Mammal Review

Mammal Review ISSN 0305-1838

REVIEW

The good, the bad, and the ugly: which Australian terrestrial mammal species attract most research?

Patricia A. FLEMING* *School of Veterinary and Life Sciences, Murdoch University, Murdoch, Western Australia, 6150, Australia. Email: t.fleming@murdoch.edu.au*
Philip W. BATEMAN *Department of Environment and Agriculture, Curtin University, Bentley, Western Australia, 6845, Australia. Email: bill.bateman@curtin.edu.au*

Keywords
eutherian, Hirsch *h*-index, metatherian, monotremes, publication bias

*Correspondence author.

Submitted: 23 September 2015
Returned for revision: 13 October 2015
Revision accepted: 14 December 2015
Editor: KH

doi: 10.1111/mam.12066

ABSTRACT

1. The Australian mammalian fauna is marked by high endemism and evolutionary distinctiveness and comprises monotreme, marsupial, and eutherian ('placental') native species. It has suffered the highest extinction rate of any mammalian fauna in any global region; surviving species are threatened by competition and predation from a range of introduced mammal species, and receive low levels of conservation-oriented funding compared with species in many other countries.
2. We investigated research foci on this unique fauna by using species *h*-indices (*SHI*), and identified both taxonomic bias and subject bias in research effort and research impact for 331 Australian terrestrial mammal species. Species broadly fell into categories we labelled as the 'good', the 'bad', and the 'ugly'.
3. The majority of studies on monotremes and marsupials (the 'good') are directed towards their physiology and anatomy, with a smaller ecological focus. By contrast, introduced eutherians (the 'bad') have attracted greater attention in terms of ecological research, with greater emphasis on methods and technique studies for population control. Despite making up 45% of the 331 species studied, native rodents and bats (the 'ugly') have attracted disproportionately little study.
4. While research on invasive species is directed towards problem solving, many Australian native species of conservation significance have attracted little research effort, little recognition, and little funding. Current global and national conservation funding largely overlooks non-charismatic species, and yet these species may arguably be most in need of scientific and management research effort.

INTRODUCTION

The average global rate of vertebrate species loss over the last century is up to 100 times higher than background rates (Pimm et al. 1995, Ceballos et al. 2015). Of mammals, nearly a quarter (22%) of the world's species are classed as threatened or extinct, while 15% are classed as data deficient (Hilton-Taylor et al. 2009). Australia, an island continent with a long history of isolation, stands out in terms of global evolutionary distinctiveness (Holt et al. 2013); it has a unique mammalian fauna of monotreme, marsupial, and eutherian ('placental') terrestrial species, of which 87% are endemic (Woinarski et al. 2014, Verde Arregoitia 2016). Australia has suffered the greatest loss of native mammal species globally (Loehle & Eschenbach 2012); 10% of 271 terrestrial mammal endemic species have become extinct in the last 200 years, and a further 21% are considered threatened (Woinarski et al. 2014).

Although the number of conservation-based publications has increased exponentially over the last two decades, the research focus has not been consistent between taxonomic groups (Griffiths & Dos Santos 2012), research topics (Stroud et al. 2014), or by geographic area (Lawler et al. 2006). Global research foci may therefore not necessarily reflect changes in conservation research needs, but tend to 'follow the money', being 'strongly associated with changes in funding priorities and monies awarded' (Stroud et al. 2014, p. 472). The 40 most severely underfunded countries in terms of conservation money spent between 2001 and 2008 contain 32% of all threatened mammalian diversity; Australia is one of these countries (Waldron et al. 2013). The estimated shortfall in conservation funding of USD $275 million for Australia is almost a quarter (23%) of the total estimated shortfall in all 40 countries (Waldron et al. 2013), and yet Australia does not receive any international biodiversity funding aid (Miller 2014). This troubling result for a 'nature-conscious, developed country with a treasure trove of biodiversity' (Waldron 2013) captures the limited funding allocated to conservation, where government support is largely directed towards triage in the face of invasive species (Bottrill et al. 2008, Kingsford et al. 2009).

Lawler et al. (2006) examined taxonomic biases in the USA's conservation literature for amphibians, mammals, and birds (the only taxa that have been sufficiently inventoried on a global scale to establish their relative taxonomic risk). The authors recorded that 95% of the surveyed taxa have been assessed for the International Union for Conservation of Nature's (IUCN) Red List, and concluded that the most at-risk taxa were those that had been least studied. Faced with an embattled and unique Australian fauna, how do we ensure that we establish transparent and evidence-based biodiversity reporting, and identify research priorities on which to focus our limited resources?

The *h*-index (Hirsch 2005) is defined as the number of papers (h) with citations $>h$, where a higher *h*-index indicates a higher number of higher cited papers for that subject and, therefore, more research on and interest in that subject. The *h*-index has been shown to be more robust across data bases than several other metrics (Calver et al. 2013a). We have calculated an *h*-index for each Australian terrestrial mammal species, comparing the literature to track changes in publication focus over the last century, both by subject and by species. Meijaard et al. (2015) explored the use of citation metrics as a measure of research impact in 231 countries, and found greater *h*-indices for countries with higher number of species of conservation concern. Robertson and McKenzie (2015) applied this method to British mammal species, ranking species by volume and impact of publications by using species *h*-indices (*SHI*), suggesting that '*SHI* provides a more reliable quantitative method to compare the volume and impact of publications than numbers of papers or numbers of citations'.

Aims

Conservation action is largely determined by what we perceive to be the most significant conservation problems, so raising awareness of potential biases in research effort and also increasing transparency in how we record and report research outcomes is important. We therefore reviewed the published literature for each of 331 Australian terrestrial mammal species in terms of research effort (numbers of published articles) and research impact (*h*-index). We analysed whether there is evidence of bias in terms of taxonomic group and origin (native or introduced), and whether there are influences of body size, current geographic range, change in geographic range, and IUCN status on the effort and impact of research on terrestrial mammals in Australia.

METHODS

We derived a list of Australian terrestrial mammal species from the *Action Plan for Australian Mammals 2012* (Burbidge et al. 2014). We worked at the species level, and so did not include subspecies as separate entities (e.g. the three subspecies of *Antechinus flavipes*). In terms of introduced species, we excluded the Pacific rat *Rattus exulans*, five-lined palm squirrel *Funambulus pennantii* and eastern grey squirrel *Sciurus carolinensis* because they have limited distributions on the Australian mainland. We considered sambar deer *Rusa unicolor* and rusa deer *Rusa timorensis* together. We did not analyse data for cattle *Bos taurus* or sheep *Ovis aries*. We consider the dingo *Canis lupus dingo* as introduced to Australia (Woinarski et al. 2014); the species was introduced to the continent relatively recently (3000–5000 years ago, Crowther et al. 2014) and a large proportion of the literature on this species is focussed on control. This left a list of 311 native species (271 endemic species plus 40 with extralimital geographic ranges) and 20 introduced mammal species.

In May 2015, we searched the Murdoch University Web of Science, which includes searches of books, journals and conference proceedings. At the time of these searches, the Web of Science subscription service included access to the Web of Science Core Collection, BIOSIS Citation Index, BIOSIS Previews, Current Contents Connect, CABI: CAB Abstracts, KVI-Korean Journal Database, Medline, SciELO Citation Index, Zoological Record (1864–1980), and Journal Citation Reports. We elected to use this inclusive data base since some collections (e.g. Web of Science Core Collection) do not include access to key Australian journals; this would have limited our search outcomes. Our inclusive approach also reduced our reliance on one data base (Calver et al. 2013a). We searched for the scientific name of each species and for variants thereof (e.g. *Macropus* *rufus* and *Megaleia rufa*). Because 87% of Australian species are endemic, most searches were not restricted by research domain or research area; we did include a filtering term ('Australia') for the native species with geographic ranges outside Australia, e.g. brushtail possum *Trichosurus vulpecula* and tammar wallaby *Macropus eugenii* that have been introduced to New Zealand, and domestic species with global geographic ranges. For the domestic cat *Felis catus*, banteng *Bos javanicus*, horse *Equus caballus*, pig *Sus scrofa*, and donkey *Equus asinus*, we included the term 'feral' with our search. Although the data base accessed records back to 1864, we truncated the analyses at 1900 because most publication citations were captured more recently (largely within the last three decades). The Web of Science only searches for terms in titles of papers published before 1990, but expands this to titles, keywords and abstracts for more recent papers (Pautasso 2014); this artefact influences all our species searches equally. We extracted title, authors, source, publication date, and number of citations for each year since 1900 (i.e. the last 115 years) for every one of 14248 publications.

Robertson and McKenzie (2015) excluded papers on British mammals that dealt solely with anatomy or genetics, and captive or laboratory studies (unless the authors directly related these to the ecology of the species); however, because we were interested in potential changes in focus of research, we elected to include these papers in our study but identify them separately. Therefore, the title of each paper was filtered using a series of search terms (see Appendix S1) and then titles were also individually reviewed and papers were categorised into five mutually exclusive research topics: 'physiology/anatomy', 'genetics/taxonomy', 'parasites/disease', 'methods/techniques', or 'ecology'. The first three categories included studies of physiology, genetics, or parasites in isolation from their effects upon the ecology of the species. The 'physiology/anatomy' category also included studies of ethology and behaviour, 'genetics/taxonomy' included species descriptions, and 'parasites/disease' included studies where the parasite was the obvious focus of the study, not the animal host. The 'methods/techniques' category included baiting and control investigations, methodological studies (e.g. trap design, monitoring methods), and work on captive/laboratory animals (e.g. nutrition of captive animals). The 'ecology' category included all other papers.

We analysed the average citation rate (number of citations per year since publication) and total number of published papers (*n*) for each Australian terrestrial mammal species (research effort), and the research impact (*SHI*) for all publications together, and then separated by research topic.

We compared the numbers of species in each order with the numbers of publications by χ^2 test; the expected numbers of publications was calculated in proportion to the number of species in each order. We examined whether there was an effect of taxonomic group (independent factor) and origin (native or introduced) on the number of papers in each of the five research topic categories for each species by multivariate analysis of variance (MANOVA).

Variables likely to influence *SHI* were collated. We recorded the species' average body mass in grams (Van Dyck & Strahan 2008, Johnson & Isaac 2009), and converted their conservation status (IUCN Red List of Threatened Species category, June 2015; Woinarski et al. 2014) into numerical values: Extinct = 1, Critically Endangered = 2, Endangered = 3, Vulnerable = 4, Near Threatened = 5, Least Concern = 6. Geographic range data were extracted from Van Dyck and Strahan (2008) by using a cartographic method to estimate historical geographical range (% Australian landmass; includes recent fossil distribution) and current geographical range (% Australian landmass). We calculated the change in geographical range as −2 = lost from >25% of Australian landmass, −1 = lost from 0–25% of Australian landmass, 0 = no recorded change in geographic range, 1 = increased in range by 0–25% of Australian landmass, 2 = increased to >25% of Australian landmass. We tested whether there was a correlation between the *SHI* values as response variables (*SHI-all* or *SHI* values calculated for each of the five research topic categories) and predictor variables: taxonomic group, origin (native or introduced), body mass ($\log_{10}$-transformed values), IUCN status (1–6), current geographical range ($\log_{10}$-transformed values), and change in geographical range (−2 to 2), using a generalised nonlinear multiple regression model (Statistica 8.0). To test for potential effects of body size, we compared data for marsupial and eutherian (rodent and bat) taxa weighing <35 g, i.e. below the minimum limit of the 'Critical Weight Range' (35 g–5.5 kg; Burbidge & McKenzie 1989, McKenzie et al. 2007, Johnson & Isaac 2009).

We compared *SHI* and the number of publications (*n*) for each of the five research topics by repeated-measures analysis of variance (ANOVA) for the 96 species that had publications in all five research topics.

RESULTS

Research effort (number of studies)

Of the 331 mammal species reviewed in this study, two are monotremes (0.6%), 161 are marsupials (49%), and 168 are eutherians of which 148 (45%) are native and 20 (6.0%) are introduced to the Australian continent (Table 1). By contrast, of the 14248 publications assessed, 4% of studies were carried out on monotremes, 73% on marsupials, 11% on native eutherians and 12% on

Table 1. Total numbers of species included in the analyses and the numbers of publications (published since 1900) reviewed for each mammal order (***$P < 0.001$ for χ^2 test comparing the number of publications with expected numbers based on the proportions of species in each order). We also give the species h-index (*SHI*) averaged for all species within the order, and the average citation rate (number of citations per year since publication; averaged across all papers for each species).

							SHI-all		Citation rate	
	Origin	Taxonomic group	Order	Number of species	Number of publications	χ^2 test	*x*	SD	*x*	SD
The 'good'	Native	Prototheria	Monotremata	2	567	***	33.5	2.1	1.7	0.8
		Metatheria	Dasyuromorphia	59	3259	***	11.4	10.1	1.0	0.5
			Diprotodontia	89	6693	***	11.9	11.6	1.0	0.6
			Notoryctemorphia	2	13	***	3.0	4.2	1.6	1.4
			Peramelemorphia	11	389	***	9.8	6.0	1.0	0.5
The 'ugly'	Native	Eutheria	Chiroptera	83	622	***	3.0	4.5	1.0	1.0
			Rodentia	65	965	***	5.9	6.2	1.2	0.9
The 'bad'	Introduced	Eutheria	Artiodactyla	10	347	***	9.1	7.6	1.1	0.5
			Carnivora	3	629	***	35.3	10.0	2.4	0.6
			Lagomorpha	2	344	***	21.0	22.6	1.3	0.3
			Perissodactyla	2	39	***	5.5	3.5	0.9	0.4
			Rodentia	3	381	***	20.7	19.9	1.2	0.4
	Total			331	14248		8.6	10.0	1.1	0.7

introduced eutherians (Table 1). χ^2 tests comparing the number of publications with the number predicted from the proportions of species were significant ($P < 0.001$) for all orders. The majority of publications on marsupials have been carried out for Dasyuridae and Macropodidae (Fig. 1), which are also the two most speciose Australian marsupial families (57 and 45 species, respectively). By contrast, few publications exist for native rodents and bats, despite a diversity of these eutherian species (65 and 83 species, respectively).

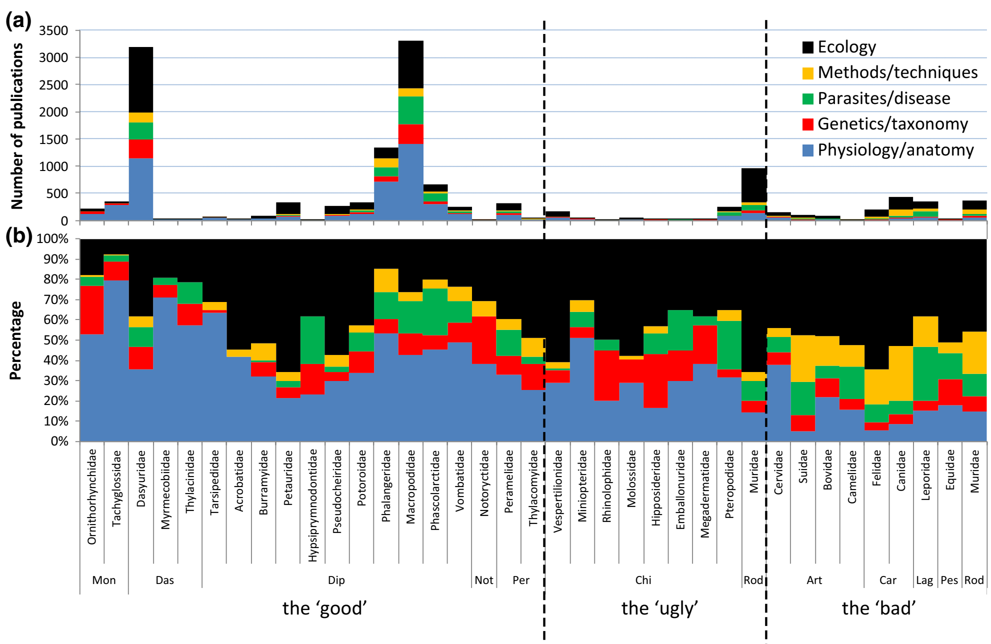

Fig. 1. Total numbers of publications (a) and percentages of publications (b) in each of five subject areas shown for each of the Australian terrestrial mammal taxonomic groups; 14248 publications (published since 1900) pertaining to 311 native species and 20 introduced species are included. Native monotremes and marsupials are identified as the 'good', introduced eutherians as the 'bad', native eutherians as the 'ugly'. Orders: Mon, Monotremata; Das, Dasyuromorphia; Dip, Diprotodontia; Not, Notoryctemorphia; Per, Peramelemorphia; Chi, Chiroptera; Rod, Rodentia; Art, Artiodactyla; Car, Carnivora; Lag, Lagomorpha; Pes, Perissodactyla. Within the orders, families are arranged left to right by increasing average body mass.

There are significant differences between taxonomic groups in the numbers of publications across each of the five research topic categories (MANOVA $F_{15,246} = 10.37$, $P < 0.001$; Fig. 2). 69% of studies on monotremes and 40% of studies on marsupials pertain to aspects of their physiology/anatomy, but only 11% and 31% (respectively) relate to their ecology. By contrast, the majority (57%) of studies on native eutherians pertain to their ecology (21% of studies relate to physiology/anatomy). For introduced eutherians, 48% of studies are on their ecology while a further 19% relate to methods/techniques, particularly baiting and control practices (only 14% of studies relate to physiology/anatomy). Studies on genetics/taxonomy (6–15%) and parasites/disease (4–14%) are reasonably consistently applied to the taxonomic groups (Fig. 2).

Research impact (citation rate and *SHI*)

The citation rate (number of citations per year) for papers on Australian terrestrial mammals was influenced only by their current geographical range; the positive relationship reflected a greater citation rate for more widely dispersed species (data not presented).

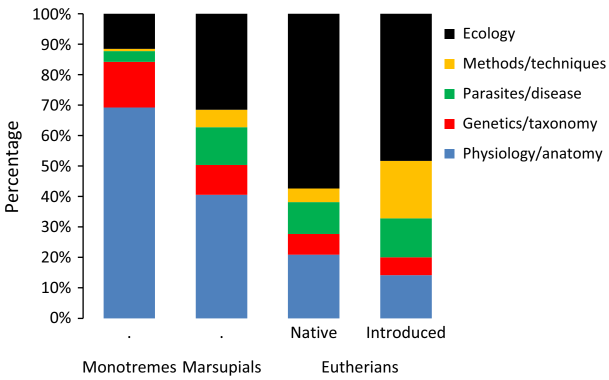

Fig. 2. Percentages of publications on each of the five subject areas, shown for each taxonomic group. There are significant differences in the proportions of publications in each of the five subject areas between the taxonomic groups (MANOVA $F_{15,246} = 10.37$, $P < 0.001$).

The *SHI* values captured differences between species where there were very few publications, enabling greater differentiation of research impact between these species than was possible by using average citation rate. *SHI-all* values were influenced by taxonomic group, origin, body mass, current geographical range, and the change in geographical range, but not by IUCN status (Table 2). In all research topics, there was greater impact of research on more widely distributed species (positive relationships between *SHI* values and current geographical range values; Table 2). With the exception of *SHI-methods/techniques* (no significant relationship), there was greater impact of research on larger species. With the exception of *SHI-parasites/disease* (no significant relationship), there was greater impact of research on species that have shown a decrease in their geographical range over the last 200 years. There was greater research impact for physiology/anatomy, genetics/taxonomy, and methods/techniques papers for species of conservation concern.

SHI-ecology was influenced by taxonomic group as well as by origin (Table 2; Fig. 3a). Although there are few ecology studies for monotremes, these two species have relatively large *SHI-ecology* values. The greatest spread in *SHI-ecology* values was for eutherians, with higher *SHI-ecology* values for introduced than native eutherian species (Fig. 3a). Although most native eutherians are small species (i.e. rodents and bats), this difference between taxonomic groups was still evident when only small animals were considered (<35 g; smaller than the minimum limit of the Critical Weight Range; McKenzie et al. 2007; Fig. 3b). Ecological studies on larger (Fig. 3c) and more widely distributed (Fig. 3d) species also had the greatest research impact, as did studies on species that have shown a decrease in geographical range over the last 200 years (Fig. 3e). The somewhat surprising lack of significant relationship

Table 2. Summary of generalised nonlinear multiple regression models testing for effects of six factors on the *SHI* values calculated for each research topic. Values are the Wald statistics with significance shown as *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$. Signs (+/–) indicate the direction of significant relationships for continuous variables.

	Citation rate	*SHI-all*	*SHI*-physiology	*SHI*-parasites	*SHI*-genetics	*SHI*-methods	*SHI*-ecology
	$n = 282$	$n = 330$	$n = 201$	$n = 153$	$n = 202$	$n = 131$	$n = 308$
Origin (introduced/native)	0.63 ns	67.13***	5.99*	1.11 ns	4.98*	32.41***	24.88***
Taxonomic group	0.07 ns	218.01***	110.00***	5.13*	87.87***	4.73*	100.56***
IUCN status	1.27 ns	0.09 ns	– 19.13***	1.82 ns	– 4.66*	– 27.35***	0.06 ns
Body mass log(g)	0.00 ns	+ 73.33***	+ 10.76**	+ 57.69***	+ 13.20***	0.18 ns	+ 45.14***
Current range log(%)	+ 4.93*	+ 419.57***	+ 210.44***	+ 80.79***	+ 101.54***	+ 99.40***	+ 232.13***
Change in geographic range	0.94 ns	– 61.87***	– 14.69***	3.49 ns	– 4.53*	– 5.24*	– 15.64***

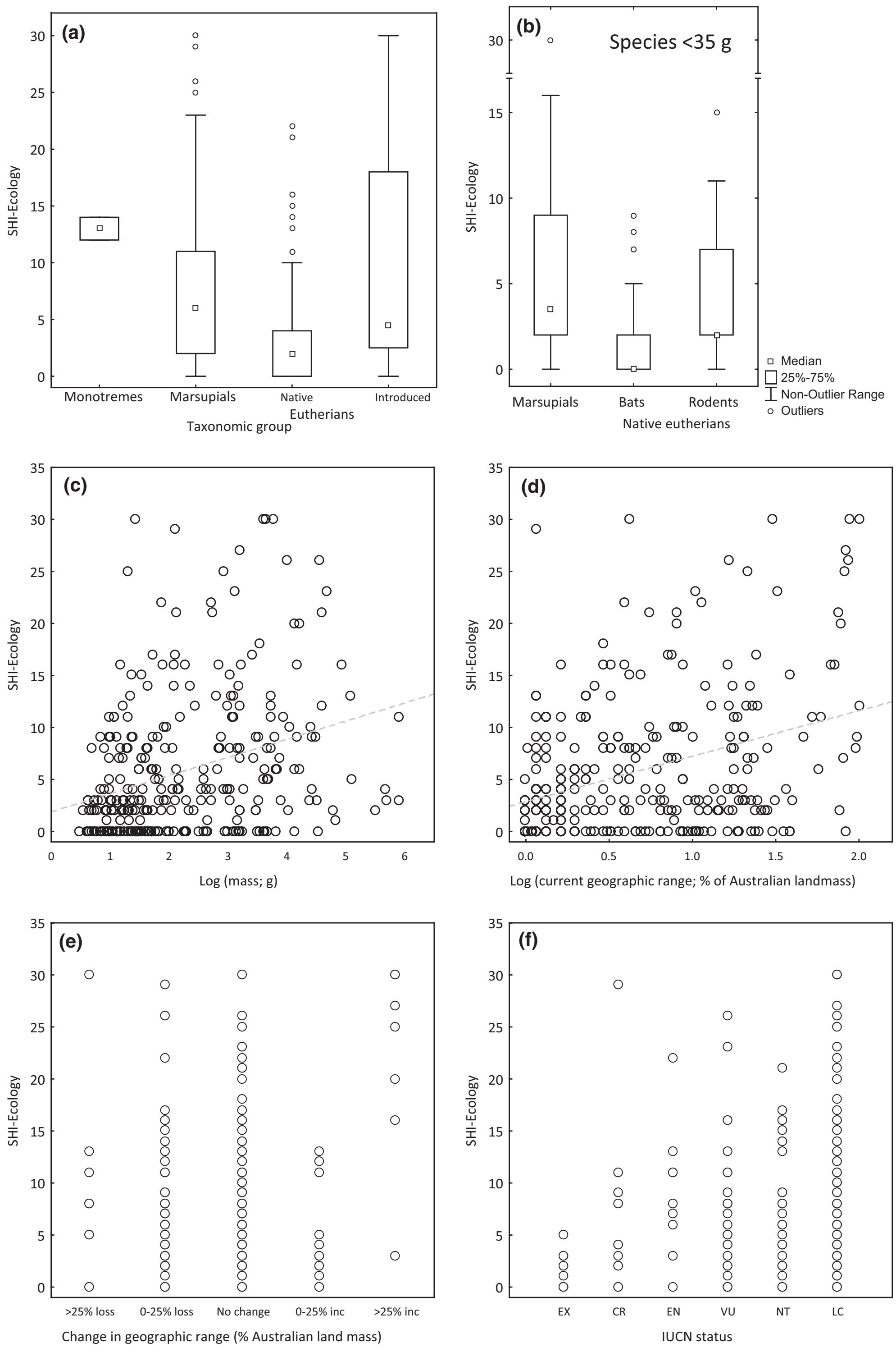

Fig. 3. Factors significantly associated with the *SHI-ecology* calculated for each of the 331 Australian terrestrial mammal species: (a) taxonomic group and origin for all species, (b) taxonomic group and origin, only for species below the Critical Weight Range, body weight <35 g, (c) body mass, (d) current geographical range, and (e) change in geographic range over the last 200 years. Once other factors were taken into account, there was no significant effect of (f) IUCN status. Dashed lines in (c) and (d) are lines of best fit for these single factors considered in isolation.

between IUCN status (Fig. 3f) and *SHI-ecology* values could reflect the redundancy of status measures when taxonomic group, origin, and change in range factors are considered simultaneously.

Comparison between *SHI-all* and *SHI-ecology* reflected the greater proportion of published studies on monotremes and marsupials in disciplines other than ecology (principally physiology/anatomy), and therefore species that had the highest overall research impact (*SHI-all*) did not have high *SHI-ecology* values (Fig. 4). Studies on introduced eutherian mammals were largely in ecology, and therefore there was little difference between the *SHI-all* and *SHI-ecology* metrics (Fig. 4). The exceptions were data for the red fox *Vulpes vulpes* and house mouse *Mus musculus*, where a considerable number of publications were identified as techniques/methods studies, particularly around baiting and other control methods.

Repeated-measures ANOVA for the 96 species that had publications in all five research topics indicated a significant difference in *SHI* calculated between research topics ($F_{4,384}$ = 69.40, P < 0.001). *SHI-ecology* values (average h = 12.57) were significantly higher than *SHI-physiology/anatomy* values (average h = 9.97), and both of these research topics had greater research impact than the remaining three topics, which had statistically similar *SHI* values (*SHI-parasites/disease*: h = 5.14, *SHI-genetics/taxonomy*: h = 5.18, *SHI-methods/techniques*: h = 3.71). This difference between research topics was not just an artefact of the numbers of publications (n) in each research topic,

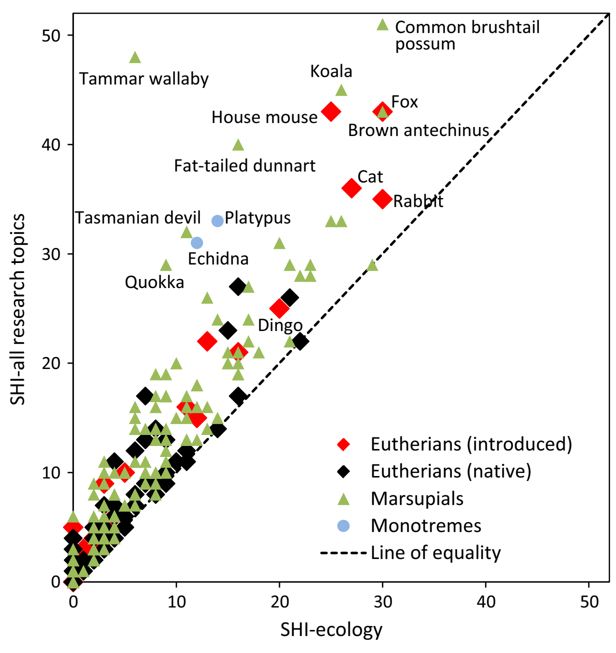

Fig. 4. Comparison of the *SHI* for papers in ecology only (*SHI-ecology*) with all published studies (*SHI-all*).

since although there was a significant difference in n between topics ($F_{4,384}$ = 15.09, P < 0.001), there was no significant difference between ecology (average n = 40) and physiology/anatomy (average n = 49). Average numbers of publications for parasites/disease: n = 16, genetics/taxonomy: n = 11, methods/techniques: n = 10 were not significantly different from each other.

DISCUSSION

Taxonomic bias in research efforts

Our analysis indicates marked taxonomic bias in the volume and impact of research on mammals in Australia. We identified three main categories of species that have received different levels of research attention – species that we here refer to as the 'good', the 'bad', and the 'ugly'. A global review of publications in conservation research shows that, since the 1990s, there has been a continuing emphasis on charismatic taxa (Griffiths & Dos Santos 2012). To some degree, charismatic species can act as umbrella species: their study and conservation can indirectly benefit less charismatic species living in the same habitat. However, this study reveals that research on Australian terrestrial mammals is not only taxonomically biased but has also been markedly subject-biased. Publications on monotreme and marsupial fauna (the 'good') have largely been focussed on their physiology and anatomy. Research on introduced and invasive eutherian species (the 'bad') has largely been on their ecology and methods/techniques (particularly for control of these species). Receiving the least attention, however, have been native eutherian mammals (bats and rodents; the 'ugly'); although they make up nearly half of Australian terrestrial mammal species, for the majority of species, researchers have done little more than catalogue their existence. In addition to these taxonomic patterns of research effort (numbers of published studies), we recorded taxonomic bias in research impact (species h-indices) with ecology studies showing greater impact.

The 'good' – Australian monotreme and marsupial species

Given their interesting and unique biology, it is probably not surprising that many studies on monotremes and marsupials have been focussed on their basic biology (physiology/anatomy, parasites/disease, or genetics/taxonomy), while fewer studies have been focussed on their ecology and conservation biology. Monotremes have largely been studied in terms of their physiology/anatomy or genetics/taxonomy. The echidna *Tachyglossus aculeatus* has the IUCN status 'Least Concern', while the platypus *Ornithorhynchus anatinus* has recently been recognised as

'Near Threatened' (Woinarski et al. 2014). For such iconic vertebrates, it is surprising how little is known about their population abundance and trends over time. Similarly, there has been a considerable research focus on physiology/anatomy of marsupials, and a number of species have been used as models for mammalian reproduction or neurobiology research (Warburton 2014), most notably the tammar wallaby, common brushtail possum, quokka *Setonix brachyurus*, and the fat-tailed dunnart *Sminthopsis crassicaudata*. This research has far outstripped research on the ecology of these mammals.

The 'bad' – introduced and invasive eutherian mammals

Research on Australian introduced invasive species has largely been ecology-focussed. Invasive species have reshaped the function and composition of biomes across the globe (Loehle & Eschenbach 2012). Accompanying European colonisation, 26 eutherian species have been introduced to the continent and have significantly influenced the ecology of environments (Fisher et al. 2003, Doherty et al. 2015). In northern Australia, introduced animals are now present in far greater biomass than native animals (Woinarski 2014), while invasive species (particularly predators) have been identified as major

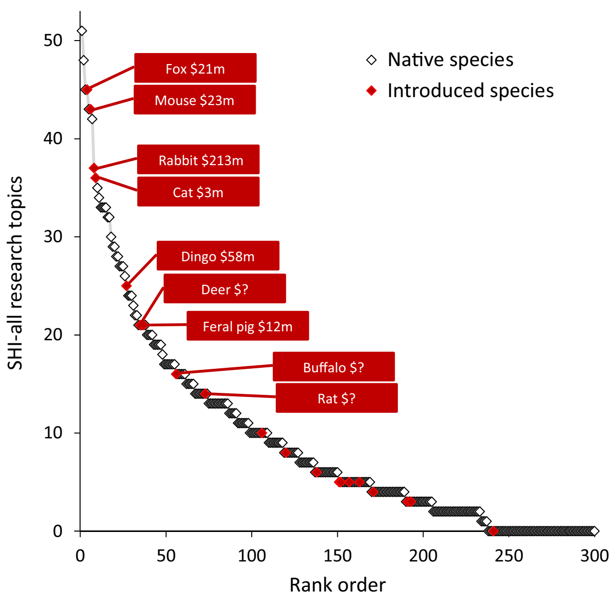

Fig. 5. Research impacts (in rank order of decreasing *SHI-all*) compared with the economic impacts (2007–2008 AUD terms) of some species in terms of agricultural losses and control costs on agricultural land and conservation estates (Gong et al. 2009; Table 4.4). There are no reliable data for the estimated environmental costs of introduced species for comparison.

contributors to conservation crises for Australian native species (Kingsford et al. 2009, Woinarski et al. 2011, 2015). Consequently, introduced eutherian mammals have received a disproportionate amount of research focus (this study) and funding (Gong et al. 2009) over the last century in Australia (Fig. 5); considerable cost is associated with minimising their ecological, social and economic impacts (Scalera 2010). Of the top nine *SHI* for Australian mammals, four are for introduced species: the red fox, house mouse, European rabbit *Oryctolagus cuniculus*, and feral cat. Together, these invasive eutherian species annually cost the Australian economy at least AUD 270 million through agricultural losses (Gong et al. 2009) in addition to the costs of population control in conservation estates (McLeod & Norris 2004).

The red fox and feral cat have had marked impacts on Australian fauna, particularly affecting ground-dwelling species in low-rainfall areas that fall within the Critical Weight Range (35 g–5.5 kg; Burbidge & McKenzie 1989, McKenzie et al. 2007, Johnson & Isaac 2009, but see Cardillo & Bromham 2001). The red fox and feral cat are believed to have contributed to the extinction of more than 25 mammal species and subspecies in Australia, and are recognised as the greatest threat to many extant Australian species (Woinarski et al. 2015). These predators also put considerable toll on translocated 'insurance' populations (captive and wild animals moved to new locations as a mitigation against risk to existing populations), requiring significant investment in baiting programs, predator-proof fencing, and monitoring of conservation estates (Armstrong et al. 2015).

The house mouse has the second highest *SHI* of the introduced species. There has been substantial research investment in control methods for mice in agricultural and conservation environments (Gong et al. 2009, Gregory et al. 2014, Campbell et al. 2015). Eruptions of mice have been associated with weather patterns (plagues of the house mouse are preceded by drought conditions the year before) and seed availability (e.g. Saunders & Giles 1977, Singleton 1989, Pech et al. 1999), and large numbers of these introduced rodents can threaten conservation-significant species, particularly on islands (Burbidge & Morris 2002, Croxall et al. 2012).

European rabbits have been 'Australia's most costly vertebrate pest' (Cooke et al. 2013). Rabbits are a major environmental and agricultural pest, particularly in semi-arid and subalpine areas where rabbit (and sheep) grazing has fundamentally altered the environment (Williams et al. 1995, Cooke et al. 2013). Expenditure on rabbit control varies considerably over time due to changing population numbers and varying levels of efficacy of biological control. Recent estimates (Gong et al. 2009) suggest that AUD 60–70 million is currently being spent annually on the control of rabbits; however, these costs are offset against the massive potential economic losses in the absence of control due to extensive and progressive deterioration of agricultural land and competition with livestock (Cooke et al. 2013). For example, the economic benefits to agriculture of controlling rabbits over the last 60 years has been estimated to total AUD 70 billion (2011 AUD terms; Cooke et al. 2013). In addition to their agricultural costs, rabbits also compete with native animals for food and shelter, and cause devastating damage to native vegetation through ringbarking (removing the living cortex of trees), grazing and browsing activities; impacts that we cannot reliably calculate the financial costs of (Williams et al. 1995, Cooke 2012, Cooke et al. 2013).

Although we considered the dingo as introduced, its status is controversial. Dingoes were introduced to the continent relatively recently and they are now the largest terrestrial predator on the continent. Although an argument has been made for dingoes to be recognised as an important part of Australian ecosystems, suppressing smaller introduced predators (such as foxes and cats) and therefore benefiting biodiversity (e.g. Letnic et al. 2012), we considered the species as introduced for our analyses. Dingoes are genetically distinct from domestic dogs, but they readily hybridise (Crowther et al. 2014). In Australia, 'wild dogs' is used to refer to free-living domestic dogs *Canis lupus familiaris*, dingoes *Canis lupus dingo* and their hybrids. Wild dogs are a major pest species of livestock throughout Australia, resulting in lost productivity and significant control costs. Estimates suggest that total economic surplus losses and control costs for wild dogs are in the order of AUD 58 million annually (Gong et al. 2009), although these values are likely to be conservative (Bell 2015).

The 'ugly' – native eutherian mammals (native rodents and bats)

Despite the diversity of native rodent and bat fauna across Australia (45% of the 331 terrestrial mammal species we considered), these animals have received very little attention beyond their original taxonomic descriptions. Arguably, they are the least charismatic of Australian mammals, and their small size and cryptic behaviour can make rodents and bats difficult to study. However, their conservation status is often decided based on scarce or non-existent data, their geographical ranges (and changes in their geographic ranges) are scarcely mapped, and for many species we have insufficient information about their biology (e.g. diet and habitat requirements) to be able to identify potential threats to their persistence (Lumsden & Bennett 2000, Amori & Gippoliti 2001). Smaller species may be less vulnerable to extinction risk in mesic areas, but in arid areas, where predation from introduced predators is the main threat, there is no apparent effect of body size on extinction risk (Cardillo 2003). Therefore understanding their biology is an important consideration towards their conservation.

It is often surprising to people that Australia has such a diversity of native rodents (Woinarski et al. 2014). We considered 65 rodent species in this study (20% of the 331 species reviewed), although the taxonomy for some groups is still ambiguous (Woinarski et al. 2014) and the number could well be larger (Burbidge et al. 2009). In fact, 'after more than 200 years of study the taxonomy of Australian mammals remains far from firmly resolved' (Burbidge et al. 2014). Australian rodents (and marsupials) have shown higher extinction rates than other mammal groups (Woinarski et al. 2015). 14 of the 30 Australian mammal species (47%) that have become extinct since 1788 were rodents (Woinarski et al. 2015). For many of these species, we have had little chance to study their biology before they were lost. For example, remains of three hitherto unknown extinct species of native rodents were found in caves in the southern Kimberley in 2004 (Start et al. 2012), a new species of rabbit-rat *Conilurus capricornensis* was described in 2010 from bone deposits in Queensland (Cramb & Hocknull 2010), while *Notomys robustus* was described only from remains in owl pellets in the Flinders Ranges (Mahoney et al. 2008).

In terms of species biology, a handful of species have been targeted in many studies (e.g. bush rat *Rattus fuscipes*, swamp rat *Rattus lutreolus*, broad-toothed rat *Mastacomys fuscus*, spinifex hopping-mouse *Notomys alexis*, grassland melomys *Melomys burtoni*, fawn-footed melomys *Melomys cervinipes*, and some *Pseudomys* species). Native rodents have been studied through the proxy of examining impacts of predation on overall biodiversity (e.g. Johnson et al. 2007, Letnic et al. 2009, 2011). For the majority of species, however, native rodents have appeared to attract disproportionately less research focus than other taxa, a conclusion mirrored in a recent review for studies across the globe (Verde Arregoitia 2016).

We considered 83 bat species in this study, 25% of the 331 species reviewed. Most bat families have low research impact, with the exception of the Pteropodidae (flying foxes), several species of which live in urban areas where disease transmission and their large population density can cause conflict with humans (e.g. Williams et al. 2006, Plowright et al. 2011). Australian bats have shown lower rates of extinction than marsupials and rodents (Woinarski et al. 2015), presumably because their high mobility allows them to move to suitable habitat, and because foraging and denning above ground gives bats protection from introduced predators. However, some bat species show strong correlations between abundance and tree health, which suggests that future habitat loss due to habitat change, plant pathogens, and changing climate could detrimentally affect bats (Lumsden & Bennett 2000). In 2009, the last Christmas Island pipistrelle *Pipistrellus murrayi* died (Martin et al. 2012); although the cause of decline of this species is unknown, the colonisation of its habitat by a suite of invasive species and introduced diseases are likely to be responsible. Other bat species may similarly be vulnerable to present and future threats; without better understanding of their basic biology (diet, habitat requirements, vulnerability to disease, etc.), we may not be aware of these threats until it is too late to act effectively.

Research is largely focused on large, widely distributed species

In addition to taxonomic biases, we also found greater *h*-indices for larger species (larger body mass) and those with greater geographical ranges than for smaller species with smaller ranges. We found a pattern of greater research impact for species that have shown a decrease in range over the last 200 years, but no main effect of IUCN status (when other factors are simultaneously taken into account). There was also a greater citation rate for papers on widely distributed species. It is evidently much easier to undertake ecological studies on more accessible or common species, which probably also reflects public perception and awareness of Australian mammal species (Burbidge et al. 2015) and thus the allocation of conservation funding.

Should we be talking about research effort, or research impact?

The *SHI* calculation is sensitive to small numbers of publications, allowing distinction of the impact of research between species based on only a few published studies. The *SHI* calculation captures whether studies have an impact in terms of being cited in the scientific literature, although a true testimony from a conservation perspective would be whether they have an impact in terms of changing policy or legislation. Studies of specific aspects of a threatened species' biology are most likely to influence how we manage the recovery or conservation of that species; however, such studies are likely to be turned away by the editorial boards of the highest impact international journals as being parochial and of limited interest. Nevertheless, these studies would enlighten efforts to conserve Australian native mammals, and need to be recognised for their important contribution (Calver et al. 2013b).

Patterns between studies

The pattern of research on Australian mammals revealed through *SHI* has some interesting commonalities and differences with that of British mammals (Robertson & McKenzie 2015). For species common to both countries, red deer *Cervus elaphus* and fallow deer *Dama dama* have higher *SHI* values in British than in Australian studies, while feral cats and house mice have higher *SHI* in Australian studies. The red fox and the European rabbit have similar *SHI* values for both countries. Both studies indicated taxonomic biases (with rodents and bats having small *SHI*), and positive relationships between *SHI* and geographical range and body size. Neither study found a significant relationship with IUCN status, although we found greater impact for species that had declined in range over the last 200 years. Native British species have higher ecology research impact (*SHI*) than introduced species; similarly, we found greater *SHI* values for monotremes and marsupials than for introduced eutherians, but we also recorded the lowest values of all for native eutherians.

Conservation funding in Australia

Global extinction rates of mammals are 177 times higher on islands (including Australia) than on continents (Loehle & Eschenbach 2012), and Australia is home to the highest levels of threatened mammalian biodiversity globally. Within Australia, federal government funding is largely, unavoidably, directed towards triage in the presence of invasive species (Bottrill et al. 2008, 2009), and in the absence of global funding to support biodiversity conservation research, Australian mammalian fauna face a significant plight. Australia is responsible for the stewardship of an extraordinary endemic mammalian fauna, and yet current levels of funding are several orders of magnitude below what is needed to return rates of extinction to natural levels (Bottrill et al. 2009).

Conservation funding should be directed not only towards control actions and fire management (Carwardine et al. 2012), but also towards long-term monitoring and basic research undertakings that enable appropriate decisions to be made (Lindenmayer et al. 2012, Woinarski et al. 2014, 2015). Carwardine et al. (2012, p. 202) argue that 'data collection should be undertaken when it can cost-effectively improve decisions', but we cannot make cost-benefit assessments if we still do not have basic knowledge of species' biology and understand the issues that are faced. Unless we know where potential threats lie (e.g. disease, habitat loss, predation), action can easily be misdirected.

Many Australian government and non-government conservation agencies strive to protect threatened species from predation, undertake translocations to restore populations or to create insurance populations, and manage conservation estates for biodiversity protection. These are expensive but necessary undertakings if we are to turn policies into actions swiftly enough to prevent declines and extinction of species (Martin et al. 2012). In the face of a booming resource sector and rapidly changing climate, the budgets allocated to conservation agencies need to be increased (not decreased, as has been happening over recent years), and increasing support of conservation research throughout Australia must be a societal and political decision (Bottrill et al. 2009). We also require good legislation and policy to protect threatened species and conservation estates (Ritchie et al. 2013), and policy that would support our capacity to undertake large-scale management actions. Recognising the roles of various non-government sectors (conservation trusts, service providers, indigenous landholders) in conservation actions is also vital to increase awareness and promote action. For example, engaging with people via citizen science is a powerful way to increase research capacity, especially for basic biological studies (Mulder et al. 2010, Coulson et al. 2014, Sequeira et al. 2014), and also has the benefit of increasing awareness of Australian fauna and importance of conservation action (Tulloch et al. 2013).

CONCLUSIONS

1. Marked taxonomic bias in the volume and impact of research on mammals in Australia indicates that, among the 331 terrestrial species reviewed, most research is focussed on larger, widely distributed species.
2. Most research on monotremes and marsupials has been on their physiology or anatomy, while most research on introduced eutherians is directed towards ecological questions.
3. We found greater research impact (*SHI*) for ecological studies than for studies in other research topics for the same species.
4. We need to support natural history studies of species we know little about (documenting observations of their diet, habitat selection, space use, and reproduction), because we cannot identify threats and management options to make enlightened conservation decisions without this information (McDonald-Madden et al. 2010). Armed with such information, funding priorities could be based on conservation needs at both the immediate and long-term scales (Stroud et al. 2014).

ACKNOWLEDGEMENTS

We thank Murdoch and Curtin Universities for funding support. Thanks to Mike Calver for valuable comments.

REFERENCES

Amori G, Gippoliti S (2001) Identifying priority ecoregions for rodent conservation at the genus level. *Oryx* 35: 158–165.

Armstrong DP, Hayward MW, Moro D, Seddon PP (2015) *Advances in Reintroduction Biology of Australian and New Zealand Fauna*. CSIRO Publishing, Clayton, South Victoria, Australia.

Bell K (2015) *Assessment of the Impact of Wild Dogs on the Western Australian Rangeland Goat Industry*. Meat and Livestock Australia Ltd., Sydney, Australia.

Bottrill MC, Joseph LN, Carwardine J, Bode M, Cook C, Game ET et al. (2008) Is conservation triage just smart decision making? *Trends in Ecology and Evolution* 23: 649–654.

Bottrill MC, Joseph LN, Carwardine J, Bode M, Cook C, Game ET et al. (2009) Finite conservation funds mean triage is unavoidable. *Trends in Ecology and Evolution* 24: 183–184.

Burbidge AA, McKenzie NL (1989) Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* 50: 143–198.

Burbidge AA, Morris KD (2002) Introduced mammal eradications for nature conservation on Western Australian islands: a review. *Turning the Tide: The Eradication of Invasive Species*: 64–70. IUCN SSC Invasive Species Specialist Group, Gland, Switzerland.

Burbidge AA, McKenzie NL, Brennan KEC, Woinarski JCZ, Dickman CR, Baynes A, Gordon G, Menkhorst PW, Robinson AC (2009) Conservation status and biogeography of Australia's terrestrial mammals. *Australian Journal of Zoology* 56: 411–422.

Burbidge AA, Eldridge MDB, Groves C, Harrison PL, Jackson SM, Reardon TB, Westerman M, Woinarski JCZ (2014) A list of native Australian mammal species and subspecies. In: Woinarski J, Burbidge A, Harrison P (eds) *Action Plan for Australian Mammals 2012*, 16–32. CSIRO Publishing, Clayton, South Victoria, Australia.

Burbidge AA, Woinarski JCZ, Harrison P (2015) Western Australia's mammals: ensuring their future. *Landscope* 30: 42–47.

Calver MC, Beatty SJ, Bryant KA, Dickman CR, Ebner BC, Morgan DL (2013a) Users beware: implications of database errors when assessing the individual research records of ecologists and conservation biologists. *Pacific Conservation Biology* 19: 320–330.

Calver MC, Lilith M, Dickman CR (2013b) A 'perverse incentive' from bibliometrics: could National Research Assessment Exercises (NRAEs) restrict literature availability for nature conservation? *Scientometrics* 95: 243–255.

Campbell KJ, Beek J, Eason CT, Glen AS, Godwin J, Gould F et al. (2015) The next generation of rodent eradications: innovative technologies and tools to improve species specificity and increase their feasibility on islands. *Biological Conservation* 185: 47–58.

Cardillo M (2003) Biological determinants of extinction risk: why are smaller species less vulnerable? *Animal Conservation* 6: 63–69.

Cardillo M, Bromham L (2001) Body size and risk of extinction in Australian mammals. *Conservation Biology* 15: 1435–1440.

Carwardine J, O'Connor T, Legge S, Mackey B, Possingham HP, Martin TG (2012) Prioritizing threat management for biodiversity conservation. *Conservation Letters* 5: 196–204.

Ceballos G, Ehrlich PR, Barnosky AD, García A, Pringle RM, Palmer TM (2015) Accelerated modern human–induced species losses: entering the sixth mass extinction. *Science Advances* 1: e1400253.

Cooke BD (2012) Rabbits: manageable environmental pests or participants in new Australian ecosystems? *Wildlife Research* 39: 279–289.

Cooke B, Chudleigh P, Simpson S, Saunders G (2013) The economic benefits of the biological control of rabbits in Australia, 1950–2011. *Australian Economic History Review* 53: 91–107.

Coulson G, Cripps JK, Wilson ME (2014) Hopping down the main street: eastern grey kangaroos at home in an urban matrix. *Animals* 4: 272–291.

Cramb J, Hocknull S (2010) New Quaternary records of *Conilurus* (Rodentia: Muridae) from eastern and northern Australia with the description of a new species. *Zootaxa* 2634: 41–56.

Crowther MS, Fillios M, Colman N, Letnic M (2014) An updated description of the Australian dingo (*Canis dingo* Meyer, 1793). *Journal of Zoology* 293: 192–203.

Croxall JP, Butchart SHM, Lascelles B, Stattersfield AJ, Sullivan B, Symes A, Taylor P (2012) Seabird conservation status, threats and priority actions: a global assessment. *Bird Conservation International* 22: 1–34.

Doherty TS, Dickman CR, Nimmo DG, Ritchie EG (2015) Multiple threats, or multiplying the threats? Interactions between invasive predators and other ecological disturbances. *Biological Conservation* 190: 60–68.

Fisher DO, Blomberg SP, Owens IPF (2003) Extrinsic versus intrinsic factors in the decline and extinction of Australian marsupials. *Proceedings of the Royal Society of London B: Biological Sciences* 270: 1801–1808.

Gong W, Sinden J, Braysher ML, Jones R, Wales NS (2009) *The Economic Impacts of Vertebrate Pests in Australia*. Invasive Animals Cooperative Research Centre, Canberra, Australia.

Gregory S, Henderson W, Smee E, Cassey P (2014) *Eradications of Vertebrate Pests in Australia*. Invasive Animals Cooperative Research Centre, Canberra, Australia.

Griffiths RA, Dos Santos M (2012) Trends in conservation biology: progress or procrastination in a new millennium? *Biological Conservation* 153: 153–158.

Hilton-Taylor C, Pollock CM, Chanson JS, Butchart SHM, Oldfield TEE, Katariya V (2009) State of the world's species. In: Vié J-C, Hilton-Taylor C, Stuart SN (eds) *Wildlife in a Changing World – An Analysis of the 2008 IUCN Red List of Threatened Species*, 15–42. IUCN, Gland, Switzerland.

Hirsch JE (2005) An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America* 102: 16569–16572.

Holt BG, Lessard J-P, Borregaard MK, Fritz SA, Araújo MB, Dimitrov D et al. (2013) An update of Wallace's zoogeographic regions of the world. *Science* 339: 74–78.

Johnson CN, Isaac JL (2009) Body mass and extinction risk in Australian marsupials: the 'Critical Weight Range' revisited. *Austral Ecology* 34: 35–40.

Johnson CN, Isaac JL, Fisher DO (2007) Rarity of a top predator triggers continent-wide collapse of mammal prey: dingoes and marsupials in Australia. *Proceedings of the Royal Society of London B: Biological Sciences* 274: 341–346.

Kingsford RT, Watson JEM, Lundquist CJ, Venter O, Hughes L, Johnston EL et al. (2009) Major conservation policy issues for biodiversity in oceania. *Conservation Biology* 23: 834–840.

Lawler JJ, Aukema JE, Grant JB, Halpern BS, Kareiva P, Nelson CR et al. (2006) Conservation science: a 20-year report card. *Frontiers in Ecology and the Environment* 4: 473–480.

Letnic M, Crowther MS, Koch F (2009) Does a top-predator provide an endangered rodent with refuge from an invasive mesopredator? *Animal Conservation* 12: 302–312.

Letnic M, Story P, Story G, Field J, Brown O, Dickman CR (2011) Resource pulses, switching trophic control, and the dynamics of small mammal assemblages in arid Australia. *Journal of Mammalogy* 92: 1210–1222.

Letnic M, Ritchie EG, Dickman CR (2012) Top predators as biodiversity regulators: the dingo *Canis lupus dingo* as a case study. *Biological Reviews* 87: 390–413.

Lindenmayer DB, Gibbons P, Bourke M, Burgman M, Dickman CR, Ferrier S et al. (2012) Improving biodiversity monitoring. *Austral Ecology* 37: 285–294.

Loehle C, Eschenbach W (2012) Historical bird and terrestrial mammal extinction rates and causes. *Diversity and Distributions* 18: 84–91.

Lumsden LF, Bennett AF (2000) *Bats in Rural Landscapes: a Significant but Largely Unknown Faunal Component*. Bushcare, Natural Heritage Trust, Environment Australia, Canberra, Australia.

Mahoney JA, Smith MJ, Medlin GC (2008) A new species of hopping-mouse, *Notomys robustus* sp. nov. (Rodentia: Muridae), from cave deposits in the Flinders and Davenport Ranges, South Australia. *Australian Mammalogy* 29: 117–135.

Martin TG, Nally S, Burbidge AA, Arnall S, Garnett ST, Hayward MW et al. (2012) Acting fast helps avoid extinction. *Conservation Letters* 5: 274–280.

McDonald-Madden E, Baxter PW, Fuller RA, Martin TG, Game ET, Montambault J, Possingham HP (2010) Monitoring does not always count. *Trends in Ecology and Evolution* 25: 547–550.

McKenzie NL, Burbidge A, Baynes A, Brereton RN, Dickman CR, Gordon G et al. (2007) Analysis of factors implicated in the recent decline of Australia's mammal fauna. *Journal of Biogeography* 34: 597–611.

McLeod R, Norris A (2004) *Counting the Cost: Impact of Invasive Animals in Australia, 2004*. Cooperative Research Centre for Pest Animal Control, Canberra, Australia.

Meijaard E, Cardillo M, Meijaard EM, Possingham HP (2015) Geographic bias in citation rates of conservation research. *Conservation Biology* 29: 920–925.

Miller DC (2014) Explaining global patterns of international aid for linked biodiversity conservation and development. *World Development* 59: 341–359.

Mulder RA, Guay P, Wilson M, Coulson G (2010) Citizen science: recruiting residents for studies of tagged urban wildlife. *Wildlife Research* 37: 440–446.

Pautasso M (2014) The jump in network ecology research between 1990 and 1991 is a Web of Science artefact. *Ecological Modelling* 286: 11–12.

Pech RP, Hood GM, Singleton GR, Salmon E, Forrester RI, Brown PR (1999) Models for predicting plagues of house mice (*Mus domesticus*) in Australia. In: *Ecologically-based Management of Rodent Pests*, 81–112. Australian Centre for International Agricultural Research, Canberra, Australia.

Pimm SL, Russell GJ, Gittleman JL, Brooks TM (1995) The future of biodiversity. *Science* 269: 347–349.

Plowright RK, Foley P, Field HE, Dobson AP, Foley JE, Eby P, Daszak P (2011) Urban habituation, ecological connectivity and epidemic dampening: the emergence of Hendra virus from flying foxes (*Pteropus* spp.). *Proceedings of the Royal Society of London B: Biological Sciences* 278: 3703–3712.

Ritchie EG, Bradshaw CJA, Dickman CR, Hobbs R, Johnson CN, Johnston EL et al. (2013) Scale governance and the hastening of loss of Australia's biodiversity. *Conservation Biology* 27: 1133–1135.

Robertson PA, McKenzie AJ (2015) The scientific profiles of terrestrial mammals in Great Britain as measured by publication metrics. *Mammal Review* 45: 128–132.

Saunders GR, Giles JR (1977) A relationship between plagues of the house mouse, *Mus musculus* (Rodentia: Muridae) and prolonged periods of dry weather in south-eastern Australia. *Wildlife Research* 4: 241–247.

Scalera R (2010) How much is Europe spending on invasive alien species? *Biological Invasions* 12: 173–177.

Sequeira AMM, Roetman PEJ, Daniels CB, Baker AK, Bradshaw CJA (2014) Distribution models for koalas in South Australia using citizen science-collected data. *Ecology and Evolution* 4: 2103–2114.

Singleton GR (1989) Population dynamics of an outbreak of house mice (*Mus domesticus*) in the mallee wheatlands of Australia—hypothesis of plague formation. *Journal of Zoology* 219: 495–515.

Start AN, Burbidge AA, McDowell MC, McKenzie NL (2012) The status of non-volant mammals along a rainfall gradient in the south-west Kimberley, Western Australia. *Australian Mammalogy* 34: 36–48.

Stroud JT, Rehm E, Ladd M, Olivas P, Feeley KJ (2014) Is conservation research money being spent wisely? Changing trends in conservation research priorities. *Journal for Nature Conservation* 22: 471–473.

Tulloch AI, Possingham HP, Joseph LN, Szabo J, Martin TG (2013) Realising the full potential of citizen science monitoring programs. *Biological Conservation* 165: 128–138.

Van Dyck S, Strahan R (2008) *The Mammals of Australia*. Reed New Holland, Sydney, Australia.

Verde Arregoitia LD (2016) Biases, gaps, and opportunities in mammalian extinction risk research. *Mammal Review* 46: 17–29.

Waldron A (2013) Australia is underfunding biodiversity conservation. In: *The Conversation*. http://theconversation.com/australia-is-underfunding-biodiversity-conservation-15672.

Waldron A, Mooers AO, Miller DC, Nibbelink N, Redding D, Kuhn TS, Roberts JT, Gittleman JL (2013) Targeting global conservation funding to limit immediate biodiversity declines. *Proceedings of the National Academy of Sciences* 110: 12144–12148.

Warburton NM (2014) Relicts, reproduction and reintroductions – a century of marsupial research in Western Australia. *Journal of the Royal Society of Western Australia* 97: 65–85.

Williams CK, Parer I, Coman BJ, Burley J, Braysher ML (1995) *Managing Vertebrate Pests: Rabbits*. Bureau of Resource Sciences/CSIRO Division of Wildlife and Ecology, Australian Government Publishing Service, Canberra, Australia.

Williams NSG, Mcdonnell MJ, Phelan GK, Keim LD, Van Der Ree R (2006) Range expansion due to urbanization: increased food resources attract grey-headed flying-foxes (*Pteropus poliocephalus*) to Melbourne. *Austral Ecology* 31: 190–198.

Woinarski JCZ (2014) The illusion of nature: perception and the reality of natural landscapes, as illustrated by vertebrate fauna in the Northern Territory, Australia. *Ecological Management & Restoration* 15: 30–33.

Woinarski JCZ, Ward S, Mahney T, Bradley J, Brennan K, Ziembicki M, Fisher A (2011) The mammal fauna of the Sir Edward Pellew island group, Northern Territory, Australia: refuge and death-trap. *Wildlife Research* 38: 307–322.

Woinarski JCZ, Burbidge AA, Harrison PL (2014) *The Action Plan for Australian Mammals 2012*. CSIRO Publishing, Collingwood, Victoria, Australia.

Woinarski JCZ, Burbidge AA, Harrison PL (2015) Ongoing unraveling of a continental fauna: decline and extinction of Australian mammals since European settlement. *Proceedings of the National Academy of Sciences* 112: 4531–4540.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.

Appendix S1. Search terms used for subject categories.

