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The threats endangering Australia's at-risk fauna

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ABSTRACT

Reducing the rate of species extinctions is one of the great challenges of our time. Understanding patterns in the distribution and frequency of both threatened species and the threatening processes affecting them improves our ability to mitigate threats and prioritize management actions. In this quantitative synthesis of processes threatening Australian at-risk fauna, we find that species are impacted by a median of six threats (range 1–19), though there is considerable variation in numbers of threats among major taxonomic groups. Invasive species, habitat loss, biological resource use, natural systems modification and climate change are the processes most commonly affecting Australian threatened species. We identified an uneven distribution of research knowledge among species, with half of the total number of species-specific peer-reviewed scientific publications associated with only 11 threatened species (2.7%). Furthermore, the number of threats associated with each species was correlated with the research effort for that species, and research effort was correlated with body mass. Hence, there appears to be a research bias towards larger-bodied species, and certain charismatic species, that could result in inferences biased towards these favored species. However, after accounting for these effects we found that for birds, amphibians, reptiles and marine mammals body mass is positively correlated with the number of threats associated with each species. Many threats also co-occur, indicating that threat syndromes may be common.

1. Introduction

Biodiversity is threatened by many factors, and is currently in crisis on a global scale despite worldwide conservation efforts (Butchart et al., 2010). Processes driving species declines are affecting ecosystem services on which humans depend and are also leading to species extinction rates up to 100–1000 times higher than background rates (Pimm et al., 2014; Ceballos et al., 2015). Moreover, the number of threatened species at risk of extinction far exceeds resources available for conservation, which inevitably leads to some species being prioritized over others (Bottrill et al., 2008). This prioritization process can be usefully informed by understanding the link between threats and extinction vulnerability (Myers et al., 2000): assessing species' vulnerability to threats is part of an integrated scientific framework for establishing priorities and conservation plans (Margules and Pressey, 2000; Pressey et al., 2007).

Developing an understanding of the link between threatening processes (henceforth ‘threats') and extinction risk is useful for more than one reason. First, synergies and feedbacks among threats may increase risk of extinction (Myers, 1987; Brook et al., 2008; Laurance and Useche, 2009; Doherty et al., 2015). Identifying such synergies is important for both quantifying the risk of extinction and for prioritizing threat mitigation. Second, it may be inefficient to base conservation prioritization on an evaluation of species and threats that are assumed to be independent as this may fail to account for possible efficiency gains that could be achieved by addressing threats affecting multiple species. There may be, for example, economies of scale that can be achieved when mitigating a threat at large spatial scales (e.g. national scales), perhaps through legislative change or the development of incentive programs. Threat mitigation in an area may also benefit more than one species (e.g. reduction of feral cat and fox densities may benefit several species; Dexter and Murray, 2009). Or there may simply be cost-efficiencies resulting from sharing of infrastructure or implementation costs among several species occurring in the same area. Third, resolving some threats may require strong cross-jurisdictional cooperation, which can be facilitated by explicitly identifying the threats that can be most effectively addressed cooperatively (Kark et al., 2015). Thus, there are several ways in which considering the distribution and frequency of threats among all threatened species can improve conservation prioritization.

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A comparative approach to threat analysis may also provide useful insight into taxonomic and life history related patterns of association between threats and threatened species. Such patterns could inform a stronger mechanistic understanding of how threat mitigation may lead to a reduction in extinction risk and the time frame over which that may happen, and could provide a basis for estimating the types and impacts of threats affecting species that have not yet been assessed. Species characteristics such as body mass and generation time are often correlated with population viability and extinction risk (Jennings et al., 1998; Purvis et al., 2000; Fisher and Owens, 2004; O'Grady et al., 2004; Cardillo et al., 2005), although the associations between such characteristics and threats are not currently well understood. Given that the ultimate goal of management and conservation is to ensure the long-term persistence of species, management has arguably already failed by the time a species becomes listed as threatened. In some cases, it is likely to be less costly and more feasible to mitigate threats and prevent further population declines before a species becomes threatened. Understanding the link between threats and extinction risk could, therefore, facilitate the identification of species that are likely to become threatened in the future and the processes that are likely to affect them.

Australia is one of 17 megadiverse countries (Lindenmayer et al., 2010), with many endemic species. Since European settlement, the rate of species extinction in Australia has been high; for example, mammal extinctions are the highest in the world, with > 10% of endemic terrestrial mammal species now lost (Woinarski et al., 2015). Given the urgency of the situation, we present a continental-scale quantitative synthesis of threat status and threats for Australian threatened fauna. We map spatial patterns in the distribution of threatened species and threats across Australia. We then develop a statistical model to identify predictors of the number of threats associated with each species to evaluate the following questions: (i) are there differences in the numbers of threats associated with each species among taxonomic groups and conservation status groups?; (ii) are larger mass species typically associated with greater numbers of threats?; and (iii) are more threats described for species associated with larger numbers of peer-reviewed scientific papers? We also evaluate whether threats typically co-occur versus whether the distribution of threats among species is random.

2. Methods

A total of 497 animal species and subspecies, including birds, mammals, fishes, frogs, reptiles, and invertebrates, are listed as threatened under the Australian Commonwealth Environmental Protection and Biodiversity Conservation Act 1999 (EPBC). For each of these species we compiled information on threats, threat status (EPBC and IUCN), 16 taxonomic and morphological characteristics, distribution and abundance characteristics and research effort. Specifically, information for each species included threat status, phylum, class or order (bird, mammal, fish, reptile, amphibian, invertebrate), adult body mass, body length, generation time, number of offspring, species range area, population size, number of subpopulations, lifespan, threats recorded in the EPBC and IUCN Red List listings, number of species-specific scientific publications, and geographical distribution (state/territory of occurrence). When measures of mass could not be found, mass was estimated on the basis of body length-mass relationships (Suppl. Mat. Figs. 1–3). This open access database has been published on the University of Queensland data repository (Allek et al., 2018).

Information from the EPBC list and the IUCN Red List provided the core of the database, supplemented with data from many other sources (peer-reviewed and grey literature, books, reports and other databases). Data were located using systematic searches of Thomson Reuters Web of Science and Google Scholar between November 2014 and August 2015. Some data for mammals were sourced from PanTHERIA (Jones et al., 2009), and for birds from the Action Plan for Australian Birds 2010 (Garnett et al., 2010) and the Australian Bird Data Version 1.0. Scientific Data (Garnett et al., 2015). The source of each entry is recorded in the database and a complete description of each field is included in the database metadata (Allek et al., 2018). The number of species-specific peer-reviewed scientific publications was quantified using Web of Science by searching for the genus and species name of each species (in quotes) and retaining only research article and review document types.

Following the Salafsky et al. (2008) categorization, threats were divided into 11 broad types: 1. Urban and residential development; 2. Agriculture and aquaculture; 3. Energy production and mining; 4. Transportation and services corridors; 5. Biological resource use, which refers to consumptive use and harvest of wild populations; 6. Human intrusions and disturbance; 7. Natural system modifications; 8. Invasive and other problematic species and genes; 9. Pollution; 10. Geological events; and 11. Climate change and severe weather. Within each of these threat types, there are up to six subdivisions, with more detailed specifications of the threats (Suppl. Mat. Table 1). A key aim of this classification system is to identify the causes of processes that impact threatened species. Hence, there is no single habitat loss category in this system. Rather, habitat loss effects are attributed to the causes of habitat loss: usually either Urban and residential development (category 1) or Agriculture and aquaculture (category 2).

The Salafsky et al. (2008) categorization threat type 8, 'Invasive and other problematic species and genes' is here subdivided into three parts: 8.1. Invasive non-native/alien species; 8.2. Problematic native species; and 8.3. Introduced genetic material. In our database, to be more precise, and as it is especially relevant to Australia, we included three additional subcategories: 8.4. Invasive/non-native/alien pathogens; 8.5. Problematic native pathogens and; 8.6. Diseases - Unknown origin or cause.

Other threats that did not fit into any of the Salafsky et al. (2008) categories and were listed in the EPBC were found to be numerically rare and were omitted from our analysis. Only current and potential threats were classified and included in this database; past threats were omitted. Potential threats are defined as those that could jeopardize species persistence in the future and are recorded separately from current threats.

We used generalised linear models with Poisson distributed errors to identify predictors of the number of threats associated with each threatened species. We evaluated permutations (including interaction terms) of the covariates: body mass (natural log transformed), taxonomic group (mammals, fish, reptiles, birds, and amphibians), number of peer-reviewed published papers, and threat status (critically endangered, endangered, conservation dependent and vulnerable), under the condition that the taxonomic group factor was always required in the model. Competing models were ranked using Akaike information criteria (AIC; Suppl. Mat. Table 2).

To examine co-occurrence of threats among species, we used a fixed-equiprobable null model approach (cf. Gotelli and Ellison, 2002), whereby numbers of occurrences of each threat were held constant while individual occurrences among species were shuffled 10,000 times. Tail probabilities for the null hypothesis of $0.05 < P > 0.95$ were determined as the frequency of randomized numbers of co-occurrences $\leq$ or $\geq$ the true number of co-occurrences (Gotelli, 2000). We tested patterns of threat co-occurrences among all species, and among taxonomic groups as per the analysis of threat predictors above.

3. Results

Threatened animal species are widely distributed across Australia with considerable regional variation in the relative proportion of major taxonomic groupings of species (Fig. 1a). Birds constitute the single largest proportion of threatened species in all areas except the Northern Territory, where mammals make up the largest proportion. Most taxonomic groups are represented in all areas with the exception of amphibians, which occur almost exclusively in Queensland, New South Wales and Victoria.