

Draft Revision (2009)

Draft Flora and Fauna Guarantee Action Statement No. 106

Golden Sun Moth *Synemon plana*

Description

The Golden Sun Moth (*Synemon plana*) is a small diurnal moth belonging to the family Castniidae in the insect order Lepidoptera. The Castniidae includes 30 genera with representatives in the Neo-tropical, Oriental and Australian regions, indicating a Gondwanan origin. The Australian species are represented by a single endemic genus (*Synemon*) which contains about 43 species, and in Victoria, at least five other species are considered threatened (Douglas 2003). The adults of all the species are generally dull-coloured; females have brighter hind wings.

Golden Sun Moth adults are unique among *Synemon* species for having semi-flightless females and exhibiting a high degree of sexual dimorphism. The forewings of the male are dark brown with grey scales and the hindwings are bronzy-brown and black. The underside of the male is pale grey with brown patches. The forewings of the female are brown and grey, and the hindwings are bright orange with black submarginal spots. The underside of both wings of the female is white with black submarginal spots. The male has a wingspan of about 3.4 cm whilst the female is smaller with a wingspan of about 3.1 cm. Coloured illustrations of adults may be found in Common (1990) and in Dear (1997).

Genetic studies suggests that at least five discrete groups have been identified (Clarke & O'Dwyer 2000; Clarke & Whyte 2003), of which the southern Victorian population is quite distinct and has been isolated from the NSW and ACT populations since ancient times (DEWHA 2009a).

Distribution

At the time of European settlement, the Golden Sun Moth was widespread and relatively continuous throughout its range, inhabiting grassy open-woodlands and grasslands (Edwards 1993). Historical records show that the Golden Sun Moth was found as far north as Winburndale near Bathurst and the Yass Plains in New South Wales (Edwards 1991; Venn 1993). In Victoria the Golden Sun Moth once inhabited vast areas around Bendigo, Williamstown, Mansfield, Eildon, Salisbury and Nhill. Bordertown was the only record in South Australia (CNR 1995). It also occupied large areas of the Australian Capital Territory (Edwards 1991).

At the time of writing of the original Action Statement (O'Dwyer *et al.* 2000), the moth was known from only six sites in Victoria, 10-12 sites in the ACT, and 29 sites in New South Wales (Dear 1996, Clark & O'Dwyer 1998). No populations of the Golden Sun Moth have been found recently in South Australia (Edwards 1994), and is thought to be locally extinct in that State (DEWHA 2009a).

In Victoria, there have been no widespread targeted surveys undertaken for the Golden Sun Moth across its distribution, but a range of targeted, opportunistic or pre-development surveys have been responsible for most of the recent data about the Golden Sun Moth. These have increased the number of known sites in Victoria to around 60 from the six recorded in 2000. Targeted Golden Sun Moth surveys in the Port Phillip area occurred over flight seasons 2006/07 (Gilmore 2007) and 2007/08 (Gilmore 2008) and other assessments across the expanding urban growth area of Melbourne have encountered widespread but disjunct populations (Bainbridge & North 2007; DSE 2009a; Endersby & Koehler 2006; Gilmore *et al.* 2008, Van Praagh 2004). Further to this, reports from regional areas include Golden Sun Moth populations occurring in Melton, Toolern Vale, Cressy, Meredith, Yea, Gobur, Mount Piper, Taggerty, Ararat, Smeaton, St Arnaud, Nhill, Kiata, Echuca, Carboor, and Kinypaniel Grasslands on the Northern Plains.

Over the same period, Golden Sun Moth interstate surveys have increased the number of sites in NSW to 42 (previously 29) and in the ACT to 32 (previously 12) (DEWHA 2009a).

Habitat

At the time of writing the initial Action Statement (O'Dwyer *et al.* 2000), the Golden Sun Moth was thought to only occur in native grasslands dominated by species from the genus *Austrodanthonia* (Wallaby-grasses), in particular, *Austrodanthonia carphoides*, *A. auriculata*, *A. eriantha*, and *A. setacea*, having a percentage cover of greater than 40%. Subsequent surveys and research throughout the species range have shown that it is much more widespread and occurs in native and modified grassy ecosystems, including "secondary grasslands" that have a history of pasture

improvement but since reverted to a dominance of volunteer *Austrodanthonia* species (ACT 2005; Braby & Dunsford 2005; DEWHA 2009a, DEWHA 2009b, DEC 2007; Gilmore *et al.* 2008; O'Dwyer 2003).

In recent surveys around Melbourne which did not target native grasslands specifically, Golden Sun Moths were found at 19 of 24 sites searched (Gilmore 2008). At some sites the Golden Sun Moth is occurring in weedy sites heavily invaded with the weed Chilean Needle-grass (*Nasella neesiana*).

Female moths have been seen ovipositing on the leaves (Bainbridge pers. comm.) and pupal casts located within the base of such tussocks (author pers. obs.). Initial dietary studies of Golden Sun Moth larvae have shown that they may feed on the roots of native and introduced grasses (Braby & Dunsford 2005; Richter pers. comm). Research to investigate further dietary analysis of Golden Sun Moth larvae will be undertaken in Victoria in the 2009-10 period (Richter pers. comm.).

It appears that a key aspect of Golden Sun Moth habitat is an open sward with sufficient inter-tussock spaces for females to display, and for males to fly-over and detect females. This is critical due to the very short life-span of 2–4 days to mate and breed. However a suspected 2–3 year life-cycle should provide for emergence the following year from eggs laid previously.

Life history and ecology

Little is known about the reproductive life cycle of the Golden Sun Moth, although it is likely that it takes 2–3 years, as for other Castniids (Edwards 1994), with no evidence of any new research deviating from this view (DEWHA 2009a). In general female sun moths emerge from the pupa with fully developed eggs, ready to mate. After mating, the female deposits the eggs (est. 100–150) singly between the tillers of the food plant, and the soil, where they hatch in about 21 days. Although Golden Sun Moth females can fly, they tend to lay in wait, flashing their small bright orange wings to attract the attention of patrolling males (Harwood *et al.* 1995). They do not feed as they lack functional mouthparts, and are thought to survive for between one to four days, if they can avoid predation by robber-flies and small birds hawking for insects.

It is suspected that the first instar larvae tunnels into the tillers of the plant, feeding internally on the plant tissue for about eleven months. The number of larval instars is unknown, but the underground life-cycle may extend over two years. The larvae construct short, silk-lined tunnels into the soil to feed externally on the rhizomes and roots, branching off along the rhizomes, thus developing a tunnel system. Before pupation a vertical tunnel to the soil surface is constructed, housing the pupa until emergence. After six weeks, adult moths emerge, and are active in the hottest part of sunny days between mid November and late December, depending on the aspect of the site and warmth of the season. They survive for about two days, unable to feed because they lack functional mouthparts (Edwards 1991).

A more detailed review of life history is provided in ACT (2005) and DEWHA (2009a), which outline contemporary information on the species. The ACT (2005) report provides information on population densities at certain sites in Canberra, with a crude estimate of up to 3 500 moths per hectare based on a three-year observation of population estimates.

Conservation status

National conservation status

The Golden Sun Moth has been listed as “critically endangered” under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

It is listed as “threatened” in both New South Wales and the ACT, and thought to be extinct in South Australia.

Victorian conservation status

The Golden Sun Moth has been listed as “threatened” under the *Flora and Fauna Guarantee Act (FFG) 1988*.

The Golden Sun Moth is considered “endangered” in Victoria according to DSE’s *Advisory List of Threatened Invertebrate Fauna in Victoria - 2009* (DSE in press).

The lack of widespread surveying and recent survey results indicate that the Golden Sun Moth may be more widespread than originally perceived at the time of original listing under the FFG Act (and EPBC Act). As surveys proceed, it is likely that the large number of sites around Melbourne will link up and become fewer but larger in area as the Golden Sun Moth distribution becomes known across its range. However, this view needs to be balanced with the likely loss of extensive known Golden Sun Moth habitat associated with Melbourne’s proposed urban expansion (DSE 2009a).

It is critical that any review of the species conservation status needs to be informed by detailed and widespread regional surveys across its range, using agreed survey protocols within appropriate flight seasons.

Threats

The greatest threats to the Golden Sun Moth are the loss and degradation of its grassland habitat (Lunt 1991, Hadden 1998), resulting in less than 5% of native grassland remaining in Victoria. This is primarily due agriculture and urban development, but also due to weed invasion closing inter-tussock spaces and loss of open ground space for females to display. Fragmentation is a long-term threat to extant populations due to the poor mobility of the species. Males are unlikely to travel more than a couple of hundred metres from site of emergence, and females generally have limited flight ability and this lack of mobility means that long term prospects of persistence at such sites is low if local extinctions occur.

Despite the recent findings that Golden Sun Moths have been found to occur in exotic grassland habitat, it remains apparent that open grassland with suitable habitat and food plants is essential. The ability of Golden Sun Moths to occupy areas with introduced grass species may be an artefact of the extended ten-year dry period that has limited the vigorous growth of such plants observed under previous weather patterns. In previous seasons, invasive grassy weeds crowded out native grasslands and made the areas unsuitable for Golden Sun Moth persistence over the longer term.

The Commonwealth's *Significant Impact Guidelines* for the Golden Sun Moth (DEWHA 2009b) provide the following thresholds as a guide for determining whether an action is likely to result in a significant impact:

- Loss or degradation of more than 0.5 ha from a habitat area of more than 10 ha
- Any loss or degradation from a habitat area of less than 10 ha
- Fragmentation by more than 200 metres of an existing population (for example, by buildings, fences, breaks).

<i>Standard threat</i>	<i>Source Of Threat</i>	<i>Explanation</i>
Habitat damage or loss	Invasion by environmental weeds	Weed invasion closes inter-tussock spaces and causes loss of open ground space for females to display.
Habitat damage or loss	Earthworks	The underground larval stage (1–2 years feeding on plant roots) can be easily destroyed by cultivation or ground disturbance.
Habitat damage or loss	Land use changes - other	Key areas of known Golden Sun Moth occurrence are subject to massive urban expansion which will destroy habitat.
Habitat fragmentation	Vegetation clearance	Poor mobility and site fidelity means that Golden Sun Moths are unable to avoid direct impacts nor to recolonise adjacent areas.
Inappropriate fire regimes	Fire - season or time	Burning of habitat during the critical period of adult emergence or egg-laying will destroy breeding opportunities/success.

Important populations

Note: The following locations are listed on a regional and then alphabetic basis – the order does not reflect priority.

<i>Location name</i>	<i>Land manager</i>	<i>Catchment</i>	<i>Bioregion</i>
Craigieburn Grasslands Flora and Fauna Reserve (FFR) (320 ha)	Parks Victoria (PV)	Port Phillip and Westernport	Victorian Volcanic Plain
Cooper St Grassland Nature Conservation Reserve (NCR) (40 ha)	Parks Victoria	Port Phillip and Westernport	Victorian Volcanic Plain
Derrimut Grassland Reserve (152 ha)	Parks Victoria	Port Phillip and Westernport	Victorian Volcanic Plain
Woodlands Historic Park (40 ha)	Parks Victoria	Port Phillip and Westernport	Victorian Volcanic Plain Central Victorian Uplands
Aurora Reserve (4 ha)	VicUrban	Port Phillip and Westernport	Victorian Volcanic Plain
Amberfield Reserve (2 ha)	Hume City Council	Port Phillip and Westernport	Victorian Volcanic Plain
Amaroo Woodland Craigieburn (20 ha)	private	Port Phillip and Westernport	Victorian Volcanic Plain

Highlands property Craigieburn (40 ha)	private	Port Phillip and Westernport	Victorian Volcanic Plain
Yuroke	Private landowner in cooperation with Trust for Nature (TfN)	Port Phillip and Westernport	Victorian Volcanic Plain
Altona Reserve, Kororoit Creek Road (4 ha)	Hobsons Bay Council	Port Phillip and Westernport	Victorian Volcanic Plain
Broadcast Australia Reserve	Broadcast Australia	Port Phillip and Westernport	Victorian Volcanic Plain
Port Phillip DSE – various	Undetermined (mostly private)	Port Phillip and Westernport	Victorian Volcanic Plain
Ararat private land sites: Steep Hills area	Private landowners	Glenelg-Hopkins	Victorian Volcanic Plain
Dunkeld Arboretum	Public	Glenelg-Hopkins	Central Victorian Uplands
Dunkeld South and road reserves	Private land, public roadsides	Glenelg-Hopkins	Victorian Volcanic Plain
Hamilton Community Parkland	Southern Grampians Shire Council	Glenelg-Hopkins	Victorian Volcanic Plain
Mt Piper NCR	Parks Victoria	Goulburn-Broken	Central Victorian Uplands
Taggerty	Private Landowner	Goulburn-Broken	Central Victorian Uplands
Sheoaks property, Yea.	Melbourne Water	Goulburn-Broken	Central Victorian Uplands
Carboor - private land	Private	North East	Central Victorian Uplands
Gobur (2 sites)	Private	North East	Central Victorian Uplands
Salisbury Bushland Reserve	Parks Victoria	Wimmera	Wimmera
Golden Sun Moth Reserve, Belcher St Nhill	Golden Sun Moth Reserve Committee of Management	Wimmera	Wimmera

Of the approximately 60 known sites, around half are less than 10 ha in size, and less than 10 are in conservation reserves. The two largest being the Craigieburn Grassland FFR and the Derrimut Grassland Reserve. The others are smaller conservation reserves in regional Victoria, or more predominantly, in urban areas already approved for development whereby they are often Council-managed as part of existing development offsets, often isolated within the urban area. One recent exception to this is the Melbourne Water “Sheoaks” property, of around 150 ha at Yea that has been purchased as an offset site for a number of threatened species, including the Golden Sun Moth and Striped Legless Lizard, associated with the construction of the Sugarloaf Pipeline Project.

Past management actions

<i>Action</i>	<i>Result explanation</i>
Undertake threat monitoring.	Liaison was undertaken between PV, DSE and Melbourne University on aspects of threat management. Monitoring was undertaken at Craigieburn with the assistance of the Friends of Merri Creek (FoMC) and the Merri Creek Management Committee (MCMC) in November

	2004.
Construct/maintain information boards.	An interpretation sign was constructed for the Nhill site.
Establish/maintain working group.	An informal Port Phillip Recovery Team was established in early 2002 but became inactive.
Develop or amend planning scheme overlays and schedules.	An area of Golden Sun Moth habitat was retained in a Public Open Space (POS) reserve to be managed by Hume Council. POS along Merri Creek will be included the Regional Park.
Conduct survey to confirm existing records.	Nine males and two females were recorded at Salisbury during a survey by F. Douglas on 10 Nov 2007.
Liaise with private landholders.	The fire event of 2009 affected the Taggerty location and ~5 kms of firebreaks were installed, partially through Golden Sun Moth habitat. Rehabilitation works have included mulching of debris and direct seeding of native grass in previously grassy areas. This has required lengthy negotiations with the landholder, TfN and DSE staff.
Undertake research into management requirements.	At Taggerty, a biomass control was trialled by various methods including grazing, slashing and burning. Grazing and slashing are most effective and easily managed. Done annually in spring, this maintains ideal habitat structure, although some over-grazing has occurred. This has not had an adverse effect on the Golden Sun Moth's ability to fly and lay eggs but ideally would not be done too often. A report on management techniques at the Nhill site was compiled by Clive Crouch, Manager of the Golden Sun Moth Reserve in Nhill, and the report was disseminated to key management agencies. Management of Craigieburn Grasslands FFR and Cooper Street Grassland NCR by Parks Victoria takes into account Golden Sun Moth in relation to timing of ecological burning and weed control programs.
Conduct priority research projects as specified.	A PhD on Golden Sun Moth was undertaken at Craigieburn Grasslands. DSE staff participated in the DEWHA Golden Sun Moth Research Workshop, Canberra, April 2008 to determine research priorities. Some larval monitoring was undertaken at the Altona site by A. Richter, Canberra University, as part of larval diet preference research.
Develop, provide input to or implement park, reserve or land management plan.	A Management Plan for Craigieburn Grasslands is being prepared by PV and DSE is providing input on Golden Sun Moth management requirements.
Maintain captive populations for research / display.	Attempts were made to establish a captive colony at the Zoo. Two pairs of moths were collected from Mt Piper. One female laid eggs (~100 eggs) but after two years no larvae have hatched. Plots of Golden Sun Moth habitat associated with the Sugarloaf Pipeline project have been investigated for research purposes, particularly for larval stage monitoring (A. Yen pers. comm.).
Maintain vegetation structure.	At Craigieburn MCMC undertook <i>Austrodanthonia</i> spp. establishment with a Federal Threatened Species Network Grant. Areas were fenced and weed control undertaken. Dry conditions hampered re-establishment.
Apply ecological burning.	At Hamilton Community Parklands the fenced Eastern Barred Bandicoot section of the enclosure was divided into a 3 year rotation for ecological burning purposes. Zones 1 and 3 were burnt during the 05/06 season. The golf course section of the Hamilton Community Parklands was not burnt but rather slashed, and the frequency is dependent on whether it is located in the rough or on fairways.
Conduct survey to determine abundance/extent.	At the Nhill site, regular monitoring of <i>Austrodanthonia</i> habitat was undertaken after active management by grazing and slashing. MCMC undertook annual surveys to determine Golden Sun Moth populations along pre-determined transect lines at Craigieburn Grasslands. In November and December 2008, NatureWatch ran its first season of Grasslands and

	<p>Golden Sun Moth monitoring at Derrimut Grassland. Volunteers recorded 33 Golden Sun Moths at the site.</p> <p>At Mt Piper NCR monitoring was conducted by community volunteers (Friends of Mt. Piper) with support from DSE/Melbourne University.</p>
Develop habitat monitoring protocols.	MCMC have developed a survey sheet that has been used at the Craigieburn Grasslands site.
Design survey.	<p>DSE, in conjunction with DEWHA, has developed a set of “survey protocols” for adults in the flight season. The most effective survey method is a number of repeatable site visits on suitable days during the active flight season (Gibson 2006; Gibson & New 2007). These protocols require four site visits at weekly intervals:</p> <ul style="list-style-type: none"> • Monitor populations on a minimum of four site visits on suitable days (no wind, warm/hot day, clear skies, late morning -mid afternoon period) at weekly intervals during the main flight period (i.e. November-January). • Use a transect approach at 10 m wide intervals up and down (across) the study area - this closeness helps to disturb resting males and make them more observable. • Ensure moths are active by first checking that they are active at nearby known sites e.g. Craigieburn Grassland Reserve. • Employ an experienced entomologist familiar with survey techniques for Golden Sun Moth (males fast, erratic low flying in search of females on the ground displaying golden hindwings to attract passing males). • It is often necessary to follow males to where they alight on the ground to locate females, but this takes away from survey protocols. It is preferable to have another observer solely searching for females using this approach and having dedicated observer(s) surveying for flying males as they move along each transect at walking pace. (Note that females are known to fly small distances, but this is unusual as they prefer open areas on the ground to attract males). <p>Evidence of the occurrence of Golden Sun Moths in grasslands can also be determined if the pupal castes of the emerging moths are found at the base of tussocks, but often these can be difficult to locate and can breakdown quickly in the field environment (A. Richter pers. comm.).</p> <p>The effectiveness of pupal cast surveys has been investigated on trial basis (A. Richter pers. comm.)</p>
Develop guidelines, systems procedures or design manuals.	Detailed monitoring protocols have been adopted in the Precinct Planning Biodiversity Toolkit (DSE 2009b).
Prepare/revise Recovery Plan.	A Draft National Recovery Plan is in preparation (DEC 2007)
Conduct survey to locate additional populations.	<p>Sixty new populations were discovered and information submitted to the DSE Wildlife Atlas database.</p> <p>Melbourne University conducted new surveys of grasslands and grassy woodlands in the Goulburn-Broken catchment.</p> <p>DSE undertook a community awareness/education program to survey for Golden Sun Moths in the North East and found a number of new sites following presentations and products to community groups and schools.</p> <p>Education material was developed to encourage the community to identify and report new sites in the 2008 flight period. This included input by the Threatened Species Network, MCMC, Catchment Management Authorities (CMAs) and was disseminated in natural resource management newsletters and periodicals (e.g. Zimmer 2007).</p> <p>Surveys of remnant grassland sites subject to development have found three other sites with Golden Sun Moth - Craigieburn West, Summerhill Road, Wollert and Upfield.</p>
Identify grazing management priorities and	A Grazing Management Plan was completed for Mt. Piper. Ongoing habitat monitoring is required to contribute to this plan. Habitat monitoring was conducted by Melbourne

develop detailed plan.	<p>University undergraduate students every summer.</p> <p>Grazing is being phased out at Craigieburn Grasslands on a trial basis but biomass management will be critical to maintain an open sward and prevent weed invasion.</p>
Liaise with government agencies.	<p>Ongoing liaison was undertaken between Parks Victoria, DSE and Melbourne University. Management advice was provided to PV as needed.</p> <p>Ongoing liaison was undertaken with local government regarding planning applications and requirements to survey and consider the Golden Sun Moth in planning outcomes.</p> <p>Golden Sun Moth Conservation Management Plans have been prepared, in conjunction with DEWHA and DSE, to offset losses of habitat associated with development proposals.</p>
Develop, publish and distribute educational, technical or publicity material and/or displays.	<p>A Golden Sun Moth brochure was produced by DSE, PV, Broadford Environment Action Movement (BEAM) and Melbourne Zoo. A species description and an outline of key aspects of the earlier Action Statement was put onto the SWIFFT wiki website.</p> <p>MCMC prepared and distributed a Golden Sun Moth brochure and flyer.</p>
Liaise with stakeholder groups.	<p>A "Friends of Mt Piper Group" was formed. Adjoining landholders were invited to Golden Sun Moth Biodiversity Month Activity Sept 2008. Training for community volunteers was undertaken in October 2008. Volunteers participated in a survey of Mt. Piper during the flight season.</p> <p>MCMC undertook annual Golden Sun Moth surveys at Craigieburn Grasslands with volunteers and other community groups along pre-determined transect lines.</p> <p>Staff of the DSE Alexandra office instigated public meetings and coordinated volunteer surveys for Golden Sun Moths.</p>
Establish / maintain Committee of Management.	<p>A Committee of Management was formed for the Nhill Golden Sun Moth Reserve.</p>
Manage environmental weeds.	<p>Weed control was undertaken at Mt Piper and Craigieburn Grasslands (particularly for <i>Nassella trichotoma</i> (Serrated Tussock) and <i>Nassella neesiana</i> (Chilean Needle-grass).</p> <p>Ecological burning was undertaken at Salisbury in May 2008 to help control Wild Oats (<i>Avena</i> spp.).</p>
Restore habitat.	<p>At Salisbury, 500 <i>Austrodanthonia</i> (Wallaby-grass) seedlings were planted in early July 2008. Success was only partial because of Rabbit damage, and approximately 50% of seedlings survived by Sept 2008. A native nursery has been employed to grow seedlings for planting in 2009.</p> <p>Restoration of <i>Austrodanthonia</i> habitat at Nhill was completed and is currently being managed by Golden Sun Moth Reserve Committee.</p> <p>At Craigieburn MCMC undertook <i>Austrodanthonia</i> spp. establishment with the assistance of a Federal Threatened Species Network Grant. Areas were fenced and weed control undertaken. Dry conditions have hampered re-establishment.</p>
Undertake habitat monitoring.	<p>Vegetation monitoring was conducted at Dunkeld in 2009 in association with the Striped Legless Lizard project at this site. The vegetation was found to be in very good condition following good rainfall.</p> <p>The habitat at Mt Piper was monitored by University of Melbourne students in 2008. Monitoring of <i>Austrodanthonia</i> growth was undertaken at Salisbury and Hamilton Community Parklands every year from 2005.</p>

Research

The conservation of Golden Sun Moth is hampered by (1) lack of scientific knowledge on its life history, its feeding behaviour and food preferences and (2) accurate methods to monitor populations. Consequently, the current conservation strategy is to conserve areas known to have Golden Sun Moth, but recent surveys have shown that the species occurs on a large number of locations but with population sizes ranging from very small to large. The quality of these habitats (generally open grasslands/grassy woodlands) also varies, and the apparent use of the declared Chilean Needle-grass by the Golden Sun Moth as a food plant needs further consideration.

Key research priorities are outlined in Appendix 1. The list of projects is not in any order of priority, and some overlap.

Conservation objectives

Long term objective

To ensure that the Golden Sun Moth can survive, flourish and retain its potential for evolutionary development in the wild.

Objectives of this Action Statement

- To increase the number of populations or individuals.
- To improve condition and extent of habitat.
- To secure populations or habitat from potentially incompatible land use or catastrophic loss.
- To increase knowledge of biology, ecology or management requirements.

Intended management actions

The intended management actions listed below are further elaborated in DSE's Actions for Biodiversity Conservation (ABC) system. Detailed information about the actions and locations, including priorities, is held in this system and will be provided annually to land managers and other authorities.

<i>Standard objective</i>	<i>Targets</i>	
To increase the number of populations or individuals.	<ul style="list-style-type: none"> • Significant increase in the number of known populations. 	
<i>Action</i>	<i>Details</i>	<i>Responsible agents</i>
Undertake surveys.	Undertake broader regional Golden Sun Moth surveys to identify new populations across their range.	DSE, PV, CMAs
Protect habitat.	Continue to protect, secure and reserve areas of Golden Sun Moth habitat for conservation purposes.	DSE, DEWHA, PV, local governments
Maintain captive populations for research / display.	Investigate the need for and feasibility of establishing a captive colony to study ecological requirements and gain a better understanding of its complex life cycle.	DSE, Melbourne University, Melbourne Zoo

<i>Standard objective</i>	<i>Targets</i>	
To improve condition and extent of habitat.	<ul style="list-style-type: none"> • Significant increase in the extent and condition of Golden Sun Moth habitat, based on periodic monitoring and the development of a species-specific habitat suitability index. 	
<i>Action</i>	<i>Details</i>	<i>Responsible agents</i>
Apply ecological burning.	Undertake ecological burning at sites at Craigieburn, Cooper Street and Hamilton to ensure that grassland biomass remains low and habitat structure is suitable for Golden Sun Moths.	DSE Biodiversity & Ecosystem Services (BES), DSE Statewide Services (SWS) - South West, Port Phillip
Control introduced animals.	Monitor and control rabbits at Carboor as required with assistance from DSE.	DSE SWS - North East, landholder
Identify grazing management priorities and develop detailed plan.	Monitor the cessation of grazing at Craigieburn Grasslands to ensure that grassland habitat maintains an open sward free of weeds.	DSE BES, DSE SWS, PV
Manage environmental weeds	Monitor and control weeds at Carboor, particularly pasture grasses and emerging shrubs and trees. DSE will provide assistance to the landholder if required. Encourage Dunkeld landholders to remove Cat's Ear (<i>Hypochoeris radicata</i>) and Capeweed (<i>Arctotheca</i>	DSE SWS, PV, landholder

	<p><i>calendula</i>).</p> <p>At Mt Piper undertake further removal of wattle seedlings and grazing management to control annual pasture species. Spray pasture species on the boundary of the reserve.</p> <p>Continue to monitor and control invasive exotic grass weeds (e.g. Serrated Tussock, Chilean Needle-grass) at all sites.</p> <p>Undertake follow-up weed management at Salisbury following the 2008 fire.</p>	
Restore habitat	<p>Restore the <i>Austrodanthonia</i> grasslands around the Nhill College.</p> <p>Undertake planting of <i>Austrodanthonia</i> in disturbed areas at Salisbury.</p> <p>Monitor the <i>Austrodanthonia</i> restoration site at Craigieburn Grasslands to ensure effective establishment.</p>	DSE SWS - South West, Port Phillip

<i>Standard objective</i>	<i>Targets</i>	
To secure populations or habitat from potentially incompatible land use or catastrophic loss.	<ul style="list-style-type: none"> No avoidable loss of important Golden Sun Moth populations. 	
<i>Action</i>	<i>Details</i>	<i>Responsible agents</i>
Incorporate actions to protect item into planning processes.	Contribute to the whole of government strategic assessment addressing the long-term conservation of Golden Sun Moth as part of the Urban Growth Boundary expansion and transport investigations (DSE 2009a).	DSE BES, DSE SWS - Port Phillip, Growth Areas Authority (GAA), Dept of Planning and Community Development (DPCD)
Develop, provide input to or implement park, reserve or land management plan.	<p>Develop a reserve management plan for the Mt Piper Education Reserve to fulfil the requirements of the Action Statements for Golden Sun Moth and Butterfly Community No. 1.</p> <p>For the Merri Creek Regional Park, establish Master Plans for recreational nodes and Management Plans for biodiversity that take into account Golden Sun Moth habitat requirements.</p> <p>Ensure that remnant grassland sites on adjacent private land are considered and protected in land use change proposals e.g. Barry Road protection area, south of Cooper St grasslands.</p>	DSE BES, DSE SWS – Port Phillip, PV, City of Hume
Liaise with government agencies.	<p>At Mt Piper, liaise with Parks Victoria and adjacent landholders to ensure that the land is managed to provide optimal habitat for the Golden Sun Moth.</p> <p>Propose a Biodiversity Strategic Impact Assessment approach to aid other government agencies (DEWHA, local governments, DPCD) to understand Golden Sun Moth requirements in the Melbourne area.</p>	DSE SWS - North East, DSE BES, DSE SWS - Port Phillip, South-West
Liaise with private landholders.	<p>Liaise with private landholders to promote improved site management, weed management and raise awareness with adjoining landholders.</p> <p>Liaise with landholders affected by the Urban Growth Boundary (UGB) assessment process in areas where Golden Sun Moth habitat may be affected.</p>	DSE SWS - Port Phillip, North-East, South-West
Liaise with stakeholder groups.	Liaise with stakeholder groups regarding the management of historic sites at Tallarook and Flowerdale.	DSE SWS - North East
Negotiate a Memorandum	Negotiate with Melbourne Water to establish a framework and	DSE SWS – Port

Of Understanding or appropriate management agreement for public land.	agreement to ensure the Sheoaks property is managed to maintain or enhance the Golden Sun Moth population in perpetuity.	Phillip, Melbourne Water
Negotiate voluntary acquisition or exchange of land.	Negotiate with the owners of key private land sites to determine their willingness to sell or exchange land.	DSE SWS – South-West, TfN
Prepare/revise Recovery Plan.	Liaise with the NSW Department of Environment and Climate Change (DECC) to finalise the Draft National Recovery Plan.	DECC, DSE BES, DSE SWS

<i>Standard objective</i>	<i>Targets</i>	
To increase knowledge of biology, ecology or management requirements.	<ul style="list-style-type: none"> Research and management priorities developed to assist in understanding life cycle, behaviour and key habitat requirements and direct management actions. 	
<i>Action</i>	<i>Details</i>	<i>Responsible agents</i>
Assess threats.	Undertake an initial assessment of the Carboor site for potential threats and management requirements.	DSE SWS - North East
Conduct priority research projects as specified.	Investigate the research proposals developed at the Golden Sun Moth Workshop in Canberra (DEWHA 2008): <ul style="list-style-type: none"> Translocation/reintroduction. Captive breeding. DNA diet analysis. Host plant specialisation. Habitat assessment. Genetic studies. 	DSE BES, DSE SWS
Undertake research into management requirements.	Study the ecological effects of grazing, fire, mowing and gap dynamics on all sites. Undertake research into habitat management, including biomass requirements, different methods of management (grazing/mowing/burning) and their intensity and frequency. Conduct studies to provide information on larval food plants.	DSE BES, DSE SWS University of Canberra, DSE, DPI Knox,
Conduct survey to confirm existing records.	Survey historic sites at Wannon Township, Tallarook and Flowerdale to confirm if the species still exists.	DSE SWS - North East, South West
Conduct survey to locate additional populations.	Undertake surveys for previously unknown populations in regional Victoria, including the Carboor area, Hamilton Community Parklands, Hexham, Mt Piper and Gobur. Continue to generate community education programs to involve community groups in survey activities, as undertaken by DSE SWS – North East NE in 2008-2009 flight season. Undertake additional Golden Sun Moth surveys, at both a regional and sub-regional approach, as part of the DSE Biodiversity Strategic Impact Assessment for the UGB expansion project and Golden Sun Moth assessment.	DSE SWS, DSE BES, GAA
Develop habitat monitoring protocols.	Refine techniques for monitoring extant populations. Develop a species-specific habitat suitability index.	DSE BES, DSE SWS
Undertake habitat monitoring.	Monitor the growth of <i>Austrodanthonia</i> spp. at the Nhill, Dunkeld, Hamilton Community Parkland, Hexham, Salisbury and Mt Piper sites.	DSE SWS – South West, North East
Undertake periodic surveillance monitoring of populations.	Monitor all populations during the flight period, November – December, with the assistance of community groups where possible (e.g. VNPA Naturewatch program, MCMC, Friends	DSE SWS, PV, MCMC

	groups).	
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<i>Standard objective</i>	<i>Targets</i>	
To increase community awareness and support.	<ul style="list-style-type: none"> Demonstrable increase in community awareness and support based on periodic surveys. 	
<i>Action</i>	<i>Details</i>	<i>Responsible agents</i>
Involve community groups and volunteers in recovery activities.	Continue to liaise with volunteers and community groups to raise awareness of Golden Sun Moth conservation and promote identification, reporting and protection of new locations and to assist in field surveys.	DSE SWS, PV
	Design and implement a method to assess community awareness of Golden Sun Moth.	DSE BES

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Appendix 1. Research Projects for Consideration

1. Translocation/reintroduction

To assist with habitat offsets and to increase scientific knowledge, Golden Sun Moths from areas targeted for development could be translocated to safe sites, such as the area established at Victoria's Open Range Zoo (which is also an educational facility). It is probable that larvae only reside in the first 10-15 cm of soil which will need to be dug up and translocated to a new site. Trials will need to be undertaken to investigate the long-term feasibility of the technique. Further work on the genetics of the Golden Sun Moth would be required before attempting translocation beyond the local vicinity.

Results from current trials on the Sugarloaf Pipeline project, of topsoil slab removal, followed by replacement and tussock removal, followed by reinstatement, may provide information on the likelihood of success of translocations

2. Captive breeding

The aim of this project is to raise the Golden Sun Moth through a full generation to determine the length of its life cycle and to enable the investigation of various stages of the moth's development. The larvae will be raised on different types of grasses: the native Wallaby Grass (*Austrodanthonia* spp), Kangaroo grass (*Themeda triandra*) and the introduced Chilean Needle-grass (*Nassella neesiana*). It is proposed to study the life cycle of these moths over a two year period, following an initial 6 month trial period to test the feasibility of the project.

3. DNA diet analysis

It is assumed that all stages of Golden Sun Moth development (egg, larvae, and adult) are reliant on native grass species and require in particular the occurrence of *Austrodanthonia carphoides* (Wallaby-grass) for its survival. A major threat to native grasslands is the invasion of exotic species such as Chilean Needle-grass, a weed of national significance. It is thought that Golden Sun Moth larvae feed restrictively on *Austrodanthonia* grass species based on observations of pupal casts near Wallaby grasses. However, recent observations have revealed that Golden Sun Moth adults occur in high abundances in Chilean Needle-grass infested areas. This has led to the conclusion that larvae possibly feed also on root systems of Chilean Needle-grass and are not grassland specialist as currently assumed.

The aim is to determine the diet of Golden Sun Moth to test the hypothesis that Chilean Needle-grass is not restrictively feeding on native Wallaby-grasses and utilizes a broad range of grass species, including Chilean Needle-grass.

This proposed study will identify the diet of Golden Sun Moth larvae by applying these molecular techniques in larvae to achieve a comprehensive picture on the dietary choice of Golden Sun Moths that will improve our strategies managing native grasslands and invertebrate species in future.

4. Host plant specialisation in Golden Sun Moth: how biochemically similar is Chilean Needle-grass to Wallaby-grass?

Insect host- plant utilisation is one of the most intensively studied types of species interaction and two general patterns have emerged from insect host-plant studies: a strong predominance of specialists over generalists and a strong taxonomic conservatism in host plant utilisation.

Analysis of the Golden Sun Moth will aim to detect the unique metabolites to determine which plant the Golden Sun Moth has fed on in the field.

5. Habitat assessment

A habitat survey was undertaken on 14 sites (3 in Victoria), in 1997 (C. Dear, MSc thesis University of Melbourne). However, since this initial survey a number of new sites (~65) have been identified varying in density and composition of native grasses. An updated field survey, a complete floristic and soil survey, including these new sites would provide a better understanding of habitat requirements such as plant species diversity and abundance across their entire known distribution, and hence potential distribution.

6. Genetic Studies

Further studies to investigate the extent of taxonomic differentiation across the species range is desirable. The current understanding that the Victorian population may be a discrete entity is evidence enough to warrant more detailed investigations, particularly given the small sample size used.