The following file contains two documents for the listed taxon:

1) Federal Conservation Advice[1] and 2) Victorian Threatened Species Assessment[2]

This taxon is listed under the *Flora and Fauna Guarantee Act 1988* (FFG Act), and uses the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) conservation status.

The Threatened Species Assessment Report is the outcome from the bulk assessment process held between 2018 and 2021, and documents the Victorian conservation status, listing criteria and the reasons for satisfying those criteria. All these assessments were conducted in accordance with the national Common Assessment Method (CAM).

The EPBC conservation advice is the repot of the national assessment under the EPBC Act, also conducted in accordance with the CAM.

Both documents help inform the threats and management actions relevant to the species in Victoria.

Under the CAM, Victoria adopts the conservation category and extinction risk for all taxa that have been assessed as nationally threatened, and listed under the EPBC Act. Over time. this alignment at the state and national level will lead to a Single Operational List (SOL) – a list where all FFG-listed taxa have the EPBC status, if that status has been applied in accordance with the CAM.

However, we do not yet have a SOL, because many EPBC taxa (mostly prior to 2014) are not compliant with the CAM (i.e., are 'legacy" taxa), and there will be inconsistencies between the FFG and EPBC lists until these legacy taxa are re-assessed.

[1]National assessment under the national *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

[2.] Victorian assessment under the *Flora and Fauna Guarantee Act 1988* (FFG Act).

Threatened Species Assessment

Synemon plana
Golden Sun Moth

Taxonomy

Synemon plana Walker, 1854

Current conservation status

Listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*.

Listed as threatened under the *Flora and Fauna Guarantee Act 1988* (SAC 1994).

Categorised as Critically endangered in the 2009 Advisory list of threatened invertebrate fauna in Victoria (DSE 2009).

Proposed conservation status

Vulnerable in Victoria

Criterion B2ab(i,ii,iii,v)

Species Information

Description and Life History

In colouration the taxon has dark brown forewing upper-sides with delicate white, roughly circular markings and a scalloped white line around the edge. The hindwing upper-sides of the male are dark brown or rusty brown with a subtle greenish sheen in fresh specimens and one or two very diffuse darker spots near the anal angle (tornus). The hindwing upper-sides of the female are bright yellow or yellowish-orange often with two or three small black spots near the apex and usually with another group of slightly larger black spots near the anal angle (tornus). The females have a pale whitish underside with the small black hindwing spots in the same position as on the upper-side. Males have a darker brownish underside with the hindwings suffused whitish and marked with one or more brownish spots at near the apex and also near the anal angle (tornus). It is the bright golden-yellow colouration of the hindwing upper-sides of the female that give S. plana its common name of Golden Sun-moth.

The adults have a very small and non-functional haustellum (proboscis) and do not feed. For their brief adult lives of approx. 3 days they are sustained by nutrients that are stored in their bodies during the larval stage. Adults are strictly diurnal. However, the females are semi-flightless and are not so easily observed as the males which are usually seen while flying above the sward of grasses as they search for virgin females. Under normal circumstances they only fly during periods of sunshine unless they are disturbed when they will rapidly fly to a new resting place when the sun is obscured by clouds or it is late in the day after the normal flight period has finished.

The Golden Sun-moth is unique within the family Castniidae because it has semi-flightless females. The degree of flightlessness in the females of the taxon varies. For example, females from Nhill and Salisbury in north-western Victoria have comparatively larger wings and are able to fly reasonably well (F. Douglas pers. obs.) However females from Mount Piper, near Broadford, have very small wings and would probably be unable to fly at all. The females of all the other known species of sun-moths are capable of rapid and sustained flight.

The taxon is also unusual in that it exhibits sexual dimorphism to a marked degree. While the males of a number of the other sun-moth species are a little smaller than the females of their respective species, the males of *S. plana* have a larger wingspan than the females, i.e. about 3cm for males vs about 2.5cm for the majority of females. It also is unusual in the Castniidae for the sexes to differ as much in colouration.

The larvae excavate and live in underground tunnels where they feed on the roots of their larval food plants. Pupation finally occurs in a more or less vertical tunnel to the soil surface that is sealed at it upper end with a thin cap of soil and larval silk. The pupa is able to move up or down this tunnel at will with the aid of several transverse rows of well sclerotized serrations on its abdominal segments. After adult emergence the pupal exuviae are left protruding from the ground and are sometimes found lying loose on the soil surface after being blown out of their pupal tunnels by strong wind. The adult flight period of Golden Sun-moths is from late October to mid/late November in the Wimmera area but is later at Mount Piper, where the period ranges from early December to about the end of the third week of January. The females commence oviposition shortly after emergence and mating and oviposit into the ground at the base of their larval food plants with a long extensible ovipositor which can be withdrawn back into the abdomen when not in use.

Generation Length

The generation length of the Golden Sun-moth is estimated to be 24 months. It can be longer in some circumstances, e.g. prolonged dry periods.

Distribution

This taxon occurs in Victoria, New South Wales and the Australian Capital Territory. There are known to be numerous occurrences from near Bathurst to the Southern Tablelands in New South Wales, the Australian Capital Territory and central and western Victoria to as far west as Bordertown, South Australia.

Habitat

The taxon inhabits grasslands dominated by a mixture of native wallaby grasses *(Rytidosperma* spp. (formerly *Austrodanthonia))* and spear grasses *(Austrostipa* spp.) and/or Redleg Grass (*Bothriochloa macra*). Richter *et al.* (2013) noted "In contrast to earlier suggestions that *S. plana* is entirely confined to natural temperate grassland, mature and immature life stages of the species were also present in grasslands comprised entirely of the exotic Chilean Needle-grass (*Nassella neesiana*)".

Threats

The taxon's habitat is temperate lowland native grasslands. Since European settlement more than 95% of these grasslands have been lost or highly modified as a result of agricultural, rural and urban development. Remaining natural temperate grasslands are often small in size and highly isolated and are considered to be endangered communities. Large scale native grassland losses, reductions, degradation and fragmentation have resulted in the local extinction and reduction of Golden Sun-moth populations throughout its former range (Braby and Dunford 2006; Clarke and O'Dwyer 2000).

Subpopulations and habitat are considered at risk from habitat loss as a result of more uncultivated grassland near Melbourne's outer western suburbs being developed into housing estates or industrial areas. Most grassland remnants inhabited by the taxon are smaller than five hectares and face the ongoing pressures of rapid urban and rural expansion and habitat degradation (Braby and Dunford 2006; Gibson and New 2007; Gilmore et al. 2008). In addition to this large scale loss of habitat, the taxon has also suffered from site specific disturbances that have led to a loss of host plants, further loss of connectivity and reductions in the size of local populations.

Further loss of habitat may occur on private farmland from native perennial grasslands being cultivated for agriculture (cropping) and/or limited clearing of native grassy woodlands for the same purpose. Habitat quality is affected by ecological succession and invasion of exotic grasses in areas throughout the taxon's range that have had grazing animals removed (sheep) or culled on private land (kangaroos). In the absence of sustained grazing the habitat progressively becomes unsuitable. The taxon has recently been discovered to occur in areas infested by Chilean Needle-grass, a Weed of National Significance and declared noxious in Victoria. Eradication attempts would therefore be a further cause of habitat loss.

There may be a potential influx of new weeds under the impacts of climate change, as well as the possibility of extensive fires in the Little Desert National Park and/or the Birdcage Flora and Fauna Reserve.

IUCN Criteria

Criterion A. Population size reduction.
Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered	Endangered	Vulnerable
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

Evidence:

Ineligible under Criterion A

There is insufficient evidence to determine whether there has been or will be a reduction in population sufficient to meet any threshold for Criterion A.

Criterion B. Geographic range in the form of either B1 (extent of occurrence) and/or B2 (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 subpopulations; (v) number of mature individuals			
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

Evidence:

Eligible under Criterion B2 as Vulnerable

The Area of Occupancy (AoO) across the taxon's range is estimated to be 1,028 km², based on 2 x 2 km grids derived from accepted, post-1970 records in the Victorian Biodiversity Atlas.

The taxon is inferred to be severely fragmented. Males are active fliers and are capable of moving distances of several 100 metres. Females rarely fly, although they can fly short distances (usually less than 5 m, but on occasions up to 20 m (Richter et al. 2013). However most of the subpopulations are separated by considerably more than 1 km (A. Tolsma pers. comm.), so if a subpopulation was lost, there would be little or no chance of recolonization. Many of the subpopulations are possibly not viable, given their small size and the range of current threats.

It is inferred to have a continuing decline in (i), (ii), (iii) and (v) above. These declines are expected as a result of ongoing losses of its native grassland habitat, eradication of Chilean Needle-grass habitat, potential influx of new weeds under the impacts of climate change, clearing of remnant mallee eucalypts for agriculture, and/or the possibility of extensive fires in the Little Desert National Park and/or the Birdcage Flora and Fauna Reserve.

Criterion C. Small Population size and decline				
		Critically Endangered	Endangered	Vulnerable
Number of mature individuals		< 250	< 2,500	< 10,000
AND at least one of C1 or C2				
C1	An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):	25% in 3 years or 1 generation (whichever is longer)	20% in 5 years or 2 generations (whichever is longer)	10% in 10 years or 3 generations (whichever is longer)
C2	An observed, estimated, projected or inferred continuing decline AND least 1 of the following 3 conditions:			
(a)	(i) Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
	(ii) % of mature individuals in one subpopulation =	90 – 100%	95 – 100%	100%
(b) Extreme fluctuations in the number of mature individuals				

Evidence:

Ineligible under Criterion C

It is inferred that there are 13500 mature individuals, which exceeds the thresholds for criterion C.

Criterion D. Very small or restricted population			
	Critically Endangered	Endangered	Vulnerable
Number of mature individuals (observed or estimated)	<·50	<·250	<·1,000
D2 Only applies to the VU 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: AoO <·20 km2 or number of locations ≤ 5

Evidence:

Ineligible under Criterion D

It is inferred that there are 13500 mature individuals.

Criterion E (Quantitative Analysis) was not addressed as the taxon does not have a detailed Population Viability Analysis.

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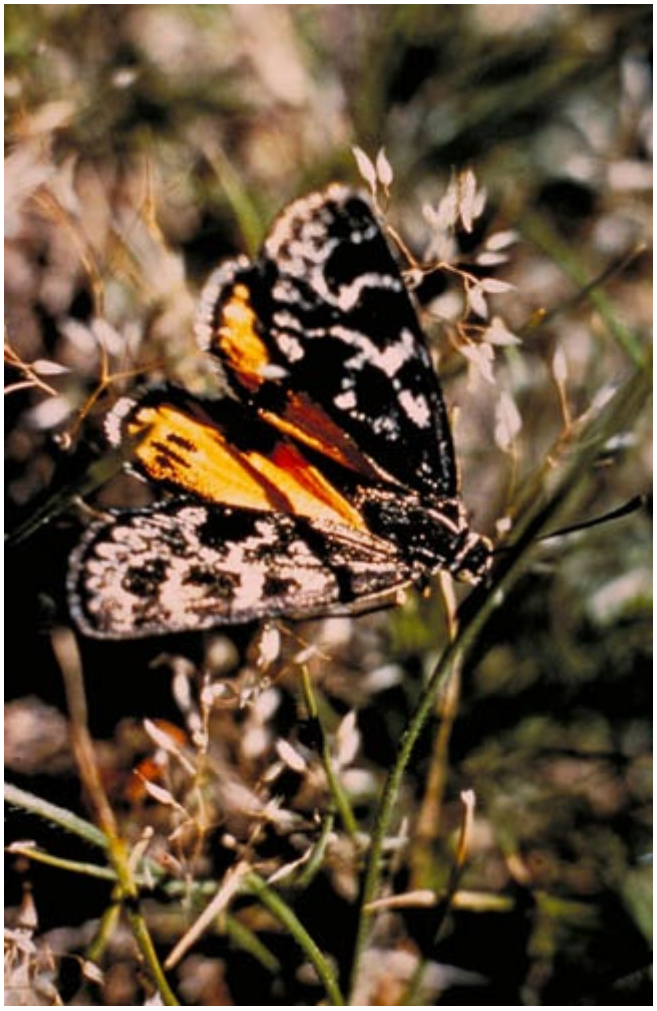
SAC (1994). Flora and Fauna Guarantee Scientific Advisory Committee: Final Recommendation on a Nomination for Listing. Nomination No. 323 *Synemon plana.*

Australian Government
Department of Agriculture, Water and the Environment

Conservation Advice for *Synemon plana* (Golden Sun Moth)

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



Female Golden Sun Moth © Copyright, Edwards, E D

Conservation status

Synemon plana (Golden Sun Moth) is listed in the Vulnerable category of the threatened species list under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act) effective from 7 December 2021.

Synemon plana was assessed by the Threatened Species Scientific Committee (the Committee) to be eligible for listing as Vulnerable under Criterion 2. The Committee's assessment is at

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

- Criterion 1: Insufficient data
- Criterion 2: B2ab(ii,iii,iv,v): Vulnerable
- Criterion 3: Not eligible
- Criterion 4: Not eligible
- Criterion 5: Insufficient data

The main factors that make the species eligible for listing in the Vulnerable category are a limited area of occupancy, severe fragmentation, and a continuing decline in the area of occupancy, area, extent, and quality of habitat, number of locations or subpopulations and number of mature individuals.

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

Species information

Taxonomy

Conventionally accepted as *Synemon plana* Walker (1854).

Description

The Golden Sun Moth, a member of the family Castniidae, is a medium-sized day-flying (diurnal) moth (OEH 2019). It has green eyes, clubbed antennae, no functional mouthparts, and females have a long extensible ovipositor (Clarke & Spier-Ashcroft 2003; ACT Government 2017). Males have a wingspan of approximately 34 mm with the upper side of the forewing dark brown with pale grey patterning and the hind wing a dark bronze-brown with dark brown patches. Females have a wingspan of approximately 31 mm with the upper side of the forewing dark grey with pale grey patterning, and the hind wing bright orange with black submarginal spots (Clarke & Spier-Ashcroft 2003). The sexes can be distinguished by their wing colours, with only females having bright orange hind wings. Additionally, male moths having a larger wingspan than the females is unique in the Australian Castniidae family (ACT Government 2017).

Golden Sun Moth eggs are just over 2 mm long, and the larvae develop and pupate underground. Larvae are cream in colour, and late instars have a red-brown head capsule. At emergence, the empty red-brown pupal case is left protruding from the ground, usually at the base of, or close to a grass tussock. The pupal cases of female moths are larger than those of males, reflecting the larger abdomen size of the gravid female (Richter 2010 cited in ACT Government 2017).

Distribution

Historically, the Golden Sun Moth was widespread in south-eastern Australia and relatively continuous throughout its range. The species extended from Winburndale near Bathurst in central New South Wales (NSW), through the NSW Southern Tablelands (including large areas of the Australian Capital Territory (ACT)), down to central and western Victoria (Vic) and into Bordertown in eastern South Australia (SA) (Edwards 1991 cited in O'Dwyer & Attiwill 1999; Office of Environment & Heritage 2019). The species distribution shows a close correlation to

that of native temperate grasslands dominated by *Rytidosperma* spp. (formerly *Austrodanthonia, Danthonia*) (Wallaby Grasses) (Edwards 1993 cited in O'Dwyer & Attiwill 1999). Temperate grasslands once covered approximately 2 000 000 ha of south-eastern Australia, and it is probable that the species occurred wherever there were high densities of Wallaby Grasses (Edwards 1993 cited in DEWHA 2009). Since European settlement, native temperate grasslands, and as such, areas of habitat for the Golden Sun Moth, have been heavily reduced and fragmented (DAWE 2020). Many of the known subpopulations are confined to small grassland remnants of fewer than five hectares; however, some sites are larger (more than 300 ha) (Gibson & New 2007; Richter et al. 2013b; EPSDD 2020). The species is often restricted to discrete areas within grassy sites and breeding areas where the females occur are likely to be highly specialised and dependent on the presence of food plants and heterogenous bare ground cover (EPSDD 2021. pers comm 23 February).

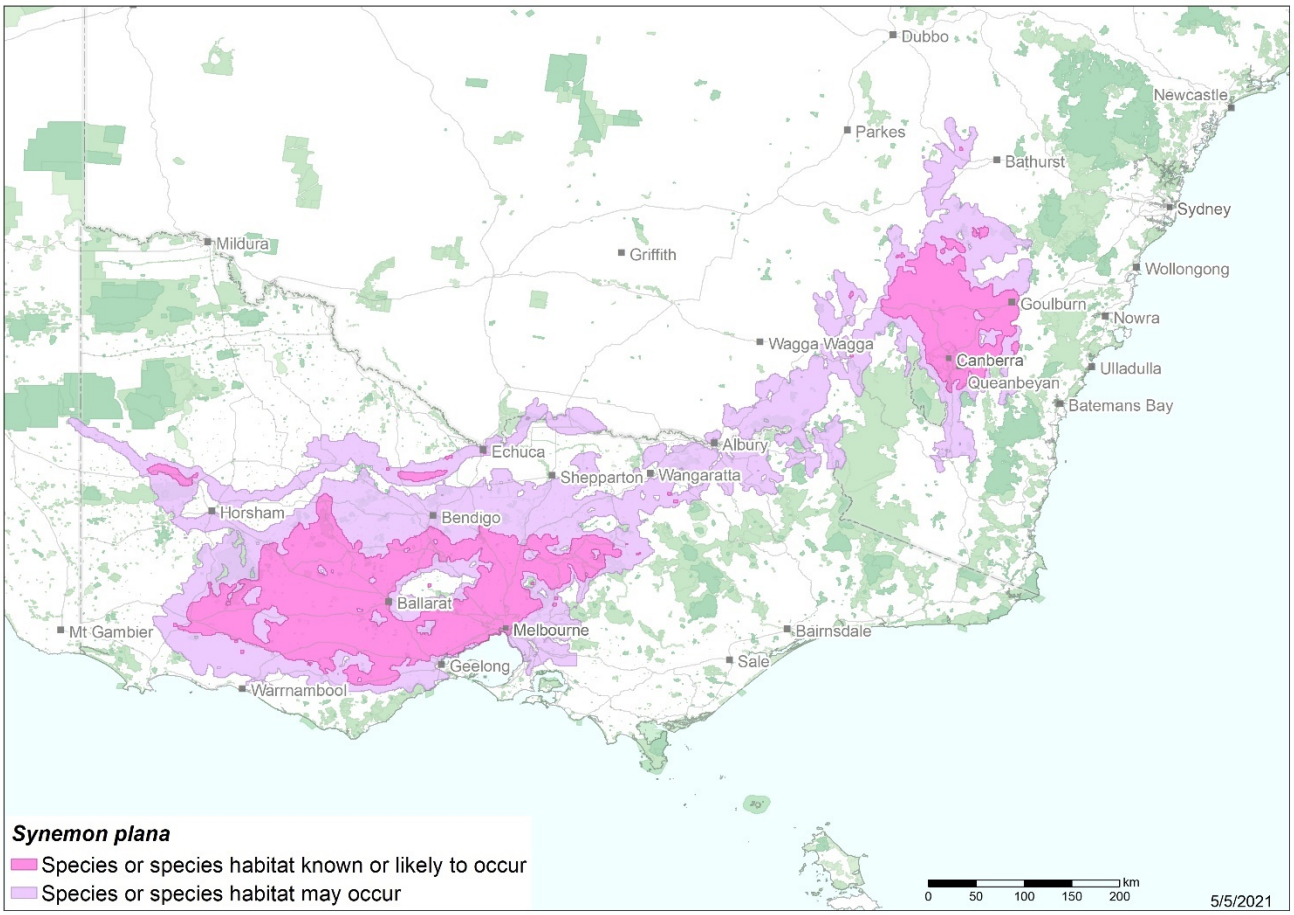
At the time when the species was listed as Critically Endangered under the EPBC Act (2002), the extent of occurrence (EOO) of the species was estimated to be approximately 131 100 km^2 and the area of occupancy (AOO) estimated to be approximately 8.8 km^2 (TSSC 2002). Since its listing, understanding of the species distribution and habitat has improved and EOO and AOO are now understood to be around 145 322 km^2 and at least 1596 km^2 respectively (using the Threatened Species Scientific Committee *Guidelines for assessing the conservation status of native species according to the EPBC Act and EPBC Regulations 2000* and the *Guidelines for Using the IUCN Red List Categories and Criteria* (2019)). This new understanding of the species distribution is predominately due to an increase in survey effort in areas proposed for development and increased conservation interest in the species since its listing. This has led to the discovery of extant site localities, particularly in Vic, and the ACT and in NSW to the north of the ACT (DEPI 2013; Hogg 2010 cited in ACT Government 2017). Surveys aimed at detecting the species presence/ absence in potential habitat have also been undertaken by state and territory agencies. Survey effort in southern NSW is still considered to be insufficient, largely due to the majority of habitat occurring on private land (EES 2021. pers comm 22 February), with further habitat mapping and targeted surveys identified as a priority action in the draft National Recovery Plan for the species (DEWHA 2009; OEH 2012).

This species is known from approximately: 104 sites in Vic, of which at least 36 are extant (ACT Government, 2017; V Craigie 2020. pers comm 7 October; F Douglas 2020. pers comm 27 October), at least 59 sites in NSW (OEH 2012; Gibbons & Reid 2013) and 78 sites in the ACT (ACT Government 2017). No extant sites are known from SA and the species is likely to be locally extinct (Edwards 1994 cited in DEWHA 2009). The known NSW and ACT subpopulations generally occur at elevations between 480 m and 720 m above sea level (asl) and Vic subpopulations generally occur at lower elevations, between 95 m and 406 m asl (DAWE 2020).

Within regions, genetic differentiation among subpopulations is correlated with geographic distance, that is, subpopulations show an isolation by distance model (Clarke & O'Dwyer 2000). The isolation by distance model describes increasing genetic differentiation correlated with increasing geographic distance (Janes & Batista 2016). For mobile organisms, lack of significant genetic differentiation over relatively short distances is primarily due to the migration of individuals between subpopulations maintaining genetic diversity. However, in the case of the Golden Sun Moth, given their limited dispersal ability, the lack of genetic differentiation between closely located subpopulations may indicate recent fragmentation of historically connected subpopulations (Clarke & O'Dwyer 2000). Genetic studies have suggested that the Vic

subpopulations are evolutionarily distinct from the NSW/ACT subpopulations, representing different evolutionarily significant units (Clarke & O'Dwyer 2000; Clarke & Whyte 2003).

Map 1 Modelled distribution of Golden Sun Moth



Source: Base map Geoscience Australia; species distribution data Species of National Environmental Significance database.
Caveat: The information presented in this map has been provided by a range of groups and agencies. While every effort has been made to ensure accuracy and completeness, no guarantee is given, nor responsibility taken by the Commonwealth for errors or omissions, and the Commonwealth does not accept responsibility in respect of any information or advice given in relation to, or as a consequence of, anything containing herein.
Species distribution mapping: The species distribution mapping categories are indicative only and aim to capture (a) the specific habitat type or geographic feature that represents to recent observed locations of the species (known to occur) or preferred habitat occurring in close proximity to these locations (likely to occur); and (b) the broad environmental envelope or geographic region that encompasses all areas that could provide habitat for the species (may occur). These presence categories are created using an extensive database of species observations records, national and regional-scale environmental data, environmental modelling techniques and documented scientific research.

Cultural and community significance

The cultural significance of the Golden Sun Moth is not well understood. However, Indigenous Australians have a long and profound history of occupation and management of local native grassland habitats, some of which provide habitat for the Golden Sun Moth. Given the species has a broad geographic distribution, the lands on which the species historically and currently occur belong to a number of Traditional Owner groups. Traditional Owner groups where the species occurs include, but are not limited to Wiradjuri People, Dharug People, Gundungurra People, Ngunnawal People, Ngarigo People, Yorta People, Taungurung People, Wurundjeri People, Dja Wurrung People, Wadawurrung People. Eastern Maar People, Gunditjmara People,

and the Wotjobaluk, Jaadwa, Jadawadjali, Wergaia and Jupagalk Nations (AIATSIS 2021; DPC 2021). Engagement of Traditional Owners in conservation actions is a priority identified in the conservation and recovery actions.

Relevant biology and ecology

Habitat

Across the historical range of the Golden Sun Moth, habitat includes areas containing, or having once contained, native grassland, open grassy woodlands and secondary grasslands, that retain a component of larval food species. This includes degraded habitats that retain a component of native larval food species, or have been invaded by the exotic species, Chilean Needlegrass (*Nassella neesiana*), which the Golden Sun Moth is also known to feed on (DEWHA 2009). Large subpopulations of the species have been reported on sites with high infestations of Chilean Needlegrass in the ACT and Vic, including sites comprised completely of this exotic grass (New 2012; Richter et al. 2013b). Chilean Needlegrass was introduced from South and Central America and is a distant relative of the native *Austrostipa* spp. (Speargrasses) (DEWHA 2009). All Golden Sun Moth sites in the ACT that are dominated by Chilean Needlegrass are adjacent to native grasslands (Richter et al. 2011 cited in ACT Government 2017) suggesting that the species has been able to persist in native grasslands that have suffered infestation of this weed or have been able to disperse into this habitat following the establishment of the weed.

Sites where the Golden Sun Moth is found are generally flat or gently sloping (<5°) and exposed to full sun. Increases in shading, such as from trees or buildings, can negatively affect the temperature, moisture and plant characteristics of a site. Eighty-eight percent of habitat in the ACT occurs in areas without trees or in very sparse woodland (Mulvaney 2012; OEH 2012; ACT Government 2017). It has been suggested that subpopulations of the species occurring in open woodland and secondary native grassland habitat may be the result of the species spreading outside of its preferred habitat (native temperate grassland) into adjacent woodlands following tree clearing (Hogg 2010 cited in ACT Government 2017). Open woodland and secondary native grassland habitat generally support fewer moths than native temperate grassland.

Important structural features of habitat appear to be grass tussocks for shelter, egg-laying and larval development and inter-tussock species for basking to increase body temperature and for displaying females to attract males. Habitat for the species is usually comprised of a moderate abundance of larval food plants with low to moderate grass height and moderate to high grass cover with inter-tussock space (ACT Government 2017). Field observations at some sites indicate that where both closed and open grassland occur in close proximity, dense swards of grasses appeared to be actively avoided, with male moths showing a preference for relatively open areas with reduced biomass (Gilmore et al. 2008).

Larval food plants

Larvae are underground feeders, found in silk-lined burrows closely associated with the grass roots that they feed upon. Early research suggested that the Golden Sun Moth may be restricted to using Wallaby Grasses and Speargrasses as larval food plants, as pupal cases had been found within grass tussocks of these species. It had been suggested that habitat was comprised of 40 percent or higher cover of Wallaby Grass and that soils were low in phosphorus (O'Dwyer & Attiwill 1999). However, more recent surveys have found the species in habitat containing less

than 10 percent cover of Wallaby Grass. A site in Taylor, within the ACT, also showed strong evidence that the species could feed on another exotic species, Serrated Tussock (*Nassella trichotoma*), with many Golden Sun Moth caterpillars found deeply embedded in the roots of this weed (EPSDD 2017).

Within the ACT, sites containing a relatively large number of the species do tend to have a larger percentage cover of Wallaby Grasses (Mulvaney 2012; ACT Government 2017). In Vic, Brown et al. (2010) found a positive relationship between cover of Wallaby Grass and number of Golden Sun Moths sighted across 46 site surveys within the Victorian Volcanic Plains (VVP). A study undertaken at the Canberra Airport found that the species of Wallaby Grass and/ or the size of grass tussocks may also have importance in larval habitat quality. This evidence was found in an assessment of two sites with the same mean percentage basal cover of Wallaby Grass but that were comprised of different species of different tussock size (*Rytidosperma carphoides* and *R. caespitosum*). A higher number of both pupal cases and flying males were observed in the site with the larger but fewer tussocks (*R. caespitosum*). This suggests that tussocks with a large root volume may be beneficial in providing for a larva throughout its entire cycle and therefore removing the need to move through the soil to find another tussock and avoiding the energy cost associated with this (Rowell 2009 in ACT Government 2017). Observations have also been made that support the hypothesis that the species may have a reproductive advantage when utilising Chilean Needlegrass, including the increased body size of larvae developing on Chilean Needlegrass (Richter et al. 2013b; ACT Government 2017). The characteristics potentially enhancing reproductive success from feeding on Chilean Needlegrass, if genetically determined, have the potential to drive genetic change in the species, potentially leading to barriers between isolated subpopulations adapted to Chilean Needlegrass and those on native grassland sites (ACT Government 2017).

Lifecycle

The adult life stage is the only life stage in which the species is readily detectable, predominately the males, which can be observed flying while female moths remain fairly stationary. Adult moths emerge from the ground during the breeding season (also referred to as the flying season) that falls between mid-October and early January (DAWE 2020). The breeding season typically lasts from six to eight weeks and timing varies slightly between localities across the species range (OEH 2019). Adults emerge on warm, dry, sunny days during the breeding season, and as they lack functional mouthparts are unable to feed or drink and live for only a few days (1-4 days) (O'Dwyer & Attiwill 2000; Gibson & New 2007; ACT Government 2017). Emergence rates and timing differ from day to day and from year to year, being highly influenced by climatic conditions (Mulvaney 2012). During the flying season, adult emergence is fairly continuous, and turnover of individuals is rapid (Gibson & New 2007). The sex ratio of the species at emergence has previously been studied by Richter et al (2013b) through the identification and analysis of pupal cases at 11 survey locations in and near to Canberra. A distinct male-biased sex ratio was found across the two years of the study and did not differ significantly between native grassland and exotic (Chilean Needlegrass dominated) grassland habitat. A mean sex ratio of 1.9 males to one female was found in natural temperate grassland habitat, with almost twice as many males than females found at sites dominated by Chilean Needlegrass. The factors that are likely to maintain a male bias in the species are unknown at this stage. It is acknowledged that males and females do differ considerably in their morphology

and behaviour that affects their predation risk, catchability, and visibility. These factors would influence any evaluation of the adult sex ratio within subpopulations (Richter et al. 2013b).

After emergence, male moths spend their few short days patrolling habitat for females by flying in low (about 1 m above the ground), rapid, short bursts over grassland during late morning and early afternoon in warm (above about 20°C), sunny conditions with low-moderate wind speeds. Females have been observed to be active later into the afternoons (Gibson & New 2007; Richter et al. 2013b; ACT Government 2017). Females are semi-flightless, tending to display themselves from sedentary positions, flashing their brightly coloured hind wings (Harwood et al. 1995 cited in O'Dwyer & Attiwill 2000; OEH 2012). After mating, females spend their time laying eggs within the base of grass tussocks of Wallaby Grasses, Speargrasses and Chilean Needlegrass (Richter et al. 2013a). Richter et al. (2013a) found in the dissection of 71 females, a mean of 74 (27.4 SD) eggs per female, with a range of 31 to 148. Males are capable of active and prolonged flight but are unlikely to travel long distances (>100 m) away from areas of suitable habitat. As such, subpopulations separated by distances of greater than 200 m are likely to be isolated sites, and sites from which the moth has gone extinct, or vacant patches of habitat, are considered unlikely to be (re)colonised (Clarke & O'Dwyer 2000).

The underground life stages (egg, larva and pupa) are not well understood. At the end of the larval period, which is likely two to three years, the larva prepares a tunnel to the surface and pupation occurs underground in spring. Once adult features have developed within the pupal case, the pupa rises to the surface and the adult emerges. The empty pupal case is left protruding from the soil (Edwards 1994 cited in DEWHA 2009; Richter et al. 2013a). Insect larvae living in temperate regions often face a pathway decision between continued growth and development to the adult stage or delaying emergence until the next season; which is often dependent on temperature, day length and quality of host plants (Gotthard 2008, Danilevskii 1965, and Friberg & Wiklung 2010, all cited in Richter et al. 2013a). High temperature, long days and quality host plants typically support continued developments while opposing condition at the beginning of colder seasons trigger entry into diapause (Friberg er al. 2012). The drivers of larval development in the Golden Sun Moth are unknown, but distinct larval cohorts at three different size classes were found by Richter et al. (2013). Further research is required to better understand the species larval biology, relationship to ecological factors, and factors that may limit this part of the life cycle.

Survey information

Certain aspects of the life cycle and behaviour of the species affect its detectability and therefore create challenges for assessing subpopulations. In addition, the lack of tested monitoring methods exacerbates comparative analysis (Richter et al. 2013b). Trialled methods for subpopulation counts and detecting presence/absence include spot counts, belt transects, line transects and mark-release-recapture (Gibson & New 2007; ACT Government 2017). These methods are all constrained by challenges associated with the species detectability and as such require surveys to be undertaken in suitable conditions during the flying season.

Richter et al. (2013b) trialled supplementation of subpopulation monitoring through the counting and sexing of pupal cases. This method has potential to be used as a valuable additional tool for monitoring local subpopulations as it is a more flexible survey method. There is also potential for this method to provide an indication of subpopulation size however the

relationship between total subpopulation of emerged adults by a given date and the total number of pupal cases that can be found is unknown. Another possible limitation of this approach may be difficulties in finding and counting pupal cases in differing conditions, e.g. in non-drought conditions where grass may be taller. While further research is required before its potential use for more detailed subpopulation analysis, this method can provide a specific and reliable indicator of habitat use by the species and could provide valuable monitoring data (Richter et al. 2013b).

Survey guidelines were prepared to provide guidance for stakeholders on the effort and methods considered appropriate when conducting a presence/absence survey for the species. These guidelines can be found here.

Habitat critical to the survival

As presented in the Matters of National Significance Significant Impact Guidelines 1.1 (DOE 2013), habitat critical to the survival of a species refers to areas that are necessary:

- for activities such as foraging, breeding, roosting, or dispersal
- for the long-term maintenance of the species (including the maintenance of species essential to the survival of the species, such as pollinators)
- to maintain genetic diversity and long term evolutionary development, or
- for the reintroduction of populations or recovery of the species.

Habitat critical to the survival of the Golden Sun Moth has yet to be identified but likely includes all native grassland and open grassy woodland habitat occupied by the species across its range. As the species has specialised habitat requirements with a fragmented distribution, all occupied habitat is important for the breeding activity of the associated subpopulation and the recovery of the species. Large subpopulations or smaller well-connected subpopulations occurring in high quality habitat would classify for their importance in the long-term maintenance of the species, including maintenance of genetic diversity and long-term evolutionary development. High quality habitat for this purpose should be defined as medium to large sites containing native grassland with an abundant component of larval food species (i.e. *Rytidosperma* spp. and/or *Austrostipa* spp.) with low weed cover, inter-tussock spaces, and land-use/ management that is consistent with the ecological values of the site. Sites occurring at or toward the limit of the species range, or sites that are a long distance from other known subpopulations are also likely to be defined as habitat critical to the survival of the species for their importance toward conserving the full range in genetic diversity.

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

Threats

The Golden Sun Moth has a number of threats, the most notable being habitat loss, fragmentation and degradation. Further, the effects of climate change on the species may be significant, and inappropriate fire regimes are likely to be impacting on the species (see Table 1). In regard to revegetation practices, some concern has been raised regarding the genetic effects of introducing plants or seeds of the same species from another area (Eddy 2002). As there is no evidence of this impacting the viability of the Golden Sun Moth this potential threat is

considered to be minor and has not been listed in Table 1. Consideration should also be given to the limited dispersal ability of the Golden Sun Moth, which means that sites where the species has gone extinct are unlikely to be recolonised. Fragmentation between sites also reduces gene flow between subpopulations which could have additional consequences for small, isolated subpopulations (DAWE 2020).

Table 1 Threats impacting Golden Sun Moth

Threat	Status and severity [a]	Evidence
Habitat loss, degradation and fragmentation		
Land clearing for urban development and agriculture	• Timing: current • Confidence: observed • Consequence: major • Trend: static • Extent: across the entire range	The natural native grassland habitat of the Golden Sun Moth has been significantly reduced and fragmented by agriculture and urban expansion. Less than one percent of pre-European settlement temperate grasslands remain (DAWE 2020). The sites at which the Golden Sun Moth occur are generally small and isolated, due to its highly fragmented distribution and limited dispersal ability and are not secure from future development (DEWHA 2009; ACT Government 2017). The species is subject to further habitat loss through both direct and indirect impacts of urban and agricultural development. Some native grassland sites supporting the species meet the condition criteria to classify as one of the following Critically Endangered ecological communities listed under the EPBC Act: Natural Temperate Grassland of the South Eastern Highlands; Natural Temperate Grassland of the Victorian Volcanic Plain. Their protection under the EPBC Act has reduced the rate of clearing and has added an extra layer of habitat protection from clearing.
Soil disturbance	• Timing: current • Confidence: observed • Consequence: major • Trend: static • Extent: across the entire range	Physical soil disturbance can be destructive to Golden Sun Moth habitat. Soil disturbance occurs through activities such as ploughing and cultivation, ripping rabbit burrows, laying infrastructure, driving of vehicles and machinery on wet soil, and grazing by hooved animals (ACT Government 2017; DAWE 2020). Soil disturbance destroys both the subterranean early stages of moth life and also kills host plants (Douglas 2004).
Lack of biomass removal	• Timing: current • Confidence: observed • Consequence: moderate • Trend: unknown • Extent: across the entire range	The absence of biomass removal (e.g. from grazing, mowing, slashing) results in a more dense, closed groundcover from tall perennial grasses. Low growing Wallaby Grass can become shaded and eventually choked out in these scenarios (Van Praagh 2004 cited in DAWE 2020). Additionally, grass cuttings left onsite following slashing/ mowing may act as mulch and prevent inter-tussock forb growth (DAWE 2020). This can change the structure of grassland sites, potentially making them unsuitable for the Golden Sun Moth.
Intensification of grazing and/or mowing	• Timing: current • Confidence: observed • Consequence: moderate • Trend: unknown • Extent: across the entire range	Excessive biomass removal through overgrazing by domestic stock/ Kangaroos or close mowing can cause soil compaction and reduce the health and root volume of native grasses. This can lower habitat quality and possibly expose eggs and/or larvae to excessive soil temperatures (ACT Government 2017). Grazing and mowing also has the potential to introduce weeds and can prevent plant flowering and seed production if undertaken too frequently or at the wrong time of year (Barlow 1998, DAWE 2020).

Threat	Status and severity [a]	Evidence
Application of chemicals such as herbicides, pesticides and fertilisers	• Timing: current • Confidence: observed • Consequence: moderate • Trend: unknown • Extent: across the entire range	Glyphosate has been shown to have a detrimental effect on established Wallaby Grass and is therefore not recommended for use in sites dominated by Wallaby Grass. Use of glyphosate within or adjacent to Golden Sun Moth habitat could therefore have negative impacts on the integrity of habitat through off-target spraying and spray drift. Established Wallaby Grasses have demonstrated tolerance to other herbicides (e.g. diclofop-methyl, simazine, fenoxaprop-ethyl, and diuron) and are as such preferable for use (Lodge & McMillan 1994). The addition or run-on of fertilisers into habitat is likely to favour exotic groundcover species over native larval food plants for Golden Sun Moth. Specifically, phosphorus fertilisers have been shown to inhibit growth of Wallaby Grasses (DAWE 2020). Fertilisers therefore have the potential to change the species composition of habitat in an unfavourable manner for the Golden Sun Moth (ACT Government 2017). Additional to the impact of chemicals on habitat, pesticide use may also directly impact upon individual Golden Sun Moths.
Planting and/ or regeneration of shrubs/ trees	• Timing: current • Confidence: observed • Consequence: moderate • Trend: unknown • Extent: across the entire range	Planting or regeneration of trees and/or shrubs can have a number of effects on Golden Sun Moth habitat such as: reducing the density of native grasses, changing the species composition and habitat structure, encouraging predatory animals to breed or forage within the site by providing perches and nesting opportunities, and shading habitat (OEH 2012). The consequences of such actions vary depending on the density of plantings/ regeneration, with higher density plantings resulting in more serious consequences.
Invasive species		
Weed invasion	• Timing: current • Confidence: observed • Consequence: major • Trend: increasing • Extent: across the entire range	Native grasslands are under threat from various introduced pasture grasses and clovers which readily out-compete the native Wallaby Grasses and Speargrasses that are characteristic of Golden Sun Moth habitat (DEWHA 2009). As well as reduction or loss of larval host plants in which the species cannot persist without, the invasion of weeds changes the structure of grasslands which may also result in loss of habitat through the change from a patchy sward of short to medium height to a dense tall sward (ACT Government 2017). Grasses posing significant threat to Golden Sun Moth habitat across parts of its range include Phalaris (*Phalaris aquatica*), African Lovegrass (*Eragrostis curvula*), Serrated Tussock, Chilean Needlegrass, Paspalum (*Paspalum dilatatum*), Oats (*Avena* spp.), St Johns Wort (*Hypericum perforatum*), and Saffron Thistle (*Carthamus lanatus*) (ACT Government 2017; OEH 2019). Conversely, unoccupied areas may become habitat for the species with the incursion of Chilean Needlegrass and possibly Serrated Tussock into areas near to existing subpopulations. However, habitat with a high component of weeds, including Chilean Needlegrass, is of lower quality than native grasslands with moderate or high cover of native larval food plants, and is at higher risk of loss through habitat modification. Additionally, Chilean Needlegrass and Serrated Tussock are both listed Weeds of National Significance (WoNS)

Threat	Status and severity [a]	Evidence
		that have been declared as such by the Australian Government and of which landowners and land managers are responsible for managing as per state and territory legislation/ regulation.
Habitat degradation by the introduced Rabbit (*Oryctolagus cuniculus*)	• Timing: current • Confidence: observed • Consequence: moderate • Trend: unknown • Extent: across the entire range	Rabbits have the potential to impact on Golden Sun Moth habitat through overgrazing and general damage to plants, preventing plant regeneration, altering ecological communities, and changing soil structure and nutrient cycling leading to significant erosion (Department of the Environment 2016).
Installation of artificial structures		
Increasing predation by native and introduced birds	• Timing: current • Confidence: observed • Consequence: moderate • Trend: static • Extent: across the entire range	Predation of adult moths by predatory birds and insects may contribute significantly to adult mortality. Observations at one site showed as many as 30 percent of the moths observed were taken by predators (Clarke & O'Dwyer 2000). Predatory birds include the native *Rhipidura leucophyrs* (Willie Wagtail), *Hirundo neoxena* (Welcome Swallow) and *Grallina cyanoleuca* (Magpie-lark), and the introduced Common Starling (*Sturnus vulgaris*) (DAWE 2020). During monitoring undertaken at the Amberfield Grassland Reserve in Craigieburn, Willie Wagtails were observed hunting in areas of the grassland where Golden Sun Moths were most commonly sighted. The birds were seen to be using an internal farm-style fence to attack prey (which included Golden Sun Moths) and then returning to the fence, a behaviour defined as a 'sally' (Remsen Jnr & Robinson 1990 cited in Bainbridge & Longmore 2016). Willie Wagtails were also observed using perimeter fences and other structures around the reserve as perches for hunting (Bainbridge & Longmore 2016). The Common Starling was also observed at this site apparently using perimeter structures to scrutinise their surroundings for prey, including the Golden Sun Moth (Bainbridge & Longmore 2016). These observations support the idea that man-made structures could increase the level of predation at grassland sites by providing perches for hunting birds.
Fire		
Inappropriate fire regimes	• Timing: current • Confidence: inferred • Consequence: unknown • Trend: decreasing • Extent: across the entire range	Little information is available on the impact of fire on the Golden Sun Moth. However, the species has been shown to withstand burning of its habitat at a site in Nhill, Victoria (Douglas 2004; Biosis 2010b cited in ACT Government 2017), and flying males were observed in higher numbers on a previously burnt patch. It is unknown whether this was due to an attraction of males to areas of low herbage mass, larvae surviving the fire, or a reduction in the dominant Kangaroo Grass exposing or allowing growth of subdominant Wallaby Grasses (ACT Government 2017). Fire may help to reduce herbage mass and residual seed of introduced grass and weed species, and patchy ecological burns are seen as a desirable method of herbage mass reduction in Victoria (Douglas 2004; Gibson 2006 cited in ACT Government 2017). Edwards (1994 cited in ACT Government 2017) reported that the Golden Sun Moth had survived well

Threat	Status and severity [a]	Evidence
		on sites without fire for 50 years and proposed that previously burnt sites may have been reoccupied from surrounding sites as opposed to surviving fire. If so, fires at certain times of the year (primarily September to January) would likely kill adults and/ or eggs, and at small sites risk local extinction. Edwards (1994 cited in ACT Government 2017) also speculated that mobilisation of grass root reserves during resprouting following fire could create a larval food shortage. The frequency and intensity of controlled burns needs to be planned and the species monitored to better understand the effects of fire. Burns should be conducted outside the pupation and flight period (September to January), and may be most preferred in Autumn between March and April (ACT Government 2017; EPSDD 2019).
Climate change		
Temperature increases, changes to rainfall patterns and hydrological flows, and more extreme weather events	• Timing: current/future • Confidence: inferred • Consequence: unknown • Trend: increasing • Extent: across the entire range	Climate change projections show that Australia's climate will get hotter and drier. Time in drought is predicted to increase over southern Australia with a greater frequency of severe droughts, and harsher fire weather (CSIRO 2015). The specialised life cycle and habitat preferences of the Golden Sun Moth may mean it is susceptible to the effects of climate change, such as increases in temperature and evaporation, changes in rainfall patterns, changes to hydrological flows, increased drought conditions, and impacts of grass fire. More research is required into the likely extent of biophysical impacts of climate change on the Golden Sun Moth (OEH 2012). Plants advantaged by climate change are likely to include C4 grasses, which are not thought to be larval food plants. Some perennial grasses have C3 photosynthetic pathways, while others have C4 pathways. The C4 grasses have an additional pathway to capture carbon dioxide during photosynthesis and have higher temperature and light tolerance and lower moisture requirements in comparison to C3 grasses (DPI, 2020). Additionally, weed species such as African Lovegrass and woody plants are likely to be at an advantage (ACT Government 2017).

Timing—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 species. 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 Golden Sun Moth risk matrix

Likelihood	Consequences				
	Not significant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	**Low risk**	**Moderate risk** Inappropriate fire regimes Temperature increases, changes to rainfall patterns and hydrological flows, and more extreme weather events	**Very high risk** Habitat degradation by the introduced Rabbit Increasing predation by native and introduced birds Lack of biomass removal	**Very high risk** Land clearing for urban development and agriculture Weed invasion	**Very high risk**
Likely	**Low risk**	**Moderate risk**	**High risk** Intensification of grazing and/or mowing Application of chemicals such as herbicides, pesticides and fertilisers Planting and/ or regeneration of shrubs/ trees	**Very high risk** Soil disturbance	**Very high risk**
Possible	**Low risk**	**Moderate Risk**	**High risk**	**Very high risk**	**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 threats 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 maintain a watching brief.

Conservation and recovery actions

Primary conservation outcome

Protect Golden Sun Moth subpopulations from decline through:

- Retaining and protecting native grassland remnants within the known distribution of the species.
- Ensuring remnant subpopulations remain connected or linked to each other; in cases where remnants have lost connective links, investigate the potential to re-establish links (e.g. revegetating sites to act as stepping stones for dispersal) (OEH 2019).

Conservation and management priorities

Habitat loss, degradation and fragmentation

- Determine priorities for conservation management and reservation for subpopulations of the Golden Sun Moth. A consistent approach to prioritisation should be developed that includes parameters of genetic variability and subpopulation structure, patch size and quality, and land tenure (OEH 2012).

- Investigate and promote opportunities to establish new reserves for the Golden Sun Moth. Protection of sites representing the range of genetic, habitat and distributional diversity are important for ensuring long-term survival (OEH 2012).
- Investigate and promote opportunities to protect Golden Sun Moth habitat on freehold and public land through voluntary agreements and incentive mechanisms (OEH 2012).
- Search for the species in habitat that is proposed for development or management actions (OEH 2019).
- Do not change management of sites where Golden Sun Moth exists unless changes are likely to be beneficial (OEH 2019). Management actions with beneficial outcomes may include but are not limited to (ACT Government 2017; OEH 2019):
  - controlling invasions of weeds and pasture species, but use herbicides with caution
  - maintaining appropriate grazing levels (domestic stock and/ or native herbivores) and/ or mowing regimes so that grasslands supporting the Golden Sun Moth remain relatively low and open but are not overgrazed
  - mowing/slashing to avoid the seeding period of significant weeds and not undertaken when the ground is wet, to avoid soil disturbance
  - mowing machinery dispersing slashed material, or if windrows are produced, these should be raked and removed from the grassland to avoid excess biomass
  - avoiding planting of shrub or tree species within habitat, removing any woody weeds, and minimising natural regeneration of shrub and tree species in secondary grassland habitats (additional considerations regarding desired conservation outcomes should be made prior to controlling regeneration in secondary grassland habitat that are consistent with listed woodland ecological communities)
  - not using fertiliser within and adjacent to habitat.
- Add actions to relevant management plans and protocols for local government and state/territory lands to ensure management activities (such as for infrastructure, roads, and track easement) occurring on lands supporting the Golden Sun Moth avoid impacts on the species and its habitat.
- Do not destroy habitat and surrounding areas by ploughing or other soil disturbance activities (OEH 2019).
- Mark known sites onto operational maps and plans (OEH 2019).
- Ensure land managers where the Golden Sun Moth occurs are aware of the species' presence and provide protection measures against key and potential threats.

Invasive species (including threats from grazing)

- Continue to control invasive weeds, particularly exotic grasses posing significant threats to the species, but be aware of the impact of herbicide use in Golden Sun Moth habitat. Where possible use methods that directly target weeds such as spot spraying and hand removal (OEH 2019).
- Undertake Rabbit control where their abundance poses a threat to Golden Sun Moth habitat. Consider the impacts of ripping burrows on the Golden Sun Moth when planning and implementing control measures.

- In areas burnt by grass fires, where necessary, control introduced herbivores to aid habitat recovery.
- Implement suitable weed hygiene protocols when undertaking survey, monitoring and management activities. Refer to the *Arrive Clean, Leave Clean Guidelines to help prevent the spread of invasive plant diseases and weeds threatening our native plants, animals and ecosystems* (Department of the Environment 2015).

Impacts of domestic species

- Do not allow heavy, prolonged grazing on Golden Sun Moth habitat (OEH 2019).

Predation

- Avoid the planting of shrubs and trees or installation of fencing surrounding Golden Sun Moth habitat (unless necessary for other conservation reasons) that may act as perches and encourage predatory birds to breed or forage on the site.

Fire

- Prescribed burns must be managed to ensure that they do not disrupt the life cycle of the Golden Sun Moth (i.e. avoid the pupation flight period of September to January), support rather than degrade the habitat necessary to the Golden Sun Moth, do not promote invasion of exotic species, and do not increase impacts of grazing/predation.
- Physical damage to the habitat and individuals of the species must be avoided during and after fire operations.
- Fire management authorities and land management agencies should use suitable maps and install field markers to avoid damage to known Golden Sun Moth habitat.
- Undertake active weed control after fire management along urban roadsides.

Stakeholder engagement/community engagement

- Engage and involve Traditional Owners in conservation actions, including the implementation of survey, monitoring, and management actions.
- Increase public awareness about the conservation of the Golden Sun Moth. Continuation of the production and dissemination of information, presentations to interest groups and media releases about specific achievements already being undertaken. These activities should continue as they encourage land owners/managers to consider this species in their general management and operations, and also encourage the community to become involved in conserving this species (OEH 2012).
- Engage the community in survey and monitoring of the Golden Sun Moth. The use of volunteers for survey and monitoring has been used in various programs for survey and monitoring. This should continue to be fostered, particularly for sites within or close to urban areas (OEH 2012).
- Establish interpretation displays at key sites to provide opportunities to improve community understanding of the ecology and conservation requirements of the Golden Sun Moth. The sites most suitable for this action are those close to urban areas and other regularly visited conservation reserves where the species occurs (OEH 2012).

- Encourage landowners with Golden Sun Moth subpopulations on their properties to join conservation management networks relevant to Natural Temperate Grassland and Box-Gum woodland in NSW and the ACT, the Land for Wildlife scheme in Vic, or engage with NSW Local Land Services. This aims to increase the level of knowledge of the conservation values of the habitat and its component species (OEH 2012).
- Establish and maintain processes for interjurisdictional communication of research and monitoring findings and for coordination of conservation activities for the Golden Sun Moth.

Survey and monitoring priorities

- Undertake systematic surveys for the Golden Sun Moth in areas of potential habitat that have not been adequately surveyed to gain a detailed understanding of the species current distribution. This will help identify and address threats operating at individual sites, prioritise management and aid in securing additional habitat for conservation. Additional surveys should be focused on Vic and the South West Slopes and Riverina bioregions in NSW as these areas likely contain potential habitat that has not been adequately surveyed (OEH 2012).
- Implement an effective monitoring program across the species range to assess ongoing conservation status and subpopulation response to management actions.
- Monitor the response of the Golden Sun Moth to fire, using an appropriate measure (occupancy, subpopulation abundance, individual mortality, ranging behaviour, breeding success, etc.) based on knowledge of the ecology of the species, and with a monitoring design that aims to improve understanding of the species' response to fire.
- Investigate and trial measures to reduce the impact of habitat and subpopulation fragmentation within and between priority sites and monitor subpopulation responses. Connectivity improvement measures could include weed control, habitat rehabilitation, or assisted dispersal (subject to further research). The need for and potential benefits of translocations or assisted dispersal will be investigated through molecular genetic techniques (OEH 2012). Glasshouse and field trials have indicated that the species can be translocated, but long-term survival in a new location is still being assessed (ACT Government 2017).

Information and research priorities

- Determine the extent of potential habitat for the Golden Sun Moth. This is important to identify and prioritise areas for further survey and for informing Commonwealth and State impact assessment processes and prioritising on-ground management for the species (OEH 2012).
- Initiate, promote and support projects to investigate the life history, demographics and important habitat requirements of the Golden Sun Moth. Knowledge gaps exist on the ecology of the species, particularly the biology of the larval stage, fecundity and demography, dispersal ability within and between habitat patches and their ecological requirements (e.g. flora associations, soils and moisture). This will be important for informing effective management of the species (OEH 2012) and defining habitat critical to the survival.

- Investigate the impact of grazing, mowing, ploughing, weed invasion, fertiliser application, pesticide use, fire and tree planting on the Golden Sun Moth and its habitats. This action will help identify and better understand threats to the species and inform appropriate mitigation, amelioration and ongoing management (OEH 2012).
- Identify the nature and extent of processes that impact on the Golden Sun Moth and determine the relative priority for research and management of these threats at each site (OEH 2012).
- Develop and implement adaptive management guidelines to mitigate or remove the threats to the Golden Sun Moth and its habitats. Management guidelines would be implemented on sites currently reserved or under long-term conservation management in accordance with the threats identified at each site. Land managers of other sites where the species occurs will also be encouraged to adopt the management guidelines and acknowledge and support where current management is compatible with the guidelines (OEH 2012).
- Model the influence of predicted climate change on the life cycle and habitat of the Golden Sun Moth to develop strategies to address impacts including decline and local extinctions. This will help to inform whether some parts of the species range are more likely to be resilient to climate change impacts and function as 'refuges' that should be high priority for long-term conservation management. Modelling would require a comprehensive understanding of the species' distribution, habitat and life cycle (OEH 2012).

Links to relevant implementation documents

ACT: Species Profile

ACT: Golden Sun Moth Action Plan

ACT: Conservation Advice 2020

NSW: Species Profile

Vic: Species Profile

Vic: Sub-regional strategy for the Golden Sun Moth

Vic: Action Statement Golden Sun Moth

Commonwealth: Species profile

Commonwealth: Threat abatement plan for competition and land degradation by rabbits

Commonwealth: EPBC Act Policy Statement 3.12 - Significant Impact Guidelines for the Critically Endangered Golden Sun Moth (Synemon plana)

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Attachment A: Listing Assessment for *Synemon plana*

Reason for assessment

The Golden Sun Moth was listed as Critically Endangered under the EPBC Act in 2002.

This assessment follows prioritisation of a nomination from the Committee.

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	>10 000	>10 000	>10 000	There are insufficient data available to determine a minimum and maximum plausible value of the number of mature individuals. However, given the large number of known occurrences of the species and available survey data from many sites, it is highly likely that the number of mature individuals exceeds 10 000. The Victorian threatened species assessment inferred the state of Victoria had 13 500 mature individuals (DELWP 2020b), and in ACT an estimate of 17 250 has been used (see Criterion 3 below). In addition, 59 subpopulations are known from the state of NSW (OEH 2012; Gibbons & Reid 2013). These figures are based on available information and may not account for sites impacted/lost and discovered in recent years. Pupal case surveys have indicated that a male biased sex ratio exists, with a mean of 1.9 (range: 0.6 to 3.5). Using the mean value, any estimate of population size should be reduced by approximately 31 percent to obtain an estimate of mature individuals.

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Trend	Declining			Insufficient monitoring data to demonstrate the trend in number of mature individuals in extant sites. There is a known ongoing decline in the extent, area, and quality of native grassland habitats due to a number of ongoing threats. As such, it is inferred that the number of mature individuals of the species is likely to be declining.
Generation time (years)	2-3 years	2 years	3 years	The larval period is thought to be two to three years (Edwards 1994 cited in DEWHA 2009; Richter et al. 2013a), after which adult moths emerge, living for only a few days to breed (O'Dwyer & Attiwill 2000; Gibson & New 2007).
Extent of occurrence	145 322 km^2	145 322 km^2	171 536 km^2	The minimum plausible value has been estimated based on known occurrences, using record data from the past 20 years (2000-2019) and applying the shortest continuous imaginary boundary that can be drawn to encompass these records as outlined in the *Guidelines for Using the IUCN Red List Categories and Criteria* (IUCN 2019). With such a wide-ranging species with many occurrence records and ongoing threats, the data are not available to confirm the status (i.e. extant or extinct) of the species in all recorded locations. The TSSC's standard approach is to use the last 20 years of record data, unless there is evidence that a different time period is more appropriate. As the species is not well surveyed across its range, a shorter time-frame was not considered appropriate. The maximum plausible value has been calculated using the same method but utilising all record data for the species (dating back to 1897). Use of all data to estimate the maximum EOO is considered appropriate as subpopulations near/ at the edge of the species range may still persist, and this value represents the maximum potential EOO based on the known historic distribution of the species. It should be noted that even using just the most recent one year of data (2019), the EOO estimate would be 24 692 km^2, which is above any of the threatened category thresholds under the listing assessment Criteria.

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Trend	Unknown			There are insufficient data to show the trend in the species EOO. The known EOO for the species has been increasing since its discovery, with more rapid increases since the species listing under the EPBC Act likely due to increased survey effort (Hogg 2010 cited in ACT Government 2017).
Area of Occupancy	~1596 km^2	Insufficient data	Insufficient data	The estimate has been calculated based on known occurrences, using record data for the past 20 years (2000-2019) and applying 2 x 2 km grid cells as outlined in the *Guidelines for Using the IUCN Red List Categories and Criteria* (IUCN 2019). For such a wide-ranging species, with many occurrence records and ongoing threats, the data are not available to confirm the status (i.e. extant or extinct) of the species in all recorded locations. The TSSC's standard approach is to use the last 20 years of record data, unless there is evidence that a different time period is more appropriate. As the species is not well surveyed across its range, a shorter time-frame was not considered appropriate. This is discussed further under Criterion 2. There are insufficient data to estimate a minimum or maximum plausible value of AOO. New occurrences of the species are continuing to be discovered from increased awareness and survey for the species across its range. As such, it is expected that new occurrences of the species will continue to be discovered. However, many threats continue to operate on the species, in particular the threats of habitat loss to development and agriculture, and degradation of habitat from weed invasion are very high risk. In recent years considerable amounts of habitat, particularly in urban areas such as Canberra and Melbourne, have been lost to development and it is expected that this will continue. As such, the AOO was calculated based on known records for the species, with the acknowledgement that this is an estimate only.

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Trend	Declining			There are insufficient data to demonstrate a rate of decline in the species AOO. Further survey data would be required to gain a comprehensive understanding of the species current occurrence within its range. It is thought that the species was once more abundant across its range, based on past habitat availability and genetic evidence suggesting recent fragmentation. Additionally, many threats continue to operate on the species and areas of habitat are known to have been lost in more recent years, predominately from urban development.
Number of subpopulations	164	<164	>164	This species is known from 104 sites in Victoria, of which at least 36 are extant (ACT Government 2017; V Craigie 2020. pers comm 7 October; DELWP 2020a), 59 sites in NSW (OEH 2012; Gibbons & Reid 2013) and 78 sites in the ACT (ACT Government 2017), totalling 164 sites. These figures are based on available information and may not account for sites impacted/lost and discovered in recent years. The number of sites may not necessarily represent individual subpopulations; however, the species has a limited dispersal capability, and as such, sites separated by more than 200 m of unsuitable habitat are likely to be geographically isolated. An assumption has been made that known sites are not within 200 m of another known site nor are connected by suitable habitat.
Trend	Declining			It is thought that the species was once more abundant across its range based on past habitat availability and genetic evidence suggesting recent fragmentation. The species continues to face ongoing threats and a considerable amount of habitat is known to have been lost in recent years to urban development. As such, a decline in the number of subpopulations is inferred.
Basis of assessment of subpopulation number	The limited dispersal ability of the species indicates that all sites separated by greater than 200 m of unsuitable habitat are likely to be geographically isolated and therefore represent individual subpopulations.			

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
No. locations	>10-164	>10	>164	This species is known from 104 sites in Victoria, of which at least 36 are extant (ACT Government, 2017; V Craigie 2020. pers comm 7 October; DELWP 2020a), 59 sites in NSW (OEH 2012; Gibbons & Reid 2013) and 78 sites in the ACT (ACT Government 2017), totalling 164 sites. The biggest ongoing threat to the species is habitat loss, degradation and fragmentation from urban development and agricultural expansion. Depending on the scale of a development or agricultural threat, several sites/subpopulations could be encompassed in one location. For example, a new residential development in outer Melbourne could threaten several sites and would therefore be considered one location in the face of this particular threat. However, based on the relatively large distribution of sites and likely scale of primary threats (e.g. habitat loss occurring from developments, where each development proposal is treated separately), the minimum plausible value estimate would be greater than 10 locations. Further analysis to get a more accurate estimate of locations is not required as the estimate of >10 locations is above any of the threatened category thresholds under the listing assessment Criteria.
Trend	The number of locations is likely to decline in response to the inferred decline in subpopulations/sites.			As described above.
Basis of assessment of location number	Any single development proposal or land use change due to agricultural practices is likely to impact on only a small number of sites.			
Fragmentation	The species is considered to be severely fragmented due to the known subpopulations of the species occurring predominately in small sites, the limited dispersal ability of the species, and the remaining extent of native habitat across the species range.			
Fluctuations	There is no evidence that the species experiences wide, rapid and frequent variation in populations size or distribution.			

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

Insufficient data to determine eligibility

It is well understood that the habitat for the Golden Sun Moth (temperate grassland) has been severely reduced, fragmented and degraded since European settlement. The species and its habitat continue to face a number of significant ongoing threats. A considerable portion of known subpopulations of Golden Sun Moth overlap with urban growth areas or already occur within a matrix of housing and industrial development (Gilmore et al. 2008; Mata et al. 2017). Continued development and agricultural practices are the most prominent threat to the species. In 2012, 21 percent of known Golden Sun Moth habitat within the ACT had been approved or proposed for clearance, with an additional 23 percent on Commonwealth land with an uncertain future (Mulvaney 2012). In Vic, the Melbourne Strategic Assessment included planning measures to mitigate impacts to the Golden Sun Moth, however, collective habitat clearance will be significant (DEPI 2013). Departmental records show that in NSW, the species has been facing development pressure from the renewable energy sector. Between 2010-2018, 11 referrals for renewable energy projects in NSW were submitted to the Commonwealth with potential impacts to the Golden Sun Moth. Of these, four triggered the EPBC Act for the species and have been approved with conditions. The species' ability to persist and thrive in some degraded and exotic grasslands has undoubtably mitigated some of the population decline previously inferred to have been associated with the decline in native temperate grassland habitat across its range. While a decline in population size can be inferred from the significant loss and degradation of native temperate grassland habitat, there are insufficient monitoring and absence data available to estimate extent of past and ongoing declines in the population over a ten-year period. Some data are available surrounding urban areas that have been subject to development pressure (i.e.

in the ACT) which could be used to estimate potential declines in AOO due to habitat clearing in recent years (EPSDD 2021. pers comm 23 February). However, this data is not considered representative of the broader distribution of the species where the threat of urban development is not as prominent.

The Committee considers that there is insufficient information to determine the eligibility of the species for listing in any category under this Criterion.

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 subpopulations; (v) number of mature individuals			
(c)	Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

Criterion 2 evidence

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

The species EOO was estimated using record data from the past 20 years (2000-2019) and applying the shortest continuous imaginary boundary that can be drawn to encompass these records as outlined in the IUCN guidelines (IUCN 2019). The EOO of 145 322 km² does not meet the criteria for listing in any category under B1. The use of most recent 20 years of data is a standard approach by the TSSC, however it should be noted that even with the use of only the most recent one year of record data (2019), the species would still not meet the EOO thresholds under B1 (see Table 4).

The Golden Sun Moth qualifies for a limited AOO (<2000 km²) under Criterion 2B2. A range of estimates of AOO have been considered to determine the most appropriate threshold category under B2. Estimates for AOO were calculated using the standard 2 x 2 km grid cell method outlined in the IUCN guidelines (IUCN 2019). The estimate used in the assessment (~1596 km²) was calculated using species record data from the most recent 20 years (i.e. records from 2000–2019) and fits within the threshold values for the Vulnerable category under Criterion 2B2. The TSSC's standard approach is to use the most recent 20 years of record data, unless there is evidence that a different time period is more appropriate. As the species is not well surveyed across its entire range, a shorter time-frame was not considered appropriate. Conversely a longer time period was not used to calculate the most plausible estimate, as the species has a short generation length and considerable ongoing threats. Despite such, even if all available record data was used, the AOO estimate would be 1792 km², which remains consistent with the thresholds for the Vulnerable category.

The Golden Sun Moth is a wide-ranging species with many occurrence records, however, the data are not available to confirm the status (i.e. extant or extinct) of the species in all recorded

locations. In the ACT, a large number of records have been identified to be no longer extant due to recent development (EPSDD 2021. pers comm 23 February). Records within the ACT that were clearly no longer extant due to recent land clearing for development were removed for the purpose of calculating the AOO and resulted in a reduction of the species AOO a marginal amount. This is because extant records occur nearby and within the same grid cells, resulting in a reduction of site numbers but not AOO. This was not undertaken for records within NSW or Vic, however, is expected to have a similarly negligible impact on the AOO and would certainly not impact the category outcome of the assessment. While the species has undoubtedly been lost from a number of recorded locations, predominantly around Melbourne (and potentially others in the ACT) due to urban development, there are also extensive areas of potential habitat, particularly in NSW, which have not been surveyed for the species and their presence is unknown.

Therefore, the estimate used in this assessment is not considered to be an accurate figure but is considered to be the most plausible estimate based on available data and is suitable for the purpose of the assessment. Table 4 below sets out the AOO values estimated from the inclusion of record data dating back 20 years from 2019. Only the seven most recent years of record data (2012-2019) are necessary for the estimation of AOO to meet the lower Vulnerable threshold. This provides more confidence that even with the known loss of the species from many recorded sites, the AOO is still beyond the threshold for Endangered (<500 km^2), and undoubtedly beyond that of the listing category it was in at the time the current assessment commenced (Critically Endangered (<10 km^2)). It should also be made explicit, that the inclusion of records within all habitat (exotic and native) have been used in the assessment as guided by the IUCN. Records within Chilean Needlegrass habitat have been included as the species is known to be able to utilise and persist in this habitat.

Table 4 Golden Sun Moth AOO and EOO calculations using up to 20 years of record data (2000-2019)

Year(s) of record data	AOO (km^2)	EOO (km^2)
2019	80	24 692
2018-19	176	54 692
2017-19	200	54 692
2016-19	308	56 372
2015-19	412	119 422
2014-19	468	119 422
2013-19	512	120 554
2012-19	684	126 574
2011-19	872	132 324

2010-19	972	134 206
2009-2019	1228	145 282
2008-2019	1404	145 286
2007-2019	1436	145 322
2006-2019	1456	145 322
2005-2019	1472	145 322
2004-2019	1480	145 322
2003-2019	1492	145 322
2002-2019	1492	145 322
2001-2019	1492	145 322
2000-2019	1596	145 322

With respect to the most plausible estimate of AOO described above it is noteworthy that the species known range (EOO and AOO) has continued to grow from its initial discovery until now (Table 4). The most significant increases are observed following attention being drawn to the conservation position of the species and its subsequent listing under the EPBC Act in 2002. The increase in AOO observed since its listing has resulted from the increased survey effort due to conservation interest and requirements under the EPBC Act and relevant state and territory legislation, as well as increased knowledge on the species' habitat requirements and survey techniques. Since 2002, the AOO for the species based on all record data has increased by over 1300 km^2. New locations are frequently being identified and it is anticipated that in coming years, with continued survey, the knowledge of the species occupancy will continue to improve, providing a more accurate estimate of AOO based on record data.

The species distribution is considered to be severely fragmented due to the known subpopulations of the species occurring predominately in small, discrete sites (Gibson & New 2007; Richter et al. 2013b; EPSDD 2020), the limited dispersal ability of the species (Clarke & O'Dwyer 2000), and the remaining extent of native habitat across the species range (DAWE 2020). Genetic studies have suggested that the lack of genetic differentiation between closely located subpopulations may indicate recent fragmentation of historically connected subpopulations (Clarke & O'Dwyer 2000). The NSW/ACT subpopulations are thought to have derived from a small founding subpopulation that underwent rapid demographic expansion in ancient times. This was then followed by more recent population bottlenecks resulting from habitat fragmentation associated with the widespread introduction of agriculture into the region (Clarke & Whyte, 2003).

Many sites containing the Golden Sun Moth are on private lands that are generally not managed for conservation and some are under threat from development and agricultural expansion (Gilmore et al. 2008). All three jurisdictions (Vic, NSW, ACT) in which the species occurs, are

facing development pressures from various land uses, with current protection for the species mitigating some of the impacts. Further, invasion of weeds into native grassland is also considered to be a major threat to the species and habitats in which the species depend on Chilean Needlegrass may be lost from weed control. A complex issue as while the invasion of Chilean Needlegrass into native grasslands may lead to a decline in the quality of habitat, its removal may contribute to the decline in the area of habitat for the Golden Sun Moth where suitable native grasses do not persist/ occur. These threats are inferred to result in a continuing decline in the AOO (ii) and the area, extent and quality of habitat available (iii). As reductions in AOO and available habitat are inferred due to threats operating on the species, it is also considered likely that the number of subpopulations (iv), and the number of mature individuals (v) will also face ongoing declines.

The Committee considers that the species' AOO is limited (B2), its distribution is severely fragmented (a), and continuing decline (b) is inferred in the area of occupancy (ii), area, extent and/or quality of habitat (iii), number of locations or subpopulations (iv), and number of mature individuals (v). Therefore, the species has met the relevant elements of Criterion 2 to make it eligible for listing as Vulnerable.

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 subpopulation	**≤ 50**	**≤ 250**	**≤ 1,000**
	(ii) % of mature individuals in one subpopulation =	**90 – 100%**	**95 – 100%**	**100%**
(b) Extreme fluctuations in the number of mature individuals				

Criterion 3 evidence

Not eligible

The biology of the Golden Sun Moth creates difficulties in quantitative population assessments and comparisons of subpopulations (Gibson & New 2007). There is no robust estimate of the national population size for the Golden Sun Moth, however the number of mature individuals exceeds 10 000.

The Threatened Species Assessment undertaken by the Victorian Government in 2020 states the inferred number of mature individuals to be 13 500 within the state of Victoria. Mulvaney (2012) specifies a rough estimate of the total ACT population to be around 25 000 individuals based on maximum male moth counts from all ACT sites and a male to female moth ratio of 1.5 (Richter et al. 2009 cited in Mulvaney 2012). Discounting the population estimate by 31 percent[1], gives a rough estimate of at least 17 250 mature individuals in the ACT. There are no comprehensive monitoring or survey data to indicate population size in NSW. The estimate of

[1] It should be noted that pupal case surveys have indicated that a male biased sex ratio exists, with a mean of 1.9 (range: 0.6 to 3.5). Any future calculations of mature individuals should consider this information; and using the mean value, it would be appropriate for estimates of population size to be reduced by approximately 31 percent.

mature number of individuals in the ACT and Vic is therefore 30 750, and without an estimate for NSW, still exceeds any thresholds for eligibly under Criterion 3.

The total number of mature individuals is greater than 10 000 which exceeds the threshold for listing under Criterion 3. Therefore, the species has not met this required element of 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

There is no robust estimate of population size or number of mature individuals for the Golden Sun Moth. However, as per the evidence above under Criterion 3, the number of mature individuals exceeds 1000. Therefore, the species has not met this required element of this criterion. Additionally, the Golden Sun Moth does not meet the quantitative threshold for Vulnerable under sub-criterion D2.

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

A population viability analysis has not been undertaken. Therefore, there is insufficient information to determine the eligibility of the species for listing in any category 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 34 business days between 5 January 2021 and 23 February 2021.

Listing and Recovery Plan Recommendations

The Threatened Species Scientific Committee recommends:

(i) that the list referred to in section 178 of the EPBC Act be amended by transferring *Synemon plana* from the Critically Endangered category to the Vulnerable category.

(ii) that there not be a recovery plan for this species.

Cataloguing data

This publication (and any material sourced from it) should be attributed as: Department of Agriculture, Water and the Environment 2021, *Conservation Advice for Synemon plana* (Golden Sun Moth), Canberra. 

This publication is available at the SPRAT profile for *Synemon plana* (Golden Sun Moth).

Department of Agriculture, Water and the Environment
GPO Box 858, Canberra ACT 2601
Telephone 1800 900 090
Web awe.gov.au

Version history table

Document type	Title	Date [dd mm yyyy]
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