Journal & Proceedings of the Royal Society of New South Wales, vol. 157, part 1, 2024, pp. 5–14. ISSN 0035-9173/24/0105-10

Rapid progress on the photographic documentation of Australia's flora

Thomas Mesaglio,[1,2,3] Hervé Sauquet,[1,4] William K Cornwell[1]

1 Evolution & Ecology Research Centre; School of Biological, Earth and Environmental Sciences, UNSW Sydney; 2 Centre for Ecosystem Science; School of Biological, Earth and Environmental Sciences, UNSW Sydney; 3 CSIRO Atlas of Living Australia, Sydney; 4 National Herbarium of NSW, Botanic Gardens of Sydney, Mount Annan

thomasmesaglio@gmail.com

Abstract

Photographs are an increasingly important botanical resource which often capture information absent or lost from physical vouchers. With more than 21,000 native vascular plant species, Australia is one of the world's most plant-rich countries, and photographically documenting this flora is a large but important endeavour. As of April 2022, 3,715 (17%) Australian plant species were still unrepresented by photographs of live individuals in any one of 33 major online databases. In the two years since we brought this gap to national attention, 821 of these species have had images uploaded online, with important contributions from both amateur and professional botanists. A further 18 species have been crossed off the unphotographed list through taxonomic changes. Many of these species had already been photographed — sometimes decades ago — but the photographs had never been published, or the photographs had yet to be conclusively identified. The challenge is ongoing: most of the remaining unphotographed species are shrubs or herbs and can be found in Western Australia or Queensland.

Introduction

Photographs of live plants are an invaluable botanical resource. They form the cornerstone of identification resources such as field guides and are increasingly used in identification keys (Wäldchen et al., 2022). Photographs are also a powerful tool for engaging the public with plant science and driving greater interest in plants and the natural world more broadly (Pitman et al., 2021). The importance of plant photographs has also been emphasised in recent years through the development of the extended specimen concept; it is clear that photographs complement physical vouchers by capturing information that may otherwise be absent or lost in specimens, especially features such as flower colour (Gómez-Bellver et al., 2019; Heberling and Isaac, 2018).

For example, *Caesia* is a small genus of perennial herbs native to Australia, Papua New Guinea, South Africa and Madagascar. Many of the morphological characters required for identifying species of *Caesia* are either collected infrequently, or the most important details are lost in vouchers, so photographs are invaluable for recording some of these features (Webb et al., 2023). Indeed a newly described species from Queensland, *Caesia walalbai* A.T.Webb, Birch & R.L.Barrett, largely went unnoticed until photographic observations uploaded to the biodiversity citizen science platform iNaturalist[1] were seen by the authors, and further collections were made based on these records (Webb et al., 2023).

1 https://www.inaturalist.org

Australia has one of the richest floras in the world, with more than 21,000 described native vascular plant species (Australian Plant Census[2]); an estimated ~91% of these are endemic, found nowhere else in the world (Chapman, 2009). Given the diversity and uniqueness of Australian plants, their photographic documentation is important for research, conservation, and public engagement.

We recently assessed the Australian vascular plant flora and found that, of 21,077 native Australian species (described up until 2018), 3,715 did not have photographs of live plants in any of the 33 major online databases that we surveyed as of April 2022 (Mesaglio et al., 2023). As part of our study, we released a publicly accessible, dynamic database of all unphotographed Australian vascular plant species, which we regularly update when new photographs are published online for these species. In December 2023, the total number of unphotographed species dropped below 3,000, a significant milestone. As of April 2024, there are now 2,876 species still on our unphotographed list, with more than 800 species crossed off the list in just two years since April 2022. Almost all of these have had photographs uploaded to the online biodiversity citizen science platform iNaturalist; just 5 species had photographs in a different database such as PlantNET[3], the Flora of New South Wales maintained by the National Herbarium of NSW. Here, we explore the different ways these species are being "ticked off" the list, summarise the species that have recently been photographed, and highlight the most "unphotographed" taxa still requiring documentation.

The how

To fill this important gap, in April 2022 we embarked on a two-fold effort: a traditional and social media campaign — including interviews with radio stations around the country — and targeted searches. This combined approach proved successful for engaging the community, including both amateur and professional botanists, and increasing awareness of the species on our unphotographed list, as well as the importance of the photographic documentation of Australia's flora more broadly.

Species targeted by TM and colleagues (75 species)

In 2022 and 2023, Thomas Mesaglio (TM) conducted fieldwork with several colleagues in Western Australia to collect data for his PhD, visiting Kalbarri and Lesueur National Parks (July 2022), Yeo Lake Nature Reserve and Stirling Range National Park (August 2022), and Fitzgerald River National Park (October 2023). Before commencing each trip, TM cross-referenced our unphotographed list with all digitised vouchered plant records stored in the Australasian Virtual Herbarium[4] from the target area, building a list of unphotographed plant species known to occur in the region. Although each expedition was focused on documenting all encountered taxa, not just unphotographed species, this was a prime

2 https://biodiversity.org.au/nsl/services/search/taxonomy

3 https://plantnet.rbgsyd.nsw.gov.au

4 https://avh.chah.org.au

opportunity to target many of the latter, given the dominance of Western Australian endemics in the unphotographed species list (Mesaglio et al., 2023).

This approach was a great success, with more than 50 unphotographed species found, photographed and uploaded to iNaturalist across these trips. The expedition to Yeo Lake Nature Reserve, a vast ephemeral salt lake in the Great Victoria Desert, yielded six newly photographed species, including the desert daisy bush *Olearia eremaea* Lander and *Stenopetalum salicola* Keighery, a small herb usually associated with gypsum-rich saline lakes; the latter also represented a 250 km range extension for the species. Other exciting finds included the short-range endemic *Acacia diminuta* Maslin (Figure 1a), which we photographed in Lake Magenta Nature Reserve (a ~60 km western range extension); *Wurmbea dilatata* T.D.Macfarl. (Figure 1b), a widespread but rarely collected herb growing in sand in Kalbarri National Park; the easily missed sedge *Morelotia microcarpa* (S.T.Blake) R.L.Barrett & K.L.Wilson (Figure 1c), which we found growing in a weedy empty lot in the middle of Kalbarri; the poorly known Priority Two species *Philotheca cymbiformis* (Paul G.Wilson) Paul G.Wilson (Figure 1d) along a trail at the base of West Mount Barren in Fitzgerald River National Park; and, *Dodonaea ericoides* Miq. (Figure 1e), an increasingly rare small shrub impacted by agricultural land clearing, on a small, roadside rocky outcrop in Coomalloo Nature Reserve.

Other species were targeted on an individual basis. The chenopod species *Maireana microcarpa* (Benth.) Paul G.Wilson (Figure 1f) had been collected multiple times in 1975 and once in 2022 from the University of New South Wales' Fowlers Gap Research Station, north of Broken Hill. TM and botanist Guy Taseski took advantage of fieldwork at the station in March 2024 to relocate and photograph this species at both known populations, plus a new third population. On a drive back to Sydney from another Fowlers Gap trip in 2023, TM and Taseski noted that the journey would take them past one of the few known populations of the rare unphotographed shrub *Bertya oblonga* Blakely (Figure 1f). It was then a simple matter of stopping at the location, scrambling up a ridgeline along an abandoned railway line, and photographing the plants growing at the top.

TM also engaged colleagues to target individual species. In February 2023, an observation of *Insulascirtus christiani* Otte & Rentz, 1985, a species of bush cricket endemic to Norfolk Island, was uploaded to iNaturalist by James Tweed, a PhD candidate researching insect conservation. TM was browsing James' Norfolk Island insect observations out of interest, and when he stumbled upon this record, he noticed that the observation notes stated "On *Melicope littoralis* foliage at night." At the time, *Melicope littoralis* (Endl.) T.G.Hartley (also endemic to Norfolk Island) was still on the unphotographed plant list. After contacting James and letting him know, he uploaded photographs of *M. littoralis* to iNaturalist within the week.

Mobilising old treasure (304 species)

Over the decades, Australian botanists, ecologists, and consultants have taken untold numbers of photographs of plants across the country. In many cases, however, they have not had the time or resources to process and upload these photographs. Equally importantly, until the emergence of

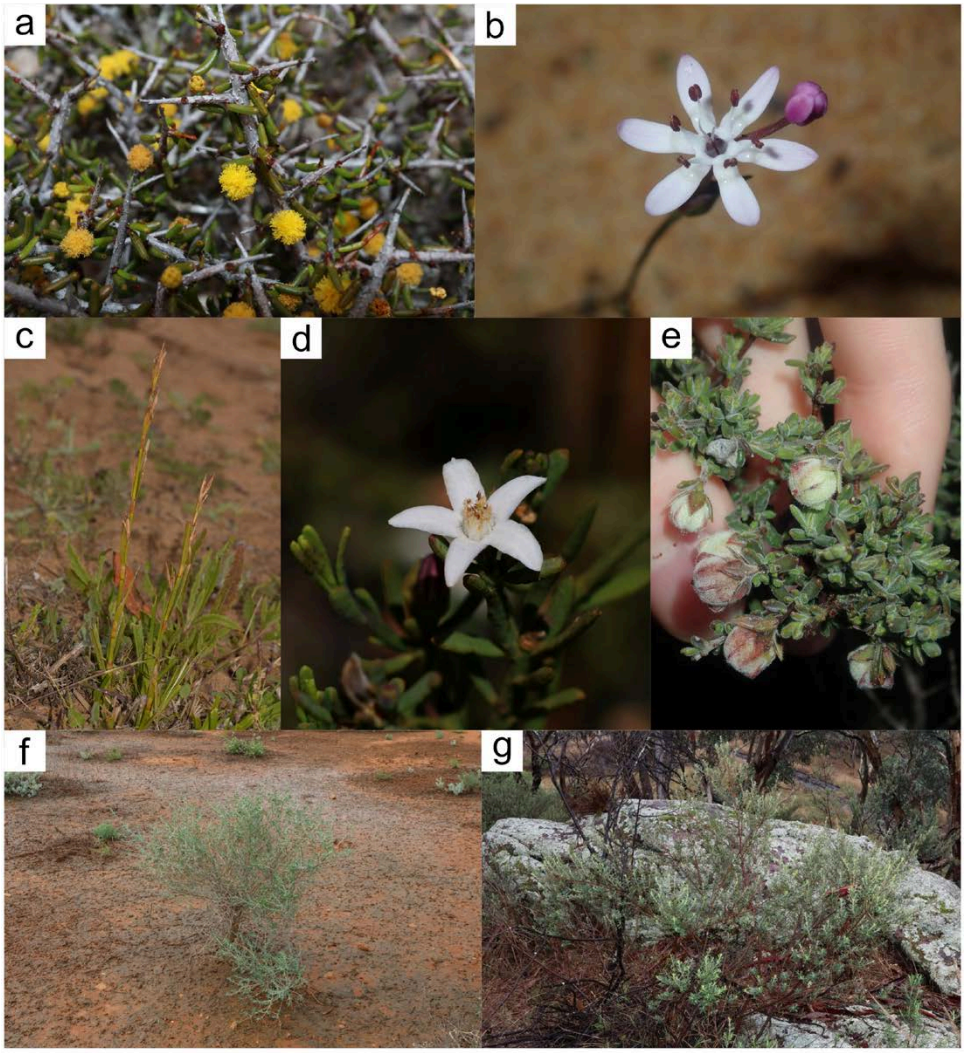

Figure 1: Some of the plant species recently ticked off our unphotographed list by Thomas Mesaglio and colleagues. a) *Acacia diminuta* Maslin, photographed by Thomas Mesaglio on sandy clay in Lake Magenta Nature Reserve, WA (https://www.inaturalist.org/observations/189098133); b) *Wurmbea dilatata* T.D.Macfarl., photographed by Thomas Mesaglio in deep sand near the Z Bend in Kalbarri National Park, WA (https://www.inaturalist.org/observations/132521908); c) *Morelotia microcarpa* (S.T.Blake) R.L.Barrett & K.L.Wilson, photographed by Nick Lambert at an empty lot in Kalbarri, WA (https://www.inaturalist.org/observations/136132894); d) *Philotheca cymbiformis* (Paul G.Wilson) Paul G.Wilson, photographed by Greg Tasney in heath near West Mount Barren in Fitzgerald River National Park, WA (https://www.inaturalist.org/observations/189704635); e) *Dodonaea ericoides* Miq., photographed by Thomas Mesaglio on a small rocky outcrop in Coomalloo Nature Reserve, WA (https://www.inaturalist.org/observations/129657506); f) *Maireana microcarpa* (Benth.) Paul G.Wilson, photographed by Thomas Mesaglio in a drying gilgai at Fowlers Gap, NSW (https://www.inaturalist.org/observations/204362193); g) *Bertya oblonga* Blakely, photographed by Thomas Mesaglio on a rocky ridge near Larras Lee, NSW (https://www.inaturalist.org/observations/152807404).

platforms such as iNaturalist, there has not been an easy, reliable, and free online repository to upload such treasures until recently (i.e., the main options were to upload to a state or other online flora — an option available mostly to professional botanists working at institutions maintaining these resources — or build one's own website, which is often not viable in the long run). There has probably also been, for a long time, a sense of pride and ownership for high-quality photographs before smartphones and the culture of open access sharing became dominant, leading to potential reluctance in sharing these photographs publicly. Consequently, thousands and thousands of images are collecting virtual dust on computers and hard drives across the country. These photographs represent a treasure trove waiting to be "discovered." Uploading these photographs will be a huge asset to our shared knowledge of species, including those already with publicly available photographs: the more photographs are available, the more features and variation are documented.

During a conversation with Bevan Buirchell, a Western Australian botanist and *Eremophila* expert, TM mentioned that there were still thirty unphotographed species of *Eremophila*, one of Australia's most diverse plant genera. Bevan asked TM for the list, and soon after posted photographs for twenty of these missing species, most of them from remote desert regions of Western Australia. Almost all of these images were 15–20 years old, highlighting the value of mobilising these old records.

This was just one case among many where Australian botanists contacted us to say they had indeed photographed some of the unphotographed species on our list — but that the images had never been published in any of the major databases we had assessed — and uploaded their images to iNaturalist directly in response to our research. These "historical" photographs were taken anywhere between a few months before our analyses were conducted in April 2022, all the way back to the 1980s. That many of these botanists were made aware of our list through the media attention our research received in both traditional media (e.g., radio interviews, newspaper articles) and on social media platforms reinforces the importance of a strong mixed-media campaign in the modern research environment.

Significant contributions were also made (and continue to be made) by Geoff and Ruth Byrne, experienced naturalists who have spent decades collecting and photographing plants across Western Australia and volunteering at the Western Australian Herbarium. They have now spent the past few years uploading tens of thousands of photographs across thousands of these historical observations to iNaturalist. Excitingly, these records have thus far included more than 100 species which had been on our unphotographed list (and indeed, many of the species that we ticked off as already photographed during our initial study were also represented only by photographs taken by Geoff and Ruth), a tremendous contribution with particularly high value given each set of photographs is associated with a physical voucher held in the Western Australian Herbarium.

Across all of these examples, it is clear that greater institutional support for curating and publishing these old photographic records online will be a crucial step forward in the quest to better document Australia's flora.

Expert engagement with old iNaturalist records (51 species)

In a similar vein to our last point, a number of unphotographed species had already been photographed, and in fact had already been uploaded to iNaturalist several years ago before our original study, but were either languishing at an identification that had never progressed finer than family, or had been misidentified as a more common, already photographed species, and thus had remained unrecognised. It was not until an expert reviewed one of these old observations and offered an identification that we could tick each species off our list, demonstrating the high value of expert engagement with the platform (Callaghan et al., 2022; Campbell et al., 2023). As more Australian botanists join iNaturalist and contribute their expertise, the more of these records will be recognised.

Although species have been ticked off our unphotographed list courtesy of identifications from numerous Australian experts, three botanists in particular have made strong contributions over the past two years:

- Tony Bean has not only identified a number of Queensland plant species previously listed as unphotographed, but also made important inroads in *Solanum*. One of the most unphotographed genera from our original list, with 54 unphotographed species, *Solanum* is one of Tony's research specialties, and indeed of the 21 species that have now been ticked off the list thanks to his identifications of iNaturalist observations, 15 of them were described by him.
- Tim Hammer has made similar important contributions for the genus *Hibbertia*. One of the most diverse plant genera in Australia, *Hibbertia* is often difficult to identify to species, especially from photographs, and thus many observations on iNaturalist are initially uploaded with only a genus identification. Tim's systematic review of thousands of old iNaturalist observations of *Hibbertia* has unearthed a number of "unphotographed" species that are now identified and crossed off our list.
- Russell Barrett, an authority in the flora of the Kimberley region in northern Western Australia, has been identifying thousands of iNaturalist observations from the Kimberley and the nearby Pilbara region. Among these have been a number of rare species from our unphotographed list, including the unusual wattle *Acacia claviseta* Maslin, M.D.Barrett & R.L.Barrett and the richly pink-flowering *Hibiscus stewartii* Craven, F.D.Wilson & Fryxell.

Synonymised species (18 species)

A small number of species were removed from our list as a result of taxonomic revisions. For example, *Drosera coalara* Lowrie & Conran was recently synonymised with *Drosera citrina* Lowrie & Carlquist (Krueger and Fleischmann, 2020), and *Eucalyptus filiformis* Rule was recently synonymised with *Eucalyptus polybractea* R.T.Baker (Fahey et al., 2022). Both *D. citrina* and *E. polybractea* had already been photographed and ticked off.

Overlooked (24 species)

Another small handful of species had actually been photographed at the time of our original analyses, but had been initially overlooked for miscellaneous reasons, including being identified under an old synonym that we did not search for, being missed by one of our automatic scripts, and being represented only by a Casual grade iNaturalist record due to missing metadata such as observation date.

Organic accumulation (367 species)

Finally, previously unphotographed species are increasingly being documented on iNaturalist simply by virtue of the continued exponential growth of the site, especially in Australia (Mesaglio, 2024; Mesaglio and Callaghan, 2021); an incredible ~1.4 million records (approx.) of vascular plants in Australia were added to iNaturalist over the last two years. As more and more users join the platform, and existing users continue to photograph plants across the country, it is inevitable that many previously unphotographed species will be recorded and images made available on iNaturalist (Figure 2).

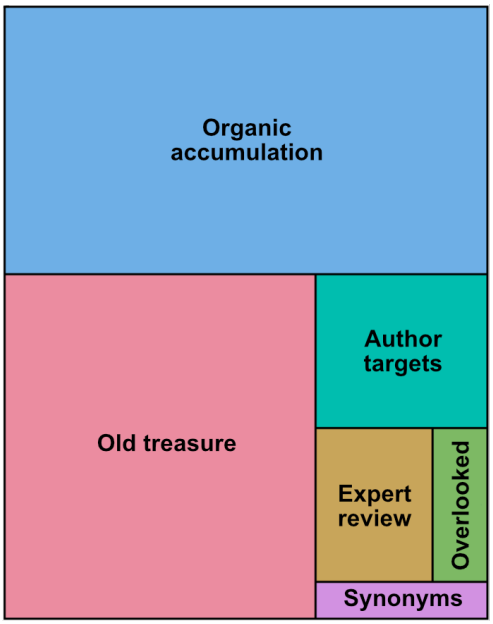

Figure 2: Treemap categorising Australian vascular plant species ticked off the unphotographed list from April 2022 to April 2024

It is important to also recognise the invaluable efforts of experts to identifying these records. Just as many botanists are reviewing historical observations on iNaturalist, so too are they constantly contributing identifications to the thousands of new plant observations from Australia uploaded to iNaturalist each week. Increasing support for taxonomists, botanists and other professional plant researchers to contribute time to identifying iNaturalist observations should be an important priority for many institutions.

A note on print field guides

The Australian flora is covered by a wealth of high-quality print field guides. Whilst these are fantastic identification resources, print field guides often lack the accessibility of digital platforms. Most field guides cost money, with some larger volumes selling for several hundred dollars. Some field guides focus on specific reserves or small regions and are not sold online, being purchasable only from local visitor centres or national parks offices, whilst others go out of print and become almost impossible to find. A number of the species on our unphotographed list have indeed been photographed, but the images only exist in these print materials. Increasingly, however, these species are being ticked off our list through the upload of images to iNaturalist, including by the original photographers.

TM was recently contacted by Glenn Leiper, a botanist from south-east Queensland and the co-author of, and principal photographer for, *Mangroves to Mountains*, the most comprehensive field guide to the flora of south-east Queensland (Leiper et al., 2022). Glenn had seen our paper, and let us know that his guide features photographs for 18 species which were on our unphotographed list, including the small shrub *Androcalva leiperi* (Guymer) C.F.Wilkins & Whitlock, a species that Glenn discovered,

and *Bertya ernestiana* Halford & R.J.F.Hend., a rare species found only within Mt Barney National Park. Glenn was kind enough to provide his high-quality photographs to TM who uploaded them to iNaturalist to a proxy account created for Glenn, ensuring these photographs are now accessible online to anyone.

The what

Since 15 April 2022, 821 (22%) of the 3,715 species without images on any of the 33 major databases we surveyed have now been photographed, with an extra 18 crossed off due to taxonomic changes: as of April 2024, there are now 2,876 remaining species on our list.

The standout families have been Asteraceae and Myrtaceae, with 76 and 74 species ticked off respectively, although this is unsurprising given that they are two of Australia's most diverse plant families and were also in the top five most unphotographed families to begin with. The big winners at a genus level have been *Stylidium* (18 species ticked off), *Solanum* (21), *Eremophila* (22) and *Hibbertia* (29). These inroads have been achieved thanks in large part to the efforts of botanists Juliet Wege, Tony Bean, Bevan Buirchell and Tim Hammer, respectively, through both identifying iNaturalist records uploaded by other users and uploading their own. In our original paper, we reported that of the 2,190 genera containing at least one native Australian species, 1358 were photographically "complete" genera, i.e., all Australian species in each of these genera had been photographed. That number has now increased to 1,452, meaning 66% of Australia's genera have had all of their species photographed. Progress has been slower at a family level, moving from 101 to 106 complete families out of a total of 259.

The problem of "grass blindness" (Marcenò et al., 2021; Thomas, 2019) that we discussed in our original analysis has somewhat improved, with 53 grass species ticked off, ~15% of the total number (343) from our unphotographed list. Shrubs and herbs dominated the newly photographed species, with 343 and 304 species respectively. Most of the 821 species have a distribution including Western Australia or Queensland, but this was also expected, given these two states are the most diverse in Australia, and also had the most unphotographed species to start with.

What next?

The progress made in photographically documenting Australia's flora has been very promising, but there is still plenty of work to be done, with 2,876 species waiting for images to be uploaded to one of our 33 major online databases. Here is a small taste of some of the species still waiting to be photographed:

1. *Eucalyptus kenneallyi* K.D.Hill & L.A.S.Johnson — Myrtaceae

The final unphotographed eucalypt from the more than 700 species in one of Australia's most iconic genera, *Eucalyptus kenneallyi*, is found only on two tiny islands, Storr Island and Koolan Island, off the Kimberley coast in Western Australia.

2. *Schoenus lanatus* Labill. — Cyperaceae

The earliest described, unambiguously valid Australian endemic to still lack any photograph across the 33 major databases is *Schoenus lanatus*, described all the way back in 1805. This sedge species is quite widespread, with 104 records in the Atlas

of Living Australia across coastal Western Australia stretching from Leeman north of Perth all the way to the South Australian border.

3. *Corokia carpodetoides* (F.Muell.) L.S.Sm. — Argophyllaceae

A shrub or small tree found only on Lord Howe Island, however, it is locally common near the summits of Mount Gower and Mount Lidgbird and should be a relatively low-hanging fruit (pun intended) for anyone visiting the island.

4. *Litsea bennettii* B.Hyland — Lauraceae

This tree species only grows on granite-derived soils in rainforests near the peaks of mountains in tropical Queensland, with a distribution stretching from Hinchinbrook Island northwards to Cedar Bay National Park.

5. *Hydrocotyle comocarpa* F.Muell. — Araliaceae

A small, innocuous herb found in South Australia (mostly from Kangaroo Island and Pearson Island, with a few mainland locations), Victoria (known from only a single location in South Gippsland) and Tasmania (Flinders, Cape Barren and Deal Islands). This species seems to be fairly short-lived and often difficult to detect, which helps to explain its current unphotographed status.

Zooming back out to a broader perspective, four of the top five most unphotographed genera — *Acacia* (81 unphotographed species), *Fimbristylis* (53), *Hibbertia* (49), and *Leucopogon* (45) — are the same as when we first conducted our census, with *Heliotropium* (43) moving into the top five to replace *Solanum* (33). At a family level, the top five — Poaceae (290), Fabaceae (273), Cyperaceae (206), Asteraceae (188), Myrtaceae (171) — are still the same.

There are still more than 1,000 unphotographed shrub species (1,063), with herbs in close second (983). Just 153 tree species are left to tick off; more than half of these are tropical rainforest trees from northern Queensland. A daunting 1,462 plant species from Western Australia still remain unphotographed, with Queensland sitting at 884 and the Northern Territory 647. Excitingly, some of the more diverse (>150 species) states and territories are nearing "completion." Norfolk Island and Lord Howe Island have just 9 and 13 remaining unphotographed species respectively, whilst the ACT is also very close, with only 10 of 998 species left to photograph.

We suggest that continued community engagement and mobilisation is the best approach to find and photograph these outstanding species. To maximise accessibility and usability, we recommend that any contributors intending to upload images of previously unphotographed species do so to iNaturalist, given the platform 1) is free and openly accessible and contributable to by anyone in the world, 2) covers all taxa and locations, and thus is suitable for photographs of any plant species from anywhere in Australia, and 3) is already the most comprehensive plant photograph database in Australia, containing photographs for more plant species than any other Australian database.

Acknowledgements

We thank the Royal Society of New South Wales for the Royal Society of New South Wales 2022 Scholarship awarded to TM, the funding from which was used for valuable fieldwork in Western Australia. We also thank the many naturalists and researchers who have contributed to the documenta-

tion of Australia's flora, both photographers and identifiers, including the amazing contributors mentioned throughout this paper. Thanks to the anonymous reviewer whose suggestions improved this manuscript.

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