CaPTrends: a database of large carnivoran population trends from around the world

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DATA ARTICLE

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CaPTrends: A database of large carnivoran population trends from around the world

Thomas F. Johnson[1] | Paula Cruz[2,3] | Nick J. B. Isaac[4] | Agustin Paviolo[2,3] | Manuela González-Suárez[1]

[1]Ecology and Evolutionary Biology, School of Biological Sciences, University of Reading, Reading, UK

[2]Instituto de Biología Subtropical, CONICET-Universidad Nacional de Misiones, Puerto Iguazú, Argentina

[3]Asociación Civil Centro de Investigaciones del Bosque Atlántico, Puerto Iguazú, Argentina

[4]UK Centre for Ecology and Hydrology, Wallingford, UK

Correspondence
Thomas F. Johnson, Ecology and Ecology and Evolutionary Biology, School of Biosciences, University of Sheffield, Sheffield, UK.
Email: thomas.frederick.johnson@outlook.com

Present address
Thomas F. Johnson, Ecology and Evolutionary Biology, School of Biosciences, University of Sheffield, Sheffield, UK

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Abstract

Motivation: Population trend information is an 'essential biodiversity variable' for monitoring change in biodiversity over time. Here, we present a database of 1,122 population trends from around the world, describing changes in abundance over time in large mammal species ($n = 50$) from four families in the order Carnivora. For this subset of taxa, we provide approximately 21 times more trends than BioTIME and three times more trends than the Living Planet database.

Main types of variables included: Key data fields for each trend: species, coordinates, trend time-frame, methods of data collection and analysis, and population time series or summarized trend value. Population trend values are reported using quantitative metrics in 75% of records that collectively represent more than 6,500 population estimates. The remaining records qualitatively describe population change (e.g., increase).

Spatial location and grain: Trends represent 621 unique locations across the globe (latitude: −51.0 to 80.0; longitude: −166.0 to 166.0). Most trends (86%) are found within the Northern Hemisphere.

Time period and grain: On average (mean), trends are derived from 6.5 abundance observations, and span in time from 1726 to 2017, with 92% of trends starting after 1950.

Major taxa and level of measurement: We conducted a semi-systematic search for population trend data in 87 species from four families in the order Carnivora: Canidae, Felidae, Hyaenidae and Ursidae. We compiled data for 50 of the 87 species.

Software format: .csv.

KEYWORDS
abundance, BioTIME, carnivorans, density, essential biodiversity variable, Living Planet database, population trend, predator

1 | INTRODUCTION

Rapid global change is threatening biodiversity (IPBES, 2019). However, biodiversity changes are not happening at the same rate across all places and species, with the fate of species populations varying across regions (Dornelas et al., 2019; Polaina et al., 2019), levels of protection (Amano et al., 2018), and the intrinsic traits of the affected species (Cardillo et al., 2005; Daskalova et al., 2020; Gonzalez-Suarez et al., 2013). An example of these variable population trends can be seen in the largest terrestrial mammals in the order Carnivora, where there is evidence for population recoveries and recolonizations (Chapron et al., 2014), alongside declines and extinctions (Ripple et al., 2014). Data compilation efforts are needed to document these trends and understand their drivers.

Here, we present a newly compiled database, CaPTrends, which uses a semi-systematic search approach to compile trend data in large carnivorans from across the primary literature. This makes CaPTrends different from other trend databases like BioTIME and the Living Planet database, as we focus primarily on providing a far greater depth (i.e., more trends per species) for a smaller selection of species in the order Carnivora. This depth contrasts with BioTIME (Dornelas et al., 2018) and the Living Planet database (WWF, 2020), currently the largest sources of mammalian population trend data, which provide millions of abundance observations that offer a vast spatial and taxonomic breadth, but have comparably fewer records per species.

Our rationale for focusing on depth over breadth is multi-fold:

1. Methodological improvement – by restricting the taxonomic extent, we were able to utilize more robust methods of data identification (e.g., the primary literature compiled in CaPTrends was sourced semi-systematically) and collect a more diverse array of data fields (including drivers of population trends), relative to BioTIME and the Living Planet data;
2. Inference comparison – by utilizing a semi-systematic approach and collecting substantially more data for this selection of species, CaPTrends is ideal for comparison against databases like BioTIME and the Living Planet, for instance, do global carnivoran and species-specific trends change when data are collected systematically?;
3. Assessment of trend drivers – by boosting the number of trend records per species, CaPTrends is well suited for studying how environmental change influences species trends differentially, for example, with over 100 trends for some species, our ability to accurately parameterize species-level responses to global drivers like habitat loss will be greater than building models solely off the smaller selection of trends per species in BioTIME and the Living Planet database;
4. Species-level assessment – a greater number of trend records per species also enables CaPTrends data to be useful in species-level assessments at the international [e.g., International Union for Conservation of Nature (IUCN)] and national (e.g., State of Nature) scale, especially as CaPTrends addresses important data biases, with records from less well studied regions, species and time-frames;
5. Use alongside BioTIME and the Living Planet data – CaPTrends can be easily incorporated into trend analysis workflows, boosting trend records for large carnivorans.

The current iteration of CaPTrends is focused solely on 87 species (following the IUCN taxonomy), falling across four families in the order Carnivora: Canidae, Felidae, Hyaenidae and Ursidae. For these families, we compiled published population trend data from abundance time series, as in BioTIME (Dornelas et al., 2018) and the Living Planet database (WWF, 2020). However, to expand on these databases, we also searched for and included summarized estimates of change (e.g., mean population growth rate) and qualitative descriptions of population change, allowing us to increase the large carnivore data. This expanded search resulted in 1,122 trends, a large increase relative to BioTIME (Dornelas et al., 2018) and the Living Planet database (WWF, 2020), which only include 52 and 392 trends for these species, respectively. Further, 96% of these 1,122 trends were not previously available in a compilation, as they do not occur in either BioTIME (Dornelas et al., 2018) or the Living Planet database (WWF, 2020).

The species in our four families generally represent the top terrestrial trophic levels and so are functionally important fauna and good indicator species (Ripple et al., 2014). These species are also charismatic and receive adoration but also induce fear. This combined ecological and cultural value makes large carnivorans an important collection of species to study. Moreover, these species represent some of the most studied fauna on the planet, and so we expected there would be a large amount of trend data to be recovered (i.e., compiled), which was essential to ensure our depth over breadth approach was feasible. As such, these species were a logical first step in the data collection process. CaPTrends provides the most comprehensive global overview of population status for these species and we envisage a variety of applications, from studying factors that influence population changes to better understanding species' status.

2 | METHODS

2.1 | Locating population trend records

We used a systematic literature search to identify population trends in the primary literature. This search involved searching Scopus and Web of Science for population trend related terms (e.g., 'population trend', 'declin*' and 'increas*') alongside taxonomic information (e.g., species names). We searched for terms in English and Spanish. We found 30 articles in Spanish and 3,233 articles in English. We narrowed down these articles to a highly relevant subset (i.e., likely to contain population trend information; $n = 516$) using titles and abstracts (see Supporting Information). A selection of these highly relevant articles were syntheses of other studies – in this case, we referred to the primary source and included the article within our list, expanding the number of highly relevant articles to 536. We were unable to obtain the full text for 19 of these highly relevant articles, reducing our sample to 517 articles, which were to be read in full (see below).

2.2 | Extracting information from sources

When a source contained population trend information, we recorded the trend and additional metadata describing taxonomy, location, study period, and methodology (Supporting Information Table S1). Population changes were reported in a variety of formats, but broadly fall into two groups, quantitative where the trend was described numerically (e.g., %change), and qualitative where the trend was described categorically (e.g., increase). In the quantitative group, we recorded the trend as presented in the original source, and we recorded five distinct types: (a) time series of population abundances or population chan, (b) mean finite rate of population change (λ), (c) mean instantaneous rate of population change (*r*), (d) percentage change between two time points, and (e) fold change between two time points; further described in Supporting Information Table S1. For studies that reported trends in multiple formats, we recorded the most informative, for example, where raw abundance data were available this was preferred over summary estimates of population change. If the population values were only reported in a graph, we used a graphic digitizer to estimate the values (Rohatgi, 2015).

For each population trend, we recorded sampling effort. For population trends calculated from time series data, we recorded the number of individual estimates used to derive the trend. For population trends based on matrix models and demographic parameters, we recorded the number of sampling years used to estimate the demographic parameters. For estimates of annual rates of change (λ and *r*) derived from three or more data points, we also noted any available estimate of dispersion (e.g., variance) and test-statistic values. For the qualitative descriptions of trends, we inferred the trend based on the description in the primary sources, with trends falling into the following four categories: increase – source described the population abundance as exhibiting overall growth during the monitored period; stable – source described the population abundance as exhibiting a stable or unchanged trend over the monitored period; decrease – source described the population abundance as exhibiting an overall decline during the monitored period; varied – source described the population abundance as exhibiting both growth and declines over the monitored period, without any clear directional trend. The specific terminology used to describe each trend varied between the primary sources, but the general message was largely consistent. However, we do acknowledge that each primary source likely has a different definition for a given trend (i.e., how much growth is necessary to be classed as an increase?), which introduces an opportunity for inconsistency and subjectivity, and so these qualitative trends should be interpreted cautiously.

For each trend we recorded the binomial species name following the IUCN taxonomy – we report discrepancies between the IUCN taxonomy and another taxonomy (Wilson & Reeder, 2005) in Supporting Information Table S2. When the species name in the primary literature did not match the IUCN taxonomy, we referred to the list of IUCN taxonomy synonyms to locate the accepted IUCN species name. Subspecies names were also available in some primary sources, and we noted these as recorded in the primary source. For location, we recorded the name of the study site given in the primary source, whether the site was described as a protected area, and the country or countries it overlapped. If provided, we recorded the study site's coordinates (minimum and maximum, or mid-point) converted into decimal degrees. Coordinate precision was likely variable among studies and is overall unknown. If studies did not report coordinates, we used the name given to the study site and location country to populate the coordinates using OpenCage (Salmon, 2018). OpenCage provides coordinates and a degree of confidence in the estimate, where 1 is low and 9 is high. For all coordinates were the confidence level fell below 7, we manually checked and if needed amended coordinates. When reported in the primary source, we also recorded the area (size) of the study site. For the study period in each record, we noted the start and end date of the population monitoring, and if available the corresponding population sizes on these dates. We captured the data collection and analysis methods from each source using several descriptors (Supporting Information Table S1). For studies that combined multiple methods, we precautionarily recorded the least robust approach. If we could not identify the method, the record was assigned 'undefined'.

2.3 | Causes of change

Some sources tested or discussed the role of distinct factors to explain observed population changes. We recorded these factors reclassified into a modified version of the IUCN standardized classification schemes for Threats (v3.2) and Conservation Actions (v2.0), see Supporting Information Table S6. For each recorded factor we noted its effect (associated with increase or with decrease) and how this influence was determined. It is important to note that effects were not always negative for the threat scheme or positive for the conservation actions scheme. For example, urbanization is listed under the threat scheme but has led to population increases in red fox *Vulpes vulpes* (Hegglin & Breitenmoser, 2001). Finally, we note that factors not listed for a given record do not imply a threat or conservation action was not important or did not occur in that population, but simply that the factor was not mentioned in the primary literature.

2.4 | Validating records

Authors TFJ and PC read the English and Spanish sources, respectively. TFJ entered all data. To validate the records and ensure quality control, 10% of the records were reviewed by an additional author (either PC or MGS). We selected the 10% sample with a random stratified approach to ensure each of the different formats of trends were reviewed, for example, percentage change, population time series, and qualitative descriptions. TFJ then further scrutinized and double-checked records to detect errors in TFJ's original work, that of the second readers (PC and MGS), and identify causes of discrepancies in data entry. We tested the reproducibility of our methods using the Grames and Elphick (2020) checklist and scored highly (Supporting Information Table S8).

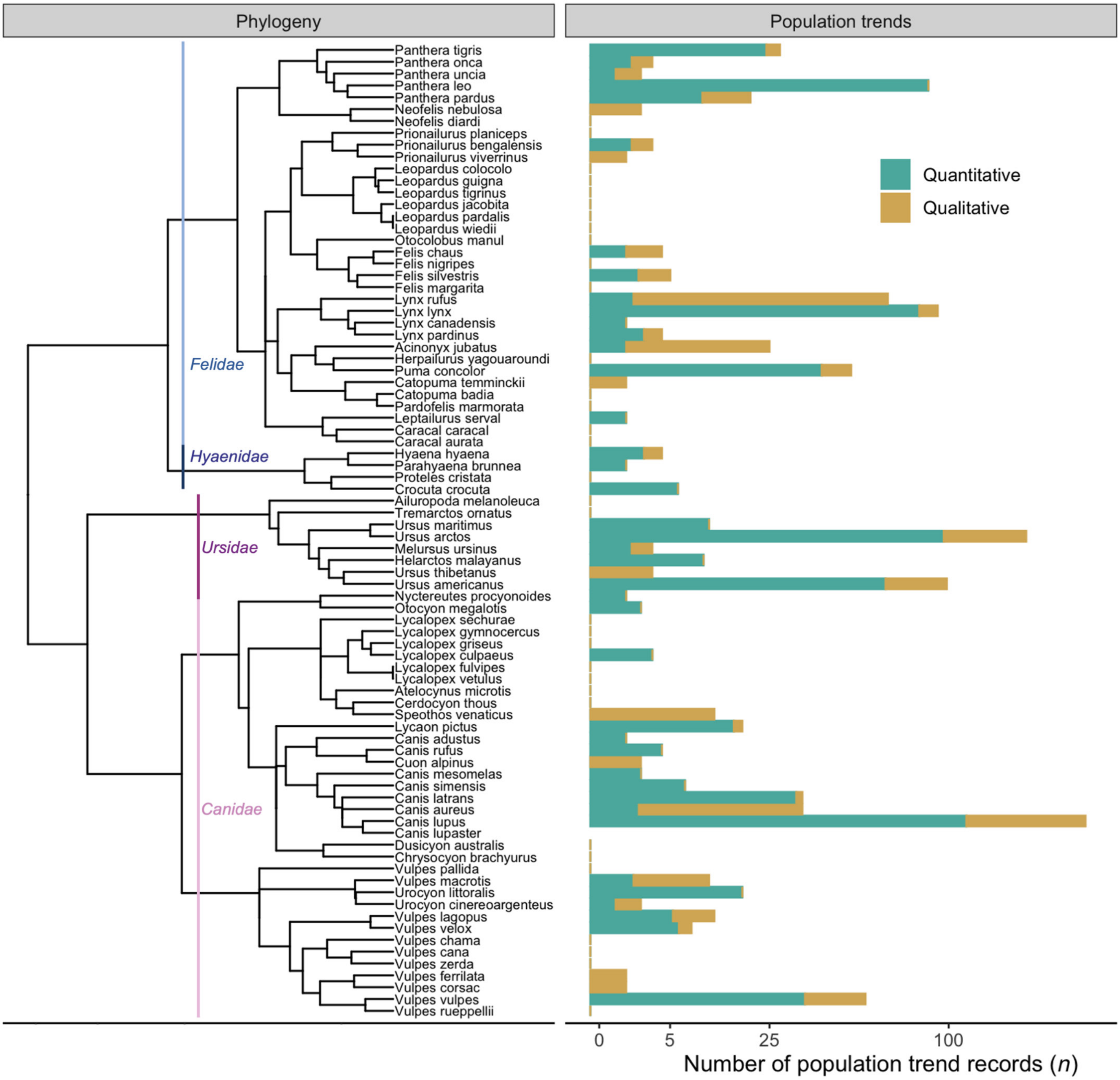

FIGURE 1 Number of population trend records per studied species, shown across the Carnivora phylogeny. The tree represents four taxonomic families: Canidae, Ursidae, Felidae and Hyaenidae. We show records for both quantitative (teal) and qualitative (gold) trends. We use a subset of the Upham et al. (2019) mammal phylogeny, restricted to relevant clades and with small amendments to accommodate differences between the phylogeny and International Union for Conservation of Nature (IUCN) taxonomy – see Supporting Information: Using the IUCN taxonomy with a phylogeny

3 | RESULTS

From the 517 sources read in full, 202 did not contain the population trend information we required and were excluded from the database. Trends were excluded for a variety of reasons, examples include: the trend was simulated (*n* = 23), the trend referred to primary sources already captured in the database (*n* = 20), the trend described geographic distribution range change instead of abundance change (*n* = 6). Results from the validation step are reported in Supporting Information: Validating records.

We identified and recorded 1,122 population trends from the remaining 315 sources. These represented 50 (57%) of the studied species covering all four taxonomic families and 25 (69%) out of 36 genera (Figure 1). Some species had a single trend estimate, while we compiled 621 trend estimates for the top five species: grey wolf (*Canis lupus*), brown bear (*Ursus arctos*), grizzly bear

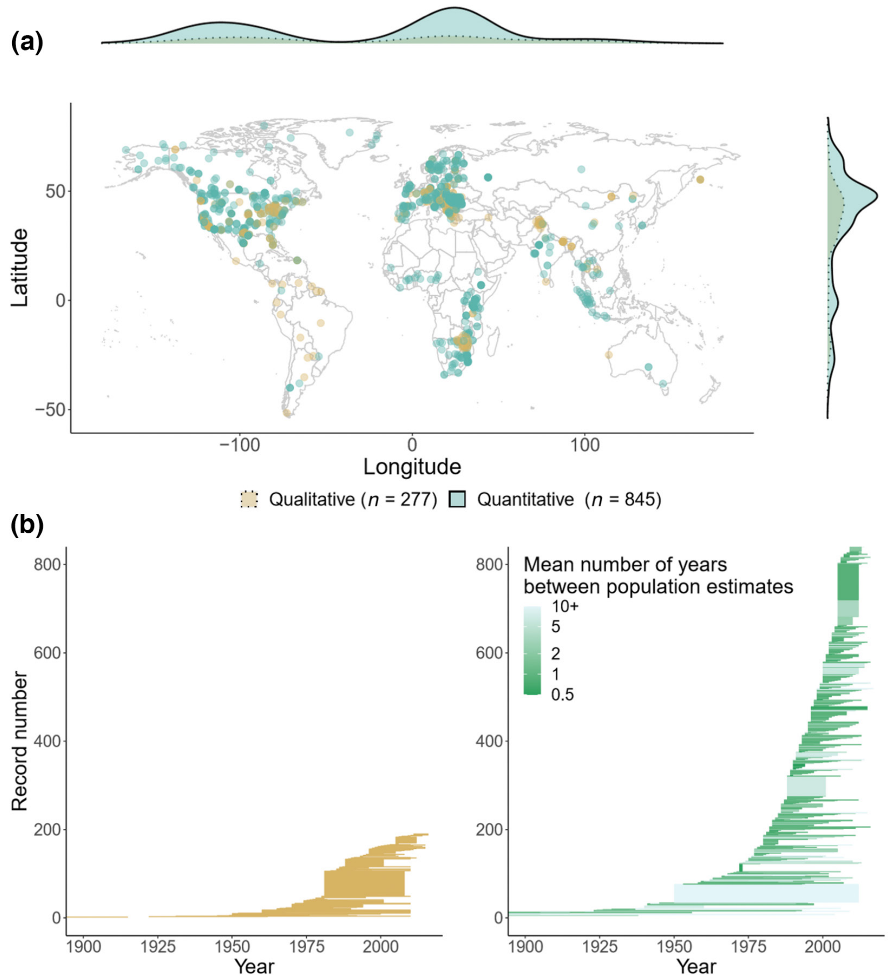

FIGURE 2 (a) Location of study populations from which we compiled quantitative (teal) and qualitative (gold) trend records. Density plots indicate the frequency of the data points at varying latitudes and longitudes. Coordinates are decimal degrees. (b) Distribution of qualitative (gold) and quantitative (green) population trend records between 1900–2017. Start and end date of each population trend record, ranked in ascending order of study start date. For the quantitative plot, we display the mean number of years between population estimates in each trend as a proxy for sampling effort, with darker green indicating greater sampling effort

(*Ursus americanus*), lion (*Panthera leo*) and Eurasian lynx (*Lynx lynx*). Many of the records represented populations within the Northern Hemisphere (Figure 2a), particularly in Europe (n = 384) and North America (n = 415), where population trends in both regions are relatively evenly distributed across space (Supporting Information Figure S2). There was also a cluster of records in East and Southern Africa (n = 170) – with records in 86 countries in total. We located very few records in Central, North and West Africa, Central and South America, or Northern Asia. The database includes records extending in time from 1726–2017 (Figure 2b), with the vast majority (92%) of trends starting after 1950.

Most of the 1,122 population trends represent quantitative estimates (n = 845), with a quarter (n = 277) providing only qualitative descriptors. The quantitative records collectively represent 6,597 population size estimates. Most of the quantitative trends are recorded as a time series of abundance values (63.9%), followed by population lambdas (17.4%), percentage change (7.5%), fold change (5.8%), and annual slope coefficients (5.4%). The quantitative population trends cover declines [annual instantaneous rate of change (r_t) less than −0.02; n = 234], stability (r_t between −0.02 and 0.02; n = 210) and recoveries (r_t greater than 0.02; n = 401). The qualitative trends were distributed accordingly: decrease = 77, stable = 52, varied = 11, increase = 88, and unknown = 49.

4 | DISCUSSION

We searched the literature to retrieve population trend records for the 87 species represented in the four families that include the largest living carnivorans, and located 1,122 estimates of population change representing 50 species. These records cover a wide temporal window (1726–2017) and represent diverse locations (n = 621) around the globe, although there is temporal and spatial heterogeneity with more records in recent years and temperate areas of the Northern Hemisphere. Our effort expands on and complements previous databases for these species. For instance, as of September 2021, the Living Planet database includes 392 trends across 45 species, and BioTIME includes 52 trends across 3 species. Furthermore, 96% of the 1,122 trends in CaPTrends are unique (i.e., not occurring in the Living Planet database or BioTIME – no CaPTrends records occur in BioTIME), and the CaPTrends records fill some important spatial and taxonomic gaps (Supporting Information Figures S3 and S4). Thus, CaPTrends provides a valuable resource to address ecological questions, complete a more comprehensive assessment of population status for these species, and explore potential predictors of observed population changes (Johnson et al., 2021).

Our database located additional time series records not reported in the Living Planet database, but also added less precise and

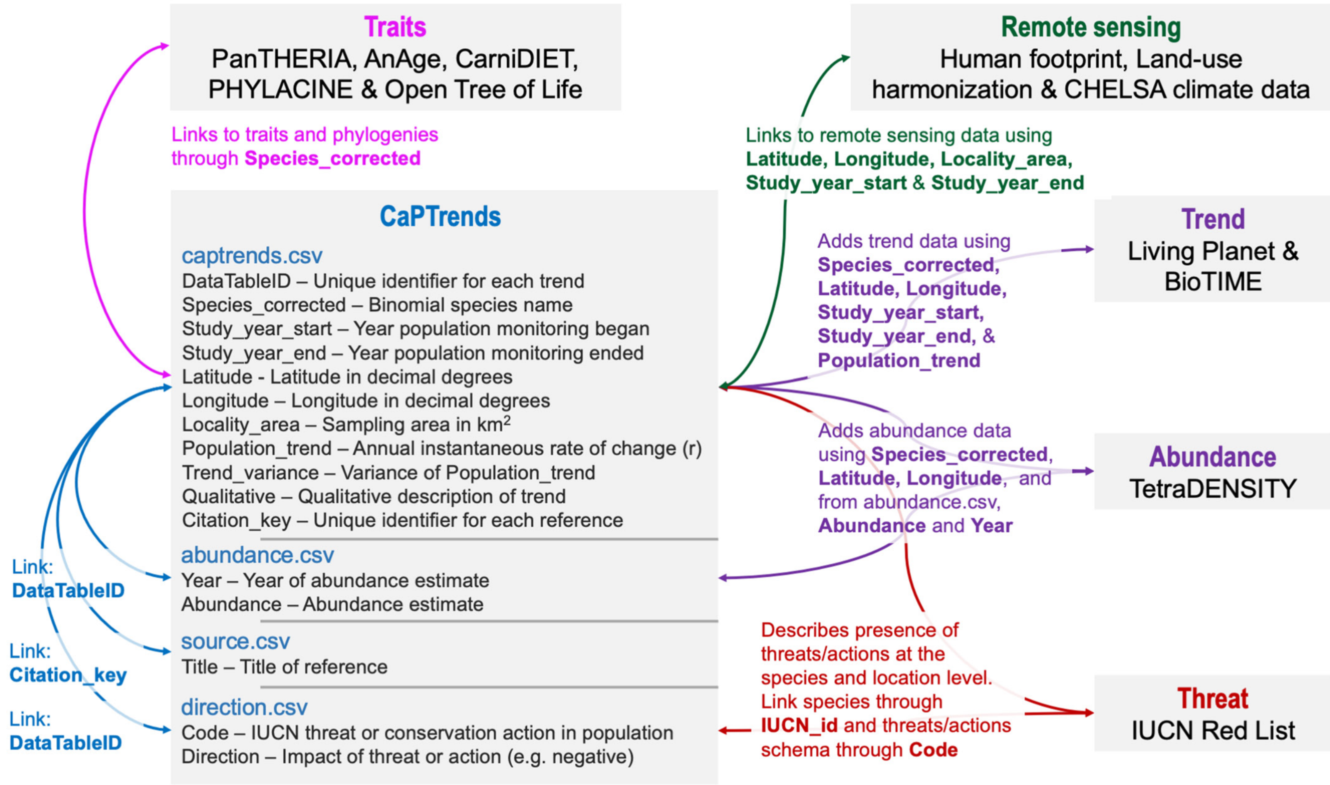

FIGURE 3 Diagram depicting how the CaPTrends databases (blue) can be linked with one another, and the wider data landscape. Bold text indicates the column name in CaPTrends that can be used to link to other datasets. We highlight a selection of datasets that CaPTrends can link to (e.g., trend: BioTIME)

qualitative descriptors, which need to be interpreted with caution. For example, we found that studies that provided summarized quantitative metrics (e.g., annual population growth) did not always offer estimates of their error and thus, we could not extract uncertainty around the trend in all cases. This issue is even more emphasized in the qualitative descriptions (e.g., increase, decrease), where both the error and magnitude of the trend are unknown. However, if used cautiously, the lower resolution metrics could be important in addressing data gaps for species and locations for which high resolution population trend records are not available. This is particularly important, as these data gaps are most prevalent in biodiverse regions (WWF, 2020), which are experiencing a greater increase in human impacts (Venter et al., 2016). Incorporating lower resolution metrics into models of biodiversity change could reduce some of these biases – providing a robust modelling approach is used. For example, in Johnson et al. (2021), trends are treated as a latent state, with qualitative estimates acting as an imperfect realization of the trend.

4.1 | Using CaPTrends in the data landscape

CaPTrends is presented as a relational database (Figure 3). The main file 'captrends.csv' includes all master data (e.g., unique id, species, location and time-frame), as well as all population data, except the population time series. Time series of population abundances are located in 'abundance.csv', which are linked to 'captrends.csv' through the 'DataTableID' field. 'direction.csv' also links to 'captrends.csv' through 'DataTableID' and describes positive and negative influences of each trend. Finally, 'sources.csv' links to 'captrends.csv' through 'Citation_key' and contains information on where the trend was sourced from (full reference). However, CaPTrends also links seamlessly (relatively) with the rest of the data landscape, and can be easily combined with trait (De Magalhães & Costa, 2009; Faurby et al., 2018; Jones et al., 2009; Michonneau et al., 2016; Middleton et al., 2021), remote sensing (Hurtt et al., 2020; Karger et al., 2017; Mu et al., 2022), threat (IUCN, 2017), and other abundance or trend data (Dornelas et al., 2018; Santini et al., 2018; WWF, 2020), with the intention of making global change and conservation research easier (Supporting Information Figure S3). And given CaPTrends far exceeds the reach of other trend databases (for our selected taxonomic scale), CaPTrends should also enable less biased and greater reaching research into large carnivorans. Comprehensive metadata are available for each of the CaPTrends databases in the Supporting Information and in the data download link (see Data availability).

To support the use of this database, each population trend record has been annotated (Supporting Information Table S1). Much of this information would be helpful in filtering the database to exclude trends that are deemed of low quality or irrelevant to a given research question. For example, for investigating extinction risk, one may opt to remove data for invasive populations. Other indicator tags can be found in Supporting Information Table S1.

Different subsets of the CaPTrends data may be analyse. Including qualitative descriptors provides the most records but highest uncertainty. Focusing only on quantitative records reduces the scope and increases biases (not all species and areas are equally like to have quantitative records as shown in Figure 2). Approaches like data integration (Isaac et al., 2020), which can incorporate both data types, are likely to be least biased (spatially, temporally and taxonomically).

The biggest strength of the CaPTrends database is that it provides greater depth (i.e., number of trends per species) than existing trend databases like BioTIME and the Living Planet database. To provide this depth we compromised on taxonomic breadth, which potentially limits the use of CaPTrends to a smaller array of researchers and research questions. Nevertheless, CaPTrends makes a valuable contribution to the data landscape, especially as the data recovery approach we used provides much needed information on some data sparse carnivore species, locations and time-frames, with 96% of the CaPTrends records not represented within BioTIME or the Living Planet database. The depth of CaPTrends allows different questions to be posed, and when combined with the breadth of databases like BioTIME, we can evaluate potential biases and methodological issues. The final goal should be creating in-depth databases with broad taxonomic and geographic coverage. As such, we plan to expand the CaPTrends search and compilation protocols to new species and languages (see Data availability), developing a database that further complements the breadth offered by BioTIME and the Living Planet.

AUTHOR CONTRIBUTIONS

All authors contributed to project design. TFJ entered the data with support from PC. Data were validated by MGS and PC. TFJ wrote the first draft of the manuscript; all authors contributed to revisions.

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CONFLICT OF INTEREST

We report no conflicts of interest.

DATA AVAILABILITY STATEMENT

CaPTrends can be downloaded from: https://zenodo.org/record/6949487. The beta version of CaPTrends, where we will continue to add new trends for different species and languages can be found at: https://github.com/GitTFJ/CaPTrends.

ORCID

Thomas F. Johnson https://orcid.org/0000-0002-6363-1825
Manuela González-Suárez https://orcid.org/0000-0001-5069-8900

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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