Australian Government

Department of the Environment, Water, Heritage and the Arts

Background Paper to EPBC Act Policy Statement 3.12 – Nationally Threatened Species and Ecological Communities

Significant Impact Guidelines for the Critically Endangered Golden Sun Moth (*Synemon plana*)

Department of the Environment, Water, Heritage and the Arts

2009

Contents

Introduction 2
Conservation status 2
About the golden sun moth 2
Description 2
Distribution and populations 3
Habitat 4
Diet 5
Breeding 6
Key threats and recovery priorities 6
Loss and degradation of habitat 6
Small, isolated and fragmented populations 6
Frequent and/or intense fire 7
Predation 7
Recovery priorities 7
Significant impact assessment 8
Significant impact thresholds 8
Mitigation measures 10
Translocation 12
Survey guidelines 12
Survey guidelines for detecting the golden sun moth 13
References 16

Introduction

This paper provides background to *EPBC Act Policy Statement 3.12 – Significant Impact Guidelines for the Critically Endangered Golden Sun Moth (*Synemon plana*)*, hereafter referred to as the policy statement. This background paper provides the biological and ecological context for the habitat areas, significant impact thresholds, and mitigation measures defined for the golden sun moth in the policy statement. The information provided in this paper has been prepared based on the best available scientific information in consultation with a wide range of experts. Increases in knowledge will be accounted for in future policy revisions.

Conservation status

The golden sun moth is listed as critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The species is also listed as a threatened taxon under the Victorian *Flora and Fauna Guarantee Act 1988*, and as endangered under the Australian Capital Territory *Nature Conservation Act 1980* and the New South Wales *Threatened Species Conservation Act 1995*.

About the golden sun moth

Description

The golden sun moth is a medium-sized, day-flying moth with green eyes and clubbed antennae (Clarke & Spier-Ashcroft 2003). Adult female golden sun moths have a wingspan of about 3.1 cm, and a long tapered abdomen. The upper-side of the female's forewing is dark grey with paler grey patterning, while the hindwing is bright orange with black spots along the edges (figure 1a). The under-side of both wings is white with small black spots along the margins. Adult males are larger than females (wingspan of 3.4 cm), and have dark brown upper forewings with patterns of pale grey scales (figure 1b). Their hindwings are bronze/brown with dark brown blotches. The underside of male wings is pale grey with dark brown spots (Edwards 1991).

Figure 1: far left Female golden sun moth, upperside (A. Richter); **near left** Male golden sun moth, upperside (R. Zollinger).

Distribution and populations

Historic distribution

At the time of European settlement the golden sun moth had a wide and probably continuous distribution in native temperate grasslands and open grassy woodlands, occurring wherever there were high densities of wallaby grasses (Edwards 1993). In New South Wales (NSW) golden sun moths occurred from Winburndale, near Bathurst, on the Yass Plains, and south through large areas of the Australian Capital Territory (ACT). In Victoria, they were recorded across vast areas around Bendigo, Williamstown, Mansfield, Eildon, Salisbury and Nhill, to Bordertown in South Australia (DSE 2004). Today however, less than one per cent of the approximately two million hectares of native temperate grasslands remain, and weeds have invaded much of this. As a result, golden sun moth populations are greatly reduced and highly fragmented (Braby & Dunford 2006; Clarke & O'Dwyer 2000).

Current distribution

The golden sun moth is known from 125 sites (post-1990) across its range. Forty-five sites are known to occur in Victoria, 48 sites occur in NSW and 32 sites occur in the ACT (ACT Government 2005; Braby & Dunford 2006; Clarke & Whyte 2003; DEC 2007; Biosis Research 2008). No extant populations are known to exist in South Australia and the species is thought to be locally extinct (Edwards 1994).

The majority of known sites are smaller than five hectares in area, and most of the NSW/ACT sites lie within a narrow band 100 km long x 30 km wide (Clarke & Whyte 2003). While increased survey effort has uncovered new sites (e.g. 39 sites in Victoria since 2003), most of these are not secure and are under threat from rapidly expanding urban and industrial areas (Van Praagh 2004; Gilmore et al. 2008). For example, a series of surveys for the golden sun moth in the Melbourne area during the 2006/2007 flying season noted that the largest populations occurred on private land (7/12 sites) (Gilmore et al. 2008). Because of their highly fragmented distribution and limited dispersal ability, all populations of this critically endangered moth are considered to be important for the long-term survival and recovery of the species.

Two maps have been produced to accompany this background paper. Map 1 shows the known and predicted distribution of the golden sun moth in the ACT and surrounds. Note that southern NSW has not been mapped as survey effort in this region is insufficient. This region will be progressively mapped as more information becomes available. Map 2 depicts the known and predicted distribution of the golden sun moth in Victoria.

Populations

Genetic studies suggest that the Victorian populations have been isolated from the NSW and ACT populations since ancient times, and that the northern (NSW/ACT) and southern (Victoria) populations represent discrete evolutionary units (Clarke & O'Dwyer 2000; Clarke & Whyte 2003). Samples taken from four Victorian sites (only six were known at the time of study) suggest that the southern populations cluster into a single genetic group. In contrast, four discrete genetic groups were identified within the northern populations:

Group 1: Two NSW populations (Grace's Flat and Washpen Creek).

Group 2: 15 populations in the general area between Yass and Boorowa.

Group 3: Six populations in the zone centred on the Murrumbateman.

Group 4: 16 populations primarily occurring in the ACT and immediate environs.

The genetic studies suggest that significant genetic variation exists across the range of the golden sun moth. In particular, the northern and southern populations should be treated separately in management terms, with efforts made to conserve the unique genetic composition of each unit. Attention should also be paid to maintaining the genetic characteristics within each of the four northern genetic groups.

At a local level, observations of colonies in the Craigieburn/Epping area suggests that at least two discrete populations may exist. The populations emerge and fly in alternate years, with one being substantially more numerous than the other. This means that single year surveys may fail to accurately assess the number of Golden Sun Moth inhabiting a site, or that sites showing no moths one year may support a large flying population the next. This is consistent with the life cycle of the species, with larvae thought to remain underground for two or more years, creating cohorts that emerge and breed together (Endersby & Koehler 2006).

Habitat

Potential habitat for the golden sun moth includes all areas which have, or once had, native grasslands or grassy woodlands (including derived grasslands) across the historical range of the species. The golden sun moth is also known to inhabit degraded grasslands, including those dominated by the exotic chilean needlegrass (*Nassella neesiana*), a weed of national significance.

The golden sun moth occurs in two threatened ecological communities listed under the EPBC Act - the 'Natural Temperate Grassland of the Victorian Volcanic Plain' (see *EPBC Act Policy Statement 3.8*) and the 'Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory'.

Host plants

The 'typical' plant assemblage present at golden sun moth habitat is extremely difficult to define, especially in light of the recent discovery of the species at many sites previously considered 'unsuitable'. The golden sun moth has shown a preference for *Austrodanthonia* species, such as short wallaby grass (*A. carphoides*), bristly wallaby grass (*A. setacea*), hill wallaby grass (*A. eriantha*), lobed wallaby grass (*A. auriculata*) and clustered wallaby grass (*A. racemosa*). However, previous definitions of 40 per cent *Austrodanthonia* cover (O'Dwyer & Atwill 1999) are no longer considered accurate (Braby & Dunford 2006; Gilmore et al. 2008). The species has been found flying and presumably breeding grasslands dominated by native redleg grass (*Bothriochloa macra*), speargrasses (*Austrostipa* spp.), weeping grass (*Microlaena stipoides*), kangaroo grass (*Themeda triandra*) and in degraded and weed infested patches dominated by the exotic chilean needlegrass

(Braby & Dunford 2006; Endersby & Koehler 2006; Gibson 2006; Gilmore et al. 2008). In the case of the introduced chilean needlegrass, it has been suggested that golden sun moth larvae have been able to supplement or even switch their diet to this exotic host. Chilean needlegrass is distantly related to the Australian native grasses (*Austrostipa* spp.) and was introduced to Australia from South and Central America. Braby and Dunford (2006) stress that such a switch in diet does not necessarily imply that the Golden Sun Moth is dependent on chilean needlegrass, nor that it has adapted to a range of other introduced grasses, many of which are weeds in the Australian landscape. Dietary studies are needed to confirm the use of different plant species as a foraging, and therefore breeding, resource.

Site features

While a number of flat sites are known, it appears that golden sun moths prefer slightly sloping sites (at 3° or less), particularly those with a northerly aspect (DEC 2007). Shading is generally very minimal at golden sun moth sites, and increases in shading (e.g. from buildings or tree planting) can negatively affect the temperature, moisture and plant characteristics of a site.

The grassland habitats of the golden sun moth are predominantly found in soils low in phosphorus, and are characterised by grass tussocks separated by areas of bare ground (inter-tussock space) (DEC 2007; O'Dwyer & Attiwill 2000). Inter-tussock space is thought to be important in helping males locate displaying females (Gibson 2006). At one site containing both closed and open grassland in close proximity, dense swards of grasses appeared to be actively avoided. Male moths showed a preference for relatively open areas with reduced biomass (Gilmore et al. 2008). It is likely that two ACT populations have become extinct as a result of degradation of grassland quality, including build-up of biomass (DEC 2007).

Site history

The site history can be extremely important in determining the suitability of a site for the golden sun moth. While ploughed or cropped sites are unlikely to support the species, there is considerable potential for populations to occur on private lands and sites with a low intensity grazing history (DEC 2007). Limited grazing can be beneficial to maintaining the species diversity on grasslands, but at high intensities can be extremely destructive. A number of golden sun moth populations occur in paddocks alongside sheep and cattle agistment. For the most part, these sites have not undergone extensive pasture improvement or fertiliser usage and retain areas of primary native grass cover. Suitable sites can often be found in the corners of paddocks or areas along fence lines and gateways.

Diet

golden sun moth larvae spend two to three years under ground feeding on the roots of native perennial grasses including wallaby grass (*Austrodanthonia* spp.), speargrass (*Austrostipa* spp.), and *Bothriochloa* (Edwards 1994). The belief that the golden sun moth larvae feed on these grasses is based on the presence of cast pupa shells and tunnels leading up to nearby tussocks. It has recently been discovered that golden sun moth larvae may also feed on introduced grass species, with cast pupa shells found protruding from introduced chilean needlegrass tussocks. This discovery suggests that in

some circumstances the species may feed on exotic grasses (Braby & Dunford 2006; A. Richter 2008, *pers. comm.*).

Breeding

Adult moths emerge from underground during the breeding season, between mid October and early January, depending on climate and location. They are active only during the hottest part of hot, sunny, and relatively still days. Adult emergence occurs continuously across the breeding season, although the distribution and abundance of emerging adults varies with the microclimate and microhabitat features of the site (DEC 2007). Adult moths lack functional mouthparts, are unable to feed and live for only one to four days (O'Dwyer & Attiwill 2000).

Adult males spend their time patrolling the grassy patches in search of displaying females, who flash their brightly coloured hindwings to attract the males. Once mated, the females lay their eggs (oviposit) between the tillers of a tussock or between tillers and the soil (Gibson 2006). Females are estimated to lay between 100 and 150 eggs (Edwards 1994). Females are reluctant to fly, and most likely walk between tussocks during display and egg laying. In contrast, adult males are capable of active and prolonged flights, although it is estimated that they will not travel more than 100m away from suitable habitat patches (Clarke & O'Dwyer 2000).

Key threats and recovery priorities

Loss and degradation of habitat

The native grasslands and grassy woodlands habitat of the golden sun moth are the most threatened of all vegetation types in Australia, with more than 99.5% estimated to have been grossly altered or destroyed (Kirkpatrick et al. 1995; Lunt 1991). The integrity of the remaining native grasslands has been further compromised by vigorous introduced pasture grasses and clovers, which out-compete the native *Austrodanthonia* and *Austrostipa* species, as well as changes in vegetation due to ploughing, weed invasion, tree planting, pesticide use, altered fire, grazing and hydrological regimes, and urbanisation. These areas are under further threat from fertiliser application, which increases soil concentrations of phosphorous to the detriment of native grasses (DSE 2004; Lunt 1991; TSSC 2002).

Small, isolated and fragmented populations

Whilst the golden sun moth is locally abundant at many small patches, most of these sites are in public areas such as cemeteries, along railway lines, roadside verges and on private property where weed invasion and further disturbance threaten the integrity of the habitat. These small remnants are also vulnerable to fire and other stochastic events.

The isolation and fragmentation of populations also impedes the ability of the relatively immobile females to recolonise areas, thereby reducing the likelihood of genetic exchange, and increasing the rate of inbreeding. Inbreeding may lead to the accumulation and expression of deleterious genes and eventually lead to population collapse (DSE 2004). Females rarely fly and tend to walk from tussock to tussock to lay eggs. Even the relatively mobile males will not fly more than 100 m away from suitable habitat. Populations

separated by distances greater than 200 m can therefore be considered effectively isolated, and sites from which the species has gone extinct are unlikely to be naturally recolonised (Clarke & O'Dwyer 2000).

Frequent and/or intense fire

The effects of fire on the species have been largely unstudied (ACT Government 1998). However, based on observations at the Nhill Sun Moth Reserve, it appears that the moth can withstand its habitat being burnt under particular circumstances (Douglas 2004). It seems likely that the effects of infrequent wildfires are not catastrophic and can be withstood (E. Edwards pers. comm. cited in ACT Government 1998). Controlled burning needs to be carefully planned and conducted outside of the pupation (September – November) and flight period (October – January) (Biosis Research 2008). Controlled and well planned fires may help control biomass and reduce the seed residue of introduced grasses (Douglas 2004).

Predation

At some sites predation by birds and predatory insects may be a significant contributor to adult golden sun moth mortality. At a NSW site (Rye Park) for example, 11 adult males were taken within a single half-hour period. Predatory birds include the willie wagtail (*Rhipidura leucophyrs*), starling (*Sturnus vulgaris*), welcome swallow (*Hirundo neoxena*) and magpie lark (*Grallina cyanoleuca*). Predatory insects include the robber fly (Asilidae) (Clarke & O'Dwyer 2000).

Recovery priorities

A national recovery plan for the golden sun moth is currently in preparation by the NSW Department of Environment and Climate Change. Until this plan becomes available, the following research priorities are provided to support the recovery of the golden sun moth. In addition, the NSW Department of Conservation and Climate Change (DECC) threatened species website outlines priority actions to help the golden sun moth recover (DECC 2005).

<u>Research priorities:</u>

- Investigate the effects of chilean needlegrass on golden sun moth (e.g. breeding, feeding and habitat).
- Increase understanding of the basic biology, life history and habitat requirements of the species (e.g. generation time, mating system, minimum patch size, larval diet breadth and food plant preferences etc).
- Conduct surveys to increase the knowledge of the distribution of the species, especially in Victoria and on private lands in NSW.
- Investigate the impacts of disturbances such as fire, grazing, herbicides, pesticides, and drought on the species.
- Investigate the genetic relationships between populations of golden sun moth to assist in determining high priority areas of unique genetic diversity.

Significant impact assessment

The potential for a significant impact on a listed threatened species will depend on:

- the intensity, duration, magnitude and geographic extent of the impact
- the sensitivity, value and quality of the environment on and around the site
- the cumulative effect of on-site, off-site, direct and indirect impacts, and
- the presence of this and other matters of national environmental significance.

Having considered the threats to the Golden Sun Moth and its habitats in Australia, and in consultation with species experts, the Department of the Environment, Water, Heritage and the Arts is of the view that the following actions may constitute a significant impact on the species. Where there is a possibility of a significant impact on a matter of national environmental significance, a referral under the EPBC Act should be considered.

Significant impact guidelines

Ecological element affected	**Impact threshold**	**Comment**
Large or contiguous habitat area (>10 ha)	Habitat loss, degradation or fragmentation >0.5 ha	Habitat is a similar or connected area within which the golden sun moth is found during surveys or known from records. The function of the area may include, but is not limited to: feeding, breeding, dispersal.
Small or fragmented habitat area (<10 ha)	Any habitat loss, degradation or fragmentation	Small areas of habitat are more likely to suffer significant impacts from loss, degradation and fragmentation than larger areas. The limited dispersal ability of the golden sun moth means habitat areas separated by >200 m are effectively isolated and should be considered as separate habitat areas. Extremely small, isolated and degraded habitat patches (e.g. <0.25 ha) may support populations of golden sun moth but are unlikely to contribute to the overall ecological health of the species.
Habitat connectivity	Fragmentation of a population through the introduction of a barrier to dispersal	Barriers to dispersal could include: breaks in habitat of >200 m; structures that prohibit movement (e.g. buildings, solid fences).

Note: The elements and thresholds in the table above give guidance to the level of impact that is likely to be significant for the species at a site. They are not intended to be exhaustive or prescriptive, but rather to highlight the need to maintain the ecological function of the habitat area.

The amount of habitat can, and often will, extend beyond the boundary of a site. The same is true for populations. If the amount of golden sun moth habitat adjoining the site of the action cannot be determined, the area of habitat will be considered to be the same as that identified within the site.

The thresholds outlined above were developed in consultation with experts to provide guidance in determining which actions may have a significant impact on the golden sun moth. However, decisions on significance will always need to be made on a case by case basis with consideration for the context of the action.

The significant impact thresholds take into account the highly fragmented nature of much of the golden sun moth's habitat. Small areas of isolated habitat are more likely to suffer significant impacts from loss, degradation and fragmentation than larger areas. However, the conservation outcome associated with retaining a patch of habitat will be determined by the size of the patch, its quality, extent of isolation and other factors such as its history. Extremely small (e.g. <0.25 ha), isolated and degraded habitat patches may not effectively contribute to the ecological health and conservation goals for this species.

Loss includes, but is not limited to:

- Clearing and removal of native temperate grassland or open grassy woodland.

Degradation includes, but is not limited to:

- Introduction of exotic weeds to a grassland or the ground layer of an open grassy woodland such that it affects the per cent cover of wallaby grass, eg. by vehicular movements through the area as part of construction works where the grass cuttings are not removed and/or the vehicle is not appropriately cleaned.
- Introduction of intensive, ongoing grazing of a site.
- Introduction of fertilisers and/or the addition of high concentrations of phosphorous to the soil. In particular, Glyphosate herbicides are not recommended for sites dominated by wallaby grass as they have been shown to have a detrimental effect on both newly sown and established wallaby grass grassland (DPI 2000; Lodge & McMillan 1994a, b).
- Changes in mowing/slashing practices in the grassland. In particular, substantial increases in the frequency of mowing/slashing, particularly during the flowering and seeding season of native grasses, may degrade habitat quality.
- Tree or shrub planting, where the introduction of trees/shrubs will reduce the density of native grasses, change the species composition, and/or encourage predatory animals to breed or forage on the site.
- Changes to the hydrology regime at a site, which will reduce the density or quality of native grasses or alter the species composition.
- Introduction of frequent or heavy traffic (stock, vehicular or human) within a grassland area such that it results in trampling, or a change in the species composition.

- Increased shading, from buildings, fences or trees that change the wind, light, moisture or temperature patterns of the habitat.
- Increased weed and fire threat from the construction of adjacent residential blocks.
- Grassland and soil degradation resulting from increased access and use of the grassland.
- Application of herbicides or pesticides which are harmful to the golden sun moth or its habitat, including spray drift from adjacent land management activities.

Fragmentation includes, but is not limited to:

- The fragmentation of a golden sun moth population into two or more populations separated by an absence of suitable habitat for a distance of 200 m or greater.
- The construction of solid barriers (such as timber-paling or sheet-metal fencing) higher than 1 m through an extant site resulting in a divided population.

Mitigation measures

Mitigation activities are generally undertaken on the site of the development to avoid or reduce impacts. Ideally, mitigation measures should be incorporated into the design of a development so that significant impacts are unlikely to occur.

Care should be taken to ensure that any mitigation and/or management actions implemented for the golden sun moth do not have a negative impact on other matters of NES present at a site. The mitigation and management proposed at a site needs to take into account the needs of all matters of NES in a project area.

The following measures may assist in minimising impacts on the Golden sun moth. They should be used with the aim of reducing the impact of an action to below the thresholds laid out in this document. Avoidance measures should be considered the priority, followed by measures to reduce the level of impact. In many cases, a combination of mitigation measures may give the highest benefit.

Avoid impacts	• Retain habitat patches known or likely to contain the golden sun moth, and manage for the species (see "Managing habitat" below). • Re-site roads or easements so as to avoid habitat disturbance • Use trenchless installation of pipelines by subterranean tunnelling at a depth of >0.5m. • Conduct temporary or discrete activities at a time when they will not have a negative impact on the golden sun moth population. e.g. mosaic management such as patch burning or staggered weed control measures designed to avoid affecting the whole population at the same time. • Avoid introducing trees or structures that could encourage predatory birds to nest and breed.

Minimise impacts	• Reduce the impact of construction works by employing an appropriate buffer around golden sun moth habitat (e.g. 100-200 m around breeding habitat), restricting vehicular movement during times of high soil moisture, and when adult moths are flying. • Design fences to: o allow the passage of golden sun moth adults, and o limit birds perching close to habitat patches, to limit predation on golden sun moths. • Maintain previous management regime, or adapt it in a temporal and spatial mosaic so that experimental and adaptive management can be applied. • Avoid shading (from buildings, landscaping or other structures) in the middle of the day (in winter between 0900 and 1500 hrs) to avoid negative effects on soil temp and moisture. • Maintain hygiene on maintenance and construction vehicles and machinery passing through golden sun moth habitat, to ensure that weeds are not spread. • Avoid landscaping that would introduce weeds or non-Indigenous plants into site.
Manage habitat	• Implement a biomass management program that aims to encourage native host plants and maintain the relatively open habitat structure preferred by the golden sun moth: o Mow or slash grass outside of the local flying season for the golden sun moth. The appropriate cutting height will depend on the grassland structure and species composition. A 6-8 cm cutting height is employed successfully at the Nhill Sun Moth Reserve in western Victoria (Douglas 2004), while a greater than 10 cm height is reported to be appropriate for ACT grasslands (Cooper 2009). Equipment must be properly cleaned and grass cuttings removed to prevent the transport of weeds between sites. o Avoid fires, especially during and immediately following the flying season. If necessary, late summer or autumn fire is favourable for many of the host grasses used by the golden sun moth. o Use pulse grazing, at low intensities, with grazers removed prior to the commencement of the flying season. • Control and reduce weeds in the area, taking care to avoid drift of herbicides onto native vegetation, and onto the soil crust: o Through carefully applied and targeted spot-spraying or 'wiping' o For some weed species (e.g. *Phalaris*) a combination of fire and herbicide application has proven most successful. • Where the action may lead to habitat degradation, or where degraded habitat occurs on the site, restoration

	should be undertaken through the planting of locally collected wallaby grass seedlings, weed removal and continued management (O'Dwyer & Attiwill 2000; O'Dwyer 2003). Note however, that revegetation can be both intensive and expensive. • Fence habitat on three sides to limit use as a thoroughfare. • Place pathways (if necessary) outside of the reserve and interpretive/educational signage to highlight conservation significance.

Reserve design: general principles

- Retain as large an area as possible.
- Design reserve to capture area(s) with the highest concentrations of golden sun moth, particularly females or identified breeding areas.
- Design reserve to capture areas of highest quality grassland patches, as these will require less management than degraded areas.
- Reduce edge effects by avoiding narrow designs (block shapes better than linear).
- Maintain or promote connectivity to adjacent habitat (especially connectivity with other areas of secure land).
- Include management and monitoring programs and facilities to adapt management as necessary. Maintenance of existing regime is most likely to maintain the existing diversity.
- Small areas, well managed, can still be of long term value. However, the costs associated with managing small reserves can be far greater than larger, buffered reserves.

Translocation

Translocation does not reduce the impact of an action below the significance threshold. Translocation of the golden sun moth is not considered to mitigate or offset the impact of an action, as it is unlikely to result in a positive conservation outcome for the species.

Salvage translocation may be tried as an experiment in addition to mitigating measures in circumstances where damage to the habitat of the species is unavoidable. Any translocation experiment for the species should be undertaken in association with a fully costed and funded monitoring and adaptive management strategy with clearly stated criteria for identifying success. Additional permits may be required to undertake salvage translocation.

Survey guidelines

Surveys for the golden sun moth should be conducted at any location containing habitat likely to support the golden sun moth, including sites dominated by the exotic weed chilean needlegrass. Habitat likely to support the golden sun moth includes all areas which have, or once had, native grasslands (including derived grasslands) or grassy woodlands within the historical range of the species (from far western Victoria through to southern

NSW, including the ACT). The EPBC Act Protected Matters Search Tool will provide a good starting point for determining the likelihood of having golden sun moth habitat in your area. Survey results should be lodged with the Commonwealth and relevant State or Territory authority.

Surveys should be designed to maximise the chance of detecting the golden sun moth, and should also be used to determine the context of the site within the broader landscape. In designing surveys, it is first necessary to define the purpose of the survey: identification/presence of a species, distribution, breeding etc. Consideration should also be given to the timing, effort, methods and area to be covered. The guidelines below give guidance for surveys aimed at detecting the presence of male golden sun moths at a site. Once detected, survey effort should be adjusted appropriately to determine the relative distribution of the species on the site.

The presence of golden sun moths on a site can usually not be determined until the flying season, when adult males may be observed fluttering about 1 m above the grass searching for females. At other times of the year, the larvae are hidden underground and spent pupal shells may be the only evidence of occupation at a site, although even these can be very difficult to locate.

Where it is not possible to conduct surveys in the manner recommended (methods, timing and effort), the precautionary principle should be used. In these circumstances failure to detect the golden sun moth should not be considered indicative of its absence.

Survey guidelines for detecting the golden sun moth

Aim	To detect flying males, but also to detect laying females/eggs and/or pupal shells to confirm that reproduction is taking place on the site.
Timing	During the local flying season (late October-January) • As the timing of the flight season varies annually and geographically, the best indicator of key survey period is the presence of flying males at known local reference sites. Reference sites should be monitored during the expected flying period and used to guide survey timing at the target site(s).
Effort	Over at least four suitable days. Once presence is established, surveys should focus on determining the relative distribution of the species on the site.
Conditions	• Warm to hot day (above 20°C by 1000 hrs) • warmest part the day (i.e. 1000 – 1400 hrs) • clear or mostly cloudless sky • still or relatively still wind conditions during the survey period, and • at least two days since rain.
Additional data	Surveys should also document the characteristics of the site, including: • presence of pupal casings

	• abundance of suitable host plants (e.g. *Austrodanthonia* spp.*, Austrostipa* spp. *Nassella neesiana*) • other vegetation (native and exotic) • exposure (amount of shading from trees, buildings etc.) • aspect • amount of bare ground (inter-tussock space) • presence of rocky areas • soil characteristics • site history (e.g. grazing, cropping, biomass management, fertiliser/pesticide/herbicide use), including current management regime • proximity to other known populations, including on adjacent sites, and • presence of similar habitat connecting the site to occupied areas or other areas of grassland or grassy woodland.

Timing

Throughout the cooler parts of the golden sun moth's range, the flying season can vary between early November to mid-December and late November to early January. In warmer areas, such as the Wimmera area in western Victoria, adults may first appear in late October and fly until late November (Douglas 2004). In years with a cold, wet spring, adult moths may not start flying until early December and continue through until mid to late January (DEC 2007). Because of the variability in the timing of the flying season, a known occupied reference site near the study site should be monitored to indicate the start and duration of the local flying season.

Effort

Surveys aiming to detect the presence of the golden sun moth at a site should be undertaken over at least four suitable days during the flying season of the species. The very short adult life-span and the variable timing of adult emergence means that surveys conducted only a few days apart can differ appreciably from each other. It is therefore recommended that detection surveys be staggered at least a week apart to increase the likelihood that at least some members of the population are observed (Gibson & New 2007). If detection is the aim of the survey, surveying can be stopped once the species is identified. However, information on the distribution and relative density of the species on the site, as well as indications of breeding such as the presence of pupal cases or laying females can also be important.

Conditions

Adult male golden sun moths will fly about one metre above the ground in bright sunlight during the warmest part of the day (1000 – 1400 hrs, above 20°C), and when cloud cover and wind are minimal (Clarke & O'Dwyer 2000; Gibson & New 2007). Despite their display behaviour, adult female golden sun moths prove extremely difficult to survey. Surveys should therefore target flying males, but aim to record females if they are detected. Anecdotal evidence suggests ovipositing females might be more obvious later in the day, between 1300 and 1600 hrs (T. O'Sullivan 2008, *pers. comm.*).

Additional data

Surveys for golden sun moth should be accompanied by a detailed description of the habitat present on the site, its history of management, and the context of the site in the surrounding landscape. Where surveys cannot be conducted outside of the site, other aids such as aerial photographs, historical records, and vegetation datasets can be useful in giving context to the site.

Survey methods

Both fixed point (or "spot count") and transect surveys may be useful for detecting golden sun moth.

Fixed point method

- Best suited to very small sites or sites which harbour a small population (DEC 2007).
- Observer chooses a reference point typically on the edge of the site (or area of activity) from which the whole site can be observed. Using a hand counter and stopwatch the observer records the number of moths seen in a given time period (typically three to six minutes) taking care not to record the same individual twice.
- Repeat point count as many times as necessary (e.g. three to five) with a five minute interval between counts.
- If the whole area cannot be surveyed from a single position the observer may alternate positions between successive counts (DEC 2007).

Transect method

- Most commonly used method for monitoring butterfly populations (Pollard 1997, cited in DEC 2007).
- Particularly suited to large sites with extensive populations (DEC 2007). This method has been trialled with success at a large site in the ACT (Clarke & Dunford 1999), and was the chosen method for recent surveys around Melbourne (Gilmore et al. 2008).
- Observer walks a number of transects recording all individuals seen using a hand counter and a recording device (e.g. a portable electronic note taker).
- Transects are typically marked along the long axis of the site, and should be between 5 and 100 m apart, depending on the size and topography of the site. At very large sites 200 m intervals may be needed in order to cover the whole site in a reasonable time (i.e. while moths are active).
- Observer walks for 100 m, recording the number of moths seen per 100 m, taking care not the count the same individual twice.
- On large sites multiple observers may be required starting at opposite sides of the site. Two observers walking transects 200 m apart would require about two hours to survey a 100 ha site (Clarke & Dunford 1999).

Surveys conduced using the fixed point or transect method can also be used to estimate the relative abundance of the species on a site, although this may require an increase in search effort (see Gibson & New 2007).

Other survey techniques

Area or transect surveys may also be undertaken outside the flying season to look for the pupal casings of golden sun moths. These can often be found protruding out of the soil amongst grass tussocks (Braby & Dunford 2006).

The presence of pupal casings may be used to indicate the presence of the golden sun moth, however the lack of casings does not indicate its absence from a site.

Large scale larval surveys are not considered an appropriate survey technique for determining the presence of the species on a site due to the large search effort required and the potential for damage to the soil, plants and larvae. However, where small amounts of soil are disturbed (e.g. in installing pit-fall traps for other grassland fauna) soil could be inspected for golden sun moth larvae. Larval surveys may also be incorporated into monitoring programs to assess the effectiveness of management or experimental practices (e.g. burning, experimental translocation).

References

ACT Government (1998). *Golden Sun Moth (*Synemon plana*): An endangered species*. Action Plan No. 7, Environment ACT, Canberra.

ACT Government (2005). *ACT Lowland Native Grassland Conservation Strategy*. Action Plan No. 28, Environment ACT, Canberra.

Biosis Research Pty. Ltd. (2008). *Targeted Surveys for the Golden Sun Moth in the Melbourne Area.* Final Report May 2008. Provided to the Department of the Environment and Heritage on behalf of FKP Commercial Developments Pty. Ltd.

Braby, M.F. & M. Dunford (2006). Field Observation on the Ecology of the Golden Sun Moth, *Synemon plana* Walker (Lepidoptera: Castniidae). *Australian Entomologist* 33 (2): 103-110.

Clarke, G.M. & M. Dunford (1999). Survey of the Belconnen naval transmitting station for the endangered golden sun moth *Synemon plana*. A report prepared for Wildlife Research and Monitoring. Environment ACT, Canberra.

Clarke, G.M. & C. O'Dwyer (2000). Genetic variability and population structure of the endangered golden sun moth, *Synemon plana*. *Biological Conservation* 92: 371-381.

Clarke, G. & F. Spier-Ashcroft (2003). *A Review of the Conservation Status of Selected Australian Non-Marine Invertebrates*. Environment Australia, Canberra. Available at: http://www.environment.gov.au/biodiversity/threatened/publications/action/non-marine-invertebrates/index.html

Clarke, G.M. & L.S. Whyte (2003). Phylogeography and population history of the endangered golden sun moth (*Synemon plana*) revealed by allozymes and mitochondrial DNA analysis. *Conservation Genetics* 4: 719-734.

Cooper, M. (2009). Report on ACT Lowland Native Grassland Investigation. Report prepared for the ACT Government by the Commissioner for Sustainability and the Environment. Canberra. Available at: http://www.envcomm.act.gov.au/investigations_and_consultation/investigation. Viewed 24 April 2009.

Department of Environment & Climate Change (DECC) (NSW) (2005), *Synemon plana - Priority actions* (NSW Threatened Species Priority Action Statement). Available at:

http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/pas_profile.aspx?id=10791. Viewed 03 January 2008.

Department of Environment & Conservation (DEC) (NSW) (2007). *Draft* NSW and National Recovery Plan for the Golden Sun Moth *Synemon plana.* Department of Environment and Conservation, Queanbeyan, NSW.

Department of the Environment and Water Resources (DEW) (2007). *Use of environmental offsets under the* Environment Protection and Biodiversity Conservation Act 1999 – *Draft EPBC Act Policy Statement 4.1*. Available at: http://www.environment.gov.au/epbc/publications/draft-environmental-offsets.html. Viewed 2 January 2008.

Department of Primary Industries (DPI) (NSW) (2000). *Wallaby grass – a domesticated native grass*. Available at: http://www.agric.nsw.gov.au/reader/past-varieties/p2539.htm. Viewed 16 October 2006.

Department of Sustainability & Environment (DSE) (2004). *Golden Sun Moth* Synemon plana, *Action Statement No. 106*. Department of Sustainability and Environment, East Melbourne. Available at: http://www.dse.vic.gov.au/CA256F310024B628/0/6277E110F4C5BA95CA2570ED00017CA9/$File/106+Golden+Sun+Moth+2000.pdf. Viewed 22 November 2007.

Douglas, F. (2004). A dedicated reserve for conservation of two species of *Synemon* (Lepidoptera: Castniidae) in Australia. *Journal of Insect Conservation* 8: 221-228.

Edwards, E.D. (1991). *Synemon plana* - A grassland case history. In: The ACT's Native Grasslands. Proceedings of a workshop held at the National Museum of Australia, Canberra. 17 February 1991. Page(s) 20-33. Conservation Council of South East Region and Canberra, Canbera.

Edwards, E.D. (1993). *Synemon plana* site, Belconnen Naval Station, Lawson. In: Sharp, S., Rehwinkel, R. (Eds.), *Management of Relict Lowland Grasslands*. Proceedings of a workshop and public seminar, 1993. Conservation Series 8. ACT Parks and Conservation Service, Canberra, pp. 150-152.

Edwards, E. D. (1994). Survey of lowland grassland sites in A.C.T for the Golden Sun Moth, Synemon plana. CSIRO Report to the Wildlife Research Unit. ACT Parks and Conservation Service, Canberra.

Gibson, L. (2006). Surveys of the Golden Sun Moth (Synemon plana Walker) population and ant assemblages at the Craigieburn Grassland Reserve. BSc (Hons) Thesis, La Trobe University, Bundoora, Vic.

Gibson, L. & T.R. New (2007). Problems in studying populations of the golden sun moth *Synemon plana* (Lepidoptera: Castniidae), in south eastern Australia. *Jounal of Insect Conservation* 11: 309-313.

Gilmore, D., Koehler, S., O'Dwyer, C. & W. Moore (2008). Golden Sun Moth *Synemon plana* (Lepidoptera: Castniidae): results of a broad survey of populations around Melbourne. *The Victorian Naturalist*, 125, (2):39-46.

Kirkpatrick, J.B., K. McDougall & M. Hyde (1995) *Australia's most threatened ecosystem – the southeastern lowland native grasslands*. Surrey Beatty and Sons, Chipping North, NSW.

Lodge, G.M., M.G. McMillan, A.J. Schipp, & A.S Cook (1994a). Effects of herbicides on wallaby grass (*Danthonia app.*) 1. Establishment. *Australian Journal of Experimental Agriculture*, 34, (6): 753-757.

Lodge, G.M., & M.G. McMillan (1994b). Effects of herbicides on wallaby grass (*Danthonia* spp.) 2. Established plants. *Australian Journal of Experimental Agriculture*, 34, (6): 759-764.

Lunt, I.D. (1991) Management of lowland grasslands and grassy woodlands for nature conservation: a review. *Victorian Naturalist* 108, (3): 56-66.

O'Dwyer, C. & P.M. Attiwill (1999). A comparative study of habitats of the Golden Sun Moth Synemon plana (Lepidoptera: Castniidae): implications for restoration, *Biological Conservation* 89: 131-141.

O'Dwyer, C. & P.M. Attiwill (2000). Restoration of Native Grassland as Habitat for the Golden Sun Moth (*Synemon plana*) Walker (Lepidoptera: Castniidae) at Mount Piper, Australia. *Restoration Ecology* 8, (2): 170-174.

O'Dwyer, C. (2003). Re-establishment of Grasslands for Golden Sun Moths. In Hamilton, S.D. & C. O'Dwyer (eds) (2003). Sustainability and beyond: Proceedings of the 3rd Stipa nominated conference on the management of grasses and pastures, Cooma (NSW), 26-28 November 2003, pp.214-216. University of Melbourne (Dookie Campus), Vic.

O'Sullivan, T. (2008). *Personal communication*. Biosis Research Pty. Ltd.

Richter, A. (2008). *Personal communication*. University of Canberra.

Threatened Species Scientific Committee (TSSC) (2002). *Commonwealth Listing Advice on* Synemon plana *(Golden Sun Moth)*. Available at: http://www.environment.gov.au/biodiversity/threatened/species/s-plana.html. Viewed 3 January 2008.

Van Praagh, B.D. (2004). New sightings of the Golden Sun Moth Synemon plana (Lepidoptera: Catniidae) at Craigieburn and Cooper St Grasslands, Mebourne Victoria 2003/2004, Report prepared for the Department of Sustainability and Environment (Victoria).