




REVIEW


COVID-19, media coverage of bats and related Web searches: a turning point for bat conservation?

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ABSTRACT

1. SARS-CoV-2, the virus that caused the COVID-19 pandemic, is genomically similar to a SARS-like beta-coronavirus found in Asian rhinolophid bats. This evolutionary relationship impressed the global media, which then emphasised bats as key actors in the spillover that resulted in the pandemic. In this study, we highlight changes in the traditional and new media coverage of bats and in Internet search volumes that occurred since the beginning of the COVID-19 pandemic in 2020.
2. We analysed Google and Wikipedia searches for bats and coronaviruses in 21 countries and eight languages, as well as television broadcasts in the USA, some of which have global coverage, between January 2016 and December 2020. In January 2020, the amount of television news about bats boomed, and news associated with the term 'bat' shifted to COVID-19-related topics. A nearly identical pattern was observed in Google searches during 2020 at the global scale. The daily time series of television coverage and Internet search volumes on bats and coronavirus in the USA covaried in the first quarter of 2020, in line with the existence of a media bubble. Time-series analysis revealed that both the Google Trends index and visits to Wikipedia pages about bats boomed in early 2020, despite the fact that this time of year is usually characterised by low search volumes.
3. Media coverage emphasised, correctly or not, the role of bats in the COVID-19 pandemic and amplified public interest in bats worldwide. The public image of these mammals, in many cases threatened and important ecosystem service providers, was seriously compromised. We therefore recommend that policymakers and journalists prioritise scientifically accurate communication campaigns about bats, which would help counteract the surge in bat persecution, and leverage interest towards positive human–bat interactions.

Palabras clave

COVID-19, conservación, Google, murciélagos Chiroptera, noticias televisivas, SARS-CoV-2, Wikipedia

RESUMEN EN ESPAÑOL

1. SARS-CoV-2, el virus causante de la pandemia COVID-19, es genómicamente similar al SARS-tipo beta-coronavirus encontrado en los murciélagos rinolofidos asiáticos. Esta relación evolutiva impresionó a los medios mundialmente, hasta

- tal punto que se ha enfatizado el papel de los murciélagos como uno de los principales vectores en la expansión de la pandemia. En este estudio, se resaltan los cambios producidos en la percepción de los murciélagos por los medios de comunicación (nuevos y tradicionales), y en las búsquedas en Internet que ocurrieron desde el inicio de la pandemia COVID-19 en 2020.
2. Para ello se han analizado las búsquedas del término ‘murciélago’ en Google y Wikipedia en 21 países y ocho lenguas, así como las retransmisiones televisivas en EE.UU. (algunas de las cuales con cobertura global) entre enero 2016 y diciembre 2020. En enero 2020, la cantidad de noticias televisadas sobre murciélagos se disparó, y el número de noticias previamente asociadas con el término ‘murciélago’ cambiaron por temáticas relacionadas con el COVID-19. Un patrón idéntico puede ser observado a escala global en las búsquedas de Google durante el 2020. La serie temporal de cobertura televisiva y búsquedas en internet sobre murciélagos y coronavirus en EE.UU. covaría durante el primer cuarto del 2020, en línea con la existencia de la burbuja mediática. El análisis de la cobertura diaria televisiva revela que tanto el índice Google Trend como las visitas a páginas de Wikipedia sobre murciélagos incrementaron al comienzo del 2020, a pesar de que esta época del año suele caracterizarse por bajos volúmenes de búsqueda.
 3. La cobertura mediática enfatizó, correctamente o no, el papel de los murciélagos en la propagación de la pandemia COVID-19, ampliando el interés público a lo largo del globo. La imagen pública de estos mamíferos, en muchos casos especies amenazadas o proveedoras de importantes funciones ecosistémicas, ha sido seriamente comprometida. Por lo tanto, se recomienda a periodistas y responsables políticos la priorización de campañas de comunicación científicamente fundamentadas que ayuden a contrarrestar este aumento en la persecución de los murciélagos aprovechando el interés actual para concienciar al público de sus interacciones positivas con el hombre.

INTRODUCTION

COVID-19, the global pandemic caused by the SARS-CoV-2 coronavirus, was first detected in the city of Wuhan, China, in December 2019. By 7 December 2020, SARS-CoV-2 was estimated to have infected 116166652 people, killing 2582528 (WHO 2021).

Genetic comparisons showed that SARS-CoV-2 is most similar to RaTG13 and RmYN02, two Sarbecoviruses found in bats from China, respectively, in *Rhinolophus affinis* (Zhou et al. 2020a) and *Rhinolophus malayanus* (Zhou et al. 2020b). Although these viruses are very similar to SARS-CoV-2 (RmYN02 shares 93% of its nucleotide with SARS-CoV-2, and RaTG13, 96%; Zhou et al. 2020b), their spike protein – the external part of the virus that allows attachment to the host cells – cannot bind efficiently to human cells, so they are not infectious to humans (Zhou et al. 2020a, b). Sarbecoviruses found in the Malayan pangolin *Manis javanica* (Zhang & Holmes 2020) are very similar to SARS-CoV-2 in the receptor-binding domain on the spike protein, yet they differ more from

SARS-CoV-2 when the entire viral genome is examined (79–85% of nucleotides are shared; Zhou et al. 2020b). The discovery of viruses similar to SARS-CoV-2 in bats and pangolins suggests that there is a wide and overlooked diversity of Sarbecoviruses in wildlife, some of which may be directly involved in the emergence of SARS-CoV-2.

As expected, given the COVID-19 pandemic’s dramatic evolution and impacts, both traditional and new media relentlessly covered nearly every aspect of it (Cinelli et al. 2020), including the potential role of bats in the spillover event. Both the printed press and television broadcasters jumbled up evidence about bats as reservoirs of many viruses and their role in zoonotic spillovers, often overstating available evidence or neglecting the complex interplay of these dynamics with broader environmental issues (e.g. <https://www.washingtontimes.com/news/2020/mar/30/china-researchers-isolated-bat-coronaviruses-near/>). On social media, the situation was even more critical, and the circulation of fake documents and news contributed to massive spread of misinformation (see: <https://www.bbc.com/news/blogs-trending-51271037>).

This has sparked concern among conservationists, because misinformation could result in increased negative attitudes and bat persecution by humans (MacFarlane & Rocha 2020, Rocha et al. 2020, Tuttle 2020, Zhao 2020, Lu et al. 2021). Worldwide, bats are often persecuted by people due to conflicts with colonies in buildings, negative beliefs or superstitions, and, in some places, crop raiding by frugivorous species (Frick et al. 2019). In the last few years, the media increasingly covered the topic of bat-borne zoonoses, also raising public concern (López-Baucells et al. 2018). This increase followed that of scientific publications on this topic in the late 1990s (Calisher 2006) and may have adverse consequences for bat conservation. Culling operations aimed at mitigating zoonotic risks, such as those targeting vampire bats to limit the spread of rabies (Mickleburgh et al. 2002), may in fact increase human exposure to pathogens, since bats are handled during culling operations, sometimes without adequate personal protective equipment.

The global importance of the COVID-19 pandemic and the associated ‘infodemic’ (Cinelli et al. 2020) poses an unprecedented risk of global escalation in bat persecution, by amplifying pre-existing negative attitudes towards bats (Lu et al. 2021). It is therefore important to assess: 1) to what extent COVID-19 led to increased media coverage of bats; 2) whether the coverage resulted in changes in how bats are framed; and 3) if changes occurred, how the public responded to these changes. To answer these questions, we: 1) explored temporal changes in the frequency at which large television companies in the USA covered bats; 2) explored qualitative changes in bat-related news presented by television broadcasting companies in the USA, and in global Google searches on bats; and 3) assessed temporal changes in the volume of Google and Wikipedia searches about bats in 21 countries.

METHODS

In this study, we distinguished between the traditional media, characterised by a top-down information flow from journalists and media companies to news consumers, and the new media, such as social media, characterised by crowdsourced propagation of news, and quantified in our case by Internet searches. This classification is widely adopted in the social sciences, as the two media systems coexist and interact, but have minor overlap (Langer & Gruber 2020).

Data collection: traditional media

To quantify temporal changes in the extent to which traditional media covered bats, before and after the beginning of the COVID-19 pandemic, we accessed the Television

News Archive (<https://www.gdeltproject.org/>). The archive contains a complete collection of daily news from the nine largest television broadcasters in the USA. We focused on this country, since it is the only one for which a comprehensive archive of television news is available, and because television broadcasting companies in the USA include some with a global audience of several hundred million people, such as CNN and Fox News (<https://cnnpressroom.blogs.cnn.com/2020/02/19/cnn-digital-breaks-all-records-largest-digital-audience-in-history-in-january-2020/>).

For each month, between January 2016 and 8 December 2020, we extracted the GDELT Television News Archive relative index, for the ‘bats’ keyword. The index shows the relative coverage that is attained by a certain keyword on television (further details are available on <https://blog.gdeltproject.org/gdelt-2-0-television-api-debuts/>), in our case, the extent to which all the major television broadcasting companies in the USA covered bats in the period of time considered.

Moreover, since archive news is indexed with multiple keywords, we also extracted other keywords characterising news indexed with the keyword ‘bats’. This approach summarised news on bats, enabling us to detect qualitative changes in how television broadcasts had framed these mammals. Data were extracted with the package ‘newsflash’ (<https://github.com/hrbrmstr/newsflash>) within the R software environment (R Core Team 2019).

Data collection: Google and Wikipedia

Information-searching behaviour on the Internet can be used as a barometer to evaluate whether a certain topic is salient to laypeople (Ripberger 2011). Internet penetration has increased over the last 15 years (ITU 2020), and people search online for information about scientific (Segev & Sharon 2017), environmental (Ficetola 2013, Anderegg & Goldsmith 2014, Burivalova et al. 2018, Mittermeier et al. 2019), and health-related (Tizzoni et al. 2020) topics. To quantify whether, and if so to what extent, people reacted to the media coverage of bats that followed COVID-19, we analysed bat searches in Wikipedia and on Google, the leading search engine accounting for ca. 87% of the global volume of Internet searches.

Google automatically classifies related searches, i.e. those searches made together with a certain query, into various topics. To measure whether people changed their types of Internet searches about bats, we extracted the most common topics characterising related searches about bats on Google between 2016 and 2020.

Moreover, to detect changes in the volume of Internet searches about bats, we downloaded the weekly value of the Google Trends index for the query ‘bats’, between

January 2016 and 8 December 2020. The Google Trends index (<https://support.google.com/trends/?hl=en#topic=6248052>) is a relative metric obtained by: 1) dividing the total number of searches for a certain query by the total number of Google searches in the same time span; and 2) normalising each value of this relative index, for the maximum point of the time series, and multiplying it by 100. The Google Trends index showed the overall volume of searches about bats on Google, and their evolution through time, adjusting for temporal changes in the overall volume of Google searches.

We downloaded Google Trends index data for 21 countries: Argentina, Australia, Austria, Brazil, Canada, Chile, Colombia, France, Germany, Ireland, Italy, Japan, Mexico, New Zealand, Portugal, Republic of Korea, Spain, the UK, Uruguay, South Africa, and the USA. We did not consider China, where Google is out-competed by Baidu. Google data were downloaded with the 'gtrendsR' package (Massicotte et al. 2016) of the statistical software R (R Core Team 2019).

To complement our analysis of Internet search volumes, we also downloaded visits to Wikipedia pages about bats between 2016 and 2020. Wikipedia is the largest online encyclopaedia; visits to its pages cannot be extracted at the country level, but can be extracted separately for different languages. We downloaded data for the main languages that are spoken in the 21 countries considered for Google: English, Spanish, French, Portuguese, German, Italian, Japanese, and Korean. The choice of the countries for which Google Trends data were extracted was due to the need to harmonise data from Google and Wikipedia. Therefore, we selected countries characterised by a high level of Internet penetration, where the eight languages downloadable from Wikipedia were spoken as the main idiom.

In Wikipedia, daily visits were downloaded from PageViews (<https://pageviews.toolforge.org/pageviews/?project=en.wikipedia.org&platform=all-access&agent=user&redirects=0&range=latest-20&pages=Cat|Dog>) and aggregated

on a weekly basis to reduce noise. Moreover, to account for temporal changes in the overall Wikipedia usage, we analysed the numbers of visits to Wikipedia pages about bats per million visits to Wikipedia. For each country and language, the query 'bats' was translated accordingly (Table 1).

Data analysis

We adopted word clouds to depict qualitative changes in keywords associated with news about bats, as well as qualitative changes in the topic of related searches about bats on Google. Word clouds were computed for each year between 2016 and 2020. Google topics and news keywords had already been ranked by Google and GDELT according to, respectively, their average Google Trends index and their GDELT Television News Archive index. In our word clouds, we assigned a size to each word that was proportional to these indices, to make popular related searches and keywords more evident.

We used the Pearson correlation coefficient to measure the covariation of the GDELT Television News Archive index, the Google Trends index, and visits to Wikipedia, about coronaviruses and bats, between January and September 2020, a time span of nine months for which daily values of the Google Trends index could be extracted. For this analysis, we considered time series from the USA, the only country for which television data were available. In the case of a media bubble about bats and COVID-19, we expected time series to be positively correlated, as a result of a rapid flow of information between traditional and new media.

We adopted Bayesian generalised additive models to identify temporal changes in Internet search volumes, before and after 31 December 2019. Changes in the number of visits to Wikipedia pages about bats, per million visits to Wikipedia, were modelled through a first-order random walk smoother with a gamma distribution of the error and penalised complexity prior (Zuur et al. 2017). Temporal

Table 1. Complete list of Google searches carried out and Wikipedia pages that were considered, in the eight languages spoken in the 21 countries

Language	Countries for which Google Trends data were extracted	Google query search terms for which results were found	Wikipedia pages
English	Australia, Canada, Ireland, New Zealand, South Africa, the UK, and the USA	Bats	https://en.wikipedia.org/wiki/Bat
French	Canada, France	Chauves-souris	https://fr.wikipedia.org/wiki/Chiroptera
German	Austria, Germany	Fledermaus	https://de.wikipedia.org/wiki/Fledertiere
Italian	Italy	Pipistrelli	https://it.wikipedia.org/wiki/Chiroptera
Japanese	Japan	コウモリ	https://ja.wikipedia.org/wiki/コウモリ
Korean	Republic of Korea	박쥐	https://kn.wikipedia.org/wiki/박쥐
Portuguese	Brazil, Portugal	Morcegos	https://pt.wikipedia.org/wiki/Morcego
Spanish	Argentina, Chile, Colombia, Mexico, Spain, Uruguay	Murciélagos	https://es.wikipedia.org/wiki/Chiroptera

changes in the Google Trends index were modelled with a B-spline with 128 knots and a gamma distribution of the error, using the various weeks of the time series as a predictor (Gómez-Rubio 2020). The number of knots was selected through information criteria and leave-one-out cross-validation (Zuur et al. 2017). As values of the Google Trends index from different countries could not be aggregated, we included a random intercept term for each country. The reproducible software code, our datasets, and the country-specific analyses are available on the OSF website (<https://osf.io/wxh6a/>).

RESULTS

News coverage of bats on televisions in the USA was low until the end of December 2019. Then, from January 2020, in parallel with the first cases of SARS-CoV-2, it peaked

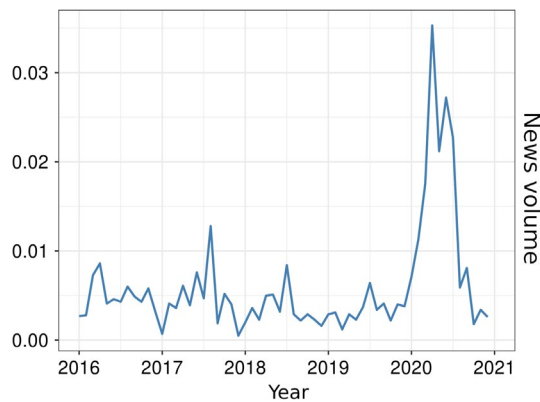


Fig. 1. Volume of news about bats in the years 2016 to 2021, on major television broadcasts in the USA, expressed as the GDELT Television News Archive index (further details can be found here: <https://blog.gdeltproject.org/gdelt-2-0-television-api-debuts/>).

and remained high throughout the first quarter of 2020 (Fig. 1).

The analysis of indexed keywords shows a clear change in how televisions in the USA framed bats before and after December 2019. Until 2019, most news about ‘bats’ was focused on a wide range of topics, also marginally including health-related ones such as ‘Ebola’, ‘virus’, ‘MERS’, and ‘HIV’. However, these topics became dominant in 2020, when most news about bats were indexed with keywords such as ‘virus’, ‘SARS’, ‘coronavirus’, and ‘humans’ (see Supporting Information: <https://osf.io/wxh6a/>). A similar change was observed in the Google Trends index around the world. Until 2019, searches related to bats also covered topics unrelated to Chiroptera, such as Halloween and baseball (due to ‘baseball bat’), or topics limited to bat biology. Since 2020, there was a clear shift in Google searches about bats towards a focus on the role of Chiroptera in disease transmission and the COVID-19 pandemic (Fig. 2; see also Supporting Information: <https://osf.io/wxh6a/>).

Daily values of the GDELT Television News Archive index, the Google Trends index in the USA, and visits to English Wikipedia pages on coronavirus and bats co-varied between January and September 2020. Their correlation was even higher between late February and early June. Only television programmes that were focused specifically on bats had a lower correlation, peaking later, in early summer 2020 (Fig. 3). These television programmes were documentaries or in-depth reports about bats and viruses, rather than news items about COVID-19, which also mentioned bats.

Bayesian smoothing showed that both Wikipedia searches and the Google Trends index boomed in early 2020, despite the fact that this time of the year was characterised by low volumes of Internet searches about bats in the years preceding the pandemic (Fig. 4).

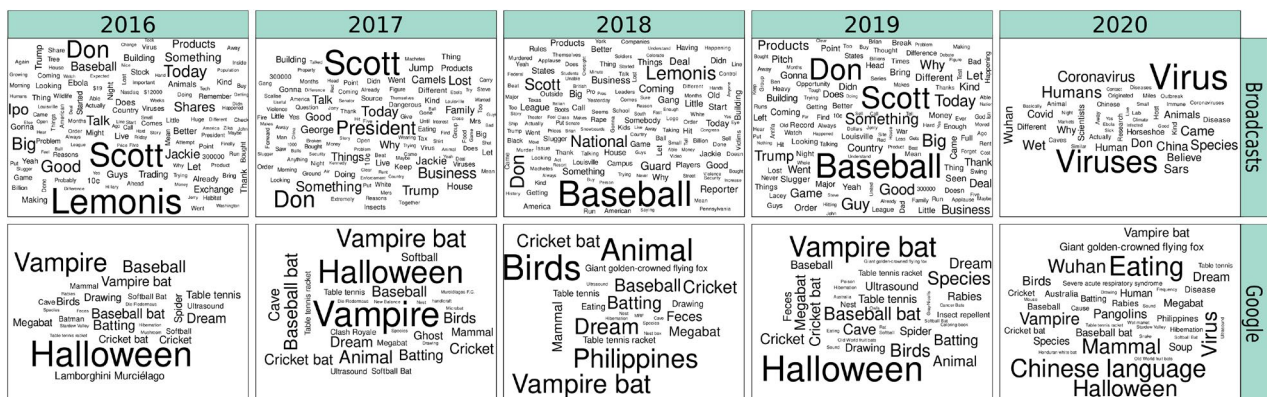


Fig. 2. Word clouds for the years 2016 to 2020 representing keywords associated with news about bats on television broadcasts in the USA (top row), and representing topics of Google searches related to bats in 21 different countries (bottom row).

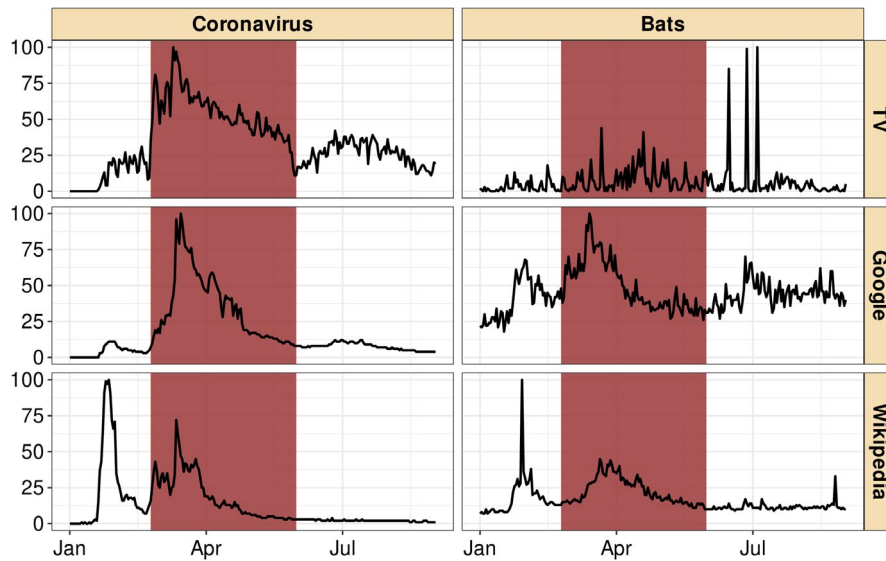


Fig. 3. Daily time-series of television news in the USA (top panel) and the Google Trends index (middle panel), and Wikipedia searches (bottom panel) about bats and coronavirus in the USA. Data were extracted for January to September 2020, the maximum time span for which daily Google Trends data could be obtained. The highlighted rectangular area represents the period, between late February and early June 2020, when the correlation between time series was maximised. Television news was measured with the GDELT Television News Archive index, Google searches with the Google Trends index, and Wikipedia searches as the number of visits. Each variable was rescaled between zero and 100, to facilitate comparisons between time series.

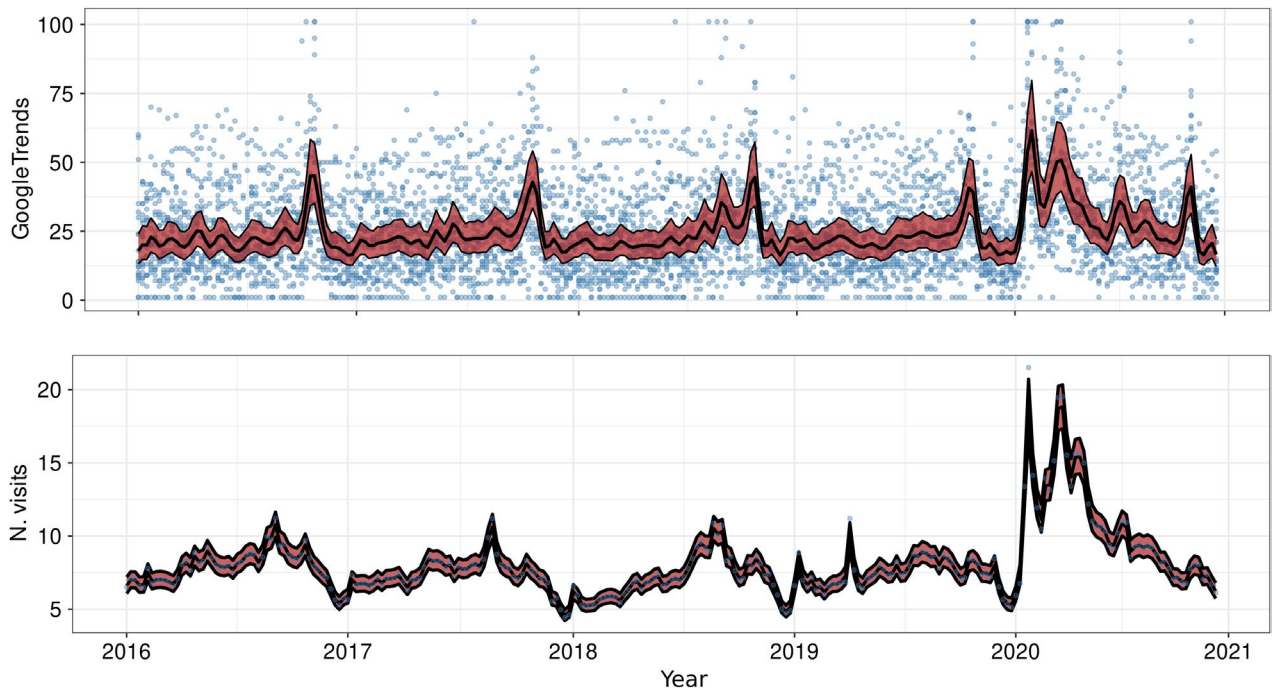


Fig. 4. Temporal evolution in the years 2016 to 2021 of Google searches about bats, in 21 different countries, measured through the Google Trends index (upper panel), and as the number of aggregated visits to Wikipedia pages about bats in the main languages spoken in the 21 countries (lower panel). Google searches are expressed as weekly values of the Google Trends index (points in the upper panel). Points in the upper panel are scattered, as values of the Google Trends index cannot be aggregated across countries. Wikipedia visits are expressed as weekly visits to pages about bats per one million visits to Wikipedia in the same week (points in the lower panel). The shaded areas and solid lines represent fluctuations in Google and Wikipedia searches, summarised through our Bayesian generalised additive models: the shaded area represents the 95% credibility intervals, and the solid line represents predicted values from the model.

DISCUSSION

This study constitutes the first effort to link systematic changes in media coverage of bats to shifts in public interest towards them, following the beginning of the COVID-19 pandemic. Our findings are highly suggestive that, in early 2020, a media bubble formed around bats and their role in the spillover of SARS-CoV-2, following the 'infodemic' that surrounded COVID-19. This media bubble in turn affected public interest in these mammals, boosting Internet searches.

Newscasts in the USA increasingly covered bats, since the beginning of the COVID-19 pandemic in January 2020. Moreover, they changed how bats were framed, focusing on health-related issues and bats' potential role in the COVID-19 pandemic. Indeed, before 2020, most television news about bats in the USA did not even talk about Chiroptera, but referred to other meanings of the word 'bat', such as 'baseball bat'. This change in media coverage was synchronous with a change in the topic of related searches about bats on Google, at the global scale: in all 21 countries, we observed that searches related to bats shifted from a wide range of disconnected topics to health-related ones (Fig. 2).

Changes in media depiction of and Internet searches about bats were also quantitatively synchronised, at least in the USA. The fact that the amount of television coverage, and Google and Wikipedia searches had a very similar variation in time, being highly correlated in the second quarter of 2020, supports the idea that bats were affected by the COVID-19 'infodemic' and that a media bubble formed around them and their role in the SARS-CoV-2 spillover in the first quarter of 2020. Traditional media, in the early stages of the COVID-19 pandemic, mentioned bats as reservoirs for many diseases, including SARS-CoV-2, or identified bat consumption in China as the main cause of the spillover. Following this information campaign, people probably searched the topic on the Internet, generating volumes of Internet searches that were temporally correlated with the above-mentioned television news and that further inflated the appeal of bat-related news for traditional media.

Specific news about bats was relatively scarce, compared with news about COVID-19. The former peaked between early June 2020, when the CNN broadcast specific programmes about bats and the spillover of SARS-CoV-2 (<https://cnnpressroom.blogs.cnn.com/2020/06/09/cnn-to-air-special-on-the-connection-between-bats-and-covid-19/>), and late July 2020, when Chinese scientists published a detailed reply to accusation of them having fabricated SARS-CoV-2 in their laboratories in Wuhan, from which it was suspected to have leaked (<https://www.sciencemag.org/news/2020/07/trump-owes-us-apology-chinese-scienc>

tist-center-covid-19-origin-theories-speaks-out). However, considering the huge amount of news about COVID-19 in the second quarter of 2020, and the resulting sensitivity of people to this topic, even marginally mentioning bats within the coronavirus television coverage in spring 2020 probably sufficed to synchronise Internet searches about such topics in the same period.

It is therefore not surprising that our time-series analysis found a massive increase in Internet searches about bats in early 2020. We showed a threefold increase in the Google Trends index about 'bats' in early 2020 over the same period in previous years, and a similar increase in weekly visits to Wikipedia pages on bats compared with the average seasonal pattern. Both in the Google Trends index and in our Wikipedia visit analysis, we accounted for the total volume of searches on Google and Wikipedia; these results were thus not influenced by any general increase in Internet searches caused by people having more time to conduct searches due to COVID-19.

Public opinion could particularly be affected by mass media when the audience has little experience with an issue (McCombs & Valenzuela 2020). Individual search for orientation depends on the relevance of a topic and its level of uncertainty (Weaver 1977). Taken together, our findings suggest that media coverage plays a fundamental role in making people inquire about wildlife and emerging zoonoses (Hasanov et al. 2018). In this case, the effect was to make bats 'go viral', although these species are often not considered iconic and are even repulsive to some people (Kingston 2016, López-Baucells et al. 2018). Bats play key roles in ecosystems, e.g. as insect suppressors, seed dispersers, and pollinators, thus providing essential services also in human-modified ecosystems (Kunz et al. 2011, Russo et al. 2018). Considering the role of the media in shaping human-wildlife attitudes (Nekaris et al. 2013), the importance of delivering evidence-based information on this topic is clear. Raising public awareness correctly has also a remarkably important role, both in disease management and in shaping attitudes towards wildlife and the environment. People's reactions to information from the media may trigger the persecution of some wildlife species, e.g. bats, if news focus is prolonged over their role as reservoirs for zoonoses without also explaining the important role of these mammals in ecosystem functions (DeMello 2012, Friant et al. 2015, MacFarlane & Rocha 2020). For instance, the media campaign about the unfounded role of bats in spreading SARS-COV-2 is likely to have encouraged bat eviction from buildings in China (Zhao 2020, Lu et al. 2021).

Attempts to control wildlife diseases or to limit zoonosis transmissions have long been based on health or hygiene measures, such as the construction of barriers, vaccination, and practices directly targeting vectors or reservoir species,

such as culling programmes (Gortázar et al. 2007). Culling poses serious problems when the spillover process is not clear and when targeted species have a threatened conservation status, are poorly known with regard to their population size and parameters, or provide key ecosystem services, as bats do (Kunz et al. 2011, Frick et al. 2019). Also, following COVID-19, inappropriate or illegal persecution of bats was reported in some countries (e.g. Indonesia: <https://www.scmp.com/video/asia/3075441/hundreds-bats-culled-indonesia-prevent-spread-coronavirus>; Peru: <https://phys.org/news/2020-03-peru-blamed-coronavirus.html>; Egypt: <https://www.arabnews.com/node/1661221/middle-east>), raising great concern among bat conservationists (Fenton et al. 2020, Rocha et al. 2020, Zhao 2020). Besides the fact that bat legal protection is restricted mostly to developed countries, persecution of bats usually occurs at very local scales (e.g. people evicting or deliberately killing bats roosting in buildings), and it is therefore difficult to record and prevent (Voigt et al. 2016). Given the severity and the media resonance of the COVID-19 pandemic and the widespread misinformation circulating on bats, it is pivotal to create trustworthy sources of information, e.g. on Wikipedia, based on solid and evidence-based statements, as well as to investigate further how increases in public attention on bats can translate into changes (positive or more likely negative) in public attitudes towards these mammals.

Although our correlative analysis of the GDELT Television News Archive index, the Google Trends index in the USA, and the English Wikipedia was focused in the USA, we anticipate that what we recorded also occurred in other countries, for two reasons: first, CNN and Fox News have global audiences and are major actors in the global circulation of news, almost certainly influencing national television viewing, at least in most English-speaking countries; and second, we observed a worldwide (21 countries) change in the Google Trends index, which matched the changes in news on bats on television in the USA.

The COVID-19 pandemic could represent a turning point for human–bat interactions in the 21st Century, by bringing bats into the spotlight to an unprecedented extent, and thus potentially representing both a challenge and an opportunity for bat conservation. A better understanding of media–public interactions on this topic is therefore fundamental for the future of bat populations worldwide, as well as for the correct media management of future pandemic zoonoses. From our analyses, it was clear that Wikipedia visits to pages on bats and Google searches for bats peaked on specific dates; understanding which type of news framing (Lecheler & De Vreese 2018) caused such trends is extremely important for tailoring communication campaigns aimed at mitigating bat persecution.

We also believe that our approach, based on Internet searches, though it is useful to detect rapid and pervasive shifts in public interest towards bats, cannot reveal long-term changes in human–bat interactions unless it is supplemented by data from other sources. Human attitude towards bats, established as the degree of tolerance expressed by people where they coexist with bats, cannot be inferred from online searches, but should be measured only using structured questionnaires based on psychometric scales. Moreover, any persecution of bats, or any action that will benefit them (e.g. the use of bat boxes in urbanised environments), will certainly be carried out by a minority of people. Minority behaviour might go unnoticed on the Internet, because approaches such as Google Trends overlook queries entered by a low number of users. Changes in minority behaviour could be detected by combining questionnaire-based surveys, administered to representative samples of people in the various countries of the world, with content analysis of traditional and new media, where persecution is likely to be reported occasionally. Lu et al. (2021) addressed the topic of public perception of bats by adopting a questionnaire-based approach, evidencing that even highly educated Chinese citizens had negative attitudes towards bats and poor knowledge of bats, and that only partial improvement was achieved by exposing such people to a specifically designed lecture on bats, viruses, and conservation. Misconceptions about bats as being directly responsible for viral transmission to humans did not change in the respondents, suggesting that capillary spread of correct information by the media is fundamental in changing public attitude on such sensitive topics. The use of questionnaire-based surveys could also broaden data collection to countries with low Internet access, which cannot be explored through the analysis of Internet search volumes, like in our study. We therefore encourage the use of questionnaires in combination with media analysis in future studies, to reassess the direction of human–bat interactions after 2020, at the global scale.

Bats are often indicated as special reservoirs of zoonotic pathogens (Brook & Dobson 2015), and indeed, they were involved in the spillover of some important zoonotic viruses, such as Ebola, Nipah, Hendra, and SARS-like coronaviruses (Olival et al. 2015). However, on many other occasions, although bats were a reservoir of pathogens, these spilled over to humans from different species of wildlife or domestic animals (Salinas-Ramos et al. 2021). Although bats have physiological and ecological traits, which make them effective viral reservoirs (e.g. Olival et al. 2015), recent research has shown that the proportion of viruses that may infect humans varies minimally across reservoirs in birds and mammals, and that the observed number of zoonoses at the order level increases in line with species richness (Mollentze & Streicker 2020). A high

proportion of emerging infectious diseases have been linked to wild animals; however, most spillover events are associated with environmental factors such as wildlife hunting, trade, consumption, forest loss, and fragmentation, or with human settlements encroaching on spaces formerly occupied by natural habitats (e.g. Karesh et al. 2012).

While pathogen surveillance in regions where future spillover events are likely to happen is crucial, messages regarding the risk of zoonoses should highlight the overwhelming role played by nature destruction and biodiversity loss within this context. Communication should avoid portraying species such as bats as the 'culprits' of zoonoses (MacFarlane & Rocha 2020), as this is also highly likely to result in the direct persecution of wildlife. In turn, the provision of essential ecosystem services can be weakened, also increasing the risk of zoonoses due to the arrival of new individuals, potentially with higher levels of active infection (Streicker et al. 2012, Amman et al. 2014). In guidance on effective communication about bats to prevent misinformation and persecution, three key areas of psychological science are identified: debunking misinformation, counteracting negative associations, and changing harmful social norms (MacFarlane & Rocha 2020).

This study shows that online information searches about zoonoses are affected by media coverage. This point was already known for other zoonoses (e.g. Zika; Tizzoni et al. 2020); however, our findings indicate that news spread in response to media coverage can involve not only pathogens, but also their potential reservoir species. Furthermore, media coverage seems to determine which aspects of a zoonotic pandemic 'go viral' and become dominant in Internet searches.

The detected increase in Internet search activity is not surprising given the massive global impacts of COVID-19. Conversely, it is difficult to know whether the rise in search activity will increase future public interest and direct attention towards bats, and whether this attention will turn out to be positive or negative. In our opinion, however, public perception of bats is of chief importance for bat conservation, which emphasises the value of providing scientifically accurate information about zoonoses in both traditional and new media, especially during emergency phases such as pandemics.

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