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Developing a global indicator for Aichi Target 1 by merging online data sources to measure biodiversity awareness and engagement

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ABSTRACT

Due to the importance of public support in fostering positive outcomes for biodiversity, Aichi Biodiversity Target 1 aims to increase public awareness of the value of biodiversity and actions that help to conserve it. However, indicators for this critical target have historically relied on public-opinion surveys that are time-consuming, geographically restricted, and expensive. Here, we present an alternative approach based on tracking the use of biodiversity-related keywords in 31 different languages in online newspapers, social media, and internet searches to monitor Aichi Target 1 in real-time, at a global scale, and at relatively low cost. By implementing the indicator, we show global patterns associated with spatio-temporal variability in public engagement with biodiversity topics, such as a clear drop in conversations around weekends and biodiversity-related topic congruence across culturally similar countries. Highly divergent scores across platforms for each country highlight the importance of sourcing information from multiple data streams. The data behind this global indicator is visualized and publicly available at BiodiversityEngagementIndicator.com and can be used by countries party to the Convention on Biological Diversity (CBD) to report on their progress towards meeting Aichi Target 1 to the Secretariat. Continued and expanded monitoring using this indicator will provide further insights for better targeting of public awareness campaigns.

1. Introduction

The world is in the middle of a mass extinction event that is driven entirely by human activity (Ceballos et al., 2017). Decisions made by consumers, policymakers, and businesses have a direct impact on efforts to conserve biodiversity, and public interest and engagement is a decisive factor in successful conservation interventions (Phillis et al., 2013). To improve the outcomes of conservation efforts, it is thus necessary to cultivate a broad public understanding of the diverse benefits that biodiversity provides and promote engagement in actions that may prevent its decline.

To this end, the Convention on Biological Diversity (CBD) Aichi Target 1 aims to make people "aware of the values of biodiversity and the steps they can take to conserve and use it sustainably" by 2020 (Convention on Biological Diversity, 2010). According to the CBD Secretariat, the success of all Aichi Biodiversity Targets depends on meeting Aichi Target 1 (Leadley et al., 2013). However, this target has traditionally been difficult to monitor. Countries have reported their progress to the CBD Secretariat using existing public-opinion surveys such as the Eurobarometer and the Biodiversity Barometer. These surveys have several limitations, including poor geographical coverage, especially in more biodiverse tropical countries (Leadley et al., 2013), as well as divergent methodologies that make it difficult to form a global picture of biodiversity awareness (McOwen et al., 2016). Similar to these public-opinion surveys, assessing factors that increase public engagement with biodiversity also relies on individual interviews (Moss

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et al., 2015), and follow-up surveys to explore long-term effects often have significant respondent attrition (Jensen et al., 2017). In addition to problems of small sample size, public opinion and social science surveys are often quite expensive (Visser et al., 1999). While the budgets behind such surveys are not released, the Biodiversity Barometer for example requires several corporate sponsors to generate data from only a small number of countries (Union for Ethical BioTrade (UEBT), 2016). Thus, existing survey-based indicators for Aichi Target 1 fail to comprehensively monitor progress, are costly and hinder the comparison of results across all the CBD countries (McOwen et al., 2016).

Concurrently, conservation scientists and practitioners have recognized the potential of sourcing data from internet and social media streams which provide a novel approach to study conservation issues (Di Minin et al., 2015; Ford et al., 2016; Ladle et al., 2016). Such data is often freely available and global in scale with fine grained temporal resolution (Soriano-Redondo et al., 2017). Work drawing from such approaches includes using internet search volume to study spatio-temporal patterns of public interest in biodiversity related topics (Funk and Rusowsky, 2014; Proulx et al., 2014); assessing the cultural salience of species and natural areas through internet content (Correia et al., 2017, 2018b); using multiple social media platforms to understand tourists' preferences in protected areas (Hausmann et al., 2018); as well as mapping species distributions (Lin et al., 2015; ElQadi et al., 2017). These analyses address questions that were unanswerable only a few years ago by using data that is extensive, scalable, and inexpensive. However, many of the projects that rely on internet data to study environmental themes utilize only one data source and are heavily biased towards the English language.

Here, we propose an approach for assessing public awareness of a variety of biodiversity-related topics that addresses these issues by synthesizing data from three different internet sources - online newspapers, Twitter, and Google search frequency - across 31 languages into one indicator that can be used to monitor global progress towards Aichi Target 1. The data behind this indicator is publicly available at BiodiversityEngagementIndicator.com and can be used by CBD countries in reporting on the progress in meeting Aichi Target 1 to the Secretariat. In this paper, we investigate the temporal and spatial dynamics of public awareness of biodiversity-related topics and demonstrate how the indicator is strengthened by drawing on three data sources that provide complementary information on the topics people read about, discuss, and search for.

2. Methods

We applied a culturomic approach (Ladle et al., 2016) to build a global indicator, and reasoned that the rates at which key issues are mentioned in digital texts would be a robust indicator of public engagement with biodiversity-related topics that could be applied across many different languages. This approach allows us to gauge public *awareness* of biodiversity (i.e., concern about and well-informed interest in biodiversity topics), because it draws from informative media like internet newspapers and web searches. It also allows us to gauge *engagement* with biodiversity (i.e., actively discussing biodiversity topics, using biodiversity contexts as a form of recreation, or taking pro-conservation behavior), because it draws from social media, where people actively discuss biodiversity topics and share environmental and pro-conservation behavior (Wallace et al., 2018). However, we are unable to precisely measure the Aichi target's specifications that people are aware of (1) the value of biodiversity and (2) the actions they can take to conserve and sustainably use biodiversity.

2.1. Keywords

We selected 23 keywords related to biodiversity issues across 31 languages (Appendix 1) to monitor. Keyword selection was based on the biodiversity glossary created by the United Nations Environmental Program World Conservation Monitoring Center (UNEP-WCMC, 2014). We refined this glossary by excluding uncommon terms that are unlikely to be used by the general public, such as “degazettement” or “Ad Hoc Technical Expert Group,” as well as words with ambiguous homonyms, such as “diversity,” “forest,” or “conservation,” which would be unrelated to Aichi Target 1 in phrases like “linguistic diversity,” “random forest algorithm,” or “conservation of momentum.” Finally, we translated the keywords into a set of 31 languages using Google Translate. We selected languages based on their overall volume and prevalence across multiple countries in a large sample of Twitter data. To ensure accurate translations, we only considered words that had significant fidelity after back-translation (e.g., “conservation” was excluded because it was back-translated as “maintenance” in some languages). However, because we began from an English-language glossary, our methodology may have missed important non-English keywords. We are aware of ongoing discussions and critiques of machine translation and potential biases in internet data and we address these and more specific limitations with the methodology in Section 4.

2.2. Data sources

In creating this indicator, we used data from online newspapers, social media, and internet search volume. By utilizing three distinct data sources, we were able to track themes covered by the traditional news media, trending topics discussed by people through social media, and the information people are searching for online. This approach ensures a broad representation of public awareness of and engagement with biodiversity.

2.2.1. Newspapers

We sourced data on the use of biodiversity-related keywords in newspapers from webhose.io, which gathers 680,000 online newspaper articles per day from 120 different countries (Webhose.io, 2018). Using the application programming interface (API), we carried out daily queries to track both the total number of news articles from each country, the total number of articles from each country that contained any keyword, and the total number of articles from each country that contained each individual keyword.

2.2.2. Twitter

Twitter is one of the most popular sources of real-time data on trends in public opinion and has been used to monitor public awareness of a variety of topics, including environmental ones (Roberge, 2014). We used the Twitter streaming API to collect a continuous sample of all tweets in real-time and then tabulated the percentage of the total tweets that contained relevant keywords. We used information from users' profiles to geo-locate 28.2% of the tweets we collected (Dredze et al., 2013). Because tweets that were not geo-located could not be associated with a specific country, we excluded them from the analysis.

2.2.3. Google searches

Using Google Trends, we obtained monthly internet search volume for our keywords across all countries. Google Trends has two search features: terms and topics. We used topics searches because they include not just the search term, but also other terms that share the same concept in any language. Google Trends does not give the absolute rate of occurrence for target words, but a relative measure of search rates scaled from 0 to 100.

2.3. Calculating the Indicator

To combine the data from the three sources, we first scaled the keyword score for Twitter and online newspapers using a similar methodology to Google Trends (Proulx et al., 2014; Le Nghiem et al., 2016). We calculated the rate of mentions of each keyword across all tweets or articles for a given geography and time period. We then scaled

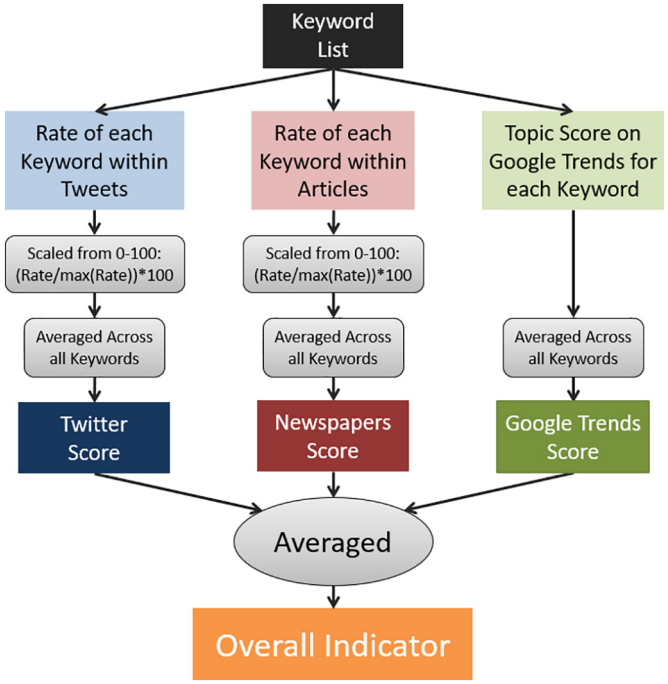

Fig. 1. Flow chart of the methodology used to calculate the indicator.

the rates by dividing them by the maximum observed rate across all keywords and multiplied that value by 100. When scaling, we excluded maximum values for areas that had less than 1000 tweets or articles across the entire study period to avoid biases related to low sample size. Then, to calculate the indicator score for a specific platform, country, or time period, we calculated the mean values across all keywords. We weighted keywords equally in order to ensure the same methodology was used across all three platforms and to avoid inflating scores due to occasional peaks for specific topics. Finally, to get an overall indicator, we calculated the mean values across all three platforms (Fig. 1).

The indicator can be calculated across multiple timeframes, and the results in this paper are for data collected over the course of one year from November 1st, 2017 through October 31st, 2018. We used Pearson correlation to evaluate the agreement between indicator scores and agreement in keyword rates for each platform and at the country level. We also assessed global temporal patterns by calculating the daily score across each platform (Fig. 4), as well as global spatial patterns by mapping overall country scores (Fig. 5). Finally, to explore how countries vary in terms of affinities towards different keywords, we conducted a Principal Components Analysis (PCA) on a matrix of countries and keywords, where each value was the average score across all three platforms for a keyword in a given country.

3. Results

During the study period, we found 2.25 million newspaper articles (approximately 1.2% of all news articles sampled) and 160 thousand tweets (0.05% of all geocoded tweets) containing any of the keywords in our list. The Pearson correlation coefficient suggested that there was only slight concordance between countries' scores across platforms (Fig. 2). However, some countries, such as Ecuador, Ethiopia, Guatemala, Canada, Fiji, and New Zealand, had consistently high scores across multiple platforms.

For online newspapers and Twitter, we were also able to collect and compare the rates of individual keyword usage. Online newspapers had much higher rates of keyword usage, with 0.31% of newspaper articles mentioning *sustainability* and 0.31%, mentioning *climate change*. On the other hand, only 0.01% of tweets mentioned *sustainability* and 0.02% mentioned *climate change*. While absolute keyword usage rates differed between Twitter and newspapers, we found a strong overall correlation (Pearson's $r = 0.85$) in the relative prominence of individual keywords between the two platforms (Fig. 3).

3.1. Temporal dynamics

For each platform, we calculated daily frequencies of keyword usage over the entire study period (Fig. 4). Overall, we found temporal variation in all three platforms, which all exhibit a weekly periodicity. However, the days of the week with the lowest and highest scores varied across platforms (for average scores by day, see Appendix 2). In newspapers, articles using the biodiversity keywords were least likely to be published on Monday and most likely to be published on Wednesday. Sunday was the lowest scoring day on Twitter, while Thursday was the highest. For Google Trends, biodiversity-related searches were least likely to occur on Saturday and the most likely to occur on Tuesday. Examining temporal patterns for individual keywords shows that changes in public engagement and awareness can follow significant events. For example, International Biodiversity Day on May 22nd shows a clear increase in the indicator for the word “biodiversity” in Google Trends and Twitter, as well as a slight increase in newspapers. Similarly, the release of the 2018 Intergovernmental Panel on Climate Change (IPCC) Special Report on October 8th, 2018 led to the highest scores for “climate change” across all three media.

3.2. Spatial dynamics

The overall indicator presents significant variation by country and region (Fig. 5). North and Central America, Andean South America, East Africa, and parts of Oceania all had disproportionately high scores. Eastern Europe, Central Asia and the Middle East had overall the lowest scores. Only a few countries lacked sufficient data to calculate the indicator. Examining maps of individual keyword scores also presents significant regional patterns (Fig. 6).

To better explore regional and country-level variation in keyword usage, we conducted a Principal Components Analysis (PCA). The first two principal components explain approximately 42% of the variation in country-level keyword usage (Fig. 7), and the association of individual keywords with each PCA axis can be found in Appendix 3. This analysis revealed a cluster of several Latin American countries with similarly high scores across multiple keywords, including keywords such as *extinction*, *protected area*, *ecology*, *endangered species*, and *biosphere*. Similarly, many African and Anglophone countries were also grouped due to high scores for keywords such as *sustainability*, *ecosystem service*, *natural capital*, and *climate change*. Also evident is a third cluster comprised of several countries where the generality of keyword usage rates in the three online sources is relatively low.

4. Discussion

The Aichi Target 1 indicator developed in this study showed significant regional, temporal, and thematic variability in public awareness of, and engagement with, biodiversity across the globe. Observed differences in keyword engagement across countries, languages and platforms suggest that, when applying any monitoring system involving internet data streams, drawing data from only one platform will provide an incomplete picture of public engagement with biodiversity topics. Thus, it is necessary to use multiple platforms and a multilingual approach to gain more informed insights.

The observed temporal variation across platforms also suggests that people are engaging with biodiversity-related topics in different ways and for different purposes, depending on the platform. In contrast to previous work utilizing Google Trends, which has mostly looked at broad, multiannual trends in keyword usage (Proulx et al., 2014; Le Nghiem et al., 2016), we examined weekly and seasonal trends. We

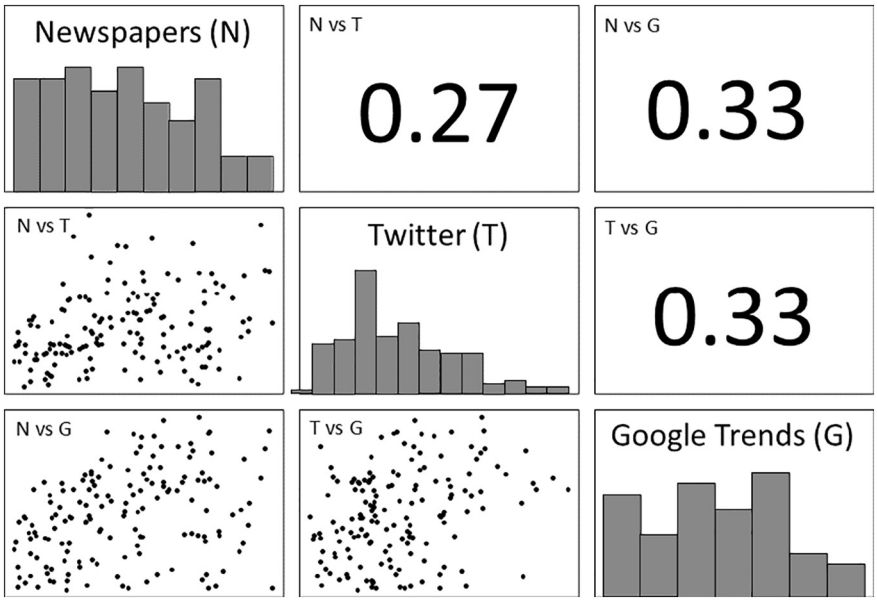

Fig. 2. Comparison of country indicator scores across platforms using biodiversity-related keywords. The diagonal shows frequencies of country scores. Scatterplots (below the diagonal) show country scores between each pair of platforms. Pearson correlation coefficients (above the diagonal) show level of agreement for scores between each pair of platforms. Scatterplot axes range from 0 to 100.

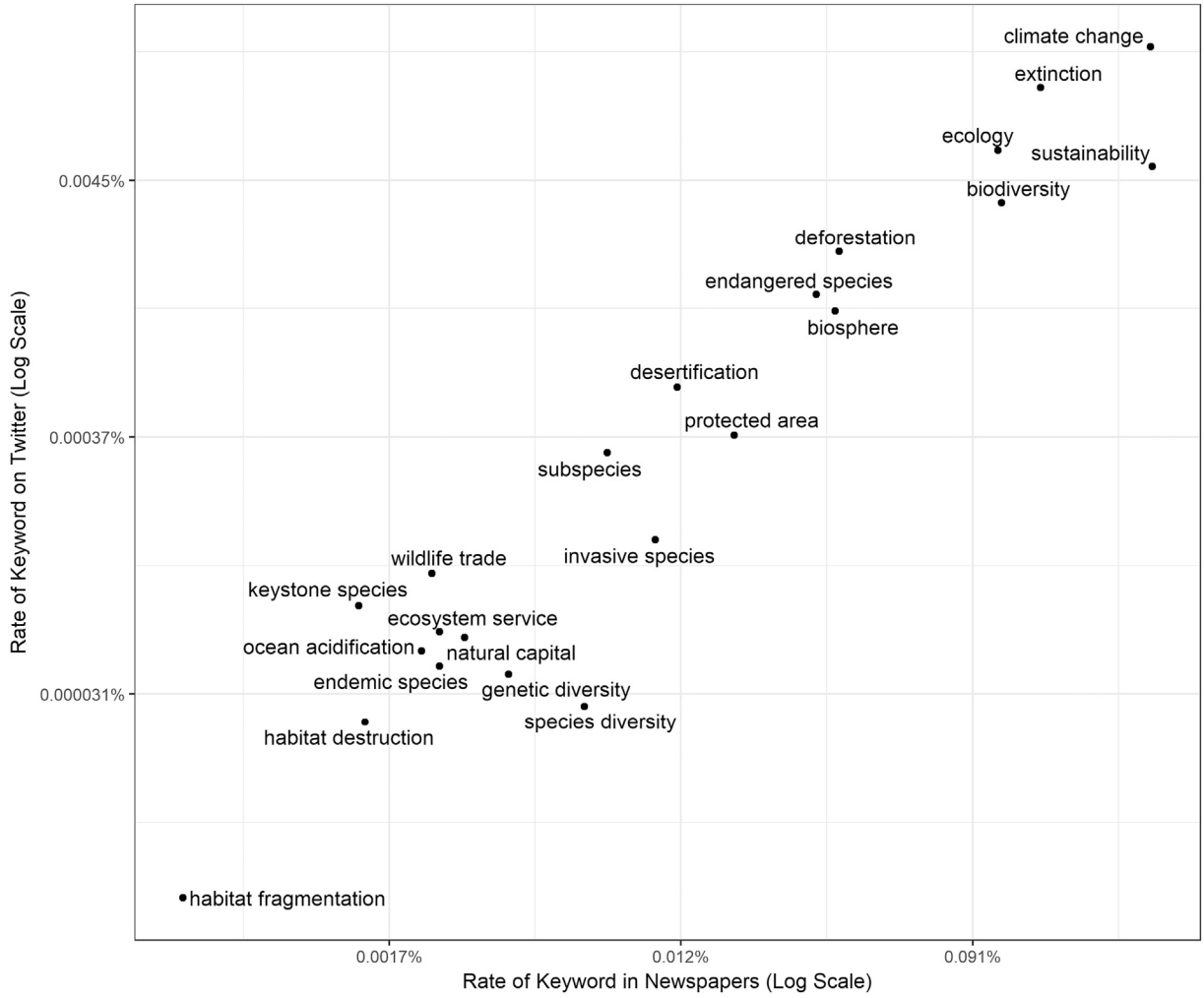

Fig. 3. Comparison of rates of usage of individual keywords between online newspapers and Twitter. The rate of each keyword was calculated as the fraction of tweets or newspaper articles that contained the keyword across the entire study period.

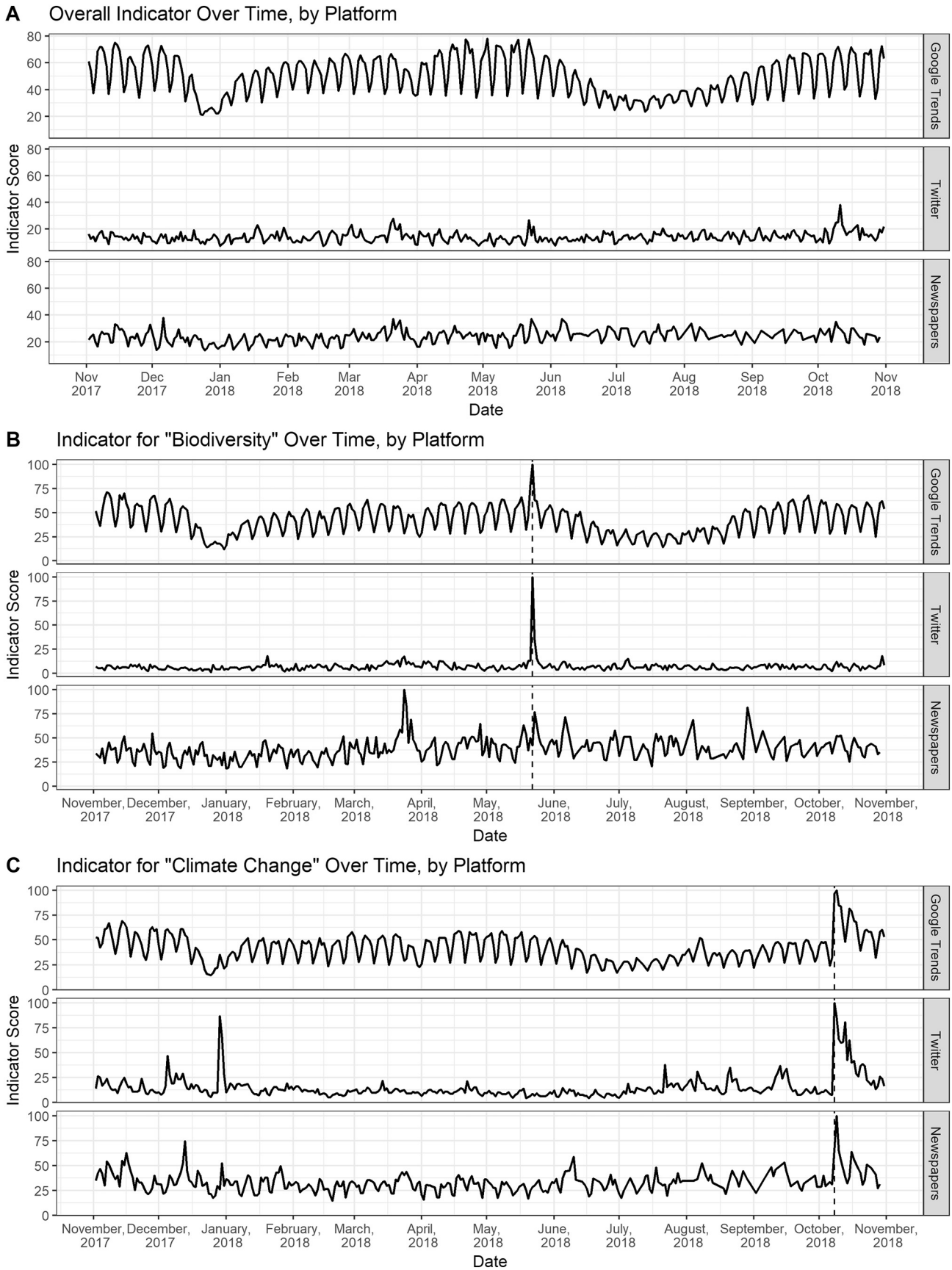

Fig. 4. Daily indicator taken as the average scaled score across all keywords, by platform. The rate of each keyword was scaled from 0 to 100 based on the highest daily score within the time window. (A) Shows the overall indicator averaged across all keywords. (B) Shows the indicator for the keyword 'biodiversity' over time, with the date of International Biodiversity Day (May 22nd) highlighted with the dotted line. (C) Shows the indicator for the keyword 'climate change' over time, with the date of the release of the IPCC Special Report (October 8th) highlighted with a dotted line.

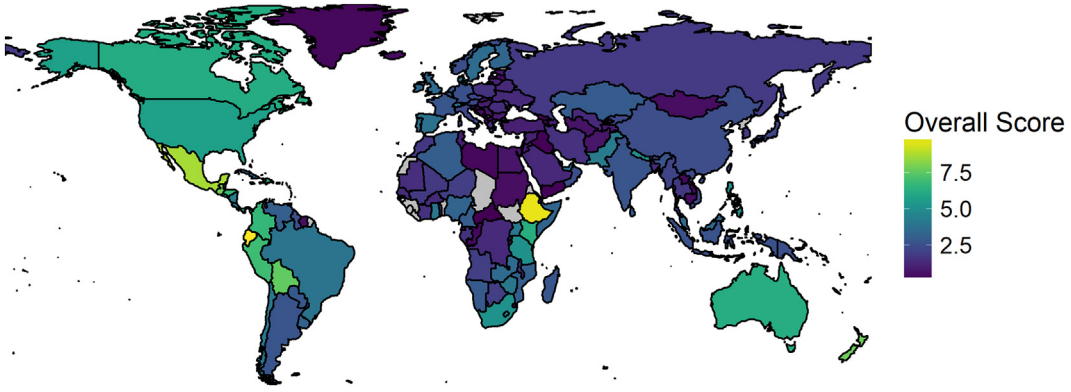

Fig. 5. Country level indicator scores across the study period. Countries with insufficient data are shaded in gray. Indicator scores range from 0 to a potential 100. For details on how indicator scores are calculated, see Section 2.3.

observed cyclical patterns including decreases in biodiversity engagement on weekends, during holidays (e.g. New Year's), and during summer months. These patterns suggest that online internet searches (e.g. by using Google Search) are driven by professional and pedagogical purposes. It is critical, however, that environmental topics are not only taught or discussed in informational and pedagogical settings but are a part of broader public discussions in order to mobilize the wider public and generate effective conservation campaigns (Brulle, 2010). Twitter and electronic newspapers may better represent such debates as engagement patterns vary substantially from one week to the next and show occasional spikes, suggesting that engagement with biodiversity on these platforms may be more event-driven (Kwak et al., 2010; Papworth et al., 2015). Twitter in particular can act as a public forum for discussions around important news events (Rudat and Buder, 2015), and we found evidence of linkages between environmental topics in online newspapers and on Twitter, as keywords were used with a similar frequency. Analyzing relative frequencies of keywords can also yield insights when compared to previous studies. For example, a 2014 study found that the European public was more aware of the issue of habitat destruction than ocean acidification (Gelcich et al., 2014). Interestingly, we found higher frequency of ocean acidification than habitat destruction in both newspapers and Twitter suggesting a shift of public attention (Fig. 3).

Spatial differences in the usage of internet platforms for biodiversity engagement were also evident between and within countries. In geographically and culturally related countries, similar keyword searches were more likely to be used, which could show evidence of shared cultural values. For example, in Latin America, we found high frequencies of keywords oriented towards ecological and scientific topics, while African and Anglophone countries exhibited higher frequencies of words related to human well-being and human impacts on biodiversity. This probably reflects how conversations, news stories, and curricula related to biodiversity diffuse across national borders to nearby and linguistically similar countries and emphasizes the need for a culturally nuanced analysis of public awareness of biodiversity (Funk and Rusowsky, 2014). Regional patterns in biodiversity discussion topics echo findings that different cultural groups can value different aspects of nature as cultural ecosystem services (Chan et al., 2012; Daniel et al., 2012). This idea is reinforced by the variation in scores across platforms within countries. Overall, our results suggest that not only do countries engage with these platforms in different ways, but distinct populations within a country may also be gravitating towards different platforms. This finding is in line with a large body of literature highlighting differences in internet and social media use between different cultural, age, gender, and income groups (Li and Kirkup, 2007; Kim et al., 2011; Jackson and Wang, 2013). Thus, it is critical to integrate data from multiple sources when studying biodiversity engagement and constructing an indicator for Aichi Target 1.

While this work expands the spatial and temporal coverage of Aichi Target 1 monitoring without requiring expensive surveys, limitations do exist. Using social media data as a proxy for human behavior is contested in the social sciences due to issues related to biased population samples, users exaggerating their own behavior on social media, or bots and spammers masquerading as humans (Hargittai and Hinnant, 2008; Ruths and Pfeffer, 2014; Tufekci, 2014). On the other hand, much work has shown how environmental education and scientific literacy are positively associated with on-the-ground activism and public support for conservation initiatives (Martín-López et al., 2009; van der Ploeg et al., 2011; Moss et al., 2015), and this indicator, by combining multiple data sources, attempts to correct for potential biases associated with each individual platform. Another issue is that the internet and social media platforms are multi-lingual, making the application of analytical techniques such as sentiment analysis challenging (Montoyo et al., 2012), and limiting the ability of the indicator to measure

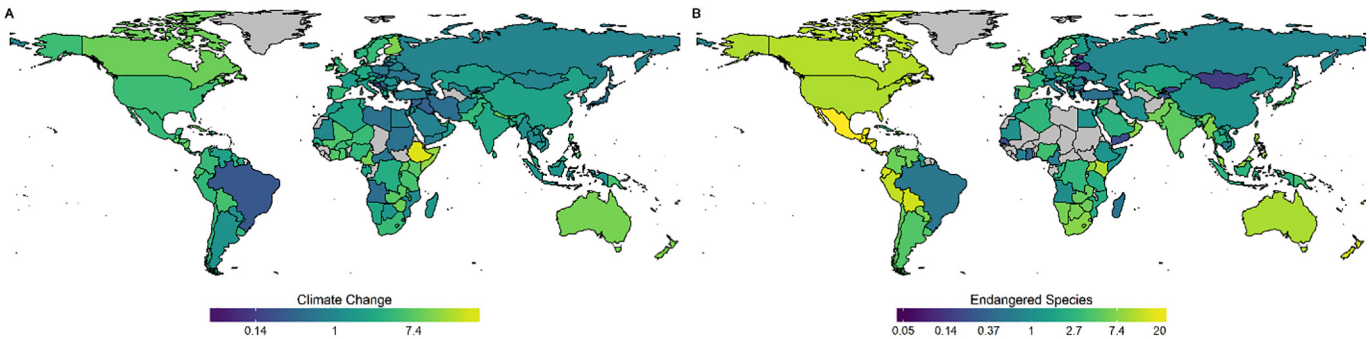

Fig. 6. Country level keyword scores for climate change (A) and endangered species (B). Countries with insufficient data are shaded in gray. Scores range from 0 to a potential 100 and are colored on a log scale. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

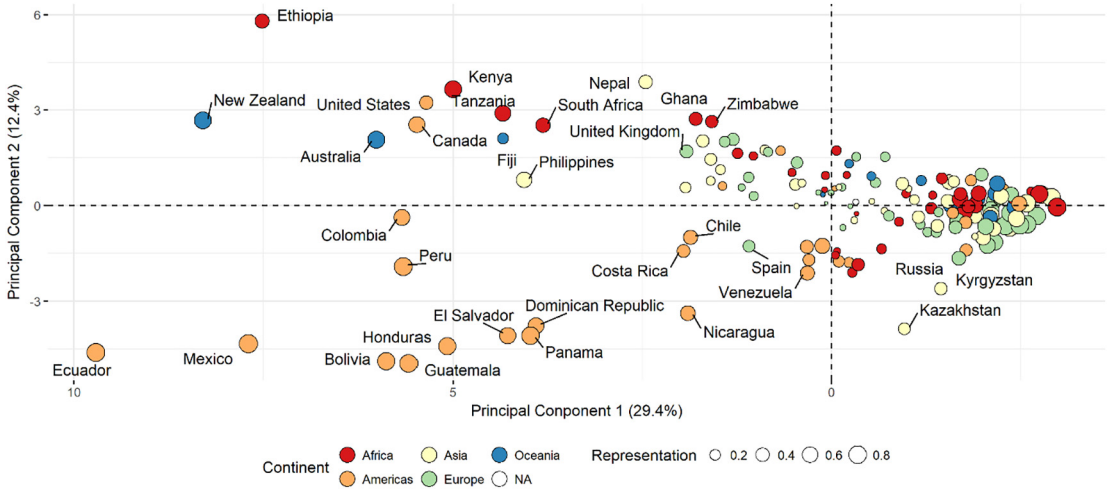

Fig. 7. Results of a Principal Components Analysis (PCA) showing regional groupings in keyword affinities. The PCA was conducted on a matrix of countries and keywords, where each value was the average score across all three platforms for a keyword in a given country.

nuanced aspects of Aichi Biodiversity Target 1, such as people's awareness of actions they can take to conserve biodiversity. Thus, at present, a robust global indicator cannot do much more than tally keywords. Nevertheless, as increasing usage of biodiversity keywords represents engagement with biodiversity, high usage may be indicative of greater pro-conservation behavior, given previously documented linkages between biodiversity knowledge and pro-conservation behaviors (Moss et al., 2017a,b). Issues associated with synonyms, homonyms and inadequate translations are prevalent in this methodology (Roll et al., 2017; Correia, 2018; Correia et al., 2018a) and can lead to biased results when comparing between countries and regions. Furthermore, this indicator cannot distinguish between promotional tweets and articles from conservation NGOs and engagement from members of the public that are not professionally affiliated with conservation. Thus, the indicator developed in this study may be more informative when applied to one country over time or when comparing engagement between linguistically similar countries (i.e., Canada and the US; Argentina and Chile, etc.). Future work should seek to develop an indicator that is more robust across language and countries. Nevertheless, this is the first indicator which allows for the global assessment of public engagement with biodiversity-related topics and further developments in text mining approaches will help to minimize such limitations in the future.

Most importantly, and despite potential limitations related to the nature of the data, the indicator developed in this study can provide novel information about spatio-temporal trends and patterns of public engagement with biodiversity when implemented in the long-term. This indicator can be used by individual countries in reporting their progress towards the Aichi Targets to the CBD Secretariat and can also serve as a tool for measuring global progress. Having established a meaningful baseline, continued and expanded monitoring will provide further insight for better targeting of public awareness campaigns. Future efforts should aim to expand and validate the set of keywords, and advances in machine learning techniques will allow for the automated integration and classification of additional text, image, and video data sources (Ladle et al., 2017; Roll et al., 2017; Di Minin et al., 2018).

Every human on earth has a stake in conserving biodiversity and in sustainably using the earth's resources. To see where and to what extent people are aware of this fact, we integrated data from multiple near-real-time internet data feeds and found evidence of public interest and engagement related to biodiversity in every country on earth. Our analysis revealed several striking patterns associated with the usage of biodiversity keywords, such as a clear drop in conversations around the weekend, only slight concordance in country's scores between platforms and the predilection towards certain biodiversity-related topics in culturally similar countries. We contend that this work can serve as a baseline for monitoring public engagement with biodiversity and as a global indicator for Aichi Target 1.

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2018.12.004.

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