Google Trends data reveal a sharp trend: teeth and claws attract more interest than feathers, hooves or fins

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CAMBRIDGE
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Summary

In nature conservation, the generation of public interest, attention or emotions is an important instrument for nature, biotope and species protection; in this, charismatic flagship species play an important role. In the present study, flagship-making affiliation to a taxonomic unit as well as morphological, ecological and conservation traits were identified by analysing vertebrate species from each of the five extant vertebrate classes (Mammalia, Aves, Reptilia, Amphibia and fishes). Google Trends data on the 20 most Googled species of each of the five classes were used, a representation index was derived and the body mass, diet and protection status of these species were analysed. A clear concentration of interest in mammalian species was evident with the help of the introduced representation index. Furthermore, species with a higher body mass were clearly overrepresented in the data. Overall, important patterns in the studied traits were determined: belonging to Mammalia, a large body mass and a carnivorous diet are frequently represented among these species. For conservation purposes, such popular species can be specifically selected as flagship species or ambassadors to help protect entire biomes, which will therefore benefit less charismatic species as well. Possible ways to use traits that are perceived to be flagship-making in order to further the global conservation endeavour are briefly discussed.

Introduction

In approaching nature conservation, it is important to arouse public interest in a targeted manner in order to raise funds and otherwise advance projects (Colléony et al. 2017, Veríssimo et al. 2017). The positive effect of flagship species is discussed intensively in this context, with appeal and familiarity influencing public attention and linking positive emotions and attitudes to interest in conservation action (Veríssimo et al. 2011, Ducarme et al. 2013). 'Charisma' is a specific characteristic that has been identified as an important aspect of flagship species (Ducarme et al. 2013), and various studies have defined charismatic species for this purpose (Home et al. 2009, Ducarme et al. 2013, McGinlay et al. 2017, Veríssimo et al. 2017, Albert et al. 2018, Davies et al. 2018). A broader 'flagship species' concept also includes nature conservation marketing to strategically address the target audience (Veríssimo et al. 2011, Ducarme et al. 2013).

Google Trends data can be used to evaluate the interests of the Internet-using population on a regional or global level based on search queries. These data have applications in many areas such as medical and economic analyses and, among other things, for biological and nature conservation applications (Zieger & Springer 2020, 2021). For example, available online data sources can be valuable indicators of public awareness of the value of biodiversity (Cooper et al. 2019). The evaluation of search engine queries, as made possible by Google Trends data, shows the search interests of the sampled population. Research has already been conducted using Google Trends to analyse interest in biodiversity, understanding of environmental risks and conservation issues (Proulx et al. 2014, Nghiem et al. 2016, Durmuşoğlu 2017, Troumbis 2017, Zieger & Springer 2021).

In this study, data from Google Trends were used to analyse public interest in different vertebrate species with flagship potential and to identify and discuss traits shared by the most Googled species from the five vertebrate classes: Mammalia, Aves, Reptilia, Amphibia and fishes (i.e., Chondrichthyes and Osteichthyes).

The differential perception of species, depending on factors such as body size and charisma, not only leads to a myopic focus of the general public, but also affects scientific research; this is commonly referred to as 'taxonomic bias' (Donaldson et al. 2016, Troudet et al. 2017). Biodiversity research often focuses on a few species and ignores most of the remainder, which includes species that play a central role in the functioning of ecosystems, the study of which could yield a great deal of knowledge (Troudet et al. 2017). This bias can therefore weigh heavily on conservation efforts, with negative effects resulting from the overly narrow focus of scientific

studies, and accordingly to the orientation of conservation projects, financing and political decisions (Donaldson et al. 2016). Thus, taxonomic bias in research activities results in a knowledge gap that affects those species that are not privileged in this way. A more precise knowledge of this bias is therefore important in order to gain more clarity about existing deficits in our knowledge.

It is often assumed that only charismatic species are able to generate enough interest, emotional attachment and funds for conservation (Sitas et al. 2009, Ducarme et al. 2013, Douglas & Veríssimo 2013). To extend such interest, which tends to be focused on charismatic mammalian megafauna (Ducarme et al. 2013), to other species, knowledge of the characteristics that make species suitable as flagships is necessary.

Identifying important features that render species more likely to be perceived as flagship species may be a first step towards dealing with or even correcting such taxonomic bias. For example, certain features could be emphasized in future presentations in order to make even small vertebrates and invertebrates more appealing. Some of these latter species may possess traits that make them good candidates for flagship status, but being lesser known they have not reached their potential to the same degree as have vertebrates (Barua et al. 2012).

The objective of this study was to examine search interest in 100 species in the Google search engine and to compare this interest among the five extant vertebrate classes (Mammalia, Aves, Reptilia, Amphibia and fishes) to identify potential taxonomic bias. Furthermore, morphological, ecological and conservation traits were identified that represent potential for high public interest. The research question was 'What flagship-making morphological, ecological and conservation traits can be identified that generate high interest in flagship species visible in Google Trends?'. This study proposes a novel representation index and calculates this for the five extant classes of the subphylum Vertebrata.

Methods and data

Google Trends data

Google Trends offers a comparison between five search terms and the individual search volume of each particular term is related to the total search volume, providing relative frequency values (Zieger & Springer 2020). Furthermore, each relative frequency value is related to the maximum relative frequency value (peak value) within this Google Trends dataset. The peak value is set to 100 by Google Trends. Therefore, it is possible to compare more than the five datasets allowed by Google Trends if the search query that contains the peak value is included in each dataset and then all data are normalized to this peak value.

Data were collected with the following settings in Google Trends. The period was set from 2004 to present with a monthly data resolution. Google Trends data were collected during July 2021. Complete years were used for the evaluation (i.e., the beginning was January 2004 and the end was December 2020). The region was selected as worldwide and all search categories were chosen and set to show web results. In this study, topics rather than search terms were used. The use of search term(s) results in matches for the term(s) in the query in the language of the search term(s), while a topic is a group of terms that share the same concept in any language.

Data were accessed for selected species of Mammalia, Aves, Reptilia, Amphibia and fishes (i.e., Chondrichthyes and Osteichthyes, thus excluding Agnatha). The 20 most popular species from each of the five vertebrate classes were selected for evaluation from the comprehensive study by Davies et al. (2018). First, the species with the maximum search topic frequency (peak value) was determined (result: topic 'Lion' showed the highest peak in search interest). This topic was used as a reference in all further requests sent to Google Trends in order to standardize all results to the same peak value.

Body mass, diet and conservation status data

The body mass data used in this study are based mainly on the raw data from O'Gorman and Hone (2012) for the five taxa, which were kindly made available by Eoin J O'Gorman (personal communication, 29 June 2021). Data regarding the predominant diet and conservation status of individual species were obtained from various available zoological sources. Conservation status data were obtained according to the International Union for Conservation of Nature (IUCN) Red List conservation categories (version 3.1; IUCN 2001).

Representation index

We propose a value as a 'representation index' (RI) for the taxa that relates the average of the relative search interest for the 20 most popular species to the total number of species over the course of the 2004–2020 period. As a simplification, we postulate that the main interest is covered within the first 20 representatives and that the rest can be neglected as they only negligibly affect the results. In the first approximation, we therefore suggest limiting analyses to the 20 most Googled species that already achieve a very high coverage. Even if this is associated with minor inaccuracies, it simplifies the evaluation handling and makes it possible to clarify general trends.

The mean of average relative monthly search interest M_j was calculated from the average relative monthly search interest S_i related to a reference such as 'Lion' of the 20 most popular species i in the study period for the taxon j:

$$M_j = \sum_{i=1}^{20} S_i : 20$$

For the calculation of RI_j, the mean average relative monthly search interest M_j of a taxonomic unit is related to the total number of species n_j of this unit:

$$RI_j = M_j : n_j$$

This index could also be applied to higher taxonomic units such as genera or families.

In order to clarify the possible over- or under-representation for a certain taxon and to be able to compare several taxa with each other, an expected value can be calculated. This represents the expected relative search interest with an assumed even distribution according to the total number of species. For m comparable taxa j, the sum of all M_j corresponds to the total search interest to be distributed. With this simplification, which does not take into account the interest in each species but limits the total interest to 20 representatives in each case, the expected value $RI_{\text{exp.}}$ results as:

(a)

(b)
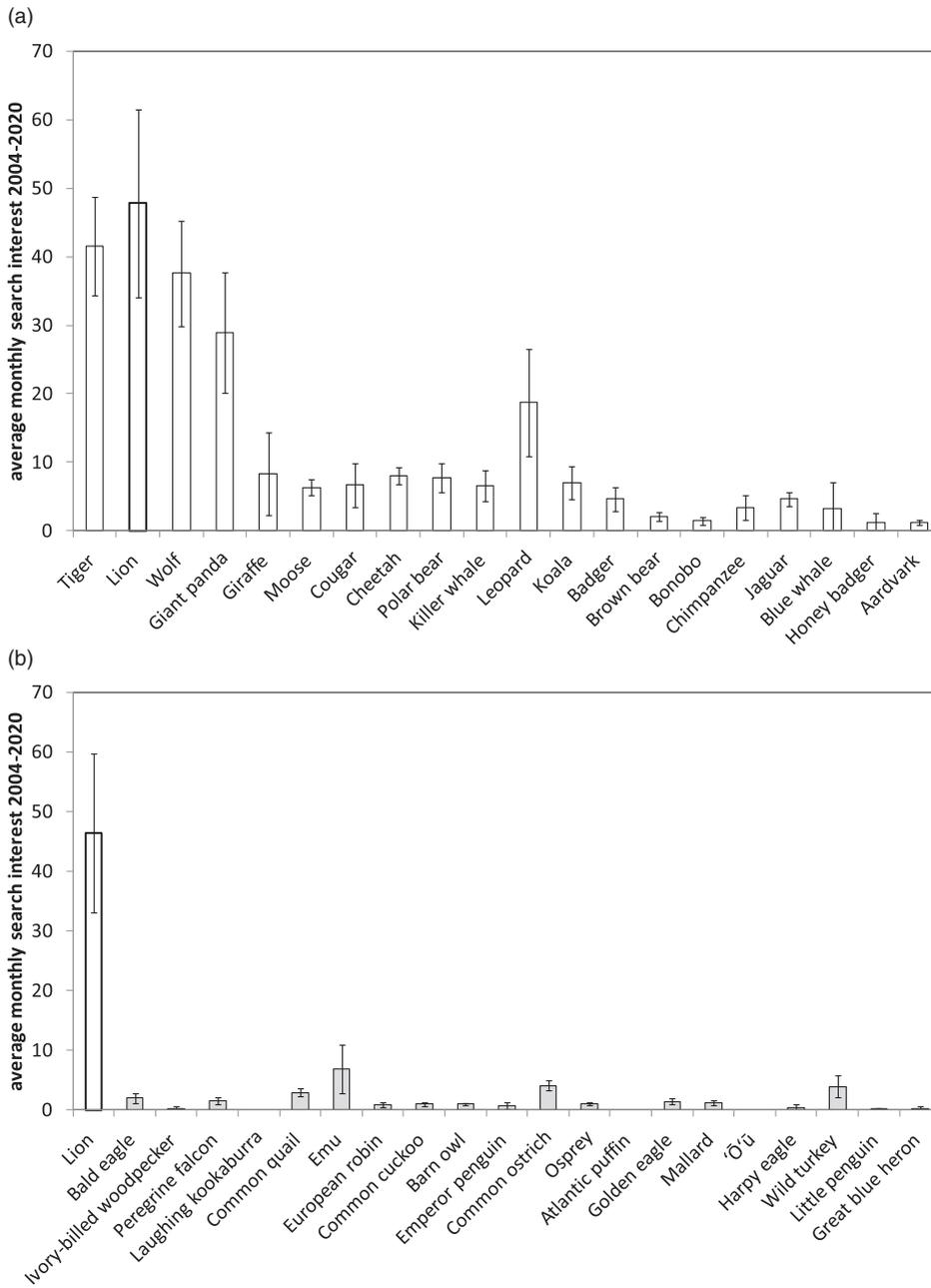
Fig. 1. Average relative monthly search interest for the 20 most Googled species (according to Davies et al. 2018). Mean values ± standard deviations are shown for species of the classes (a) Mammalia and (b) Aves (Reptilia, Amphibia and fishes data not shown). The search topic 'Lion' was used as the reference in each request in Google Trends. As far as possible, topics were selected based on the suggestions made by Google Trends and Google Trends values <1 were considered 0. The search term was used when no search topic was available on Google Trends.

$$RI_{\text{exp.}} = \sum_{j=1}^{m} M_j \; : \; \sum_{j=1}^{m} n_j$$

The relative RI rRI_j based on the expected value can now be calculated for each taxon j:

$$rRI_j = RI_j \; : \; RI_{\text{exp.}}$$

Results greater than 1 indicate a relative overrepresentation and results less than 1 indicate a relative underrepresentation.

Results

Google Trends data were accessed for selected species from five extant classes of Vertebrata and the average relative monthly search interests for 20 most Googled species (according to Davies et al. 2018) were evaluated (Fig. 1 and data not shown). The data show a dominant interest in mammalian species. This is also illustrated in Fig. 2a, which represents differences in relative search interest, where the mean values of the 20 species of the five classes examined are compared with one another.

The relative search interest results demonstrate that there is greater interest in a few species, which declines to low levels of interest in the remaining species (e.g., Fig. 1). In addition, most of the search interest is already covered by each of the 20 most popular species. Therefore, we have introduced the RI for the taxa. The RI again shows the underrepresentation in search interest for non-mammalian taxa (Table 1). The relative RI based on the expected value shows the clear relative overrepresentation of Mammalia compared to all other examined taxa (Fig. 2b & Table 1).
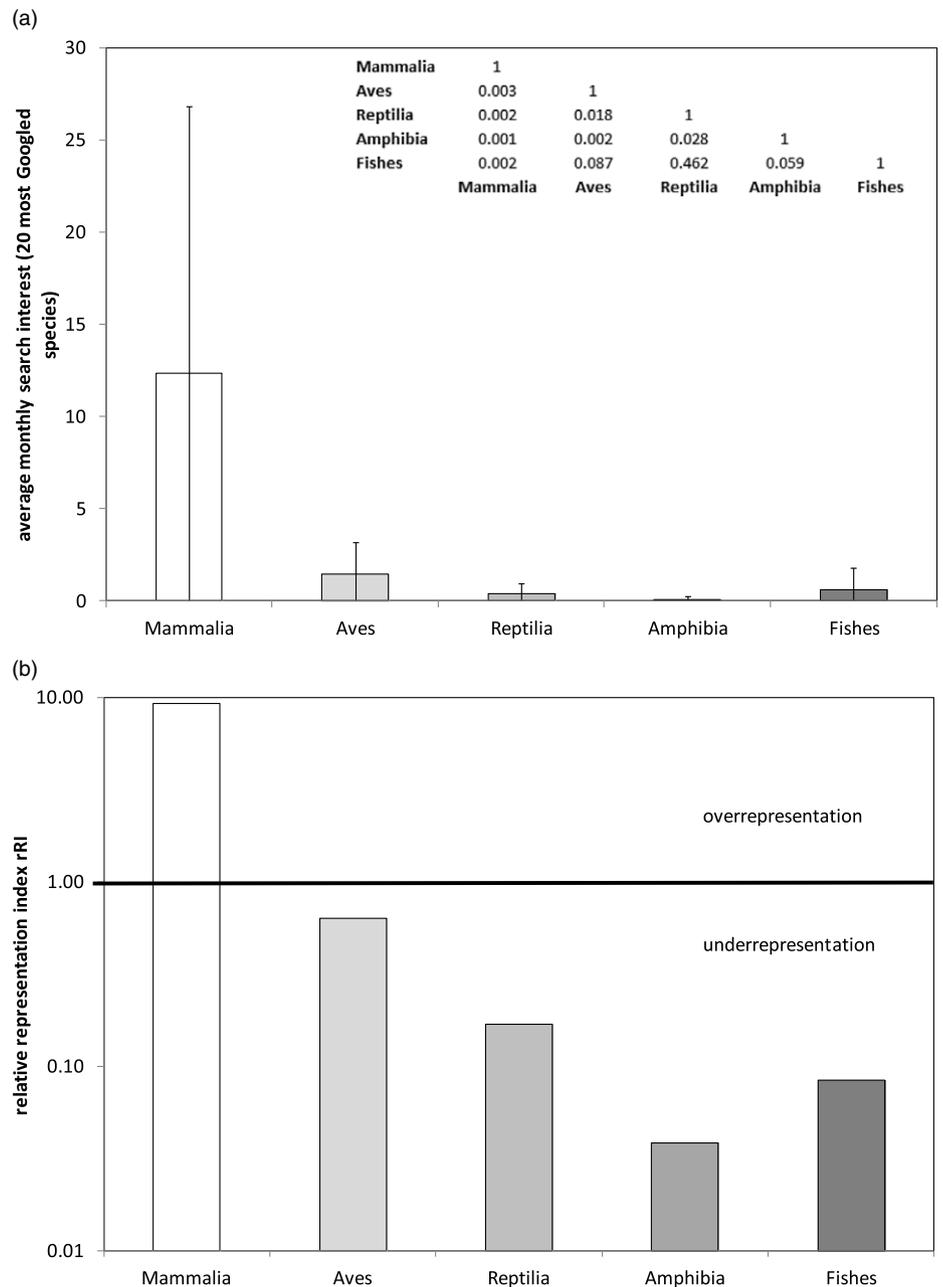
Fig. 2. (a) Mean values ± standard deviations of the average relative monthly search interest in the 20 most popular species on Google for Mammalia, Aves, Reptilia, Amphibia and fishes for 2004–2020. The search topic 'Lion' was used as the reference in each request in Google Trends. Google Trends values <1 were considered 0. Student's t-tests were conducted and the calculated p-values are shown in the insert. (b) Postulated relative representation index (rRI) of the five examined vertebrate taxa (period: 2004–2020): The rRI sets the respective RI of a taxon in relation to $RI_{exp.}$, the determined overall interest in all examined taxa related to the total number of species in all taxa.

Furthermore, differences in Google Trends results exist between the use of individual species as topics, such as African or Asian elephants, and more general familial-level topics such as 'Elephant' and 'Bears' (data not shown).

The frequency distributions of species body mass of the five extant vertebrate taxa of Mammalia, Aves, Reptilia, Amphibia and fishes were evaluated for all extant species and for the 20 most Googled species (Fig. 3 and data not shown). These data reveal a rightwards shift of the peak value for the 20 most Googled species.

We detected a strong trend towards lower conservation categories, with all but mammals (35%) being represented by at least 55% of species categorized as of Least Concern according to the IUCN Red List conservation categories (version 3.1) (Fig. 4a). No group had more than 20% of species categorized as Endangered or worse. Since this study uses the independent Davies et al. (2018) database,

extinct species were not included in the analysis. However, although none of the species is categorized as Extinct, two species are categorized as 'Possibly Extinct' by the IUCN (*Hypsirhynchus ater* (Reptilia) and *Psittirostra psittacea* (Aves)), and one (*Campephilus principalis* (Aves)) is sometimes considered to be possibly extinct by external authorities. As a comparison, the conservation status of evaluated species of the IUCN Red List (version 2021-1) for each taxon is shown (Fig. 4b).

The 20 most Googled species from the five taxa showed a strong trend towards preference for carnivorous species (Fig. 5).

Discussion

Google Trends data revealed an intense interest in mammalian species (Fig. 1), supporting the results of other studies (Albert et al. 2018, Davies et al. 2018). In contrast to Davies et al. (2018), in the

Table 1. Representation index and relative representation index for the five examined vertebrate taxa (period 2004–2020).

| Class, j	Mean relative monthly search interest (20 most Googled species), M_j	Estimated number of described species (according to the IUCN Red List version 2021-1), n_j	Representation index, RI_j	Expected value, $RI_{exp.}$	Relative representation index, $rRI_j = RI_j/RI_{exp.}$
Mammalia	12.33	6513	1893.9E−6	202.95E−6	9.33
Aves	1.45	11 158	129.53E−6	202.95E−6	0.64
Reptilia	0.39	11 341	34.103E−6	202.95E−6	0.17
Amphibia	0.06	8309	7.7874E−6	202.95E−6	0.04
Fishes	0.61	35 797	16.973E−6	202.95E−6	0.08

IUCN = International Union for Conservation of Nature.

(a)

(b)
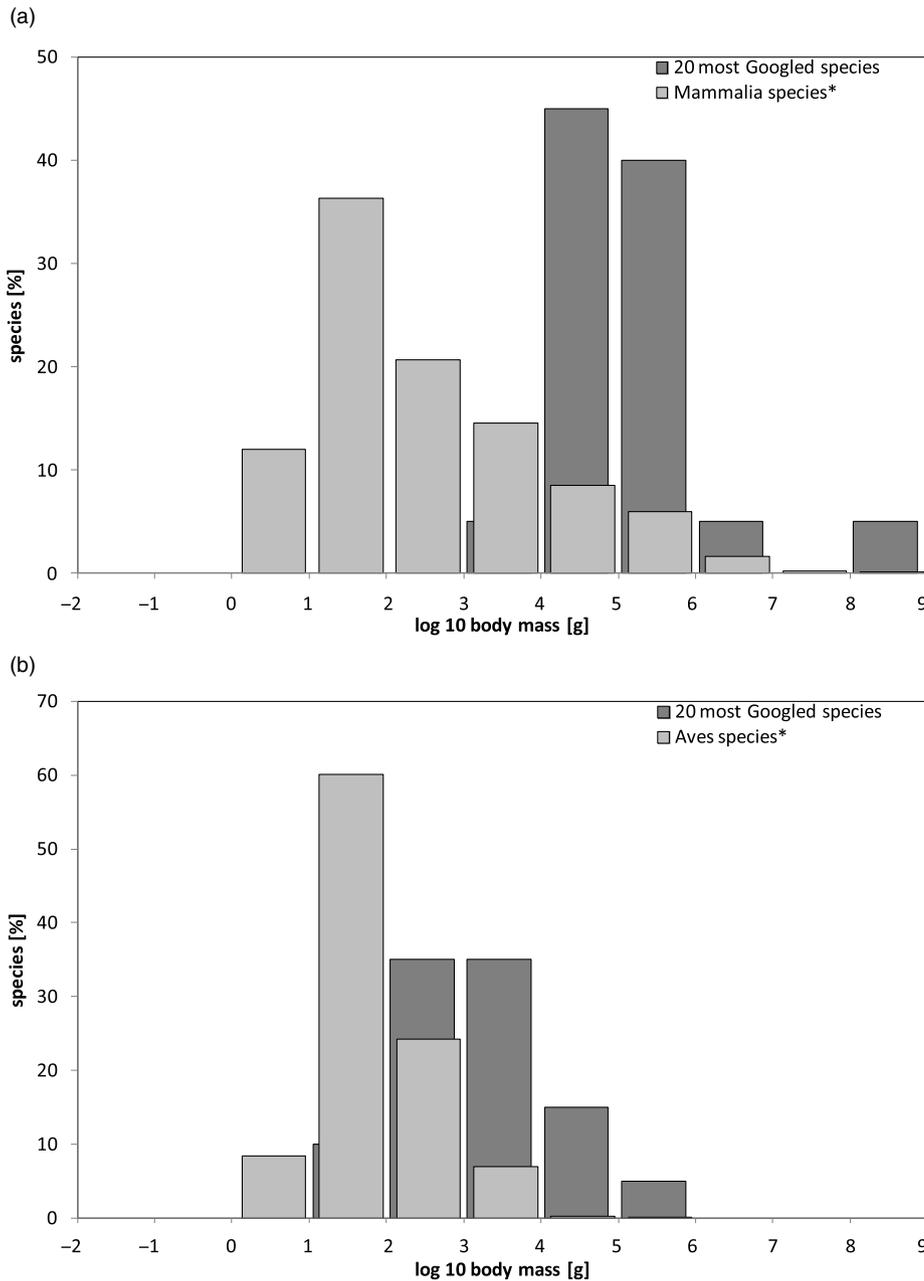
Fig. 3. Frequency distribution of species body mass of the five extant vertebrate taxa Mammalia, Aves, Reptilia, Amphibia and fishes: distributions are shown for extant species of (a) Mammalia and (b) Aves (Reptilia, Amphibia and fishes data not shown) (according to O'Gorman & Hone 2012) and for the 20 most Googled species of each taxon (according to Fig. 1). Body mass data were provided by Eoin J O'Gorman (O'Gorman & Hone 2012) and are also used for the most Googled animals where available (mean to maximum body mass values) or the data represent a best estimate. Frequency is shown as the percentage of the respective total number. *According to Eoin J O'Gorman data.

present study it was not the search term but the search topic that was queried in Google Trends in order to cover the same concept in any language. Nevertheless, the results are very comparable and show the following trend in order of search interest among the five vertebrate groups: Mammalia > Aves > fishes > Reptilia > Amphibia. This is shown by the differences in relative search interest (i.e., search volume) of the mean values of the 20 species of the five classes examined.

(a)

(b)
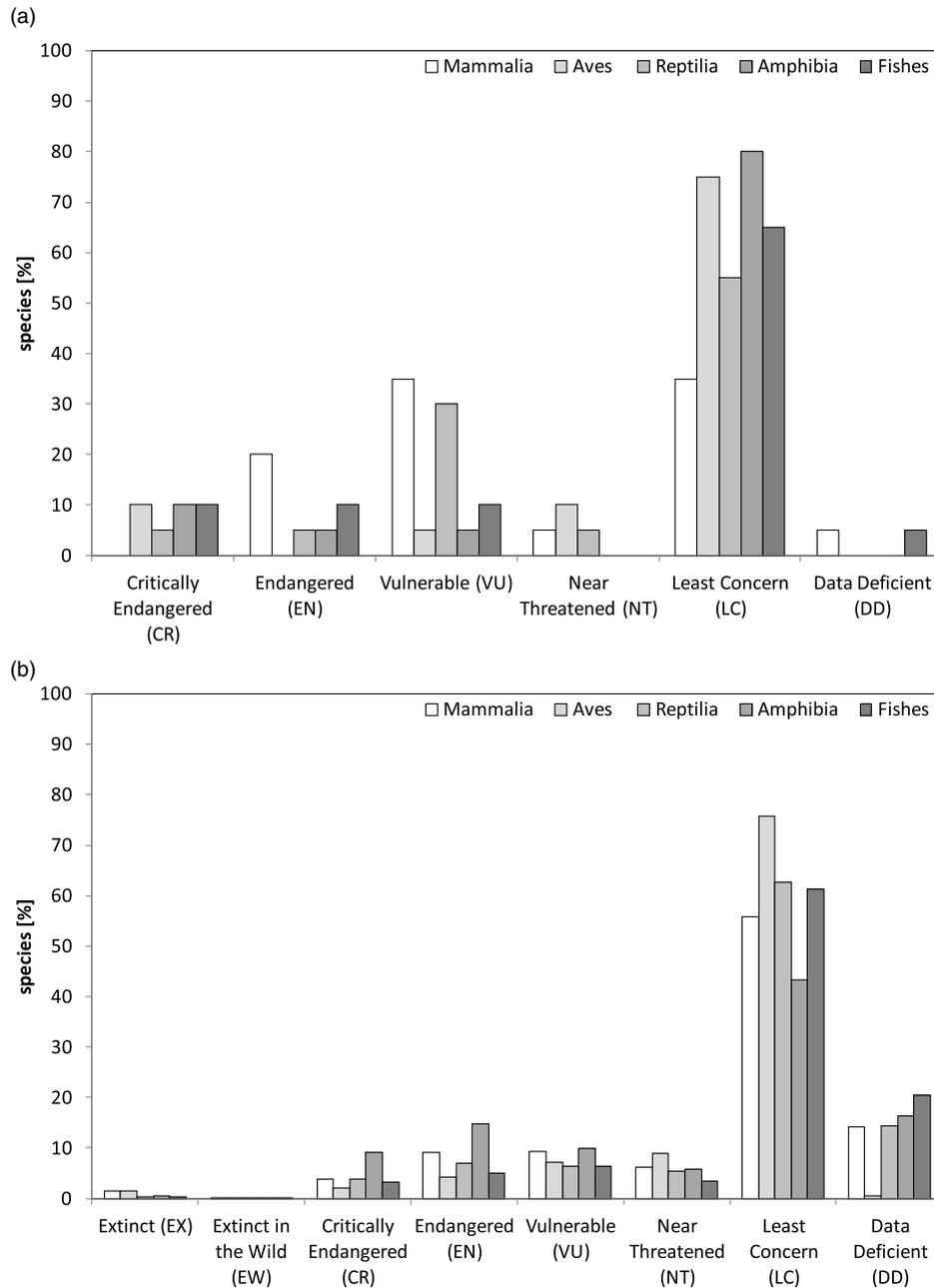
Fig. 4. (a) Conservation statuses of the 20 most Googled species (according to Davies et al. 2018) for five vertebrate taxa according to the International Union for Conservation of Nature (IUCN) Red List conservation categories (version 3.1). Since Davies et al. (2018) did not include species categorized as Extinct or Extinct in the Wild on the IUCN Red List in their analysis, these two categories are hidden in the figure. (b) Conservation status of evaluated species (100%) of the IUCN Red List (version 2021-1) for each taxon. CR = Critically Endangered (includes CR (Possibly Extinct) and CR (Possibly Extinct in the Wild)); LC – Least Concern (includes Lower Risk/Least Concern); NT = Near Threatened (includes Lower Risk/Near Threatened).

We have identified that large body size is a trait that influences search interest in flagship species on the Internet. Carnivorous diet is a second common trait among the most Googled flagships. Furthermore, among the 20 most frequently searched species on Google most are mammals. This shows the gap in attention paid to species of the four other vertebrate taxa. Even within the 20 most popular mammals, a few species dominate the search interest and cover the majority of the search volume. This also applies if the other four taxa are included.

Although this investigation has some limitations, such as the relatively small database, the dominance of a few species in search interest (which makes statistical analysis difficult) and the fact that Google is not the most used search engine in all parts of the world, the most Googled Mammalia species were confirmed. A few mammal species cover most of the search interest, and this is all the more remarkable since mammals only comprise an estimated 6500 species. By contrast, birds and reptiles with *c.* 11 000 species each, amphibians with over 8000 species and fishes with over 35 000 described species are fairly represented (IUCN Red List version 2021-1).

A practical contribution of this study on the use of search engines or search engine data is the realization that whether a
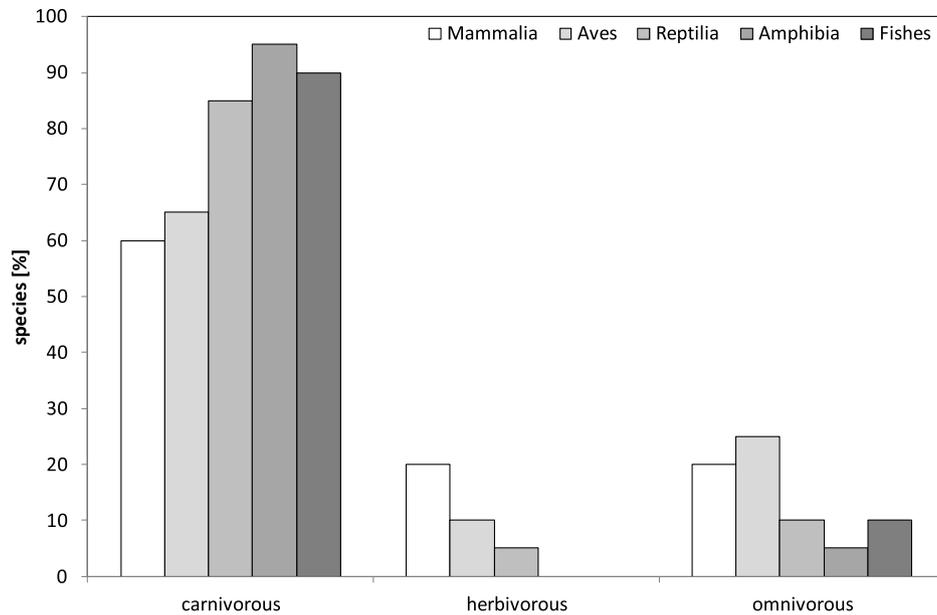
Fig. 5. The 20 most Googled species from the five taxa grouped according to their predominant type of diet.

species-specific or a more general search topic is chosen also plays a major role. The species for which generic terms are firmly anchored or widespread in common parlance or that include different subspecies also benefit from this. For example, 'Lion' and 'Tiger' are popular species-specific search topics on Google, which return far more search results than less popular species. Unfortunately, Google's data for 'Lion' are probably biased. The highest peak value was in July 2011, the same year and month that Apple, Inc. released their Lion operating system, OS X Lion. However, this is difficult to quantify at present, so it is only indicated as a potential area for further research (data not shown).

While 'African bush/forest elephant' (*Loxodonta* spp.) and 'Asian elephant' (*Elephas maximus*) were not placed in the top 20 most Googled mammals (*fide* Davies et al. 2018), the broader term 'Elephant' (encompassing all three extant species in the family Elephantidae) would easily make it into the top 20 of the current study. The topic 'Bear' (e.g., familial level, Ursidae) is also on a par with the topic 'Lion' (data not shown). The same trend can be seen for topics pertaining to even higher-level taxonomy. While amphibian species do not even come close to the popularity of 'Lion', the topic 'Frogs' – representing an entire, ecologically important group comprising more than 7000 species (Bardua et al. 2021) – does achieve comparable popularity (data not shown).

As another important finding, the examination of the frequency distributions of species body mass of the Mammalia, Aves, Reptilia, Amphibia and fishes revealed that species with a higher body mass are clearly more represented in the search queries than the normal distribution of body weight in the respective taxon would suggest.

In this study, the conservation statuses of 100 species were examined. It must be taken into account that the conservation statuses of many species have developed dynamically in recent years and have been subject to corresponding changes during the study period. According to IUCN Red List version 2021-1, 5940 mammal, 11 158 bird, 8492 reptile and 7212 amphibian species as well as 22 005 fishes were evaluated. The numbers of threatened species, which includes those categorized as Critically

Endangered (CR), Endangered (EN) or Vulnerable (VU), in 2021 are 1323 (22% of all evaluated species) mammals, 1481 (13%) birds, 1458 (17%) reptiles, 2442 (34%) amphibians and 3210 (15%) fishes. With the exception of Aves, there is a data deficit of 10–20% within the evaluated taxa. In addition, not all of the species described have yet been evaluated by the IUCN. For taxa for which less than 80% of the species within a group were assessed, the IUCN itself therefore does not actually give a percentage of threatened species because of insufficient coverage for these groups. This is the case for Reptilia (75% of described species evaluated) and fishes (61%), while Mammalia (91%), Aves (100%) and Amphibia (87%) are better covered (IUCN Red List version 2021-1).

In our setting, 11 (55%) Mammalia, 3 (15%) Aves, 8 (40%) Reptilia, 4 (20%) Amphibia and 6 (30%) fishes are classified as threatened. The relatively small dataset, each with the 20 most Googled species from five taxa, did not support the trend that the threatened species categorized as any of the above criteria (CR, EN or VU) are underrepresented in the public search interest across all five taxa, with the exception of the amphibians.

Interestingly, none of the 100 species was historically rediscovered, reinforcing the public interest for species of lower conservation concern. Other common or relatively widespread species such as *Meles meles* (Mammalia) or *Erithacus rubecula* (Aves) have already been discussed due to their place in the most Googled species list because of their abundance and visibility (Davies et al. 2018). Moreover, some species of commercial or recreational use appear among the most Googled species (Davies et al. 2018); the cane toad (*Rhinella marina*) is probably among the top 20 most Googled amphibians partly due to its invasive status in many countries (e.g., Australia and Caribbean countries). Therefore, being among the most Googled of all species is not a strict proxy for being a flagship species or ambassador for nature conservation issues.

According to the current discourse on flagship species, interest in a species is one important pillar for its status (e.g., Jepson & Barua 2015). In addition to interest in flagship species, charisma, attention and positive emotions must be present or generated in

order to promote the species for protection projects and fund-raising. Nonetheless, interest in less attractive species such as the cane toad can also be used for projects against invasive species, which also represent an integral part of nature and species conservation.

This study therefore contributes to the flagship species discussion as a contribution to the interest component of the flagship species selection process. Internet search interests have many and complex motivations, reflecting the nature of human beings. It is therefore possible that species of lower conservation concern, concomitant with being encountered more frequently, are somewhat overrepresented. However, there is no good evidence to suggest that this constitutes a significant bias in the data. Our data show that large carnivores, particularly mammals, are of great search interest. They have historically faced human persecution, with many large carnivores no longer being of lower conservation concern, which is at odds with the hypothesis that species of lower conservation concern are strictly overrepresented in the data to the point of being a serious bias. On the contrary, our data largely agree with previous studies, with larger body size and carnivory being important flagship species traits (e.g., Albert et al. 2018, Davies et al. 2018).

Bias towards species of Least Concern is particularly evident among amphibians (16 out of 20 species, or 80%) within the 20 most Googled species (Fig. 4a). The IUCN Red List version 2021-1 categorizes only 3128 (43%) amphibian species as Least Concern compared to, for example, 8460 (76%) bird species. For Aves this value fits the results of this study, where 15 out of 20 species (or 75%) are categorized as Least Concern. For the other taxa studied, no trend towards lower conservation category could be seen with these data. Previous studies (e.g., Smith et al. 2012, Albert et al. 2018) have concentrated on assessing whether high conservation categories (e.g., 'Critically Endangered' and 'Rare') are more important for public interest than medium conservation categories (e.g., 'Endangered' and 'Vulnerable').

Our study also corroborates the strong public interest in searching for species that are from the lower conservation category. In addition, based on the 100 species examined in this study, a few species cover the majority of the search volume. Therefore, this study suggests that the situation is more complex, and that there is also a public interest in searching for a high proportion of species with the lowest conservation category for all groups except mammals.

The historical tendency to concentrate on the threatened trait, which only represents part of the conservation status spectrum (Least Concern to Extinct), has potentially biased research. However. species of Least Concern tend to have larger distributions and thus are encountered more frequently both in the wild and in zoos and other *ex situ* areas, although this may not fully explain the bias, particularly among amphibians. More research is needed in this area to fully explain the intense Internet search traffic for such species.

A preference for carnivorous species was shown in the present study. A very high proportion of carnivorous species is found among amphibians in particular, with the exception of the cane toad, which has an omnivorous diet (Brandt & Mazzotti 1999). This trend is not surprising given that carnivores are highly prevalent in the animal kingdom, with carnivory being the most common dietary category (Román-Palacios et al. 2019).

This research might be extended to identify possible invertebrate flagship species candidates based on whether they share the traits identified. Further research into invertebrate flagship species needs to establish the degree to which invertebrate flagship traits are the same as for their vertebrate counterparts.

Conclusions

The most important flagship species were the carnivorous lion, tiger and wolf and the giant panda. Belonging to the class Mammalia, large body mass and a carnivorous diet are often represented within the flagship species, and thus the most Googled species. A hypothetical trend that less threatened species might be conspicuously overrepresented in terms of overall abundance could not be confirmed for most of the taxa examined.

In addition, the available data showed a clear taxonomic bias to the disadvantage of all non-mammalian vertebrate taxa examined. The main focus of public interest is on mammalian species. For a more detailed description and better comparability, we propose a RI that relates the relative search interest to the total number of species within the respective taxonomic unit.

The introduction of the RI is a major contribution of this study. The RI was applied to the five extant classes of the subphylum Vertebrata. For nature conservation issues it is important to recognize for which taxa more intensive information is necessary; for example, to draw attention to the current extinction crisis facing amphibians (Scheele et al. 2019) and to initiate countermeasures. The introduced RI is a tool that can help us to better assess the representation of a taxon.

Further research is also needed to evaluate additional traits and, if possible, to extend the results to other taxa, such as invertebrates. Even if the traits found do not represent a guarantee of flagship status for a particular species, flagship species show a particular pattern of traits. It was thus possible to identify some important characteristics that are favourable but not sufficient for rendering a candidate as suitable for flagship status. This, as well as testing using the Google Trends tool, can provide important information regarding the current and past Internet search interests or levels of popularity (Lippi et al. 2017) of particular species.

In terms of conservation, such popular species can be specifically selected as ambassadors for the protection of entire biotopes, the protection of which could benefit less attractive species as well. In this sense, the process of selecting a charismatic megafauna species for use in biotope protection (e.g., due to extended habitat requirements) is currently under debate (Ford et al. 2017).

Potential flagship species could be sought and public interest sharpened in this regard. However, greater effort is likely to be required in order to increase the public's awareness of species that do not meet these flagship criteria. As only a few species already cover the bulk of the search volume, more general terms (including higher taxonomic units) that combine broader search interests may be beneficial. Nevertheless, it will be necessary to increase conservation efforts for certain taxa in order to generate sufficient public interest in species protection.

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