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The importance of appropriate taxonomy in Australian mammalogy

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ABSTRACT

The use of correct taxonomy to describe and name the earth's biodiversity is fundamental to conservation and management. However, there are issues that need to be overcome to ensure that the described taxa and their scientific names are both appropriate and widely adopted. Obstacles to this include the use of different species definitions, taxonomic instability due to accumulation of additional specimens in analyses and the progression of science that allows better resolution of species boundaries, and the inappropriate description and naming of new taxa without adequate scientific basis in self-published journals (known as 'taxonomic vandalism'). In an effort to manage taxonomic instability, the Australasian Mammal Taxonomy Consortium (AMTC), an affiliated body of the Australian Mammal Society, has developed several tools that include: (1) a standardised list of Australian mammal common and scientific names; (2) recommendations for information that should be included in published species descriptions; and (3) support for the publication of aspidonyms (i.e. a scientifically acceptable name proposed to overwrite a pre-existing unscientific name). This review discusses these issues, reaffirms the foundations for appropriate taxonomic research, and provides guidelines for those publishing taxonomic research on Australian mammals.

Keywords: aspidonym, biodiversity, mammal, publication, species, taxonomic vandalism, taxonomy, unscientific.

Introduction

An understanding of biodiversity is fundamental to its conservation and management. An essential component of understanding biodiversity is the formal identification and description of species via the science of taxonomy. Taxonomy has two main components: (1) identifying, describing and classifying organisms into taxa; and (2) formally naming the new taxa (nomenclature), which can include subspecies, species, genera or higher ranks (Jackson and Groves 2015; Dubois 2017*a*). The primary unit of taxonomy is the 'species' rank that is comprised of the genus name and the species name (International Commission on Zoological Nomenclature 1999). For example, the Tasmanian devil is known as *Sarcophilus harrisii*, where the genus name always has a capital first letter, and the species name is always in lower case. This binominal (two-word) system of nomenclature of organisms dates back to Linnaeus (1758).

Although new taxa are being described continually, it is estimated that of the approximately 5–9 million living species on earth (not including the fossil extinct taxa), only 1.2–1.9 million species have been named and described (Costello *et al.* 2013; Mora *et al.* 2011). Conservation initiatives and legislation target described species with known conservation status. Undescribed taxa lack protection as conservation actions cannot be enacted, leading to the potential increased risk of extinction of these taxa (Costello *et al.* 2013). Therefore, correct identification and naming of species is fundamentally

important to biological, conservation, financial and legal outcomes (Frankham *et al.* 2012; Kitchener *et al.* 2022).

Most newly described mammal taxa are either subspecies or species; however, higher ranks, such as genera, are still being described and named. The status of any taxon is a scientific hypothesis, which can (and should) be subjected to testing via new methods. Therefore, although the designated names still apply to most taxa, some taxa have been described and named more than once, creating names that are considered synonyms of one another (i.e. two or more names of the same rank that denote the same taxon). In these cases, the older name (i.e. the one that was described first) is typically recognised, and the newer name is considered a junior synonym and is not recognised (International Commission on Zoological Nomenclature 1999). In rare cases, junior synonyms are again recognised as distinct subspecies, species or even genera (Table 1). A name that was thought to be a junior synonym may be recognised as valid when new taxonomic information shows it applies to a separate species, for example if: (1) new specimens provide support for splitting the original taxon into two or more taxa; (2) technology improves (e.g. modern genetic/genomic techniques that allow a finer resolution in species boundaries and identification of cryptic diversity); or (3) statistical methods improve.

Poorly implemented taxonomy, including some recent examples of taxonomic vandalism in Australian mammalogy that creates and names invalid or poorly described taxa can: (1) cause great confusion; (2) cause instability in the use of names for particular taxa and reduce confidence in taxonomic information; (3) fundamentally undermine conservation and management actions by ecologists, land managers and government administrators who rely on accurate taxonomic information; and (4) waste limited resources and funding. Therefore, there is a responsibility on those who practice taxonomy to ensure it is implemented: (1) ethically; (2) with a thorough scientific method that utilises the principles of taxonomy; and (3) with an understanding of the potential implications of the work. It is therefore timely to review the importance of correct taxonomy to Australian mammalogy and provide some recommendations. In this review we aim to: (1) discuss the importance of scientifically rigorous taxonomy in the identification of taxa; (2) examine the issues relating to taxonomy in conservation and management with a focus on Australian mammals; (3) outline how some of these issues may be resolved; and (4) make recommendations for best practice in Australian mammal taxonomy and introduce a new initiative – the Australasian Mammal Taxonomy Consortium (AMTC).

Species definitions and their application

As with every scientific discipline, taxonomy places hypothesis formation and testing as cornerstones, and although the species as a taxon is believed to represent a natural entity, a species description, as applied via adherence to one of the multitude of species concepts, is conceptually no different to any other scientific hypothesis (Wägele *et al.* 2011; Lambertz 2017).

There are approximately 30 species concepts (De Queiroz 2007; Zachos 2016), of which the most commonly applied are the biological, morphological, evolutionary and phylogenetic species concepts (Frankham *et al.* 2012). Most species represent distinct evolutionary lineages and are readily recognised (Garnett and Christidis 2017). The proliferation of species concepts reflects the difficulty that biologists have in defining complex cases, especially when populations or species have recently diverged and their percentage difference in genes and morphology is low. However, since evolution is a continuum there can be a grey zone where it is unclear if populations are sufficiently diverged to be recognised as separate species (Roux *et al.* 2016; Galtier 2018; Stankowski and Ravinet 2021). No species definition is perfect, and the primary definitions have been refined over time as the science has developed. For example, the biological species concept now accommodates evidence of gene flow between species (Rundle *et al.* 2001; Wang *et al.* 2020), while the phylogenetic species concept needs to be adapted to accommodate the rapid advancement of molecular techniques that allow increasingly powerful resolution of lineages (Baker *et al.* 2005; Bunce *et al.* 2009).

The number of species recognised can vary with species definition adopted, and individual taxonomists have been labelled ‘lumpers’ or ‘splitters’ based on their preferred species definitions and the number of species they recognise (Garnett and Christidis 2017). The splitting of species can reflect an increase in understanding of the evolutionary history of the species or group (Gippoliti *et al.* 2017). However, it can also result from a poor understanding of taxonomy or data inadequacies (Pillon and Chase 2007).

The capacity of researchers to characterise the genetic diversity of mammals in historical museum specimens has improved greatly in recent years. Genetic technology has resulted in a trend away from the biological and morphological species concepts to the phylogenetic species concept. There has been a great increase in the recognition of new species in some groups (e.g. Groves 2001; Groves and Grubb 2011; Zachos *et al.* 2013*a*). Recognising distinct species, or raising subspecies to species level, can also be motivated by potential conservation benefits (Zachos *et al.* 2013*b*; Jackson *et al.* 2019). Indeed, Zachos *et al.* (2013*a*) suggested that an uncritical acceptance of new species can create an unnecessary burden on biodiversity conservation. While Gutiérrez and Helgen (2013) agreed that the unjustified splitting of species could hamper conservation, they also suggested that uncritically lumping species has a similar result. The consistent and accurate application of these species concepts is very important in avoiding over splitting of taxa (‘taxonomic inflation’) and poor descriptions that can lead to taxonomic

Table 1. Taxa of Australian mammals validly described or recognised since 2000 (the years in square brackets in the last column indicate when the taxa were resurrected from synonymy).

Common name	Scientific name	Author and year of description
Carnivorous marsupials		
Silver-headed antechinus	*Antechinus argentus*	Baker *et al.*, 2013
Black-tailed dusky antechinus	*Antechinus arktos*	Baker *et al.*, 2014
Mainland dusky antechinus	*Antechinus mimetes*	Thomas, 1924 [2015]
Buff-footed antechinus	*Antechinus mysticus*	Baker *et al.*, 2012
Subtropical antechinus	*Antechinus subtropicus*	Van Dyck & Crowther, 2000
Tasman Peninsula dusky antechinus	*Antechinus vandycki*	Baker *et al.*, 2015
Brush-tailed mulgara	*Dasycercus blythi*	(Waite, 1904) [2005]
Northern phascogale	*Phascogale pirata*	Thomas, 1904 [2015]
Brush-tailed phascogale	*Phascogale tapoatafa kimberleyensis*	Aplin & Rhind, in Aplin *et al.*, 2015
Brush-tailed phascogale	*Phascogale tapoatafa wambenger*	Rhind & Aplin, in Aplin *et al.*, 2015
White-footed dunnart	*Sminthopsis leucopus janetzkiae*	Lavery *et al.*, 2022
Bandicoots		
Northern pig-footed bandicoot	*Chaeropus yirratji*[A]	Travouillon *et al.*, 2019
Quenda	*Isoodon fusciventer*	(J. Gray, 1841) [2018]
Cape York brown bandicoot	*Isoodon peninsulae*	Thomas, 1922 [2008]
Liverpool Plains striped bandicoot	*Perameles fasciata*[A]	J. Gray, 1841 [2018]
Marl	*Perameles myosuros*[A]	Wagner, 1841 [2018]
South-eastern striped bandicoot	*Perameles notina*[A]	Thomas, 1922 [2018]
Northern long-nosed bandicoot	*Perameles pallescens*	Thomas, 1923 [2016]
Nullarbor barred bandicoot	*Perameles papillon*[A]	Travouillon & Phillips, 2018
Possums and gliders		
Savanna glider	*Petaurus ariel*	(Gould, 1842) [2021]
Krefft's glider	*Petaurus notatus*	Peters, 1859 [2021]
Broad-toed feather-tailed glider	*Acrobates frontalis*	(De Vis, 1887) [2013]
Southern common cuscus	*Phalanger mimicus*	Thomas, 1922 [2001]
Mountain brush-tailed possum	*Trichosurus cunninghami*	Lindenmayer *et al.*, 2002
Macropods		
Desert bettong	*Bettongia anhydra*[A]	Finlayson, 1957 [2015]
Nullarbor dwarf bettong	*Bettongia pusilla*[A]	McNamara, 1997 [2008]
Long-nosed potoroo	*Potorous tridactylus trisculcatus*	(McCoy, 1865) [2012]
Western short-eared rock-wallaby	*Petrogale brachyotis victoriae*	Potter *et al.*, 2014
Black-footed rock-wallaby	*Petrogale lateralis centralis*	Eldridge & Potter, 2020
Black-footed rock-wallaby	*Petrogale lateralis kimberleyensis*	Eldridge & Potter, 2020
Purple-necked rock-wallaby	*Petrogale purpureicollis*	Le Souef, 1924 [2001]
Eastern short-eared rock-wallaby	*Petrogale wilkinsi*	Thomas, 1926 [2014]
Banded hare-wallaby	*Lagostrophus fasciatus baudinette*	Helgen & Flannery, 2003
Rodents		
Capricorn rabbit-rat	*Conilurus capricornensis*[A]	Cramb & Hocknull, 2010

(*Continued on next page*)

Table 1. (*Continued*)

Common name	Scientific name	Author and year of description
Bats		
South-eastern long-eared bat	*Nyctophilus corbeni*	Parnaby, 2009
Western long-eared bat	*Nyctophilus major major*	J. Gray, 1844 [2009]
Central long-eared bat	*Nyctophilus major tor*	Parnaby, 2009
Tasmanian long-eared bat	*Nyctophilus sherrini*	Thomas, 1915 [2009]
Holt's long-eared bat	*Nyctophilus holtorum*	Parnaby *et al.*, 2021
Cape York free-tailed bat	*Ozimops halli*	(Reardon *et al.*, 2014)
South-western free-tailed bat	*Ozimops kitcheneri*	(McKenzie *et al.*, 2014)
Northern free-tailed bat	*Ozimops lumsdenae*	(Reardon *et al.*, 2014)
Inland free-tailed bat	*Ozimops petersi*	(Leche, 1884) [2014]
South-eastern free-tailed bat	*Ozimops planiceps*	(Peters, 1866) [2014]
Bristle-faced free-tailed bat	*Setirostris eleryi*	(Reardon & McKenzie, 2008)
Whales and dolphins		
Bryde's whale	*Balaenoptera brydei*	Olsen, 1913 [2015]
Omura's whale	*Balaenoptera omurai*	Wada *et al.*, 2003
Ramari's beaked whale	*Mesoplodon eueu*	Carrroll *et al.*, 2021
Australian hump-backed dolphin	*Sousa sahulensis*	Jefferson & Rosenbaum, 2014

Where author names are given in brackets, the taxon is now placed in a different genus to that in which it was originally placed. If the species was described prior to 2000, the year in which it was again recognised at species rank, or as occurring within Australia, is shown in square brackets.
[A]Extinct.

confusion and impact conservation and legal protection (Measey 2013). Regardless, some taxa such as cryptic species and recently evolved species may have minimal genetic divergence so can be difficult to identify (Singhal *et al*. 2018). Appropriate data must ideally come from multiple and complementary perspectives, which may include morphology, genetics, geographic distribution and traditional knowledge as part of an integrative taxonomic study (Dayrat 2005; Dubois 2017*b*). Regardless of the species concept being tested in each case, a focus must be placed on a clear rationale and detailed analysis of comprehensive data (Lambertz 2017).

Taxonomic instability

One of the primary objectives of the *International Code of Zoological Nomenclature* is to 'promote stability and universality in the scientific names of animals and to ensure that the name of each taxon is unique and distinct' (International Commission on Zoological Nomenclature 1999, p. 2). Although instability as a result of poor taxonomy is a big concern, changes to taxonomy are inevitable and a necessary part of science (Bremer *et al*. 1990). Indeed, disagreements between taxonomists typically do not indicate taxonomic chaos or confusion, but rather often represent valid disagreements over aspects including species concepts, species boundaries and ranks (Thiele *et al*. 2021). In these cases, it is hoped that specific instances of instability will be rectified in the longer term, as additional specimens, further research and technological developments help to resolve taxonomic issues.

Taxonomic instability is caused by several factors including: (1) increased understanding of phylogenetic relationships of taxa, e.g. rectifying gaps in sampling and the transfer of species names between genera, such as the recognition of the taxa *Notamacropus*, *Osphranter* and *Ozimops* as full genera (De Queiroz and Gauthier 1990); (2) increased understanding of gene flow both within and among lineages (Yang and Rannala 2010); and (3) 'taxonomic vandalism' (see below).

The International Commission of Zoological Nomenclature provides advice and arbitrates in the correct use of the scientific names of animals when contentious issues arise. There is no single body that governs taxonomy more broadly. To rectify this perceived gap in responsibilities, Garnett and Christidis (2017) suggested that the governance of the taxonomy of complex organisms should be brought under the scope of the International Union of Biological Sciences (IUBS). They suggested there are four steps necessary for the IUBS to assume control: (1) IUBS agrees to take decisive leadership on taxonomy; (2) IUBS creates a taxonomic

commission to establish what rules (if any) should be applied; (3) the taxonomic commission establishes subcommittees for agreed taxonomic groups such as mammals and birds and creates standardised global species lists for these groups; and (4) the taxonomic commission establishes a judicial committee that is the final arbiter between subcommittees, responsible for upholding the rules and adjusting them as required when new knowledge becomes available. In addition to these requirements, IUBS would need strong links to the International Commission of Zoological Nomenclature (ICZN) so that names that have been considered and rejected by the IUBS due to poor description can be added to a list of rejected names that is accepted by the ICZN. This suggests that the role proposed by Garnett and Christidis (2017) would be better undertaken by the ICZN.

The proposal of Garnett and Christidis (2017) has its supporters, including Buckeridge (2017). However, there have been many critics, with some authors suggesting that it would 'create unnecessary bureaucracy, be difficult and resource intensive to apply across all taxonomic groups, and stifle scientific progress in the provision of data on species diversity and distribution' (Hollingsworth 2017, p. 600).

Cotterill *et al.* (2017) stated that conservation policies should embrace insights into evolutionary history and that this should not be referred to as 'taxonomy anarchy' that destabilises species lists. Similarly, Lambertz (2017) suggested that taxonomy is an independent biological science and a service provider to policy makers and conservation biologists. In a similar sense, Raposo *et al.* (2017) raised concerns over the suggestion by Garnett and Christidis (2017) that taxonomic revisions should be based on conservation, economic and political concerns. Thomson, and some 180 co-authors (Thomson *et al.* 2018), suggested that the proposal of Garnett and Christidis (2017) was far-reaching but represented a narrow perspective of taxonomy when considering conservation and reflected a misunderstanding of taxonomy, nomenclature and the relationship between them.

Taxonomic vandalism

All aspects of biology rely on a sound taxonomic framework, yet consistent underfunding has caused a global taxonomic impediment, and specialised taxonomy units are now rarely taught at Australian universities, resulting in a steady decline in practitioners relative to other aspects of biology (Dubois 2003; Fontaine *et al.* 2012; Taxonomy Decadal Plan Working Group 2018; Hutchings 2019, 2020). The decline in funding of taxonomy in universities and museums has coincided with an increase in amateur taxonomists who are not formally trained or associated with academic institutions (Fontaine *et al.* 2012). Though the contribution of many amateur taxonomists has been positive, the effects of some amateur taxonomists' work have been highly negative (e.g. see Kaiser *et al.* 2013; Cogger *et al.* 2017). The biggest issue relating to a small minority of amateur taxonomists has been the rise of taxonomic vandalism, which involves the unscrupulous mass-naming of taxa without an adequate scientific basis (Jäch 2007; Wüster *et al.* 2021). This includes not examining appropriate museum specimens or undertaking targeted genetic studies (Measey 2013; Naish 2013). Unfortunately, correctly identified taxa can be obscured by non-scientifically developed descriptions of new species that mislead those who are unable to discern whether a taxon was appropriately generated (Wüster *et al.* 2001; Kaiser *et al.* 2013).

Concerns have been raised by many taxonomists in recent decades that a handful of authors have been describing hundreds of new taxa in self-published journals without appropriate oversight or external review to ensure the integrity of the species descriptions. In this way, the accepted scientific peer review process is being circumvented and the publication is not part of the permanent scientific record (Kaiser *et al.* 2013). The problem with this approach is that a large number of taxonomic names are produced, including many that are clearly invalid, creating taxonomic confusion and instability.

The instability caused by taxonomic vandals leaves end-users uncertain as to which names should be recognised. It also causes frustration for many taxonomists because they are either 'gazumped' in the description of the taxon they were in the process of describing properly, or they waste time either validating or refuting the names, which are often based on inadequate science. Even valid taxa that are given descriptions and names that meet the minimum ICZN standards may be poorly defined and create extra work for other taxonomists to re-evaluate the taxa and clarify the situation in a scientifically rigorous manner.

The biggest issue relating to the publication of such names is that the Principle of Priority in the *International Code of Zoological Nomenclature* (International Commission on Zoological Nomenclature 1999) theoretically forces the adoption of the oldest available name, including those published by taxonomic vandals, regardless of whether they have been created with appropriate scientific merit (Wüster *et al.* 2021).

In Australia, concerns over taxonomic vandalism have led Taxonomy Australia, a program of the Australian Academy of Science, to develop a position statement on the issue (Taxonomy Australia 2021). Taxonomy Australia has adopted the following position (which is endorsed here):

(1) A sound, robust and scientifically justifiable taxonomy, and a sound, rigorous and agreed nomenclature based on that taxonomy, are important underpinnings to our organisation and the science that we support.
(2) Application of agreed norms of science is particularly important for taxonomy and its resultant nomenclature, because the International Codes of Nomenclature make no distinction between published names based on sound, robust science and those not so based.
(3) While it is recognised that in the great majority of cases the conditions for a vibrant, healthy and productive

science of taxonomy and its ensuing nomenclature are met, there are rare cases where important norms are deliberately and persistently broken, a pattern of behaviour dubbed 'taxonomic vandalism'.

(4) Taxonomic vandalism is characterised by some or all of the following:
   (a) naming of taxa in the absence of primary evidence of their taxonomic merit;
   (b) fabrication of evidence including diagnoses and descriptions;
   (c) lack of due diligence in assigning and citing type and other specimens [type specimen is a specimen (or specimens) that serve as the reference point for a taxon], including citation of specimens that are readily available but neither studied nor seen;
   (d) harvesting and naming clades from published phylogenies without notification or collaboration with the relevant authors or experts on the group in question;
   (e) plagiarism and wholesale, unattributed copying of text from source papers;
   (f) inappropriate content, including polemical personal attacks on others, in taxonomic works.
   (g) in addition, and because of the general unacceptability of these practices, those who practice taxonomic vandalism generally publish without (or without adequate) peer review, often in self-published 'journals' established specifically to carry their own publications.
(5) Taxonomy Australia regards that taxonomic vandalism fundamentally weakens the science we support.
(6) Given this, we strongly support members of our community who publish names in a manner that conforms with taxonomic best practice, even if in some cases these are junior synonyms of names resulting from taxonomic vandalism, and use names so published, even if those names are junior synonyms.
(7) Taxonomy Australia understands that adoption of this Position Statement may lead to a situation where some names in use do not have priority under the International Code of Zoological of Nomenclature. We are willing to accept this situation in support of our members and colleagues who do practice rigorous and robust science, and to limit the damage to taxonomy, nomenclature and biodiversity science caused by taxonomic vandalism.
(8) Taxonomy Australia calls upon the International Commission on Zoological Nomenclature to do everything in its power to deal with taxonomic vandalism, including finding appropriate solutions, supported by the taxonomic community, to the problem of dual nomenclature caused by our determination to use junior synonyms in these cases.

In a strict reading of the code, names published in journals with low scientific rigour are technically available for the purposes of nomenclature. However, because these journals diminish the referee process by competent scientists, most scientists ignore these names (Kaiser *et al.* 2013). Kaiser *et al.* (2013, p. 20) suggested that 'in the case of unscientific taxonomy, the Principle of Priority may be set aside due to lack of usage of a taxon name in scientific publications'. The ICZN has not yet made a determination on the recognition of the validity of names published in inadequately refereed self-published journals. Nonetheless, these names have increasingly not been recognised by the scientific community and replacement names have been published even though they may be junior synonyms despite being developed through a much more robust scientific process.

Most taxonomists ignore the names published in the non-refereed journals, but in the herpetological community, a small minority of scientists actively promote their usage (Rhodin *et al.* 2015), which leads to a dual nomenclature of scientific names. However, a review of the adoption of reptile names published in one of these self-published journals since 2000 identified 59 occasions when the unscientific names published in that journal were subsequently replaced with science-based names referred to as aspidonyms (a scientific name that overwrites an unscientific vandalised name) (Wüster *et al.* 2021). The review also found 1087 uses of aspidonyms by subsequent authors and only one occasion where there was a preference for the unscientific name (Wüster *et al.* 2021). Kaiser *et al.* (2013) proposed that all taxonomic vandalism scientific names that have been proposed since 1 January 2000 should be boycotted in the hope that the ICZN will eventually rule against taxonomic vandals.

In keeping with Kaiser *et al.* (2013) and the Australian Society of Herpetologists (2016) we do not consider certain names published outside the peer-reviewed literature to be part of the permanent scientific record and they will be ignored by the Australian Mammal Society. These taxa are separate from the 44 valid taxa that were described, or resurrected from synonymy, through the combined efforts of the mammal taxonomy community, in properly refereed journals between 2000 and 2022 (Table 1).

Australasian Mammal Taxonomic Consortium (AMTC)

The AMTC was established in 2021 by the membership of the Australian Mammal Society to:

(1) promote stability and consensus in the use of scientific names via the establishment of an up-to-date species list for Australasian mammals.
(2) assess the descriptions of new names to determine if they should be considered valid.
(3) provide advice and guidance on taxonomy.
(4) foster and enable collaborations on taxonomy-focussed research projects.

Best practice in the description of new taxa

In order to maintain taxonomic stability and establish scientific names that are scientifically robust and broadly recognised, the AMTC proposes that publications describing new mammal taxa should wherever possible include:

(1) a comparative assessment and diagnosis (including an identification key) of the new taxa.
(2) specimen registration and institution details of the allocated type specimen(s).
(3) illustrations and/or photographs of existing and proposed type specimens.
(4) molecular and/or morphometric analyses (including skull and dentary measurements, and genetic analysis of type or vouchered specimens to link genetics and morphology where possible).
(5) descriptions of the cranium, dentary and external appearance.
(6) a detailed geographic coverage/sampling of specimens examined.
(7) a list and details (e.g. registration numbers) of material examined from museum institutions in describing each new taxon.
(8) an indication of the species definition that was applied.

Where required, a taxonomist who proposes an aspidonym to overwrite a name published in a self-published journal can advise the publisher of the issue (Wüster *et al.* 2021). The publisher can also be advised that the description of an aspidonym is in keeping with Kaiser *et al.* (2013), Wüster *et al.* (2021), and the present publication, which do not consider certain names to be published because they are outside the peer-reviewed literature, are not part of the permanent scientific record, and therefore are not recognised.

Species lists

The management and conservation of species has often been facilitated by the development of species lists, however they need to be based on the best available taxonomic advice, not be biased towards particular political or social aims, have appropriate quality control, be current, and be widely accepted (Conix *et al.* 2021; Thomson *et al.* 2021). In an effort to assist in the study, conservation, trade and management of species, Garnett *et al.* (2020, pp. 4–5) highlighted the importance of species lists that are accepted by both the scientific community and key users. To assist in the development of species lists they proposed ten principles:

(1) The species list must be based on science and be free from non-taxonomic considerations and interference. The list must be independent of political, economic, or other non-taxonomic considerations. For example, the taxonomic list, and the included species, cannot be adapted for conservation purposes.
(2) Governance of the species list must aim for community support and use.
(3) All decisions about list composition must be transparent.
(4) The governance of validated lists of species is separate from the governance of the naming of species.
(5) Governance of lists of accepted species must not strain academic freedom.
(6) The set of criteria considered sufficient to recognise species boundaries may appropriately vary between different taxonomic groups but should be consistent when possible.
(7) A global list must balance conflicting needs for currency and stability by having archived versions.
(8) Contributors need appropriate recognition.
(9) List content should be traceable.
(10) A global listing process needs both to encompass global diversity and to accommodate local knowledge of that diversity.

With these principles in mind the AMTC has developed a species list in order to provide a robust and up-to-date taxonomic reference of all Australian mammals, that can be relied upon by both scientists and members of the public (Baker *et al.* 2021). The species list produced by the AMTC will be revised annually and updated with valid taxonomic names. Version 1.0 of the list was published in September 2021 (Australasian Mammal Taxonomy Consortium (AMTC) 2021) and relevant background information, including how to cite the list in publications, is available at: https://australianmammals.org.au/publications/amtc-species-list. Scientists who use Australian mammal scientific names in their publications are urged to utilise the names on this list in order to promote taxonomic stability.

To ensure there is a single consistent and coherent list of scientific names for Australian mammals, the committee works closely with the Federal Government's Australian Biological Resources Study to ensure that the Society list and the Australian Faunal Directory (AFD) list (Australian Government 2013) are identical. The AFD is an online catalogue of taxonomic and biological information on all animal species known to occur within Australia and its territories. Scientists who use Australian mammal scientific names in their publications are urged to utilise the names in either source of the list in order to promote taxonomic stability.

Given the uncertainty in the validity of some taxa, Kitchener *et al.* (2022) developed a traffic-light system, which indicates the level of certainty in support of the recognition of each taxon that typically included morphological, genetic and biogeographical supporting data. Similarly, Pyle *et al.* (2021) suggested that challenges in the development of global species lists include defining what each taxon represents, the scope or breadth of the taxonomic work, the ranks that are covered (e.g. unnamed taxonomic units,

Table 2. Species of Australian mammals that were described since European settlement after they were presumed extinct.

Common name	Scientific name	Author and year described	Timing of extinction
Northern pig-footed bandicoot	*Chaeropus yirratji*	Travouillon *et al.*, 2019	1950s
South-eastern striped bandicoot	*Perameles notina*	Thomas, 1922	1900s?
Nullarbor barred bandicoot	*Perameles papillon*	Travouillon & Phillips, 2018	1930s
Nullarbor dwarf bettong	*Bettongia pusilla*	McNamara, 1997	<1850?
Central hare-wallaby	*Lagorchestes asomatus*	Finlayson, 1943	1940s
Capricorn rabbit-rat	*Conilurus capricornensis*	Cramb & Hocknull, 2010	<1850?
Short-tailed hopping-mouse	*Notomys amplus*	Brazenor, 1936	1896
Big-eared hopping-mouse	*Notomys macrotis*	Thomas, 1921	1843
Darling Downs hopping-mouse	*Notomys mordax*	Thomas, 1922	1840s
Broad-cheeked hopping-mouse	*Notomys robustus*	Mahoney *et al.*, 2008	1850?
Long-eared mouse	*Pseudomys auritus*	Thomas, 1910	1850s
Blue-grey mouse	*Pseudomys glaucus*	Thomas, 1910	1956?
Percy Island flying-fox	*Pteropus brunneus*	Dobson, 1878	1874?
Lord Howe long-eared bat	*Nyctophilus howensis*	McKean, 1975	1920s?

species only, or all ranks), and the level of confidence in the taxon. Future iterations of the Australian mammal list may also use this method.

In 2020, with the same intent as the AMTC, Australasian Palaeontologists, a specialist group of the Geological Society of Australia, provided the opportunity for palaeontologists to form committees to create fossil species checklists. In November 2020, the first four checklists were published on the Australasian Palaeontologists website, including a checklist of fossil mammals for Australia and New Guinea and a checklist for fossil birds of Australia (Australasian Palaeontologists 2021). These checklists are updated yearly, to provide researchers and members of the public valid species names that have been reviewed by experts in the field.

Discussion

There is a clear imperative to undertake comprehensive morphological and molecular analyses of Australia's mammals in order to better understand and conserve them. Here we highlight the urgent need to increase the number of taxonomists within universities and museums and provide appropriate funds for field work and taxonomic research (Fontaine *et al.* 2012; Dubois 2017*b*). Since the second half of the 20th century, there has been an ever-increasing understanding of Australia's mammal decline and extinction. The 21st century has been highlighted as a period of crisis in biodiversity, and many species are likely to disappear before they are formally described and named (Dubois 2003). Australia has lost 35 mammal species since European settlement. An estimated 14 of these species (40%) were extinct prior to being formally described (Table 2). Around half of Australia's extant mammal species have declined >50% in their geographic range (Fisher and Blomberg 2011).

Outdated taxonomy and confusion about scientific names can inhibit conservation efforts because wildlife protection legislation typically does not keep up with taxonomic changes in the literature (Hazevoet 1996). For example, recently recognised species such as the savanah glider (*Petaurus ariel*) (Table 1) may not have adequate protection (*sensu* Zhou *et al.* 2016). Therefore, unsound taxonomy could provide loopholes or time-lags, where species remain unprotected by legislation such as CITES or unassessed for inclusion under the IUCN Red List of Threatened Species (Kaiser *et al.* 2013).

An important consideration is that science, such as taxonomy, must inform conservation rather than the other way around (Gippoliti *et al.* 2017). In contrast to other concerns that highlight an impact of taxonomic changes on the conservation of wildlife, Morrison *et al.* (2009) examined this issue specifically and suggested there was no evidence of consistent effect of taxonomic change on conservation. However, they did recognise that splitting taxa tends to increase protection and that name changes of charismatic species appear to have the least effect.

It is crucial to link taxonomy and conservation biology so that they support and complement one another (Dubois 2003). We see the development of an endorsed and routinely updated list of correct taxonomic names and their promoted usage for Australian mammals as an important step in achieving this. It is hoped that scientists and authors working with Australian mammals will prioritise names on the endorsed list published by the Australian Mammal Society (AMTC 2021) for modern species, and

the Australasian Palaeontologists (2021) for fossil species. We also hope that this review provides a foundation set of appropriate minimum standards for taxonomic research to help guide those participating in and publishing taxonomic research on Australian mammals.

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