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Lots of loss with little scrutiny: The attrition of habitat critical for threatened species in Australia

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Abstract

Australia has one of the worst extinction rates of any nation, yet there has been little assessment of the effect of its flagship environmental legislation, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), to prevent species extinction. By coupling remotely sensed forest and woodland data with the distributions of 1,638 terrestrial threatened species, terrestrial migratory species, and threatened ecological communities, we quantified the loss of potential habitat and communities since the EPBC Act came into force in 2000. We found that over 7.7 million ha of potential habitat and communities were cleared in the period 2000–2017. Of this clearing, over 93% was not referred to the Federal Government for assessment, meaning the loss was not scrutinized under the EPBC Act. While 1,390 (84%) species suffered loss, Mount Cooper striped skink, Keighery's macarthuria, and Southern black-throated finch lost 25, 23, and 10% of potential habitat, respectively. Iconic Australian species, such as koala, also lost ~1 million ha (2.3%) of potential habitat. Our analysis showed that the EPBC Act is ineffective at protecting potential habitat for terrestrial threatened species, terrestrial migratory species, or threatened ecological communities. We recommend that when scientifically determinable, critical habitat is demarcated for listed species and communities, which provides absolute protection that is enforced, monitored, and investigated by the regulator. Without a fundamental change in how environmental law is enforced, Australia faces an increasing extinction rate.

KEYWORDS

Australia, biodiversity conservation, Environment Protection and Biodiversity Conservation Act 1999, environmental policy, environmental regulation, habitat destruction, habitat loss, migratory species, threatened ecological communities, threatened species

1 | INTRODUCTION

Earth is in a mass extinction crisis, with species disappearing 100–1,000 times faster than the background rate (Ceballos, Ehrlich, & Dirzo, 2017; IPBES, 2018; Pimm et al., 2014). While this loss of biodiversity is occurring globally, some nations are experiencing declines faster than others (Woinarski, Burbidge, & Harrison, 2015). In Australia, at

least 90 native species have become extinct since European settlement (Australian Government, 2018a). There are many drivers of this extinction crisis including invasive species and changed fire regimes, yet the destruction of vegetation due to agricultural activities, infrastructure, mining, and urbanization is the most significant threat to biodiversity (Braby, 2018; Cresswell & Murphy, 2016; Sands, 2018; State of the Environment Committee, 2011; Taylor et al., 2018). Since European settlement, Australia has lost 33% of all native vegetation, with that loss concentrated in agricultural and coastal regions (National Land and Water Resources Audit, 2001). Furthermore, 1,136 (61%) of Australia's 1,862 federally listed threatened species are recorded by the Federal Government as being seriously affected by habitat loss (Kearney et al., 2018).

Regulation, defined as law enforced by an authority, is the primary instrument used by governments to prevent or limit such habitat loss (Rhodes, Cattarino, Seabrook, & Maron, 2017). In Australia, the key national environmental legislation is the *Environment Protection and Biodiversity Conservation Act* (EPBC Act) which was passed into law in 1999 (Australian Government, 1999). Under the EPBC Act, a person or organization must 'refer' an action to the Federal Government (i.e., provide specific information to determine whether the action requires approval) if it is likely to have a 'significant impact' on a matter of national environmental significance (MNES; see Supplementary Information for glossary). Examples of MNES include threatened species, endangered and critically endangered threatened ecological communities, or migratory species. The outcome of an EPBC Act 'referral' is one of three decisions: "action is clearly unacceptable" (i.e., the action cannot proceed as described); "controlled action" (requires assessment and approval under the EPBC Act); or "not a controlled action." In the last case, the action is essentially approved to proceed (either as described in the referral or in a "particular manner").

There have been specific investigations on the success of the EPBC Act for threatened species recovery (Macintosh & Wilkinson, 2005), regulating non-compliance (McGrath, 2006), representativeness of listed species (Braby, 2018; Taylor et al., 2018), and protecting individual species (Reside et al., 2019). However, there has been little quantitative assessment on the effectiveness of the EPBC Act in regulating the loss of habitat for terrestrial threatened species, threatened ecological communities, or terrestrial migratory species. Given Australia's history of species extinctions and ecosystem degradation, gauging the effectiveness of the nation's premier legislation in conserving threatened species and ecological communities is vital for informing whether the EPBC Act as currently implemented is achieving its objective of safeguarding Australia's biodiversity.

Here, we assess how effective the EPBC Act has been in regulating loss of potential habitat for terrestrial threatened species and terrestrial migratory species, as well as threatened ecological communities between 2000 and 2017. To do this, we determined how much woodland and forest has been lost within the distribution of 1,638 terrestrial threatened species, terrestrial migratory species, and threatened communities during this time. We restricted our analysis to two habitats, forest and woodland because these are the only habitats for which we can accurately detect anthropogenic loss using remotely sensed information. To assess the extent to which the EPBC Act has been employed to regulate this loss, we calculated the amount of loss that was referred under the EPBC Act to the Federal Government for assessment. By doing this, we could quantify the potential habitat loss for each terrestrial threatened species and terrestrial migratory species, as well as the loss of potential threatened ecological communities. We then analyzed compliance and enforcement under the EPBC Act.

2 | METHODS

Using the spatial extent of three types of matters of national environmental significance: 12 terrestrial migratory species, 39 threatened ecological communities, and 1,587 terrestrial threatened species (see Supplementary data for more detail); we calculated potential habitat and community loss within the duration of the EPBC Act (2000–2017). We used the spatial extent of every action referred under the EPBC Act (up until 2017) to quantify how much of these actions that resulted in vegetation loss was assessed by the Federal Government (Figure 1). Research was not conducted that would have required approval.

2.1 | MNES occurrence data

We used the Federal Government's 100-m gridded resolution spatial data of "likely to occur" and "known to occur" habitat (Australian Government, 2016a) for each terrestrial threatened species, terrestrial migratory species, and threatened ecological communities (see Supplementary Information), which are the most up-to-date data for these species. Those "known to occur" habitats are areas identified as suitable or preferred habitat; containing, or within, ecologically appropriate distances from known sightings or collection locations. The "likely to occur" habitats are areas of suitable or preferred habitat, within ecologically reasonable distances from known locations. We assessed the impacts of forest and woodland habitat loss only, therefore removed all ecological communities that are not forest or woodland (Australian Government, 2016b). We retained all woodland-associated, and forest-associated terrestrial threatened and migratory species under the assumption that the Federal

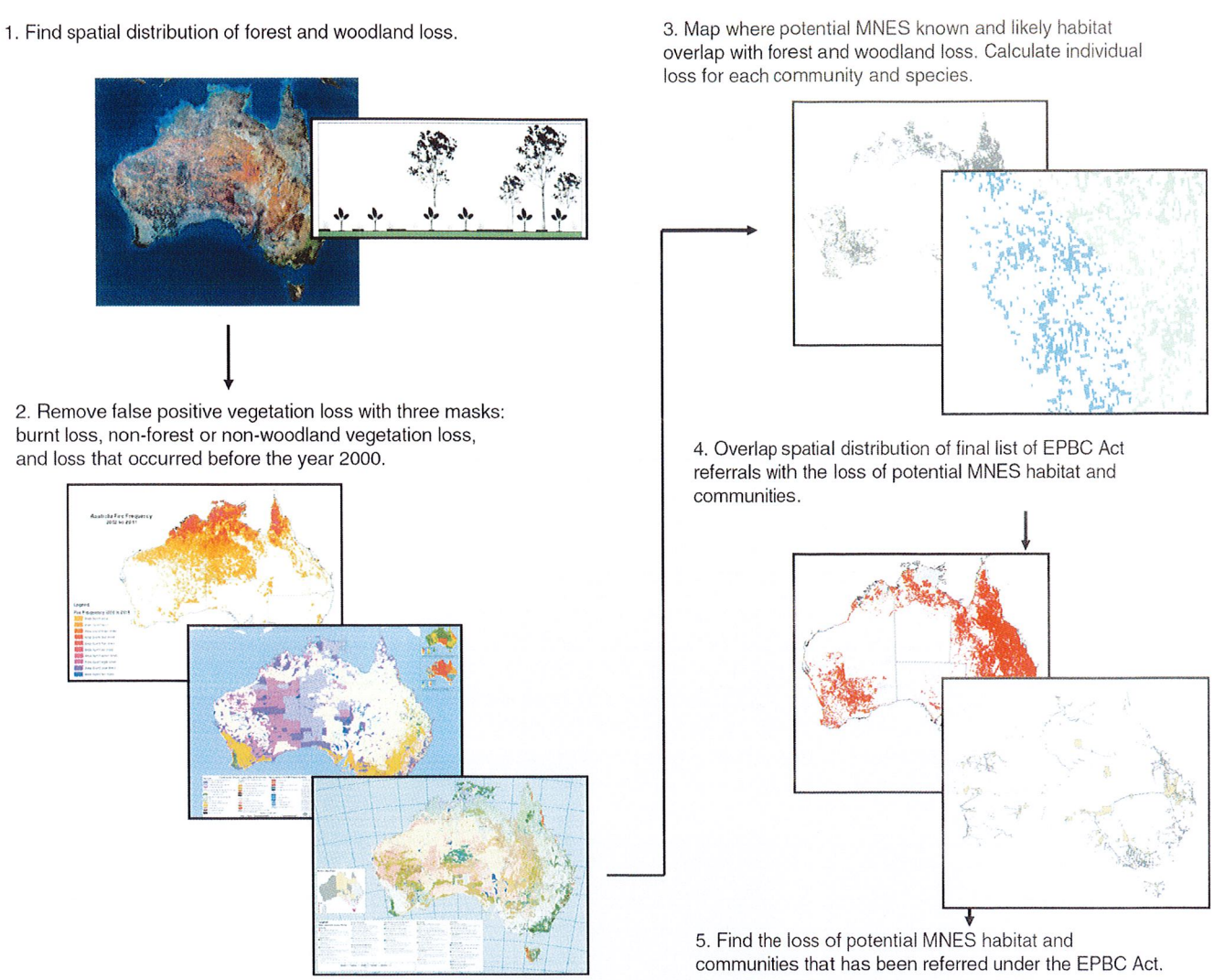

FIGURE 1 Methodological framework for analysing effectiveness of the EPBC Act used in this study

Government's mapping indicates their likely or known occurrence, and therefore loss of any such potential habitat should have a referral under the EPBC Act.

2.2 | Forest and woodland loss data

We mapped forest and woodland loss from 2000 to 2017 using Australia's National Carbon Accounting System (NCAS) forest and woodland cover data set (Australian Government, 2018b). Forest and woodland cover maps contain pixels with one of three possible values: "2" for forest, "1" for sparse woodlands, and "0" for the absence of forest or woodland vegetation. We inferred habitat loss for a given year if the difference between the average pixel value over the preceding 10-year period, as well as the average value in the two following years, was at least one (see Figure S4 for graphical representation of decision rule). This decision rule was used to filter out natural ephemeral variation from more permanent change. We generated binary maps of forest and woodland loss for 15 periods of change, including 2000–2002, 2002–2004, then annually to 2017.

2.2.1 | Masking out natural changes to forest and woodland

We took further measures to exclude other natural drivers of change to forest and woodland vegetation (Evans, 2016). We also applied three additional masks: a burn mask, a land-use mask, and a vegetation type mask because this reduced false positive errors and increased accuracy of anthropogenic habitat loss during the study period.

Burn mask

To differentiate forest and woodland loss between anthropogenic land clearing and loss due to fire, we utilized the MODIS 250-m burned area rasters for Australia. We downloaded each month from 2000 to 2017 from TERN AusCover, then filled missing data sets using MODIS

500-m resolution from the University of Maryland (Terrestrial Ecosystem Research Network, 2018). The earliest product available is April 2000, so masking the burned areas for the 2000–2002 epoch is incomplete due to the 3 months of missing data. Burned masks for each epoch were then aggregated across months and years to match the typical 5-month ranges of dates of acquisition of NCAS forest and woodland change images. Burned raster masks were binary, whereby "1" represents unburned, and "0" represents burned at any time in the date range for that epoch. We then masked out the burnt areas for each period. Similar to other analyses (see Evans, 2016), we did not incorporate other natural drivers of change to forest and woodland vegetation.

Land-use mask

We used land-use maps to remove areas that were already cleared before the EPBC Act came into force, or were unlikely to have been cleared at all. The land-use mask removed any forest and woodland under land uses which were "Conservation and natural environments" in 2015. These are areas formally reserved by the Federal Government for conservation purposes, or conserved through other legal or administrative arrangements. The Conservation and natural environment areas were mapped using the Australian Government's Catchment Scale Land Use of Australia data set (50 × 50 m pixel), by setting pixels to zero if they overlapped the primary land use category "Conservation and Natural Environments". Any area which was a natural water body (i.e., lake, river, estuary, and marsh/wetland-conservation), but not including marsh/wetland-production, was also excluded. We also removed any areas that were developed land-uses before the year 2000. These land-uses included substantially developed areas such as cropping, plantations and forestry, urban, and industrial regions (Australian Government, 2017). We mapped these developed areas using a patchwork of archived, catchment-scale land-use layers (50 × 50 m). These were as close as possible to the year 2000, ranged from 1997 to 2004, and were provided by Australian Bureau of Agricultural and Resource Economics and Sciences (Jodie Mewitt personal communication). In areas where no catchment scale archives where available, we instead used the coarser scaled (1 × 1km pixels) archived national scale land-use layer for 2000 (see Supplementary information for more detail).

Vegetation type mask

As our study focused on forest and woodland, we removed any other vegetation types using the National Vegetation Information System (NVIS) version 5 (Australian Government, 2018c). Mallee forest is particularly prone to extensive burns and lasting burn scars which resulted in significant false positives despite the burn masking described above. For this reason, we also masked out any mallee forest or woodland.

2.3 | Habitat loss data

We applied three masks, then combined the forest and woodland loss maps to create a time series of forest and woodland vegetation loss. We used this map to create a matrix of the potential habitat and community loss for the 1,638 terrestrial threatened species, threatened ecological communities, and terrestrial migratory species over each time period. We acknowledge that in some cases, calculations of habitat loss for specific species may be an overestimate (i.e., where some woodland/forest within the Federal Government's mapped known/likely occurrence of the species is infrequently or not occupied). However, we argue that all areas mapped as habitat for a threatened species, migratory species, or threatened ecological community require assessment before approving its loss, because a species' habitat preference could shift over time, for example with changes resulting from seasons or extreme events; and the full extent of species habitat preference is imperfectly understood for many species (Australian Government, 2016c; Mathieson & Smith, 2009).

2.4 | Significant impact assessment

Under the EPBC Act, all actions that have, will have, or are likely to have a significant impact on a MNES require approval from the regulator (Australian Government, 1999). The significant impact guidelines include specific "significant impact criteria" for each MNES and are available to assist in the determination of whether an impact is significant (see Supplementary Information). An example of a significant impact to a threatened species include, reducing the area of occupancy of a critically endangered or endangered species (Australian Government, 2013). If a proponent takes an action that significantly affects a MNES without first referring it to the regulator for assessment and approval, the proponent is non-compliant with the law and is liable for penalties. Here, we assume a significant impact is the loss of at least 1 ha of potential MNES habitat (Cogger, Ford, Johnson, Holman, & Butler, 2003). Therefore, non-compliant loss is defined as any loss of potential habitat for threatened species, migratory species, or threatened ecological community that is greater than 1 ha and has not been referred to the Federal Government under the EPBC Act. While the loss of 1 ha of habitat is likely to represent a significant impact for species that are highly threatened and/or with small ranges, it may not be significant in isolation for wider ranging species. However, multiple small losses will accumulate through time, and therefore, we consider them here as worthy of assessment.

We investigated how much loss would be considered non-compliant if higher minimum area thresholds for loss were used. In reality, the area threshold for non-compliant loss will depend on each species' context, but species-level assessment was outside the scope of this study. Therefore,

we investigated thresholds of greater than 10 ha, greater than 50 ha, greater than 100 ha, greater than 500 ha, and greater than 1,000 ha. To do this, we iteratively removed polygons that are smaller than the thresholds from the habitat loss layer and clipped to the referrals data set, which allowed us to make different assumptions about the size loss needed to trigger a referral. For example, if a clearing event of 9 ha occurred during the minimum 10 ha threshold assessment, these 9 ha would not be included as representing habitat loss warranting referral.

2.5 | Spatial distribution of EPBC Act referrals

We examined the extent to which the loss of potential habitat for each terrestrial threatened species and terrestrial migratory species, and threatened ecological community received referral under the EPBC Act by using the Federal Government's referral records. These included the spatial location of actions that have been referred under the EPBC Act because the action was considered likely to have a significant impact on a MNES (Australian Government, 2018d). From the full list of 6,040 referrals, we removed any unlikely to involve clearing, or unlikely to represent clearing at a scale detectable in this analysis. This included: marine actions; laying of cables; walking tracks; fossil extraction; controlled burns; actions not involving clearing; any actions where the referred area was below 1 ha in size; or actions that were outside the study period. We also systematically removed referrals where actions did not go ahead (for example, a withdrawn referral), or the surface disturbance was much smaller than the area recorded. For instance, large spatial extents are recorded for linear infrastructure such as pipelines, however, the actual removal of habitat is much smaller.

After all removals, we had a list of 3,058 referrals for actions, which were likely to explain any observed forest or woodland loss. Therefore, remaining in the data set were referrals with one of three outcomes (decisions): "clearly unacceptable," "controlled action," or "not a controlled action." Actions for which the referral decision is "clearly unacceptable" cannot proceed as described. Any "controlled actions" are likely to cause a significant impact, as determined by the regulator, and require further assessment and approval. After an assessment (which can take one of several forms), the proposed action is then "approved," "approved with conditions," or "not approved." "Not a controlled action" are actions that the Federal Government deems to not require detailed assessment, and can proceed; in effect, this represents an approval of the proposed action. We defined compliant loss as that involving clearing of potential habitat or community greater than 1 ha, where this had been referred and deemed either "not a controlled action" (approved), or a "controlled action" (See Figure 2 for decision tree of referral process under the EPBC Act).

We then iteratively reviewed the 3,058 referrals and sorted each one individually by referral outcome, jurisdiction, and industry sector. We removed any referral that did not match the time frame of the potential habitat loss. For example, if an area was referred in 2017, yet potential habitat was lost in 2016, we classified this loss as "non-compliant" because the potential habitat was lost before a referral occurred. Finally, we clipped the referral data set to the potential habitat and community loss map.

2.6 | Enforcement data

We used the case judgements information provided by the Federal Government to analyse the level of enforcement that has occurred from 2000 to 2017 (Australian Government, 2018e). These data include a person or company at fault of removing habitat without referring to the government, background information before removal of habitat occurred, the conclusion of the breach, the penalties, and future reporting required. Using these data, we quantified the fines people incurred for failure to refer actions, the distribution of enforcement among the different MNES, and the magnitude of potential MNES habitat loss that has instigated enforcement from the regulator.

2.7 | Validation of forest and woodland loss

We conducted a sensitivity analysis by repeating the above methods with the statewide landcover and Trees Study (SLATS) data provided by the Queensland Government for Queensland only (Queensland Government, 2018). As SLATS data are used for compliance purposes under state law, while the NCAS forest and woodland cover data are not, the former is generally considered to have lower error rates. We then took the subset of our national analysis for just Queensland and compared the results to identify the difference from using the national-scale NCAS data. All spatial analyses were performed using ArcGIS 10.4. We only report two significant figures when rounding.

3 | RESULTS

3.1 | Compliance of potential habitat loss

Between 2000 and 2017, 7.7 million ha of potential habitat for terrestrial threatened species has been lost, 64,000 ha of potential habitat for terrestrial migratory species has been lost, and 370,000 ha of threatened ecological communities have

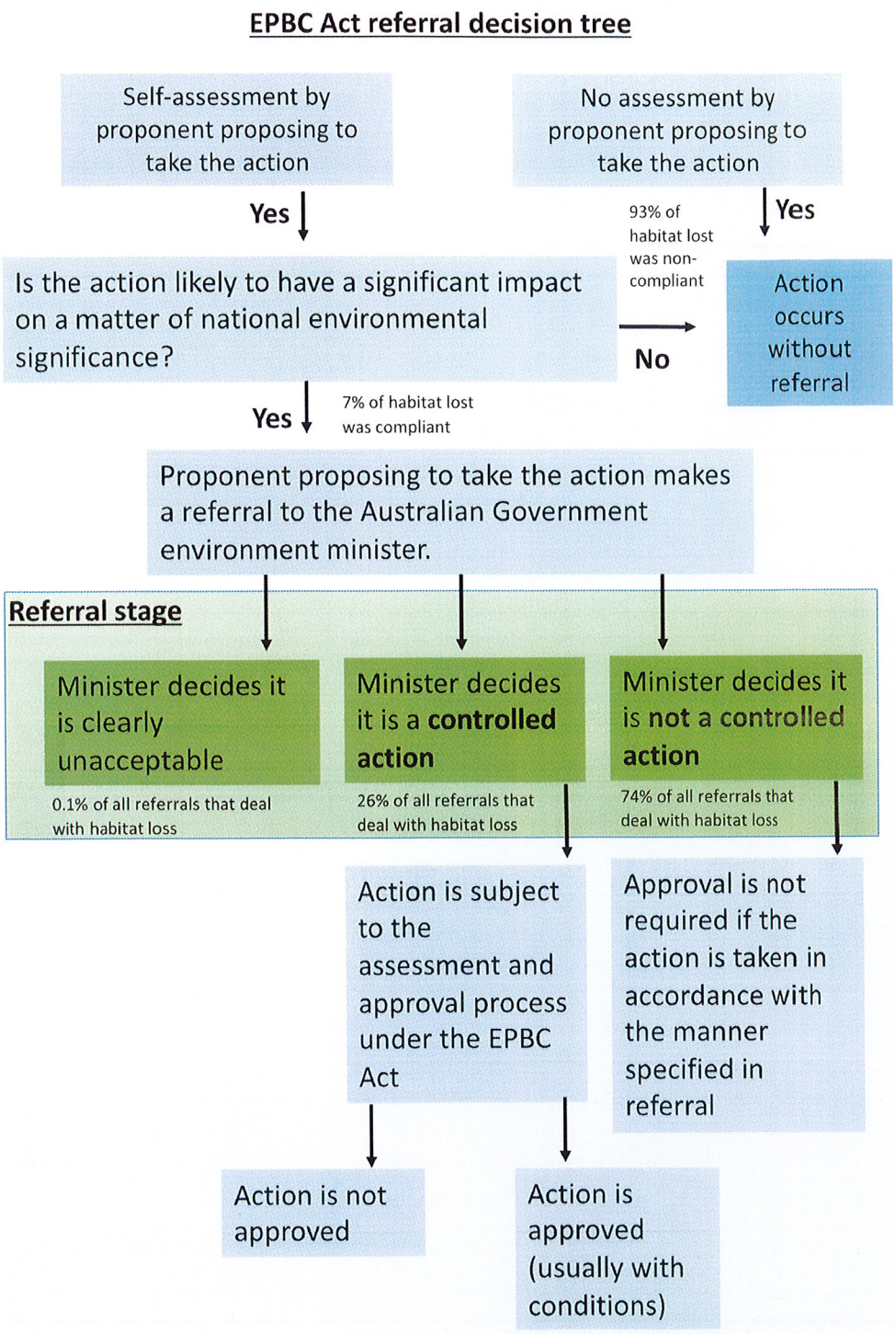

FIGURE 2 Decision tree outlining the referral process under the EPBC Act 1999 (adapted from Australian Government, 2013)

been lost (Figure 3). Of this loss, 580,000 ha (7.5%) was compliant, that is, the area coincides spatially and temporally with actions that were referred to the Federal Government under the EPBC Act. The potential terrestrial threatened species habitat within "likely to occur" areas lost 7.7 million ha, of which 7% was compliant. The potential habitat for terrestrial threatened species within "known to occur" areas lost ~1.2 million ha, of which 17% was compliant. The cumulative habitat loss of all terrestrial threatened species, threatened ecological communities, or terrestrial migratory species was 7.7 million ha, due to habitat of terrestrial migratory species habitat and threatened ecological communities overlapping with terrestrial threatened species habitat.

3.2 | Most impacted threatened species

In total, 1,390 (85% of all) terrestrial threatened species experienced some habitat loss since 2000. Among the top

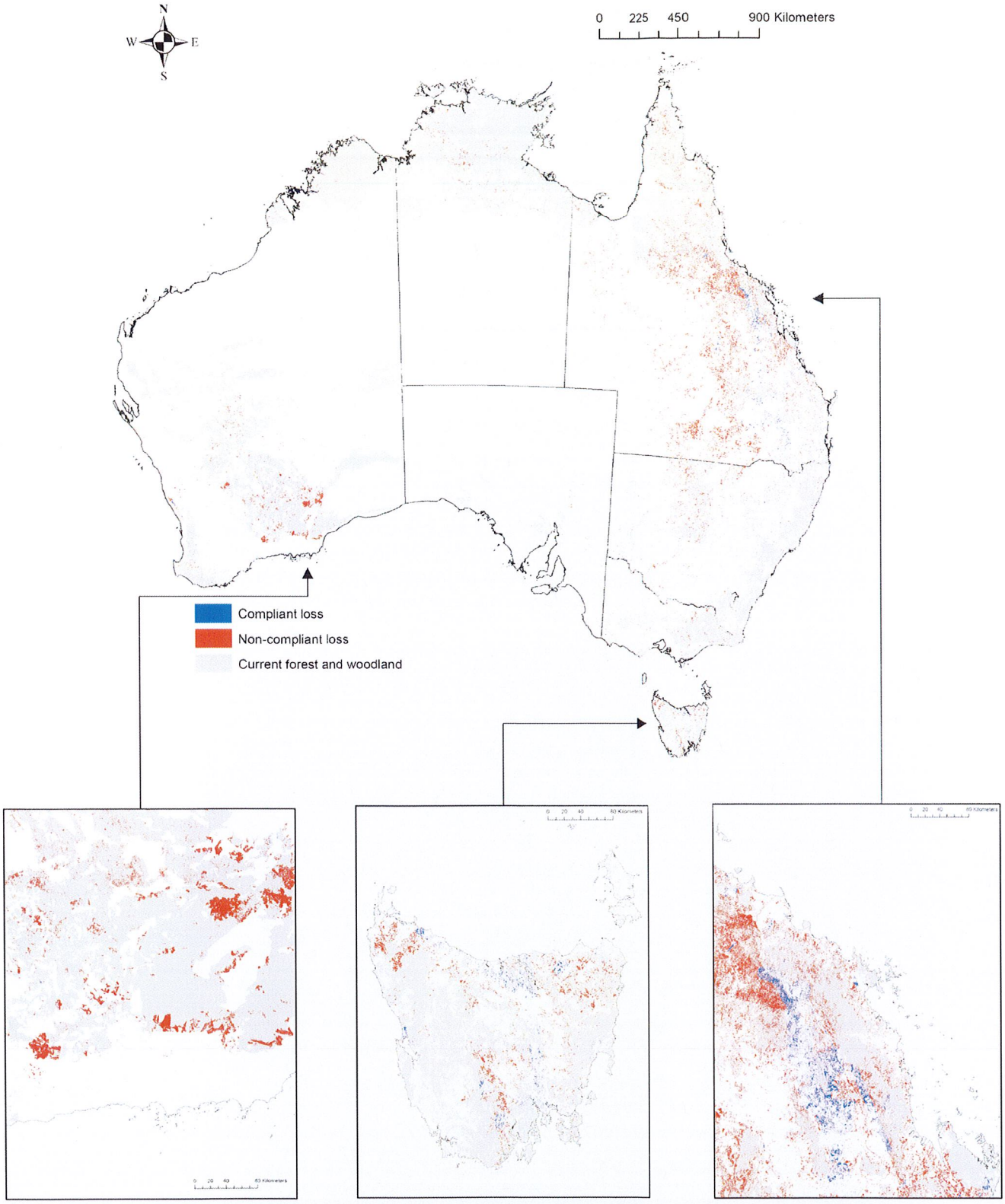

FIGURE 3 Loss of potential habitat for threatened species and migratory species, and threatened ecological communities. Dark blue represents compliant loss (or loss that occurred with a referral under the EPBC Act) and dark red represents non-compliant loss (or loss that occurred without a referral under the EPBC Act). Three panels highlight the southern Western Australia coast (left), Tasmania (middle), and northern Queensland coast (right)

10 species to lose the most potential habitat were: red goshawk (*Erythrotriorchis radiatus*), which has lost ~3 million ha (2% of potential likely and known to occur habitat); ghost bat (*Macroderma gigas*), which has lost ~2.9 million ha (2% of potential likely and known to occur habitat); and koala (*Phascolarctos cinereus*), which has lost ~1 million ha (2% of potential likely and known to occur habitat; Figure 4a). These species have extensive total suitable habitat as mapped by the Federal Government, and so proportions of habitat loss are low. Among the top 10 species with the highest proportional habitat loss where the species is likely or known to occur include Mount Cooper striped skink (*Lerista vittata*) with 25%, Keighery's macarthuria (*Macarthuria keigheryi*) with 23%, and Southern black-throated finch (*Poephila cincta cincta*) with 10% (Figure 4b; see Supplementary Information for full list of species and threatened ecological communities). The relationship between suitable habitat size and proportion of habitat loss varied widely across species (Figure 4c). The relationship between these two variables was significant (n = 1,544, $p < .01$), albeit weakly positive (Spearman's $p = .08$).

3.3 | Significant impact thresholds

Under the EPBC Act, all actions that have, will have, or are likely to have a "significant impact" on a MNES require referral to determine whether detailed assessment and approval is required. We examined the effect of categorizing different size clearing events as a "significant impact" on each threat status of terrestrial threatened species and threatened ecological communities, as well as on terrestrial migratory species. We found that vulnerable species encompass the highest level of compliant loss with 23% of losses at greater than 100 ha of clearing having been referred (Figure 5a). Critically endangered species' and critically endangered ecological communities' referral percentages peaked at 15 and 13%, respectively, for greater than 1 ha loss (Figure 5b). Endangered species was the highest at 13% for the loss of over 10 ha of habitat and endangered

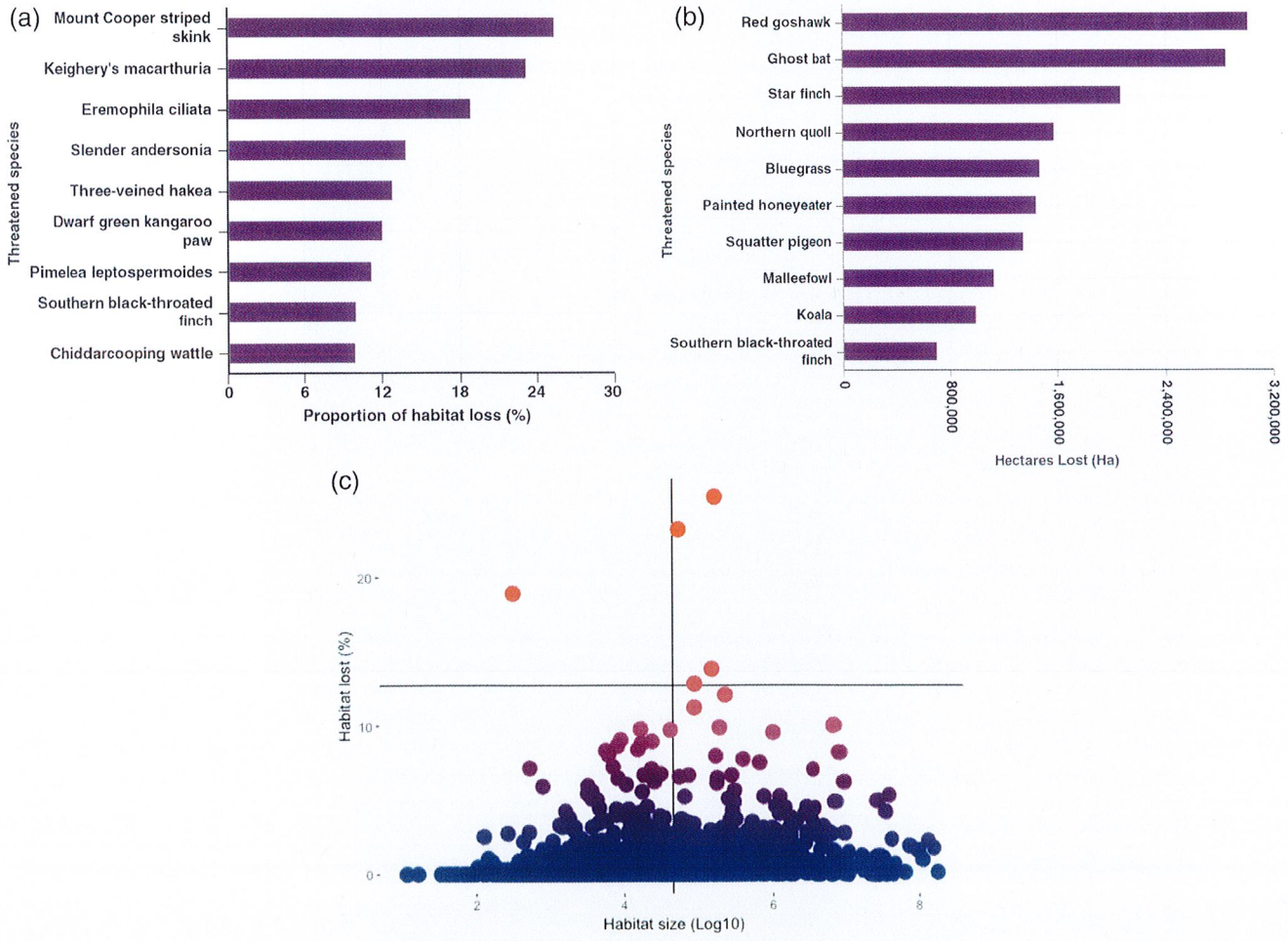

FIGURE 4 (a) The top 10 most severely impacted threatened species include those that have lost the highest proportion of their total potential habitat, and (b) species who have lost the most potential habitat (ha). (c) The relationship between potential habitat size (log10) and the proportion of potential habitat loss across all threatened species

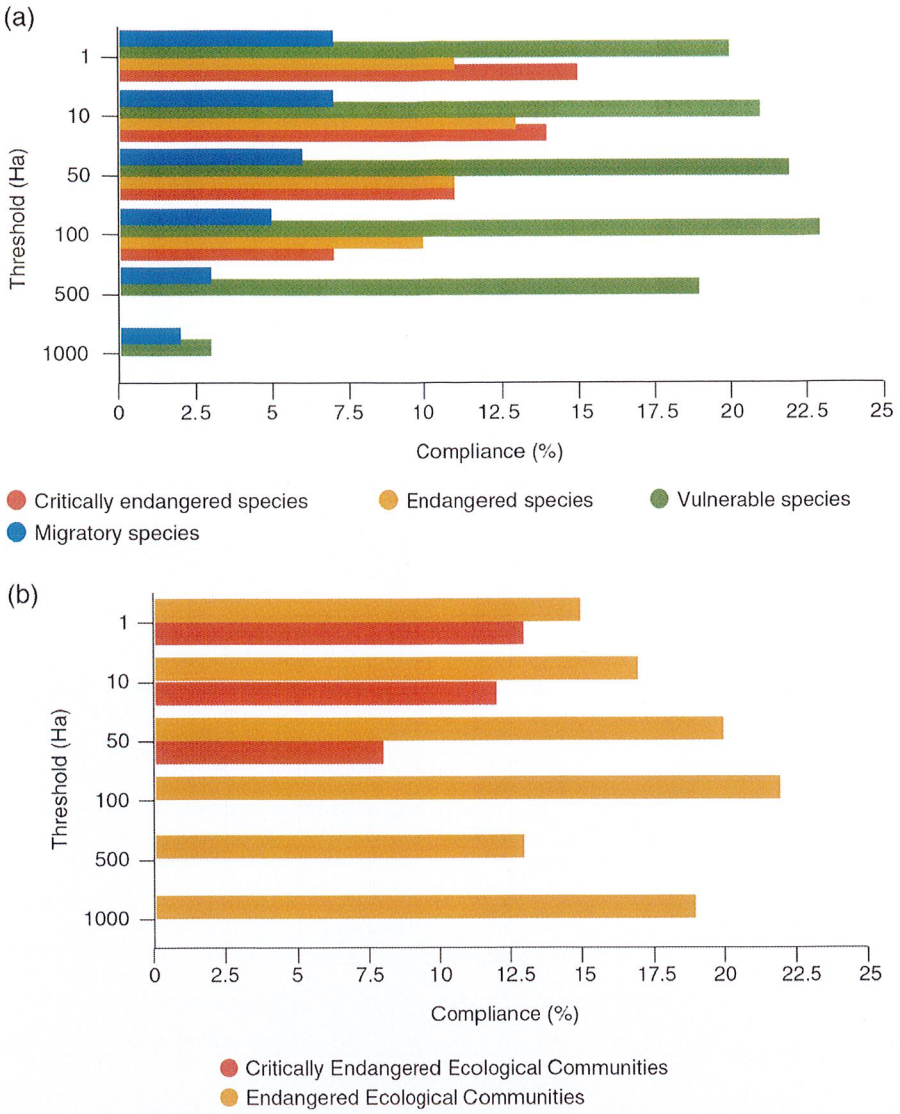

FIGURE 5 (a) The level of compliance for critically endangered species, endangered species, vulnerable species, and migratory species under different minimum area thresholds. (b) The level of compliance for critically endangered ecological communities and endangered ecological communities under different minimum area thresholds

ecological communities was referred 22% for the loss of over 100 ha.

3.4 | Referrals under the EPBC Act

During the study period, 4 of 3,058 referred actions to remove habitat have been deemed "clearly unacceptable" (0.1%), 2,252 have been deemed "not a controlled action" (i.e., not requiring approval to proceed, 74%), and 806 have been deemed a "controlled action" (26%). The area deemed "clearly unacceptable" under the EPBC Act is ~160,000 ha. However, after further investigation, 10,000 ha of this was cleared in later years (9,400 ha had an approved referral under a different application, and 190 ha was lost with no referral). The State of Queensland holds the highest rate of referrals with 35%, closely followed by Western Australia representing 26% of all national referrals (Figure 6). The industry sectors submitting the majority of applications to remove MNES habitat are residential developers (21%) closely followed by the mining industry (18%), while the sectors removing the most MNES habitat through compliant processes include mining (37% of compliant loss) and non-renewable energy generation and supply (28% of compliant loss). The agricultural sector submits 1.3% of all national referrals.

3.5 | Enforcement of the EPBC Act

Since the inauguration of the EPBC Act, there have been 18 successful court cases, whereby companies or people have not referred their actions that resulted in habitat loss, and have been penalized under the Federal Government legal system for noncompliance (see Supplementary Information for all cases). The 18 case judgements incurred a total of AUD 3.9 million in fines from the clearing of a total of 340 ha. Of these, 62% of cases have been for the removal of threatened ecological communities listed as endangered or critically endangered.

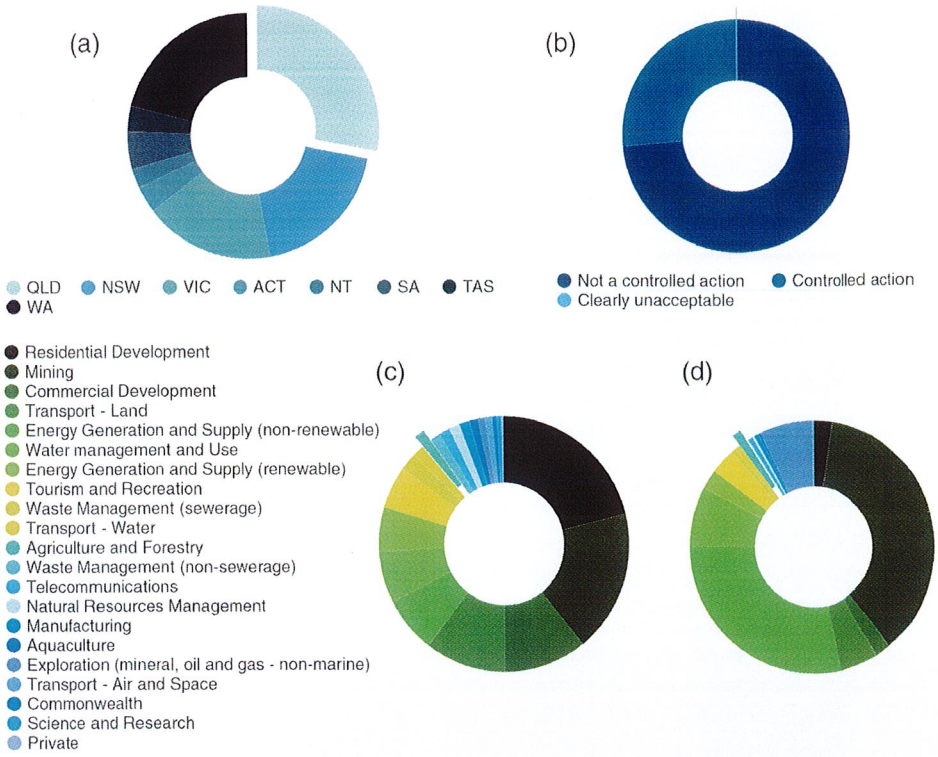

FIGURE 6 (a) Top left pie chart illustrates the proportion of referrals per state. (b) The top right pie chart represents the proportion of referrals that were not a controlled action, a controlled action, or clearly unacceptable. (c) The bottom left pie chart illustrates the breakdown of industries referring their actions by number of referrals, (d) the bottom right pie chart illustrates the breakdown of industries referring their actions by area (hectares). Both (c) and (d) highlight the agricultural sector as a low-referring industry

The size of the ecological community loss that incurred a fine ranged from 0.54 to 13 ha. This threshold may imply that over 7.1 million ha of non-compliant habitat loss could warrant investigation or could have been ignored by the regulator responsible for the enforcement of the EPBC Act.

3.6 | Sensitivity analysis

Our sensitivity analysis revealed a comparatively minor 120,000 ha (2.1%) difference between forest and woodland loss from 2000 to 2017. Our national-scale (National Climate Accounting System) data set indicated a 5.4 million ha loss of forest and woodland within Queensland, while the state landcover and tree survey (SLATS) showed a 5.3 million ha loss.

4 | DISCUSSION

We discovered that 7.7 million ha of potential habitat for terrestrial threatened species, terrestrial migratory species, and threatened ecological communities has been cleared between 2000 and 2017. Of this loss, 7.1 million ha (93%) was not referred to the Federal Government for assessment. This noncompliance means that potential habitat for terrestrial threatened species, terrestrial migratory species, and threatened ecological communities have been lost without assessment, regulation, or enforcement under the EPBC Act. Additionally, we discovered that when an action has been referred, most habitat loss has been approved, sometimes with conditions, and therefore has resulted in large areas of cumulative habitat loss. Our research highlights that Australia's flagship environmental legislation is almost completely ineffective at limiting the ongoing loss of potential habitat for listed terrestrial species and communities. As habitat loss is the primary cause of species extinction (David, Robert, Clarence, & Martin, 1994; Ehrlich & Ehrlich, 1981; Wilson, 1988; Woinarski et al., 2015), we urge mechanisms that protect habitat be embedded within the Federal legislation. This especially applies to one of the two major regimes regulated by the EPBC Act: the environmental assessment process.

As with all regulatory approaches, effectiveness depends on strong enforcement (Soares-Filho et al., 2015). The lack of enforcement of the EPBC Act may be a result of disagreement or ambiguity in the definition of what constitutes a significant impact on a matter of national environmental significance, which are the criteria for referral under the EPBC Act (McGrath, 2006; Sippe, 1999). Proponents undertaking activities that result in habitat loss for a matter of national environmental significance conduct a "self-assessment" against the significant impact guidelines and may decide that the action is unlikely to have a significant impact, therefore not warranting referral under the Federal Government. We are unable to tell to what extent non-referred actions and subsequent losses are a result of

proponents concluding their actions would have no significant impact, or simply a result of either unawareness of, or disregard for the EPBC Act. Our analysis of habitat loss thresholds and court cases indicate that many losses may have warranted referral. In fact, the Federal Government have successfully prosecuted for the removal of 0.5 ha for threatened ecological communities and 4 ha for threatened species habitat, indicating that some of the non-referred clearing would likely have met the "significant impact" criteria, particularly when clearing events exceeded high thresholds.

Nine of the 10 species that lost the most potential habitat within their range extent during the study period occur within Queensland. These species include endemic Australian species such as koala (*Phascolarctos cinereus*), northern quoll (*Dasyurus hallucatus*), and southern black-throated finch (*Poephila cincta cincta*). While other states experienced high land clearing rates before 2000 (Evans, 2016), Queensland has reached globally significant levels (Reside et al., 2017) and contributes 50–65% of Australia's total forest lost (Evans, 2016). The continued high rate of loss within potential threatened species habitat will have major impacts on Australia's last remaining wilderness areas, in which we will face an increasing extinction rate. There are many reasons for Queensland's high rate of loss, including the fact that it still has large remaining areas of natural vegetation, had fluctuations in vegetation management legislation at the State level since 2000 (Reside et al., 2017), and sectors, such as agriculture, responsible for much of the clearing (Evans, 2016), but not adhering to requirements under the EPBC Act. In fact, over the last decade, there have been no referrals to clear for pasture in Queensland.

On a national scale, the agricultural industry represents 1.3% of all referrals. While the public register is notably rich in applications for residential developments and mining actions, it is particularly low in applications for agriculture, despite the latter dominating the statistics for deforestation activities (Evans, 2016). This underreporting of matters of national environmentally significant habitat loss can consequently lead to evidence-poor decision-making from the Federal Government. Long-term strategic assessments and bioregional plans are necessary for reducing the loss of threatened habitats or communities (Hawke, 2009; Reside et al., 2019). While governments do have complete documentation of loss (through the freely available data set used within this study), transparent strategic decision-making has not occurred. Such strategic decision-making could permit some clearing of less-threatened species' habitat, therefore allowing development to continue, but then also providing strict absolute protection (i.e., no-go zones) and restoration for highly-threatened species' habitat and communities (Rhodes et al., 2017).

Effective legislation is that which is clearly defined, transparent, consistent, and enforced (Queensland Government, 2014). Our research indicates that over the last 18 years, 0.1% of 3,058 referrals have been deemed "clearly unacceptable," 74% were "not a controlled action" (i.e., not triggering) detailed assessment under the EPBC Act (i.e., allowed to proceed), and 26% were a "controlled action" (i.e., have triggered the EPBC Act) of which 11 were not approved after assessment (Australian Government, 2018f). This high rate of actions proceeding as "not a controlled action" suggests that the significant impact criteria are loose and starkly inconsistent with the fact that non-compliant clearing of areas as small as half a hectare have been successfully prosecuted. Possible reasons for this may include confusion around the criteria itself, lack of political will to protect the environment, fear of being forced to compensate property owners for restricting development, or significant impact being assessed on individual, isolated actions, rather than cumulative losses (see Macintosh & Wilkinson, 2005).

Cumulative losses are critical for assessing significant impact, yet currently, actions referred under the EPBC Act are individually assessed. The EPBC Act does not require the regulator to address the cumulative impact multiple actions can have at the landscape, ecosystem, or species' scale (Dales, 2011; Tulloch et al., 2016). While small amounts of habitat loss may not seem significant; the successive, incremental, and combined removal of habitat over time can lead to "death by a thousand cuts" (EPA, 1999; Tulloch et al., 2016; Reside et al., 2019). In the current statutory framework, regulators are unable to reject actions based on the likelihood of this cumulative significant impact. As such, previous reviews of the EPBC Act have highlighted this as a major issue and have recommended provisions for accounting for this pitfall (Hawke, 2009).

The EPBC Act has so far been ineffective for preventing habitat loss for three matters of national environmental significance. To increase effectiveness, we recommend the inclusion of (a) when scientifically-determinable, critical habitat is demarcated for threatened species, migratory species, and threatened ecological communities, which provides absolute protection (i.e., no activities that adversely modify the habitat and/or demographic processes) that is enforced, monitored, and investigated by the regulator. Critical habitat maps and plans should be publicly available to all landholders; (b) explicit, quantitative guidelines for what constitutes a significant impact, including, for example, habitat amount thresholds, should be determined and provided to inform the referral and assessment process under the EPBC Act; (c) unreferred habitat loss must be monitored and investigated, and appropriate enforcement action taken; (d) clear language and definitions used throughout the EPBC Act and

guidelines; (e) documentation and assessment of cumulative impacts of all developments, including the trajectory of threatened species habitats. This may be done through effective utilization of bio-regional planning.

We acknowledge that our analysis measured the loss of *potential* habitat caused by anthropogenic clearing for forest- or woodland-associated terrestrial threatened species and terrestrial migratory species, as well as the loss of (forest or woodland) threatened ecological communities. We recognize that this is not a complete study of the loss of occupied habitat incurred by these species, as species can be extirpated from uncleared native vegetation that represents suitable habitat due to a range of factors, including fire, drought, invasive species, and pollution. However, our analysis is based on the precautionary assumption that if forest or woodland is lost, and this overlaps spatially with where (forest- or woodland-associated) MNES are considered likely or known to occur, then such loss warrants consideration under the EPBC Act via the referral process. This study provides a foundation upon which to examine the extent to which particular species or threatened ecological communities have changed in population, range or both, and whether the EPBC Act referral process has effectively safeguarded MNES from further declines (for example, Reside et al., 2019).

5 | CONCLUSION

Our research highlights that Australia's flagship environmental legislation is ineffective at halting habitat loss for terrestrial threatened species, terrestrial migratory species, and threatened ecological communities. This significant loss of habitat has contributed to one of the worst extinction rates in the world, with no sign of slowing in the near future. Without strict, comprehensive application and enforcement, as well as explicit guidance and requirements, policies such as the EPBC Act will remain ineffective at regulating habitat loss and protecting biodiversity.

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AUTHOR CONTRIBUTIONS

M.S.W. and M.T. conceived the manuscript. All authors interpreted these data. M.S.W. wrote the manuscript with the input from all authors.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

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

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