Attachment E

Alison Rowell (Ecologist),
Survey and Impact Assessment –
Golden Sun Moth

Survey and impact assessment at Golden Sun Moth *Synemon plana* site, Blocks 3 and 7, Section 22 Barton (York Park)

Report prepared for Parsons Brinckerhoff

by

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Survey and impact assessment at Golden Sun Moth *Synemon plana* site, Blocks 3 and 7, Section 22 Barton

1. Background

1.1 The project

The south-eastern part of Block 3 and eastern part of Block 7, Section 22 Barton ACT contain a population of Golden Sun Moth *Synemon plana*, in about 0.5 ha of Natural Temperate Grassland dominated by species of Wallaby Grasses (*Austrodanthonia*) (ACT Government 1997, 1998, 2005). The Department of Finance and Administration, the owner of Block 3 Section 22 Barton, has appointed a Planning Consultant to develop a Master Plan to explore development opportunities for the block. Block 7 is Territory land. This part of Barton is part of an area known as 'York Park', and this term is often also applied to the Golden Sun Moth site itself.

The Golden Sun Moth is listed as Critically Endangered under Section 179 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999,* Endangered (Schedule 1) on the NSW *Threatened Species Conservation Act 1995* (TSC Act), Endangered (Section 21) of the ACT *Nature Conservation Act 1980* and Threatened on the Victorian *Flora and Fauna Guarantee Act 1988* .

The species is found in natural temperate grasslands and grassy areas in open box-gum woodlands of south-eastern NSW, the ACT and Victoria (ACT Government 1998, DSE 2000). These plant communities are also listed as endangered under the above Acts (definitions vary). Action Plans (ACT Government 1997, 1998, 2005) and Recovery Plans (Environment ACT 2005, DCE 1992) have been prepared for the Golden Sun Moth and its habitat. A National Recovery Plan is in the final stages of preparation by Department of Environment and Conservation (NSW) and the Commonwealth Department of Environment and Water Resources.

Nationally threatened species and communities are identified as Matters of National Environmental Significance under the *EPBC Act.* Any proposed action on or near a site, which may have a significant effect on such values, must be referred by the proponent to the Minister for Environment and Heritage, for assessment as to whether the action requires approval under the Act.

For Blocks 3 and 7 Section 22 Barton, development on the currently undeveloped north-western portion of Block 3 has the potential to significantly affect the parts of Blocks 3 and 7 which contain Golden Sun Moth and Natural Temperate Grassland. Negative impacts could arise from loss of buffer area (increasing edge effects), tree planting, nutrification, run-on and altered drainage patterns. Most significantly, various building options would also result shading of the Golden Sun Moth habitat. Golden Sun Moths are generally found in flat or undulating habitats that are not subject to significant shading by hills, ridges or trees. Plants and animals in grassland communities are generally not adapted to shading, which can affect soil temperature and moisture and plant growth on a site.

1.2 Environmental values of the site

1.2.1 Natural Temperate Grassland

Status of the community
Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory is listed as an endangered community under the *EPBC Act 1999*. The community is found between 560 and 1200 metres in valleys and broad plains. The dominant cover is native tussock grasses, with forbs such as daisies, lilies and native legumes in the intertussock spaces. It is estimated that about 5% of the original area of the community in the ACT survives in moderate to good condition, and up to about 1.5% remains in this condition over its whole previous range. Over 200 hectares of this community is reserved in the ACT, and about the same area in NSW (ESSS 2000).

Study site
The grassland on the York Park site has been given a Botanical Significance Rating of 4 (Low), and a Conservation Rating of 2 (Complementary Conservation Site). The Conservation Rating reflects that the site has only a low to moderate Botanical Significance, but contains a population of a threatened species that is considered to be viable in the medium term (ACT Government 2005).

The Natural Temperate Grassland on this site is part of a long-term grassland monitoring program being undertaken by Environment ACT, and the vegetation quality in Block 3 has been previously been assessed and mapped (Davis & Hogg 1992, ERM 2005).

1.2.2 Golden Sun Moth *Synemon plana*

Status of the species
The Golden Sun Moth is currently listed as Critically Endangered nationally, and Endangered in all the States and Territories in which it occurs. A Critically Endangered species is considered to be facing an extremely high risk of extinction in the wild in the immediate future.

Distribution
Prior to European settlement the species was widespread in native grasslands in south-eastern Australia, from near Bathurst NSW through the Australian Capital Territory and Victoria to Bordertown, SA (Edwards 1993, 1994). This distribution was correlated with grasslands dominated by low-growing Wallaby Grasses (*Austrodanthonia* species), and has contracted substantially (O'Dwyer & Attiwill 1999). The species is now only found in a few relatively small breeding areas due to habitat loss, fragmentation and degradation. Possibly less than one percent of the original habitat now remains, much of it degraded by weed invasion (Clarke & O'Dwyer 1997, O'Dwyer & Attiwill 1999, ACT Government 2005).

Description and life history
The Golden Sun Moth is a medium sized day-flying moth in the family Castniidae. The male has a wingspan of about 34 mm, the female slightly less. The upper forewings of both are grey/brown with paler patterns. The male has dark brown upper hindwings, and in the female these are bright yellow/orange edged with black spots (Figures 3 & 4).

Golden Sun Moth larvae feed on the underground parts of Wallaby Grasses (Edwards 1993, O'Dwyer & Attiwill 1999), and may sometimes feed on other native and introduced grasses (Braby & Dunford 2006). Larval development time (and thus generation time) is unknown and may vary between one and three years.

The adults live for only 1–4 days after emerging during spring, and do not feed as they have no functional mouth parts. In the middle of the day when conditions are sunny and warm, males patrol the grassland in search of the females, which have reduced hindwings and are poor fliers. The starting date and duration of the flight season vary from year to year, probably depending on spring weather conditions, with the season starting earlier in a warm dry spring (Cook & Edwards 1993).

Conservation
The Golden Sun Moth occurs in one conservation reserve in NSW, eight populations are reserved in the ACT and two in Victoria (ACT Government 2005, DEC unpublished). Four of the larger habitat areas in the ACT have been given a High Conservation Value rating (ACT Government 1998). Six ACT populations in small areas of habitat (0.1 to 3 ha) have been identified as being of doubtful long-term viability, even under optimum conditions. The limited flight ability of the female moths adds to the species' vulnerability to extinction on small sites, and makes natural re-colonisation from other sites unlikely.

Study site
The York Park (current study) site, although small, has received a Moderate Conservation Value rating, increased because of the previous scientific work carried out on the site (ACT Government 1998). Clarke (1998) also considered that this site warranted special attention due to its 'high profile and considerable research focus in past years'.

The area of the Golden Sun Moth habitat on this site is about 5600m². The Golden Sun Moth population has been intensively surveyed in the past. The previous studies include three mark-release-recapture surveys producing estimates of population size (Cook & Edwards 1993 & 1994, Edwards 1994, Harwood *et al.* 1995), and genetic analysis of the population (Clarke & O'Dwyer 1998). Provisional management recommendations have also been prepared for the site (Frawley 1995, Edwards 1995). These included rehabilitation of the vegetation by translocation of soil and grassland plants from a nearby area which was being developed (Davis & Hogg 1992, Harwood *et al.* 1995).

2. Aim

The brief for this project requires an assessment of environmental factors for Block 3 Section 22 Barton, with a comprehensive study of the Golden Sun Moth *Synemon plana*, 'including a Capture-Mark-Release study for the 2006-07 season'. Mark-release-recapture methods require that individuals from a population be captured, marked and released. Sampling the population on subsequent occasions allows the determination of the proportion of the population carrying marks and hence an estimate of the number of individuals in the population.

It was recognised that survey data from a single season can only reliably detect large changes in the population, as numbers of flying male Golden Sun Moths vary considerably from year to year, probably affected by seasonal conditions. However, repeating the surveys carried out 14-16 years ago allows broad comparison of the population estimates, and provides some information on the effects of site management and environmental conditions on the population in the intervening period.

The mark-release-recapture survey required for this site was recognised as having the potential to damage individual animals and disrupt their behaviour throughout the breeding period. A Permit to Take under Section 201 of the *EPBC Act 1999* was therefore sought and obtained from the Department of Environment and Heritage (now Department of the Environment and Water Resources). This permit (E2006-0007) allowed up to 400 Golden Sun Moths to be handled and marked, and during the survey was amended to allow more moths to be handled.

Figure 1. Male Golden Sun Moth after capture and numbering.
(Photograph: Anett Richter)

3. Methods

3.1 Golden Sun Moth survey

The methods employed in the current mark-release-recapture survey differed slightly from those used in the 1992-1995 surveys, for several reasons. The previous surveys did not use exactly the same methods each year, so the methods selected for 2006 were a combination of past methods. The earlier surveys also covered almost the whole flying period of the Golden Sun Moth at the site, but the date of issue of the 2006 Permit to Take meant that the 2006 survey did not include the first 2 to 3 weeks of adult moth activity. Both male and female moths were captured in the earlier surveys, but captures and recaptures of females were so low that the data could not be used in estimating the population. It was therefore decided not to capture females in 2006, to reduce interference to mating and egg-laying.

The Permit to Take was issued on 16 November 2006. A trial of methods was conducted on 17 November, and adult male Golden Sun Moths were sampled daily from 18 November to 19 December. The site was divided into 9 equal sectors (3 x 3, see Figure 7). Collection was undertaken for one hour (excluding handling and marking time), generally between 1030 and 1230 hours (Eastern Daylight Saving Time). This was before the peak activity period, to reduce disruption to mate-seeking and mating. Moths were captured from all parts of the site with 40cm butterfly nets, and marked with a number on the underside of the hindwing, using a quick-drying xylene-free metallic ink pen (Artline 999XF Silver) (Figure 1). The mark number, location of capture and condition of each moth were recorded on a daily data sheet (see following page). Sightings of females were also noted (see Photograph 2).

After marking, moths were kept in the shade in a mesh-sided holding cage with a cloth cover, to reduce damage from fluttering (Figure 2). All moths were released in the centre of the site (Sector 5, Figure 7) at the end of the collection period each day.

The capture and recapture data were analysed by Ms Anett Richter (University of Canberra) using appropriate open-capture models in the programs MARK and JOLLY, and estimates of the male population were produced. An open population is one which is subject to changes due to birth (emergence), death, immigration and emigration during the sampling period. The previous method of analysis (Fisher-Ford) was not used due to technical difficulties, but the methods chosen were suitable for populations with low survival and recapture rates.

YORK PARK GOLDEN SUN MOTH SURVEY, 2006

Date:	**Start time:**	**Finish time:**

Weather conditions:

Cloud/8:	**Cloud density:**	**Wind speed:**	**Direction:**

Temp. during survey:	**Daily temp. range:**

Surveyors:

Sector	**Number (today)**	**Mark**	**Condition**	**Comments**

Comments:

Long grass area and fence **North**

7	**4**	**1**
8	**5**	**2**
9	**6**	**3**

National Circuit

Condition

1: Upperwing markings clear, wing margins intact
2: Markings less distinct, wing margins intact
3: Markings obscure, wing margins worn

3.2 Habitat assessment

Three 20 metre by 20 metre vegetation quadrats were surveyed in the Golden Sun Moth habitat area in March 2007 (Appendix 3). The quadrats were placed centrally in sectors 2, 5 and 8. Species composition and percentage cover were recorded. Notes were also made on the vegetation of the unmanaged portion of Block 3, and on the vegetation of the median strip of Sydney Avenue, east and west of National Circuit.

3.3 Assessment of shading effects

Diagrams showing the extent of shading of the subject site at different times of the day in various seasons were produced by Colin Stewart Architects. These were examined to assess the potential effect of shading on the Golden Sun Moth habitat.

Figure 2. Male Golden Sun Moths in temporary mesh holding cage.
(Photograph: Anett Richter)

Figure 3. Female Golden Sun Moth showing upperwing pattern.
(Photograph: A Rowell)

Figure 4. Female Golden Sun Moth, ventral view.
(Photograph: A Rowell)

4. Results

4.1 Golden Sun Moth survey

4.1.1 Flying season and captures of males

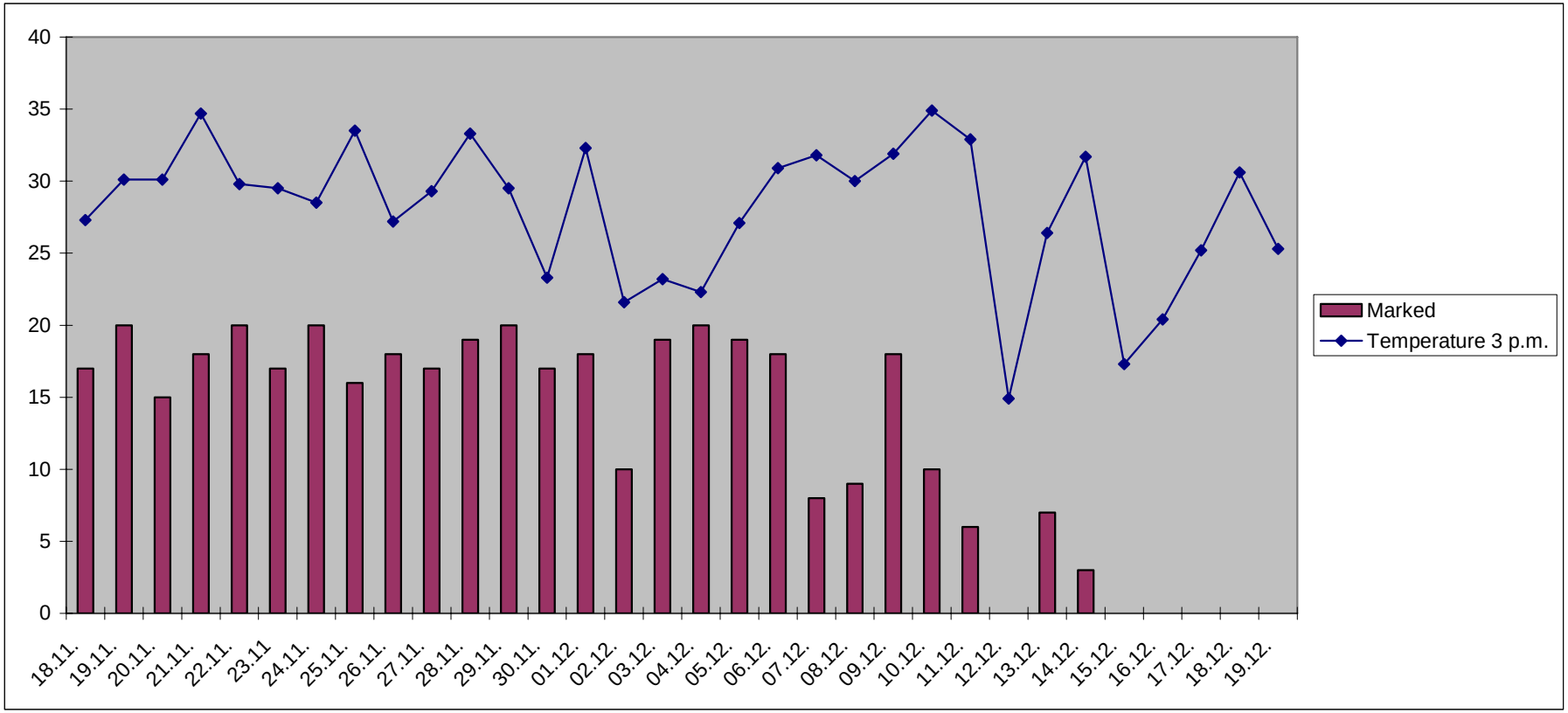
The first report of flying male Golden Sun Moths in the district in 2006 was at Mulligans Flat in the north of the ACT on 16 October (Steven Holliday, pers. comm.). This is exceptionally early, and probably a result of the unusually warm conditions in early spring 2006. Male moths were first observed flying at the York Park site on 30 October by Ms Anett Richter, a PhD student from the University of Canberra who is studying grassland invertebrates in the ACT. Reasonable numbers were flying on this date, so the date of first appearance in 2006 is likely to have been earlier. The dates on which males were first seen flying on this site in previous years were 23, 16 and 17 November.

The Permit to Take was issued on 16 November 2006, the trial of methods was conducted on 17 November, and capture sessions were undertaken daily from 18 November to 19 December. 419 male Golden Sun Moths were captured and marked between 17 November and 14 December. No moths were seen or captured on 12 December, when the temperature during the collection period was 11-12 degrees Celsius. Only one moth was seen between 15 and 19 December, and none were captured in this period. When no moths had been captured for 5 days despite suitable conditions, it was decided that the breeding season had ended (see Figure 5).

398 of the moths captured were used in the population study. The 21 males excluded from the population study were those handled in the trial of methods, and others caught after the end of the capture period on the first three days of the study (due to miscalculation of capture period). Seven female Golden Sun Moths were observed during the survey. No moths were killed during handling and marking, and all marked moths were able to fly away from the holding cage at the end of the daily survey period.

From the 398 individual male moths captured and marked, there were 25 recaptures. 21 of the recaptures were on the day following first capture, and 4 recaptures were 2 days after first capture. No moths were captured more than 2 days after marking.

Figure 5. Daily first captures of male Golden Sun Moths at York Park, spring 2006.
(Graph by Anett Richter)



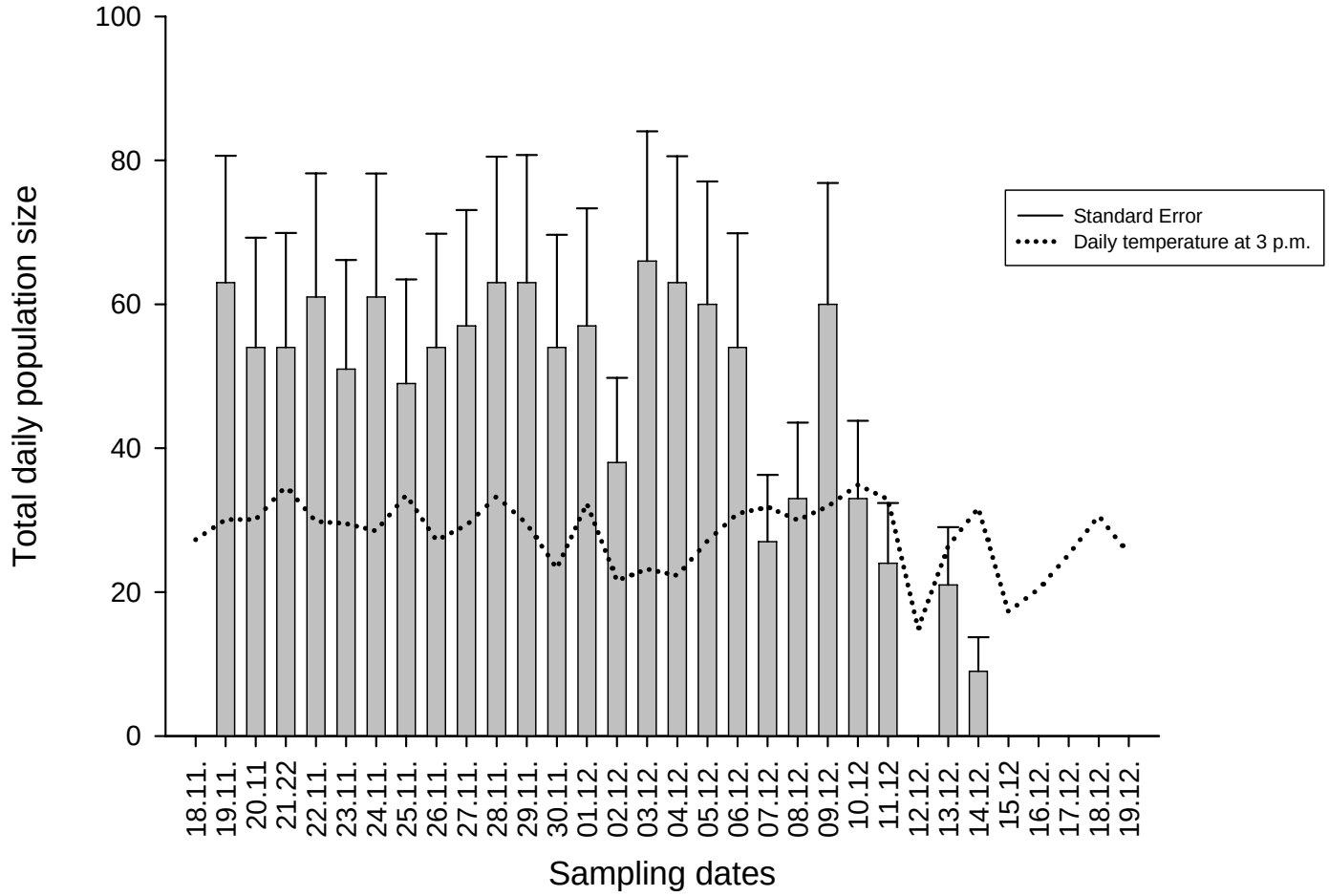


Figure 6. Estimated daily male population size at York Park, Barton, spring 2006.
(Jolly-Seber model D). (Graph by Anett Richter)

4.1.2 Distribution and movements

As observed in previous seasons, captures were made in all sectors (see Figure 7), but the distribution of captures changed over the survey period, with more moths captured in the central and northern sectors in November, and greater numbers in the southern sectors in December (Table 1). This pattern also appeared in the sightings of female moths. In the previous surveys it was also suggested that changes in the capture sites of the males may reflect a change in the distribution of females during the season (Cook & Edwards 1993, 1994).

Noting the sector of capture enabled some observations to be made of movements of male moths around the site. Moths could be recaptured in the same sector, or could move one or two sectors (laterally and/or diagonally) away from the site of previous capture. 16% of recaptures were made in the same sector as the previous capture, 60% were made in an adjacent sector (ca 15 to 40 metres away), and 24% of recaptures were two sectors from the previous capture site (ca 30 to 80 metres away). This suggests that the males are not attached to particular parts of the site over time.

All 423 releases (new captures plus recaptures) at the end of the daily survey period were made in the central sector. Recaptures could then be made in the same sector as release, or in an adjacent sector. 24% of the 25 recaptures were made in the sector of release (sector 5). A similar figure of 21% of total captures were made in sector 5, suggesting that recaptured animals were not much more likely to be found in this sector than other individuals were, i.e. releasing animals in the middle of the site did not skew recapture results towards this sector.

Male moths were observed to fly from the study site to degraded vegetation on the median strip of Sydney Avenue. Many males were seen flying over this median strip, both east and west of National Circuit, but no females were seen there. Some males were seen to fly through the wire fence into the weedy long grass west of the site, but these usually returned quickly to the mown area.

Male moths were seen circling over or landing near stationary females. Males performed the same manoeuvres around pieces of amber glass, which occasionally led to more than one being captured with a single sweep of the net.

Figure 7. Sectors of the Golden Sun Moth survey site.

National Circuit

3	**6**	**9**	Sydney Ave
2	**5**	**8**	
1	**4**	**7**	

Table 1. Change in distribution of captures of male Golden Sun Moths during survey period.

Sector	Captures for whole survey period	Captures in November	Captures in December	Change over survey period
1	33 (8%)	22 (9%)	11 (6%)	↓
2	28 (7%)	15 (6%)	13 (7%)	≈
3	14 (3%)	10 (4%)	4 (2%)	↓
4	116 (27%)	67 (28%)	49 (27%)	≈
5	89 (21%)	66 (27%)	24 (13%)	↓↓
6	19 (5%)	13 (5%)	6 (3%)	↓
7	37 (9%)	14 (6%)	23 (13%)	↑↑
8	69 (16%)	29 (12%)	40 (22%)	↑↑
9	17 (4%)	8 (3%)	9 (5%)	↑

4.1.3 Moth condition

Condition of captured male moths was assessed as follows:

- Condition 1 - Upperwing markings clear, wing margins intact
- Condition 2 - Markings less distinct, wing margins intact
- Condition 3 - Markings obscure, wing margins worn

Condition 1 moths had probably emerged on the morning of capture. Their fine wing markings were clear because most of the wing scales were intact. These scales rub off with activity and wear, and the markings become less distinct. Condition 3 moths had lost many of their wing scales, and the margins of their wings were worn or damaged. These moths had probably emerged on a previous day. Condition 2 moths could have emerged early on the day of capture, or on a previous day.

Handling and marking of moths caused loss of wing scales, but did not generally damage the wing margins. This meant that moths captured as Condition 1 were often released as Condition 2. This did not appear to impair their ability to fly after release. All recaptures were either Condition 2 or Condition 3.

The proportion of first-capture moths in Condition 1 each day was 25-80%, while Condition 3 moths made up 0-53% of first captures each day. This result supports the interpretation that Condition 3 moths are older animals, with their numbers declining through mortality. A possible cohort effect could sometimes be seen, with relatively high numbers of Condition 1 moths on one day being followed by relatively high numbers of Condition 3 moths on the two subsequent days.

Some variation in the size of the male moths was also noted. A few Condition 1 individuals were recorded as being unusually large or small, but this was not confirmed by measurement. Condition 3 moths often appeared smaller due to loss of wing area.

4.1.4 Predation

Several species of birds were seen to take Golden Sun Moths, mainly from the ground. These were Common Starling, Magpie-lark and Black-faced Cuckoo-shrike. The Magpie-larks were nesting nearby, and feeding moths to their young. Australian Magpies and Common Mynahs also frequented the site, and probably took Golden Sun Moths. No instances were seen of predation by Robber Flies or Dragonflies, although this has been a common occurrence on this and other sites in previous years (Cook & Edwards 1993 & 1994, Edwards 1994, Harwood *et al.* 1995, A. Rowell pers. obs.). Invertebrate numbers have been generally low in local grasslands in the last year (pers. obs., Anett Richter pers. comm.), presumably due to the prolonged drought.

4.2 Population estimates

The data set of 398 encounter histories was initially analysed by Ms Anett Richter (University of Canberra) using open-capture models in the software MARK (Windows 95). A set of models was developed, analysed and ranked following analysis. The best fitted model for open populations was the POPAN model, which includes constant parameters for apparent daily survival rate, (re)capture probability and probability of entry to the population.

The data were re-analysed by Ms Richter using the program JOLLY, calculating daily population estimates with an open population model that assumes the survival rate and capture probability to be constant per unit time (Figure 6). This model was considered to give a more accurate total population estimate than the model used in MARK. The details of both analyses are attached as Appendix 1 and Appendix 2.

A summary of these analyses are shown with the results from previous surveys in Table 2. The MARK analysis gives a male population slightly lower than previous estimates, and the JOLLY analysis gives an estimate two to three times higher. It should be noted that the population estimates are of the number of male moths present during the capture period, and that this period was both shorter in 2006 and a smaller proportion of the total flying season. Sampling was carried out for almost the entire flying season in the earlier surveys, while up to two weeks (or one third) of the flying season was missed in 2006. This means that both population estimates for 2006 underestimate the total numbers of males emerging on the site in that season, and that the male population was almost certainly larger in 2006 than in 1992-95.

It is not known whether being captured once reduces the chances of a moth being captured again, either through increased morbidity/mortality or increased wariness. If this were the case, the reduced recapture results would result in an overestimate of the population. This could be expected to affect the population estimates from all years in a similar way, as the methods used are essentially the same.

It would be advantageous if the data from all seasons could be analysed using the same programs, and to this end efforts are being made to obtain the raw data from the earlier surveys for re-analysis.

No attempt was made to capture females in 2006, and care was taken to avoid disturbing them. In 1992-1995, both males and females were captured, and the observed male:female sex ratios were 9:1, 36:1 and 38:1. The ratio of males (captured) to females (observed during surveys) was 57:1 in 2006, but this figure cannot be compared to the earlier ratios, due to the difference in methods. After the earlier surveys it was assumed that the behavioural differences between the sexes partially explained the variation in numbers caught, with the sampling method favouring the capture of males. However, the possibly skewed sex ratio was still considered to be of concern, with the number of reproductive females being critical to population viability (Harwood *et al.* 1995).

Table 2. Summary of mark-release-recapture results for male Golden Sun Moths for all surveys.

Year (period of captures)	**1992** (69 days)	**1993** (48 days)	**1994** (45 days)	**2006** (27 days)
Number of individuals captured	317	321	375	398
Total captures	354	389	419	423
Recaptures after 1 day	25	54	30	21
2 days	8	8	10	4
3	2	2	2	0
4	1	1	1	0
5	1	0	0	0
Estimated total male population during period of captures:				
Fisher-Ford method	**524**	**456**	**736**	
MARK method				**440**
JOLLY method				**1230**

4.3 Habitat assessment

4.3.1 Vegetation

The 0.56 ha of Golden Sun Moth habitat on this site is defined by the fenced and mown area, and includes native pasture (adjacent to Sydney Avenue) and Natural Temperate Grassland (0.4 ha). The verges and median strips of the adjacent roads provide a degraded grassland buffer, which has the potential to become auxiliary habitat if rehabilitated.

Previous descriptions of habitat for this species have suggested that a minimum density of 40% Wallaby Grass *Austrodanthonia* cover is required to sustain a Golden Sun Moth population (*e.g.* Dear 1997 in ACT Government 2005, O'Dwyer & Attiwill 1999). Wallaby Grass cover can vary considerably on a site over a year, being affected by factors such as heavy grazing and low summer growth rates. Recent surveys in the ACT have found Golden Sun Moths on sites which have much lower cover of Wallaby Grasses, but the condition and population trends of the Golden Sun Moth populations on these sites is not known (Braby & Dunford 2006, Rowell 2005). Recent detailed studies at a Victorian site found that Wallaby Grass cover at Golden Sun Moth sites varied from 0% to 37%, and did not find a strong correlation between numbers of flying males and Wallaby Grass cover (Gibson 2006).

Five species of Wallaby Grass were recorded on the study site, the most common being Short Wallaby Grass *Austrodanthonia carphoides* and *A. laevis*. Three 20 metre x 20 metre vegetation quadrats in the north, centre and south of the site were assessed. Wallaby Grasses were present in all quadrats, but none had cover greater than 25% (see Appendix 3 and Figures 9 to 11). More moths were captured in the central sector which had lower cover of Tall Speargrass *Austrostipa bigeniculata*, higher cover of forbs (non-grass species) and more open ground than the other two sectors where the vegetation was surveyed.

The unmown part of Block 3, west of the study site, was dominated by exotic species such as Phalaris *Phalaris aquatica*, Hoary Mustard *Hirschfeldia incana* and Wild Oats *Avena* species. It also contained scattered native grasses, including Wallaby Grasses *Austrodanthonia laevis* and *A. bipartita*, which is an uncommon species in the ACT (Isobel Crawford pers. comm.). This part of Block 3 is very disturbed, and may have received fill during the construction of the R G Casey Building (to the west). It is not considered to be Golden Sun Moth habitat, and it is currently a source of weeds for the habitat area (Figure 8).

The vegetation on the Sydney Avenue median strips was also dominated by exotic species, the most common being Chilean Needlegrass *Nassella neesiana*. This exotic grass was recently found to be the dominant species on a floodplain of Ginninderra Creek where Golden Sun Moths occur, and it has been suggested that it is a possible food plant of Golden Sun Moth larvae, but this has not been confirmed (Braby & Dunford 2006). Wallaby Grasses made up less than 5% of the vegetation cover on the median strips, and no evidence was found that Golden Sun Moths had emerged there, nor were any females observed there (Figure 12).

Figure 8. Disturbed vegetation in Block 3, west of Golden Sun Moth habitat. Dominated by Phalaris, with scattered Wallaby Grass *Austrodanthonia bipartita.*

Figure 9. Vegetation in Sector 2 (Block 7) of Golden Sun Moth site. Low quality Natural Temperate Grassland, low diversity of native grasses with some common forbs.

Figure 10. Vegetation in Sector 2 (centre of Block 3) of Golden Sun Moth site. Moderate quality Natural Temperate Grassland, moderate diversity of native grasses and forbs, patches of bare ground.

Figure 11. Vegetation in Sector 8 (south end Block 3) of Golden Sun Moth site. Native pasture, low diversity of native grasses and exotic species, few native forbs.

Figure 12. Median strip of Sydney Avenue, east of National Circuit. Dominated by exotic species, low cover of native grasses, much bare ground.

4.3.2 Canberra Raspy Cricket *Coorabooorama canberrae*

Active burrows of the uncommon Canberra Raspy Cricket *Coorabooorama canberrae* were found scattered across the site. This is a large wingless cricket, known only from relatively undisturbed grasslands in the lower parts of the Majura, Jerrabomberra and Molonglo valleys, and a small number of other locations in the ACT and nearby NSW (Queanbeyan-Bungendore). Much of its known habitat has been lost to housing in the ACT, and it is vulnerable to habitat fragmentation because it is flightless. It makes distinctive vertical burrows with a round cross-section, a clay and silk cap and a circle of bare soil around the entrance (Figures 13 & 14). The endangered Grassland Earless Dragon is known to use the abandoned burrows of this species as shelter sites. Information about this animal could be included in interpretative signage on the site.

Figure 13. Capped burrow of Canberra Raspy Cricket.

Figure 14. Female Canberra Raspy Cricket.
(5mm grid)

4.4 Assessment of shading effects of building options

The features of the building design options (Colin Stewart Architects) are summarised in Tables 3 and 4, and their potential effect on the Golden Sun Moth population is discussed below.

Table 3. Building design options.

Design option	Building height	Setback from reserve	Time shadow enters habitat area on 21 June	*Portion of habitat shaded on 21 June at 1500 hrs (EST)
1	5 storeys	28 metres	ca 1330 hours	ca 47%
2	5 storeys	40	1415	26%
3a	4 storeys	24	1400	25%
3b('wings')	4 storeys	24	1300 (wing)	26%

***** assumes access road to Block 7 is not constructed north of Block 3.

Table 4. Details of shading by Option 3b.

Date	Time shadow enters habitat (EST)	Portion of habitat shaded at time
21 June	1300 hrs	1500 hrs: 27.0%
21 March/23 September	1400 hrs	1500 hrs: 4.4% 1600 hrs: 32.0%
22 December	1700 hrs	1800 hrs: 8.4%

4.4.1 Option 1 (November building design)

This building has 5 levels and a 40 m frontage to Sydney Avenue. It is set back 28 m from the current grassland reserve boundary.

The effect of shading on the grassland and Golden Sun Moth habitat by this building is likely to be significant. The shadow enters the site by 1330 hrs in winter, and 47% is shaded by 1500 hrs. In spring and autumn the building shadow enters the grassland at about 1430 hrs. In summer the effect is less, and the building shadow has not reached the grassland boundary by 1600 hrs.

This level of shading will reduce soil temperatures and increase soil moisture, particularly between autumn and spring. This is likely to favour weed species over the native grasses and forbs, which are not adapted to shading. This could reduce the density of Wallaby Grasses, the roots of which are thought to be the primary food for the moth.

4.4.2 Option 2 (January building design)

This building has a 35 m frontage to Sydney Avenue. It has 5 levels with the uppermost level being set back from the edge nearest the reserve. It is placed closer to Windsor Walk than Option 1, and set back about 40 m from the boundary of the grassland reserve.

Reducing the profile and footprint of the building and moving it further from the reserve boundary reduces the amount of shading of the grassland reserve. The building shadow does not enter the site until about 1430 hrs in winter, and by 1500 hrs about 26% of the site is shaded.

This building design is likely to have a lesser effect on the activity of adult Golden Sun Moths during their breeding period in early summer, and reduces the daily number of hours of shading from autumn to spring.

4.4.3 Option 3a (February Building Design)

This building causes slightly more shading of the Golden Sun Moth site at the winter solstice than Option 2. The building is lower than the other two options, but is closer to the reserve boundary than Option 2.

4.4.4 Option 3b, with 'wings' (March Building Design)

This option results in slightly more shading of the site than Options 2 and 3. The small shadow of the 'wings' enters the site earlier, and the main building shadow enters at the same time as for Option 3a.

4.4.5 Access road to Block 7

The construction of this road and its associated landscaping would destroy or negatively affect about 21% of the existing natural temperate grassland and Golden Sun Moth habitat in Section 22.

5. Discussion

5.1 Significance of the York Park Golden Sun Moth population

5.1.1 Species conservation status

In 2002, the conservation status of the Golden Sun Moth was raised from Endangered to Critically Endangered under the *EPBC Act 1999.* A Critically Endangered species is considered to be facing an extremely high risk of extinction in the wild in the immediate future. Many new populations of this species have been discovered in recent years (Clarke & O'Dwyer 1998, Clarke 2000, Clarke 2001, A. Rowell pers. obs., Mark Dunford pers. comm.), but many are small and relatively few are in reserves. Eight populations in the Canberra-Queanbeyan area are currently reserved.

5.1.2 Genetic status

Genetic analysis of Golden Sun Moth populations across its entire range in the ACT, NSW and Victoria has identified five distinct population groups based on genetic variation and diversity (Clarke & O'Dwyer 1998, revised in Clarke 2000 and 2001). The genetic distance between groups corresponds with geographic separation, and it was recommended that the groups be treated as separate units for conservation management. It was also recommended that a minimum of two populations from each genetically defined cluster should be considered for priority conservation management, with the aim of conserving and maintaining as much genetic diversity and variability as possible within the species. Selection of priority sites for conservation is based on the genetic variation and diversity of the population, as well as site size, quality and tenure.

The most recent genetic analysis (Clarke 2001) puts the York Park population in a genetic sub-group (within a larger ACT/NSW group) that includes large populations at the Belconnen Naval Station, Majura Valley East, Mulanggary Grassland Reserve and Jerrabomberra Reserve (Woden) in the ACT and Letchworth Reserve in NSW, and smaller sites at Black Street in Yarralumla, Mulligans Flat Reserve and Campbell Park paddocks in the ACT. Four of the ten populations in this group have been given a High Conservation Value rating by the ACT Government, and four are already in reserves. A large part of the decommissioned Belconnen Naval Station (High Conservation Value site) is likely to be incorporated into a reserve in the future, and the Campbell Park site is also likely to become part of the Canberra Nature Park. On current information it appears that the genetic characteristics of the group containing the York Park population are reasonably well protected.

5.1.3 Population trends

Numbers of males at this site appear to be stable or increasing, but the sex ratio still appears skewed. A refinement of survey methods would be necessary to determine the actual sex ratio, which is relevant to the long-term viability of the population. The length of the larval period is still uncertain. A larval period longer than one year could mean that there is a lag between events that have an impact on the population and the detection of that impact by surveys of adult abundance.

As noted previously, the York Park population has been given a Moderate Conservation Rating by the ACT Government, and is considered to warrant special attention due to its long research history. The life history of the Golden Sun Moth is still poorly known, and apart from genetic studies, little biological and ecological research has been undertaken on the species. The previous population surveys carried out at the York Park site are the only such detailed studies carried out on the species so far.

To obtain information necessary for the recovery of the species, it is important to undertake long-term monitoring of Golden Sun Moth populations and their habitat, to determine population trends and the viability of populations. The results of such monitoring can be used in the refinement of management guidelines for the species.

With four seasons of mark-release-recapture surveys already undertaken between 1992 and 2006, there is a database of information on medium-term population trends at this site that is unmatched elsewhere. Baseline genetic data has also been collected (Clarke & O'Dwyer 1998), and future genetic surveys can test this small isolated population for continued viability and to find if it is affected by inbreeding or genetic drift. This information is important in setting conservation priorities for other small populations, and in predicting the effect of fragmentation of populations.

5.1.4 Educational opportunities

Education and community involvement are also important in the recovery of threatened species. The location of this site in the central Canberra area makes it ideal for educating local people and visitors about the biology and conservation of the Golden Sun Moth and Natural Temperate Grassland. Access is good, and the two street frontages provide the opportunity for interpretative signage and viewing areas that do not damage the habitat.

5.2 Potential impacts of proposed development

5.2.1 General effects of shading

There is little specific data on the effect of shading on Golden Sun Moth populations, but the available information (summarised below) suggests that it would be deleterious for the moths and for the Natural Temperate Grassland, as it would reduce soil temperature and increase soil moisture.

More adult moths tend to emerge after a dry winter (Edwards 1995), suggesting that higher soil moisture between autumn and spring has a negative effect on the survival of larvae and pupae. Soil changes caused by shading could affect larval development directly, change the proportion of food plants in the grassland and encourage weed growth. Ongoing reduced larval survival could lead to the extinction of the Golden Sun Moth population on this site.

The 2006 Golden Sun Moth survey at York Park found that the moths were more numerous at (and possibly emerged from) the central to northern part of the site early in the season, and the southern end of the site later on. This has been noted in previous surveys on the site (Cook & Edwards 1993, 1994, Harwood *et al.* 1995), and is probably due to the effect of soil conditions on the timing of larval development and/or adult emergence, as the northern part of the site is better drained. Changes in the distribution of moth activity during the flying season has also been noted at larger local sites (Braby 2005, Clarke & Dunford 1999), probably indicating the effects of aspect and slope on soil temperature and moisture.

Small populations of Golden Sun Moth are known from a few sites in Canberra containing remnants of native grassland with exotic tree plantings (M. Dunford, Environment ACT pers. comm., A. Rowell pers. obs.). Few of these urban sites are subject to significant shading, being sparsely planted with small trees and/or containing deciduous trees which minimise winter shading. A small (0.9 ha) site near Dudley Street Yarralumla (ACT Government 1998) has mature radiata pines to the south-east and north-west. In November/December 2006 it was noticeable that the male moths were not flying near the north-western group of pines. The shade from these trees was associated with an area of denser vegetation, with more weeds and less Wallaby Grass than the sunnier parts of the site (A. Rowell pers. obs.). A very small site (<0.05ha) discovered in the suburb of Griffith in November 2006 (A. Rowell pers. obs.) is subject to some shading from buildings and evergreen hedges, but nothing is known about the size and viability of the Golden Sun Moth population on this site.

5.2.2 Natural versus artificial shading

All of the building designs subject the site to more shading than it currently receives, and provide more than the natural shading of known Golden Sun Moth habitats in the district. For instance, a site on Ginninderra Creek in West Macgregor ACT (Braby 2005) includes a steep slope, which rises 20 metres over a distance of 150 metres, west of known habitat. This hillslope would cause loss of sunlight to the lower habitat area earlier in the afternoon than a site with a flatter topography would experience, but the shading would be less than that caused by all the building options for Section 22, which are a similar height but much closer to the habitat.

5.2.3 Assessment of building options

Option 1 shades the Golden Sun Moth habitat to an unacceptable degree. This is likely to change environmental conditions on the site to the extent that the composition and structure of the grassland are altered, and the continued survival of the Golden Sun Moth population is put at risk.

Option 2 reduces the potential for such effects on the natural temperate grassland and the Golden Sun Moth habitat, but the long term effect of shading by this option on the Golden Sun Moth population on this small site is unknown.

Options 3a and 3b would have slightly more impact on the reserve than Option 2.

Access road

The construction of the access road through the narrow extension of Block 7 at the northern end of the grassland reserve is inadvisable, due to the damage it is likely to cause to the Golden Sun Moth population. The loss of 21% of an already small area of habitat would greatly increase the risk of the extinction of the species on this site. Six other ACT sites ranging from 0.1 to 3 ha in area are rated as being so small that the continued survival of their moth populations is in doubt (ACT Government 1998).

Associated structure

All options include paved areas and landscaping between the building and the reserve. This area can be managed in a way that limits its impact on the grassland and Golden Sun Moth habitat (run-off, run-on, nutrification, shading etc). The natural contours of the site prevent run-on from the west at the moment, and this situation should be maintained.

Landscaping between the building and the Golden Sun Moth habitat should be designed to minimise shading and weed incursion. Trees should be lower than the building shadow. It would be desirable to plant a buffer zone between the carpark/road and the habitat with non-invasive ground covers that do not require irrigation. This zone could also be planted with native grasses and mown, to provide a ‘soft edge’ to the habitat. If this were done, it would be essential to use seed or other propagation material sourced from the central Canberra area. Wallaby Grasses (*Austrodanthonia* species) native to the site could provide an extension of the habitat area.

6. Recommendations

Blocks 3 and 7 Section 22 Barton contain a population of the Golden Sun Moth *Synemon plana*, which is listed as a critically endangered species under the *EPBC Act 1999.* This population:

- has proved to be viable in the medium term
- is located in an endangered vegetation community
- is of scientific value due to its research history
- and may suffer adverse impacts from development of the adjacent part of Block 3.

Therefore, the following recommendations are made:

- Proposed development on or adjacent to Block 3 Section 22 Barton should be the subject of a referral to the Department of Environment and Water Resources under the *EPBC Act 1999.*
- The Golden Sun Moth habitat on Block 7 (Territory land) should be treated as an integral part of the habitat.
- If development takes place on or adjacent to Block 3 Section 22 Barton, the site should be protected as far as possible during and after construction from impacts to the site from shading by buildings or trees, vehicle and pedestrian traffic, soil compaction and disturbance, dumping, weed invasion, run-on of water and nutrients etc. The present log fence at the National Circuit side of the site has portions that have been lifted out to allow vehicles unauthorised access to the site.
- Fencing on three sides would reduce through traffic and protect the site from damage, while allowing access for education, maintenance and research activities. A fence which discourages perching by predatory birds and allows passage of moths is desirable.
- The site should be used for interpretation and education activities related to the Golden Sun Moth and the Natural Temperate Grassland. This could include signs and viewing platforms suitable for school groups and bus tours, incorporation of stylised moth and plant designs into the fence etc. Local grassland plants (particularly Wallaby Grasses) could be used in landscaping in buffer areas, to extend the existing habitat. If this is done, it would be preferable to source the seed from the existing site.
- Future management of the site should follow the guidelines previously laid down (Edwards 1995).

- The existing database of population estimates should be built on. Future surveys on the site should use the Robust Design every 4-5 years, and a standard monitoring protocol should be used to develop an index of abundance based on observation for use in both capture-survey years (for calibration) and in the intervening years. Robust Design uses mark-recapture methods in a nested sampling structure, which removes the necessity to capture animals every day. Primary sampling sessions are undertaken at fixed intervals, with mortality and immigration taking place between primary sessions, so that open population models apply at this level. The second level of sampling has a short mark-recapture study within each primary session, and closed population models are then used to estimate the species abundance at each primary session.

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APPENDIX 1
MARK ANALYSIS
Method

The data set of 398 encounter histories was analysed with the open-capture models in MARK (White & Burnham 1999). A set of a priori models was initially developed, analysed and then ranked by the AICc (Akaike's information criterion) values following analysis in the program MARK. The model with the lowest AIC's criteria is the best fitted model and was used to analyse N (super population size), phi (apparent survival), p ((re)capture probability) and pent (probability of entry).

Results

The best approximating model for open populations used for this analysis was the POPAN model (included in the program MARK). Constant parameters for "apparent survival (phi)"; "recapture (probability of capture p)" and "probability of entry (pent)" are included in this model that provides a parameterization of the Jolly Seber model (Schwarz and Arnason 1996). We used the "POPAN" model rather then the "Jolly Seber" model because the likelihood function better converged with "POPAN".

Estimation of real Function Parameters of Phi(.) p(.) pent(.) N(.)

			95% Confidence Interval	
Parameter	Estimate	Standard Error	Lower	Upper
1:Phi	0.0660405	0.0118929	0.0462169	0.0935331
2:p	0.9044230	0.0489270	0.7573096	0.9663250
3:pent	1.0000000	0.4294350E-07	0.9999999	1.0000001
4:N	439.57621	24.782598	412.10894	520.51671

The very low survival probability (phi) results from the extremely low life expectancy for *S. plana* males. The maximum life span was estimated as 2.0 days, where as the average life span of males was estimated as 1.08 days (n=24, SE= 0.057). The total population size was estimated with 440 individuals varying between 412 and 520.

Reference

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement:120-138.
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APPENDIX 2

```
                    P R O G R A M    J O L L Y
                     =============    =========
                     LAST REVISED :   01/21/98
```

Program JOLLY output contains analyses for as many as 5 different capture-recapture models.

Model A is the standard Jolly-Seber model for open populations (Jolly 1965; Biometrika 52: 225-241).

Model A' is the "Death But No Immigration" model of Darroch (1959: Biometrika 46: 344-349) and
Jolly (1965; Biometrika 52: 241-242).

Model 2 is the capture-resighting model of Brownie and Robson (1983; Biometrics 39:437-453) permitting an effect
of initial capture and tagging on first period survival rate.

Model B is the Jolly-Seber model with survival rate assumed constant per unit time
and time-specific capture probability.

Model D is the Jolly-Seber model with both survival rate and capture probability assumed constant per unit time.

Model AX is equivalent to model A except it includes between-period resighting data.
The following capture-history codes have been added:
3 - not captured in time i, resighted between i and i+1,
4 - captured in time i, resighted between i and i+1.

******** Definitions and Notation
****

M(i) = Estimated number of marked animals in the population at time i.

p(i) = Estimated probability that an animal alive at time i is captured in the i-th sample

N(i) = Estimated population size at time i

PHI = Estimated probability that an animal alive at time i survives to time i+1

PHI* = Estimated probability that an animal caught for the first time in sample i
survives to time i+1 (Model 2 only)

B(i) = Estimated number of new animals recruited during the interval i to i+1
and alive at time i+1 (Recruitment includes birth and immigration)

SE(x) = Standard error of parameter x including non-sampling error terms

SE'(x) = Standard error of parameter x excluding non-sampling error terms

COV(X(i,j)) = Covariance between estimates X(i) and X(j).

r(i) = Number of animals caught in sample i, and recaptured later

z(i) = Number of animals caught before and after sample i, but not caught in sample i

z'(i) = z(i) + animals caught for the first time subsequent to sample i

```
 Notes: Estimates of PHI,N,M,and B under models A and A' are computed using bias
corrected formulae
        of Seber (1973:204; The Estimation of Animal Abundance and Related Parameters,
Griffin, London)
        except when z(i)=0;then N(i)= Number caught in sample i.

        95% Confidence intervals are computed using the standard error which includes
sampling variation (SE(x)).

        Estimates which cannot be computed due to poor data (m(i),r(i),z(i),... = zero)
are denoted by "Div/0".
        (Means do not include these values.)

 INPUT==>TITLE=GSM TEST RUN
 CONTROL RECORD:TITLE=
 GSM TEST RUN
 INPUT==>NUMBER OF PERIODS=32
 CONTROL RECORD:PERIODS= 32
 INPUT==>FIRST=2006
 CONTROL RECORD:FIRST= 2006
 INPUT==>INTERVALS=1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1
 INPUT==>  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.
  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.  1.
 INPUT==>FORMAT=(32(I1),I1)
 INPUT==>10000000000000000000000000000000 1;
```

```
 JOLLY (Ver:01/21/98)  GSM TEST RUN
4/13/07  10:52

 Number of sampling periods =    32
 Input format         = (32(I1),I1)
 Max iterations       =    100
 Convergence criterion = 0.1000E-03

 Time period interval lengths =
   1.00000000   1.00000000   1.00000000   1.00000000   1.00000000   1.00000000
1.00000000   1.00000000   1.00000000   1.00000000
   1.00000000   1.00000000   1.00000000   1.00000000   1.00000000   1.00000000
1.00000000   1.00000000   1.00000000   1.00000000
   1.00000000   1.00000000   1.00000000   1.00000000   1.00000000   1.00000000
1.00000000   1.00000000   1.00000000   1.00000000
   1.00000000
 Data type:CAPTURE HISTORY (1)  -
 (32(I1),I1)

    404 Input records read


 Data summarized in "B-Table" format (See Leslie, Chitty and Chitty 1953; Biometrika
40:137-169).

 Time of !
    last !          Time of recapture
 capture ! 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020
2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037
 ------------------------------------------------------------------------------------
----------------------
    2006 !    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2007 !    0    0    3    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2008 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2009 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2010 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2011 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2012 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2013 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2014 !    0    0    0    0    0    0    0    0    0    2    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2015 !    0    0    0    0    0    0    0    0    0    0    2    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2016 !    0    0    0    0    0    0    0    0    0    0    0    1    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2017 !    0    0    0    0    0    0    0    0    0    0    0    0    1    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2018 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2019 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    2
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2020 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
1    2    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2021 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2022 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    1    0    0    0    0    0    0    0    0    0    0    0    0    0
    2023 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2024 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    1    0    0    0    0    0    0    0    0    0    0    0
    2025 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    2    0    0    0    0    0    0    0    0    0    0
```

```
    2026 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    2    0    0    0    0    0    0    0    0    0    0
    2027 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    1    0    0    0    0    0    0    0    0    0
    2028 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    2    0    0    0    0    0    0    0    0
    2029 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2030 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2031 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2032 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2033 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2034 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2035 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2036 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2037 !    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

 Marked  !    0    1    3    0    0    0    0    0    0    2    2    1    1    0    3
1    2    1    0    1    2    2    1    2    0    0    0    0    0    0    0    0
 Unmarked!   17   20   15   18   20   17   20   16   18   17   19   20   17   18   10
19   19   19   18    8    9   18   10    6    0    7    3    0    0    0    0    0
 Caught  !   17   21   18   18   20   17   20   16   18   19   21   21   18   18   13
20   21   20   18    9   11   20   11    8    0    7    3    0    0    0    0    0
 Released!   17   21   18   18   20   17   20   16   18   19   21   21   18   18   13
20   21   20   18    9   11   20   11    8    0    7    3    0    0    0    0    0

 Other summary stats:

 R(i)    !    1    3    0    0    0    0    0    0    2    2    1    1    1    2    3
0    1    0    1    2    2    1    2    0    0    0    0    0    0    0    0    0
 z(i)    !    0    0    0    0    0    0    0    0    0    0    0    0    0    1    0
2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 z'(i)   !  381  361  346  328  308  291  271  255  237  220  201  181  164  147  136
119   98   79   61   53   44   26   16   10   10    3    0    0    0    0    0    0


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4/13/07  10:52

 Model D - Constant survival rate per unit time, constant capture probability.

  Parameters: PHI = Estimate of survival rate
              p   = Capture probability


  Definitions:
    THETA  = Vector of parameters
    1-X(i) = Probability that an animal alive just after period i is subsequently
recaptured
    T(i)   = Time units between periods i and i+1


 Starting values of THETA :           0.1810      0.8765

 Final values after     35 iterations:


                                    Standard
 Parameter                Variance    error        95% confidence interval
Covariance(P,PHI)
 ---------------------------------------------------------------------------------------
---------
```

PHI 0.1599 0.00079606 0.0282 0.1046 - 0.2153 - 0.00177829

p 0.3300 0.00510956 0.0715 0.1899 - 0.4701

Period	M	Variance	Standard error	95% confidence interval
2007	2.71	4.8039	2.19	-1.59 - 7.00
2008	8.12	15.7044	3.96	0.35 - 15.88
2009	0.00	0.0000	0.00	0.00 - 0.00
2010	0.00	0.0000	0.00	0.00 - 0.00
2011	0.00	0.0000	0.00	0.00 - 0.00
2012	0.00	0.0000	0.00	0.00 - 0.00
2013	0.00	0.0000	0.00	0.00 - 0.00
2014	0.00	0.0000	0.00	0.00 - 0.00
2015	5.41	9.9915	3.16	-0.78 - 11.61
2016	5.41	10.1798	3.19	-0.84 - 11.66
2017	2.71	4.9071	2.22	-1.64 - 7.05
2018	2.71	4.8609	2.20	-1.62 - 7.03
2019	2.71	4.8566	2.20	-1.61 - 7.03
2020	8.12	15.7234	3.97	0.35 - 15.89
2021	8.12	16.0097	4.00	0.27 - 15.96
2022	5.41	10.3056	3.21	-0.88 - 11.70
2023	2.71	4.9138	2.22	-1.64 - 7.05
2024	0.00	0.0000	0.00	0.00 - 0.00
2025	2.71	4.8095	2.19	-1.59 - 7.00
2026	5.41	10.0911	3.18	-0.81 - 11.64
2027	5.41	10.1940	3.19	-0.85 - 11.67
2028	2.71	4.9080	2.22	-1.64 - 7.05
2029	5.41	10.1114	3.18	-0.82 - 11.64
2030	0.00	0.0000	0.00	0.00 - 0.00
2031	0.00	0.0000	0.00	0.00 - 0.00
2032	0.00	0.0000	0.00	0.00 - 0.00
2033	0.00	0.0000	0.00	0.00 - 0.00
2034	0.00	0.0000	0.00	0.00 - 0.00
2035	0.00	0.0000	0.00	0.00 - 0.00
2036	0.00	0.0000	0.00	0.00 - 0.00
2037	0.00	0.0000	0.00	0.00 - 0.00
MEAN	2.44	11.2803	3.36	-4.14 - 9.03

Period	N	Variance	Standard error	95% confidence interval
2007	63.32	311.9989	17.66	28.70 - 97.94
2008	53.57	232.4437	15.25	23.69 - 83.46
2009	54.55	253.8202	15.93	23.32 - 85.78
2010	60.61	295.7702	17.20	26.90 - 94.32
2011	51.52	229.0995	15.14	21.85 - 81.18
2012	60.61	295.3599	17.19	26.93 - 94.29
2013	48.49	208.6926	14.45	20.17 - 76.80
2014	54.55	250.3096	15.82	23.54 - 85.56
2015	56.93	259.1699	16.10	25.38 - 88.48
2016	62.99	307.4358	17.53	28.62 - 97.36
2017	63.32	314.8583	17.74	28.54 - 98.09
2018	54.22	245.2944	15.66	23.53 - 84.92
2019	57.25	267.0851	16.34	25.22 - 89.29
2020	38.42	138.7512	11.78	15.33 - 61.51
2021	65.70	325.8699	18.05	30.31 - 101.08

2022	62.99	309.1549	17.58	28.53 -	97.45
2023	60.29	291.3501	17.07	26.83 -	93.74
2024	54.55	251.7103	15.87	23.45 -	85.64
2025	26.95	86.3764	9.29	8.73 -	45.17
2026	32.69	111.5742	10.56	11.98 -	53.39
2027	59.96	284.2105	16.86	26.92 -	93.00
2028	33.01	116.8001	10.81	11.83 -	54.19
2029	23.59	70.0911	8.37	7.19 -	40.00
2030	0.00	0.0000	0.00	0.00 -	0.00
2031	21.21	64.2895	8.02	5.50 -	36.93
2032	9.09	22.3381	4.73	-0.17 -	18.36
2033	0.00	0.0000	0.00	0.00 -	0.00
2034	0.00	0.0000	0.00	0.00 -	0.00
2035	0.00	0.0000	0.00	0.00 -	0.00
2036	0.00	0.0000	0.00	0.00 -	0.00
2037	0.00	0.0000	0.00	0.00 -	0.00
MEAN	39.69	2331.2585	48.28	-54.95 -	134.32

Period	B	Variance	Standard error	95% confidence interval
2007	38.96	146.5820	12.11	15.23 - 62.69
2008	49.68	207.3209	14.40	21.46 - 77.90
2009	54.76	237.7612	15.42	24.54 - 84.99
2010	45.02	178.3026	13.35	18.85 - 71.19
2011	55.09	240.5426	15.51	24.69 - 85.49
2012	41.99	162.0113	12.73	17.04 - 66.94
2013	49.35	204.8482	14.31	21.30 - 77.40
2014	45.67	182.4908	13.51	19.19 - 72.15
2015	52.06	221.0530	14.87	22.92 - 81.20
2016	54.44	235.0296	15.33	24.39 - 84.49
2017	45.02	178.3026	13.35	18.85 - 71.19
2018	49.03	202.4254	14.23	21.14 - 76.91
2019	24.46	83.6935	9.15	6.53 - 42.39
2020	54.33	240.4888	15.51	23.94 - 84.73
2021	51.41	215.9484	14.70	22.61 - 80.21
2022	51.41	215.9484	14.70	22.61 - 80.21
2023	48.38	197.7292	14.06	20.82 - 75.94
2024	18.40	63.2230	7.95	2.81 - 33.98
2025	24.68	80.6233	8.98	7.08 - 42.28
2026	51.63	223.2035	14.94	22.34 - 80.91
2027	24.46	83.6935	9.15	6.53 - 42.39
2028	14.94	46.9778	6.85	1.50 - 28.37
2029	-1.95	3.4785	1.87	-5.60 - 1.71
2030	21.21	64.1906	8.01	5.51 - 36.92
2031	6.82	22.2835	4.72	-2.43 - 16.07
2032	-0.97	1.5150	1.23	-3.39 - 1.44
2033	0.00	0.0000	0.00	0.00 - 0.00
2034	0.00	0.0000	0.00	0.00 - 0.00
2035	0.00	0.0000	0.00	0.00 - 0.00
2036	0.00	0.0000	0.00	0.00 - 0.00
MEAN	32.34	1112.3485	33.35	-33.03 - 97.71

JOLLY (Ver:01/21/98) GSM TEST RUN
4/13/07 10:52

Per	Test of model D vs model A T1	T2	Test of model B vs model A T1	T2	Test of model D vs modelB T1	T2
2006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2007	1.4549	0.0000	0.0000	0.0000	0.0000	0.0000
2008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2014	4.2943	0.0000	0.0000	0.0000	0.0000	0.0000
2015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2016	0.1815	0.0000	0.0000	0.0000	0.0000	0.0000
2017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2018	0.0430	0.0000	0.0000	0.0000	0.0000	0.0000
2019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2021	1.3892	0.0000	0.0000	0.0000	0.0000	0.0000
2022	0.0000	0.5109	0.0000	0.0000	0.0000	0.0000
2023	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2024	0.6745	0.0000	0.0000	0.0000	0.0000	0.0000
2025	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2027	3.1217	0.0000	0.0000	0.0000	0.0000	0.0000
2028	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2029	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2030	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2031	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2032	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2034	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2035	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

```
  2036           0.0000           0.0000           0.0000           0.0000
0.0000           0.0000

 Total          11.1591           0.5109           0.0000           0.0000
0.0000           0.0000

     Total chi-square   =      11.6701     Total chi-square   =       0.0000     Total
chi-square   =       0.0000
     Degrees of freedom =        6         Degrees of freedom =      -32         Degrees
of freedom =      -31
     Probability        =       0.0697     Probability        =       1.0000
Probability        =       1.0000

 Likelihood-Ratio test of model A versus model 2:

   Hypothesis: Survival rate of newly captured animals =  survival rate of previously
captured animals.

               Chi-square =     0.0000 with   0 degrees of freedom (Probability =
1.0000)

 Goodness-of-fit tests:

 Model   Chi-square     DF    Probability
 -----   ----------     --    -----------
   A        0.0000       0      1.0000

   2        0.0000       0      1.0000
```

APPENDIX 3
VEGETATION ASSESSMENT
QUADRANT 1

Site No.	Block 3(part), Block 7(part), Section 22 Barton	**Date**	14-Jan-07	**Recorder**	A. Rowell
AMGE		**Location**	York Park Golden Sun Moth site, NW corner of National Circuit and Sydney Avenue intersection. In sector 5 (centre of site).		
AMGN					

Veg type	grassland	**Groundlayer**	NTG
G'layer diversity	Moderate	**G'layer structure**	high
Rocky	0	**Fallen timber**	0
Bare ground	3	**Topography**	footslope
Litter	3	**Moss/lichen**	2

Notes 20 metre x 20 metre quadrat. Dominant species *Austrodanthonia/Bothriochloa/Austrostipa/Chrysocephalum*.
Flush of summer growth in response to storms. *Austrostipa bigeniculata, Tricoryne, Goodenia, Chrysocephalum, Wahlenbergia* flowering.

Native species	f code
Austrodanthonia laevis + A. carphoides	3
Bothriochloa macra	3
Austrostipa bigeniculata	3
Chrysocephalum apiculatum	3
Wahlenbergia communis	2
Wahlenbergia luteola	2
Tricoryne elatior	2
Lomandra sp.	2
Goodenia pinnatifida	2

Exotic species	f code
Hypochaeris radicata	2
Plantago lanceolata	2
Gnaphalium americanum	1
Hypericum perforatum	1
Vulpia sp.	1
Lactuca serriola	1
Tragopogon porrifolius	1

1 - <5% u
2 - <5% c
3 - 5-25%
4 - 25-50%
5 - 50-75%
6 - >75%

Calocephalus citreus	2
Panicum effusum	1
Themeda triandra	1
Lomandra filiformis var. *filiformis*	1
Eryngium ovinum	1
Pimelea curviflora	1
Elymus scaber	1

More species on back (y/n)	n

QUADRANT 2.

Site No.	Block 3(part), Block 7(part), Section 22 Barton	**Date**	14-Jan-07	**Recorder**	A. Rowell
AMGE		**Location**	York Park Golden Sun Moth site, NW corner of National Circuit and Sydney Avenue intersection. In sector 8 (southern end of site).		
AMGN					

Veg type	grassland	**Groundlayer**	NTG/NP
G'layer diversity	L/M	**G'layer structure**	medium
Rocky	0	**Fallen timber**	0
Bare ground	2	**Topography**	footslope
Litter	3	**Moss/lichen**	2

Notes 20 metre x 20 metre quadrat. Dominant species *Austrostipa bigeniculata/Austrodanthonia*.
Disturbance in quadrat, large tree roots, stump hole? + rabbits? Active holes of Canberra Raspy Cricket *Cooraboorama canberrae,* Wolf Spiders

Native species	f code
Austrostipa bigeniculata	4
Austrodanthonia laevis (+ *A. bipartita)*	3
Bothriochloa macra	2
Goodenia pinnatifida	2
Wahlenbergia communis	2
Wahlenbergia luteola	2
Eryngium ovinum	2
Asperula conferta	2
Lomandra (2 species)	1
Chrysocephalum apiculatum	1
Rumex brownii	1

Exotic species	f code
Plantago lanceolata	3
Dactylis glomeratum	3
Paspalum dilatatum	2
Nassella neesiana	2
Avena sp.	1
Bromus sp.	1
Festuca arundinacea	1
Hypochaeris radicata	1
Lactuca serriola	1
Tragopogon porrifolius	1
Festuca sp.	1

1 - <5% u
2 - <5% c
3 - 5-25%
4 - 25-50%
5 - 50-75%
6 - >75%

Glycine tabacina	1
Convolvulus erubescens	1
Acaena sp.	1
Calocephalus citreus	1

More species on back (y/n)	n

QUADRANT 3

Site No.	Block 3(part), Block 7(part), Section 22 Barton	**Date**	14-Jan-07	**Recorder**	A. Rowell
AMGE		**Location**	York Park Golden Sun Moth site, NW corner of National Circuit and Sydney Avenue intersection. In sector 2 (northern end of site).		
AMGN					

Veg type	grassland	**Groundlayer**	NTG
G'layer diversity	medium	**G'layer structure**	medium
Rocky	0	**Fallen timber**	0
Bare ground	2	**Topography**	footslope
Litter	3	**Moss/lichen**	2

Notes 20 metre x 20 metre quadrat. Dominant species *Austrostipa bigeniculata/Bothriochloa/Austrodanthonia.*
Less diverse than Quadrat 1, less weedy than Quadrat 2.

Native species	f code
Austrostipa bigeniculata	4
Austrodanthonia laevis + *A.* species	3
Bothriochloa macra	3
Chrysocephalum apiculatum	2
Wahlenbergia communis	2
Lomandra filiformis var. *filiformis*	2
Wahlenbergia luteola	1
Tricoryne elatior	1
Plantago varia	1
Goodenia pinnatifida	1
Panicum effusum	1

Exotic species	f code
Hypochaeris radicata	2
Plantago lanceolata	2
Paspalum dilatatum	1
Centaurium erythraea	1
Nassella trichotoma	1

1 - <5% u
2 - <5% c
3 - 5-25%
4 - 25-50%
5 - 50-75%
6 - >75%

More species on back (y/n)	