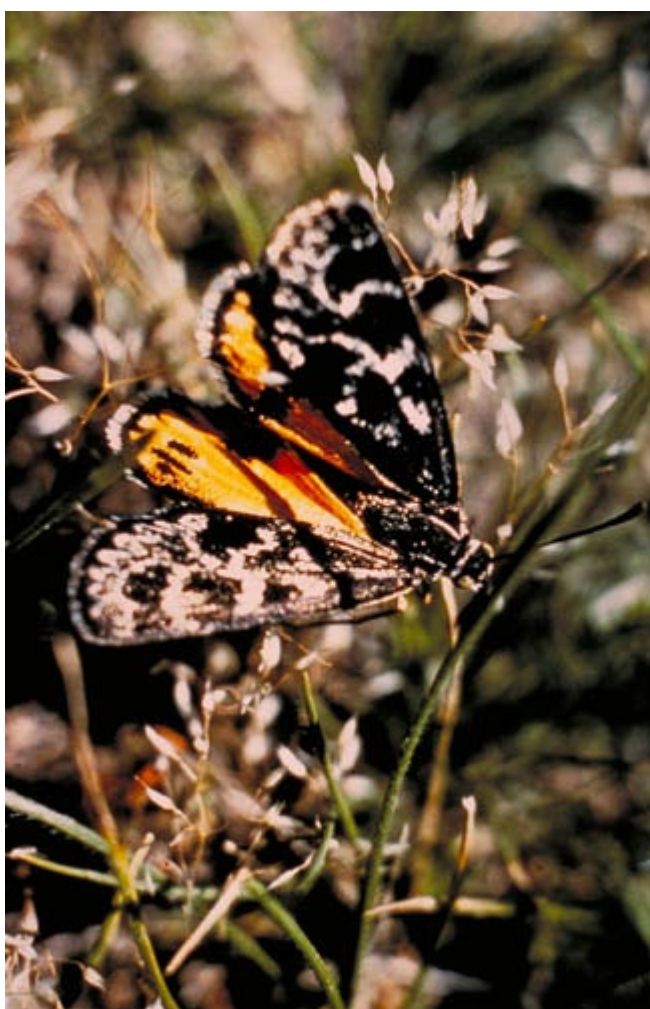




Consultation Document on Listing Eligibility and Conservation Actions for *Synemon plana* (Golden Sun Moth)

This document combines the proposed 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 currently listed in the Critically Endangered category of the threatened species list under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act).

Synemon plana is being 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(iii): 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 of populations and a continuing decline in the area, extent, and quality of habitat.

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

Golden Sun Moth, a member of the family Castniidae, is a medium-sized day-flying (diurnal) moth (OEH 2019). The moth 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 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;

Threatened Species Scientific Committee

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, habitat for the Golden Sun Moth, has been heavily reduced and fragmented (DAWE 2020). Many of the known populations 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).

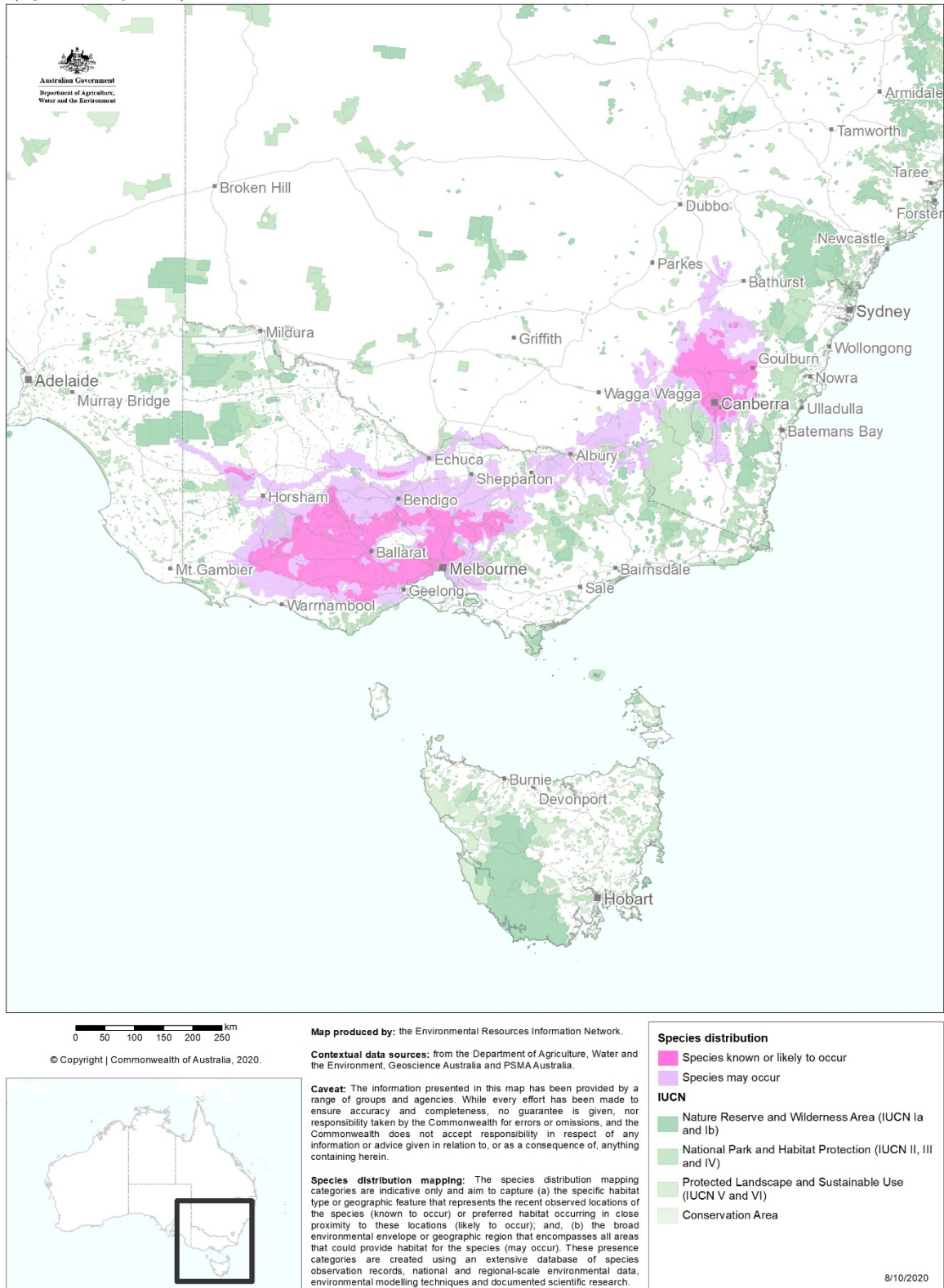
At the time when the species was listed as Critically Endangered under the EPBC Act (2002), the extent of occurrence (EOO) of the species was estimated to be approximately 131 100 km² and the area of occupancy (AOO) estimated to be approximately 8.8 km² (TSSC 2002). Since its listing, understanding of the species distribution and habitat has improved and EOO and AOO are now understood to be around 141 472 km² and 1572 km² respectively (using the EPBC Act assessment criteria). This new knowledge is predominately due to an increase in survey effort in areas proposed for development, leading to the discovery of extant site localities, particularly in Vic, and the ACT and surrounding regions (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, 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 100 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), 48 sites in NSW (OEH 2012) and 78 sites in the ACT (ACT Government 2017). No extant sites are known from South Australia and the species is likely to be locally extinct (Edwards 1994 cited in DEWHA 2009). The NSW and ACT populations generally occur at elevations between 480 m and 720 m and Vic populations generally occur at lower elevations, between 95 m and 406 m (DAWE 2020).

Within regions, genetic differentiation among populations is correlated with geographic distance, that is, populations 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 populations 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 populations may indicate recent fragmentation of historically connected populations (Clarke & O'Dwyer 2000). Genetic studies have suggested that the Vic populations are evolutionarily distinct from the NSW/ACT populations, representing different evolutionary significant units (Clarke & O'Dwyer 2000; Clarke & Whyte 2003).

Map 1 Modelled distribution of Golden Sun Moth

Indicative distribution of Golden Sun Moth (*Synemon plana*)



Source: Base map Geoscience Australia; species distribution data [Species of National Environmental Significance](#) database.

Cultural and community significance

Indigenous peoples 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.

Relevant biology and ecology

Across the historical range of the Golden Sun Moth, potential habitat includes areas containing, or having once contained, native grassland, grassy woodlands and secondary grasslands, that retain a component of larval food species. This includes degraded habitats which retain a component of native larval food species, or have been invaded by the exotic species, Chilean Needlegrass (*Nassella neesiana*), which the species feeds on (DEWHA 2009). Large populations 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 which 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 which 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 populations of the species occurring in open woodland and secondary native grassland habitats 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 habitats generally support fewer moths than native temperate grassland, or sites with high Chilean Needlegrass components.

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 (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).

Larvae are underground feeders, found in silk-lined burrows closely associated with the grass roots which 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 suitable habitat was comprised of 40 per cent 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 per cent cover of Wallaby Grass. Additionally, the species has also been associated with the exotic Chilean needlegrass, and occasionally with *Microlaena stipoides* (Weeping Grass), *Bothriochloa macra* (Redleg Grass), and *Aristida ramosa* (Purple

Wiregrass) (ACT Government 2017), with some evidence suggesting these species may be larval food plants. 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. This suggests that tussocks with a large root volume may be beneficial in providing for a larva throughout its 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 which support the hypothesis that the species may have a reproductive advantage when utilising Chilean Needlegrass based on a number of factors, including the increased body size of larvae developing on Chilean Needlegrass (Richter et al. 2013b; ACT Government 2017).

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) which 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 distinctive male-biased sex ratio was found across the two years of the study which did not differ significantly between native grassland and exotic (Chilean Needlegrass dominated) grassland habitats. A mean 1.9 sex ratio of males to females 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 which affects their predation risk, catchability and visibility. These factors would influence any evaluation of the adult sex ratio within populations (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, populations 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 suitable 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 et 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 in Richter et al (2013). Further research is required to better understand the species larval biology, relationship to ecological factors, and factors which may limit this part of the life cycle.

Certain aspects of the life cycle and behaviour of the species affect its detectability and therefore create challenges for assessing populations. In addition, the lack of tested monitoring methods exacerbates comparative analysis (Richter et al. 2013b). Trialled methods for population 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. Richter et al. (2013b) trialled population monitoring through the counting and sexing of pupal cases. This method could be used as a valuable tool for monitoring local populations as it is a more flexible survey method and could provide more conclusive data than alternate methods. There is also potential for this method to provide an indication of population size but a possible limitation of this approach may be difficulties in finding and counting pupal cases in differing conditions, e.g. in wetter growing seasons where the grass is taller. Additionally, the relationship between total population of emerged adults by a given date and the total number of pupal cases that can be found is unknown. While further research is required before its potential use for more detailed population 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. The guidelines can be found at:

<http://www.environment.gov.au/system/files/resources/b945f32e-3f75-4739-a793-9f672893f3bb/files/background-paper-golden-sun-moth.pdf>.

Habitat critical to the survival

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

The draft National Recovery Plan for the Golden Sun Moth states that habitat critical to the survival of the species has not yet been identified and actions to address this have been included in the plan (NSW Office of Environment & Heritage 2012).

While no habitat critical to the survival of the Golden Sun Moth has yet been identified, large populations or well-connected subpopulations occurring in good quality habitat are likely to classify for their importance in long-term maintenance of the species, including maintenance of genetic diversity and long-term evolutionary development. Good quality habitat for this purpose should be defined as medium to large sites containing native grassland with an abundant component of larval food species, inter-tussock spaces, and land-use/ management that is consistent with ecological values of the site. Additional consideration should be made for sites occurring toward the limit of the species range, or sites which are a long distance from other known populations as they are likely important for conserving the full range in genetic diversity.

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 populations which could have additional consequences for small, isolated populations (DAWE 2020).

Table 1 Threats impacting Golden Sun Moth

Threat	Status and severity ^a	Evidence
Habitat loss, degradation and fragmentation		
Urban and infrastructure development and agriculture	<ul style="list-style-type: none"> • Status: current • Confidence: known • Consequence: severe • Trend: static • Extent: across the entire range 	The natural native grassland habitat of the Golden Sun Moth has been significantly reduced and fragmented over its original distribution from 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.

Synemon plana (Golden Sun Moth) Conservation Advice

Threat	Status and severity ^a	Evidence
		<p>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.</p> <p>The species has demonstrated its ability to persist in grazed sites however repeated ploughing and cultivation of the soils is destructive, destroying both the subterranean early stages of life but also killing the perennial grasses that are their host plants resulting in local extinctions (Douglas 2004).</p>
Soil disturbance	<ul style="list-style-type: none"> • Status: current • Confidence: known • Consequence: severe • 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 cultivation, ripping rabbit burrows, laying infrastructure, driving of vehicles and machinery on wet soil, 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).
Dense vegetation creating closed grasslands	<ul style="list-style-type: none"> • Status: current • Confidence: known • 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	<ul style="list-style-type: none"> • Status: current • Confidence: known • Consequence: moderate • Trend: unknown • Extent: across the entire range 	Continual and intense grazing by domestic stock or even native Kangaroos encourages invasion of weeds and degrades native vegetation (Barlow 1998). Mowing and slashing also has the potential to introduce weeds and threaten grassland integrity as it can prevent flowering and seed production if undertaken too frequently or at the wrong time of year (DAWE 2020).
Application of chemicals such as herbicides and fertilisers	<ul style="list-style-type: none"> • Status: current • Confidence: known • Consequence: moderate • Trend: unknown • Extent: across the entire range 	<p>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).</p> <p>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</p>

Synemon plana (Golden Sun Moth) Conservation Advice

Threat	Status and severity ^a	Evidence
		composition of habitat in an unfavourable manner for the Golden Sun Moth (ACT Government 2017). Additional to the impact of chemicals on habitat, chemical use may also directly impact upon individual Golden Sun Moths.
Planting and/ or regeneration of shrubs/ trees	<ul style="list-style-type: none"> • Status: current • Confidence: known • 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	<ul style="list-style-type: none"> • Status: current • Confidence: known • Consequence: moderate • Trend: increasing • Extent: across the entire range 	Native grasslands are under threat from various introduced pasture grasses and clovers which out-compete the native Wallaby Grasses and Speargrasses which 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 unsuitable habitat through the change from a patchy sward of short to medium height to a dense tall sward (ACT Government 2017). Conversely, unsuitable habitat may become suitable for the species with the invasion of Chilean Needlegrass and potentially other exotic species such as Serrated Tussock. These two species are both listed Weeds of National Significance (WoNS) which 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 (<i>Oryctolagus cuniculus</i>)	<ul style="list-style-type: none"> • Status: current • Confidence: known • 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).
Predation		
Predation by birds	<ul style="list-style-type: none"> • Status: current • Confidence: known • 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 <i>Rhipidura leucophrys</i> (Willie Wagtail), <i>Hirundo neoxena</i> (Welcome Swallow) and <i>Grallina cyanoleuca</i> (Magpie-lark), and the introduced Common Starling (<i>Sturnus vulgaris</i>) (DAWE 2020).

Synemon plana (Golden Sun Moth) Conservation Advice

Threat	Status and severity ^a	Evidence
Predation by insects	<ul style="list-style-type: none"> • Status: current • Confidence: known • Consequence: moderate • Trend: static • Extent: across the entire range 	Predatory insects including Robber Flies may be a significant contributor to adult mortality (family Asilidae) (Clarke & O'Dwyer 2000; DAWC 2020).
Fire		
Inappropriate burning regimes	<ul style="list-style-type: none"> • Status: current • Confidence: inferred • Consequence: unknown • Trend: decreasing • Extent: across the entire range 	<p>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 however 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 species, and Patchy ecological burns are seen as desirable methods of herbage mass reduction in Victoria (Douglas 2004; Gibson 2006 cited in ACT Government 2017).</p> <p>Edwards (1994 cited in ACT Government 2017) reported that the Golden Sun moth had survived well 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.</p> <p>As such, the frequency and intensity of controlled burns need 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).</p>
Climate change		
Temperature increases, changes to rainfall patterns and hydrological flows, and more extreme weather events	<ul style="list-style-type: none"> • Status: current/future • Confidence: inferred • Consequence: unknown • Trend: increasing • Extent: across the entire range 	<p>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).</p> <p>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 unplanned fire. More research is required into the likely extent of biophysical impacts of climate change on the Golden Sun Moth (OEH 2012).</p> <p>Plants advantaged by climate change are likely to include C4 grasses, which are not thought to be larval</p>

Threat	Status and severity ^a	Evidence
		food plants. Some perennial grasses have C3 photosynthetic pathways, while others have C4 pathways. 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 (<i>Eragrotis curvula</i>) and woody plants are likely to be at an advantage (ACT Government 2017).

Status—identify the temporal nature of the threat;

Confidence—identify the extent to which we have confidence about the impact of the threat on the species;

Consequence—identify the severity of the threat;

Trend—identify the extent to which it will continue to operate on the species;

Extent—identify its spatial content in terms of the range of the species.

Each threat has been described in Table 1 in terms of the extent that it is operating on the 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 Fire Climate Change	Very high risk Habitat degradation by the introduced Rabbit, and predation	Very high risk Urban and agricultural development	Very high risk
Likely	Low risk	Moderate risk	High risk Inappropriate habitat management actions	Very high risk	Very high risk
Possible	Low risk	Moderate Risk	High risk Weed invasion Soil disturbance	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

- Retain and protect native grassland remnants within the known distribution of the species.
- Ensure remnant populations 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 populations of the Golden Sun Moth. A consistent approach to prioritisation should be developed which includes parameters of genetic variability and population 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 suitable habitat in areas that are 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:
 - 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 avoiding the seeding period of significant weeds and not undertaken when the ground is wet, to avoid soil disturbance
 - mowing machinery should disperse slashed material, or if windrows are produced, these should be raked and removed from the grassland to avoid excess biomass
 - avoid planting 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 which are consistent with listed woodland ecological communities)
 - only using herbicides where necessary to protect Golden Sun Moth and its habitat (ACT Government 2017)
 - 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 management 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)

- Control invasions of weeds and pasture 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 bushfires, control of introduced herbivores will 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) which may act as perches and encourage predatory birds to breed or forage on the site (OEH 2012).

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

- 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 will 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 will 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 populations on their properties to join conservation management networks relevant to Natural Temperate Grassland and Box-Gum woodland in NSW and the ACT, and the Land for Wildlife scheme in Vic. 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 for 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 population response to management actions.
- Monitor the response of the Golden Sun Moth to fire, using an appropriate measure (occupancy, population 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 population fragmentation within and between priority sites and monitor population 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).

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 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).
- 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 lands where the species occurs will also be encouraged and to adopt the management guidelines and acknowledges and supported 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 functions as 'refuges' which 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: Golden Sun Moth Action Plan -

https://www.environment.act.gov.au/cpr/conservation_and_ecological_communities/threatened_species_factsheets/factsheets2/golden-sun-moth2

Vic: Sub-regional strategy for the Golden Sun Moth –

https://www.msa.vic.gov.au/_data/assets/pdf_file/0032/64868/Sub-regional-Species-Strategy-for-the-Golden-Sun-Moth-May-2013.pdf

Vic: Action Statement Golden Sun Moth -

https://www.environment.vic.gov.au/_data/assets/pdf_file/0015/32514/Golden_Sun_Moth_Synemon_plana.pdf

NSW: Golden Sun Moth – profile -

<https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10791>

Threat abatement plan for competition and land degradation by rabbits -

<https://www.legislation.gov.au/Details/F2017L00031>

EPBC Act Policy Statement 3.12 - Significant Impact Guidelines for the Critically Endangered Golden Sun Moth (*Synemon plana*) - <http://www.environment.gov.au/resource/significant-impact-guidelines-critically-endangered-golden-sun-moth-synemon-plana>

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THREATENED SPECIES SCIENTIFIC COMMITTEE

Established under the *Environment Protection and Biodiversity Conservation Act 1999*

The Threatened Species Scientific Committee draft assessment

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 covering a number of 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). In addition, data from the ACT show 78 subpopulations of varying size occur within the Territory (ACT Government 2017), and 48 subpopulations are known from the state of NSW (OEH 2012). 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 30 percent to obtain an estimate of mature individuals.
Trend	Unknown			Insufficient monitoring data to demonstrate the trend in number of mature individuals. While so, there is a known ongoing decline in the extent and quality of potential native grassland habitats.

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Generation time (years)	2-3 years	2 years	3 years	The larval period is thought to be two-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	142 472 km ²	142 472 km ²	168 256 km ²	The minimum plausible value has been calculated using record data from the past 20 years (1999-2019) and applying the shortest continuous imaginary boundary which can be drawn to encompass these records as outlined in the Guidelines for Using the IUCN Red List Categories and Criteria (IUCN 2019). The maximum plausible value has been calculated using the same method but utilising all record data for the species (dating back to 1897).
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).

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Area of Occupancy	<2000 km ²	1572 km ²	5664 km ²	<p>The minimum plausible value has been calculated using record data for the past 20 years (1999-2019) and applying 2 x 2 km grid cells as outlined in the Guidelines for Using the IUCN Red List Categories and Criteria (IUCN 2019).</p> <p>The maximum plausible value of AOO has been calculated based on mapping of potential habitat and using considerations from past surveys to obtain a likely area of occupied habitat. This value has been calculated at a 1 km x 1 km scale, however due to limitations has not been scaled up to meet the IUCN guidelines. However, scaling-up to meet the guidelines for a maximum estimate would result in a higher value, but would have no further implication as it is already above the threshold for the Vulnerable listing category. While known occurrences of the species are continuing to rise from increased survey across the species range, the threat of habitat loss and degradation is continuing and it is expected that known sites will continue to be lost. Therefore, a more precautionary approach has been taken and the minimum plausible value has been used for the assessment.</p>
Trend	Likely to be contracting due to loss of native grasslands primarily for agriculture and development.			<p>There are insufficient data to demonstrate a rate of decline in the species AOO as further surveys are required to better understand the distribution of the species. The known AOO 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). However, 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 habitat loss, degradation and fragmentation from a number of threats.</p>

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
Number of subpopulations	164	164	>164	This species is known from 100 sites in Victoria, of which at least 36 are extant (ACT Government 2017; V Craigie 2020. Pers comm 7 October; DELWP 2020a), 48 sites in NSW (OEH 2012) and 78 sites in the ACT (ACT Government 2017), totalling least 164 sites. These figures are based on available information and may not account for sites impacted in recent years. Sites may not necessarily represent different subpopulations however as the species has limited dispersal capability, sites separated by more than 200 m of unsuitable habitat are likely to be geographically isolated and an assumption has been made that known sites are not within 200 m of another known site. As a reliable maximum plausible estimate cannot to specified, the minimum plausible value has been utilised as the estimate.
Trend	Likely to be declining due to loss of native grasslands primarily for agriculture and development			There are insufficient data to show the trend in the number of subpopulations. However, 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 habitat loss, degradation and fragmentation from a number of threats and therefore a decline in number of subpopulations is inferred.
Basis of assessment of subpopulation number	The limited dispersal ability of the species indicates that all sites separated by more than 200 m of unsuitable habitat are likely to be geographically isolated.			

Metric	Estimate used in the assessment	Minimum plausible value	Maximum plausible value	Justification
No. locations	>10-164	>10	164	This species is known from 100 sites in Victoria, of which at least 36 are extant (ACT Government, 2017; V Craigie 2020. Pers comm 7 October; DELWP 2020a), 48 sites in NSW (OEH 2012) and 78 sites in the ACT (ACT Government 2017), totalling at least 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 could be encompassed in one location. For example, a new residence development in outer Melbourne could threaten several subpopulations and would therefore be considered one site in the face of this particular threat. However, based on the distribution of sites (from Victoria to NSW) and likely scales of primary threats (habitat loss), the minimum plausible value is >10 locations.
Trend	Number of locations is likely to decline in response to the inferred decline in subpopulations/ sites.			As above
Basis of assessment of location number	A single development proposal or land use change due to agriculture is likely to impact on only a small number of sites.			
Fragmentation	The species is considered to be severely fragmented due to the known populations of the species occurring predominately in small sites, the limited dispersal ability of the species, and the remaining extent of its primary habitat (temperate grassland) 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%
<p>A1 Population reduction observed, estimated, inferred or suspected in the past and the causes of the reduction are clearly reversible AND understood AND ceased.</p> <p>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.</p> <p>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]</p> <p>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.</p> <p>Based on any of the following</p> <ul style="list-style-type: none"> (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 primary native habitat for the Golden Sun Moth (temperate grasslands) has been severely reduced and fragmented since European settlement and continues to face a number of significant ongoing threats causing further habitat loss, degradation and fragmentation. 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 at the time 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.

Of interest is the species ability to use degraded grasslands, and even grasslands dominated entirely by the exotic Chilean Needlegrass. It is currently unknown whether the Golden Sun Moth can utilise other exotic grass species for their critical life stages, with the exception of evidence suggesting use of Serrated Tussock (EPSDD 2017). Monitoring at an environmental

offset site in Canberra showed a substantial decline in native pasture and increase in exotic pasture over recent years, with the continued incursion of significant perennial grassy weeds (i.e. African Lovegrass and Chilean Needlegrass) at the site. While a decline in native habitat quality has been observed since monitoring on the site began in 2013 (Umwelt 2019, 2020), total habitat area has increased due to the spread of Chilean Needlegrass creating additional habitat with record numbers of Golden Sun Moth observed during timed transverse surveys in 2018. The average number of Golden Sun Moths observed each survey during 2018 was 549.7. This is considerably more than the averages recorded in 2013 (64), 2014 (74.3), 2015 (25.7), 2016 (277), and 2017 (87). In 2019 the average dropped to 60.7. Variation between survey days and between years is likely partly due to climatic factors and normal seasonal and daily stochasticity respectively (Umwelt 2020).

The species ability to persist and thrive in some degraded and exotic grassland habitats has undoubtedly mitigated some of the population decline inferred to have been associated with the decline in native temperate grassland habitat across the species range. While a decline in population size can be inferred from the significant loss of native temperate grassland habitat, there are insufficient monitoring data available to calculate extent of past and ongoing declines. Our understanding of the species distribution is still developing, and as such as more comprehensive understanding of the species occurrence and habitat availability is required.

The Committee considers that there is insufficient information to determine the eligibility of the species for listing in any category under this Criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

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(iii) for listing as Vulnerable

The species EOO was calculated using record data from the past 20 years (1999-2019) and applying the shortest continuous imaginary boundary which can be drawn to encompass these records as outlined in the IUCN guidelines (IUCN 2019). The EOO of 142 472 km² does not meet the criteria for listing in any category under B1.

A range in estimates of the AOO for the Golden Sun Moth have been considered for the purpose of this assessment. The minimum plausible value for AOO was calculated using the 2 x 2 km grid cell method outlined in the IUCN guidelines (IUCN 2019) using species record data from the last 20 years (i.e. records from 1999 – 2019). Due to the large number of sites the species occurs at and limited data on the current status of the majority of sites, it was not possible to determine the precise number of extant sites nationally. A 20 year period was selected for use in calculating the minimum plausible estimate as the species has a short generation time, and the threat of habitat loss and degradation is considered to be ongoing. While some sites which have not been surveyed in over 20 years could still be extant, a number of other sites are known to have been lost or impacted by development in this time. Additionally, records from new sites are accumulating rapidly, largely due to Environmental Impact Assessment surveys as outlined below. The minimum plausible value of 1572 km² is considered to be an estimate.

The maximum plausible estimate of AOO has been calculated based on the area of known and likely habitat obtained from the Department's species distribution model (Map 1), and an estimate of the percentage of occupied habitat based on available survey data which targeted previously unsurveyed locations within modelled habitat in Victoria (Brown & Tolsma 2010; Brown et al. 2011).

The maximum plausible value has many uncertainties associated with its calculation and is therefore considered to be an inferred value. The Department's species distribution modelling identified 37 763 km² of known or likely habitat across Australia. This value is an estimate of potential habitat and likely a substantial overestimate of occupied habitat. To generate a more plausible estimate of an upper bound of plausible AOO the modelled estimate was adjusted for the proportion occupied over a relatively well sampled subset of the species distribution.

Surveys commissioned from 2009 to 2011 in the VVP bioregion aimed to further determine the distribution of the Golden Sun Moth (Brown & Tolsma 2010; Brown et al. 2011). Surveys were undertaken across a variety of land tenures within the VVP bioregion (along roadsides, public land and private land), which were identified by combining a distribution model based on all known sightings with a probability model for native grassland/ native pasture. Of the 307 sites surveyed, 46 (15 percent) sites detected the presences of the Golden Sun Moth. Split by land tenures, results across the two survey periods were fairly similar, with presence detected at 17 percent of privately owned sites, 13 percent of public land sites, and 16 percent of roadside sites. Thus if 15 percent of the modelled distribution is occupied, the maximum estimate of occupied habitat is approximately 5664 km². Key assumptions made in this estimate were that potential habitat modelled across the whole range was not significantly different from that of the VVP (no access was available to modelling used in the Brown & Tolsma 2010 and Brown et al. 2011 survey work); rates of detection in the VVP bioregion were inferred and extrapolated across the

species modelled distribution; and that land tenure across potential habitat does not differ significantly from the distribution of sites surveyed in the VVP.

With respect to the most plausible estimate of AOO between the minimum and maximum described above it is noteworthy that the species known range (EOO and AOO) has continued to grow from its initial discovery until now. The most significant increases observed following attention being drawn to the conservation position of the Golden Sun Moth and its subsequent listing under the EPBC Act in 2002. The increase in AOO observed over this time has resulted from the increased survey effort due to the species listing 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 record data has increased by over 1316 km². 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.

As there is a significant range in plausible AOO which spans the Vulnerable listing threshold, and there is higher uncertainty regarding the maximum plausible estimate, a precautionary approach has been taken to consider the actual AOO to be closer to the minimum plausible value (see Section 3.2.4 of the Guidelines for Using the IUCN Red List Categories and Criteria). However, the species range in NSW and some parts of Victoria, are not considered to have been adequately surveyed and as such a number of undetected sites are likely to occur (OEH 2012). Thus, while AOO is likely to be greater than 1572 km², it is considered to be less than the 2000 km² threshold for Vulnerable under B2.

The species distribution is considered to be severely fragmented due to the known populations 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 primary habitat (native temperate grassland) across the species range (DAWE 2020). Genetic studies have suggested that the lack of genetic differentiation between closely located populations may indicate recent fragmentation of historically connected populations (Clarke & O'Dwyer 2000). The NSW/ACT populations are thought to have derived from a small founding population 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 which are generally not managed for conservation and some are under threat from development (Gilmore et al. 2008). All three jurisdictions (Vic, NSW, ACT) in which the species occurs, are facing development pressures from various land uses (see evidence under Criterion 1), with current protection for the species mitigating some of the impacts. Additionally, habitats in which the species depend on Chilean Needlegrass are threatened by weed control. A complex issue but one that may also contribute to the decline in the area of habitat for the Golden Sun Moth. Pressures of urban development and agricultural expansion are inferred to result in a continuing decline in the area, extent and quality of habitat available for the Golden Sun Moth.

The Committee considers that the species' AOO is limited, and it is severely fragmented, and continuing decline is observed in the area, extent, and quality of habitat. Therefore, the species

has met the relevant elements of Criterion 2 to make it eligible for listing as Vulnerable. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

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 generations (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
(a) (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 population size for the Golden Sun Moth, however it likely exceeds 10 000 mature individuals.

The Threatened Species Assessment undertaken by the Victorian Government in 2020 states an inferred population size of 13 500 mature individuals for the state of Victoria. This exceeds the threshold for Criterion 3 for the species alone but only covers a portion of the taxon's distribution. Several subpopulations within the ACT have been subject to detailed survey or monitoring. These subpopulations make up only a small number of the 78 known sites covering 1803 hectares of suitable habitat with the territory (ACT Government, 2017). A summary of results regarding counts of mature individuals (primarily flying males) are presented below:

- Yarralumla Equestrian Park: 184 individuals recorded over three survey days in the 2019/2020 flying season (Umwelt 2020).

- One Tree Hill: 35 individuals recorded in over one survey day during the 2010/2011 flying season (Eco Logical Australia, 2011).
- Kinleyside: three individuals recorded over one survey day during the 2010/2011 flying season (Eco Logical Australia, 2011), and 119 recorded over three surveys days in the 2011/2012 flying season (Eco Logical Australia, 2012).
- Throsby: 51 individuals recorded over two survey days during the 2010/2011 (Eco Logical Australia, 2011).
- Mulligans Flat: 127 individuals recorded over two surveys days during the 2011/ 2012 flying season (Eco Logical Australia, 2012).
- Mulanggari Nature Reserve: 24 individuals recorded over three surveys days during the 2011/2012 flying season (David Hogg, 2012).
- West Macgregor: 2400 individuals recorded over three surveys days during the 2017/2018 survey period (SMEC 2018).

The results presented above are merely counts of observed adult Golden Sun Moths (primarily males) recorded over only a few surveys at each site. They therefore do not represent an estimated subpopulation size for these sites but can be used to gain an understanding of the density and abundance of the species at each site by comparison. Large subpopulations (containing more than 500 mature individuals) are also known to occur at the Majura training area, Canberra Airport, and Lawson Grasslands. Other less extensive populations occur in reserved areas including Dunlop Grasslands Reserve, Jarramlee Nature Reserve, Jerrabomberra Grasslands (east and west), and in the Crace and Goorooyarroo Nature Reserves (ACT Government 2017; ACT Government 2020). While the species has been recorded at 48 sites in NSW, there are no comprehensive monitoring or survey data to indicate likely population size.

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 30 percent.

The data presented above demonstrates the species is not eligible for listing under Criterion 3, as the number of mature individuals is inferred to be greater than 10 000. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

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 reasoning above under Criterion 3, it is highly unlikely that the number of mature individuals is less than 1000. Additionally, the Golden Sun Moth does not meet the quantitative threshold for Vulnerable under sub-criterion D2.

The data presented above appear to demonstrate the species is not eligible for listing under this Criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered to be tentative at this stage, as it may be changed as a result of responses to this consultation process.

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

No population viability analysis appears to have been undertaken for the Golden Sun Moth, and there is insufficient data to demonstrate if the species is eligible for listing under this Criterion. However, the purpose of this consultation document is to elicit additional information to better understand the species' status. This conclusion should therefore be considered tentative at this stage, as it may be changed as a result of responses to this consultation process.

Adequacy of survey

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

Listing and Recovery Plan Recommendations

No recovery plan is in place for the Golden Sun Moth. A draft National Recovery Plan has been produced.

A decision about whether there should be a recovery plan for this species has not yet been determined. The purpose of this consultation document is to elicit additional information to help inform this decision.

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