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Supplementary material for

The threats to Australia's imperilled species and implications for a national conservation response

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Text S1

Methods

Threat data

Australian species and subspecies (hereafter, taxa) considered to be at risk of extinction are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as Vulnerable, Endangered or Critically Endangered to reflect their risk of extinction (Commonwealth

of Australia 2017*c*). As of November 2017, 1714 taxa were listed under the EPBC Act as threatened with extinction (Commonwealth of Australia 2017*a*, Commonwealth of Australia 2017*b*). Here we focus on Australia's freshwater and terrestrial threatened taxa. Included in this study are 1,533 plant, vertebrate and invertebrate taxa. Tables S1 and S2 provide a summary of the number of taxa in each taxonomic group and category of endangerment. This formal listing is notably incomplete, as evidenced by differences between the EPBC Act list for mammals and birds and those developed for group-specific Action Plans (e.g. Garnett *et al.* 2011, Woinarski *et al.* 2014).

Information on EPBC Act listed threatened taxa and the processes that threaten them are available through the Species Profiles and Threats (SPRAT) Database (Commonwealth of Australia 2015). In many cases this documentation is conjectural or based on limited evidence, and often does not discriminate between primary causal factors and factors that may have contributed in a minor way to decline. This is not necessarily a failing of the database, but reflects the lack of knowledge of the threats affecting some Australian taxa. The SPRAT database has been used in a number of studies assessing the threats and pressures affecting Australian taxa (e.g. Evans *et al.* 2011, Cresswell and Murphy 2017). Information on the threats impacting taxa is compiled from numerous sources including species listing advice, species recovery plans, published literature and individual experts (Commonwealth of Australia 2015). Taxa can be listed as being impacted by one or more threats. The database for the threats to threatened taxa used in this analysis was current as of March 2016. We note that the listing of individual threats that are detrimentally affecting threatened taxa in the SPRAT database has some limitations. For example, many threats operate synergistically (the combined impact of multiple threats is greater than the sum of their individual impacts; Brook *et al.* (2008)) or antagonistically (the combined impact of multiple threats is smaller than the sum of their individual impacts; Côté *et al.* (2016)) and simple comparative tallies of individual threats do not necessarily reflect the impacts of such interactions.

The SPRAT database follows the standardised Threat Classification Scheme (Salafsky *et al.* 2008) used for the IUCN Red List (IUCN 2017). A threat is a process that threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community (Commonwealth of Australia 2017*c*). These are generally human-forced activities and processes that have caused, are causing or may cause the impairment of a species (Salafsky *et al.* 2008). The Threat Classification Scheme is based on a three-level hierarchy (the equivalent of families, genera, and species in the Linnaean system), with broad threat category (e.g. 7 - natural system modifications), sub-class threat (e.g., 7.1 - Fire and fire suppression, 7.2 - Dam and water management, and 7.3 -

Other ecosystem modifications). These are further divided into a number of specific threats (e.g. 7.1 - Fire and fire suppression is subdivided into threats 7.1.1 - increase in fire frequency/intensity, 7.1.2 - suppression in fire frequency/intensity, and 7.1.3 trend unknown/unrecorded; Salafsky *et al.* 2008).

For ease of presentation, we modified the broad threat categories and sub-class threat names. For example, we shortened the broad threat categories Residential & Commercial Development to Urban development. Similarly, we shortened sub-class threat Annual & Perennial Non-Timber Crops to Cropping. See Table S3 for a full list of abbreviated threat names.

Analyses

Summary of threats to EPBC Act listed threatened taxa

We analysed the prevalence of each threat to EPBC Listed threatened taxa. To do this we summed the number of taxa that each threat is listed as impacting at the broad threat category, and within that at the major subdivisions ('sub-class threats'). This information is presented graphically in Fig. 1, and summarised in Table S3. In Fig. 1 we use pie charts to illustrate the prevalence of each threat to EPBC Listed taxa. The size of each circle in Fig. 1 is scaled based on the number of taxa listed as being threatened by each broad threat category. The pie chart segment represents the number of taxa listed as being threatened by each sub-class threat within the relevant broad threat category. For example, the top left pie chart represents the broad threat category Invasive species. The size of the overall pie chart is scaled based on which of the 1257 taxa are threatened by this threat. The size of the segments represents the number of taxa impacted by the sub-class threats Non-native species (n = 1235) and Problematic native species (n = 353). In Fig. 1 we removed broad threats that affect <20 taxa (e.g. Geological events) and sub-class threats that impact <5 taxa (e.g. Renewable energy) as they were too small to be presented effectively. One threat in the SPRAT listed under the threat of agricultural activity is "Land clearing, habitat fragmentation and/or habitat degradation". The SPRAT database provides no further details on the agricultural activity that is the cause of this land clearing so we refer to this as 'Agriculture'.

Summary of threats to EPBC Act listed threatened taxa across broad taxonomic groups, vertebrate taxonomic groups and degree of extinction risk

We investigated the breakdown of broad level threats affecting taxa in each broad taxonomic group (plants, vertebrates and invertebrates), vertebrate group (birds, mammals, reptiles, freshwater fish and amphibians) and degree of extinction risk (Vulnerable, Endangered and Critically Endangered).

We present this information in Fig. 2. The colour of each cell corresponds with the percentage of that species group listed as being affected by each threat. The more red the colour, the greater the number of species affected, the more blue, the fewer the number of species affected. For example, cells that represent species groups for which 100% of taxa are affected by a particular threat (e.g. amphibians by invasive species) are coloured red. Cells that represent species groups for which only a small percentage are threatened by a particular threat (e.g. plants by geological events) are shaded blue. Cells representing groups that have no species listed as being affected by a particular threat are left blank (e.g. vertebrates by geological events). We tested for statistical significance in the difference in the percentage of each group affected by each IUCN Red List threat category across broad taxonomic groups; vertebrate groups and degree of extinction risk with a Kruskal-Wallis test using R statistical package version 3.2.4 (R Core Team 2016).

Comparison of threats to Australian species and species globally

We compared the prevalence of each broad threat category to Australian taxa with the prevalence of these threats to species globally. For threats to global species, we used the IUCN Red List data used in the Maxwell *et al.* (2016) analysis. This database contains threat information on Near Threatened, Vulnerable, Endangered and Critically Endangered terrestrial, freshwater and marine species. As the SPRAT database contains threat information on Vulnerable, Endangered and Critically Endangered terrestrial and freshwater taxa, we removed species listed as Near Threatened and species groups comprised of wholly (e.g. Anthozoa – a class of marine invertebrate which includes sea anemones) and mostly marine species (e.g. Actinopterygii) from the Maxwell *et al.* (2016) database to enable a more accurate comparison. In total, 5,296 IUCN Red Listed species were included. We summarised the threats listed as affecting these IUCN Red listed species and compared these results with the threats listed as impacting to EPBC Act listed taxa.

It is important to note that the listing process for the IUCN Red List and the EPBC Act are different procedures. Specific to the data used in the Maxwell *et al.* (2016) analysis, they include species groups that had been comprehensively assessed (Maxell *et al.* 2016). This means that all species from these species groups have been assessed and assigned to one of the eight IUCN Red List categories (Data Deficient; Least Concern; Near Threatened; Vulnerable; Endangered; Critically Endangered; Extinct in the Wild; Extinct). Whereas species listed under the EPBC Act must be nominated and are assessed on a case-by-case basis (Commonwealth of Australia, 2017*c*). For species to be listed under the EPBC Act, they can only be listed as threatened (Vulnerable, Endangered and Critically Endangered), Conservation Dependent, Extinct in the Wild or Extinct.

These differences likely have an influence on the species that are listed under on each list and therefore the threats listed in each database.

We tested for statistical significance in the difference the percentage of Australian and global threatened species affected by each IUCN Red List threat category with a chi-square test using R statistical package version 3.2.4 (R Core Team 2016).

The number of threats to EPBC Act listed species

We assessed the number of threats that impact upon each taxon. We tallied the number of threats that impact each taxon, and summarised these across all taxa overall. We did this at the broad threat categories level (Fig. S1*a*) and the threat sub-class level (Fig. S1*b*).

The number of species threatened by each invasive species

As invasive species was the most prevalent threat to EPBC Act listed threatened taxa, we further investigated this by listing the top 10 invasive species in Australia based on the number of EPBC Act threatened taxa they are listed as affecting. These top 10 invasive species and the number of species they are listed as affecting are presented in Fig. 3.

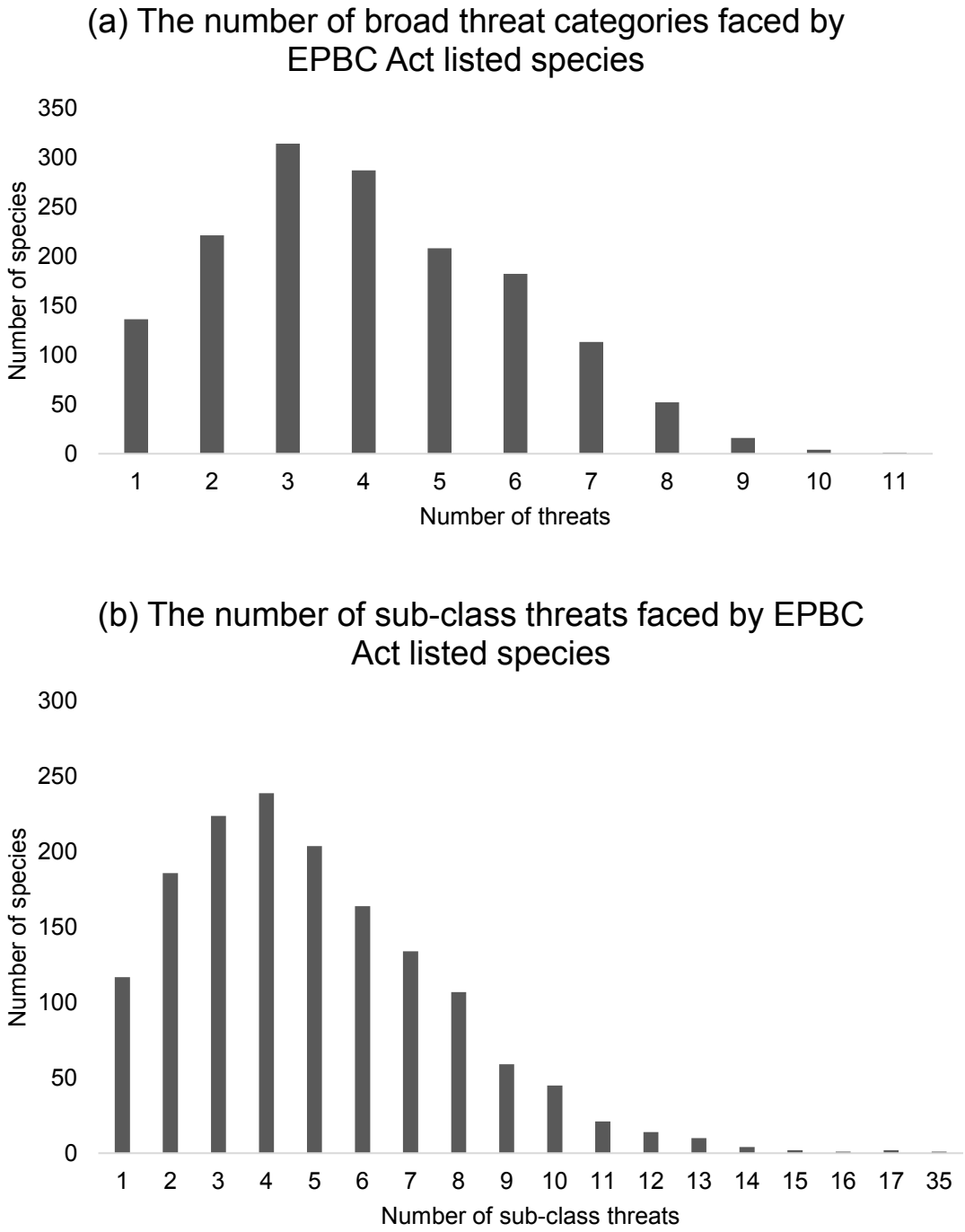

Fig. S1. The number of broad threat categories (*a*) and sub-class threats (*b*) listed as impacting EPBC Act threatened terrestrial and freshwater species (n = 1533). The majority of Australian species face multiple threats, with each species facing between one and 11 broad threat categories (*a*, mean = 4.0, s.d. = 1.9) and one and 35 sub-class threats (*b*, mean = 4.9, s.d. = 2.7).

Table S1. The number of EPBC Act threatened plant, vertebrate and invertebrate species included in this review and their conservation status.

	Plants	Invertebrates	Vertebrates	Total
Vulnerable	562	10	137	709
Endangered	518	17	111	646
Critically Endangered	132	22	24	178
Total threatened	1212	49	272	1533

Table S2. The number of EPBC Act threatened bird, mammal, reptile, fish and amphibian species included in this review and their conservation status.

	Birds	Reptiles	Amphibians	Mammals	Fish	Total
Vulnerable	39	29	10	43	16	137
Endangered	38	16	14	28	15	111
Critically Endangered	7	6	5	3	3	24
Total threatened	84	51	29	74	34	272

Table S3. IUCN classification of direct threats to biodiversity (Salafsky, Salzer *et al.* 2008), the abbreviated title used in our figures and the number and percentage of EPBC Act terrestrial and freshwater threatened species (n = 1533) listed as being impacted by each broad (and sub-class) threat classifications

IUCN broad (and sub-class) threat categories	*Abbreviated threat name*	*Number of species*	*Percentage of species (%)*
1 Residential & Commercial Development	**Urban development**	**341**	**22.2**
1.1 Housing & Urban Areas	Housing	322	21.0
1.2 Commercial & Industrial Areas	Industrial	36	2.3
1.3 Tourism & Recreation Areas	Tourism and recreation	1	0.1
2 Agriculture & Aquaculture	**Agricultural activity**	**873**	**56.9**
2.1 Annual & Perennial Non-Timber Crops	Cropping	13	0.8
2.2 Wood & Pulp Plantation	Timber plantations	33	2.2
2.3 Livestock Farming and Ranching	Livestock grazing	621	40.5
2.4 Marine and Freshwater Aquaculture	***		
### Agriculture	Agriculture	572	37.3
3 Energy Production & Mining	**Energy production**	**289**	**18.9**
3.1 Oil and Gas mining	Oil and Gas	5	0.3
3.2 Mining and Quarrying	Mining	287	18.7
3.3 Renewable Energy	Renewable energy	3	0.2
4 Transportation and Service Corridors	**Transportation**	**465**	**30.3**
4.1 Roads and Railroads	Roads and railroads	445	29.0
4.2 Utility and Service Lines	Service lines	59	3.8
4.3 Shipping Lanes	Shipping lanes	1	0.1
4.4 Flight Paths	***		
5 Biological Resource Use	**Overexploitation**	**420**	**27.4**
5.1 Hunting and Collecting Terrestrial Animals	Hunting	55	3.6
5.2 Gathering Terrestrial Plants	Gathering plants	186	12.1
5.3 Logging and Wood Harvesting	Logging	229	14.9
5.4 Fishing and Harvesting Aquatic Resources	Fishing	20	1.3
6 Human Intrusion & Disturbance	**Human disturbance**	**588**	**38.4**
6.1 Recreational Activities	Recreation	360	23.5
6.2 War, Civil Unrest and Military Exercises	War	3	0.2
6.3 Work and Other Activities	Work and other	340	22.2

7 Natural System Modifications	**Ecosystem modifications**	**1136**	**74.1**
7.1 Fire and Fire Suppression	Fire	1008	65.8
7.2 Dams and Water Management/Use	Water use	296	19.3
7.3 Other Ecosystem Modifications	Other	127	8.3
8 Invasive & Other Problematic Species, Genes and Diseases	**Invasive species**	**1257**	**82.0**
8.1 Invasive Non-Native/Alien Species/Diseases	Introduced species	1235	80.6
8.2 Problematic Native Species/Diseases	Problematic native species	353	23.0
8.3 Introduced Genetic Material	Introduced Genetic Material	1	0.1
8.4 Problematic Species/Diseases of Unknown Origin	***		
8.5 Viral/Prion-induced Diseases	***		
8.6 Diseases of Unknown Cause	***		
9 Pollution	**Pollution**	**272**	**17.7**
9.1 Domestic and Urban Waste Water	Domestic	18	1.1
9.2 Industrial and Military Effluents	Industrial	31	2.0
9.3 Agricultural and Forestry Effluents	Agricultural	205	13.4
9.4 Garbage and Solid Waste	Solid waste	72	4.7
9.5 Air-Borne Pollutants	***		
9.6 Excess Energy	***		
10 Geological Events	**Geological Events**	**16**	**1.0**
10.1 Volcanoes	***		
10.2 Earthquake/Tsunami	***		
10.3 Avalanche/landslide	Avalanche/landslide	16	1.0
11 Climate Change and Severe Weather	**Climate change**	**533**	**34.8**
11.1 Habitat Shifting and Alteration	Habitat modification	432	28.2
11.2 Droughts	Drought	118	7.7
11.3 Temperature Extremes	Extreme temperatures	9	0.6
11.4 Storms and Flooding	Storms and flooding	50	3.3
11.5 Other Impacts	***		
12 Other Options	***		
	Grand Total	**1533**	**100.0**

*** A threat from the Salafsky, Salzer *et al.* (2008) threat classification scheme that is not listed as impacting any EPBC Act terrestrial or freshwater species. ### One threat in the SPRAT listed under the threat of agricultural activity is "Land clearing, habitat fragmentation and/or habitat degradation". The SPRAT database provides no details on the agricultural activity that is the cause of this land clearing so we refer to this as 'Agriculture'.

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