The role of privately protected areas in achieving biodiversity representation within a national protected area network

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Abstract

As the world nears the target of protecting 17% of terrestrial environments, there remain significant gaps in achieving the ecologically representative system of protected areas (PAs) called for under the Convention on Biological Diversity. There is increasing recognition of the contribution that privately protected areas (PPAs) can make to protecting biodiversity, offering the potential to increase existing levels of protection for species and ecosystems, but also to protect biodiversity that currently lies outside existing PA networks. Despite the potential importance of PPAs for achieving an ecologically representative PA network, the complementarity between public and private PAs has received little attention. Our study provides a detailed assessment of the role PPAs play in protecting biodiversity in a megadiverse country. Using the Australian PA network as an example, we provide a comprehensive assessment of the contribution PPAs make to the representation and level of protection of species, ecosystems, and key biodiversity areas. We found that while making up only 1.3% of Australia’s land area, PPAs protect a wide range of biodiversity, contributing to the protection of 85% of vertebrate species, 80% of threatened ecological communities, 95% of major vegetation types, and 40% of key biodiversity areas. However, our findings reveal that PPAs largely protect biodiversity already within the PA network, and because of their small size, they currently make only minor contributions to the adequacy of protection for biodiversity. Nevertheless, we show that conservation on private land will be critical to strengthening the PA network, with between 70 and 90% of currently unprotected or poorly protected biodiversity occurring largely on private land. Analyses such as ours, which examine the importance of both public and private PAs to achieve conservation targets, are essential to ensure effective planning of PA networks into the future.
1 | INTRODUCTION

Protected areas (PAs) are a critically important and cost-effective tool for the continued conservation of global biodiversity (Balmford et al., 2002; Gaston, Jackson, Cantú-Peón, & Dudacy, 2008; Watson, Dudley, Segan, & Huckings, 2014). Their effectiveness centers on the goal of permanently protecting biodiversity from land use change and maintaining habitat integrity (e.g., Geldmann et al., 2013), which, alongside effective management, can help ensure the long-term preservation of ecological values. The importance of PAs to biodiversity conservation has led to internationally agreed targets for the protection of lands and waters within ecologically representative networks by 2020 (Aichi Target 11; CBD, 2010). These targets have successfully catalyzed considerable growth in PA coverage worldwide (Watson et al., 2014), including through a growing number of PAs on private or indigenous lands (UNEP-WCMC, IUCN and NGS, 2018).

As countries near their area-based protection targets under the Convention on Biological Diversity (CBD), the focus has increasingly shifted toward ensuring that the diversity of species and ecosystems is represented within PA networks. Unfortunately, there are still important gaps in protection for biodiversity: 17% of threatened species have no protection within the global PA network (Venter et al., 2014) and even in the country with the largest PA network (the United States), over 20% of vegetation communities remain unprotected (Dietz, Belote, Aplet, & Ayrcrigg, 2015). The well-recognized bias toward declaring public PAs in regions with few opportunity costs, such as areas with limited value for agriculture, has left some environments with low levels of protection (Joppa & Pfaff, 2009; Sayre et al., 2020). Ecosystems that occur in highly productive landscapes not only tend to have been extensively cleared and modified, but they are also more likely to occur on private lands (Knight, 1999; Norton, 2000), making it important to consider alternative governance models to achieve ecologically representative PA networks (Bhagwat & Rutte, 2006; Fitzsimons & Wescott, 2001).

Privately protected areas (PPAs) are areas declared for the primary purpose of preserving biodiversity, recognized by the IUCN as being under private governance (Stolton, Redford, & Dudley, 2014). PPAs are usually administered by a variety of bodies with varying standards, encompassing a broad range of owners and managers, and currently constitute less than 1% of the total global coverage of PAs (Bingham et al., 2017). However, they make considerable contribution to PA networks in North America (>20% by number), Africa and Latin America (>10% by number; UNEP-WCMC and IUCN, 2018). They are also known to make significant contributions to the protection of important biodiversity, such as large mammals in South Africa (Clements et al., 2018), as conflicts over land use objectives on public land grow, the ability to expand public PAs is likely to be reduced (Cook, Valkan, & McGeoch, 2019), and existing protections are being removed from some PAs (i.e., PA downgrading, downsizing, and degazettement—Cook, Valkan, Mascia, & McGeoch, 2017; Golden Kroner et al., 2019). Therefore, the contribution PPAs can make to achieving global biodiversity targets is only likely to grow. As the world increasingly moves toward a multi-tenure perspective on PAs (Bingham et al., 2017; Drescher & Brenner, 2018) it is important to consider the role PPAs play in representing biodiversity, both in their own rights, and by filling gaps in the representation of biodiversity within the broader PA network.

To date, there are significant gaps in our understanding of the contribution PPAs make to achieving ecologically representative PA networks. The few studies that have considered PPAs have been focused on specific aspects of biodiversity, such as large mammals (Clements et al., 2018) or ecosystems (Pliscoff & Fuentes-Castillo, 2011), or have been high-level assessments, such as estimating the representation of ecoregions (Shanee et al., 2017). Such specific or broad assessment of the contribution of PPAs leaves major gaps in our understanding of the degree to which PPAs contribute to the protection of biodiversity, and the complementarity between PAs on different land tenures.

To help address this gap, our study examined how Australian PPAs contribute to the representation of a broad suite of biodiversity, from species through to ecosystems, and the level of protection PPAs offer to biodiversity not otherwise protected within the predominantly public PA network. Australia has the largest PPA estate in the world by area (Bingham et al., 2017), comprised of many small PPAs spread across the country. We hypothesized that the small size of many PPAs (Hardy, 2014).
Fitzsimons, Bekessy, & Gordon, 2017) would mean that they make only a small contribution to the overall representation of biodiversity within the network. However, given that private lands tend to be more productive than those under public tenure (Robinson, Allred, Naugle, & Jones, 2019) they have the potential to address well-documented bias in PA allocation (Joppa & Pfaff, 2009). Therefore, we expected a high level of complementarity between public PAs and PPAs. With the potential for PPAs to protect ecosystems that have already been heavily cleared for agriculture, we also expected PPAs to play an important role in increasing the levels of protection for biodiversity otherwise inadequately protected within the network. Much of Australia is private land (over 62% of the landmass; Australian Surveying and Land Information Group (AUSLIG), 1993), so if PPAs can be used to protect biodiversity which occurs in heavily modified landscapes, they could offer an effective pathway to achieving an ecologically representative PA network.

## 2 | METHODS

### 2.1 | Study system

Australia is one of the world’s 17 mega-diverse countries based on its exceptionally high species richness and endemism (Mittermeier, Gil, & Mittermeier, 1997), but is also a global epicenter for extinction (>10% of mammals have gone extinct since European settlement; Woinarski, Burbidge, & Harrison, 2015). The governance structures for PAs in Australia are complex, with eight government agencies declaring and managing public PAs, and 10 different agencies administering PPAs (Fitzsimons, 2015). Australia not only has the largest PA estate in the world (Bingham et al., 2017), but the dominant mechanism for declaring PPAs involves legally binding, multiparty agreements (Figgis, 2004), giving them a high level of permanence (Hardy et al., 2017). PPAs are counted toward Australia’s international commitments, yet there has been little consideration of the contribution PPAs make to protecting biodiversity beyond conserving broad vegetation types (Archibald et al., 2020).

### 2.2 | Protected area data

To quantify the extent of the Australian PA network, we sourced spatial data from the publicly accessible Collaborative Australian Protected Area Database (CAPAD) (CAPAD, 2018) (Table S1.1 in Appendix S1). CAPAD does not contain a comprehensive list of PPAs, so we augmented this dataset with PPA data from each of the known conservation covenanting programmes in Australia which legally qualify as PPAs (Fitzsimons, 2015; Table S1.2 in Appendix S1).

We clipped all data to the extent of the Australian landmass and most associated offshore islands and standardized the projected coordinate system to GDA_1994_Albers. We resolved spatial inconsistencies and overlaps (see Appendix S1), deleting duplicates and employing the commonly used rule of working with PAs over 1 ha in size (e.g., Dietz et al., 2015) to minimize geoprocessing errors. Separate data layers were created for public PAs (which included PAs on public land, Indigenous PAs and PAs under joint management, see Appendix S1), PPAs, as well as a layer containing both public PAs and PPAs across Australia. We calculated the number of reserves, their total area, as well as the mean size of reserves ± standard error for each of the two PA types.

### 2.3 | Species data

To evaluate the representation of vertebrate species, we obtained data on the distributions for all Australian mammals, amphibians, and reptiles from the IUCN Red List database (IUCN Red List version 2019-1) in May 2019 (range polygons; see Appendix S1). Following Beresford et al. (2011), we sourced Australian bird distribution data from BirdLife International in May 2019. This yielded distributions for a total of 277 mammal, 219 amphibian, 936 reptile, and 764 bird species. The threat status of all vertebrate species was derived from the IUCN Red List.

In line with standard practice (e.g., Rodrigues et al., 2004), we retained distributions where species were described as: (a) extant, probably extant or possibly extant; (b) native, reintroduced or introduced; and (c) resident throughout the year, in breeding season or in nonbreeding seasons. These data were also used to generate species richness maps for analytical purposes.

To more accurately calculate each species’ likely distribution, we refined the available coarse distributions (i.e., polygons bound by known occurrences of the species; IUCN Red List Technical Working Group, 2019) to areas with native vegetation still present. This was done by creating a spatial layer for natural land-use, including areas of “Nature Conservation,” “Managed Resource Protection,” “Other Minimal Use,” and “Grazing Native Vegetation” but omitting areas converted to alternative land uses such as “Cropping” and “Mining” (Table S1.4 in Appendix S1). We used the resulting layer to create a set of distributions likely to better represent the areas species may be occupying, hereafter referred to as “natural land-use distributions.”
2.4 | Other biological data

To assess the representation of biodiversity beyond a vertebrate species level, we obtained spatial data for broad vegetation types—84 major vegetation subgroups (MVSs)—based on the National Vegetation Information System (NVIS) Version 5 (Table S1.3 in Appendix S1).

We also extracted the distributions of the 79 threatened ecological communities (TECs) classified as Ecological Communities of National Environmental Significance, refining these distributions using the natural land-use layer.

Finally, we also included the distributions of 305 Key Biodiversity Areas (KBAs) in Australia, sourced from BirdLife International (Table S1.3 in Appendix S1). KBAs are sites recognized for making significant contributions to the global persistence of biodiversity (International Union for the Conservation of Nature (IUCN), 2016).

2.5 | Land tenure and human pressure data

Spatial data on Australia’s land tenure was obtained from the Australian Government (Geoscience Australia, 2004) to determine the current distribution of biodiversity across different land tenures. Land tenure types were grouped into the broad categories of public (predominantly government lands) and private lands (private freehold or leasehold) (Table S1.6 in Appendix S1).

To assess the pressures on biodiversity that occur on public versus private lands, we used the Human Footprint Index (HFI). The HFI data from Venter et al. (2018) were extracted, reprojected and used to compare pressures on PPAs and public PAs. The mean HFI scores were calculated for each PA within the network by overlaying the HFI raster layer with a PA raster layer.

2.6 | Data analysis

We assessed the contribution of PAs in two ways. First, we calculated the representation of biodiversity, where vertebrate species, TECs, KBAs, and MVSs were deemed to be represented if any part of their distribution overlapped with a PA (Riggio, Jacobson, Hijmans, & Caro, 2019). Second, we assessed the adequacy of protection of ecological features based on the percentage of their distribution contained within PAs. We defined “adequate” protection by scaling the proportion of the distribution to the IUCN threat status of the species or TECs, where species with a higher threat status required greater proportions of their distributions within PAs to be considered adequately protected (Table S1.5 in Appendix S1). The threshold for least concern species, KBAs and MVSs was set to the 17% target defined by the CBD (Table S1.5 in Appendix S1).

We assessed the contribution PPAs make to biodiversity protection in relation to the area they contribute to the Australian PA network to capture whether they achieve coverage greater than would be expected for their area. Complementarity was assessed in terms of whether PPAs protect ecological features that would otherwise fall outside the PA network.

The potential of private versus public land to fill representation gaps and increase the adequacy of protection was assessed based on the degree of overlap between land tenure types and the distributions of unrepresented species and inadequately protected TECs, KBAs, and MVSs.

Finally, a Welch’s t test was used to compare the HFI values for private versus public PAs, and therefore the likely anthropogenic pressures on the biodiversity they contain.

All spatial analyses and map outputs were carried out using the software packages ArcGIS Pro Version 2.3.0 and ArcGIS Desktop Version 10.7.

3 | RESULTS

Australia was shown to have an extensive PA network, made up of 17,935 PAs that constituted 19.9% of the country’s landmass (Figure 1a). PPAs accounted for over half of PAs (n = 9,886). The majority of PPAs were small (10.3 ± 1.5 km²) relative to public PAs (177.7 ± 24.5 km²), constituting only 6.6% of the area protected and around 1.3% of Australia’s total landmass (Figure 1b). We found that PPAs and public PAs were under similarly low pressure from human activities—PPAs scored a mean value of 6.6 (±0.4 SE) out of 50 on the HFI relative to 6.9 (±0.5 SE) for public PAs (t(8692) = −2.3, p = .02).

3.1 | Vertebrate species

The vast majority of Australian vertebrate species (97.6%) were represented within the PAs, with only 53 of the 2,196 species without protection (Figure 3a; Appendix S2), 13 of which are threatened (Table 1; Appendix S2). PPAs also represented the vast majority of vertebrates (85%), with only 273 species being exclusively protected within public PAs (Table 1). However, PPAs only made a small contribution (four species) to protecting vertebrates that would otherwise have been without protection (Table 1; Appendix S2). PPAs contributed to the protection of 72% of all threatened species (n = 156), and up to 96% of threatened birds (Table 1).
There were no threatened species within PPAs that would otherwise have lacked protection.

While PPAs offered protection to the vast majority of vertebrate species, particularly mammals, their small size meant that the overall contribution PPAs made to increasing the level of protection for species was also small (Figure 2). Australian PAs protected 44% of vertebrate species' distributions on average, to which PPAs contributed 2.6%.

Australian PAs offered threatened species higher levels of protection than non-threatened species, with protection being generally lower for birds and reptiles (Figure 2). The PA network as a whole protected 48.9% of threatened vertebrate species' distributions on average, to which PPAs contributed 2.7%. However, when considering the adequacy of protection, scaled according to the threat status of species, a third of all vertebrate species were inadequately protected within the PA network. Of threatened vertebrate species, 44.4% (95/214) were inadequately protected by the PA network at large. PPAs make larger than expected contributions to the level of protection for 25.3% of TECs and 31.3% of inadequately protected TECs. While all are represented, many TECs have low levels of protection—particularly in Eastern Australia (Figure 3b), where levels of protection are much lower and associated with habitat clearing and fragmentation (Figure 1).

All 84 MVSs are represented within PAs, with all but 3 of these (96%) also represented in PPAs (Appendix S2). The PA network at large protects 25.6 ± 2.1% of MVS distributions, to which PPAs contribute 1.8 ± 0.2%. At only 6.6% of the PA network, PPAs contribute to over 6.6% of protection for the distributions of 46.4% (39/84) MVSs. Despite the strong overall representation across the PA network, 34 MVSs (40%) have less than 17% of their area protected (Figure 3c), with PPAs making unexpectedly large contributions to 70.6% (24/34) of these.

**3.2  |  TECs and broad vegetation groups**

PPAs are particularly important for protecting Australia’s TECs, representing two critically endangered communities that would otherwise lack coverage within the network (Appendix S2). As a result, all 79 TECs receive some level of protection by the network. PAs as a whole protected on average 36.7 ± 3.0% of TECs' distributions, to which PPAs contributed an average of 2.3 ± 0.7%, increasing the protection of 81.0% of TECs (including all critically endangered ones). PPAs make larger than expected contributions to the level of protection for 25.3% of TECs and 31.3% of inadequately protected TECs. While all are represented, many TECs have low levels of protection—with over 77% being inadequately protected by the PA network at large—particularly in Eastern Australia (Figure 3b), where levels of protection are much lower and associated with habitat clearing and fragmentation (Figure 1).
3.3 | **Key biodiversity areas**

There are major gaps in representation of Australia’s 305 KBAs with 12.5% currently receiving no protection by the network. The adequacy of protection is quite high for some KBAs, with on average $50.8 \pm 2.3\%$ of KBA distributions covered by PAs. However, 20.3% are considered inadequately protected based on a 17% target (Figure 3d; Appendix S2). PPAs make a significant contribution to the protection of 39.7% of all KBAs assessed, including representing 10 KBAs that would otherwise not be protected, and enabling 5 KBAs in reaching their target for adequate protection (Appendix S2).

3.4 | **Spatial distribution of the PA network and potential for future expansion**

Comparing patterns of species richness with the distributions of PAs largely explains the patterns of protection reported for biodiversity. The highest PA coverage occurs across the desert regions of central Australia (Figure 1a), while species richness
hotspots tend to occur along the eastern seaboard for mammals and amphibians, southern parts of the mainland for bird species, and across northern Australia for reptiles (Figure S3.2 in Appendix S3). PA coverage is lower in eastern Australia, particularly along the Great Dividing Range, which coincides with patterns of underrepresentation for MVSs and inadequately protected TECs and KBAs (Figure 3). PPAs are often scattered throughout less protected, but not unrepresented, areas of the country (Figure 1b).

Biodiversity in Australia is widely distributed across unprotected private lands, with gaps in representation and adequacy of protection more prevalent on private land than public land: 88.5% of inadequately protected TECs, 70.0% of inadequately protected KBAs, 91.2% of inadequately protected MVSs, and 83.0% of unrepresented species have the majority of their distributions on private lands (Appendix S2, Figure 3).

**4 | DISCUSSION**

Knowledge of the location of PPAs, and the levels of protection they afford to biodiversity, is limited globally. Yet PPAs have the potential to increase the breadth and level of protection for biodiversity. While we expected high levels of complementarity between PPAs and the rest of the PA network, we found that PPAs make only a small contribution to increasing the representation of species and ecosystems, but expand the level of protection for the vast majority of biodiversity assessed. Beyond the current contribution of PPAs, we found that private land is likely to play an important role in future PA expansion, with the overwhelming majority of poorly represented biodiversity features occurring primarily on private land. Studies such as ours can provide critical knowledge about the role of PPAs, and serve as a guide to countries seeking to strengthen their PA networks.

Despite the strikingly low complementarity we found between PPAs and public PAs, PPAs contribute to the protection of the vast majority of all vertebrates, including threatened vertebrate species, TECs, and major vegetation types (70–96%), along with 40% of KBAs. So, while PPAs do not add greatly to complementarity with the rest of the network, they do add to the level of protection for most of Australia’s biodiversity, often contributing well above what would be
The similarity of protection offered by PAs of different tenures (Table 1) is particularly interesting in light of the active stance many Australian PPA programmes take in contributing to the national goals of a comprehensive, adequate, and representative PA network (Fitzsimons, 2015). PPAs still constitute a minority of the existing network, so the impact of these targeted efforts may not yet be apparent. The commonality in the biodiversity protected within public and private PAs may also indicate that the spatial bias caused by opportunity costs, such that productive lands are preferred for exploitative land uses rather than conservation (Joppa & Pfaff, 2009), are relevant irrespective of PA tenure type (Schutz, 2018).

While current levels of complementarity between public and private PAs are not high, most of the current gaps in the representation of and levels of protection for biodiversity will require greater protection within private lands (Figure 3). The 53 species that remain outside the PA network are largely reptiles and birds (the most speciose vertebrate groups in Australia), most with small or restricted distributions (Figure S3.1 in Appendix S3) and distributed across private land tenures. Between 70 and 90% of inadequately protected biodiversity is also distributed predominantly on private land, often in areas that retain some native vegetation and are primarily used for grazing (Figure 3; Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), 2019). The importance of private land to the protection of species has been demonstrated in a number of countries (e.g., Clancy et al., 2020; Gallo, Pasquini, Reyers, & Cowling, 2009; Shumba et al., 2020). Even in a large PA network like Australia, strategic growth in PPAs could be
instrumental to filling the existing gaps in the ecological representation and adequacy of protection for biodiversity.

While performing well overall, the Australian PA network lags behind in the protection of KBAs, with over a third of these areas being inadequately protected (<17% protection) or lacking protection altogether (Appendix S2). While KBAs are currently considered in global PA representation reviews by the CBD (UNEP-WCMC, IUCN and NGS, 2018), they are admittedly a relatively new concept with a global standard to their identification established only a few years ago (International Union for the Conservation of Nature (IUCN), 2016), so the presently poor uptake is not unexpected. PPAs make an important contribution to the representation of KBAs, being exclusively responsible for protecting 10 of these areas. While poorly or unrepresented KBAs are scattered across the country, 70% fall primarily within private land tenures (Figure 3d), often in areas desirable or currently used for agriculture (Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), 2019). As such, PPA establishment in these regions may also be a key avenue to increasing protection for KBAs. Given KBAs have a historic link to Important Bird Areas (International Union for the Conservation of Nature (IUCN), 2016), improving the capacity for PPA establishment in these regions will likely have a significant impact on the overall protection of birds as well.

Of the biodiversity metrics assessed, TECs are most in need of protection as they have already been heavily cleared (Office of Legislative Drafting, 2004). It is therefore encouraging that all TECs have some protection within PAs. While PPAs make a small contribution to complementarity, protecting two critically endangered TECs, importantly they bolster protection for almost all TECs, protecting vital remnants of these ecosystems scattered across agricultural landscapes. These are contexts where PPAs, created through conservation covenants, can be a useful mechanism for protection, as they allow a portion of a property to be set aside to permanently protect these community remnants (Figgis, 2004). Increasing this type of protection will be important for the 88% of inadequately protected TECs that occur largely on private land to ensure these remnant communities remain intact.

In this study, we assessed the role of PPAs in representing biodiversity and increasing the adequacy of protection through the degree to which distributions are protected. However, PPAs also have the potential to serve as critical connectors through otherwise transformed habitats (e.g., the Gondwana Link project; Bradby, Keesing, & Wardell-Johnson, 2016), and to provide stepping stones for species that range widely (Shumba et al., 2020). PPAs that protect small fragments of habitat in agricultural landscapes may play a particularly important role in connectivity. PPAs that adjoin other PAs could be important extensions of the overall PA cluster size, as well as serving as corridors or buffers, helping to increase the viability of the populations they contain (Stolton et al., 2014). The current positioning of PPAs in the landscape appears to be very similar to that of public PAs in the level of pressure received from human impacts, which points to a likely comparable degree of protection the two PA types can give to the biodiversity they contain. As such, the broader role PPAs can play, beyond representation and adequacy of protection to ensure the long-term protection of biodiversity, warrants greater attention.

Our study attempted to move beyond the 17% CBD target (CBD, 2010) to consider the degree to which the distributions of species and TECs have already been reduced, a key element of their threat listing. Using this graded set of targets for adequacy arguably enables us to better account for the importance of and urgency for protection. Another innovation of our study was that we refined the distributions commonly used by representation studies according to land use type, providing greater emphasis on where species are actually likely to be found. As such, our estimates of the degree and adequacy of protection provide a more accurate and nuanced consideration of the contribution PPAs make to the protection for biodiversity. Given the number of species, TECs and KBAs for which we found that PPAs increased the degree of protection, our results suggest PPAs can play a considerable role in moving PA networks toward higher levels of protection. And for poorly represented biodiversity, even small gains may be significant.

While PAs are an important conservation tool, including biodiversity within PAs is not sufficient to ensure ongoing protection. It is important to acknowledge that the success of PPAs in conserving biodiversity also requires that they are able to restrict threats and mitigate their impacts. It has been demonstrated that PAs are more effective at protecting biodiversity when they offer stricter protection from human activities (e.g., IUCN categories I and II; Taylor et al., 2011; but see Shumba et al., 2020), have more robust management regimes (Leverington, Costa, Pavese, Lisle, & Hockings, 2010) and higher levels of resourcing (Gardner et al., 2018; Githiru et al., 2015; Waldron et al., 2013). However, we know little about the capacity of PPAs to achieve conservation outcomes, and the conditions that facilitate effective protection. While PPAs do not appear to be under greater human pressure than public PAs based on our study, private landholders responsible for many PPAs often have limited training and resources to manage their properties...
(Groce, 2019), and changes in human pressure levels are possible. Therefore, achieving the conservation outcomes that are assumed when countries count PPAs toward their international PA targets will require that these areas are properly resourced to deliver the anticipated benefits for the biodiversity they contain.

With much of the world yet to meet the 2020 Aichi targets (UNEP-WCMC, IUCN and NGS, 2018), and with bolder targets expected for 2030, PPAs can play an instrumental role in helping countries to achieve their current and future commitments as we demonstrate here for Australia. While it is difficult to actively plan for PPAs given the frequently opportunistic nature of their establishment, countries can encourage more PPAs, particularly in priority areas, through financial incentives and by providing ongoing support to the existing network (Bingham et al., 2017). It will be essential that countries consider the contribution made by public and private PAs, and the complementarity between the two, in order to prioritize the most efficient way to achieve an ecologically representative PA network. Our assessment shows that despite their relatively small area, PPAs can protect a wide range of ecological features, and make significant contributions to increasing the protection of biodiversity already within the PA network. Targeting future growth in PAs will require planning for PAs across both public and private land tenures to achieve systematic and efficient gains for biodiversity.

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CONFLICT OF INTEREST
The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS
Both authors contributed in equal measure to the conceptualization of the project. I. M. I. was primarily responsible for the development of the methodology, data collection and analysis, as well as the writing of the original draft. C. N. C. provided oversight of the project and manuscript review and editing.

DATA AVAILABILITY STATEMENT
Summary data outputs are contained in the supplementary material; however, access to the full dataset is restricted by data sharing agreements. Please direct all additional data requests to the corresponding author.

ETHICS STATEMENT
No ethics approval was required for this research.

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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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