1   # CaPTrends: A global database of Carnivoran Population Trends

2   Authors: Thomas F. Johnson[1^,2*], Paula Cruz[3,4], Nick J. B. Isaac[5], Agustin Paviolo[3,4], Manuela
3   González-Suárez[2]

4   Corresponding author: Thomas Frederick Johnson (Thomas.frederick.johnson@outlook.com)
5   1: Ecology and Evolutionary Biology, School of Biosciences, University of Sheffield, Sheffield, UK. ^Present address
6   2: Ecology and Evolutionary Biology, School of Biological Sciences, University of Reading, Reading, UK
7   3: Instituto de Biología Subtropical, CONICET-Universidad Nacional de Misiones, Bertoni 85, (N3370AIA) Puerto Iguazú,
8   Misiones, Argentina
9   4: Asociación Civil Centro de Investigaciones del Bosque Atlántico, Bertoni 85, (N3370AIA) Puerto Iguazú, Misiones, Argentina
10   5: UK Centre for Ecology and Hydrology, Wallingford, OX10 8BB, UK.

11

12   **Abstract**

13   Motivation

14   Population trend information is an 'Essential Biodiversity Variable' for monitoring change in

15   biodiversity over time. Here, we present a global dataset of 1122 population trends

16   describing changes in abundance over time in large mammals from the Order Carnivora –

17   some of the world's most charismatic and functionally important fauna.

18   Main types of variables included

19   Key data fields for each record: species, coordinates, trend timeframe, methods of data

20   collection and analysis, and population timeseries or summarised trend value. Population

21   trend values are reported using quantitative metrics in 75% of records that collectively

22   represent more than 6500 population estimates. The remaining records qualitatively

23   describe population change (e.g. increase).

24   Spatial location and grain

25   Records represent locations across the globe (latitude: -51.0 to 80.0; longitude: -166.0 to

26   166.0) with more trends found within the northern temperate zone.

27   Time period and grain

28   Records span from 1726 to 2017, with 92% of trends starting after 1950.

29   Major taxa and level of measurement

30   We conducted a semi-systematic search for population trend data in 87 species from four

31   families in the order Carnivora: Canidae, Felidae, Hyaenidae and Ursidae. We compiled data

32   for 50 of the 87 species.

33   <u>Software format</u>

34   .csv

35

36   **Introduction**

37   Rapid global change is threatening biodiversity (IPBES, 2019). However, biodiversity

38   changes are not happening at the same rate in all places and species, with the fate of

39   populations varying across regions (Fritz *et al.*, 2009; Polaina *et al.*, 2016), levels of

40   protection (Amano *et al.*, 2018), and the intrinsic traits of the affected species (Cardillo *et al.*,

41   2005; Gonzalez-Suarez *et al.*, 2013; González-Suárez & Revilla, 2013). An example of this

42   variability in extinction can be seen in the largest terrestrial mammals in the order Carnivora,

43   where there is evidence for population recoveries and recolonizations (Chapron *et al.*, 2014),

44   alongside declines and extinctions (Ripple *et al.*, 2014).

45   Currently, the largest sources of mammalian population trend data are within BioTIME

46   (Dornelas *et al.*, 2018) and the Living Planet Index (WWF, 2020), which combined, provide

47   millions of abundance observations. Here, we expand upon both datasets for four families in

48   the order Carnivora: Canidae, Felidae, Hyaenidae and Ursidae - which represent some of

49   the world's most charismatic and functionally important fauna (Ripple *et al.*, 2014). For the

50   87 species in these families, following the IUCN taxonomy, we compiled published

51   population trend data from abundance time-series as in BioTIME and the Living Planet data

52   (Dornelas *et al.*, 2018; WWF, 2020). However crucially, we also searched for and included

53   summarised estimates of change (e.g. mean population growth rate) and qualitative

54   descriptions of population change, allowing the expansion of available data. These data

55   provide the most comprehensive global overview of population status for these species and

56 can be used to evaluate different factors that influence population changes and describe

57 species' status.

Methods

Locating population trend records

60 We used a systematic literature search to identify population trends in the primary literature.

61 This search involved searching Scopus and Web of Science for population trend related

62 terms (e.g. 'population trend', 'declin*' and 'increas*') alongside taxonomic information (e.g.

63 species names). We searched for terms in English and Spanish. We found 30 articles in

64 Spanish and 3233 articles in English. We narrowed down these articles to a highly relevant

65 subset (i.e. likely to contain population trend information; N = 516) using titles and abstracts

66 (see Supplementary: Systematic search). A selection of these highly relevant articles were

67 syntheses of other studies – in this case, we referred to the primary source and included the

68 article within our list, expanding the number of highly relevant articles to 536. We were

69 unable to obtain the full text for 19 of these highly relevant articles, reducing our sample to

70 517 articles, which were to be read in full (see below).

Extracting information from sources

72 When a source contained population trend information, we recorded the trend and additional

73 metadata describing taxonomy, location, study period, and methodology (Table S1).

74 Population changes were reported in a variety of formats, but broadly fall into two groups,

75 quantitative where the trend was described numerically (e.g. %change), and qualitative

76 where the trend was described categorically (e.g. increase). In the quantitative group, we

77 record the trend as presented in the original source, and we recorded five distinct types: 1)

78 population abundance time-series, 2) mean finite rate of population change (λ), 3) mean

79 instantaneous rate of population change (r), 4) percentage change between two time points,

80 and 5) fold change between two time points; further described in Table S1. For studies that

81 reported trends in multiple formats, we recorded the most informative e.g. where raw

82 abundance data were available this was preferred over summary estimates of population

83 change. If the population values were only reported in a graph, we used a graphic digitiser

84 (https://apps.automeris.io/wpd/) to estimate the values (Rohatgi, 2015).

85

86 For population trends calculated from time-series data, we recorded the length of the time-

87 series (number of individual estimates used to derive the trend). For population trends based

88 on matrix models and demographic parameters, we recorded the number of sampling years

89 used to estimate the demographic parameters. For estimates of annual rates of change (λ

90 and r) derived from three or more data points, we also noted any available estimate of

91 dispersion (e.g. variance) and test-statistic values. For the qualitative descriptions of trends,

92 we inferred the trend based on the description in the primary sources, with trends falling into

93 the following four categories: increase – source described the population abundance as

94 exhibiting overall growth during the monitored period; stable – source described the

95 population abundance as exhibiting a stable or unchanged trend over the monitored period;

96 decrease – source described the population abundance as exhibiting an overall decline

97 during the monitored period; varied – source described the population abundance as

98 exhibiting both growth and declines over the monitored period, without any clear directional

99 trend. The specific terminology used to describe each trend varied between the primary

100 sources, but the general message was largely consistent. However, we do acknowledge that

101 each primary source likely has a different definition for a given trend (i.e. how much growth is

102 necessary to be classed as an increase), which introduces an opportunity for inconsistency

103 and subjectivity, and so these qualitative trends should be interpreted cautiously.

104 For each trend we recorded the binomial species name following the IUCN taxonomy – we

105 report discrepancies between the IUCN taxonomy and another taxonomy (Wilson & Reeder,

106 2005) in Table S2. When the species name in the primary literature did not match the IUCN

107 taxonomy, we referred to the list of IUCN taxonomy synonyms to locate the accepted IUCN

108 species name. Subspecies names were also available in some primary sources, and we

109 noted these as recorded in the primary source. For location, we recorded the name of the

110 study site given in the primary source, whether the site was described as a protected area,

111   and the country or countries it overlapped. If provided, we recorded the study site's

112   coordinates (minimum and maximum, or mid-point) converted into decimal degrees.

113   Coordinate precision was likely variable among studies and is overall unknown. If studies did

114   not report coordinates, we used the name given to the study site and location country to

115   populate the coordinates using OpenCage (Salmon, 2018). OpenCage provides coordinates

116   and a degree of confidence in the estimate, where 1 is low and 9 is high. For all coordinates

117   were the confidence level fell below 7, we manually checked and if needed amended

118   coordinates. When reported in the primary source, we also recorded the area (size) of the

119   study site. For the study period in each record, we noted the start and end date of the

120   population monitoring, and if available the corresponding population sizes at these dates.

121   We captured the data collection and analysis methods from each source using several

122   descriptors (Table S1). For studies that combined multiple methods, we precautionarily

123   recorded the least robust approach. If we could not identify the method, the record was

124   assigned 'undefined'.

125   Causes of change

126   Some sources tested or discussed the role of distinct factors to explain observed population

127   changes. We recorded these factors reclassified into a modified version of the IUCN

128   standardized classification schemes for Threats (v3.2) and Conservation Actions (v2.0), see

129   Table S7. For each recorded factor we noted its effect (associated to increase or to

130   decrease) and how this influence was determined. It is important to note that effects were

131   not always negative for the threat scheme or positive for the conservation actions scheme.

132   For example, urbanisation is listed under the threat scheme but has led to population

133   increases in red fox *Vulpes vulpes* (Gloor *et al.*, 2001). Finally, we note that factors not listed

134   for a given record do not imply a threat or conservation action was not important or did not

135   occur in that population, but simply that the factor was not mentioned in the primary

136   literature.

137   Validating records

138　Authors TJF and PC read the English and Spanish sources, respectively. TFJ entered all

139　data. To validate the records and ensure quality control, 10% of the records were reviewed

140　by an additional author (either PC or MGS). We selected the 10% sample with a random

141　stratified approach to ensure each of the different formats of trends were reviewed e.g.

142　percentage change, population time-series, and qualitative descriptions. TFJ then further

143　scrutinised and double-checked records to detect errors in TFJs original work, that of the

144　second readers (PC and MGS), and identify causes of discrepancies in data entry. We

145　tested the reproducibility of our methods using the Grames & Elphick (2020) checklist and

146　scored highly (Table S9).

147

148　**Results**

149　From the 542 sources read in full, 232 did not contain the population trend information we

150　required and were excluded from the dataset. Trends were excluded for a variety of reasons,

151　examples include: the trend was simulated (N = 23), the trend referred to primary sources

152　already captured in the dataset (N = 20), the trend described geographic distribution range

153　change instead of abundance change (N = 6). Results from the validation step are reported

154　in Supplementary: Validating records.

155　We identified and recorded 1122 population trends from the remaining 310 sources. These

156　represented 50 (57%) of the studied species covering all four taxonomic families and 25

157　(69%) out of 36 genera (Figure 1). Some species had a single trend estimate, while we

158　compiled 621 trend estimates for the top five species: gray wolf (*Canis lupus*), brown bear

159　(*Ursus arctos*), grizzly bear (*Ursus americanus*), lion (*Panthera leo*) and Eurasian lynx (*Lynx*

160　*lynx*). Many of the records represented populations within the northern hemisphere (Figure

161　2a), particularly in Europe (N = 384) and North America (N = 415), but there was also a

162　cluster of records in East and Southern Africa (N = 170) – with records in 86 countries in

163　total. We located very few records in Central, North and West Africa, Central and South

164　America, or Northern Asia. The dataset includes records extending from 1726-2017 (Figure

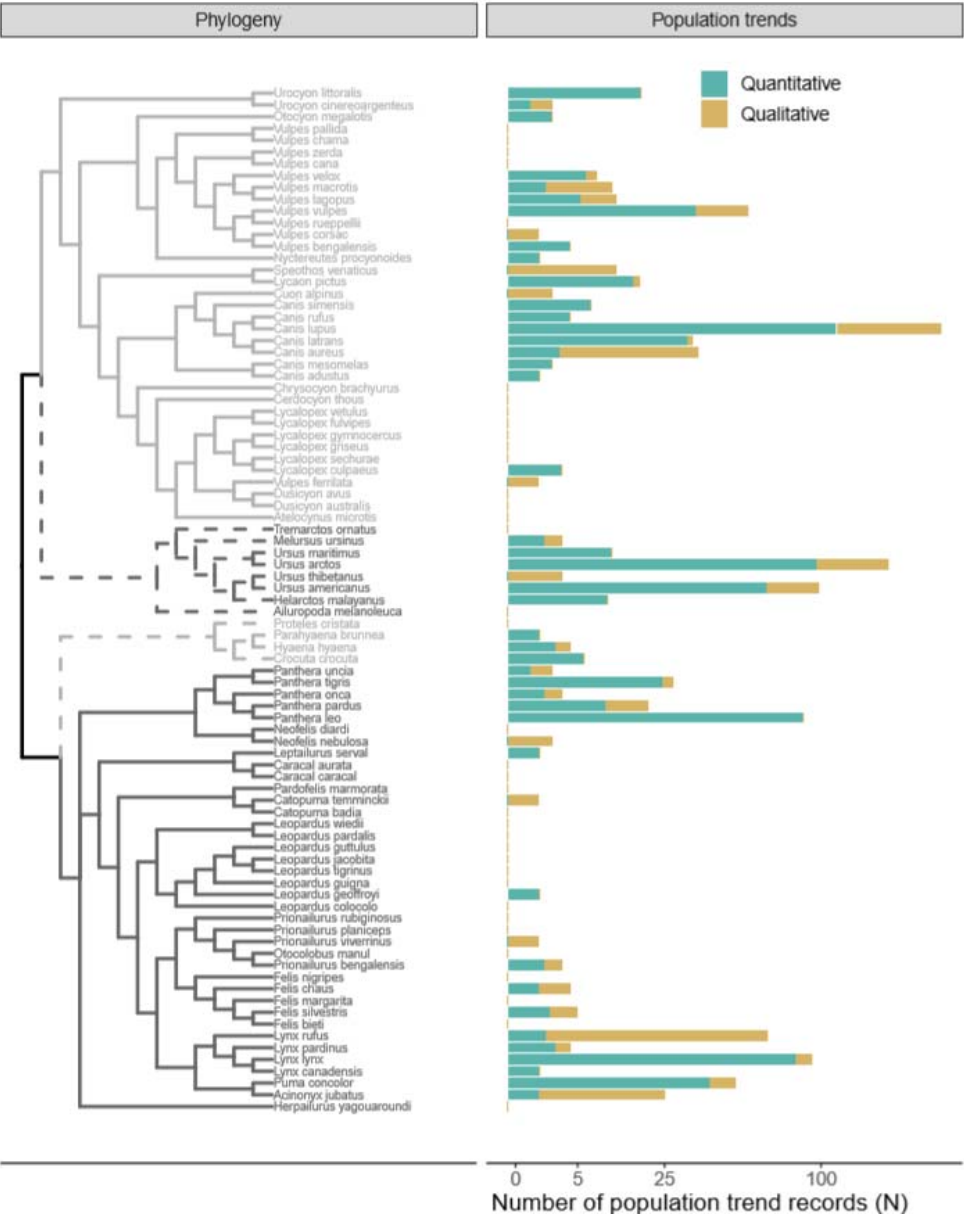165　2b), with the vast majority (92%) of trends starting after 1950.
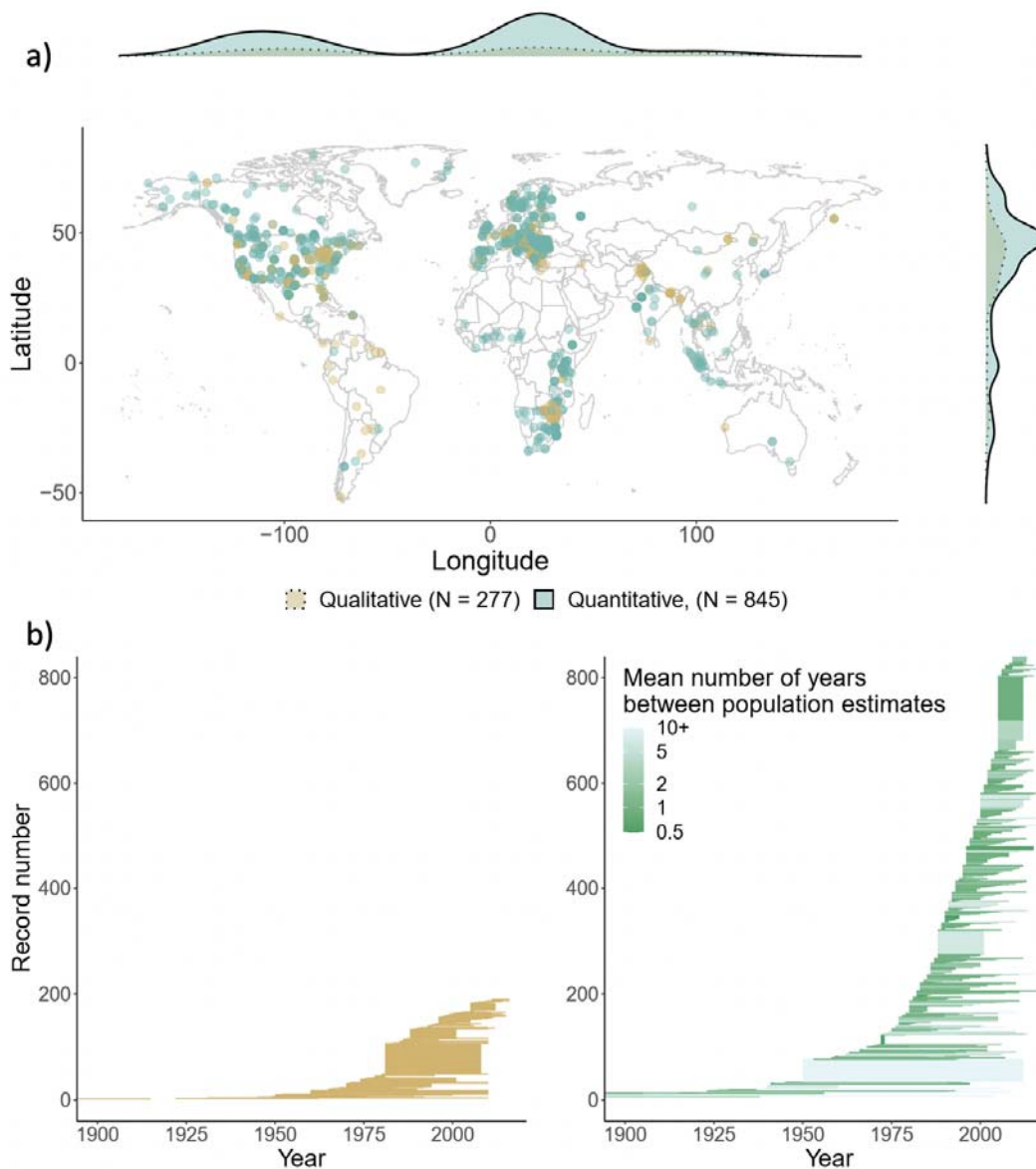
166

167

Figure 1. Number of population trend records per studied species, shown across the phylogeny. The

tree represents four taxonomic families: Canidae (light grey – solid line), Ursidae (dark grey – dotted

line), Hyaenidae (light grey – dotted line) and Felidae (dark grey – solid line). We show records for

both quantitative (teal) and qualitative (gold) trends.

172

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.

Most of the 1122 population trends represent quantitative estimates (N = 845), with a quarter (N = 277) providing only qualitative descriptors. The quantitative records collectively represent 6597 population size estimates. Most of the quantitative trends are recorded as a

184   time-series of abundance values (63.9%), followed by population lambdas (17.4%),

185   percentage change (7.5%), fold change (5.8%), and annual slope coefficients (5.4%).

186

187   **Discussion**

188   We searched the literature to retrieve population trend records for 87 species of large

189   carnivorans, and located 1122 estimates of population change representing 50 species.

190   These records cover a wide temporal window (1726-2017) and represent diverse locations

191   around the globe, although, there is temporal and spatial heterogeneity with more records in

192   recent years and temperate areas of the Northern hemisphere. Our effort expands on and

193   complements previous datasets for these species (as of September 2021, the Living Planet

194   Index includes 465 trends across 39 species, and BioTIME includes 72 trends across 4

195   species) and thus, CaPTrends provides a valuable resource to address ecological questions,

196   complete a more comprehensive assessment of population status for these species, and

197   explore potential predictors of observed population changes (Johnson, *et al.*, 2021)

198   Our dataset located additional time-series records not reported in the Living Planet Index,

199   but also added less precise and qualitative descriptors which need to be interpreted with

200   caution. For example, we found that studies that provided summarised quantitative metrics

201   (e.g. annual population growth) did not always offer estimates of their error and thus, we

202   could not extract uncertainty around the trend in all cases. This issue is even more

203   emphasised in the qualitative descriptions (e.g. increase, decrease), where both the error

204   and magnitude of the trend are unknown. However, if used cautiously, the lower resolution

205   metrics could be important in addressing data gaps for species and locations for which high

206   resolution population trend records are not available (WWF, 2016). This is particularly

207   important, as these data gaps are most prevalent in biodiverse regions (WWF, 2016), which

208   are experiencing the greatest negative-change in human footprint (Venter *et al.*, 2016).

209   Incorporating lower resolution metrics into models of biodiversity change could reduce some

210   of these biases - providing a robust modelling approach is used. For example, in Johnson et

211   al. (2021), trends are treated as a latent state, with qualitative estimates acting as an

212   imperfect realisation of the trend.

213   **Usage notes**

214   CaPTrends is presented as a relational dataset (Figure 3). The main file 'captrends.csv'

215   includes all master data (e.g. unique id, species, location and time-frame), as well as all

216   population data, except the population time-series. Time-series of population abundances

217   and population changes are located in 'ts_abundance.csv' and 'ts_change.csv', respectively,

218   both of which are linked to 'captrends.csv' through the 'DataTableID' field. 'direction.csv' also

219   links to 'captrends.csv' through 'DataTableID' and describes positive and negative influences

220   of each trend. Finally, 'sources.csv' links to 'captrends.csv' through 'Citation_key' and

221   contains information on where the trend was sourced from (full reference). Comprehensive

222   metadata is available for each of these datasets in the supplementary material.
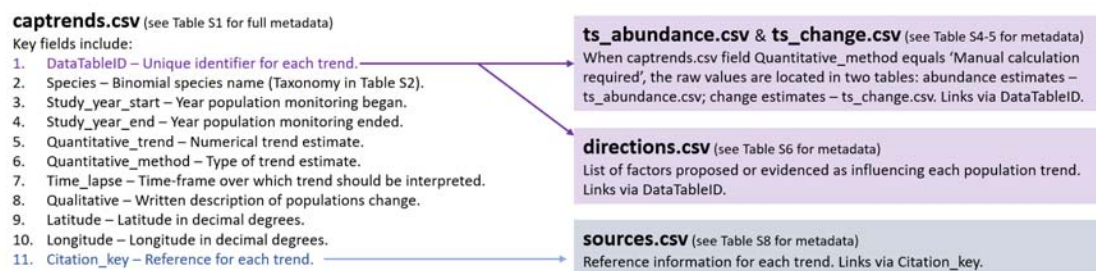
223

224   **Figure 3.** Diagram depicting relational database, including each datasets contents, and how each

225   dataset is linked (arrows).

226   To support the use of this dataset, each population trend record has been annotated and

227   labelled (Table S1). Much of this information would be helpful in filtering the dataset to

228   exclude trends that are deemed of low quality or irrelevant to a given research question. For

229   example, for investigating extinction risk, one may opt to remove data for invasive

230   populations, which is just one of the indicator tags available for each trend.

231   This dataset may be analysed focusing on different descriptors. Including qualitative

232   descriptors provides the most records but highest uncertainty. Focusing only on quantitative

233   records reduces the scope and increase biases (not all species and areas are equally like to

234   have quantitative records as shown in Figure 2). Approaches like data integration (Isaac *et*

235 *al.*, 2020), which can incorporate both data types, are likely to be least biased (spatially,

236 temporally, and taxonomically).

237 **Acknowledgements**

238 Thanks to Ella Coley, Jasmine Ashley, Jessica Marshall, Matthew Bemment, Monty

239 Jefferson, Sarah Granger that assisted in data collection, and Julia Martínez Pardo that

240 helped in project design. This work was funded by NERC (NE/P012345/1) and Royal Society

241 (IE160539).

242

243 **Data accessibility**

244 Data will be stored in an online repository. Location TBC

245

246 **Author contributions**

247 All authors contributed to project design. TFJ entered the data with support from PC. Data

248 was validated by MGS and PC. TFJ wrote the first draft of the manuscript, all authors

249 contributed to revisions.

250

251 **References**

252 Amano, T., Székely, T., Sandel, B., Nagy, S., Mundkur, T., Langendoen, T., Blanco, D., Soykan, C.U.
253   & Sutherland, W.J. (2018) Successful conservation of global waterbird populations depends
254   on effective governance. *Nature*.
255 Cardillo, M., Mace, G., Jones, K.E., Bininda-Emonds, O.R.P., Bielby, J., Sechrest, W., Orme, C.D.L. &
256   Purvis, A. (2005) Multiple causes of high extinction risk in large mammal species. *Science*.
257 Chapron, G., Kaczensky, P., Linnell, J.D.C., von Arx, M., Huber, D., Andren, H., Lopez-Bao, J. V.,
258   Adamec, M., Alvares, F., Anders, O., Bal iauskas, L., Balys, V., Bed , P., Bego, F., Blanco,
259   J.C., Breitenmoser, U., Broseth, H., Bufka, L., Bunikyte, R., Ciucci, P., Dutsov, A., Engleder,
260   T., Fuxjager, C., Groff, C., Holmala, K., Hoxha, B., Iliopoulos, Y., Ionescu, O., Jeremi , J.,
261   Jerina, K., Kluth, G., Knauer, F., Kojola, I., Kos, I., Krofel, M., Kubala, J., Kunovac, S., Kusak,
262   J., Kutal, M., Liberg, O., Maji , A., Mannil, P., Manz, R., Marboutin, E., Marucco, F., Melovski,
263   D., Mersini, K., Mertzanis, Y., Mys ajek, R.W., Nowak, S., Odden, J., Ozolins, J., Palomero,
264   G., Paunovi , M., Persson, J., Poto nik, H., Quenette, P.-Y., Rauer, G., Reinhardt, I., Rigg, R.,
265   Ryser, A., Salvatori, V., Skrbin ek, T., Stojanov, A., Swenson, J.E., Szemethy, L., Trajce, A.,
266   Tsingarska-Sedefcheva, E., Va a, M., Veeroja, R., Wabakken, P., Wolfl, M., Wolfl, S.,
267   Zimmermann, F., Zlatanova, D. & Boitani, L. (2014) Recovery of large carnivores in Europe's
268   modern human-dominated landscapes. *Science*, **346**, 1517–1519.
269 Dornelas, M., Antão, L.H., Moyes, F., Bates, A.E., Magurran, A.E., Adam, D., Akhmetzhanova, A.A.,
270   Appeltans, W., Arcos, J.M., Arnold, H., Ayyappan, N., Badihi, G., Baird, A.H., Barbosa, M.,
271   Barreto, T.E., Bässler, C., Bellgrove, A., Belmaker, J., Benedetti-Cecchi, L., Bett, B.J.,

272   Bjorkman, A.D., Błażewicz, M., Blowes, S.A., Bloch, C.P., Bonebrake, T.C., Boyd, S.,
273   Bradford, M., Brooks, A.J., Brown, J.H., Bruelheide, H., Budy, P., Carvalho, F., Castañeda-
274   Moya, E., Chen, C.A., Chamblee, J.F., Chase, T.J., Siegwart Collier, L., Collinge, S.K.,
275   Condit, R., Cooper, E.J., Cornelissen, J.H.C., Cotano, U., Kyle Crow, S., Damasceno, G.,
276   Davies, C.H., Davis, R.A., Day, F.P., Degraer, S., Doherty, T.S., Dunn, T.E., Durigan, G.,
277   Duffy, J.E., Edelist, D., Edgar, G.J., Elahi, R., Elmendorf, S.C., Enemar, A., Ernest, S.K.M.,
278   Escribano, R., Estiarte, M., Evans, B.S., Fan, T.Y., Turini Farah, F., Loureiro Fernandes, L.,
279   Farneda, F.Z., Fidelis, A., Fitt, R., Fosaa, A.M., Daher Correa Franco, G.A., Frank, G.E.,
280   Fraser, W.R., García, H., Cazzolla Gatti, R., Givan, O., Gorgone-Barbosa, E., Gould, W.A.,
281   Gries, C., Grossman, G.D., Gutierréz, J.R., Hale, S., Harmon, M.E., Harte, J., Haskins, G.,
282   Henshaw, D.L., Hermanutz, L., Hidalgo, P., Higuchi, P., Hoey, A., Van Hoey, G., Hofgaard,
283   A., Holeck, K., Hollister, R.D., Holmes, R., Hoogenboom, M., Hsieh, C. hao, Hubbell, S.P.,
284   Huettmann, F., Huffard, C.L., Hurlbert, A.H., Macedo Ivanauskas, N., Janík, D., Jandt, U.,
285   Jażdżewska, A., Johannessen, T., Johnstone, J., Jones, J., Jones, F.A.M., Kang, J.,
286   Kartawijaya, T., Keeley, E.C., Kelt, D.A., Kinnear, R., Klanderud, K., Knutsen, H., Koenig,
287   C.C., Kortz, A.R., Král, K., Kuhnz, L.A., Kuo, C.Y., Kushner, D.J., Laguionie-Marchais, C.,
288   Lancaster, L.T., Min Lee, C., Lefcheck, J.S., Lévesque, E., Lightfoot, D., Lloret, F., Lloyd,
289   J.D., López-Baucells, A., Louzao, M., Madin, J.S., Magnússon, B., Malamud, S., Matthews, I.,
290   McFarland, K.P., McGill, B., McKnight, D., McLarney, W.O., Meador, J., Meserve, P.L.,
291   Metcalfe, D.J., Meyer, C.F.J., Michelsen, A., Milchakova, N., Moens, T., Moland, E., Moore,
292   J., Mathias Moreira, C., Müller, J., Murphy, G., Myers-Smith, I.H., Myster, R.W., Naumov, A.,
293   Neat, F., Nelson, J.A., Paul Nelson, M., Newton, S.F., Norden, N., Oliver, J.C., Olsen, E.M.,
294   Onipchenko, V.G., Pabis, K., Pabst, R.J., Paquette, A., Pardede, S., Paterson, D.M.,
295   Pélissier, R., Peñuelas, J., Pérez-Matus, A., Pizarro, O., Pomati, F., Post, E., Prins, H.H.T.,
296   Priscu, J.C., Provoost, P., Prudic, K.L., Pulliainen, E., Ramesh, B.R., Mendivil Ramos, O.,
297   Rassweiler, A., Rebelo, J.E., Reed, D.C., Reich, P.B., Remillard, S.M., Richardson, A.J.,
298   Richardson, J.P., van Rijn, I., Rocha, R., Rivera-Monroy, V.H., Rixen, C., Robinson, K.P.,
299   Ribeiro Rodrigues, R., de Cerqueira Rossa-Feres, D., Rudstam, L., Ruhl, H., Ruz, C.S.,
300   Sampaio, E.M., Rybicki, N., Rypel, A., Sal, S., Salgado, B., Santos, F.A.M., Savassi-
301   Coutinho, A.P., Scanga, S., Schmidt, J., Schooley, R., Setiawan, F., Shao, K.T., Shaver,
302   G.R., Sherman, S., Sherry, T.W., Siciński, J., Sievers, C., da Silva, A.C., Rodrigues da Silva,
303   F., Silveira, F.L., Slingsby, J., Smart, T., Snell, S.J., Soudzilovskaia, N.A., Souza, G.B.G.,
304   Maluf Souza, F., Castro Souza, V., Stallings, C.D., Stanforth, R., Stanley, E.H., Mauro Sterza,
305   J., Stevens, M., Stuart-Smith, R., Rondon Suarez, Y., Supp, S., Yoshio Tamashiro, J.,
306   Tarigan, S., Thiede, G.P., Thorn, S., Tolvanen, A., Teresa Zugliani Toniato, M., Totland, Ø.,
307   Twilley, R.R., Vaitkus, G., Valdivia, N., Vallejo, M.I., Valone, T.J., Van Colen, C.,
308   Vanaverbeke, J., Venturoli, F., Verheye, H.M., Vianna, M., Vieira, R.P., Vrška, T., Quang Vu,
309   C., Van Vu, L., Waide, R.B., Waldock, C., Watts, D., Webb, S., Wesołowski, T., White, E.P.,
310   Widdicombe, C.E., Wilgers, D., Williams, R., Williams, S.B., Williamson, M., Willig, M.R.,
311   Willis, T.J., Wipf, S., Woods, K.D., Woehler, E.J., Zawada, K. & Zettler, M.L. (2018) BioTIME:
312   A database of biodiversity time series for the Anthropocene. *Global Ecology and*
313   *Biogeography*, **27**, 760–786.
314 Fritz, S.A., Bininda-Emonds, O.R.P. & Purvis, A. (2009) Geographical variation in predictors of
315   mammalian extinction risk: Big is bad, but only in the tropics. *Ecology Letters*.
316 Gloor, S., Bontadina, F., Hegglin, D., Deplazes, P. & Breitenmoser, U. (2001) The rise of urban fox
317   populations in Switzerland. *Zeitschrift fur Saugetierkunde*.
318 Gonzalez-Suarez, M., Gomez, A. & Revilla, E. (2013) Which intrinsic traits predict vulnerability to
319   extinction depends on the actual threatening processes. *Ecosphere*, **4**, 1–16.
320 González-Suárez, M. & Revilla, E. (2013) Variability in life-history and ecological traits is a buffer
321   against extinction in mammals. *Ecology Letters*, **16**, 242–251.
322 Grames, E.M. & Elphick, C.S. (2020) Use of study design principles would increase the reproducibility
323   of reviews in conservation biology. *Biological Conservation*, **241**, 108385.
324 IPBES (2019) *Summary for policymakers of the global assessment report on biodiversity and*
325   *ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and*
326   *Ecosystem Services,*.
327 Isaac, N.J.B., Jarzyna, M.A., Keil, P., Dambly, L.I., Boersch-Supan, P.H., Browning, E., Freeman,
328   S.N., Golding, N., Guillera-Arroita, G., Henrys, P.A., Jarvis, S., Lahoz-Monfort, J., Pagel, J.,
329   Pescott, O.L., Schmucki, R., Simmonds, E.G. & O'Hara, R.B. (2020) Data Integration for
330   Large-Scale Models of Species Distributions. *Trends in Ecology and Evolution*.
331 Johnson, T.F., Isaac, N.J.B., Paviolo, A. & Gonzalez-Suarez, M. (2021) Socioeconomics drive
332   population change in the world's largest carnivore. *bioRxiv - preprint*.
333 Polaina, E., Revilla, E. & González-Suárez, M. (2016) Putting susceptibility on the map to improve
334   conservation planning, an example with terrestrial mammals. *Diversity and Distributions*.

335 Ripple, W.J., Estes, J.A., Beschta, R.L., Wilmers, C.C., Ritchie, E.G., Hebblewhite, M., Berger, J.,
336   Elmhagen, B., Letnic, M., Nelson, M.P., Schmitz, O.J., Smith, D.W., Wallach, A.D. & Wirsing,
337   A.J. (2014) Status and ecological effects of the world's largest carnivores. *Science*, **343**.
338 Rohatgi, A. (2015) WebPlotDigitizer.
339 Salmon, M. (2018) opencage: Interface to the OpenCage API.
340 Venter, O., Sanderson, E.W., Magrach, A., Allan, J.R., Beher, J., Jones, K.R., Possingham, H.P.,
341   Laurance, W.F., Wood, P., Fekete, B.M., Levy, M.A. & Watson, J.E.M. (2016) Sixteen years
342   of change in the global terrestrial human footprint and implications for biodiversity
343   conservation. *Nature Communications*.
344 Wilson, D.E. & Reeder, D.M. (2005) *Mammal Species of the World*,.
345 WWF (2016) *Living Planet Report 2016: Risk and resilience in a new era*, Gland, Switzerland.
346 WWF (2020) *Living Planet Report 2020 - Bending the curve of biodiversity loss*,.
347