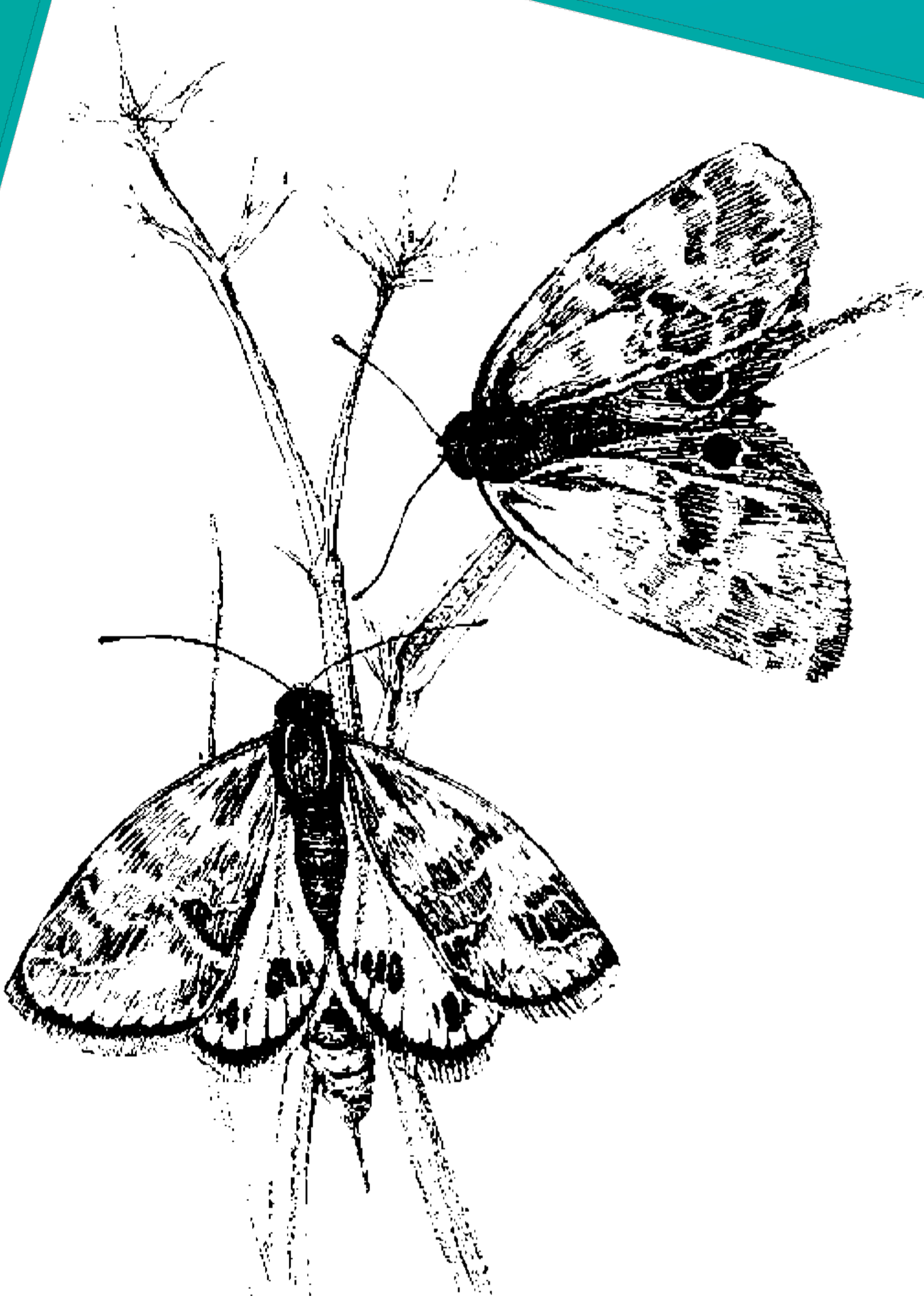
GOLDEN SUN MOTH
SYNEMON PLANA

ACTION PLAN



PREAMBLE

The Golden Sun Moth (*Synemon plana* Walker, 1854) was declared an endangered species on 15 April 1996 (Instrument No. DI1996-29 under the *Nature Conservation Act 1980*). Under section 101 of the *Nature Conservation Act 2014*, the Conservator of Flora and Fauna is responsible for preparing a draft action plan for listed species. The first action plan for this species was prepared in 1998 (ACT Government 1998). This revised edition supersedes the earlier edition. This action plan includes the ACT Native Grassland Conservation Strategy set out in schedule 1 to the 'Nature Conservation (Native Grassland) Action Plans 2017', to the extent it is relevant.

Measures proposed in this action plan complement those proposed in the action plans for Natural Temperate Grassland, Yellow Box/Red Gum Grassy Woodland, and component threatened species such as the Striped Legless Lizard (*Delma impar*) and the Grassland Earless Dragon (*Tympanocryptis pinguicolla*).

CONSERVATION STATUS

Synemon plana is recognised as a threatened species in the following sources:

National

Critically Endangered – Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth).

Australian Capital Territory

Endangered – *Nature Conservation Act 2014*. Special Protection Status Species - *Nature Conservation Act 2014*.

New South Wales

Endangered – *Threatened Species Conservation Act 1995*.

Victoria

Threatened – *Flora and Fauna Guarantee Act 1988*.

CONSERVATION OBJECTIVES

The overall conservation objective of this action plan is to maintain in the long term viable, wild populations of *S. plana* as a component of the indigenous biological resources of the ACT and as a contribution to regional and national conservation of the species. This includes the need to maintain natural evolutionary processes.

Specific objectives of the action plan are to:

- Conserve large populations in the ACT. Protect other populations from unintended impacts (unintended impacts are those not already considered through an environmental assessment or other statutory process).
- Manage the species and its habitat to maintain the potential for evolutionary development in the wild.
- Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations.

SPECIES DESCRIPTION AND ECOLOGY

DESCRIPTION

The Golden Sun Moth (*Synemon plana* Walker 1854) is a moth in the family Castniidae. Genera in this family are found in Central and South America and in Australia, suggesting a Gondwanan origin for the family (Edwards 1991). All adult moths in this family are diurnal, and their larvae feed on monocotyledonous plants (Common 1990).

Synemon plana adults are medium-sized, with clubbed antennae and no functional mouth-parts. In males, the upper side of the forewing is dark brown with pale grey patterning, the hind wing is dark bronzy brown with dark brown patches, and the underside of both wings is mostly pale grey with dark brown spots.

In females the upper side of the forewing is dark grey with pale grey patterning, the hind wing is bright orange with black submarginal spots, and the underside of both wings is silky white with small black submarginal spots. The male wingspan is about 34 mm, and the female wingspan is about 31 mm. The male having a larger wingspan than the female is unique in the Australian Castniidae. Females have a long extensible ovipositor.

Synemon plana eggs are just over 2 mm long, and the larvae develop underground where they are found associated with the roots of a few species of grasses or at the upper end of silk-lined tunnels below the tussock base (Richter 2010). Larvae are cream in colour, and late-instars have a red-brown head capsule. The empty red-brown pupal cases protrude from the ground, usually at the base of or close to a grass tussock. The pupal cases of female moths are larger than those of males, reflecting the larger size of the gravid female abdomen (Richter 2010).

DISTRIBUTION AND ABUNDANCE

Historically *S. plana* was widespread in south-eastern Australia and relatively continuous throughout its range, showing a close correlation with the distribution of temperate grasslands dominated by Wallaby Grasses (*Rytidosperma* spp., formerly *Austrodanthonia*) (Edwards 1993; O'Dwyer and Attiwill 1999).

Areas dominated by Wallaby Grasses probably occurred as part of a grassland mosaic, interspersed with patches dominated by other grass species. Museum records indicate *S. plana* was still common and widespread prior to 1950, with collections showing its distribution extended from Bathurst, NSW, through the Southern Tablelands of NSW and central Victoria to the South Australian border (Edwards 1993).

The area of temperate grassland in Australia at the time of European settlement is estimated to have been about two million hectares, though two centuries later this had been reduced to less than 1% of the original area (Kirkpatrick 1993), with the remaining remnants degraded by stock grazing and weed invasion.

A recent review of the status of *S. plana* across its range found that between the years 2000 and 2010 the known area of occupied habitat had increased from 10 km^2 to 150 km^2 due mainly to increased survey of areas proposed for development (Hogg 2010). Currently, the species is known from 100 (mainly small) sites north and west of Melbourne and in south-west Victoria (Brown and Tolsma 2010; Brown *et al.* 2011; DSE 2013), 48 sites in NSW (OEH 2012) and 78 sites in the ACT.

Most of the populations of *S. plana* in the ACT region are smaller than five hectares and lie within an area about 100 km long and 30 km wide, extending from the Queanbeyan district in the south-east to the Boorowa area in the north-west (Clarke and Whyte 2003; NSW Wildlife Atlas 2015). In the ACT the species occurs in lowland areas adjacent to the city of Canberra, and in mostly small sites within the city (Table 1).

Table 1 shows the area of habitat at sites where the species is known to occur in the ACT. These sites are defined as areas of contiguous, apparently suitable habitat, rather than by land ownership/management. For example, relatively large areas of habitat at Canberra Airport and the Majura Training Area are counted as one site because the habitat is continuous across the tenure boundary, while two small areas of habitat at the University of Canberra are counted as two sites because they are separated by more than 200 metres of non-habitat.

Because males are unlikely to fly more than 100 m away from suitable habitat (Clarke and O'Dwyer 2000), and females move even less distance, populations separated by 200 metres or more are likely to be isolated and are therefore treated as separate sites.

Populations of *S. plana* tend to have a patchy distribution (and density) within an area of apparently suitable habitat (and this area can vary between years), which means actual areas occupied by *S. plana* are likely to be less than the habitat areas shown in Table 1.

Table 1. Location of *Synemon plana* populations in the ACT

District	Number of sites	Habitat area (hectares)
Belconnen	9	355
Central Canberra	25	110
Gungahlin	32	812
Jerrabomberra	7	60
Majura	5	466
Total	**78**	**1803**

The area of apparently suitable (or potential) habitat for *S. plana* in the ACT is estimated to be about 1800 hectares, with individual sites varying in size from 0.055 ha to more than 300 ha, and a median size of 2.8 ha. There are large populations on Commonwealth Land at the Majura Training Area and Canberra Airport in the Majura Valley, at the Lawson Grasslands (former Belconnen Naval Transmission Station site) and at the West Macgregor offset area. Less extensive populations occur in the Dunlop Grasslands Reserve and Jarramlee Nature Reserve in Belconnen, in the Jerrabomberra Grasslands (east and west), and in the Mulanggari, Crace, Mulligans Flat and Goorooyarroo nature reserves in Gungahlin. Based on the known former distribution of lowland Temperate Grassland in the ACT and areas surveyed for *S. plana*, it is unlikely any significant populations of the species remain undiscovered.

Numerous difficulties arise when attempting to estimate population size in *S. plana* (Gibson and New 2007). Flying adult males are the only life stage and sex that are readily detected and counted, but they are short-lived and emerge across a season of many weeks.

Counts or density estimates at a site on a single day will mostly reflect a single emergence cohort, and daily emergence and flight activity is affected by weather conditions. Daily emergence patterns between sites and across a site can also vary, with the flying season starting earlier on north facing sites, those with light ground cover and drier sites (Edwards 1994).

More adults emerge on hot dry days, making it difficult to detect the difference between long-term population trends and short-term seasonal effects at a site without surveying the whole site on every day of a season. Mark–release–recapture studies are labour-intensive and need to be carried out every day of the flying season in order to estimate the number of adult males present in the population.

The length of the larval period is not clear, nor is it known if it can vary according to environmental conditions, so it is not known what proportion of the standing population is represented by the number of adults that fly in one season. Detecting and sampling larvae is difficult due to their patchy subterranean distribution and is destructive of larvae and their habitat. Late-season surveys of above-ground pupal cases can provide a useful indication of *S. plana* density as well as locations where larvae have developed underground because pupal cases are readily recognisable and have been found to persist in the field for longer than three weeks. However, pupal cases are likely to be more difficult to find on sites with denser vegetation or in wetter years (Richter *et al.* 2012; Rowell pers. obs).

Population estimates based on mark–release–recapture surveys have been undertaken four times for the small (0.4 ha) site at York Park in Barton. The number of flying males was estimated to be 520 (1992), 456 (1993) and 736 (1994) (Harwood *et al.* 1995), giving an average population estimate for those years of 1400 males per hectare This would be an annual adult cohort of about 2300 per hectare if the male:female sex ratio is 60:40 as suggested by Richter *et al.* (2012). A two or three-year life cycle would mean that double or triple the number of emerging adults estimated is potentially present on this site.

A similar survey at York Park in 2006 using a different analysis gave estimated male numbers of 440 (Rowell 2007a), with daily male population size during the peak flying period of about 55 to 65. A further mark–release–recapture survey in 2011 found similar daily male population sizes of 49 and 66 during the peak flying season (Rowell 2012).

Given the difficulties with measuring absolute population sizes for *S. plana*, measures of relative abundance or maximum daily abundance are likely be more practical for monitoring population trends. Counts of flying males have been undertaken at most ACT sites, but these have often involved different survey methods and years. Some ACT sites have been counted regularly, and others only once or twice. Richter *et al.* (2009) reported relative abundance of flying males at 28 sites in one season by using the highest number of individuals summed from 12 'rotational' counts (standing in one spot and counting all flying males within a defined radius whilst the observer rotates though 360 degrees) during 2–4 site visits, and characterised the abundance at each site from low (1–20 moths) to very high (several hundred). Richter (2010) conducted surveys at 24 locations over three seasons using counts along a 100 metre transect and found only a small number of sites had relatively high abundance (hundreds) of moths.

Golden Sun Moth (photo K. Nash)

Hogg (2010) proposed three levels of *S. plana* activity (low, moderate, high) based on numbers of flying males counted during a standard time (fixed or transect counts) or distance travelled (walked transects and meandering traverses) and then rated the *S. plana* population size/activity at 56 ACT sites based on recent survey records. Mulvaney (2012) used the above and other data to apply the Richter *et al.* (2009) maximum moth count abundance classes to 73 ACT sites.

Standardised survey methods are detailed in DEWHA (2009) and have been developed by the ACT Government. These mainly cover transect, fixed point and fixed time counts of flying males, carried out in a way that allows some comparison of relative *S. plana* abundance between years and sites. Draft monitoring guidelines for the ACT include habitat monitoring methods to be used in conjunction with standardised moth counts.

Transect surveys covering some large ACT sites have been repeated in several seasons, mostly using transects across the site spaced 100 metres apart with numbers of flying males recorded per 100 metres of transect. These include:

- Lawson Grasslands (former Belconnen Naval Transmission Station) (Clarke and Dunford 1999; AECOM 2009),
- West Macgregor (Braby 2005; Biosis 2015; Rowell 2015),
- Canberra Airport (Crawford 2001; Rowell and Bishop 2004; Biosis 2008; Rowell 2006, 2010, 2012),
- Majura Training Area (AECOM 2009, 2012).

Some general findings from the above surveys:

- Where it could be calculated, the average number of flying males per 100 metres for each site in the above surveys ranged from 0.2 to 34.
- When whole sites were taken into account, moth numbers were consistently highest at Canberra Airport (a site managed by regular mowing), but similar densities were recorded for the portion of West Macgregor dominated by grazed Chilean Needlegrass (*Nassella neesiana*).
- At West Macgregor, numbers of flying males were consistently higher on the creek flats

dominated by Chilean Needlegrass than on the drier east-facing slope dominated by weedy native Speargrass (*Austrostipa* spp.)/Wallaby Grass (*Rytidosperma* spp.) pasture.

- There is a tendency for seasons to be characterised by either a high, moderate or low abundance of flying males at most sites across the northern ACT at the same time, with some local variation at particular sites (probably reflecting vegetation condition).
- A reduction in numbers of flying males between years appeared to be associated with excess biomass at one site and with overgrazing by kangaroos at another.
- The highest single count (per 100 metre sector) for a site is related to the abundance for the whole site, i.e. very high single counts occur in 'good' years when the count for the whole site is high.
- In seasons when males are abundant they may be detected across most of a site, but in poor years they may be found thinly scattered or have a patchy distribution which may match locations of high male abundance in previous seasons.
- Evidence of breeding (mating, oviposition, pupal cases) occurs in both Natural Temperate Grassland and native grassland, and is detected more often in areas and seasons of high male abundance.
- The number of females detected rises with the abundance of flying males, but rarely exceeds 1% of males recorded in walked transect surveys. This reflects the low probability of detecting females by the transect method.

The presence of flying males is a fairly coarse measure of breeding habitat, as they are able to fly some distance from their site of emergence and may also congregate in areas of low herbage mass (which may or may not contain the less mobile females), or shelter on the lee side of ridges on windy days (AECOM 2009; Rowell unpublished data).

Survey methods that detect females, pupae or larvae are valuable as they indicate more accurately the current and previous breeding and larval development sites, and allow better mapping and characterisation of breeding habitat. These surveys are more time-consuming and often less successful than surveys for flying males, but can be undertaken in a different time period to when males are flying. Surveys for females are best undertaken after the main period of male flying activity each day, when the females are more easily seen as they walk quickly from tussock to tussock to lay eggs.

Females are most readily seen on very hot afternoons (35–38°C) when they will perch on tall grass stems, presumably to escape the hot soil surface (Rowell, pers. obs). Searches of defined areas or timed searches for females can be combined with searches for empty pupal cases, as both require close inspection of the ground. Pupal case surveys are best undertaken towards the end of the flying season, when they will be more numerous, as they remain intact at the soil surface for several weeks under some conditions (Richter *et al.* 2012).

Unfortunately females and pupal cases are not easily found on sites with sparse or small *S. plana* populations. Surveys for larvae are destructive and require a permit to disturb the habitat, as tussocks are uprooted and the roots searched. There is no formal published description of the larvae, which need to be identified by an expert. Larvae are also patchily distributed in the habitat, possibly reflecting laying by individual females.

The most up to date distribution data for this species is publicly available on the ACT Government's mapping portal [(Visit the ACTmapi website)](#).

HABITAT AND ECOLOGY

Synemon plana is found in native grassland, native pasture, open woodland with a grassy understorey and 'secondary' grassland (open grassy woodland that has been cleared of trees). Occupied sites have generally not been pasture improved through the application of fertiliser, or ploughed (Richter *et al.* 2010). Sites are generally flat or gently sloping (< 5°), and in the ACT aspect does not appear to be a good predictor of habitat. Shading of habitat is generally minimal, with 88% of habitat in the ACT occurring in areas without trees or in very sparse woodland (Mulvaney 2012). Hogg (2010) suggested that populations of *S. plana* in open woodland and secondary grassland may be the result of the species spreading outside its preferred habitat (Natural Temperate Grassland) to adjacent woodlands following partial or complete clearing of the trees. This idea is supported by observations that habitat in secondary grassland and open woodland generally supports fewer moths than primary grassland.

Habitat for *S. plana* is characterised by the moderate abundance of larval food plants and the structure of the grassy layer. Sites occupied by *S. plana* tend to be open grasslands dominated by tussocks of *Rytidosperma* species (Wallaby Grasses), and to a lesser extent Tall Speargrass (*Austrostipa bigeniculata*) and Kangaroo Grass (*Themeda triandra*), that are generally low to moderate in grass height and have a moderate to high grass cover with areas of bare ground (inter-tussock space) (Clarke and Dear 1998; O'Dwyer and Attiwill 1999; Gilmore *et al.* 2008; Mulvaney pers. obs.; Rowell pers. obs.).

Edwards (1994) surveyed eight *S. plana* sites in the ACT and described six as containing patches of Wallaby Grasses in Tall Speargrass grasslands, while two had patches of Wallaby Grasses associated with *Themeda* grassland. Most sites were on low ridges, hillocks or low hills.

Richter (2010) surveyed 47 grassland sites within the distribution of pre-1750 Natural Temperate Grassland in the ACT, and found that 69% of sites containing *S. plana* were dominated by Wallaby Grasses with a smaller proportion of occupied sites dominated by Tall Speargrass, Kangaroo Grass or Chilean Needlegrass. Chilean Needlegrass is a Weed of National Significance and a declared pest plant in the ACT (DECCEW 2009), and has spread along creeks and roadsides and through urban parks. No sites dominated by Phalaris (*Phalaris aquatica*) contained *S. plana*.

A study of native pasture sites in NSW showed that *S. plana* is more likely to be found at sites with higher cover of Wallaby Grasses, provided that the tussock structure and inter-tussock bare ground is maintained, and suggested that while high grazing pressures might increase Wallaby Grass cover at the expense of other grasses, this is unlikely to favour *S. plana* due to the loss of tussocks (Gibbons and Reid 2013). Important structural features appear to be tussocks for shelter, egg-laying and larval development, and inter-tussock spaces for basking to increase body temperature and for females to display and attract mates (Edwards 1994; Gibson 2006; Gibbons and Reid 2013). Where vegetation height and density varies, male moths show a preference for flying over areas of relatively low open grassland with reduced herbage mass (Gibson 2006; Gilmore *et al.* 2008; Brown *et al.* 2011).

Adult moths emerge from pupal cases at the soil surface on warm dry sunny days during the breeding season. The adults have no functional mouth parts, so cannot feed or drink. Mark–release–recapture studies have shown that most live for only one or two days (Edwards 1993; Edwards 1994; Harwood *et al.* 1995; Rowell 2007a; Rowell 2012). In the ACT the flying period is usually between mid-October and early January with a peak from mid-November to early December, but varies according to seasonal conditions. Examination of 650 pupal cases from eleven ACT sites showed that the sex ratio on emergence was about 60% males and 40% females. This ratio was similar over two seasons, for native and exotic-dominated sites (Richter 2010; Richter *et al.* 2012).

The proportion of males detected in field counts and mark–release–recapture surveys is very much greater than this, probably due to behavioural differences affecting detectability (Edwards 1993; Edwards 1994; Harwood *et al.* 1995; Gibson 2006; Rowell 2007a; Rowell 2012).

Adult females contain up to 200 (mean 74) fully-formed eggs on emerging from pupation, and with their smaller wings are only able to walk or flutter for short distances (Edwards 1994; Richter 2010). Males are active fliers, able to move several hundred metres over suitable habitat (Richter *et al.* 2013). Males fly low and rapidly over the grassland during the late morning and early afternoon, searching for females. Males do not fly far from habitat, and usually turn back after 50 metres or less when they move into unsuitable vegetation. Females sit on the ground, exposing their golden hindwings when a male flies overhead (Edwards 1994; Gibson 2006). After mating, the females move from tussock to tussock, laying eggs into their bases. Field observations suggest females lay their eggs within a few metres of the mating site (Gibson 2006).

Synemon plana larvae are underground feeders, and are found in silk-lined tunnels closely associated with the roots of grasses (Edwards

1994; Richter 2010). Edwards (1994) suggested the larval period could be 1–3 years. Larvae collected just prior to adult emergence in October fell into three distinct size cohorts, which appeared likely to be one, two and three years old (Richter *et al.* 2013). In temperate climates, lepidopteran larvae can face a pathway decision between continuing development to the adult stage or entering diapause and delaying emergence until the following season (Gotthard 2008). It is possible that this occurs facultatively in *S. plana*, perhaps in larvae hatched from eggs laid late in the season or larvae which encounter poor conditions for development and growth, meaning that the larval period could be two and sometimes three years.

The main larval food plants are native C3 grasses, especially Wallaby Grasses and Speargrasses, and more recently the introduced Chilean Needlegrass (Edwards 1994; Braby and Dunford 2006; Gibson 2006; Gilmore *et al.* 2008; Richter *et al.* 2011, 2013; Sea and Downey 2014b). Oviposition and pupal shells have also frequently been associated with these species (e.g. Edwards 1994, Gibson 2006; Braby and Dunford 2006; Richter *et al.* 2013). Larvae were more often found among the roots of Speargrasses or a mix of Speargrass and Wallaby Grass than with Wallaby Grass alone (Richter *et al.* 2013).

These are all C3 grasses, and there was no indication from the stable isotope studies of gut contents that any of the C4 grasses commonly found in and around *S. plana* habitat were eaten in significant quantities (Richter *et al.* 2011). However, only a few tussocks of C4 grass species were searched for larvae in that dietary study (Osborne pers. comm. 2015). C4 species commonly found scattered at or near *S. plana* sites include *Themeda triandra, Bothriochloa macra, Panicum effusum, Aristida ramosa* and the introduced African Lovegrass (*Eragrostis curvula*).

Further work is required to identify or eliminate other food species, and to find the density of food plants required to sustain a population of *S. plana*. Some features of *S. plana* suggest it may require a high density of larval food plants in its habitat. These features include the low mobility and very short life span of the female which must walk or flutter to tussocks suitable for oviposition, and the probably limited distance that larvae could move through the soil if unable to complete their development on the roots of a single tussock (Edwards 1994). A study of a relatively small number of sites in Victoria and the ACT found that that sites inhabited by *S. plana* had Wallaby Grass cover greater than 40% on soils low in phosphorous, with up to five species of Wallaby Grass present (O'Dwyer and Attiwill 1999), but areas occupied by *S. plana* at one larger Victorian site all contained less than 37% Wallaby Grass cover (Gibson 2006). Surveys at 66 occupied Victorian sites found that most sites containing *S. plana* had ≥10% Wallaby Grass cover (Brown *et al.* 2011; Brown *et al.* 2012).

One survey found that in two seasons there was a significant positive relationship between the cover of Wallaby Grass and the number of flying males recorded (Brown *et al.* 2012), but other surveys have not found such a correlation (Gibson 2006; Brown *et al.* 2011). Low numbers of *S. plana* have been reported where Wallaby Grasses occur as a minor component in grassland dominated by presumed non-food species such as Kangaroo Grass or some exotic grasses (e.g. Brown *et al.* 2012).

Synemon plana sites in the ACT region typically contain up to six species of Wallaby Grass, but their cover and distribution vary. EcoLogical (2012) reported Wallaby Grass cover of 25% or less in areas of high *S. plana* abundance at Mulligan's Flat Nature Reserve, but noted that Wallaby Grass density varied considerably at a small scale, with patches of high density scattered across the site. The Wallaby Grasses with highest cover are often the low-growing *Rytidosperma carphoides* and *R. auriculatum*, with *R. caespitosum* and *R. laeve* also often present (five NSW sites, Clarke and Dear 1998; eight ACT sites, O'Dwyer and Attiwill 1999; Lawson Grasslands, AECOM 2009; York Park Barton, Rowell 2012; Majura Training Area, AECOM 2014; Canberra Airport, Rowell 2015).

A survey of two habitat areas at Canberra Airport found that both had the same mean percentage basal cover of Wallaby Grasses (3%), but that this was made up of 23 tussocks/m² at the site dominated by *R. carphoides*, and seven tussocks/m² at the site dominated by the larger *R. caespitosum* (Rowell 2009). The site with the larger tussocks contained more pupal shells and has also had consistently higher numbers of flying male *S. plana* in several annual surveys. This suggests the species of Wallaby Grass and/or the size of its tussocks may also be important in determining larval habitat quality. Tussocks with a large root volume may allow a larva to complete its cycle on a single tussock without the risk and energy cost potentially involved in moving through the soil to find another tussock.

Of 55 *S. plana* larvae collected from the roots of native grasses at ACT sites, 87% were associated with either Speargrass or Wallaby Grass, with twice as many associated with Wallaby Grass tussocks (Richter *et al.* 2013). Speargrass (mainly *Austrostipa bigeniculata*) are also a major component of *S. plana* habitat in the ACT.

Apparent oviposition has been observed into Speargrass tussocks (Gibson 2006; Richter *et al.* 2013) and larvae have been found among their roots. At York Park in Barton, a small well-studied site with high numbers of *S. plana*, the cover of Wallaby Grasses has been relatively low over several years (ca. 4-7% of the vegetation cover), while Speargrass cover has been around 30%. At Canberra Airport and the Majura Training Area, Speargrass cover in *S. plana* habitat over several years has also been consistently higher than Wallaby Grass cover (AECOM 2014; Rowell 2015) and at Lawson Grasslands Speargrass and Wallaby Grass cover has been roughly equal (AECOM 2009).

Other surveys have found a strong association between *S. plana* and the introduced Chilean Needlegrass in the ACT and Victoria, with high numbers of flying males observed in areas dominated by this grass (Braby and Dunford 2006; Gilmore *et al.* 2008; Richter *et al.* 2009; Sea and Downey 2014a), apparent oviposition into its tussock bases (Gibson 2006), many pupal cases protruding from them (Braby and Dunford 2006; Richter *et al.* 2010) and larvae being found among its roots (Richter *et al.* 2013; SMEC 2015). Larvae collected from the roots of this grass were found to weigh significantly more than larvae collected from the roots of native grasses in the same season (Richter *et al.* 2013; Sea and Downey 2014b), and several larvae can apparently be supported by a single tussock (SMEC 2014, 2015).

ACT sites which contain *S. plana* and are dominated by Chilean Needlegrass are all adjacent to native grasslands (Richter *et al.* 2011).

Chilean Needlegrass is of South American origin, and is related to Australian *Austrostipa* species. It is a long-lived grass which readily invades disturbed sites or those with enhanced nutrients (Faithfull 2012).

Other grass species have been less often linked with *S. plana*, through the following observations:

- Weeping Grass (*Microlaena stipoides*, C3 grass): apparent oviposition, females probing with ovipositor but egg-laying not confirmed (Victorian site, Gibson 2006).
- Redleg Grass (*Bothriochloa macra,* C4 grass): apparent oviposition and pupal cases protruding from tussock (Reid ACT, Braby and Dunford 2006), larvae associated with roots (ACT sites, Richter *et al.* 2013).
- Purple Wiregrass (*Aristida ramosa,* C4 grass): larvae associated with roots (ACT sites, Richter *et al.* 2013).

Studies of *S. plana* populations across the range of the species show considerable genetic variation, which increases with the geographic distance between populations (Clarke and O'Dwyer 2000; Clarke and Whyte 2003). Five major genetic clusters have been identified, one encompassing the populations from the ACT and nearby NSW. These studies suggest the ACT/NSW cluster radiated from a small founding population that originated from Victoria in recent evolutionary time, and that populations in this cluster have recently undergone further genetic differentiation resulting from habitat fragmentation associated with the introduction of agriculture (Clarke & Whyte 2003).

PREVIOUS AND CURRENT MANAGEMENT

In the ACT *S. plana* occurs on land under a range of tenures and land management regimes. Sites where *S. plana* occur include land owned and managed by the Commonwealth Government, Territory land gazetted as nature reserve, 'Hills, Ridges and Buffers', urban open space, or broadacre, and Territory rural land leased for grazing. *Synemon plana* often occurs on sites that contain the endangered Natural Temperate Grassland community and other threatened grassland species, and sometimes with remnants of the critically endangered White Box–Yellow Box–Blakely's Red Gum Grassy Woodland and Derived Native Grassland community.

Currently occupied *S. plana* habitat in the ACT has generally had some regime of herbage mass reduction in the past, which may have helped to maintain the habitat in a condition that allowed the moths to survive. This has included grazing by sheep, cattle and/or kangaroos, occasional high slashing, occasional or frequent low mowing and occasional burning (planned and unplanned).

Parts of the Canberra Airport grassland have consistently high counts of *S. plana* (including 85 females counted in one year) despite being mown several times per year since the 1960s (Rowell 2010).

Some areas of the airport that currently support *S. plana* have previously been subject to earthworks (soil levelling), over-sowing with Subterranean Clover (*Trifolium subterranean*) and years of very close mowing associated with helicopter training (Canberra Airport pers. comm. 2015), indicating some resilience of *S. plana* to past incompatible land management practices. However, the loss of *S. plana* from Yarramundi Grassland in the last 20 years appears to be associated with over a decade of sustained high herbage mass and weed invasion due to a lack of grazing or mowing (Sharp 2009, Faithfull 2012).

Small central Canberra grassland sites where conservation of *S. plana* is a primary aim, such as York Park in Barton (which has a site-specific management plan, Parsons Brinckerhoff 2008), are mostly maintained by mowing or slashing which is timed to avoid the breeding period of *S. plana*, with weed control as required. However, *S. plana* also persists in small patches in urban open space (such as road verges, median strips and parks) that are slashed or mown annually (or more frequently), which may include during the emergence season. Other sites are grazed by horses, such as the North Curtin horse paddocks and the larger Yarralumla Equestrian Park, which has an offset management plan that aims to integrate *S. plana* conservation with the equestrian use of the site (Jessop 2014).

In Gungahlin the larger sites are mainly within the Crace, Mulligans Flat and Goorooyarroo nature reserves. These areas were formerly grazed by sheep and/or cattle, and are all now grazed by controlled numbers of kangaroos. Parts of Crace and Goorooyarroo nature reserves are grazed by cattle at times. Crace Nature Reserve also contains populations of Striped Legless Lizard (*Delma impar*) and Button Wrinklewort (*Rutidosis leptorhynchoides*).

Mulligans Flat and Goorooyarroo nature reserves are mainly woodland and in some parts the ecological condition is being enhanced by kangaroo exclosures and the addition of coarse woody debris (Manning *et al.* 2013).

In the Majura Valley, much of the Canberra Airport habitat is regularly mown to about 10 cm for aviation safety reasons, while the adjacent large Majura Training Area site is mostly lightly grazed by regulated numbers of kangaroos.

The Majura West/Campbell Park grassland was formerly grazed by sheep, and is currently grazed by kangaroos. All three sites contain Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and Perunga Grasshopper (*Perunga ochracea*) populations, and the Majura Training Area and Majura West also have Striped Legless Lizard. The Majura Training Area has a grassland management plan that takes account of the threatened species present.

In Belconnen, the enclosed Lawson North (former Department of Defence naval transmission station) site was previously grazed by sheep, later slashed, and is now grazed by regulated numbers of kangaroos. This site has a grassland management plan that takes account of the threatened species on the site, which include the endangered Ginninderra Peppercress (*Lepidium ginninderrense*) and the Perunga Grasshopper. An area of *S. plana* habitat has been retained on Reservoir Hill within the South Lawson suburban development, and is subject to an environment management plan requiring herbage mass management, weed control, corridor retention and regular monitoring of *S. plana* and its habitat. West Macgregor, Jarramlee and the Dunlop Grasslands Nature Reserve are lightly grazed by kangaroos and (parts are) grazed by cattle for herbage mass control as required. Jarramlee (ACT Government 2013) and West Macgregor are subject to offset management plans, which aim to control herbage mass and weeds in *S. plana* habitat.

The Jerrabomberra West and East nature reserves were formerly grazed by sheep and are now grazed by kangaroos, with some areas protected by kangaroo grazing exclosures. These reserves also contain Grassland Earless Dragon, Striped Legless Lizard and Perunga Grasshopper populations, and small experimental patch burns are being undertaken at both sites.

THREATS

Synemon plana is a grassland specialist, being found in areas of Natural Temperate Grassland, native pasture, secondary native grassland or clearings in grassy woodland. A very high proportion of these grassy ecosystems have been cleared for agriculture and urban development, and most of the remnants are fragmented and degraded.

Further loss, fragmentation and degradation of habitat continue to be the major threats to *S. plana* (ACT Government 1998; DEWHA 2009; OEH 2012; ACT Government 2016).

Mulvaney (2012) reported that of the estimated 1800 ha of *S. plana* habitat remaining in the ACT, 22% has been approved or proposed for urban development, 23% is on Commonwealth land with an uncertain future, and 45% is in existing or proposed nature reserves or existing/proposed EBPC offset areas. Proposed urban development will most likely involve complete loss of some small sites and partial loss and fragmentation of some larger sites. Larger losses include clearance of habitat at Canberra Airport (airport development), South Lawson (urban development), and parts of Gungahlin (urban development). The proposed habitat loss at Gungahlin has been covered by the Gungahlin Strategic Assessment, which details the quality and area of *S. plana* habitat lost, the proposed avoidance and mitigation measures, and the offset strategy. Offsets include the creation of the Kinlyside Nature Reserve, addition of land to the Mulligans Flat–Goorooyarroo Nature Reserves, and adding land to the 'Hills, Ridges and Buffers' zone. Smaller losses are likely (or have occurred) at York Park, Majura West and West Macgregor for road building, and at Dudley Street in Yarralumla for housing (Mulvaney 2012).

Many *S. plana* sites in the ACT are small, and are therefore particularly vulnerable to invasion by weeds. It is likely that *S. plana* requires a high density of larval food plants in its habitat, and would therefore be susceptible to the dilution of food plants by weed species that are not food plants. Weeds also fill inter-tussock spaces and alter the low and open grassland structure favoured by *S. plana*. Invasive weeds of concern in *S. plana* habitat include:

- Perennial tussock grasses, such as Phalaris, African Lovegrass, Serrated Tussock (*Nassella trichotoma*) and Chilean Needlegrass.
- Tall annual grasses such as Wild Oats (*Avena* sp.).
- Some broad-leaved weeds such as St Johns Wort (*Hypericum perforatum*) and Saffron Thistle (*Carthamus lanatus*).

Chilean Needlegrass in *S. plana* habitat presents unusual issues. It is a Weed of National Significance but has become an additional food plant for *S. plana* larvae, and appears to pose both risks and potential opportunities for *S. plana* conservation.

At Canberra Airport, Chilean Needlegrass has invaded disturbed sites, e.g. former soil dumps, where soil has been disturbed by machinery, drainage swales and beside disturbed track and paved edges, especially where there is additional run-off. It has been slower to invade adjacent, well-drained intact Natural Temperate Grassland (Rowell, pers. obs.). Similar situations have occurred at Jarramlee, West Macgregor and the former Constitution Avenue site. Chilean Needlegrass can invade Kangaroo Grass dominated grasslands when they suffer tussock collapse and death due to lack of renewal through herbage mass reduction (grazing, mowing, burning), and this appears to have happened at Yarramundi Grassland and part of the Dudley Street site (Faithfull 2012). At Dudley Street *S. plana* occupied the Chilean Needlegrass area, but at Yarramundi Grassland the moth seems to have disappeared before the main invasion of Chilean Needlegrass. This may be due to the small amount of *S. plana* habitat originally present at Yarramundi Grassland, and the years of excessive herbage mass that preceded the invasion of Chilean Needlegrass.

The spread of Chilean Needlegrass appears to have allowed the distribution of *S. plana* to expand into adjacent areas that previously may not have been suitable habitat. This may be the source of the apparently isolated population in the grassed roundabout on the northern approaches of Commonwealth Avenue Bridge. When Chilean Needlegrass invades disturbed sites which are not *S. plana* habitat, these are often relatively well-watered or fertile, and it may displace native grasses, native or exotic pasture, or the planted exotic dryland grass mix (Tall Fescue, White Clover). This process has led to linear infestations of Chilean Needlegrass along waterways such as Ginninderra Creek and Gooromon Ponds. The spread of Chilean Needlegrass is also facilitated by mowing, leading to a near monoculture on many roadsides, nature strips and traffic islands in central Canberra. Chilean Needlegrass is assisted in replacing other grasses by its ability to form cleistogamous seeds which can mature at ground level, thus producing fertile seed even under close mowing. This seed is also present and ready to germinate following the death of the tussock due to age, drought or herbicide use, while mowing inhibits seeding of taller grass species and restricts their contribution to the soil seed bank (Faithfull 2012).

The use of Chilean Needlegrass as a food plant by *S. plana* has allowed the moth to survive in disturbed habitats and to spread along roadsides and creeklines. This has the potential to connect populations which are currently isolated on native-dominated sites, e.g. the complex of sites at Ginninderra Creek, Gooromon Ponds, Dunlop Nature Reserve and NSW border properties near Hall, and at Yarralumla Equestrian Park, Lady Denman Drive, North Curtin horse paddocks, Dudley Street and Kintore Street. At the same time, these linear infestations of Chilean Needlegrass could act as invasion corridors for the weed to enter native grasslands.

Synemon plana numbers are often much higher on Chilean Needlegrass-dominated sites where biomass is controlled by mowing or grazing than on adjacent native grassland (e.g. Constitution Avenue, West Macgregor/Jarramlee). This could be due to a number of factors:

- Chilean Needlegrass tussocks often form a continuous sward, providing a high density of food plants.
- More *S. plana* larvae can develop on a single Chilean Needlegrass tussock than on native grasses (Sea and Downey 2014b; SMEC 2015).
- *Synemon plana* larvae which develop on Chilean Needlegrass are larger (Sea and Downey 2014b).
- In Lepidoptera, large final body size often correlates with a high reproductive capacity (Gotthard 2008), because females produce more eggs and larger males may fly further and longer, and have greater mating success.
- Faster-growing larvae may lead to a shorter generation time in some Lepidoptera (Gotthard 2008).

The potentially enhanced reproductive success of *S. plana* using Chilean Needlegrass may be due to metabolic plasticity, but if these characteristics are genetically determined they have the potential to drive genetic change in *S. plana*, which could eventually lead to genetic barriers between isolated populations adapted to Chilean Needlegrass and those on native-dominated sites. For example, characteristics that enable *S. plana* to complete its life cycle under dry conditions in relatively sparse native vegetation on poor soils, could be lost in *S. plana* developing with more reliable food availability on fertile sites dominated by Chilean Needlegrass.

Other threats to *S. plana* populations or habitat include:

- **Wildfire or inappropriate fire regimes:** Lowland grasslands were regularly burnt by Indigenous people before European settlement (Nicholson 1981 in Lunt 1991) and virtually all perennial grassland plants resprout after fire in lowland grasslands (Morgan 2015). However, little information is available about the role of fire in low productivity grasslands of the type inhabited by *S. plana*, or of the effects of fire on *S. plana* in the ACT (Edwards 1994; ACT Government 1998). *Synemon plana* have been found to withstand burning of their habitat on some Victorian sites (Douglas 2004; Biosis 2010b), and flying males were observed in higher numbers on a previously burnt patch. However, it was not determined whether this was due to attraction of males to areas of low herbage mass, larvae surviving the fire, or reduction of the dominant *Themeda* grass exposing or allowing an increase in the growth of subdominant *Rytidosperma* grasses (Gibson 2006). Patchy ecological burns of *S. plana* habitat are seen as desirable for herbage mass reduction in Victoria, but the frequency and intensity of controlled burning needs to be planned and burns should be conducted outside the pupation and flight period (September–January) (Biosis 2010b). Edwards (1994) reported that ACT *S. plana* populations had survived well without fire for 50 years, and suggested that in the past they may have reoccupied burnt sites from surrounding areas rather than surviving fires, and that fires at small sites at certain times risked local extinction by killing vulnerable adults and eggs. Edwards (1994) also speculated that the mobilisation of the root reserves of grasses resprouting after fire could create a food shortage for *S. plana* larvae.

- **Herbage mass extremes:** Lack of herbage mass control on most sites is likely to lead to a shift from shorter *Rytidosperma* grasses to taller grasses, resulting in shading of the soil and reducing the availability of bare ground and open areas for basking, displaying and egg-laying. Excessive biomass removal by overgrazing or close mowing may cause soil compaction and reduce the vigour and root volume of the native grasses and hence lower the quality or availability of the larval food source, possibly expose eggs or larvae to excessive soil temperatures and/or increased the risk of desiccation.
- **Cultivation and pasture improvement:** Ploughing is likely to damage or kill larvae and/or their food plants, and pasture improvement leads to loss of the native grasses that the moth depends on for habitat.
- **Herbicides and pesticides** have the potential to damage the moths and/or their food plants, and should only be used where necessary to protect the moths or their habitat.
- **Excess nutrients:** Addition or run-on of fertilisers is likely to favour exotic grassland species over the preferred native food plants of *S. plana*.
- **Shading:** As a grassland specialist, *S. plana* is presumed to have a life cycle adapted to unshaded sites, and in open woodland habitat it appears to be confined to large clearings. Planting of trees around small sites is likely to alter soil moisture, nutrients and temperature, and also the type and density of grasses, while shading by buildings is likely to reduce soil temperature, increase soil moisture and favour weeds. Such changes are likely to reduce the extent and quality of *S. plana* habitat.
- **Altered drainage:** Changes to drainage on or adjacent to *S. plana* sites have the potential to alter the vegetation and soil conditions preferred by the moth.

CHANGING CLIMATE

The predicted changes in climate in the next 50 years are likely to see the ACT become warmer and drier, with increases in extreme weather events and bushfire risk (ACT Government 2009). Species that tolerate such conditions will have an advantage over those species more sensitive to change. The likely direct effects on *S. plana* are not known, but plants advantaged by climate change are likely to include C4 grasses that are not thought to be *S. plana* larval food plants. Climate change may advantage some weed species, including African Lovegrass, which is an invasive C4 grass and is highly competitive on the low-nutrient soils that are typical of drier native grasslands in the ACT (Sharp 2011). Higher predicted CO_2 levels may also favour woody species over grasses, and lead to increased invasion of woody plants into grasslands (Berry & Roderick 2005; Morgan *et al.* 2007). This effect could be hastened by rising temperatures in the ACT, where cold air drainage in winter is thought to be one environmental factor inhibiting the growth of trees in the local grassy valleys (ACT Government 2005).

CONSERVATION ISSUES AND INTENDED MANAGEMENT ACTIONS

PROTECTION

Populations of *S. plana* occur on land under a variety of tenures including nature reserve (Territory Land), rural leasehold Territory Land, Commonwealth owned and managed land (National Land) and unleased Territory Land. These sites are separated from one another by unsuitable habitat, roads and urban development. While there are some large areas of habitat, most sites are less than 5 ha and many sites are less than 1 ha.

Mulvaney (2012) rated the relative importance of known ACT sites using the following criteria:

- habitat size

- maximum moth count
- connection to other habitat patches
- main vegetation type
- understorey quality
- presence of other threatened species.

There are very few *S. plana* sites on ACT-owned land where future land-use decisions (protection or development) are still to be decided. The majority of the habitat in large or highly ranked sites is, or is proposed to be, under conservation management. Mulvaney (2012) noted that while about 30% of the habitat at large ACT sites was approved or proposed for clearance in the next five years, 800 ha (57% of known ACT habitat) is likely to be under conservation management within the same time period. Highly ranked sites from each main area (Gungahlin, Belconnen, Jerrabomberra, Majura) are already either in nature reserves or under ACT Government management as offsets under the EPBC Act. Many of these sites are also to be subject to long-term monitoring to ensure the protection of key populations (Rowell and Evans 2014).

Synemon plana occurs on Territory land managed as public open space (where current management practices, including regular herbage mass control though mowing or slashing, generally appear to be compatible with the persistence of the species at these sites), and leasehold rural land where it can be the subject of a Land Management Agreement or Conservator's Directions. Where the species occurs on Commonwealth land, the ACT Government will liaise with the Commonwealth Government and Canberra Airport to encourage continued protection and management of *S. plana* populations on their land.

Larger populations on larger sites should have highest priority for protection, as these are expected to have the greatest chance of long-term viability. Larger populations of the species are considered to be those containing 500 or more adult moths that occupy habitat patches of 50 ha or more. Medium-sized populations are considered in this plan to contain 200 or more adult moths (but do not meet the criteria for a 'large' population). A medium-sized population has the potential to be viable over the longer term if habitat quality is maintained though appropriate management. Small populations (less than 200 adults) can still form a significant contribution to the conservation of the species, particularly if small populations are connected by habitat so they function as a cluster of sub-populations or are connected by a habitat corridor to a larger population.

Small populations at sites that contribute to research or public education related to the species (e.g. York Park in Barton) should be a priority for protection.

ENVIRONMENTAL OFFSET REQUIREMENTS

Environmental offset requirements for species and ecological communities in the ACT are outlined in the ACT Environmental Offsets Policy and associated documents such as the ACT Environmental Offsets Assessment Methodology and the Significant Species Database. In the Assessment Methodology and Database, some of the threatened species have special offset requirements to ensure appropriate protection. The special offset requirements for *S. plana* is "no loss of habitat patches >50 ha AND supporting populations of more than 50 moths (population must be counted at a time when large populations are observed at nearby known sites)". Given this special offset requirement, a survey is required for this species for both the number of individuals as well as the extent of habitat in hectares.

SURVEY, MONITORING AND RESEARCH

Over the past two decades there have been numerous surveys in the ACT to determine the distribution of potential habitat and the presence of *S. plana* populations. Some of these surveys have been extensive and involved university researchers and Citizen Science volunteers (e.g. Richter *et al.* 2009), though the majority of surveys have been undertaken to identify ecological constraints to proposed urban development. There is now a good understanding of the distribution of *S. plana* and its habitat in the ACT and it is unlikely any significant populations of the species remain undiscovered. It is probable that smaller populations (less than 5 ha) will continue to be found, especially in good flying seasons and during pre-development surveys.

If Chilean Needlegrass continues to spread in Canberra, this may also extend the local range of *S. plana*.

Several key *S. plana* sites in the ACT are subject to regular or *ad-hoc* population and/or habitat condition monitoring, with the longest and most consistently monitored sites being York Park and Canberra Airport.

More recently, standardised monitoring of *S. plana* is being established at sites that include nature reserves and offset areas, as part of the ACT Government's management of offset areas under EPBC Act approval conditions (Rowell and Evans 2014). This monitoring includes quantitative surveys of flying male moths (which may be combined with searches for female moths and pupal cases), measurement of habitat parameters and photographic records. The long-term monitoring will include at least 100 ha of habitat in each of the main areas of occurrence (Gungahlin, Belconnen, Jerrabomberra, Majura), and sites containing Natural Temperate Grassland, native pasture, secondary grassland and open woodland.

Monitoring of a range of sites provides information on district-wide fluctuations in *S. plana* populations, trends at particular sites and the habitat parameters associated with these trends. This monitoring will also provide baseline information for assessment of other sites for which data is available from only one or a few seasons. Monitoring methods will need ongoing review to incorporate the results of research on *S. plana* ecology and habitat management, and to take account of new monitoring methods.

Soil survey methods have been trialled by SMEC (2014b, 2015), to determine the presence of Golden Sun Moth larvae outside of the flying season. Whilst this method can be destructive for larvae and habitat, it does provide information on density, age cohorts and feed species, which is not necessarily achieved from flight surveys.

To date glasshouse and field trials undertaken since 2010 have indicated that Golden Sun Moths can be translocated, but long term survival in a new location is still being assessed by ongoing monitoring. The University of Canberra, in collaboration with the ACT Government and Forde Developments Pty Ltd, successfully translocated Golden Sun Moth larvae from West Macgregor into a glasshouse at the University of Canberra. The larvae were kept alive for nine months and then placed out in a new field location (Sea and Downey 2014b). As part of the Majura Parkway environmental commitments, a methodology was developed for harvesting Golden Sun Moth larvae and translocating soil containing larvae directly from a development area to translocation sites (SMEC 2016). Moths were subsequently recorded emerging from the translocation sites (Sea and Downey 2014b, SMEC 2016). Soil searches at the larvae translocation site following the flight season resulted in the recovery of live Golden Sun Moth larvae (SMEC 2014a), and annual flight surveys at the soil translocation site have resulted in regular moth sightings (SMEC 2016). Translocation of soil with Golden Sun Moth larvae is more cost effective than individual larvae translocation, and has been repeated again in a 2016 transfer of larvae and soil containing larvae from the new proposed suburb of Taylor to the nearby environmental offset area of Kinlyside.

Research and adaptive management is required to better understand the life history and ecology of *S. plana*, habitat requirements and techniques to maintain the species' habitat. Specific research priorities include:

- Habitat management – optimal habitat requirements (grass species, structure, biomass) and techniques compatible with or required to maintain habitat condition, including regimes of grazing, fire, slashing/mowing.
- Habitat creation – development of methods to create *S. plana* habitat with the aim of increasing available habitat and facilitating connections between fragmented populations (e.g. Dunlop-Jarramlee grasslands, Canberra Airport).
- Habitat use – identify habitat characteristics that act as sources and sinks for adult moths, to reduce threats to the breeding population. Males are attracted to shorter areas and these can include areas where females might not be present, such as rock outcrops in tall grassy paddocks, mown areas (roadsides, median strips, fire breaks), golf course fairways, foot tracks, recently burnt areas).
- Food plants – further laboratory research is needed to clarify the grass species eaten by *S. plana* larvae, their relative dietary

importance and density of food plants required to sustain populations of *S. plana*.

- Chilean Needlegrass – improved methods to control or manage the spread of this invasive species and what role this food plant may play in the conservation of the species.
- Translocation – further development of reliable translocation methods to facilitate establishment of new populations (which could be within the urban open space, or newly created grassy areas in large roundabouts, playing fields etc.), to maintain genetic integrity of small or isolated ACT populations.

MANAGEMENT

Habitat requirements for *S. plana* are generally consistent with the requirements of other threatened grassland fauna including the Grassland Earless Dragon (*Tympanocryptis pinguicolla*) and the Perunga Grasshopper (*Perunga ochracea*), which often co-occur with *S. plana*. Habitat management for these species aims to keep herbage mass within a moderate range to maintain tussock structure and inter-tussock spaces. The Striped Legless Lizard (*Delma impar*) occurs in grassland of intermediate to high herbage mass/height, and this threatened species may not be tolerant of shorter grass swards or management practices (regular mowing) that are compatible with the conservation of *S. plana*. Where the aim is to conserve multiple threatened species at a site, management will need to take into account any differing habitat requirements (see the ACT Native Grassland Conservation Strategy). This will most likely include maintaining or promoting a 'patchy' sward structure that contains a mosaic of habitat patches that differ in tussock height and/or density. Management of secondary grassland or open grassy woodland sites containing *S. plana* may be problematic, as the natural or assisted regeneration of trees and shrubs in these areas that favour conservation of bird, mammal, reptile, insect and plant diversity will most likely come at the expense of *S. plana*'s preferred open grassland habitat.

Based on current knowledge of the habitat requirements of *S. plana*, management actions should aim to maintain a native grass sward that is short to medium (5 cm - 15 cm) in height (i.e. the height of the bulk of the tussock leaves, not including the often few higher leaves and seed-bearing culms), has an intermediate density (cover) of tussocks, low weed cover and tussocks interspersed with areas of bare ground. Management should promote a sward that has a high proportion of known food plants, especially Wallaby Grasses.

Where possible, management activities should be undertaken outside the seeding period of major weeds, and should minimise disturbance and compaction of soil. The development of barriers within habitat areas such as areas of rank grass growth, dense weed patches, roads and linear tree/shrub plantings should be avoided.

Most grassland sites containing *S. plana* will require some management of herbage mass to maintain the habitat in good condition. The preferred method of managing grass structure and biomass is grazing by native herbivores (kangaroos), which are a natural fauna component of native grasslands. Kangaroo numbers will need to be managed on some sites, especially during droughts, to avoid overgrazing and loss of tussock structure.

Where kangaroo grazing may not be sufficient to maintain biomass within the desirable range, other methods of herbage mass control may need to be used, such as slashing or grazing by stock. If stock grazing is used, light or intermittent grazing is preferable, timed to avoid excessive trampling during the *S. plana* breeding period (late October to January). The average tussock height should not be reduced below 10 cm during grazing. Internal fencing will be required on some sites to allow control over grazing intensity in particular areas. On sites containing Chilean Needlegrass cattle are preferred to sheep as they are less likely to transfer seed, and grazing should take place in winter or early spring where possible, before the seeding period of the grass.

If slashing is used, tussock height should not be slashed below 10 cm, and slashing should be minimised between November and January to avoid the adult flying period.

Slashing should be undertaken before November but if the grass sward is tall and dense during the *S. plana* breeding season (little or no bare ground) then slashing is preferable to leaving a long, dense sward for the remainder of the breeding season. Machinery should be thoroughly cleaned before entering *S. plana* sites, and after slashing on sites containing Chilean Needlegrass and other significant weeds. Slashing should avoid the seeding period of significant weeds where possible and should not be undertaken when the ground is wet, to avoid soil disturbance. Mowing machinery should disperse the slashed material, or if windrows are produced, these should be raked and removed from the grassland.

Any burning in *S. plana* habitat should be patchy and low-intensity, and the effects on grassland composition and *S. plana* activity in subsequent years should be monitored.

Burning should be restricted to March–September to avoid the breeding and egg-hatching period, and to allow the grassland to start regrowing before the emergence of the next generation of adults. Post-fire weed control will be necessary on some sites.

Weed control on *S. plana* sites should, as a minimum, aim to eliminate woody weeds and control other high threat species. Preventing excessive reduction of biomass will make native grasslands more resistant to weed invasion. The strategic use of biomass control methods can assist in reducing seed set in some weed species. Perennial exotic grasses such as Chilean Needlegrass, Serrated Tussock and African Lovegrass can invade disturbed native grasslands. Where dense patches of these species have developed in or adjacent to *S. plana* habitat, they can be suppressed and contained if eradication and rehabilitation are not an option (DECCEW 2009). One method suggested for containment is to poison a barrier strip, then maintain a layer of deep, seed-free mulch between the native grassland and the weed-dominated areas, and manage the areas separately as far as possible (DPI 2007).

IMPLEMENTATION

Implementation of this action plan and the ACT Native Grassland Conservation Strategy will require:

- Land planning and land management areas of the ACT Government to take into account the conservation of threatened species.
- Allocation of adequate resources to undertake the actions specified in the strategy and action plans.
- Liaison with other jurisdictions (particularly NSW) and other land holders (Commonwealth Government and Canberra International Airport) with responsibility for the conservation of a threatened species or community.
- Collaboration with universities, CSIRO, Australian National Botanic Gardens and other research institutions to facilitate and undertake required research.
- Collaboration with non-government organisations such as Greening Australia to undertake on-ground actions.
- Engagement with the community, where relevant, to assist with monitoring and other on-ground actions, and to help raise community awareness of conservation issues.

OBJECTIVES, ACTIONS AND INDICATORS

Table 2. Objectives, Actions and Indicators

Objective	Action	Indicator
1. Conserve large populations in the ACT. Protect other ACT populations from unintended impacts (unintended impacts are those not already considered through an environmental assessment or other statutory process).	Apply formal measures to protect all large populations on Territory-owned land. Encourage formal protection of all large populations on land owned by other jurisdictions.	All large populations protected by appropriate formal measures.
	Protect all medium size populations on Territory-owned land from unintended impacts. Encourage other jurisdictions to protect all medium size populations from unintended impacts.	All sites with medium size populations are protected by appropriate measures from unintended impacts.
	Ensure sites where small populations occur on Territory owned land are protected from unintended impacts, where this contributes to broader conservation aims (such as protecting multiple threatened species at a site). Encourage other jurisdictions to undertake similar protection of small populations.	All sites with small populations are protected by appropriate measures from unintended impacts, where sites have broader conservation value.
2. Manage the species and its habitat to maintain the potential for evolutionary development in the wild.	Monitor abundance at a representative set of sites, together with the effects of management actions.	Trends in abundance are known for representative sites, management actions recorded.
	Manage habitat to maintain its suitablilty for the species, including implementing an appropriate grazing / slashing / burning regime (recognising current imperfect knowledge).	Habitat is managed appropriately (indicated by maintenance of an appropriate sward structure and herbage mass). Potential threats (e.g. weeds) are avoided or managed. Populations are apparently stable or increasing (taking into account probable seasonal/annual effects on abundance fluctuations).
3. Enhance the long-term viability of populations through management of adjacent grassland to increase habitat area and connect populations, or to establish new populations.	Manage grassland adjacent to the species' habitat to increase habitat area or habitat connectivity. If suitable habitat exists, re-establish populations where they have become locally extinct.	Grassland adjacent to or linking habitat is managed to improve suitability for the species (indicated by an appropriate sward structure and plant

Objective	Action	Indicator
		species composition). If suitable habitat exists, research and trials have been undertaken to establish new populations.
4. Improved understanding of the species' ecology, habitat and threats.	Undertake or facilitate research on habitat requirements, techniques to manage habitat, and aspects of ecology directly relevant to conservation of the species.	Research undertaken and reported and where appropriate applied to the conservation management of the species.
5. Promote a greater awareness of, and strengthen stakeholder and community engagement in the conservation of the species.	Undertake or facilitate stakeholder and community engagement and awareness activities.	Engagement and awareness activities undertaken and reported.

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