Trends and biases in the listing and recovery planning for threatened species: an Australian case study

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Abstract Many countries rely on formal legislation to protect and plan for the recovery of threatened species. Even though the listing procedures in threatened species legislation are designed to be consistent for all species there is usually a bias in implementing the laws towards charismatic fauna and flora, which leads to uneven allocation of conservation efforts. However, the extent of bias in national threatened species lists is often unknown. Australia is a good example: the list of threatened species under the Environmental Protection and Biological Conservation Act has not been reviewed since 2000, when it was first introduced. We assessed how well this Act represents threatened species across taxonomic groups and threat status, and whether biases exist in the types of species with recovery plans. We found that birds, amphibians and mammals have high levels of threatened species (12–24%) but $< 6\%$ of all reptiles and plants and $< 0.01\%$ of invertebrates and fish are considered threatened. Similar taxonomic biases are present in the types of species with recovery plans. Although there have been recent improvements in the representation of threatened species with recovery plans across taxonomic groups, there are still major gaps between the predicted and listed numbers of threatened species. Because of biases in the listing and recovery planning processes many threatened species may receive little attention regardless of their potential for recovery: a lost opportunity to achieve the greatest conservation impact possible. The Environmental Protection and Biological Conservation Act in Australia needs reform to rectify these biases.

Keywords Australian conservation, Environmental Protection and Biological Conservation Act, legislation, recovery plan, species listing, taxonomic group, threatened species

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Introduction

In pursuit of biological conservation at a national scale many countries have actively developed formal environmental legislation to specifically focus on slowing the rates of species extinction. These include the United States' Endangered Species Act 1973, Australia's Environmental Protection of Biological Conservation (EPBC) Act 1999 and Canada's Species at Risk Act 2002. A primary purpose of these acts is to identify, classify and list species that are threatened with extinction in the near future so that threats are abated and recovery is undertaken.

Although these legislations are intended to encompass all aspects of biodiversity, or at least represent a broad range of species, reviews from the USA, UK and Canada have found that threatened species lists are biased in the types of species that receive attention (Metrick & Weitzman, 1996; Ferraro et al., 2007; Mooers et al., 2007; Schwartz, 2008; Findlay et al., 2009; Laycock et al., 2009). For example, charismatic species such as birds and mammals are more likely to be listed as threatened under the Endangered Species Act than invertebrates and plants (Metrick & Weitzman, 1996). The Species at Risk Act is biased against marine and more northerly distributed species (Mooers et al., 2007) and species that are harvested or of commercial value (Findlay et al., 2009).

Biases in listing towards charismatic species may influence where investments are allocated for conservation actions (Farrier et al., 2007) and ignore other species that may have greater ecological importance or recovery potential if protected. Another possible implication of a biased listing and planning process is an inability to assess accurately overall biodiversity improvements or declines. The threatened species lists provide only a snapshot of overall trends, the threatened status of listed species are often outdated and the status of unlisted species remain unknown (Commonwealth of Australia, 2009).

Few countries have a level of data on species richness sufficient to identify existing biases in their threatened species lists (Zamin et al., 2010). Australia, with relatively accessible data on species richness and threatened species, is a good case study to assess these biases. Even though Australia's EPBC Act has been active for a decade, little is known about the current patterns and biases in threatened species listed on the EPBC Act National List of Threatened

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Species (EPBC List; Burgman, 2002; McCarthy, 2006; but see Commonwealth of Australia, 2009). Threatened species on this List are protected and given priority for recovery planning and conservation investment. With an estimated 570,000 species (Chapman, 2009) Australia is a megadiverse country with a very high percentage of endemic species (Mittermeier et al., 1997): approximately 85% of its flowering plants, 84% of its mammals, 45% of its birds and 89% of its reptiles occur only in Australia (Saunders et al., 1996). In addition, a multitude of anthropogenic threats have resulted in a country with one of the highest extinction rates (Cork et al., 2006; Lindenmayer, 2007; Kingsford et al., 2009). In particular, in the previous 2 centuries Australia has experienced more mammal extinctions than any other country (Johnson, 2006).

Threatened species lists are complemented with the formulation and implementation of species recovery plans, aimed at managing threatened species recovery to avoid further population declines. Australia has taken a similar approach to Canada and the USA by legislating in the EPBC Act that all species included on the National List of Threatened Species require a recovery plan. In the past decade, single species and multi-species plans have been the main types of recovery plans developed under the Act, although regional and landscape recovery plans are becoming the preferred planning tool for threatened species (Garrett, 2009). Furthermore, in 2007 there was a legislated change in the Act so that it was no longer a formal requirement for every EPBC listed species to have a recovery plan. This alteration of the Act occurred because time and budget limitations within the federal and state government departments made it impossible to fulfil the legislated expectations. Now, shorter and less costly Conservation Advices are developed for all species that are added to the EPBC Act (Commonwealth of Australia, 2010a). Evidence from other countries shows that taxonomic biases similar to those of threatened species lists occur for the species that receive recovery plans (Hoekstra et al., 2002; Taylor et al., 2005; Schwartz, 2008). Despite the potential consequences for conservation that may result from these biases, to date there has been no assessment of which Australian species have or have not received recovery plans.

A review of the trends and patterns in the Australian EPBC List is timely given a need to track progress since its establishment more than a decade ago, recent shifts in priorities from a single species approach to landscape focused management, and continuing species declines. Here we examine which species are currently listed and the distribution of these species across the major taxonomic groups and classifications of threat status. We then assess the trends in species listing over time from when the EPBC Act was enforced (July 2000), to determine if temporal biases occur and if any such biases have been overcome more recently. We also summarize which species have received national recovery plans, to investigate the trends and biases observed in this section of the federal legislation. We conclude by discussing the implications of these results in terms of conservation policy and management in Australia. This investigation will highlight potential gaps in the EPBC List or taxonomic groups that are currently receiving less attention, and will provide conservation managers and policy makers with useful information to improve transparency of management priorities and trade-offs made between threatened species. This study also provides a baseline to track progress towards national and international biodiversity targets.

Methods

Information about the Australian species listed on the EPBC List and national recovery plans were assembled in a database. The content of this database was based on information provided by the Recovery Plan Section within the Department of Sustainability, Environment, Water, Populations and Communities (SEWPAC; previously known as the Department of Environment, Water, Heritage and Arts), the department's threatened species and recovery plan websites (Commonwealth of Australia, 2010c,e) and the Species Profile and Threats Database (Commonwealth of Australia, 2010d). For every listed threatened species, information was collated on the taxonomic group, EPBC threat status, the date when the species was listed in the EPBC Act and whether it had a recovery plan. The taxonomic groups included mammals, birds, amphibians, reptiles, fish, invertebrates and plants and were based on the classifications used by SEWPAC. Species can be classed under the EPBC Act as Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable or Conservation Dependent, based on criteria adapted from the IUCN Red List (Commonwealth of Australia, 2001). We defined threatened species as those listed under the three main threat status categories (Critically Endangered, Endangered and Vulnerable).

We collated details on all national recovery plans that were adopted prior to June 2010, revised or in preparation; these data were provided by the Recovery Team Section (SEWPAC) as of June 2010, and a Recovery Plan database developed by Ortega-Argueta (2008). The information included the scope of the plan (either single species, multi-species, ecological community or regional plan), the year of the plan's citation and when the plan was adopted by the Minister of Environment. For consistency we only considered species that had plans formally recognized by the federal government. There were > 200 species that had draft plans in preparation or plans that had been adopted by state and territory governments but were not yet formally recognized. Draft plans were not included in this summary

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of recovery plans as it is uncertain whether they will be adopted by SEWPAC as a formal legislated recovery plan. The state and territory recovery plans not yet adopted by SEWPAC were not included in our analysis to avoid inconsistencies between these legislations on the recovery plan process. Ecological community and regional plans were not addressed because there were too few plans of each type to make reliable interpretations. Conservation Advices for threatened species were not included in the analysis because they were introduced to the EPBC Act in 2007, do not provide detailed information on how to manage the species and lack specific objectives for recovery.

Threatened species on the EPBC List

The number of species listed under the EPBC Act in each taxonomic group was compiled to examine whether taxonomic biases exist in the threatened species list. Firstly, we assessed the representation of threatened species across taxonomic groups by comparing the percentage of threatened species on the EPBC List with three alternative hypotheses. The first hypothesis is that the percentages of threatened species across taxonomic groups are equal. As birds, amphibians and mammals are relatively well studied in Australia, it is possible that the percentage of EPBC listed species in these taxa is an accurate estimate of the percentage of species actually threatened in other taxonomic groups. Based on this, we calculated the average percentage of EPBC listed species from these three well-studied groups (i.e. 16.6%; Table 1) and compared the current percentage of species across taxonomic groups listed under the EPBC Act with this estimate.

As the percentage of threatened mammals in Australia is unusually high (24.1%) compared to other taxonomic groups, we tested a second equal representation hypothesis which estimated the expected percentage of threatened species using the mean percentage of threatened birds and amphibians, excluding mammals (12.8%). The third alternative hypothesis is that each taxonomic group has a different percentage of threatened species. To test this we compared the percentages of threatened species for each taxonomic group listed under the EPBC Act with those on the IUCN Red List. As with the EPBC List only mammal, amphibian and bird species have been fully assessed (or at least 90% of amphibians) for the IUCN Red List and these are the only taxonomic groups with published estimated percentages of threatened species (IUCN, 2011). The IUCN cautions that predictions for other taxonomic groups would be unreliable because of lack of data. In these cases we manually calculated a crude estimate of the percentage of threatened species by dividing the number of currently threatened species globally within a taxonomic group by the total number of species in that group after subtracting the number of Data Deficient and Extinct species from the total species richness (Chapman, 2009; IUCN, 2011).

Secondly, we used these three hypotheses as benchmarks to predict the number of species in each taxonomic group that should be listed under the EPBC Act (McCarthy, 2006). We then compared these predicted numbers of threatened species with the actual number of threatened species listed in each taxonomic group to determine where gaps exist in the EPBC List.

Thirdly, we examined the temporal patterns of when species were added onto the EPBC List. We calculated the number of species listed each year and the increase in the number of listed species over time from 2000 to 2010 (Schwartz, 2008). Prior to 2000, 1,355 species were listed on the Endangered Species Protection (ESP) Act 1992. Unfortunately, the information as to when these species were listed during the 1990s was not available and, as a result, we were only able to assess the trends of when species were listed on the EPBC List after 2000. To determine whether efforts have been made to improve the representation of species that are listed as threatened we calculated the annual and overall percentage increases of species across taxonomic groups and threat status. Using the average rate of increase in the number of species added to the EPBC List annually from 2000 to 2009 we calculated how long it would take for each taxonomic group to have an equal representation of threatened species, based on the average percentage of bird, mammal and amphibian species currently threatened (see above). The year 2010 was excluded from these calculations because data were only available for the first half of the year.

Threatened species recovery plans

We compared the distribution of species with nationally adopted single species and multi-species recovery plans across taxonomic group and threat status. The trends in the timing of recovery plan approvals were evaluated based on when the plans were adopted by the Minister for the Environment and patterns were assessed across taxonomic group. The legislation on recovery plans changed in 2007 so that recovery plans are no longer compulsory for every threatened species and are now only prepared for some species selected by the Threatened Species Scientific Committee. We analysed the annual percentage increase in the number of species with plans before and since 2007 across taxonomic groups, to determine whether specific attention has been given to particular taxonomic groups and whether taxonomic biases have been exacerbated or reduced since the change in the legislation. Based on the average annual rate of increase in the number of plans adopted since 2007 we calculated the hypothetical number of years it would take for each species that is currently threatened to

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TABLE 1 The number of Australian species that are threatened, by taxonomic group and threat category, on the EPBC Act as of June 2010. The total number of species that occur in Australia includes chordates, invertebrates, plants and algae (Chapman, 2009). Three fish are listed as Conservation Dependent but, for clarity, are not included in this table.

	No. of Australian species	No. of species (%) in each threat category[1]					Total threatened (%)[2]
		EX	EW	CR	EN	VU	
All species	c. 131,547	103	1	142 (8.5)	664 (39.9)	857 (51.5)	1,663 (1.26)
Mammals	386	27	0	4 (4.3)	35 (37.6)	54 (58.1)	93 (24.09)
Birds	828	23	0	6 (5.6)	42 (39.3)	59 (55.1)	107 (12.92)
Amphibians	227	4	0	2 (6.9)	15 (51.7)	12 (41.4)	29 (12.78)
Reptiles	917	0	0	2 (3.7)	15 (27.8)	37 (68.5)	54 (5.89)
Fish	c. 5,000	0	1	3 (6.7)	16 (35.6)	26 (57.8)	45 (0.90)
Invertebrates	c. 98,703	1	0	19 (47.5)	14 (35.0)	7 (17.5)	40 (0.04)
Plants	c. 24,716	48	0	106 (8.2)	527 (40.7)	662 (51.1)	1,295 (5.24)

[1]EX, Extinct; EW, Extinct in the Wild; CR, Critically Endangered; EN, Endangered; VU, Vulnerable
[2]Includes CR, EN and VU species in each taxonomic group

have an adopted recovery plan. Revised plans (a new version of the original plan) were not included as additional recovery plans because the species would have received a recovery plan at least 5 years earlier.

Results

Threatened species on the EPBC List

As of June 2010 1,663 (1.3%) of Australian taxa were formally listed as threatened by the EPBC Act (Table 1). Approximately 1,431 (86.0%) are species and 232 (14.0%) are subspecies. There are 103 (6.2%) species known to be Extinct, one Extinct in the Wild species (c. 0.001%) and three species (0.002%) listed as Conservation Dependent. Since 2000 46 species have been recategorized with a higher threat status because of either a real decline (71.7%) or better knowledge (28.3%). During this same time 18 species have been recategorized with a lower threat status based on improved knowledge (94.4%) or taxonomic changes (5.6%) but none because of conservation recovery. A total of 56 species (3.4% of species currently threatened in 2010) have been removed from the EPBC Act since 2000 as a result of increased knowledge or taxonomic changes.

Mammal species have the greatest percentage of threatened species in Australia relative to other taxonomic groups, with 93 (24.1%) of all known Australian mammals listed on the EPBC List (Table 1, Fig. 1a). Other well-studied taxa (amphibians and birds) are also highly represented in the EPBC Act relative to the number of Australian species within each taxonomic group. Invertebrates, for example, have only 40 species formally listed as threatened (47.5% of which are Critically Endangered), equivalent to c. 0.0004% of all known invertebrates in Australia.

Based on the hypothesis that the percentage of threatened species should be equal across taxonomic groups at 16.6%, we estimated that a total of approximately 21,837 species should be listed under the EPBC Act. From this estimation only 7.6% of the species that may be threatened are listed under the Act. If the Australian federal agency were to achieve this level of representation across taxonomic groups, approximately 16,345 invertebrate species, 785 fish species and 2,808 plant species would have to be added to the EPBC List (Fig. 1b). This equates to 410 times more invertebrates, 18 times more fish and three times more plants than the number of species currently listed as threatened. Currently none of the 11,846 known species of fungi are on the EPBC List, and 1,967 species would have to be added to reach a level of representation equal to birds, mammals and amphibians. Under the second hypothesis, which assumes equal representation but excludes mammals from the estimated mean percentage (12.8%), we found that almost 10% of the species expected to be threatened are listed under the EPBC Act, which is a slight increase compared to when mammals were included in the estimate.

When comparing the percentage of threatened species across taxonomic groups between the EPBC List and IUCN Red List, we found that the IUCN Red List has a similar uneven distribution of threatened species across taxonomic groups, with 25% of mammals, 13% of birds and 31% of amphibian species worldwide listed as threatened, compared to only 3% of all plant species listed (Fig. 1a). The IUCN warns that the estimates for taxonomic groups other than mammals, birds and amphibians may be inaccurate because many species have not been fully assessed (IUCN, 2011). Even so, amphibians, fish, reptiles and invertebrates have received much more attention on the IUCN Red List than under the EPBC Act. For example, the percentage of IUCN listed fish species is 7.5 times higher than fish on the EPBC List.

Prior to 2000, 1,355 threatened and 100 extinct species were listed under the ESP Act (Table 2). With the establishment of the subsequent EPBC Act these listed species were automatically transferred without any reassessment or review. Our analysis reveals that the number of

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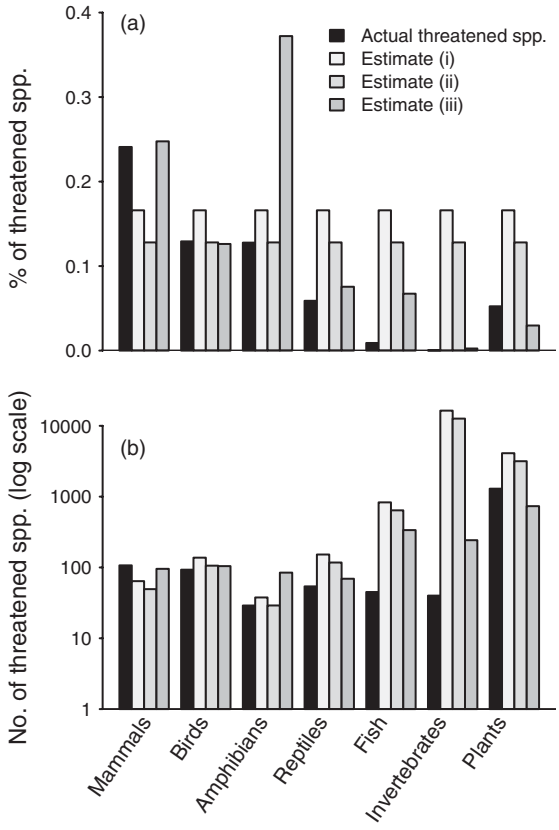

FIG. 1 (a) A comparison between the actual and estimated percentages of species that should be listed as threatened under the EPBC Act, and three alternative null hypotheses: (i) assuming an equal percentage of threatened species across taxonomic groups, estimated using an average percentage of mammal, bird and amphibian species listed under the EPBC Act (16.6%); (ii) assuming equal representation similar to (i), but excluding mammals from the mean estimate (12.8%); (iii) assuming that each taxonomic group has a different percentage of threatened species, estimated using the percentage of species per taxonomic group that are threatened globally on the IUCN Red List. (b) A comparison between the actual number of species on the EPBC List and the predicted number of species that should be listed as threatened, determined using the three alternative hypotheses.

species listed on the EPBC Act has increased on average 2.3% each year since 2000 (Table 3), equating to a total of 308 species added during this 10-year period (an overall increase of 22.7%).

There were few dramatic changes in the number of threatened species across years for most taxonomic groups (Fig. 2). However, 36 invertebrate species have been added to the List since 2000, increasing the representation of this taxonomic group on the EPBC List by 900.0% (Table 2, Fig. 2). When considering the temporal trends across threat status categories, the listings between 2000 and 2010 have been dominated by highly threatened species, with c. 50% of all newly listed species being categorized as Critically Endangered (Table 3). At the mean annual rates that species within different taxonomic groups are being added to the EPBC List it would take c. 123, 141, 436 and 4,540 years for reptile, plant, fish and invertebrate species, respectively, to be equally represented on the EPBC List (at 16.6% of known species in a taxonomic group; Table 3).

Threatened species recovery plans

As of June 2010, 508 species had national recovery plans that were adopted, which accounted for 30.5% of all threatened species in Australia (Table 4). These plans were either single species recovery plans (18.0% of all threatened species) or multi-species plans (12.9% of all threatened species). Approximately 120 of the adopted plans had been revised, as required after 5 years since adoption. There were two adopted regional recovery plans in Australia and six draft regional plans in preparation, although it was not possible to calculate the number of threatened species covered by each plan because they do not focus on individual species.

There are biases in the species that have received recovery plans across taxonomic groups and threat status (Table 4). Amphibians and birds have the greatest percentages of threatened species in a taxonomic group with a recovery plan, with 65.5 and 57.9% respectively. Fish and mammals have similar percentages of listed species with a recovery plan (42.2 and 41.9% respectively). Invertebrates, plants and reptiles are poorly represented in the species that have plans, similar to the biases seen across taxonomic group for the species that are listed as threatened in Australia. The percentage of species with single species vs multi-species recovery plans differs between taxonomic groups, with amphibians having a higher percentage of multi-species recovery plans than single species plans. Endangered species (42.3%) are twice as likely to have a plan as Vulnerable species (21.1%), although only 31.7% of Critically Endangered species have plans (Table 4).

Our trend analyses show that after the initial addition of recovery plans to the EPBC Act in 2001 the number of species with adopted recovery plans increased on average 15.9% each year (Table 3). In 2007 recovery plans were no longer compulsory for every threatened species. After this legislation change the rate at which the number of species with recovery plans increased was lower than that of pre-2007, although we found that preference was given to taxonomic groups with few existing recovery plans in proportion to their species diversity (Table 3). Although reptiles had the highest rate of increase in the number of species with plans before 2007, no plans were adopted for this taxonomic group after this. Since 2007, plant species had the highest percentage increase of single species and multi-species recovery plans adopted, followed by invertebrate species, whereas fewer amphibian, fish, bird and mammal species received plans.

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TABLE 2 The number of threatened species listed on the National Threatened Species List in June 2000 (when the EPBC Act was enforced) and in June 2010, showing the number of Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) species that have been added and the total percentage of increase for all threatened species during this period.

	Listed in 2000	Listed in 2010	CR species added	EN species added	VU species added	Total % increase
All species	1,355	1,663	142	75	71	22.7
Mammals	71	93	4	7	11	31.0
Birds	86	107	6	10	5	24.4
Amphibians	25	29	2	2	0	16.0
Reptiles	46	54	2	5	1	17.4
Fish	27	45	3	4	11	66.7
Invertebrates	4	40	19	14	3	900.0
Plants	1,096	1,295	106	53	40	18.2

TABLE 3 The mean annual percentage increase in the number of threatened species in Australia and species with nationally adopted single species and multi-species recovery plans. The pre-2007 and post-2007 annual increases show the different trends in recovery planning before and after the EPBC Act legislation was changed so that recovery plans were no longer compulsory for all listed species. The pre-2007 percentage increase was calculated using the mean rates of increase from 2002 to 2006, excluding the initial addition of multiple recovery plans to the EPBC Act in 2001. The post-2007 rates of increase represent the mean annual increase between 2007 and 2009 (2010 is excluded because data were collected for only the first half of the year). The year of adoption was unknown for 14 recovery plans, which were excluded from this analysis, and the six species with multiple plans were only counted once, when their first plan was adopted.

	Mean annual % increase of species listed as threatened (2000–2009)	Mean annual % increase of species with recovery plans		
		Pre-2007	Post-2007	2002–2009
All species	2.3	19.8	9.3	15.9
Mammals	3.1	20.4	4.9	14.6
Birds	2.5	14.9	4.8	11.1
Amphibians	1.3	7.1	1.9	5.1
Reptiles	1.8	36.1	0.0	22.5
Fish	6.0	21.8	3.9	15.1
Invertebrates	33.6	12.3	9.5	11.3
Plants	1.8	22.9	12.5	19.0

Despite these apparent changes in the species that receive recovery plans it would take approximately 36 years for all species currently listed as threatened to have recovery plans adopted (based on the average annual post-2007 rate of increase of 9.3%; Table 3). When calculating these hypothetical time-frames for individual taxonomic groups we found that at current rates of recovery plan adoption (post-2007 rates) all threatened invertebrates could have plans within 47 years, and it would take c. 30 years for all plants listed under the EPBC Act to receive a plan. However, this does not include the species that are truly threatened but not yet listed on the EPBC List. This ambitious (and unrealistic) target demonstrates that the National List of Threatened Species is not a comprehensive or representative sample of Australian threatened biodiversity.

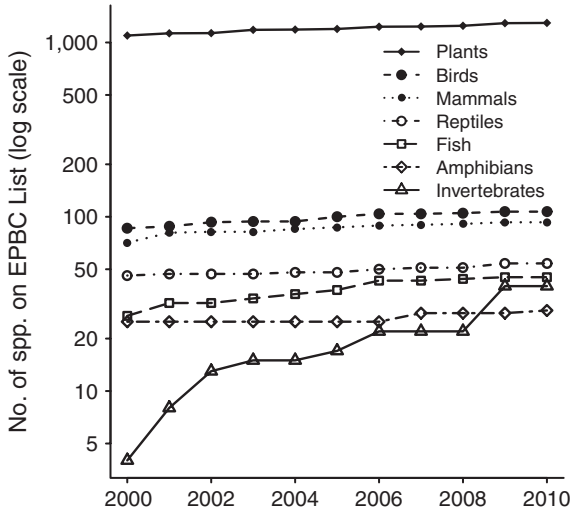

FIG. 2 The cumulative number of threatened species listed under the EPBC Act from 2000 to 2010, across taxonomic groups.

Discussion

In this assessment we found that only 1.3% of species currently known to exist in Australia are listed as threatened on the EPBC Act and of these only 30% have adopted recovery plans. By comparing species listing and recovery planning across taxonomic groups we found that plant, fish, reptile and invertebrate species are under-represented,

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TABLE 4 The number of species in each taxonomic group and threat status that have a nationally adopted single species or multi-species recovery plan, the total number of species with plans, and the percentage of threatened species with a plan. Note that one species listed as Extinct in the Wild also has an adopted multi-species recovery plan. Six species were included in more than one plan, either in a single species and multi-species plan, or in two multi-species plans.

	No. of species with single species plans	No. of species with multi-species plans	No. of species with plans	% of threatened species with a plan
All species	300	214	508	30.5
Taxonomic group				
Mammals	25	14	39	41.9
Birds	25	37	62	57.9
Amphibians	4	15	19	65.5
Reptiles	8	8	16	29.6
Fish	10	9	19	42.2
Invertebrates	5	4	9	22.5
Plants	223	127	344	26.5
Threat status				
Critically Endangered	17	28	45	31.7
Endangered	206	78	281	42.3
Vulnerable	77	107	181	21.1

consistent with the biased composition of other national threatened species lists (Metrick & Weitzman, 1996; Ferraro et al., 2007; Zamin et al., 2010). Since 2007, when recovery plans were no longer mandatory under the EPBC Act, some progress has been made to reduce the bias across taxonomic groups, as species that have received plans post-2007 are mostly from poorly represented taxonomic groups. Even so, the extreme biases in the listings and recovery plans still exist against several taxonomic groups, and much work would be required to remove these inequalities from within the current system.

It is possible that mammals, birds and amphibians are predisposed to greater risk of extinction from anthropogenic threats than reptiles, fish, invertebrates or plants, making our equal representation hypothesis questionable. However, the alternative hypothesis that the EPBC List may reflect the percentages of threatened species across taxonomic groups in the IUCN Red List is also flawed. For example, both threatened species lists are subject to similar biases in the nomination, evaluation and data collection processes and it is difficult to justify why one list should have a more accurate distribution of threatened species across taxonomic group than the other. Rather than trying to predict the total number of threatened species that should be listed, which because of limited evidence is not currently possible (May, 2011), it could be more beneficial to improve the efficiency of the listing process while prioritizing species from under-represented taxonomic groups.

There are several reasons why the EPBC List and other national threatened species lists are incomplete and biased. Few species are listed on the EPBC Act each year and this could be attributed to limited staff, resources and funding or bureaucratic constraints within government agencies responsible for the protection of threatened species and environments. The number and types of species that are listed could also be restricted by the limited time available to process the nominations or the rate at which nominations are received. Currently, the public nomination process of listing species on the EPBC List (Commonwealth of Australia, 2010e) is inherently biased as species that are charismatic, large in body size, well-studied and easily accessible to the general public and special interest groups are more likely to be nominated and therefore listed as threatened than less well known, lower order species (Metrick & Weitzman, 1996; Ferraro et al., 2007). Similarly, the fact that few species have recovery plans may be explained by the limited funding available to develop the plans but also the lengthy process of writing and adopting recovery plans and absence of a method to prioritize species planning.

The biases across taxa may not simply be a result of limited resources within the governments and non-targeted nomination and planning processes. The incomplete state of the EPBC List and subsequent planning could be because of shortfalls in knowledge and research, coupled with relatively recent European settlement in Australia. Knowledge of the overall biodiversity in Australia remains inadequate, and even for many well studied species we have insufficient knowledge of their spatial distribution and the processes that threaten them (Kingsford et al., 2009). These knowledge shortfalls, known as the Linnean and Wallacean shortfalls (Whittaker et al., 2005), are not unique to Australia and are a significant problem in the listing of threatened species worldwide (Wilcove et al., 1998; Hutchings, 2004; Rodrigues, 2006). They can only be overcome with increased funds for threatened species

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research, taxonomy and ecology, not just in Australia but globally (Stuart et al., 2010). A related problem is that most anthropogenic threats have occurred more recently in Australia compared to other continents. As a consequence Australian conservation scientists and managers have had less time to observe and respond to the declining population trends and high extinction rates caused by threats such as habitat loss and invasive species (Kingsford et al., 2009; Evans et al., 2011). In addition, the extent of the declines may still be hidden from detection as a result of extinction debt from previous land-use changes (Lindenmayer, 2007), further complicating threatened species listing and management.

There are several implications of the biases demonstrated in species listing and recovery planning under the EPBC Act. It is known that listed threatened species are more likely to receive management and investment than species that are not listed (Shields, 2004; Farrier et al., 2007), often with greater beneficial outcomes if there is substantial investment (Taylor et al., 2005; Ferraro et al., 2007). Another potential consequence of these taxonomic biases is that entire phylogenies of less charismatic species may miss out on conservation resources and management planning for recovery at a global scale. This is particularly important given that the under-represented species, such as invertebrates, plants and fungi, are vital in functional processes and ecosystem services (Lydeard et al., 2004; Lavelle et al., 2006; Schatz, 2009). Most importantly, species that are not listed are not protected and no legal mechanism exists to prevent destruction or degradation of their habitats.

A final implication of biased and incomplete listing and planning processes is that funding for conservation is being distributed inefficiently because the listing and planning processes for threatened species in Australia appear to be driven by charisma, body size and level of knowledge or appeal. The important factors contributing to cost-effective conservation strategies, such as genuine threat status, recovery potential and the cost and likelihood of success of conservation actions (Harvey et al., 2002; Farrier et al., 2007), are not incorporated into this approach. Inefficient and biased allocation of conservation efforts prevents debates about the adequacy of funds available for conservation and about how more efficient solutions could otherwise be achieved (Bottrill et al., 2008). Even with increased efforts there is limited scope within the existing Australian framework to produce a complete threatened species list and plan efficiently for these species.

Regardless of whether these biases between taxonomic groups and threat status are intentional, the Australian federal government should explicitly acknowledge these faults and increase efforts to concentrate on listing under-represented species as threatened. A focus towards listing and protecting Australian threatened communities (Commonwealth of Australia, 2010b) rather than individual species would help reduce the biases for threatened invertebrates and plants. Another way to address this issue would be to integrate the multiple threatened species lists from federal, state and territory jurisdictions to form a single national threatened species list, as suggested in an independent review of the EPBC Act (Hawke, 2009). This would greatly increase the speed and efficiency of the listing process by avoiding duplicate assessments for listings across state and national legislation, promoting knowledge and data sharing between state and federal governments and facilitating more effective use of limited funding by coordinating recovery actions for species between states (Hawke, 2009).

If scarce conservation resources are to be used efficiently we recommend that the Australian federal government should objectively plan for threatened species management using a national strategic plan (Hawke, 2009; Bottrill et al., 2011). Alternatives to the existing recovery planning process, such as the project prioritization protocol (Joseph et al., 2009), are not reliant on the threatened species list, are less expensive and can be used to plan strategically for cost-effective management actions that will benefit the greatest number of threatened species (Joseph et al., 2008). New Zealand has used this transparent approach to develop action plans for c. 660 species in a short period of time (Joseph et al., 2011).

The implementation of a national strategic plan is feasible and timely but would require an overhaul of the current recovery planning process (Watson et al., 2010). Less emphasis should be placed on Conservation Advices as they do not provide detailed information on objectives, recovery actions and management costs. The information collated in recovery plans provides an excellent source of knowledge that could be utilized during the development of a national strategic plan. Recovery plans have been successful at facilitating community and stakeholder engagement; these skills should be integrated into this new approach (Watson et al., 2010). Implementation of a national strategic plan would lead to a more transparent and cost-efficient framework for species prioritization while reducing the taxonomic biases in the current approach.

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Biographical sketches

Jessica Walsh is interested in quantifying and managing the impacts of invasive species while increasing management effectiveness through evaluation and evidence-based conservation. James Watson works on identifying conservation solutions to the problem posed by climate change for species and ecosystems. Madeleine Bottrill's research focuses on the use of impact evaluation to generate knowledge on the effectiveness of different conservation interventions. Liana Joseph works on finding solutions to the overexploitation of wildlife and identifying management priorities for threatened species. Hugh Possingham is interested in decision-making for conservation, including spatial planning, optimal monitoring, value of information, population management, prioritization of conservation actions, structured decision-making, bird ecology and dynamic systems control.

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