



1 **#UbirajaraBelongstoBR: social media activism**
2 **against (neo)colonial practices in palaeontology**

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11 #UbirajaraBelongstoBR: social media activism against (neo)colonial 12 practices in palaeontology

14 Abstract.

15 Social media has revolutionized the engagement between scientists and the public, offering platforms to
16 challenge unethical practices and advocate for change. In December 2020, Brazilian paleontologists and
17 supporters initiated the hashtag #UbirajaraBelongstoBR on Twitter (now X) to protest the alleged illicit
18 acquisition and export of the dinosaur fossil *Ubirajara jubatus* from Brazil to Germany. This movement not only
19 demanded the fossil's repatriation but also sparked global discussions on neo-colonial practices in paleontology.

21 In this study, we analyze 39,728 tweets containing the hashtag #UbirajaraBelongstoBR, collected between
22 December 2020 and February 2023. Employing social network analysis and computational text analysis, we
23 examine the dynamics of this online movement, identify key influencers, and assess its reach and impact. Our
24 results reveal that the campaign transcended the paleontology community, engaging a diverse international
25 audience including scientists, artists, activists, and the general public. Sentiment analysis indicates shifts
26 corresponding to pivotal events, such as official statements and the eventual repatriation of the fossil.

28 Our findings demonstrate the power of social media in mobilizing grassroots movements and influencing
29 scientific discourse and policy. The #UbirajaraBelongstoBR case illustrates how digital platforms can facilitate
30 international advocacy against unethical scientific practices, highlighting social media's potential to effect change
31 in scientific governance and promote ethical standards. This study contributes to the understanding of digital
32 activism in science communication and underscores the evolving landscape of public engagement in scientific
33 issues.

36 **Keywords** — Social Network Analysis, Ubirajara, Palaeontology, Social Movement, illicit fossil traffic.



39 1 Introduction

40 Social media has transformed the way in which scientists communicate their research and communication with
41 both other scientists and non-scientists (Ocon et al., 2021; Entradas et al., 2020; Walter et al., 2019). Social
42 media is also serving an important role in providing a platform, especially for marginalised voices in academia,
43 who are harnessing its power to challenge existing power structures (Yamine et al., 2018). It has also been used
44 to call out unethical practices and other issues in the academy. For example, Elisabeth Bik who is known for
45 posting on wrongful image manipulation in the biomedical literature, that has led to the retraction of several
46 papers, has amassed more than 130,000 followers on Twitter (now X) (Bik, 2022; Shen, 2020).

47 In a similar fashion, Brazilian palaeontologists took to social media in December 2020 to raise their concerns
48 about a newly described Brazilian dinosaur *Ubirajara jubatus* (henceforth Ubirajara). Originating from the
49 Araripe Basin, north east of Brazil, Ubirajara has now come to represent the fight against colonial practices in
50 modern palaeontology. The article in which Ubirajara was described raised several ethical and legal concerns
51 over the appropriation and study on this fossil: 1) the authors and the German institution where it was repositied
52 claimed to have obtained the fossil legally although there did not seem to be any legal avenue for such a fossil to
53 have found its way to Germany; 2) the authors did not seem to have involved any Brazilian institutions in the
54 process of acquiring and researching this specimen—also against the law; 3) The region of Brazil where the fossil
55 originated has been targeted by fossil smugglers for years; (4) Some authors in the study had been involved in
56 controversies with irregular fossils from Brazil before (Cisneros et al., 2022a, b; Christakou, 2015; Gibney, 2014;
57 Raja and Dunne, 2023).

58
59 The hashtag #UbirajaraBelongstoBR, protesting for the return of the fossil to Brazil, took Twitter by storm, along
60 with other social media platforms, such as Facebook, Instagram and YouTube, bringing together both Brazilian
61 and non-Brazilian palaeontologists, paleoartists, students and other members of the general public together. It
62 also fuelled discussions on colonialism in palaeontology, a topic of growing interest and importance in the
63 discipline, e.g. (Monarrez et al., 2021; Raja et al., 2022). Palaeontology as a discipline has been shaped through
64 centuries of colonial practices, influencing not only the distribution of fossil data around the world, but also the
65 people who have access to these data (Monarrez et al., 2021; Raja et al., 2022). These practices, including the
66 theft of fossils and exclusion of local scientists as in the case of Ubirajara (Cisneros et al., 2022a), remain to this
67 day and continue to deepen this bias (Raja et al., 2022). The modern materialisation of colonialism in



68 palaeontology is especially directed at the lower and middle income countries which are disproportionately
69 underrepresented in paleontological research and literature (Raja et al., 2022).

70



71

72 **Figure 1: Examples of images shared with the hashtag #UbirajaraBelongsToBR by Twitter users. Image**
73 **credits (from left to right, top to bottom): @arturvic (Artur, 2020), @_themingau (Mingau, 2020),**
74 **@Emily_Art (Stepp, 2020), @herbertologist (Herbert, 2020), @valent801 (Valent801, 2020),**
75 **@Brenda7Kauane (Kauane, 2021), @freakyraptor (Alli, 2020), @Waxosaurus (Waxosaurus, 2020),**
76 **@THSpike (Paleonecromante, 2020), @antoniopedroalb (Albuquerque, 2021).**

77

78 Ubirajara is not the only Brazilian fossil studied by foreign researchers that is believed to have been illegally
79 exported and/or acquired. Brazil, especially the Araripe Basin, has been the victim of fossil smuggling for
80 decades, e.g. holotypes of *Irritator challengeri* described in 1996 and *Mirischia asymmetrica* in 2004 (Cisneros et
81 al. 2022a ; Cisneros et al. 2022b). These have however not attracted as much attention from the public and the
82 media until Ubirajara (e.g.), probably because these were published before the “golden age” of social media and
83 science communication on these platforms.

84 In the case of Ubirajara, social media was crucial in the dissemination of information on the specimen and
85 updates on the case. Eventually, the State Museum of Natural History Karlsruhe (SMNK) took to Instagram



86 posting a statement that the fossil was the property of the German state of Baden-Württemberg and it would not
87 repatriate it in response to the backlash it was receiving and attracting more criticism. The corresponding research
88 article was permanently withdrawn soon after this when it was found out that the authors lied and misrepresented
89 information on how it was acquired. The Minister of Science of Baden-Württemberg, after an investigation,
90 recognized misconduct by SMNK, declared that the export of the fossil to Germany violated Brazilian laws, and
91 that the museum should repatriate it to Brazil, which has now happened (Black 2022). Since the
92 #UbirajaraBelongsToBR movement, several other Brazilian fossils, from the US and Belgium, have been
93 repatriated (Black 2022).

94
95 The #UbirajaraBelongsToBR case shares commonalities with other recent social movements with large online
96 participation, such as Black Lives Matter (BLM), #MeToo, and the Occupy Wall Street movement. Like these
97 movements, it leverages the reduced coordination costs and enhanced organizational modes provided by social
98 and digital technologies. Scholars like Earl and Kimport (Earl and Kimport, 2011) have highlighted how these
99 technologies not only amplify existing forms of activism but also create fundamentally new ways of operating
100 within social movements. They argue that digital infrastructures personalize online content, giving individuals
101 specific reasons to protest and facilitating their ability to push for change across various platforms. This
102 transformation has demanded a new framework of understanding, as it shifts how activists organize,
103 communicate, and interact in efforts to achieve widespread societal impact.

104
105 Considering the similarity between the #UbirajaraBelongsToBR protest and the other ones cited above, it is
106 natural to study them using similar approaches. For the Occupy Wall Street anti-capitalist movement in the
107 United States, for instance, the movement on Twitter appeared to draw a group of people who were already
108 involved in local politics and other social movements abroad and who were well-connected. Conover et al
109 (2013a; 2013b) use a sizable sample from Twitter to track trends in Occupy member activity, interests, and
110 socialisation over a period of fifteen months, starting three months before the regime's first resistance
111 movements. They find that users who were vocal in the early months of the movement decreased their
112 involvement in Occupy-related activity during the analysis (Conover et al., 2013a). For comparison, related
113 studies looking at the expression of the Black Lives Matter movement on Twitter found that BLM activity on
114 Twitter predicted mainstream news coverage of police brutality, which in turn was the strongest driver of
115 attention to the issue from political elites (Freelon et al. 2016). At the same time, Ince et al. show how that BLM
116 was not a monolithic movement with a single message or way to frame structural racism issues, but rather a



117 movement with "distributed framing" (Ince, Rojas, and Davis 2017), where different hashtags co-occurring with
118 #BlackLivesMatter emphasized different aspects of the movement, such as solidarity towards those protesting,
119 strategic tactics, violent reactions from the police, counter-movement sentiment, among others.

120

121 Here, taking inspiration from studies such as the ones mentioned above, we analyse a collection of all tweets
122 containing the hashtag #UbirajaraBelongsToBR during a given period, and investigate ~~the~~ how the
123 #UbirajaraBelongsToBR movement evolved over time, in terms of its tone, language, and groups of participants,
124 as important milestones in the case of Ubirajara happened over many months. Finally, our results indicate that the
125 #UbirajaraBelongstoBR managed to burst the palaeontology bubble, and to go even beyond science and science
126 journalism.

127 **2 Materials and Methods**

128 **2.1 Data**

129 Tweets posted during the period December 2020 and February 2023 that contain the hashtag
130 #UbirajaraBelongsToBR were downloaded using the Twitter API (now unavailable, after the rebrand to X) using
131 the python library Tweepy (Roesslein 2009).

132 The final dataset includes 39,728 tweets that included the hashtag #UbirajaraBelongstoBR and related metadata
133 such as the user account from which the tweet was posted, the tweet type, the data and time, the number of likes
134 and retweets, as well as other information. The preprocessing stage involved the removal of duplicate tweets,
135 along with the conversion of all hashtag text to lowercase. By adopting this approach, we ensured the inclusion of
136 identical hashtags (e.g. #UbirajaraBelongsToBR and #ubirajarabelongstobr). **The presence of repeated hashtags**
137 **within a single tweet.**

138 Ethical clearance for this project was obtained at the University of Exeter, including for the publication of user
139 identifiers (e.g. twitter handles), provided that the data did not include any sensitive content. Since it did not
140 include any non-public or sensitive content, the project was approved.

141 **2.2 Language detection**

142 For tweets with undefined languages, the Google Translate API was used to detect the language of the original
143 tweet and or referenced tweet. When that failed, the detected language by Google Translate API has been used as
144 the final value, by priority of Original Tweet language rather than Referenced Tweet language.



145 **2.3 Country detection**

146 Over 90% of the returned data by Tweepy listed an undefined country. We used a combination of tools such as
147 pycountry, CountryInfo, and the Google Maps v3 API to infer the country of residence of the users. This was
148 done by using the Location feature which is filled by users in their user accounts. This feature includes different
149 types of data such as addresses, cities, or maybe countries, written in full or as abbreviations (e.g. BRA for
150 Brazil). Countries could only be detected for approximately 50% of the tweets, as many users do not provide any
151 country-specific information in their profile. For the users with undefined countries, we only tagged the language
152 of their tweets. For instance, a user with an undefined country posting primarily in Portuguese was set as
153 “Unknown (Portuguese)”.

154 **2.4 Sentiment analysis**

155 We also carried out a sentiment analysis for each tweet using Natural Language Processing (NLP) to analyse the
156 polarity in opinions, sentiments and feelings expressed in each tweet. This was done using the function
157 SentimentIntensityAnalyzer() from the Natural Language Toolkit (NLTK) in Python. The foundation of
158 sentiment analysis is a lexicon that associates lexical traits with emotional intensity scores. The intensity of each
159 word in a text may be added together to determine the sentiment score of that text. Words like "loving," "joy,"
160 "glad," and "like" carry positive connotations whereas terms, such as that "did not love" is deemed as a negative
161 statement.

162 NLTK returns a list of scores for each of the following four parameters for a string:: Negative, Neutral, Positive
163 and Compound (calculated by averaging the preceding scores). For instance, for 'This was a good movie.' the
164 result will be: ['neg': 0.0, 'neu': 0.508, 'pos': 0.492, 'compound': 0.4404]. In essence, this tool can detect the
165 intensity of positivity and negativity of each phrase according to their words and punctuation (Kumar et al. 2022).
166 It is worth noting that the SentimentIntensityAnalyzer tool is limited in its ability to detect nuanced forms of
167 conversations such as irony or sarcasm, but assuming that the majority of the tweets in our dataset do not fall in
168 that category, it should still produce useful results.

169 **2.5 Network analysis**

170 We use Gephi, an open source tool for manipulating networks (Bastian et al. 2009), to analyse the interaction
171 between users and explore the structure of their connection as well as the connections amongst
172 #UbirajaraBelongsToBR and co-occurring hashtags. This allows us to identify the structure of interactions and



173 attributes of members and possible patterns within them, to recognise regional and global patterns, significant
174 people, and network dynamics.

175 Since we focus on studying interactions between individuals, we only considered tweets that were either a
176 retweet, a quoted tweet or a reply to the original tweet and built a directed network that considers the direction of
177 communication, e.g..

178 User A has replied to User B by a tweet. Each interaction between two specific users was assigned a value
179 depending on the number of times it happened, e.g. if user A retweets a tweet from user B for 5 times, a weight of
180 5 was assigned.

181 We carry out community detection using the Louvain algorithm (Blondel et al., 2008). A community in a network
182 can be roughly defined as a group of nodes more densely connected to each other than to nodes outside the group.
183 For a network inferred from posts and hashtags, these communities are centred around a topic of conversation, or
184 based on shared interests or attributes. Finally, to estimate the centrality of authors in the protest network, we use
185 multiple network science statistics, defined below.

186

187 **Degree centrality:** this is the simplest measure of centrality and counts the number of edges (or connections) a
188 node has. Nodes with a high degree centrality are often hubs or highly connected nodes in a network. In a social
189 network, for example, a person with a high degree centrality might have many friends.

190

191 **Betweenness Centrality:** this measure looks at all the shortest paths between pairs of nodes and counts how
192 often a particular node lies on these paths. Nodes with high betweenness centrality act as bridges or gateways in
193 the network. They are often crucial for ensuring flow or connectivity between different parts of the network.

194

195 **Eigenvector Centrality:** this centrality measure assigns relative scores to all nodes in the network based on the
196 idea that connections to high-scoring nodes contribute more to the score of a node than equal connections to low-
197 scoring nodes. Nodes with high eigenvector centrality are connected to many nodes who themselves have high
198 scores. It's a measure of "influential" connectivity.

199 Each centrality measure gives a different perspective on the importance or influence of nodes within a network.

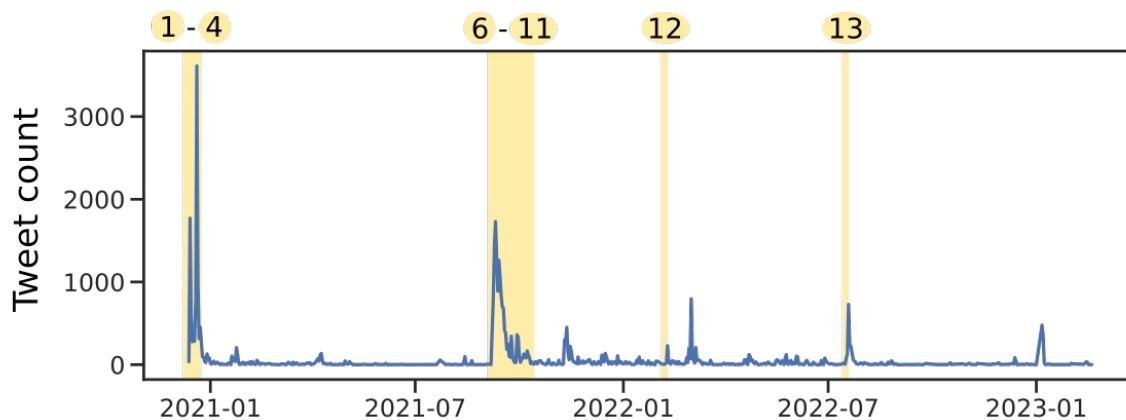
200 Depending on the research question or the nature of the network, one might be more relevant than the others.



201 **3 Results**

202 **3.1 Protest timeline**

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- 1 In press article on “Ubirajara jubatus” appears on the journal Cretaceous Research and the hashtag #UbirajaraBelongstoBR is first used on Twitter.
- 2 The Brazilian Society of Palaeontology contacts Cretaceous Research.
- 3 First report on the controversy by international media (National Geographic).
- 4 Article temporarily removed by Cretaceous Research.
- 5 SMNK informs the Brazilian Society of Palaeontology that it will not repatriate the fossil. The Brazilian Society of Palaeontology informs its members.
- 6 SMNK releases a statement on Instagram refusing repatriation of “Ubirajara jubatus”.
- 7 A petition is created at Change.org asking for the fossil to be returned.
- 8 Article withdrawn by Cretaceous Research.
- 9 SMNK Instagram account is deactivated.
- 10 Article in the journal Science reveals that the dinosaur was imported to Germany by fossil dealers in 2006 and purchased by SMNK in 2009.
- 11 The USA repatriates 35 fossil spiders to Brazil.
- 12 Belgium repatriates a pterosaur to Brazil.
- 13 Germany announces that “Ubirajara jubatus” will be repatriated to Brazil.

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Figure 2: Timeline of events during the #UbirajaraBelongstoBR protest.

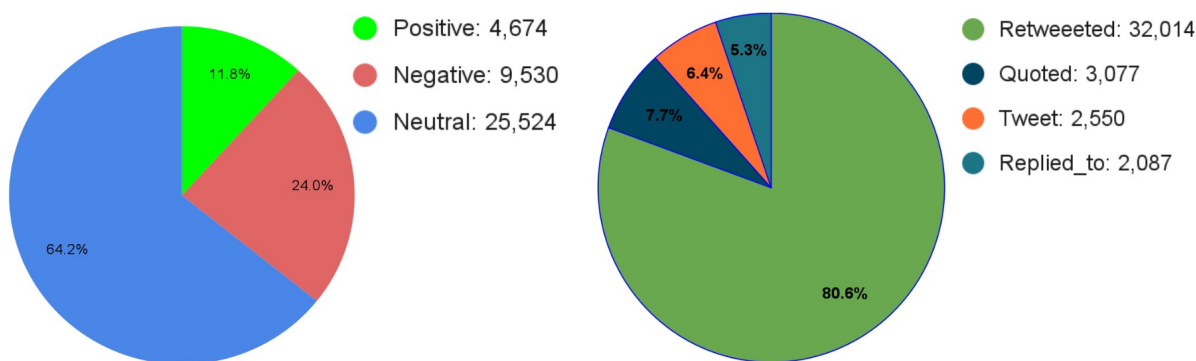
207

208 There are two significant moments (Figure 2) with a high number of tweets over the selected time duration,

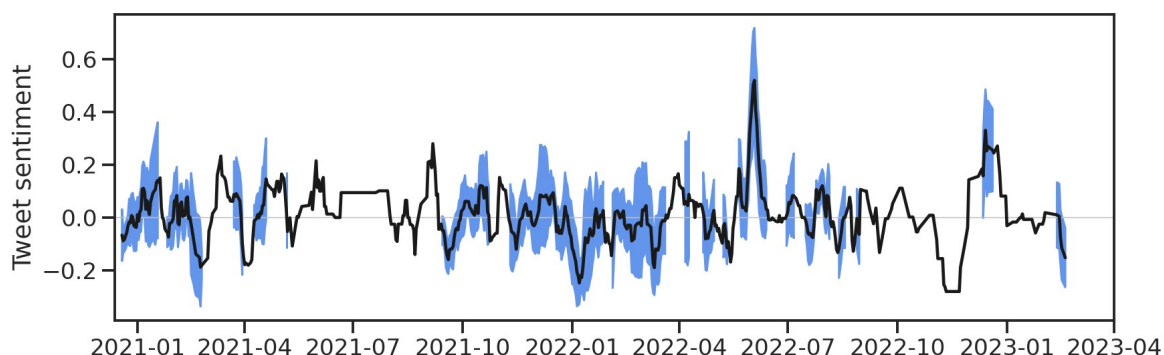
209 namely the start of the protest and the first report on the controversy by international media, and the moment



210 when SMNK informed the Brazilian Society of Palaeontology that it would not repatriate the ~~forum~~, both of
211 which led to many manifestations on twitter. Specific dates and links to each event are provided in Appendix A.
212
213
214



215 **Figure 3: (left) Distribution of tweet sentiment (right) Distribution of Tweet groups**



216
217 **Figure 4: Overall tweet sentiment over time. The black line represents the average sentiment of all tweets**
218 **containing #UbirajaraBelongstoBR, and the shaded blue area represents the average plus or minus one**
219 **standard deviation of the tweet sentiment.**

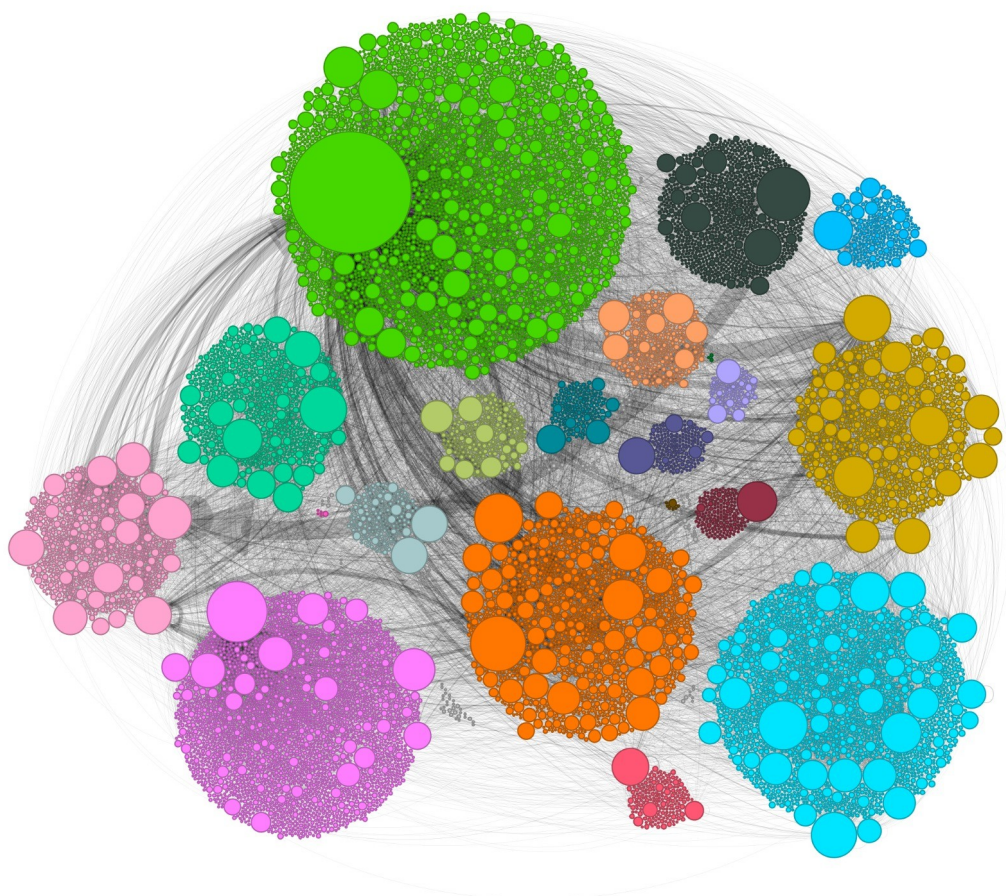
220
221 The sentiment analysis results (Figures 3 and 4) reveal that while a majority of tweets show neutral sentiment, the
222 number of negative tweets is more than two times the number of positive tweets. They also show how most of the
223 tweets related to #UbirajaraBelongstoBR were retweets, i.e. amplified material from other accounts. The overall
224 sentiment is on average neutral, as shown more clearly over time (Figure 4). There are several moments of larger



225 standard deviation on the number of tweets, marked by peaks of higher positive sentiment in July 2022, when
226 Germany announced that the fossil would be repatriated to Brazil.

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228 3.2 Social network structure of the protest



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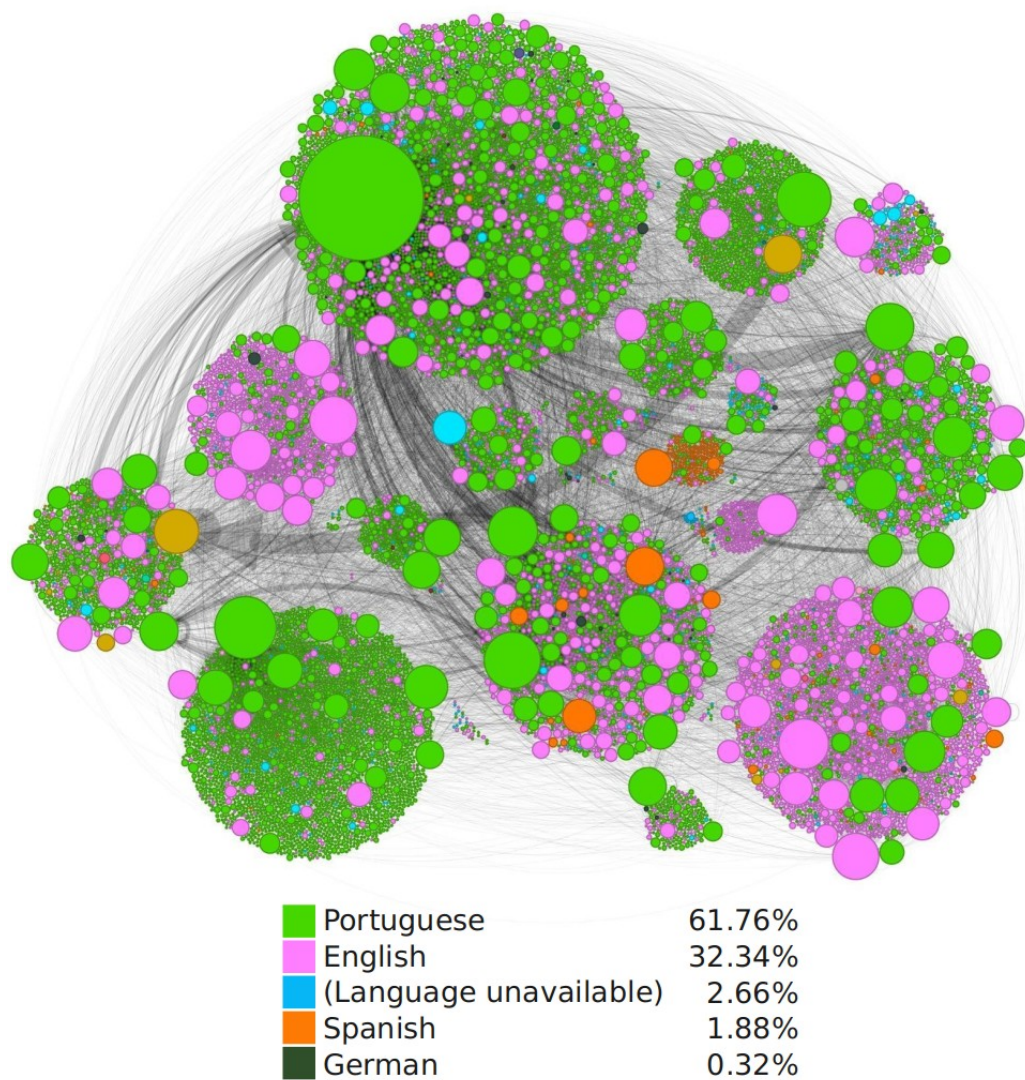
230 **Figure 5: social network of users participating in #UbirajaraBelongstoBR, connected by their shared**
231 **interactions. Node colours indicate communities in the network.**

232

233 The social network of users participating in #UbirajaraBelongstoBR shows that each community involves one
234 user as a leader and some others that follow the leader (Figure 5). The size of each node indicates the in-degree of



235 each user, i.e. the number of people interacting with them, and the colour of each node indicates the community
236 where each user belongs, as identified by the Louvain community detection algorithm. We find several well-
237 separated communities of users, which we describe in more detail below.



239 **Figure 6: social network of users participating in #UbirajaraBelongstoBR, connected by their shared**
240 **interactions. Node colours indicate tweet language.**

241



242 Comparing the social networks of users (Figures 5 and 6) reveals that most of the members in each community
 243 share the same language. Most people protesting about Ubirajara were Portuguese speakers as evidenced by
 244 61.76% of the nodes shown in green. There is also a large fraction (32.34%) of users tweeting in English, shown
 245 in pink, and smaller proportions of users tweeting in Spanish, German, and other languages.

246

Degree Centrality	Betweenness Centrality	Eigenvector Centrality
alinemghilardi	alinemghilardi	alinemghilardi
BiodiversidadeB	BiodiversidadeB	PaleoCisneros
PaleoCisneros	mikannn	MMarcosaurus
mikannn	PaleoCisneros	BiodiversidadeB
pansybeast	pansybeast	oTroianoleo

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Table 1: Highest centrality users, as calculated using different centrality metrics.

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249 We also assess the most central users of the protest network, as measured by the three centrality metrics defined
 250 above, namely degree centrality, betweenness centrality, and eigenvector centrality. Despite the differences
 251 between how each centrality measure is defined, the three measures point at a roughly consistent set of main
 252 actors pushing the conversation: @alinemghilardi, paleontologist and Professor at the Brazilian Federal
 253 University of Rio Grande do Norte, @BiodiversidadeB, a Twitter account covering biodiversity content run by
 254 João Pedro Salgado, @PaleoCisneros, paleontologist and professor at the Brazilian Federal University of PiauÍ,
 255 @PansyBeast, the account of Julian Francis Miholics, an illustrator who contributed to the protest. The top 5
 256 accounts according to each centrality measure also include @mikannn, corresponding to Miriam Castro,
 257 journalist and pop culture influencer, @MMarcosaurus, corresponding to Marcos K. Pinheiro, geoscience student
 258 and artist, and @oTroianoleo, historian and archaeologist, all of which supported the protest.

259

260 The high centrality of paleontologists and biodiversity accounts in the protest network draws into question the
 261 actual reach of the movement. This can be assessed by examining the users present in each community (Figure
 262 7). The figure shows the type of account for the 10 top members of each community which has over 100
 263 members, from community 1 (with 3064 members) to community 16 (with 151 members). Each community
 264 shows a different composition in terms of accounts, as shown by the different colours on the pie charts. While the
 265 largest community in the network is made of mostly palaeontologists, the remaining communities have a diverse

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266 breakdown of other account types, ranging from scientists and science journalists to artists, politicians,
267 institutional accounts, as well as a large fraction of personal user accounts. While it is not possible to examine
268 each and every account present in all the communities on the network, this result suggests that the
269 #UbirajaraBelongstoBR did indeed reach beyond the palaeontology bubble, and even beyond science and science
270 journalism. The full table of the highest degree users per community is shown in Appendix B.

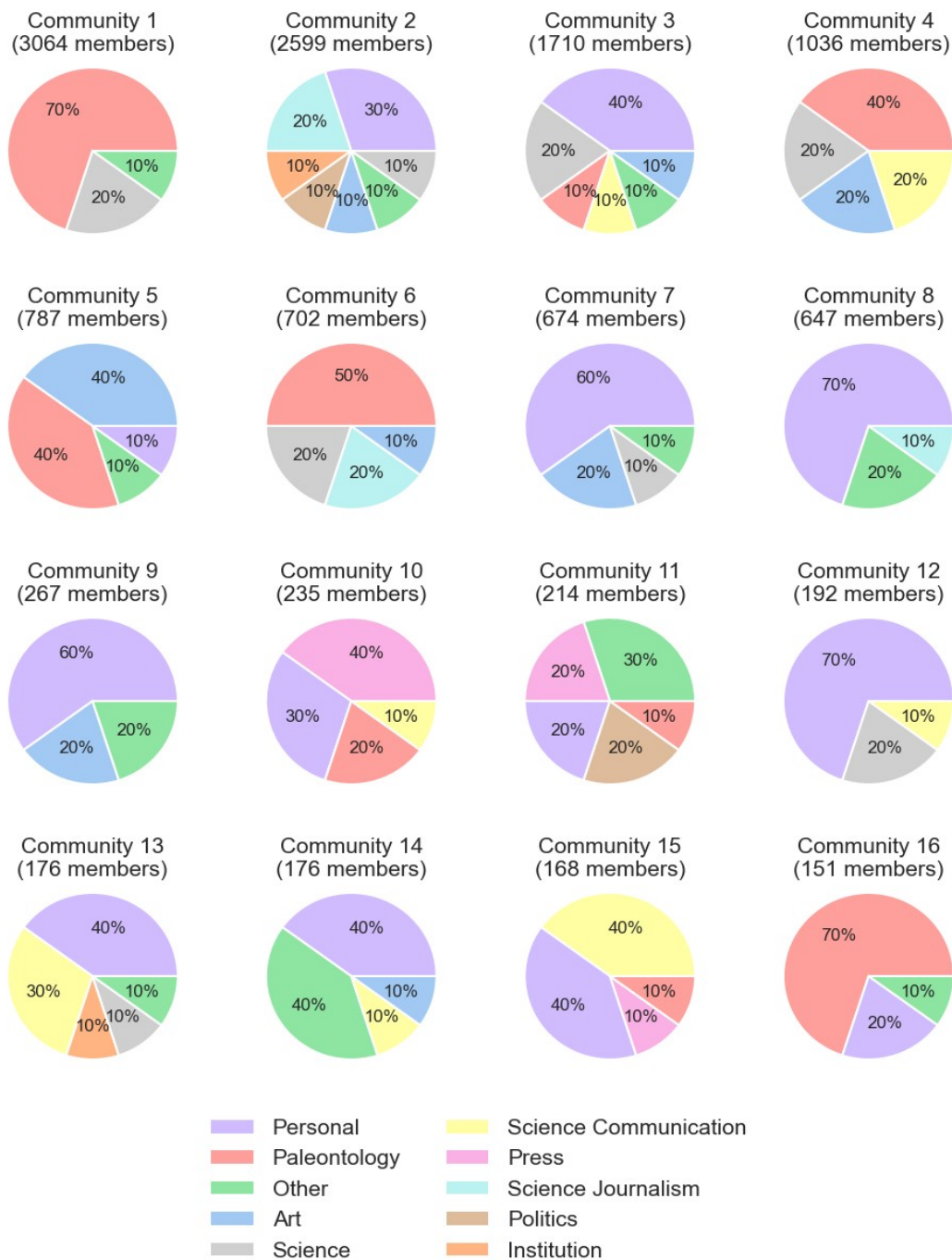
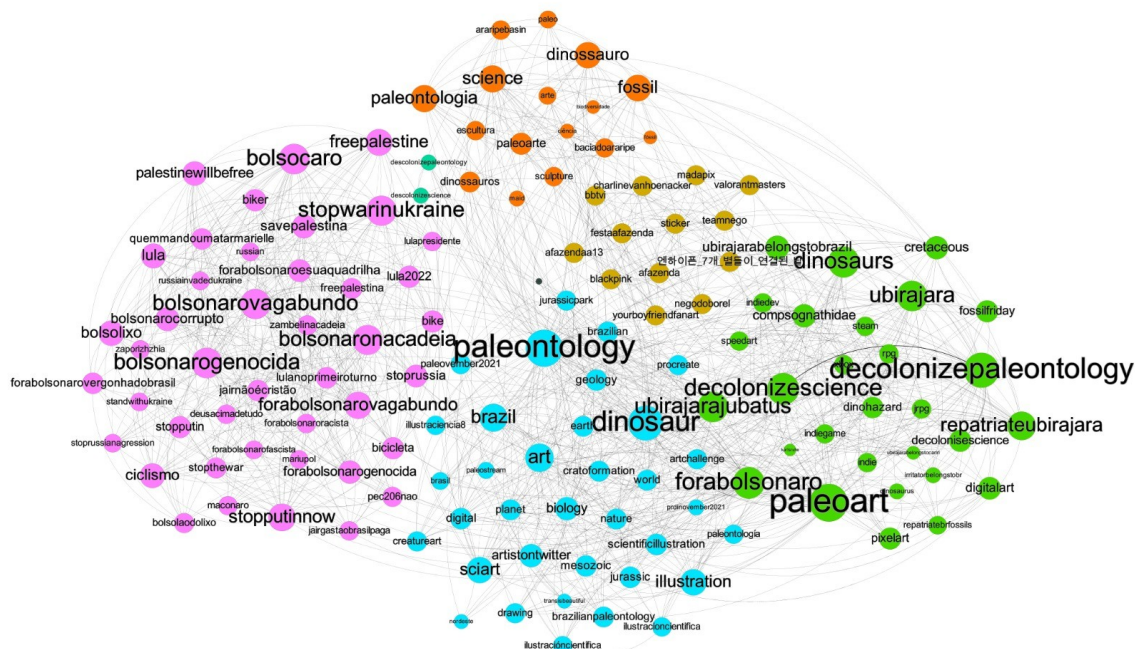


Figure 7: Type of account for the 10 top members of each community with over 100 members.



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Figure 8: A figure with the network of co-occurring hashtags, with node colour indicating different communities of hashtags used in the same tweets.

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Finally, hashtags such as #paleontology, #decolonizepaleontology, and #paleoart as central and important nodes in the main community (Figure 8). Those hashtags, shared by the palaeontologists who led the movement, appear co-occurring with several minor hashtags, such as #brazil, #art, or #repatriatubirajara. It is also worth noting how the Ubirajara protest hashtags also appeared alongside other protest hashtags relating to international political events, such as #stopwarinukraine and #freepalestine, as well as to Brazilian politics, such as #Bolsonarogenocida, #Bolsonarovagabundo, #Bolsocaro, #Forabolsonaro (meaning “genocidal Bolsonaro”, “Bolsonaro bum”, “Bolsonaro expensive”, “Bolsonaro out”, respectively) and #Lula (Lula da Silva, Bolsonaro’s main opponent at the time and current president of Brazil). This spillover of the protest event towards other political topics can be interpreted as an indication of the political leaning of the Twitter users who were concerned about #UbirajaraBelongstoBR.

286

4 Discussion and Conclusion

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The #UbirajaraBelongstoBR movement represents a clear example of the intersection of social media activism and the politics of science and academia, particularly within the realm of paleontology. Our analysis highlights

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289 that individuals with pre-existing social media influence, such as paleontologists and science communicators,
290 played crucial roles in amplifying the movement. This pre-existing presence provided a platform that effectively
291 raised awareness and mobilized public opinion, as evidenced in the widespread sharing and engagement with the
292 hashtag. Notably, the involvement of paleontologists brought authoritative voices into the public discourse,
293 lending credibility and urgency to the concerns raised about colonial practices in paleontology. At the same time,
294 the impact of non-paleontologists, including artists and the general public, demonstrates the movement's reach
295 beyond academic circles, enabling a broader societal engagement.

296 Our detailed analysis of Twitter data reveals not only the significant role of Portuguese speakers in propelling the
297 discussion but also underscores the contribution of the English-speaking community in a predominantly
298 Portuguese discourse. This bilingual dynamic indicates a broader international concern and engagement with
299 issues of neo-colonial practices in science.

300 We also find that fluctuations of retweeting and sentiment correlated to important events in the study case. The
301 first one happens in the period between the release of the *in press* manuscript and its temporary removal by
302 Cretaceous Research two weeks later (2020-12-24). The hashtag #UbirajarabelongstoBR was widely mentioned
303 in local media and also appeared on international outlets around this time (Greshko, 2021). The second
304 fluctuation happens after the announcement by SMNK that the Brazilian dinosaur would not be repatriated
305 (2021-09-09). This is reflected in the negative sentiment of the tweets. The German museum—who lacks a
306 Twitter account—published a statement on Instagram and Facebook declaring the Brazilian fossil to be
307 “property of the State of Baden-Württemberg”, generating great backlash on both platforms. Only two weeks
308 after this announcement, the manuscript was permanently withdrawn by Cretaceous Research and it was revealed
309 that the authors of the manuscript provided false information regarding the export of Ubirajara (Pérez Ortega,
310 2021). Finally, the last fluctuation, reflecting positive tweet sentiment, is connected to the announcement (2022-
311 07-15) by Germany that the dinosaur would be repatriated (Pérez Ortega, 2022).

312 The Ubirajara case is far from being an isolated one (Cisneros et al., 2022b). The Araripe Basin in Brazil has
313 been a hub of illegally exported fossils for museums and private collectors since the end of the twentieth century
314 (Cisneros et al., 2022a). This issue has long been a source of concern for local scientists and authorities, and
315 echoed by the local press but largely overlooked by both the international scientific community and the foreign
316 media. An exception to this trend was a report by the journal *Nature* (Gibney, 2014) on Brazil’s efforts to fight
317 illegal fossil trade, and the case of the snake-like lizard *Tetrapodophis* in 2015 (Christakou, 2015). The latter
318 represents, to our knowledge, the first instance of an Araripe fossil study whose legal and ethical circumstances



319 were publicly questioned outside Brazil. This case, however, had only a mild presence on social media and did
320 not achieve the repercussions that Ubirajara had.

321 As mentioned above, social media activism allows underrepresented voices to attract attention and concentrate
322 discussions around topics that normally would be ignored or misrepresented. The large use of
323 #UbirajaraBelongstoBR on Twitter is a clear example of that, in how it quickly spread and gained attention,
324 collecting efforts from a wide public and forcing the issue to be noticed by stakeholders and news vehicles. This
325 was possible by both the large social media penetration in Brazil and its potential for use as a science
326 communication tool. Some studies point that Brazil is now a leader in science communication on social media
327 platforms, with Facebook, Twitter and Youtube being the main venues (Entradas et al., 2020; Velho and Barata,
328 2020; Velho et al., 2020). Moreover, the integration of artworks through the #Paleoart among others not only
329 enriched the movement's aesthetic but also broadened its appeal and accessibility, allowing for a more diverse
330 demographic engagement. This inclusion of artistic expressions underscores the multidimensional impact of
331 social media movements, bridging science, art, and activism.

332

333 Historical contexts such as the one of the Araripe Basin and the continuous illegal fossil trade emphasize the
334 systemic issues within paleontological research and highlight the need for **stricter regulations** and more ethical
335 conduct within the scientific community. The significant media coverage that followed the spread of the hashtag
336 #UbirajaraBelongstoBR illustrates the power of social media in bringing international attention to local issues,
337 which have been previously overlooked by global audiences and the scientific community alike. The
338 interconnection of the #UbirajaraBelongstoBR movement with broader political movements against Brazil's far-
339 right government at the time also further contextualizes the social and political dimensions of the protest. This
340 alignment suggests that the movement was not only about scientific and ethical issues but also reflected broader
341 societal and political dissent.

342 As with any study relying on data collected from social media, our analysis has its limitations: although all tweets
343 with #UbirajaraBelongstoBR from the study period were collected, this study does not include related tweets
344 which did not include this specific hashtag. Tweet language inference is also not 100% accurate, and the
345 anonymity enabled by platforms such as Twitter/X means that even upon close examination it is not always
346 possible to infer a user's language, location, or field of activity (e.g. if they are palaeontologists or not). Finally,
347 after the recent changes in its data access policy, Twitter/X is no longer an easily accessible data source for
348 scientific research on social movements – a phenomenon which reflects the current state of research on online
349 platforms (Freelon et al. 2018)



350 Still, this study opens potentially fruitful avenues for future research. One potential direction is the examination
351 of the impact of social media on the governance of scientific research and the enforcement of ethical standards,
352 whether for scientific research or not. Another area could involve exploring the role of digital activism in shaping
353 public policy and international agreements on cultural and scientific heritage, such as the policies around illicit
354 fossil trafficking in the case of *Ubirajara*. Additionally, further studies could investigate the long-term impacts of
355 such movements on public trust in science and on the practices within the paleontological community.
356 In conclusion, the #UbirajaraBelongstoBR movement not only challenged neo-colonial practices in paleontology
357 but also showcased the transformative potential of social media as a tool for global awareness and advocacy. This
358 case study serves as a testament to the power of collective action through digital platforms and highlights the
359 evolving landscape of public engagement in scientific discourse.

360



361 **5 Appendix A: Full timetable of events**

Date	Event
2020-12-13	<i>In press</i> article on “Ubirajara jubatus” appears on the journal <i>Cretaceous Research</i> . [1]
2020-12-13	The hashtag #UbirajaraBelongstoBR is first used on Twitter by Aline M. Ghilardi. [2]
2020-12-14	The Brazilian Society of Palaeontology contacts <i>Cretaceous Research</i> .
2020-12-22	First report on the controversy by international media (National Geographic). [3]
2020-12-24	Article temporarily removed by <i>Cretaceous Research</i> .
2021-09-08	SMNK informs the Brazilian Society of Palaeontology that it will not repatriate the fossil. The Brazilian Society of Palaeontology informs its members.
2021-09-09	SMNK releases a statement on Instagram refusing repatriation of “Ubirajara jubatus”.
2021-09-10	A petition is created at Change.org asking for the fossil to be returned. [4]
2021-09-22?	Article withdrawn by <i>Cretaceous Research</i> .
2021-09-28	SMNK Instagram account is deactivated.
2021-09-29	Article in the journal <i>Science</i> reveals that the dinosaur was imported to Germany by fossil dealers in 2006 and purchased by SMNK in 2009. [5]
2021-10-15	The USA repatriates 35 fossil spiders to Brazil. [6]
2022-02-08	Belgium repatriates a pterosaur to Brazil. [7]
2022-07-19	Germany announces that “Ubirajara jubatus” will be repatriated to Brazil. [8]

362 **Table A1: Timeline of the #UbirajaraBelongstoBR protest.**

363

364



- 365 [1] <https://www.sciencedirect.com/science/article/pii/S0195667120303736>
- 366 [2] <https://twitter.com/alinemghilardi/status/1338199196348919816?s=20&t=Uv9P5IZAXaSwBFXR1GyYWA>
- 367 [3] [https://www.nationalgeographic.co.uk/science-and-technology/2021/01/one-of-a-kind-dinosaur-removed-](https://www.nationalgeographic.co.uk/science-and-technology/2021/01/one-of-a-kind-dinosaur-removed-from-brazil-sparks-backlash)
- 368 [from-brazil-sparks-backlash](https://www.nationalgeographic.co.uk/science-and-technology/2021/01/one-of-a-kind-dinosaur-removed-from-brazil-sparks-backlash)
- 369 [4] <https://www.change.org/p/ubirajara-belongs-to-brazil>
- 370 [5] [https://www.science.org/content/article/maned-dinosaur-fossil-will-head-back-to-brazil-after-controversy-](https://www.science.org/content/article/maned-dinosaur-fossil-will-head-back-to-brazil-after-controversy-over-import-to-germany)
- 371 [over-import-to-germany](https://www.science.org/content/article/maned-dinosaur-fossil-will-head-back-to-brazil-after-controversy-over-import-to-germany)
- 372 [6] [https://www.opovo.com.br/noticias/cariri/2021/10/15/traficada-aranha-fossil-que-homenageia-pablo-vittar-](https://www.opovo.com.br/noticias/cariri/2021/10/15/traficada-aranha-fossil-que-homenageia-pablo-vittar-retorna-ao-cariri.html)
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- 374 [7] [https://g1.globo.com/ce/ceara/noticia/2022/02/02/fossil-de-cranio-de-pterossauro-originario-da-bacia-do-](https://g1.globo.com/ce/ceara/noticia/2022/02/02/fossil-de-cranio-de-pterossauro-originario-da-bacia-do-araripe-no-ceara-e-devolvido-ao-brasil-por-museu-da-belgica.ghtml)
- 375 [araripe-no-ceara-e-devolvido-ao-brasil-por-museu-da-belgica.ghtml](https://g1.globo.com/ce/ceara/noticia/2022/02/02/fossil-de-cranio-de-pterossauro-originario-da-bacia-do-araripe-no-ceara-e-devolvido-ao-brasil-por-museu-da-belgica.ghtml)
- 376 [8] [https://mwk.baden-wuerttemberg.de/de/service/presse/pressemitteilung/pid/land-gibt-dinosaurier-fossil-aus-](https://mwk.baden-wuerttemberg.de/de/service/presse/pressemitteilung/pid/land-gibt-dinosaurier-fossil-aus-naturkundemuseum-karlsruhe-an-brasilien-zurueck-1)
- 377 [naturkundemuseum-karlsruhe-an-brasilien-zurueck-1](https://mwk.baden-wuerttemberg.de/de/service/presse/pressemitteilung/pid/land-gibt-dinosaurier-fossil-aus-naturkundemuseum-karlsruhe-an-brasilien-zurueck-1)



378 **6 Appendix B: Users with highest degree in each community**

Community	Top 10 members by in-degree
0	alinemghilardi, PlantaSim, willibrunow, MaximusSpino, schrarstzhaupt, JoanaOrfao, TewBlack, SerpInFormes, kimim01, pedrowisq
1	boringsuchus, paleoeddye, [suspended user], catalina_leite, pilgrimcetus_, luizacaires3, MatheusKnothe, BRodriguesOhana, o_weverton, MarinesWitzke
2	WryCritic, MF_gadelha, PPaleoartist, DiAmador4, JuliotheArtist, sadtheropod, [suspended user], _PaleoGeek_, PalaeoVsRacism, LionsDenArtwork
3	ProjetoCiencia, tito_aureliano, dpaulocarvalho, kalebmelkor, ruzzibarbara, Pirulla25, bioriderjr, RabelloAnderson, eosauria, paleopirata
4	PaleoCisneros, Machado_DSc, mauritiantales, mathchaos, palaeodaniel, rpocisv, paleoTsimoes, PStewens, Yara_Haridy, RenanBantim
5	Colecionadores2, _themingau, Joseane_sf, Albertossauro, nishi_kazue, tainancia, PedroHTunes, ArqueoPreHist, CoelhoPre, nighthstrange
6	FlavianaJorge, JornalOGlobo, xicosa, elis_sntn, [suspended user], VenomaniaKou, revistapiaui, mwk__bw, wolverinegeo, NatGeo
7	smcarvalho42, giordaness, GabrielBritozz, portsmouthuni, [suspended user], sr_kenway, ikessauro, poeirinhadoalem, capetaman, pauloal97618063
8	mikannn, PrazerCembraia, Sybylla_, rogan dopraga, CamaradaHidalgo, _ohcrab, lentevermelha, pifalcao, DiegoCrux, analesnovski
9	oTroianoleo, dwnews, R0dr1got3, paleorocha, Camila_18FJ, vleonelss, mponcci,



	LutzLeo, AmbBrasilia, dw_brasil
10	antoniopedroalb, lucaskias, PaleoBlogBR, MarcosTeo2, marciolcastro, pteroana, saradrawspaleo, Hypnos_art, Vinsevlal, THSpike
11	FeliPinheir, jutyranus, tylerstoneart, tupaguerra, JersonTatu, DimetroDude, o_eco, almeidacm3, victor_debrito, allen_pancake
12	DaltonPinheiro1, nenel_leonam, MeioDeCultura, casavoguebrasil, MarcusRibeiroM2, saturns005, Brenin_m_b, rosecoloredjoca, C4iman15, jbadue
13	MMarcosaurus, ValeriaRoman, luc14nobio, sgufmg, rraf_aelbio, beccarivictor, Rafa_paleo, ramonsilvaas, iMalvikaGaur, TomHoltzPaleo
14	brunobittar91, viadescendens, fadelandia, HaruJiggly, ratgroundpear, Nido_Quing, Lillyywho, badwitchmaris, subjetividdfeia, jinkitopia
15	BiodiversidadeB, PerboniRenato, MarjorieMbeller, Akamezinha, galileufanacc, LUNAtichenr, paulamariane27, rozzz_zz, folha_ciencia, PetraDeQuartzo
16	InsetoLand, isisrnd, Leo_Tusi, ttlua, ClelsonFraga, brunojose_, Luigi0131, LyraSid, _themonie_, Bugseelf
18	PesquisaFapesp, AllBrPolitics, Fenix_glacialis, 2XVIINI, LuanMoldanMotta, hummyeonbird, anai_pari_, Rabiaandrea, robsongfreire, anabee
19	KerberLeonardo, PsychoAna_xD, PaleoCameron, Jorllyrey, doralcoelho, [suspended user], MosaFabim, sasimarie, edvardvallek, saurianboy
20	fedkukso, adagamante, HenriqueRandom, peregrino0788, [suspended user], stephaneww, balsedie, centaurus_crux, barroso2501, gustavoburin

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Table B1: Top 10 members by in-degree for each community in the protest network.

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381 **7 Code and data availability**

382 All code and data are available at <https://github.com/evoluchico/ubirajarabelongstobr>.

383 **8 Author contributions**

384 CQC coordinated the project and designed the study. MARFK collected the data and carried out the initial
385 analyses, CQC carried the later ones. MARFK and CQC produced all figures. NBR contributed with the literature
386 review and motivation. MARFK wrote the initial material, CQC produced the first draft of the paper, and all
387 authors gave final approval for publication.

388 **9 Competing interests**

389 The authors declare that they have no conflict of interest.

390 **10 Ethical statement**

391 The authors confirm the research received ethical clearance from the University of Exeter's Computer Science
392 department.

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