How many bird and mammal extinctions has recent conservation action prevented?

Authors: Friederike C. Bolam[1], Louise Mair[2], Marco Angelico[3], Thomas M. Brooks[4], Mark Burgman[5], Claudia Hermes[6], Michael Hoffmann[7], Rob W. Martin[8], Philip J.K. McGowan[9]*, Ana S.L. Rodrigues[10], Carlo Rondinini[11], James R.S. Westrip[12], Hannah Wheatley[13], Yuliana Bedolla-Guzmán[14], Javier Calzada[15], Matthew F. Child[16], Peter A. Cranswick[17], Christopher R. Dickman[18], Birgit Fessl[19], Diana O. Fisher[20], Stephen T. Garnett[21], Jim J. Groombridge[22], Christopher N. Johnson[23], Rosalind J. Kennerley[24], Sarah R.B. King[25], John F. Lamoreux[26], Alexander C. Lees[27], Luc Lens[28], Simon P. Mahood[29], David P. Mallon[30], Erik Meijaard[31], Federico Méndez-Sánchez[32], Alexandre Reis Percequillo[33], Tracey J. Regan[34], Luis Miguel Renjifo[35], Malin C. Rivers[36], Nicolette S. Roach[37], Lizanne Roxburgh[38], Roger J. Safford[39], Paul Salaman[40], Tom Squires[41], Ella Vázquez-Domínguez[42], Piero Visconti[43], John C.Z. Woinarski[44], Richard P. Young[45], Stuart H.M. Butchart[46]

* Corresponding author

1 School of Natural and Environmental Sciences, Newcastle University, UK; friederike.bolam@ncl.ac.uk

2 School of Natural and Environmental Sciences, Newcastle University, UK; louise.mair@ncl.ac.uk

3 Global Mammal Assessment Program, Department of Biology and Biotechnologies, Sapienza University of Rome, Italy; angelico.marco@yahoo.com

4 IUCN, Switzerland; World Agroforestry Center (ICRAF), University of The Philippines Los Baños, Laguna 4031, The Philippines; Institute for Marine & Antarctic Studies, University of Tasmania, Hobart, Tasmania 7001, Australia; thomas.brooks@iucn.org

5 Imperial College London, United Kingdom; m.burgman@imperial.ac.uk

6 BirdLife International, UK; claudia.hermes@birdlife.org

7 Zoological Society of London, United Kingdom; mike.hoffmann@zsl.org

8 BirdLife International, UK; rob.martin@birdlife.org

9 School of Natural and Environmental Sciences, Newcastle University, UK; philip.mcgowan@ncl.ac.uk

10 Centre d'Ecologie Fonctionnelle et Evolutive CEFE, CNRS – Univ. de Montpellier – Univ. Paul-Valéry Montpellier – EPHE, Montpellier, France; ana.rodrigues@cefe.cnrs.fr

11 Global Mammal Assessment Program, Department of Biology and Biotechnologies, Sapienza University of Rome, Italy; carlo.rondinini@uniroma1.it

12 Global Species Programme, IUCN (International Union for Conservation of Nature), Cambridge, United Kingdom; james.westrip@iucn.org

13 BirdLife International, United Kingdom; hannah.wheatley@birdlife.org

14 Grupo de Ecología y Conservación de Islas, A.C., Mexico; yuliana.bedolla@islas.org.mx

15 Department of Integrated Sciences, University of Huelva, Spain; javier.calzada@dbasp.uhu.es

16 South African National Biodiversity Institute, South Africa; Mammal Research Institute, University of Pretoria; m.child@sanbi.org.za

17 The Wildfowl & Wetlands Trust, UK; Peter.Cranswick@wwt.org.uk

18 School of Life and Environmental Sciences, University of Sydney, Australia; Threatened Species Recovery Hub, National Environmental Science Program, Australia; chris.dickman@sydney.edu.au

19 Charles Darwin Research Station, Charles Darwin Foundation, Ecuador/ Galapagos; birgit.fessl@fcdarwin.org.ec

20 School of Biological Sciences, University of Queensland, Australia; d.fisher@uq.edu.au

21 Research Institute for the Environment and Livelihoods, Charles Darwin University, Australia; Threatened Species Recovery Hub, National Environmental Science Program, Australia; stephen.garnett@cdu.edu.au

22 Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, UK; J.Groombridge@kent.ac.uk

23 School of Natural Sciences and ARC Centre for Australian Biodiversity & Heritage, University of Tasmania, Australia; c.n.johnson@utas.edu.au

24 Durrell Wildlife Conservation Trust, United Kingdom; rosalind.kennerley@durrell.org

25 Natural Resource Ecology Laboratory, Colorado State University, USA; sarah.king@colostate.edu

26 Reston, Virginia, USA; john.lamoreux@gmail.com

27 Department of Natural Sciences, Manchester Metropolitan University, Manchester, UK; and Cornell Lab of Ornithology, Cornell University, Ithaca, USA; alexander.lees@mmu.ac.uk

28 Department of Biology, Terrestrial Ecology Unit, Ghent University, Belgium; luc.lens@ugent.be

29 Wildlife Conservation Society, Cambodia; Research Institute for the Environment and Livelihoods, Charles Darwin University, Australia; smahood@wcs.org

30 Department of Natural Sciences, Manchester Metropolitan University, Manchester, UK; IUCN Species Survival Commission; dmallon7@gmail.com

31 Borneo Futures, Brunei Darussalam; Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, UK; emeijaard@gmail.com

32 Grupo de Ecología y Conservación de Islas, A.C., Mexico; Centro de Investigaciones Biológicas del Noroeste, S.C., Mexico; federico.mendez@islas.org.mx

33 Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, Brasil; percequillo@usp.br

34 The Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning, Heidelberg, Victoria, Australia; School of BioSciences, University of Melbourne, Parkville, Victoria, Australia; tracey.regan@delwp.vic.gov.au

35 Department of Ecology and Territory, Pontificia Universidad Javeriana, Colombia; lmrenjifo@javeriana.edu.co

36 Botanic Gardens Conservation International, United Kingdom; malin.rivers@bgci.org

37 Texas A&M University, USA; Global Wildlife Conservation, USA; nroach@tamu.edu

38 Endangered Wildlife Trust, South Africa; lizanner@ewt.org.za

39 BirdLife International, UK; roger.safford@birdlife.org

40 Rasmussen Family Foundation, USA; psalaman@gmail.com

41 Department of Natural Sciences, Manchester Metropolitan University, Manchester, UK; tom.squires@stu.mmu.ac.uk

42 Departamento de Ecología de la Biodiversidad, Instituto de Ecología, Universidad Nacional Autónoma de México, Mexico; evazquez@ecologia.unam.mx

43 International Institute for Applied System Analysis, Austria; University College London, Centre for Biodiversity and Environment Research, UK; visconti@iiasa.ac.at

44 Research Institute for the Environment and Livelihoods, Charles Darwin University, Australia; Threatened Species Recovery Hub, National Environmental Science Program, Australia; john.woinarski@cdu.edu.au

45 Durrell Wildlife Conservation Trust, United Kingdom; richard.young@durrell.org

46 BirdLife International, United Kingdom; Department of Zoology, University of Cambridge, UK; stuart.butchart@birdlife.org

Running title: Prevented bird and mammal extinctions

Keywords: Convention on Biological Diversity, Delphi method, extinction risk, Aichi Biodiversity Target 12, species conservation

Type of article: Letter

Word count abstract: 149

Word count manuscript: 3,000

Number of references: 30

Number of figures and tables: 6

Corresponding author: Philip J.K. McGowan, email: philip.mcgowan@ncl.ac.uk, phone number: +44 191 208 6664, School of Natural and Environmental Sciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, United Kingdom.

Abstract

Aichi Target 12 of the Convention on Biological Diversity (CBD) contains the aim to 'prevent extinctions of known threatened species'. To measure the degree to which this was achieved, we used expert elicitation to estimate the number of bird and mammal species whose extinctions were prevented by conservation action in 1993 - 2020 (the lifetime of the CBD) and 2010 - 2020 (the timing of Aichi Target 12). We found that conservation action prevented 21–32 bird and 7–16 mammal extinctions since 1993, and 9–18 bird and 2–7 mammal extinctions since 2010. Many remain highly threatened, and may still become extinct. Considering that ten bird and five mammal species did go extinct (or are strongly suspected to) since 1993, extinction rates would have been 2.9–4.2 times greater without conservation action. While policy commitments have fostered significant conservation achievements, future biodiversity action needs to be scaled up to avert additional extinctions.

Introduction

The Parties to the Convention on Biological Diversity (CBD) adopted an ambitious strategic plan for 2011-2020, comprising 20 'Aichi Biodiversity Targets'. Target 12 states that '*By 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained*'. A mid-term assessment concluded that further extinctions were likely by 2020, but that conservation measures had prevented some extinctions (CBD 2014).

Considering compelling evidence of a continued deterioration of the state of nature under increasing pressures (IPBES 2019, Díaz et al., 2019), investigating the impact of conservation efforts is key to evaluating whether we have the knowledge and techniques to reverse negative trends, and to galvanise further action. Previous assessments of conservation impact investigated whether trends in extinction risk would have changed if no species had improved in conservation status (Hoffmann et al., 2010, Szabo et al., 2012), or if no conservation actions had taken place (e.g. Hoffmann et al., 2015, Young et al., 2014). Butchart et al. (2006) estimated which bird species would have gone extinct without conservation action during 1994-2004, based on expert knowledge. Looking ahead, green listing will provide standardised methods to quantify species recovery (Akçakaya et al., 2018).

Here we build on these studies to quantify the extent to which the commitment to prevent '*the extinction of known threatened species*' was achieved. Our aim was to identify those species for which there is high certainty that conservation action prevented their extinction. We focused on birds and mammals as some of the best documented taxonomic Classes on the IUCN Red List of threatened species (hereafter Red List). We considered two time periods: 1993-2020 (the lifetime of the CBD) and 2010-2020 (approximately the timing of Aichi Target 12).

Methods

We identified a list of bird and mammal species for which conservation action prevented extinction by: (a) identifying candidate species that could plausibly have gone extinct (i.e. the death of the last individual in the wild) without conservation action; (b) documenting for these species the key information to evaluate whether the actions implemented could plausibly have prevented their extinction; (c) using a Delphi technique to estimate the probability that each candidate species would have gone extinct in a counterfactual scenario without conservation action; and (d) retaining species with a high probability that conservation action prevented their extinction. We combined our results with the number of known extinctions to quantify the effect of conservation action on observed extinction rates. For full details on methods see the supplementary material.

Identifying and documenting candidate species

To be included as candidates, species had to be listed as Extinct in the Wild, Critically Endangered or Endangered on the Red List at any time since 1993, with ongoing threats to their persistence and with conservation actions implemented. We examined all bird and mammal species. First, species currently classified as Extinct in the Wild would be extinct without captive breeding; therefore we considered them to have 100% probability that extinction was prevented. Second, among Critically Endangered and Endangered species, we retained those with fewer than 250 mature individuals at any point since 1993, leaving 368 bird and 263 mammal species. Third, of those species, we used information in the species' Red List accounts to identify those with persistent threats, and implemented conservation actions, leaving 48 bird and 25 mammal species. Fourth, we compiled standardised information for these 73 species on their population size and trends in 1993, 2010 and in the latest assessment year, and on threats and conservation actions. We also summarised what

we considered to be key arguments that the species would have gone extinct without conservation action. Taxon experts reviewed this information. Based on their feedback, we reduced the final candidate list to 39 bird and 21 mammal species for 1993-2020, and 23 bird and 17 mammal species for 2010-2020. Our resulting candidate list therefore represents a suite of species that we adjudge to have benefited positively from conservation actions at some point since 1993. All excluded species were considered to have 0% probability that conservation action prevented extinction.

Delphi exercise

We asked 28 bird and 26 mammal evaluators (all authors of this publication) to estimate independently and anonymously the probability that each candidate species would have gone extinct in the wild without conservation action. We used a Delphi expert elicitation technique following the IDEA protocol (*Investigate, Discuss, Estimate, Aggregate;* Hemming et al., 2018), which is based on Delphi techniques (Mukherjee et al., 2015). Specifically, we asked evaluators three questions for each time period: *Realistically, what do you think is the (1) lowest plausible probability / (2) highest plausible probability / (3) best estimate for the probability that conservation action prevented extinction for this species during the period (i.e. what is the probability that, if action had ceased in 1993/2010, and no subsequent actions were implemented, the species would have gone extinct in the wild by 2020)?*

To answer these questions, evaluators were instructed to use the information summarised for each species and any other information they had access to, and to assume that all conservation action would have ceased at the start of the period.

We aggregated the results across evaluators for each species and time period, by calculating the median lowest (question 1), highest (question 2) and best estimate (question 3) of probabilities that extinction was prevented (von der Gracht, 2012). We calculated agreement by defining seven classes of probability (Table S1), with high agreement if >50% of evaluators had placed their estimates within the same class, medium agreement if >50% of evaluators had placed their estimates within two adjacent classes, and low agreement otherwise. These results were shared with all evaluators, followed by teleconference calls in which evaluators discussed each species in turn. Evaluators could then revise their scores (independently and anonymously) to incorporate insights gained during the calls. We then calculated final median scores (Table S7).

Analysis

We summarised the median scores as the number of species whose extinction was prevented as X–Y, with X representing species with a median best estimate ≥90% that extinction was prevented and Y representing species with a median best estimate >50%, following an analogous approach for defining Extinct and Critically Endangered (Possibly Extinct) species (Butchart et al., 2018). For all species with a median best estimate >50% for 1993-2020, we analysed their distribution, threats, actions implemented, current Red List category, and current population trend, as documented on the Red List. Finally, we compared the total number of these species with numbers of species confirmed or strongly suspected to have gone Extinct in the same period (Tables S2, S3).

Results

Prevented bird extinctions

Of 39 candidate bird species for the 1993-2020 period, 15 had a median best estimate ≥90% that their extinction was prevented, of which 11 had high and four had medium agreement (Fig. 1a), with a further 11 species having a median best estimate >50% (three had high and eight had medium agreement). Including six additional species listed as Extinct in the Wild during the time period

(Table S4), we consider that 21–32 bird species would have gone extinct without conservation during 1993-2020. In contrast, there were 10 confirmed or suspected extinctions since 1993 (Table S2). Hence, in the absence of conservation, the total number of bird extinctions since 1993 would have been 3.1–4.2 times higher (31–42 vs. 10) (Table S3).

Of 23 candidate bird species for 2010-2020, three had a median best estimate ≥90% that their extinction was prevented (Fig. 1b), with a median best estimate >50% for a further nine species. Agreement among evaluators for these 12 species was high for one and medium for 11 species. Including six species listed as Extinct in the Wild, we consider that 9–18 bird species would have gone extinct without conservation during 2010-2020. In contrast, one bird species went extinct since 2010 (Table S2). Overall, the number of bird extinctions since 2010 would have been 10–19 times higher without conservation (10–19 vs. 1) (Table S3).

Prevented mammal extinctions

Of 21 candidate mammal species for 1993-2020, four had a median best estimate ≥90% that their extinction was prevented (Fig. 2a), and a further nine a median best estimate >50%. Agreement among evaluators for these 13 species was high for eight and medium for five species. Three species were listed as Extinct in the Wild during the time period (Table S4). Hence, we consider that 7–16 mammal species would have gone extinct without conservation during 1993-2020. Given that five mammal species are confirmed or suspected to have gone extinct since 1993 (Table S2), the number of mammal extinctions since 1993 would have been 2.4–4.2 times higher without conservation (12–21 vs. 5) (Table S3).

Of 17 candidate mammal species for 2010-2020, none had a median best estimate of ≥90% that their extinction was prevented and five had a median best estimate >50% (Fig. 2b). Agreement among evaluators for these five species was high for one and medium for four species. Including two species listed as Extinct in the Wild, we consider that 2–7 mammal species would have gone extinct without conservation during 2010-2020. No mammal species have been documented to have become extinct since 2010, so for this group all extinctions have been prevented by conservation.

These numbers of prevented extinctions are broadly consistent with values obtained by summing the median best estimates across all candidates (analogous to the approach for estimating the number of extinctions proposed by Akçakaya et al., 2017): 32.9 bird and 15.9 mammal species in 1993-2020, and 18.7 bird and 9.0 mammal species in 2010-2020.

Characteristics of species whose extinction was prevented

The 32 identified bird species whose extinction was likely prevented during 1993-2020 occur (or occurred, for Extinct in the Wild species) in 25 countries, including six in New Zealand, five in Brazil, and three in Mexico (Fig. 3a); 65% are restricted to islands (excluding mainland Australia). The 16 identified mammal species occur in 23 countries, including five in China and three in Vietnam and the USA, respectively (Fig. 3b); 19% are restricted to islands.

Of the 32 identified bird species, 16% are currently classified as Extinct in the Wild, 47% as Critically Endangered, 28% as Endangered, and 9% as Vulnerable, with 53% having increasing or stable populations (Fig. 4a). Of the 16 identified mammal species, 13% are Extinct in the Wild, 56% Critically Endangered and 31% Endangered (Fig. 4b), with 31% having increasing or stable populations.

The most frequent current and past threats to the 32 identified bird species are invasive species, followed by habitat loss through agriculture and aquaculture, and hunting (impacting 78%, 56% and 53% of species, respectively) (Fig. 5a). The most frequent threats to the 16 identified mammal

246 species are hunting, agriculture and aquaculture, and invasive species (impacting 75%, 75% and 50%
247 of species, respectively) (Fig. 5b).

248 The most frequently implemented actions for the 32 identified bird species were invasive species
249 control, ex-situ conservation, and site/area protection (for 66%, 63%, 59% of species, respectively)
250 (Fig. 6a). For the 16 mammal species, the most frequent actions were legislation, reintroductions,
251 and ex-situ conservation (for 88%, 56%, 56% of species, respectively) (Fig. 6b).

252 Discussion

253 Our results indicate that the extinction of at least 28–48 bird and mammal species was prevented
254 between 1993-2020, and of 11–25 bird and mammal species between 2010-2020. At the same time,
255 15 confirmed or strongly suspected bird and mammal extinctions were documented since 1993,
256 including one since 2010 (Alagoas Foliage-gleaner *Philydor novaesi*). Hence the number of
257 extinctions would have been at least 2.9–4.2 times higher for 1993-2020, and 12–26 times higher for
258 2010–2020. Further extinctions since 2010 may come to light due to time-lags before detecting
259 extinctions (Butchart et al., 2018). If the rate of extinctions observed in 1993-2009 (8.2/decade) is
260 found to have continued during 2010-2020, the number of extinctions without conservation would
261 still be two to four times higher (19.2-33.2 vs 8.2). Our counterfactual analyses therefore provide a
262 strikingly positive message that conservation has substantially reduced extinction rates for birds and
263 mammals.

264 Our analyses underestimate the impact of conservation in several ways. First, our process to identify
265 candidate species may have potentially missed some species whose extinction was prevented, such
266 as Endangered species that are rapidly declining. Others may have been missed owing to lack of
267 information (for example, Critically Endangered species tagged as Possibly Extinct, whose continued
268 survival is uncertain). Second, we used the definition of extinction (the death of the last individual)
269 adopted by IUCN (2012). Without conservation in the time periods considered, some additional
270 long-lived species may have become functionally extinct. Third, we considered only birds and
271 mammals, yet an additional 70 species in other taxa are listed as Extinct in the Wild on the Red List
272 (IUCN 2020). These would be extinct without ex-situ efforts, while other extant species would have
273 gone extinct without in-situ efforts. Lastly, we examined only species at the brink of extinction: a
274 huge amount of species would have deteriorated in conservation status in the absence of
275 conservation (Hoffmann et al., 2015).

276 Conversely, not all species we identified as prevented extinctions are conservation successes, and
277 we did not investigate the future survival prospects of the species. For example, for the Vaquita
278 *Phocoena sinus*, of which just six individuals were known to remain in September 2018 (Jaramillo-
279 Legorreta et al., 2019), conservation may have slowed the catastrophic decline but appears to be
280 failing to halt it.

281 The conservation actions implemented for species whose extinctions were prevented echo the
282 respective main threats. The most frequent threat to birds was invasive species, and management of
283 invasive species was the key response. For mammals, the prominence of legislation as a
284 conservation action likely reflects efforts to curb the main threat of hunting and collecting. Site/area
285 protection are featured frequently as actions for both taxa, considering that agriculture and
286 aquaculture, logging, and residential development are persistent threats. The importance of ex-situ
287 conservation and reintroductions reflects the large numbers of species whose persistence has relied
288 on captive-bred populations, sometimes completely (for the Extinct in the Wild species, Table S4), or
289 for translocations and population reinforcements (Table S6). Two formerly Extinct in the Wild

species have been the subject of successful conservation translocations since 1993: Przewalski's Horse *Equus ferus* and Guam Rail *Hypotaenidia owstoni*.

We investigated conservation actions associated with avoided extinctions, but not specifically which actions worked for individual species, or the effectiveness of the actions. Similarly, we did not investigate what conservation actions took place for those species that did go extinct since 1993.

Assessing the probability that species would have gone extinct under a counterfactual scenario inherently involves a degree of uncertainty. Judgements are more certain with better information available, and it is possible that we missed information that would have changed the probabilities assigned to species. We attempted to minimise this risk by starting with all Red List assessments of bird and mammal species, incorporating up to date information from 124 species experts, and asking each evaluator to examine more thoroughly a small subset of species prior to the calls. We undertook two calls per taxon, with largely different sets of evaluators per call. As slightly different information was discussed during each call, there were some differences in probability estimates between calls. To reduce this effect, we relayed information gained during the first call to evaluators on the second call, but in some cases new information came to light during the second call (see Supplementary Information). However, differences between calls had little effect on the overall results. Two mammal species had an overall probability ≤50%, but would be included (i.e. an estimate >50%) based on scores from the second call only, and two bird and one mammal species had an overall probability >50%, but would be excluded (i.e. an estimate ≤50%) based on scores from the second call only.

The costs of conservation actions undertaken for each species were not known. Quantifying these investments and comparing them with investments for species that did go extinct, should be prioritised for future research.

Our results show that despite the ongoing loss of biodiversity, a substantial number of extinctions was prevented since the inception of the CBD. While Aichi Target 12 has not been met (Diaz et al., 2019), the rate of extinctions since its adoption would have been at least twice as high (and potentially an order of magnitude higher) without conservation action. These actions were implemented by a combination of governments, NGOs, zoos, scientists, volunteers and others. Nevertheless, the species we identified remain highly threatened, and most require continued substantial conservation investment to ensure their survival. Given the ongoing scale and projected growth in pressures on biodiversity (IPBES 2019), considerably greater efforts are needed to prevent the extinction and improve the status of the 6,811 species currently assessed as Critically Endangered on the Red List (IUCN 2020). Our results should motivate the world's governments currently negotiating goals and targets on nature conservation in the CBD's post-2020 global biodiversity framework to redouble their commitments to prevent extinctions. Not only is this hugely important (Gascon et al., 2015) but also, as we have demonstrated here, eminently feasible.

Acknowledgements

We thank the following species experts for providing input to this project: Antonio Ortiz Alcaraz, Giovanni Amori, Arthur Barbosa Andrade, Helder Farias Pereira de Araujo, Andrew Bamford, António Eduardo Araújo Barbosa, Gobind Sagar Bhardwaj, Caroline Blanvillain, Luca Borghesio, Chris Bowden, Lee Boyd, Dave Boyle, Amedee Brickey, Rachel M. Bristol, Andrew Burbidge, Ian Burfield, Rick Camp, Fernando Solis Carlos, Kevin Carter, Simba Chan, Susan Cheyne, Francesca Cunninghame, Dave Currie, Pedro Ferreira Develey, Andrew Digby, John Dowding, Márcio Amorim Efe, Jorge Fernández Orueta, Julie Gane, Thomas Ghestemme, Mwangi Githiru, Amanda Goldberg, Andrew Grant, Rhys

Green, Terry Greene, Rod Hitchmough, Alan Horsup, Simon Hoyle, John Hughes, John Innes, Todd Katzner, Jonathan Kearvell, Bruce Kendall, Cecilia Kierulff, Andrew Legault, Neahga Leonard, Jorgelina Marino, Juan Esteban Martínez, Pete McClelland, Neil McCulloch, Michael McMillan, Patricia Moehlman, Julio Hernández Montoya, Tilo Nadler, Steffen Oppel, Antonio Ortiz, Oliver Overdyck, Erica C. Pacifico, Phil Palmer, Fernando C. Passos, Erica Perez, Benjamin T. Phalan, Mike Phillips, Huy Hoàng Quốc, Lily-Arison Réné De Roland, Johanna Rode-Margono, Carlos Ramon Ruiz, Michael J. Samways, H. Martin Schaefer, Jessica Scrimgeour, Gono Semiadi, Claudio Sillero-Zubiri, Herminio Alfredo Leite Silva Vilela, Luis Fábio Silveira, Elenise Angelotti Bastos Sipinski, Fernando Solis, Christine Steiner São Bernardo, Bibhab Talukdar, Vikash Tatayah, Bernie Tershy, Cobus Theron, Jean-Claude Thibault, Jeff J. Thompson, Sam Turvey, Thomas White, Peter Widmann, Yu Xiao-Ping, Ding Li Yong, Glyn Young, Francis Zino, Christoph Zöckler.

Authors' Contributions

The study was conceived and designed by FCB, SHMB, LM, MB, MH, PJKM, and ASLR. FCB, LM, PJKM, CH, RWM, JRSW, HW, and MA undertook the first filtering of candidate species. FCB, SHMB and LM compiled information per candidate species. All authors participated in the Delphi exercises for birds and/or mammals, i.e. they reviewed the information across all species and estimated the probabilities that each species would have gone extinct without conservation. The following authors took part in the Delphi exercise for birds: FCB, LM, CH, MH, RWM, PJKM, ASLR, HW, YBG, MFC, PAC, BF, SG, JJG, JFL, ACL, LL, SPM, DPM, FMS, LMR, MCR, RJS, PS, TS, JRSW, RPY, SHMB. The following authors took part in the Delphi exercise for mammals: FCB, LM, TMB, MH, PJKM, ASLR, CR, JC, MFC, CRD, DOF, CNJ, RJK, SRBK, JFL, DPM, EM, ARP, TJR, NSR, LR, EVD, PV, JCZW, RPY, SHMB. All authors reviewed and commented on the draft manuscript and approved the final text. This study also benefited from the input of external experts who reviewed and corrected when needed the information compiled for each candidate species. They are listed in the acknowledgements.

Ethics Statement

This research has been granted approval by the Newcastle University Ethics Committee (Reference 15388/2018).

Data Accessibility Statement

All code and data can be found at http://github.com/rbolam/Prevented_bird_and_mammal_extinctions.

Conflict of Interest

The authors declare no conflict of interests.

References

Akçakaya, H.R., Keith, D.A., Burgman, M., Butchart, S.H., Hoffmann, M., Regan, ... Boakes, E. (2017). Inferring extinctions III: A cost-benefit framework for listing extinct species. *Biological Conservation, 214*, 336-342. *doi:* 10.1016/j.biocon.2017.07.027

Akçakaya, H.R., Bennett, E.L., Brooks, T.M., Grace, M.K., Heath, A., Hedges, S., ... Mallon, D.P. (2018). Quantifying species recovery and conservation success to develop an IUCN Green List of Species. *Conservation Biology, 32*(5), 1128-1138. *doi:* 10.1111/cobi.13112

373 BirdLife International (2017). Apteryx rowi. The IUCN Red List of Threatened Species 2017:
374 e.T22732871A119169794. Retrieved 05/02/2020 from
375 https://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T22732871A119169794.en

376 BirdLife International (2019). Hypotaenidia owstoni. The IUCN Red List of Threatened Species 2019:
377 e.T22692441A156506469. Retrieved 10/02/2020 from
378 https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T22692441A156506469.en

379 Butchart, S.H., Stattersfield, A.J. and Collar, N.J. (2006). How many bird extinctions have we
380 prevented? *Oryx, 40*(3), 266-278. *doi:* 10.1017/S0030605306000950

381 Butchart, S. H. M., Akçakaya, H. R., Chanson, J., Baillie, J. E. M., Collen, B., Quader, S., ... Mace, G. M.
382 (2007) Improvements to the Red List Index. *PLoS ONE 2*: e140. *doi:*
383 10.1371/journal.pone.0000140

384 Butchart, S.H., Lowe, S., Martin, R.W., Symes, A., Westrip, J.R. and Wheatley, H. (2018). Which bird
385 species have gone extinct? A novel quantitative classification approach. *Biological Conservation,*
386 *227*, 9-18. *doi:* https://doi.org/10.1016/j.biocon.2018.08.014

387 CBD (2014). Global Biodiversity Outlook 4. Montréal, 155 pages.

388 Diamond, I.R., Grant, R.C., Feldman, B.M., Pencharz,P.B., Ling, S.C., Moore, A.M. & Wales, P.W.
389 (2014). Defining consensus: a systematic review recommends methodologic criteria for reporting
390 of Delphi studies. *Journal of Clinical Epidemiology, 67*, 401–409. *doi:*
391 10.1016/j.jclinepi.2013.12.002

392 Díaz, S., Settele, J., Brondízio, E.S., Ngo, H.T., Agard, J., Arneth, A., ... Garibaldi, L.A. (2019). Pervasive
393 human-driven decline of life on Earth points to the need for transformative change. *Science,*
394 *366*(6471). *doi:* 10.1126/science.aax3100

395 Gascon, C., Brooks, T.M., Contreras-MacBeath, T., Heard, N., Konstant, W., Lamoreux, J., ... Al
396 Mubarak, R.K. (2015). The importance and benefits of species. *Current Biology, 25*(10), R431-
397 R438. *doi:* 10.1016/j.cub.2015.03.041

398 Hemming, V., Burgman, M.A., Hanea, A.M., McBride, M.F. and Wintle, B.C. (2018). A practical guide
399 to structured expert elicitation using the IDEA protocol. *Methods in Ecology and Evolution, 9*(1),
400 169-180. *doi:* 10.1111/2041-210X.12857

401 Hoffmann, M., Hilton-Taylor, C., Angulo, A., Böhm, M., Brooks, T. M., Butchart, S. H. M., … Stuart, S.
402 N. (2010). The impact of conservation on the status of the world's vertebrates. *Science 330*,
403 1503-1509. *doi:* 10.1126/science.1194442

404 Hoffmann, M., Belant, J.L., Chanson, J.S., Cox, N.A., Lamoreux, J., Rodrigues, A.S., … Stuart, S.N.
405 (2011). The changing fates of the world's mammals. *Philosophical Transactions of the Royal*
406 *Society B: Biological Sciences, 366*(1578), 2598-2610. *doi:* 10.1098/rstb.2011.0116

407 Hoffmann, M., Duckworth, J.W., Holmes, K., Mallon, D.P., Rodrigues, A.S. and Stuart, S.N. (2015). The
408 difference conservation makes to extinction risk of the world's ungulates. *Conservation Biology,*
409 *29*(5), 1303-1313. *doi:* 10.1111/cobi.12519

410 IPBES (2019): Summary for policymakers of the global assessment report on biodiversity and
411 ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and
412 Ecosystem Services. S. Díaz, J. Settele, E. S. Brondízio E.S., H. T. Ngo, M. Guèze, J. Agard, A.
413 Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J.

Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany. 56 pages.

IUCN (2019). The IUCN Red List of Threatened Species. Version 2019-1. Retrieved 24/01/2019 from https://www.iucnredlist.org

IUCN (2020). The IUCN Red List of Threatened Species. Version 2020-2. Retrieved 03/08/2020 from https://www.iucnredlist.org

Jaramillo-Legorreta, A.M., Cardenas-Hinojosa, G., Nieto-Garcia, E., Rojas-Bracho, L., Thomas, L., Ver Hoef, J.M., … Tregenza, N. (2019). Decline towards extinction of Mexico's vaquita porpoise (Phocoena sinus). *Royal Society open science, 6*(7), 190598. *doi:* 10.1098/rsos.190598

Keith, D.A., Butchart, S.H., Regan, H.M., Harrison, I., Akçakaya, H.R., Solow, A.R. and Burgman, M.A. (2017). Inferring extinctions I: A structured method using information on threats. *Biological Conservation, 214*, 320-327. *doi:* 10.1016/j.biocon.2017.07.026

Knol, A.B., Slottje, P., van der Sluijs, J.P. and Lebret, E. (2010). The use of expert elicitation in environmental health impact assessment: a seven step procedure. *Environmental Health, 9*(1), 19. *doi:* 10.1186/1476-069X-9-19

Martin, T.G., Burgman, M.A., Fidler, F., Kuhnert, P.M., Low-Choy, S., McBride, M. and Mengersen, K. (2012). Eliciting expert knowledge in conservation science. *Conservation Biology, 26*(1), 29-38. *doi:* 10.1111/j.1523-1739.2011.01806.x

Morgan, M.G. (2014). Use (and abuse) of expert elicitation in support of decision making for public policy. *Proceedings of the National Academy of Sciences, 111*(20), 7176-7184. *doi:* 10.1073/pnas.1319946111

Mukherjee, N., Huge, J., Sutherland, W.J., McNeill, J., Van Opstal, M., Dahdouh-Guebas, F. and Koedam, N. (2015). The Delphi technique in ecology and biological conservation: applications and guidelines. *Methods in Ecology and Evolution, 6*(9), 1097-1109. *doi:* 10.1111/2041-210X.12387

Pacifici, M., Santini, L., Di Marco, M., Baisero, D., Francucci, L., Marasini, G.G., … Rondinini, C. (2013). Generation length for mammals. *Nature Conservation, 5*, 89. *doi:* 10.3897/natureconservation.5.5734

Salafsky, N., Salzer, D., Stattersfield, A.J., Hilton-Taylor, C., Neugarten, R., Butchart, S.H.M., … Wilkie, D. (2008). A standard lexicon for biodiversity conservation: unified classifications of threats and actions. *Conservation Biology, 22*(4), 897-911. *doi:* 10.1111/j.1523-1739.2008.00937.x

Szabo, J.K., Butchart, S.H., Possingham, H.P. and Garnett, S.T. (2012). Adapting global biodiversity indicators to the national scale: A Red List Index for Australian birds. *Biological Conservation, 148*(1), 61-68. *doi:* 10.1016/j.biocon.2012.01.062

Timmins, R.J., Hedges, S. & Robichaud, W. (2016). Pseudoryx nghetinhensis. The IUCN Red List of Threatened Species 2016: e.T18597A46364962. Retrieved 30/01/2020 from https://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T18597A46364962.en

von der Gracht, H.A. (2012). Consensus measurement in Delphi studies. Review and implications for future quality assurance. *Technological Forecasting and Social Change, 79*, 1525–1536. *doi:* 10.1016/j.techfore.2012.04.013

455 Young, R.P., Hudson, M.A., Terry, A.M.R., Jones, C.G., Lewis, R.E., Tatayah, V., ... Butchart, S.H.M.
456 (2014). Accounting for conservation: Using the IUCN Red List Index to evaluate the impact of a
457 conservation organization. *Biological Conservation, 180*, 84-96. *doi:*
458 10.1016/j.biocon.2014.09.039

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Figures

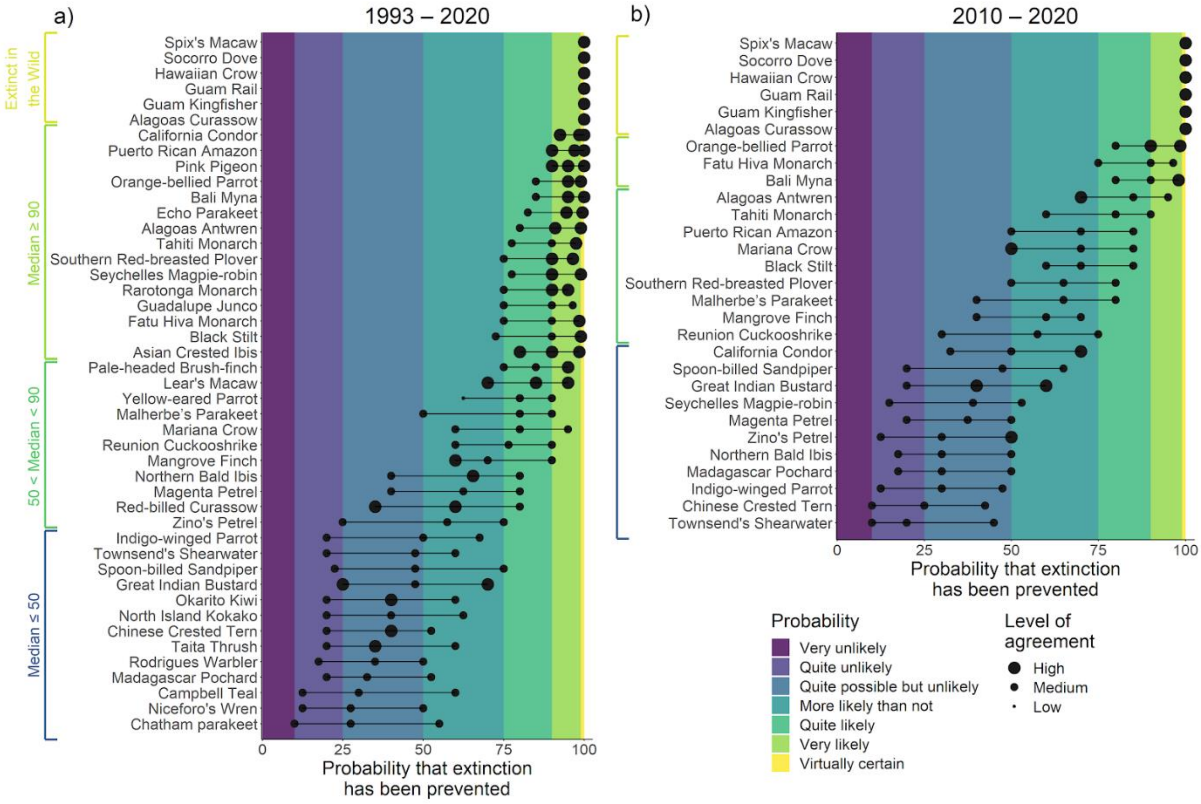
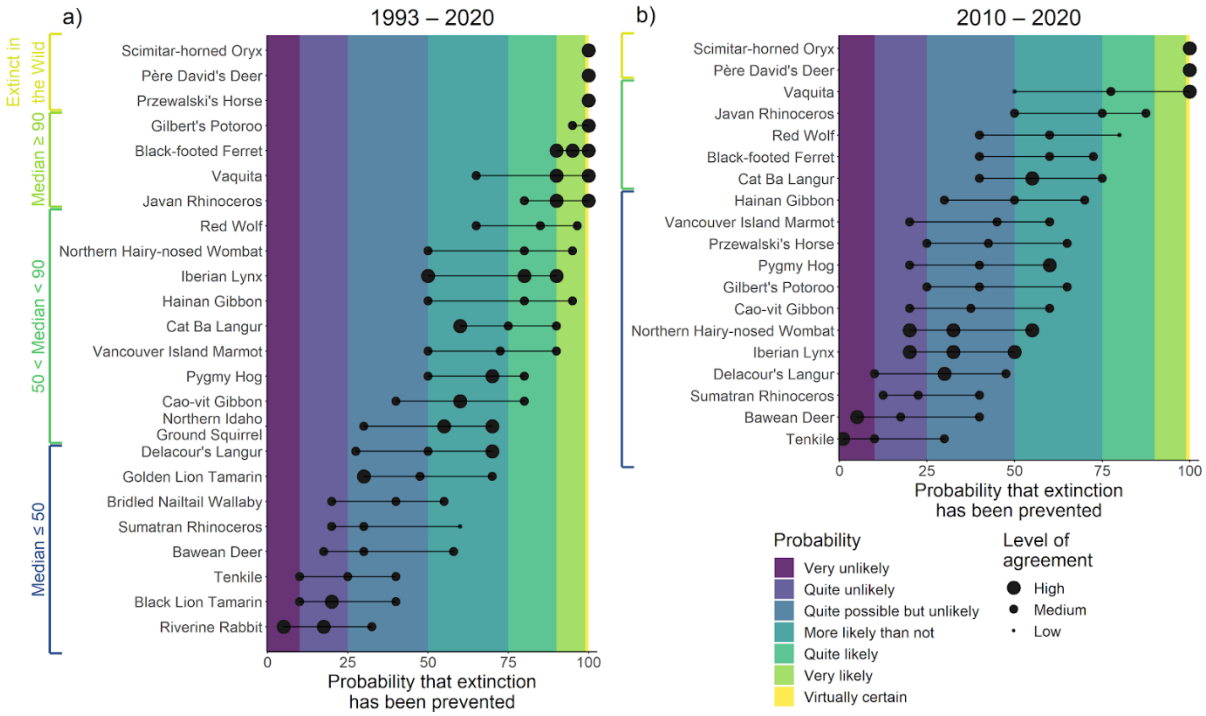


Figure 1. Probability that extinction of bird species would have occurred in the absence of conservation action during (a) 1993-2020 (N = 45 species) and (b) 2010-2020 (N = 29 species). Values represent medians calculated from estimates by 28 evaluators, except for species that are Extinct in the Wild, where it was set at 100%. For a description of the probability categories see Table S1, based on Keith et al. (2017). Guam Rail was assessed as Extinct in the Wild until 2016, but was reintroduced and assessed as Critically Endangered by 2019 (BirdLife International, 2020). We therefore set its probability to 100% for both time periods.



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470 **Figure 2.** Probability that extinction of mammal species would have occurred in the absence of
471 conservation action during (a) 1993-2020 (N = 24 species) and (b) 2010-2020 (N = 19 species). Values
472 represent medians calculated from estimates by 26 evaluators, except for species that are Extinct in
473 the Wild, where it was set at 100%. For a description of the probability categories see Table S1,
474 based on Keith et al. (2017). Przewalski's Horse was assessed as Extinct in the Wild in 1996, but was
475 reintroduced and assessed as Critically Endangered by 2008. We therefore set its probability to 100%
476 for 1993-2020, but asked evaluators to score for 2010-2020.

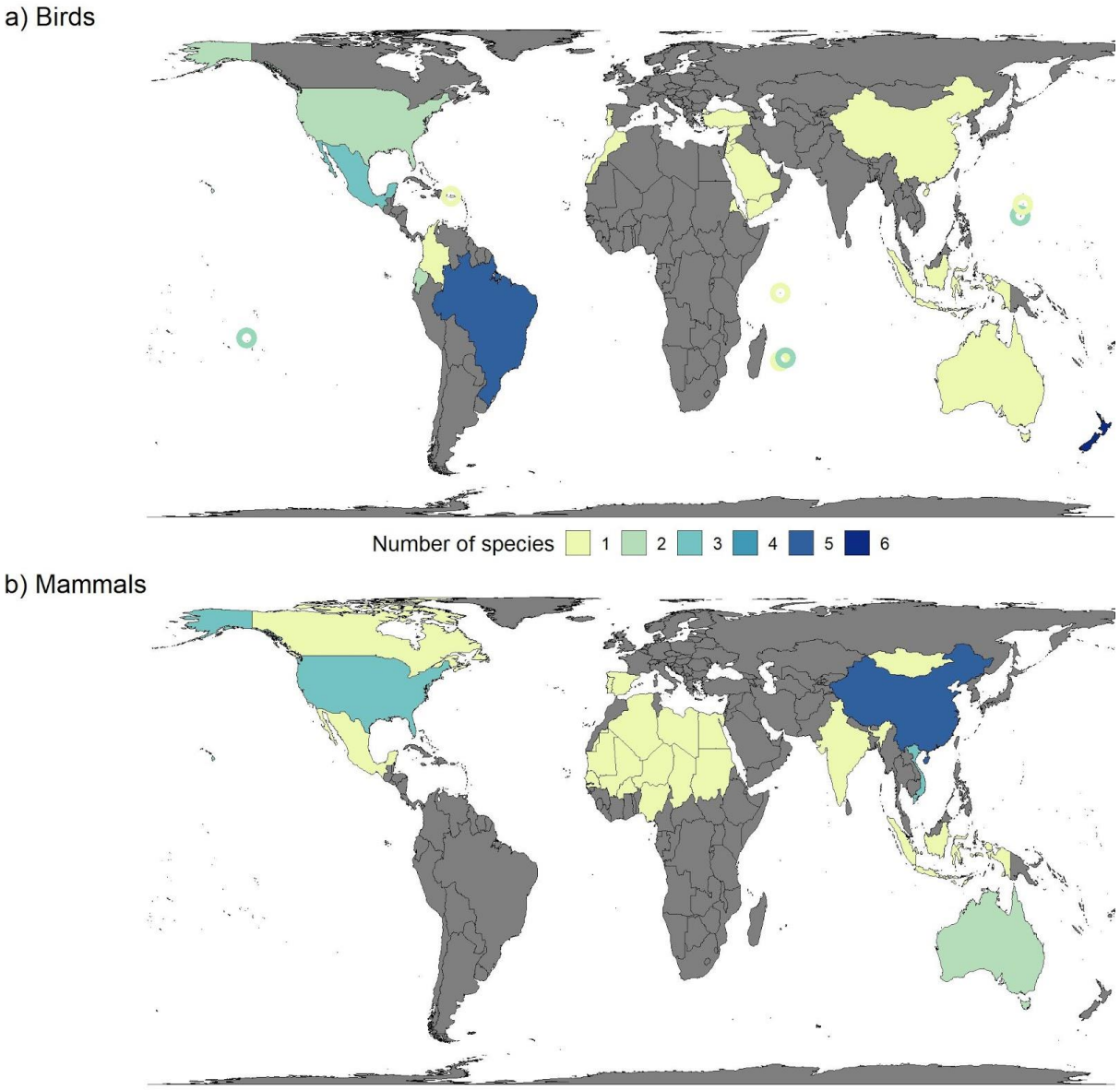
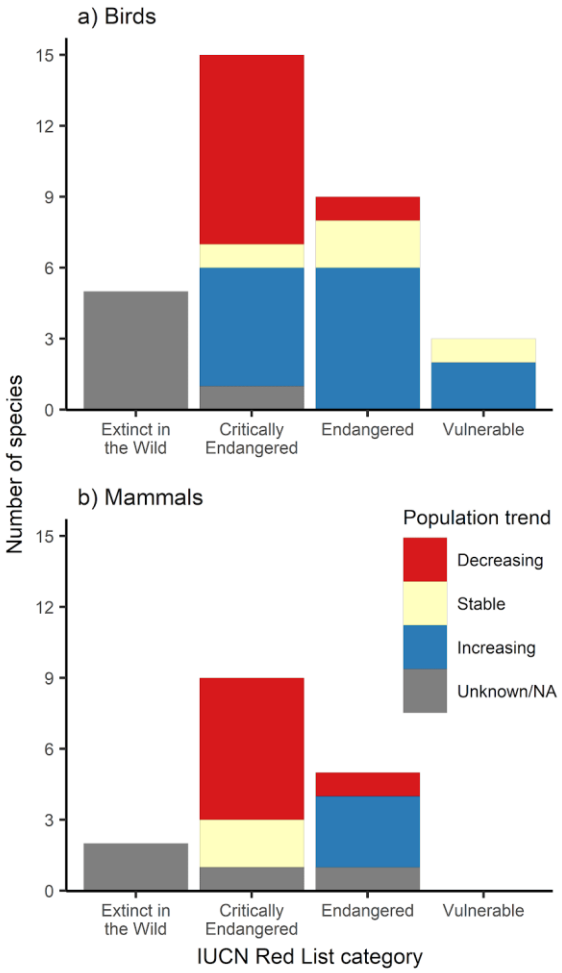


Figure 3. Number of (a) bird (N = 32) and (b) mammal (N = 16) species for which extinction is likely to have occurred (i.e. median probability >50%) in the absence of conservation action during 1993-2020, per country. Circles show small island nations and overseas territories, and are coloured according to the key. Species listed as Extinct in the Wild (IUCN, 2020) were mapped in the last countries where they occurred, or are presumed to have occurred.



483

484 **Figure 4.** 2019 IUCN Red List categories and population trends of (a) bird (N = 32) and (b) mammal (N
485 = 16) species for which extinction is judged to have been likely (i.e. median probability >50%) to have
486 occurred in the absence of conservation action, during 1993-2020.

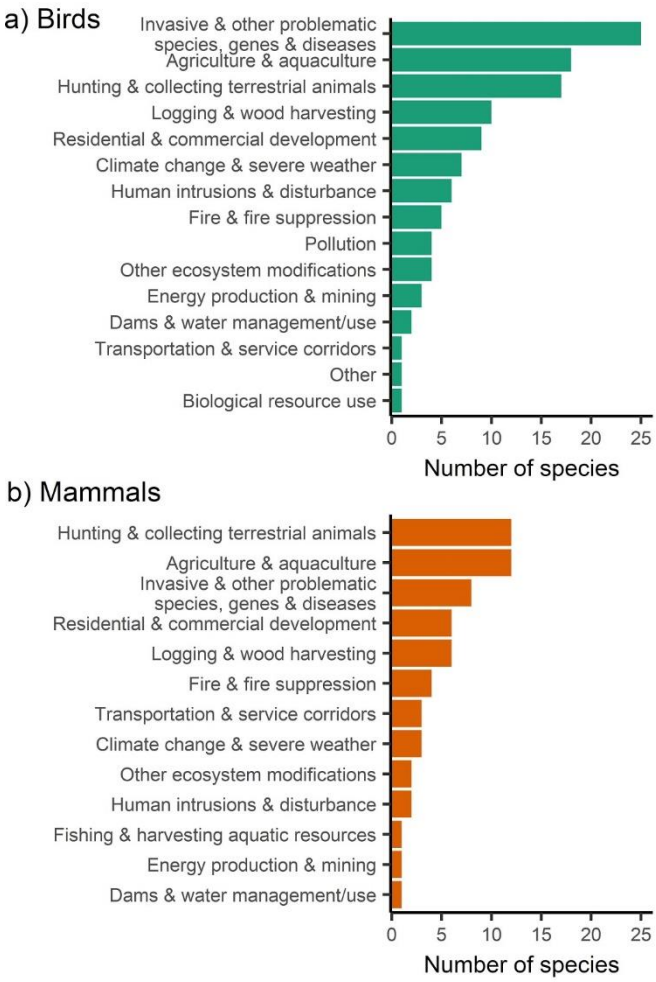
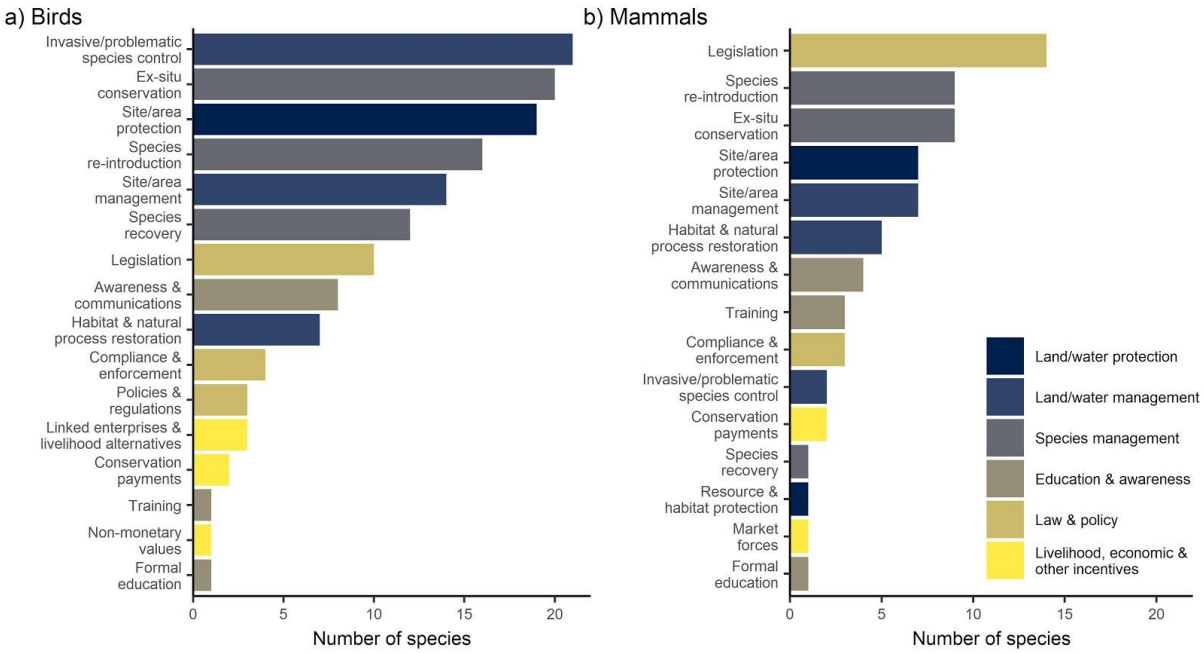


Figure 5. Current and past threats to (a) bird (N = 32) and (b) mammal (N = 16) species for which extinction is judged to have been likely (i.e. median probability >50%) to have occurred in the absence of conservation action during 1993-2020. Threats are taken from the IUCN threat classification scheme level 1 (Salafsky et al., 2008).



493

494 **Figure 6.** Conservation actions for (a) bird (N = 32) and (b) mammal (N = 16) species for which
495 extinction is judged to have been likely (i.e. median probability >50%) to have occurred in the
496 absence of conservation action during 1993-2020. Actions are taken from the IUCN action
497 classification scheme level 2, while colours denote level 1 (Salafsky et al., 2008). Both in-situ and ex-
498 situ actions are included for species that are Extinct in the Wild.