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# The estimated cost of preventing extinction and progressing recovery for Australia's priority threatened species

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**The global extinction crisis is intensifying rapidly, driven by habitat loss, overexploitation, climate change, invasive species, and disease. This unprecedented loss of species not only threatens ecological integrity but also undermines ecosystem services vital for human survival. In response, many countries have set ambitious conservation targets such as halting species extinctions, yet the necessary financial commitments to achieve this are rarely prescribed. Estimating costs can be achieved using an ensemble of spatially variable species-specific cost models for threat abatement activities. We employ this method to provide a cost assessment to halt extinctions for Australia's priority terrestrial and freshwater species. We show that it will cost ~AUD15.6 billion/year for 30 y to halt extinctions for these 99 priority species (comparable to 1% of Australia's GDP). The more ambitious objectives to move priority species down one threat category (~AUD103.7 billion/year) or remove from the threatened species list entirely (~AUD157.7 billion/year) would require considerably more investment. Regardless of what is spent, we found that 16 (16%) priority species could not be removed from the threatened species list due to extensive historical declines and pervasive, ongoing, unmanageable threats, such as climate change. But implementing these efforts could ensure conservation benefits for over 43% of all nationally listed nonmarine threatened species. Adequate funding is crucial for meeting government commitments and requires both government leadership and private sector investment.**

biodiversity | conservation planning | conservation finance | complementarity | prioritization

## Significance

Every year, more species are driven to extinction by human impacts. In response, most countries have ratified global targets under the Convention of Biological Diversity to reduce the rate of extinctions. Despite these ambitious targets, financial commitments are often overlooked, leading to ineffective action due to resource constraints. Our research utilizes a unique approach using existing cost models to provide a robust cost estimate to halt extinctions among Australia's priority threatened species. We find that addressing species-specific needs could benefit a vast number of other threatened species, but the cost is substantial. Our estimate is in stark contrast to previous cost estimates which underscores the necessity for updated financial planning and substantial private sector involvement to meet conservation goals effectively.

Earth is currently experiencing a mass extinction (1, 2). Species are being lost at a rate 100 to 1,000 times greater than previously experienced in pre-Anthropocene epochs (3), largely due to habitat destruction, the spreading of invasive species and diseases, changed fire and water regimes, and overexploitation of wildlife (4–8). While almost all countries face serious biodiversity decline, Australia stands out as a wealthy country with many endemic species and a relatively high recent extinction rate (9). With the loss of over 100 endemic species in the last three centuries (10), and the eighth largest list of threatened species (with more than 2,000 species nationally listed as threatened with extinction and many more under assessment) of any nation (10, 11), Australia sits at the forefront of Earth's species extinction crisis.

The Australian Commonwealth Government has made a formal commitment to halt species extinction across the continent and reduce extinction risk for 110 priority species (12). The priority species list includes plants and animals found across Australia's diverse environments. The 110 priority species were selected using a multicriteria decision analysis process, mostly using six prioritization principles: risk of extinction, cobenefits to other species, feasibility and cost-effectiveness, cultural importance, genetic uniqueness, and representativeness across taxa, land and seascapes, tenures, and jurisdictions (12) (although these principles seem not to have not been followed for some species or groups). The Commonwealth Government has dedicated AUD$12 million (as of July 2024) in community grants for on-ground activities to support the recovery of these 110 priority species (12). The most recent estimate of net Australian expenditure on all threatened species recovery across all states and territories is ~AUD$122 million in 2019 (13).

The formal goal of halting species extinction by reducing extinction risk for 110 priority species has been welcomed by the Australian conservation community given the extinction crisis and the low priority afforded to the nation's biodiversity crisis in recent decades. The use of prioritization is a considerable improvement for how governments effectively use limited allocated funds to get the most "bang for buck" for species outcomes (14). Yet, while 110 priority species have now been identified, the true cost of achieving the specified goal has not been estimated. This is a significant deficiency because costs are essential for

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budgeting species conservation alongside other societal actors such as environmental nongovernment organizations and the private sector (15–17). Moreover, although "multiple benefits to other species" and representativeness were criteria for selecting priority species, no assessment has been undertaken as to how other listed threatened species will benefit from actions implemented for the priority species. Identifying the gap species that do not receive any attention is crucial because failure to take any action will almost certainly lead to further decline (18). Ongoing decline without management stems from the unique concoction of threats facing Australian species, including invasive species, disease, inappropriate fire regimes, and habitat degradation, working in concert with human-induced climate change, necessitating active management to enable most species to persist in the long-term (19).

Estimating the costs of recovering threatened species is challenging due to the lack of recovery success cases for empirical reference. But there have been estimates for different conservation activities attempted. For example, a global analysis conducted in 2012 indicated that an annual cost of USD3.41 to USD4.76 billion (~USD6.11 billion or AUD9.17 billion in 2024, with 2% annual inflation) was needed to reduce the extinction risk of all threatened species (20). A more recent global estimates suggest this is closer to USD722-967 billion each year over the next 10 y (21). A European Commission report identified an estimated annual financing need of around EUR48 billion between 2021 and 2030 to fully implement the entire EU Biodiversity Strategy for 2030 (22). In New Zealand, analyses of data from recovery plans show that between NZD71,810 for plants and NZD1.1 million for mammals (approximately USD74,756 and USD1.119 million in 2024 using a 2% inflation rate) were needed to achieve positive species outcomes (23), while annual funding to effectively manage protected areas covering 10% of each of Africa's 118 ecoregions was estimated to cost USD630 million/year (~USD936.15 million in 2024 using a 2% inflation rate) (24). In the United States, the average annual cost of recovering threatened species was estimated to be between USD125,000 for plants to USD3.43 million for birds (~USD903,000/species/year) (25). Using information from the United States, Wintle and colleagues (13) estimated the costs required for halting extinction of Australia's approximately 2,000 threatened species in 2019, was USD1.27 billion/year (~AUD2.10 billion/year in 2024 using an average annual 2% inflation rate and 1.5 exchange rate). While extrapolating estimates across countries provides a valuable approximation, differences in key threatening processes, site-specific variation of costs, and sizes of management areas complicate comparisons. For example, Wintle and colleagues (13), in line with estimates of US recovery expenditure, did not include the cost of broad-scale habitat restoration and widespread invasive species control likely required for recovery and down-listing.

An alternative approach is to overlay information on threatened species distributions with information on threat occurrence, combined with estimates on the costs of site-specific management to abate these threats (17, 26). This spatially variable (i.e., the cost varies due to site specificity such as topographic ruggedness and vegetation type) method offers a bottom–up, consistent, and transparent approach to budgeting for threat abatement strategies that more accurately reflects the cost of addressing threats at scale. These spatial cost models can then be applied across species-specific protection and management area targets. While difficult to determine the exact area needed to meet conservation objectives, like halting extinctions, there is an opportunity to assign species-specific area targets by reverse-engineering the International Union for Conservation of Nature (IUCN) Red List for Threatened Species criteria (27), to ensure each species does not meet thresholds defined in the criteria. For example, under criterion B1, a species must have protection and management of all threats across 100 $km^2$ of Extent of Occurrence to remain at a Critically Endangered level, thus halting extinction.

Here, utilizing a recently published assessment of threat management costs across Australia (17), we provide an assessment of the overall areal extent of threat management and associated cost of managing 99 of the 110 species that are prioritized in current policy (12). We exclude the 10 marine species and one intercontinental migratory shorebird on this list, largely on the grounds that cost estimates for marine and intercontinental migratory species remain too poorly resolved; and we recognize that this lack of evidence represents a major knowledge shortfall. We examine three different conservation objectives: i) halting species extinction (ensuring no species moves to a more perilous threat status than Critically Endangered for at least 30 y); ii) reducing the extinction risk for all species (i.e., moving species down one threat category within 30 y. For example, moving from Endangered to Vulnerable); and iii) delisting each species from the threatened species list [i.e., reducing the extinction risk until it no longer meets the criteria for listing under Australian legislation within 30 y; and noting that for Vulnerable species, this delisting equates to the downlisting considered in (ii)]. We explore two threat management scenarios: i) manage all known threats and ii) manage a subset of "existential" threats that, optimistically, could be sufficient to enable the species' status and trend to improve enough to meet the objective. Using the objective of extinction risk reduction, we also assess how many other threatened species will likely cobenefit from management threats for priority species, as well as how much carbon and carbon funding could be generated from the restoration of some key areas. We also identify "gap species" that will not receive any cobenefit from managing the priority species. For all prioritized areas under the objective of extinction risk reduction, we also determined the land tenure over their distribution (Fig. 1).

## Results

**Costs and Areal Extent.** Using the existential threat management scenario, the cost summed across priority species to halt extinctions is estimated to be AUD15.6 billion/year for 30 y across 270,000 $km^2$ (~3.5% of Australia). To downlist priority species, the cost increases to approximately AUD103.7 billion/year for 30 y across 1.7 million $km^2$ (noting that six priority species could never meet this objective within 30 y) and AUD157.7 billion/year for 30 y across 1.2 million $km^2$ to delist all priority species (noting that 16 priority species are unlikely to meet this objective within 30 y; Fig. 2). The cost of meeting the three different objectives when we manage all threats (as opposed to only existential threats) changes to ~AUD15.8 billion/year for 30 y to prevent species extinction, ~AUD106.4 billion/year for 30 y to downlist all priority species, to ~AUD158 billion/year for 30 y to delist all priority species. These costs include on-ground management of threats (both in Australia and on off-shore island; Dataset S1, Tabs 1–3), nonspatial costs (e.g., policy changes, mapping, education, compliance; Dataset S1, Tab 4), and emergency actions (e.g., captive breeding, translocations) required for species to meet objectives (Dataset S1, Tab 5).

We estimated, through expert opinion, that 71 of the 99 species assessed (71%) require emergency actions to meet the objectives (Fig. 3 and Dataset S1, Tab 6). Twenty-nine species needed emergency actions to prevent extinctions, 29 species required emergency actions to be downlisted, and 60 species required emergency actions to be delisted. In total, these costs are estimated at AUD14 million/year (halting extinctions), AUD17.4 million/year (downlisting species), and AUD29.2 million/year (delisting species), in

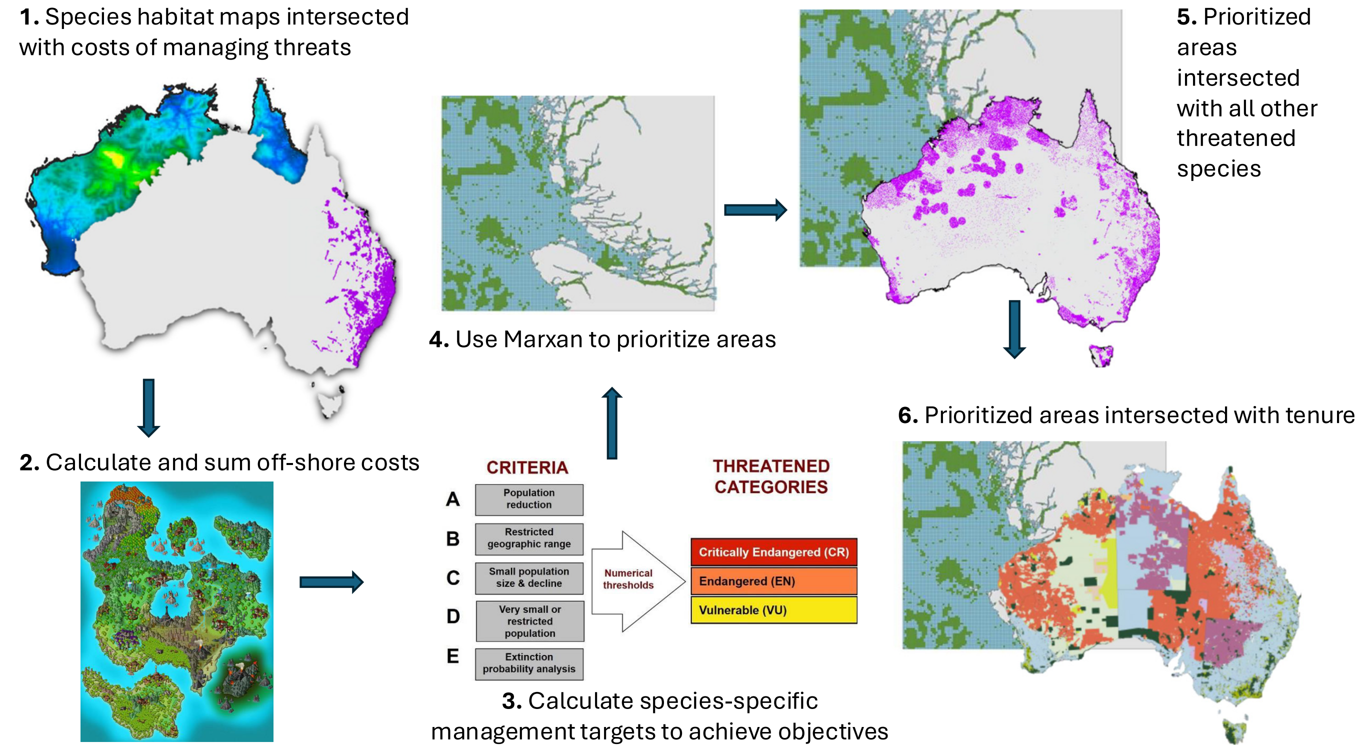


**Fig. 1.** Methods graphic: schematic representation of the methodological steps utilized to obtain results (27–29).

addition to the costs calculated for managing direct threats. Even with these emergency actions, we found that while extinctions of all terrestrial and freshwater priority species could be avoided, six (6%) priority species could never meet the objective of being downlisted, and 16 (16%) priority species could never meet the objective of being delisted because their range could never reach above the target area or population threshold, in conjunction with ongoing threats that cannot be eliminated (Dataset S1, Tab 5).

Habitat restoration was the key action required by most priority species ($n$ = 59, 19 of which were plants and 17 were birds), closely followed by ecological fire regime management ($n$ = 25), and mapping and protecting climate refugia ($n$ = 18; Dataset S1, Tab 2). Under the halting extinctions objective, these actions are estimated to cost AUD8.3 billion/year, AUD213.4 million/year, and AUD2.6 million/year, respectively, when actions are prioritized for the downlisting objective. Habitat restoration was the most expensive action required per unit area (AUD4,023/ha), followed by Phytophthora (*Phytophthora cinnamomi*) management (costing AUD732.7 million or AUD1,404/ha) and weed management (costing AUD3.8 billion or AUD525/ha; see Dataset S1, Tab 7).

**Cobenefits for Other Threatened Species and Carbon.** When using the halting extinction objective, our results indicate that 860 of Australia's 2,004 (43%) nonmarine threatened species will likely receive some cobenefit (using a threshold of 10% overlap) of managing the terrestrial and freshwater priority species. Of the 1,045 not receiving cobenefit, most had very small ranges. These unrepresented species include McDowall's galaxias (*Galaxias mcdowalli*), Grey Range thick-billed grasswren (*Amytornis modestus obscurior*), and Snowy River westringia (*Westringia cremnophila;* Dataset S1, Tab 8). We also calculated that approximately 273 million tonnes of Carbon Dioxide Equivalent ($tCO_2e$) could be sequestered through restoration of habitats if all the actions were implemented for the 99 priority species to halt extinction, translating to ~AUD8.8 billion over 30 y in revenue through the carbon market (Dataset S1, Tab 9).

**Cost of Halting Extinction for All Nonmarine Threatened Species.** Utilizing the species-specific cost models for the 99 priority species, we were able to extrapolate for all terrestrial and freshwater species to estimate the broad costs for halting extinction for all nonmarine threatened species. When we calculated the median cost for each taxonomic group, we found mammals were the most expensive (~AUD153 million per species), followed by reptiles (~AUD43 million), plants (~AUD20 million), freshwater fish (~AUD18 million), other animals (~AUD10 million), birds (~AUD8 million), and frogs (~AUD3 million). After multiplying these median per-species costs, it is estimated that ~AUD63.3 billion is required to halt extinctions for nonmarine threatened species across Australia (Dataset S1, Tab 10).

**Land Tenures.** We found that conservation actions are required on 1.7 million km$^2$ (22% of Australia) to meet the downlisting objective. The most extensive actions are required on freehold (~588,000 km$^2$; 7.6% of Australia and 25.5% of all freehold land), closely followed by pastoral term lease ($n$ = ~366,000 km$^2$; 4.7% of Australia and 16.9% of all pastoral term lease land), and other crown land ($n$ = ~260,000 km$^2$; 3.3% of Australia and 25.7% of all other crown land; Fig. 4). Only 8% ($n$ = 137,000 km$^2$) was on nature conservation land (Dataset S1, Tab 11).

## Discussion

Currently, the Commonwealth Government has directly committed only 0.08% (AUD12 million in community grants) of what we estimated is required to halt extinction for priority species (~AUD15.6 billion/year). We found that this cost increases to ~AUD103.6 billion/year for 30 y to downlist and ~AUD157.7 billion/year for 30 y to delist the 99 priority species (0.01% of

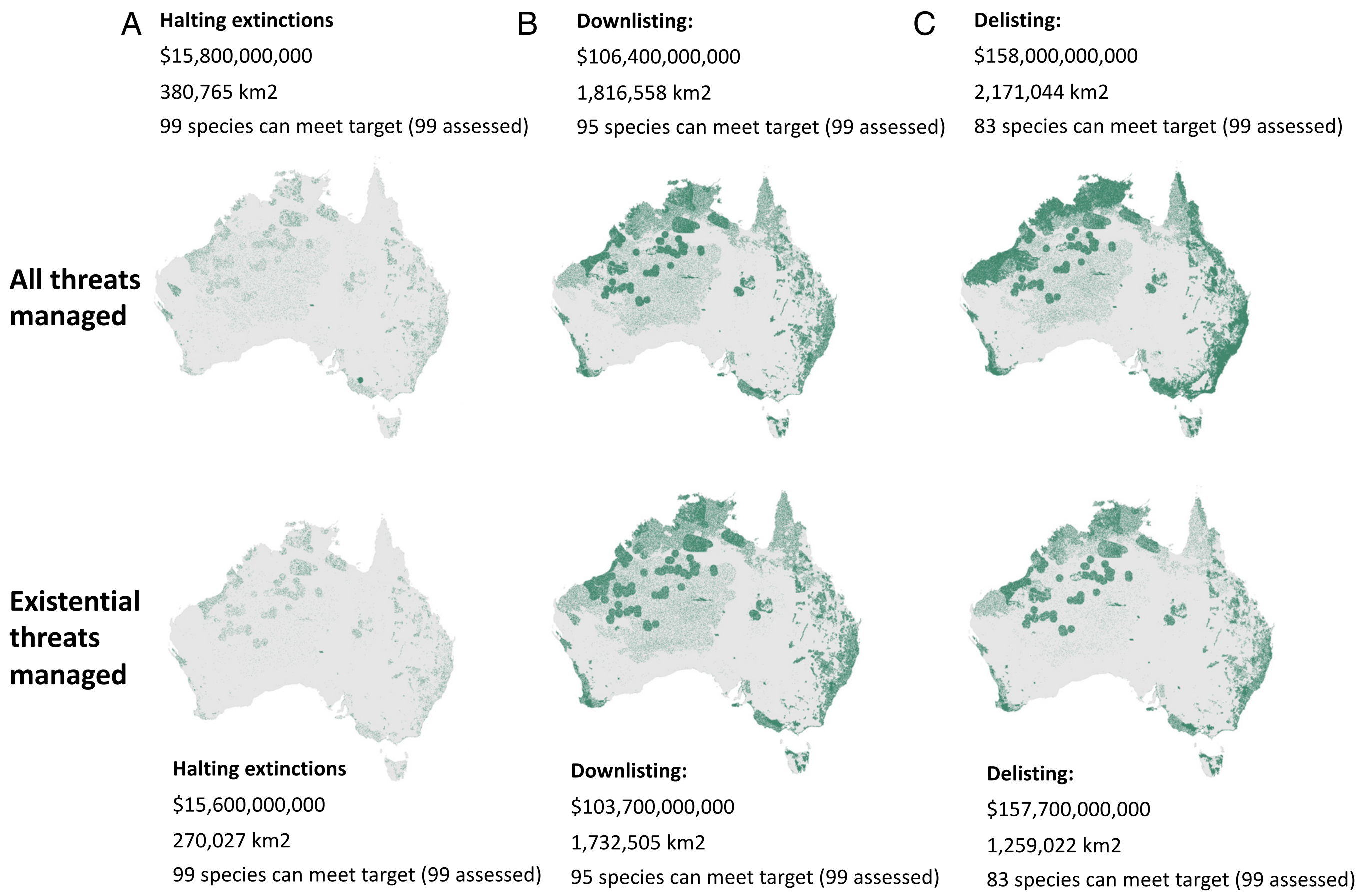


**Fig. 2.** Priority areas to meet the three objectives for the two threat management scenarios. (*A*) Highlights areas chosen to halt extinctions including costs (AUD/year for 30 y), area (km$^2$), and number of species that is predicted to meet the objective. (*B*) Highlights areas chosen to downlist species' conservation status including costs (AUD/year for 30 y), area (km$^2$), and number of species that can meet the objective. (*C*) Highlights areas chosen to delist species including costs (AUD/year for 30 y), area (km$^2$), and number of species that can meet the objective. The maps in the bottom row ("Existential threats managed") may not be a subset of those in the top row ("All threats managed") because the areas identified in the top row are already the optimal selection to meet the species targets. When Marxan is rerun using only the existential threat management scenario, different areas may be chosen based on factors like irreplaceability, cost, and the number of species benefiting. Consequently, the different scenario might prioritize entirely different areas. Additionally, the single color used in the maps can appear lighter where fewer pixels are chosen, reflecting a lower density of selected areas.

Commonwealth Government priority species funding). Although there may be other funding streams, there is no centralized system for tracking government investment in threatened species conservation (30). We estimated that the cost of halting extinction is only 1% of Australia's GDP (AUD2.55 trillion) (31), which at face value suggests investment feasibility, particularly if coupled with appropriate private sector funding (32). If this level of investment is achieved, the activities implemented will likely contribute to other environmental goals including enhancing the integrity of ecosystems and sustainably managing nature's contributions to people (31). But we note the amount of investment needed is nontrivial and the challenge in raising this type of funding will need a step-change in how nature is accounted for by government and private sector (33). We found that most of the prioritized land occurs on freehold land (588,000 km$^2$) and pastoral term lease (366,000 km$^2$), offering opportunities for partnerships between government, private industry, and landholders. Private sector funding could be supported through the development of robust biodiversity markets and well-functioning carbon markets, which incentivize the protection and restoration of habitats (32).

**Effective Conservation Management.** When using the halting extinction objective, our results indicate that 43% of Australia's terrestrial and freshwater threatened species will likely receive some cobenefit (using a threshold of 10% overlap of the known and likely habitat ranges) when managing the 99 terrestrial and freshwater priority species. This suggests that prioritizing efforts for a subset species can have broader positive impacts across multiple threatened species when well planned (14). But the results also highlight the risk of prioritizing a subset of species, as we also estimate that ~1,045 of Australia's threatened species would not receive any cobenefit. Without other planning efforts in place, this lack of attention will likely result in the continued decline and increased extinction risk of less than half of all listed threatened species. Nongovernment organizations, state or local governments, or the private sector could target actions that would benefit these ~1,045 species that do not receive any cobenefits from the actions needed to conserve the 99 priority species. We also calculated that approximately 273 million t$CO_2$e could be sequestered through restoration of habitats if all the actions were implemented for the 99 priority species, translating to ~AUD8.8 billion total in revenue through the carbon market (Dataset S1, Tab 9). While not quantified here, we can assume that implementing actions for priority species will also likely yield other cobenefits such as enhanced ecosystem services and job creation.

Effective management of threatened species often requires a consistent effort over extended periods, often spanning decades—similar periods over which the declines have occurred (34). The ecological dynamics of many Australian ecosystems, marked by cycles of drought and wet periods that can span years, as well as

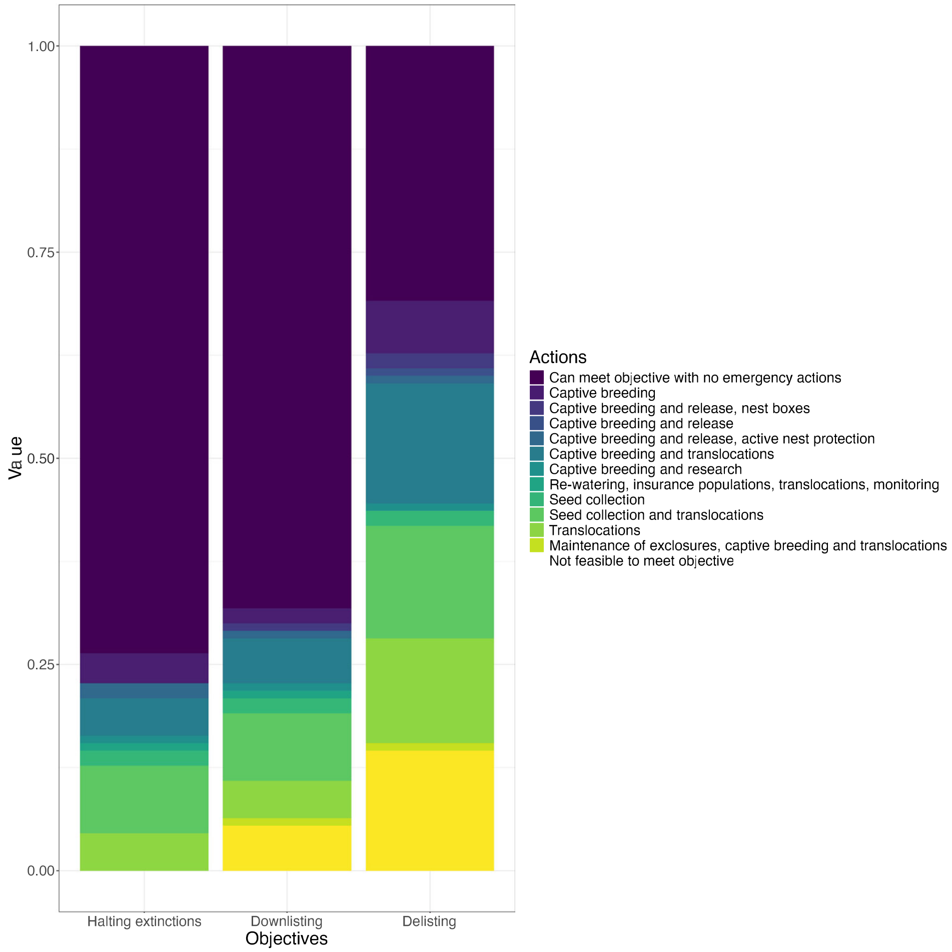


**Fig. 3.** Emergency actions required by priority species. Stacked bar chart highlighting the proportion of species that require emergency actions to meet each objective.

irregular, severe disturbances like fires or floods means that conservation funding needs to be flexible (35). For example, after the 2019–2020 megafires, the conservation funding response for threatened species was one-thirteenth the AUD2.7 billion needed to reverse decline associated with all threats of severely impacted species (36). Reversing decline of these species demands funding strategies that include much higher annual investments coupled with pulse investments after major disturbance events, allowing for the swift allocation of resources to mitigate disturbance impacts and capitalize on opportunities to build resilience when conditions are favorable. Additionally, the ability to monitor the effectiveness of conservation efforts or to respond swiftly to sudden declines in species populations is greatly hindered without dedicated investment in robust, ongoing monitoring systems (37).

Research suggests that protecting species before they become threatened is likely more cost-effective and efficient than attempting to reverse declines (38–40). When species are protected while their populations are still robust, they retain their ecological roles, including predation, seed dispersal, and pollination, which are vital for the health and stability of ecosystems (41). Reversal of declines, on the other hand, is often complex as we must undo the damage done by habitat loss, disease, altered fire regimes, and other threats, which we have found can be an expensive and uncertain process (26). For example, we found that delisting is not possible for 16 priority species, mostly due to extensive historical declines and pervasive ongoing threats, such as climate change. Moreover, genetic diversity, which is higher in stable and large populations, is critical for a species' long-term survival and ability to adapt to changing environmental conditions (42). Once a species' population falls below a threshold, genetic bottlenecks can lead to inbreeding and a reduction in resilience (43). Additionally, protecting species proactively is typically more cost-effective than the in situ management actions or emergency measures required for species recovery, as the latter requires intensive management strategies such as restoration, captive breeding, and reintroduction programs (39). We found that 60% of terrestrial and freshwater priority species require emergency actions to prevent extinction or reverse decline. We recognize that in some cases, extra investment may not be warranted for some nonthreatened species as they have proved able to cope with threats. In other cases where species are declining and are extremely widespread, the costs of halting declines may be higher. However, in most cases, we assume that the early protection of species is not only a more reliable conservation strategy but also a more economical and ecologically sound approach, especially with climate change predicted to intensify many threatening processes (such as fire, drought, and floods).

**Addressing Uncertainties in Cost Estimates.** Estimating the costs of managing threatened species in Australia is fraught with uncertainties, which need to be recognized and addressed to improve conservation outcomes and cost-effectiveness in managing threats. This includes improving knowledge and data to refine the extent to which threats are existential, that is that they need to be managed to successfully meet conservation objectives (i.e., halt extinction, downlist or delist species) and the extent to which species respond to conservation actions. There are major

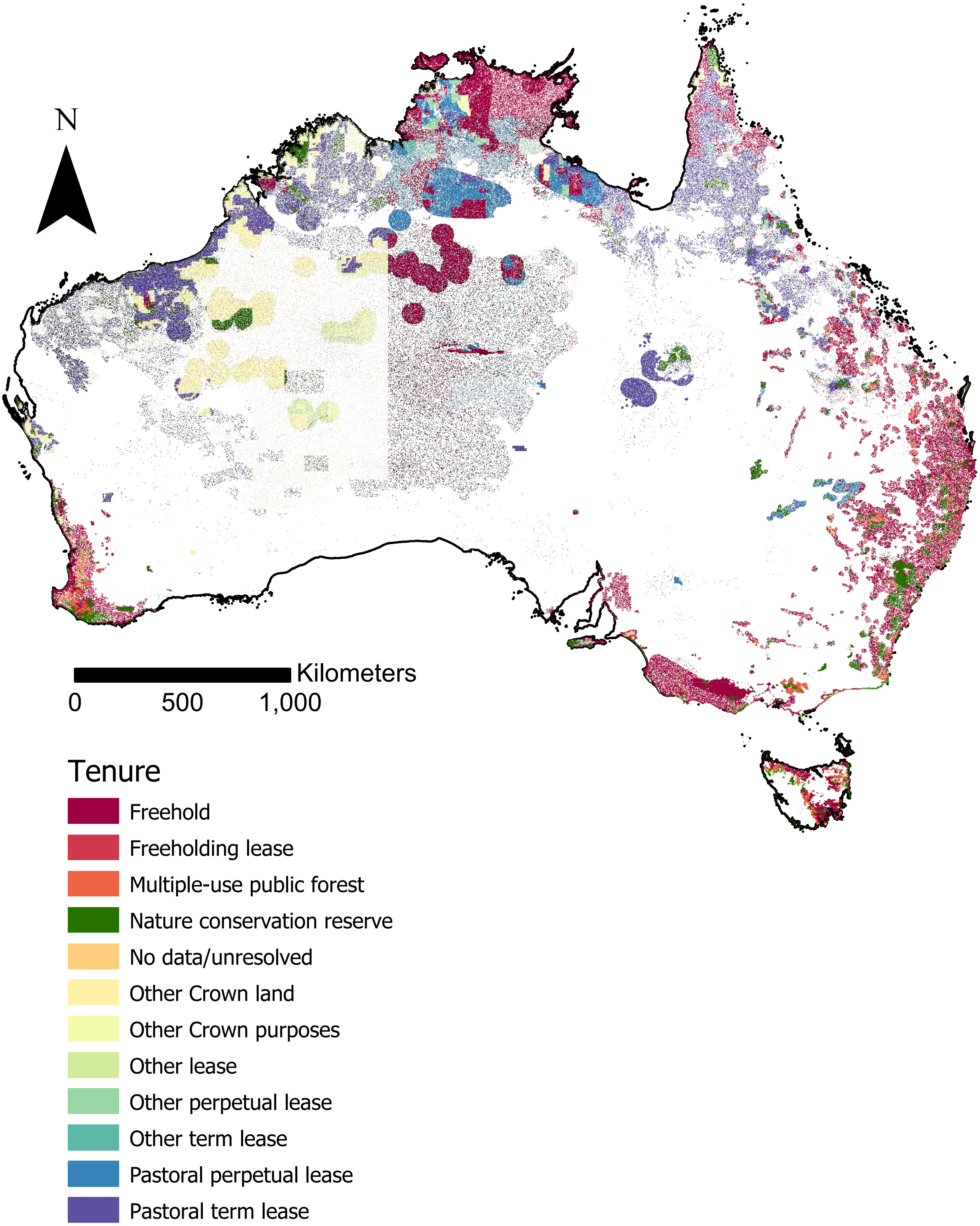


**Fig. 4.** Tenure types of priority areas. Map of mainland Australia where actions are needed for priority species under the downlisting objective, whereby the color shows the tenure types.

knowledge gaps in the evidence for management effectiveness for even widely implemented conservation interventions (44), and thus management could lead to ineffective investment. Thus, we need to improve our knowledge of management effectiveness, as well as improve knowledge and data to refine information on why species are threatened and how these threatening processes are currently distributed and how this will change under different climate scenarios, to better target areas to implement actions. A limitation of our work is that it does not account for projected changes in species distributions or threat patterns under climate change. We still lack a clear understanding on what the likely impacts of climate change will have on many Australian species, but we do know there will likely be changes to distributions. For example, over the next 60 y, most Australian eucalypt species are predicted to contract due to the climate change, with roughly 90% of the current areas with highly restricted eucalypts predicted to disappear or shift location (45). As such, the costs we identify may change in a spatially heterogeneous manner depending on whether species or threat distributions increase, decrease, or shift entirely.

Our approach to estimating the costs associated with conservation actions for Australia's priority species involved several key assumptions. We utilized a binary management framework that categorizes decisions as either action or no action. Specifically, if a species is impacted by a particular threat, we proceed with implementing the associated threat abatement strategy and calculating its cost over the target area. However, within these binary threat abatement strategies, the existing cost models we used here included key assumptions aimed at approximating real-world scenarios. For instance, when addressing the impact of cattle grazing on a species, Yong et al. (17) assumed that only 40% of each 1 $km^2$ habitat requires fencing to mitigate damage (Dataset S1, Tab 1). Similarly, in cases where a species is threatened by invasive weeds, we estimate only 30% of the 1 $km^2$ habitat necessitates weeding management. These estimates are adjusted based on factors such as vegetation type, rainfall, and the degree of habitat degradation. To achieve national consistency in the cost models, Yong et al. (17) opted to simplify these assumptions; however, this introduces significant uncertainty in the cost estimates, with variations ranging from −34% to +55% (17). This level of uncertainty underscores the importance of continuing to report conservation costs, to refine the assumptions, and enhance accuracy and precision in cost projections.

Our total estimate to halt extinctions for nonmarine threatened species [~AUD15.6 billion/year for priority species ($n$ = 99 and ~AUD47.7 billion/year for all other nonmarine threatened species ($n$ = 1,905), totaling ~AUD63.3 billion/year] greatly exceeds a previous Australian estimate of ~USD1.27 billion/year (13). The primary reason for these substantial differences lies in the methods employed. Wintle et al. (13) used US data on expenditure on the conservation of individual species under the Endangered Species Act (1973), based on the logic that the United States has achieved stabilization and in some instances recovery of several threatened species. The US expenditure data do not incorporate broad-scale habitat restoration and threat management, so those activities are not embedded in Wintle and colleagues' cost estimates for Australia. It is more closely related to the estimates we use for emergency actions, though their estimate covers ~2,000 species, not just the 99 priority species we model here. In contrast, our study took advantage of recently generated cost ensemble models (17) to employ a bottom–up approach, meticulously mapping site-specific costs for various management actions, which may provide an improved estimate of species and site-specific conservation actions and costs.

There is a vast range in the cost estimates required to meet the halting extinction objective for different species. For example, the cost for halting extinction for koala (*Phascolarctos cinereus,* AUD3.7 billion) is approximately 9,000 times more expensive than that for Mountain-top nursery frog (*Cophixalus monticola;* AUD410,000; Dataset S1, Tab 12). These comparisons highlight the substantial differences in the financial resources required for the conservation of different species, emphasizing the need for strategic prioritization in conservation funding (46, 47). The difference between cost estimates for species in our analysis is driven predominantly by whether or not they need habitat restoration and weed management and the area over which that needs to occur to meet particular Red List criteria.

We have assumed that active restoration is required for species to meet the three different objectives. However, in some cases, it might be possible to manage all other threats impacting priority species, such as weeds, invasive large herbivores, and fire, and rely on passive restoration. A passive restoration approach would reduce the cost of halting extinction by more than half (AUD7.4 billion/year, rather than AUD15.6 billion/year). Rather than "halting extinctions", this strategy would be more akin to "delaying extinctions." It would not restore ecosystem function but rather focus on what is needed to ensure species persistence. For example, our analysis indicates that halting extinction for the Forked Spyridium (*Spyridium furculentum*), a small shrub growing in western Victoria, requires active restoration of 2,500 $km^2$ of Wimmera woodlands habitat and cinnamon fungus (*Phytophthora cinnamomic*) management, costing ~AUD1.8 billion/year (see Dataset S1, Tab 13 for size of restoration per species to halt extinction). However, a cheaper strategy of actively protecting occupied habitat patches by weeding, stock exclusion, and translocation planting into unoccupied suitable habitats could likely keep this species' persisting for a much lower price tag (48). This approach would not likely lead to downlisting or delisting until active restoration occurs.

Our approach to estimating costs of avoiding extinction and recovering species relies on reverse-engineering of the IUCN Red List criteria to identify the minimum habitat area or number of populations required to ensure species stay in an existing threat category or move to a lower one. The IUCN Red List is a comprehensive inventory that evaluates the global conservation status of plant and animal species, classifying them into categories ranging from Least Concern to Extinct based on criteria such as population size, rate of decline, and geographic range (49). This system works well for many well-known species, providing critical information for conservation efforts, including on the threats most impacting the species survival (50). However, it has limitations (51). The extinction risk ranking rules do not seem to apply readily to many plant species, particularly those that can persist in small, isolated habitats (52). Many plant species exhibit unique survival strategies and ecological dynamics that challenge traditional extinction models, in which case our approach may have overestimated the size of the area requiring management and protection. We have attempted to overcome these limitations using expert knowledge to identify what are the key threats and to refine targets; however, overestimations may have still occurred.

**National and Global Implications.** Many nations have set ambitious targets to reverse the declining trends in biodiversity (53). Here, we have provided a national estimate of the funding commitment needed to meet targets for avoiding extinction in species prioritized in national policy. Although there are some specific characteristics of conservation in Australia that may have contributed to the high costs estimated here, it is likely that our approach, analyses, and conclusions have global applicability. Our results demonstrate a sobering likelihood that these targets will fail to be met under current levels of funding commitments. Far higher levels of investment, coupled with supporting legislation, strong governance, and transparent monitoring systems, are required to ensure that nations meet conservation commitments, and to succeed in our obligations to future generations.

## Materials and Methods

Using the Commonwealth Government's Species of National Environmental Significance (SNES) dataset (downloaded March 2024), we extracted the 110 priority species habitat maps (54). These 110 individual species maps were mostly at one $km^2$ resolution, with 19 at 10 $km^2$ resolution. These maps are broken into "known to occur" (recent occurrence records with a 1 to 10 $km^2$ buffer), "likely to occur" (including less recent occurrence records with a 1 to 10 $km^2$ buffer), and "may occur" [MaxEnt developed species distribution models (54)].

Using the study by Ward et al., we extracted all threats impacting each of the 110 priority species (19). Every species habitat map was clipped to each corresponding spatial "Threat Abatement Strategy" map developed in ref. 17

(Dataset S1, Tab 1). These action maps included Critical sites access management, Disease management (general), Disease management (*Phytophthora*), Ecological fire regime management, Forestry management, Grazing management, Hydrology management, Invasive fish management, Invasive herbivore management, Invasive predator management, Invasive rabbit management, Invasive weed management, Invasive/problematic bird management, Map and protect climate refugia, and Habitat restoration (cleared and restorable). Here, cleared is defined as per the National Vegetation and Information System (Commonwealth of Australia, 2020a). Restorable areas were identified via the Catchment Scale Land Use of Australia layer–2020 (28) and include "Nature Conservation", "Managed resource production", "Other minimum use", "Grazing native vegetation", "Production native forests", "Grazing modified pastures", "dryland cropping", "dryland horticulture", and "land in transition." As such, we assumed areas were unrestorable if they were active mines, waste, rural residential and farm infrastructure, urban intensive uses (vegetated areas within urban areas were retained), irrigated uses, and plantations. While water is restorable, we removed water bodies and focused on restoration along riparian zones. For all areas that could be used for agriculture, we used the price per ha from an Australian broadacre farmland value layer (55) to identify land owner opportunity costs (i.e., lost income due to native vegetation being restored and managed on agricultural land) for the areas that would require protection and management.

To align with the annualized costs of the other spatial layers, we used an 8% annual leasing cost on the total farmland value (56, 57). Some species required additional actions not captured above, such as captive breeding programs and/or translocations (Dataset S1, Tab 5). To identify the species that need these actions (and the costs of such actions), we searched gray and peer-reviewed literature such as species' recovery plans and conservation advices. In some instances, these actions were only needed to meet specific objectives (e.g., to meet delisting but not required for downlisting). These actions were verified by experts (coauthors of this paper) and associated costs were added after the spatial prioritization. Some costs were calculated and published many years earlier, so to bring all costs to 2023 amounts we used real inflation estimates over time (58) (Dataset S1, Tab 14). We also explored two threat management scenarios: i) manage all known threats and ii) manage a subset of the existential threats that, optimistically, would be sufficient to enable the species to increase (see threats labeled "Essential" in Dataset S1, Tab 2). This subset of threats was identified via expert elicitation (see below for details).

The spatial action maps were available for terrestrial and freshwater ecosystems on mainland Australia only (17). Therefore, for all species outside of mainland Australia (Dataset S1, Tab 3), we used the cost per km$^2$ as outlined by Yong et al. and the Norfolk Island Region Threatened Species Recovery Plan (59). As we do not have threat distribution maps for these off-shore threats (unlike mainland threats), we assumed that if the species is impacted by a particular threat, then the management is required across the entire terrestrial or inland waters habitat. We excluded all marine and perimarine species including Australian sea-lion (*Neophoca cinerea*), olive ridley turtle (*Lepidochelys olivacea*), green turtle (*Chelonia mydas*), short-nosed sea snake (*Aipysurus apraefrontalis*), White's seahorse (*Hippocampus whitei*), cauliflower soft coral (*Dendronephthya australis*), red handfish (*Thymichthys politus*), freshwater sawfish (*Pristis pristis*), Maugean skate (*Zearaja maugeana*), and gray nurse shark (*Carcharias taurus* east coast subpopulation) as we do not have spatially explicit costs for managing all marine threats. We also excluded eastern curlew (*Numenius madagascariensis*) as their biggest threats are in other countries, so regardless of the management practices employed in Australia, without that international corporation, we cannot guarantee the three different objectives of halting extinction, downlisting, or delisting to be successful (see below for more details of objectives). With these exclusions, 99 priority species remained within our analysis.

We merged the spatial action maps together to create one distinct map of each action, meaning that management of a given threat at a given site for one species is not double counted for the management of the same threat at the same site for another species. This ensured complementarity across the costs and actions, as well as allowed for quantifications of total land and finances needed per action. There were nonspatial actions and costs for Policy and Education, Critical Sites Access Management, Forestry Management, Grazing Management, Habitat Restoration, Hydrology Management, Invasive Fish Management, Biosecurity, and Map Refugia which were added to the total cost after the spatial prioritization of actions (Dataset S1, Tab 4). To find the total cost, we summed each of the cost maps.

We estimated the cost of meeting three conservation objectives including preventing species extinction (i.e., ensuring no species slips below Critically Endangered levels), downlisting all species (i.e., moving species from Critically Endangered to Endangered, Endangered to Vulnerable, and Vulnerable to off the list), and delisting species from the threatened list (i.e., removing all extinction risk). We acknowledge that while the federal government aims to "reduce the risk for all priority species" (12), this objective can be interpreted in various ways. Our interpretation is that this goal involves downlisting all species to a lower conservation status, thereby reflecting a significant reduction in their risk of extinction. To meet each objective, we defined species-specific management targets. However, in the absence of species-specific knowledge on an adequate, species-specific protection and management area target, we reverse-engineered the IUCN Red List criteria to ensure the species does not meet these thresholds (27). As some species are listed under different criteria, we first calculated the area targets that would be required under criteria A2, A3, A4, and B1 and used the upper area threshold for each species (Table 1). For birds and mammals, we are also considered D1 (very small or restricted populations) and how much area may be needed to reach objectives. We recognize that while A2, A3, and A4 are not area targets, it can be based on a comparably proportionate decline in Extent of Occurrence (EOO). We chose to focus on B1 rather than B2 as B1 is conservative estimate, particularly when the maps available in Australia are a midway estimate between EOO and Area of Occupancy (AOO). For example, koala (*P. cinereus*) has an EOO of approximately 760,000 km$^2$. To meet the A2 criterion for Critically Endangered, koala need to be reducing in population size by ≥80%. Therefore, for koala, we set the target to 20% (or 152,000 km$^2$ that is required to be protected and managed for all threats) of current distributional extent to ensure the species remains at Critically Endangered levels and thus preventing extinction. As the Critically Endangered threshold for B1 for this species is 100 km$^2$ (and 10 km$^2$ under B2), we chose the target identified using A2 (152,000 km$^2$) as it is larger and more conservative to halt extinction for this species. Whereas for Christmas Island goshawk (*Accipiter hiogaster natalis*) the EOO is 136 km$^2$. Therefore, for this species we set the target to 100 km$^2$ (using the B1 criterion), rather than 27 km$^2$ (or 20% using the A2 criterion). This species was identified as one that could never meet the criteria to be delisted, as it would never have >1,000 mature individuals. We use the known and likely to occur habitat sizes to set targets, except for six species which have experienced severe habitat contractions, for which we set targets using the known, likely, and may occur habitats for species-specific management targets. In addition, we verified these targets with eight species experts using a modified Delphi approach. Here, we sent via email the precalculated targets for each species. Experts then checked the targets and made recommendations for changes. If any target was identified as too low among any of the experts, we revised the estimate to the upper area threshold recommended. We also asked experts to verify whether species required a minimum number of locations to ensure objectives could still be met in the face of large stochastic events, such as the 2019–2020 megafires (60). We then sent these revisions back to experts to ensure consensus was achieved in estimated targets.

To prioritize areas under each objective, we used Marxan version 4.0.6 on ArcGIS version 10.8.1 (61). Marxan is a decision-support tool which helps decision-makers find solutions to conservation planning problems. We used the above-described total cost layer and variable targets depending on the objectives in Dataset S1, Tab 5. The planning units were 1 km × 1 km (resulting in over 5.8 million planning units) with a Species Penalty Factor (i.e., the multiplier that determines the size of the penalty that will be added to the objective function if the target for a conservation feature is not met in the current reserve scenario) of 10, chosen to ensure our solutions met all conservation targets. Each conservation feature used in Marxan was the habitats as per the Commonwealth Government's habitat maps (Species of National Environmental Significance). Swift parrot (*Lathamus discolor*) and orange-bellied parrot (*Neophema chrysogaster*) both have specific breeding habitats in Tasmania, then migrate to mainland Australia. Similarly, the red goshawk (*Erythrotriorchis radiatus*), has very specific breeding habitat, almost always found within 2.5 km of rivers. As such, we split these three species into breeding habitat and nonbreeding habitats to ensure enough habitat was prioritized in both areas (Dataset S1, Tabs 15–17).

To analyze which species may receive some cobenefit from halting extinction of the priority species, we overlayed all other threatened species listed under the EPBC Act (as of October 2024). To be included as a cobenefit, we used an

**Table 1. IUCN Red list thresholds for each objective**

| Objective | IUCN listing criteria A2, A3, and A4 | Reversed IUCN listing criteria to estimate A2, A3, and A4 target extent to achieve objective | IUCN listing criteria B1 | Reversed IUCN listing criteria to estimate B1 target extent to achieve objective | IUCN listing criteria D1 | Reversed IUCN listing criteria to estimate D1 target extent to achieve objective |
|---|---|---|---|---|---|---|
| **Halting extinctions** | CR listing: ≥80% population size reduction | Remain CR or better: ≥20% protected and managed | CR listing: <100 km$^2$ EOO | Remain CR or better: ≥100 km$^2$ EOO (≥2 locations) *Or 100% if EOO is less than above target | CR listing: <50 mature individuals | Remain CR or better: ≥50 mature individuals |
| **Downlistings CR to EN** | EN listing: ≥50% population size reduction | Move to EN: ≥50% protected and managed | EN listing: <5,000 km$^2$ EOO | Move to EN: ≥5,000 km$^2$ EOO (≥5 locations) | EN listing: <250 mature individuals | Move to EN: ≥250 mature individuals |
| **EN to VU** | VU listing: ≥30% population size reduction | Move to VU: ≥70% protected and managed | VU listing: <20,000 km$^2$ EOO | Move to VU: ≥20,000 km$^2$ EOO (≥10 locations) | VU listing: <1,000 mature individuals | Move to VU: ≥1,000 mature individuals |
| **VU to not listed** | Not stated | Move off list: ≥80% protected and managed | Not stated | Move off list: ≥30,000 km$^2$ EOO (≥10 locations) *Or 100% if EOO is less than above target | Not stated | Move off list: ≥2,000 mature individuals |
| **Delistings** | Not stated | Move off list: ≥80% protected and managed | | Move off list: ≥30,000 EOO km$^2$ *Or 100% if EOO is less than above target | Not stated | Move off list: ≥2,000 mature individuals |

overlap threshold of 10%, following other studies (30). We recognize that not all species will derive a significant cobenefit from managing threats that do not directly impact them. For instance, a plant species may not benefit from the management of invasive predators. We therefore limited benefits from certain actions to select taxonomic groups (Dataset S1, Tab 18). For example, most species, including both plants and animals, will cobenefit from efforts such as habitat retention, ecological restoration, and appropriate fire management. These actions generally improve the overall ecosystem health, thereby supporting a broader range of species and enhancing biodiversity. We also explored the carbon cobenefits that could be a mechanism to cover the costs of threatened species recovery, by intersecting the prioritized area for halting species extinction with an existing layer that predicts the maximum aboveground biomass across Australia (62). As the maximum above ground biomass is at a resolution of 250 m × 250 m, yet the units of measurement are tonnes per dry matter per ha, we multiplied each pixel by 6.25. To estimate the total carbon sequestered, we assumed that 50% of the dry matter is elemental carbon (63). This elemental carbon was then converted to tonnes of Carbon Dioxide Equivalent ($tCO_2e$) by multiplying by 3.67. Acknowledging the typical carbon crediting period is 25 y, we applied a 25% reduction. To translate $tCO_2e$ to potential revenue, we calculate the present value of \$35/$tCO_2e$ over 25-y timeframe using a 4% discount rate.

We also provide an estimate of the total cost for all threatened species listed under the EPBC Act as of October 2024 by calculating the median cost per taxonomic group for the 99 species analyzed and multiplying by the total number of species per group (13).

To analyze the opportunities for different stakeholders to engage in conservation on these priority areas, we explored land tenure. To identify land tenures, we overlayed prioritized areas for downlisting with a land tenure layer (64).

**Data, Materials, and Software Availability.** All study data are included in the article and/or *SI Appendix*.

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