television, print newspaper) weakened their application with a high associated cost. More recently, rapidly developing social media platforms (e.g. Twitter, Facebook, WeChat, Sina Weibo) have already transformed all aspects of our society as everyday communication tools [2]. Globally, the number of active social media users has reached ~3.8 billion (~ 50% of world population) [3]. As a highly open and flexible online platform, many institutes are moving towards this emerging technology to improve biodiversity
used an ordinal multi-nominal approach to model the sources of wildlife-related information and spreads rapidly across peer-to-peer networks. Conversely, this has created a more complex dissemination model compared with conventional methods. However, seldom propagation feature (incident via media to online public) is known for wildlife-related information on a social media platform, and restricts the promotion of this new approach.

Previous research has primarily focused on mining data from social media in order to analyse human–nature interactions and monitor biodiversity [9–12]. Only a few studies have analysed the communicational propagation process of wildlife-related information on social media platforms. Among these limited studies, the majority extracted coverage intensity (ending of online communication) from Twitter [13–16], Flickr [17], Facebook [16, 18] and YouTube [19] for the different national endangered species, International Union for Conservation of Nature (IUCN) red list species or common species to interpret public attention differences towards wildlife or tracking illegal wildlife trade. Although some studies have investigated the relationship between message sending and receiving (information transferring), they limited their studies to professional or organised activities, such as protecting the Great Barrier Reef [20], determinations of invasive alien species within a forest [21], online citizen science communities of garden birds [22], and live-tweeting of conservation science from international conferences [23, 24]. Many results were based on qualitative analyses [22, 23]. Daily information of environmental incidents have a wider number of sources and audiences on social media [25]. Our previous study analysed the spread of wildlife incidents on WeChat, but the small sample size and challenges with user data access restricted the scope of the result [26]. In addition, past questionnaire surveys indicated that online public awareness (attention, sentiment and opinion) might be influenced by internal factors, such as gender [27], direct feelings or emotions [28, 29], personal experience with wildlife [30], and external factors including social [31], economic [32] and cultural [33] parameters. However, only a few empirical case studies interpreted online influence of public attention or opinion from species attractiveness [34], article [34] or video [8, 35] content, as well as by celebrity endorsement [35].

Considering the knowledge gaps, this present study focused on a systematic analysis of daily wildlife-related incident propagation process on social media, and aimed to identify influence factors of online evoked public biodiversity conservation awareness (attention, sentiment and opinion). Incidents of charismatic-cetacean strandings [26, 34] were chosen for analysis due to sufficient data availability. We used a popular Chinese social media, Sina Weibo (founded in 2009, 516 million active users as of April 2020 [36]), as platform. We analysed various links of ‘incident-social media-public’ to clarify online communication process. In 2.2, a GIS model was applied to analyse incident distribution pattern. Section 2.3 used an ordinal multi-nominal logistic model (OLM) to identify social, economic and technical factors impacting incident popularity (degree of post forwarding). User relations between message sending (posting) and receiving (re-posting and leaving comment) were quantitatively analysed in section 2.4. Public awareness was extracted by content analysis and statistic of emoticons in section 2.5.

2. Materials and methods

2.1. Data collection

We used word groups containing Chinese characters ‘鲸’ (whale) or ‘海豚’ (dolphin) or ‘江豚’ (porpoise) + ‘搁浅’ (stranding) in the search engine of Sina Weibo (https://weibo.com/) to retrieve the posts on cetacean stranding along the Chinese mainland coast between January,. 2009 and December, 2018. To avoid omitting any relevant information, we divided the overall retrieval plan into multiple searches, with a suitable time period (displayed a complete post list on the web pages) dedicated to each operation. The preliminary retrieved posts were screened manually and singularly in order to delete irrelevant text (e.g. incidents that happened overseas, or those with incomplete location and date) and any repeated incidents were combined. We identified a total of 230 independent cetacean stranding incidents along the Chinese mainland coast. Following this, the data on incident time, location, species involved, outcome, gender of posting users, and the forwarding counts of posts were extracted and recorded.

A commercially machine-trained web crawler (http://www.wrd.cn/login.shtml), purchased by Sina Weibo, was applied to extract highly popular posts (forwarding counts ⩾ 500) for conveyor location, forwarding layer, user type, emoticons, key propagating users (popular re-posts, which induced forwarding counts ⩾ 100), forwarding time and the topics of online comments.

2.2. Incidents distribution pattern analysis

Cetacean stranding incident time, and geographic distribution were analysed to understand incident distribution patterns. A Pearson correlation test was undertaken using the annually accumulated data to determine mutual relations of incident counts, popular incident counts (an incident has at least one post with ⩾ 100 forwarding counts) and Sina Weibo user counts [37]. All data analysis was conducted on R
version 3.5.1 (https://www.r-project.org/). In addition, ArcGIS (10.2.2 edition) was used to calculate the Kernel density spatial distribution for the geographic points of all incidents, and this was then overlaid with the popular incident layer.

2.3. Factors affecting incident popularity
Incident popularity (forwarding counts level of one, or sum of three posts) was classified into three levels: low popularity (0, 100), medium popularity [100, 500) and high popularity [500, ∞). In view of non-normal distribution of dependent variables and having category independent variables, OLM was built in order to identify significant correlation factors for the popularity of incidents (equation (1)). Eleven binary classified variables were analysed in the model (table 1). The probability of the three types of incidents were \( p_{\text{low}} \), \( p_{\text{medium}} \) and \( p_{\text{high}} \) and their sum is 100%. OLM building and analysis was carried out using SPSS 19.0. Regression coefficient was tested
Table 1. Description of independent variables ($x_i$) used in the ordinal multi-nominal logistic model (OLM).

| Variables ($x_i$)                  | Description                           | Category Definition                                                                 | Data sources                                                                 |
|------------------------------------|---------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| City GDP                           | Gross Domestic Product, GDP            | Numerical variable                                                                  | Provincial statistical yearbook (2011 ~ 2016)                                   |
| Happiness Index                    | Citizens' feeling of happiness         | Numerical variable                                                                  | Tsinghua University released ‘H+ Lab Happy China White Paper’ in 2016         |
|                                    |                                       |                                                                                     | [https://www.sohu.com/a/167878646_406163](https://www.sohu.com/a/167878646_406163) |
| Nature Reserve                     | National or provincial level protected area | The presence or absence of a natural reserve in the city where incident occurred | Obtained from the website of Chinese Ministry of Ecology and Environment [http://www.mee.gov.cn](http://www.mee.gov.cn) |
| Tourism Area                       | Natural Scenery Tour Area              | Incident located closely to a popular tourism area or not                           | Identified in Baidu Tourism Map                                                 |
| Attractive                          | Attractiveness of incident or species | Individual counts $\geq 3$ or not; Big size whale or not                             | Sina Weibo                                                                     |
| Grade                              | National level of protected wildlife   | Grade I or not                                                                      | Legal list of wild animals with a priority protection status in China          |
| Incident Outcome                   | The final survival status of cetacean | Dead or not                                                                         | Sina Weibo                                                                     |
| Conservation Administration        | Natural reserve building, including cetacean conservation | Have a natural reserve of a provincial or higher level                             | Sina Weibo                                                                     |
| User Type                          | Information releasing users            | Central media user or not                                                            | Sina Weibo                                                                     |
| Social Ethics                      | Spiritual reverence and ethical concern for wildlife | Damaging behaviours to wildlife species or rescuing them                             | Sina Weibo                                                                     |
| Fresh or Sea water                 | Natural location of cetacean stranding | Along the coast or by the body of freshwater                                        | Sina Weibo                                                                     |
by the likelihood ratio, and model fitness was tested using the parallel lines’ method.

\[
\ln\left(\frac{p(Y < j)}{1 - p(Y < j)}\right) = \alpha_1 + \beta_1 \cdot x_1 + \beta_2 \cdot x_2 + \cdots + \beta_i \cdot x_i
\]  

(1)

Where \( j = 1 \) (low), or 2 (low and medium), OLM has two equations.

2.4. Incident dissemination process analysis

Highly popular posts (forwarding counts \( \geq 500 \)) were screened for analysing the online dissemination feature. The network relations of post user and the key re-post users (induced secondary forwarding counts \( \geq 100 \)) were analysed by R v.3.5.1. The users were divided into ten categories according to their social influence and business scope (appendix S3 (available at https://stacks.iop.org/ERL/15/094082/mmedia)): A—central media users; B—national community users; C—local media users; D—entertainment users; E—popular science users; F—tourism society users; G—celebrity users; H—celebrity users from green/popular science groups; I—local government/college users; J—green groups/public service users; and N—regular people users. As the largest ratio (~39%) of highly popular posts was released by central media users, the A and non-A groups were further divided in order to analyse the differences of forwarding counts, public comment counts, online dissemination layers and popular forwarding re-posts between these groups. A Wilcoxon test was applied to determine array differences. Spearman correlation tests (for abnormal distribution data set) were conducted to analyse mutual relationships among post or re-post forwarding counts, public comment counts, and post forwarding layers.

The geographic distribution of the online forwarding and comments was investigated to understand the incident spreading scope. The relationship between the audience location and the incident location in posts or city GDP was analysed using a Spearman correlation test. We also analysed the gender ratio of the users. Wilcoxon tests were applied to determine the array differences between freshwater and sea water incidents, forwarding counts and comment counts.

The temporal dissemination pattern of highly popular posts was analysed, and the posting, cooling (decrease in forwarding or comment counts), and the status retention times were calculated. The mutual relationships among status retention, climbing (increase in forwarding or comment counts), forwarding and comment counts were analysed by R v.3.5.1, using the Spearman correlation test.
2.5. Statistic of emoticons and content analysis of online public comments

Emoticons were collected automatically from comments of high popular posts by the machine-trained web crawler to analyse public sentiment towards wildlife-related posts. Emoticons refer to electric graphic facial expression that is used to reflect the emotions of users [38]. In this study, the emoticons were classified manually into five categories: joy, sad, anger, disgust and surprise, based on the method described by Liu and colleagues (2016)[39].

To provide a reliable and valid analysis for online public comments, content analysis was applied. Content analysis is a classical method used to analyse narrative material and has been previously applied to investigate public media communication of wildlife information [17, 40, 41]. In this study, content analysis was first carried out automatically through a commercial social media data mining software with a natural language processing function (www.wrd.cn/login.shtml). Then, the preliminarily extracted top topics were analysed by a trained coder following inductive content analysis procedures described in previous studies [42]. Based on the theory of planned behaviour [43], the sub-themed topics were classified into eight categories: attitude, individual responsibility, moral laws, awareness of the consequences, conservation knowledge, conservation management, conservation behaviours, and damage behaviours. The final integrated public opinions were displayed using the e! Sankey 4.0 tool (figure 6).

3. Results

3.1. Incident distribution patterns

We identified a total of 230 independent cetacean stranding incidents that occurred along the Chinese mainland shoreline and were mentioned on the Sina Weibo platform from 2009 to 2018. These incidents were reported in high-density along the coast of the Yellow Sea and the Bohai Sea, the Yangtze River Estuary, the western coast of the Taiwan Strait, and the northern coast of the South China Sea (figure 1). The majority of popular incidents were located in, or close to the regions with a high-density distribution of incidents (S = 13 157, p < 0.001, rho = 0.470), figure 1). We identified 43 popular incidents (i.e. an incident has at least one post with 100 forwarding counts). No clear temporal trend was identified on total incident counts (23 ± 14, coefficient of variation [CV] = 60%), popular incident records (4 ± 3, CV = 78%) and Sina Weibo user counts (2.5 ± 0.7 ten thousand, CV = 30%). Significant positive correlations were found between counts of total incidents or popular incidents and the number of Sina Weibo users (t = 2.48, p < 0.05, cor = 0.66; t = 4.07, p < 0.05, cor = 0.82).

3.2. Factors affecting incident popularity

The OLM analysis revealed that three factors — user type, attractiveness of species or incident, and social ethics, were significantly related to the incident popularity (table 2). The model was then optimized by reducing insignificant variables. A minimum of one regression coefficient of independent variable was not zero (−2 log likelihood was 126.77, decreasing to 33.91 by inducing variables; df = 3, p < 0.001) based on the final model fitness calculation. The parallel lines test demonstrated that parameter estimation was stable and reliable (p = 0.236). Hence, the OLM model was considered suitable for data analysis. Central media users increased the possibility of upgrading post popularity level by ~ 75 times (exp [β]) when compared with non-central media users. Further, attractive incidents (i.e. individual counts ≥ 3 or a large sized cetacean) increased the possibility of upgrading post popularity level by ~ 5 times in comparison with regular incidents. Finally, negative social ethics increased the possibility of upgrading post popularity level by ~3 times, when compared with neutral and positive social ethics incidents.

3.3. Incident dissemination process analysis

Highly popular posts (N = 48) were mainly released by A (39%), followed by B (14%), C (14%) and D (10%). Among the most influential users, the most connected users were group A, followed by group G and group N (figure 2 [1]). The strongest relationship was identified between ‘A–N’, followed by ‘A–A’ and ‘A–G’. Generally, close relationships were exhibited between users of the same or similar type. We also observed a wide and diverse connection with other user types for group N (regular people).

No significant difference was identified (figure 2 [2]) between central media users (N = 20) and other users (N = 28) in terms of number of post forwarding (χ² = 47, df = 46, p > 0.05), comments (χ² = 47, df = 47, p > 0.05), popular re-post users (boosting, χ² = 4.67, df = 6, p > 0.05) and layers (χ² = 15.56, df = 14, p > 0.05). A significant relationship was found between post forwarding counts and comment counts (S = 4877.6, p < 0.001, rho = 0.735), post forwarding counts and popular re-post users counts (S = 9655.3, p < 0.001, rho = 0.476), and popular re-post users counts and layer counts (S = 11 105, p < 0.05, rho = 0.397).

The two counts of highly popular post forwarding (1109, 624 ~ 2301) and comments (496, 279 ~ 1317) exhibited a large fluctuation (CV = 192% and 151%). Post forwarding layer (5, 4 ~ 9, CV = 60%) was mainly derived from the first layer (72%, 42% ~ 92%, CV = 46%), followed by the second layer (14%, 6% ~ 34%, CV = 87%).

The highly popular posts were primarily released during working hours (8:00 ~ 16:00), especially in the morning (8:00 ~ 12:00) (figure 3 [2]). The heat
### Table 2. Summary of ordinary logistic model results (N = 230).

| Parameter Estimation | SD  | Wald     | df | p       | Lower Bound | Upper Bound |
|----------------------|-----|----------|----|---------|-------------|-------------|
| Low popularity       | 2.681 | 0.316    | 76.725 | <0.001 | 2.081 | 3.281 |
| Medium popularity    | 3.890 | 0.414    | 88.132 | <0.001 | 3.078 | 4.702 |
| Central media users  | 4.316 | 0.577    | 55.920 | <0.001 | 3.185 | 5.447 |
| Non-central media users | 0 | – | – | – | – | – |
| Location             | 1.619 | 0.503    | 10.386 | <0.05 | 0.635 | 2.604 |
| Attractive           | 0 | – | – | – | – | – |
| Neutral and positive social ethics | 1.001 | 0.488 | 4.198 | <0.05 | 0.043 | 1.958 |

*This parameter is redundant and set to 0.*
Figure 3. Conceptual analysis of dissemination process of highly popular post (forwarding counts $\geq 500$): (1) Variation of forwarding and comment counts with the time; (2) Distribution of post releasing time; (3) Relations among post forwarding counts, comments counts, heat lasting and heat climbing.

Figure 4. User distribution of forwarding and comment of highly popular post (forwarding counts $\geq 500$) across mainland China.
climbing time (~ half a day) was much shorter (figure 3 [1]) than cooling time (2 ~ 3 d). The dissemination peak value mainly appeared at the end of the first day (~85%). The first trough value was predominantly observed at end of the fourth day (~56%) or third day (~27%). The retention time was $3 \pm 1$ d (CV = 32%). We found a significant relationship between heat climbing time and comment counts, status retention time and forwarding counts, and status retention time and comment counts (figure 3 [3]). No significant relationships were identified between status retention time and heat climbing time, or heat climbing time and post forwarding counts.

The re-posting audiences (i.e. users responsible for post forwarding) were derived from 28 provincial administrative divisions and comment audiences (i.e. those who commented on the posts) were sourced from 30 divisions (figure 4). Approximately 81% of the posts were related to incidents that occurred along the coast, and approximately 19% were related to the incidents that happened in the freshwater area. The dissemination difference among the divisions was found to be very large (CV = 129% for forwarding, CV = 135% for comments). The relationship between the audience location and the incident location was weak ($s = 150.46$, rho = 0.088, p > 0.05; $s = 144.23$, rho = 0.126, p > 0.05). We found a positive significant relationship between the re-post or comment audience location, and the city GDP ($S = 404.00$, rho = 0.877, p < 0.001; $S = 526.00$, rho = 0.839, p < 0.001). No significant difference was revealed ($W = 586.5$, p > 0.05) between the counts of post forwarding (1797, 141 ~ 2917, CV = 129%) and comments (1131, 97 ~ 2002, CV = 135%), but with positive significant relationship ($S = 151.15$, rho = 0.972, p < 0.001). The re-post on sea water incidents (1306, 84 ~ 2234, CV = 138%) was far greater ($W = 327.5$, p < 0.05) than recorded for freshwater incidents (486, 27 ~ 768, CV = 104%). Furthermore, comment counts were increasingly related to ($W = 209.5$, p < 0.001) sea water incidents (1052, 94 ~ 1803, CV = 138%) in comparison to the freshwater incidents (100, 3 ~ 188, CV = 107%). Finally, we identified a higher level of engagement within female users for re-posting ($62 \pm 9\%$, CV = 9%) and providing comments ($54 \pm 10\%$, CV = 18%) for highly popular posts.

### 3.4. Analysis of emoticons and content analysis of online comments

There were 64 983 online comments related to the highly popular posts (N = 48). The posts were divided into three categories: death of the animals involved, negative social ethics, and revived animals. The comment count was 32 790 for the death incidents, 26 867 for negative social ethics, and 5326 for the revival incidents. In negative social ethics incidents, the main emoticons expressed were those of anger and sadness (figure 5). In death incidents, the emoticons expressed were mainly those of sadness and joy (primarily regarding ‘love’). For the revival incidents, the joy emoticon was most frequently expressed. Overall, in all the cetacean stranding incidents, online users predominantly used three emoticons: sadness, anger and joy.

Most of the online comments expressed one or two types of opinions (figure 6). Generally, the online public expressed a larger proportion of supportive
‘attitudes’ towards wildlife and ‘conservation behaviours’, and unsupportive attitudes towards ‘damaging behaviours’. In the negative social ethics incidents, the public expressed a high ratio of negative opinions towards ‘damaging behaviours’ (54 ± 35%, CV = 64%), followed by providing ‘conservation knowledge’ (13 ± 24%, CV = 195%) and positive ‘attitudes’ towards wildlife conservation (11 ± 24%, CV = 233%). In death incidents, positive ‘attitudes’ towards wildlife conservation accounted for the highest ratio (46 ± 27%, CV = 59%), followed by negative ‘attitude’—public were dissatisfied with ‘conservation management’ (17 ± 29%, CV = 170%). Finally, in the revival incidents, praise of ‘conservation knowledge’ and a negative opinion of ‘conservation management’ (especially in negative social ethics incidents). Supportive ‘individual responsibility’ was commonly identified in the revival incidents, while ‘awareness of the consequences’ was primarily expressed in death incidents.

4. Discussion

In order to investigate methods to improve environmental education or raise public environmental awareness based on the use of social media, we analysed the information propagation pattern of wildlife incidents. We demonstrated that popular incidents were closely related to high-incidence areas, but weakly related to locations of online audiences (see section 3.3). This indicates that in addition to direct experience [30, 44], indirect experience from online frequently released wildlife-related message can also increase public attention towards the subject. Furthermore, social media removes the geographic restrictions on public information receiving [2]. Wildlife-related incident propagation on social media broadens the audience scope to include users based in distant locations from the incident (figures 1 and 4).

Our study revealed that the open access of social media weakened the influence of city features (i.e. where the incident occurred) on communication effects (e.g. city GDP, happiness index, natural reserve building, and tourism area building) but increased the impacts of the internal attributes of the platform and incident (e.g. annual counts of registered users, user type, and social ethics). Traditional media users with significant numbers and faithful audiences play a crucial role in popularising the incidents [26]. We demonstrated that central media users were the most effective popular incident or post generators among traditional media users. Opinion leaders (e.g. celebrities) accelerated propagation effects (figure 7). Ecotourist users were immune to the body size and the shape of the ‘attractive’ terrestrial mammals [45]. However, results suggested that a large body size or a group of cetaceans aroused interest in online audiences. A similar study used social media to track special populations (ecotourists) [45] and disseminate a survey questionnaire, while our study focused on general public and user generated information. Our findings are in consensus with those of previous studies by demonstrating that whales and dolphins have aesthetic value for the online public [34]. Large numbers of trapped
wildlife, even though these species size are relatively small (such as ≥ 3 individuals of dolphin strandings), often cause public environmental concerns [46, 47]. Additionally, although negative social ethics content (e.g. ‘baby dolphin dies from stress surrounded by tourists taking photos’) can upgrade post popularity, cautions should be taken to protect public confidence towards wildlife conservation [48]. We suggest that traditional media users should release additional content of less attractive species or incident to meet the need for integrity in biodiversity conservation.

Our study revealed that diverse social groups were involved in releasing information on cetacean stranding. This indicates that the importance of cetacean conservation has been recognised by mainstream society in China. In addition to traditional users, non-traditional media users, such as entertainment, and celebrity users, participate in post forwarding which increases the popularity of wildlife-related information on social media. The role of opinion leaders (non-traditional news media users with powerful social influence) should not be underestimated [49]. A ‘real-life’ friend sharing the story can amplify this influence [49]. We found that a regular netizen can act as a key promoter for disseminating wildlife-related information. However, most of the highly influential posts originate from central media users. Although traditional media users produce a majority of highly popular posts with wide coverage, opinion leaders and ‘grass-roots’ users can also enhance the depth of communication on wildlife-related information on social media.

We observed that online forwarding and commenting were concomitant public responses. These can be used when evaluating the popularity of wildlife-related incidents, or posts on social media. The posts with higher popularity had a higher number of secondary boosted points and forwarding layers. The participation of more influential users in post forwarding enlarges the scope for dissemination and depth. However, most of the popular posts only have one popular re-post and shallow propagation layers. Not surprisingly, highly popular posts were formed within a short time (half a day). This suggests that online netizens are inclined to share information with, or follow users with similar interests on social media platforms [25, 38]. For example, a frequent interaction was identified between the users who cared about environmental issues [50]. In this present study, we demonstrated that a group of users were enthusiastic in sharing wildlife-related information. Although a single post has the potential to reach tens of thousands of netizens in one instant, its popularity can only persist for less than a week. Long-term effect of public awareness raising through social media is a stepwise process and requires continuous efforts. When undertaking every operation, our findings in section 3.3 (figure 3 [3]) suggest that, additional efforts should focus on attracting enough comments rather than forwarding in the first day of posting for maintaining longer popularity.

Although open access weakens the geographic impact on the popularity of an incident, local economic development can affect social media technology application [51 ] or influence public education level [52]. We found that users living in relatively developed areas displayed more active online involvement in popular wildlife-related incidents. The Sina Weibo Annual Development Report stated that a large ratio of active users was highly educated [53]. Citizens with higher education level are more inclined to support wildlife conservation [54, 55]. In this study, the majority of the public expressed a positive attitude towards cetaceans (see section 3.4). Furthermore,
despite the use of social media, we should not ignore targeted environmental education for the public from underdeveloped regions. Previous studies have shown the asymmetric coverage of species in media reports [33, 34]. Here, we found that on Chinese social media sites a higher number of stranding incidents involving sea water cetaceans were reported, compared to those involving freshwater species. Hence, public response to saltwater incidents was more active. Past research on the general public has demonstrated that males had a higher awareness towards the conservation of endangered marine species than females [56]. However, in this study, we found an increased number of female users were active in cetacean stranding incidents. This might be explained by the respondent types in previous studies, which included village inhabitants living near wildlife habitats where women mainly stayed at home and had less experience of wildlife. Females were also found to be more susceptible to emotional influences [57] or to show a better recognition of ecological function values [57]. In addition, females often have a relatively higher willingness to support wildlife conservation [38].

Our results revealed that online audiences expressed ‘friendly’ sentiments with supportive ‘attitude’ towards cetaceans. The societal attitude to animal welfare has been changing over the past decades [59]. Our findings indicate that the active response of netizens was driven by curiosity or entertainment needs, but also by compassion (empathy). Overall, Chinese social media users are interested in wildlife conservation. Wide social concerns are helpful to engage additional people in wildlife conservation [16]. However, only simply emotion cannot form an effective joint force to address environmental issues since environmental damage is a complex problem affected by many man-made as well as natural processes [60]. Our results also identified individual responsibility views in the cetacean revival incidents, and conservation knowledge provision in negative social ethics incidents. Successful rescue of trapped wildlife encouraged public confidence and motivates their enthusiasm for participation [48]. Any news of deaths or anthropogenic injuries inflicted on wildlife leads to the feelings of disappointment and helplessness in the online public. These insecure feelings prompt the public to seek stronger reassurance [61], including hope that the governments increase effort in environmental conservation. Public opinion may drive improvements in government efforts to address these issues, but it may also breed public discontent with the government. Public participation plays a crucial role in wildlife conservation, as the government cannot complete or fix everything [62]. Lastly, cetacean species are protected by wildlife conservation legislation in China, however very few public comments mention it. Social media-based environmental education should include provision of knowledge on wildlife protection laws and regulations in order to raise public awareness.

5. Conclusions and limitations

As an open virtual community, social media is advantageous for gathering the public for wildlife conservation. It is an emerging tool for environmental education. Social media-based education of biodiversity conservation should have rapid response ability, include more positive emotions to arouse sense of individual responsibility, popularise knowledge of wildlife biology and relevant legislation to influence public opinions. Traditional users (especially central media users) should be utilised to broaden social influence of less attractive species or incidents in order to meet the integrity need of biodiversity conservation. Efforts should be made to attract highly educated and female users to ensure more comments in the first day of posting. Finally, continuous efforts are required in order to attract long-term attention to wildlife concerns.

In this study, we only considered cetacean species when evaluating public awareness. Other endangered species may result in different levels of public attention and concern. The data collection was also limited to Chinese social media. Public awareness towards cetacean stranding incidents in foreign social media platforms (e.g. Twitter) may enrich the analytical data, and increase the power of the quantitative model. Further, content analysis of unrestricted online comments used in this study broadened the sample size at the cost of reducing the depth of the analysis, where a conventional questionnaire survey could provide more targeted analysis. In the future, an attached online questionnaire with wildlife-related posts could be used to extract more useful information for further analysis of public awareness.

Appendix A Supporting information

Main processes of content analysis (appendix S1), websites of public comments on highly popular tweets (appendix S2), and user classification (appendix S3) are available online. The authors are solely responsible for the content and functionality of these materials. All queries (other than on the absence of the data) should be directed to the corresponding author.

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Data availability statements

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID iDs

Zengwei Yuan @ [https://orcid.org/0000-0002-6533-4170](https://orcid.org/0000-0002-6533-4170)
Songyan Jiang @ [https://orcid.org/0000-0003-1751-5548](https://orcid.org/0000-0003-1751-5548)

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