COVID-19 has led to a global increase in web searches on bats: a risk for conservation ?

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Abstract

Following coronavirus COVID-19 epidemic, global media and the Internet started mentioning bats as key actors in the spillover. This depiction often misinterprets scientific evidence about the relationship between bats and SARS-CoV-2, and may contribute to increase bat persecution worldwide if not accompanied by sufficiently clear explanations. Moreover, it is unclear whether people adjusted their information-searching behavior following this coverage.

We analyzed Google and Wikipedia searches on bats and coronavirus across 20 countries in 8 languages, in January 2016 - April 2020. We *i*) inspected bat-related searches on Google before and after January 2020, *ii*) checked whether Google and Wikipedia searches on bats and coronavirus increased during the pandemic and *iii*) carried out causal impact analysis to assess how much the pandemic increased daily visit rates to Wikipedia pages on bats. Before 2020, searches about bats included neither viruses nor zoonoses, China, and bat consumption as a food. All these topics have become dominant since January 2020. Likewise, the number of searches about bats and coronavirus increased since January. Causal impact analysis indicated a mean 175% increase in the daily number of visits to the Wikipedia pages about bats, following the announcement of the first COVID-19 victim the 11th of January 2020.

Increased media coverage of COVID-19 and the potential role of bats as SARS-CoV-2 origin and spillover source seem to have massively amplified people interest towards this mammal group worldwide. Whether this might result in a stable attitude change towards bats, or affect emotions associated with their presence is unknown, yet research about this is urgently needed, as such dynamics are likely to have major implications for bat conservation.

Introduction

COVID-19, the global pandemic caused by the SARS-CoV-2 coronavirus which appeared in the city of Wuhan (China) in December 2019, and subsequently spread globally between January and March 2020. By the 12th of April 2020 SARS-CoV-2 is estimated to have infected 1.685.588 people, killing 105.992 [1]. SARS-CoV-2 may likely infect several mammals [2, 3], but the intermediate host which led to the spillover, as well as about where and when this happened, is still debated. To date, available evidence suggests that a bat virus similar to SARS-CoV-2 evolved in an intermediate host (probably a pangolin) and, then, infected humans [4-7].

As bats are in general more familiar to laypeople than pangolins, at least in most Western countries, there has been an extensive media coverage about the role of bats in the spillover. Moreover, media deepened in the world of zoonoses, collating evidences about bats as reservoirs of many viruses, as well as about the bats' role in transmitting diseases to humans. Sometimes, yet not systematically, media interviewed experts and based their reports on scientific evidence. The consequent worsening of bat public image raised concern among conservationists that incorrect and partial media coverage of COVID19 and bats may result in an increase bat persecution by humans [8].

Such concerns are, unfortunately, well founded. Worldwide, bats are regularly persecuted by people due to conflicts with colonies roosting in buildings, negative beliefs or superstitions and the frugivorous habits of some species, which may locally be considered as fruit crops pests [9, 10]. Over the last few years, media increasingly covered the topic of bat-borne zoonoses [11]. This increase followed that of scientific publications about this topic in late 1990s and is deemed to have increased bat killing to counter bat zoonoses, an ineffective albeit relatively common practice [12, 13]. The global importance of the COVID-19 pandemic, and the extent of news coverage about bats and SARS-CoV-2 in both traditional and social media [14], pose an unprecedented risk of global escalation in bat persecution. However, whether people had been responsive to news coverage about bats and COVID-19 is unknown.

Available evidence indicates that information-searching behavior on the Internet can be a barometer to evaluate whether a certain topic is salient to laypeople, and if people are curious about major events affecting society [15, 16]. This depends on global Internet penetration, which has increased steadily over the last 15 years [17]. In developed countries, where 70-90% of the population has access to the Internet, people routinely search on-line for information about scientific [18, 19], environmental [20-23] or health-related topics, such as epidemics [24]. Therefore, the volumes of Internet searches on search engines and Wikipedia, if carefully analyzed and interpreted [25], can reveal temporal patterns of public interests.

In this study, we assess to what extent Internet users from 20 countries were responsive to media coverage of COVID-19, in terms of information searching about bats on Google and Wikipedia. Based on extensive global news coverage of COVID-19, and evidence linking media exposure and on-line information searching about diseases, we hypothesize that people became interested towards this topic, and predict that searches on Google on bats and coronaviruses and visits to the Wikipedia page about bats both increased.

Methods

Our study area included 20 countries, where 8 languages are mainly spoken: English (USA, Australia, Canada, Ireland, New Zealand, and United Kingdom), Spanish (Spain and most Central and South American countries), German (Germany and Austria), Portuguese (Portugal and Brazil), Italian (Italy), French (France), Japanese (Japan) and Korean (South-Korea). Overall, these countries have a population of over 1.3 billion people, ca. 18.9% of the global

population, and 977 million Internet users (15% of global Internet users).

To measure the volume of searches about bats and coronavirus, we focused on Wikipedia and Google. Wikipedia is the largest on-line encyclopedia and the number of daily visits to each of its pages is freely available from the Wikimedia foundation. Wikipedia does not provide spatially explicit data per country; so, we downloaded daily visits to pages about bats and coronavirus, between the 1st of January 2016 and the 14th of April 2020, for each of the 8 languages we considered. Daily visits were downloaded through the R package "wikipediatrend" [26-27].

Google is the largest online search engine, dominating by far its competitors and accounting for over 95% of total searches from mobile devices. Google does not show the total number of searches (https://support.google.com), but provides Internet users with Google Trends, a relative metric obtained by: *i*) dividing the total number of searches for a certain keyword over the total number of Google searches in the same time span, *ii*) dividing each value of this relative index, for the maximum point of the time-series, and *iii*)multiplying it by 100. GoogleTrends ranges from 0 to 100 and sometimes it cannot be computed by Google, if the number of searches is too low. We downloaded weekly values of the GoogleTrends metric for the keyword "bats" and "coronavirus", for each country, between the 1st of January 2016 and the 14th of April 2020.

Google also shows the most common words associated to a certain search, over a monthly period. To verify if media exposure changed the searching behaviour about bats (i.e., if it had increased pandemic-related searches), we downloaded the most common keywords searched altogether with "bats" in Google in September-December 2019 and in January-April 2020. Google data were accessed with the "gtrendsR" package [28].

Data analysis was conducted in three consecutive steps. First, we inspected whether the proportion of COVID-19 related searches, among bat-relates searches Google had changed, before and after the 1st of January 2020. We pooled together the total number of the most popular bat-related searches conducted in Google and we calculated the proportion of pandemic-related searches done before and after the 1st of January 2020. By "pandemic-related" we meant those searches emphasizing diseases, bats as food, or China. Then, we visually inspected scatterplots to see whether bat-related and coronavirus-related searches on Wikipedia and Google had increased through time, especially after the news about the first victim of COVID-19 in China, the 11th of January 2020. Daily Wikipedia views were pooled across the 8 different pages, to reduce noise. While the GoogleTrends pattern for "coronavirus" was clear from the scatterplot, we fitted a Bayesian Generalized Additive Mixed Model with INLA [29], based on a Beta distribution [30], to highlight the temporal evolution of the GoogleTrends index for "bats".

Finally, we carried out causal impact analysis to estimate how the announcement of the first COVID-19 victim changed the aggregated number of Wikipedia searches in the study area. Causal impact analysis was based on Bayesian Structural Time series [31], adopting synthetic controls. Causal impact analysis estimates the impact of an intervention over a target time series, by using untreated control series to build a counterfactual and to estimate the causal effect as the difference between post-treatment observed vs. control values. In this case, no control series existed: there were no Wikipedia pages whose views were associated with those of bats which were likely to be unaffected by COVID-19 outbreak. As the yearly number of Wikipedia searches did not increase through time between January 2016 and December 2019, thus showing predictable seasonal patterns, we adopted 2016-2019 data as the control condition. Therefore, we estimated the causal impact of COVID-19 outbreak, comparing post-COVID-19 values vs. a counterfactual representing Wikipedia visits between January and April in the previous years. For both target and control series, the pre-treatment timespan included visits between May and December. Causal impact analysis was done with the statistical package

"CausalImpact" [31]. Reproducible software code, our datasets and country-specific analyses are available in the Supplementary Information.

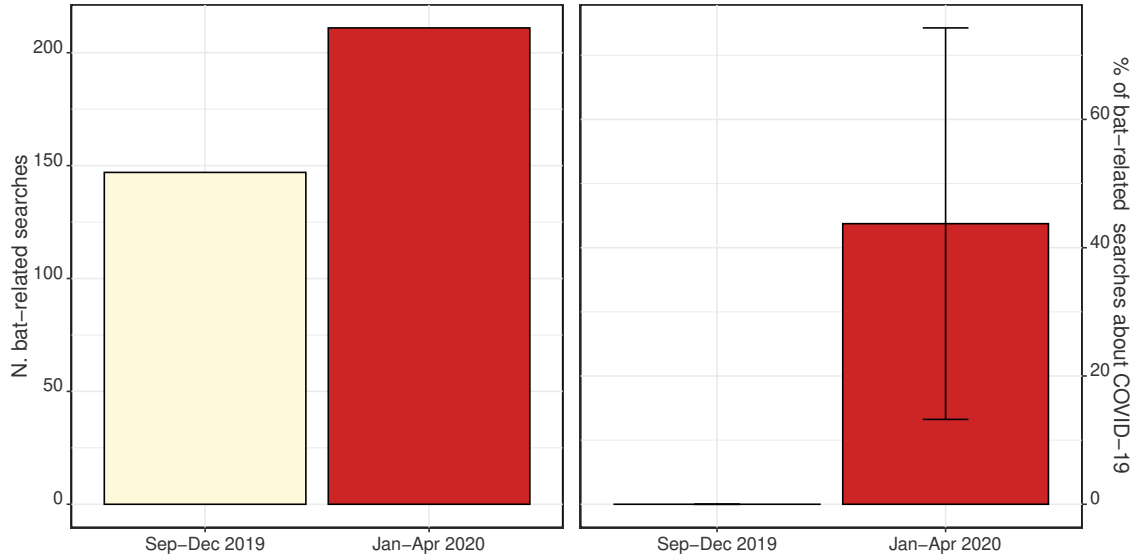

Figure 1 | Total number of bat-related searches on Google (left) and percentage of coronavirus-related searches among them (right, bars represent the median percentage and the standard deviation of different countries).

Results

The analysis of related searches on Google indicated that, since January 2020, the number of bat-relates searches on Google has changed significantly. First, searches on bats have qualitatively changed their associated words: since January 2020, there was an unprecedented interest towards "bats and diseases", "bats and China", and "bats used as food". These searches were completely absent before January 2020 (**Figure 1**), consistently across all considered countries.

Our exploratory analysis of both GoogleTrends and Wikipedia data revealed a sudden increase in the searches about keywords "bats" and "coronavirus", following the news about the first victim of COVID-19, the 11th of January 2020 (**Figure 2**). Finally, causal impact analysis revealed that, since the announcement of the first COVID-19 victim was made, the aggregated number of visits to Wikipedia pages about bats rose massively, compared to usual seasonal patterns from the three previous years (**Figure 3**). We observed an average daily number of 1710 visits/day in the study area, versus an expected value of 660-1540 visits (95% Bayesian credibility interval). For the whole period, we expected a cumulated amount of 58.520 visits, while we observed a cumulated amount of 161.150 visits, i.e. equaling to a +175% increase. The probability of obtaining this increase by chance, according to the Bayesian one-sided tail-area, was extremely small ($p = 0.000$). While these findings refer to the overall amount of visits to Wikipedia, obtained by summing all the daily values from the 8 Wikipedia pages about bats, we observed similar patterns across languages (**Figure 4**).

Discussion

We provided strong evidence that laypeople significantly increased and modified their interest in bats as a consequence of pandemic-related media news, namely after the international announcement of the first victim of COVID-19, so fulfilling our hypothesis.

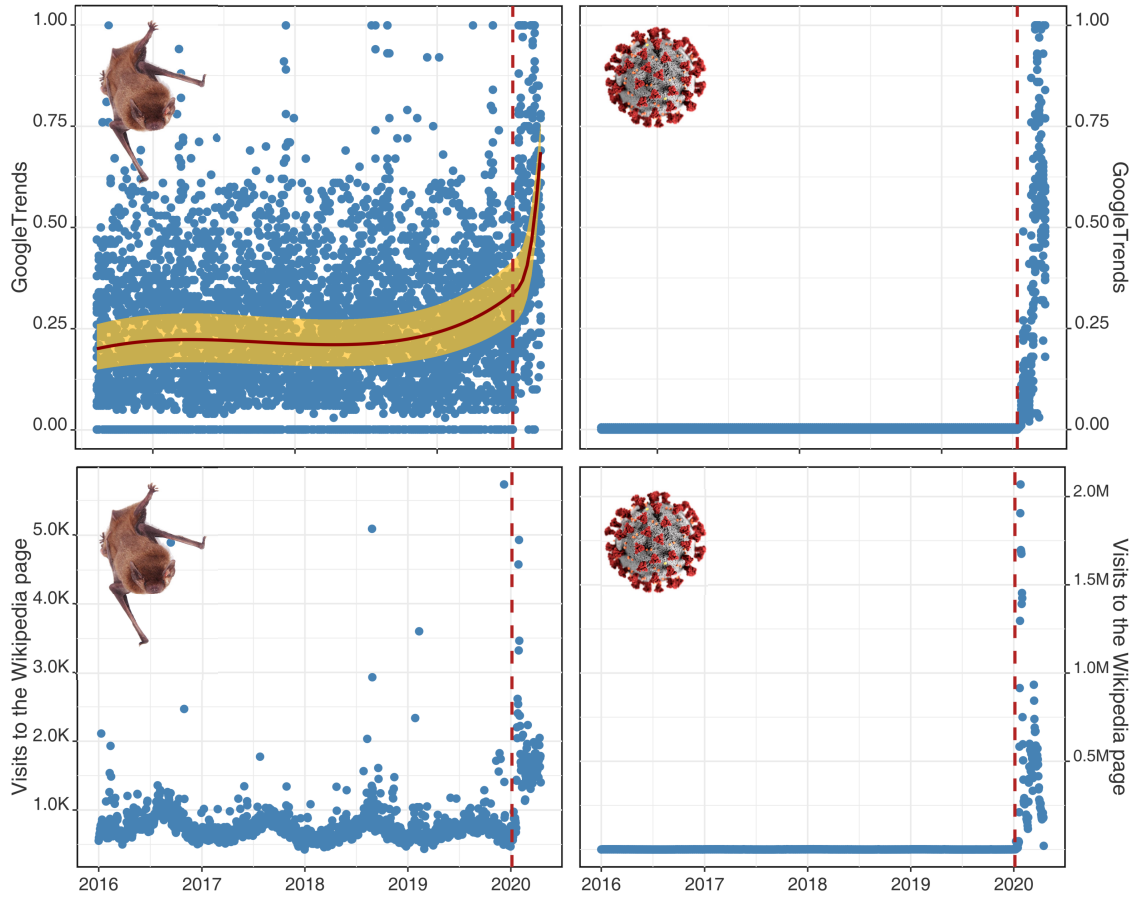

Figure 2 | Temporal evolution of Google and Wikipedia searches about bats (left) and coronavirus (right). The dashed vertical bar represents the 11th of January 2020, when the first victim of COVID-19 was announced.

The exploration of Google-related searches about bats, before and during the emergency, in 20 countries, indicated that once people heard about the first victim, they started searching for information about how bats might be responsible for the spillover of SARS-CoV-2. Although Google does not provide its algorithms, searches not quickly increasing through time or performed by small groups of people are filtered out (for available details, see support.google.com). Therefore, our findings indicated that this phenomenon involved a significant portion of Internet users and/or that it grew quickly in a few weeks. These qualitative changes in bat-related searches, were coupled with a boom in search volumes on Wikipedia and Google about bats and coronavirus. For Wikipedia, it has also been possible to quantify the magnitude of this change: after the first COVID-19 victim, Wikipedia visits to page about bats grew by 2.75 times. This result may represent an underestimation of the phenomenon, as the English version of Wikipedia has a page on "Bat-borne virus", which had 280.839 views since January 2016. Considered the qualitative and quantitative changes in search volumes about bats, altogether with their synchrony with COVID-19 and their compatibility with our proposed causal mechanism, our findings strongly suggested that Internet users from at least 20 different countries were responsive to the announcement of the first victim of COVID-19 in China, the 11th of January 2020.

Public opinion could particularly be affected by mass media when the audience has little

experience with a particular issue [32, 33]. Individual search for orientation depends on the relevance of a topic and its level of uncertainty [34]. Taken together, our findings suggest that media coverage play a fundamental role to make people inquire about wildlife and emerging zoonoses [35]. In this case, the effect was to make bats viral, although these species are often not iconic and even repulsive to some people [11, 36, 37]. Bats play key roles in the ecosystems, e.g. as insect suppressors, seed dispersers and pollinators, thus they provide essential services also in human-modified ecosystems [38, 39]. Considering the role of the media in shaping human-wildlife attitudes [40], the importance of delivering evidence-based information on this topic too is fundamental. Raising public awareness correctly has also a remarkably important role both in disease management and in shaping attitudes towards wildlife and the environment [41]. People reactions to information by media may trigger persecution of some wildlife species, e.g. bats, in case news are based on falsehoods that report wildlife as plague greasers [42].

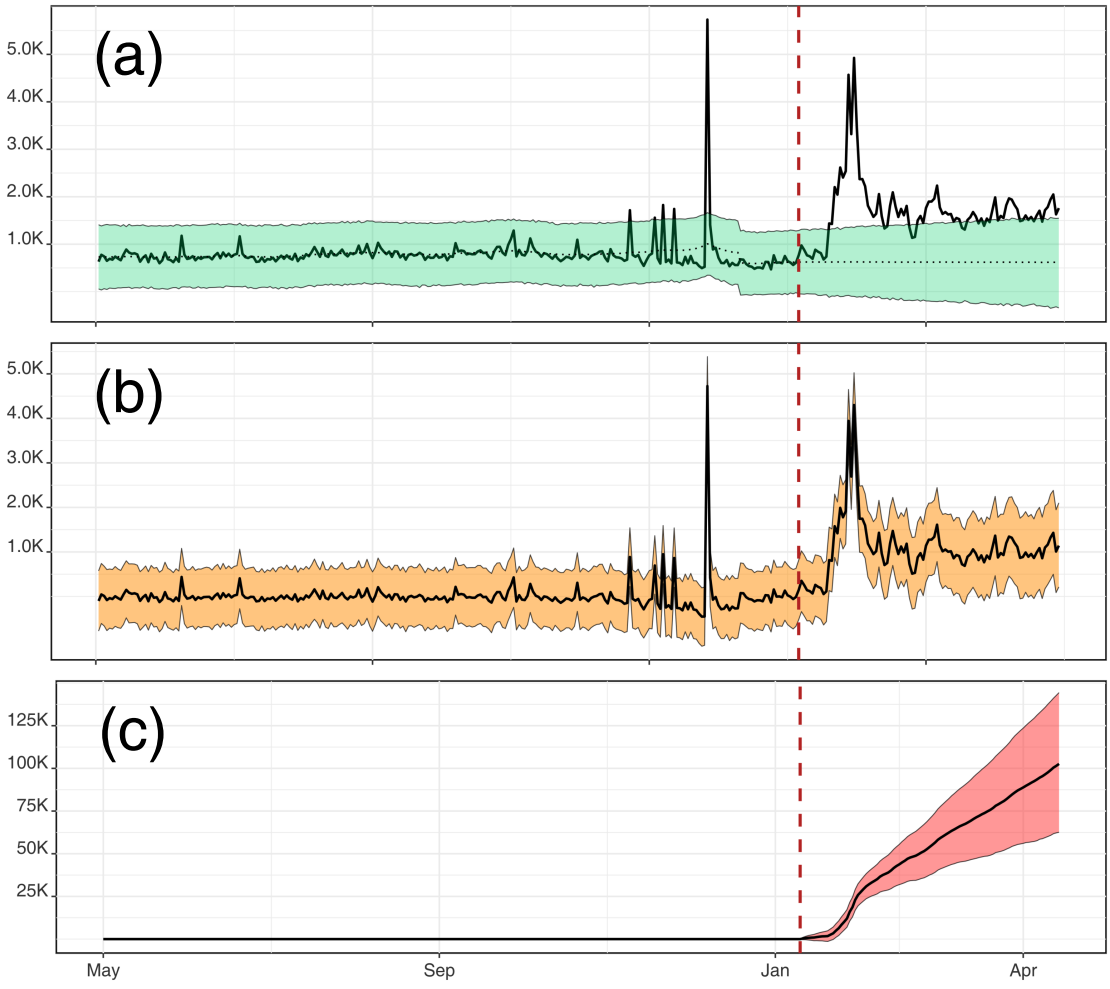

Figure 3 | Causal effect of the announcement of the first victim of COVID-19 over the total number of visits to Wikipedia pages about bats. Dashed line represents the 11th of January 2020. The upper panel (a), compares observed daily visits (solid line) with predictions from previous years (green, dotted line). The middle panel (b), represents the causal effect, as the difference between observed and expected daily visits. The lower panel (c) represents the cumulated causal effect through time.

Attempts to control wildlife diseases or to limit zoonosis transmissions have been long based

on health/hygienic measures such as construction of barriers and vaccinations, as well as on practices directly targeting vectors or reservoir species such as culling programs [43]. The latter of course pose serious problems when targeted species have a threatened conservation status, and are thus protected, or provide key ecosystem services, such as bats [9, 38]. Also in the recent context we investigated, inappropriate/illegal persecution of bats has been recently reported in some countries (https://www.scmp.com/video/asia/3075441/hundreds-bats-culled-indonesia-prevent-spread-coronavirus; https://phys.org/news/2020-03-peru-blamed-coronavirus.html), raising great concern among bat conservationists [8]. 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 as such difficult to record and actually prevent [44]. Given the severity and the media resonance of the COVID-19 pandemic and the widespread misinformation circulating on bats, it is pivotal to found available sources such as Wikipedia on solid and evidence-based statements, as well as further investigate how such increase in public attention on bats translated into a change (positive, or more likely negative) in public attitude towards such mammals.

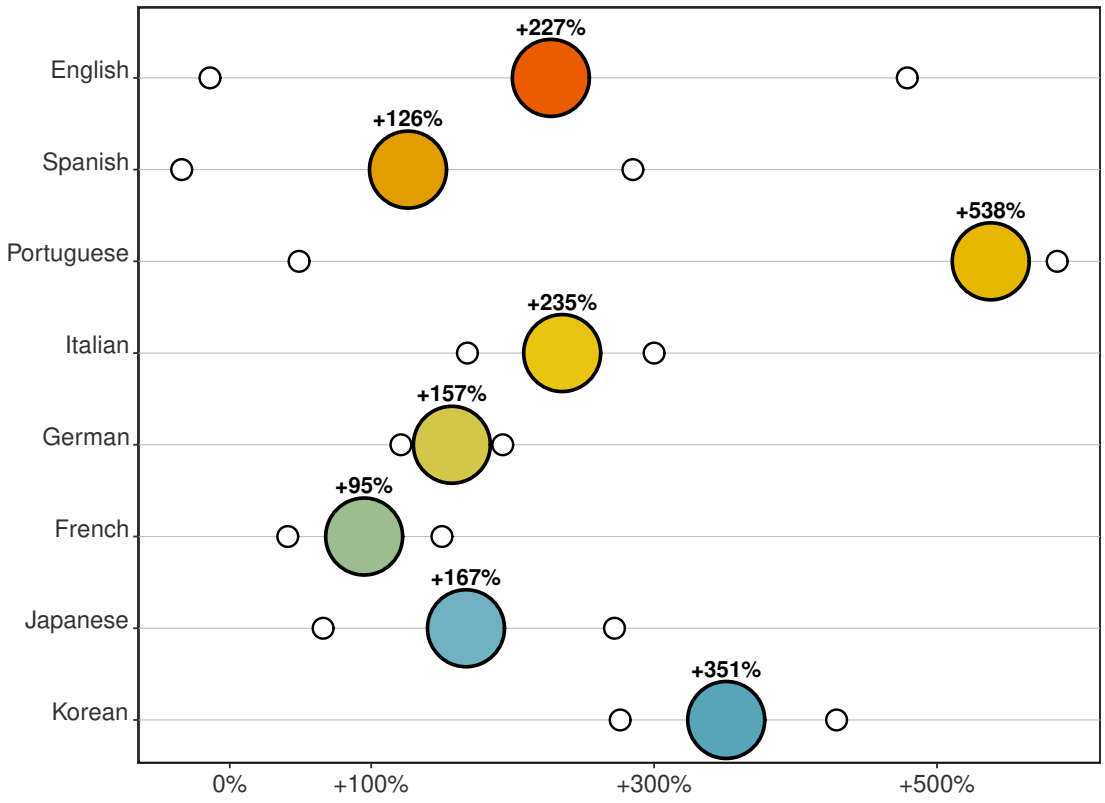

Figure 4 | Percentage increase in the number of cumulated visits to Wikipedia pages about bats, in 8 languages, after the 11th of January 2020. Colored circles represent mean increase, while white circles represent 95% Bayesian credibility intervals.

A caveat of our approach is that we assumed news coverage to increase the number of Internet searches by increasing curiosity towards bats through a total mediation mechanism. The most obvious criticism to this assumption might be that, as some countries implemented lockdown measures, forcing millions of people to stay home, visits to Wikipedia pages about bats rose because of people simply searching more about animals in general, including bats.

Therefore, there would be two mediating factors linking media coverage to increased Wikipedia visits: increased curiosity, and increased spare time. While we cannot reject this alternative causal structure [45], we deem this second mediating mechanism to play a small role in the total causal effect, for two reasons. First, searching information on Wikipedia is not time-consuming, accounting for few minutes per search. People already visit pages about wildlife regularly [23] and we do not believe most of them did it less before the pandemic, because of a lack of time. Most importantly, the largest increase in Wikipedia visits occurred between January and February (**Figure 2**, **Figure 3**), before most lockdown measures were implemented. It could also be argued that while Google data were extracted at the country level, Wikipedia visits were extracted at the language level. Some of these languages are officials or second languages in many countries: English is spoken in more than 20 and French in 31 African countries, and Spanish in all Latin America. Wikipedia visits could therefore have been inflated by Internet users from these countries. This might in principle make our findings even more "global", increasing the relevance of our analyses, yet we acknowledge the potential effect of the spatial component on the phenomenon we observed. The Wikimedia foundation can share data from previous years at the country level [24], behind non-disclosure agreements: while we could not stipulate them for this study, we believe that spatially-explicit studies should be done in the future. Finally, we acknowledge that our study did not assess how strongly daily or weekly news volumes about COVID-19 were associated with volumes of online searches about bats. From our analyses it was clear that Wikipedia visits and Google searches had some spikes at some precise dates: understanding which type of news framing [46] caused such trends [47] would be extremely important to tailor communication campaigns aimed at mitigating bat persecution. We encourage more research on this topic, also using large datasets such as GDELT [48] and multivariate time-series analysis [49]. COVID-19 pandemic might be a turning point for human-bat interactions in the 21st century, which is bringing bats in the spotlight at an unprecedented extent, potentially representing both a challenge and an opportunity to 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.

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