Conservation of the graceful sun-moth (*Synemon gratiosa*)

Survey results from the Swan, South West and southern Midwest Regions 2010 – 2012

Summary Report

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Cover photos: Coastal heathland habitat of the graceful sun-moth (*Synemon gratiosa*) at Burns Beach, with *Lomandra maritima* in the foreground, image by Carly Bishop. Graceful sun-moth (inset, 1.2 magnification), image by David Pike.

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This report presents results for the *Conservation of graceful sun-moth habitat* project up to 2012. This report should not be quoted or used as final results for the *Conservation of graceful sun-moth habitat* program. This report and associated information will be available on the DEC website at www.dec.wa.gov.au.

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Summary

Surveys of the graceful sun-moth (*Synemon gratiosa*) were conducted during 2010 – 2012 in the Department of Environment and Conservation (DEC) Swan, South West and southern Midwest Regions by DEC staff, volunteers and environmental consultants. Results of most 2010 surveys were presented in the previous interim report (available at http://www.dec.wa.gov.au/content/view/5695/1813/). The 2011 – 12 surveys were designed to determine the size and extent of the graceful sun-moth distribution in the northern part of its range, clarify its taxonomy, collect additional life history details, and provide the data needed to better assess its conservation status.

The major findings were:

1. Survey data from across the species' range showed that it typically occurs in very low density, so that populations are small by typical lepidopteran standards.
2. Genetic analysis has confirmed the graceful sun-moth as a distinct species, limited to coastal and near-coastal areas between Binningup and Kalbarri. Genetic diversity is low to moderate and varies with region. There is no genetic distinction between populations breeding on the two alternate host plants.
3. The life cycle takes two or more years to complete. Graceful sun-moth numbers in sequential years are reasonably consistent, although in some instances it was not detected in sites where it had been recorded in the previous year. There is no genetic distinction between cohorts.
4. The predicted future population decline in graceful sun-moth over the next 10 yr, based on the method recommended by the IUCN, is 18.3%. Projected future loss of habitat is less, at 11.3%. These projected losses account only for urban and other development and does not include any associated declines in habitat quality, genetic diversity or reduced sustainability of any resulting small or fragmented populations.
5. Four areas are particularly important for graceful sun-moth conservation, having high graceful sun-moth density, large areas of contiguous habitat in good condition, and/or being representative of genetic variation within the species: the area near Coolimba, north of Jurien Bay; Wanagarren and Nilgen Nature Reserves; the Alkimos/Eglinton/Yanchep area; and Yalgorup NP and adjacent areas. Several other smaller populations are also important for the overall conservation of the species.
6. Because of its specific habitat requirements, vulnerability to disturbance and associated habitat alteration, and the substantial projected future losses of habitat and population, ongoing monitoring of the graceful sun-moth is recommended.
7. This project has effectively collated and analysed large amounts of data from numerous DEC staff, community volunteers and environmental consultants using standardised survey protocols. It should serve as a model for the assessment of the conservation status and needs of other threatened taxa in Western Australia.

1. Introduction

The graceful sun-moth (*Synemon gratiosa* Westwood 1877, family Castniidae) is a day-flying moth endemic to south-west Western Australia. Prior to 2010 the graceful sun-moth was known from remnants of native vegetation within the greater Perth metropolitan region between Mandurah and Neerabup. Historical records showed that its distribution and area of occupancy had declined substantially as a result of habitat loss for housing, industry and agriculture (Burbidge, 2004). In 1997 the graceful sun-moth was listed as declared rare fauna under the *WA Wildlife Conservation Act 1950* due to its small range, the lack of any known sub-populations in protected areas, and the ongoing loss of existing habitat through land clearing. This listing was based on expert opinion, which was an accepted assessment method at that time, although this method has since been supplanted and the current listing process uses standard criteria (IUCN Standards and Petitions Subcommittee, March 2010). In 2009 the species was listed as Endangered under the Commonwealth *EPBC Act 1999* (Threatened Species Scientific Committee, 2008). The reasons for listing the graceful sun-moth as a threatened species were that it had a restricted geographic distribution, small area of occupancy, and the remaining sub-populations were both severely fragmented and declining.

Prior to 2009, the graceful sun-moth had only been recorded in a single habitat type: *Banksia* woodland containing the host plant (i.e. the plant on which larvae feed) *Lomandra hermaphrodita* (C. R. P. Andrews) C. A. Gardner. In 2009 new subpopulations of the graceful sun-moth were located in the Perth metropolitan region, but in coastal heathland habitat associated with a different host plant, *Lomandra maritima* T. S. Choo. This species is closely related to *L. hermaphrodita*. As *L. maritima* is locally abundant in coastal and near-coastal areas between Binningup and Shark Bay, the discovery of this new host plant prompted surveys beyond *Banksia* woodland. This project was established by the Department of Environment and Conservation (DEC) in 2009, to better delimit the potential and occupied range of both the two host plants and the graceful sun-moth.

Like other organisms, many species of butterflies and day-flying moths are increasingly dependent on remnant vegetation for survival, especially in urbanised areas (Connor et al., 2002; Newland, 2003; Ruszczyk & De Araujo, 1992). The threats to conservation of these taxa are generally the same as for other fauna: destruction or alteration of habitat; changes to management practices; isolation of remnant habitat; pollution and use of chemical insecticides and herbicides; climate change; and potential genetic effects such as inbreeding (Beaumont & Hughes, 2002; New, 1991; Pollard & Yates, 1993). In Australia, several studies have documented the conservation status of individual butterfly taxa (Braby, 2000; Kitching & Dunn, 1999; New, 2009; Sands & New, 2002). These studies cite the lack of systematic surveys in conservation reserves as the major impediment to establishing the conservation status of many species. Information about the habitat resources needed (e.g. density and quality of host plants) to conserve remnant populations of day-flying moths is also required (Garden et al., 2006). Other than the studies of Williams (2008; 2009) and Willers (unpublished) there have been no targeted, systematic surveys of the graceful sun-moth. Williams (2009) examined approximately 40 urban habitat remnants in the Perth metropolitan region, all of which contained apparently suitable *Banksia* woodland habitat, but located only six graceful sun-moth populations. These studies were restricted to the Perth metropolitan area and sampled few sites in coastal heathland, which were only subsequently found to be important breeding habitat.

Typically, it is the requirements of the immature life stages that define habitat quality for insects, and the importance of host plant density for butterflies and day-flying moths has been demonstrated both in Western Australia and elsewhere (Dennis et al., 2004; Dover, Dennis & Atkins, 2008b; Williams, 2010). Because of this obligate dependence on suitable plants for breeding, the distribution of the host plants determines the potential habitat. The larvae of the graceful sun-moth feed only on the two mat-rushes *L. hermaphrodita* and *L. maritima,* both of which are widespread in and around the Perth metropolitan region including future development corridors. As a result, much of the habitat of the graceful sun-moth (as known in 2009) was in areas proposed for clearing,

particularly in the coastal and sub-coastal parts of the greater Perth metropolitan region. This situation created an urgent need to clarify the distribution and habitat requirements of the species to minimize and mitigate potential conflict between the conservation of the graceful sun-moth and proposed development.

The project aimed to:

- Determine the distribution and habitat requirements of the graceful sun-moth, and the factors affecting habitat occupancy;
- Provide a regional context for environmental impact assessment processes and identify key habitat for conservation;
- Undertake a preliminary assessment of within- and between-population genetic variation;
- Provide information to better determine the conservation status of the species, and re-assess that status should any substantial changes be found in its previously known distribution or rate of decline;
- Assess the effectiveness of current survey prescriptions for detecting the graceful sun-moth and assess additional techniques; and
- Make recommendations for future surveys and conservation actions.

This report documents the results and key outcomes from the 2010, 2011 and 2012 survey seasons in relation to the above aims.

2. Methods

2.1 Graceful sun-moth surveys

Data on the graceful sun-moth's distribution and habitat were collected by DEC research and operational staff, community volunteers and environmental consultants. Full details of the graceful sun-moth survey and habitat assessment methods are given by Bishop et al. (2009). In the 2011 and 2012 surveys DEC staff focused on surveying the northern extent of the graceful sun-moth's distribution, especially in conservation estate, and on collecting genetic material for analysis. In addition, surveys were undertaken to confirm whether or not a population of *S. gratiosa* inhabited the Jarrah forest inland from Perth, based on one historical record of an unusual sun-moth from Bannister. Surveys were carried out from Wilbinga to Jurien Bay, and from the northern limit (as of 2010) at Coolimba, north to Kalbarri and Shark Bay. Site selection was based on aerial photography combined with accumulated knowledge of likely potential habitat based on landform, vegetation types, and herbarium records of *Lomandra maritima*.

At each site the presence of the *Lomandra* host plant was recorded, their approximate density (High, Medium, or Low), and the presence and abundance of graceful sun-moth adults determined. Where no adults were detected but *L. maritima* density was medium or high, a search for larvae and pupae was conducted. A technique for locating larvae and pupae in the subterranean parts of the host plant was trialled during the 2011 and 2012 surveys. The ability to reliably locate larvae at any time of the year would facilitate and increase the effectiveness of current survey methods.

2.2 Habitat mapping

Due to the large area of potential habitat for the graceful sun-moth between Binningup and Shark Bay (approximately 800 km in extent), it was not possible to thoroughly survey all areas. To obtain the data necessary to map the distribution and assess the conservation status of the graceful sun-moth against IUCN criteria, two habitat classes were defined and mapped: confirmed occupied and potentially occupied.

2.2.1 Confirmed occupied habitat

Confirmed occupied habitat was determined using field survey for both coastal heathland and *Banksia* woodland. Confirmed habitat was mapped in Geographical Information System (ArcMap) by buffering individual graceful sun-moth records by 100 m. When records were close together and buffers overlapped, the boundaries were dissolved to create a single polygon. Clearly unsuitable areas adjacent to sun-moth records, such as roads and cleared land, were clipped from the polygon to increase accuracy. This method is the same as that used to map the occupied habitat of the (critically endangered) golden sun-moth (*S. plana*) in Victoria (see "Final prescription for the golden sun-moth" at http://www.dse.vic.gov.au/).

2.2.1 Potentially occupied habitat

A desktop study was conducted to identify potentially occupied habitat. The latter was restricted to the distribution of the *L. maritima* host plant, as coastal heathland could be identified through a combination of existing records of *L. maritima* and the presence of suitable landforms and soil types from GIS layers. This approach was effectively subjective. To verify the accuracy of this approach, sites were selected randomly from within the area of mapped potential habitat, as well as sites where the graceful sun-moth was not expected to occur, and "ground-truthed" using standard survey methods. This provided an independent, objective estimate of the accuracy of the desktop identification of potentially occupied coastal heathland habitat. This process was unable to be completed for *Banksia* woodland as suitable habitat features for graceful sun-moth occur at a comparatively finer site-based scale for which spatial GIS layers do not currently exist.

2.3 Population estimates

To estimate current population sizes and projected future population losses we used two methods, based on habitat area and estimated population sizes. The habitat area method effectively treats all habitat as having equal density of graceful sun-moth across the range, whereas the population size method incorporates between-site variation in graceful sun-moth density.

Transect counts have been validated as an accurate index of population size in butterfly communities (Isaac et al., 2011; Lewis & Senior, 2011; Pollard & Yates, 1993). They therefore provide a means of estimating an index of population size for the graceful sun-moth, and a method of determining potential future population losses based on current land-clearing proposals. To apply the index of abundance method to the transect counts and habitat mapping of *S. gratiosa*, the following data were tabulated:

- the area of occupied and potential habitat at each site;
- the density of individual adult moths counted at the site, per unit effort (i.e. the total count/hr of survey, the *index of abundance*); and
- the area of occupied and potential habitat proposed to be retained or cleared at each site in the 10 year time window 2012 – 2021 inclusive.

For areas of mapped potential habitat that had been adequately surveyed, but where the graceful sun-moth was not detected, the index of abundance was zero. However, there were also areas of unsurveyed potential habitat in several regions, particularly in the northern parts of the distribution between Wilbinga and Jurien Bay. This mapped potential habitat had not been surveyed, so as an estimate of the index of abundance for these areas the mean index for the region was calculated (i.e. the average density in occupied sites nearby). Similarly, at three sites where no adult graceful sun-moths were recorded, but where early stages (larvae or pupae) were detected, an arbitrary

index of 0.1 was used. For sites surveyed in more than one year, the annual density measurements were averaged (using the harmonic mean[1]) to incorporate variability between years.

Based on the success rate of ground-truthing the habitat mapping (see below), a lower bound for the fraction of potential habitat that is actually actual occupied habitat is 0.79 (79%). To calculate an index of the population size at each site, the index of abundance was multiplied by the site areas for occupied habitat and for (occupied + 0.79 x potential) habitat.

Thus, the Population Index was calculated using the standard method:

Population Index = *IOA x A*,

where *IOA* = the Index Of Abundance, and *A* = the Area of graceful sun-moth habitat on the site (either occupied, or occupied + 0.79 x potential).

The population index was calculated for the present (2012) and for the expected area of remaining mapped habitat in 2021, a time window of 10 years. The extent of future clearing was determined from maps of development proposals either already submitted to SEWPaC (i.e. "referrals"), from published or web-based maps of future proposed development (such as "structure plans"), or from government sources (such as the Department of Transport). In the vast majority of cases, the proposals are currently projected to be completed or near completion by 2020.

2.4 Genetics

Genetic analysis was undertaken to determine whether the graceful sun-moth is a single, monophyletic species and to undertake a preliminary assessment of the level of genetic variation across the species' range. Using mitochondrial DNA (mtDNA), the levels of mitochondrial genetic diversity were quantified and historical levels of gene flow among geographic regions assessed. Full details of the genetic study are reported elsewhere (Williams, 2011). Approximately five adult graceful sun-moth specimens were sampled from each of 30 sites between Binningup and Kalbarri. The phylogeny of *S. gratiosa* was then examined in relation to several other sun-moth taxa using the mtDNA gene COII. Eleven other *Synemon* spp. taxa, both described and putative, were included: *S. maja*; *S. catocaloides*; *S. ?discalis*; *S.* 'Perth'; *S.* 'Leeman'; *S.* 'Yarloop'; *S. sophia*; *S. austera*; *S.* 'Mt Dale'; *S.* 'Kukerin'; and *S. jcaria*.

3. Results

3.1 Graceful sun-moth distribution and habitat

3.1.1 Surveys and confirmed occupied habitat

Over the three survey years 2010 – 2012 the graceful sun-moth was recorded at more than 80 transects across three DEC regions: Swan, Midwest and South West. Many records from individual transects were clearly sub-sites or subpopulations within larger sites – thus, they have been grouped into approximately 60 sites within 11 regions (Appendix 1). The distribution extends from north of the Murchison River near Kalbarri, in the north, to Binningup, in the south. The majority of confirmed habitat was found in the Swan Region (15.3 km² – 82%), where the largest number of surveys were conducted, with less in coastal parts of the Midwest Region (3.0 km² – 16%) and the northern coastal section of the South West Region (0.3 km² – 2%), and most confirmed habitat was on freehold lands (due to the survey bias favouring sites subject to development proposals Table 1).

[1] The harmonic mean is an appropriate estimator of average density for count data, which follows an approximately log-normal distribution.

Table 1: Confirmed area of occupancy (cAOO) and mapped potential habitat by land tenure.

Tenure	cAOO (km²)	cAOO (%)	Potential habitat (km²)	Potential habitat (%)
Freehold	10.9	59%	50.3	31%
Crown reserve	7.2	39%	76.5	47%
Other (UCL, crown lease etc.)	0.5	2%	36.8	22%
TOTALS	**18.6**	**100%**	**163.6**	**100%**

The recorded density of adult graceful sun-moths was highly variable, with the number seen per hour of survey very low by lepidopteran standards. Densities were considerably lower than the 52 adults/hr of survey recorded in belt transect surveys of the Golden sun-moth in Victoria (Gibson & New, 2007). Densities of < 1 adult/hr of survey were common, especially in *Banksia* woodland sites. However, in sites with extensive and dense cover of *Lomandra*, such as at Wanagarren and Nilgen Nature Reserves, in the Alkimos/Eglinton area, and at Yalgorup NP, densities were moderate, with up to 20 adults/hr recorded (averaged across several repeat surveys, Appendix 2).

3.1.2 Potential habitat

Although the majority of confirmed occupied habitat was in freehold land, the majority of mapped potential occupied habitat was in Crown reserve or other Crown lands (Table 1). The majority of mapped potential habitat was in the Midwest Region (62%), with less in the Swan (37%) and South West (1%) Regions (Appendix 1). Of the 19 sites identified as potential habitat and subsequently surveyed in 2012, 15 were correctly predicted to have *L. maritima* and the graceful sun-moth present, a success rate of 79% (Table 2).

Table 2: Results of ground-truthing mapped potential occupied habitat in coastal heathland.

Ground-truthing site	Lomandra present?	Lomandra density	Adult *S. gratiosa* present	Predicted correctly
Kalbarri South transect 1	No	Absent	No	Yes
Port Denison	Yes	Low	Yes	No
Geraldton	No	Absent	No	Yes
Coolimba N	Yes	Low	Yes	No
Jurien E[1]	Yes	Low	No	No
Jurien transect 1	Yes	High	Yes	Yes
Jurien transects 2 – 4	Yes	Moderate	Yes	Yes
Nambung NP, Hansen Rd	No	Absent	No	Yes
Nilgen transect 2	No	Absent	No	Yes
Nilgen transect 3	Yes	Low	Yes	Yes
Wanagarren transect 2	Yes	High	Yes	Yes
Wanagarren transect 3	Yes	Moderate	Yes	Yes
Wanagarren transect 4	Yes	High	Yes	Yes
Cervantes transect 2[1]	Yes	High	No	No
Ledge transect 1	Yes	Moderate	Yes	Yes
Seabird transect 1	Yes	High	Yes	Yes
Wilbinga transect 4	Yes	High	Yes	Yes
Two Rocks BWD	Yes	High	Yes	Yes
Port Kennedy	Yes	Moderate	Yes	Yes

[1] These sites were subsequently removed from mapped potential habitat.

3.1.3 Surveys of larvae and pupae

Surveys in coastal heathland during the adult flight season of 2011 and 2012 were consistently able to locate larvae and occasionally pupae. Larvae ranged in size from approximately 4 to 12 mm, clearly a distinct generation (or generations) from the current cohort of adults. The presence of both immature and mature larvae as well as pupae and adults moths is consistent with a life cycle of at least two years. Similarly, larvae and occasional pupae were located at the base of *L. hermaphrodita* plants, but required considerably greater search effort and success rates were low.

3.2 Projected future habitat and population losses

The total population index and area of habitat was calculated for the present (2012) and for the expected area of remaining habitat in 2021, assuming current development proposals proceed. For confirmed occupied habitat only, the projected future decline is 35%. If mapped potential habitat is included, and assuming that 79% of this habitat is occupied, projected loss over the next 10 years is 18.3% of the population and 11.3% of the area of habitat (Table 3 & Appendix 2).

An interesting result of this analysis is that although there are more than 60 sites with the graceful sun-moth present, relatively few make a substantial contribution to the result. The largest potential population losses are in the northern Perth suburbs of Alkimos, Eglinton and Yanchep, although this region still retains large populations in conservation areas and other habitat retained after clearing (Table 4). Sites in Yalgorup NP, Wanagarren and Nilgen NRs, and near Coolimba retain the largest areas of habitat and populations in conservation estate and other crown lands.

Table 3: Projected declines in graceful sun-moth habitat and population 2012 – 2021.

	AREA (ha)		**INDEX OF ABUNDANCE (IOA)** [1]
	Confirmed occupied habitat (cAOO)	**Confirmed occupied habitat plus area of mapped potential habitat (iAOO)**	**(cAOO + iAOO @79%) x IOA**
Total as at 2012	1,853	18,211	37,199
Total projected remaining in 2021	1,209	16,262	30,390
Percentage loss	-34.8%	-11.3%	-18.3%

[1] The method recommended by the IUCN for estimating future population decline.

Table 4: Projected graceful sun-moth population losses and retention 2012 – 2021.

PROJECTED POPULATION LOSSES		PROJECTED POPULATION RETENTION	
Sites with greatest projected population losses (confirmed + potential habitat)	**Amount lost (of total population index)**	**Sites with greatest projected population retention (confirmed + potential habitat)**	**Amount retained (of total population index)**
Perth Northern suburbs (Jindalee, Butler, Alkimos, Eglinton and Yanchep)	14.3%	Coolimba – Port Denison	17.8%
Lancelin, Ledge Point, Seabird, Moore River South, Wilbinga, Two Rocks	1.4%	Lancelin, Ledge Point, Seabird, Moore River South, Wilbinga, Two Rocks	14.9%
Lake Clifton, Yalgorup NP, Preston Beach, Myalup, Binningup	1.6%	Lake Clifton, Yalgorup NP, Preston Beach, Myalup, Binningup	8.4%
		Wanagarren NR, Nilgen NR	22.7%
Other sites with projected population losses	1.0%	Other sites with retained populations	12.8%
Total	**18.3%**	**Total**	**76.6%**

3.3 Genetics

The phylogenetic analysis supported the graceful sun-moth as a single (monophyletic) entity (Figure 1). The morphologically similar species *S. jcaria*, the only other Western Australian species with a *Lomandra* host plant, was determined to be a very close relative. Similarly, the undescribed species *S.* sp. 'Kukerin', was found to be the nearest relative to [*S. gratiosa + S. jcaria*]. The host plant of *S.* sp. 'Kukerin' was determined to be a close relative of *Lomandra*, strong evidence in support of this species being a sister taxon to *S. gratiosa* and *S. jcaria*.

Several populations of sun-moths discovered in the jarrah forest east of Perth were found to have mtDNA from both *S. gratiosa* and *S. jcaria*, and represent introgression or hybridization between these two taxa. The significance of these populations will require additional study (i.e. of nuclear genes) to resolve. These populations have been excluded from the current delineation of *S. gratiosa*.

Genetic variation within the graceful sun-moth was low to moderate, but followed a definite north – south pattern consistent with isolation by distance. The large clade below *S. jcaria* in Fig. 1 (identified by site, lower section of tree) contains all mtDNA haplotypes from across the graceful sun-moth's range. From top to bottom, the first 10 are from south of the Swan River, the next 16 from between Perth and Jurien Bay, and the remaining five from between Coolimba and Kalbarri. Three major regions were resolved: south and north of the Swan River, and Coolimba – Kalbarri. The five Coolimba – Kalbarri subpopulations were the most genetically diverse. Subpopulations of the graceful sun-moth that breed on the two alternate host plants were not genetically distinct, nor were specimens collected in the same site but in alternate years (Williams 2011). Additional analysis based on two other mtDNA genes (results not shown) both confirms this general pattern and more clearly distinguishes the three regions.

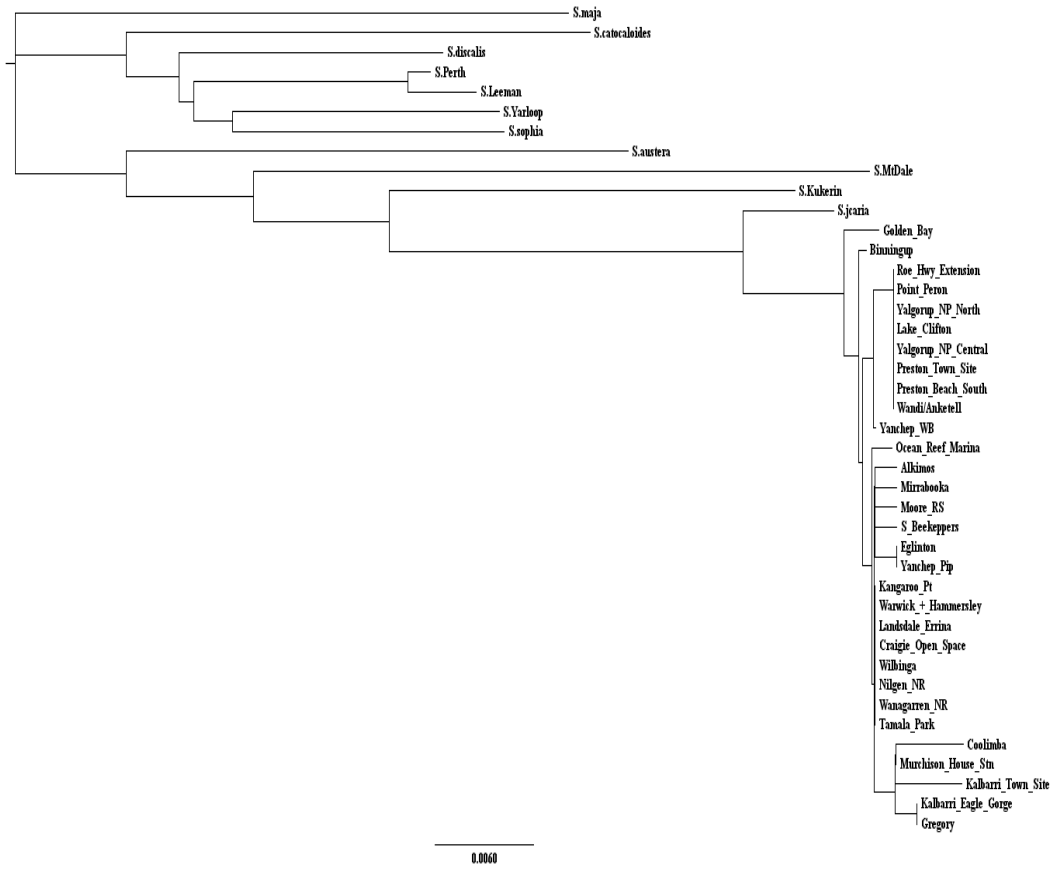

Figure 1: Phylogeny of *S. gratiosa* and 11 other sun-moth taxa, based on mitochondrial DNA.

4. Discussion

The graceful sun-moth has an extensive but disjunct distribution between Kalbarri and Binningup. Across this geographic range the species shows low to moderate levels of genetic diversity, and there is no genetic differentiation between populations in coastal heathland and Banksia woodland. It is genetically distinct from the two similar-looking species that also occur in the south-west: *S. jcaria* and the undescribed *S*. sp. "Kukerin", but there appears to be hybridization between the graceful sun-moth and *S. jcaria* in a zone of contact in the eastern jarrah forest.

The transect-based survey methodology has proved to be effective in detecting the species and provided useful index-of-abundance data. The wide variation in population index estimates reflects the high level of variation in the graceful sun-moth density across its range. Although the survey methodology was standardized, with the aim of minimizing between-site and between-observer variation, various effects including weather conditions, time of year, observer differences, as well as natural year-to-year variation in abundance may affect the transect counts. Nonetheless, average densities within each region were generally consistent. The collection of data by DEC staff, community volunteers and environmental consultants provides a valuable paradigm for assessment, monitoring and re-assessment of the conservation status of a threatened species in an area of rapid development. Mapping of potential habitat was an accurate means of mapping habitat in large areas of the range, where on-ground field surveys are either impractical or beyond the logistical capacity of the project. The ability to detect larvae within their *Lomandra* host plants, particularly in coastal heathland, provides an additional (although destructive) method of determining the presence of the graceful sun-moth.

The combination of widespread field surveys, assessment of population abundance by an index of abundance, and accurate habitat mapping, has enabled a comprehensive assessment of the conservation status of the graceful sun-moth. Large areas of the known occupied habitat (i.e. those areas identified as habitat by direct field survey) are threatened by development within the next 10 years. However, this certainly overestimates the true fraction of occupied habitat that is actually threatened, because of the large survey effort targeted at sites subject to development proposals.

Results from 2011 and 2012 show that the species is both more widespread and better represented in conservation reserves and other Crown lands than was previously thought.Large areas of both known occupied habitat and mapped potential habitat occur within secure conservation reserves. The most notable of these are Wanagarren and Nilgen Nature Reserves and Yalgorup National Park, although other subpopulations occur in several other reserves within the moth's range. Four regions are particularly important for graceful sun-moth conservation, having high graceful sun-moth density, large areas of contiguous habitat in good condition, and being representative of genetic variation within the species: the Coolimba – Kalbarri region; Wanagarren and Nilgen Nature reserves; the Alkimos/Eglinton/Yanchep region; and Yalgorup NP and adjacent areas. Of these, large areas of the Alkimos/Eglinton/Yanchep region are proposed for development in the next 10 – 20 years. The five Coolimba – Kalbarri subpopulations are all isolated by lack of contiguous habitat, and are the most genetically diverse. There are currently no imminent or severe threats to these subpopulations, other than goat grazing on Murchison House Station and adjacent crown land, and the threats inherent in their small size or proximity to settlements. The populations in the two remaining important regions appear to be currently stable and not subject to imminent threat.

The predicted future population decline of the graceful sun-moth over the 10 year period 2012 – 2021 is 18.3%. This is based only on projected losses due to urban and semi-rural development and does not include any associated declines in habitat suitability or possible loss of any resulting small or fragmented populations. Based on this information, the species does not currently qualify for listing as threatened under IUCN criteria. The DEC prepared a recommendation to remove the graceful sun moth from the list of declared rare fauna (fauna in need of special protection) under the *Wildlife Conservation Act 1950* and this has been supported by the WA Threatened Species Scientific Committee.

Although the range is extensive, the graceful sun-moth is restricted to a narrow corridor of suitable habitat that is discontinuous and fragmented, both by natural fragmentation caused by intervening areas of unsuitable vegetation types and landforms, in addition to past urban and rural development. Many sites, both natural and remnant, are small in area (< 10 ha) or represented by low numbers of individuals (with often fewer than five individual adult moths being recorded). This type of distribution, combined with future land clearing and other anthropogenic effects (such as altered fire regimes, invasion by weeds and feral herbivores, and climate change), suggest that the species is vulnerable to future population declines. Ongoing monitoring of the graceful sun-moth is therefore strongly recommended, particularly in or adjacent to sites subject to habitat alteration, together with undisturbed 'reference' sites for comparison. The graceful sun-moth has therefore been included on the DEC Priority fauna list as a Priority 4 species. These are Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection, but could be if present circumstances change. These taxa are usually represented on conservation lands.

The potential for out of season larval surveys should be explored further, based on moderately successful field trials during 2011 – 2012. Further refinement of larval searches is required to facilitate reliable out of season surveys, and their destructive nature needs careful consideration. Larval searches at *Banksia* woodland sites are not practical due to the comparatively low abundance of *Lomandra hermaphrodita*, the generally small areas of these sites, and the resulting high impact

of sampling. Larval surveys should be based upon *L. maritima* density and other site characteristics identified from habitat suitability modelling, such as vegetation condition and proximity to known populations. For example, a survey using destructive sampling of host plants within an area proposed for clearing could continue until either larvae are found or until sufficient plants have been sampled to preclude graceful sun-moth presence with high probability. In the latter case, the destructive sampling would be of no consequence, given that clearing would then proceed.

A quantitative habitat suitability model should be developed using the site-based habitat assessment data. This would provide an insight into those habitat characteristics important for graceful sun-moth presence and abundance, provide a baseline against which to measure future changes, and guide the placement of future monitoring sites. Determining potential habitat in *Banksia* woodland requires additional study, as the low detectability of the graceful sun-moth in such sites makes development of a suitability model more problematic in this habitat type. However, the low contribution of this habitat type to the total population and therefore overall conservation of the species makes such modeling less important.

Further research is also required to resolve gaps in knowledge of the biology of the graceful sun-moth. Mark-recapture studies in particular could assist in determining adult lifespan and population size, and may be used to calibrate the relationship between transect counts and actual population size (see Collier, Mackay & Benkendorff, 2008). Critical life history information should be determined to enable transect counts to be converted to population estimates and to determine dispersal distances, both of which will influence future survey methodology, and inform conservation planning.

A pilot translocation trial has been conducted where *Lomandra* plants were potted and maintained in a nursery (Amy Mutton, DEC, pers. comm.). Several were later found to contain living graceful sun-moth larvae. Although most plants died, further refinement of horticulture practices could increase success. However, the larvae survived for extended periods even after the plants died, consistent with them having the ability to diapause for extended periods. Further experimental translocations of the larval host plants could be attempted in appropriate cases. This will determine if translocation is a viable option for mitigating the impact of any future clearing of graceful sun-moth habitat, or for maintaining populations in small isolated remnants.

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