

# Daisies Down Under:

## Review of the state of taxonomy and phylogenetics of native Australian Asteraceae

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### ABSTRACT

Because of the long history of isolation of Australia, the continent is home to a unique diversity of Asteraceae. The native daisy flora of *ca.* 1,105 species is dominated by Gnaphalieae, Astereae, Senecioneae, and Inuleae, whereas other globally diverse tribes such as Cardueae, Cichorieae, or Heliantheae are poorly represented. The last *ca.* forty years have seen taxonomic revisions of most major genera of Australian Asteraceae with the notable exceptions of *Olearia* and *Ozothamnus*. Despite this, current genus-level classification is often based on few morphological characters traditionally considered important (e.g., presence of pappus or capitulum scales). It is therefore likely that many genera are non-monophyletic in their current circumscriptions, as recently confirmed (e.g., for *Coronidium*, *Olearia*, and *Ozothamnus*). As of writing, phylogenetic studies of several other taxa are being conducted or under review. Once phylogenetic relationships have been resolved, the research focus will shift to understanding the evolution of the continental Asteraceae flora in time and space and the impact of Australia's aridification and key evolutionary and biogeographic events on patterns of diversification.

**Keywords:** Australia, phylogenetics, taxonomy, review

### INTRODUCTION

The Australian Asteraceae comprise *ca.* 1,105 formally described native species, plus *ca.* 354 introduced species (Australian Plant Census, <https://biodiversity.org.au/nsl/services/search/taxonomy>, accessed June 2021). The continent is dominated by only four of the more than 40 tribes of the family (Figure 1). The vast majority of the native Asteraceae flora belongs to tribes Gnaphalieae Cass. ex Lecoq & Juillet (510 spp., Figure 2), Astereae Cass. (334 spp., Figure 5), Senecioneae Cass. (103 spp.), and Inuleae Cass. (65 spp., incl. Plucheae (Cass. ex Dum.) A. Anderb.), whereas the other globally diverse tribes Cardueae Cass., Vernonieae Cass., Cichorieae Lam. & DC., Anthemideae Cass., Eupatorieae Cass., and Heliantheae Cass. are represented with only few species (e.g., Heliantheae, 25 spp; Cichorieae, 23 spp.).

All tribes except the two largest have been treated in the Flora of Australia series (Wilson, 2015), meaning, conversely, that *ca.* 80% of the diversity are yet to be included in a flora treatment at the national level. Although the Australian Plant Census and Australian Plant Name Index (<https://biodiversity.org.au/nsl/services/search/names>) provide up-to-date taxonomic and nomenclatural information, other details such as descriptions and keys are consequently scattered across an enormous number of papers in journals published predominantly by state herbaria and state floras of varying age.

The present review summarizes the state of knowledge of taxonomy, molecular phylogenetics, and biogeography of Australian Asteraceae with a focus on the most important publications of the last *ca.* forty years, i.e., to the exclusion of some papers

# Back o' Bourke

The genus *Calotis* (Astereae) exhibits a great diversity of fruit morphologies. The fruit of this arid zone species has both numerous barbs and two broad, woolly wings. Here in full glory with a background iconic of the the red continent, at the very edge of the Great Australian desert.



*Calotis plumulifera* F. Muell. near Bourke, New South Wales  
Photo by Alexander Schmidt-Lebuhn

presenting only new species and combinations or revisions of very small genera. Its purpose is to (1) serve as a guide to the existing literature, and (2) identify gaps for future research.

## GNAPHALIEAE

Gnaphalieae are the largest tribe of Asteraceae in Australia. Their centres of diversity are in the southwest and the southeast of the continent, including the southeastern mountain ranges and Tasmania. They comprise significant parts of the vegetation in the subalpine and alpine zones and, transiently, in the arid zone of the continent, where carpets of ephemeral species appear after strong rainfall events (Figure 2A).

Over the last *ca.* forty years, the genus level classification of Australian Gnaphalieae has changed considerably. The changes were prompted to a great degree by the realization that the genera *Helipterum* DC. and *Helichrysum* Mill., to which many of the species previously belonged, were polyphyletic (Anderberg, 1991).

Species formerly classified as *Helichrysum* were accommodated in the newly described or reinstated genera *Argentipallium* Paul G. Wilson and *Anemocarpa* Paul G. Wilson (Wilson, 1992c), *Coronidium* Paul G. Wilson (Wilson, 2008), *Leiocarpa* Paul G. Wilson (Wilson, 2001), *Ozothamnus* R.Br. (Anderberg, 1991), and *Xerochrysum* Tzvelev (Bayer, 2001), supplemented by later additions of species (e.g., Walsh, 2014; Wilson, 2017; Schmidt-Lebuhn et al., 2018). Those formerly in *Helipterum* have been accommodated in the genera *Hyalosperma* Steetz (Wilson, 1989), *Leucochrysum* (A.Cunn. ex DC.) Paul G. Wilson (Wilson, 1992b), and *Rhodanthe* Lindl. (Wilson, 1992a).

Concurrently, most large and medium-sized genera underwent taxonomic revisions, or at least saw the publication of synopses including identification keys. They include *Angianthus* J.C.Wendl. and relatives (Short, 1983; Keighery, 2004; Lyons & Keighery, 2015), *Chthonocephalus* Steetz (Short, 1990), *Cassinia* R.Br. and its satellite genera (Orchard, 2004d, 2004c, 2004b, 2004a, 2006; Orchard & Orchard, 2005, 2009), *Calocephalus* R.Br. and *Gnephosis* Cass. (Short, 2015), *Chrysocephalum* Walp. in part (Wilson, 2016), *Millotia* Cass. (Short, 1995),

*Myriocephalus* Benth. (Short, 2000), *Podolepis* Labill. (Jeanes, 2015, 2020), *Rutidosia* DC. (Holland, 1994, 1999), and *Waitzia* J.C.Wendl. (Wilson, 1992d). *Craspedia* G.Forst., a genus of rosette plants with a centre of diversity in alpine areas, has received significant taxonomic attention (Everett & Doust, 1992a; Everett & Thompson, 1992; McDougall & Walsh, 2008; Rozefelds et al., 2011; Schmidt-Lebuhn, 2013), including the reinstatement of its previously synonymized sister group *Pycnosorus* Benth. (Everett & Doust, 1992b).

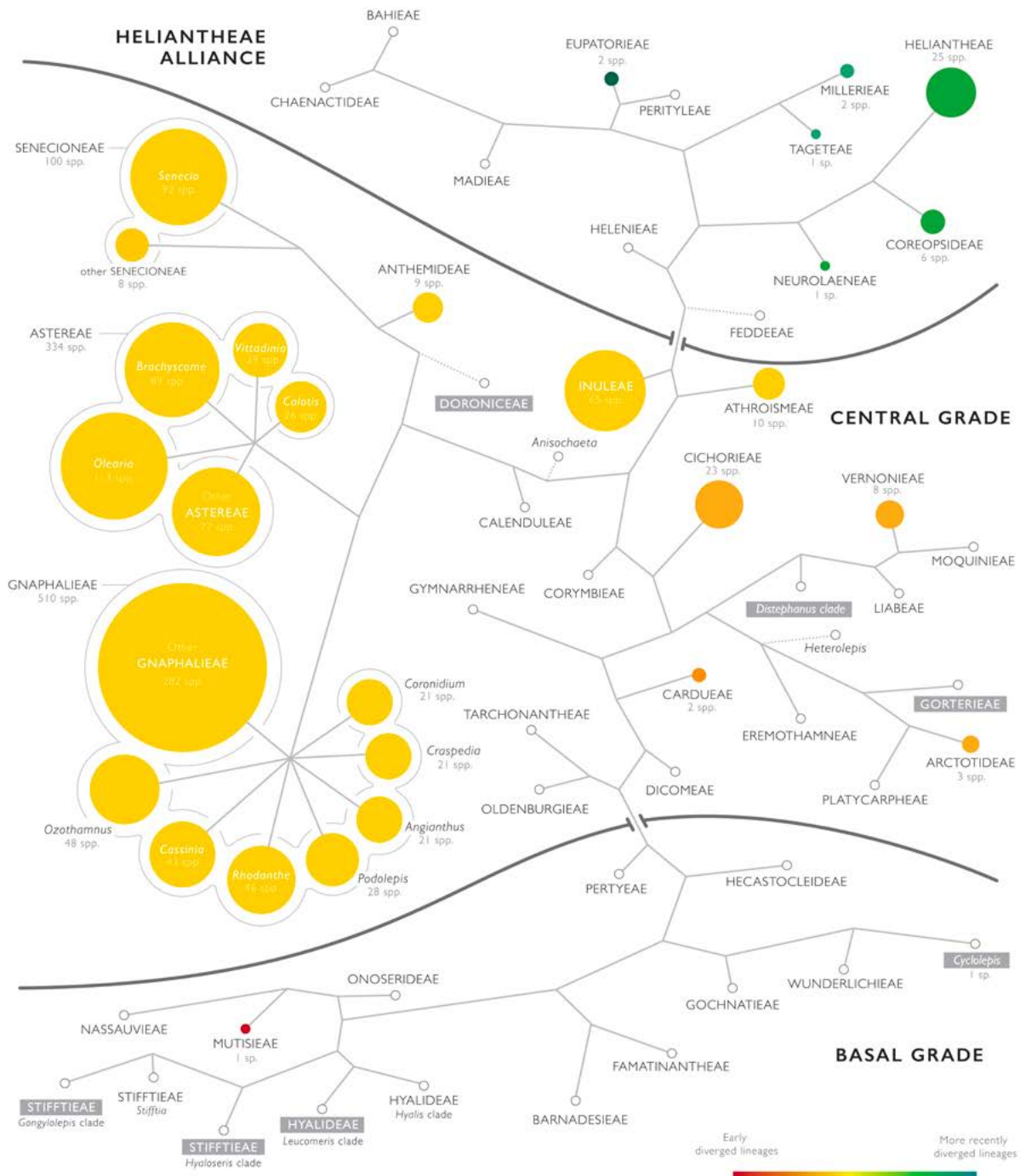
Apart from Anderberg's cladistic analyses of morphological data (Anderberg, 1990, 1991; Short & Anderberg, 1995), and excepting a limited number of studies on the delimitation of species, i.e. below the genus level (Dennis & Walsh, 2010; Ohlsen et al., 2010; Salas & Schmidt-Lebuhn, 2018), none of these changes were supported by formal analysis or explicit consideration of natural groups and synapomorphies. Many generic concepts are consequently based on single character states, e.g. absence or presence of pappus or receptacle scales, suggesting that they may represent apomorphic segregates.

Molecular phylogenies allowing the testing of these concepts remain sparse. The first molecular phylogeny at the tribal level was published by Bayer et al. (2002). More recently, a study using sequence capture data resolved four major lineages, the predominantly annual and arid zone-centred *Angianthus* clade (Fig. 2A), the shrubby *Cassinia* clade (Figure 2B; see page 43), the *Euchiton* clade (Figure 2C; Figure 3) largely of cudweed-like and cushion plants, and the predominantly perennial and eastern-temperate *Waitzia* clade (Schmidt-Lebuhn & Bovill, 2021; see page 40). Neither study, however, sampled densely enough to address genus boundaries. Conversely, a molecular phylogeny of *Podolepis* (Konishi et al., 2000) did not include sufficient potential relatives to test monophyly.

Where studies were designed to test genus boundaries, they generally confirmed the problems described above. All genera of the *Cassinia* clade, including the large genus *Cassinia* itself, are nested in *Ozothamnus* (Schmidt-Lebuhn & Constable, 2013); *Haeckeria* F.Muell. and *Odixia* Orchard are epappose *Cassinia* and *Ozothamnus*, respectively, and *Cassinia* is *Ozothamnus* with receptacle scales.

# COMPOSITAE of AUSTRALIA

PLOTTED ON CURRENT TRIBAL CLASSIFICATION



**Figure 1.** Diversity of native Australian Compositae (Asteraceae) plotted on current classification (Susanna et al., 2020). Circle size is indicative of species number; empty circles indicate taxa absent as natives in the continent; only genera with at least twenty native species are shown.

Of the three species groups of *Coronidium*, two are paraphyletic to *Xerochrysum*, and the third is unrelated (Schmidt-Lebuhn et al., 2015). Comprehensive taxonomic revisions and phylogenetic analyses of the two genera have recently been completed (Tim Collins, ms. in prep.; Figure 4), but the affinities of the *Coronidium scorpioides* group are still unclear. One species of *Leucochrysum* was found to be sister to *Waitzia*, which was not recognized previously because *Watzia* had been defined by the beak of the cypsela (Weber & Schmidt-Lebuhn, 2015). It is to be expected that similar results will be obtained from phylogenetic analyses of other genera. Current work focuses on the *Angianthus* and *Euchiton* clades, which have so far received the least attention (Schmidt-Lebuhn, unpubl. data).

An interesting aspect of some arid zone taxa in the *Angianthus* clade is the impact of breeding systems on species concepts. There are several pairs of otherwise indistinguishable populations differing only in their outcrossing versus asexual reproduction, in the latter case diagnosable by smaller anthers with an order of magnitude fewer pollen grains. Often the asexual forms occupy much larger ranges, presumably because they need only a single seed to establish a new population. The pairs have been recognized as separate species (Short, 1985, 1986), but the species concept underlying this taxonomy was not made explicit.

## ASTEREAE

Australian Astereae show a wide diversity of morphologies ranging from minuscule ephemeral herbs to treelets prized by woodworkers (*Olearia argophylla* (Labill.) F. Muell. ex Benth.). Their centre of diversity is in the temperate southeast of the continent, but they are found across most major ecological zones.

Although considerable revisionary work has been conducted over recent decades, the tribe has seen much less dramatic taxonomic changes than the Gnaphalieae. The large herbaceous genus *Brachyscome* Cass. (Figure 5C) has recently been revised, and another segregate, *Roebuckiella* P.S.Short, was created (Short, 2014a, 2014b), adding to the growing number of small satellite genera including *Allittia* P.S.Short, *Hullisia* P.S.Short, and *Pembertonia* P.S.Short. The widespread southern hemisphere

genus *Lagenophora* Cass. likewise has an up-to-date treatment (Wang & Bean, 2019), although the status of potentially phylogenetically nested *Solenogyne* Cass. remains unclear, as has *Camptacra* N.T.Burb. (Bean, 2020b).

Older but still comparatively recent taxonomic revisions are available for *Minuria* DC. (Lander & Barry, 1980) and *Vittadinia* A.Rich. (Burbidge, 1982). *Calotis* R.Br. (see page 34), which is of interest for its diverse pappus morphologies ranging from standard bristles to barbed spines, has not been reviewed since Davis (1952).

Comprehensive treatments are lacking for other medium-sized genera, although *Celmisia* Cass. (Figure 5D), which in Australia constitutes an important part of the alpine vegetation, saw the addition of three new species and one new combination (Gray & Given, 1999), and a group of mostly alpine species previously classified as *Erigeron* L. has been segregated as *Pappochroma* Raf. (Nesom, 1998) (Figure 5B).

In its current circumscription, *Olearia* Moench. (Figure 5A) is with ca. 113 species the largest genus of Asteraceae in Australia, but, perhaps because of its size, no monographic treatment is available. Various new species have been described in recent years (Walsh, 2004; Bean & Mathieson, 2015; Messina & Walsh, 2019; Bean, 2020a). The most detailed work was conducted on *Olearia* section *Asterotriche* Benth. using both morphological (Messina et al., 2013) and molecular data (Messina et al., 2014).

Although several of the smaller genera of Australian Astereae are very likely natural units, the largest of them, *Olearia* and *Brachyscome*, are more problematic. Molecular phylogenetic studies of *Olearia* and relatives suggested that the genus is non-monophyletic (Cross et al., 2002; Wagstaff et al., 2011). A recent Ph.D. project in New Zealand on the *Celmisia* group confirmed this and also found *Celmisia* to be non-monophyletic, which may have implications for the Australian members of that genus (Patricio Rodrigo Saldivia Pérez, unpubl. data). Recently the splitting of *Olearia* into ten new genera was suggested (Nesom, 2020) with reference to the phylogeny of Cross et al. (2002), but this new taxonomy has not yet found widespread acceptance and may at any rate have to be reconsidered in the light of Saldivia Pérez' results.



**Figure 2.** Australian Gnaphalieae. **A.** *Cephalipterum drummondii* A.Gray mass-flowering in Western Australia in spring. **B.** *Cassinia longifolia* R.Br., a representative of the woody *Cassinia* group. **C.** *Euchiton sphaericus* (Willd.) Holub in the Australian Capital Territory. Photos: A.N. Schmidt-Lebuhn.



**Figure 3.** The Euchiton clade of Australian Gnaphalieae contains several alpine cushion plants, such as this *Ewartia*. *Ewartia nubigena* (F. Muell.) Beauverd in Kosciuszko National Park, New South Wales. Photo: A.N. Schmidt-Lebuhn.

A molecular phylogeny of *Brachyscome* has long been available (Denda et al., 1999). Although its sampling was limited compared to the size of the genus, the results already demonstrated that *Allittia*, *Pembertonia*, and *Roebuckiella* are deeply nested in *Brachyscome* and constitute apomorphic segregates, even before they were in fact segregated. A more broadly sampled phylogenetic study of *Brachyscome* has recently been completed (Megan Hirst, unpubl. data.).

Phylogenies of the remaining genera, where they exist, provide little evidence on generic delimitation. A phylogeny of the Vittadinia group suggested that *Minuria* may be non-monophyletic and was unable to resolve *Vittadinia* and *Tetramolopium* Nees as entirely reciprocally monophyletic, but the results had limited resolution and support (Lowrey et al., 2001). A study of *Calotis* showed little resolution at the base of the genus and included only two outgroup samples (Watanabe et al., 2006).

## SENECIONEAE

The vast majority of Australian Senecioneae species belong to *Senecio* L. *sens.str.* (Figure 6A), which is most diverse in the temperate southeast of the continent. The most recent, very thorough revision of the genus in Australia led to the description of several new species and recognised seven species groups (Thompson, 2004c, 2004a, 2004b, 2005a, 2005b, 2006).

Few of the species groups, however, were resolved as natural groups in subsequent molecular phylogenies. Ribosomal and chloroplast trees both resolved three clades but showed marked incongruence, suggesting some reticulate evolution and the existence of four Australasian species groups partly defined by chromosome numbers (Liew et al., 2018). Subsequently, several Australian species previously treated as *Senecio* were found to be only distantly related to that genus, leading to the description of

# Habitat specialists

*Leucochrysum* (Gnaphalieae) is only a small genus, but its five species have adapted to very diverse habitats. This adaptive radiation must have been very recent, because four of the species can still be crossed with each other.

The species depicted here is alpine; the others occur, respectively, on red sand in the western part of the arid zone, on heavy soils in the eastern part of the arid zone, in temperate areas along the mountain ranges of eastern Australia, and only on ironstone-sandstone rock pagodas in a small area near the Blue Mountains.

*Leucochrysum alpinum* (F. Muell.) R.J. Dennis & N.G. Walsh in Kosciuszko National Park, New South Wales  
Photo by Alexander Schmidt-Lebuhn

## OTHER TRIBES



**Figure 4.** The genus *Xerochrysum*, commonly called the golden everlastings, is the horticulturally most important group of Australian native Asteraceae. Colorful hybrid variants are cultivated globally as cut-flowers. *Xerochrysum viscosum* (Sieber ex DC.) R.J.Bayer, mass-flowering in the Australian Capital Territory.

a new genus of alpine rosette plants, *Scapisenecio* Schmidt-Leb., and the expansion of previously monotypic *Lordhowea* B.Nord. (Schmidt-Lebuhn et al., 2020).

Recent taxonomic treatments exist for most of the larger genera representing other tribes in Australia. Molecular phylogenies are available and well-sampled for some important taxa but entirely absent for others.

In contrast to the top three, the regionally fourth largest tribe, Inuleae, is most diverse in the northern half of the continent. Several genera have been taxonomically revised in recent years, including *Pluchea* Cass. (Hunger, 1996, 1997; King-Jones, 2001; Bean, 2011b, 2013b), *Pterocaulon* Elliott sect. *Monenteles* (Labill.) Kuntze (Bean, 2011a), *Streptoglossa* Steetz (Dunlop, 1981), and *Sphaeromorphaea* DC. and *Ethuliopsis* F.Muell. (Bean, 2013a). Australian *Blumea* DC. was last reviewed in the Flora of Australia (Dunlop & Orchard, 2015), not in a dedicated monograph. No phylogenetic studies have been published with a focus on diversification in Australia.

Genus limits have been redrawn in Heliantheae, in particular with the segregation of *Apowollastonia* Orchard (seven Australian species) from *Wedelia* Jacq. (Orchard, 2013). This new taxonomy was subsequently supported by phylogenetic analysis (Edwards et al., 2018). *Pentalepis* F.Muell., with six Australian species, was revised twice in recent decades (Karis et al., 1993; Orchard & Cross, 2012).

Apart from a variety of introduced weeds, two genera of Cichorieae are significant in Australia. The regionally largest is *Picris* L. with ca. ten species, all which had for several decades been considered to represent introduced *P. hieracioides* L., which, however, had never established after an early incursion (Holzapfel, 1994). Species delimitation in Australian *Microseris* D.Don. (Figure 6D) is traditionally controversial, but it is currently considered to comprise three species (Walsh, 2016). The root tubers of the genus, commonly known as murnong or yam daisy, were an important food source for indigenous people (Gott, 1983).

Anthemideae are represented with only nine species of *Cotula* L. and *Leptinella* Cass., part of a southern hemisphere clade of the tribe. *Cotula alpina* (Hook.f.) Hook.f. (Figure 6B) is nested in *Leptinella* Cass. (Himmelreich et al., 2012), as morphologically



**Figure 5.** Australian Astereae. **A.** *Olearia tomentosa* (J.C.Wendl.) DC., coastal New South Wales. **B.** *Pappochroma setosum* (Benth.) G.L.Nesom. **C.** *Brachyscome stolonifera* G.L.Davis. **D.** *Celimisa* sp. in the alpine zone of Kosciuszko National Park, New South Wales, where Asteraceae constitute ca. 20% of the vascular flora. Photos: A.N. Schmidt-Lebuhn.

# Amaranth Daisy

Most species of the predominantly woody *Cassinia* clade belong to the large, shrubby genera *Cassinia* and *Ozothamnus*. Of the smaller genera, some are apomorphic segregates very similar to the former, but some are highly unusual. Monotypic *Calomeria* ("incense plant") is a woody biennial up to 2 m tall with rich pyramidal capitulescences and tiny capitula of only 2-4 florets.

*Calomeria amaranthoides* Vent. (Gnaphaleae) in the Blue Mountains, New South Wales  
Photo by Alexander Schmidt-Lebuhn



**Figure 6.** **A.** *Senecio gunnii* (Hook. f.) Belcher (Senecioneae). **B.** *Cotula alpina* (Hook. f.) Hook. f. (Anthemideae), Kosciuszko National Park, New South Wales. **C.** *Cymbonotus* sp. (Arctotideae), Australian Capital Territory. **D.** *Microseris lanceolata* (Walp.) Sch.Bip. (Cichorieae), New South Wales. **E.** Fruits of *Picris angustifolia* DC. (Cichorieae), Namadgi National Park, Australian Capital Territory. Photos: A.N. Schmidt-Lebuhn.

suggested by its stoloniferous habit, but the species has not yet been transferred.

*Centipeda* Lour. (Athroismeae) has been studied taxonomically (Walsh, 2001), and phylogenetically (Nylinder et al., 2013). The only Australian genus of Arctotideae, *Cymbonotus* Cass. (Figure 6C), has been expanded to three species (Holland & Funk, 2006).

## BIOGEOGRAPHY OF AUSTRALIAN ASTERACEAE

There is no general pattern of biogeographic history across the Australian Asteraceae, as already suggested by the large number of tribes that are present and their enormous differences in species numbers. Despite the long isolation of the continent, numerous natural introductions must have occurred, in some cases across large distances.

With few exceptions in *Gnaphalium* L. and *Pseudognaphalium* Kirp., the Australian Gnaphalieae are all part of a single clade, the Australasian clade (Smitsen et al., 2020). This informal clade name contrasts with the other clade names in the tribe, which are derived from genus names. This is a consequence of its species richness and splitting into many genera in combination with narrow occurrence in that biogeographic region, whereas the other clades are either small (and thus comfortably named after a single core genus) or widespread. It is likely that the clade is derived from a single dispersal event from southern Africa, perhaps as recent as ca. 15 MYA (Bergh & Linder, 2009; Nie et al., 2016).

Even in Australasia, and even accounting for oversplitting, few genera of Gnaphalieae are widespread, suggesting that dispersal capability is limited. The *Euchiton* group (Schmidt-Lebuhn & Bovill, 2021) is the most mobile, ranging across Australia, New Zealand, New Guinea, and into the Pacific area. *Craspedia* originated in Australia and dispersed into New Zealand, radiating there into a bewildering array of forms awaiting taxonomic resolution (Ford et al., 2007). *Ozothamnus* follows the same pattern, with the New Zealand species presumably related to the Tasmanian *O. ledifolius* (A.Cunn. ex DC.) Hook.f. complex (Breitwieser & Ward, 1997). *Xerochrysum*, finally, is found in both Australia and New Guinea; all other genera are endemic.

Senecioneae, in contrast, appear to be highly mobile. Some genera have dispersed to Australia but did not diversify (*Arrhenechthites* Mattfeld, *Gynura* Cass.), but, more importantly, the Australasian ribosomal and chloroplast clades of *Senecio* are nested between various non-Australasian clades (Liew et al., 2018), suggesting repeated dispersals from different directions followed by diversification. The small woody genera *Bedfordia* DC. and *Centropappus* Hook.f. are nested within New Zealand *Brachyglottis* J.R.Forst. & G.Forst. (Wagstaff & Breitwieser, 2004), suggesting they are derived from a trans-Tasman dispersal. The alpine cushion plants of the genus *Abrotanella* Cass. have what appears to be a classic Gondwanan distribution, including in southeastern Australia, but clade ages in the genus are too young to be explained by vicariance (Swenson et al., 2012).

The recent expansion of *Lordhowea* to include mainland species resolved the puzzle of the origin of previously isolated *Lordhowea insularis* (Benth.) B.Nord. (Schmidt-Lebuhn et al., 2020). In doing this, however, the puzzle was shifted to a deeper phylogenetic level, because *Lordhowea* and the new genus *Scapisenecio* appear to form two lineages seemingly on a grade below the northern hemisphere Adenostylinae Benth. & Hook.f. It is possible that this unexpected pattern is the result of relatively ancient dispersal events and extinctions. A well-sampled, time-calibrated backbone phylogeny of the tribe will be required to infer the most probable scenario.

The *Celmisia* group in Astereae shows biogeographic connections to New Zealand and subantarctic islands (Wagstaff et al., 2011). The *Vittadinia* group likewise ranges across Australia and New Zealand but also the Pacific, with *Tetramolopium* most speciose in New Guinea and Hawai'i. The most thoroughly studied case in the tribe may, however, be *Lagenophora* (Sancho et al., 2015), which parallels *Abrotanella* in both its Gondwanan pattern and the absence of a pappus that would facilitate wind dispersal.

Several other tribes show striking disjunctions of Australian species from their areas of origin, again with divergence dates too recent for vicariance to be feasible. A single species of Mutisieae Cass., *Trichocline spathulata* (A.Cunn. ex DC.) J.H.Willis, occurs in southwestern Western Australia. Despite

# A model of evolution

The *Senecio pinnatifolius* A. Rich. (formerly *S. lautus* auct. non G.Forst. ex Willd.) complex comprises several varieties ranging in ecological adaptation from coastal dunes to the alpine zone. It is used as a model system for the study of evolution and speciation by the lab of Daniel Ortiz-Barrientos at the University of Queensland.

*Senecio pinnatifolius* var. *alpinus* (Alf.) J. Thoms.  
in Kosciuszko National Park, New South Wales.  
Photo by Alexander Schmidt-Lebuhn

the diversity of Cardueae on other continents, only two potentially native species are found in Australia, *Hemisteptia lyrata* (Bunge) Fisch. & C.A.Mey and *Rhaponthicum australe* (Gaudich.) Sojak. *Cymbonotus* is deeply nested inside otherwise southern African Arctotideae Cass. (Funk et al., 2007). In Cichorieae, *Microseris* (Figure 6D) is North American and Australasian (Vijverberg et al., 1999). A comprehensive biogeographic study on the ancestral range evolution of *Picris* (Figure 6E) inferred its dispersal to Australia from Asia (Slovák et al., 2018). Several genera of the Heliantheae alliance occur with few species in Australia, often in the northern half of the continent.

## THE WAY FORWARD

Although it can be assumed that the vast majority of Asteraceae have already been discovered, remote parts of Australia remain insufficiently explored. Most herbarium specimens were collected close to major cities, whereas the eastern half of the largest state, Western Australia, is so poorly sampled that it is difficult to even estimate the local species numbers (Schmidt-Lebuhn et al., 2012). As the Australian taxonomic community enacts its Decadal Plan ([www.taxonomyaustralia.org.au/decadal-plan](http://www.taxonomyaustralia.org.au/decadal-plan)), targeted collecting in under-collected areas will be critical to complete the inventory of continental biodiversity.

As of the writing of this manuscript, the Australian Plant Census accepted 48 phrase name species in Asteraceae. These are placeholder names following the format “*Rhodanthe* sp. Point Lookout (J.J.Bruhl 2078) NE Herbarium” and are used to enable the conservation of and communication about species while their formal scientific publication is in preparation (Barker, 2005). Unfortunately, it can often take a decade or more before a phrase name species is validated. It is possible that this is partly due to the taxonomic impediment, i.e. lack of taxonomists. It is also possible, however, that the custom of using phrase names actually discourages their validation, as taxonomists might be worried either about ‘scooping’ the person who registered the phrase name or about being scooped themselves if they invested the time, because that person may already have a manuscript under review. Whatever the cause, it would be desirable to accelerate the description of new species that are already known to exist.

A greater gap than species discovery are, however, genus-level studies. Several important genera have not been comprehensively revised, including some of the largest, *Olearia* and *Ozothamnus*. Even genera recently having seen taxonomic changes and additions of species are frequently lacking identification keys covering all their species (e.g., *Pycnosorus*). Many existing keys are outdated, and with the exception of the *Cassinia* group ([keys.lucidcentral.org/keys/v3/cassinia/](http://keys.lucidcentral.org/keys/v3/cassinia/)), interactive identification tools using terminology accessible to non-taxonomists are all but non-existent. Collections technicians, researchers, conservation managers, biosecurity practitioners, and the general public therefore find it difficult to reliably identify Asteraceae specimens and would benefit from the publication of additional modern, electronic identification tools and field guides.

On the other hand, phylogenetic studies have been produced at an increasing rate in recent years. Publications of well-sampled phylogenies covering major groups of interest such as *Olearia* and *Celmisia*, *Brachyscome*, and *Coronidium* and *Xerochrysum* are currently in preparation. The Australian Angiosperm Tree of Life (AAToL) initiative in the Genomics for Australian Plants consortium (GAP, [www.genomicsforaustralianplants.com](http://www.genomicsforaustralianplants.com)) has produced sequence capture data for one species of each genus. In this case, the over-splitting of Gnaphalieae genera means that a very densely sampled backbone phylogeny will soon be available to guide future research.

Significant gaps in our knowledge of phylogenetic relationships will be filled in the next few years. In Gnaphalieae, a particular focus will be the Angianthus clade, where major changes in the circumscription of genera can be expected due to the large number of potential apomorphic segregates. Genomic data will be required to resolve conflicting ribosomal and chloroplast signals in Senecioneae.

Once species-level data have become available for all major groups, attention can turn towards evolutionary questions, ideally in the context of time-calibrated phylogenies: How was the Australian Asteraceae flora assembled in time and space? What was the impact of the aridification of the continent on patterns of diversification? What are key innovations that drove adaptive radiations into arid and alpine areas?

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