It's all right to have butterflies in your stomach. Just get them to fly in formation.
Dr. Rob Gilbert

Community Monitoring of Golden Sun Moths in the Australian Capital Territory Region, 2008-2009

Funded by the Threatened Species Network, a community-based program of the Australian Government and WWF-Australia

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UNIVERSITY OF CANBERRA

Threatened Species Network

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Project summary

Starting in October 2008, members of the Institute for Applied Ecology at the University of Canberra and the community group, Friends of Grasslands (FOG) successfully ran a pilot program to monitor the endangered Golden Sun Moth (*Synemon plana*) (GSM) in natural temperate and exotic grasslands in the ACT region (including nearby sites in NSW). The pilot study:

- developed, tested and reviewed procedures suitable for use by community groups for the purpose of counting flying moths and moth pupal cases and recording habitat, including vegetation and habitat quality;
- recruited and trained volunteers from the community who used the procedures to survey and collect baseline data from 28 sites across the ACT and surrounding region;
- analysed the data and summarised the results, so providing a basis for making recommendations to the managers of the grasslands surveyed; and
- raised public awareness of the GSM and natural temperate grassland conservation by involving members of the community in the survey and through presentations, posters, media releases and a web page devoted to the project.

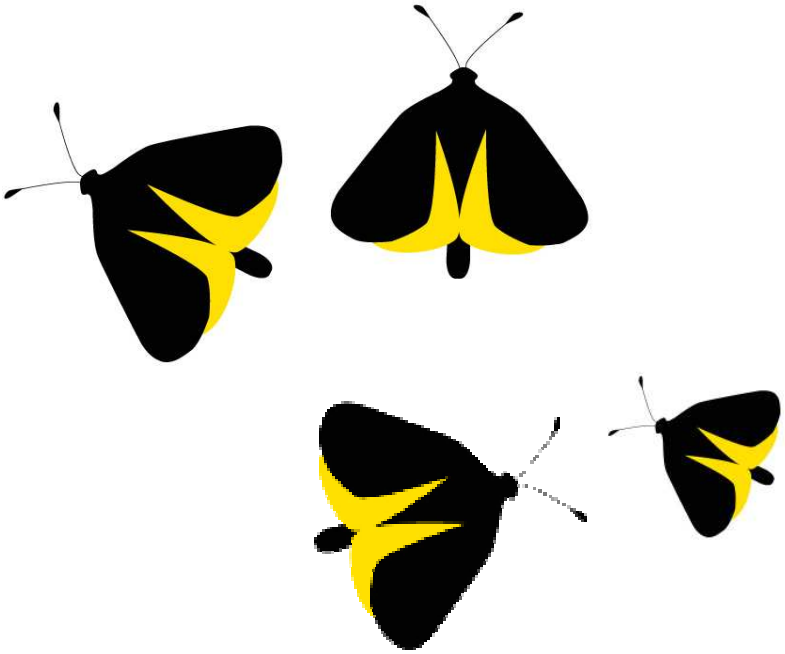
The main findings relating to the conduct of this study were that:

- recording the presence and absence of GSM is an appropriate aim for community monitoring;
- GSM adults and pupal cases can be reliably identified by the public after training and with supervision by experts;
- vegetation surveys require expert supervision and advice and cannot be achieved by community volunteers working alone;

- the greatest challenge for volunteers appeared to be matching the time they are available to conduct the surveys to the times at which the moths are flying; and
- there is widespread support by government, universities, land managers and the community for ongoing GSM monitoring. Currently, Friends of Grasslands is working with key stakeholders to develop an ongoing monitoring program.

Highlights drawn from the data relating to the moth's distribution, abundance and biology include the following points:

- Male and female moths were active until mid January 2009 which is later than expected on the basis of observations in past years and by other observers.
- GSM were found at 20 (71%) of the 28 locations surveyed. At half of the locations, they were present in low-moderate numbers. They were in high-very high abundance at six sites and absent from eight locations. Casual observations in a further six locations revealed that moths also occurred there.
- Two of the most abundant populations recorded were present at grasslands dominated by the exotic Chilean needle grass.
- GSM populations were discovered at some sites where they had not been recorded before, and conversely were absent from previously occupied sites.
- Examination of the pupal cases collected showed the sex ratio to be 60% male to 40% female, when it had been expected to be 50:50.
- A number of threats (e.g. weed invasion and lack of biomass reduction) to GSM habitats were identified and informed the recommendations suggested for the future management of individual grassland sites.



The most beautiful thing we can experience is the mysterious. It is the source of all true art and science.

Albert Einstein

Introduction

- The Golden Sun Moth – A flagship species in natural temperate grassland
- Community involvement in monitoring projects
- Project aims and objectives

Introduction

The Golden Sun Moth - A flagship species in natural temperate grassland

The endangered Golden Sun Moth (GSM) (*Synemon plana*, Castniidae) is a small diurnal moth that is one of the few Australian listed endangered insect species in south-eastern Australia (ACT Government 2005). *S. plana* is one of the most iconic moth species in natural temperate grasslands in south-eastern Australia. It is currently nationally listed as critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999*, and listed as critically endangered in New South Wales (NSW), Victoria and the Australian Capital Territory (ACT). The moth's original habitat, the natural temperate grassland in south-eastern Australia, has been reduced to less than 0.3% of its former extent due urban and agricultural development (Kirkpatrick, McDougall et al. 1995). The remaining natural temperate grassland is threatened by habitat loss, fragmentation and alteration. Consequently, natural temperate grassland is an endangered ecological community and species that inhabit it are at great risk of becoming extinct. The moth's conservation status has been acknowledged recently by WWF Australia which listed the GSM as one of the ten 'battlers of Australia'.

Community involvement in monitoring projects

Many conservation objectives can only be achieved with the help of a broader community. Information that is obtained on species, populations, communities and ecosystems from members of the community can have a wide application in interpreting trends, abundances and distribution patterns. The findings

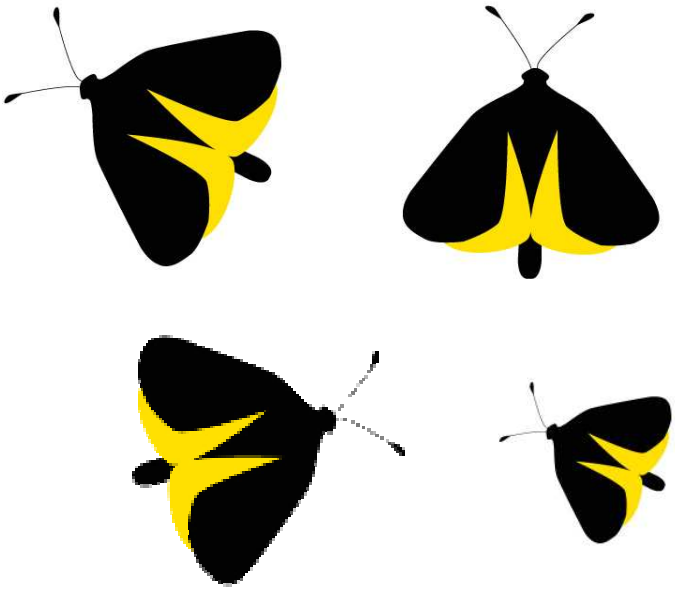
derived from volunteers' observations in conservation biology are particularly useful for elucidating necessary management actions and for recording the effectiveness of applied management strategies. However, to obtain results that are reliable, methods need to be standardised and evaluated. In addition, field training sessions that include demonstrations of the proposed methods, combined with workshops on the theoretical background, are essential for successful monitoring studies (New 2006). Collaborations between community groups and research institutions can be of great value in monitoring programs. Therefore, the coordinators of the 'Sun Moth Count' project, the Institute for Applied Ecology at the University of Canberra and Friends of Grasslands, collaborated with the members of a variety of other community groups within the ACT and NSW (e.g. Ginninderra Creek Catchment Group, Field Naturalists' Association of Canberra), with government agencies, and associates from other research institutions such as CSIRO Entomology. All volunteer participants in the Sun Moth Count were active in natural temperate grassland conservation and had a keen interest in understanding and protecting Australia's threatened insect biodiversity.

Project aims and objectives

The overall aim of this pilot study was to develop and evaluate standardised monitoring protocols for use by community groups and to trial the approach with volunteers recruited by Friends of Grasslands from their own and various other groups. The study also set out to establish a basic information guide for future GSM monitoring that could provide information on the moths as well as helping to provide guidelines for site management.

The specific objectives were:

1. to review current knowledge on the distribution and abundance of GSM populations in the ACT region and to set the current distribution into a national context;
2. to determine the most suitable and cost effective method(s) that community volunteers can use to (a) detect the presence of GSM and (b) to estimate the abundance of known GSM populations at discrete sites;
3. to floristically survey GSM habitat and assess its condition;
4. to identify current and potential threats to GSM and natural temperate grassland at monitoring sites;
5. to actively involve a variety of community groups;
6. to foster long term awareness of GSM and its conservation status, in the broader context of natural temperate grassland among the general public; and
7. to evaluate the effectiveness of the GSM monitoring program as a community capacity building program.



A Symbol of Hope

A butterfly lights beside us like a sunbeam
And for a brief moment its glory and beauty belong to our world
But then it flies again
And though we wish it could have stayed...
We feel lucky to have seen it.
Unknown

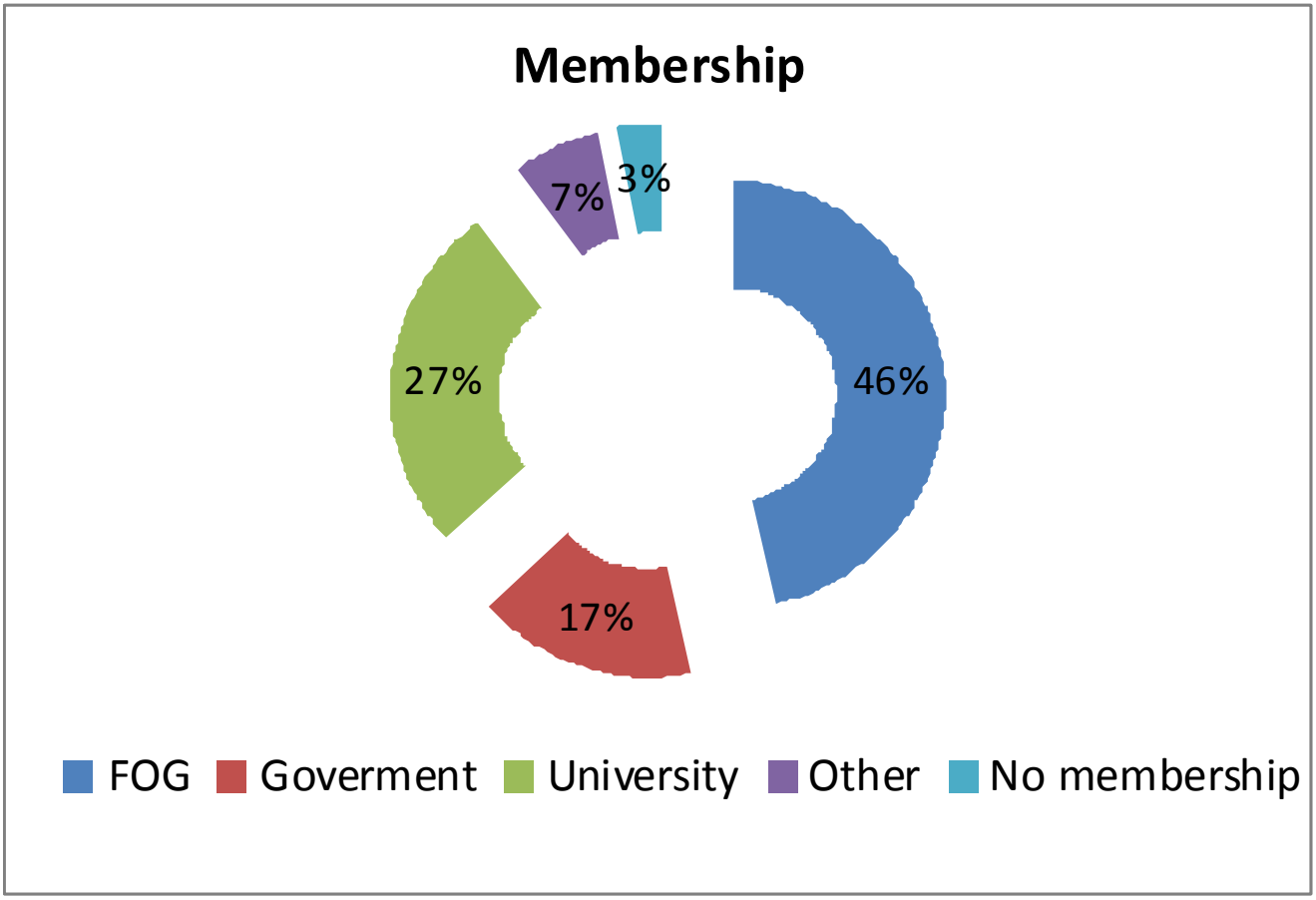
Community involvement and capacity building

Community involvement and capacity building

Participant demography and feedback

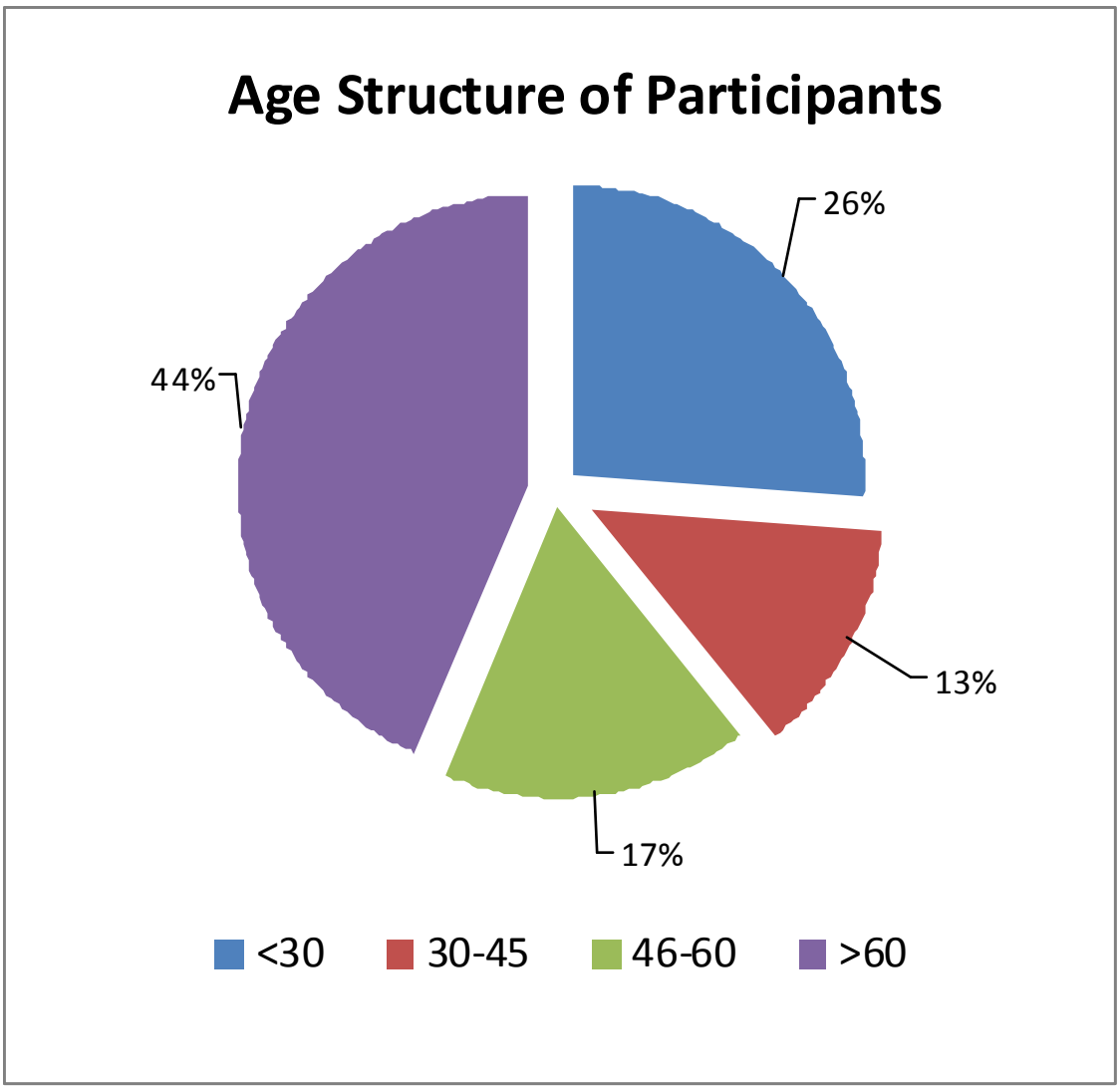
Data were gathered and analysed in a pilot, volunteer-based GSM monitoring project between September 2008 and April 2009 in the ACT and surrounding region. A total of 37 volunteers (48% males, 52% females) were actively involved in the project. More than 50 members of the community from the ACT and NSW took part in workshops, training sessions and the on-ground monitoring program. Many of them belonged to a variety of organisations and institutions such as Friends of Grasslands, the University of Canberra, the Institute for Applied Ecology at the University of Canberra, Field Naturalists Association of Canberra, Ginninderra Catchment Group, and government agencies (Figure 1).

Figure 1: Breakdown of volunteer affiliation (Friends of Grasslands - FOG), government agencies (e.g. Department for Environment, Water, Heritage and the Arts, ACT Parks, Conservation and Lands), universities (e.g. University of Canberra) and others (ornithologists, Frogwatch).



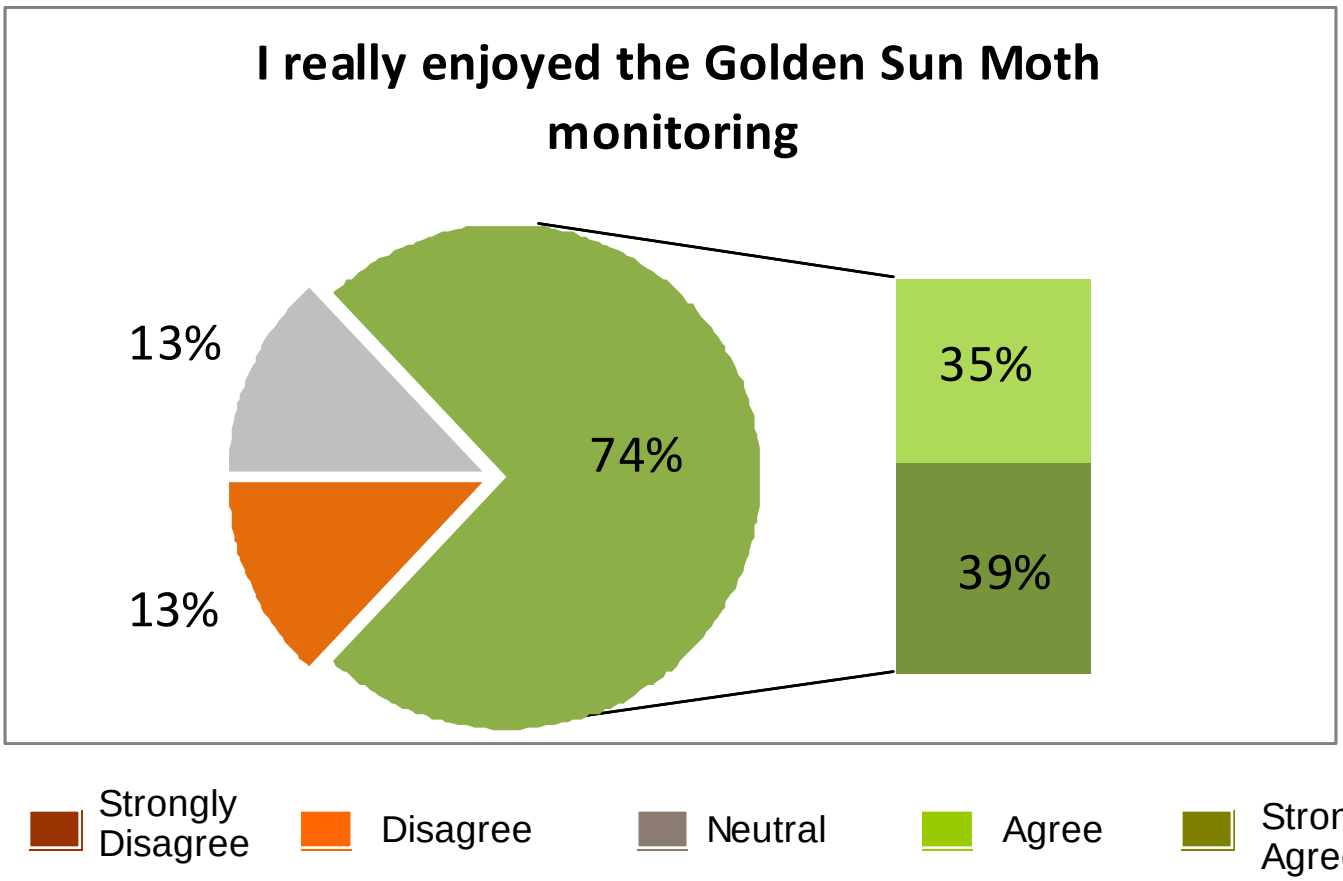
Questionnaires were sent out to all participants at the close of the project. From the 24 responses received, we are able to show that the age structure of the participants was relatively balanced, probably as a consequence of the involvement of people from a variety of community groups. The majority (44%) of participants were >60 years old, 17% were between 46-60, 13% between 30-45, and a quarter of the participants were aged under 30 (Figure 2).

Figure 2: Pie chart indicating the overall age structure of the Golden Sun Moth project participants.



About 30% of all participants had not heard of the GSM prior to our project and the overall majority (74%) really enjoyed their involvement in the project (Figure 3).

Figure 3: Volunteer ratings of their enjoyment of Golden Sun Moth monitoring.



At the beginning of the project, four workshops of more than six hours each and three field training sessions were held to introduce the participants to the program, to moth identification and to the monitoring methodology. Copies of presentations and other materials mentioned in this report are available from Friends of Grasslands. On site assistance to volunteers when monitoring was underway was available throughout the complete project. A coordinating group of two volunteers and a project coordinator allowed comprehensive communication between them and participants and a weekly update on the progress of the project. During the project, six online newsletters were produced and sent to all participants. In addition to the coordinating group, two full time volunteers visiting from Germany assisted with preparations for the workshop, field work and the preparation of the GSM web page and poster material. Each participant received a 'letter of appreciation' at the final workshop.

According to the information provided by participants, they contributed more than 500 volunteering hours during the project. In addition, a total of 480 hours were required for organisation, field assistance, analysis, report writing and other matters.

Publicity

One major aim of the project was to foster long-term awareness in the general public of the endangered GSM and its conservation status, in particular in the broader context of natural temperate grassland conservation. In order to promote the project, to recruit participants, and to sensitise a broader public about GSM and natural temperate grassland conservation, we created and launched a web page (http://aerg.canberra.edu.au/teams/osborne/moth-count/?page_id=22) that gained wide popularity due to its informative character and well-structured design. `

The web page contains information about the biology and ecology of the GSM, information about the project including guidelines, contact details and joint collaborators (WWF Australia, Friends of Grasslands and Institute for Applied Ecology at the University of Canberra). In addition, the web page was used to announce 'News and Events' and to provide access to the published GSM Newsletters.

Two posters were prepared as part of this project to inform a wider public and to encourage them to become involved in future monitoring activities. One poster was shown at the 'Snakes Alive' exhibition at the Australian National Botanic Gardens in Canberra from 15-21 January 2009. More than 4,000 people attended the exhibition and many expressed great interest in the poster. The second poster illustrates the species characteristics and highlights the potential habitats where the moths can be seen by the public. It provides an overview of the main flight activities of the moths and details of whom to contact in the case of future sightings. The poster is designed to be distributed to schools, community groups and public places prior to the next round of community monitoring.

Three press releases (one prepared by WWF Australia and two by Anett Richter and Geoff Robertson) increased public awareness about the threats to the GSM and the vulnerability of natural temperate grassland. An article (see page 17) appeared in the Sydney Sunday Herald reporting that WWF had nominated the GSM as one of the ten Aussie battlers, species that are at great risk of extinction and require urgent help to survive. One research result from the project that attracted much media interest was the finding that the moths have a biased sex ratio. The 'story' was published in the Morning Bulletin, the Daily Telegraph, the Daily Liberal, AAP Newswire and the Sunday (Canberra) Times (see page 18).

Regular updates on the project's progress and summaries of presentations were published in the Friends of Grasslands Newsletter.

Article from the Sydney Sun Herald, around 23 January 2009. We understand the same article was in the Melbourne Herald Sun on 23 January.

At the end of the line

Megan McNaught
environment reporter

THE World Wildlife Fund is commemorating Australia Day with an honours list of its own.

It has nominated 10 "Aussie Battlers" — endangered species which it says need urgent help to survive.

WWF Threatened Species Program Manager Kat Miller said 346 animal and 1249 plant species were now listed as threatened under federal law.

"Australia has the worst record of mammal extinction in the world," Ms Miller said.

WWF's top 10 Aussie Battlers are:

1. GREEN and gold frog — one of Australia's largest frogs, its home has been decimated by drought.

2. CASSOWARY — being large and flightless means road kills are one of the major causes of adult cassowary deaths.

3. GREEN sawfish — evolved from ancient sharks with a unique jaw lined with teeth made from modified scales.

4. YELLOW-FOOTED rock wallaby — the golden fur of this rock wallaby was more likely to be seen on a London street than in outback Australia.

5. RED-TAILED black cockatoo — their nesting hollows are scarce and these endangered birds are left out in the cold.

6. YELLOW-SNOUTED gecko — living in Kakadu National Park doesn't protect from fire and weeds.

7. SWIFT parrot — this parrot has a habit of not looking where it's flying and many are killed due to collisions with cars and home windows.

8. GOLDEN sun moth — this threatened insect has a very short lifespan, living just a few days as an adult.

9. WOOLLY wattle — closely related to Australia's national flower, the golden wattle, and is seen only in a small patch in southwest Australia.

10. BRIDLED nailtail wallaby — named for its horn shaped "nail" at the tip of the tail, this wallaby was once common through eastern Australia. It was believed to be extinct before being rediscovered in 1973 in Queensland.

Article from the Sunday (Canberra) Times, 13 March 2009 by Kate Leigh.

Moth's a puzzling case

HOW THE golden sun moth survives is an astonishing feat.

The critically endangered moth lives for just two or three days after breaking free of its cocoon. In its small window of existence, the purpose of the moth is to mate and keep the population alive. The moth has no mouth or gut and it will eventually die of starvation. Rather than waste time feeding, it lays as many eggs as possible.

Now a University of Canberra entomologist has uncovered a phenomenon that casts doubt on the future of the golden sun moth.

Anett Richter, with the help of 40 Friends of Grasslands volunteers across Canberra, has discovered there are more male moths than females.

"Based on our analysis, it's estimated that the sex ratio is 60 per cent males to 40 per cent females," Ms Richter said.

"In theory it should be approximately one to one ... We don't know why at the moment."

Male moths are relatively easy to identify during flight. Their wings are dull brown compared with the bright orange underwings of the female moths.

But pupal cases can reflect a much more accurate number of males and females as the environment does not have the same influence on them.

"This little moth has a great personality," says Anett Richter. Photo: KATE LEITH

Unlike the female pupal cases, the male ones have two tiny bumps at the base, discernible only under a microscope. Ms Richter examined more than 500 pupal cases.

The moth larvae can live for up to two years in the soil before cocooning themselves in these pupal casings.

Ms Richter said temperature changes, pressure for food or high predation rate in the soil might influence the moth's sex ratio.

The golden sun moth is found in various sites across Canberra, including York Park in State Circle and the native grasslands at Majura. The moth was once common and widespread throughout south-east Australia, but it has become one of Australia's most endangered insects.

This year, WWF Australia listed the moth in its top 10 Aussie battlers list of endangered species that needed urgent funds to survive.

"This little moth has a great personality," Ms Richter said.

"I have always wondered how the moths can survive in this climatically extreme ecosystem."

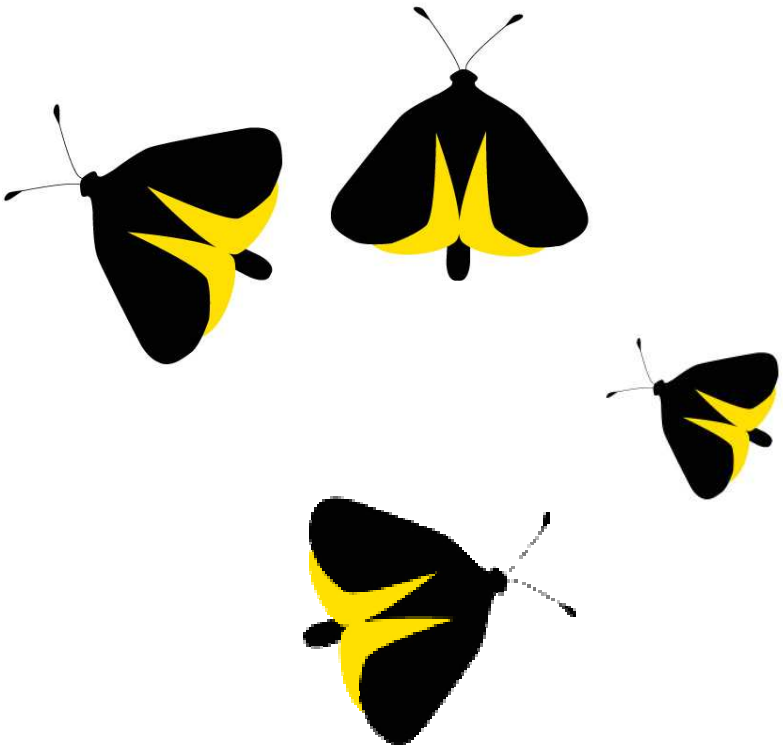
Moths fly during the hottest part of the day between late October and mid-January.

Ms Richter said she had worked in the moths' native temperate grassland habitats during their flying time and it could become extremely hot.

"The moths don't mind it – they need the high temperatures," she said.

"If you look at the dry hard soil and the pupal cases, then you wonder how a little moth can emerge out of this soil that must feel like a rock. The moths can do it easily."

She said more research was needed to shed more light on the moths' biology and ecology to secure their survival.



For a community to be whole and healthy, it must be based on people's love and concern for each other.

Millard Fuller

Project methodology

- The Golden Sun Moth monitoring scheme
- Counting moths and pupal cases
- Vegetation survey and habitat quality assessment

Project methodology

The Golden Sun Moth monitoring scheme

We encouraged each participant to become a monitoring coordinator for a grassland site that was either provided by the project coordinators or selected by the participants themselves.

For each monitoring site we provided a digital map with the location of 12 randomly selected $1m^2$ survey plots. Each plot was surveyed four times before the survey was considered to be finished.

Counting moths and pupal cases

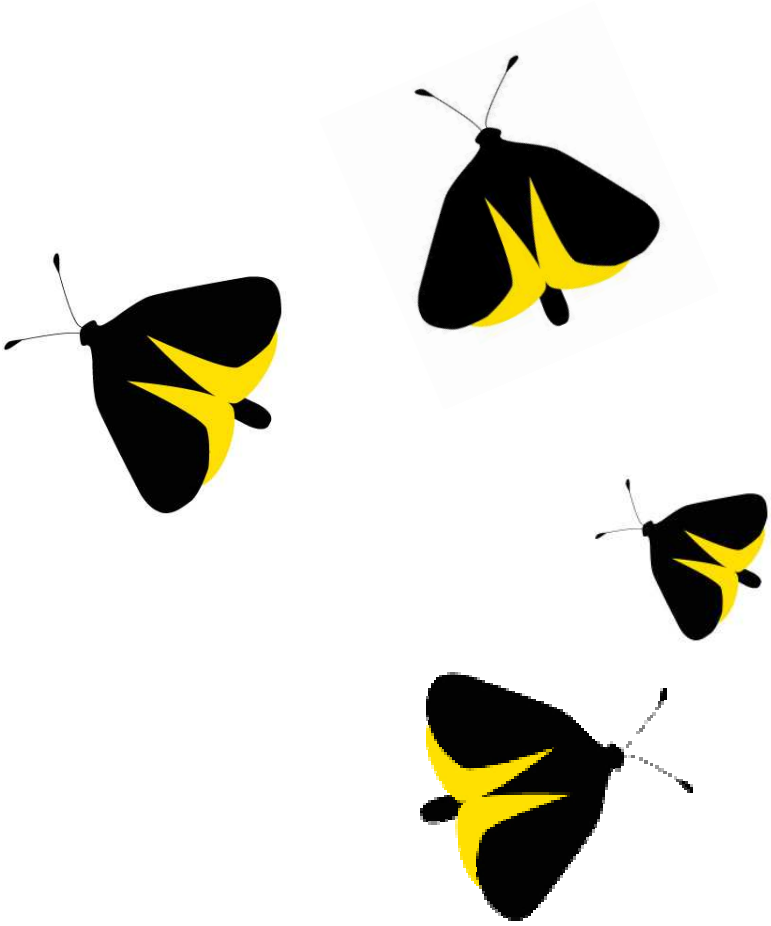
We asked participants to count empty GSM pupal cases in the 12 survey plots and to record their exact location within the plot. Participants then collected the cases in specimen jars for later measurement and sex determination. At the same time, circular plot counts of flying adult moths were made over 30 seconds within a radius of 15 metres of each $1m^2$ plot. All information obtained in the field was recorded on the data sheets provided.

Vegetation survey and habitat quality assessment

As the presence of native grass species such as wallaby (*Austrodanthonia* spp.) and spear (*Austrostipa* spp.) grasses are assumed to be the main food source for GSM larvae, we encouraged participants to record floristic data at all 12 plots. The data recorded included a list of grass and forb species present,

the percentage of the plot that comprised bare ground, and the abundance and basal cover of dominant plant species.

In order to evaluate the current conservation status and quality of natural temperate grasslands that are considered as the main habitat for GSM, a habitat quality assessment recording sheet was provided. The form included questions about current biomass reduction, weed invasion, indicators of intense grazing activity, and other observations made at the time of the surveys.



Project results

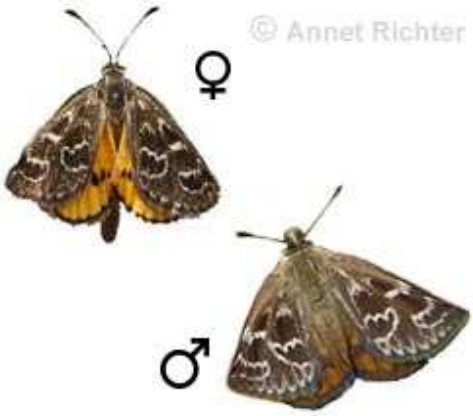
- Current distribution of the Golden Sun Moth
- Insight into the sex ratio of the Golden Sun Moth
- Identification of current threats to the Golden Sun Moth
- Management recommendations

Project results

Current distribution of the Golden Sun Moth

Prior to European settlement it is assumed that the GSM was widespread in south-eastern Australia in natural temperate grassland. This native grassland had an extensive although patchy distribution in the region. Based on historical records it is known that the GSM was found as far north as Winburndale near Bathurst and the Yass Plains in New South Wales. The GSM also inhabited large areas of central Victoria from Bright in the east to Nhill in the west, through to Bordertown in South Australia, and large areas of the ACT.

The transformation of native temperate grassland into urban and agricultural land has caused more than 95% of the former habitat of the moths to disappear or became highly degraded. As a result of the significant alteration of the moths' habitat and the loss of native grasses on which the species is dependent, the GSM has undergone an extensive reduction in its area of occupancy. This reduction has been accompanied by population decline and local extinctions.



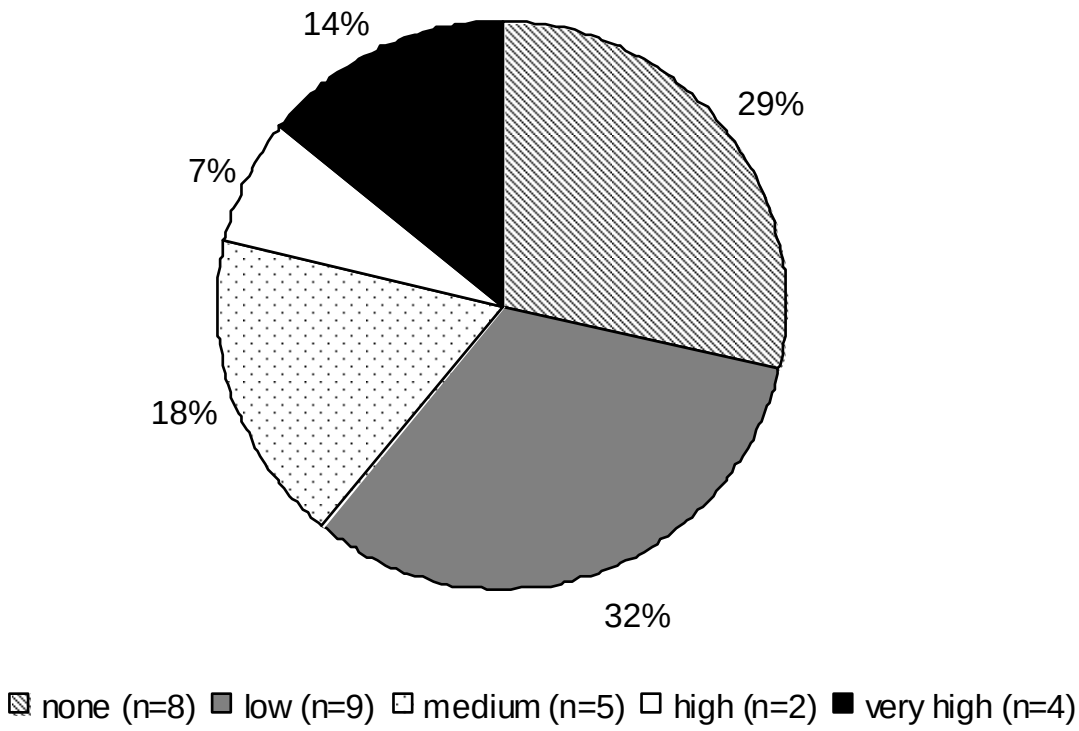
Today, the GSM is restricted to small, often highly fragmented, native grassland remnants. These remnants are threatened by ongoing habitat disturbance, destruction from urban and industrial development, and weed invasion.

The recognition of the species as highly threatened has resulted in an increase in research and survey activity directed at obtaining new information on its distribution. For example, in 1994, *S. plana* was known from only 10 sites in the ACT, five sites in Victoria and one site in NSW. However, surveys in subsequent years have discovered more sites with the species throughout its historic range. Currently, we know that the GSM is present at approximately 30 locations in the ACT, 45 in Victoria and 48 in NSW. It is not entirely clear if this increase in GSM populations is a reflection of increasing survey effort or a general population increase. It does however demonstrate the importance of undertaking active surveys and monitoring programs.

Despite this increase in the number of known populations, at most sites the species occurs in low numbers and many of these sites are of no more than a few hectares. This is true for example in Victoria (Gilmore, Koehler et al. 2008), New South Wales (Gibson and New 2007) and the ACT (Edwards 1994; ACT Government 2005).

During our GSM monitoring project, 28 locations were surveyed by the participants. The summation of moth sightings during site visit was used to provide an estimate of the relative abundance of GSM at these 28 sites. This allowed us to compare GSM populations across these locations. The highest number of counted individuals was used to categorise each population into: (a) small populations (low numbers of individuals = 1-20), (b) medium-sized populations (medium numbers of individuals = 21-50), (c) large populations (high numbers of individuals = 51-100) or very large populations (very high numbers of individuals = several hundreds). The main finding from these counts was that GSM were found at 71% of the sites surveyed. At half the locations populations were characterised by low or medium numbers of individuals. The species was present as small populations at nine locations and medium-sized populations at five locations. At only at six locations (21%) were GSM recorded in high or very high abundances and therefore classified as large-very large populations. The species was not found at eight locations (29%) (Figure 4).

Figure 4. Golden Sun Moth site occupancy and relative abundance



One important finding was the discovery of new GSM populations and the confirmation of the absence of *S. plana* at previously occupied sites. A list of total sightings with a description of the locations is provided in Table 2 of this report (see page 35). GSM were also observed during informal visits to grasslands that were not monitored. Several medium to large GSM populations were found over a large area in north-west Yarralumla, south of Lake Burley Griffin and along the Molonglo River (see Table 2, footnote 7). Flying GSM adults were also seen at Goorooyaroo, Throsby, and St John's, Reid, locations which are listed in the shaded cells in Table 2. In addition, a few moths were observed at sites where no moths were counted in the monitoring plots; they were seen whilst observers walked towards the plots and disturbed

them. These sightings include the locations of Gundaroo Common and Lawson (ACT). Adding these sites to the 20 identified with moths during the counts, a total of 26 sites were recorded with GSM in the ACT region over the 2008-09 summer.

Insight into the sex ratio of the Golden Sun Moth

In the vast majority of organisms that sexually reproduce, individuals of the two sexes are produced in approximately equal numbers independent of the sex determining system. The system of equal sex ratios is maintained by natural selection processes because selection equalises parental contributions by the two sexes (Fisher 1930). This fundamental principle in sex ratio theory argues that members of the minority sex tend to have higher fitness than members of the majority sex. This tendency has been acknowledged since the beginning of evolutionary theory (Darwin 1859) and has inspired evolutionary biologists ever since.

Previous research has been conducted on the biology and ecology of the GSM. This has included its general biology and distribution in the ACT (Edwards 1991; Edwards 1992; Edwards 1994; Clarke and Dunford 1999), habitat requirements and restoration (O'Dwyer and Attiwill 1999; O'Dwyer and Attiwill 2000), genetic population structure (Clarke and O'Dwyer 2000; Clarke and Whyte 2003) and population dynamics (Gibson and New 2007). However, prior to this study, nothing was known about the sex ratio within the species.

Part of this monitoring project was to contribute to a better understanding of the species biology. A total of 651 pupal cases were collected in 2007 and in 2008

as part of the GSM monitoring project. Because it is possible to determine the sex of the individual moth from morphological characteristics of the pupal case, they were examined by microscope at the laboratory at the University of Canberra, revealing a sex ratio of 60% males to 40% females (A. Richter 2009, in preparation) (Figure 5), but with the notable exception of two sites where more than 60% of individuals were female.

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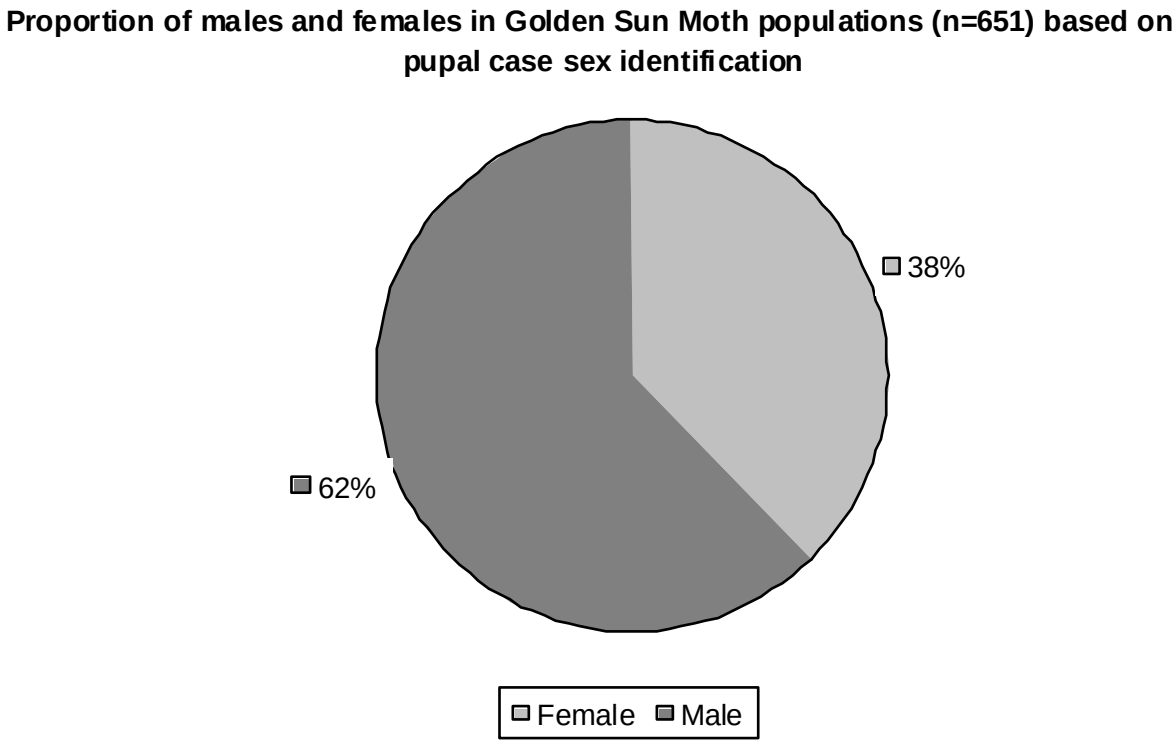
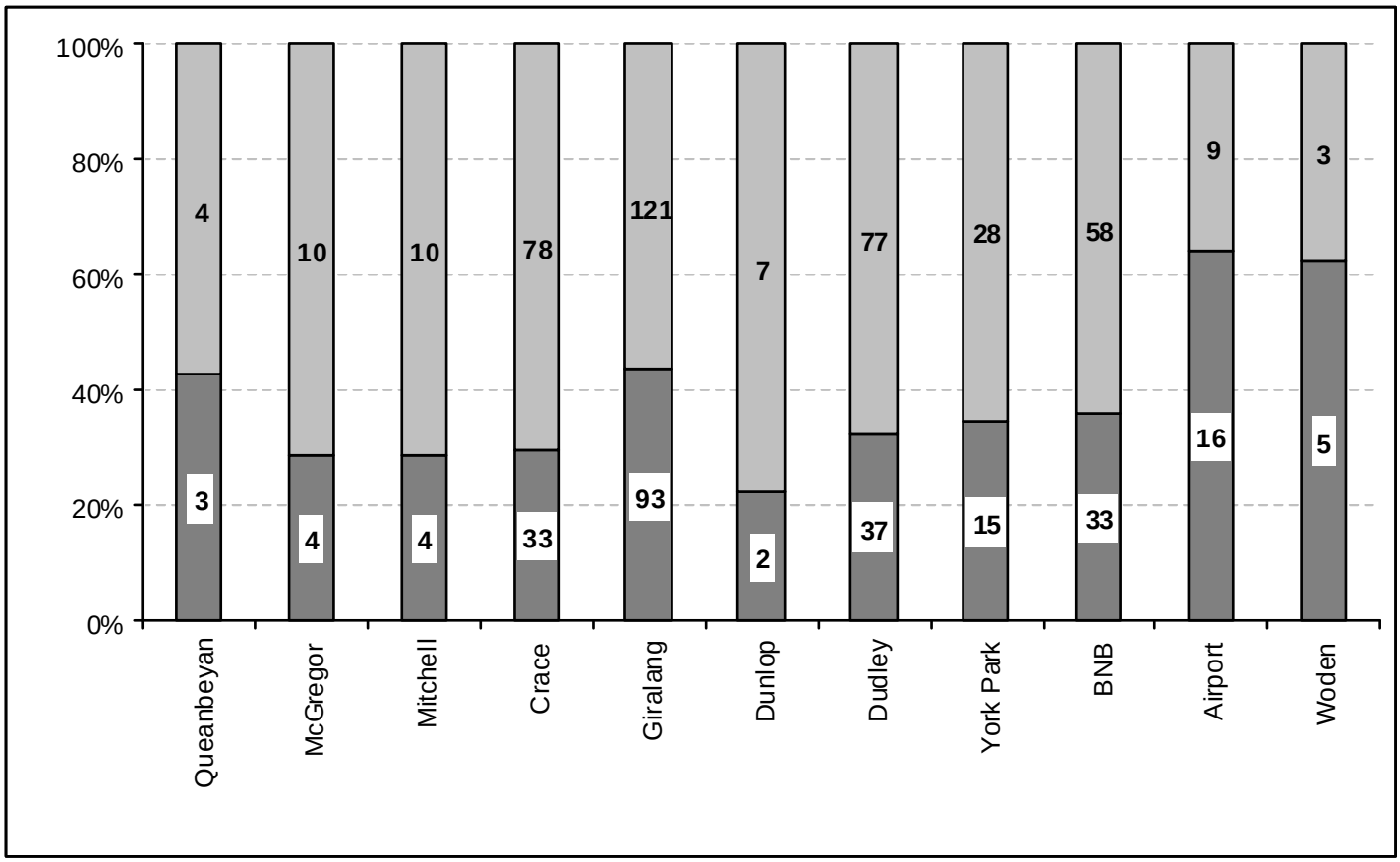
Figure 5. Proportion of males and females in Golden Sun Moth populations



In order to test if this pattern of more males than females in *S. plana* was consistent across different sites, the results for each locality were plotted (Figure 6). A biased sex ratio was detected at all sites but the proportion of 60:40 was not consistent. There was, however, a general under representation of females (A.Richter 2009, in preparation).

Figure 6. Numbers of *S.plana* male (light grey) and female (dark grey) pupal cases identified at 11 sites in the ACT and NSW.



These findings are of considerable interest in evolutionary biology, and in a broader sense such results can be important in conservation programs. From a scientific perspective it is important to unravel the mechanisms of environmental, genetic or demographic interactions that are involved in sex determination. Generally, variability in sex ratios has been reported for many lepidopteran species, ranging from those with male biases, through species with males and females with an almost 1:1 sex ratio, to species that produce only female offspring (Jiggins, Hurst et al. 1998; Adamski 2004). In the debate about this variation it has been argued that the biased sex ratio produced in butterfly species can be maternally inherited (Jiggins, Hurst et al. 1998), might be the result of biased predation as a consequence of sexual dimorphism, or results from microhabitat selection, differences in 'catchability' or lags in

emergence times of females relative to males (protandry) (Ehrlich, Launer et al. 1984; Frey and Leong 1993).

In our study we recorded the sex ratio based on pupal cases (Figure 7). This is likely to be a less biased estimator than the sex ratio estimation based on flying adults because pupal cases are not influenced by detecting probabilities and have equal 'survival' probabilities under natural conditions. Thus, it is expected that the pupal case sex ratio discovered in GSM populations in the ACT is a robust measurement for the sex ratio within *S. plana*.

Figure 7: Dorsal and ventral view of empty Golden Sun Moth male pupal cases under the microscope.

Future research will be needed to validate these findings over several years and among the wider distributional range of the GSM in NSW and Victoria. In addition, it is essential to investigate the underlying processes of sex determination in *S. plana* in order to better understand this phenomenon.

Identification of current threats to the Golden Sun Moth and natural temperate grasslands

The GSM and its habitat are threatened by ongoing native grassland losses and fragmentation due to urban and agricultural development, grassland degradation (e.g. weed invasion) and inappropriate management. In order to effectively conserve species and their populations, the conservation of the species habitat, based on ecological information about the species' specific habitat requirements, is of high priority. To identify current and potential threats to GSM and natural temperate grassland, participants were asked to record

- level of biomass reduction
- signs of grazing activity
- type of grazers
- rubbish sightings and
- any other miscellaneous observations.

The consequences of historical and ongoing losses to natural temperate grassland and continuing fragmentation of the remaining patches continues to be a major threat to the GSM. The two largest populations found in the ACT region occur in the largest patches of natural temperate grassland (Belconnen Naval Transmitting Base (BEO8) and Jerrabomberra Valley "Wooden" (JEO3). At most other native sites the GSM populations are in low abundance; these sites are characterised by small native grassland relicts or degraded grassland.

Urban and infrastructure development over recent years have changed significantly the surroundings of some GSM habitats and consequently increased their degree of isolation. At some sites, invasion by weeds such as Chilean needle grass (*Nassella neesiana*), saffron thistle (*Carthamus lanatus*) and St. Johns wort (*Hypericum perforatum*) is apparent and reducing the quality of the natural temperate grasslands.

Here, we feel it is important to highlight that our survey found very large GSM populations at four grasslands that are dominated by the exotic Chilean needle grass (*Nassella neesiana*). The presence of the species in this habitat has also been recorded in the past in the ACT (Braby and Dunford 2006) and Victoria (Gilmore, Koehler et al. 2008). Based on the presence of cast pupal cases found protruding from Chilean needle grass tussocks (A. Richter 2006, cited in DEWHA 2009) and findings of larvae in several Chilean needle grass grasslands (Richter et al. 2009, in preparation), it is possible that Chilean needle grass is an important component of the GSM larval diet at these sites.

During this project several volunteers recorded hundreds of flying GSM adults at Dudley Street, Constitution Avenue, outside York Park and at Giralang. All these sites are dominated by Chilean needle grass (*Nassella neesiana*) and are characterised by high levels of disturbance. The very large GSM population (up to 685 individuals) at Dudley Street is highly significant for the ACT. Further research is urgently required to understand the relationship between Chilean needle grass (*Nassella neesiana*). *D*ietary investigations on the species are currently underway (A. Richter, pers. communication). Until more is known about the relationship between GSM and exotic grasses, we suggest a dual approach to managing grasslands with both GSM and Chilean needle grass (*Nassella neesiana*): the maintenance of existing Chilean needle grass grasslands with large or very large GSM populations (e.g. Dudley Street and Constitution Avenue) to ensure the survival of these populations which might act as source populations to disperse into other grasslands, while preventing the spread of Chilean needle grass into other areas.

Grazing by native ungulates has always been an important component in the viability of natural temperate grassland. Most sites that are large enough are grazed by kangaroos; with some sites being grazed so low that bare ground dominates the site. At other sites, soil disturbance and increasing weed invasion have been caused by livestock grazing and rabbit activity.

Nearly all locations that were surveyed as part of this monitoring project were located in an urban-semiurban setting. A certain amount of rubbish was reported to be present at most sites. Whilst the presence of rubbish is more an aesthetic issue than an immediate threat, it gives the impression that the site is unmanaged and of little importance. This was recognised by the project coordinators, and one site where *S. plana* is known to occur was completely cleared of rubbish as part of the national 'Clean Up Australia' activity. Approximately 10 kilos of rubbish were removed by hand at a 16ha site in the northern part of Canberra.

Several sites that were monitored had not had any biomass reduction before our survey. The dense growth of a dominant grass species (e.g. kangaroo grass, *Themeda australis*) is considered a threat to the GSM, as it is known that the moths require bare ground and a variety of native grass species for their survival.

Management recommendations

Based on observation and quantitative information gained during our study, we have formulated conservation goals, objectives and actions that we consider important to improve the conditions for the GSM and its habitat (Table 1). We have also drawn on our data and the best current available scientific knowledge to make recommendations for the management of each site surveyed and their GSM populations (Table 2). These recommendations will be discussed with land managers, community groups and other GSM stakeholders with a view to improving the management of GSM sites, and continuing and building a community-university-government GSM monitoring program.

Table 1. Conservation goals, objectives and actions to improve the conditions for the Golden Sun Moth and its habitat

GOAL	*OBJECTIVE*	*ACTION*
Community involvement	*Community groups are actively involved in GSM conservation.*	*Maintain the involvement of community groups in protecting GSMs by:* • *facilitating coordination that links community activities with stakeholders and government agencies,* • *encouraging the formation of a national (including NSW and Victoria) GSM Conservation Network based on community involvement,* • *building on the ACT community program, and* • *continuing to raise community awareness through public environmental education (including school and university programs).*
Information	*Ongoing monitoring of the distribution and the conditions of all GSM populations in the ACT region is carried out on an ongoing basis.*	*Undertake ongoing monitoring to maintain up-to-date information on the presence and absence of GSM populations and the relative abundance of selected key populations*
	A database of GSM populations is maintained.	*Maintain a database of information about the GSM gained from community surveys to support planning, management and research relating to the GSM.*
	Information is included in state and national databases.	*Link data about ACT GSM populations to the* ACT Lowland Native Grassland Conservation Strategy—Action Plan No. 28 *and national databases.*
	Ecological information is used to underpin adaptive management for GSM populations.	*Increase research that addresses current management, management under climate change, and improved management, e.g. in relation to fire and GSM habitat rehabilitation and restoration.*
Threats	*Threats to GSM populations are significantly reduced or removed.*	*Describe and monitor threats to GSM populations (including urban development in adjunct habitats, fragmentation, overgrazing, weed invasion, and lack of management).*
	The impact and occurrence of weeds of concern is reduced.	*Provide information about the spread of weeds of concern and monitor the response of GSM to control programs.*
Management	*Ecological conditions of GSM habitat are maintained or improved.*	*Continue to develop and promote 'best practice' management by:* • *identifying practicable methods for GSM habitat restoration and regeneration,* • *monitoring the effectiveness of management actions and experimenting with alternative management strategies, and* • *linking research with monitoring outcomes to develop and apply 'adaptive management'.*

Table 2. Golden Sun Moths in ACT and region grasslands. Unshaded cells provide abundance and threats to GSM at each site surveyed, and management recommendations for those sites. Shaded cells refer to grasslands not surveyed but for which some information is available.

Name of the site by geographical area	***Site code (following the ACT Lowland Native Grassland Conservation Strategy, 2005)***	***Abundance of GSM observed in 2008/09 ****	***Threats to GSM identified in this and previous surveys***	***Recommended immediate action***	***Recommended long-term action***
ACT SITES					
Gungahlin					
Mulanggari Nature Reserve (2 sampling sites)	GUO1	Low (2, 2)	No recent biomass reduction, weed invasion from surrounding area, encroaching urban development	Consider biomass reduction	Control weed invasion
Gungaderra Nature Reserve (2 sampling areas)	GU02	Low (0, 4)	No recent biomass reduction	Currently no immediate action required	
Crace Nature Reserve (2 sampling areas)	GUO3	Medium (13, 30)[1]	Weed invasion and disturbance by cattle grazing under drought conditions	Currently no immediate action required Install information sign about native grassland and GSM	Monitor the extent of weed invasion and weed dispersal by livestock
North Mitchell	GUO4	Medium (28)[2]	Rapid urban development and habitat reduction, increasing fragmentation and isolation	Currently no immediate action required	Increase connectivity and minimise habitat reduction

[1] Both sampling areas visited only once

[2] Total calculated from15 points at 1st - 3rd visits.

Name of the site by geographical area	*Site code (following the ACT Lowland Native Grassland Conservation Strategy, 2005)*	*Abundance of GSM observed in 2008/09 **	*Threats to GSM identified in this and previous surveys*	*Recommended immediate action*	*Recommended long-term action*
Goorooyaroo Reserve	Not listed	Many GSM were observed on a FOG field trip (9 Nov 2008).	Nil at present	Currently no immediate action required	Collect better data on site
Throsby	Not listed	One male GSM was observed here in late Dec 08.[3]	Proposed urban development	Currently no immediate action required	Collect better data on site
Majura Valley					
Canberra International Airport (2 sampling areas)	MAO3	Low (17, 17)	Intensively mowed to maintain very low grass structure, weed invasion and fertiliser supplement	Create mosaic of heterogeneous habitats	Apply weed control programs and monitor the responses of GSM population
Campbell Park (2 sampling areas)	MAO5	Low (3, 9)	Weed invasion, rabbit activities and overgrazing by kangaroos	Weed control (St. Johns wort, Chilean needle grass, serrated tussock) and clear area of rubbish and encroaching wood	Control rabbit and kangaroo activities
Jerrabomberra Valley					
Woden Station/ Jerrabomberra West Reserve (2 sampling areas)	JEO3	High (23, 72)	Weed encroachment (saffron thistle, serrated tussock, African lovegrass)	Weed control	Ongoing weed management
Amtech	JEO9	Low (1)	Degradation by weed invasion and livestock activities	Weed management and livestock exclusion	Native grassland restoration

[3] Recorded as GSM site in AP28.

Name of the site by geographical area	*Site code (following the ACT Lowland Native Grassland Conservation Strategy, 2005)*	*Abundance of GSM observed in 2008/09 **	*Threats to GSM identified in this and previous surveys*	*Recommended immediate action*	*Recommended long-term action*
Belconnen					
Dunlop Nature Reserve	BEO2	Low (7)	Urban expansion at edges, weed invasion and isolation from other large populations	Weed control (phalaris and Paterson's curse)	Secure current grassland size and increase connectivity
McGregor	BE03_A	Low (1)	Weed invasion (Chilean needle grass)	Until relationship between GSM and Chilean needle grass is established, no weed control	
Umbagong Park, Florey	BEO4	None	Wood and bush encroachment, weed invasion	Weed control	Tree and bush removal, continuous weed management
Lawson (ACT)	BEO7	None	Livestock grazing, weed invasion, urban development	Remove livestock and control weeds (saffron thistle, African lovegrass and serrated tussock)	Continuous weed management and maintain connectivity to BEO8
Lawson (Commonwealth) (2 sampling areas)	BEO8	Very High (23, 930)	Urban development and degradation through kangaroo overgrazing, weed invasion	Maintain moderate kangaroo population size, weed control (serrated tussock)	Weed control, habitat restoration and rehabilitation
Kaleen East Paddock[4]	BEO9	None	Horse grazing	Currently no immediate action required	Maintain as potential stepping stone to secure habitat connectivity to adjunct grasslands (GUO3)
Glenloch Interchange	BE11	None[5]	No biomass reduction	Reduce biomass	Maintain biomass reduction
Giralang roadside (2 sampling areas)	Not listed	Medium (1[6], 21)	Intense mowing, weed invasion	Weed control	Facilitate connectivity to BE08

[4] Six plots were in Kaleen East Paddock and 6 in a horse paddock north of Ellenborough Street.
[5] Total calculated from 2 visits.
[6] Total calculated from 6 plots.

Name of the site by geographical area	*Site code (following the ACT Lowland Native Grassland Conservation Strategy, 2005)*	*Abundance of GSM observed in 2008/09 **	*Threats to GSM identified in this and previous surveys*	*Recommended immediate action*	*Recommended long-term action*
The Pinnacle	Not listed	None	Nil at present	Currently no immediate action required	
Canberra Central[7]					
CSIRO Headquarters, Campbell	CCO1	None	Weed invasion and exotic tree and shrub encroachment,	Weed control and tree/ bush removal	Native grassland restoration
Constitution Avenue, Reid	CCO2	Medium (38)[8]	Weed invasion and no biomass reduction, small site size	Reduce biomass	Restore buffer zone to stop weed encroachment and increase habitat size
Constitution Avenue, Reid	CCO2 (Exotic)	High (105)	Weed invasion (Chilean needle grass)	Until relationship between GSM and Chilean needle grass is established, no weed control	Monitor population dynamics in Chilean needle grass habitats
St Marks, ACCC, Barton	CC04	Low (5)[9]	No biomass reduction	Grassland recently burnt	Maintain biomass reduction
York Park, Barton (2 sampling areas)	CCO5	Very High (76[10], 413)	Urban development and weed invasion, lack of biomass reduction	Control weeds, reduce biomass Install information sign about native grassland and GSM	Increase connectivity
Lady Denman Drive, Yarralumla	CCO7	Medium (33)[11]	Small site size and isolation	Survey for adjunct populations (Royal Canberra Golf Club course)	Increase connectivity
Dudley Street, Yarralumla	CCO8	Very High (320)[12]	Small site size, weed invasion	Currently no immediate action required	Increase connectivity
Dudley Street, Yarralumla	CCO8 (Exotic)	Very High (685)	Weed invasion through Chilean needle grass	Until relationship between GSM and Chilean needle grass is established, no weed control	Monitor population dynamics in Chilean needle grass habitats

[7] Moths have also been observed in Yarralumla south of Alexandrina Drive between Novar Street and Hopetoun Circuit; south of Guilfoyle Street; and in an area running from the bicycle path beside the Molonglo River to Lady Denman Drive (and along it), and continuing on both sides of Cotter Road as far as Denman Street.

[8] Eleven plots surveyed at one visit.

[9] Total calculated from 3 visits.

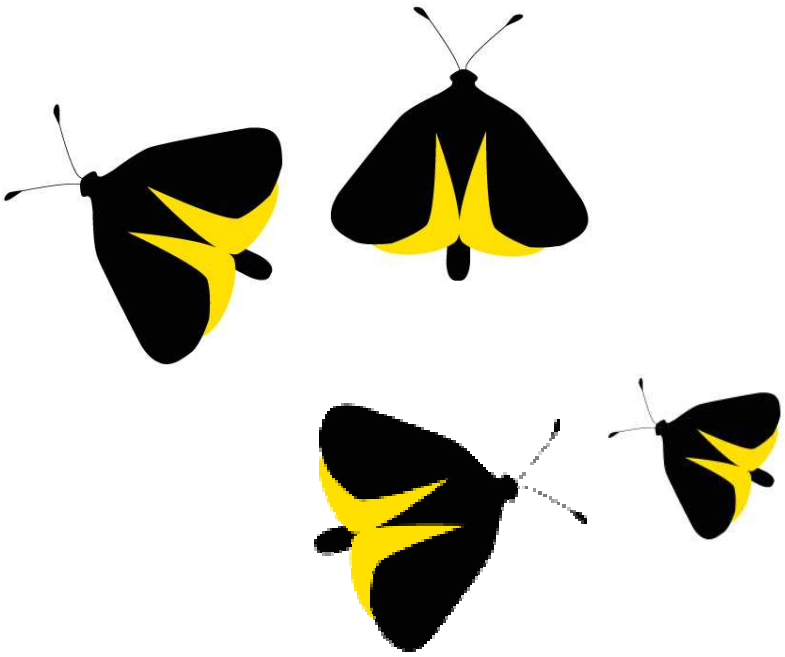
[10] Total calculated from 3 visits.

[11] Total calculated from 2 visits.

[12] Total calculated from 3 visits.

Name of the site by geographical area	*Site code (following the ACT Lowland Native Grassland Conservation Strategy, 2005)*	*Abundance of GSM observed in 2008/09 **	*Threats to GSM identified in this and previous surveys*	*Recommended immediate action*	*Recommended long-term action*
St Johns Church, Reid	CCO3	Moths observed here on 11 Dec. 2008.	Fragmentation and weed invasion	Control weeds	Increase patch sizes and connectivity
NSW SITES					
Gundaroo Common	n.a.	None Some moths seen outside sampling areas.	Currently no information available	Currently no information available	Currently no information available
Queanbeyan Nature Reserve (2 sampling areas)	n.a.	Low (2, 2)	Intensive kangaroo grazing, herbicide spraying	Continue current management	Continue current management
Lulilly Pass Road, Collector	n.a.	None	Nil at present	Currently no immediate action required	

*Abundance classes are based on the total number of adults counted during site visits at 12 random points with circular spot counts method in 2008/09. Low (1-20), Medium (21-50), High (51-100), Very High (several hundreds). Numbers in brackets indicate the total moth count. Where there was more than one sampling area at a site, the higher (highest) number was rated.



It's not a 9-5 job. It's an every moment you're awake job because you actually enjoy the work that you're doing.

Jeffrey Kalmikoff

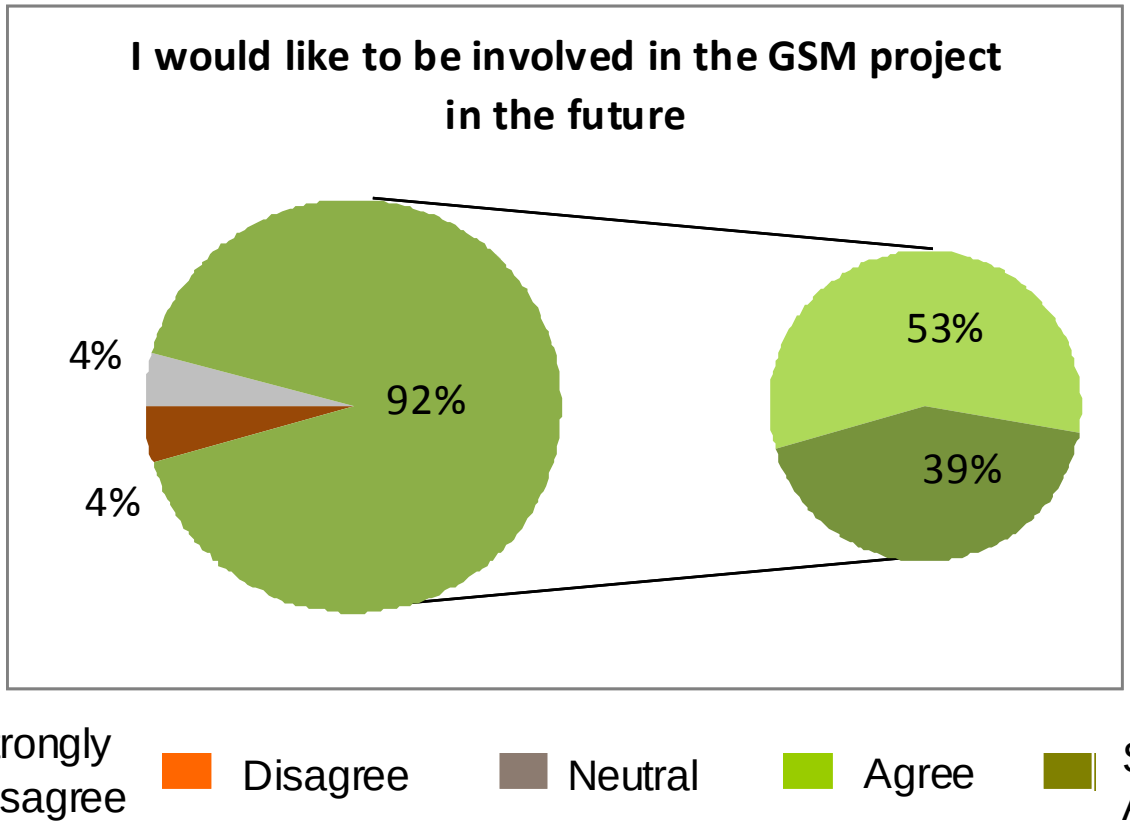
Future Golden Sun Moth monitoring

- What have we learned from the pilot study?
- Ideas and suggestions for future Golden Sun Moth monitoring

What have we learned from the pilot study?

Almost all participants felt that they had contributed to the conservation of the GSM and their habitats and expressed an interest in being involved in future GSM monitoring projects (Figure 8). The project contributed successfully to community capacity building and reached a wide public audience. There was great interest in community participation in a program involving an endangered insect species. Each of the 37 participants spent approximately 22 hours in training, workshops, field work and recording during the six week project.

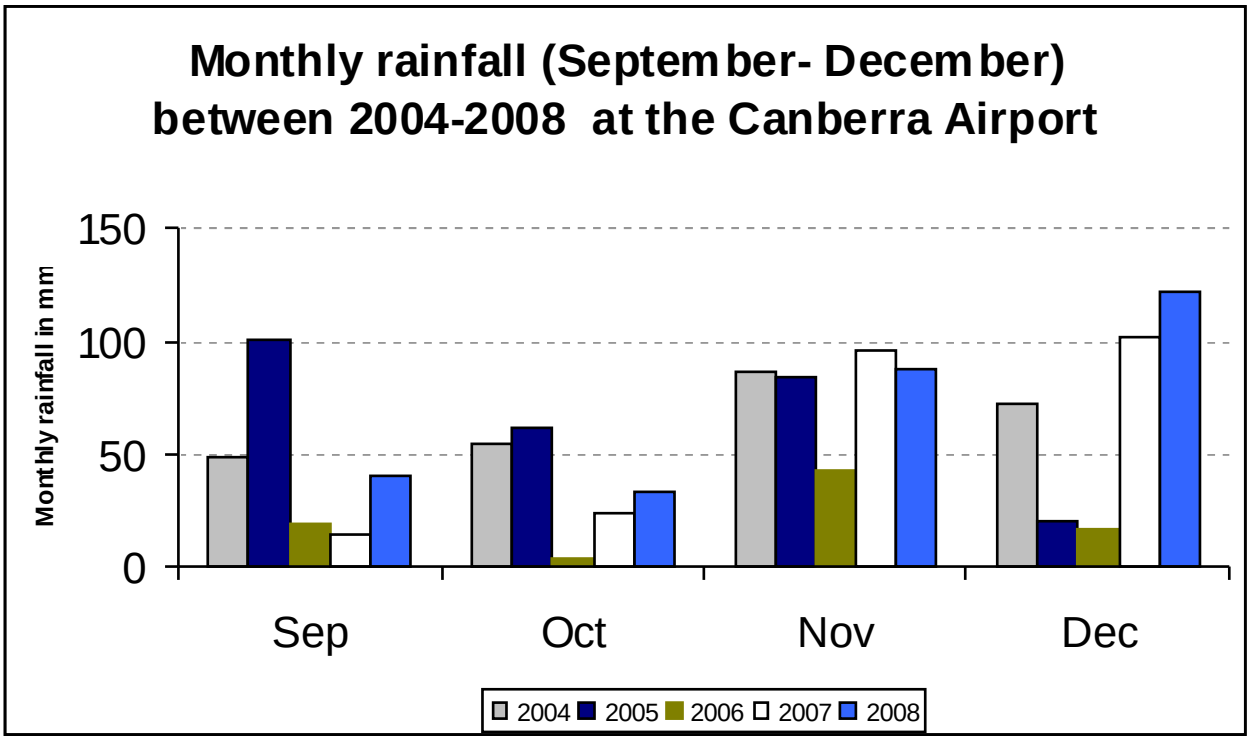
Figure 8. Level of interest among participants in future involvement in Golden Sun moth monitoring



According to our questionnaire, the greatest challenge for the participants was the difficulty of matching the time they had available to conduct the surveys to the times at which the moths were flying. The moths can be seen flying in the ACT region between the end October and mid January during the hottest part of the day between 11 am – 3 pm (A. Richter, unpublished) on warm to hot, cloudless and slightly windy days.

Two difficulties arise with this very limited window of activity by the GSM. Most people have personal commitments between 11 am - 3 pm during the week and are only available to volunteer on weekends, which do not always provide the most suitable weather conditions for GSM surveys. The spring and summer months during the GSM season in 2008-09 were characterised by cold and rainy weather conditions. The meteorological station at Canberra Airport recorded cool days with maximum temperatures well below the average and well above the average rainfall for December in 2008. Although there were plentiful sunshine hours, the weather conditions were not 'perfect' for the GSM during the duration of the project (Figure 9).

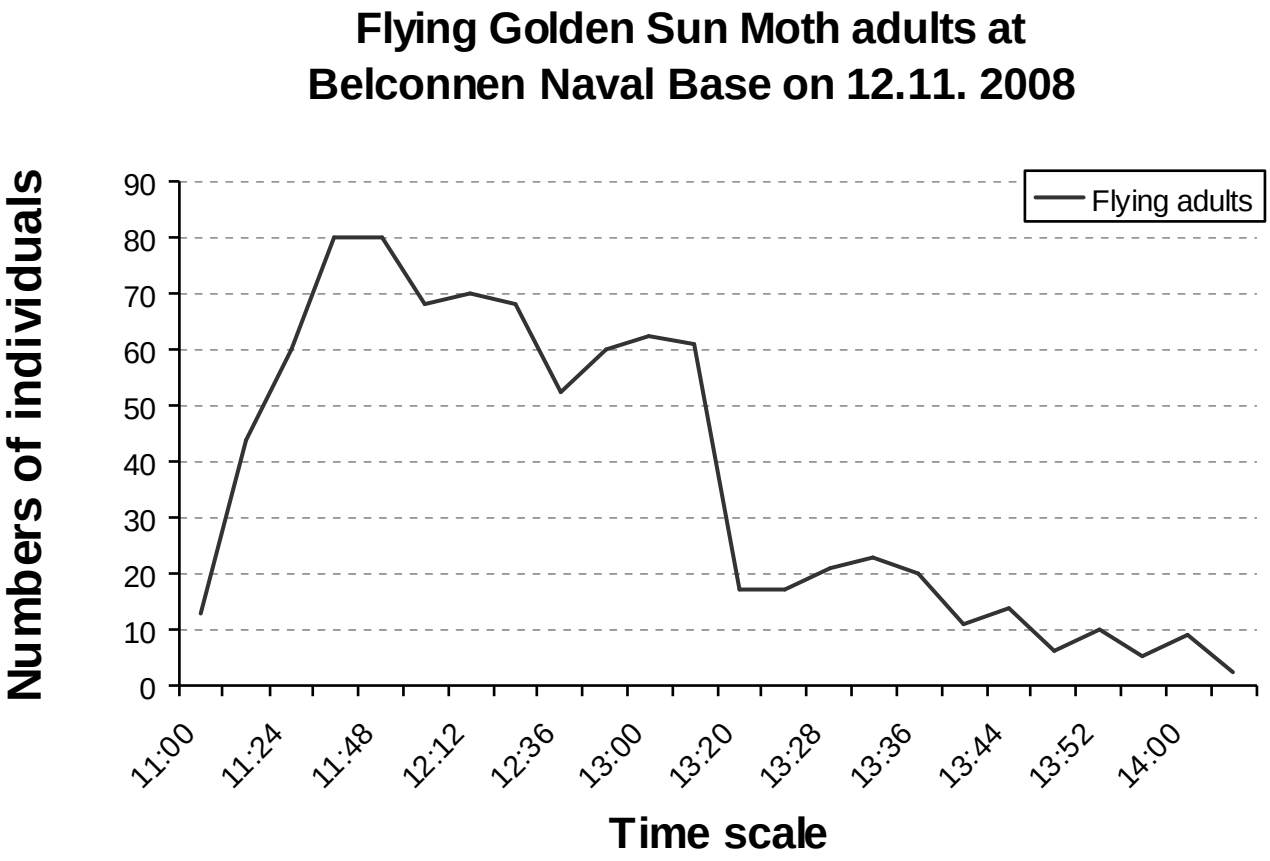
Figure 9. Monthly rainfall at Canberra Airport, September – December 2004-08



The literature refers to the moth's flight activity from about mid November until early January. Between years there is seasonal variation with flights occurring earlier in a warm dry spring and later and extending in a cool moist spring (Cook and Edwards 1994). As a result of cold and rainy days during November and December 2008, which presumably delayed moth emergence, active male and female moths were detected until mid January 2009.

The appropriate timing of the surveys is essential in order to estimate the relative abundance of *S. plana*. The hourly activity pattern in one of the largest GSM populations at the Belconnen Naval Base shows that the moths are most active between 11:30 am and 1:30 pm (A. Richter, unpublished data) (Figure 10).

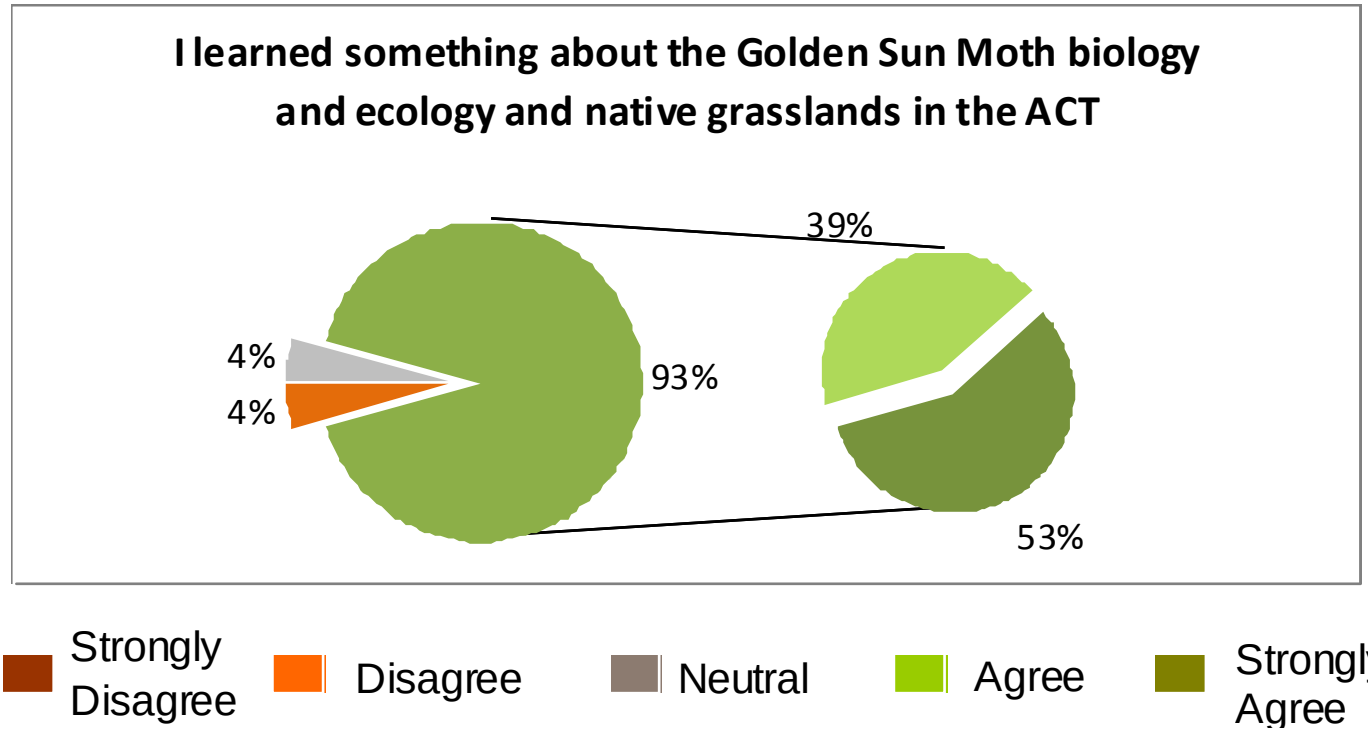
Figure 10. Flying time of Golden Sun Moth adults at Belconnen Naval Station, 11 am – 2.04 pm, 12.11.2008. Data collected by Dana Weinhold.



Many participants reported occasionally seeing moths in grass tussocks and flying away as they walked to the survey plots; by the time they reached the plots they counted no moths.

We received very positive feedback on the workshops and training sessions and considered them to be essential components in future monitoring programs. The aims of the workshops were to introduce the project, to highlight the importance of monitoring programs, to train the participants in species detection and to discuss concerns among the participants relating to the project (Figure 11).

Figure 11. Participants' rating of the material presented at workshops



Participants reported having encountered a number of difficulties. Firstly, the maps that we provided, which showed the location of each survey area and the associated study plots, were considered helpful for some sites but not in other areas that lacked significant landmarks. In addition, participants found it challenging without assistance to set up the plots using the materials provided in the monitoring kit (map, marking sticks, jars, and recording sheets). Some participants reported that re-finding the marked plots on subsequent visits (n=4) was somewhat problematic due to the random location of the plots, tall grass, lost site markers and interference by animals (horses/cattle).

The actual moth count and the identification of pupal cases in the field were considered feasible. Due to the moth's unique colour pattern and distinctive flying behaviour and the workshop introduction to the species with presentations of photos and pinned individuals, participants easily identified flying adults. The accuracy of estimating the relative abundance of the GSM was not evaluated during the project but is recommended for future monitoring. With most counts where there were large abundant populations, the counting method was varied by increasing up to 10 the number of circular counts made per plot in order to average the total number of moths that were counted within the predefined radius.

All pupal cases that were considered to be GSM by the participants were recorded, collected and kept for later checking. Most pupal cases were correctly identified. However, a minor proportion (<2%) of pupal cases did not belong to the GSM (Figure 12) and was mistakenly identified as *S. plana*.

Figure 12. Female Golden Sun Moth pupal case (left) and other invertebrate case (right), misidentified as *Synemon plana* case

Ideas and suggestions for future Golden Sun Moth monitoring

The following modifications to the monitoring program are suggested:

Earlier start in the season

- It is recommended that GSM monitoring program commence at the beginning of October. By mid October, participants should have been trained to identify *S. plana*. As soon as the moths are active, field training sessions with the moths present are essential. It is recommended that the survey plots to be set up and marked prior to the start of monitoring.

Simpler aims and objectives

- We recommend a simplification of the aims and objectives in future GSM programs. This should involve recording only the presence and absence of the species during a standardised amount of time spent on the site. Only sightings under appropriate weather conditions are considered as reliable and the absence of the moths needs to be confirmed by conducting at least three repeat visits. Pupal cases provide independent confirmation of the presence of the moths and unlike the outcomes of flying moth counts, are independent of climatic conditions.
- In order to simplify the project we suggest having the plots set up and vegetation surveys undertaken by a full time employed project coordinator and volunteers that have undertaken to do the vegetation surveys, as these tasks require special skills. Any participant that is not skilled in plant identification should be encouraged to join the vegetation team and be trained.

Stratified design

- One major improvement that we are suggesting is the establishment of permanent plots where selected key populations

and key GSM habitats are monitored regularly. This new approach has the advantage of enabling changes over time within the populations to be detected. Other grassland sites would be monitored on a less intensive basis.

The authors of this report are still absorbing the many findings and are keen to refine the procedures used in the survey and find ways of undertaking a suitable community-based monitoring effort in future, working with government and landholders. Our plans for monitoring during the summer of 2010-11 involve trialling simplified survey procedures during visits to grasslands not surveyed in 2008/09, and to large ones not adequately surveyed. We are also continuing to work on the design of procedures for the more detailed monitoring of a number of permanent sites where GSM are known to occur.

Acknowledgements

First of all we would like to acknowledge all participants for showing such a great interest in, and enthusiasm for, the conservation of the GSM and its habitat - the native grasslands. Their active involvement in this pilot monitoring study and their willingness to spend many hours in workshops and in the field are greatly appreciated.

WWF Australia (Threatened Species Network) provided financial support and encouragement that was critical to the successful conduct of the study. Without its support, we could not have obtained the same quantity and quality of information about the GSM nor such extensive experience with community involvement in a survey designed to contribute to the conservation of a threatened, biodiverse ecosystem. We also acknowledge the financial assistance provided to Anett Richter by the ACT Government (Parks, Conservation and Lands, Department of Territory and Municipal Services).

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The volunteers who were involved with the monitoring were:

Frank Antram	Mark Hall	Anett Richter
Mary Appleby	Eleanor Hearder	Cathy Robertson
Adrienne Carpenter	Lynne Heffernan	Geoff Robertson
Ian Clark	Sarah Hnatiuk	Alison Rowell
Margaret Considine	Anna Lashko	Andy and Janet Russell
Emma Cook	Nola McKeon	Sam Walker
Cathy Crozier	Ian McVay	Tess Ward
Rosamund Dalziell	Michael Mulvaney	Chris Watson
Meg Doepel	Kris Nash	Dana Weinhold
Pam Fawke	Margaret Ning	David Wong
Madeleine Fletcher	Will Osborne	Matthew Young
Matthew Frawley	Rod Pietsch	
Sybil Free	Stewart Pittard	
Jean Geue	Kim Pullen	

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List of available documents

The following documents are available on request from Friends of Grasslands

- Presentations given at training workshops and to report results to participants at the end of the survey
- Field recording sheets and explanation of their use
    - For moth and pupal case counts
    - For vegetation characteristics (abundance and cover)
    - For feedback from volunteers at the end of the project
- Newsletters

Contact Friends of Grasslands at PO Box 987, Civic Square, ACT 2608, on 02 6241 4065 or 02 6251 8949, or at **info@fog.org.au**.

For additional information about this project, you may visit the Golden Sun Moth web site (http://aerg.canberra.edu.au/teams/osborne/moth-count/?page_id=22).