Disentangling the global drivers of species use and use-driven extinction risk

Oscar Morton[1], Sharon Baruch-Mordo[2], Chris R. Cooney[1], & David P. Edwards[3,4]

[1] Ecology and Evolutionary Biology, School of Biosciences, the University of Sheffield, S10 2TN, UK.

[2]TRAFFIC International, Cambridge, UK.

[3] Department of Plant Sciences and Centre for Global Wood Security, University of Cambridge, Cambridge, UK

[4] Conservation Research Institute, University of Cambridge, Cambridge, UK

Correspondance: o.morton@sheffield.ac.uk

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This PDF file includes:

Main Text

Figures 1 to 5

Supplementary Information (Supplementary Figures 1-33, Supplementary Tables 1-14)

Abstract

The use and trade of wild species is a cornerstone of subsistence livelihoods and global economies. Understanding which drivers of use threaten species is critical in distinguishing between beneficial sustainable exploitation and harmful overexploitation, and ensuring that conservation efforts are targeted where they are most urgently needed. We provide the first nuanced global assessment of exactly how 16,967 bird and mammal species are utilised by integrating 11 global datasets spanning trade and seizure records, case studies, expert assessments, and over 16,000 species-specific encyclopaedia entries. We find that 58% (6,358) of birds and 41% (2,439) of mammals are used by humans, primarily as pets, food, sport, ornamental products, apparel, and medicine. Avian use is best predicted by taxonomy and range size, while mammalian use is driven by body mass and demography. Using a novel, automated text-classification pipeline, we analyse expert-led conservation assessments to identify use-specific extinction risk. Specific uses are a known threat for just 3.1% (518) of extant species, with use as pets and food the primary extinction threat for birds and mammals, respectively. These results highlight that although wildlife use is nearly ubiquitous, the pool of species most impacted is relatively small. Because the intensity and nature of use-related threats evolves rapidly over time, our automated pipeline provides the essential mechanism to track this and maintain up-to-date conservation priorities. Integrating targeted understanding of how species are used – and when this poses a threat – is critical to meeting global aspirations for the safe and sustainable use of wild species.

Significance statement

We present the first nuanced use-specific understanding of species exploitation for pets, food, sport, ornamental products, apparel, and medicine. A total of 58% of birds and 41% of mammals are used, predominantly for pets and food, and food and sport, respectively. Using a novel text classification pipeline interpreting tens of thousands of sentences of expert-led conservation assessment, we find that only 3.1% (518) of all extant birds and mammals are threatened by a specific use. This insight is critical in ensuring policy moves beyond broad trade bans and targets the precise drivers of decline. By distinguishing currently benign use from overexploitation, we provide a scalable roadmap for safe and sustainable wildlife use.

Main text

Introduction

The hunting and use of species is an essential component of the benefits humans derive from nature[1]. In some cases, benefits are driven by a reliance on the natural world for protein or livelihood subsistence[2,3], cultural norms, or the preservation of traditional practices [4]. These range from the local aesthetic use of individual turaco feathers in communities from West Africa and the highlands of Cameroon to denote social position or distinction[5,6], to the sport hunting and harvest of approximately 18 million wildfowl in the United States annually[7]. In other cases, benefits are heavily commercialised, with almost a quarter of terrestrial vertebrates commercially traded[8] and more than 2.8 billion organisms being moved for trade over a 22-year period[9]. When poorly managed, any facet and purpose of use has the potential to threaten species and drive population declines[10–14]. However, when well-managed, the sustainable use of species is a key tool to incentivise conservation and generate income[15,16].

The large human ecological niche, coupled with diverse interconnected global markets, results in a vast breadth and diversity of our use of biodiversity, spanning scales and drivers[17,18]. Despite global efforts to quantify the litany of species commercially traded or used for subsistence[8,19,20], we still have critical gaps in understanding how the majority of species are specifically used. Current understanding operates predominantly at a coarse level, for example, indicating whether a species has simply been recorded (alive or dead) in commercial trade[8]. This tells us little about the true motivations or actual use of the species, with many live-traded species destined for use as products (e.g. oriental rat snake *Ptyas mucosa*, exported live from Indonesia for the skin and leather trade[21]). Consequently, our understanding of species traits in use is likely confounded and potentially misleading when looking across such a diversity of uses simultaneously [8,22,23].

How we use species is a critical aspect of the ongoing biodiversity crisis, with both a role as a key threat or solution[24]. Working towards the sustainable use of biodiversity for the benefit of nature and people is enshrined in multiple global frameworks, including Target 5 of the Kunming Montreal Global Biodiversity Framework (KM-GBF) and multiple articles of the Convention on Biological Diversity[25,26]. Recent work suggests that up to 29% of threatened or near-threatened used species are likely experiencing some level of overexploitation[27], with international demand identified as likely driving threat to 2211 species[28]. Yet little progress has been made in identifying what species-specific uses are actually driving threats, limiting mechanistic understanding of how humankind is exploiting and threatening global biodiversity, and in turn the planning of effective conservation interventions where use threatens species[29]. Until we can disentangle the specific motivations behind species use, our ability to mitigate the threat overexploitation poses remains blunt. Achieving sustainable use for people and species requires a transition from observing or documenting species in use and trade to understanding exactly how they are used and disentangling the distinction between examples of sustainable use and those directly driving elevated extinction risk.

Leveraging a series of vast global datasets of species use and trade, including novel online encyclopaedia data, detailed ecological and morphological trait databases, and expert-led conservation assessments, we compile the first truly global and nuanced assessment of species use for birds and mammals. We then leverage this to address three core aims: (1) understand how and where species are used globally; (2) determine which intrinsic traits and extrinsic environmental variables are predictive of how we use species; and (3) quantify the extent to which specific uses contribute to species extinction risk as part of a reproducible pipeline.

Results

Diverging patterns of species use across taxonomy and space

We drew on 11 key global data sources, encompassing legal trade, illegal trade, seizure reports, libraries of case studies, >16,000 species Wikipedia pages, field data and market records of wildlife use (see Methods), totalling more than 6.7 million trade or use records. Overall, we find evidence for 6358 bird (of 11021 extant species; 57.7%) and 2439 mammal (of 5946 species; 41.0%) species being used by people in some form (Supplementary Figure 1). Of these, we can attribute at least one known use to 6785 species, leaving 2012 species (22.9% of used species) being recorded as used but without documented end-uses. Birds are most commonly used as pets (4187 species, 38.0%), food (1708 spp., 15.5%), or hunted for sport and recreation (1148 spp., 10.4%; Figure 1a). Conversely, in mammals, use as food dominates (1429 spp., 24.0%) with far fewer species used for sport hunting (502 spp., 8.4%), apparel (453 spp., 7.6%, e.g. fur or leather-bearing species), or as pets (374 spp., 6.3%, Figure 1b).

Use varied distinctly across taxonomic families (Figure 1c, d). Most species used as pets were Passeriformes (perching birds; 1990 sp., 30.0%) and Primates (202 sp. 38.5%), but the highest percentage of species used as pets were in the Psittaciformes (parrots; 367 sp., 90.6%), Anseriformes (waterfowl; 140 sp., 82.4%), and Accipitriformes (most diurnal birds of prey; 204 sp., 81.3%). Conversely, Galliformes (land fowl; 246 sp. 79.9%), Anseriformes (119 sp. 70.0%) and Columbiformes (pigeons and doves; 179 sp., 50.8%) had the highest proportion of species used for food. In mammals, high numbers of Primates (353 sp., 67.2%), Artiodactyls (even-toed ungulates; 276 sp., 84.1%), and Rodents (246 sp., 10.5%) were utilised for food. Hunting for sport was proportionately confined to the Anseriformes (136 sp. 80.0%), Artiodactyls (175 sp., 53.6%), and Carnivora (111 sp., 38.1%). Use for clothing and apparel was similarly largely restricted to Carnivora (153 sp., 52.6%) and Artiodactyls (118 sp., 36.0%).

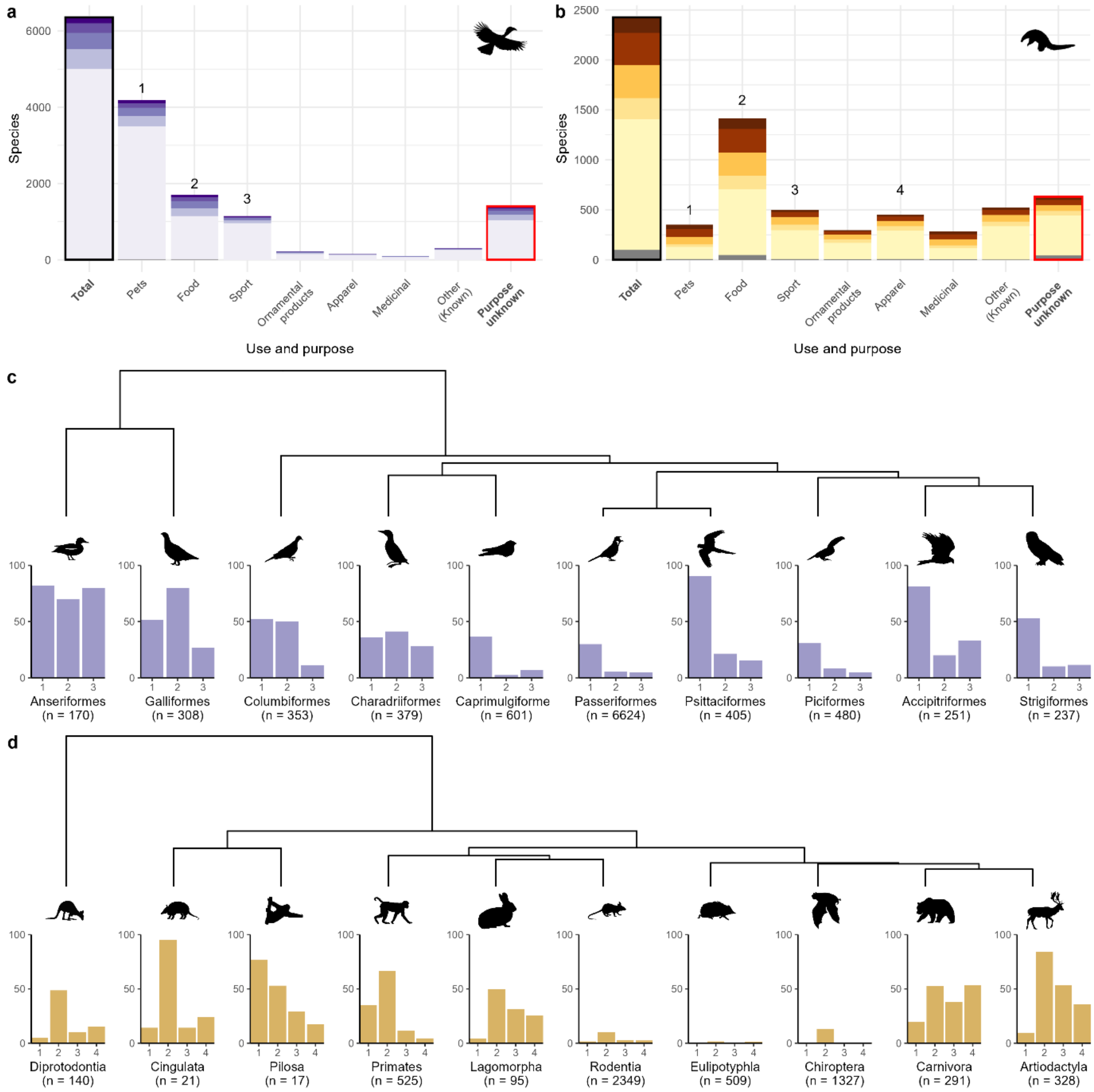

Figure 1. Human uses of all extant birds and mammals. Summary of the number of birds (a) and mammals (b) used for each purpose. Use across the 10 most speciose clades for the top 3 uses for birds (1 – pets, 2 - food and 3 - sport), (c) and the top 4 uses for mammals (1 – pets, 2 – food, 3 – sport and 4 - apparel) (d). Bar colours denote species IUCN Red List assessments (grey - DD, and increasingly dark purple and orange shades show the number of LC, NT, VU, EN and CR species respectively). Black and red borders were added to emphasise the overall total tally of used species and used species without discernible end purposes, respectively. Silhouettes from public domain images from https://www.phylopic.org/.

Hotspots of species occurrence vary substantially across uses (Figure 2), highlighting previously obscured use-specific hotspots in North America and across Eurasia. Hotspots for both bird and mammal species used as pets are centred across the Amazon basin, India, and Southeast Asia (Figure 2a). These encompass a highly diverse array of species from the small, highly threatened, but abundantly captive-bred Java Sparrow (*Padda oryzivora*), to the larger Red-cheeked Gibbon (*Nomascus gabriellae*), which is illicitly trapped to satisfy demand from private collections and zoos[30]. Species used for food showed a similar tropical bias with additional avian hotpots across Northern Eurasia, reflecting the occasional hunting of breeding and migrating waders across Asia and Eastern Russia, such as Spoon-billed Sandpiper (*Calidris pygmaea*), Black-tailed Godwit (*Limosa limosa*), and Far Eastern Curlew (*Numenius madagascariensis*). Sport hunting was predominantly centred across the African continent, with additional avian and mammalian hotspots in North America and eastern Europe and Russia, respectively (Figure 2c). Ornamental use for both birds and mammals encompassed a much-reduced species pool, with species use being highly culture-specific and localised, reflected in the disparate and scattered hotspots across North America, Europe, West Africa and Australasia (Figure 2d). Species use for apparel was similarly disparate, encompassing waterfowl across northern Europe (e.g. for down filling) and the use of fur and leather-bearing mammals across South and North America(Figure 2e). Medicinal use for both taxa was largely centred on central and West Africa, Indochina, and across Southeast Asia (Figure 2f), reflecting known hotspots of medicinal use for highly threatened species including White-backed Vulture (*Gyps africanus*), Greater One-horned Rhino (*Rhinoceros unicornis*), and Giant Ground Pangolin (*Smutsia gigantea*).

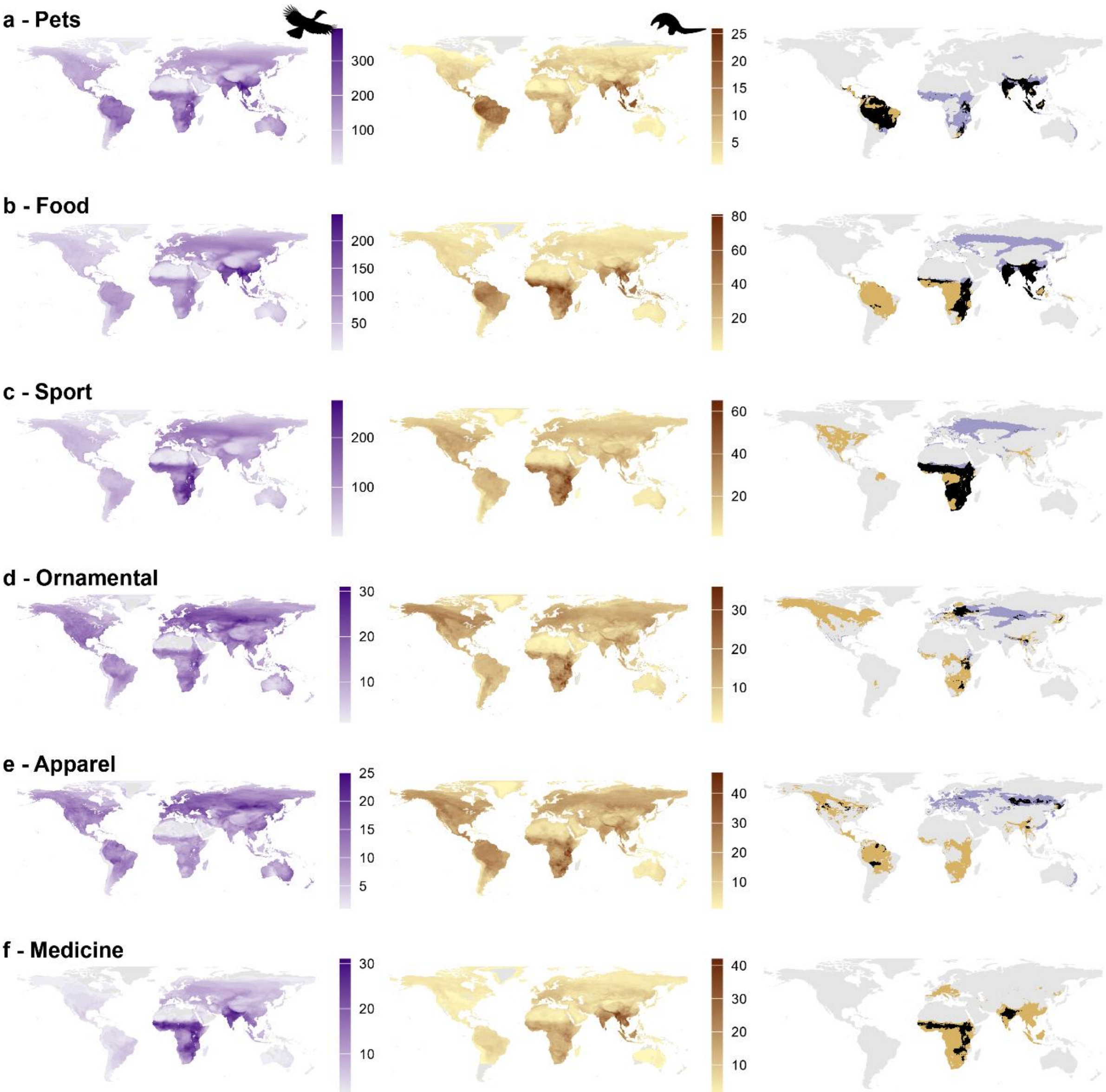

Figure 2. Distribution of species use across space. Species richness for birds used as pets (leftmost plot), for mammals used as pets (centre plot) and hotspots of use as pets for birds and mammals (rightmost plot) (a). Hotspots are defined as cells containing values equal to or greater than the top 5% quantile for birds and mammals individually. Bird hotspots are shown in lilac, and mammal hotspots are shown in brown, areas common to both taxa are shown in black. b – f repeats this for use as food (human consumption), sport, ornamental or decorative use, clothing or apparel, and medicine. See Supplementary Figure 2 and 3 for maps of all used species, and those without known uses, respectively.

Environmental and ecological traits predict species use

The use of birds as food, pets and for sport hunting was moderately to highly predictable (Cohen's kappa = 0.66, 0.65 and 0.53, Figure 3) as a function of >50 taxonomic, demographic, ecological, and environmental variables, whereas use for aesthetic, ornamental, or medicinal purposes was considerably less predictable (Supplementary Table S3). Broadly, a combination of distribution features (e.g. range latitude, area, region) and intrinsic traits, including size and dietary traits, were the most important predictors of use in birds (Figure 3).

In birds, consumption as food was best predicted by taxonomic order and range size, with a relative preference for Galliformes and a preference against Passeriformes (Figure 3a, b). Conversely, use as pets was most strongly predicted by larger ranges, greater beak depth, and herbivory (Figure 3c, d). The presence of specific colours and species' colour diversity had relatively low importance, despite certain colours being particularly prevalent in some trade databases[22,31]. Similarly, sport hunting was best predicted by larger ranges, generally more northern range centroids, and larger body sizes (Figure 3e, f).

In mammals, all uses apart from medicinal were at least moderately predictable (kappa 0.50 – 0.76, Supplementary Table S3, Figure 4). Broadly, intrinsic traits encompassing mass and demography were most predictive of use, with distribution-based characteristics having a much-reduced influence (Figure 4). Consumption as food was most strongly predicted by increasing body mass and longevity (Figure 4a, b). Increasing body mass was also highly predictive for sport hunting (Figure 4c, d), use as apparel (Figure 4e, f) and as pets (Figure 4g, h). Specific taxonomic families were also highly predictive, with preferences for Artiodactyls for sport hunting and Primates as pets, reflecting the extensive history of known use within these taxa (Figure 4).

For used species lacking documented or inferable end-use (1326 birds and 564 mammals with complete modelling data), we were able to predict at least one likely end-use for 561 (42.4%) bird and 111 (18.7%) mammal species (Supplementary Figure 4). For birds, these were predominantly common species likely used as food or pets (Supplementary Figure 4a-c), and for mammals, primarily likely used for food (Supplementary Figure 4d-g). Species without any inferable or predictable use are most likely those that are infrequently traded and thus are distinct from most utilised species.

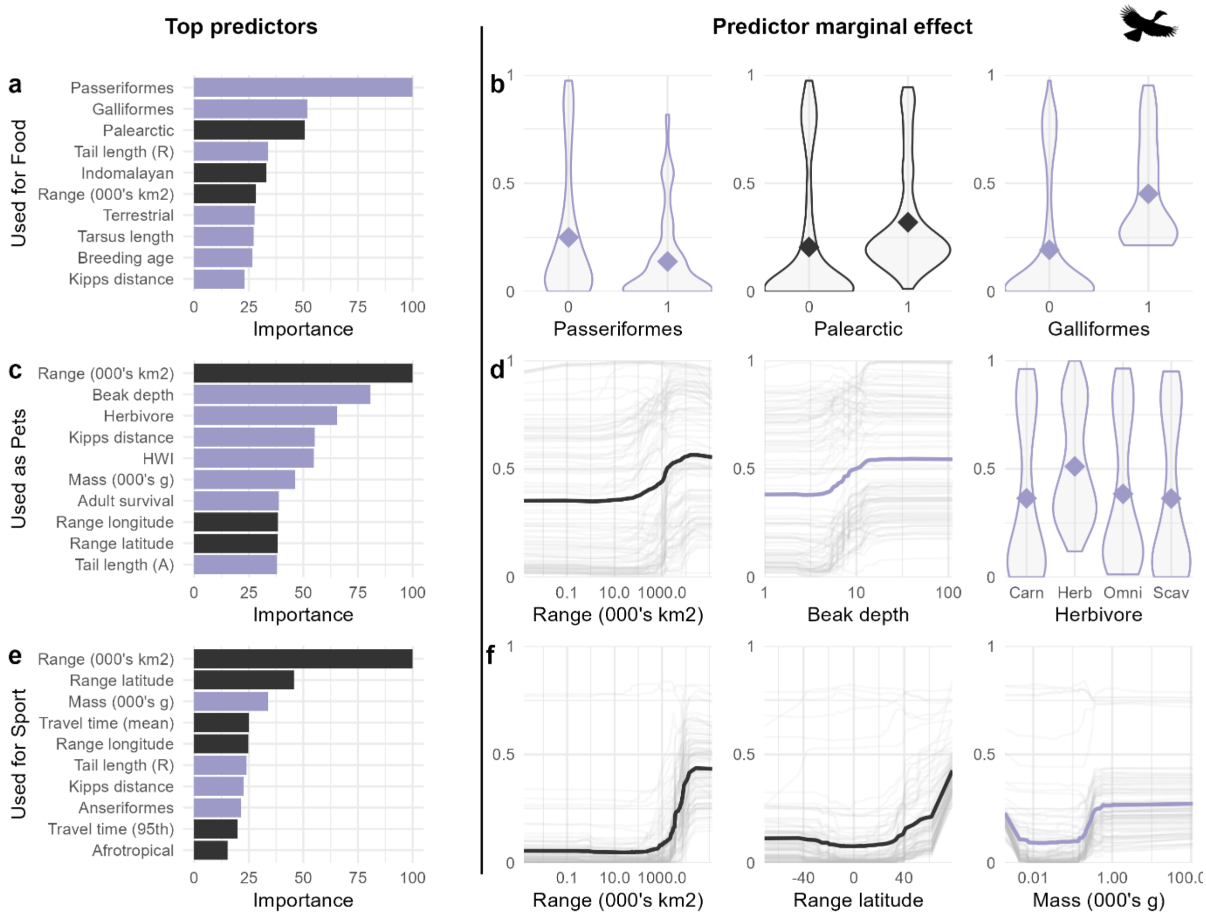

Figure 3. Ecological and environmental predictors of the top 3 uses for birds. Variable importance plots of the 10 most important predictors of species use as food (a), with partial dependency plots shown for the three most important variables (b). The same is shown for use as pets (c, d) and sport hunting (e, f). In the partial dependency plots the central bold line denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black). Partial dependency plots for all variables are shown in Supplementary Figures 5-16.

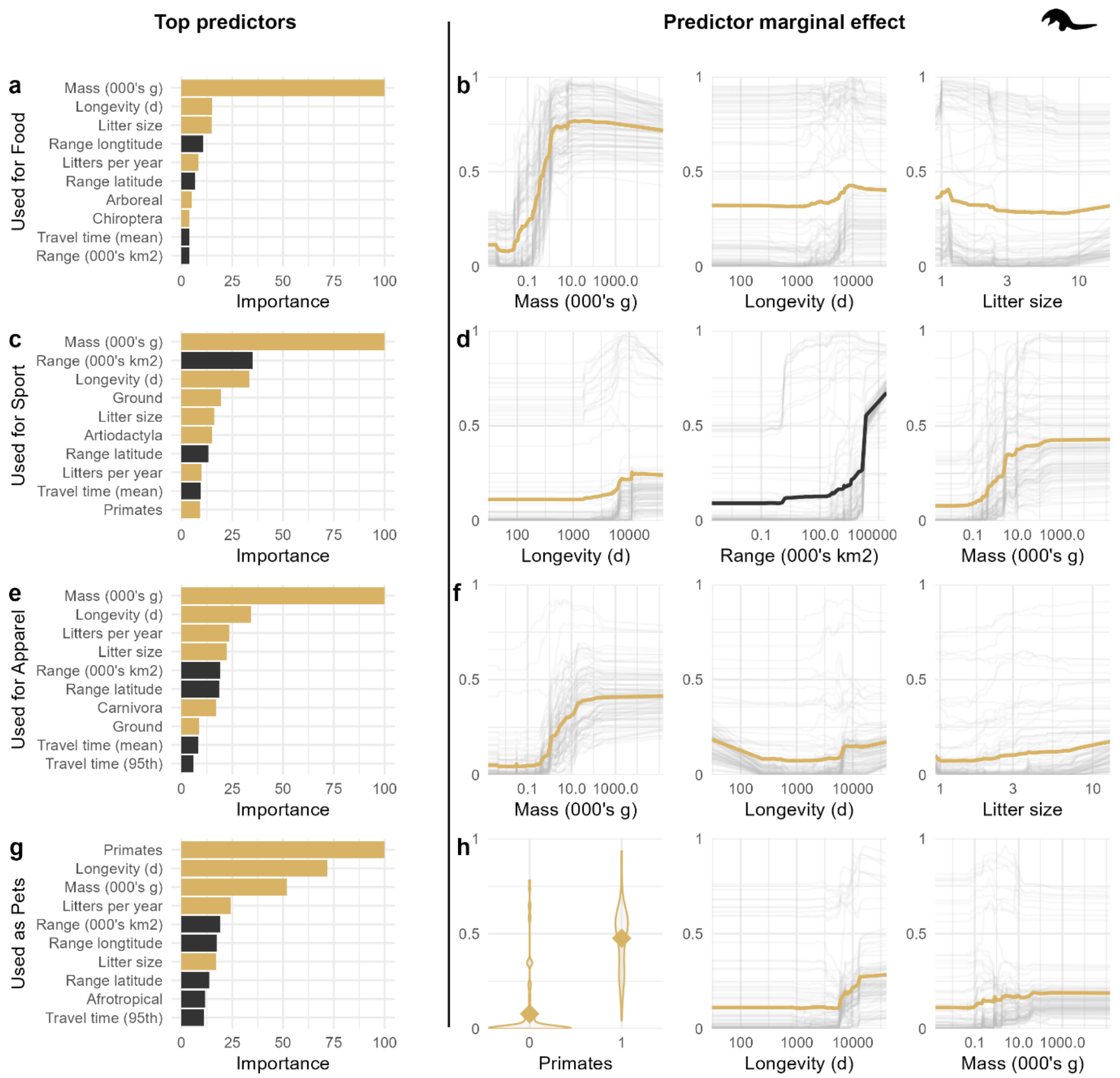

Figure 4. Ecological and environmental predictors of the top 3 uses for mammals. Variable importance plots of the 10 most important predictors of species use as food (a), with partial dependency plots shown for the three most important variables (b). The same is shown for use in sport hunting (c, d), as apparel or clothing (e, f) and as pets (g, h). In the partial dependency plots the central bold line denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and denote the heterogeneity around the average. Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black). Partial dependency plots for all variables are shown in Supplementary Figures 17-31.

Identifying specific uses as drivers of threat

For 1558 near threatened or globally threatened species with Biological Resource Use listed as a current threat as per the IUCN Red List (Figure 5a), we applied a novel automated rule-based approach that searched >39,000 sentences of expert-led Red List assessment text using >20,000 flexible word and phrase combinations to assess if specific end-uses of wildlife are known to be negatively contributing to species populations or driving threat (see Methods).

Testing this rule-based text classifier against manually classified subsets revealed a very high level of agreement across uses and categories (Supplementary Table S4). Overall, we find strong evidence explicitly linking specific uses to threat or negative impacts for 3.1% of extant bird and mammal species (518 of 16,961).

In birds, use as a pet was highly likely to threaten the greatest number and proportion of species, with 140 species (28.4%) likely adversely impacted by the pet trade (Figure 5a). This is followed by use for food, which was highly likely to be a driver of threat for 69 species (14.7%) (Figure 5a). For mammals, a greater proportion of end-uses could be explicitly linked to drivers of threat (Figure 5b). With the most prominent uses likely driving threat being collection for the pet trade (n = 88, 40.0%), consumption (n = 241, 37.4%) and medicinal use (n = 55, 37.4%). Across taxa, the use of species for ornamentation or apparel was rarely a likely driver of threat (Figure 5). Previous work has highlighted much of Southeast Asia as a key overexploitation hotspot[12,32,33], our findings confirm this, particularly for species used as pets, food or medicinal products (Supplementary Figure 1). Additionally, we highlight hotspots of threat from the pet trade across Central and South America, from hunting for food in the Amazon basin and central and west Africa, and for species used for medicinal products, particularly across sub-Saharan Africa and much of Asia (Supplementary Figure 32).

For many species, it was impossible to discern which specific uses were driving negative impacts, as these were often discussed solely in the context of *collection* or *trapping* without contextualising the likely purpose or end use. Likewise, 16.5% (n = 81) of birds and 33.6% (n = 74) of mammals used for pets, and 24.4% (n = 114) of birds and 24.5% (n = 159) of mammals used for food, were mentioned in the context of threats but not as specific drivers (*Potentially* threatened species, Figure 5). The scarcity of uses identified by this method as non-threatening likely reflects the focus of the Red List on direct threats. While there is progress towards incorporating the success and potential effects of conservation actions (e.g. the Green Status of Species), this remains incomplete for most species[34]. Previous approaches have used the reported scope, timing, and severity of use to infer sustainable or unsustainable use in general across species[27], but this is the first attempt to link specific end uses to expert-perceived impacts on species.

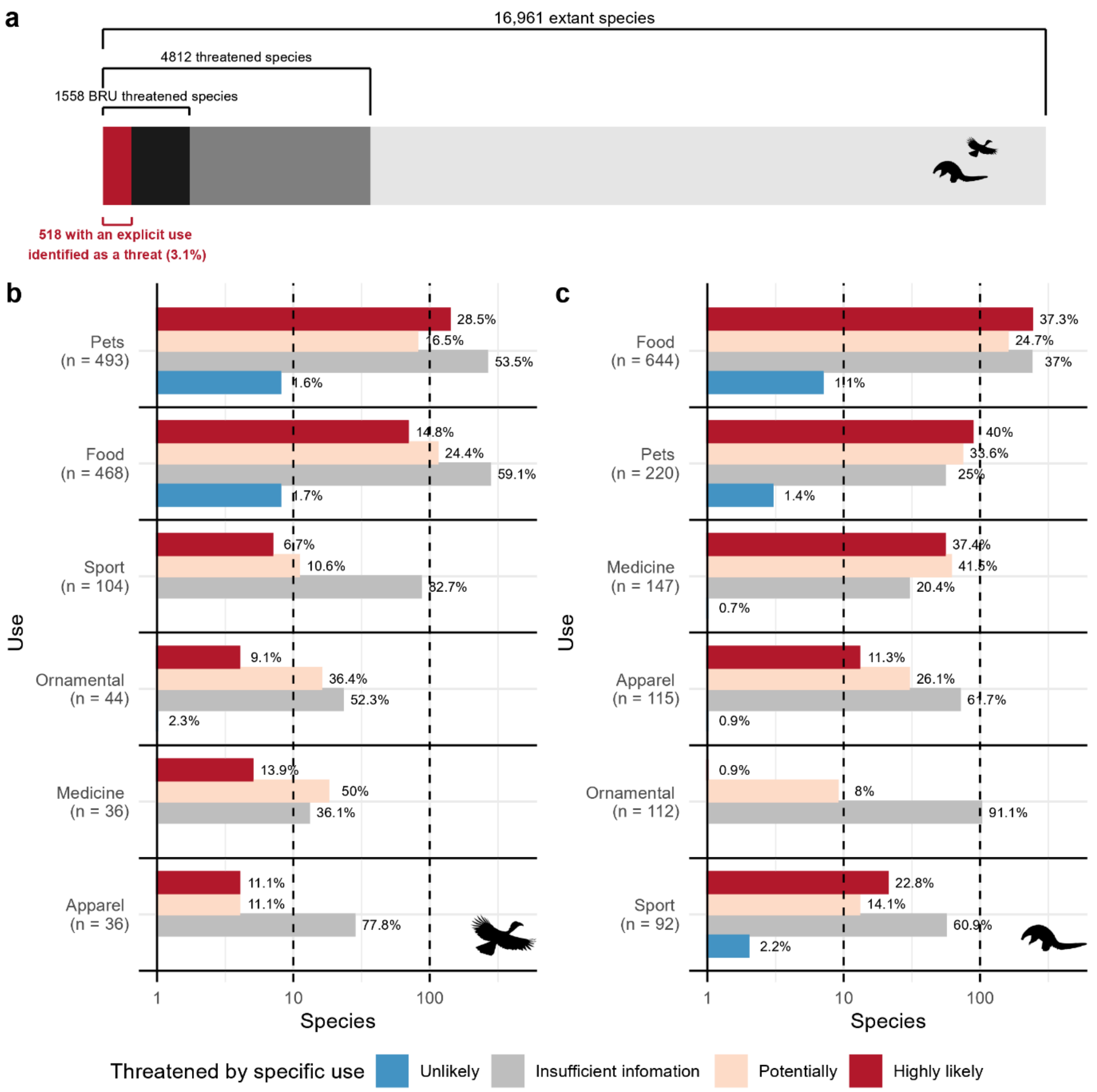

Figure 5. Evidence of use as a threat for globally threatened or near-threatened species. Summary of the number of species highly likely to be explicitly threatened by at least one known end use (a). Number of species that are "*Unlikely*", "*Potentially*", or "*Highly likely*" to be experiencing threat or negative population impacts from specific uses out of all globally threatened or near threatened species with Biological Resource Use given as a threat for birds (*n* = 798) (b) and mammals (*n* = 760) (c). Where specific uses were not explicitly discussed or it was not clear on the impact of use-species combinations are classed as "*Insufficient information*". See methods for a detailed description of the methodology.

Discussion

This study provides comprehensive evidence that more than half of all bird and mammal species are used by humans in some form. We attribute six specific use types to ~7000 species, highlighting diverse use-specific hotspots, in both the tropics [8,18,19] and in North America (sport hunting, apparel and ornamentation) and eastern Europe (apparel). Critically, specific uses are identified as driving a current threat or negative impact for only 3.1% of extant birds and mammals. This targeted understanding of use-specific threat is sorely needed to better guide holistic conservation action. Our findings also underscore that while overexploitation is a key global threat, the pool of species likely most impacted is relatively small, giving hope to bending the curve on biodiversity loss.

A suite of traits and distribution characteristics, including body mass[8,35], reproductive ecology[23,35], colouration[22,31,36], song[37], range size[19], dietary niches, and habitat preference[18] have been examined as drivers or correlates of species use and presence in trade. When studied in isolation and across all uses, clear patterns often emerge (e.g. larger-ranged, more colourful, bigger-bodied species[8,19,22]), with our study emphasising the need to incorporate use-specific nuance and multi-trait approaches when predicting species' likely uses. A further challenge for large-scale predictive or inferential studies of use and trade is the likely spatially heterogeneous mechanistic drivers of demand. Specific traits may be highly predictive of species use (e.g. as a pet), but these can be largely disconnected from the local drivers of demand in different regions[38,39].

Prior studies have assessed the threat of specific spatial scales of non-specific uses (e.g. international wildlife trade)[28], and this study links threat from specific uses from local to international scales. A challenge for future work is to coalesce these to identify both facets simultaneously. A key example of the importance of targeted understanding is seen in the conservation of Lions (*Panthera leo*). The species has recently been a focal species of multiple controversial campaigns to ban trophy hunting imports in a number of European countries[40], campaigns that ultimately succeeded in the UK, despite the impact of trophy hunting on lions having been well studied, and known to drive management-dependent positive or negative impacts[41]. Currently, a more pressing threat to the species is increasing poaching for body parts for traditional medicine[42,43], yet this receives scant media and policy attention. Of the 2511 verified species use combinations (from 1558 near or globally threatened species across up to six uses), only 25.8% (657 out of 2511) were highly likely to be driving threat to the species. Misguided policy focusing on controversial examples of use, rather than evidence-based impact assessments, risk squandering limited conservation resources at a critical point of the ongoing biodiversity crisis.

Key resources such as the IUCN Red List provide a rigorous and consistent framework for assessing typologies of threat[44]. In contrast, the same level of consistency for quantifying humanity's use of species is lacking, with key trade and use datasets all extracting different, often incomparable data[45]. Even among the Red List's own General Use and Trade Classification Scheme there are inconsistencies with how use categories are applied (e.g. overlap between apparel or ornamental use). We argue that ensuring interoperable standards to collect trade data with consistent reporting across purpose and item types is essential for developing a coherent and informed global strategy for the sustainable use of species to the benefit of people and populations[45–47]. Where taxa are less well represented in authoritative global datasets (e.g. the IUCN Red List), future efforts should similarly embrace the wealth of information captured through citizen science enterprises (e.g. Wikipedia)[48] .

Achieving global aspirations of sustainable wildlife use will require broad policy changes, but these must be based on nuanced data and evidence[49,50]. Targets 5 and 9 of the KM-GBF directly centre on the sustainable use of species, aiming to both protect populations and benefit people, but this can only be achieved through precise conservation actions reconciling the exact types of use driving population declines with the needs of those reliant on those species.

Our approaches and results can directly contribute towards this endeavour by providing a scalable and nuanced pipeline for understanding the specific drivers of threats for exploited species.

Materials and Methods

Building a database of used species end uses

We focused on birds and mammals as two taxonomic groups with the greatest coverage in key datasets, including the IUCN Red List. We combined eleven separate data sources to build the most complete assessment of species use. For clarity and to maximise the future relevance of this database, we followed the IUCN General Use and Trade Classification Scheme v1 to define types of species end use (see Supplementary Table 1). The schema classifies 18 specific end-uses, including "*Other*", "*Unknown*" and "*Ex-situ Conservation*". From each data source, we determined whether and what records could be confidently assigned to specific end uses. Most datasets only capture certain types of use with confidence (e.g. most records in international trade databases cannot be confidently linked to an end use). Species recorded in the datasets that could not be assigned a clear end use were simply categorised as broadly used per that source. Where possible, we also extracted the year the use was documented, as future users may wish to only focus on species that have documented uses in recent years. We considered the cut-off for relevancy to be 1900; this cut-off was only relevant to the Wikipedia data scrape, where some species were only reported as historically used or hunted -e.g. in early colonial India.

Each of the eleven databases were processed separately and subject to different tidying and cleaning steps (see below). All taxonomies were aligned to the Handbook of the Birds of the World/BirdLife Taxonomic Checklist (v10) and the current IUCN mammal taxonomy (due to the large number of IUCN aligned data used for subsequent analyses), which closely aligns to the Mammal Diversity Database v2.0 taxonomy[51]. This totalled 16,967 extant species (11,021 birds and 5946 mammals).

(1) IUCN Use and Trade assessments – The IUCN is the largest independent assessment of species conservation status and regional assessors will have a broad understanding of how species are used. Using the IUCN Red List API v4 we accessed all bird and mammal assessments and extracted all species with uses recorded under any of the IUCN's 18 use classes as defined in their General Use and Trade Classification Scheme v1. We included all levels of use and trade, including subsistence use, as the primary aim here is to develop a comprehensive database of how species are used, not only traded.

(2) IUCN Threat Classification tables – For a species to be threatened by use, it logically must be used by humans currently or in recent history. This data for all current bird and mammal assessments was also accessed via the API . All species with classification 5.1.1 (Biological Resource Use [BRU] - Hunting & collecting terrestrial animals - Intentional use and the species being assessed is the target) were considered used. The majority of species with intentional BRU listed as a threat also had uses listed under the IUCN Use and Trade classification, but not all. The specific end use cannot be determined by the presence of BRU threat alone.

(3) IUCN Sustainable Use and Livelihoods Specialist Group (SULi) Species Use Database (SpUD) – The database explicitly aims to capture examples of the vast diversity of ways species are used through case studies, peer-reviewed studies, and grey literature. This was accessed and downloaded for all mammals and birds directly from the publicly accessible database, totalling 266 records. We further filtered the purpose descriptions provided to remove all incidences of pure human wildlife conflict ("*Also killed in*

response to instances of human-wildlife conflict.", "Killed in human-wildlife conflicts; animals destroyed crops or killed humans (elephants)") and conservation-focused activities (e.g. "*Conservation Management*"). Details of how species are used are recorded in the database in a semi-structured free-text string. We determined that five end uses could be confidently linked to an end use. Strings containing "*food*" were classed as Food – human consumption, "*Medicine and hygiene*" were classed as Medicinal, "*Decorative and aesthetic*" were classed as ornamental aesthetic, "*pet*" and "*Keeping/companionship/display*" were classed as pets, and those including "*Recreation*" were classed as used for sport. Terms such as "*offer for sale/commercial trade*", "*amusement*", "*monetary*", "*collection/display*" could not confidently be linked to any definitive use. Likewise, "Scientific Research" could not confidently be considered a research use as in some cases these referred to species used for judiciously for research; but in other cases, they were simply species ringed as part of wider research programs. Similarly for species kept in zoos we did not consider every species ringed or kept in zoos to be used. We also extracted the end year the use was documented.

(4) Benítez-López et al., 2017 Science – The study remains one of largest systematic searches for hunting studies at a global level. There will be overlap between the studies captured here, in Morton et al., 2021 and the WILDMEAT database. We considered all species recorded in the database as used for Food - human consumption. Per species reported in the database we also extracted the year the source study was published; where a species was reported in multiple studies we took the most recent year.

(5) Morton et al., 2021 Nature Ecology & Evolution – This is a peer-reviewed meta-analysis of the impact of exploitation for subsequent trade on terrestrial birds, mammals, and reptiles synthesizing 31 published studies. The rationale for this source is that, despite its reduced sample size, the study remains one of the largest systematic searches for traded species studies at a global level. We extracted the reported purpose from the original articles, this covered human consumption, pet trade and unknown/assorted/unreported. Per species reported in the database we also extracted the year the source study was published, where a species was reported in multiple studies we took the most recent year.

(6) WILDMEAT Database – The database provides a detailed review of patterns and consumption across sub-Saharan Africa. All studies contributing to the database are cited in full in the Supplementary References. This was accessed from the online data portal (https://www.wildmeat.org/database/). The full data for each individual study uploaded to the database is not currently available publicly, but species lists of all species recorded in the database are accessible from this portal. All species recorded were downloaded and databased. All species in the database can be considered to have been hunted for human consumption, whether directly by the collector or after sale (Pers. Comm D. Ingram, 2025).

(7) The United States Fish and Wildlife Service (USFWS) Law Enforcement Management Information System (LEMIS) database accessed from Marshal et al., 2025 PNAS – Despite its spatial restriction to species imported and exported from the US, this database remains the most species diverse data on traded species and captures species in trade but not listed in the CITES Appendices. All records for birds, terrestrial and marine mammals were extracted from the dataset. Individual records with the following specific reported purposes: E (educational), B (breeding in captivity), Y (introduction to the wild), L (law enforcement), S (scientific), Z (zoos), G (botanic

gardens), and Q (circuses) were excluded. As in previous sources the movement of individual specimens for science or education is not viewed as a clear end use for a species, likewise we do not consider simply occurring in zoos, gardens or circuses to be used. From the reported purposes and item descriptions, sport hunting, medicinal use, aesthetics, apparel, non-manufacturing chemicals, fibre, research, household goods and human consumption end uses where identified (See Supplementary Table 2 for details). We did not consider reference to "meat" sufficient to deem that a species is used for food, given its potential crossover with animal food or medicine. Per species, per use the most recent year the species was identified in trade for that specific end use was also extracted.

(8) CITES Trade Database v2025.1 – This is currently the only consistently collected database of the international trade in wildlife, capturing trade to and from 185 countries. However, only species listed in the CITES Appendices are recorded (~903 mammal and ~1510 bird species, and multiple subspecies). All records for birds and mammals were extracted from the dataset. Individual records with the following specific reported purposes: E (educational), B (breeding in captivity), L (law enforcement), N (reintroduction), S (scientific), Z (zoos), G (botanic gardens), and Q (circuses) were excluded for the reasons previously described. From the reported purposes and item descriptions, sport hunting, medicinal use, aesthetics, apparel, non-manufacturing chemicals, fibre, household goods and human consumption end uses were identified (See Supplementary Table 3 for details). Per species, per use, the most recent year the species was identified in trade for that specific end use was also extracted.

(9) TRAFFIC Wildlife Trade Information System (WITIS) Database – all records concerning birds or mammals were downloaded - see the point of access for a detailed description of the data format (https://www.wildlifetradeportal.org/about). Incident types described as "5. Animal Injury / Mortality / Welfare", "6. Human-Wildlife Conflict", "7. Breeding / Ranching - unclear if conservation or use" or "4. Live Animals on Display (not for sale)" were removed. From the remaining commodity descriptions, we able to confidently identify the following end uses; human consumption, medicinal, non-manufacturing chemicals and aesthetic goods. See Supplementary Table 4 for details on the classification.

(10) Donald et al., 2023 Conservation Biology – This database aimed to collate a list of all wild bird species reported as traded (not used at the local or subsistence level). As such there is overlap with older versions of the IUCN, LEMIS, CITES and WITIS databases. However, Donald et al., also carried out a separate review of the grey literature of species recorded in markets and shops that may not be captured in any other datasets, thus it is included in our database. All birds in from this database can be considered used but from this source alone no end uses can be determined.

(11) Wikipedia – this online encyclopaedia, curated and written by volunteers from around the globe, often contains verbose and detailed text accounts drawing from multiple sources and is increasingly used for conservation monitoring [52]. Species accounts often include detailed sections on species ecology, cultural importance and conservation actions. A SPARQL (SPARQL Protocol and RDF Query Language) query was used to extract all species-level mammal and bird English language Wikipedia URLs (n = 16,835). These were matched to the IUCN bird and mammal taxonomies; 48 bird and 73 mammal species could not be linked back to a species account. All species-specific URLs were then scraped in full for all text contained in the main body of the article (e.g. excluding images, tables). All scraping was carried out using the "*rvest*" R package [53].

We then used a dictionary of key words and phrases capturing the 6 main end uses (as per the IUCN Red List), and a more generic use and trade keyword set to systematically search each species Wikipedia text for reference to these specific uses (see Supplementary Table 5 for details of search terms used). Novel species end use combinations not detected in any other data source were then manually reviewed. We did not consider any uses only described in the context of use pre-1900. Where the article referred only to possible occurrences of the species in trade these were ignored. References that species may be threatened by hunting in isolation were ignored. Statements describing that the species was listed in CITES were also ignored.

End-use data across sources were collated and summarised to record specific end-uses per species (Supplementary Table 6). All mapping of species were undertaken using the species range maps provided by the IUCN Red List.

Predicting species use

Given the prevalence of use across taxa, we built random forest models for the 6 main uses (food, pets, medicine, apparel, ornamental products, sport) for birds and mammals to test the predictability of use (totalling 12 models). For birds, we collated data on species ecology and morphology [54], life history [55], colouration [56], and key environmental variables including species regional distribution, range sizes, range centroids, and travel time from human settlements [57]. For mammals, we sought to create a similarly comprehensive suite of predictive variables encompassing ecological and life history traits [58], key environmental variables including species regional distribution, range sizes, range centroids, and travel time from human settlements with a population of at least 5,000[57]. Travel time was summarised as the mean, 5th and 95th percentile of travel time values across each species range. The full variable set was tested for high collinearity and highly colinear variables dropped (Pearson's correlation coefficient >0.7). See Supplementary Table 7 for a full list of included variables. We removed all species known to be used but with no known end uses (1393 birds and 619 mammals), leaving 9628 birds and 4991 mammals with known end-uses and complete predictor data.

The random forest models were fit using "*ranger*"[59] and applied using "*caret*"[60]. We trained the models on 75% of the data and held back 25% for model testing. Model hyperparameters were tuned to optimize prediction. Specifically, we tested all combinations of a range of "mtry" (the number of features, randomly sampled, to split at each node) values (1-40) and the number of trees (100-1500) under fivefold cross-validation. We selected the combination that yielded the highest accuracy. Full details of selected values per use and class are presented in Supplementary Table 8. We assessed variable importance through permutation and created partial dependence plots for each variable using "*Dalex*"[61]. All analyses and visualisation were undertaken using R Statistical Software v4.4.1[62].

A key knowledge gap is that for many species known to be used in some form (e.g. their high prevalence in international trade databases) we cannot confidently ascribe a specific or likely end use. Thus, for end-uses we found to be highly predictable, we predicted likely end-uses for the withheld subset of species known to be used but with no known end-uses, that had coverage across all of our predictors (2012 species reduced to 1920 with full coverage). We considered a use predictable when the taxon-use-specific model had a Cohens Kappa >0.4, generally considered moderate agreement. We note most models had considerably higher

Kappa values. Species with no known but predicted uses are not included in the main text figures, but are shown in Supplementary Figure 3 and 4.

Assessing end-use driven threat

Here, we focus only on the subset of uses identified by the IUCN. The reason for this is that the IUCN Red List remains the only standardised global assessment of threat informed by experts, and if assessors are not aware or did not record the use of a species that is captured in another database then it is likely those same assessors cannot deduce that use to be a driver of threat. The tabulated schema of threats used by the IUCN does not provide any further insight into the type or motivation of use. Therefore, we developed a text-based classification system based on the large quantities of expert-led text submitted as part of species Red List assessments.

We focused on all globally threatened or Near Threatened species with a Biological Resource Use (intentional or unknown) threat code recorded, totalling 1558 species (776 species with a single use identified, 153 species with no use given per the IUCN and 629 species with multiple uses given). For all species, we extracted the assessment text specifically supplied as part of the "*Assessment Information*", "*Population – Description*", "*Population – Trend Justification",* "*Threat*" and "*Use and Trade*" fields. All text was accessed and collated using the IUCN API. All IUCN text was cleaned, removing any remaining html syntax, stop words and a predefined key of phrases that could be incorrectly conflated with specific end uses (Supplementary Table 10). This yielded almost 40,000 sentences of expert-written text. We randomly selected a subset of 200 species for manual classification to test against the automated classification.

Our classification logic is sentence-based. Thus, to detect if a specific use is or is not a threat for a species, a sentence must refer to both a specific use and a positive or negative statement of that use as a threat or driver of impact. We built a dictionary of keywords and phrases describing each of the 6 dominant end uses, which are subsequently termed *use-strings*. A full list of all use-strings is in Supplementary Table 11. Likewise, we built separate dictionaries capturing whether a statement is conveying the presence of a threat (positive statement), the lack of a threat (negative statement) or that there is specifically insufficient information to conclude if there is a threat (uncertain statement); these are subsequently termed *threat-strings*. These are detailed in full in Supplementary Table 12. These search strings are designed to be both specific and flexible, incorporating, where appropriate, both forward and backwards exclusions to exclude text containing qualifying words and statements, and in other cases allow for a specified number of non-specific separating words between key terms, reflecting the diversity of ways statements can be phrased. Combined, this yielded 21,009 flexible phrases.

We ran the following four parallel classification tasks per species (see Supplementary Figure 1a for a visual summary). The classifications are purposely distinct and not hierarchical, as it is possible for species text to refer to multiple levels of threat from a specific use.

(1) *Positive statement* - Does a use string and a positive statement threat string occur in the same sentence in the "*Assessment Information*", "*Population – Description*", "*Population – Trend Justification",* "*Threat*" and "*Use and Trade*" text.
(2) *Uncertain statement* - Does a use string and an uncertain statement threat string occur in the same sentence in the "*Assessment Information*", "*Population – Description*", "*Population – Trend Justification",* "*Threat*" and "*Use and Trade*" text.

(3) *Negative statement* - Does a use string and a negative statement threat string occur in the same sentence in the "*Assessment Information*", "*Population – Description*", "*Population – Trend Justification",* "*Threat*" and "*Use and Trade*" text.
(4) *General mention* - Is a use string mentioned in isolation but in the context of threats "*Assessment Information*", "*Population – Description*", "*Population – Trend Justification",* or "*Threat*" text (excluding the "*Use and Trade*" text).

Following this logic, we manually classified 200 species as to whether they made general mention, negative, positive, or uncertain threat statements and then applied the classifier using the resulting confusion matrix to assess the classifier's accuracy (Supplementary Table 13). The classifier performed excellently at discerning different threat statements across end uses, with most Cohens kappa statistics >0.8 and balanced accuracies >0.9. Using the combinations of presences/absences of these classification statements, we categorised species to four subsequent categories where a specific use is: (1) highly likely to be a threat; (2) potentially a threat; (3) unlikely a threat; or (4) there is insufficient information to judge. See Supplementary Figure 33 for how the classification statements are aligned with the categories and Supplementary Table 14 for a detailed description of each category and examples.

By design, all species with a positive, negative, or uncertain statement will also have a general mention of the end use. A small number of species were flagged as having multiple conflicting explicit threat statements, e.g. a specific use was both explicitly stated as a threat and not as a threat (n = 40 species). Each of these instances were manually reviewed. In cases where one statement was clearly global/broad in nature and the other specific to a given smaller area, we gave inferential preference to the broader statement. If a use was clearly stated as both a threat and not a threat in equivalent spatial scales (often in different text blocks), we classed the species to have "*Insufficient information*". As a final precaution, we extracted all records for species and use combinations where threat was categorised as highly likely or unlikely (n = 713, as these are the categories of greatest conservation relevance) and manually checked the entire text accounts to confirm or modify the automatic categorisation, in total we changed the categorisation of 42 records (5.9%). Given the high specific statement classification accuracy, and the small number of resulting categorisations altered we are confident our approach provides robust classifications and therefore has great potential to be applied over future updated Red List assessments.

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Data, code, and materials availability: All input data sources are cited clearly in the methods. The detailed data generated here on species end-uses and threats are available here https://doi.org/10.6084/m9.figshare.31346797 [private repository until peer-reviewed – but reasonable requests can be sent directly to the lead author]. All code used can be accessed here https://github.com/OMorton/Use-TradePurposes.

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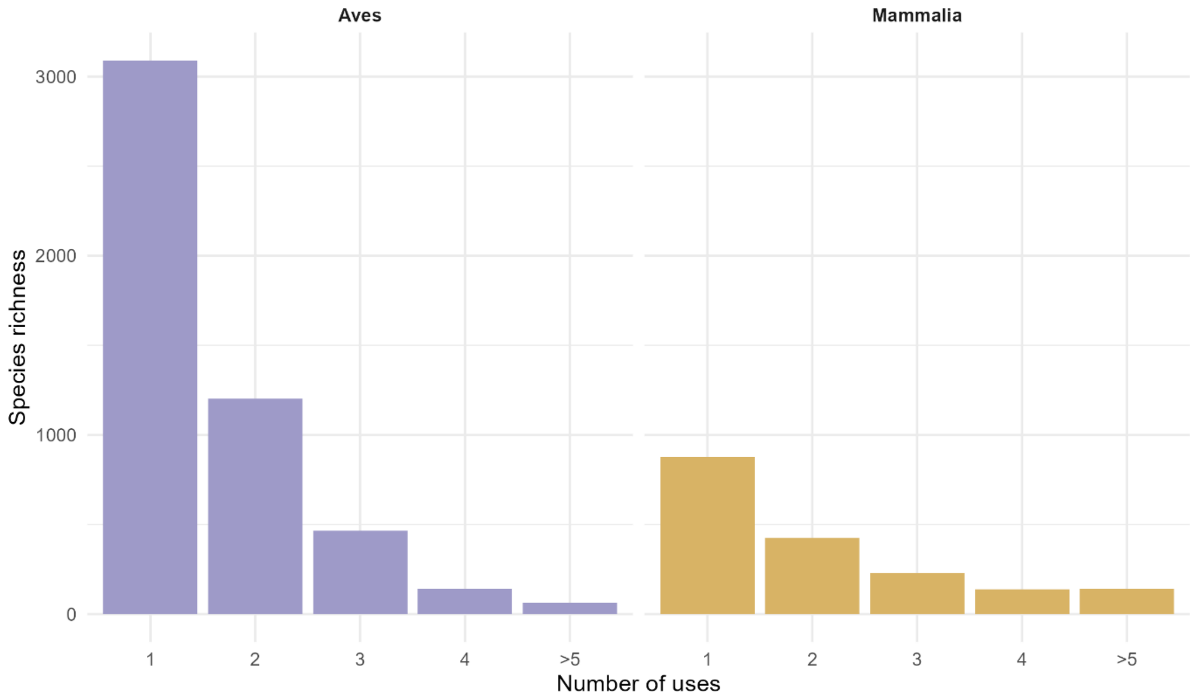
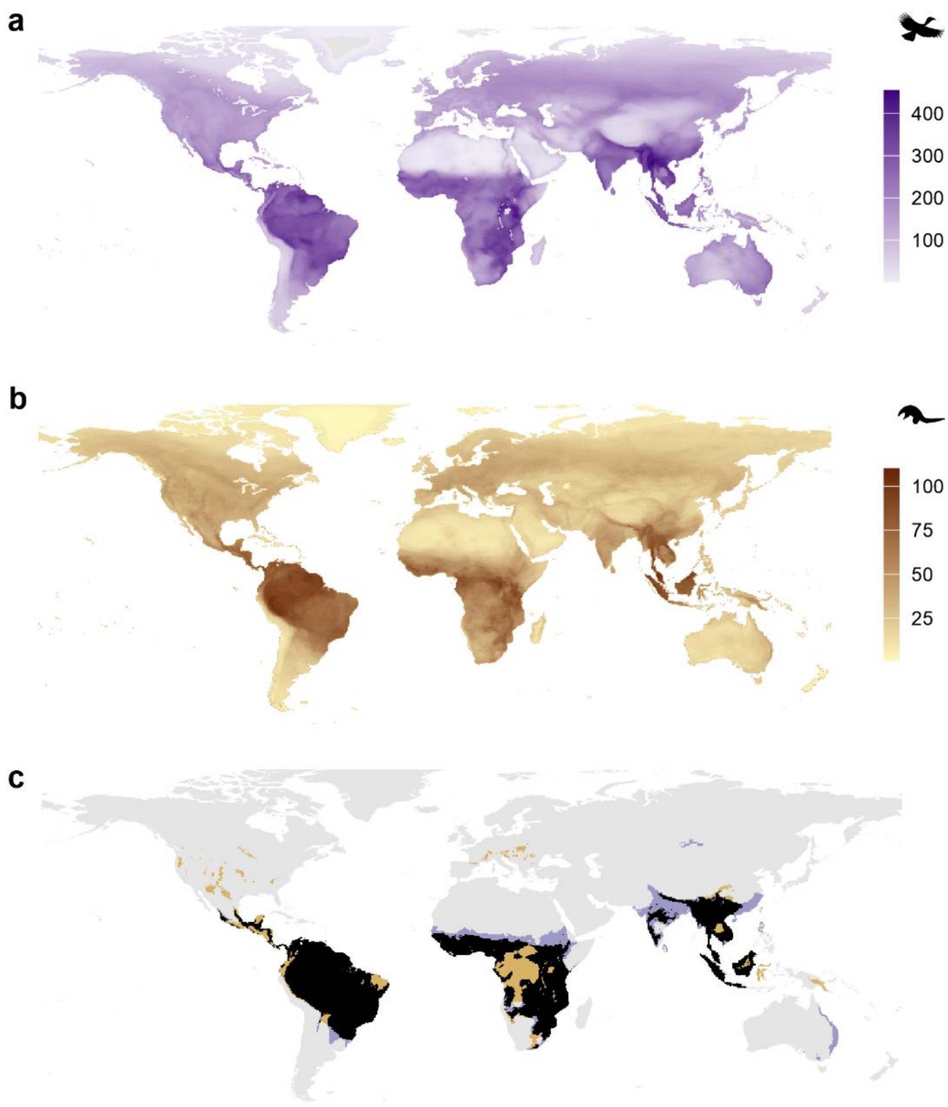
Supplementary Information

Oscar Morton[1], Sharon Baruch-Mordo[2], Chris R. Cooney[1], & David P. Edwards[3,4]

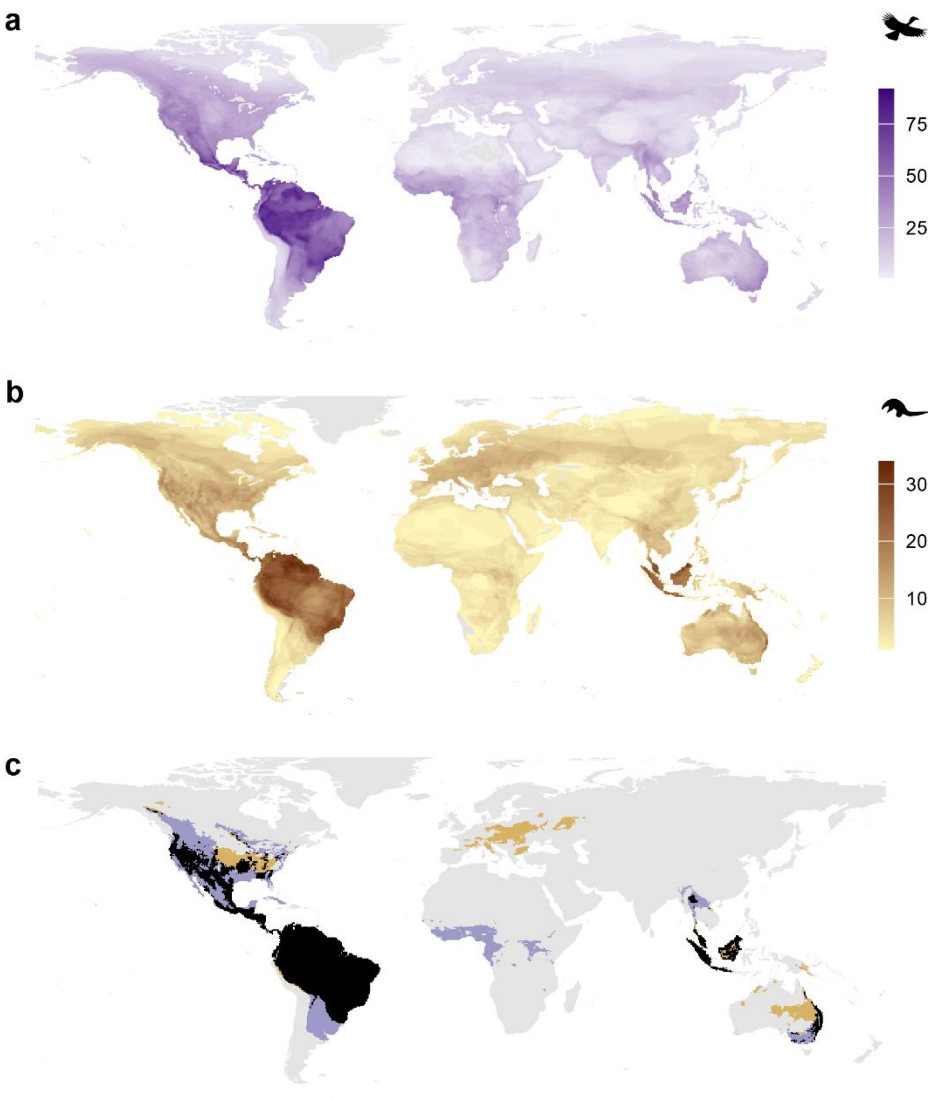
Corresponding author: o.morton@sheffield.ac.uk



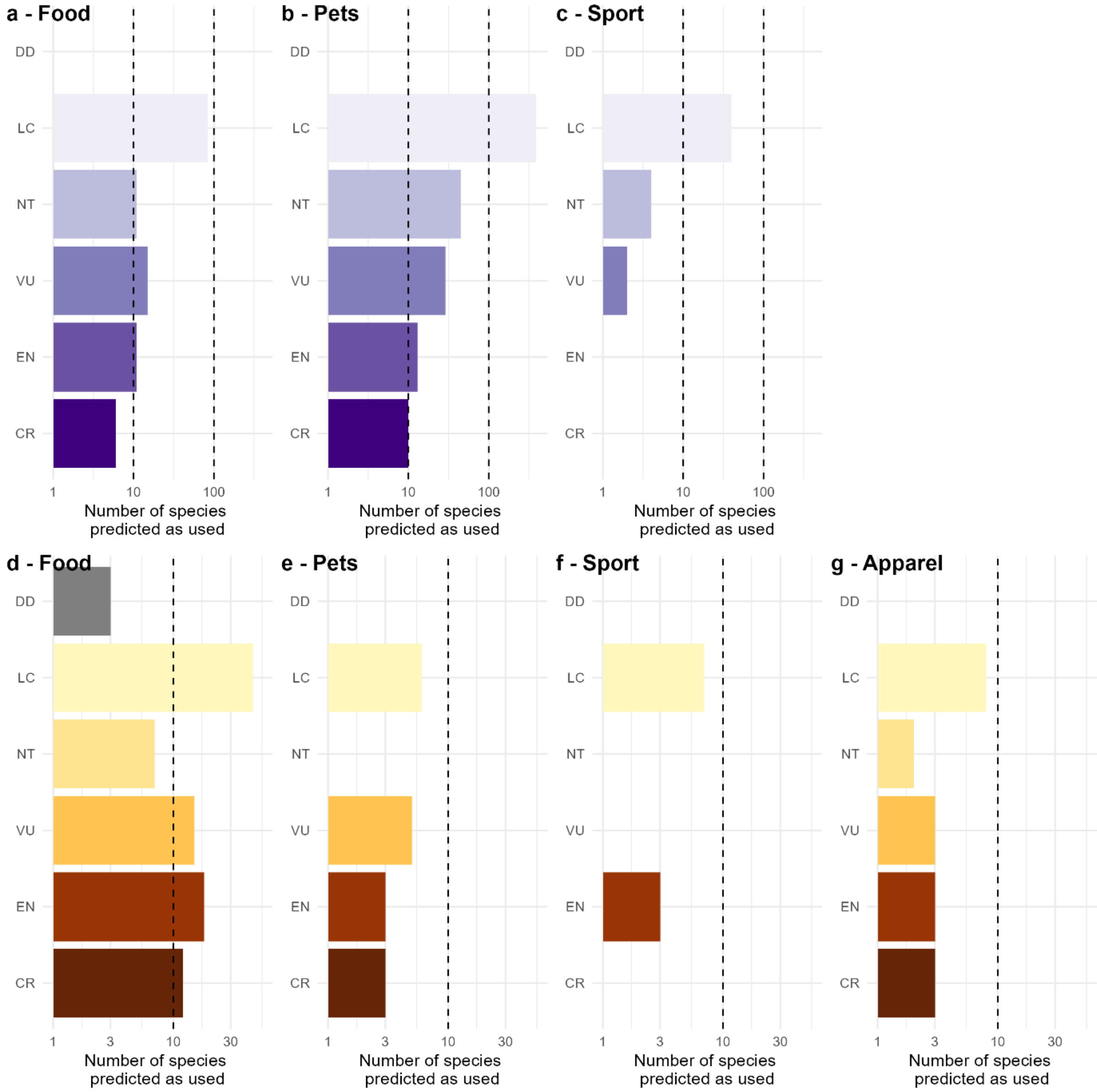
Supplementary Figure 1. Summary of the number of uses per species of bird and mammal.



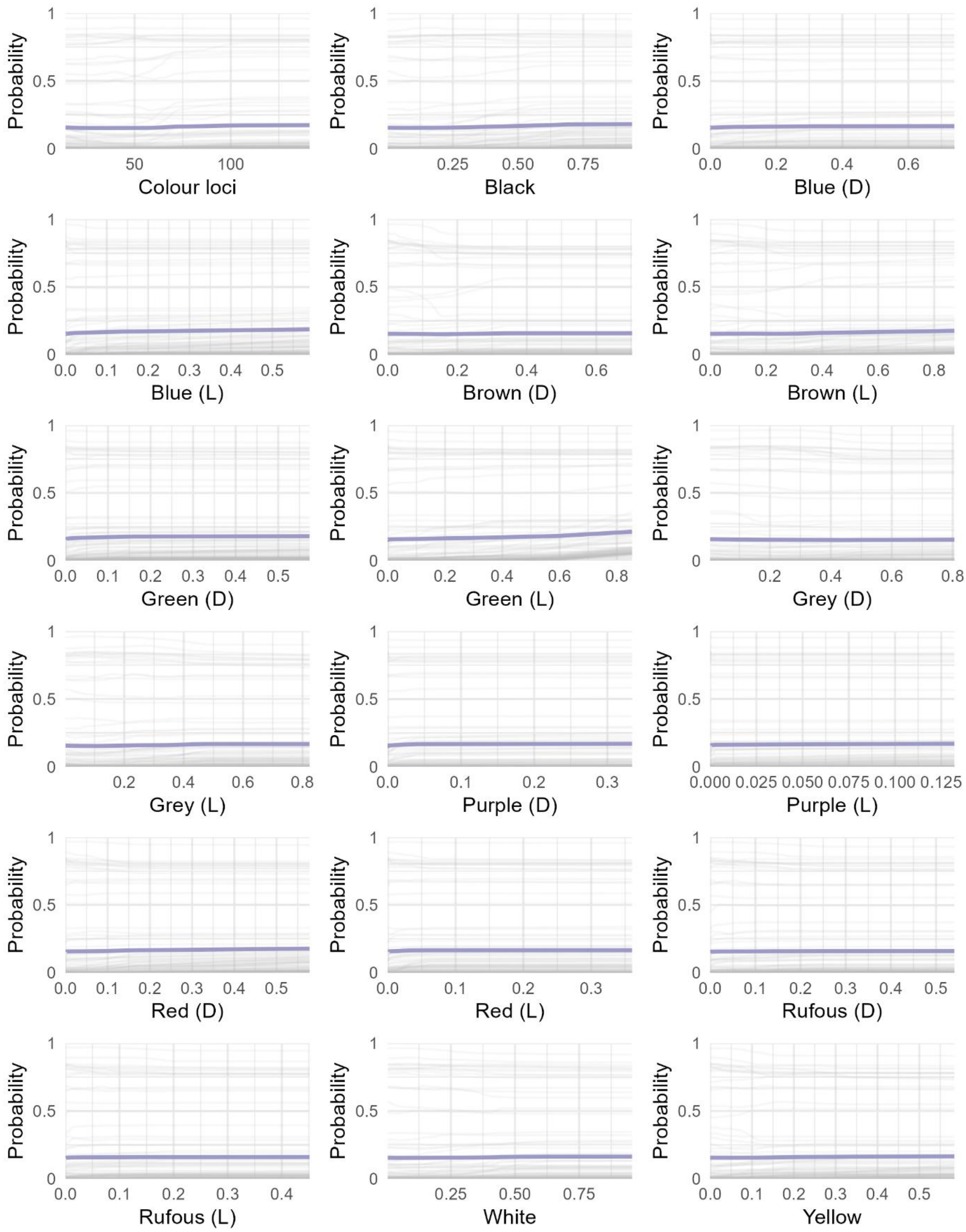
Supplementary Figure 2. Distribution of all used species. Species richness for used birds (a), used mammals (b) and hotspots of use (c). Hotspots are defined as cells containing values equal to or greater than the top 5% quantile for birds and mammals individually. Bird hotspots are shown in lilac, and mammal hotspots are shown in brown, areas common to both taxa are shown in black.



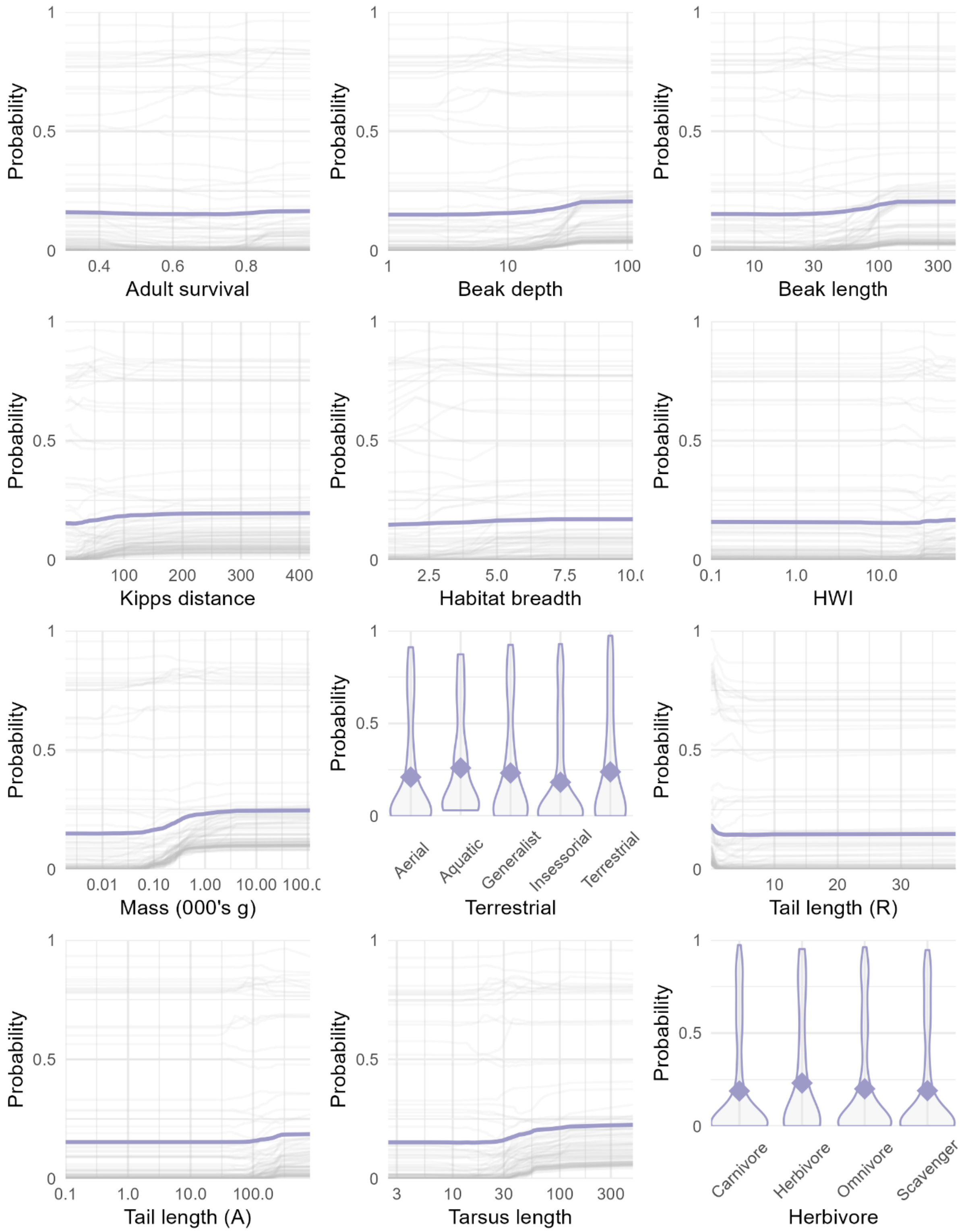
Supplementary Figure 3. Distribution of all used species with no clear inferable (unknown) use. Species richness for birds (a), mammals (b) and hotspots of unknown species diversity (c). Hotspots are defined as cells containing values equal to or greater than the top 5% quantile for birds and mammals individually. Bird hotspots are shown in lilac, and mammal hotspots are shown in brown, areas common to both taxa are shown in black.



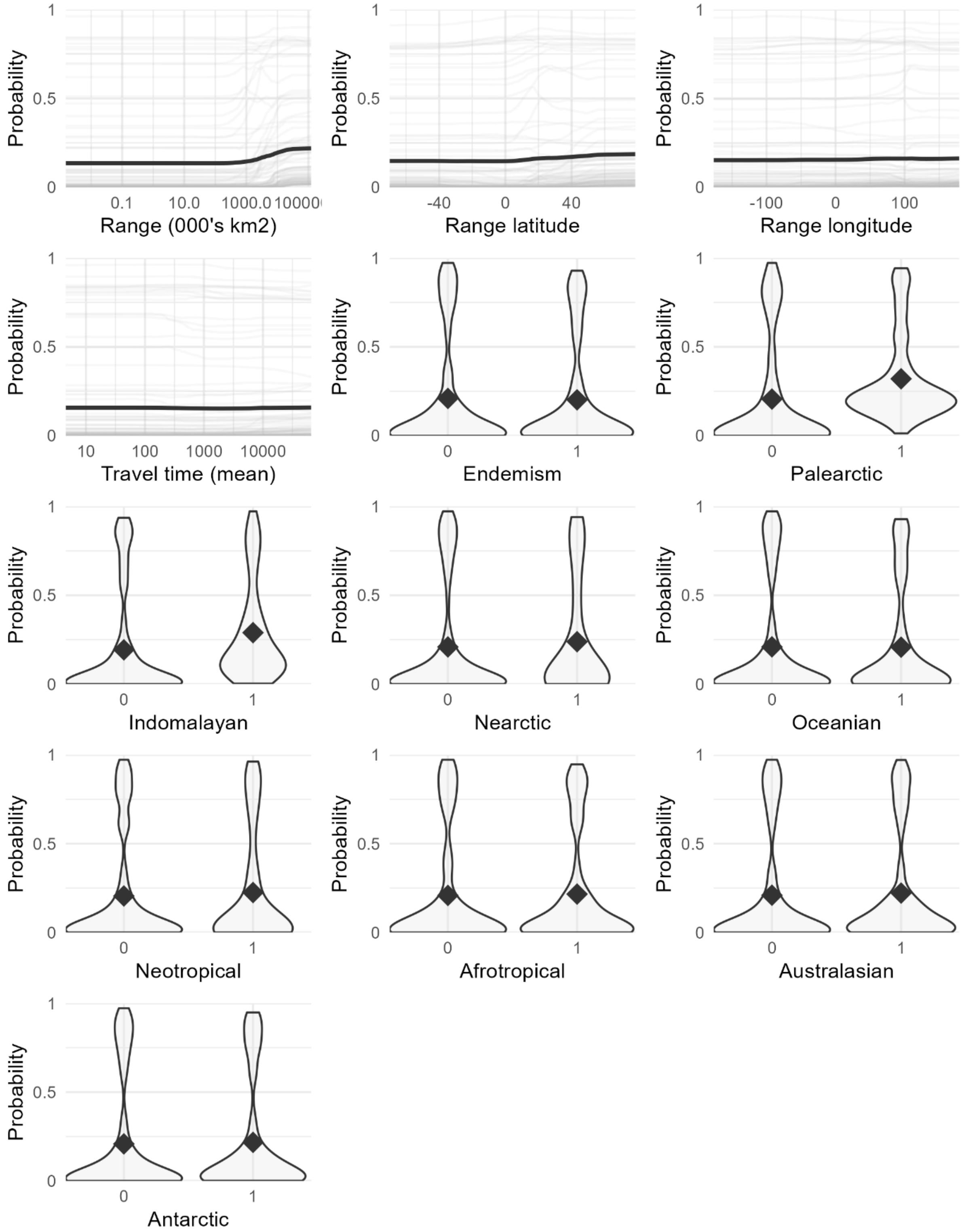
Supplementary Figure 4. Predicted end-uses for the 1326 bird and 564 mammal species reported as used but without clearly known uses. Note only 561 birds and 111 mammals could be clearly predicted to have at least one likely end use. X-axis on a log scale for visualisation.



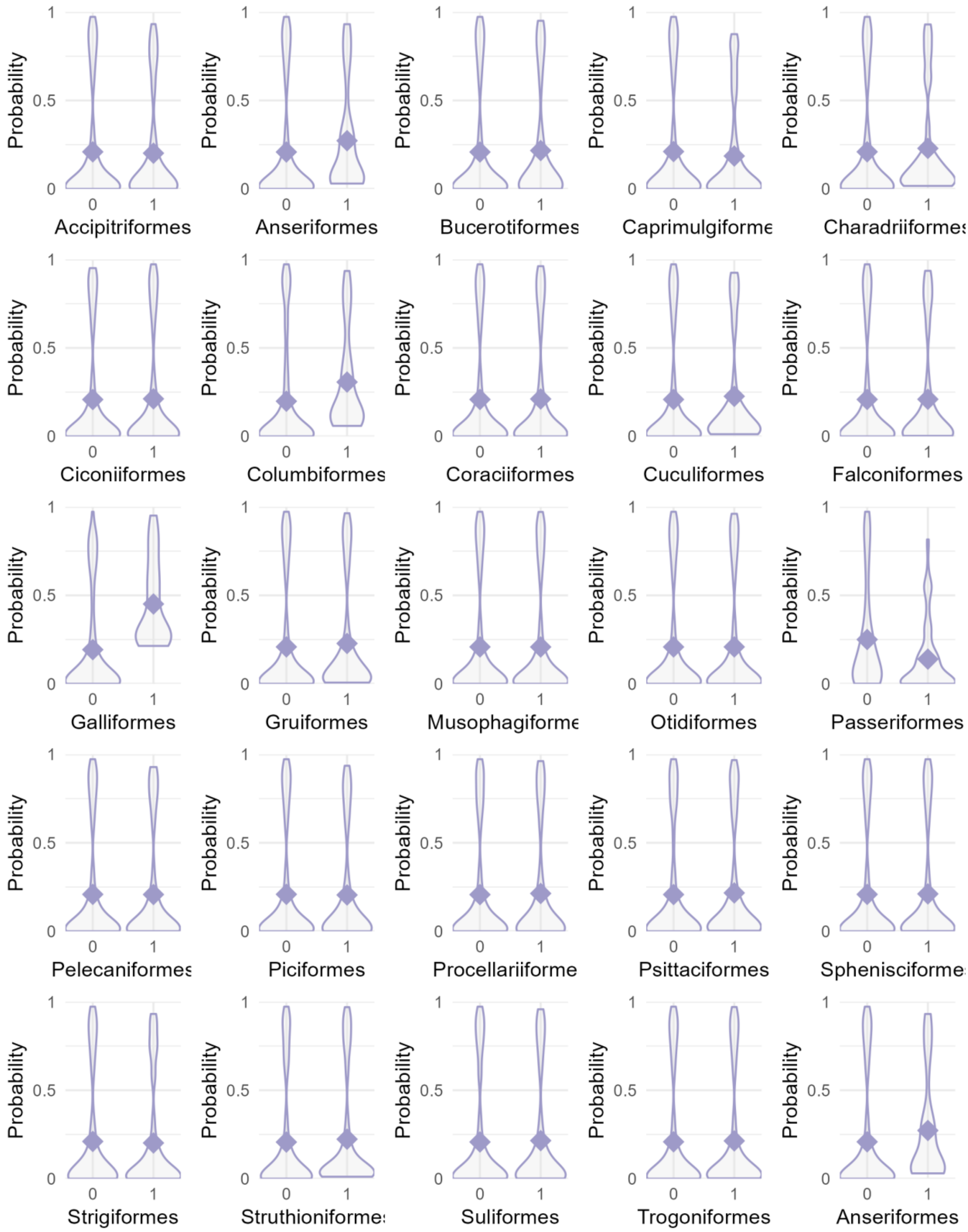
Supplementary Figure 5. Partial dependency plots for birds used as food, showing all aesthetic traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



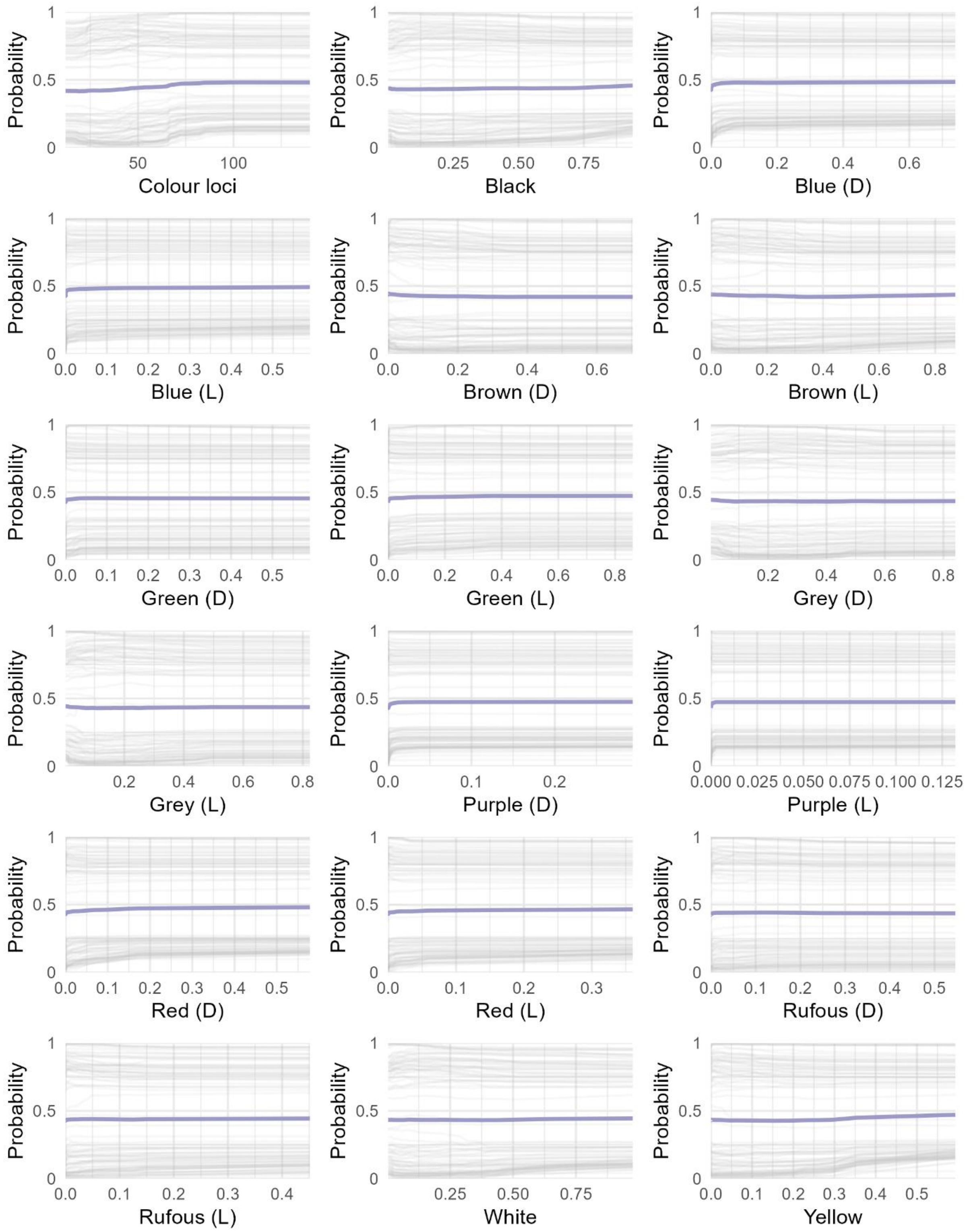
Supplementary Figure 6. Partial dependency plots for birds used as food, showing all ecological traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



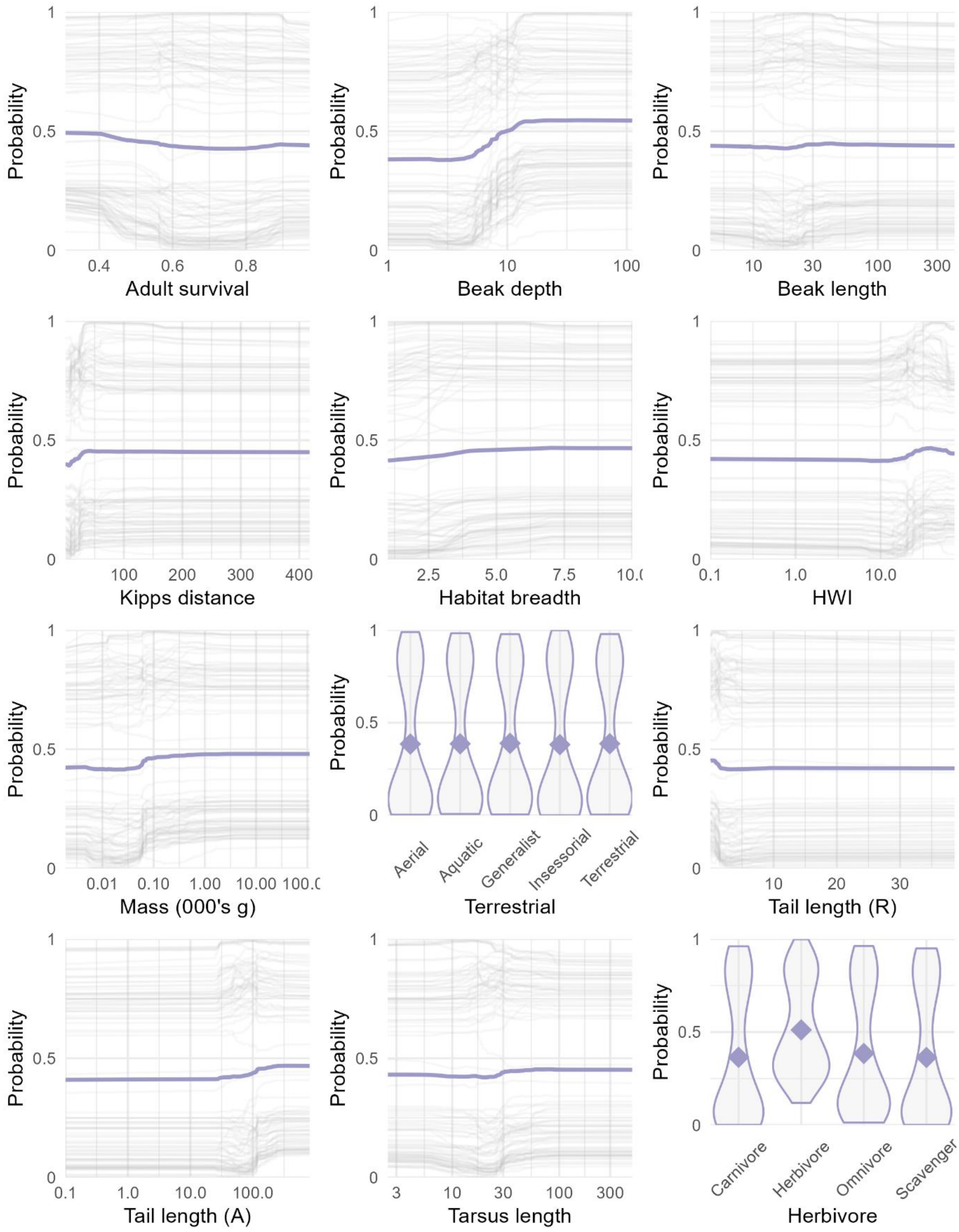
Supplementary Figure 7. Partial dependency plots for birds used as food, showing all range-based characteristics. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



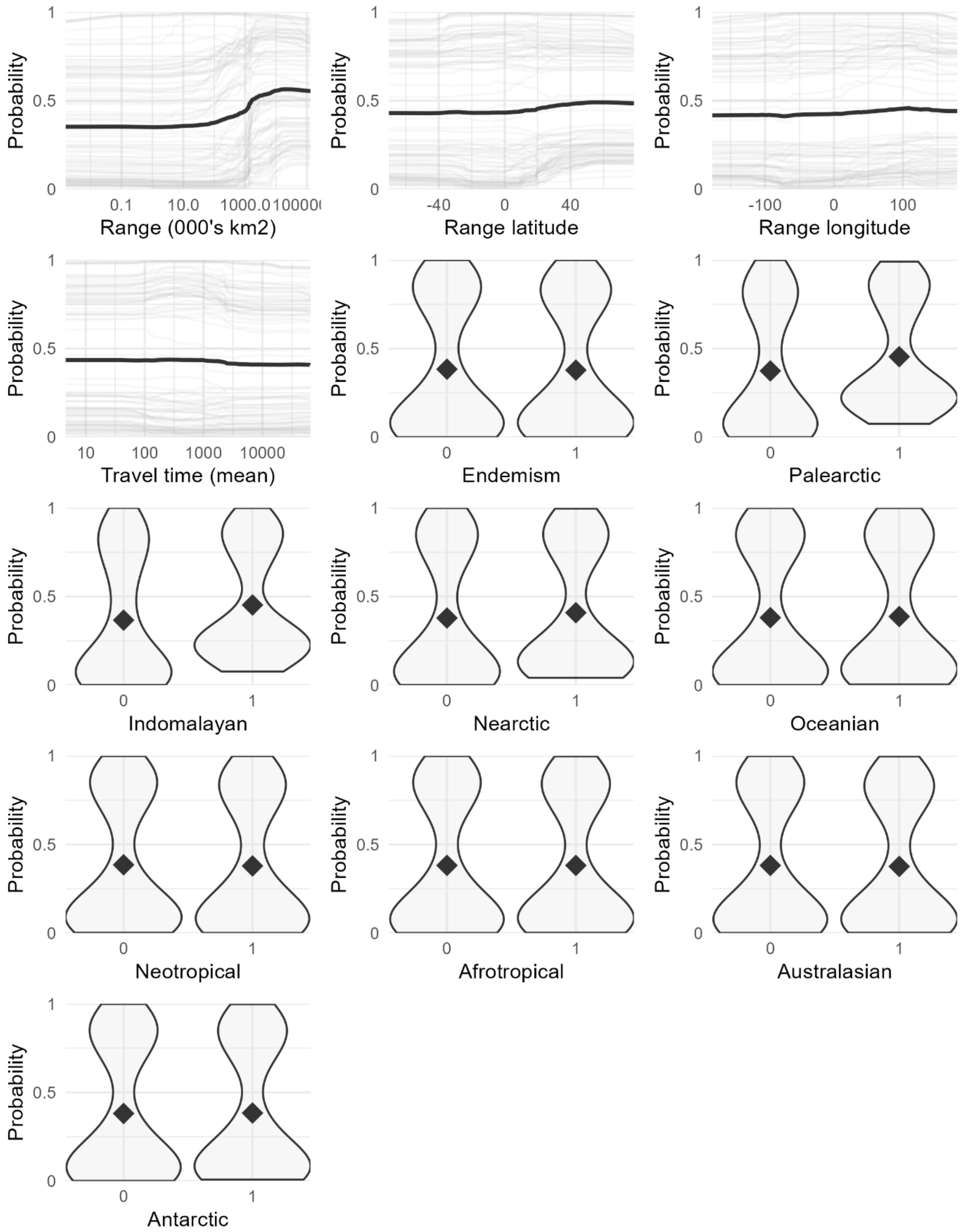
Supplementary Figure 8. Partial dependency plots for birds used as food, across taxnomic orders. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



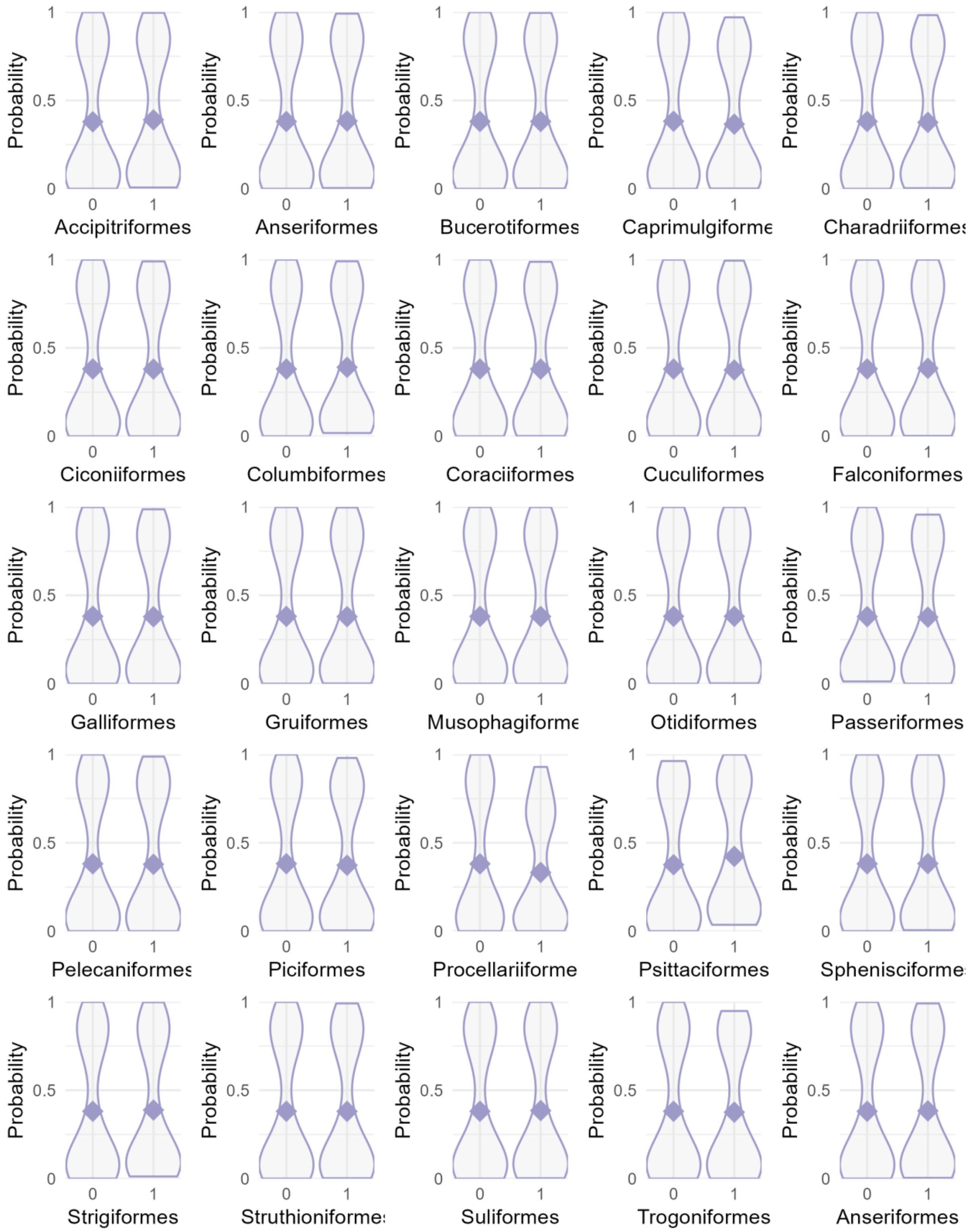
Supplementary Figure 9. Partial dependency plots for birds used as pets, showing all aesthetic traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



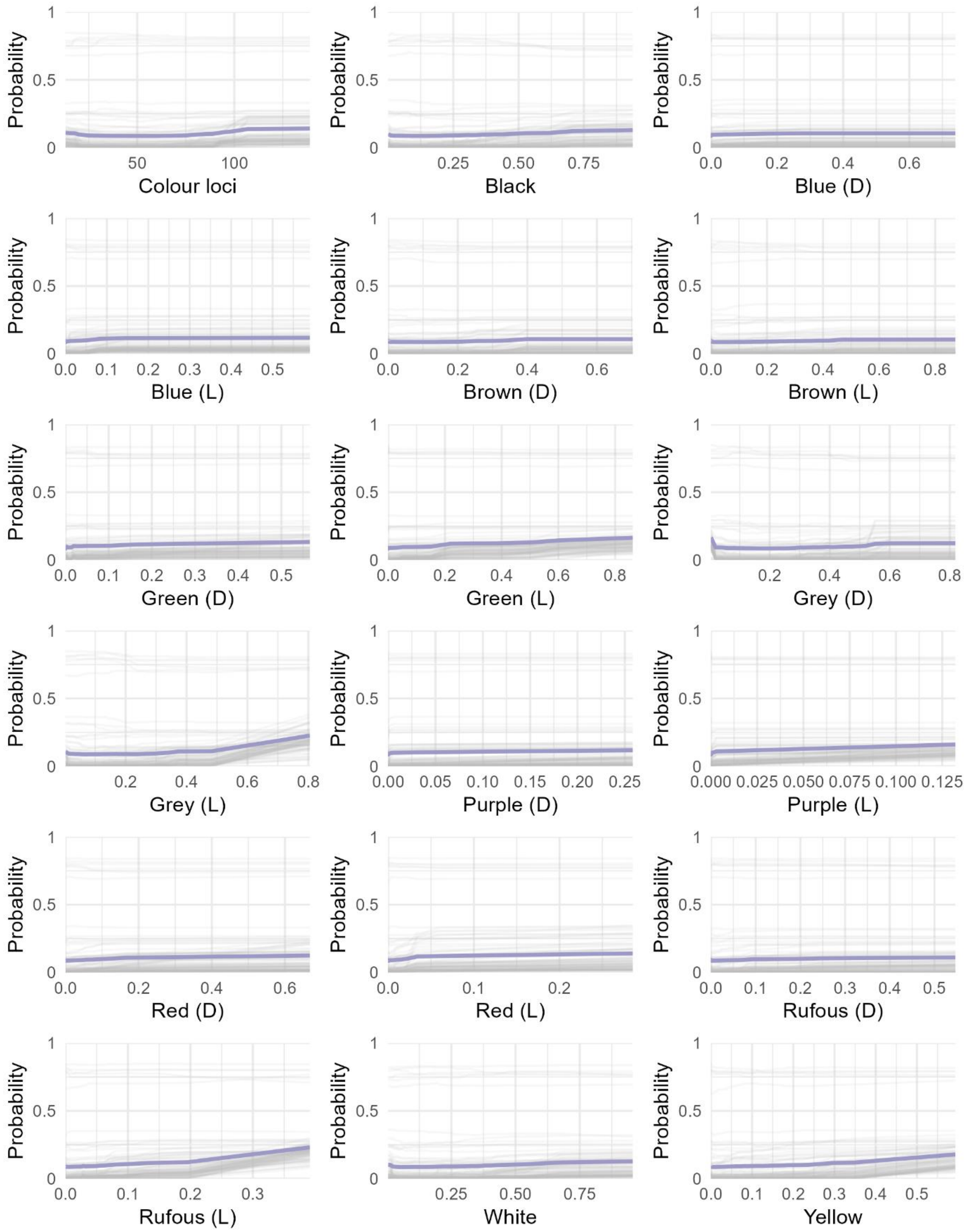
Supplementary Figure 10. Partial dependency plots for birds used as pets, showing all ecological traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



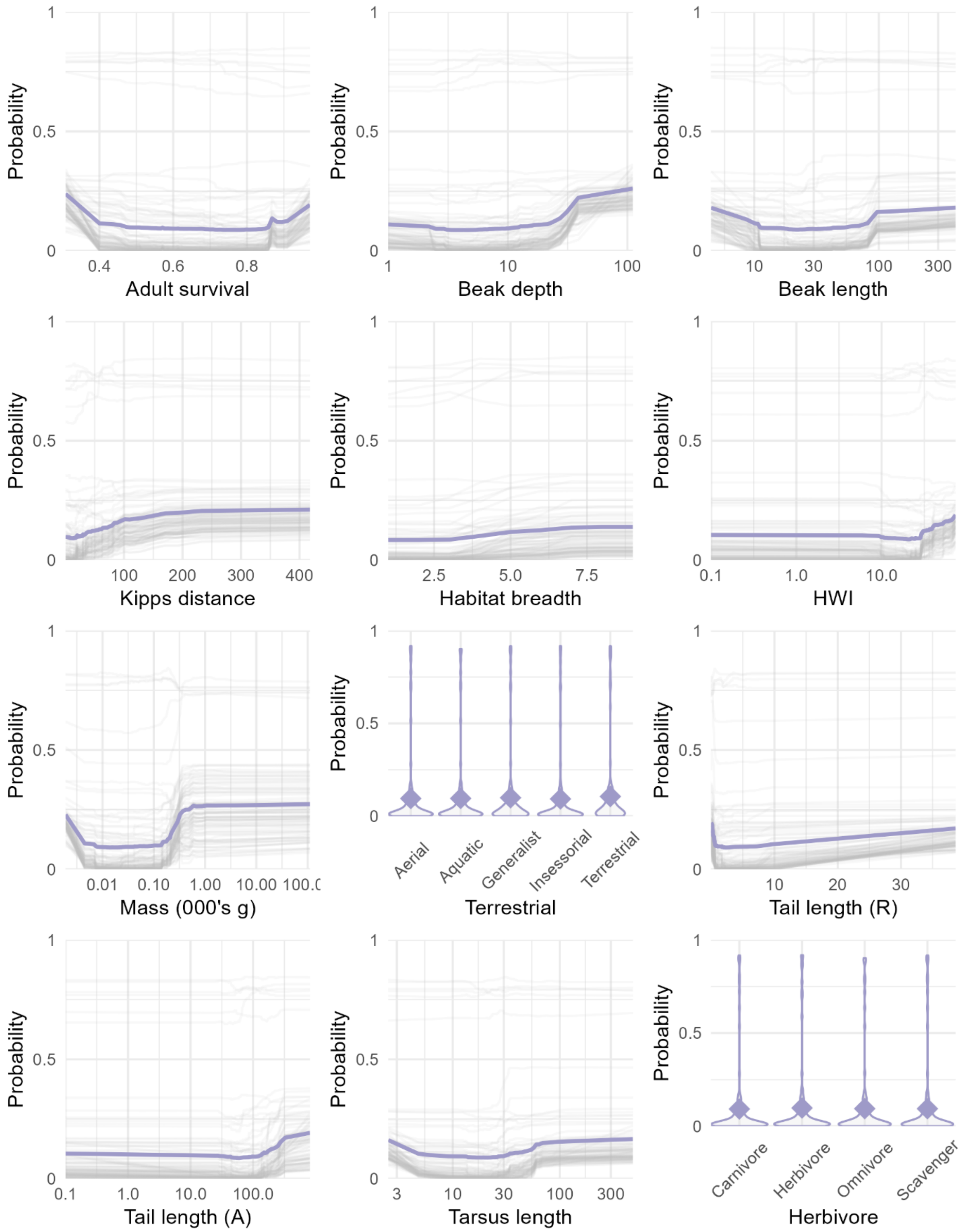
Supplementary Figure 11. Partial dependency plots for birds used as pets, showing all range-based characteristics. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



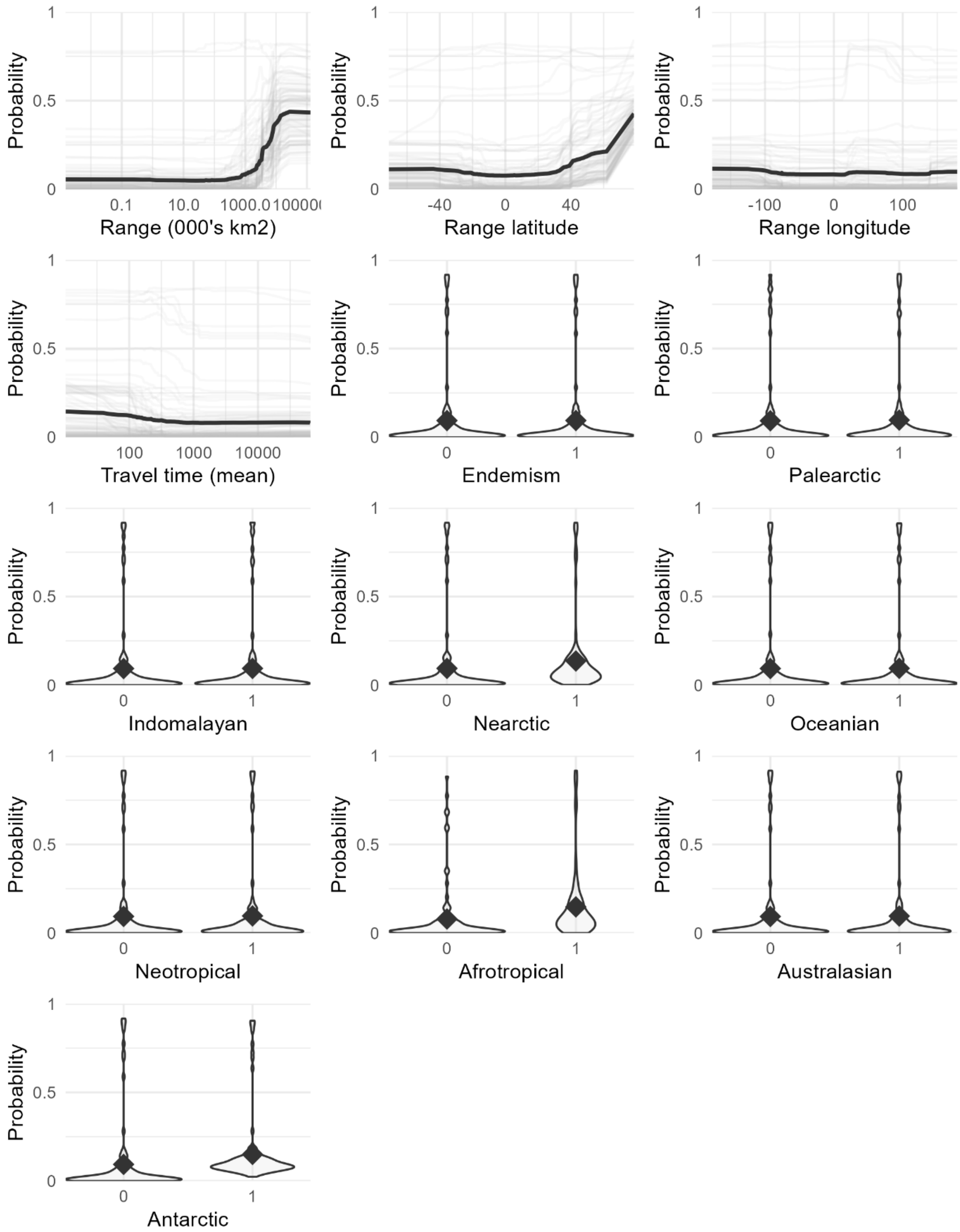
Supplementary Figure 12. Partial dependency plots for birds used as pets, across all taxonomic orders. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



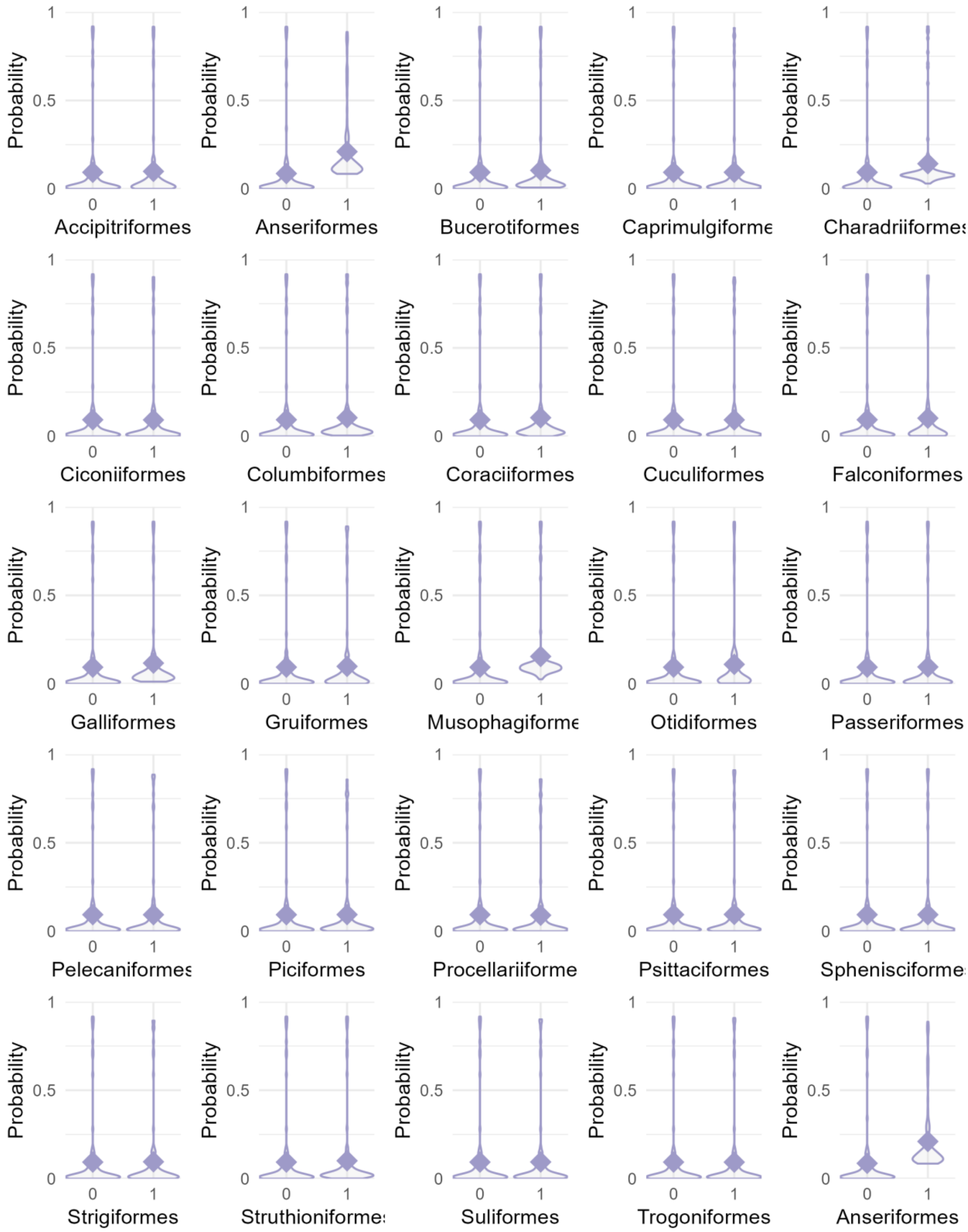
Supplementary Figure 13. Partial dependency plots for birds used for sport, across all aesthetic traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



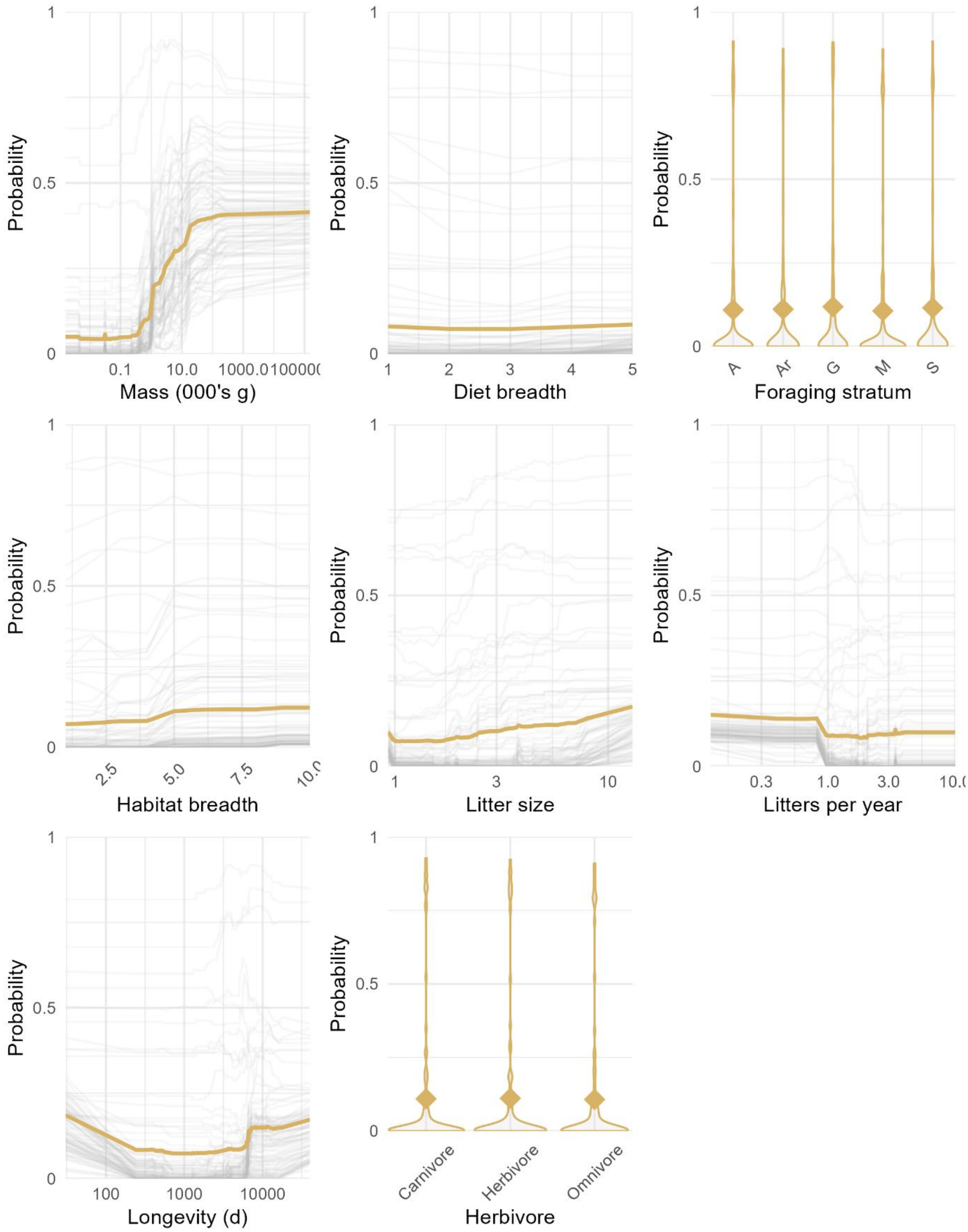
Supplementary Figure 14. Partial dependency plots for birds used for sport, across all ecological traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



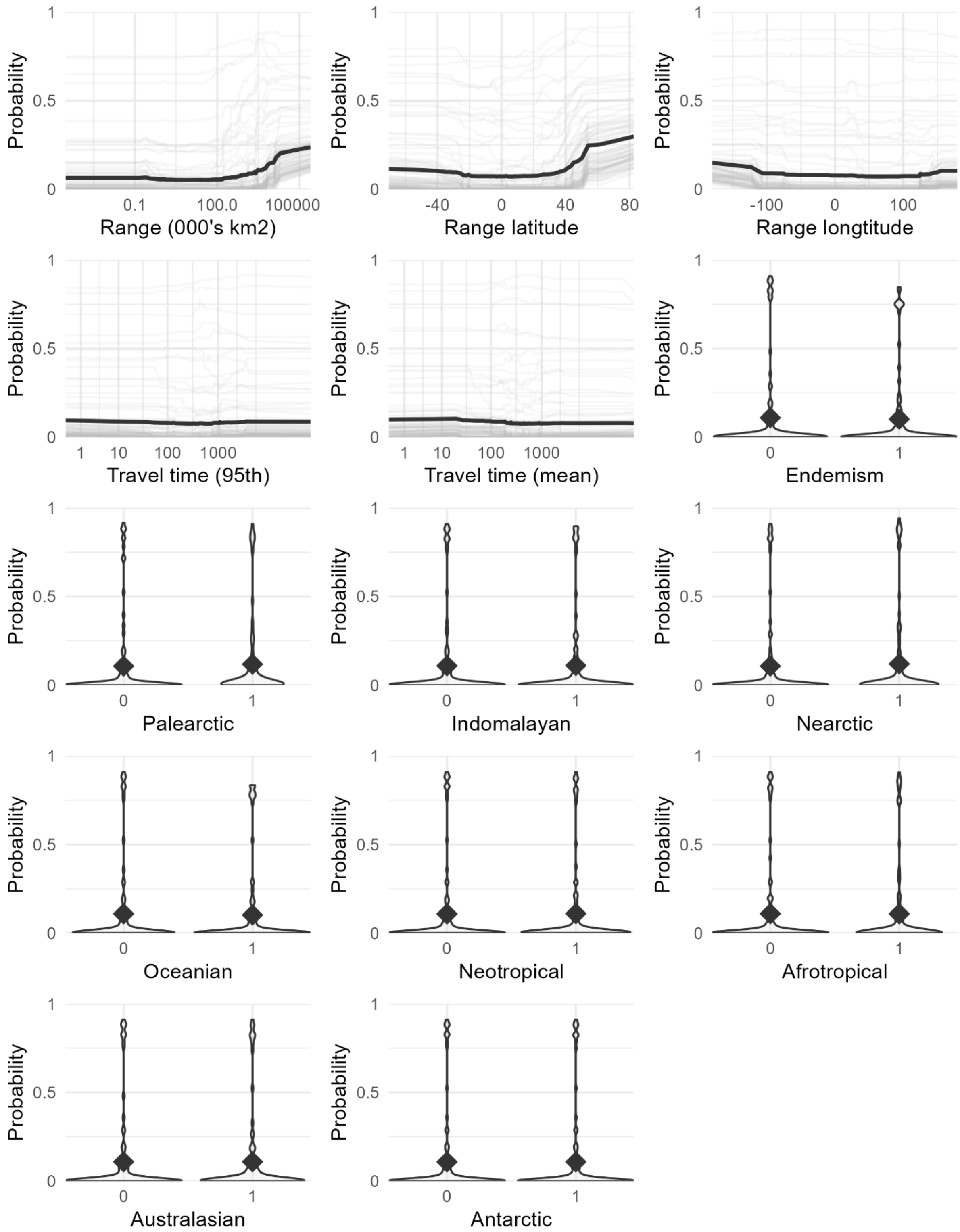
Supplementary Figure 15. Partial dependency plots for birds used for sport, across all range-based characteristics. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



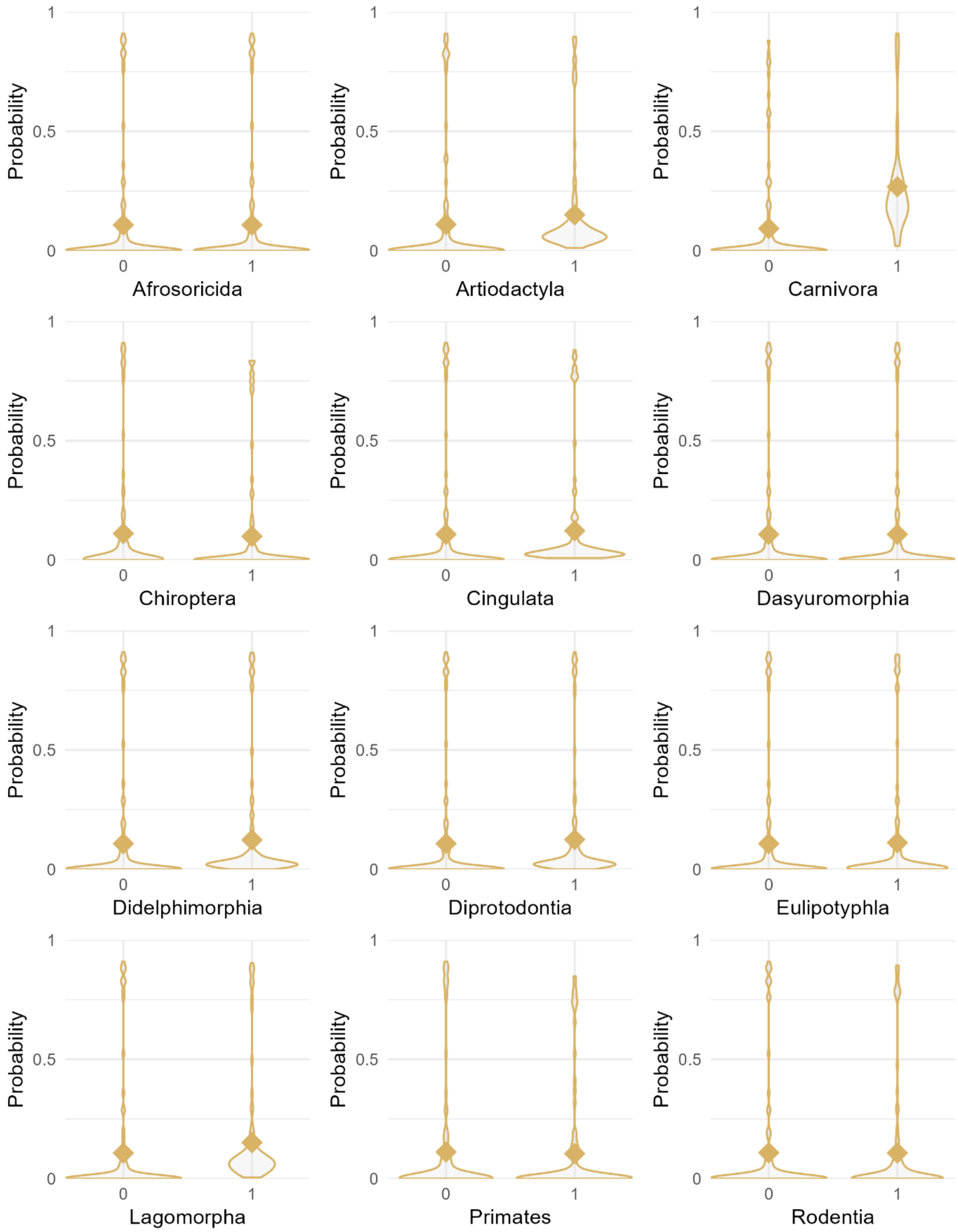
Supplementary Figure 16. Partial dependency plots for birds used for sport, across all taxonomic orders. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



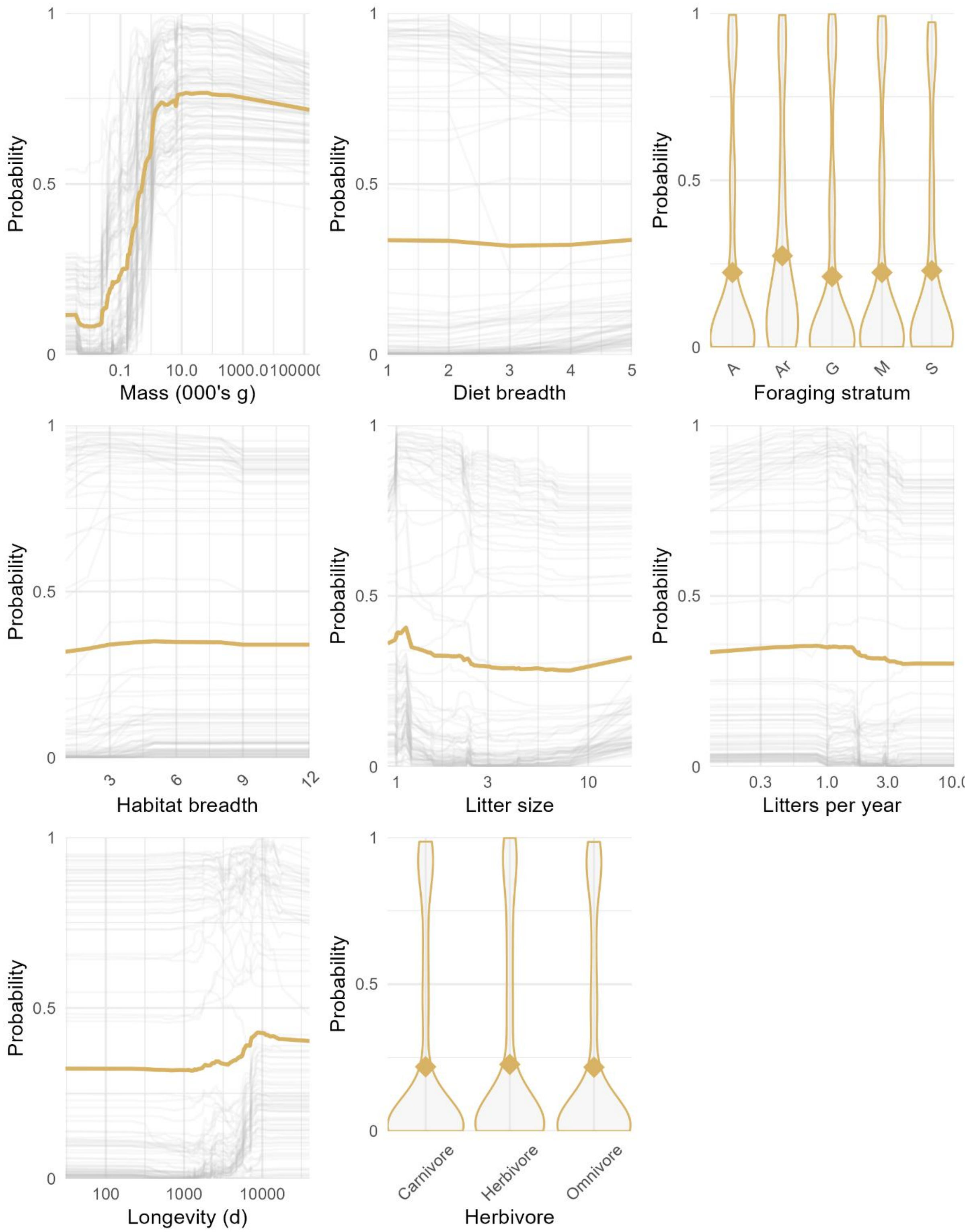
Supplementary Figure 17. Partial dependency plots for mammals used for apparel, across all ecological traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



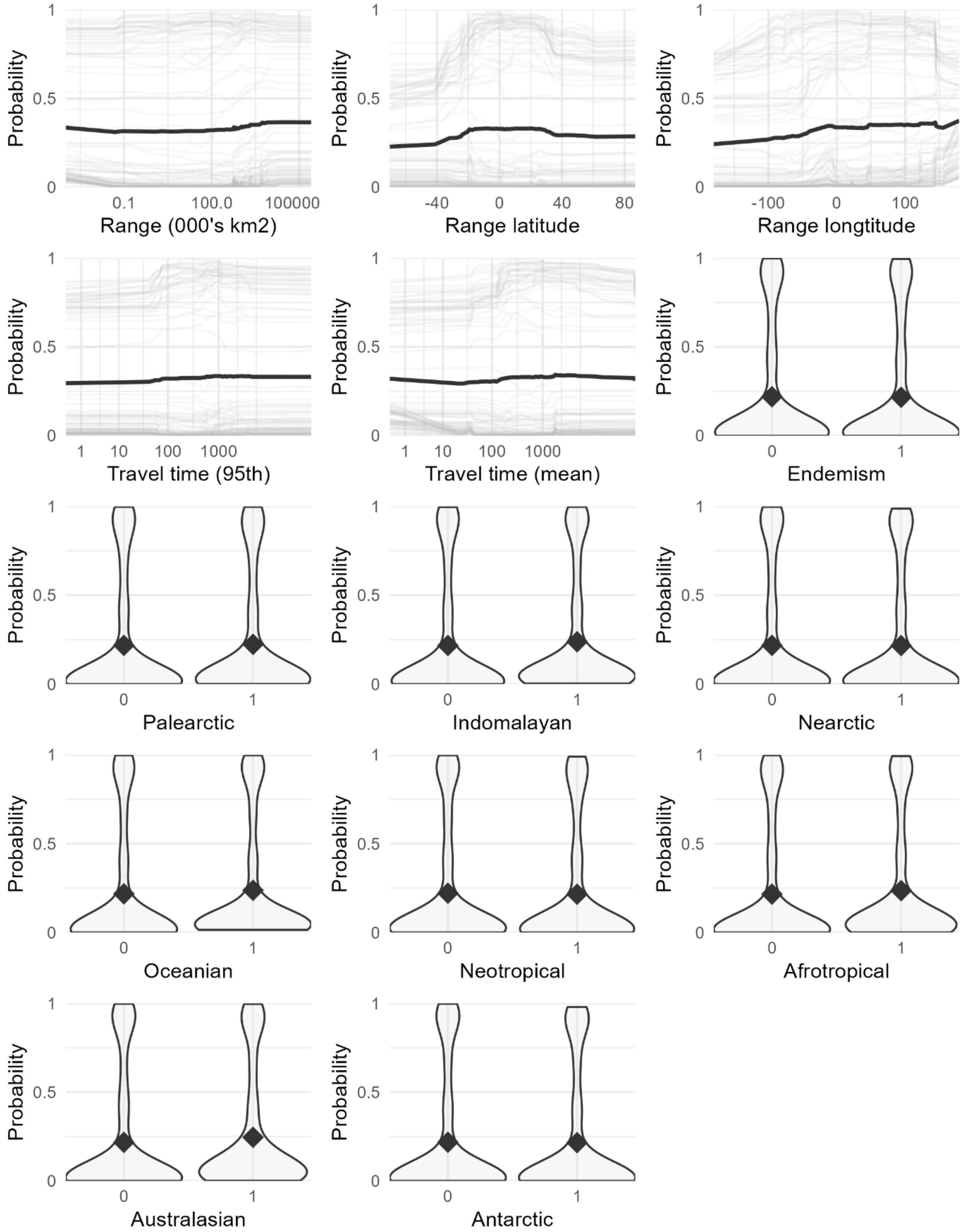
Supplementary Figure 18. Partial dependency plots for mammals used for apparel, across all range-based characteristics. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



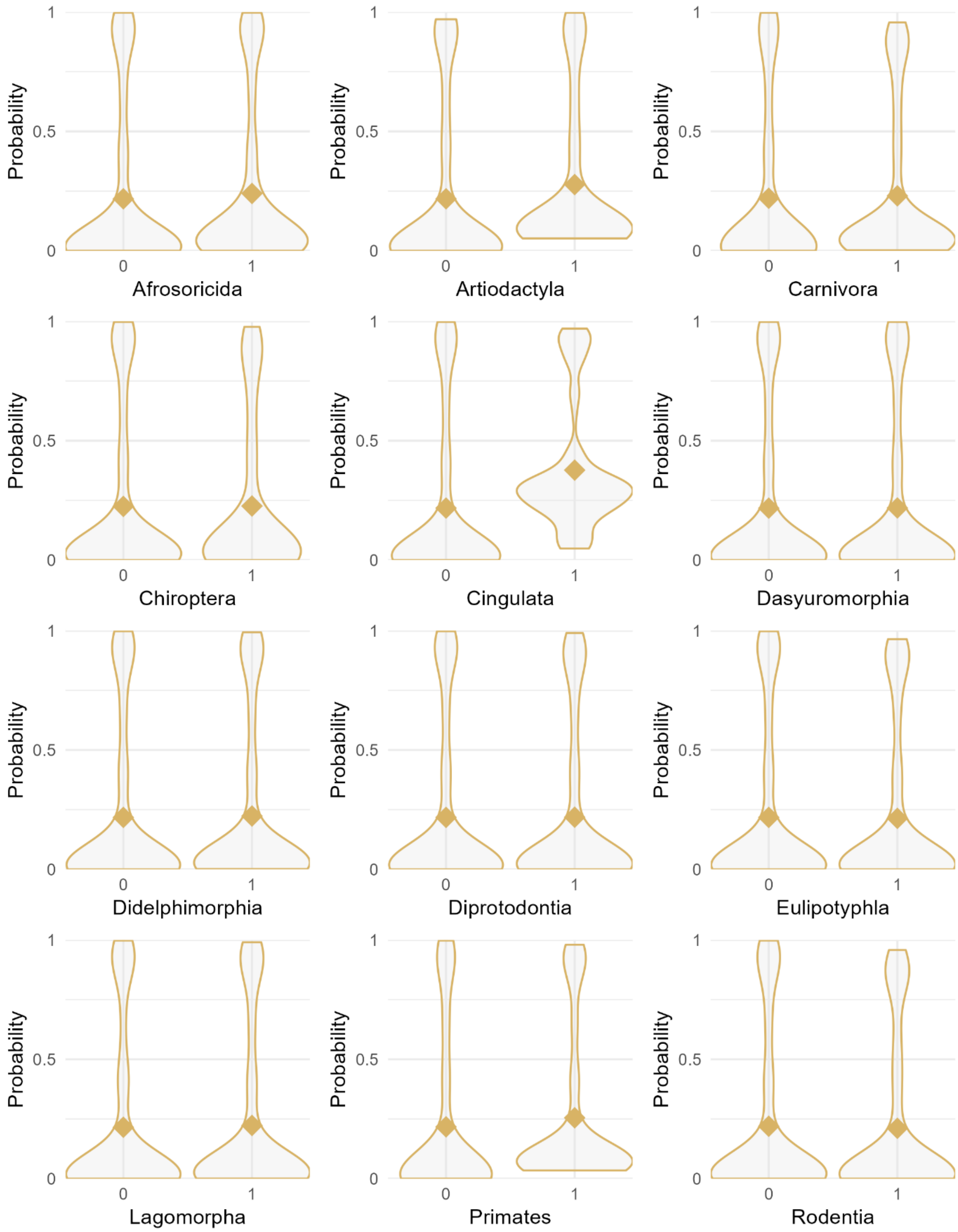
Supplementary Figure 19. Partial dependency plots for mammals used for apparel, across all taxonomic orders. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



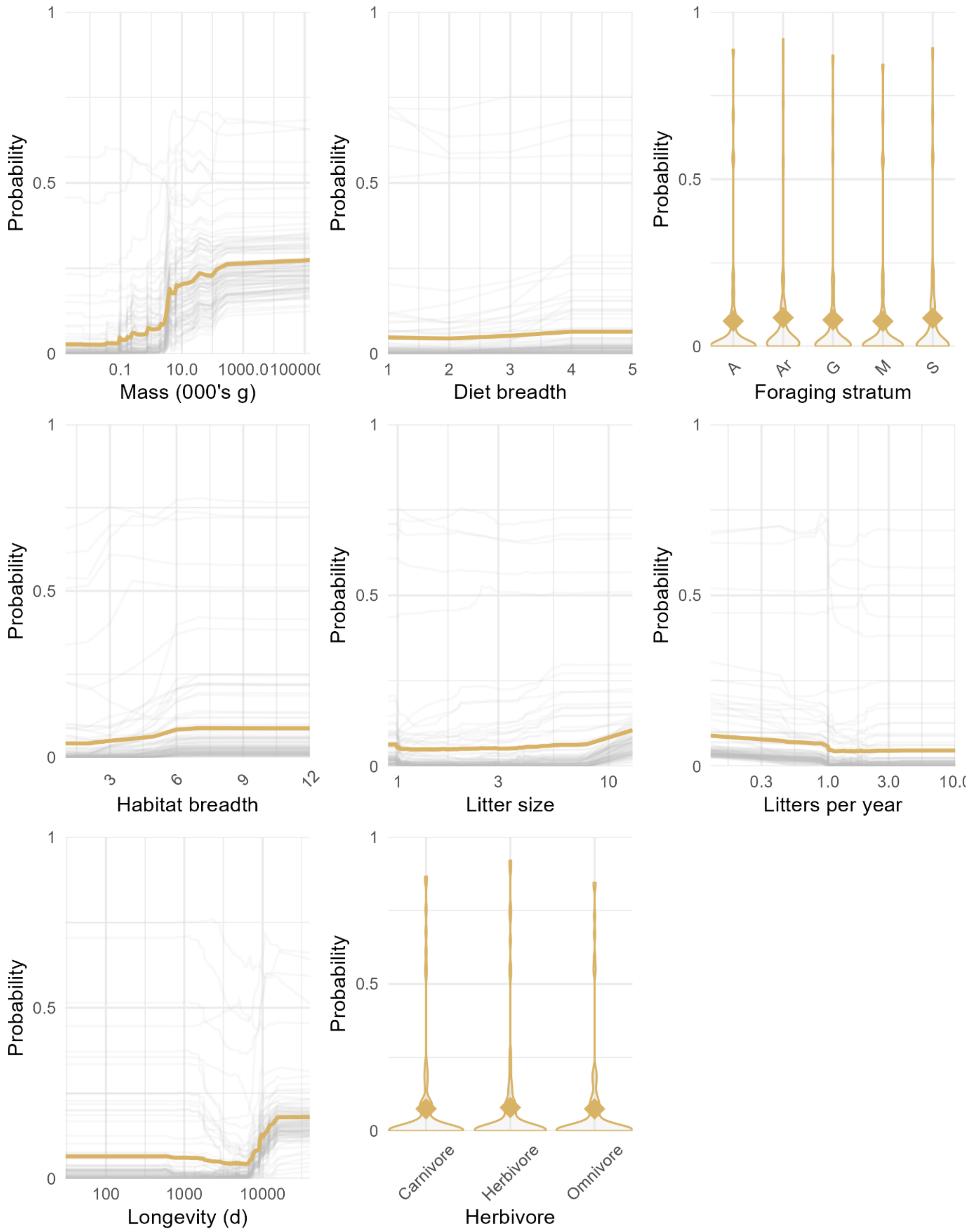
Supplementary Figure 20. Partial dependency plots for mammals used for food, across all ecological traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



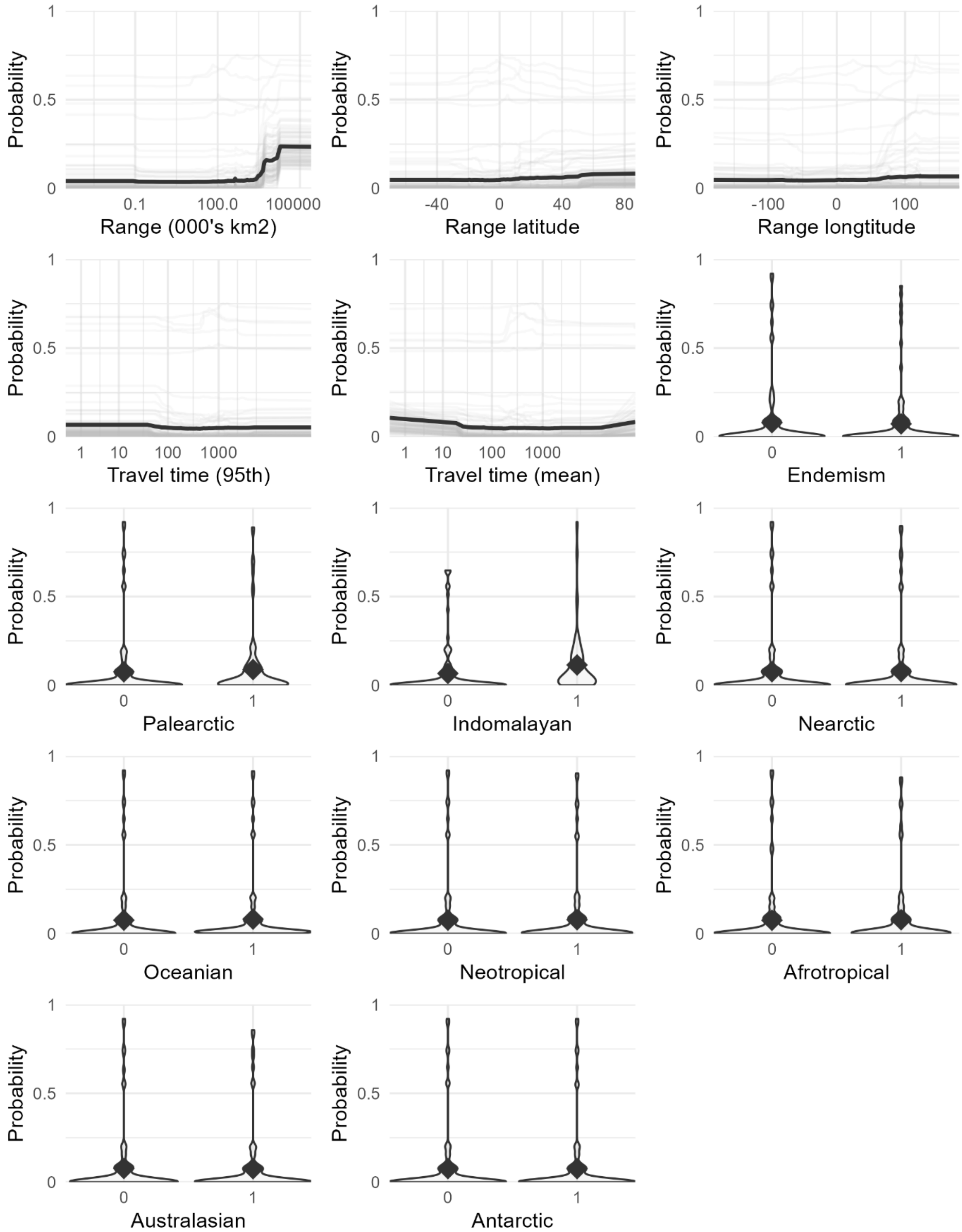
Supplementary Figure 21. Partial dependency plots for mammals used for food, across all range-based characteristics. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



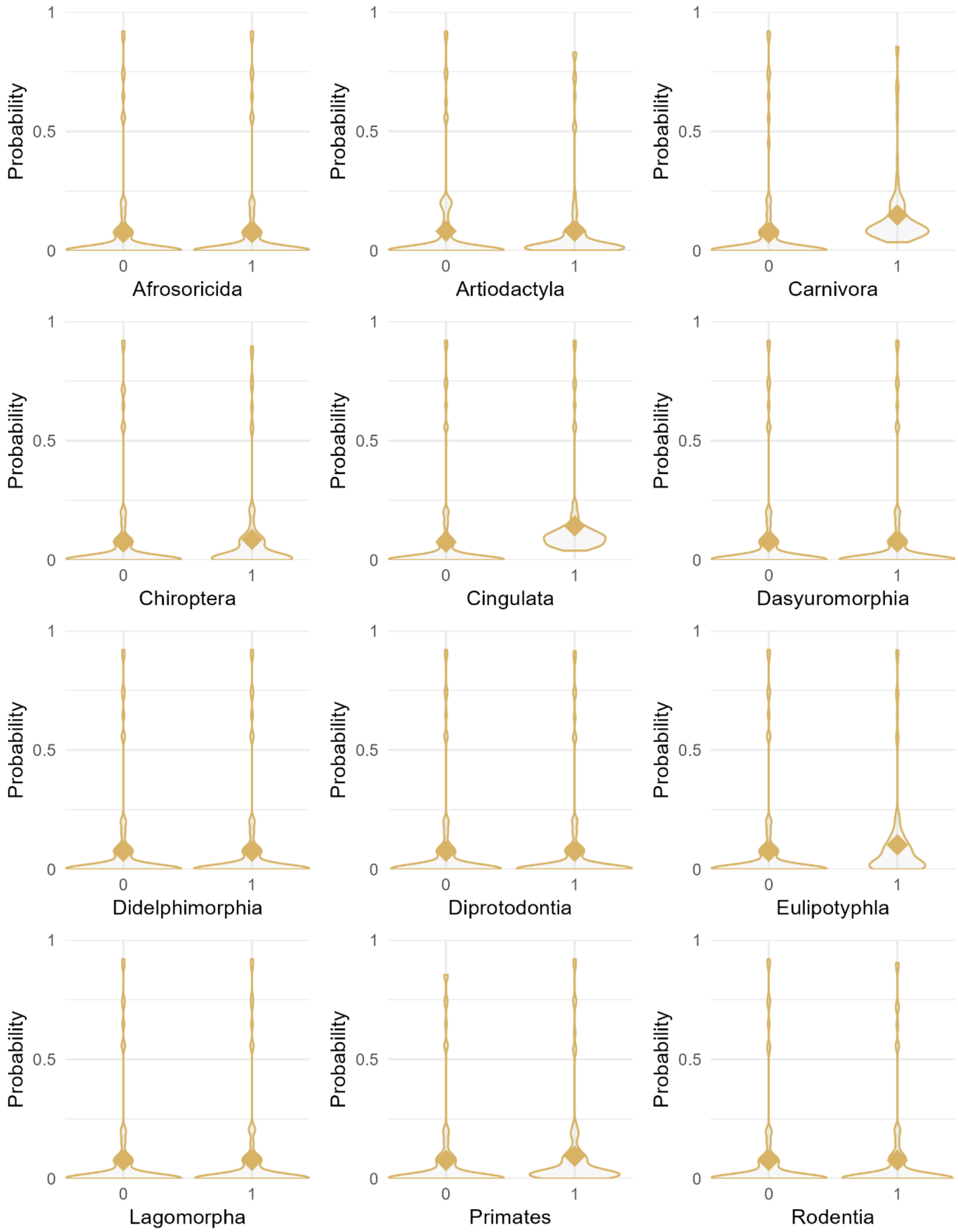
Supplementary Figure 22. Partial dependency plots for mammals used for food, across all taxonomic orders. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



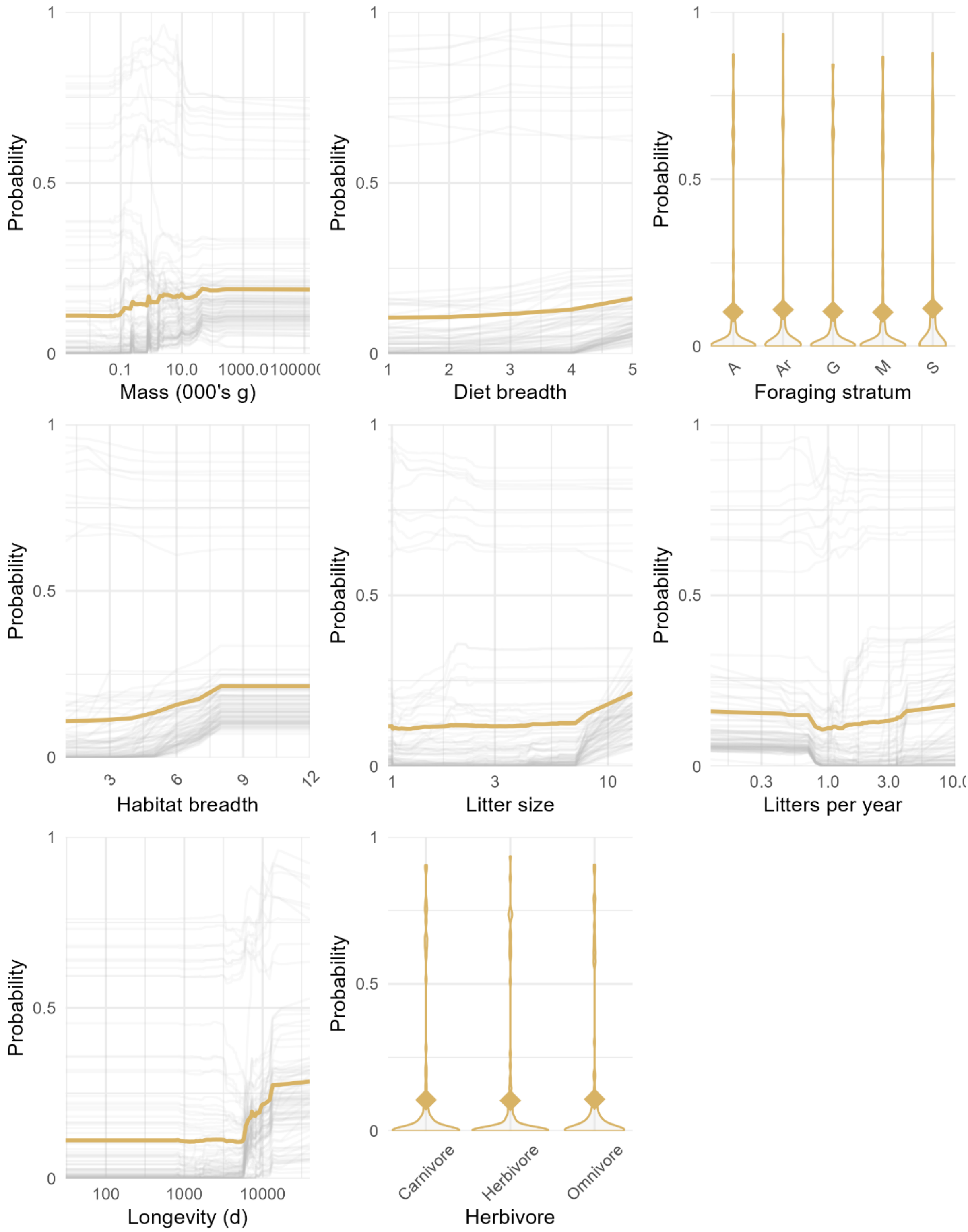
Supplementary Figure 23. Partial dependency plots for mammals used for medicinal purposes, across all ecological traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



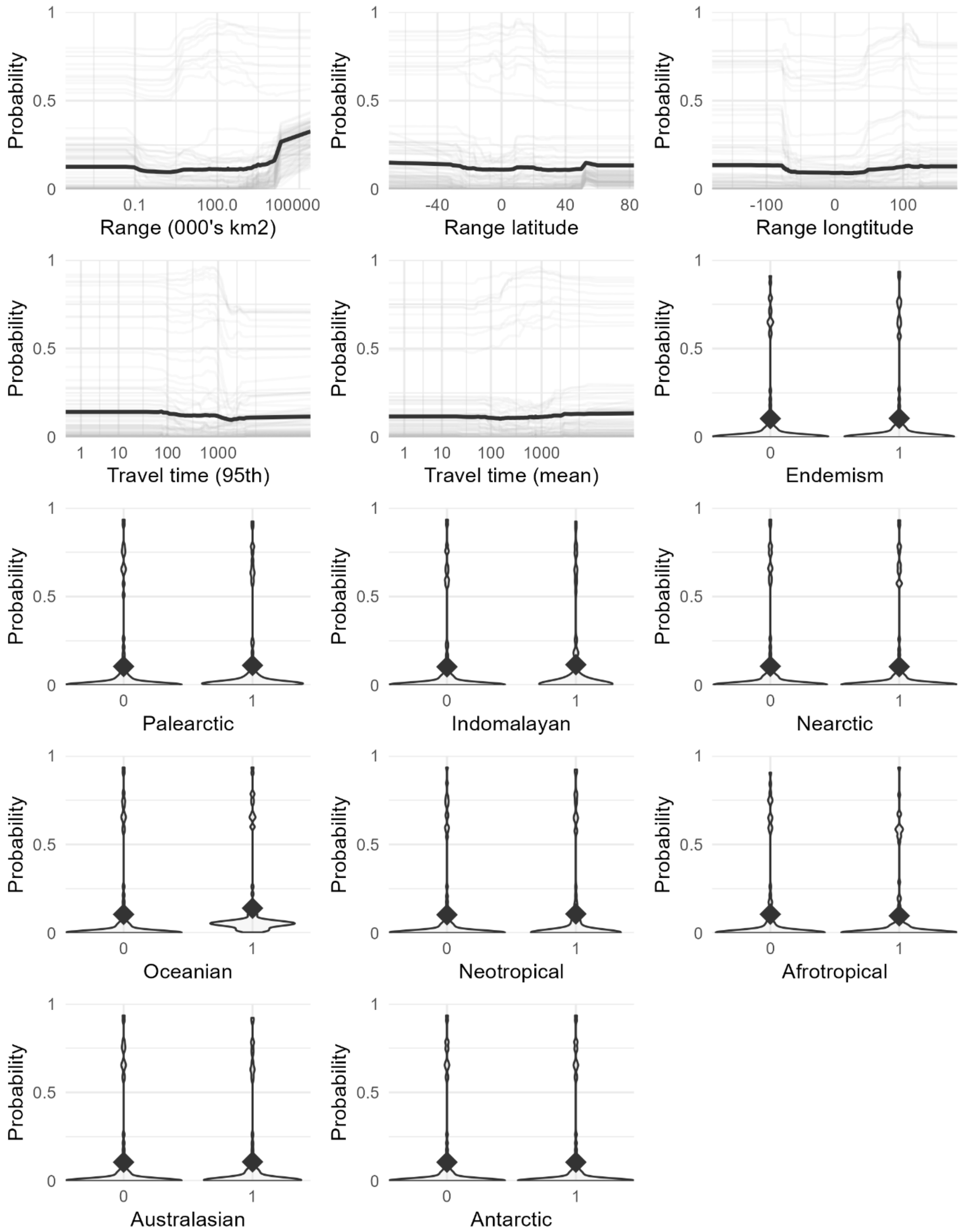
Supplementary Figure 24. Partial dependency plots for mammals used for medicinal purposes, across all range-based characteristics. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



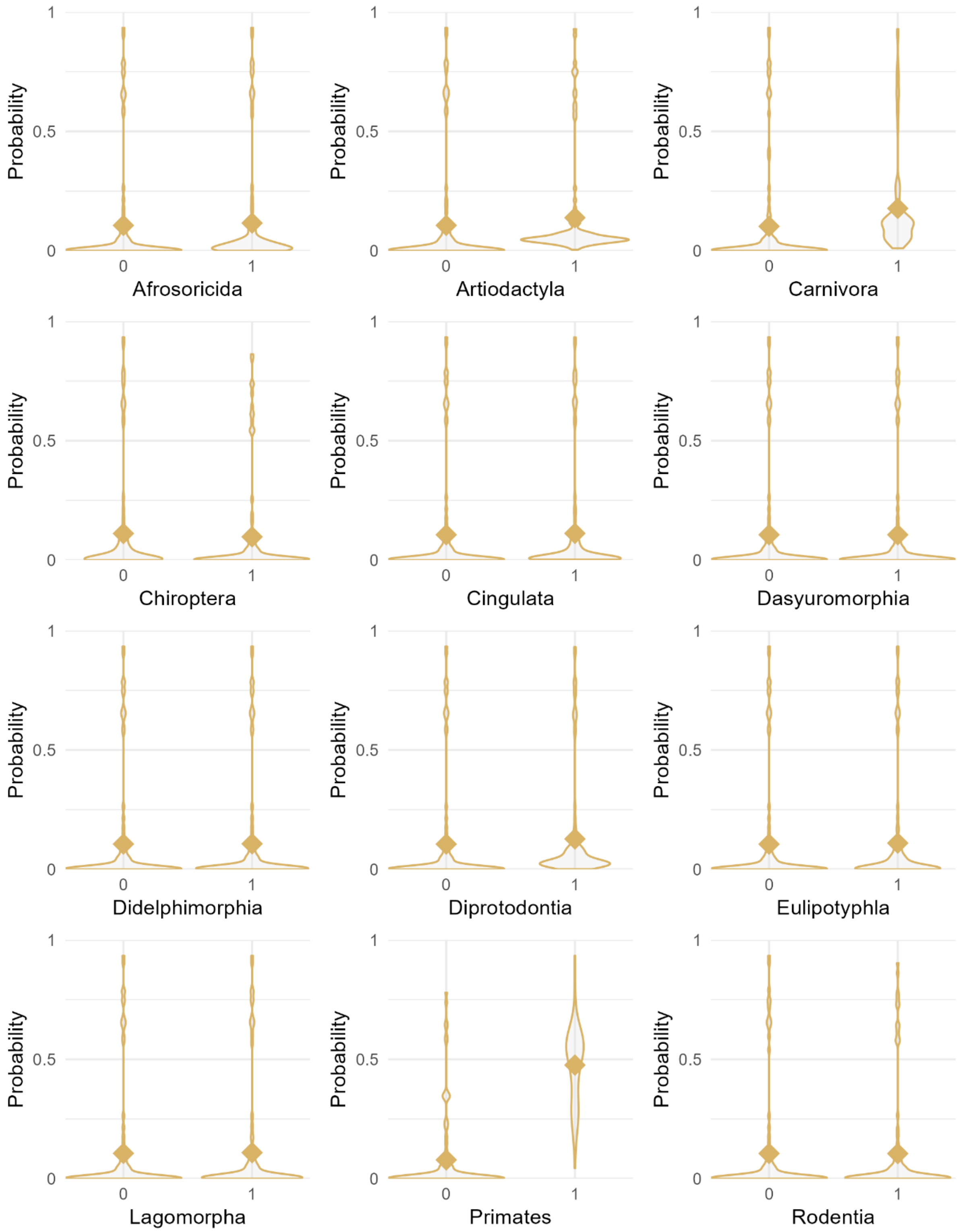
Supplementary Figure 25. Partial dependency plots for mammals used for medicinal purposes, across all taxonomic orders. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



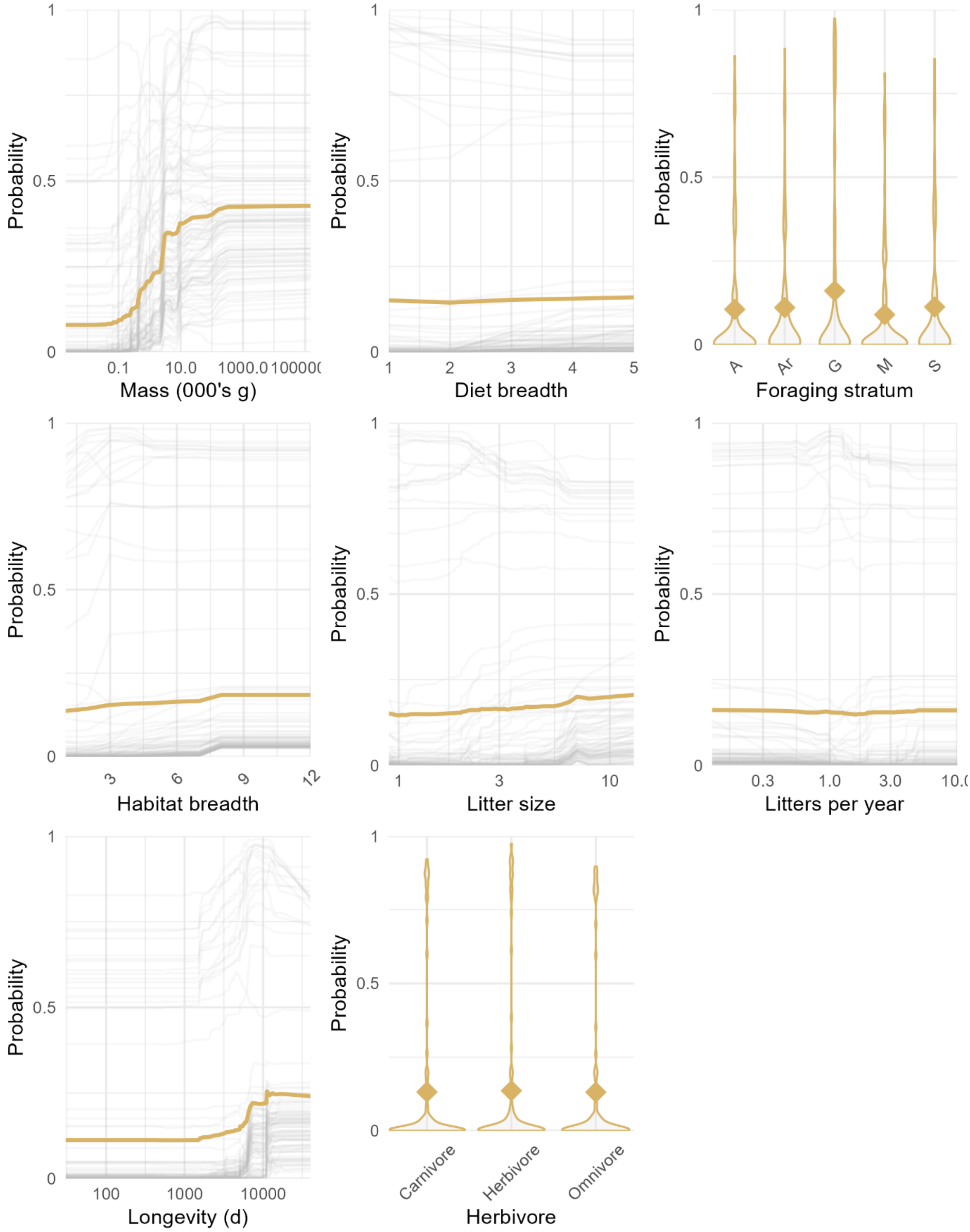
Supplementary Figure 26. Partial dependency plots for mammals used as pets, across all ecological traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



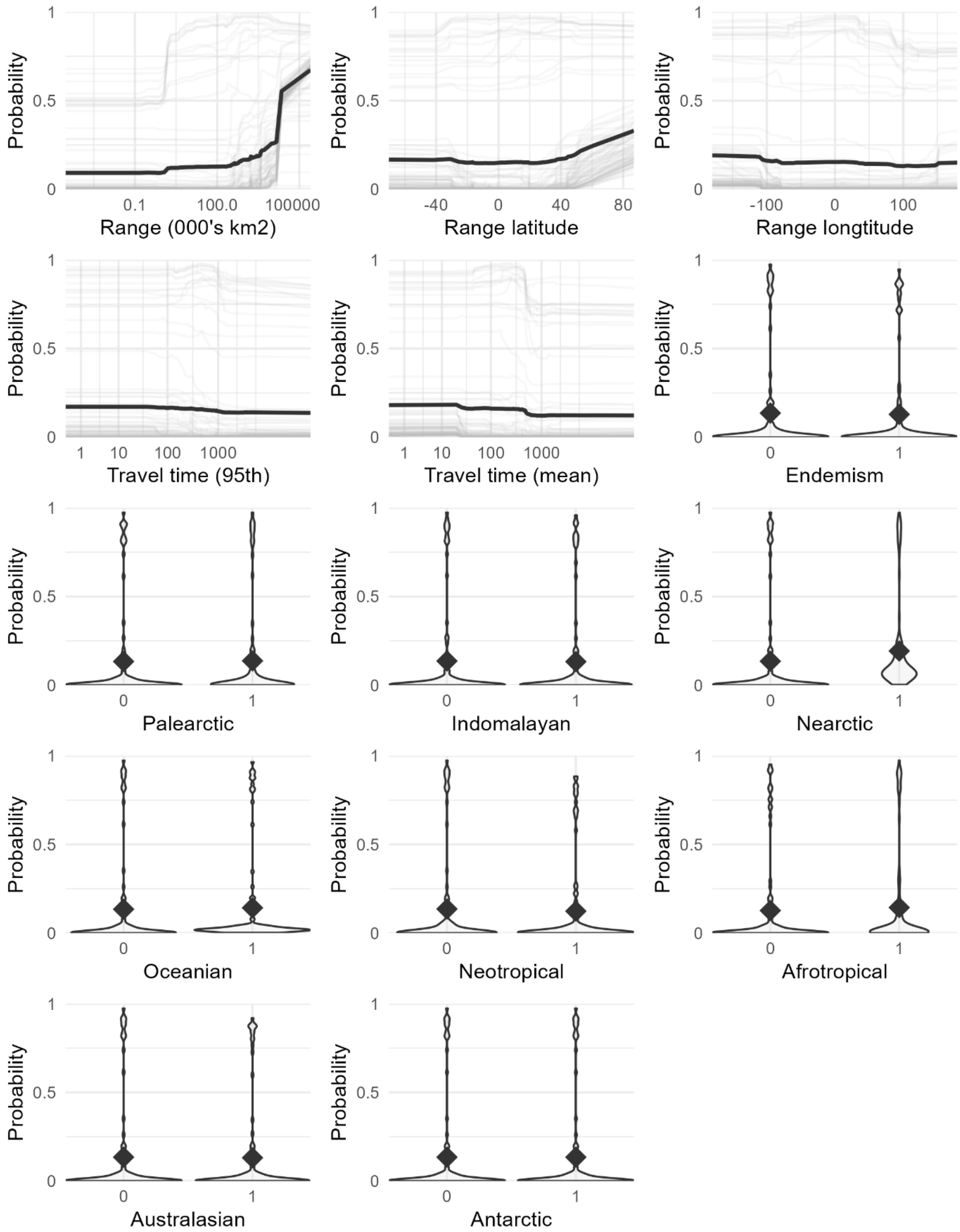
Supplementary Figure 27. Partial dependency plots for mammals used as pets, across all range-based characteristics. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



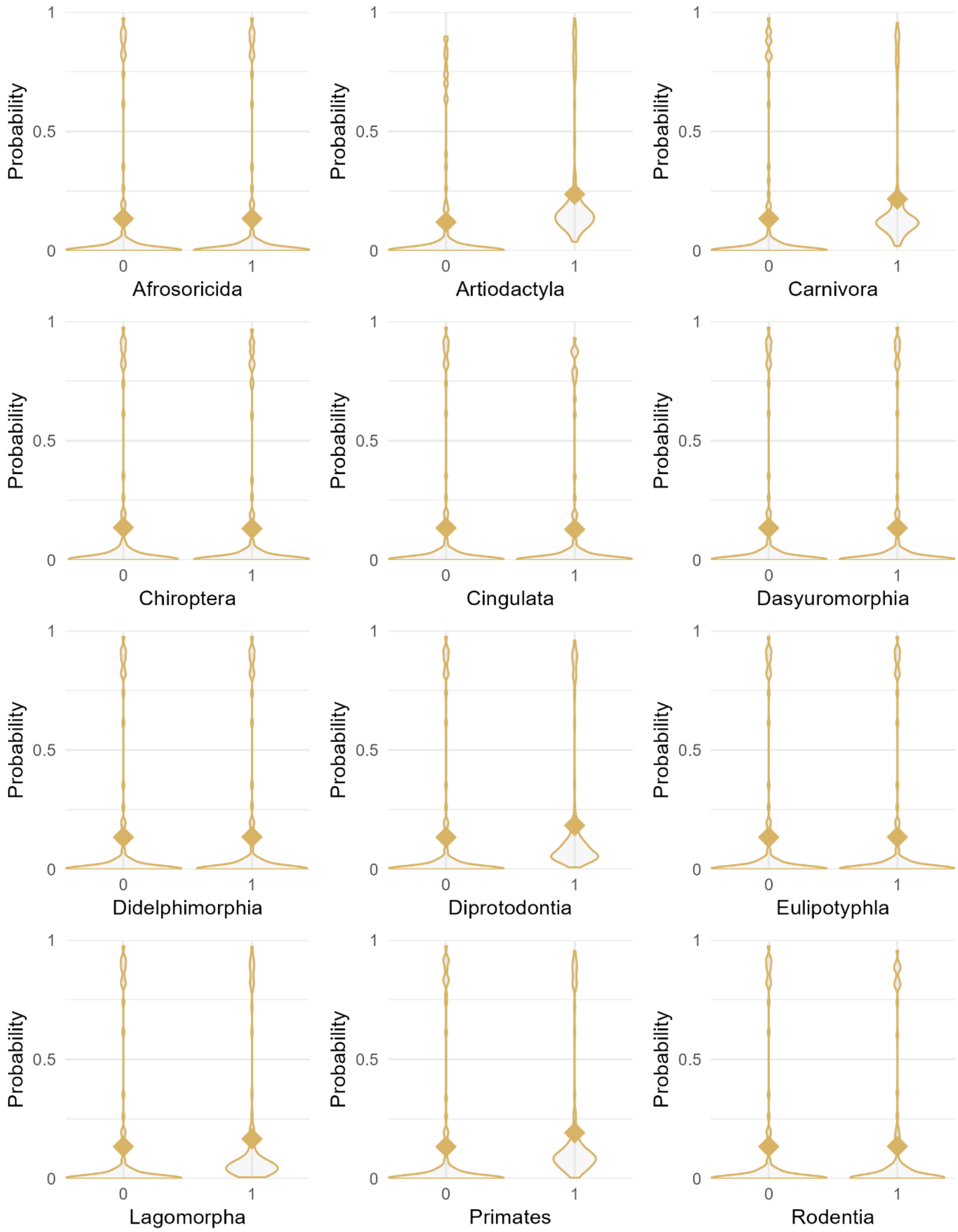
Supplementary Figure 28. Partial dependency plots for mammals used as pets, across all taxonomic orders. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



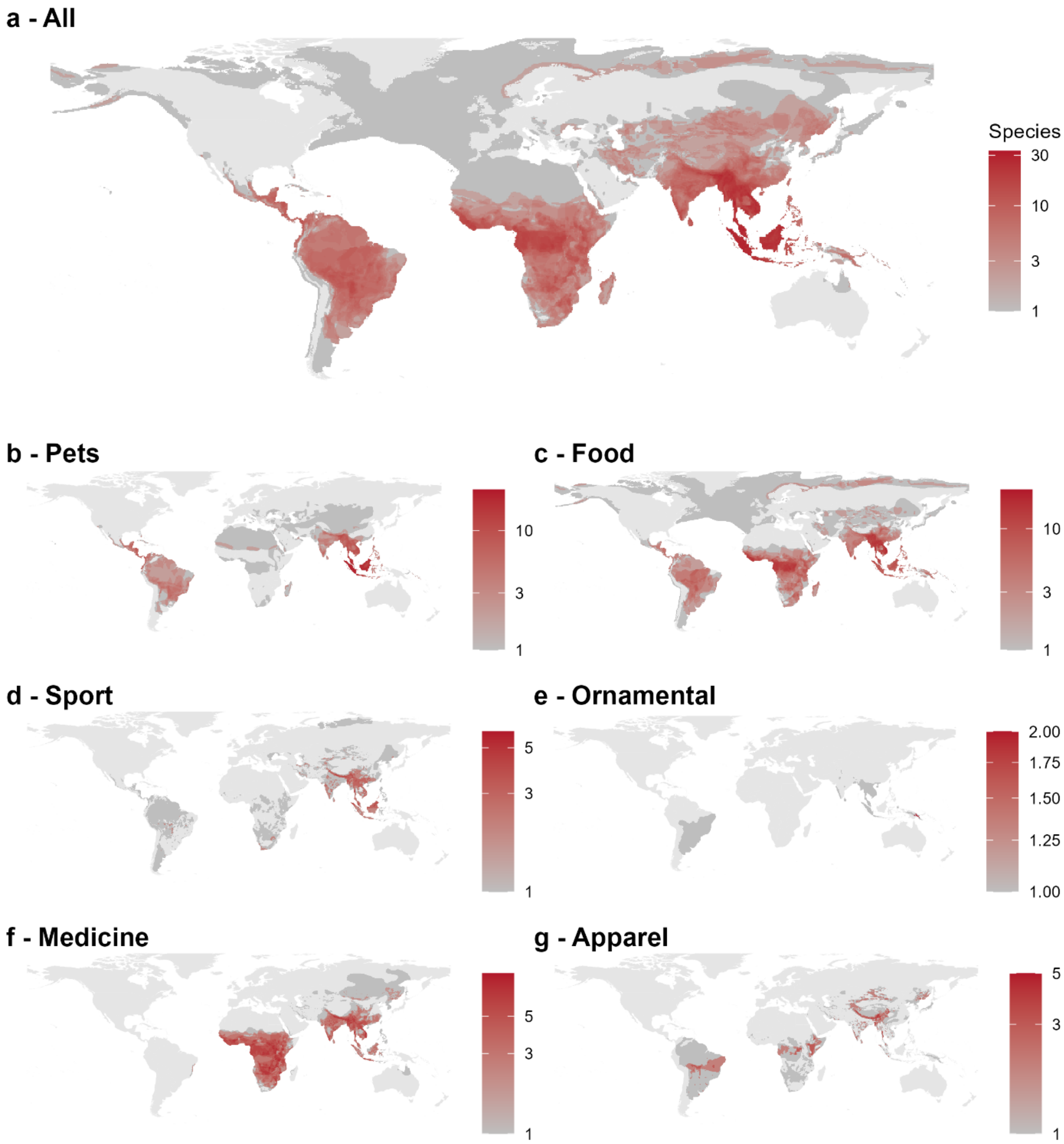
Supplementary Figure 29. Partial dependency plots for mammals used for sport, across all ecological traits. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



Supplementary Figure 30. Partial dependency plots for mammals used for sport, across all range-based characteristics. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).

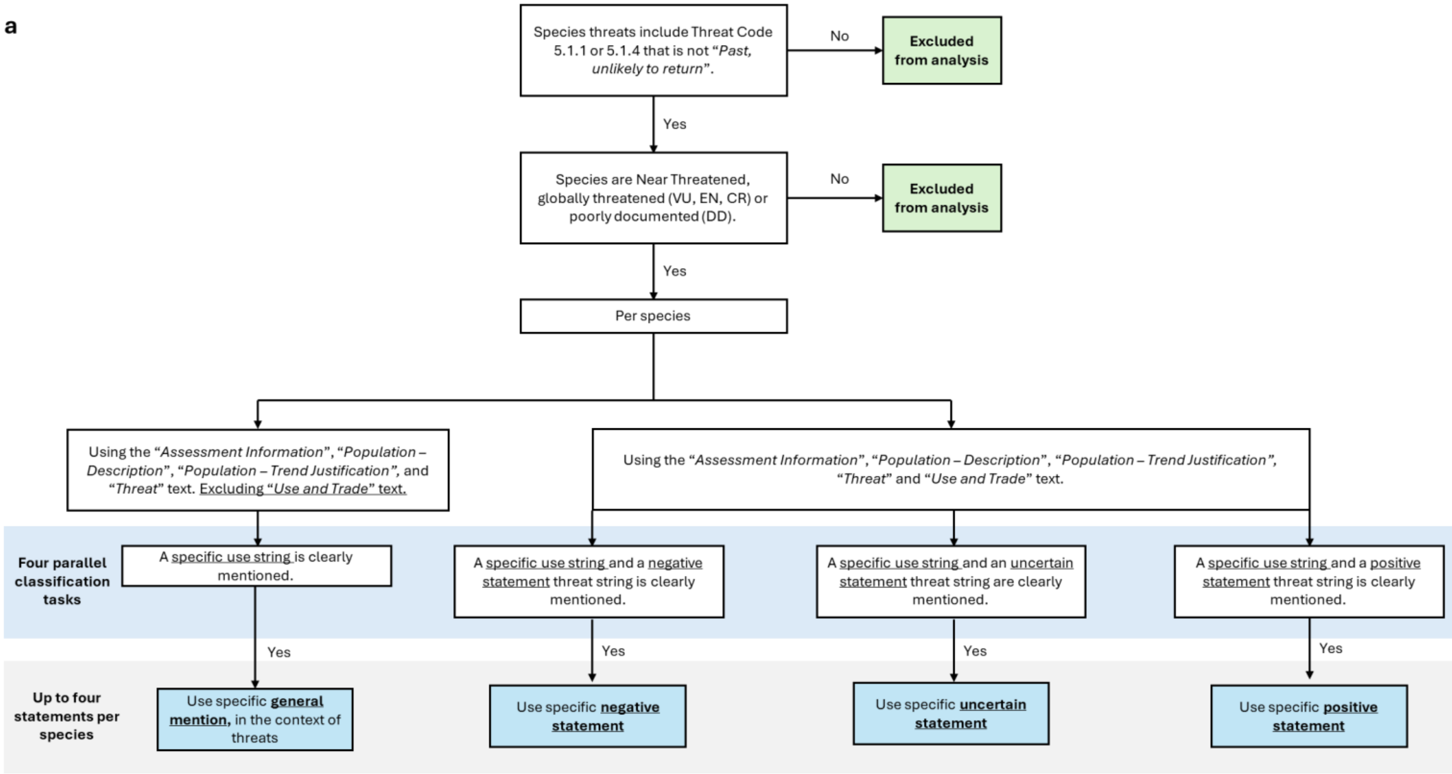


Supplementary Figure 31. Partial dependency plots for mammals used for sport, across all taxonomic orders. In the partial dependency plots the central bold lines denotes average conditional profiles, and the grey lines denote the individual conditional profiles for each observation and reflect the heterogeneity around the average (for categorical variables, their distribution is summarised as violin plots). Variables are coloured to denote intrinsic traits (purple) and extrinsic environmental variables (black).



Supplementary Figure 32. Maps of species richness for species threatened by at least one known use (a) . Also shown disaggregated to each specific end use (b-g).

a



b

		Statements			
		General mention	Positive statement	Negative statement	Uncertain statement
Outcome category	Insufficient information				T
		T			T
	Unlikely			T	
		T		T	
	Potentially	T			
	Highly likely	T	T		
			T		

Supplementary Figure 33. Workflow for assessing use-specific threats.

Supplementary Table 1. Data summarised from the IUCN General Use and Trade Classification Scheme (Version 1.0). Use and Description are taken directly (in some cases paraphrased) from the IUCN classification. The additional notes column denotes any clarifications or details on how we have interpreted this specific use category in this study.

Use	Description	Additional notes
Food – human (1)		
Food – animal (2)		Aggregated as "Other" due to limited representation.
Medicine (3)		
Poisons (4)		
Manufacturing chemicals (5)		
Other chemicals (6)		Aggregated as "Other" due to limited representation.
Fuels (7)		Aggregated as "Other" due to limited representation.
Fibre (8)		Aggregated as "Other" due to limited representation.
Construction/structural (9)		Aggregated as "Other" due to limited representation.
Apparel (10)		
Other household goods (11)		Aggregated as "Other" due to limited representation.
Handicrafts, Jewellery (12)		
Pets/display animals (13)		We do not consider a species presence in a zoo as sufficient evidence the species is "used" for that purpose.
Research (14)		Aggregated as "Other" due to limited representation.
Sport hunting/specimen collecting (15)		
Ex-situ conservation (16)		Aggregated as "Other" due to limited representation.
Other (17)		Aggregated as "Other" due to limited representation.
Unknown (18)		Aggregated as "Other" due to limited representation.

Supplementary Table 2. Breakdown of the descriptions and purposes matched to specific end uses from the USFWS LEMIS database.

End use	Criteria
Food – human consumption	Description – "CAL", "CAV", "LEG", or "SOU" & Purpose not "H"
Medicine	Description – "MED" & Purpose not "H"
Other chemicals	Description – "MUS"
Fibres	Description – "FIB"
Apparel	Description -"GAR", "LPS", "SHO", or "TRI" & Purpose not "H"
Other household goods	Description - "KEY", "LPL", "PIV", or "RUG" & Purpose not "H"
Handicrafts, Jewellery	Description - "BOC", "CAR", "HOC", "IJW", "IVC", or "JWL" & Purpose not "H"
Research	Purpose – "M"
Sport hunting	Purpose – "H" or Term – "TRO

Supplementary Table 3. Breakdown of the terms and purposes matched to specific end uses from the CITES Trade Database.

End use	Criteria
Food – human consumption	Term – “soup” & Purpose not “H”
Medicine	Term – “medicine” & Purpose not “H”
Other chemicals	Term – “musk”
Fibres	Term – “fibres”
Apparel	Term -"garments", "leather products (small)", or "shoes" & Purpose not “H”
Other household goods	Term - "furniture", "leather products (large)", or "sets of piano keys" & Purpose not “H”
Handicrafts, Jewellery	Term - "bone carvings", "carvings", "horn carvings", or "ivory carvings" & Purpose not “H”
Sport hunting	Purpose – “H” or Term – “trophies

Supplementary Table 4. Breakdown of the commodity types matched to specific end uses from the WITIS Trade Portal.

End use	Criteria
Food – human consumption	Commodity type – "Meat" (checked likely for consumption)
Medicine	Commodity type – “Wine” (all checked to refer to medicinal tiger bone wine)
Other chemicals	Commodity type – “Musk”
Handicrafts, Jewellery	Commodity type – "Bone - Worked", "Ivory - Worked", "Carvings", or "Horn - Worked"

Supplementary Table 5. Wikipedia search terms.

End use	Criteria
Food – human consumption	"consumption", "eaten", "eating", "delicacy", "consumed", "cooking", "meat", "bushmeat", "bush meat", "culinary", "cuisine"
Pet	"pet", "pet", "cagebird", "cage-bird", "cage bird", "collector", "aviculture", "aviculturist", "domesticated"
Sport hunting	"game bird", "gamebird", "sport shoot", "sports shoot", "shoot", "drive", "shot", "game", "recreational", "water fowling", "fowling", "open season", "closed season"
Handicrafts, Jewellery	"ornamental", "decorative", "jewel", "handicrafts", "artisanal", "decoration", "earring", "necklace", "carving", "adornment"
Medicine	"medicine", "medicinal", "remedy", "cure", "curative", "therapy", "therapeutic", "healing", "charm", "to treat"
Apparel	"pelts", "furs", "hides", "clothes", "cloth", "leather", "clothing", "garments", "coat", "trousers", "leather", "belts", "shoe"
Generic use	"trade", "market", "sold", "hunt", "trapped", "trapping", "sustainable", "unsustainable", "exploited", "shot", "subsistence"

Supplementary Table 6. Summary of uses extracted per data source. Columns highlighted in grey represent the 6 most dominant use categories. Columns highlighted in red refer to ambiguous uses (Establish ex-situ production, Other, and Unknown). Row wise sums will not add to the total in most cases as not all species can be clearly given a use from all data sets (e.g. in WiTIS the vast majority of species are simply reported as "Individual – Live" and "Seizure".

Data Source	Use and Trade Codes																		Total
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	
IUCN UT	2867	33	295	0	1	13	14	3	3	223	71	188	4448	35	612	36	45	9	6283
IUCN BRU																			2415
IUCN SpUD	125		24									45	20		20				161
Benitez-Lopez et al.,	315																		315
Morton et al.,	101												7						120
WILDMEAT	182																		182
LEMIS	11		61			7		1		378	172	253		431	1181				3305
CITES	1		37			9		6		202	50	173			385				2027
WiTIS	126		1			3						10							1518
Donald et al.,																			4930
Wikipedia*	210		70							58		25	198		35				2085

**Wikipedia totals are not all species classed to those uses, but all species novelly classed to those uses and thus not appearing in other datasets.*

Supplementary Table 7. Variables included in predictive modelling for birds and mammals after dropping highly correlated variables.

Birds	Mammals
Adult mass (g), taxonomic Order (dummy coded), realms the species has range in (Afrotropical, Antarctic, Australasian, Indomalaya, Nearctic, Neotropical, Oceanian, Palearctic, dummy coded), range latitudinal centroid, range longitudinal centroid, range area, age at first breeding, beak depth, beak length (culmen), proportion of individual colours (black, light blue, dark blue, light brown, dark brown, light green, dark green, light grey, dark grey, light purple, dark purple, light red, dark red, light rufous, dark rufous, white, yellow), number of distinct colour loci, habitat breadth, hand wing index, Kipps distance, primary lifestyle, relative tail length, absolute tail length, tarsus length, travel time (mean and 95th percentile), trophic level.	Adult mass (g), taxonomic Order (dummy coded), realms the species has range in (Afrotropical, Antarctic, Australasian, Indomalaya, Nearctic, Neotropical, Oceanian, Palearctic, dummy coded), range latitudinal centroid, range longitudinal centroid, range area, diet breadth, foraging stratum, trophic level, habitat breadth, endemism (0/1), litter size, litters per year, maximum longevity, travel time (mean and 95th percentile).

Supplementary Table 8. Hyperparameters selected after tuning.

Taxa	Use	Number of trees	Minimum node size	Number of features to split at
Birds	Food	1500	5	30
	Medicinal	1000	5	30
	Apparel	100	5	40
	Aesthetic	100	5	20
	Pets	500	5	10
	Sport	500	5	40
Mammals	Food	1500	5	20
	Medicinal	1500	5	15
	Apparel	100	5	10
	Aesthetic	1500	5	10
	Pets	1500	5	15
	Sport	1500	5	20

Supplementary Table 9. Predicted end-use model fit performance metrics. Rows in grey are those uses we found to be moderately to highly predictable. We note that the use as aesthetics in mammals was moderately predictable as per the Kappa value, in light of the small number of species used we elected to not consider this use predictable. Likewise for medicinal use, the non-significant p-value testing if the model accuracy was greater than the no-information rate precluded our use of the model.

Class	Use	Accuracy	Specificity	Sensitivity	Balanced accuracy	Acc > NIR	Kappa
Aves	Food	0.903	0.688	0.95	0.819	0	0.658
	Medicine	0.989	0.154	0.998	0.576	0.552	0.231
	Apparel	0.985	0.108	0.999	0.553	0.478	0.178
	Aesthetics	0.978	0.222	0.996	0.609	0.426	0.306
	Pets	0.826	0.809	0.84	0.824	0	0.648
	Sport	0.914	0.479	0.974	0.726	0	0.527
Mammalia	Food	0.909	0.808	0.947	0.877	0	0.767
	Medicine	0.952	0.338	0.987	0.663	0.175	0.411
	Apparel	0.941	0.639	0.97	0.805	0	0.622
	Aesthetics	0.957	0.577	0.98	0.779	0.019	0.58
	Pets	0.943	0.456	0.981	0.718	0.019	0.507
	Sport	0.941	0.603	0.977	0.79	0	0.631

Supplementary Table 10. Specific words and phrases cleaned from IUCN text.

Type	Words removed
Stop words	a, about, also, an, and, any, are, as, at, be, been, being, by, can, for, from, has, have, if, in, into, include, including, included, includes, is, it, its, much, of, on, or, so, still, such, than, that, the, there, therefore, this, to, were, where, which, with, within, would, wild, species, species's, sp., thought, believed, considered
Confusion terms	medicine trees, medicinal trees, medicinal plants, medicine plants, medicinal herbs, medicine herbs, recreational activities, recreational watersports, recreational chasing, subsistence logging, subsistence cropping, subsistence farming, subsistence agriculture, leather leaf, leather fern, leather leaf, ornamental crop, ornamental shrub, ornamental plant
Other	et al., pers comm., sp., litt.

Supplementary Table 11. Use-string terms used. The text in brackets details specific regex coding, such as the exclusion of the species words or allowing gaps of alternate words between the target words.

End use	Terms
Food	exploitation (0–3 words) food, exploited (0–3 words) food, hunted (0–3 words) food, hunting (0–3 words) food, trapping (0–3 words) food, trapped (0–3 words) food, shot (0–3 words) food, snared (0–3 words) food, snaring (0–3 words) food, harvesting (0–3 words) food, killed (0–3 words) food, capture (0–3 words) food, exploitation (0–3 words) consumption, exploited (0–3 words) consumption, hunted (0–3 words) consumption, hunting (0–3 words) consumption, trapping (0–3 words) consumption, trapped (0–3 words) consumption, shot (0–3 words) consumption, snared (0–3 words) consumption, snaring (0–3 words) consumption, harvesting (0–3 words) consumption, killed (0–3 words) consumption, capture (0–3 words) consumption, exploitation (0–3 words) subsistence, exploited (0–3 words) subsistence, hunted (0–3 words) subsistence, hunting (0–3 words) subsistence, trapping (0–3 words) subsistence, trapped (0–3 words) subsistence, shot (0–3 words) subsistence, snared (0–3 words) subsistence, snaring (0–3 words) subsistence, harvesting (0–3 words) subsistence, killed (0–3 words) subsistence, collection (0–3 words) subsistence, capture (0–3 words) subsistence, hunting food, hunted food, trapped food, trapping food, snared food, snaring food, sold food, hunting consumption, hunted consumption, trapped consumption, trapping consumption, snared consumption, snaring consumption, shot food, shot consumption, local consumption, meat, body parts food, venison, bushmeat, restaurant, delicacy, subsistence hunting, subsistence trapping, subsistence harvest, killed subsistence, hunted subsistence, trapped subsistence
Medicine	medicin, remedy, remedies, curative, pharmaceutical product, pharmaceutical licence
Apparel	clothes, clothing, cloth, hat, hats, leather, fur trade, fur buyers, hunted (0–3 words) fur, trapped (0–3 words) fur, killed (0–3 words) fur, skins, skin trade, skin (0–2 words) trade, skin (0–2 words) market, hides
Ornamental products	souvenir, curio, curios, headdress, carving, carved, casque, tourist key ring, arrow fletch, ornament, decorate, decorative, plumes
Pet	cagebird, cage-bird, cage bird, aviary bird, aviary-bird, songbird, song bird, falconry, pet, pets, live-capture, captive trade, captive-trade, nest poaching, bird market, bird-market, live animal market, live-animal market, wildbird trade, wild bird trade, companion
Sport	trophy, recreational hunting, sport hunting, trade (0–2 words) trophies, exploitation (0–2 words) sport, exploitation (0–2 words) trophies, exploitation (0–2 words) recreation, exploited (0–2 words) sport, exploited (0–2 words) trophies, exploited (0–2 words) recreation, hunting (0–2 words) sport, hunting (0–2 words) trophies, hunting (0–2 words) recreation, hunted (0–2 words) sport, hunted (0–2 words)

	recreation, hunted (0–2 words) trophies, killed (0–2 words) sport, killed (0–2 words) trophies, killed (0–2 words) recreation, killing (0–2 words) sport, killing (0–2 words) trophies, killing (0–2 words) recreation, hunting (0–3 words) using falcons, hunting (0–3 words) using falconry, hunted (0–3 words) using falcons, hunted (0–3 words) using falconry

Supplementary Table 12. Threat-string terms used. The text in brackets details specific regex coding, such as the exclusion of the species words or allowing gaps of alternate words between the target words.

Impact	Terms
Threat or negative impact or unsustainable	declin [not: “not”, “poaching”, “hunting”, “offtakes”, “volumes”], decreas [not: “not”, “poaching”, “hunting”, “offtakes”, “volumes”], negative impact [not: “not”, “nor”], negatively impact [not: “not”, “nor”], serious impact [not: “not”], seriously impact [not: “not”], negative effect [not: “not”, “nor”], negatively effect [not: “not”, “nor”], serious effect [not: “not”, “nor”], seriously effect [not: “not”, “nor”], negative affect [not: “not”, “nor”], negatively affect [not: “not”, “nor”], serious affect [not: “not”, “nor”], seriously affect [not: “not”, “nor”], reduced numbers [not: “not”, “nor”], reduced population [not: “not”, “nor”], population reduc [not: “not”], unsustain [not: “not”], not sustainab, exceed sustainab [not: “not”], above sustainab [not: “not”], overexploit [not: “not”], reduction [not: “not”], overharvested [not: “not”], driving population impacts [not: “not”, “nor”], driving population reductions [not: “not”, “nor”], causing population impacts [not: “not”, “nor”], causing population reductions [not: “not”, “nor”], driving impacts [not: “not”, “nor”], driving reductions [not: “not”, “nor”], causing impacts [not: “not”, “nor”], causing reductions [not: “not”, “nor”], threat [not: “potential”, “potentially”, “possible”, “possibly”, “suspected”, “not”, “nor”], drive extinct [not: “not”, “nor”], cause extinct [not: “not”, “nor”], increase extinct [not: “not”, “nor”]
No threat, impacts or is sustainable	not decline, no decline, no evidence of decline, unlikely drive decline, likely not drive decline [not: “not”, “nor”], unlikely drive impact, likely not impact [not: “not”, “nor”], unlikely drive effect, likely not effect [not: “not”, “nor”], unlikely drive affect, likely not affect [not: “not”, “nor”], minimal impact, no impact, negligible decline [not: “not”], negligible impact [not: “not”], does not appear to cause decline, not decrease, no decrease, no evidence of decrease, unlikely decrease, unlikely drive decrease, likely not drive decrease [not: “not”, “nor”], does not appear to cause decrease, likely not threat [not: “not”, “nor”], unlikely threat, likely not constitute threat [not: “not”, “nor”], likely not pose threat [not: “not”, “nor”], likely not seem major/key/important threat [not: “not”, “nor”], likely not major/key/main threat [not: “not”, “nor”], likely not currently major/key threat [not: “not”, “nor”], likely not currently threat [not: “not”, “nor”], likely not considered threat/key/main/major threat [not: “not”, “nor”], likely not meaningful/significant/substantial threat [not: “not”, “nor”], likely not drive/cause/increase extinct [not: “not”, “nor”], not elevate extinct, sustainable [not: “not”], sustainably [not: “not”], not overexploit, likely not negatively impact/effect [not: “not”, “nor”], not thought significant, not significant, likely not driving population reduction [not: “not”, “nor”], no population reduction, unlikely causing declines, unlikely decline, unlikely impact, unlikely reduction, positive impact [not: “not”, “no”]
Uncertain impacts or insufficient	unknown effect, unknown impact, impacts unknown, impact unknown, threat posed unknown, unquantified, not known [up to 2

information to deduce	words between “not” and “known”], not quantified [up to 2 words between “not” and “quantified”], not established [up to 2 words between “not” and “established”], threat unknown [up to 2 words between “threat” and “unknown”], threat uncertain [up to 2 words between “threat” and “uncertain”]

Supplementary Table 13. Performance metrics for the rule-based text classifier. Frequency denotes the raw number of total occurrences and the proportion of the test data they were recorded in. Rows in grey denote where no examples were detected in the manually classified test data, a product of the incredibly low occurrence frequency.

Use	Reference type	Frequency	Kappa	accuracy	Acc > NIR	Specificity	Sensitivity	Balanced accuracy
Food	General	103 (0.52)	0.94	0.97	0	0.98	0.96	0.97
	Negative	49 (0.24)	0.84	0.94	0	0.94	0.94	0.94
	Non-negative	2 (0.01)	0.49	0.98	0.86	0.5	0.99	0.74
	Insufficient	1 (0)	-0.01	0.98	0.98	0	0.99	0.49
Medicine	General	31 (0.16)	0.94	0.98	0	1	0.98	0.99
	Negative	9 (0.04)	0.85	0.98	0.02	1	0.98	0.99
	Non-negative	0 (0)	-	1	1	-	1	-
	Insufficient	0 (0)	-	1	1	-	1	-
Apparel	General	15 (0.07)	0.76	0.96	0.01	0.8	0.98	0.89
	Negative	4 (0.02)	0.89	1	0.09	1	0.99	1
	Non-negative	1 (0)	0	1	0.74	0	1	0.5
	Insufficient	1 (0)	0	1	0.74	0	1	0.5
Aesthetic	General	8 (0.04)	0.87	0.99	0.01	0.88	0.99	0.93
	Negative	1 (0)	0.66	1	0.74	1	0.99	1
	Non-negative	0 (0)	-	1	1	-	1	-
	Insufficient	0 (0)	-	1	1	-	1	-
Pets	General	69 (0.34)	0.97	0.98	0	0.97	0.99	0.98
	Negative	38 (0.19)	0.79	0.94	0	0.84	0.96	0.90
	Non-negative	3 (0.01)	1	1	0.05	1	1	1
	Insufficient	3 (0.01)	0.8	1	0.2	0.67	1	0.83
Sport	General	18 (0.09)	0.8	0.97	0	0.72	0.99	0.86
	Negative	7 (0.04)	0.87	0.99	0.03	1	0.99	0.99
	Non-negative	2 (0.01)	1	1	0.13	1	1	1
	Insufficient	0 (0)	-	1	1	-	1	-

Supplementary Table 14. Justification and explanation for threat categories. In the examples column we also clearly denote the text flagging the threat statement (green) and the link to one or more specific uses (yellow). Examples are non-exhaustive and highlight a single instance per species for brevity (e.g. threat from a given use might be flagged in the assessment, threat and trend justification).

Category	Explanation	Example
Highly likely	Across all the assessed text (including the "Use and Trade" section) this category captures instances where a specific end use is referred to in the same sentence as a positive statement of threat. Due to the diversity of way threat and negative impacts to a species can occur or be phrased, we purposely used a broad interpretation of these terms. Our interpretation captures population reductions, general negative impacts, unsustainable levels of offtake, offtake deemed as overexploitation, increases in extinction risk, and more general references to the use being a threat to the species.	**Mindoro Bleeding-heart** (*Gallicolumba platenae*) "Hunting (using snares) for food and collection for the pet trade are additional threats.." **Greater Green Leafbird** (*Chloropsis sonnerati*) "The population is believed to be declining at a very rapid rate due to exceptionally high rates of trapping to supply the cage bird trade."
Potentially	This focuses only on the parts of the IUCN assessment specifically focused on threats and impacts on species (e.g. not the "Use and Trade" section). Our reasoning being that where uses are explicitly mentioned in text dedicated to the population status or threats facing a species, without any qualifiers negating the notion that this impacts a species, we precautionarily consider the species to be potentially threatened by this use.	**Northern Bald Ibis** (*Geronticus eremita*) "...disturbance from other human activities, and this population was also potentially threatened by trophy hunters, combined with a lack of safe areas with water sources..."
Unlikely	Across all the assessed text (including the "Use and Trade" section) this categories capture instances where a use is specifically stated as not being a threat to the species. As with the *highly likely* category we take a broad view of not a threat or impact, encompassing where use is stated to be sustainable, not driving impacts or declines, having a negligible effect, is not considered a likely/key/major/relevant threat or where use is having a positive impact on the species.	**Common Eider** (*Somateria mollissima*) "...shooting by indigenous peoples for food, especially in spring (Byers and Dickson 2001, Kear 2005), but this subsistence hunting is likely to be sustainable at current levels..." **Red-crowned Barbet** (Psilopogon rafflesia) "...recorded in the songbird trade (Marthy and Farine 2018) in Indonesia although this is not considered to be a

		main threat for this species, nor is it likely to be driving declines…”
Insufficient information	Across all the assessed text (including the “Use and Trade” section) this category captures where it is explicitly stated that there is insufficient information for a threat to be assessed. This category was also used when resolving occurrences where species have both negative and positive statements. Likewise, where a species use is known, but none of the previous categories apply e.g. the species use is never mentioned in the assessment, this category is applied.	**Socotra Buzzard** (*Buteo socotraensis*) “Young birds are taken from nests in the mistaken belief that they can be sold into the falconry trade whilst adults are captured and sold; however, it is not known whether this has a significant impact on the species…” **Urial** (*Ovis vignei*) “Newborn lambs are captured as pets but the impact on the population is not known.”

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