Conservation Advice for *Leucochrysum albicans* subsp. *tricolor* (Hoary Sunray)

In effect under the *Environment Protection and Biodiversity Conservation Act 1999* from 20 December 2021.

This document combines the approved conservation advice and listing assessment for the species. It provides a foundation for conservation action and further planning.

Photo of *Leucochrysum albicans* subsp. *tricolor* (Hoary Sunray) © Copyright, Murray Fagg (2012)

Conservation status

Leucochrysum albicans subsp. *tricolor* (Hoary Sunray) is currently listed in the Endangered category of the threatened species list under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act) effective from 16 July 2000.

Leucochrysum albicans subsp. *tricolor* was assessed by the Threatened Species Scientific Committee to be eligible for listing as Endangered under Criterion 1. The Committee's

assessment is at Attachment A. The Committee's assessment of the species' eligibility against each of the listing criteria is:

- Criterion 1: A2abc: Endangered
- Criterion 2: B2ab(ii,iii,iv): Vulnerable
- Criterion 3: Ineligible
- Criterion 4: Ineligible
- Criterion 5: Insufficient data

The main factor that makes the subspecies eligible for listing in the Endangered category is its severe population reduction over the last three generations.

Species can also be listed as threatened under state and territory legislation. For information on the current listing status of this subspecies under relevant state or territory legislation, see the Species Profile and Threat Database.

Species information

Taxonomy

Conventionally accepted as *Leucochrysum albicans* subsp*. tricolor* (DC.) N.G. Walsh (2015).

Hoary Sunray was eligible for listing under the EPBC Act as *Leucochrysum albicans* var*. tricolor* (DC.) Paul G. Wilson on 16 July 2000. Following the elevation of rank by Walsh (2015), the name of this taxon is now conventionally accepted as *Leucochrysum albicans* subsp*. tricolor* (DC.) N.G. Walsh (CHAH 2020).

Description

Hoary Sunray is a perennial everlasting daisy belonging to the family Asteraceae. Stems are 10–15 cm tall, and have narrow leaves 2–10 cm long, covered in white cottony hairs. The yellowish flower heads are 2–5 cm in diameter and surrounded by numerous white overlapping ovate-oblong bracts, with the outer layer often tinged purple or brown. The fruits are brown, ovoid, 2–3 mm long, with 14–20 pappus bristles (Wilson 1992; Short 1999). The flowering period for Hoary Sunray is November–December in Victoria (Vic), October–January (earlier at lower elevations and later at higher elevation sites) in Tasmania (Tas) and probably October–December in New South Wales (NSW) and the Australian Capital Territory (ACT) (DPIPWE 2017; VicFlora 2020). Surveys should be undertaken during its flowering period, when the taxon is most conspicuous (McClaren 2013), as non-flowering plants can be difficult to locate in grassy habitat.

Distribution

Hoary Sunray is endemic to south-eastern Australia, where it occurs in three geographically separate areas (Map 1).

The majority of Hoary Sunray subpopulations are in NSW and the ACT where the taxon is still locally common (K McDougall 2020 pers comm 23 Sept) although some roadside subpopulations may be declining (FOG 2021 pers comm 20 June). The species currently occurs on the Southern Tablelands roughly from Bombala to Goulburn, with several records from further north near Mudgee (ALA 2020). The species once occurred more widely in NSW, with records from near

Tarcutta, Bega valley, Moss Vale and Delegate (Sinclair 2010; ALA 2020). Large subpopulations of a *Leucochrysum* from subalpine parts of Kosciuszko National Park (e.g. Happy Jacks Plain) are referable to *Leucochrysum alpinum* (Alpine Sunray) and not Hoary Sunray (N Walsh 2020 pers comm 23 Sept).

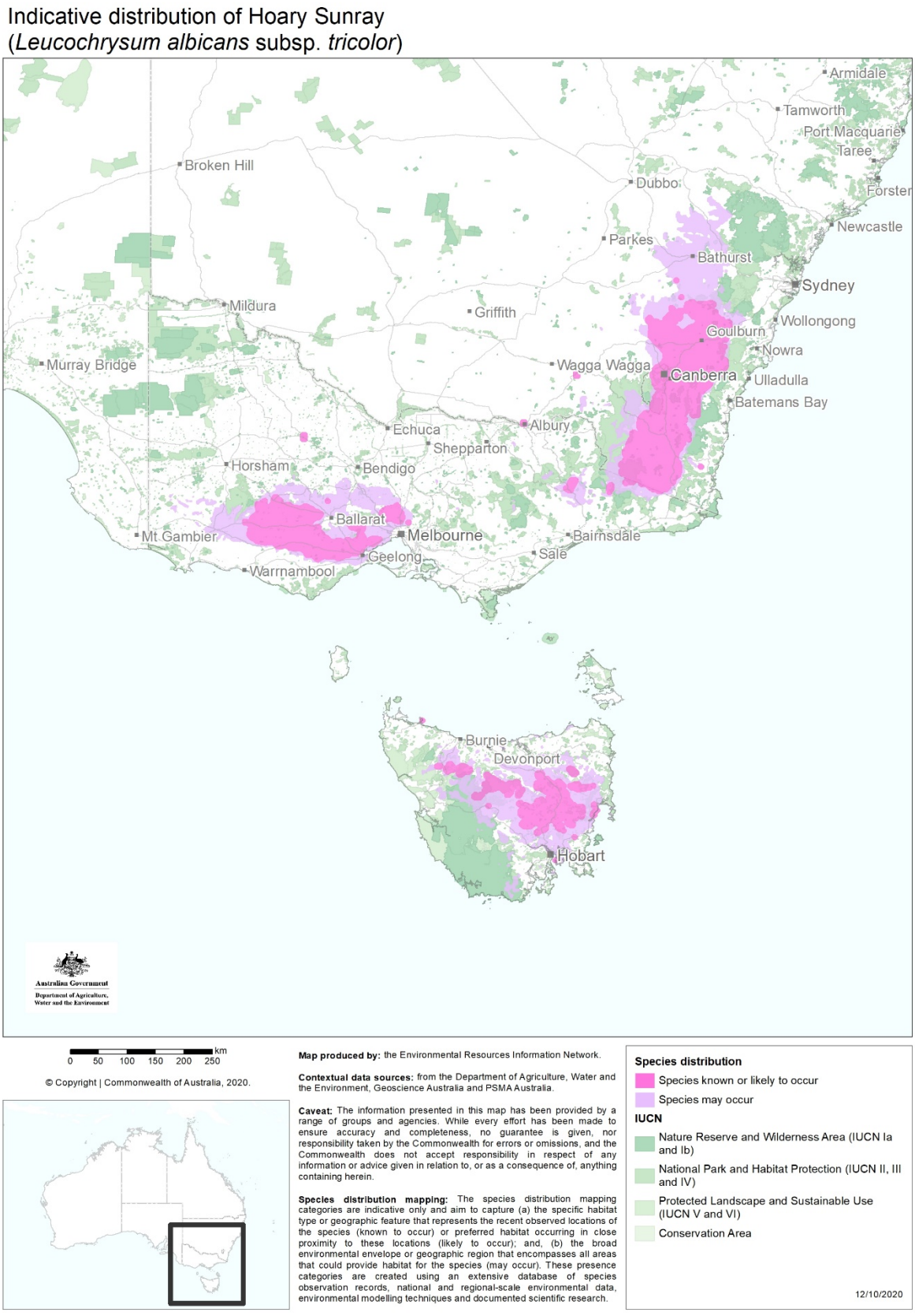
In NSW, there are 88 records from approximately 30 subpopulations recorded since 2000, with 246 records from a similar number of subpopulations in the ACT (ALA 2020; Canberra Nature Map 2020). Sinclair (2010) estimated the total number of plants in NSW and ACT to be >200 000 plants. Although there is little recent information on subpopulation sizes in NSW and ACT, there is no evidence to suggest that the estimate in Sinclair (2010) has changed substantially, although some roadside subpopulations may be declining (FOG 2021 pers comm 20 June). Approximately half of the subpopulations in NSW occur on roadsides, around a third on unsecured private land and the remainder in reserves or state forest (ALA 2020). In the ACT, around 20 of the approximate 30 subpopulations occur in public land reserves, with the remainder occurring on roadsides or unsecured private land (ALA 2020; Canberra Nature Map 2020).

In Victoria, Hoary Sunray occurs in the south-west, between Colac, Inverleigh, Ballarat, Ararat and Hamilton, in the Victorian Volcanic Plain bioregion (ALA 2020). It was once more widespread in the region, with records from Port Fairy, Macarthur, Creswick and Mt Cole (ALA 2020). Victoria has approximately 53 subpopulations recorded since 2000 and, with the exception of one subpopulation at Inverleigh Nature Conservation Reserve, all are in roadsides, rail reserves or cemeteries (Morgan et al. 2013) where many have declined and some have gone extinct. Of the seven significant Victorian subpopulations listed in Sinclair (2010), two subpopulations have decreased from several thousand plants to several hundred (Wickliffe-Willaura Rd, Wickliffe and Lismore-Scarsdale Rd, Wallinduc, in McClaren 2013), three have decreased from several thousand plants to a few dozen (Glenelg Hwy, Streatham, Bolac Plains Rd, Woorndoo and Rokewood Cemetery and roadsides) and one was destroyed by roadworks (Hamilton Highway, Cressy, noting that Hoary Sunray was incorporated in restoration works) (J Morgan 2020 pers comm 23 Sept). Only one important subpopulation listed in Sinclair (2010) was stable or increasing (Ararat-Glenthompson Rd, Willaura, in McClaren 2013). McClaren (2013) reported on subpopulation changes in 27 Victorian subpopulations from 2003 to 2012, representing about half of all Victorian subpopulations, including most of the larger subpopulations. In 2012, the size of 17 subpopulations had decreased including six that went locally extinct (and a seventh reduced to a single plant), while the size of 10 subpopulations remained stable or increased (McClaren 2013). The total number of plants recorded by McClaren (2013) was approximately 22 870, although noting that not all Victorian subpopulations were surveyed. Data on other subpopulations not surveyed by McClaren (2013) is limited, although a subpopulation at Inverleigh Nature Conservation Reserve also appears to be in decline (N Anderton 2020 pers comm, 25 Sept). Given the inferred continued decline of Hoary Sunray in the last decade, its Victorian population is estimated at 20 000–30 000 plants (DELWP 2020b).

In Tasmania, Hoary Sunray is scattered across the midlands, particularly around Ross, Tunbridge and Campbelltown, in the north at Stanley and in several localities in the Great Western Tiers (DPIPWE 2017). It previously occurred in southern Tasmania, between Buckland and Oatlands, on the north coast near Wynyard and may once have occurred on the west coast (L Gilfedder pers comm in Sinclair 2010). Tasmania has 91 records from approximately 16 subpopulations recorded since 2000 (ALA 2020). The total size of the Tasmanian population has

been estimated at >100 000 (Sinclair 2010) and >175 000 (DPIPWE 2017), although Schahinger (2020 pers comm 24 Oct) estimated that a subpopulation along Tooms Lake Road in the midlands in 2011 contained many hundreds of thousands of plants, which suggests that the total population size in Tasmania in 2011 was considerably higher than the estimates of Sinclair (2010) and DPIPWE (2017). However, in October 2020 this subpopulation at Tooms Lake Road appeared to only number a few hundred plants, likely due to localised conversion of the habitat to dryland introduced pasture species, indicating a significant recent decline (R Schahinger 2020 pers comm 24 Oct; L Gilfedder 2020 pers comm 4 Nov). A subpopulation at Vale of Belvoir was estimated at 30 000 plants in the late 2000s (Sinclair 2010; C Dickson 2020 pers comm 28 Sept) however it has also recently undergone a large decline, recording less than half the cover of Hoary Sunray along monitoring transects through the largest patches in 2018–2019 (10.2 cm of Hoary Sunray cover per transect) compared with 2014–2015 (26.5 cm / transect) (Tasmanian Land Conservancy 2019). These declines in the monitored patches are likely to be indicative of general trends across the Vale of Belvoir subpopulation more broadly (C Dickson 2020 pers comm 28 Sept) and the reason for the decline of this subpopulation is unclear. Other Tasmanian subpopulations are relatively small and many are in decline or have gone locally extinct. A subpopulation of 50–100 plants at Liawenee Conservation Area was driven to local extinction in the 2000s due to lack of biomass reduction (i.e. burning or light grazing) (J Kirkpatrick 2020 pers comm 23 Sept), while a disjunct subpopulation at The Nut State Reserve declined from 4778 plants in 2009 to 42 plants in 2016, likely due to drought conditions, perhaps in combination with grazing (Collier 2016). A subpopulation on private land north-west of Ross declined from around 200 plants to a single plant in 2010 (Schahinger 2020 pers comm, 24 Oct) and a subpopulation on Stony Gully Road north-east of Ross has also declined due to weed invasion, with <100 Hoary Sunray present in 2020 (L Gilfedder 2020 pers comm 4 Nov). However, a subpopulation at Township Lagoon Nature Reserve increased from five plants in 1990 to 4614 ± 554 in 2015, likely due to several (unauthorised) burns maintaining intertussock space (Carter & Schahinger 2015), although this is the only subpopulation known to have increased in size in Tasmania.

Map 1 Modelled distribution of Hoary Sunray



Source: Base map Geoscience Australia; species distribution data Species of National Environmental Significance database.

Cultural and community significance

The cultural significance of Hoary Sunray is not well understood, although the grasslands and woodlands where it occurs have a long and profound history of occupation and management by Indigenous people.

Relevant biology and ecology

Reproductive ecology

Although perennial, Hoary Sunray plants die back over summer, when they survive as a perennial rootstock (Sinclair 2010). Individual plants probably live for a maximum of about 15 years (Gilfedder & Kirkpatrick 1994a; DELWP 2015). Numbers of plants can fluctuate widely between years (Berechee 2003; McClaren 2013; Collier 2016). The subspecies is reliant on cross-pollination by Hymenoptera and Diptera (McClaren 2013) and does not set seed when self-pollinated (Costin et al. 2001). When pollinated, it produces many small, wind-blown seeds that generally have high seed viability and germinate quickly (Morgan et al. 2013). Seeds are thought to be short-lived in the soil seed bank (Morgan et al. 2013), although germination from soil cores has been observed, suggesting they may be capable of surviving at least for short periods of time (Gilfedder & Kirkpatrick 1993). Germination usually occurs in June – July (Gilfedder & Kirkpatrick 1993). Adult plants usually resprout following fire (DELWP 2015).

Habitat Ecology

Hoary Sunray occurs in a wide variety of grassland, woodland and forest habitats, generally on relatively heavy soils. Hoary Sunray is known to occur in several Threatened Ecological Communities including, but not limited to, Natural Temperate Grassland of the South Eastern Highlands, and White Box–Yellow Box–Blakely's Red Gum Grassy Woodlands and Derived Native Grasslands (NSW and ACT); Natural Temperate Grassland of the Victorian Volcanic Plain, and Grassy Eucalypt Woodland of the Victorian Volcanic Plain (Vic); and, Lowland Native Grasslands of Tasmania (Tas) (Threatened Species Scientific Committee 2006, 2008, 2009a, 2009b, 2013, 2016). It also has potential to occur in Lowland Grassy Woodland of the South East Corner Bioregion (NSW) where it is known from several historical records (ALA 2020).

In Tasmania, Hoary Sunray has a broad climatic and ecological range, occurring in temperate grassy habitats on clay loam soils (Gilfedder 1991; Gilfedder & Kirkpatrick 1994a, b; Sinclair 2010). Sites range from 60–1160 m altitude, with annual rainfall varying from 450 mm in the midlands to 2000 mm (occasionally 3000 mm) in the northwest. In lowland areas, the most common habitat type is grassy woodland of *Eucalyptus viminalis* (White Gum), *E. ovata* (Swamp Gum) or *E. pauciflora* (Snow Gum), with a grassy layer of *Themeda triandra* (Kangaroo Grass), *Austrostipa* spp. (Spear Grass) and *Dichelachne crinita* (Long-hair Plume-grass). Hoary Sunray also grows in woodlands of White Gum or *E. amygdalina* (Black Peppermint) with a diverse heathy and grassy understorey. Other habitats include grasslands of *Poa labillardierei* (Common Tussock-grass) with shrubs including *Correa alba* (White Correa), *Pomaderris apetala* (Pomaderris), *Bursaria spinosa* (Sweet Bursaria), *Acacia verticillata* (Prickly Moses) and *Melaleuca ericifolia* (Swamp Paperbark), and often with a significant component of introduced weeds (Sinclair 2010). In montane areas of Tasmania, Hoary Sunray grows in shrubby grasslands containing *Poa* spp. (tussock grasses), *Dichelachne rara* (Common Plume-grass), *Trisetum spicatum* (Bristle-grass), *Deyeuxia* spp. (Bent Grass) and a diversity of herbs and shrubs (Sinclair 2010).

In Victoria, Hoary Sunray occurs almost exclusively on acidic clay soils derived from basalt, occasionally on nearby sandy-clay soils derived from sedimentary material (Costin 1999; Costin et al. 2001). All known Victorian occurrences are in grassland or grassy woodland (usually *Eucalyptus camaldulensis* (River Red Gum)) communities dominated by Kangaroo Grass, Long-hair Plume-grass, *Rytidosperma carphoides* (Short Wallaby-grass) and other *Rytidosperma* spp. (Wallaby Grass). Hoary Sunray is generally found in the spaces between grass tussocks in association with other herb species, often including *Eryngium ovinum* (Blue Devil), *Calocephalus citreus* (Lemon Beauty-heads), *Acaena echinata* (Sheep's Burr) and *Leptorrhynchos squamatus* (Scaly Buttons) (DELWP 2015; DELWP 2020a).

In NSW and ACT, Hoary Sunray occurs in grasslands, grassy areas in woodlands and dry open forests, and modified habitats, on a variety of soil types including clays, clay loams, stony and gravely soil (Sinclair 2010; ALA 2020; Canberra Nature Map 2020). Associated species are varied, but commonly include Kangaroo Grass and Wallaby Grass in the ground layer, and often with *E. melliodora* (Yellow Box), *E. blakelyi* (Blakely's Red Gum), *E. polyanthemos* (Red Box), *E. mannifera* (Brittle Gum) or Snow Gum where a tree stratum is present. Other species occurring with Hoary Sunray include *Beyeria viscosa* (Wallaby Bush), *Pultenaea* spp. (Bush Pea), *Acacia rubida* (Red-stem Wattle), *Acacia genistifolia* (Spreading Wattle), *Cassinia longifolia* (Shiny Cassinia), *Allocasuarina* spp. (Sheoak) and *Kunzea parvifolia* (Violet Kunzea).

Within all these habitats, the taxon relies on the presence of bare ground for germination and establishment, free from competition with grasses (e.g. Kangaroo Grass) (Sinclair 2010). In lowland areas, periodic disturbance such as fire creates these bare areas. Hoary Sunray can sometimes colonise roadsides that have been scraped (R. Rehwinkel, I. Crawford pers comm in Sinclair 2010). In drier, high altitude grasslands (e.g. Southern Tablelands of NSW and ACT), there is generally a sparser grass sward with more inter-tussock spaces, which provide suitable sites for germination in the absence of periodic disturbance (Sinclair 2010).

Habitat critical to the survival

No Critical Habitat as defined under section 207A of the EPBC Act has been identified or included in the Register of Critical Habitat.

The determination of critical habitat was a proposed action in the previous Recovery Plan (Sinclair 2010) but has not yet been undertaken. However, habitat critical to the survival of Hoary Sunray likely includes suitable native grassland and grassy woodland habitat occupied by Hoary Sunray in Vic, Tas and NSW/ACT. In Victoria this includes Natural Temperate Grassland of the Victorian Volcanic Plain and Grassy Eucalypt Woodland of the Victorian Volcanic Plain. In Tasmania, habitat critical to the survival of Hoary Sunray includes Lowland Native Grasslands of Tasmania, grassy woodland with an overstorey of White Gum, Swamp Gum or Snow Gum, woodlands of White Gum or Black Peppermint and, in montane areas, shrubby native grasslands. In NSW and ACT, habitat critical to the survival of Hoary Sunray includes Natural Temperate Grassland of the South Eastern Highlands and White Box–Yellow Box–Blakely's Red Gum Grassy Woodlands and Derived Native Grasslands. For more detailed habitat descriptions refer to *Relevant biology and ecology* above. Within the range of Hoary Sunray, these habitats are likely necessary for dispersal activities, the maintenance of genetic diversity and the long-term evolutionary trajectory of Hoary Sunray.

Important populations

In this section, the word population is used to refer to subpopulation, in keeping with the terminology used in the EPBC Act and state/territory environmental legislation.

All populations of Hoary Sunray in Victoria and Tasmania are considered to be important populations, due to the declining number of populations in those states and, therefore, the likely importance of all remaining populations for genetic diversity of Hoary Sunray. Lack of genetic diversity is a known threatening process impacting Hoary Sunray which is self-incompatible and even small populations have inherent conservation value as they are likely to harbour novel S alleles (genes that prevent self-fertilisation, which can help reduce inbreeding depression; Porcher & Lande 2005) that contribute to the maintenance of genetic diversity and ecological function (Morgan et al. 2013). In NSW and ACT there is no evidence of a substantial decline of Hoary Sunray. Therefore, important populations in NSW and ACT are considered to be:

- All the large populations of greater than 10 000 individuals, due to their potential as key source populations for dispersal of Hoary Sunray propagules and gene flow; and,
- All populations near the limit of the range of the NSW/ACT region (including but not limited to those near or south of Cooma (e.g. around Jindabyne and Bombala) and near or north of Goulbourn (e.g. around Burraga and Mudgee)).

Threats

The major threats to Hoary Sunray are clearing of native grasslands (land use change) on private land, a lack of biomass reduction (e.g. burning, light grazing) in productive grassland habitat in Victoria and Tasmania, road maintenance works damaging roadside subpopulations, weed invasion, drought and genetic risks associated with small, fragmented subpopulations (Table 1).

Table 1 Threats impacting Hoary Sunray

Threat	Status and severity [a]	Evidence
Habitat loss, disturbance and modifications		
Land use change	• Status: historical/current • Confidence: known • Consequence: catastrophic • Trend: static • Extent: across part of its range	Subpopulations on private land are at risk of clearing, especially where land use might change such as from grazing to cropping, which can permanently destroy subpopulations (Sinclair 2010; McClaren 2013; DPIPWE 2017). For instance, part of a large subpopulation at Tooms Lake Road, Ross in Tasmania was destroyed by conversion of habitat to dryland introduced pasture species and some pivot-irrigated cropping (L Gilfedder 2020 pers comm 4 Nov). Conversion of grazing land to cropping is ongoing in western Victoria (SAC 2021 pers comm 23 June).
Roadworks	• Status: current • Confidence: known • Consequence: major • Trend: static • Extent: across part of its range	The restriction of many subpopulations to roadside remnants, particularly in Vic and NSW, places the taxon at risk from road and utilities construction and maintenance (DELWP 2015, Sinclair 2010). Subpopulations have previously been impacted due to

		roadworks, such as along the Snowy Mountains Highway near Adaminaby in NSW, and near Skipton in Vic (Sinclair 2010), and along the Hamilton Highway near Cressy in Vic (J Morgan 2020 pers comm 23 September). Roadside widening activities (often undertaken by local government) to increase road safety can impact the species and its native grassland habitat occurring on roadsides (SAC 2021 pers comm 23 June).
Roadside herbicide use	• Status: current • Confidence: known • Consequence: major • Trend: static • Extent: across part of its range	Roadside spraying for fire control (typically undertaken by farmers under permit from the Country Fire Authority) has been employed over a long time period for the reduction of native grassland seen to be a fire-hazard on roadsides and road reserves in Vic (SAC 2021 pers comm 23 June). This is likely to have had an impact on Hoary Sunray and native grassland occurrence along roadsides in the vicinity of Streatham, Lake Bolac, Ararat, Chatsworth, Vic (SAC 2021 pers comm 23 June). Spraying for road safety purposes may also be a threat (SAC 2021 pers comm 23 June).
Fire		
Inappropriate fire regimes	• Status: current • Confidence: known • Consequence: major • Trend: static • Extent: across part of its range	Long fire-free intervals are detrimental to Hoary Sunray as they result in high biomass accumulation in productive grasslands that kills forbs like Hoary Sunray (DELWP 2015; Morgan 2015). Once Hoary Sunray senesces, it may not recover as it probably lacks a long-lived soil seedbank (Morgan et al. 2013). When biomass accumulates over periods of 7-11 years or more, the longer-term integrity of productive Kangaroo Grass-dominated grasslands can be compromised by death of the dominant Kangaroo Grass sward, followed typically by weed invasion (Morgan 2015), which is likely to negatively affect the habitat suitability and likelihood of recovery for Hoary Sunray. Lack of biomass reduction in Vic and Tas appears to have resulted in local extinction or decline of subpopulations, such as at Liawenee in Tasmania (J Kirkpatrick 2020. pers comm 23 September) and Chepstowe in Vic (McClaren 2013). Burning of roadsides in Vic is often undertaken by local farmers through the Country Fire Authority and has become increasingly difficult to organise (SAC 2021 pers comm 23 June). As a

		result, burning of some roadsides is being undertaken less frequently than is necessary to maintain habitat for the Hoary Sunray (SAC 2021 pers comm 23 June). Biomass appears to be less of an issue in NSW and the ACT, likely due to the lower productivity of the vegetation in that region (Sinclair 2010). Timing of fire is likely important, and Hoary Sunray could be negatively impacted by fire during its germination and growing season in winter and spring (DELWP 2015).
Invasive species		
Competition with weeds	• Status: current • Confidence: known • Consequence: major • Trend: static • Extent: across all of its range	Hoary Sunray is often restricted to small, linear remnants often surrounded by agricultural land that is highly susceptible to weed invasion (Hobbs & Yates 2003). Hoary Sunray does not tolerate strong competition and is at high risk from the effects of weeds throughout its range (Sinclair 2010; DELWP 2015). Weeds currently threatening the taxon include Cat's Ear (*Hypochaeris radicata*), Clovers (*Trifolium* spp.), Toowoomba Canary-grass (*Phalaris aquatica*), Brown-top Bent (*Agrostis capillaris*), Paspalum (*Paspalum dilatatum*), Cocksfoot (*Dactylis glomerata*) and South African Weed Orchid (*Disa bracteata*) (Sinclair 2010; McClaren 2013). The native Hedge Wattle (*Acacia paradoxa*) acts similar to an invasive species at Inverleigh Nature Conservation Reserve and threatens the subpopulation there (N Anderton 2020 pers comm 25 Sept).
Genetic threats resulting from small and fragmented subpopulations		
Low genetic diversity	• Status: current • Confidence: known • Consequence: moderate • Trend: static • Extent: across part of its range	Many small, isolated subpopulations of Hoary Sunray are subject to the effects of fragmentation on genetic diversity, with allelic richness, observed and expected heterozygosity, percent seed set, and seed germination all positively correlated with subpopulation size (Morgan et al. 2013). Many subpopulations of Hoary Sunray are small and it is likely that genetic threats are a serious threat to those subpopulations.
Climate Change		
Increasing frequency and intensity of drought	• Status: current • Confidence: suspected • Consequence: moderate • Trend: increasing • Extent: across entire range	Climate projections for south-eastern Australia include increasing frequency and intensity of drought (CSIRO & Bureau of Meteorology 2015).

		Drought appears detrimental to Hoary Sunray, probably by negative effects on adult growth and increasing mortality and reducing recruitment (Gilfedder & Kirkpatrick 1994a; McClaren 2013) and has been implicated in the decline of a subpopulation at The Nut State Reserve in Tasmania (Collier 2016).
Herbivory		
Over-grazing by domestic stock	• Status: historical/current • Confidence: suspected • Consequence: minor • Trend: unknown • Extent: across part of its range	Light stock grazing appears beneficial to Hoary Sunray by maintaining low biomass conditions, and in Tasmania Hoary Sunray is often present in paddocks that are grazed by sheep, cattle or horses (Gilfedder & Kirkpatrick 1994a,b; DPIPWE 2017). However, the absence of Hoary Sunray from grazed private land in Vic suggests historic over-grazing pressure may have contributed to its decline (Sinclair 2010). Changes to grazing regimes that were previously beneficial to Hoary Sunray may subsequently cause a shift in conditions that no longer favour Hoary Sunray, and allow other species, especially invasive weeds, to establish and exclude it (Sinclair 2010).

[a] Status—identify the temporal nature of the threat;
Confidence—identify the extent to which we have confidence about the impact of the threat on the species;
Consequence—identify the severity of the threat;
Trend—identify the extent to which it will continue to operate on the species;
Extent—identify its spatial content in terms of the range of the species.

Each threat has been described in Table 1 in terms of the extent that it is operating on the subspecies. The risk matrix (Table 2) provides a visual depiction of the level of risk being imposed by a threat and supports the prioritisation of subsequent management and conservation actions. In preparing a risk matrix, several factors have been taken into consideration, they are: the life stage they affect; the duration of the impact; and the efficacy of current management regimes, assuming that management will continue to be applied appropriately. The risk matrix and ranking of threats has been developed in consultation with in-house expertise using available literature.

Table 2 Hoary Sunray risk matrix

Likelihood	**Consequences**				
	Not significant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Low risk	Moderate risk	Very high risk **Increasing frequency and intensity of drought**	Very high risk	Very high risk
Likely	Low risk	Moderate risk	High risk **Low genetic diversity**	Very high risk **Inappropriate fire regime**	Very high risk **Land use change**

Likelihood	Consequences				
	Not significant	Minor	Moderate	Major	Catastrophic
				Competition with weeds	
Possible	Low risk	Moderate risk	High risk **Over-grazing by introduced herbivores**	Very high risk **Roadworks**	Very high risk
Unlikely	Low risk	Low risk	Moderate risk	High risk	Very high risk
Unknown	Low risk	Low risk	Moderate risk	High risk	Very high risk

Priority actions have then been developed to manage the threat particularly where the risk was deemed to be 'very high' or 'high'. For those threats with an unknown or low risk outcome it may be more appropriate to identify further research or continue monitoring.

Conservation and recovery actions

Primary conservation outcome

No important populations are damaged, destroyed, or decline.

Conservation and management priorities

Inappropriate fire regimes

- Continue appropriate burning of grassland subpopulations of Hoary Sunray in late summer to mid-autumn. In Victoria, cessation of such management will likely result in the decline or local extinction of Hoary Sunray. Country Fire Authority brigades in Western Victoria should be encouraged and supported to implement frequent burning of roadside grassland sites containing Hoary Sunray subpopulations. Recommended frequency of fire is typically 2–5 years in kangaroo grass-dominated grasslands (McDougall 1989).
- If burning is unfeasible, explore options for slashing (noting that high biomass may necessitate the removal of slash) or temporary grazing over the summer and early autumn periods.

Habitat loss, disturbance and modifications

- Explore options to purchase areas of key populations and incorporate into the conservation reserve system.
- Ensure all subpopulations of Hoary Sunray are recorded in relevant databases used by decision makers and land managers so that subpopulations are not destroyed or damaged unknowingly, e.g. during road maintenance work.
- Ensure contractors undertaking road maintenance activities are aware of the significance and location of Hoary Sunray subpopulations.
- Explore options for signage or permanent markers around roadside subpopulations to reduce the risk of accidental destruction.
- Engage with private land owners with subpopulations of Hoary Sunray on their properties and explore options to covenant or protect unsecured subpopulations on private land.

Invasive species

- Where weeds are in strong competition with Hoary Sunray, organise control of high threat weeds in significant subpopulations, if possible to coincide with burning (i.e. post-fire).
- Burning programs should include planned and funded post-fire weed control.

Genetic threats resulting from small and fragmented subpopulations

- Collect and maintain ex situ seed and living collections (to ensure a supply of fresh seed is maintained as viability is likely to decline rapidly) from across the subspecies range at Botanic Gardens or appropriate institutions to manage the risk of losing genetic diversity. Ensure collections are large, monitored for viability and cover a broad spread of subpopulations within each State, particularly declining subpopulations, to ensure genetic diversity is captured. Refer to the Plant Germplasm Conservation Guidelines (Martyn Yenson et al. 2021).
- Investigate the potential for conservation translocations to create new subpopulations of Hoary Sunray in Tasmania and Victoria. Translocated subpopulations could include genetic mixing, although careful consideration should be given to risks associated with gene pool mixing as demonstrated in other Asteraceae (e.g. ploidy differences between subpopulations). Any conservation translocations should be undertaken in accordance with the *Guidelines for the Translocation of Threatened Plants in Australia* (Commander et al. 2018) and monitored to maturity and seed set to ensure new subpopulations contribute to a decrease in the threatened status of Hoary Sunray.
- Monitor gene flow among declining subpopulations, particularly where there are no obvious physical threats driving the decline. Exchange of self-incompatibility alleles (S alleles) is important for population viability in this self-incompatible species, and such knowledge could inform genetic rescue attempts for affected subpopulations (Young & Pickup 2010; Thrall et al. 2014).
- Restore habitat following the National Restoration Standards (Standards Reference Group SERA 2021).

Climate Change

- Identify and protect current and future habitat likely to remain or become suitable for Hoary Sunray under future climate conditions.
- Undertake a review of monitoring data to determine the role of drought in population decline of Hoary Sunray.

Herbivory

- Continue grazing regimes where they have been shown to be effective at managing Hoary Sunray. If there is evidence of a decline in Hoary Sunray in a grazed subpopulation, the role of grazing should be carefully considered, and other options for biomass reduction (e.g. fire) could be investigated to determine if grazing is a factor in the decline.
- Undertake herbivore control where necessary.

Stakeholder engagement/community engagement

- Engage and involve traditional owners in conservation actions, including the implementation of Indigenous fire management and other survey, monitoring and management actions. Fire management for Hoary Sunray typically involves small-scale burns in autumn on roadsides or private property, which could benefit from the knowledge embedded in cultural burning programs, particularly in Victoria and Tasmania.
- Encourage greater awareness of the subspecies among the general public in the rural communities in which it occurs. Hoary Sunray is a relatively attractive and charismatic grassland plant that lends itself to better public awareness that could result in better management of its grassland habitat.
- Engage with land management agencies to encourage ongoing management of its subpopulations, e.g. encourage local Country Fire Authority brigades to continue burning of remaining roadside subpopulations at appropriate intervals (e.g. 2–5 years; McDougall 1989).
- Engage and encourage private landowners with subpopulations of Hoary Sunray on their properties and explore options for covenanting or assisting with management or monitoring on private land.

Survey and monitoring priorities

- Survey NSW and ACT populations to estimate population size in these jurisdictions to provide baseline data for detecting any future decline.
- Design and implement a monitoring program or support and enhance existing programs to:
    - determine trends in population size and distribution;
    - determine threats and their impacts; and,
    - monitor the progress of recovery, including the effectiveness of management actions and the need to adapt them where necessary.
- Where possible, monitoring data should be published or shared as it becomes available, to bring attention to any future decline of Hoary Sunray.

Information and research priorities

- Investigate the causes behind declining subpopulations where this is not well understood, e.g. at Vale of Belvoir and The Nut State Reserve in Tas.
- Investigate the potential for creating new subpopulations of Hoary Sunray in protected areas in Vic and Tas, including genetic mixing where appropriate (Morgan et al. 2013).
- Estimate minimum viable subpopulation sizes and how these vary relative to the genetic diversity of individuals (Young & Pickup 2010; Thrall et al. 2014).

Recovery plan decision

The Conservation Advice is considered to provide sufficient guidance on the recovery of the subspecies and a Recovery Plan is unlikely to lead to substantial additional conservation benefits at this time.

Links to relevant implementation documents

National: 2010 Hoary Sunray Recovery Plan – http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=89104

Tas: Hoary Sunray Notesheet – https://dpipwe.tas.gov.au/Documents/Leucochrysum%20albicans%20subsp.%20tricolor.pdf

Vic: White Sunray Action Statement – https://www.environment.vic.gov.au/__data/assets/pdf_file/0019/33058/White-Sunray_action-statement.pdf

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The Threatened Species Scientific Committee finalised this assessment on 9 September 2021.

Attachment A: Listing Assessment for *Leucochrysum albicans* subsp. *tricolor*

Reason for assessment

Hoary Sunray was listed as Endangered under the *Endangered Species Protection Act 1992* and transferred to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) when it commenced in July 2000.

Assessment of eligibility for listing

This assessment uses the criteria set out in the EPBC Regulations. The thresholds used correspond with those in the IUCN Red List criteria except where noted in Criterion 4, sub-criterion D2. The IUCN criteria are used by Australian jurisdictions to achieve consistent listing assessments through the Common Assessment Method (CAM).

Key assessment parameters

Table 3 includes the key assessment parameters used in the assessment of eligibility for listing against the criteria.

Table 3 Key assessment parameters

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Number of mature individuals	250 000 – 280 000	250 000	>280 000	In NSW and ACT, the taxon is still locally common (K McDougall 2020 pers comm 23 Sept) and there is no evidence to suggest that the total NSW and ACT population estimate in Sinclair (2010) of >200 000 plants has changed substantially, although some roadside subpopulations may be declining (FOG 2021 pers comm 20 June). In Victoria, Hoary Sunray is inferred to be declining (McClaren 2013) and the estimated total population is approximately 20 000–30 000 plants (DELWP 2020b), down from the estimate of <40 000 in the early 2000s in Sinclair (2010). In Tasmania, at least one subpopulation has gone extinct (J Kirkpatrick 2020 pers comm 23 Sept) and several others have declined substantially over the past decade (Collier 2016; Tasmanian Land Conservancy 2019, Schahinger 2020 pers comm 24 Oct). The largest subpopulation in Tas, spread across several private properties at Ross with many hundreds of thousands of plants in 2011, had declined to a few hundred plants in 2020, likely due to conversion of its grassland habitat to dryland introduced pasture (R Schahinger 2020 pers comm, 24 Oct; L. Gilfedder 2020 pers comm 4 Nov). In 2011, an uncertain population estimate for

				Tas is suspected to have been between 200 000 – 400 000 plants. In 2020, a similarly uncertain estimate is between 30 000 – 50 000 plants. Therefore, there total population of Hoary Sunray is likely to be 250 000 – 280 000.
Trend	contracting			The total population size of Hoary Sunray is inferred to be contracting due to the decline and extinction of many subpopulations in Vic and Tas (McClean 2013; Collier 2016; Tasmanian Land Conservancy 2019; J Morgan 2020 pers comm, 23 Sept; J Kirkpatrick 2020 pers comm, 23 Sept; R Schahinger 2020 pers comm 24 Oct).
Generation time (years)	7 years	5 years	10 years	Individual plants probably live for a maximum of about 15 years (Gilfedder & Kirkpatrick 1994a; DELWP 2015). The generation length of Hoary Sunray is inferred to be 5–10 years by DELWP (2020b), with J Morgan (pers comm in DELWP 2020b) suggesting five to seven years. Therefore, a generation length of around seven years appears appropriate.
Extent of occurrence	438 166 km^2 (using records from the last 20 years)	417 188 km^2 (using records from the last 10 years)	464 618 km^2 (using records from the last 40 years)	The EOO figure is based on the mapping of point records from 2000 to 2020, obtained from state governments, herbaria and CSIRO. The EOO was calculated using a minimum convex hull, based on the IUCN Red List Guidelines 2014.
Trend	contracting			In Vic, McClaren (2013) documented the extinction of approximately 25% of surveyed subpopulations from 2003–2012. In Tas, a subpopulation at Liawenee went extinct in the 2000s (J Kirkpatrick 2020 pers comm 23 Sept). Therefore, there is an inferred decline in EOO based on the extinction of these subpopulations and the continuing decline of other subpopulations in Vic and Tas (McClaren 2016, Tasmanian Land Conservancy 2019; J Morgan 2020. pers comm 23 Sept; J Kirkpatrick 2020 pers comm 23 Sept; R Schahinger 2020 pers comm 24 Oct).
Area of Occupancy	1376 km^2 (using records from the last 20 years)	836 km^2 (using records from the last 10 years)	1812 km^2 (using records from the last 40 years)	The AOO figure is based on the mapping of point records from 2000 to 2020, obtained from state governments, herbaria and CSIRO. The AOO was calculated using a 2 x 2 km grid cell method, based on the IUCN Red List Guidelines 2014. Hoary Sunray is a very conspicuous plant during its flowering period. It also has a relatively high profile

				owing to its threatened status under the EPBC Act and its habitat is limited due to it being mostly confined to critically endangered ecological communities also listed under the EPBC Act. Therefore, it is not unreasonable to assume that most subpopulations of Hoary Sunray are known and recorded, and therefore the AOO figure of 1376 km^2 is near the actual AOO of the taxon (i.e. it is unlikely to be substantially under-reported).
Trend	contracting			In Vic, McClaren (2013) documented the extinction of approximately 25% of surveyed subpopulations from 2003–2012. In Tas, a subpopulation at Liawenee became extinct in the 2000s (J Kirkpatrick 2020 pers comm 23 Sept). Therefore, there is an inferred decline in AOO based on the extinction of these subpopulations and the continuing decline of other subpopulations in Vic and Tas (McClaren 2016, Tasmanian Land Conservancy 2019; J Morgan 2020 pers comm 23 Sept; R Schahinger 2020 pers comm 24 Oct).
Number of subpopulations	129 (using records from the last 20 years)	84 (using records from the last 10 years: 5 (Tas), 22 (Vic), 30 (ACT), 27 (NSW))	160 (using records from the last 40 years: 25 (Tas), 60 (Vic), 35 (ACT), 40 (NSW))	In NSW the Atlas of Living Australia displays records from approximately 30 subpopulations since 2000, with the ACT also recording approximately 30 subpopulations in that timeframe (ALA 2020; Canberra Nature Map 2020). Morgan et al. (2013) noted 53 subpopulations in Victoria. Tasmania has approximately 16 subpopulations recorded since 2000 (ALA 2020).
Trend	contracting			In Victoria the number of subpopulations is declining. In a study of approximately half of all Victorian subpopulations, McClaren (2013) documented the extinction of approximately 25% of surveyed subpopulations from 2003–2012. In Tas, the number of subpopulations also appears to be declining, with 11 subpopulations recorded since 2000 (ALA 2020) compared to an estimated 20 subpopulations in the 1990s and early 2000s (Gilfedder & Kirkpatrick 1994a; Sinclair 2010). A subpopulation at Liawenee became extinct in the 2000s (J Kirkpatrick 2020. pers comm 23 Sept) and several other subpopulations at Ross, The Nut State Reserve and Vale of Belvoir appear to be declining (Collier 2016; Tasmanian Land Conservancy 2019; R Schahinger 2020 pers comm 24 Oct).

Basis of assessment of subpopulation number	Morgan et al. (2013) found little genetic exchange between subpopulations in western Victoria, therefore it is inferred that most geographically distinct records of Hoary Sunray further than a few kilometres apart represent distinct subpopulations.			
No. locations	Unknown but certainly more than 10 (likely to be around 100)	-	-	Lack of fire, habitat loss, clearing, weeds and genetic threats from small subpopulations are the main threats facing Hoary Sunray. While these threats are widespread across the taxon's range, each threat operates at relatively small spatial scales, meaning that the majority of subpopulations could be considered separate locations.
Trend	decreasing			The number of locations is likely to be decreasing due to subpopulations continuing to become extinct (e.g. McClaren 2013; J Kirkpatrick 2020. pers comm, 23 Sept).
Basis of assessment of location number	Lack of fire, habitat loss, clearing, weeds and genetic threats from small subpopulations are the main threats facing Hoary Sunray. While these threats are widespread across the subspecies range, each threat operates at relatively small spatial scales, meaning that the majority of subpopulations could be considered separate locations.			
Fragmentation	Hoary Sunray is considered to be severely fragmented. Despite the presence of several large subpopulations, the majority of extant subpopulations of Hoary Sunray are probably small and likely to contain less than 1000 individuals (Sinclair 2010; McClean 2013; DPIPWE 2017; J Morgan 2020 pers comm 23 Sept). This rudimentary estimate is suggested by Frankham et al. (2014) as being a general minimum viable subpopulation size for resilience to genetic threats associated with small subpopulations. Morgan et al. (2013) studied the genetic effects of fragmentation on 19 subpopulations occurring on roadsides, cemeteries and rail lines in Victoria, concluding that subpopulations were genetically isolated from each other, and predicted further genetic erosion to occur over time and the continued loss of subpopulations. It is assumed that the pattern of genetic isolation among subpopulations observed in western Victoria by Morgan et al. (2013) is likely to be repeated elsewhere where Hoary Sunray occurs in similarly isolated subpopulations. Therefore, Hoary Sunray is considered to be severely fragmented, based on the majority of its subpopulations (and by extension AOO) being smaller in size than a rudimentary estimate of minimum viable subpopulation size of 1000 individuals (Frankham et al. 2014) and the majority of subpopulations being separated by sufficient distance to render them genetically isolated, based on the findings of Morgan et al. (2013).			
Fluctuations	Not subject to extreme fluctuations in EOO, AOO, number of subpopulations, locations or mature individuals.			

Criterion 1 Population size reduction

Reduction in total numbers (measured over the longer of 10 years or 3 generations) based on any of A1 to A4			
	Critically Endangered **Very severe reduction**	**Endangered** **Severe reduction**	**Vulnerable** **Substantial reduction**
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3, A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred or suspected in the past and the causes of the reduction are clearly reversible AND understood AND ceased.

A2 Population reduction observed, estimated, inferred or suspected in the past where the causes of the reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction, projected or suspected to be met in the future (up to a maximum of 100 years) [(*a) cannot be used for A3*]

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

Based on any of the following

(a) direct observation [except A3]

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy, extent of occurrence and/or quality of habitat

(d) actual or potential levels of exploitation

(e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites

Criterion 1 evidence

Eligible under Criterion 1 2abc for listing as Endangered

The generation length of Hoary Sunray is inferred to be seven years, giving a 21 year timescale for this criterion (three generations).

In NSW and ACT, the taxon is still locally common (K McDougall 2020 pers comm 23 Sept) and there is no evidence to suggest that the total NSW and ACT population estimate in Sinclair (2010) of >200 000 plants has changed, although some roadside subpopulations may be declining (FOG 2021 pers comm 20 June). In Victoria, Hoary Sunray is inferred to be declining (McClaren 2013) and the estimated total population is approximately 20 000–30 000 plants (DELWP 2020b), down from the estimate of <40 000 in the early 2000s in Sinclair (2010). In Tasmania, at least one subpopulation has recently gone extinct (J Kirkpatrick 2020 pers comm 23 Sept) and several others have declined substantially over the past decade (Collier 2016; Tasmanian Land Conservancy 2019, Schahinger 2020 pers comm 24 Oct). The two largest subpopulations in Tasmania appear to have both declined. The largest, spread across several private properties along Tooms Lake Road near Ross, with many hundreds of thousands of plants in 2011, has declined to likely just a few hundred plants in 2020, apparently due to conversion of its grassland habitat to dryland, introduced pasture (R Schahinger 2020. pers comm, 24 Oct; L Gilfedder 2020. pers comm 4 Nov). The cover of Hoary Sunray at the second largest subpopulation at Vale of Belvoir (estimated at 30 000 plants in Sinclair 2010) declined by approximately 50 percent from 2015–2019 (Tasmanian Land Conservancy 2019), although the

reason for this decline is unknown. In 2011, an uncertain population estimate for Tasmania would have been approximately 200 000 – 400 000 plants. In 2020, a similarly uncertain estimate is probably between 30 000 – 50 000 plants.

The decline and extinction of many subpopulations in Victoria and Tasmania suggests that the total population size of Hoary Sunray is contracting. The total population size in the early 2000s is suspected to have been around 440 000 – 640 000 plants (NSW and ACT = 200 000, Vic = 40 000, Tas = 200 000 – 400 000). In 2020, the total population size is suspected to be around 250 000 – 280 000 plants (NSW/ACT = 200 000, Vic = 25 000, Tas = 40 000) indicating a decline of 56–43 percent (lower estimates – upper estimates).

Given the uncertainty around population estimates, anecdotal observations that some subpopulations in the ACT and NSW are declining (FOG 2021 pers comm 20 June), and the very large and ongoing recent declines in Tas and Vic, a precautionary approach demonstrates that the Hoary Sunray is eligible for listing as Endangered (A2bc) under this criterion, using an estimated decline of ≥50 percent.

Criterion 2 Geographic distribution as indicators for either extent of occurrence AND/OR area of occupancy

		Critically Endangered Very restricted	Endangered Restricted	Vulnerable Limited
B1.	Extent of occurrence (EOO)	**< 100 km²**	**< 5,000 km²**	**< 20,000 km²**
B2.	Area of occupancy (AOO)	**< 10 km²**	**< 500 km²**	**< 2,000 km²**
AND at least 2 of the following 3 conditions:				
(a)	Severely fragmented OR Number of locations	**= 1**	**≤ 5**	**≤ 10**
(b)	Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or populations; (v) number of mature individuals			
(c)	Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or populations; (iv) number of mature individuals			

Criterion 2 evidence

Eligible under Criterion 2 B2ab(ii,iii,iv) for listing as Vulnerable

The area of occupancy (AOO) of Hoary Sunray is limited and estimated at 1376 km² (Department of Agriculture, Water and Environment 2020). This figure is based on the mapping of point records from 2000 to 2020, obtained from state governments, herbaria and CSIRO. The AOO was calculated using a 2 x 2 km grid cell method, based on the IUCN Red List Guidelines 2014. The AOO does not increase beyond the 2000 km² threshold for Vulnerable when records from an earlier time period are included; when records from 30 years are included AOO is 1704 km² and when records from 40 years are included AOO is 1812 km². Hoary Sunray is a very conspicuous

plant during its flowering period. It also has a relatively high profile owing to its threatened status under the EPBC Act and its habitat is limited due to it being mostly confined to critically endangered ecological communities, which are also listed under the EPBC Act (Threatened Species Scientific Committee 2006, 2008, 2009a, 2009b, 2013, 2016). Therefore, it is not unreasonable to assume that most subpopulations of Hoary Sunray are known and recorded, and therefore the AOO figure of 1376 km^2 is near the actual AOO of the taxon (i.e. it is unlikely to be substantially under-reported).

Hoary Sunray is deemed to be severely fragmented. Despite the presence of several large subpopulations, the majority of extant subpopulations of Hoary Sunray are probably small and likely to contain less than 1000 individuals (Sinclair 2010; McClean 2013; DPIPWE 2017; J Morgan 2020. pers comm, 23 Sept). This rudimentary estimate is suggested by Frankham et al. (2014) as being a general minimum viable subpopulation size for resilience to genetic threats associated with small subpopulations. A large minimum viable subpopulation size is likely to be particularly applicable to taxa with short generation lengths, such as short-lived plants with transient seedbanks (Matthies et al. 2004) like Hoary Sunray and larger estimates of 5000 individuals (Flather et al. 2011) or a few thousand individuals (Traill et al. 2007) could also be applicable. Victoria contains 53 subpopulations (Morgan et al. 2013). McClaren (2013) surveyed over half of these (including most large subpopulations) and only five out of 27 subpopulations contained more than 1000 plants in 2012. Tasmania contains an estimated 16 subpopulations (ALA 2020), although only four are known to contain more than 1000 plants (Sinclair 2010). Both NSW and ACT likely contain around 30 subpopulations each and, although there appear to be many large subpopulations in these jurisdictions (K McDougall 2020 pers comm 23 Sept), half of the subpopulations with estimates in Sinclair (2010) were smaller than 1000 plants. This suggests that the majority of subpopulations of Hoary Sunray are smaller than the rudimentary estimate of minimum viable subpopulation size in Frankham et al. (2014). As large subpopulations are often concentrated in relatively small areas (Sinclair 2010; Tasmanian Land Conservancy 2019; R. Schahinger 2020 pers comm 24 Oct), it is likely that most large subpopulations occupy similar AOO (in terms of 4 km^2 grid square occupancy) to small subpopulations, and therefore that most (>50%) of AOO of Hoary Sunray is in habitat patches supporting small subpopulations with less than 1000 individuals. It should also be noted that most subpopulations of Hoary Sunray occur in unsecure land tenure, often on roadsides in Vic and NSW and on private land in Tas, where even large subpopulations can decline to near extinction with poor management or clearing (McClean 2013; Collier 2015; J Morgan 2020 pers comm 23 Sept).

Morgan et al. (2013) studied the genetic effects of fragmentation on 19 subpopulations occurring on roadsides, cemeteries and rail lines in Victoria, concluding that subpopulations were genetically isolated from each other, and predicted further genetic erosion to occur over time and the continued loss of subpopulations. In the absence of studies investigating the genetic isolation of subpopulations in other jurisdictions, it is assumed that the pattern of genetic isolation among subpopulations observed in western Victoria by Morgan et al. (2013) is likely to be repeated elsewhere where Hoary Sunray occurs in similarly isolated subpopulations. The majority of subpopulations in these jurisdictions occur as isolated remnants on road or rail reserves (Vic and NSW) or on isolated private land and public conservation reserves (Tas), in grassland or grassy woodland habitat that has been extensively cleared for agriculture (Threatened Species Scientific Committee 2006, 2008, 2009a, 2009b, 2013, 2016). Although this

may not be the case in the ACT, where many subpopulations occur in nature reserves (Sinclair 2010) in relatively intact habitat, it is still likely that most subpopulations across its range are genetically isolated. Additionally, the species is self-incompatible (Costin et al. 2001), which increases the need for gene flow between subpopulations to maintain genetic diversity and viability.

Therefore, Hoary Sunray is considered to be severely fragmented, based on the majority of its subpopulations (and by extension AOO) being smaller in size than a rudimentary estimate of minimum viable subpopulation size of 1000 individuals (Frankham et al. 2014) and the majority of subpopulations being separated by sufficient distance to render them genetically isolated, based on the findings of Morgan et al. (2013).

There is an inferred continuing decline in area of occupancy, area, extent, and/or quality of habitat and number of subpopulations, particularly in Vic and Tas. In a study of approximately half of all Vic subpopulations, McClaren (2013) documented the extinction of approximately 25% of surveyed subpopulations from 2003–2013. In Tas, the number of subpopulations also appears to be declining, with a subpopulation at Liawenee becoming extinct in the 2000s (J Kirkpatrick 2020 pers comm 23 Sept). There is an inferred decline in AOO due to the extinction of these subpopulations. The current declines are expected to continue as all threats underlying these declines continue to operate and habitat continues to decline due to poor management and clearing. Damage to subpopulations from road maintenance activities has continued to occur since the release of the Recovery Plan, with a large subpopulation impacted at Hamilton Highway, Cressy, Vic (J Morgan 2020 pers comm 23 Sept 2020). Lack of biomass reduction continues to threaten productive grassland subpopulations in Vic and Tas and was a major factor behind the decline or extinction of 17 subpopulations in Vic (McClaren 2013) and the extinction of the subpopulation at Liawenee in Tas (J Kirkpatrick 2020 pers comm 23 Sept). The predicted frequency and severity of climate change-driven drought events is expected to increase in the region (CSIRO & Bureau of Meteorology 2015). The genetic consequences of fragmentation are expected to continue to affect isolated subpopulations of Hoary Sunray across its range (Morgan et al. 2013).

The data presented above demonstrate that the species is eligible for listing as Vulnerable (B2ab(ii,iii,iv)) under this criterion.

Criterion 3 Population size and decline

		Critically Endangered Very low	Endangered Low	Vulnerable Limited
Estimated number of mature individuals		**< 250**	**< 2,500**	**< 10,000**
AND either (C1) or (C2) is true				
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future)		**Very high rate 25% in 3 years or 1 generation (whichever is longer)**	**High rate 20% in 5 years or 2 generation (whichever is longer)**	**Substantial rate 10% in 10 years or 3 generations (whichever is longer)**
C2. An observed, estimated, projected or inferred continuing decline AND its geographic distribution is precarious for its survival based on at least 1 of the following 3 conditions:				
(a)	(i) Number of mature individuals in each population	**≤ 50**	**≤ 250**	**≤ 1,000**
	(ii) % of mature individuals in one population =	**90 – 100%**	**95 – 100%**	**100%**
(b) Extreme fluctuations in the number of mature individuals				

Criterion 3 evidence

Not eligible

The total number of mature individuals is estimated at approximately 250 000 – 280 000 (Table 3), which is not considered limited.

The data presented above demonstrate the species is not eligible for listing under this criterion.

Criterion 4 Number of mature individuals

	Critically Endangered Extremely low	Endangered Very Low	Vulnerable Low
D. Number of mature individuals	< 50	< 250	< 1,000
D2.[1] *Only applies to the Vulnerable category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the species to critically endangered or Extinct in a very short time			D2. Typically: area of occupancy < 20 km^2 or number of locations ≤ 5

[1] The IUCN Red List Criterion D allows for species to be listed as Vulnerable under Criterion D2. The corresponding Criterion 4 in the EPBC Regulations does not currently include the provision for listing a species under D2. As such, a species cannot currently be listed under the EPBC Act under Criterion D2 only. However, assessments may include information relevant to D2. This information will not be considered by the Committee in making its recommendation of the species' eligibility for listing under the EPBC Act, but may assist other jurisdictions to adopt the assessment outcome under the *common assessment method*.

Criterion 4 evidence

Not eligible

The total number of mature individuals is estimated at approximately 250 000 – 280 000 (Table 3), which is not considered low.

The data presented above demonstrate the species is not eligible for listing under this criterion.

Criterion 5 Quantitative analysis

	Critically Endangered Immediate future	Endangered Near future	Vulnerable Medium-term future
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

Criterion 5 evidence

Insufficient data to determine eligibility

Population viability analysis has not been undertaken. There are insufficient data to demonstrate if the species is eligible for listing under this criterion.

Adequacy of survey

The survey effort has been considered adequate and there is sufficient scientific evidence to support the assessment.

Public consultation

Notice of the proposed amendment and a consultation document was made available for public comment for 30 business days between 6 May 2021 and 24 June 2021.

Listing and Recovery Plan Recommendations

The Threatened Species Scientific Committee recommends:

(i) that *Leucochrysum albicans* subsp. *tricolor* retain its current listing status of Endangered in the list referred to in section 178 of the EPBC Act, as there is insufficient evidence to support transferring it to a different category and inclusion of the species in that category is having a beneficial impact on the continued survival of the species.

AND

(ii) that there not be a recovery plan for this species as an approved and detailed conservation advice for the species provides sufficient direction to implement priority actions, mitigate against key threats and enable recovery.

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Cataloguing data

This publication is available at the SPRAT profile for *Leucochrysum albicans* subsp. *tricolor* (Hoary Sunray).

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