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ECOSYSTEMS

Public awareness and engagement in relation to the coastal oil spill in northeast Brazil

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Abstract: Social media data is a rich source of information to assess human activities in catastrophic events. Here, we use social media data to understand how the 2019 Brazilian oil spill influenced social attitudes. Data were collected from the globally popular Instagram platform between August 1, 2019 and March 1, 2020. First, we manually identified the 5 most popular (portuguese language) hashtags related to the oil spill #oleononononordeste; #desastreambiental; #marsemoleo; #sosnordeste; #marsempetroleo. In the sequence, we collected information on captions, post metadata and users associated with posts retrieved using the selected hashtags. We identified a total of 7,413 posts. These posts were grouped in topics: government (47.76%), protest (24.37%), volunteers (24.45%), biodiversity (0.003%), origin (0.006%), tourism (0.008%) and others (0.016%). All topics had the peak of posts in October and November 2019. Nevertheless, interest in the oil spill was temporary, with most posts appearing in the 2-4 months after the beginning of the disaster. Our findings illustrate the enormous potential of using social media data for understanding and monitoring human engagement with environmental disasters, but also suggest that conservationists and environmental groups may only have a limited 'window of opportunity' to engage and mobilize public support for remediation and restoration efforts.

Key words: Risk perception, social media, big data, disaster management.

INTRODUCTION

The enormous global growth in social media use (Perrin 2015) is providing unparalleled opportunities to study social attitudes, including political (Ceron et al. 2014) and commercial preferences (Hajli 2014). Studying social attitudes is also important for environmental conservation (Jepson & Canney 2003), and the potential of large online databases and social media platforms for supporting conservation research and action has led to the recent development of 'conservation culturomics' (Correia et al. 2021, Ladle et al. 2016). This emerging sub-discipline encompasses the study of all forms of human-nature interactions in the digital realm, but is particularly valuable for understanding debates or discussions about nature conservation online (Di Minin et al. 2015, Toivonen et al. 2019). For example, researchers have used online data to assess human sentiment in support of environmental monitoring (Becken et al. 2017), analyze public interest in endangered animals (Otsuka & Yamakoshi 2020) and investigate attitudes towards protected areas (Hausmann et al. 2020). Social media can also be be used for near real-time monitoring of public reactions to events (Fink et al. 2020), including environmental disasters, since they

provide a fast and democratic means for people to inform themselves and to share information (Alexander 2014), as well as a platform to demand government action and to mobilize support for environmental actions (Jurgens & Helsloot 2018).

The way the public responds to environmental disasters on social media platforms can thus provide valuable information about attitudes, sentiments and motivations. Indeed, social media data have been used to monitor the public perception of disasters (Alexander 2014), as well as tracking public actions to address and solve environmental problems (Jurgens & Helsloot 2018). Specific examples include the use of social media data to evaluate public mood after an earthquake (Bai & Yu 2016), public behaviour during a flood evacuation (Du et al. 2017) and the public discourse about a major oil spill (Beedasy et al. 2020). In this latter study of the 2010 Deepwater Horizon oil spill off the coast of Mexico, Beedasy et al. (2020) concluded that social media had empowered users within local communities, giving them access to power brokers, providing reliable information and allowing the formation of strong online networks that contributed to societal resilience.

In August 2019, the Brazilian coast suffered a major oil spill, as oil from a (still) unidentified source began to wash up on beaches and reefs (Soares et al. 2020b). Despite its unknown provenance (Escobar 2019), the extent of the spillage was large enough to affect 3,000 km of coastline, impacting more than 55 marine protected areas with significant consequences for biodiversity and local livelihoods (Soares et al. 2020a, b, Ladle et al. 2020). This enormous tragedy generated much public discourse about the origins of the oil spill and demands for action by the Brazilian federal government - whose response was considered both slow and inadequate (Brum et al. 2020, Soares et al. 2020b). Indeed, the response of the federal government was characterized by a lack of transparency about mitigation actions combined with inadequate communication of public risk (Brum et al. 2020, Soares et al. 2020a). Not only did this response sow confusion, it also risked increasing public anxiety about the threat of risk since this is sometimes incommensurate with existing scientific evidence (Shook & Turner 2016). The lack of federal government action was in contrast to local governments, universities and NGOs, who immediately began researching the origin of the oil and to mobilize campaigns to clean up affected areas (Magalhães et al. 2021). Examples of online users and groups that raised engagement in instagram are 'tribunadonorte', 'biologiatotaloficial' and 'salvemaracaipe' whose posts about the oil spill generated 3,242, 1,965 and 1,774 likes in September, respectively.

Here, we aim to better understand public responses to the 2019 Brazilian oil spill in northeastern Brazil through an analysis of the Instagram (www.instagram.com) social media platform. Specifically, we, i) analyze the content of relevant posts and categorize the most relevant topics; ii) relate thematic groups to the user profiles (e.g., personal account, government, celebrities, etc.); and, iii) identify the temporal trend of public interest in the oil spill. In this way we hope to provide a more nuanced account of public responses to the oil spill that captures key aspects of public discourse.

MATERIALS AND METHODS

Data collection

In order to assess public interest in the 2019 oil spill, we collected data from Instagram posts and from online news from national websites. In the first phase, a manual search was conducted to identify the most popular hashtags related

to the oil spill on the northeast coast. The search was conducted by reading posts related to the environmental disaster in question and identifying the hashtags used in the posts. We selected the five (5) most popular hashtags (#oleononononordeste, #desastreambiental, #marsemoleo, #marsempetroleo, #sosnordeste) and downloaded data associated with all posts containing the targeted hashtags published in the period 01-Aug-2019 to 01-Mar-2020. This time interval covers from 15 days before the first official oil observation until the COVID-19 pandemic outbreak began to dominate virtual discussions in Brazil. For each post, we collected the following data: post ID, user ID, username, text, publication date and hour, and likes (number of likes received).

In the second phase, after defining the hashtags, the python language instaloader library was used, in which it was possible to perform an automated search and download all posts containing the hashtags selected in this research, in the period of the disaster. It is important to note that Instagram only provides access to detailed information of non-personal accounts (business accounts) - private accounts data are limited to the username. We recorded the following information for each business user: business category, number of followers, number of followers and biography (the autobiographic text of an Instagram profile). The full list of (fully anonymised) users, including the metrics used, can be found in the Supplementary Material-Table SI.

A total of 15,495 posts from 8,222 private and business Instagram users were initially identified. After filtering out profiles with inappropriately allocated hashtags (i.e. used to boost the visibility of posts about unrelated topics) we were left with a total of 7,413 valid posts from 3,255 users. R software was used to produce all figures and statistical analysis. All data about Instagram posts and users are in the public domain; private users were not identified. Nevertheless, all users were given unique codes and results are presented in aggregated format to preclude personal identification.

In order to quantify the online news about the oil spill in national websites, we used the Google Search actor of the apify platform for web scraping. We defined the search parameters to retrieve all web pages written in Brazilian Portuguese containing the words oil and northeast (search string: *oleo* AND *nordeste*) and published during the same time frame we used for the Instagram posts. We then filtered the data in order to maintain only news pages.

Data analysis

In order to group posts by their content similarity, we applied a clustering analysis technique (Wards' method) based on word composition of the posts in our dataset. Before the analysis, we filtered and excluded all portuguese stopwords, symbols and hashtags from each post. The main output of the clustering analysis was a dendrogram where branch distances are related to the similarity between each pair of posts (see supplementary materials for more details). This allowed us to define groups of posts with similar content. Then, after determining an optimal number of clusters (Langfelder et al. 2008), five researchers independently analyzed the 15 most frequent words of all posts in each cluster in order to attribute an appropriate category name for each one. This was followed by an online meeting to discuss the classifications and to reach a consensus on the category name to represent each cluster (Table II). This step allowed us to attribute a thematic category to each post.

The dates of posts in each category were then analyzed to identify temporal patterns. We used the dates of national online news stories to

explore similarities with both posts and official oil observations.

RESULTS

We retrieved a total of 7,413 valid instagram posts about the 2019 Brazilian oil spill generated by 3,255 instagram users. Our clustering analysis identified seven thematic categories, according to the most frequent words in each cluster. Posts in 'Government', 'Protest' and 'Volunteers' categories made up approximately 97% of all posts and accounted for 95% of users (Table I). Posts about 'Biodiversity', 'Tourism' and the 'Origin' of the oil spill were much less numerous and had a short temporal peak which lasted about a week (Figure 1a).

Instagram posts peaked between the second week of October and the second week of November. In contrast, internet news showed four main peaks spread between the first week of October and the last week of November (Figure 1b). Specific events seem to have triggered an increase in the volume of social media posts and online news. For example, the day with the most posts on instagram about the oil spill event was October 25th, when posts within the topic "Government" surpassed 300 posts and posts in the categories "Protests" and "Volunteers" reached 200 posts. However, impressively, on this day, there were very few online news reports about the topic. Similar behavior is seen on October 19 (see Figure 1).

Slightly more than half (53.4%) of instagram users were 'personal users', with 45.5% associated with business accounts. We used Instagram's 'types' classification of business accounts, in which each type of account has one or more categories. The most common type of business account was type 4 (31%), which is mainly composed of creators & celebrities, followed by type 9 (16%) which represents Home Services, Home Goods Stores, Personal Goods & General Merchandise Stores. Type 6 (government agencies) and type 3 (food-related accounts) represented only 0.4% and 2% of all business accounts, respectively.

We also explored the contribution of each type of business account to each post topic (Figure 2). In general, all post topics were most discussed by personal accounts and the categories "Government", "Protest" and "Volunteers" comprised more than 50% of all posts, regardless of user type. If we consider these contributions from post topics by each type of account as public interest about the event,

Table I. Number of posts and users and the top frequent words in each cluster category.

Post category	Posts number	Users	Top frequent words
Government	3541	1913	oil; government; people
Protest	1807	1180	fight; warning; call
Volunteers	1813	1141	help; volunteers; nature
Biodiversity	26	22	animal; turtles; oil
Oil origin	44	44	origin; leak; uncertain
Tourism	63	57	tour; buggy; reserve
Other	119	105	amazon; coal; event

type 3 and 8 business accounts (which represent branches of food and accommodation) had poor engagement. The same could be observed for Government Agencies. However, type 4 accounts (which represent Creators & Celebrities jointly with Lifestyle services - colloquially known as 'influencers') were the type of users with most interest in the oil spill.

DISCUSSION

Our aim was to assess the digital profile of public interest in the 2019 oil spill using automated processing of textual content shared on Instagram (Hausmann et al. 2020). Our results clearly show that posts tended to have similar characteristics and content regardless of user type. Specifically, posts from both personal and corporate accounts were strongly focused on government inaction, with posts relating to protesting and volunteering also prominent. Business accounts — encompassing *creators & celebrities* — tended to address volunteering more than posts from personal profiles, though the differences were relatively minor. These results reflect the enormous power of social media to capture public feeling and also its role in mobilizing public action. Popular social

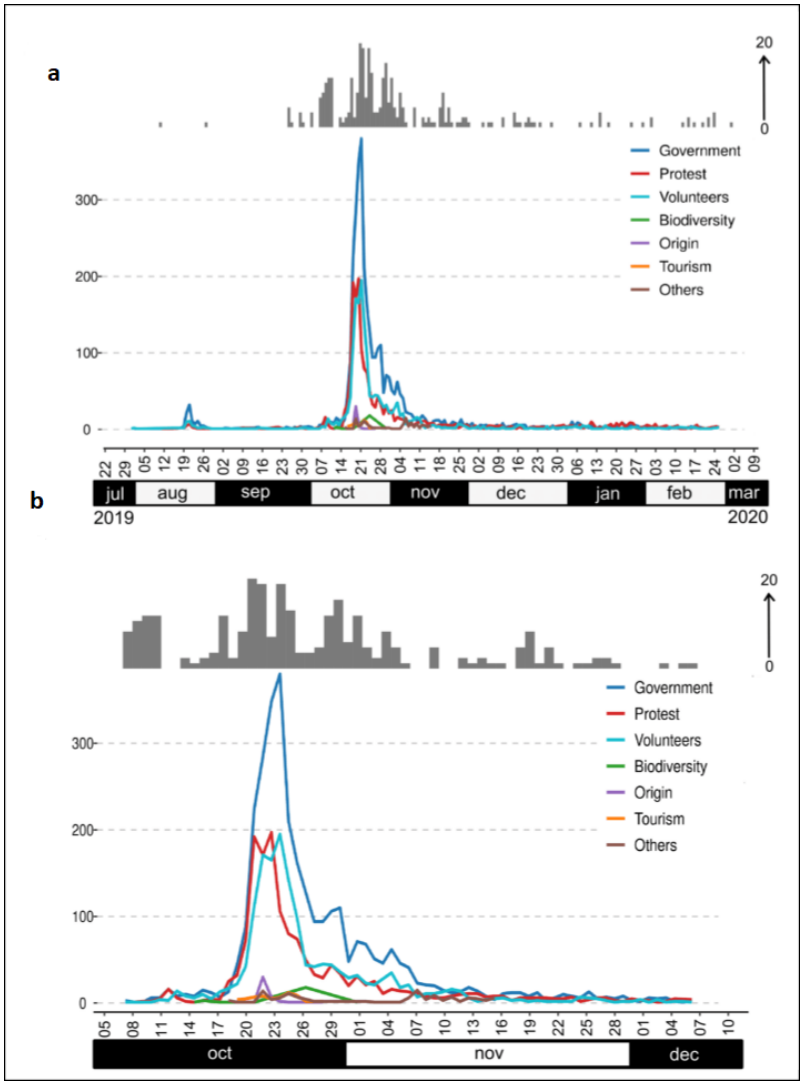

Figure 1. (1a) Temporal distribution of Instagram posts (line graph below) and news (bar graph above) about the oil spill event in the period from 01 August to 01 March. (1b) Temporal distribution of Instagram posts (line graph below) and news (bar graph above) about the oil spill event in the period from 05 October to 10 December. Each colour in the graph represents a different category of user. The gray scale represents the online news.

media platforms such as Instagram are ideally placed to facilitate the creation of online activist communities and recent research suggests that they can be effective at changing public perceptions and mobilizing real-world action (e.g. Stanley 2020). More generally, it also demonstrates the power of social media analysis to monitor trends, patterns and reactions to conservation-related events (Fink et al. 2020, Harrington et al. 2018, Soriano-Redondo et al. 2017).

The high volume of posts related to the government sphere probably reflects various interacting factors, including: i) despair at government inaction in response to the disaster; ii) the urgent need for effective responses, and; iii) an expectation that, as an event that affected a large proportion of the Brazilian coastline, that the federal government should be responsible for coordinating remediation measures. Significantly, it is clear that the public used Instagram (and other social media platforms) to seek information or to demand action from the Brazilian government. These demands were justifiable given that it was widely reported that coordinated remediation actions were exceedingly delayed (Brum et al. 2020, Soares et al. 2020b), as were official efforts to discover the origins of the oil spill (Soares et al. 2020b). To date, it is still not clear how much oil was released - it proved impossible to detect and track the submerged oil (Lourenço et al. 2020) - or who was directly responsible (Magalhães et al. 2021). These factors may also have fuelled the high number of protest-related and volunteer posts, many of which mentioned government inaction and sought to mobilize voluntary actions to contain the effects of the oil spill.

Other topics, such as 'Biodiversity', 'Tourism' and the 'Origin of oil' were far less represented in posts, possibly due to less public awareness/interest in these issues or the characteristics of Instagram users. The 'Other' category, which incorporated various topics that were not in

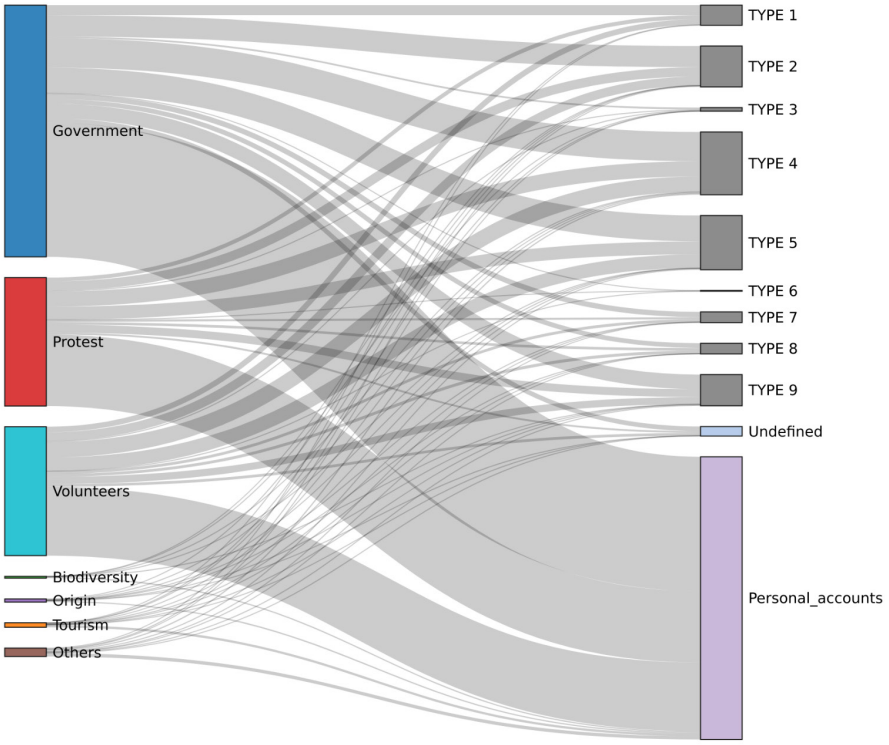

Figure 2. Contribution of each type of business accounts for each type of post. Type 1: Auto Dealers, Business & Utility Services, Professional Services; Type 2: Content & Apps, Publishers; Type 3: Restaurants, Food & Personal Goods, Grocery and Convenience Stores; Type 4: Creators & Celebrities, Lifestyle Services; Type 5: Entities, Non & Profits & Religious Organizations; Type 6: Government Agencies; Type 7: General Interests; Type 8: Transportation & Accommodation Services, Local Events; Type 9: Home Services, Home Goods Stores, Personal Goods & General Merchandise Stores.

any of the other six identified categories, was also poorly represented by posts (see Figure 2). These findings perhaps reflect a general lack of public discourse on the value of biodiversity and its important role in coastal tourism in the northeast region, a deficit that could be addressed by strengthening the relationship between the public, scientists and decision-makers (Papworth et al. 2015). As the preferred method of communication and the primary source of information for many users, social media also has an important role in raising

Table II. Number of posts contributed by each type of users accounts.

Type	User category	Posts	Users
Type 1	Auto Dealers	5	3
	Business & Utility Services	107	69
	Professional Services	171	121
Type 2	Content & Apps	19	10
	Publishers	556	185
Type 3	Restaurants	24	17
	Food & Personal Goods	6	4
	Grocery & Convenience Stores	20	11
Type 4	Creators & Celebrities	870	453
	Lifestyle Services	14	10
Type 5	Entities	6	4
	Non & Profits & Religious Organizations	757	195
Type 6	Government Agencies	10	7
Type 7	General Interests	150	85
Type 8	Transportation & Accommodation Services	57	30
	Local Events	91	38
Type 9	Home Services	92	50
	Home Goods Stores	19	14
	Personal Goods & General Merchandise Stores	328	175
Personal	Personal	3977	1739
Undefined	Undefined	134	35
Total		7413	3255

environmental awareness among the public (Kaur & Chahal 2018).

Social media and other digital platforms were clearly important sources of information about the oil spill for many citizens, though not all of this information was necessarily accurate. Lemos et al. (2020) evaluated video content about the 2019 oil spill posted on the Youtube platform and identified that about 80% contained misinformation, and 14% were fabricated (fake news content). Platforms such as Instagram encourage the constant production of content which can lead to both positive effects of disseminating information and reinforcing important messages, but which can also result in negative consequences for public discourse such as creating false controversies, spreading misinformation and sensationalizing social and environmental consequences.

The volume of social media posts can have a strong influence on public engagement with an event, depending on its severity and urgency (Fink et al. 2020), its overall reach, and the way news of a given conservation event is written (Fink et al. 2020). In our results, for example, an interesting peak of posts about the oil spill event was observed on the 19th October 2019, though this was not reflected in the news media. However, on the 17th October 2019 the Federal Public Ministry filed a lawsuit against the Brazilian government to implement a contingency plan regarding the oil spill, which until then had not been started. This reinforces the perception that legal interventions in conflicts can generate high levels of public interest and engagement on social media (see, Papworth et al. 2015), even if they are not extensively covered in the traditional media. The highest peak occurred after October 25th, when a shocking photo of a child covered in oil started to be disseminated on news platforms and which was extensively shared and reposted on instagram. Similar to the findings of Fink et al. (2020), this difference in the daily volume of social media posts and the respective daily volume of online news, may well be explained by the common practice of news articles being promoted, shared and distributed on social media, which causes such news to continue to be consumed by social media users in subsequent days.

The effects of the 2019 oil spill on coastal ecosystems and the communities that rely on them may last for a long time, with considerable concern about how contamination of fish stocks may affect the local human populations' livelihoods and health (Magris & Giarrizzo 2020). In this context the apparent decrease in interest in the oil spill on social media platforms and news is worrying, since public engagement and support are crucial to attracting and maintaining government and private sector support for research and to develop public policies. Our study makes it clear that the focus of public attention on environmental disasters is relatively transient, and that a limited window opportunity exists to widely disseminate information and to mobilize action before users move on to the next issue - in this case the COVID-19 pandemic.

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SUPPLEMENTARY MATERIAL
Table SI.

How to cite
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