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# Shifting baselines clarify the impact of contemporary logging on forest-dependent threatened species

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**Abstract**
Despite the importance of protecting forests and woodlands to achieve global climate and biodiversity goals, logging impacts persist worldwide. Forestry advocates often downplay these impacts but rarely consider the cumulative threat deforestation and degradation has had, and continues to have, on biodiversity. Using New South Wales (Australia) as a case study, we quantify the extent of deforestation and degradation from 1788 (pre-European colonization) to 2021. We used historical loss as a baseline to evaluate recent logging (2000–2022) and the condition of the remaining native forest and woodland. Condition was quantified by measuring the similarity of a current ecosystem to a historical reference state with high ecological integrity. Using these data, we measured the impacts on 269 threatened terrestrial species. We show that possibly over half (29 million ha) of pre-1788 native forest and woodland vegetation in NSW has been lost. Of the remaining 25 million ha, 9 million ha is estimated to be degraded. We found recent logging potentially impacted 150 species that had already been affected by this historical deforestation and degradation, but the impacts varied across species. Forty-two species that were

identified as impacted by historical deforestation and degradation and continue to be impacted by logging, now have ≤50% of their pre-1788 extent remaining that is intact and nine species now have ≤30%. Our research contextualizes the impact of current logging against historical deforestation and highlights deficiencies in environmental assessments that ignore historical baselines. Future land management must consider both the extent and condition of remaining habitat based on pre-1788 extents.

**KEYWORDS**

conservation assessment, deforestation, degradation, environmental policy, extinction, impact assessments, species endangerment

## 1 | INTRODUCTION

The global native forest and woodland estate harbors up to 100 million different species (80% of all terrestrial plants and animals (United Nations, 2021)), sequesters a net 7.6 billion metric tonnes of $CO_2$ per year (1.5 times more carbon than the United States emits annually (Harris et al., 2021)), and provides essential ecosystem services that directly support more than 1.6 billion people (IUCN, 2021; UNEP and FOA, 2020). Despite their critical role in helping humanity overcome the challenges of biodiversity loss, climate change, and achieving global sustainability (FAO and UNEP, 2020), forests and woodlands are among the most structurally altered terrestrial biomes on Earth (Williams et al., 2020).

Deforestation is defined as the outright removal and permanent conversion of forest or woodland to a non-woody land use, whereas degradation is defined as the gradual process of function or biomass decline, changes to taxa composition, or erosion of soil quality (European Union Reducing Emissions from Deforestation and forest Degradation, 2022). Both deforestation and degradation are urgent environmental problems, driving considerable global protection agendas (e.g., Leaders pledge for Nature, 2022; Secretariat of the Convention on Biological Diversity, 2022) and restoration goals (The Bonn Challenge, 2020; Trillion Trees, 2021). Deforestation and degradation rates are increasingly well documented at both global (Beyer et al., 2019; Grantham et al. 2020a; Williams et al., 2020) and national scales (Grantham et al. 2020b; Williams et al. 2021a). However, the cumulative impact of deforestation and degradation on forest-dependent species' habitat, over the long timescales humans have been impacting forests through industrial land uses, is often ignored in contemporary environmental impact assessments.

Thus, a major knowledge gap is a holistic, contextual assessment of contemporary drivers of degradation against a historical quantification of deforestation and degradation. In Australia, there have been published studies examining the extent of deforestation and fragmentation of forests between pre-European colonization (1788) and 2009 (Bradshaw, 2012) and the extent of recent deforestation of forest-dependent threatened species habitat (Ward et al., 2019). However, no assessment of the ongoing impact of native forest and woodland logging, a manageable and contemporary driver of degradation, has been considered in the holistic context of historical impacts.

The failure to place logging within a historical conservation context means current environmental assessments and environmental accounting are perpetuating shifting baselines, making them problematic for decisions about future management (Lindenmayer & Laurance, 2012; Papworth et al., 2009; Soga & Gaston, 2018). It also impedes accurate reporting on how much habitat has been destroyed or degraded (Ward et al. 2022a). These contextual impact assessments are crucial to establish how feasible it will be for nations like Australia to meet the goals agreed upon in international agreements such as the Sustainable Development Goals (United Nations Sustainable Development Goals, 2015), the Kunming-Montreal Global Biodiversity Framework (Secretariat of the Convention on Biological Diversity, 2022), and Leaders pledge for Nature, (2022). At local management scales, it will also allow for more complete assessments when analyzing the likely consequences of current and future contemporary degradation through activities like logging. When these activities are undertaken in isolation and not considered in long-term land management histories, relatively small areas that are logged (or planned to be logged) can be presented as inconsequential. This is especially true when small areas are presented as total historical habitats, without also acknowledging how much of that former area is already destroyed or degraded (Rittenhouse et al., 2010).

Here, using New South Wales (NSW), Australia as a case study, we provide an assessment of historical forest and woodland deforestation since 1788 (pre-European colonization of Australia)—2021 alongside an assessment of degradation (from 1788 to 2018). We then assess the impacts of logging (2000–2022), one of several ongoing contemporary drivers of degradation, against historical deforestation, and degradation. This helps to provide an overall assessment of how ongoing drivers are affecting vegetation types and threatened terrestrial (and semi-terrestrial) forest-dependent species.

Australia has many endemic flora and fauna and is one of 17 mega-biodiverse countries. Many of these endemic species have suffered significant declines in recent decades. Australia has 2003 species listed as threatened with extinction by the Federal Government and 103 taxa listed as extinct (Commonwealth of Australia 2022a). Deforestation and degradation is a major cause of biodiversity loss (Fischer & Lindenmayer, 2007; Ford, 2011; Kearney et al., 2023; Mac Nally et al., 2009; Ward et al., 2021). Although we cannot change historical deforestation and degradation beyond focussing on targeted restoration where possible (Mappin et al., 2021; Ward et al. 2022b), key stakeholders and decision-makers can prevent further degradation from logging, especially in areas that are critical for securing threatened species (Ward, et al., 2022). We argue that assessments like the ones undertaken here should be used for future land management decisions, especially when considering the impact of any planned activity that degrades or destroys intact vegetation.

## 2 | METHODS

### 2.1 | Study region

Our study covers the state of NSW, Australia, which is proportionally, the second most forested and woody state on the Australian continent. NSW supports more than 1600 plant community types (NSW Government, 2022) and 532 threatened species (233 of which are endemic to NSW) listed as vulnerable, endangered, or critically endangered under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999, Australia's key federal piece of environmental legislation (Commonwealth of Australia, 1999).

### 2.2 | Threatened species data

To examine the potential impact on threatened species (as of 2022), we first created a list of nationally listed threatened species using the information available from the Federal Government's dataset (Commonwealth of Australia 2022a). The distributions of each of these taxa were then sourced from a publicly available database provided by the Federal Government's Department of Climate Change, Energy, the Environment and Water (retrieved 15th October 2022) using a combination of occurrence records and MaxEnt.

MaxEnt (or maximum entropy modeling) predicts species occurrences by considering the limits of environmental variables of known locations (Elith et al., 2011). The information used to create the MaxEnt modeled distributions of threatened species was sourced from a range of government, industry, and nongovernment organizations with expert opinion and reference to published information. As of 15th October, 2022, there were 532 threatened species, subspecies, and populations (hereafter referred to as "taxa") occurring in NSW (with at least 1% of total distribution), with most distributions generalized to $\sim 1 km^2$ or $\sim 10 km^2$ grid cells (Commonwealth of Australia, 2022a, 2022b). We refined these spatial data to 484 forest-dependent terrestrial or peri-terrestrial species. Forest-dependent is defined as a taxon's habitat that intersects with ≥5% of forest or woodland vegetation groups mapped in the pre-1788 National Vegetation Information System (NVIS 6.0; Commonwealth of Australia, 2020). We further refined this forest-dependent species list using data from Taylor & Lindenmayer, 2023, and expert verification, which resulted in 269 taxa (Taylor & Lindenmayer, 2023). Peri-terrestrial taxa included threatened frogs and turtles. We did not include aquatic or some peri-terrestrial species such as fish or crayfish as the impacts (and method to measure impact) can be markedly different relative to terrestrial systems. We use threatened taxa as the focus of this study, recognizing that historical deforestation and degradation impacts have most likely contributed to their contemporary threatened status.

### 2.3 | Historical clearing map

We identified the extent of deforestation from 1788 to 2021 using five lines of evidence (Figure 1). The first was the Australian Government's NVIS 6.0 (Commonwealth of Australia, 2020). From the NVIS, we use two spatial layers that summarizes Australia's present (~2018) and historical extent of native vegetation (~1788), classified into 32 Major Vegetation Groups determined by structural and floristic information including dominant genus, growth form, height, and cover, as well as one land cover group called "cleared, nonnative vegetation, buildings." The NVIS (1 ha resolution) current and historical


**FIGURE 1** The nine steps undertaken in this analysis to create the historical deforestation map (images created by DALL-E 2).

vegetation maps are produced by the Australian Government using a rigorous and standardized mapping methodology, and are explicitly designed for comparative purposes (Commonwealth of Australia, 2020). The maps are based on vegetation data spanning over 100 individual projects (e.g., field surveys) produced over the last 50 years (Commonwealth of Australia, 2020). While both current and historical maps are indicative, we propose that comparing these two maps is appropriate for approximating changes in vegetation coverage between 1788 and now, especially with the inclusion of the category identified as "cleared, nonnative vegetation, and buildings" in the current layer of NVIS (Simmonds et al., 2019). The "cleared, nonnative vegetation, and buildings" category corresponds to areas with all or most native vegetation removed, and is now urban areas and cropland. It also includes a wide range of grazing land where the native trees and shrubs have been removed, as well as areas where the understorey is dominated by introduced species. All areas identified as "cleared, nonnative vegetation, buildings" in the current NVIS were extracted from the state-wide native vegetation groups and made the primary subject of the analysis (i.e., all other areas are dropped).

The second map used to identify forest and woodland loss was the state vegetation type map (SVTM), which is a state-wide vegetation map using a vegetation classification hierarchy, including vegetation formations, vegetation classes, and plant community types (NSW Government, 2022). As well as vegetation groups, such as grassy woodlands, semi-arid woodlands, and freshwater wetlands, the SVTM also identifies "nonnative" and "no vegetation" as of 2021. The SVTM is more current compared to the NVIS 2018 because it is based on the best available aerial and satellite imagery (i.e., SPOT 5, SRTM, Landsat), a collection of environmental variables, and existing vegetation mapping using 93,227 vegetation plots up until 2021 (NSW Government, 2022).

We used two additional forest and woodland loss spatial maps (Ward et al., 2019; Thomas et al., 2024)—derived from Australia's National Carbon Accounting System (NCAS) forest and woodland cover dataset—to identify forest and woodland clearing from 2000 to 2021. The NCAS pixels depict forest and woodland coverage into three categories: "2" represents forests, "1" indicates sparse woodlands, and "0" signifies areas without forest or woodland vegetation. Ward et al. (2019) and Thomas et al. (2024) determined habitat loss for a specific year by comparing the average pixel value of the preceding 10 years with the average value for the subsequent 2 years. A minimum difference of one in these values indicated habitat loss. This methodology was adopted to distinguish permanent environmental changes from short-term natural fluctuations. Consequently, we produced binary maps illustrating the loss of forest and woodland over 19 distinct periods, starting from 2000 to 2002, followed by 2002–2004, and then annually up to 2021. These 19 maps were then merged together using ArcGIS Pro version 3.1.0 (ESRI, 2023).

The fifth map utilized was the habitat condition assessment system (HCAS) version 2.1 applicable to 2018 (Harwood et al., 2021; Williams et al. 2021a). HCAS is a way of combining environmental data, remote sensing data, and intact condition reference sites to provide a consistent estimate of habitat "condition" or quality for all locations across Australia (Harwood et al., 2016). Condition is defined as the predicted capacity to support the wildlife expected in a given area under natural conditions (Williams, Tom, et al., 2021). HCAS v2.1 provides, for every 250m$^2$ pixel, a score from 0 to 1, which can be broken up into five ordinal categories including residual (0.81–1), modified (0.61–0.80), transformed (0.41–0.60), replaced (0.21–0.40), and removed (0.20–0), to approximate the generalized states and transitions narrative proposed by Thackway and Lesslie (2008) for Australian native vegetation, and as used in National State of the Environment reporting (Thackway & Lesslie, 2008; Williams et al. 2021b).

To create a deforestation map from 1788 to 2021, we used a Boolean logic to identify if a given location was identified as lost in any of the five maps (i.e., the current NVIS "cleared, nonnative vegetation, and buildings" data, SVTM "nonnative" and "no vegetation" data, the two forest and woodland loss datasets from Ward et al. (2019) and Thomas et al. (2024), and HCAS "replaced" and "removed" data). To identify just deforestation of forests and woodlands, we overlayed this combined map with forest and woodland vegetation groups as per the historical NVIS map (from hereon, referred to the historical deforestation map).

We overlayed the historical forest and woodland clearing map with individual taxa distribution maps to quantify impact for the 269 EPBC Act listed forest-dependent taxa within NSW. To quantify how much of the remaining taxa distribution was degraded, we overlayed the modified (0.61–0.80) and transformed (0.41–0.60) pixels from the HCAS map (hereon referred to as the "degradation map") with individual taxa distribution maps. We acknowledge that in some cases, calculations of loss and degradation for specific taxa may be an underestimate, as we used only distributions for where species occur currently, which may not be their full historical distribution. For most taxa, their pre-European colonization distributions are unknown as vegetation was destroyed or degraded before documentation by Western science. Where historical distributions are larger than the current estimates, our analysis will underestimate the extent of historical impacts of deforestation and degradation. When reporting on species impacts, we considered only the forest or woodland portion of habitat that was within NSW.

## 2.4 | NSW logging data

Logging data were retrieved from Forestry Corporation of New South Wales (FCNSW) Open Data Site (FCNSW, 2021) (retrieved November 17, 2022). These data show forests and woodlands that have been logged between 2000 and August 2022. We removed all plantations (provided by FCNSW in August 2021) from the logging layer because plantations were captured in the above deforestation layer. To ensure no double counting of deforestation or degradation, we subtracted any logging overlaps from the historical deforestation layer and the historical degradation layer. We removed any areas that were logged prior to 2000, which is the year the EPBC Act was inaugurated. We intersected taxa distributions to the boundaries of completed logging areas to estimate the overall extent of degradation impacts by logging. To assess the condition of remaining forest and woodland within taxa distributions (i.e., not deforested, degraded, or logged), we intersected all taxa distributions with the residual (0.81–1), modified (0.61–0.80), and transformed (0.41–0.60) pixels in HCAS. Here on, we refer to residual as "intact", and modified and transformed is described as "degraded."

Under the EPBC Act, a taxon may be listed as critically endangered, endangered, or vulnerable for many reasons, including if it experiences a population size reduction of >80%, >50%, or >30%, respectively, measured over the longer of 10 years or 3 generations (where threats are ongoing and unresolved). A decline in area of occupancy, extent of occurrence, and/or quality of habitat exceeding these thresholds can be taken as an indicator of equivalent population declines. Here, we assessed the combination of historical deforestation and degradation, contemporary logging, and remaining condition of forest and woodland within taxa distributions against such criteria.

# 3 | RESULTS

By 2021, the total forest and woodland remaining in NSW was ~25 million ha. The amount of forest and woodland destroyed due to deforestation was ~29 million ha (amounting to 54% of the 1788 native forest estate, which was originally 55 million ha) (Figure 2). Most deforestation has been concentrated along the east coast of NSW,

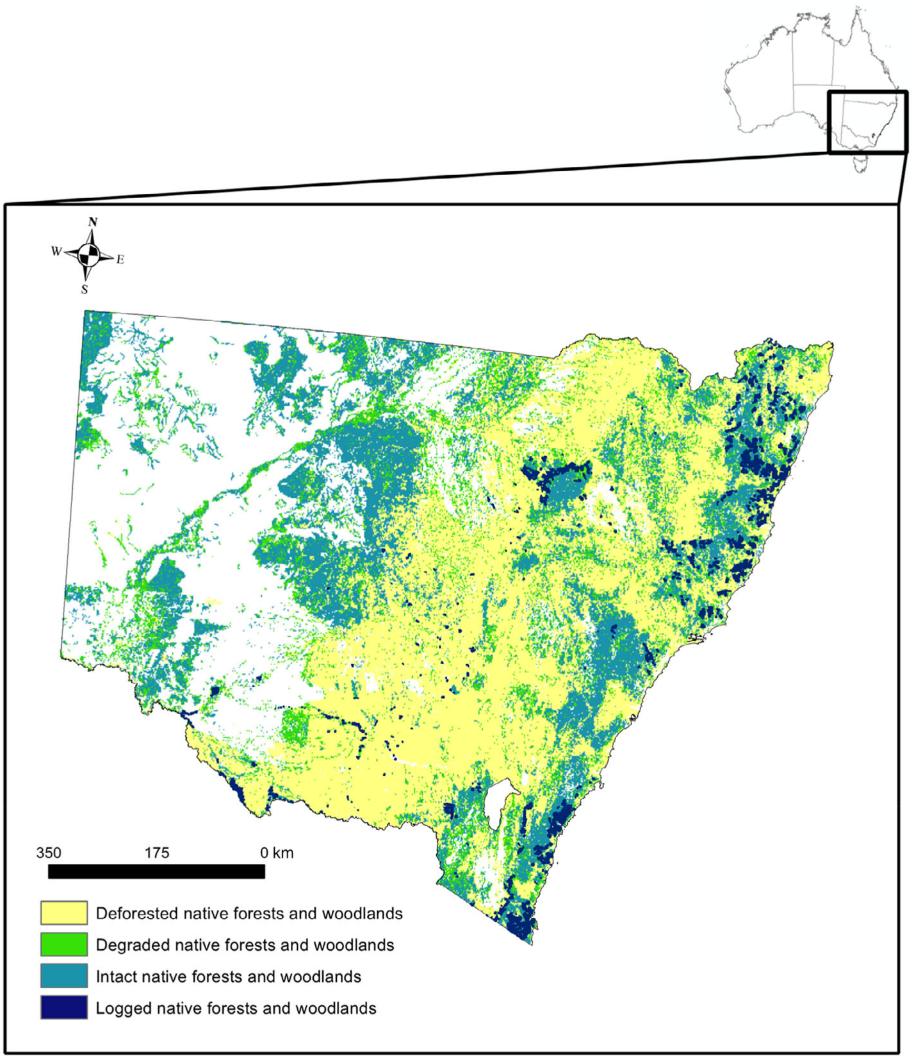


**FIGURE 2** Map of 2000–2022 logged areas in NSW represented in dark blue with dark blue border for increased visibility at this scale. From 1788 to 2021, cleared forests and woodlands is represented in yellow, whereas remaining degraded native forests and woodlands is represented in green. Remaining intact native forests and woodlands is represented as teal.

within several major vegetation groups including Eucalypt Woodlands (10 million ha [35%] remaining), Eucalypt Open Forests (5 million ha [48%] remaining), and Eucalypt Open Woodlands (1 million ha [35%] remaining), based on the historical NVIS mapping product.

Of the remaining forests and woodlands, approximately 16 million ha (30% of all pre-European forest and woodland) is intact, and 9 million ha is degraded. Some vegetation groups have been heavily degraded even if they have not been extensively cleared. When assessing the condition of remaining forest and woodland vegetation groups, 72% of remaining Casuarina forests and woodlands is degraded, 45% of remaining Melaleuca forests and woodlands is degraded, and 39% of remaining Eucalypt open woodland is degraded.

We found that contemporary degradation in the form of logging continues in 12 of 15 of the major forest and woodland vegetation groups in NSW. Our analysis found the area of logged forests constitutes mostly Eucalypt tall open forests (150,000 ha) and Eucalypt open forests (135,000 ha). The total extent of logging within NSW from January 2000 to August 2022 was estimated at 435,000 ha.

### 3.1 | Potential impact of deforestation on threatened taxa

All 29 million ha of historical deforestation overlapped with the distributions of at least one of the 269 threatened taxa considered in this study. In total, 259 (96% of taxa assessed) threatened taxa have potentially been impacted (≥1% of NSW distribution) by historical deforestation. The extent of overlap between deforestation and species distributions ranged from 1% to 99% (mean = 40%, median = 36%). Flora that have the lowest proportional distribution remaining include *Eucalyptus alligatrix* subsp. *miscella* (4% of woody distribution remaining), spiked rice-flower (*Pimelea spicata*; 9% of woody distribution remaining), and Coastal Fontainea (*Fontainea*

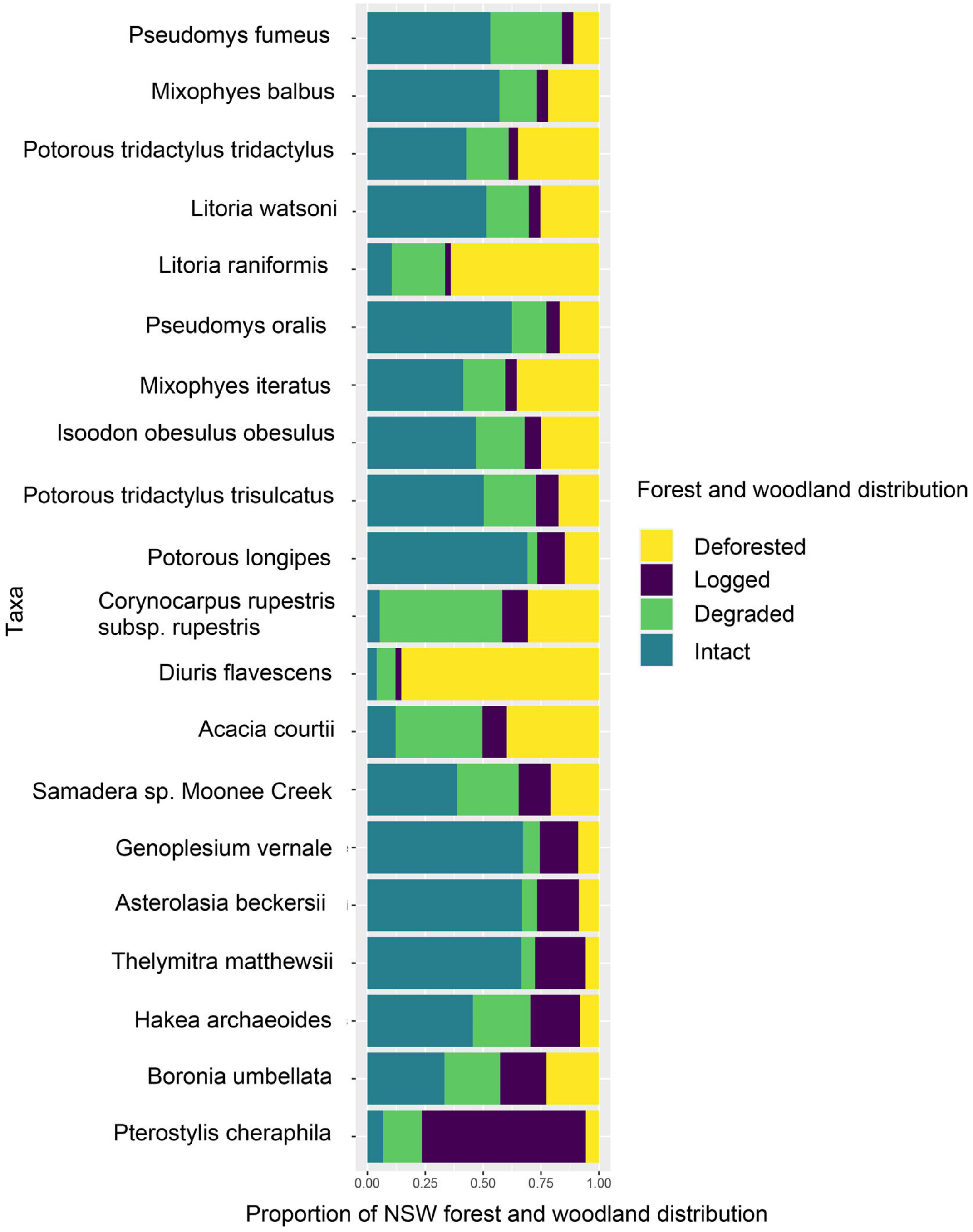


**FIGURE 3** Proportional spatial overlap of historical deforestation (purple), logging (blue), remaining degraded (green), and remaining intact (yellow) highlighting the top 10 flora and top 10 fauna likely impacted by logging. The list shows species, starting from the one most affected by logging (bottom) to the least affected (top), based on the areas that are still intact, degraded, or logged.

*oraria*; 10% of woody distribution remaining). All three species occur only in NSW. Fauna that have potentially the lowest proportional distribution remaining include Sloane's froglet (*Crinia sloanei*; 3% of woody distribution remaining in NSW), Key's matchstick grasshopper (*Keyacris scurra*; 13% of woody distribution remaining in NSW), and golden sun moth (*Synemon plana*; 14% of woody distribution remaining in NSW).

### 3.2 | Potential impact of logging on threatened taxa

Our results, based on the spatial resolution of the data, show that all areas logged between 2000 and 2022 overlapped with the modeled distributions of at least one threatened taxa and, in total, 150 taxa (56% of species assessed) were potentially impacted by logging

(Appendix S1). Of these 150 taxa, 13 are listed as Critically Endangered, 51 as endangered, and 86 as vulnerable. The flora with the highest proportion of NSW forest and woodland distribution overlapped with logging includes Floodplain rustyhood (*Pterostylis cheraphila*) (75% of remaining woody distribution overlapped with logging), Orara boronia (*Boronia umbellata*; 26% of remaining woody distribution overlapped with logging), and *Hakea archaeoides* (24% of remaining woody distribution overlapped with logging; Figure 3). Fauna with the highest proportion of NSW distribution that overlapped with logging include long-footed potoroo (*Potorous longipes*, 14% of remaining woody distribution overlapped with logging), southern mainland long-nosed potoroo (*Potorous tridactylus trisulcatus*, 12% of remaining woody distribution overlapped with logging) and southern brown bandicoot (*Isoodon obesulus obesulus*, 9% of remaining woody distribution overlapped with logging; Data S1).

Taxa with the most distribution by area that overlapped with logging included koala (*Phascolarctos cinereus*, 400,000 ha), south-eastern glossy black-cockatoo (*Calyptorhynchus lathami lathami*, 370,000 ha), and spot-tailed quoll (*Dasyurus maculatus maculatus* [SE mainland population], 310,000 ha). Across all species potentially impacted by logging, the size of the distributions in NSW varied dramatically with species such as Julian's hibbertia (*Hibbertia spanantha*) having as little as 206 ha (min), painted honeyeater (*Grantiella picta*) having 51 million ha (max), with 90,477 ha the median and 1.6 million ha the mean. The large distributions of some species such as koala have a total NSW distribution of 34 million ha, which may help explain the high overlap with logging (395,000 ha). Other species such as *H. archaeoides* have a total NSW distribution of 6000 ha, yet had ~24% of remaining woody distribution that overlapped with logging.

### 3.3 | Potential impact of degradation on threatened taxa

We assessed the condition of the remaining forest and woodland distribution after historical deforestation and degradation, and contemporary logging against EPBC Act listing criteria (see methods) and found that two taxa have ≤10% intact forest and woodland distributions remaining. These were the Endangered Sloane's froglet, of which 5% of remaining forest and woodland distribution is predicted to be intact and the vulnerable Glenugie karaka (*Corynocarpus rupestris* subsp. *rupestris*), of which 9% of remaining forest and woodland distribution is predicted to be intact. Under the EPBC Act criteria, these two species may be eligible for critically endangered status. The distributions of these species possibly continues to be impacted by logging. Forty-one taxa have between 20% and ≤50% of remaining forest and woodland habitat intact (two are critically endangered, 14 are endangered, and 25 are vulnerable; Figure 4a,b). We found 59 taxa have between 50% and ≤70% of remaining forest and woodland habitat intact (six are critically endangered, 16 are endangered, and 36 are vulnerable). When we considered all taxa (rather than just those impacted by both logging and historical deforestation and degradation), we found that two taxa (*E. alligatrix* subsp. *Miscella* and *F. oraria*) could have little to none intact forest and woodland distributions remaining, 19 taxa have ≤20%, 80 taxa have ≤50%, and 85 taxa have ≤70% (noting these species still have degraded habitat which they currently persist within).

## 4 | DISCUSSION

The area of native forest and woodland in NSW deforested between 1788 and 2021 was ~29 million ha. This equated to 54% of all native forests and woodlands across the state or an area approximately the size of New Zealand. This extensive deforestation potentially reduced the distributions of many native species, including 269 forest-dependent threatened taxa we assessed here. Despite these large historical impacts, the potential habitat of 150 of these threatened taxa continues to be logged. We found that 43 threatened species that were found to be potentially impacted by historical deforestation and degradation and continue to be impacted by contemporary logging, now have ≤50% of their precolonization extent remaining that is in intact woody vegetation. Two of these species (Sloane's froglet and pale yellow doubletail *Diuris flavescens*) have approximately <12% of their NSW forest and woodland distribution remaining.

Although deforestation has clear and immediate impacts on biodiversity such as removing habitat, resources, food, and shelter, forest degradation is more subtle and often overlooked (Thorn et al., 2020). Degradation, driven by activities such as logging, is the gradual process of forest biomass decline, changes to taxa composition, or erosion of soil quality (European Union Reducing Emissions from Deforestation and forest Degradation, 2022). Native forest logging has severe degrading impacts on forests and subsequent forest-dependent biodiversity, such as reducting critical resources necessary for taxa survival, including food, shelter, and breeding areas (Ashman et al., 2021;

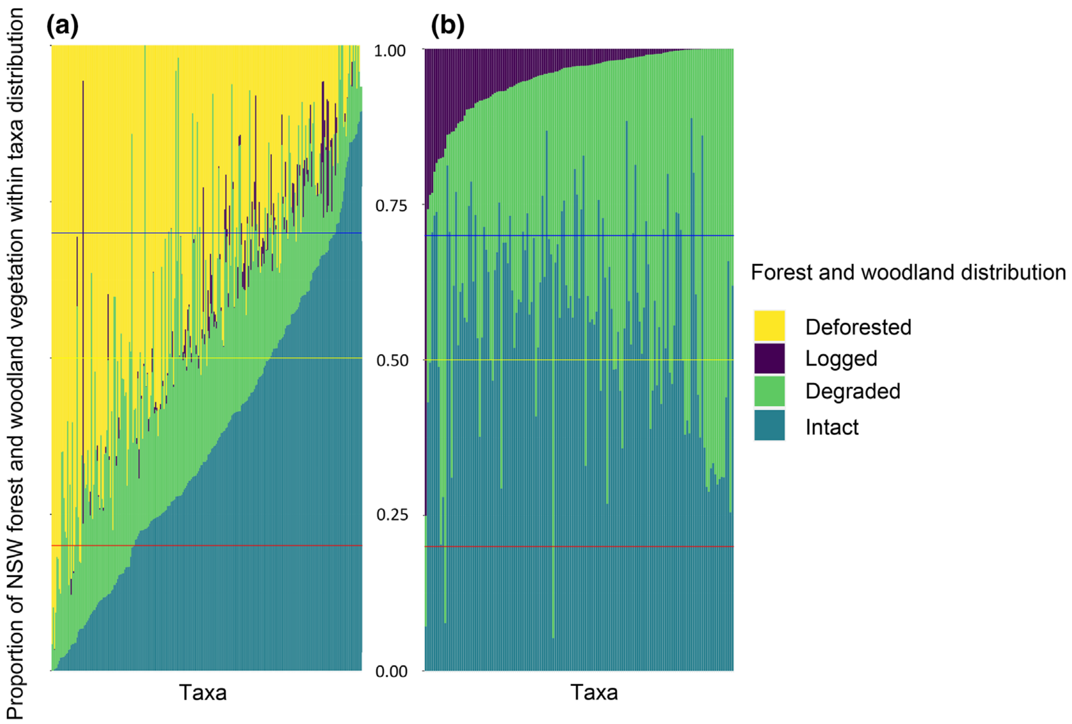


**FIGURE 4** (a) Proportion of each taxa's distribution (*x*-axis) impacted by both historical deforestation, historical degradation, and contemporary logging. We show the combination of forest and woodland distribution potentially impacted from deforestation (brown) and logging (yellow) and highlight the condition of the remaining forest and woodland vegetation within taxon distributions as either degraded (light purple) or intact (dark purple). (b) A subset of taxa highlighting only those impacted by logging. The proportion of each taxa's distribution (*x*-axis) impacted by contemporary logging (yellow) only, highlighting the condition of the remaining forest and woodland vegetation within taxon distributions as either degraded (light purple) or intact (dark purple). The horizontal lines on both figures indicate EPBC Act threat status thresholds of ≤70% (yellow), ≤50% (blue), and ≤ 20% (red) for vulnerable, endangered and critically endangered, respectively. Both figures are ordered based on proportion on forest and woodland distribution remaining that is intact.

Lindenmayer et al., 2013). Another significant impact of logging is the network of roads needed to transport timber out of forests and woodlands and into processing facilities such as sawmills. Road networks cause major problems such as facilitating invasive predator access (e.g., cats (*Felis catus*), dogs (*Canis lupus familiaris*), and foxes (*Vulpes vulpes*)), and the spread of pathogens (e.g., chytrid fungus *Batrachochytrium dendrobatidis* and *Phytophthora cinnamomi*); (Boston, 2016). These drivers of degradation often have larger effects than the reduction of vegetation from constructing the road. Some of these impacts may not manifest for several years or decades after logging, often resulting in an extinction debt (Szabo et al., 2011).

Logging native forests can lead to further degradation as it increases the severity and frequency of wildfires (Lindenmayer et al., 2020; Lindenmayer & Zylstra, 2023; Taylor et al., 2014). Logged areas burned with significantly increased severity during the record 2019/20 fire season in NSW (Lindenmayer et al., 2022). Fire is a critically important ecological disturbance that affects landscape heterogeneity, recruitment, community composition, and ecosystem function (Koltz et al., 2018; McLauchlan et al., 2020). For example, many obligate-seeding plant taxa, which are killed by fire require inter-fire intervals that are long enough to allow recruiting individuals to reach maturity and set seed into the seed-bank to ensure their continued persistence (Enright et al., 2015; Keith, 1996). However, drivers such as anthropogenic climate change and logging are resulting in fire becoming more prevalent, larger in scale, and occurring outside of historical fire seasons (Dowdy et al., 2019; Lindenmayer et al., 2020). This not only causes direct mortality of taxa, removal of habitat, and reduction in resources, fires can also shift ecosystems to different states, or interact with existing threatening process resulting in further degradation (Suding et al., 2004). Such changes in fire regimes represent a key threatening process to more than 800 Australian threatened native species, and 65 threatened communities (DAWE, 2020; Ward et al., 2020). While we cannot control future wildfires, we can implement actions that will help reduce their impact, such as decarbonization and ending native forest logging.

Our results show that is it critical to more holistically assess the impacts of potentially significant and negative actions on threatened species, by placing it in the context of past deforestation and degradation. Under the EPBC Act, proposed destructive actions are individually assessed and do not consider the cumulative impacts (Dales, 2011; Tulloch et al. 2016a) or are not assessed at all with 93% of clearing events not being referred to the EPBC Act (Ward et al., 2019). While relatively limited amounts of impact in any given year may seem insignificant; the combined deforestation and degradation of habitat over 236 years can lead to the extinction of species via many small modifications of habitat (i.e., "death by a thousand cuts") (U.S. Environmental Protection Agency, 1999; Reside et al., 2019; Tulloch et al. 2016b). Ongoing logging perpetuates the problem of shifting baselines (Lindenmayer & Laurance, 2012). The consequences of shifting baselines are significant because it can lead to a gradual decline in environmental standards and goals (Angelstam et al., 1995; Gustafsson et al., 2010). This can result in a failure to take necessary conservation and restoration measures, ultimately leading to a further decline in the health and biodiversity of ecosystems.

Our quantitative results have implications that are useful for evaluating the effectiveness of current policies in NSW. Between 2000 and 2022, NSW logged approximately 435,000 ha of native forest and woodland, all of which overlapped with the distributions of at least one threatened forest-dependent taxon. This impact assessment is likely an underestimate given the rate of new discoveries of species in Australia. For example, in 2022 alone, scientists discovered an additional 139 new species in Australia (CSIRO, 2022). Although the EPBC Act is the primary legislation aimed at protecting biodiversity, the Regional Forest Agreements (RFA) Act 2002 is geared toward ensuring access to forests while ensuring the conservation of forest biodiversity and protection of environmental integrity (The Department of Agriculture, Water and the Environment, 2020). Unfortunately, RFAs have been exempt from following EPBC Act protections (Lindenmayer & Burnett, 2022), even when there are clear breaches, such as degrading threatened taxa habitat which is likely to have a significant impact on those species (Commonwealth of Australia, 1999). Therefore, while logging in NSW has degraded 435,000 ha of native forest across 143 threatened taxa distributions, logging is still legal under current legislation (Ashman & Ward, 2022). Our research suggests that forestry regulations do a relatively poor job at limiting the impacts of logging on the landscape distribution of biodiversity; especially given historical deforestation and degradation, as well as other ongoing forms of contemporary degradation. A broad implication might be that either logging will soon have to stop (to avoid biodiversity impacts) or transform in its approaches to removing far less timber, under much more careful biodiversity spatial planning, while also restoring vast areas where habitat has been lost (using fine-scale spatial analysis to guide that restoration).

Australia has recently committed to international agreements to halt taxa extinctions (e.g., Global Biodiversity Framework; Secretariat of the Convention on Biological Diversity, 2022), prevent further forest degradation (e.g., Glasgow Climate Pact; UNFCCC, 2021), and reverse biodiversity loss (e.g., Natures Pledge; Leaders Pledge for Nature, 2022). The NSW Government has also made commitments to enhance nature conservation including stopping extinctions inside protected areas, stabilizing, or improving the trajectory of all threatened taxa, and removing threatened taxa from the threatened species list (NSW Government, 2021a). Notably, the NSW Government's Koala Strategy has also committed to doubling koala numbers by 2050 (NSW Government, 2021b). Many countries and jurisdictions are now legislating that commodity production (such as beef, cocoa, soy, and timber) must not contribute to deforestation and degradation. For example, the European Union passed new laws in December 2022 to ensure there is now a due diligence process to demonstrate that imported products have not contributed to deforestation or degradation (European Commission, 2022). In addition to driving species to extinction, and possible inaccessibility to markets, logging in its current form is also not economically viable. A recent analysis measured the costs and benefits of logging over a 30-year period to 2051 and found that ending native forest logging in the southern areas of NSW could result in a $61.96 million saving of taxpayer money (Frontier Economics, 2021). Unfortunately, there has been no commitment by the NSW Government to use holistic, landscape scale approaches to change their current practice or end logging in native forests and transition to sustainable plantations (Morgan et al., 2021).

By spatially mapping species habitats at a landscape scale that have been highly impacted by historical deforestation and degradation, our approach provides a pragmatic pathway to achieve policy objectives, demonstrating how conservation efforts can be strategically aligned with national and international commitments (e.g., Sustainable Development Goals or Global Biodiversity Framework). This approach allows for the identification of key areas where management and conservation interventions are most needed and most effective. By integrating the historical deforestation and degradation impacts with current drivers of degradation within a spatial context, the approach promotes a more holistic understanding of the landscape, encouraging contextual assessments to be the basis of all future land management decisions.

### 4.1 | Caveats and limitations

We recognize that our historical impact analysis of forest and woodland within the distributions of threatened taxa is likely an underestimate as we have used known and likely to occur distributions based on recent records of taxa. This does not include the contractions of the historical distribution of species that have occurred due to habitat loss and other threatening processes like invasive taxa and altered fire regimes (Ward et al. 2022a). There are also many nonthreatened species, such as aquatic and peri-terrestrial species, that have experienced huge historical habitat loss and ongoing contemporary degradation that have not been captured here, but it is known that sedimentation, destruction of riparian zones, and creation of roads are all major threats to aquatic communities. We recognize that we are relying on modeled datasets including NVIS and HCAS to estimate historical deforestation and degradation. As such, quantification of impacts across large spatial scales is imperfect. In addition, the high degree of overlap between species and logging may be an artifact of the spatial resolution of the species data (i.e., 1 km × 1 km). On this basis, our study can inform strategic level decisions, but not inform finer-scale operational planning. Unfortunately, the NSW Forestry Corporation do not report their impacts on threatened taxa, so we were unable to compare our results with existing data collected by industry staff.

## 5 | CONCLUSION

Despite strong evidence that Australia's biodiversity is suffering major declines (Legge et al., 2023), degradation by multiple sources including logging, deforestation, and degradation continues. Policy makers and the community must recognize and account for the critical values of intact native forests such as high biodiversity, mitigating climate change, services to people (such as clean water provision and air purification), and their capacity to reduce fire severity. Our research showcases a landscape scale approach to measure the historical impacts of deforestation and degradation, as well as contemporary degradation from one driver, logging. We highlight how threatened taxa may be impacted and emphasize the critical importance of considering these long-term impacts in contemporary settings when it comes to forest management in NSW. These holistic, contextual assessments need to be the basis of all future land management decisions.

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## REFERENCES

Angelstam, P., Majewski, P., & Bondrup-Nielsen, S. (1995). West-east cooperation in Europe for sustainable boreal forests. *Water, Air, and Soil Pollution*, *82*, 3–11. https://doi.org/10.1007/BF01182813

Ashman, K., & Ward, M. (2022). Extinction risk for Australia's iconic glider. *Science*, *378*, 608. https://doi.org/10.1126/science.adf1013

Ashman, K., Watchorn, D., Lindenmayer, D., & Taylor, M. (2021). Is Australia's environmental legislation protecting threatened species? A case study of the national listing of the greater glider. *Pacific Conservation Biology*, *28*, 3. https://doi.org/10.1071/PC20077

Beyer, H. L., Venter, O., Grantham, H. S., & Watson, J. E. M. (2019). Substantial losses in ecoregion intactness highlight urgency of globally coordinated action. *Conservation Letters*, *13*, 1–9. https://doi.org/10.1111/conl.12692

Boston, K. (2016). The potential effects of Forest roads on the environment and mitigating their impacts. *Current Forestry Reports*, *2*, 215–222. https://doi.org/10.1007/s40725-016-0044-x

Bradshaw, C. J. A. (2012). Little left to lose: Deforestation and forest degradation in Australia since European invasion. *Journal of Plant Ecology*, *5*, 109–120. https://doi.org/10.1093/jpe/rtr038

Commonwealth of Australia. (1999). Environment Protection and Biodiversity Conservation Act. Department of Energy and Environment, Commonwealth of Australia.

Commonwealth of Australia. (2020). National Vegetation Information System (NVIS). Accessed June 10, 2021. https://www.environment.gov.au/land/native-vegetation/national-vegetation-information-system

Commonwealth of Australia. (2022a). Species Profile and Threats Database. Department of Energy and Environment Accessed June 10, 2021. http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

Commonwealth of Australia. (2022b). Species of National Environmental Significance. Accessed March 1,2022. https://www.dcceew.gov.au/environment/environmental-information-data/databases-applications/snes

CSIRO. (2022). From fish to ants: 139 new species named by CSIRO. Accessed February 1, 2023. https://www.csiro.au/en/news/news-releases/2022/from-fish-to-ants-139-new-species-named-by-csiro

Dales, J. (2011). Death by a thousand cuts: Incorporating cumulative effects in Australia's Environment Protection and Biodiversity Conservation Act 1999. *Pacific rim law & Policy Journal*, *20*, 149–178. https://digitalcommons.law.uw.edu/wilj/vol20/iss1/6

DAWE. (2020). Preliminary area for environmental analysis—2019/20 fires. https://www.environment.gov.au/system/files/pages/a8d10ce5-6a49-4fc2-b94d-575d6d11c547/files/preliminary-analysis-area-19-jan-2020.pdf

Dowdy, A. J., Ye, H., Pepler, A., Thatcher, M., Osbrough, S. L., Evans, J. P., Di Virgilio, G., & McCarthy, N. (2019). Future changes in extreme weather and pyroconvection risk factors for Australian wildfires. *Scientific Reports*, *9*, 10073. https://doi.org/10.1038/s41598-019-46362-x

Elith, J., Phillips, S. J., Hastie, T., Dudík, M., Chee, Y. E., & Yates, C. J. (2011). A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*, *17*, 43–57. https://doi.org/10.1111/j.1472-4642.2010.00725.x

Enright, N. J., Fontaine, J. B., Bowman, D. M., Bradstock, R. A., & Williams, R. J. (2015). Interval squeeze: Altered fire regimes and demographic responses interact to threaten woody species persistence as climate changes. *Frontiers in Ecology and the Environment*, *13*, 265–272. https://doi.org/10.1890/140231

European Commission. (2022). Green Deal: EU agrees law to fight global deforestation and forest degradation driven by EU production and consumption. Accessed February 21, 2023. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7444

European Union Reducing Emissions from Deforestation and Forest Degradation. (2022). Deforestation and forest degradation. Accessed November 22, 2022. https://euredd.efi.int/about/about-redd/deforestation-forest-degradation/

FAO and UNEP. (2020). The State of the World's Forests 2020. Rome 10.4060/ca8642en

FCNSW. (2021). Plan Portal. Forestry Corporation of New South Wales Accessed November, 2022. https://planportal.fcnsw.net/

Fischer, J., & Lindenmayer, D. B. (2007). Landscape modification and habitat fragmentation: A synthesis. *Global Ecology and Biogeography*, *16*, 265–280. https://doi.org/10.1111/j.1466-8238.2007.00287.x

Ford, H. A. (2011). The causes of decline of birds of eucalypt woodlands: Advances in our knowledge over the last 10 years. *Emu–Austral Ornithology*, *111*, 1–9. https://doi.org/10.1071/MU09115

Frontier Economics, & Macintosh, A. (2021). Comparing the value of alternative uses of native forests in Southern NSW. https://www.frontier-economics.com.au/documents/2021/11/comparing-the-value-of-alternative-uses-of-native-forest-in-southern-nsw.pdf/

Grantham, H. S., Duncan, A., Evans, T. D., Jones, K. R., Beyer, H. L., Schuster, R., Walston, J., Ray, J. C., Robinson, J. G., Callow, M., Clements, T., Costa, H. M., DeGemmis, A., Elsen, P. R., Ervin, J., Franco, P., Goldman, E., Goetz, S., Hansen, A., … Watson, J. E. M. (2020). Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity. *Nature Communications*, *11*, 1–10. https://doi.org/10.1038/s41467-020-19493-3

Grantham, H. S., Shapiro, A., Bonfils, D., Gond, V., Goldman, E., Maisels, F., & Plumptre, A. J. (2020). Spatial priorities for conserving the most intact biodiverse forests within Central Africa. *Environmental Research Letters*, *15*. https://doi.org/10.1088/1748-9326/ab9fae

Gustafsson, L., Kouki, J., & Sverdrup-Thygeson, A. (2010). Tree retention as a conservation measure in clear-cut forests of northern Europe: A review of ecological consequences. *Scandinavian Journal of Forest Research*, *25*, 295–308. https://doi.org/10.1080/02827581.2010.497495

Harris, N. L., Gibbs, D. A., Baccini, A., Birdsey, R. A., de Bruin, S., Farina, M., Fatoyinbo, L., Hansen, M. C., Herold, M., Houghton, R. A., Potapov, P. V., Suarez, D. R., Roman-Cuesta, R. M., Saatchi, S. S., Slay, C. M., Turubanova, S. A., & Tyukavina, A. (2021). Global maps of twenty-first century forest carbon fluxes. *Nature Climate Change*, *11*, 234–240. https://doi.org/10.1038/s41558-020-00976-6

Harwood, T., Donohue, R., Williams, K., Ferrier, S., McVicar, T., Newell, G., & White, M. (2016). Habitat condition assessment system: A new way to assess the condition of natural habitats for terrestrial biodiversity across whole regions using remote sensing data. *Methods in Ecology and Evolution*, *7*, 1050–1059. https://doi.org/10.1111/2041-210X.12579

Harwood, T., Kristen, W., Eric, L., Chris, W., Peter, L., Shuvo, B., Luke, P., Becky, S., Karel, M., Tom, V. N., Anna, R., Fiona, D., Tim, M. V., & Simon, F. (2021). 9 arcsecond gridded HCAS 2.1 (2001–2018) base model estimation of habitat condition for terrestrial biodiversity, 18-year trend and 2010–2015 epoch change for continental Australia. v7 Canberra, Australia (Accessed November, 2022).

IUCN. (2021). Forests and climate change. Geneva, Switzerland https://www.iucn.org/resources/issues-briefs/forests-and-climate-change

Kearney, S. G., Watson, J. E. M., Reside, A. E., Fisher, D. O., Maron, M., Doherty, T. S., Legge, S. M., Woinarski, J. C. Z., Garnett, S. T., Wintle, B. A., Ritchie, E. G., Driscoll, D. A., Lindenmayer, D., Adams, V. M., Ward, M. S., & Carwardine, J. (2023). Threat-abatement framework confirms habitat retention and invasive species management are critical to conserve Australia's threatened species. *Biological Conservation*, *277*, 109833. https://doi.org/10.1016/j.biocon.2022.109833

Keith, D. (1996). Fire-driven extinction of plant populations: A synthesis of theory and review of evidence from Australian vegetation. https://biostor.org/reference/68152

Koltz, A. M., Burkle, L. A., Pressler, Y., Dell, J. E., Vidal, M. C., Richards, L. A., & Murphy, S. M. (2018). Global change and the importance of fire for the ecology and evolution of insects. *Current Opinion in Insect Science*, *29*, 110–116. https://doi.org/10.1016/j.cois.2018.07.015

Leaders pledge for Nature. (2022). Pledge for Nature. Accessed November 30, 2022. https://www.leaderspledgefornature.org/

Legge, S., Rumph, L., Garnett, S., & Woinarski, J. (2023). Loss of terrestrial biodiversity in Australia: Magnitude, causation, and response. *Science*, *381*, 622–631. https://doi.org/10.1126/science.adg7870

Lindenmayer, D., & Burnett, P. (2022). Biodiversity in court: Will the regional Forest agreements (RFAs) make the EPBC act irrelevant? *Pacific Conservation Biology*, *28*, 393–397. https://doi.org/10.1071/PC21035

Lindenmayer, D., Kooyman, R. M., Taylor, C., Ward, M., & Watson, J. E. M. (2020). Recent Australian wildfires made worse by logging and associated forest management. *Nature Ecology and Evolution*, *4*, 898–900. https://doi.org/10.1038/s41559-020-1195-5

Lindenmayer, D. B., Blanchard, W., Mcburney, L., Blair, D., Banks, S. C., Driscoll, D., Smith, A. L., & Gill, A. M. (2013). Fire severity and landscape context effects on arboreal marsupials. *Biological Conservation*, *167*, 137–148. https://doi.org/10.1016/j.biocon.2013.07.028

Lindenmayer, D. B., & Laurance, W. F. (2012). A history of hubris–Cautionary lessons in ecologically sustainable forest management. *Biological Conservation*, *151*, 11–16. https://doi.org/10.1016/j.biocon.2011.10.032

Lindenmayer, D. B., Zylstra, P., Kooyman, R., Taylor, C., Ward, M., & Watson, J. E. M. (2022). Logging elevated the probability of high-severity fire in the 2019–20 Australian forest fires. *Nature Ecology & Evolution*, *6*, 533–535. https://doi.org/10.1038/s41559-022-01717-y

Lindenmayer, D. B., & Zylstra, P. J. (2023). Identifying and managing disturbance-stimulated flammability in woody ecosystems. *Biological Reviews of the Cambridge Philosophical Society*, *99*, 699–714. https://doi.org/10.1111/brv.13041?af=R

Mac Nally, R., Bennett, A. F., Thomson, J. R., Radford, J. Q., Unmack, G., Horrocks, G., & Vesk, P. A. (2009). Collapse of an avifauna: Climate change appears to exacerbate habitat loss and degradation. *Diversity and Distributions*, *15*, 720–730. https://doi.org/10.1111/j.1472-4642.2009.00578.x

Mappin, B., Ward, A., Hughes, L., Watson, J. E. M., Cosier, P., & Possingham, H. P. (2021). The costs and benefits of restoring a continent's terrestrial ecosystems. *Journal of Applied Ecology*, *59*(2), 408–419. https://doi.org/10.1111/1365-2664.14008

McLauchlan, K. K., Higuera, P. E., Miesel, J., Rogers, B. M., Schweitzer, J., Shuman, J. K., Tepley, A. J., Varner, J. M., Veblen, T. T., Adalsteinsson, S. A., Balch, J. K., Baker, P., Batllori, E., Bigio, E., Brando, P., Cattau, M., Chipman, M. L., Coen, J., Crandall, R., … Watts, A. C. (2020). Fire as a fundamental ecological process: Research advances and frontiers. *Journal of Ecology*, *108*, 2047–2069. https://doi.org/10.1111/1365-2745.13403

Morgan, E., Cadman, T., & Mackey, B. (2021). Integrating forest management across the landscape: A three pillar framework. *Journal of Environmental Planning and Management*, *64*(10), 1735–1769. https://doi.org/10.1080/09640568.2020.1837747

NSW Government. (2021a). Zero extinctions–National parks as a stronghold for threatened species recovery. Sydney, Australia https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Parks-reserves-and-protected-areas/Parks-management-other/national-parks-wildlife-service-threatened-species-framework-210369.pdf

NSW Government. (2021b). NSW Koala Strategy. https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Animals-and-plants/Threatened-species/koala-strategy-2022-220075.pdf

NSW Government. (2022). The NSW state vegetation type map: Methodology for a regional-scale map of NSW plant community types. Sydney, Australia.

Papworth, S. K., Rist, J., Coad, L., & Milner-Gulland, E. J. (2009). Evidence for shifting baseline syndrome in conservation. *Conservation Letters*, *2*, 93–100. https://doi.org/10.1111/j.1755-263X.2009.00049.x

Reside, A. E., Cosgrove, A. J., Pointon, R., Trezise, J., Watson, J. E. M., & Maron, M. (2019). How to send a finch extinct. *Environmental Science & Policy*, *94*, 163–173. https://doi.org/10.1016/j.envsci.2019.01.005

Rittenhouse, C. D., Pidgeon, A. M., Albright, T. P., Culbert, P. D., Clayton, M. K., Flather, C. H., Huang, C., Masek, J. G., Stewart, S. I., & Radeloff, V. C. (2010). Conservation of forest birds: Evidence of a shifting baseline in community structure. *PLoS One*, *5*, 1–9. https://doi.org/10.1371/journal.pone.0011938

Secretariat of the Convention on Biological Diversity. (2022). Post-2020 Global Biodiversity Framework. https://www.cbd.int/doc/c/409e/19ae/369752b245f05e88f760aeb3/wg2020-05-l-02-en.pdf

Simmonds, J. S., Watson, J. E. M., Salazar, A., & Maron, M. (2019). A composite measure of habitat loss for entire assemblages of species. *Conservation Biology*, *33*, 1438–1447. https://doi.org/10.1111/cobi.13331

Soga, M., & Gaston, K. J. (2018). Shifting baseline syndrome: Causes, consequences, and implications. *Frontiers in Ecology and the Environment*, *16*, 222–230. https://doi.org/10.1002/fee.1794

Suding, K. N., Gross, K. L., & Houseman, G. R. (2004). Alternative states and positive feedbacks in restoration ecology. *Trends in Ecology and Evolution*, *19*, 46–53. https://doi.org/10.1016/j.tree.2003.10.005

Szabo, J. K., Vesk, P. A., Baxter, P. W. J., & Possingham, H. P. (2011). Paying the extinction debt: Woodland birds in the mount lofty ranges, South Australia. *Emu*, *111*, 59–70. https://doi.org/10.1071/MU09114

Taylor, C., & Lindenmayer, D. (2023). High conservation values for Australian forests and woodlands. Canberra, Australia.

Taylor, C., Mccarthy, M. A., & Lindenmayer, D. B. (2014). Nonlinear effects of stand age on fire severity. *Conservation Letters*, *7*, 355–370. https://doi.org/10.1111/conl.12122

Thackway, R., & Lesslie, R. (2008). Describing and mapping human-induced vegetation change in the Australian landscape. *Environmental Management*, *42*, 572–590. https://doi.org/10.1007/s00267-008-9131-5

The Bonn Challenge. (2020). The Bonn challenge. Accessed December 14, 2022. https://www.bonnchallenge.org/

The Department of Agriculture water and the environment. (2020). Regional Forest agreements. Accessed February 21, 2023. https://www.agriculture.gov.au/agriculture-land/forestry/policies/rfa

Thomas, H., Ward, M., Simmonds, J., Taylor, M., & Maron, M. (2024). Poor compliance and exemptions facilitate ongoing deforestation. Manuscript submitted for publication.

Thorn, S., Seibold, S., Leverkus, A. B., Michler, T., Müller, J., Noss, R. F., Stork, N., Vogel, S., & Lindenmayer, D. B. (2020). The living dead: Acknowledging life after tree death to stop forest degradation. *Frontiers in Ecology and the Environment*, *18*, 505–512. https://doi.org/10.1002/fee.2252

Trees, T. (2021). Trillion Trees. Accessed December 14, 2022. https://trilliontrees.org/

Tulloch, A. I. T., Barnes, M. D., Ringma, J., Fuller, R. A., Watson, J. E. M., & Mori, A. (2016). Understanding the importance of small patches of habitat for conservation. *Journal of*

*Applied Ecology*, *53*, 418–429. https://doi.org/10.1111/1365-2664.12547

Tulloch, A. I. T., Mortelliti, A., Kay, G. M., Florance, D., & Lindenmayer, D. (2016). Using empirical models of species invasion under multiple threatening processes to identify complementary threat-mitigation strategies. *Conservation Biology*, *30*, 867–882. https://doi.org/10.1111/cobi.12672

U.S. Environmental Protection Agency. (1999). Consideration of cumulative impacts in EPA review of NEPA. Washington, D.C. https://www.epa.gov/sites/production/files/2014-08/documents/cumulative.pdf

UNEP and FOA. (2020). The State of the World's Forests 2020. Forests, biodiversity and people. Rome https://www.fao.org/3/ca8642en/online/ca8642en.html

UNFCCC. (2021). Outcomes of the Glasgow climate change conference – Advance unedited versions (AUVs). UN Campus, Bonn, Germany Accessed November 11, 2022. https://unfccc.int/

United Nations. (2021). Goal 15: Life on land. https://www.unep.org/explore-topics/sustainable-development-goals/why-do-sustainable-development-goals-matter/goal-15

United Nations Sustainable Development Goals. (2015). Sustainable development goals. Accessed April 10, 2020. https://sustainabledevelopment.un.org/?menu=1300

Ward, M., Carwardine, J., Yong, C. J., Watson, J. E. M., Silcock, J., Taylor, G. S., Lintermans, M., Gillespie, G. R., Garnett, S. T., Woinarski, J., Tingley, R., Fensham, R. J., Hoskin, C. J., Hines, H. B., Roberts, J. D., Kennard, M. J., Harvey, M. S., Chapple, D. G., & Reside, A. E. (2021). A national-scale dataset for threats impacting Australia's imperilled flora and fauna. *Ecology and Evolution*, *11*, 11749–11761. https://doi.org/10.1002/ece3.7920

Ward, M., Simmonds, J., Reside, A., Watson, J., Rhodes, J., Possingham, H., Trezise, J., File, L., Fletcher, R., & Taylor, M. (2019). Lots of loss with little scrutiny: The attrition of habitat critical for threatened species in Australia. *Conservation Science and Practice*, *1*, e117. https://doi.org/10.1111/csp2.117

Ward, M., Tulloch, A., Stewart, R., Possingham, H. P., Legge, S., Gallagher, R. V., Graham, E. M., Southwell, D., Keith, D., Dixon, K., Yong, C., Carwardine, J., Cronin, T., Reside, A. E., & Watson, J. E. M. (2022). Restoring habitat for fire-impacted species' across degraded Australian landscapes. *Environmental Research Letters*, *17*, 084036. https://doi.org/10.1088/1748-9326/ac83da

Ward, M., Tulloch, A. I. T., Radford, J. Q., Williams, B. A., Reside, A. E., Macdonald, S. L., Mayfield, H. J., Maron, M., Possingham, H. P., Vine, S. J., O'Connor, J. L., Massingham, E. J., Greenville, A. C., Woinarski, J. C. Z., Garnett, S. T., Lintermans, M., Scheele, B. C., Carwardine, J., Nimmo, D. G., … Watson, J. E. M. (2020). Impact of 2019–2020 mega-fires on Australian fauna habitat. *Nature Ecology and Evolution*, *4*, 1321–1326. https://doi.org/10.1038/s41559-020-1251-1

Ward, M., Watson, J. E. M., Possingham, H. P., Garnett, S. T., Maron, M., Rhodes, J. R., MacColl, C., Seaton, R., Jackett, N., Reside, A. E., Webster, P., & Simmonds, J. S. (2022). Creating past habitat maps to quantify local extirpation of Australian threatened birds. *Environmental Research Letters*, *17*, 024032. https://doi.org/10.1088/1748-9326/ac4f8b

Williams, B. A., Venter, O., Allan, J. R., Atkinson, S. C., Rehbein, J. A., Ward, M., di Marco, M., Grantham, H. S., Ervin, J., Goetz, S. J., Hansen, A. J., Jantz, P., Pillay, R., Rodríguez-Buriticá, S., Supples, C., Virnig, A. L. S., & Watson, J. E. M. (2020). Change in terrestrial human footprint drives continued loss of intact ecosystems. *One Earth*, *3*, 371–382. https://doi.org/10.1016/j.oneear.2020.08.009

Williams, K., Hunter, B., Schmidt, B., Woodward, E., & Cresswell, I. (2021). Australia State of the Environment 2021–land.

Williams, K., Tom, H., Lehmann, E. A., Chris, W., Lyon, P., Bakar, S., Pinner, L., Becky, S., Karel, M., Tom, V. N., Anna, R., Dickson, F., Tim, M. V., & Simon, F. (2021). Habitat condition assessment system (HCAS version 2.1): Enhanced method for mapping habitat condition and change across Australia. Canberra, Australia.

## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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