Phylogenetic Diversity vs H-Index – does genetics or culture lead conservation research?

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Abstract

With so many species in decline it is difficult to know where conservation effort and funding should be dedicated. A common prioritization argument is species uniqueness and phylogenetic diversity, where those with unique evolutionary history are thought to be especially valuable. However, despite frequent calls for better prioritization, research interest is often idiosyncratic, pragmatic, and geographically biased, creating an uneven spread of research interest across the tree of life. Here, we aim to quantify the research interest of endemic species from Africa and Australia across 5 vertebrate groups, exploring whether research interest has any correlation with phylogenetic uniqueness. To measure research interest, Hirsch's h-index is used as it can identify biases in the research literature. In this study, we explored the relationships between phylogenetic uniqueness, h-index, and the number of publications for five vertebrate groups across the Australian and African continents: Mammalia, Aves, Reptilia, Amphibia, and Chondrichthyes. Observing the top 10 species that are the most phylogenetically unique, there was very little relationship between their phylogenetic uniqueness and research interest. The most highly researched animals were the megafauna, or those considered as charismatic – with human-perceived charisma not showing a strong phylogenetic pattern. We saw higher research interest in mammals than other vertebrate groups, and generally higher levels of research attention in fauna from Africa than Australia, which did reflect higher levels of phylogenetic uniqueness on the African continent. While phylogenetic diversity is a useful index on which to base research interest and conservation prioritization, it appears that current conservation strategies reflected by research interest do not follow this approach. We believe that our approach in this study is scalable to other geographical regions, which can help guide conservation efforts of phylogenetically unique species.

1 Introduction

Species declines due to anthropogenic causes are so high, current times are referred to as the sixth major extinction event (Ceballos et al., 2017), with estimates of up to 40% of species experiencing population declines (Ceballos et al., 2017), and 80% decline in freshwater vertebrates alone (Darwall et al., 2018). With so many species in need of conservation, difficult decisions around which species are to be prioritised are regularly made but are guided by differing systems of prioritisation. A common decision-making process is referred to as conservation triage, where conservation efforts are assigned based on the likelihood of a species' survival under constrained resources (Wilson & Law, 2016). This method has received criticism due to the instances of species recovering despite being categorised as unlikely to survive, alongside arguments against its ethicality (Wiedenfeld et al., 2021; Wilson & Law, 2016). A different approach which avoids placing critically endangered species in the "can't be saved" category is the use of mathematical models to rank species in order of conservation priority based on a wide range of attributes which may include management costs, species value (such as its contribution to phylogenetic diversity) and likelihood of success (Joseph et al., 2009).

Current conservation prioritization techniques are often based on traditional measures of biodiversity including taxonomic diversity, richness and distribution, alongside other criteria such as ecological importance and social significance (Joseph et al., 2009). Allocation of conservation funds are highly biased towards social significance, which prefers appealing and charismatic endangered species, largely dominated by mammals and birds (Davies et al., 2018). As a result, other taxonomic groups, especially invertebrate groups are highly understudied (Donaldson et al., 2016; Titley et al., 2017). For several reasons including funding and the interests of scientists themselves, research interest cannot be allocated independent of the cultural context in which the science occurs. We have chosen two locations where we hypothesize that this cultural bias is especially important: in Africa where large charismatic mammals from the savanna such as lions and elephants receive large amounts of human cultural attention (Di Minin et al., 2013; Williams et al., 2000) and in Australia, where the cute and cuddly koala bear dominates media campaigns despite a plethora of other endemic species (Bagust, 2010; Markwell, 2020; Stratford et al., 2000). Other human cultural influences apply to conservation effort outside of the research species themselves, such as geography, with 40% of studies conducted in the USA, Australia or the UK, and only 10% in Africa (Di Marco et al., 2017). There are also temporal cultural shifts which are reflected in research interest. And conservation effort. For e.g., the total proportion of articles on aquatic systems in 2017 was 50-60% higher than before 2010, however there remains a disconnect between scientific focus and conservation needs (Di Marco et al., 2017). Recognising and quantifying these biases is an important step to evaluate conservation efforts, and determine whether current efforts are justified and well placed.

There are multiple ways to measure conservation effort, the first being research output which includes the number of publications on a particular species. A complementary measure is research interest, which can be measured using Hirsch's h-index, usually applied to measure a person's scientific research, defined as the greatest number of publications cited a minimum number of times (Hirsch, 2005). In this way the h-index monitors research interest, as it includes not only the number of papers (output), but the number of times they were cited (interest).

To improve on the prioritization of species conservation, and to explore the justification of current species of focus, we suggest the inclusion of a species' unique contribution to phylogenetic diversity (PD) as an important consideration. Although originally recommended as early as 1991 (Faith, 1992; Vane-Wright et al., 1991), this metric quantifies the unique evolutionary history that an extant species represents. PD is measured in the number of million years, with a species unique contribution calculated by summing the lengths of branches that represent its independent journey throughout evolutionary history (Winter et al., 2013). In itself it is not clear if this is valuable, but there are many reasons to support the importance of this metric which include the ‘resilience argument’ which suggests phylogenetically diverse ecosystems have greater options to respond to change, the ‘historical value argument’ which suggests protecting phylogenetic diversity preserves access to and knowledge of the earth’s history, and the ‘aesthetic argument’ which suggests phylogenetic diversity conserves aesthetic differences and qualities of unique species guarding an interesting and aesthetically diverse and pleasing ecosystem (Palmer & Fischer, 2022). Human studies have found reduced microbial PD can reflect reduced resilience and can be associated with human disease, but similar arguments have not yet been solidly applied at the macrobial ecology scale (Faith, 2018). These arguments, alongside others, are combined to give power to the idea of value in phylogenetic diversity (Palmer & Fischer, 2022). Further, PD can be combined with levels of extinction threat and can serve as a way to prioritize effort when resources are scarce (Costion et al., 2015; Gumbs et al., 2021; Isaac et al., 2007; Mooers & Atkins, 2003; Posadas et al., 2001). The Noah’s Ark framework is a prioritisation tool which considers this phylogenetic contribution to diversity (Metrick & Weitzman, 1998), however it does not include the probability that the management of a species will succeed. There are, however, extensions on this framework which include this probability to succeed and have been used to identify management priorities in New Zealand (Joseph et al., 2009) and Australia (Gonzalez-Orozco et al., 2016). As a result of this approach, historic species that are evolutionary unique and therefore hold many millions of years of evolutionary history would be favoured for conservation, one such example being the Australian platypus *Ornithorhynchus anatinus*.

We aimed to explore the overlap in research interest and phylogenetic diversity for five vertebrate animal groups (mammalia, aves, reptilia, amphibia and chondrichthyes) in Australia and Africa, led by the presence of more complete taxonomic trees. We ask, 1) Are h-index and number of publications always similar for each species? 2) Do animals that contribute to high phylogenetic diversity receive more research interest? 3) How does research interest differ between the animal classes? And 4) How does research interest and the range of phylogenetic diversity differ across the African and Australian continents? In response to research question 2, we hypothesise that research interest is not strongly correlated with phylogenetic diversity but is rather influenced by human cultural factors such as charisma and size. Based on the phylogenetic diversity we suggest the top 10 animals from each class and continent that would contribute to the greatest phylogenetic diversity conserved and discuss the barriers towards their conservation. While we focus on only two continents, our methods can be duplicated to allow for location specific exploration of current research interest, to ultimately guide future conservation decisions.

2 Methods

2.1 Data collection and cleaning

We collected phylogenetic trees of five vertebrate groups from http://vertlife.org/data/ in September and October of 2022, totalling up to 34,090 species. For each group we downloaded 100 random trees, with each tree built from an arrangement of 5,911 mammals (Upham et al., 2019), 9,993 birds (Jetz et al., 2014), 7,239 amphibians (Jetz & Pyron, 2018), 9,755 squamates (Tonini et al., 2016), and 1,192 chondrichthyes (Stein et al., 2018). Each of the classes is comprised of a different number of orders, depending on the completion of each tree (Appendix 1).

To relate species phylogenetic diversity to their research interest we extracted citation information of relevant publications; those where the species' binomial name appeared in the title, abstract, or keywords, using the package *specieshindex* version 0.3.1(Tam, 2021), in late 2021. We extracted the metadata, including affiliations, and countries, separately with custom functions using the packages *httr* version 1.4.2 (Wickham, 2020) and *XML* version 3.99.0.8 (Lang, 2022). We referenced the custom functions from https://github.com/christopherBelter/scopusAPI and modified them for the use of this study. We then retrieved the classification information, including class, order, and family, of each species using the package *rotl* version 3.0.12 (Michonneau et al., 2016) and calculated their individual *h*-index with the *specieshindex* function.

Finally, to sort our species geographically, we obtained location information of the species from the Global Biodiversity Information Facility (Global Biodiversity Information, 2022) in February of 2022 using the package *rgbif* version 3.6.0. We calculated the centroids of the occurrences of each species with a modified function from the package *letsR* version 4.0. We decided to focus the data exploration on two large continents with high levels of endemism (Chapman, 2009) and charismatic species (Lindsey et al., 2007; Monsarrat & Kerley, 2018; United Nations World Tourism Organisation, 2014) so kept only species that fell within Africa and Australia (including coastal islands). We filtered the data using geographic coordinates, keeping Australian species that fell between 113 and 154 degrees of longitude and -43.665676 and -10.698671 degrees of latitude, and African species that fell between -17.580559 and 51.853036 degrees of longitude and -35.230525 and 36.964658 degrees of latitude. We further filtered out species with GBIF distributions that fell outside the continent, i.e. those that were not endemic to either Africa or Australia (such as pest and introduced species), and species whose research was predominantly based in husbandry or medicine. We also removed marine mammals and sharks with large distributions that spanned continents. A full list of the species removed for each group and continent is provided as an appendix (Appendix 2).

Data collection and cleaning were performed within the R computing environment version 1.4.1106 (R Studio Development Team, 2021).

2.2 Theoretical visualisations

To better visualise the research hypothesis associated with the question “Do animals that are more phylogenetically diverse receive more research interest?” we clipped a random point in the mammal tree, aiming to keep 10 species. We then highlighted the branch tips in green to represent the species with the highest research interest illustrated in Fig.1. We created fake datasets and scatterplots that would reflect what we would expect to see in the case of accepting the null; animals that are more phylogenetically diverse receive more research interest, rejecting the null; animals that are more phylogenetically diverse show no relationships to research interest, or the third option that animals that are more phylogenetically diverse receive less research interest, plotting research interest (h-index) against phylogenetic diversity.

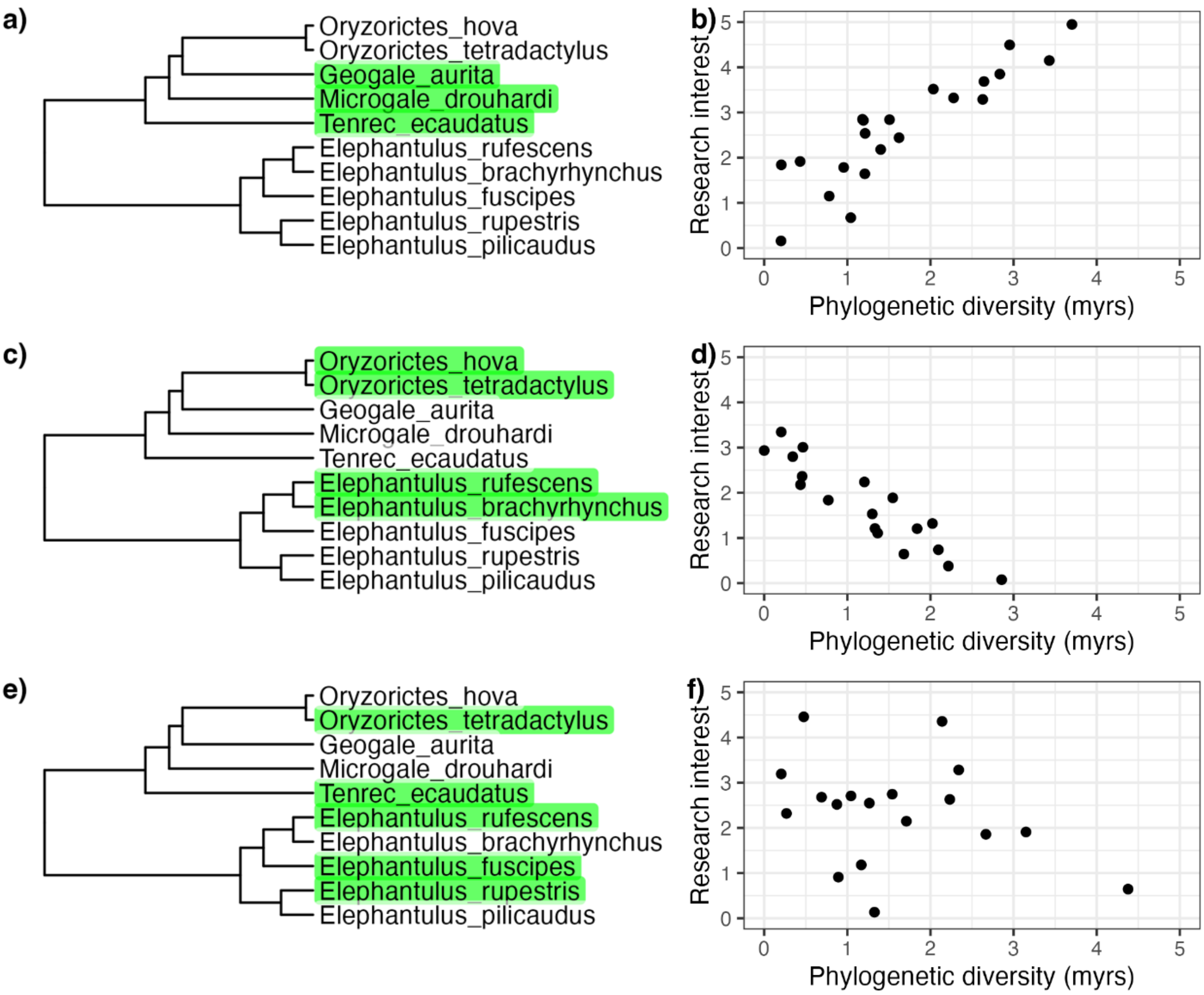

Figure 1. The three hypothetical outcomes regarding the first question of this study: Do animals that are more phylogenetically diverse receive more research interest? With potential results showing (a & b) research interest is higher in species that are highly phylogenetically diverse, (c & d) research interest is lower in species that are highly diverse or (e & f) research interest has no relationship to phylogenetic diversity.

2.3 Data Analysis

We first explored the correlation between h-index and the number of publications for all species using the Spearmans correlation coefficient, and finding a high level of correlation we continue throughout the paper looking only at h-index as the chosen measure of research interest (Fig. 2).

To compare the phylogenetic uniqueness of a species with its research interest we kept the top 10 highly researched species from each of the five vertebrate groups (sorted first by h-index, and then again by number of publications) for both Africa and Australia (Fig. 3). To explore correlative trends between research interest (h-index) and phylogenetic diversity we calculated the spearman correlation coefficient for all species separated by taxonomic group and continent (Fig. 3).

To explore differences in the phylogenetic diversity of the top researched species, we took the average diversity by group and continent (Table 2). We compared this to the average diversity of the top 10 most diverse species of each group (Table 2). To confirm the trends, we saw in research output and phylogenetic diversity were not only present in the top 10 researched species we also ran analyses that included the top 100 for each taxonomic group for each continent.

3 Results

There was a high level of correlation between a species' number of publications and its h-index (0.98, Fig. 2). Of all species, there were five species that were either outliers to this trend, or had very high levels of research interest. Four of those were African species (African clawed frog *Xenopus laevis,* Chimpanzee *Pan troglodytes,* Grivet *Chlorocebus aethiops,* and the Greater Honeyguide *Indicator indicator*), whilst the Australian region had only a single outlier species (Goat *Capra hircus (*non-native and so removed from all further analyses)).

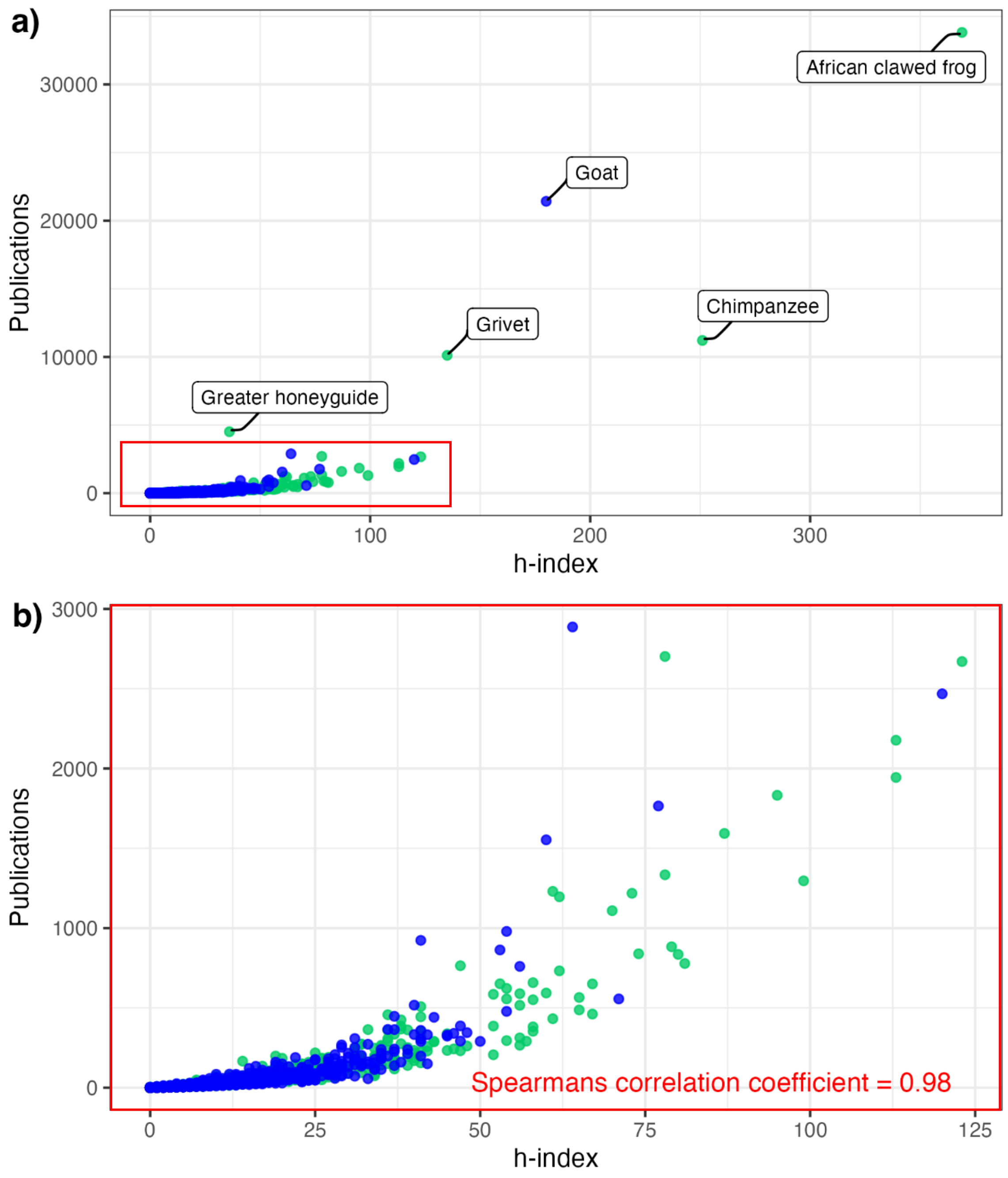

Figure 2. Species' h-index and number of publications were strongly correlated except for five outliers (a) which when removed from the figure, i.e. in b) the strong relationships between h-index and publications were more easily visualised for African (green) and Australian (blue) species.

The top 10 species of each vertebrate group for the two continents according to their research interest (h-index) are visualised in Figure 3. R^2 values showed very little correlation between research interest and phylogenetic uniqueness for any taxonomic group or continent (Figure 3). Echoing this finding, Table 1 lists the top 10 species with the highest h-index and the top 10 species that are the most phylogenetically unique from each taxon of the two continents. Once again showing that species with more research interests weren’t necessarily contributing to phylogenetic diversity.

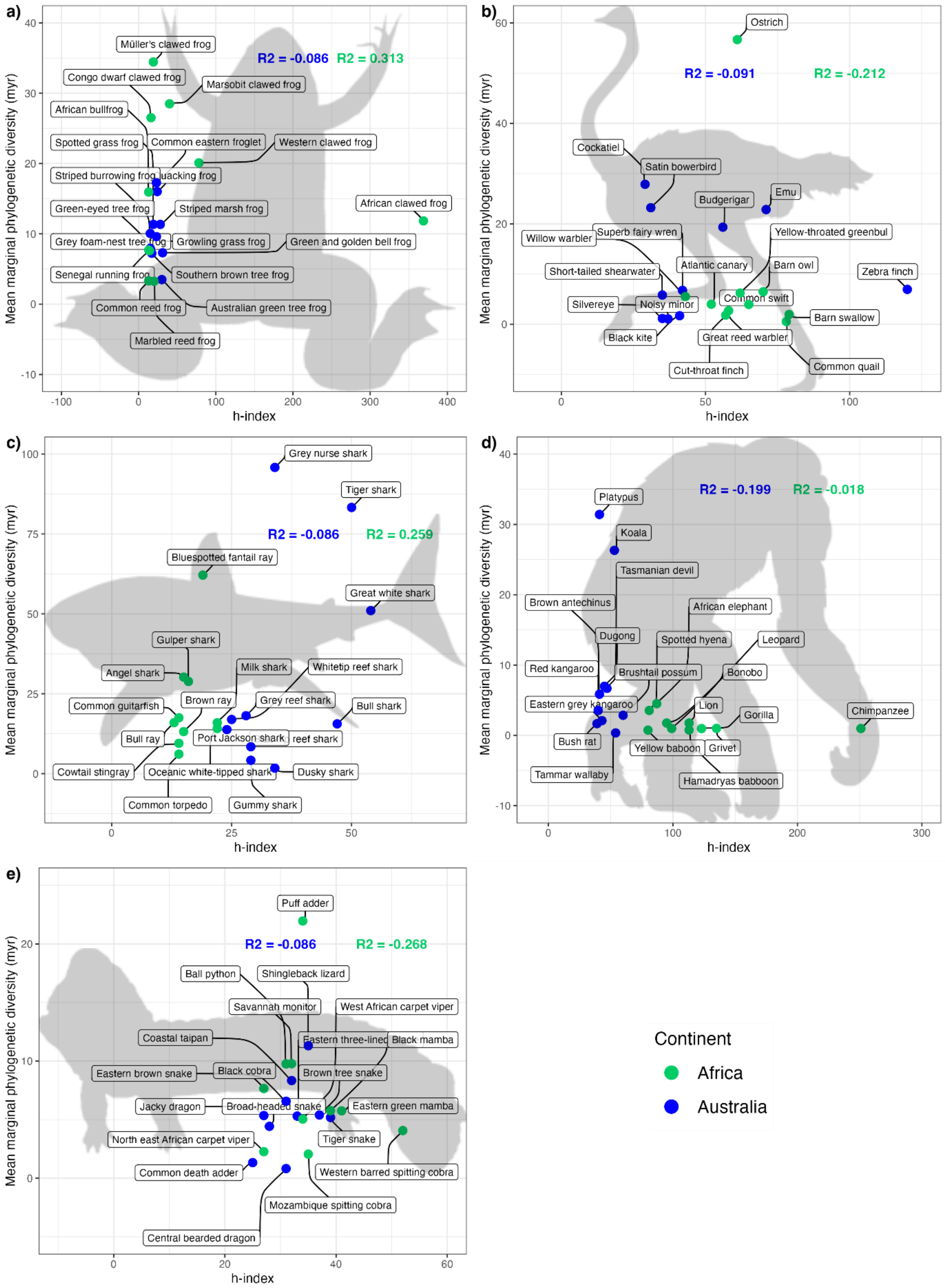

Figure 3. The top 10 researched species for the a) amphibians, b) birds, c) Chondrichthyes, d) mammals and e) reptiles for the African (green) and Australian (blue) continents. Reported

R^2 values show the correlation between research interest (h-index) and phylogenetic uniqueness for all species in the dataset, separated by taxonomic group and continent.

If conserving the top 10 most phylogenetically unique species from each of the five vertebrate groups, Australia had the highest diversity at 994 myrs in the mammal group, compared to Africa with 789 myrs. In all other groups Africa had greater potential PD than Australia. When looking at the top 10 researched species (by h-index) for each of the five vertebrate groups, Australian birds followed by Australian mammals covered the most PD at 32% and 31% respectively. The most PD researched within a group in Africa was also the mammals at 27% of the total potential PD covered in the top 10 researched species (Table 2). Interestingly, while the avian group in Australia had the highest diversity being researched, it was one of the lesser groups being researched in Africa (by PD).

The large difference between the top 10 most unique species of each group compared to the actual species being researched was consistent for both Africa and Australia, indicating neither continent was fully meeting their potential in safe guarding PD. The greatest mismatch between potential PD and actual PD being conserved in the top 10 species was in the Chondrichthyes group, with only 5% and 7% PD covered in Africa and Australia, despite being the group with the lowest summed potential PD (Table 2).

Overall, African species had a higher mean h-index (58.26 vs 51.42), number of mean publications (1733.36 vs 883.88) and a higher total sum of publications (86,668 vs 44,194) than Australian species when including the top 10 phylogenetically unique species for each taxonomic grouping and continent. Research interest and phylogenetic uniqueness for the top 10 species of each taxonomic grouping and continent can be found in the Appendix.

Table 2. Summed phylogenetic diversity conserved by selecting the top 10 most unique species for each taxonomic group on each continent, compared to the summed actual phylogenetic diversity being conserved in the top researched species. Values in brackets show the difference in possible phylogenetic diversity conserved vs actual in myrs, and as a percentage (%) of the total possible PD conserved.

Vertebrate group	Continent	Summed PD of top 10 phylogenetically diverse species (myrs)	Summed PD of top 10 h-index species (difference myrs, %)	Top 10 published species (difference myrs, %)
Amphibia	Africa	738	159 (-579, 22)	184 (-554, 25)
Amphibia	Australia	489	102 (-387, 21)	103 (-386, 21)
Aves	Africa	582	90 (-492, 15)	96 (-486, 16)
Aves	Australia	365	117 (-248, 32)	102 (-263, 28)
Chondrichthyes	Africa	311	17 (-294, 5)	17 (-294, 5)
Chondrichthyes	Australia	230	17 (-213, 7)	17 (-213, 7)
Mammalia	Africa	789	214 (-575, 27)	214 (-575, 27)
Mammalia	Australia	994	309 (-685, 31)	309 (-685, 31)
Squamata	Africa	600	74 (-526, 12)	71 (-529, 12)
Squamata	Australia	382	54 (-328, 14)	58 (-324, 15)

4 Discussion

We collected and analysed the citation information and phylogenetic uniqueness of endemic species in Africa and Australia across five taxa – Mammalia, Aves, Reptilia, Amphibia, and Chondrichthyes, and compared the relationship between phylogenetic diversity and research interest in conservation-based science. Although there was a strong statistical correlation between a species' number of publications and their h-index, we found no correlation between their h-index and phylogenetic uniqueness, suggesting phylogenetic uniqueness is not a leading contributor to rationale for research priority under current conservation triage approaches. Overall, African vertebrate groups were more phylogenetically diverse than Australian species, however Australian research interest was covering a greater proportion of phylogenetic diversity.

4.1 Charismatic species dominating the scientific literature

The top 10 researched species in both African and Australian vertebrate groups included many charismatic species (Fig. 3), including the African megafauna such as lions, leopards and elephants and the cuddly and charismatic Australian koala and platypus. The popularity of species plays an important role in their conservation since human interest tends to correlate with research interest (Tam et al., 2022). Charismatic animals that have higher appeal generally have larger bodies and forward-facing eyes (Macdonald et al., 2015; Smith et al., 2012; Tam et al., 2022), even when they are traditionally less appealing such as the Chondrichthyes (Ducatez, 2019). Vertebrates also tend to receive more interest in research than invertebrates, especially mammals and birds (Donaldson et al., 2016; Troudet et al., 2017). While targeting the conservation of charismatic flagship species can help conserve background species and address underlying ecological issues (McGowan et al., 2020), lesser-known species may be overlooked in conservation efforts.

4.2 Model species receiving disproportional amounts of research interest

Another reason why phylogenetic diversity does not correlate with the h-index of species is that model organisms are popular among researchers, for instance in the medical field, but some of these species are also a focus of conservation-based research. Historically, model organisms have provided many insights into biology and genetics that could be scaled and generalised to other species (Fields & Johnston, 2005). Such model species include the outliers Chimpanzee (*Pan troglodytes*) and the African clawed frog (*Xenopus laevis*), whom both have significantly higher h-index while not contributing as much to phylogenetic diversity as some others (Fig. 2, Fig. 3). The Chimpanzee is commonly used as a model in human studies as they are one of our closest relatives and have a very similar genomic makeup (Consortium, 2005). Whereas the African clawed frog is a model species commonly used to study vertebrate embryonic development (Liao et al., 2022).

Nevertheless, some model species are endangered in the wild. For instance, the Chimpanzee, while a model species, is also in decline due to habitat destruction and poaching. Along with other African great apes, such as the Bonobo (*Pan paniscus*), and various *Gorilla* species and sub-species, studies predicted that the habitats of these primates will shrink in the near future (Carvalho et al., 2021; Junker et al., 2012). Therefore, while they are not phylogenetically unique, their inflated research interest may be contributing to their conservation efforts, and as such were not removed from this study.

We focused on presenting the difference between phylogenetic diversity and research interest as a percentage rather than in millions of years, as this better encompassed the difference between potential PD conserved and research interest - as it was irrespective of the potential PD on each continent (Table 2). For example, the difference in millions of years of PD captured between the top 10 African squamates with the greatest phylogenetic uniqueness and the top 10 researched African squamates appeared very large at a summed 526 myrs, however taking into account the total diversity of this group and looking at this value as a percentage instead we see they are not the lowest studied of the groups, with a 12% difference between available PD and researched PD, compared to 5% for the African Chondrichthyes.

4.3 Accounting for distant relatives

Focusing research efforts on model species helps us study their close relatives, but it may not be able to capture the knowledge of distant relatives that are more evolutionarily diverse. For instance, studies of the zebra finch (6.9 myrs; Table 1), a model species for the study of neuronal mechanisms of song and vocal learning (Brainard & Doupe, 2002; Vallentin et al., 2016), are less likely to be applicable to the ostrich (56.7 myrs; Table 1) due to the long time since they diverged from their most recent common ancestor. Other aspects of biology that may be important for conservation, such as population demographics and response to environmental fluctuations, are even more challenging to conserve phylogenetically. Conserving groups of species with higher EDGE (Evolutionarily Distinct and Globally Endangered) scores is more effective as it can not only capture more phylogenetic information (Isaac et al., 2007; Redding et al., 2010), but also target species that are declining in population because species that contribute to phylogenetic diversity are not always endangered (Funk & Burns, 2019).

4.4 Phylogenetically distinct species targeted by illegal wildlife trade

Species across the tree of life that are more phylogenetically unique are vulnerable to illegal wildlife trade. Higher phylogenetic uniqueness within the family-level, especially in mammals and birds, can predict the likelihood of the species being trafficked (Scheffers et al., 2019). These species often have unique physical features that are absent in other wildlife, and thus are highly sought after for their novelty. For example, the Australian shingleback lizard (*Tiliqua rugosa*) is highly traded due to its unique physical appearance and endemism to Australia (Heinrich et al., 2022). Non-coincidentally it is also one of the top 10 phylogenetically diverse Australian reptiles encompassing 11.3 myrs of phylogenetic diversity (Fig. 3, Table 1).

4.5 Drawing boundaries and allocating research funds

Funding for wildlife conservation is usually allocated by state or country. This allocation strategy may, however, miss marine species that migrate seasonally or have large movement ranges. In the case of marine animals, while they are protected within marine protected areas established in some countries, the same cannot be ensured when they migrate out of these territories or into other countries where there are no protected areas (Jenkins & Van Houtan, 2016). In addition, protected areas with higher biodiversity can still miss species that are phylogenetically unique if their habitats are located outside of these species-rich zones (Jetz et al., 2014). We removed many of these marine animals from our analysis as their large distributions meant they could not be assigned to either Africa or Australia. Our methods, however, can be repeated to explore these creatures in depth.

4.6 Limitations of the h-index

The h-index is a good indicator for measuring the research interest, but the primary focus of this metric is restricted to peer-reviewed academic literature. As such, we did not include any grey literature that can be found on Google scholar, for instance. Excluding grey literature meant that some reports and articles that were not peer-reviewed were excluded from this study. These outputs include reports from non-governmental organisations that do not publish but manage to attain conservation goals. Nonetheless, the h-index is a suitable indicator that shows how much formal research currently exists, and is a decent indicator of overall research interest.

4.7 Wider application

While there are decisions made throughout this research that might not suit certain readers purposes, for example the removal of species with wide distributions, non-natives or pest species, our methods are repeatable and allow for flexibility in the species or area of interest. As such conservation managers from a certain area, or working on a certain group can tweak the approach to ensure it is relevant to their research, hopefully guiding a more balanced approach to conservation efforts that accounts for the phylogenetic uniqueness in the conservation prioritisation process.

5 Conclusions

In this study, we compared the differences between the h-index and phylogenetic diversity of 5 vertebrate groups on the African and Australian continents, illustrating that phylogenetic uniqueness is not a key consideration in research and conservation efforts. We suggest the use of the EDGE score when evaluating conservation priorities to better conserve populations of wildlife that are both phylogenetically diverse and endangered, and provide our methods to assist conservation managers to explore the potential imbalance of conservation effort and phylogenetic uniqueness in their area. As populations of species across the tree of life continue to decline, it is important that conservation priorities are frequently re-evaluated to maximise or as a minimum, consider, phylogenetic diversity.

Author contributions

RF and WC conceived the ideas and designed methodology; JT collected the data; RF analyzed the data; RF and JT led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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Appendices

Appendix 1. Orders within each of the five classes studied.

Class	Order
Amphibia	Anura
	Caudata
	Gymnophiona
Aves	Tinamiformes
	Struthioniformes
	Rheiformes
	Casuariiformes
	Apterygiformes
	Galliformes
	Anseriformes
	Sphenisciformes
	Gaviiformes
	Procellariiformes
	Podicipediformes
	Phoenicopteriformes
	Ciconiiformes
	Pelecaniformes
	Accipitriformes
	Falconiformes
	Gruiformes
	Cariamiformes
	Charadriiformes
	Columbiformes
	Musophagiformes
	Cuculiformes
	Psittaciformes
	Opisthocomiformes
	Strigiformes
	Caprimulgiformes
	Apodiformes
	Coliiformes
	Trogoniformes
	Coraciiformes
	Upupiformes
	Bucerotiformes
	Passeriformes
	Piciformes
	Galbuliformes
Chondrichthyes	Chimaeriformes
	Myliobatiformes
	Rajiformes

	Pristiformes/Rhiniformes
	Productida
	Torpediniformes
	Carcharhiniformes
	Squamata
	Heterodontiformes
	Lamniformes
	Orectolobiformes
	Hexanchiformes
	Squaliformes
	Echinorhiniformes
Reptilia	Squamata
	Rhynchocephalia
Mammalia	Rodentia
	Chiroptera
	Carnivora
	Diprotodontia
	Artiodactyla
	Scandentia
	Eulipotyphla
	Dasyuromorphia
	Lagomorpha
	Pilosa
	Cingulata

	Paucituberculata
	Primates
	Didelphimorphia
	Perissodactyla
	Peramelemorphia
	Dermoptera
	Hyracoidea
	Microbiotheria
	Sirenia
	Macroscelidea
	Proboscidea
	Pholidota
	Notoryctemorphia
	Monotremata
	Tubulidentata

Appendix 2. Removed species from each of the h-index plots for Australian and African species.

Continent	**Class**	**Species**
Africa	Amphibia	Salamandra infraimmaculata
	Aves	Sterna hirundo
	Chondrichthyes	Carcharhinus falciformis
	Mammalia	Microtus guatemalensis
		Microtus guentheri
		Microtus paradoxus
		Microtus qazvinensis
		Microtus socialis
		Microtus umbrosus
	Reptilia	Gallotia galloti
Australia	Amphibia	Albericus alpestris
		Albericus murritus
		Barygenys apodasta
		Barygenys resima
		Bombina orientalis
		Bufo gargarizans
		Bufo japonicus
		Callulops eremnosphax
		Callulops microtis
		Choerophryne bryonopsis
		Cophixalus caverniphilus
		Cophixalus petrophilus
		Cynops ensicauda
		Cynops pyrrhogaster
		Hyla chinensis
		Hyla japonica
		Hylophorbus atrifasciatus
		Hynobius chinensis
		Hynobius retardatus
		Liophryne magnitympanum
		Litoria axillaris
		Litoria eurynastes
		Litoria viranula
		Nyctimystes cryptochrysos
		Nyctimystes intercastellus
		Oreophryne ampelos
		Oreophryne anamiatoi
		Paedophryne dekot
		Paedophryne kathismaphlox

		Paramesotriton chinensis
		Polypedates iskandari
		Rana dybowskii
		Rana japonica
		Rana pirica
		Rhinella marina
		Staurois nubilus
		Xenorhina brachyrhyncha
	Aves	Aleadryas rufinucha
		Bradypterus castaneus
		Collocalia mearnsi
		Colluricincla boweri
		Colluricincla harmonica
		Colluricincla megarhyncha
		Colluricincla tenebrosa
		Colluricincla woodwardi
		Coturnix japonica
		Daphoenositta chrysoptera
		Daphoenositta miranda
		Eulacestoma nigropectus
		Falcunculus frontatus
		Melidectes fuscus
		Oceanodroma matsudairae
		Oceanodroma monorhis
		Oceanodroma tristrami
		Oreoica gutturalis
		Pachycare flavogriseum
		Pachycephala albiventris
		Pachycephala arctitorquis
		Pachycephala aurea
		Pachycephala griseonota
		Pachycephala homeyeri
		Pachycephala hyperythra
		Pachycephala hypoxantha

		Pachycephala inornata
		Pachycephala lanioides
		Pachycephala leucogastra
		Pachycephala lorentzi
		Pachycephala melanura
		Pachycephala meyeri
		Pachycephala modesta
		Pachycephala monacha
		Pachycephala nudigula
		Pachycephala olivacea
		Pachycephala orpheus
		Pachycephala pectoralis
		Pachycephala phaionota
		Pachycephala philippinensis
		Pachycephala rufiventris
		Pachycephala rufogularis
		Pachycephala schlegelii
		Pachycephala simplex
		Pachycephala soror
		Pachycephala sulfuriventer
		Pelagodroma marina
		Pitohui cristatus
		Pitohui dichrous
		Pitohui ferrugineus
		Pitohui kirhocephalus
		Pitohui nigrescens
		Rhagologus leucostigma
	Chondrichthyes	Platyrhina sinensis
		Platyrhina tangi
		Pristiophorus cirratus
		Pristiophorus delicatus
		Pristiophorus japonicus
		Pristiophorus nudipinnis
		Squatina albipunctata
		Squatina australis

		Squatina caillieti
		Squatina formosa
		Squatina japonica
		Squatina nebulosa
		Squatina pseudocellata
		Squatina tergocellata
		Squatina tergocellatoides
	Mammalia	Acerodon jubatus
		Aonyx cinerea
		Apodemus speciosus
		Arctocephalus pusillus
		Axis calamianensis
		Axis porcinus
		Bettongia pusilla
		Bubalus depressicornis
		Bubalus mindorensis
		Bubalus quarlesi
	Mammalia	Camelus dromedarius
		Capra hircus
		Capricornis crispus
		Capricornis swinhoei
		Catopuma badia
		Hydropotes inermis

		Lepus brachyurus
		Lepus coreanus
		Lepus mandshuricus
		Lepus sinensis
		Macaca cyclopis
		Macaca fuscata
		Macaca hecki
		Macaca maura
		Macaca nigra
		Macaca nigrescens
		Macaca ochreata
		Macaca tonkeana
		Marmosa tyleriana
		Marmota camtschatica
		Martes melampus
		Mastacomys fuscus
		Meles anakuma
		Melogale everetti
		Microtus evoronensis
		Microtus fortis
		Microtus hyperboreus
		Microtus kikuchii
		Microtus maximowiczii
		Microtus montebelli

		Microtus sachalinensis	
		Muntiacus atherodes	
		Mustela itatsi	
		Mustela kathiah	
		Mustela nudipes	
		Mustela sibirica	
		Myodes andersoni	
		Myodes regulus	
		Myodes rex	
		Myodes smithii	
		Myotis rufopictus	
		Naemorhedus caudatus	
		Neofelis diardi	
		Neophocaena phocaenoides	
		Notomys fuscus	
		Ochotona coreana	
		Ochotona hyperborea	
		Ochotona mantchurica	
		Otocolobus manul	
		Ovis nivicola	
		Pentalagus furnessi	
		Petaurista lena	

		Pipistrellus alaschanicus
		Pseudohydromys fuscus
		Pteropus speciosus
		Rattus exulans
		Rattus niobe
		Rusa alfredi
		Rusa marianna
		Rusa timorensis
		Suncus murinus
		Tarsius syrichta
		Tursiops aduncus
	Reptilia	Aipysurus fuscus
		Ateuchosaurus chinensis
		Bungarus multicinctus
		Cryptoblepharus australis
		Ctenophorus mirrityana
		Deinagkistrodon acutus
		Draco timorensis
		Gekko chinensis

		Laticauda semifasciata
		Liasis fuscus
		Myrrophis chinensis
		Oligodon chinensis
		Pareas chinensis
		Plestiodon chinensis
		Takydromus sylvaticus
		Trimeresurus stejnegeri
		Varanus komodoensis

Table 1. Top 10 researched species and top 10 phylogenetically diverse species for each continent and taxa.

Continent	**Group**	**H-index**			**Phylogenetic diversity**		
		Species	**Common name**	**h-index**	**Species**	**Common name**	**PD**
Australia	Mammalia	*Trichosurus vulpecula*	Brushtail possum	60	*Ornithorhynchus anatinus*	Platypus	31
		Macropus eugenii	Tammar wallaby	54	*Tarsipes rostratus*	Honey possum	29
		Phascolarctos cinereus	Koala	53	*Phascolarctos cinereus*	Koala	26
		Sarcophilus harrisii	Tasmanian devil	47	*Burramys parvus*	Mountain pygymy possum	25
		Dugong dugon	Dugong	45	*Hypsiprymnodon moschatus*	Musky rat-kangaroo	24
		Macropus giganteus	Eastern grey kangaroo	43	*Myrmecobius fasciatus*	Numbat	22
		Antechinus stuartii	Brown antechinus	41	*Acrobates pygmaeus*	Feathertail glider	20
		Ornithorhynchus anatinus	Platypus	41	*Distoechurus pennatus*	Feather-tailed possum	20
		Macropus rufus	Red kangaroo	40	*Gymnobelideus leadbeateri*	Leadbeater's possum	17
		Rattus fuscipes	Bush rat	39	*Sminthopsis longicaudata*	Long-tailed dunnart	13
	Amphibia	*Litoria aurea*	Green and golden bell frog	31	*Spicospina flammocaerulea*	Sunset frog	55
		Litoria caerulea	Australian green tree frog	30	*Paracrinia haswelli*	Haswell's frog	45
		Limnodynastes peronii	Striped marsh frog	28	*Adelotus brevis*	Tusked frog	45
		Crinia georgiana	Quacking frog	24	*Crinia fimbriata*	Kimberley froglet	44
		Crinia signifera	Common eastern froglet	23	*Crinia nimbus*	Moss froglet	36
		Litoria raniformis	Growling grass frog	23	*Crinia tasmaniensis*	Tasmanian froglet	36
		Limnodynastes tasmaniensis	Spotted grass frog	19	*Crinia deserticola*	Desert froglet	32
		Litoria ewingii	Southern brown tree frog	17	*Assa darlingtoni*	Pouched frog	31
		Cyclorana alboguttata	Striped burrowing frog	15	*Myobatrachus gouldii*	Turtle frog	24

		Litoria genimaculata	Green-eyed tree frog	15	*Litoria brevipalmata*	Green-thighed frog	20
	Squamata	*Notechis scutatus*	Tiger snake	39	*Crenadactylus ocellatus*	Occellated velvet gecko	54
		Boiga irregularis	Brown tree snake	37	*Carphodactylus laevis*	Smooth knob-tailed gecko	35
		Tiliqua rugosa	Shingleback lizard	35	*Hesperoedura reticulata*	Reticulated velvet gecko	33
		Bassiana duperreyi	Eastern three-lined snake	33	*Intellagama lesueurii*	Australian water dragon	33
		Oxyuranus scutellatus	Coastal taipan	32	*Anomalopus pluto*	Cape York worm-skink	27
		Pogona vitticeps	Central bearded dragon	31	*Concinnia frerei*	Blue-mountains water skink	25
		Pseudonaja textilis	Eastern brown snake	31	*Nephrurus wheeleri*	Thick-tailed gecko	24
		Hoplocephalus bungaroides	Broad-headed snake	28	*Amalosia lesueurii*	Lesueur's velvet gecko	22
		Amphibolurus muricatus	Jacky dragon	27	*Concinnia queenslandiae*	Prickly forest skink	22
		Acanthophis antarcticus	Common death adder	25	*Lophognathus longirostris*	Long-nosed water dragon	21
	Aves	*Taeniopygia guttata*	Zebra finch	120	*Anseranas semipalmata*	Magpie goose	64
		Dromaius novaehollandiae	Emu	71	*Pedionomus torquatus*	Plains wanderer	36
		Melopsittacus undulatus	Budgerigar	56	*Oreoscopus gutturalis*	Fern wren	31
		Malurus cyaneus	Superb fairy wren	42	*Leipoa ocellata*	Malleefowl	30
		Milvus migrans	Black kite	41	*Scenopoeetes dentirostris*	Tooth-billed bowerbird	29
		Manorina melanocephala	Noisy minor	37	*Nymphicus hollandicus*	Cockatiel	28
		Puffinus tenuirostris	Short-tailed shearwater	35	*Aegotheles tatei*	Tate's Owlet-nightjar	27
		Zosterops lateralis	Silvereye	35	*Probosciger aterrimus*	Palm cockatoo	26
		Ptilonorhynchus violaceus	Satin bowerbird	31	*Ptilonorhynchus violaceus*	Satin bowerbird	23
		Nymphicus hollandicus	Cockatiel	29	*Dromaius novaehollandiae*	Emu	23
	Chondrichthyes	*Carcharodon carcharias*	Great white shark	54	*Hypnos monopterygius*	Coffin ray	155
		Galeocerdo cuvier	Tiger shark	50	*Hemipristis elongata*	Snaggletooth shark	91
		Carcharhinus leucas	Bull shark	47	*Eucrossorhinus dasypogon*	Tasselled wobbegong	57
		Carcharhinus obscurus	Dusky shark	34	*Pristis zijsron*	Long-comb sawfish	50
		Carcharias taurus	Grey nurse shark	34	*Brachaelurus colcloughi*	Bluegrey carpetshark	50

		Carcharhinus melanopterus	Blacktip reef shark	29	*Brachaelurus waddi*	Blind shark	50
		Mustelus antarcticus	Gummy shark	29	*Narcine westraliensis*	Banded numbfish	48
		Carcharhinus amblyrhynchos	Grey reef shark	28	*Trygonoptera ovalis*	Striped stingaree	47
		Triaenodon obesus	Whitetip reef shark	25	*Iago garricki*	Longnose houndshark	44
		Heterodontus portusjacksoni	Port Jackson shark	24	*Furgaleus macki*	Whiskery shark	42
Africa	Mammalia	*Pan troglodytes*	Chimpanzee	251	*Orycteropus afer*	Aardvark	81
		Chlorocebus aethiops	Grivet	135	*Daubentonia madagascariensis*	Aye-aye	37
		Gorilla gorilla	Gorilla	123	*Geogale aurita*	Bushveld elephant shrew	37
		Panthera leo	Lion	113	*Heterocephalus glaber*	Naked mole-rat	27
		Papio hamadryas	Hamadryas babboon	113	*Lophiomys imhausi*	Maned rat	26
		Pan paniscus	Bonobo	99	*Petromus typicus*	Rock hyrax	23
		Panthera pardus	Leopard	95	*Nandinia binotata*	African palm civet	22
		Loxodonta africana	African elephant	87	*Potamogale velox*	Giant otter shrew	22
		Crocuta crocuta	Spotted hyena	81	*Tenrec ecaudatus*	Lowland streaked tenrec	19
		Papio cynocephalus	Yellow baboon	80	*Uranomys ruddi*	Rudd's mouse	18
	Amphibia	*Xenopus laevis*	African clawed frog	369	*Odontobatrachus natator*	Saber toothed frog	127
		Xenopus tropicalis	Western clawed frog	78	*Pseudhymenochirus merlini*	Merlin's clawed frog	98
		Xenopus borealis	Marsobit clawed frog	40	*Ericabatrachus baleensis*	Bale mountains frog	70
		Hyperolius marmoratus	Marbled reed frog	20	*Madecassophryne truebae*		70
		Xenopus muelleri	MÃ¼ller's clawed frog	19	*Boulengerula fischeri*	Fischer's Caecilian	70
		Hymenochirus boettgeri	Congo dwarf clawed frog	16	*Lanzarana largeni*	Lanza's frog	63
		Kassina senegalensis	Senegal running frog	14	*Laliostoma labrosum*	Madagascar bullfrog	62
		Chiromantis xerampelina	Grey foam-nest tree frog	13	*Tsingymantis antitra*		62
		Hyperolius viridiflavus	Common reed frog	13	*Hadromophryne natalensis*	Natal ghost frog	58
		Pyxicephalus adspersus	African bullfrog	13	*Phrynobatrachus sandersoni*	Sanderson's hook frog	56
	Aves	*Hirundo rustica*	Barn swallow	79	*Leptosomus discolor*	Madagascar hoopoe	77

		Coturnix coturnix	Common quail	78	*Sagittarius serpentarius*	Secretary bird	65
		Tyto alba	Barn owl	70	*Scopus umbretta*	Hamerkop	57
		Apus apus	Common swift	65	*Balaeniceps rex*	Shoebill	57
		Chlorocichla flavicollis	Yellow-throated greenbul	62	*Struthio camelus*	Ostrich	57
		Struthio camelus	Ostrich	61	*Pachycoccyx audeberti*	Thick-billed cuckoo	54
		Acrocephalus arundinaceus	Great reed warbler	58	*Pluvianus aegyptius*	Egyptian plover	54
		Amadina fasciata	Cut-throat finch	57	*Ceuthmochares aereus*	Blue malkoha	50
		Serinus canaria	Atlantic canary	52	*Corythaeola cristata*	Great blue turaco	43
		Phylloscopus trochilus	Willow warbler	43	*Urocolius macrourus*	Red-faced mousebird	34
	Chondrichthyes	*Carcharhinus longimanus*	Oceanic white-tipped shark	22	*Zanobatus schoenleinii*	Striped panray	186
		Rhizoprionodon acutus	Milk shark	22	*Leptocharias smithii*	Barbeled houndshark	100
		Taeniura lymma	Bluespotted fantail ray	19	*Pliotrema warreni*	Thornback skate	84
		Centrophorus granulosus	Gulper shark	16	*Iago omanensis*	Arabian butterfly ray	44
		Raja miraletus	Brown ray	15	*Ctenacis fehlmanni*	Harlequin catshark	40
		Squatina squatina	Angel shark	15	*Squatina africana*	African angelshark	36
		Pastinachus sephen	Cowtail stingray	14	*Taeniurops grabata*	White-spotted guitarfish	35
		Rhinobatos rhinobatos	Common guitarfish	14	*Rostroraja alba*	White skate	34
		Torpedo torpedo	Common torpedo	14	*Chlamydoselachus africana*	African frilled shark	32
		Pteromylaeus bovinus	Bull ray	13	*Squatina aculeata*	Sawback angelshark	30
	Squamata	*Naja nigricollis*	Western barred spitting cobra	52	*Atlantolacerta andreanskyi*	Moroccan rock lizard	69
		Dendroaspis angusticeps	Eastern green mamba	41	*Narudasia festiva*	Festive gecko	68
		Dendroaspis polylepis	Black mamba	39	*Saurodactylus mauritanicus*	Mauritania dune gecko	67
		Naja mossambica	Mozambique spitting cobra	35	*Saurodactylus fasciatus*	Moroccan dune gecko	65
		Bitis arietans	Puff adder	34	*Poromera fordii*	West African striped lizard	61
		Echis ocellatus	West African carpet viper	34	*Rhoptropella ocellata*	Namaqua day gecko	60

		Varanus exanthematicus	Savannah monitor	32	*Vhembelacerta rupicola*	Eastern mountains rock lizard	56
		Python regius	Ball python	31	*Australolacerta australis*	Southern rock lizard	55
		Echis pyramidum	North east African carpet viper	27	*Calabaria reinhardtii*	Ball python	51
		Naja melanoleuca	Black cobra	27	*Elasmodactylus tetensis*	Tete thick-toed gecko	49