

TAXONOMY AND BIOLOGY OF *SYNEMON DISCALIS* STRAND AND *S. PARTHENOIDES* R. FELDER (LEPIDOPTERA: CASTNIIDAE) IN SOUTH AUSTRALIA

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Abstract

Adults and early stages of *Synemon discalis* Strand and *S. parthenoides* R. Felder *sensu lato* from South Australia are illustrated and compared. *Synemon discalis* is shown to be monotypic, while *S. parthenoides s.l.* is polytypic, comprising at least three allopatric and morphologically distinct taxa consistent with regionally isolated populations, viz. *S. p. parthenoides sensu stricto* from Adelaide and SE South Australia to western Victoria, *S. parthenoides valma* subsp. n. from Yorke Peninsula and *S. larissa* sp. n. from Eyre Peninsula.

Introduction

Synemon discalis Strand, 1911 and *S. parthenoides* R. Felder, 1874 belong to a complex of morphologically similar (but not necessarily closely related) *Synemon* Doubleday species that commonly occur in the temperate areas of Western Australia (WA), South Australia (SA) and Victoria (Vic). The first of this complex to be described was *S. sophia* (White, 1841) from Albany, WA. For the next 30 years (and also recently – Edwards 1996, Douglas 2008), similar species in SA were ascribed to *S. sophia* until Felder (1874) proposed the new name *S. parthenoides* for a large, Adelaide-region population. Klug (1850) had previously illustrated this latter species but treated it as *S. sophia*. Tepper (1882) probably confused *S. parthenoides* with his *S. laeta* Walker, although his specimens no longer exist and thus cannot be compared. It was not until much later that Strand (1911) recognised *S. discalis* as a smaller, cryptic species similar to a small *S. sophia* in appearance, although he did not indicate a locality for it. Strand (1911) also portrayed *S. parthenoides* as a larger species than *S. sophia*, but confusingly erected *S. partita* Strand (a synonym of *S. parthenoides*: see Edwards 1996) as a new species. There are also several other similar cryptic species occurring in WA that are believed not to extend into SA (Edwards 1996, 2006).

However, the species found in SA are still very difficult to separate because of their similar pattern; consequently Tindale (1928) placed *S. parthenoides* as a subspecies of *S. sophia*. Even later, McQuillan and Forrest (1985) used the name *S. sophia* for the local *S. parthenoides* population in SA. However, subsequent *Synemon* workers (Edwards 1996, 2006, Douglas 2008) asserted that *S. sophia* occurs only in southwestern WA and that *S. parthenoides* only occurs in SA and Vic. They also stated that *S. discalis* is a valid species, possibly occurring across all three states, although Edwards (in Douglas 2004, 2008) qualified that by stating the latter may in fact be a separate new species in WA. Partial confirmation came from Kallies *et al.* (2008), using

DNA techniques based only on the COI mitochondrial gene and limited sampling of *S. discalis* [n = 1: Vic], *S. parthenoides* [n = 3: SA and Vic]) and only six other *Synemon* species; their work indicated that the first two species form a clade with a sister-taxon relationship.

When two specimens of similar size of *S. discalis* and *S. parthenoides* are compared, they can be very difficult to separate. The present authors therefore undertook a study of these two species, as presently recognised in South Australia, in order to determine if there is an easy way to reliably differentiate them.

We have an underlying interest in these species, having recognised the likely presence of both throughout temperate SA during previous surveys, but our studies were impeded by a lack of authoritative literature, compounded by the local collection of *Synemon* in the South Australian Museum, Adelaide (SAMA) being sent to the Australian National Insect Collection in Canberra in 1993, where it is still located. We have realised that our local observations are at variance with some of those previously documented and therefore present our findings here. We have examined relevant type images, descriptions and literature and have accepted Edwards' (1996, 2006) conclusions regarding the arrangement of the species discussed here, primarily because his initial revision included an examination of original type specimens plus material from WA, which we were unable to do.

Methodology and preliminary adult differentiation

Edwards (2006 and unpublished data) and Douglas (2004, 2008) believed that *S. discalis* and *S. parthenoides* are separable by wing morphology and size. We agree but these characters are not necessarily diagnostic and we therefore sought to reinforce this view by an examination of all characters, including early stages, host plants and, particularly, the male genitalia. It was found that it is often possible to utilise the upperside (UPS) patterns on the inner-margin half of the forewing (FW) and the tornal area of the hind wing (HW) UPS (and sometimes the underside (UNS) pattern) for a quick provisional separation of the two species.

In the FW UPS of *S. parthenoides* there is a broad postmedian transverse white bar with (usually) in each space a dark, horizontal flattened ovoid area devoid of white scaling. The basad side of the bar is bordered by a broad black area. In the HW UPS there is a narrow, continuous, orange-coloured link between the diffuse marginal spot in cell 1A+2A of the tornal area and the postmedian spot in cell CuA2 (Figs 1-6). On the HW UNS the macular markings are usually orange coloured but sometimes marked with white centres in the costal region of the wing.

In the FW UPS of *S. discalis* the broad postmedian white bar is usually completely filled with white scaling, with no dark intracellular ovoid area, and there is only a narrow black transverse zig-zag area basad of the white

bar, while in the HW UPS tornal area there is usually no continuous orange link between the diffuse marginal spot on the inner margin and the postmedian spot in space CuA2. On the HW UNS the macular markings are usually yellowish (Figs 52-65).

Once this separation was accomplished the male genitalia were examined. The genitalia of both species were found to be of a similar simple construction to those of the *Synemon collecta* group found in SA (Grund 2011), but differed primarily in having a long but bent, posteriorly directed ventral valva arm (harpe or valvula) about as long as the rest of the valva (e.g. Fig. 7). The ventral bulbous extension (coecum) of the aedeagal phallobase was found to be different in *S. discalis* and *S. parthenoides* (e.g. Figs 7 and 66). A broad distributional range of male genitalia were examined, initially from areas where it was generally agreed that the species occurred (not necessarily together), such as the Southeast, Adelaide and southern Eyre Peninsula Regions. The scope was then expanded to southern Yorke Peninsula and northern Eyre Peninsula, where the species were either rare or not previously recorded.

Based on the combination of male genitalia and other morphological attributes, we were able to differentiate three distinct groups in *S. parthenoides* but found no differentiation in *S. discalis*. In the former, there is a nominotypical group (1) occurring in the Adelaide and southeast regions of SA and also western Vic; a group (2) on Yorke Peninsula; and a group (3) on Eyre Peninsula. A fourth group likely exists on Kangaroo Island (A. Young unpublished data 2010) but unfortunately we were unable to obtain any study material of this population. The work of Kallies *et al.* (2008) indicated that, genetically, *S. parthenoides* identified from Kangaroo Island formed part of a monophyletic group from Goolwa, SA and the Big Desert, Vic.

As expected for seemingly non-dispersive species, there were minor gradational clinal changes in morphology (wing pattern and male genitalia) across the *S. parthenoides* groups, but sharper breaks in morphology occurred at biogeographic boundaries such as the Spencer and St Vincent Gulfs and the Mt Lofty Ranges.

Except where a holotype is illustrated, the adult images in this paper have been digitally repaired where possible, especially the termens. Adults are often damaged and scratched by their fast flight within vegetation and from copulation rituals (particularly noticeable in *S. discalis*). The FW UPS white surface scaling is also quickly lost, with a resultant loss of pattern, which was not repaired. Mounted material can also quickly fade in storage, with the FW UPS black background colour turning brown (also particularly noticeable in *S. discalis*). Most of the material examined came from the collection of R. Grund (RG); the rest came from the collections of A. Stolarski (AS), A. Lines (AL) and the residual collection at the SAMA.

Systematics and biology

Synemon parthenoides parthenoides R. Felder

(Figs 1-31)

Nominotypical Group (1) referred to above.

Synemon parthenoides R. Felder, 1874. (Type data: p. 9, pl. LXXIX, figs. 7-8. Syntype[s] [♀], in Natural History Museum, London (BMNH); type locality Adelaide [Region] [ex G.F. Angas collection?]).

Synemon partita E. Strand, 1911. (Type data: p. 1 and also J.-A. Boisduval 1875 [1874]; image in J.-A. Boisduval [1875], pl. 11, fig. 5. Type ♀ ex Becker collection; type locality Australia) (Synonymized by Edwards 1996).

Material examined (Figs 1-6, 14-19). SOUTH AUSTRALIA (ADELAIDE REGION): 1♂, 2♀, Kaiser Stuhl Scrub, 2.xii.2011; 1♀, Mt Bold, 23.xii.2003; 2♂, 1♀, Mt Bold, 22.xii.2011; 2♂, Mt Bold, 23.xii.2011; 15♂, 1♀, Mt Crawford, 24.xi.2011; 4♂, 4♀, Mt Crawford, 2.xii.2011; 1♂, Scott Ck, 22.xii.2011 (in RG); 2♂, Aldinga, 21.xi.2010; 1♂, 1♀, Cherry Gardens, 24.xi.2011; 1♂, Onkaparinga Gorge, 23.xi.2008; 2♂, Onkaparinga Gorge, 30.xi.2008 (in AL). SOUTH AUSTRALIA (SOUTHEAST): 1♂, Binnie, 11.xi.2010; 3♂, Ferries-McDonald Conservation Park (CP), 15.xi.1995; 1♂, 1♀, Gosse Hill, 12.xii.2007; 1♀, Messent CP, 12.xi.2006; 1♂, Monarto, 3.xii.2010; 1♂, Monarto, 10.xi.2011; 7♂, 6♀, Monarto, 19.xi.2011; 1♀, Mt Rescue CP, 11.xi.2008; 1♂, Mt Rescue CP, 13.xi.2008; 1♀, Malinong, 17.xi.2010 (in RG); 1♀, Binnie, 17.xi.2009; 1♂, Binnie, 4.xi.2010 (in AS). VICTORIA (NORTHWEST): 1♂, Dimboola, 4.xii.1997; 1♂, 1♀, Mirranatwa, Grampians, 3.xii.1997 (in RG).

Description (Figs 1-12, 14-19). Male. Body: frons, head and thorax dark brownish grey-black above, a white line along each side of anterior half of thorax above, abdomen above dark brown anteriorly, golden brown to orange laterally and posteriorly, thorax pale grey below with a narrow orange neck collar, abdomen fawn below, labial palpi ascending, pale grey scales appressed, extending beyond the eye to the edge of the frons, apical segment long, cylindrically tapering to a point, slightly shorter than mid segment, proboscis unscaled well developed, eyes smooth, reflective eye pattern pale grey Type III when alive, antennae reach to or slightly beyond half the length of forewing (FW) costa or the end of the discal cell, shaft scaled, black, narrowly ringed white at the end of each segment, club broad, mucronate, black above, white below, mostly scaled but underside with a brown nudum area. Wing morphology: background colour of wings is black, very slightly brownish when freshly emerged, but turn more brownish with age; FW UPS patterned with white scaling, easily dislodged; a broad white margin, partly scalloped in appearance with some white scaling continuing basad along veins; two white curved subapical bands, widely spaced at the costa, converging and terminating at cell space M2 to form a curved V shape, the inner band is broken by black veining and is usually much stronger than the outer band but can sometimes weaken close to the convergence point, the outer band is strongly scalloped; a large white irregular blotch straddles the



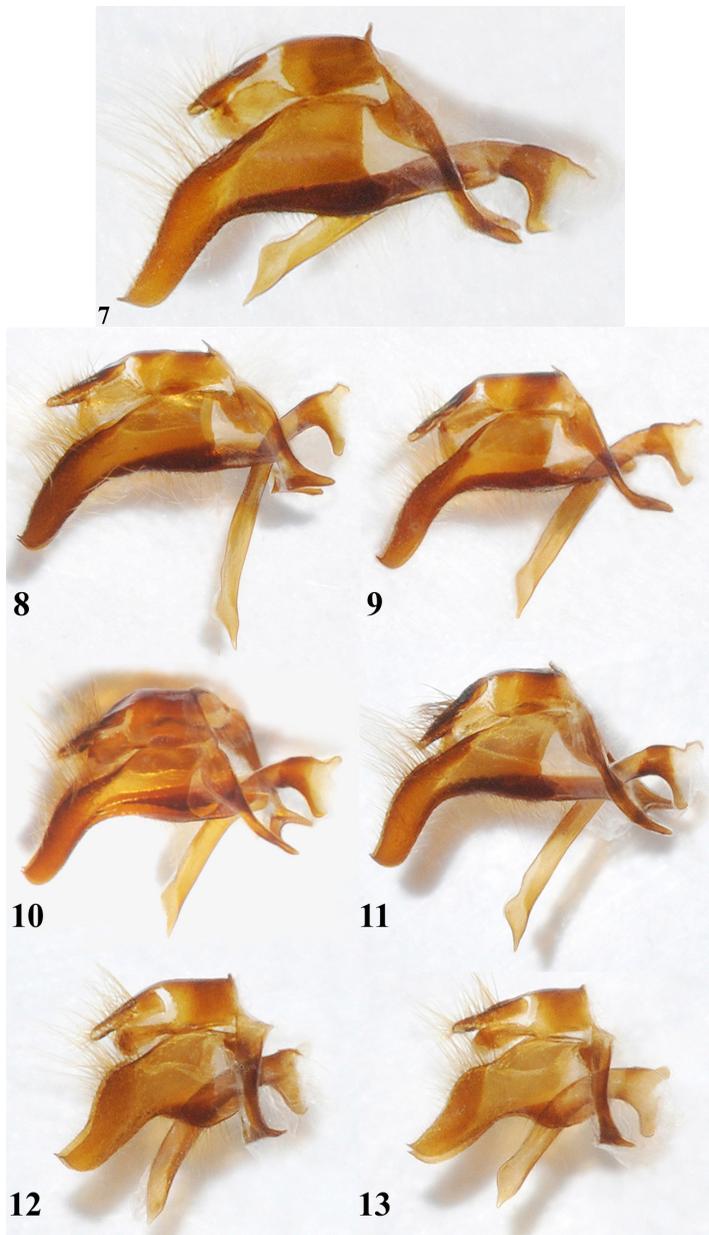
Figs 1-6. *Synemon parthenoides parthenoides*, upper and undersides: (1) male (m) wing expanse 44 mm Mt Crawford, SA 24.xi.2011; (2) (m) 42 mm Mt Crawford 24.xi.2011; (3) female (f) 48 mm Mt Crawford 2.xii.2011; (4) (m) 41 mm Onkaparinga Gorge, SA 30.xi.2008; (5) (m) 42 mm Mt Bold, SA 22.xii.2011; (6) (f) 46 mm Mt Bold 23.xii.2003.

distal cell-end of the discal cell, a large black roughly circular area basad of the white blotch within the discal cell; a wide white scaled post median band extending from cell M3 to near the inner margin at cell CuP, the inner area of the band in cells CuA1, CuA2 and CuP partially devoid of white scaling producing a dark area, usually one or two large irregular white spots incorporated into the band adjacent to the white discal cell end spot, the apical space continuing above the white band to the costa is black and devoid of white scaling; a wide and straight black tornal bar occurs distad of the white band usually coalescing with the apical black area distad of the discal cell end spot, the tornal bar constricts towards the tornus; a wide black submedian band occurs basad of the postmedian white band, weakly

coalescing with the large black distal spot in the discal cell, slightly curved basad, with the cross veins sometimes white scaled; the basal portion of the wing is covered with white scaling. HW UPS with three transverse rows of orange macular spots; an outer marginal (subterminal) row of smaller irregular spots, always three spots present in cells M3, CuA1 and CuA2, usually widely spaced with one spot per cell space, sometimes additional inconspicuous single spots extend towards the apex in the cell spaces M1 and/or M2, the major marginal spots are sometimes elongated basally and sometimes join with the row of larger postmedian spots, there is a larger diffuse tornal spot in cell 1A+2A essentially forming part of a broad orange inner margin area extending from the wing base, each of the two large postmedian spots straddle two cells, each spot is offset slightly such that the spot nearest the apex is further away from the wing base; the spot closer to the inner margin in cells CuA2 and CuA1 is divided by a black coloured vein and is joined to the tornal marginal spot by a narrow curved orange band, a fourth inconspicuous postmedian spot sometimes occurs in space Sc+R1 next to the costa; there is a large orange spot straddling the distal end of the discal cell; the basal inner margin area next to the spots is covered in orange scaling and brown hairs (setae). FW UNS black, 10 small weakly elongated marginal spots, tornal spot 10 weak or not developed, otherwise one spot per cell, the first two apical spots white coloured, the next 2-3 become increasingly more orange, the remainder are orange, spots 9-10 in tornal cells CuP and 1A+2A are usually joined together and to the postmedian band; there are broad irregular orange coloured subapical and postmedian transverse bands, the subapical band also usually overlain by a centred wash of white in each cell, sometimes there is a weak wash of white in the postmedian cells near the discal cell, the costal margin and the basal half of the discal cell is orange scaled. HW UNS black, usually seven small marginal spots that become increasingly larger and more elongated towards the tornus, the first two at the apex often inconspicuous and white, remainder mostly orange, the postmedian and discal orange spots found on the UPS are also present on UNS, the centres usually weakly washed with white, excepting the large apical postmedian spot which can have a strong wash of white, the small costal spot of the postmedian band is white coloured if present, usually a wash of white scaling at the wing apex, the inner margin and basal area is orange coloured. Termens above and below are dark brownish grey on the FW and also much of the HW but are dark yellow in the apex, tornal and inner margin areas of the HW, and pale grey along the costa of the HW.

Female. Similar to male although the white markings are generally better defined and more intense. Antennae reach to or slightly before half the length of forewing (FW) costa or the end of the discal cell.

Wing pattern morphology of both sexes is generally stable, except for minor variations mentioned above and rare aberrations, being mainly variation in the size, shape and number of macular spots and the degree of white scaling



Figs 7-13. Male genitalia, lateral views. (7-11) *S. p. parthenoides*: (7) Mt Crawford; (8) Mt Bold; (9) Monarto, SA; (10) Binnie, SA; (11) Dimboola, Vic. (12-13) *S. larissa*: (12) Hincks CP, SA; (13) Pinkawillinie CP (east), SA.

on the FW UPS. The latter is also partially controlled by the age (wear and tear after ecdysis) of the adult that can have a significant bearing on the configuration of the white scaling. There are no obvious pale and dark morphological forms as seen in the *S. collecta* species group (Grund 2011).



Figs 14-19. *S. p. parthenoides*, upper and undersides: (14) (m) 42 mm Monarto 19.xi.2010; (15) (f) 50 mm Monarto 19.xi.2010; (16) (m) 38 mm Mt Rescue CP, SA 12.xii.2007; (17) (f) 50 mm Mt Rescue CP 11.xi.2008; (18) (m) 45 mm Mirranatwa Grampians, Vic 3.xii.1997; (19) (f) 47 mm Mirranatwa 3.xii.1997.

Wing venation. Both sexes show the basic venation typical for *Synemon* (Edwards *et al.* 1999) and similar to all species examined in this project. FW discal cell about half length of costa, vein Sc reaches costa beyond the end of discal cell, bases of veins R1, R2, R3+R4+R5 originate from the discal cell, R4 and R5 stalked, bases of M1 and R3+R4+R5 not connate at discal cell, origin of M3 on discal cell usually equidistant between bases of M2 and CuA1; hind wing (HW) frenulum with one spine in males or 2-3 spines (usually 2) in females, bases of M3 and CuA1 usually not connate, origin of M3 on discal cell is much nearer to CuA1 than to M2.

Adult forewing expanse (length of forewing along the costa from centre of thorax to apex tip x 2). This is a large species. Wing expanse of females is usually considerably larger than that of males. Based on material in the authors' collections, males from the Mt Lofty Range have a wing expanse of 39-46 mm (avg. 42 mm, n = 31) and females 44-56 mm (avg. 49 mm, n = 10), while Southeast males are 35-45 mm (avg. 41 mm, n = 20) and females 41-53 mm (avg. 48 mm, n = 14).

Male genitalia (Figs 7-13). Male (n = 8). Tegumen broad (viewed from above), short and shallow viewed from side, sclerotised sides sit directly on top of valves, dorsal part of tegumen weakly fused with the uncus where the latter also downturns; uncus about same length as tegumen, shallow from side, edges rolled over, a slight posterior ventral bulge on each side, broad (arrow-head shaped) and tapering posteriorly viewed from above, half width of tegumen and constricted about midway along uncus, then tapering quickly to a blunt posterior point, uncus with long peripheral hairs (setae); the fultura superior is exposed in the area below the uncus and tegumen junction on each side of the genitalia and is membranous, containing a long broad horizontal chitinous scaphial plate adjacent to the valve and anal tube; anteroventral edge of plate weakly fused to posteroventral edge of tegumen; anterior part of valve broad, bulging from side view, flattened from top view, anterior sclerotised edge slightly concave posteriorly, valve tapered posteriorly to join in line with a long flattened tapering arm-like extension (harpe) of the valve that curves or bends ventrally at an angle and ends with a short upward and inward turned spine, some very long hairs posterodorsally and anteroventrally on the harpe, the bases of the former may be so dense as to cause a rough granulated bulge along the valva edge; vinculum in lateral view narrow ventrally, usually sloping away from the valva at an angle, the dorsal part next to the valve broadening considerably until the posterior margin attaches to a short narrow valva hinge at the anterodorsal corner of the valve, the anterodorsal margin of the vinculum fused with the tegumen at the apex angularis and then continuing around the tegumen edge but forming a prominent rounded anterodorsal appendage on the tegumen, the ventral part of the vinculum side arms are bent anteriorly to form a bifurcate saccus, but are joined together at the curve by a wide, flattened, sclerotized cross-brace (Fig. 10), in the centre of which a broad weakly sclerotised plate emanates dorsally (as part of the diaphragm) to attach wishbone-like to the underside of the aedeagus anterior of the vinculum arms, the anteroventral arms of the valva extend to attach to the dorsolateral part of the wishbone pedicle, the whole complex forming the juxta; the aedeagus is very long, tubular, slightly curving downwards, the posterior sclerotised edge slanting at a straight angle to a point ventrally, the posterior vesica without obvious cornuti, the aedeagus enlarges considerably in the vertical plain at its anterior end to form the *Synemon* sclerotised phallobase with dorsal and ventral (coecum) bulbous enlargements, the proximal orifice opening is posterior.

When compared with the male genitalia of other *S. parthenoides* group species (that have an orange join of HW UPS tornal spots 1A+2A and CuA2) from Eyre Peninsula (Figs 12-13, 51) and *S. discalis* (Figs 67-70), it is immediately seen that these three groups have genitalia that are very different from each other (see below for details).

Hostplants. Tindale (1928) found early stages of nominotypical *S. parthenoides* on *Lepidosperma carphoides* (Cyperaceae) at Highbury (a northeast foothill suburb of Adelaide) and provided the first biological details for a *Synemon* species from SA. He was the first to record *Synemon* larvae living underground within the root zone of its hostplant. He was unable to find living pupae but did notice pupal exuviae projecting from silken burrows at ground level adjacent to the hostplant.

The present authors (and Douglas 2008) found that the primary hostplant for nominotypical *S. parthenoides* is *L. carphoides*, meaning that this sun moth is usually found in the presence of that particular host if it is available. Douglas (2008) also recorded nominotypical *S. parthenoides* utilising both *L. carphoides* and *Schoenus racemosus* (Cyperaceae) as a host in the dryer, northern areas of its range in western Victoria (central Big Desert). He also saw females probing the bases of *Lepidosperma viscidum* nearby in southeast Big Desert, but apparently they did not oviposit. One of us (AS) has also seen a female probing small plants of *Austrostipa mundula* (Poaceae) in the Upper Southeast of SA. However, both of us noticed that *Synemon* females were not averse to ovipositor probing other plants in the vicinity of the primary host, based on visual sightings, but when these females were caught and examined it was noticed they were usually old and had no or few (possibly infertile) eggs left in their abdomens.

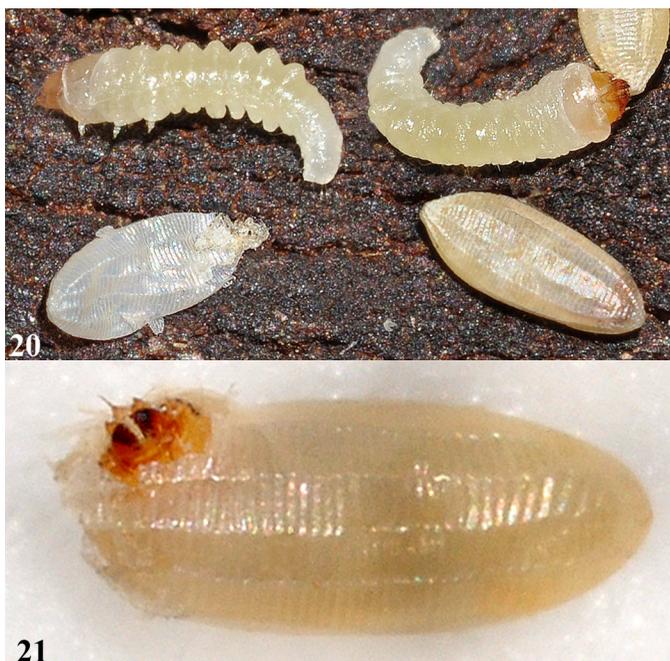
We also observed that the size of the *L. carphoides* plant for egg laying was irrelevant; females would utilise all sizes of plant, unlike many other sun moth species in SA that prefer small, stunted hostplants. They tend to prefer healthy plants in the open but will still lay on plants that are dead in the middle (similar to a *Triodia* spinifex ring and possibly killed by the activity of the *Synemon* larvae) and pupal exuviae are often found in the dead central area or along the outside of the healthy outer part of the plant.

Habitat. Adults are found flying in the vicinity of their primary hostplant *Lepidosperma carphoides*, a dryland sedge requiring moderate rainfall (35-80 cm pa). It grows in deep, usually white-sand soils occurring in open woodlands and sedgeland, but will also grow in higher-rainfall forest provided it is open and sunny.

Distribution and flight period. Nominotypical *S. parthenoides* occurs in the Adelaide-Mt Lofty Ranges and Upper Southeast Regions of South Australia (extending into western Victoria). There are no confirmed records from Eyre Peninsula or Yorke Peninsula. However, the distribution of *L. carphoides*

includes the Lower Southeast, suggesting that *S. parthenoides* will probably be found in that locality.

It is sympatric with *S. discalis* (see later) but adults tend to start flying during the later parts of the *S. discalis* flight period. (The flight period for all sun moth species documented in this paper can be instigated or delayed by the climatic nature of the season and the micro-climate of the locality). There is a tendency for adults to start flying earlier in warmer areas (and also finish flying earlier). Males also tend to fly and be more common earlier than females in any one locality, with females first appearing about a week after the males. Along the Mt Lofty Ranges the normal recorded flight times are from 3 November to 1 January. In the Southeast the flight times are from 27 October to 14 December. In western Victoria, Douglas (2008) recorded flight times from late October to early January.



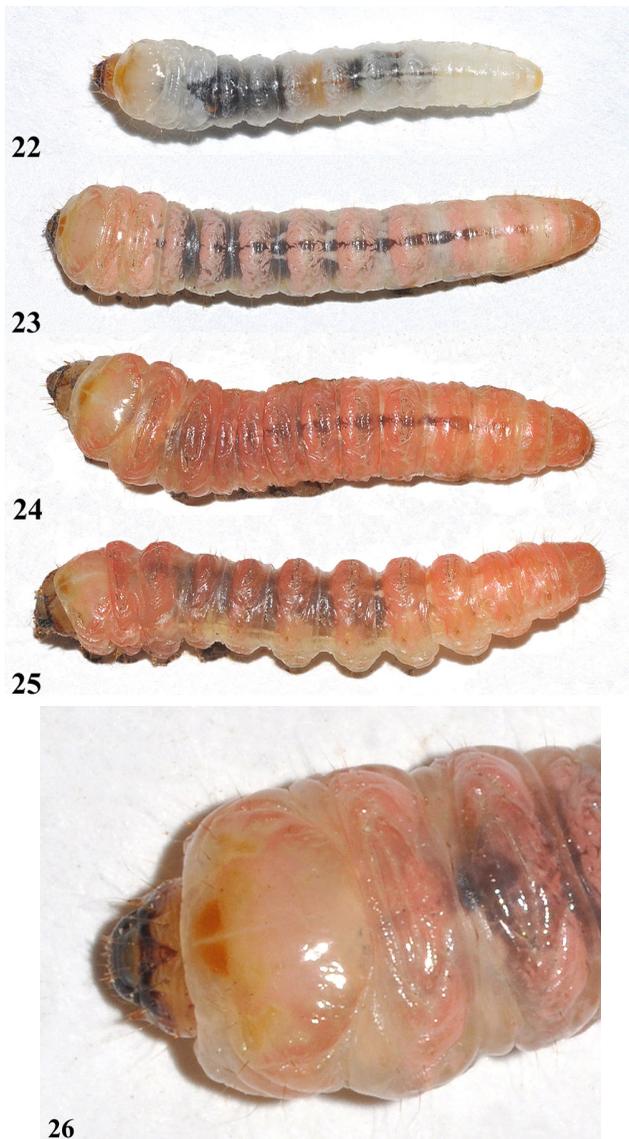
Figs 20-21. *S. p. parthenoides*, eggs and enclosed larvae. (20) egg, egg shell, enclosed larvae (4 mm), Monarto, 9.xii.2011; (21) enclosing larva with exposed spinneret, egg 2.4 mm, Binnie, 6.xii.2011.

Egg (Figs 20-21). Eggs of *S. parthenoides* (both laid and extracted) are similar to those of all other group members found in SA. Egg size is not necessarily related to female size, nor are they of the same size in an individual female; longer eggs tend to be narrower and *vice versa*. They are

of an elongate, ellipsoidal spindle shape, 2.05-3.95 x 0.85-1.1 mm (n = 11), with 10-13 (n = 8) prominent equi-spaced longitudinal ridges converging at each end of the egg and with numerous (~60) less prominent, very fine cross ridges or striae that form an interlocking disjunction at the longitudinal ridges (e.g. Fig. 2 in Common and Edwards 1981). The higher number of longitudinal ridges seems to be proportional to an increase in size of the eggs and females. The longitudinal ridges in this group have the peculiarity of sometimes dividing into two, a phenomenon not yet seen in the eggs of other *Synemon* in SA. Each end of the egg constricts to a blunt point, one of which (usually the sharpest) contains the micropyle and which is also the end from which the larvae usually eclose. Pale sub-translucent yellowish-white when freshly laid, later turning white particularly near eclosion, which occurred after 22-32 days (n = 19). Eclosion may be dependent on moisture in the soil enabling the egg chorion to become flexible, as one egg did not eclose until moistened after 45 days (not recorded in incubation period). The ovipositor of the female is typically very long and the distal end very bristly, features that are found in all the SA group species.

Larvae (Figs 20-26). First instar larvae at eclosion (Figs 20-21) are 3.5-4.0 mm long (extended) and are similar to larvae of the other group members mentioned in this paper. All larval stages have a similar shape, of witchetty-grub type, and known larvae of other species in the group in SA are also very similar in shape. Larvae are cylindrical, slightly flattened and taper posteriorly, with the posterior end rounded. Moderately long, fine, simple sensory setae are common at either end, but few laterally and elsewhere, (no attempt was made to produce a setal map). The mid-portion of each segment is enlarged; thoracic segments (TS) 1-3 are larger than abdominal segments (AbS), but AbS 3-6 are also larger than other AbS. The prothoracic plate on TS 1 is much enlarged, tending to overlap onto TS2 and smooth, presumably to help with burrowing. Roughened, elliptical-shaped ridges are present dorsally on the other segments, again presumably to help with compacting the burrow. Thoracic legs and abdominal prolegs are present but not fully functional and of little use for directional travel, although first instar larvae were able to gain traction and sometimes walk up the vertical sides of a glass jar (probably helped by moisture). Skin and head are smooth and shiny and the body subtranslucent. The colour of the first instar at eclosion is pale yellow, white posteriorly, prothoracic plate brownish yellow, head pale brown, paler dorsally, mandibles black. Larvae remain underground all their lives and, if exposed to light, will quickly burrow back into the ground.

Second instar larvae (12 mm, Fig. 22) are white (subtranslucent), the prothoracic plate off-white, brownish next to the brown head, end of posterior segment brown, sometimes a brown area dorsally midway along abdomen, stomach contents black; from about the third instar they start to show areas of pinkish colouration on the skin and on the yellowish prothoracic plate there is a pair of mid-dorsal, orange-brown frontal triangular marks next to the head,



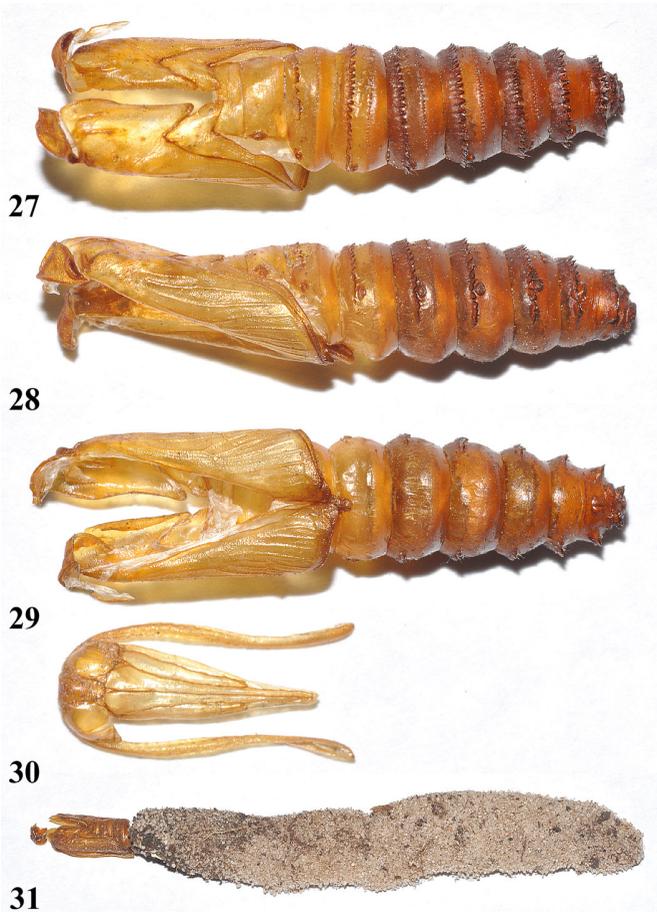
Figs 22-26. *S. p. parthenoides* larvae: (22-25) larvae in captivity ex *L. carphoides* Monarto. (22) pre-moult late 2nd instar (12 mm), 28.x.2011; (23) late 5th instar (30 mm) 24.x.2011; (24-25) late 5th instar dormant (30 mm) dorsal and lateral 24.x.2011. (26) larva on *L. carphoides* Mt Crawford, close-up of anterodorsal portion of 5th instar (30 mm) 23.x.2011, showing head, prothoracic plate, dorsal elliptical ridges, setae.

divided by a yellowish longitudinal line; the anal plate is brown, the head dark brown anteriorly, pale brown posteriorly and divided centrally by a dark brown, triangular area basally emanating from the anterior dark area. The mature fourth and final instars become increasingly darker pink (Fig. 23, 26) then red, then finally dark orange-red near pre-pupation (Figs 24-25). Earlier instars occur underground in the culm, while the mature larvae are mostly seen in the root zone.

Under adverse conditions, especially when placed together in captivity, larvae will cannibalise each other if the hostplant does not remain alive in adequate quantities. Under such conditions, larvae will live off their own fat and shrink (at least by half) until such time as a food source is generated. When small and large larvae meet, the normal first response of the smaller larvae is to try and escape but they sometimes disgorge their stomach contents and become a lot smaller, presumably as a deterrent to the larger larvae. In captivity, a disgorge response by the smaller larvae can be fatal. Larvae will not eat dead hostplant tissue. Based on the size of larvae observed, at various times over the year on their hostplant and in captivity, we believe that larvae have the growth potential to reach prepupal maturity within two years. One mature larva in captivity has already been living in a semi-torpid condition for a further two years, having ignored two potential pupating events, suggesting they require exacting conditions before pupation.

Larval predators. The only possible insect predatory activity we saw was occasional large beetle larvae found in the culm and root zone of the hostplant; these might be predatory on *Synemon* larvae since, when such beetle larvae are themselves put together, they will cannibalise each other. There were sometimes small bandicoot or echidna-like diggings at the sides of the *L. carphoides* hostplants, which might have led to predation on *Synemon* larvae. In strong colonies, none of these possible predators appeared to be in sufficient numbers to have had any threatening impact on *Synemon* larvae.

Pupae (Figs 27-31). We were unable to find living pupae, but RG was eventually able to find some exuviae protruding out of silked prepupal tunnels (essentially cocoons) in their ecdysis position. The latter were found in several colonies within the Adelaide Hills and were seen either within the dead central area of a living tussock of *L. carphoides* (see above), or adjacent to a living tussock up to 42 cm away. Up to four exuviae were found together in the former situation and up to three together were found in the latter; presumably all exuviae seen in any situation were from that flight season (considering the prolific animal, bird and insect life in the areas at the time which would have soon obliterated the exposed exuviae). Only male exuviae were observed (Figs 27-31), which have typical *Synemon* morphology (similar to the male pupa of *S. magnifica* illustrated in Common and Edwards 1981), with two rows of dorsolateral flattened spines (similar to a pointed



Figs 27-31. *S. p. parthenoides*, pupa exuvia ex *L. carphoides*. (27-30) (m) pupa exuvia (23 mm) 24.xi.2011 Mt Crawford; (31) pupa exuvia protruding from dorsal end of pre-pupa silked tunnel ‘cocoon’, (7 cm) plus exuvia, Monarto 10.xi.2011.

spade) on Abs 2-7 and with the anterior row comprising much larger spines. The spines on Abs 2 are not well developed and only a single row of (large) spines occurs on Abs 8-9. Contrary to previously published observations, only short, silk-lined pre-pupal tunnels were observed (Fig. 31); these were about 6-7 cm x 8-11 mm in size and near-vertical in the (sand) soil below the surface (but reaching the surface). The lower end of the tunnel was sealed off with silk and presumably the top part was also, but this was not seen at the time in a situation either before or after adult ecdysis (but a ‘lid’ was detected by Tindale 1928 on a similar 6 cm silk tunnel at Highbury); the entire silked structure would by definition be called a cocoon. The prepupal skin was

present at the bottom of the sealed tunnel, while the exuvia occurred halfway out of the top end (Fig. 31). The rest of the original tunnel presumably made underground by the prepupal larva back to the hostplant (as reported by Tindale 1928) was not silked and could not be discerned.

The extracted exuviae were about 23-26 mm long, equating to about 19-22 mm actual pupal length (allowing for the abdominal expansion during ecdysis). The antennae are not fused to the thorax or wings. We could find no difference in pupal morphology between *S. parthenoides* and *S. discalis* (Figs 79-82), except for some minute detail posteroventrally, which requires further confirmation. Again contrary to previous studies, the nature of the coarse, posteriorly directed, flattened spines on the abdomen of the pupa suggests that movement in only one direction would be possible for a living pupa inside a tight silk tunnel, that being upwards and out of the tunnel, presumably at the time of ecdysis. There is no cremaster to impede movement.

Adult biology. Typically, adult males tend to stay close to the hostplants, preferring open spaces and either flying about the plants or by basking or patrolling over clear ground, car tracks or plant debris nearby. The flight is less rapid than in *S. discalis*, perhaps attributable to their larger size. They usually fly just above the hostplants but at times will fly higher, particularly in wooded areas with a higher understorey. They are not known to seek out hill or dune tops to patrol but will utilise them if their host is nearby. While in flight, males can detect females on the ground from a few metres away and immediately divert to where the pheromones are coming from. When disturbed both sexes fly rapidly, resembling a skipper in flight, generally flying up to 50 metres (usually much shorter) in one direction before settling. They fly in full sun, preferring temperatures above 18C, although in hot conditions they will fly with some high cloud present. Adults become active around 0930 h (DST), typically nectaring or basking on the ground to begin with, but increasing in activity with time. By midday there is maximum activity, which continues to about 1400 h.

In the afternoon females tend to fly just above hostplant height in search of suitable food plants, seemingly sensing the presence of hostplants while in flight by a combination of sight and olfaction. Once selected, females typically land on the ground close to the hostplant then walk to the base of the plant to test it, usually by flitting up onto the leaf stalk near ground level, then backing down to the ground to start probing the edges of the stalks below ground level to lay a single egg. Sometimes she will first land on the higher outer part of the plant then work her way down to the base, either through the plant (usually impossible) or flitting lower to an outer part of the plant. During this pre-oviposition stage the wings are regularly opened and closed. When laying is completed, the female usually moves on and repeats the process on another nearby plant, but sometimes return to the same plant

or will leave the area. The time taken to lay an egg can be short (~30 secs) or can take one or two minutes depending on how experienced she is or how accessible the oviposition site is. Activity tends to decline after about 1400 h, but depends on adult numbers and ambient temperature. On warm days, some activity may continue to about 1700 h, including egg laying, but most active males are by then sitting on the ground. We did not determine where they roost at night.

We have seen adults nectaring only rarely. RG observed nectaring in SA on *Calytrix tetragona*. In west Victoria, Douglas (2008) observed nectaring on *Kunzea pomifera*, *Calytrix tetragona* and *Eucalyptus costata*. AS observed nectaring on *Leptospermum* sp. in central Victoria, where the adult flapped its wings slowly as it moved from flower to flower.

Comments. *Synemon parthenoides* adults, when in good condition, clearly differ from those of other group members in their collective wing and male genitalia morphology and other biological attributes, as documented above and elsewhere in this paper. The distribution of the nominotypical group of *S. parthenoides* was found to continue eastward from the Adelaide Region into Southeast SA and further into central Victoria (CSIRO 2012) (Fig. 37). The wing pattern of eastern material (Southeast SA and Victorian Regions) is very similar to that of nominotypical material from the Adelaide Region, differing mainly in the white markings being more suppressed in males (Figs 1-2, 4-5, 14, 16, 18). The male genitalia (Figs 7-13) are also very similar, differing mainly in the amount of bending in the 'harpe', which tends to be more exaggerated in eastern specimens.

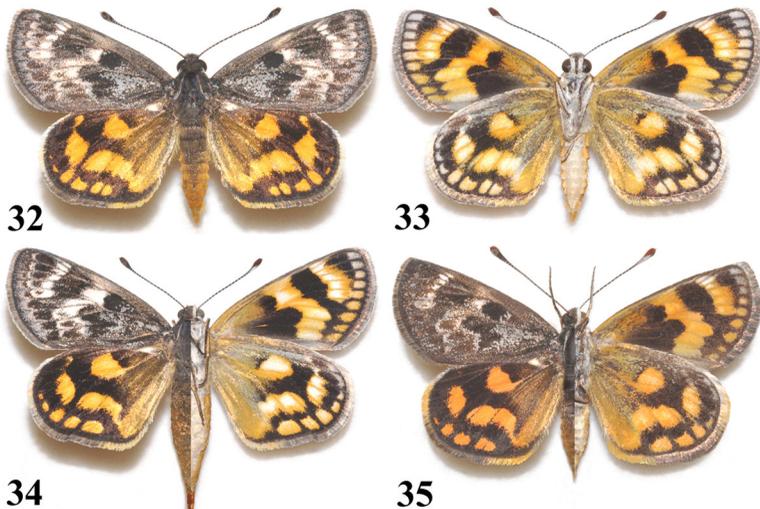
***Synemon parthenoides valma* subsp. n. (Valma's Sun moth)**

(Figs 32-36)

Yorke Peninsula Group (2) referred to above.

Types. *Holotype* ♂, 43 mm, SOUTH AUSTRALIA (YORKE PENINSULA): Hardwicke Bay, 5.xi.2011, R. Grund (in SAMA). *Paratypes* (Figs 15-16): 9♂, 5♀, Hardwicke Bay, 5.xi.2011, R. Grund; 1♂, orange form, Coonarie, 17.xi.1999, R. Grund (in RG).

Description (Figs 32-35). As for *S. p. parthenoides* from the Adelaide Region except as follows. Male (Figs 32-33): FW UPS white markings more strongly developed and the submedian dark area has a distinct 'three-leaf clover' configuration. The 'orange' markings of the HW UPS and the FW and HW UNS are distinctly yellow in *S. p. valma* and are further accentuated by a white suffusion of variable intensity. The HW marginal spot overlying vein CuA2 is sometimes distinctly divided by the black scaling of the vein. The male paratypes include one worn specimen from Coonarie (Fig. 35) that has orange markings and the white suffusion was more suppressed compared to specimens from Hardwicke Bay, although the FW 'clover-leaf' submedian pattern was present.



Figs 32-35. *Synemon parthenoides valma* subsp. n., upper and undersides: (32-33) holotype (m) 43 mm Hardwicke Bay, SA 5.xi.2011; (34) paratype (f) 50 mm Hardwicke Bay 5.xi.2011; (35) paratype (orange form) (m) 40 mm Coonarie, SA 17.xi.1999.

Female (Fig. 34). Similar to male but the white markings above and white suffusion below are significantly more obvious and distinct.

Adult forewing expanse. Males from Hardwicke Bay have a wing expanse of 39-44 mm (avg. 41 mm, n = 11) and females 46-52 mm (avg. 49 mm, n = 5). The single male from Coonarie has a wing expanse of 42 mm.

Male genitalia (Fig. 36, n = 2). Genitalia of the yellow morphs from Hardwicke Bay are very similar to those of *S. p. parthenoides*. Differences noted include: the base of the harpe (where it attaches to the rest of the valva) is noticeably constricted, although a similar constriction is seen in the male genitalia from Binnie (Fig. 10); the harpe is bent rather than gradually curved.; the uncus is only very weakly fused to the tegumen, but the scaphial plate is more strongly fused basad to the tegumen; the ventral coecum elongation of the phallobase is better developed and easily reaching down to the base vinculum sclerotised cross-brace bridge (bifurcate saccus). The vinculum side arms are attached to the tegumen at two points on the apex angularis (clearly seen in Fig. 36), by two narrow pedicles emanating from the posterior and anterior edges of the vinculum; the juxta development between the aedeagus and base vinculum brace is better developed and stronger, where the juxta is more sclerotised and forms a posteriorly bent wishbone-like structure (similar to a flattened spring-like vertical prop or strut once used under the seats of farmers' tractors). The juxta appears to be in a more advanced state than in *S. p. parthenoides*.



Fig. 36. Male genitalia, *S. p. valma* lateral view, Hardwicke Bay.

Etymology. Named in honour of the late Yorke Peninsula volunteer Valma Stone, for humanity, ecology and wildlife work.

Hostplants. *Lepidosperma carphoides* does not exist on Yorke Peninsula. Females were observed ovipositing on *L. congestum*, which was common at Hardwicke Bay and is reported to be common throughout Yorke Peninsula by the State Herbarium of SA. The host for the orange form at Coonarie was not determined.

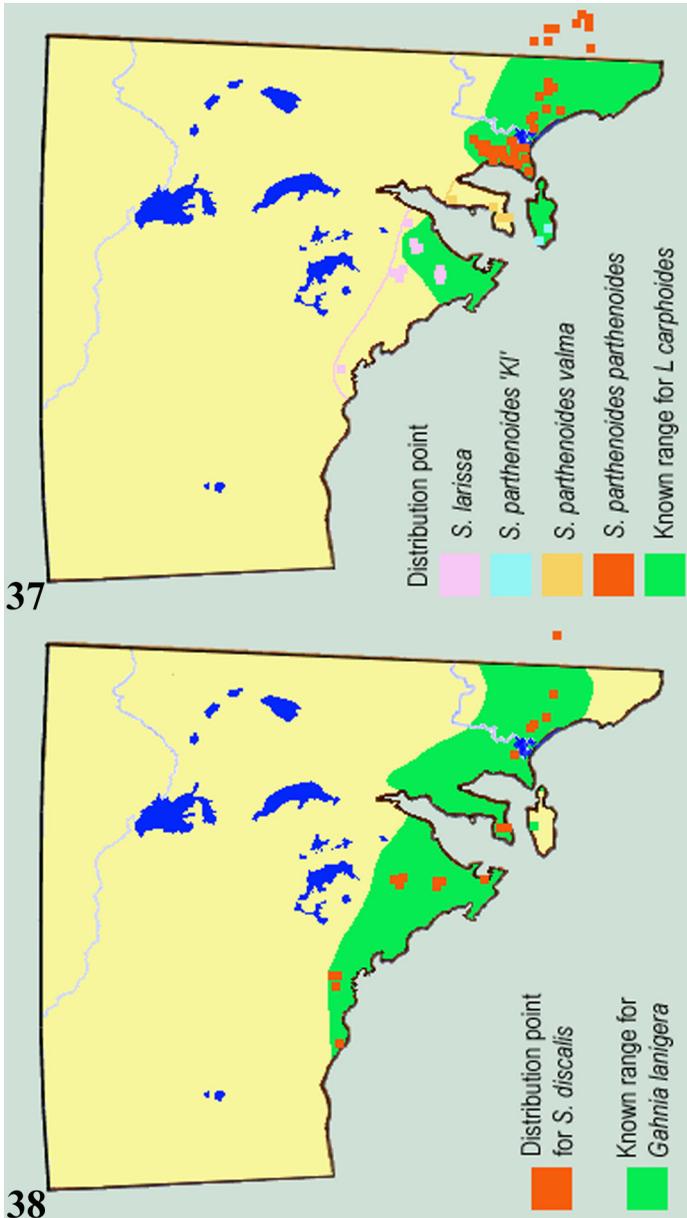
Habitat. The type locality at Hardwicke Bay is partially cleared coastal white dunes, with very open low mallee and coastal salt-tolerant type vegetation. At Coonarie the vegetation was low mallee, growing on red loam over limestone in a hill-top situation where the orange form was flying with *S. discalis*.

Distribution and flight period. *S. p. valma* is known from Hardwicke Bay and Coonarie (Fig. 37) and likely exists further west of Hardwicke Bay to Marion Bay in relict native vegetation, where author RG has previously seen single flying specimens (not examined) of either it and/or *S. discalis*. Tepper (1882) similarly reported *S. parthenoides* (as *S. laeta* Walker) occurring at Ardrossan although his specimens no longer exist for authentication. A specimen exists at SAMA (currently at ANIC) captured by N. B. Tindale at Moonta (CSIRO 2012). At Hardwicke Bay, this subspecies was common in early November. At Coonarie a few were flying in mid November.

Egg. Eggs ($n = 2$, infertile) were extracted from the ovipositor of two separate females and are very similar to others of the complex, having 14-15 longitudinal ridges (including bifurcation as for eggs of *S. p. parthenoides*), 2.35-3.1 x 0.9-1.05 mm. Pale subtranslucent yellowish white when fresh.

Larvae and pupae. Not observed.

Larval predators. While examining the hostplants for early stages, a very large dune scorpion was found in a tunnel into the root zone; presumably it would eat any *Synemon* it found.



Figs 37-38. Distribution maps for SA [and west Vic.]: (37) *S. larissa* and *S. parthenoides* subspecies and primary hostplant *L. carphoides*; (38) *S. discalis* and primary hostplant *G. lanigera*.

Adult biology. The Hardwicke Bay population was examined by RG on 5 November 2011 with temperatures reaching 34°C. Adults were already flying by 1000 h, mostly old male specimens either patrolling and sunning themselves on dune tops or flying around hostplants lower down in the inter-swale areas. By about 1130 h newly eclosed adults of both sexes were more frequent and began copulation. One newly eclosed female flew only a short distance before being chased by a newly emerged male, landing on a low plant then turning upright, the male landing below her and quickly walking to her left side before touching her abdomen, then quickly moving to her right side, facing in the same upright direction as the female and immediately commencing copulation. Soon afterwards another male arrived and terminated the copulation by flying onto the female, causing the original couple to fly off for a short distance before they again landed and copulation resumed.

Flight activity ceased between 1300-1400 h, after which a few older females began ovipositing. One landed high up on an upright leaf at the edge of the hostplant with her head downwards (resembling a flower head), then walked downwards to near ground level, turned upright, then backed down to ground level before probing deep into the sand with her ovipositor along the edge of the leaf, all while continually opening and closing her wings. This probing activity was repeated a few times on this and other leaves in the clump before she flew away. Some females landed next to a black, congested flower head near the top of the hostplant, where they cryptically blended in with the flower head, often remaining there for 20 minutes or more. A few adults were still flying at 1440 h when the author left the area.

Comments. We believe the differences in both morphology and biology between *S. p. valma* and *S. p. parthenoides* are sufficient to warrant its erection as a subspecies. There is a break in the distribution of the primary hostplants, *L. carphoides* and *L. congestum*, between Gawler and north Yorke Peninsula and, in combination with the presence of the St Vincent and Spencer Gulfs, these features likely act as barriers to dispersal, creating a distinct morphological group on Yorke Peninsula consistent with a regionally isolated population, possibly the result of Pleistocene climate cycling as suggested for other Australian Lepidoptera such as the genus *Theclinesstes* Röber (Lycaenidae) (Rod Eastwood unpublished data 2006).

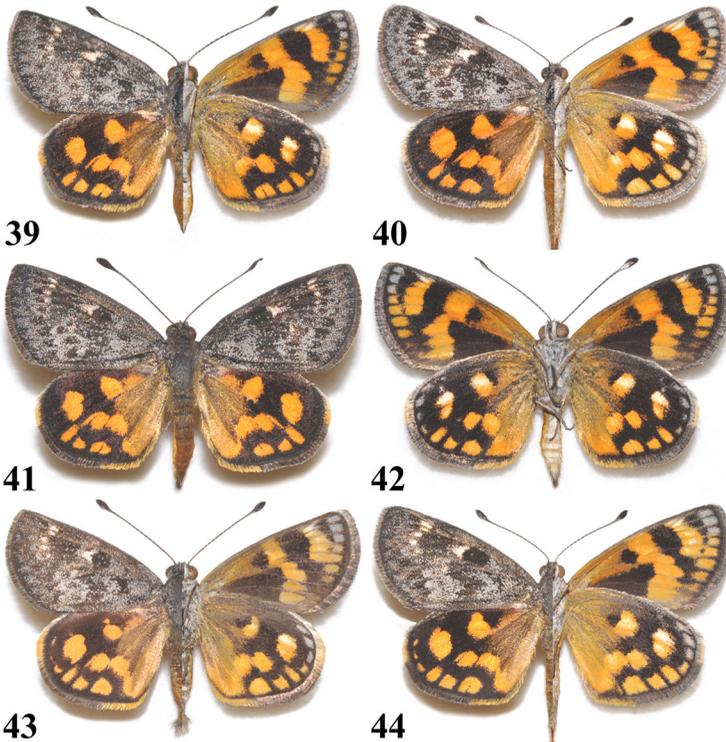
Some sun moths are renowned for their poor dispersal abilities (Douglas 2008) and *S. parthenoides*, being a large, heavy species is likely to be one such moth. Subspecies *S. p. valma* is allopatric with other *S. parthenoides*-like sun moths (orange linkage of HW UPS tornal spots 1A+2A and CuA2) and has a distinctive morphology, yet has a similar pattern and male genitalia to the latter; although it does not use the same hostplant it does utilise sedge plants comparable to those used by *S. p. parthenoides*, which is also the neighbouring taxon. Its wing colours may be influenced by a variation in

flavonoid pigments sequestered from its local host plant (such as occurs in the skipper *Hesperilla flavescens* Waterhouse: Hesperidae). The isolation of *S. p. valma*, use of a different hostplant, unique wing pattern and minor changes in male genitalia support its recognition as a subspecies.

***Synemon larissa* sp. n. (Larissa's Sun moth)**

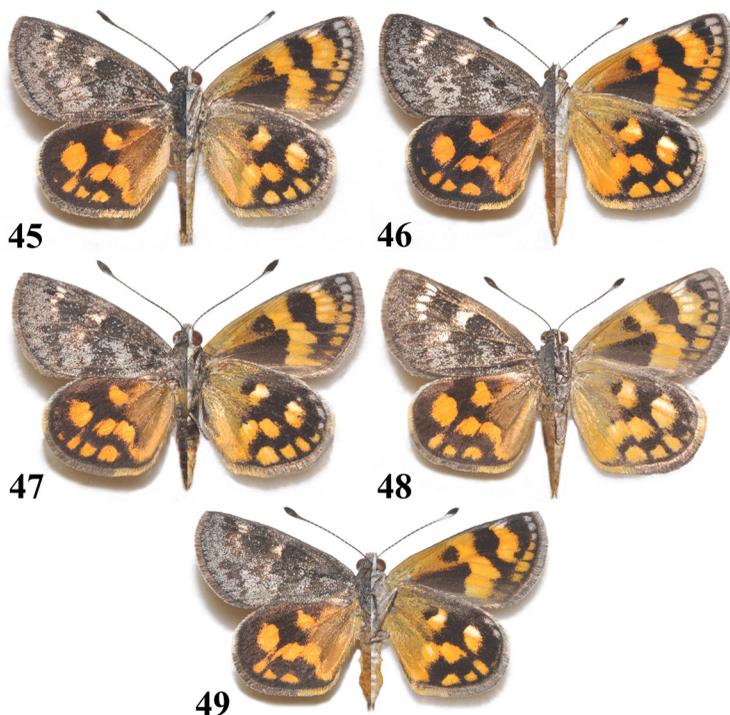
(Figs 39-50)

Eyre Peninsula Group (3) referred to above.



Figs 39-44. *S. larissa* sp. n., upper and undersides: paratypes Hincks CP, SA 3.xi.2011 (39) (m) 38 mm, (40) (f) 47 mm; Heggaton east, SA 4.xi.2011, (41-42) holotype (m) 39 mm; paratypes (43) (m) 42 mm, (44) (f) 47 mm.

Types. Holotype ♂, 39 mm, SOUTH AUSTRALIA (EYRE PENINSULA) (Figs 39-40): Heggaton east, 4.xi.2011, R. Grund (in SAMA). Paratypes (Figs 41-49): 1♂, Heggaton east, 4.xi.2005, R. Grund; 8♂, 5♀, Heggaton east, 4.xi.2011, R. Grund; 2♀, Heggaton west, 2.xi.1998, R. Grund; 1♂, 1♀, Hincks CP, 3.xi.1998, R. Grund; 31♂, 13♀, Hincks CP, 3.xi.2011, R. Grund; 4♂, Hincks CP, 4.xi.2011, R. Grund; 3♂, Pinkawillinie CP (east), 13.x.1998, R. Grund; 3♂, Pinkawillinie CP (east), 10.x.2011, R. Grund; 2♀, Pinkawillinie CP (east), 10.x.2011, R. Grund; 2♂, 1♀, Corrobinnie, 22.x.1998, R. Grund; 1♂, Kalanbi, 6.x.2011, R. Grund (in RG).



Figs 45-49. *S. larissa* sp. n., paratypes, upper and undersides: Pinkawillinie CP (east), SA (45) (m) 38 mm 13.x.1998, (46) (f) 48 mm, 10.x.2011; Corrobbinnie, SA 22.x.1998 (47-48), (m) 38 mm, (f) 43 mm; (49) (m) 40 mm Kalanbi, SA 6.x.2011.

Description (Figs 39-49). As for *S. p. parthenoides* from the Adelaide Region except as follows. Male. Thorax lacking a pair of white lines and below with only a very weak orange neck collar; antennal club with nudum black; FW UPS white subapical markings weakly developed and discal cell-end white mark tending to have an apically directed point; FW UPS white spots on the postmedian white band next to the discal cell edge seen in *S. parthenoides* usually not developed; submedian dark area in males usually with a scattering of white scales causing a dusky appearance; orange UNS markings tend to be slightly smaller, creating an overall darker aspect than in *S. parthenoides*; FW UNS tornal marginal spots tend to be weakly developed or absent; HW UNS large orange markings next to the costa always with an extensive white area, this feature is almost diagnostic within the SA species but a weaker version present in *S. discalis*; HW UNS postmedian spot next to the inner margin tending to be smaller and divided by a black vein or space creating two separate spots. The three large HW marginal spots in the tornal region of the wing tend to be more like those in *S. discalis*, with the first two (next to the

tornus) being block-like and square-sided, while the third spot in cell M3 is elongated.

Female. Similar to male, except the white subapical and discal spots are larger and better developed. The FW UPS white spots on the postmedian white band next to the discal cell edge seen in *S. parthenoides* are sometimes weakly developed.

Wing venation. Similar to other SA species in the group except the origin base of M3 in the HW is unstable, ranging from being closer to M2 or closer to CuA1 or connate with CuA1 (all on the discal cell), to being stalked on CuA1.

Adult forewing expanse. The size of *S. larissa* is quite variable, with some smaller specimens approaching *S. discalis* in size, yet some females are almost as large as those of female *S. parthenoides*. Females tend to be significantly larger than males, compared with the other group species where the size difference is less noticeable. Males have a wing expanse of 34-42 mm (avg. 38 mm, n = 54) and females 46-52 mm (avg. 47 mm, n = 24).



Fig. 50. Male genitalia, *S. larissa* lateral view, Heggaton east.

Male genitalia (Figs 12-13, 50; n = 11). Similar in appearance to those of *S. p. parthenoides* but with some significant differences. The overall size of the genitalia tends to be relatively smaller due to their more compact construction. The tegumen-uncus-scapial plate complex is similar but tends to be more robust; the posterior lateral edges of the tegumen are bulging; the anterior ventral edges of the scaphial plate are broadly fused to the tegumen. The 'harpe' is smaller and more compact, the anterior half broader, while the posterior bent half is shorter than in *S. parthenoides* and the dorsal edge is

weakly upturned rather than down-turned. The anterior dorsal edge of the harpe is bulging and roughened due to granulation of the setal bases. The ventral edge of the valva is strongly convex or bulging, the anteroventral arm of the valva extends anteriorly to very weakly join dorsally with the juxta wishbone prop. The vinculum in lateral view is wide and shortened and has a vertical or squared aspect relative to the valva (compared with *S. parthenoides*, where it is narrow and slopes away anteriorly) before sharply bending anteriorly at the base to form the combined bifurcate saccus and vinculum cross-brace (as found in *S. parthenoides*). The juxta is similar to that of *S. p. valma* but is more robust and the attachment point on the aedeagus is in line with the vinculum arms; the vinculum arms next to the lower part of the valvae gradually widen dorsally but expand significantly at its join with the tegumen just dorsal of the apex angularis (the vinculum is narrow in its basal half in *S. parthenoides* before suddenly widening dorsally), where it then becomes very narrow as it fringes the anterior side of the tegumen and also producing a rounded anterodorsal appendage on the tegumen (similar to *S. parthenoides* but half the size). The aedeagus is relatively shorter, more curved and slightly thicker; the ventral enlargement of the phallobase coecum is long as in *S. p. valma*; the dorsal enlargement of the phallobase is present but sometimes weak.

Etymology. Named in honour of a benefactor of this project.

Hostplants. One of us (RG) saw females ovipositing in the manner typical for the group on *Lepidosperma carphoides* in the Hincks and Heggaton areas of Eyre Peninsula. However, *L. carphoides* only occurs in southern Eyre Peninsula to as far north as Heggaton in northeast Eyre Peninsula; it does not occur in northwest Eyre Peninsula. In the above areas and in other areas where *S. larissa* flies in the absence of *L. carphoides*, females were attracted to the sedges *L. congestum* and *Schoenus racemosus*, which are likely hostplants although this could not be confirmed. No eggs were seen to be laid and no larvae or pupal exuviae were seen on or near the latter plants.

Habitat. *Synemon larissa* occurs primarily in mallee habitat, both open and closed.

Distribution and flight period. This species has only been seen on Eyre Peninsula (Fig. 37), occurring in mallee country as far north as the dog fence to the north of Ceduna. It has yet to be recorded from the extreme southern parts of Eyre Peninsula and was not looked for in the Port Lincoln area by the authors, but it is highly likely to occur in that area due to the presence of a primary hostplant *L. carphoides*. Its northern range is likely to be limited by the presence of its probable hostplants *L. congestum* and *S. racemosus*, being about its present known limits.

In northern Eyre Peninsula, males (n = 8) were recorded flying during 6-22 October, females (n = 3) 10-22 October. In central Eyre Peninsula, males (n =

46) were recorded flying during 3-4 November, females (n = 14) 3 November. These sparse observations imply that *S. larissa* starts flying earlier in the northern parts of its range and that males also start flying earlier in the season than females. It is sympatric with *S. discalis* and typically tends to fly later than the peak flight period of *S. discalis* in any one season.

Egg (Fig. 51). Eggs are very similar to others of the group, having 8-11 longitudinal ridges (n = 27), ~50 cross striae, 2.1-2.9 x 0.85-1.0 mm, (n = 29, both laid and extracted). The longitudinal ridges are sometimes divided. Pale subtranslucent yellowish white when freshly laid but white at eclosion, which occurred after 19-32 days (n = 19).



Fig. 51. *S. larissa*, egg shells and enclosed larvae 3.0-4.5 mm, Hincks CP 9.xii.2011.

Larvae (Fig. 51). First instar larvae at eclosion are 3.0-4.5 mm long (extended) and typically are similar to larvae of other species of the group. Older larvae were not found.

Pupae. Despite the large number of adults seen flying, no pupae or exuviae were observed.

Adult biology. This sun moth can be very common locally. In Hincks CP, RG saw potentially hundreds of males and females flying together in a small area along a track, presumably the result of a joint mass ecdysis. The numbers persisted further along the track; they were so huge that females were unable to oviposit because as soon as they stopped flying they were pounced on by the males. The track acted as a flight path for males, which continuously patrolled the area for females that ventured in to either oviposit or visit a nectar source. On a day that reached 35°C, both sexes (mostly worn) were active by 0800 h, initially sunning themselves in the open, but by 0820 h they were common and actively nectaring, doing so for most of the morning as

numbers continued to increase. When adults in the open were disturbed they did not fly very far, usually less than 30 m. Adults were still nectaring on flowers at 1000 h but some females were probing *L. carphoides* and others were seen investigating *S. racemosus*. Examination of adjacent native vegetation produced only the occasional female looking for hostplants. By midday adults were very active. Some females started nectaring again by 1400 h while the males patrolled. By 1500 h both sexes were nectaring and by 1600 h they began to disappear or bask on the ground. By 1700 h they had mostly disappeared.

In the Hincks and Heggaton areas both sexes spent a lot of time in the early morning and late afternoon nectaring from flowers; they showed a preference for *Calytrix* sp and white-flowered *Homoranthus wilhelmii*, but a yellow-flowered *Glischrocaryon* sp (Golden Pennant) was sometimes used. Elsewhere, nectaring was not obvious. At Heggaton, a few males were seen patrolling a large dune top during the midday heat and a few females in oviposition mode appeared interested in both *L. carphoides* and *S. racemosus*. A large population of these sun moths were later seen in a gully at 1500 h, the males flying near the hostplants and the females still attempting oviposition on *L. carphoides*. Activity diminished by 1630 h, with many flying off to roadside flowers for nectar.

Comments. This cryptic species has morphological features of both *S. discalis* and *S. parthenoides*, especially with the *S. p. parthenoides* population east of the Adelaide Region (and includes the orange linkage of HW UPS tornal spots 1A+2A and CuA2). Even though it is allopatric with respect to *S. parthenoides*, we believe this taxon should be treated as a new species, for reasons similar to those discussed above for *S. p. valma*. It has both distinctive wing pattern features and male genitalia. Inhibition of dispersal by the Spencer Gulf in the east and the aridity of the far northern Eyre Peninsula and the Nullarbor Plain presumably maintain its geographical isolation. We are unsure whether it could be a now stable species of hybrid origin or was historically derived from Western Australia.

***Synemon discalis* Strand**

(Figs 52-82)

Synemon discalis E. Strand, 1911. (Type data: p. 2, Castniidae, pl. 9. Holotype ♂ in Zoological Museum, Berlin (ZMB), 26 mm, type locality Australia). Precise type locality not stated, but inferred to be South Australia (Douglas 2004).

Material examined (Figs 52-65). SOUTH AUSTRALIA (SOUTHEAST): 4♂, 1♀, Binnie, 11.xi.2010; 1♀, Binnie, 16.xi.2010; 1♀, Ferries McDonald CP, 19.xi.2010; 5♂, 1♀, Malinong, 8.xi.2010; 1♂, Malinong, 11.xi.2010 (in RG); 1♀, Binnie, 17.xi.2009; 1♂, Binnie, 4.xi.2010; 1♂, Binnie, 1.xi.2010; 1♀, Malinong, 6.xi.2009; 1♀, Malinong, 9.xi.2009; 1♂, Malinong, 6.xi.2010; 4♂, Malinong, 12.xi.2010 (in AS). SOUTH AUSTRALIA (YORKE PENINSULA): 1♂, Coonarie, 17.xi.1999 (in RG). SOUTH AUSTRALIA (EYRE PENINSULA): 4♂, 3♀, Hincks CP, 6.x.1998;

3♂, 1♀, Hincks CP, 5.xi.2005; 8♂, 3♀, Inila, 8.x.2011; 1♂, Pinkawillinie CP (east), 13.x.1998; 1♀, Pinkawillinie CP (east), 1.x.2011; 1♀, Pinkawillinie CP (east), 10.x.2011 (in RG).

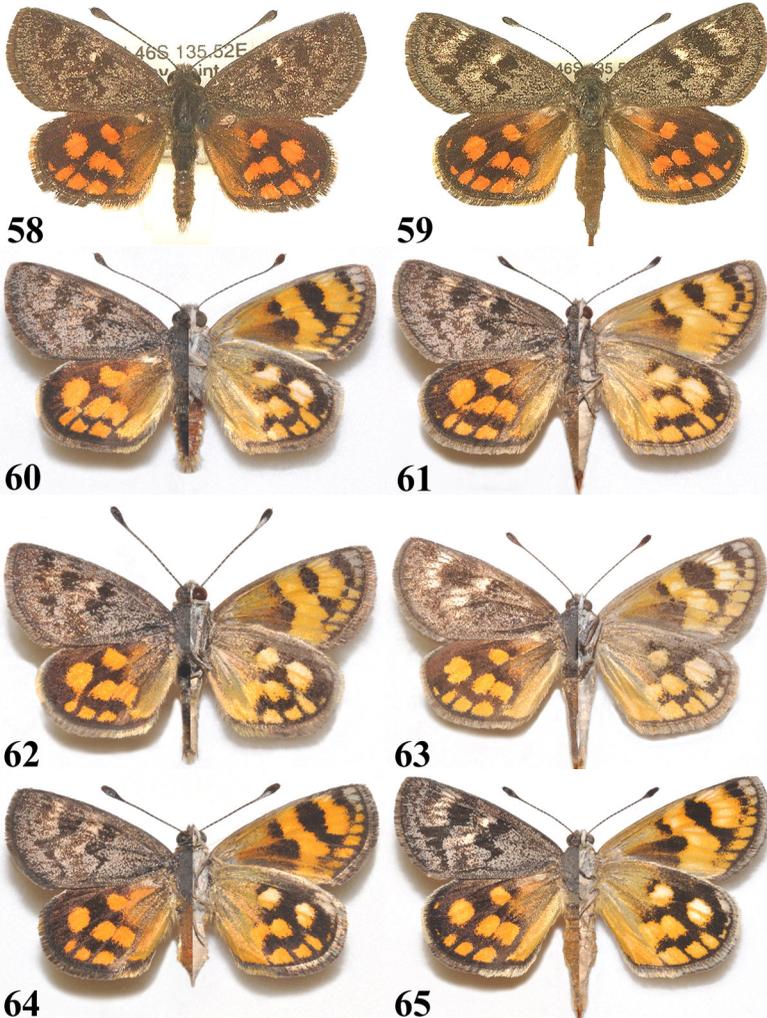


Figs 52-57. *S. discalis*, upper and undersides: Southeast Region SA. Binnie (52) (m) 32 mm 11.xi.2010, (53) (f) 40 mm 16.xi.2010; Malinong (54) (m) 32 mm, 12.xi.2010, (55) (m) 32 mm 11.xi.2010; (56) (f) 38 mm Ferries-McDonald CP 19.xi.2010; Yorke Peninsula SA. (57) (m) 32 mm Coonarie 17.xi.1999.

Comparative description with S. parthenoides and S. larissa (Figs 52-65). This cryptic species has a similar wing pattern to both *S. parthenoides* (*SP*) and *S. larissa* (*SL*) but differs as follows. Male. Body: frons, head and thorax dark grey above, indistinctly speckled pale grey, white lateral thoracic line absent (present in *SP* but not *SL*); abdomen above dark golden to orange brown, thorax pale grey below, orange neck collar absent (present in *SP* and *SL*), abdomen fawn below; labial palpi pale grey ascending with appressed scaling (similar to *SP* and *SL*), apical segment ~3/4 length of mid segment (similar to *SP* and *SL*); proboscis unscaled and well developed, eyes smooth, reflective eye pattern pale grey Type III when alive; antennae reach to or just

beyond half the length of FW costa or the end of the discal cell, similar to *SP* and *SL* except nudum area very dark brown (brown in *SP*, black in *SL*). Wing morphology: background colour of wings dark brown-black when freshly emerged, becoming paler with age; FW UPS patterned with white scaling, easily dislodged; a broad white margin (subterminal), partly scalloped in appearance with some white scaling continuing basad along veins; two white curved subapical bands, widely spaced at the costa, converging and terminating at cell M2 to form a curved V shape, the inner band much stronger and clearer near the costa than the outer band but weakening close to the convergence point, the outer band strongly scalloped; usually a poorly developed white spot at the distal end of the discal cell, a large black area basad of the white spot within the discal cell; a wide white scaled postmedian band extending from cell M3 to near the inner margin at cell CuP, the inner area of the band in cells CuA1, CuA2 and CuP with weaker scaling (but not fully black as can occur in *SP* and sometimes *SL*), the basad edge of the band at vein CuP sharply extended basad, the apical space between the white postmedian band and the costa black and devoid of white scaling; a narrow and usually straight black tornal bar distad of the white band, usually coalescing with the apical black area distad of the discal cell end spot, tornal bar constricted towards tornus; a narrow black submedian band basad of the postmedian white band, strongly angulate basad at vein CuP to produce a narrow zig-zag appearance to the submedian band that is diagnostic for *S. discalis* when not damaged (absent in *SP* and *SL*), coalescing with the large black distal spot in the discal cell; basal portion of wing covered with white scaling. HW UPS similar to *SP* and *SL* except macular spots yellowish orange in *S. discalis* (usually orange in *SP* and *SL*, ignoring *S. p. valma*), the tornal marginal spot in cell 1A+2A usually not joined to the postmedian spot in cell CuA2 by a narrow 'orange' band (almost diagnostic for *S. discalis*, whereas these spots are usually joined by an orange band in *SP* and *SL* except when aberrant), the three marginal spots in cells CuA2, CuA1, M3 tending quadrangular and closer together than in *SP* and *SL*, spot M3 (especially on UNS) and tending quadrangular while spot M3 is usually elongated basad (especially on UNS) whereas in *SP* the three spots are of similar size and of irregular shape and spaced further apart than in *S. discalis*, in *SL* the spots are similar to the latter but are smaller and spaced apart as in *SP*, the fourth inconspicuous postmedian spot sometimes occurring in space Sc+R1 next to the costa in *SP* is not present in *S. discalis* or *SL* on the UPS (but is on rare occasions seen on the UNS of females of those two species and is white coloured if present); the UNS 'orange' markings are yellowish as on UPS and tend to be similarly placed as in *SP* and *SL*, but are slightly larger than in *SL* and the FW UNS tornal marginal spots in *SL* differ by being weakly developed or absent; the FW UNS postmedian black bar often tending parallel-sided apically (a feature notably remarked upon by Strand 1911), particularly in Southeast and near Adelaide specimens, whereas in *SP* and *SL* it is usually constricted posterior of vein M2; HW UNS 'orange' markings

well developed as in *SP* whereas in *SL* the markings are slightly smaller, the 'orange' markings in *S. discalis* UNS have a white wash, particularly on the HW, this wash is also present in *SP* and *SL* to varying minor extents, except in *SL* the large spots next to the costa always have an extensive white area; the terms are similar to *SP* and *SL*.



Figs 58-65. *S. discalis*, upper and undersides: Eyre Peninsula SA. Murray Point, Port Lincoln SA 4.xi.1997, (58) (m), (59) (f); Hincks CP, (60) (m) 35 mm 5.xi.2005, (61) (f) 37 mm 6.x.1998; (62) (m) 33 mm 6.x.1998; (63) Pinkawillinie CP (east) (f) 38 mm 1.x.2011; Inila, SA 8.x.2011, (64) (m) 34 mm, (65) (f) 44 mm.

Female. Similar to males although the white markings are generally better defined and more intense. The UNS yellowish orange markings are more yellowish; the antennae reach to or just before half the length of FW costa or the end of the discal cell.

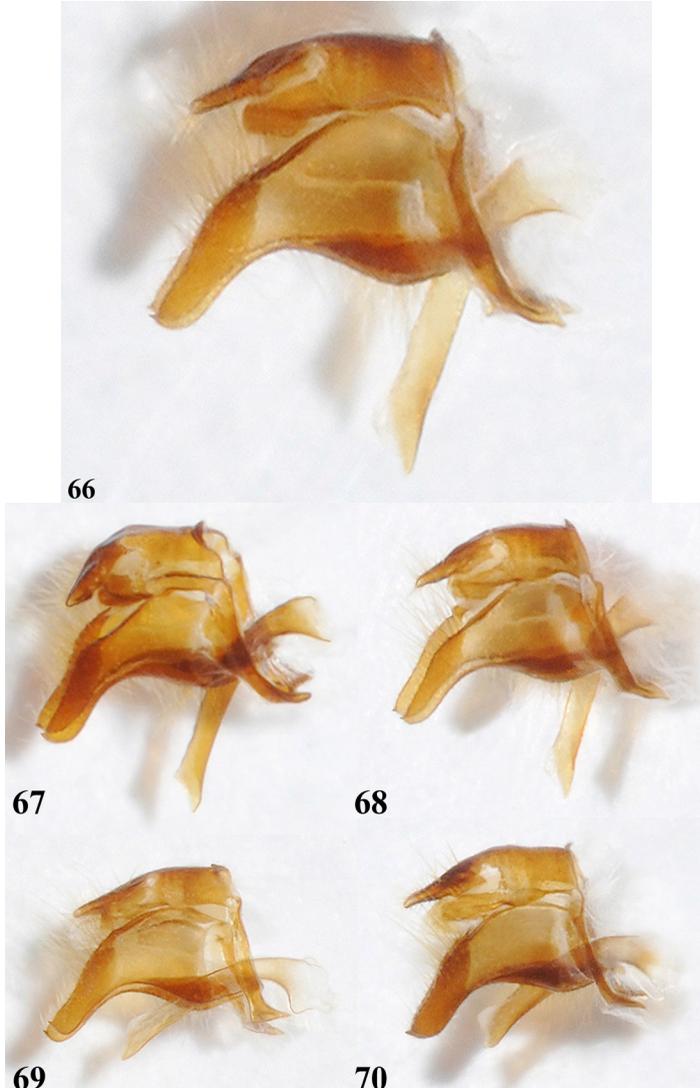
There are no obvious pale and dark morphological forms as seen in the *S. collecta* species group (Grund 2011). There seems to be some tendency for the FW of *S. discalis*, especially in the Southeast population, to be slightly narrower than for *SP* (Douglas 2008) and *SL*, but the data were not consistent.

Wing venation. Sexes similar. FW discal cell about half length of costa, vein Sc reaches costa beyond the end of discal cell, bases of veins R1, R2, R3+R4+R5 originate from the discal cell, R4 and R5 stalked, bases of M1 and R3+R4+R5 connate or nearly connate at discal cell, origin of M3 on discal cell variable but usually nearer base of M2 than CuA1; hindwing (HW) frenulum with one spine in male or 2-3 spines (usually two) in female, origin of M3 on discal cell variable but usually either connate or nearer base of CuA1 than M2.

Adult forewing expanse. This is the smallest species of the group. Males are easily separated from the others by their size, although females can be of similar size to males of the other species and can be misidentified unless the differences noted above are used. Based on material in the authors' collections, specimens from Eyre Peninsula tend to be slightly larger than those from the Southeast. The former males have a wing expanse of 31-36 mm (avg. 34 mm, n = 15) and females 37-44 mm (avg. 41 mm, n = 9), while Southeast males are 28-35 mm (avg. 32 mm, n = 17) and females 28-40 mm (avg. 38 mm, n = 7).

Male genitalia (Figs 66-70; n = 12). Closer in appearance to those of *S. larissa* (*SL*) than *S. parthenoides* (*SP*). The tegumen, uncus and scaphial plate complex are typical of the group. The 'harpe' is similar to that of *SL*, but the posterior dorsal edge is straight rather than upturned as in *SL*, the anterior dorsal edge of the harpe is not bulging and roughened due to granulation of the setae bases as in *SL*, the ventral edge of the valva is strongly convex or bulging, the harpe base is not constricted, the anterior-ventral arm of the valva extends anteriorly to very weakly dorsally join with the juxta wishbone prop (the last three attributes all similar to *SL*). The vinculum in lateral view is moderately wide, either straight-sloping or weakly curved anteriorly (different from *SL*, which has a vertical or squared aspect relative to the valva) before sharply bending anteriorly at the base to form the combined bifurcate saccus and vinculum cross-brace (as found in the group); the juxta is robust as in *SL* but the juxta wishbone pedicle is even more robust and the attachment point on the aedeagus is slightly anterior of the vinculum arms as in *SP*. The vinculum arms next to the valvae slightly widen dorsally from the base, where they attach to the valvae and also noticeably dorsal of the apex

angularis on the tegumen; a small rounded anterodorsal appendage on the tegumen is present (similar to *SL*). The aedeagus is slightly down-curved (similar to *SL*); the phallobase is not enlarged in *S. discalis*, which is diagnostic within the group in SA, the proximal orifice opening is posterior (similar to *SP* and *SL*). The female genitalia were not studied.



Figs 66-70. Male genitalia, *S. discalis* lateral views: (66) Hincks CP; (67) Binnie; (68) Hincks CP; (69) Pinkawillinie CP (east); (70) Inila.

Hostplants. The present authors, as well as others (Edwards 2006, Douglas 2008) have found that the primary hostplant for *S. discalis* is *Gahnia lanigera* (Cyperaceae), meaning that this species is usually found in the presence of that particular host. However, confirmed *S. discalis* is not averse to using other sedge plants in the vicinity of the primary host, based on visual sightings of female oviposition and the presence of early stages. In the Southeast Region, AS has seen females utilise the small sedges *Schoenus breviculmis* and *Schoenus deformis* (Cyperaceae) as hostplants. Douglas (2008) noted that in confusion after fire, female *S. discalis* oviposited on *L. carphoides* in northwestern Victoria.

Habitat. We have found *S. discalis* to occur only in the presence of its primary host *G. lanigera*. This plant is a dryland sedge favouring open mallee type habitat having a limestone base.

Distribution and flight period. *S. discalis* closely follows the distribution of its primary hostplant *G. lanigera* and has been found in the Regions of the Southeast-east Mt Lofty Ranges (extending into northwestern Vic), southern Yorke Peninsula and Eyre Peninsula (Fig. 38). There are no *S. discalis* records from Kangaroo Island, northern Yorke Peninsula or areas north of Adelaide. On the basis of *Gahnia lanigera* being the primary hostplant of *S. discalis*, then the latter should have a broader range than is currently documented.

Although sympatric with the other species in the group, *S. discalis* has always been found to be in peak flight earlier than the others. Males generally start to fly first, followed by the females about a week later, and there is usually a short peak period of emergence when both sexes tend to be more obvious (even though flight numbers tend to be fewer than for the other group species). The flight period for *S. discalis* has not been fully documented, but the flight occurs earlier in the warmer northern parts of its range than in the cooler south. It is likely contingent on weather conditions in early spring. In the Southeast the flight period lasts about three weeks, with the greatest number being present approximately 10 days after season commencement, with males seemingly outnumbering females.

On northern Eyre Peninsula, flight has been noted as early as 26 September, peaking in early October and then finishing by late October. On southern Eyre Peninsula the flight is during October to mid November, peaking in early November at Port Lincoln (CSIRO 2012). They have been recorded in early to mid November on southern Yorke Peninsula. In the Southeast they occur during November. A similar north to south range of flight periods from early-October to mid-November occurs across northwestern Victoria (Douglas 2008).

Egg (Fig. 71). Very similar to those of the other species, having 10-13 longitudinal ridges ($n = 10$), 1.9-2.5 x 0.85-1.0 mm ($n = 14$) and ~38 cross

striae (n = 1). The ridges are sometimes divided. Pale sub-translucent yellowish white when freshly laid but white at eclosion, which occurred after 32 days (n = 1 from Pinkawillinie CP east).



Fig. 71. *S. discalis* eggs and eclosed larvae: egg with 12 longitudinal ridges, ~38 striae, laid 8.x.2011, Inila; egg shell, eclosed larvae, Pinkawillinie CP (east).

Larvae (Figs 71-77). A first instar larva at eclosion (n = 1 ex Pinkawillinie CP east) was 3.0 mm long (extended) (Fig. 71). A near-mature larva (20 mm) was found by RG in a small *G. lanigera* plant from north of Ceduna. It was sub-translucent greenish grey when fresh (Fig. 72) (presumably it had been eating fresh culm or leaf material), but soon lost the greenish colour (Fig. 73) after being removed from the hostplant. It was observed in the culm just below ground level. The *Gahnia* was dead in its central part, possibly due to consumption by the larva.

Suspected immature larvae (Fig. 74) were observed by AS on *G. lanigera* and on *Schoenus breviculmis* and *S. deformis* in the Malinong-Boothby area of the Southeast Region; these were also found in the culm below ground level. (Identification of these larvae as *S. discalis* is based on adults being seen to oviposit on these plants.) These larvae were sub-translucent, pale grey-white in colour. A probable near-mature larva (21 mm) was also found in the culm of *G. lanigera* and had a sub-translucent pinkish white colour, with some dark brown dorsal areas and a dorsal line (Figs 75-77). The pink

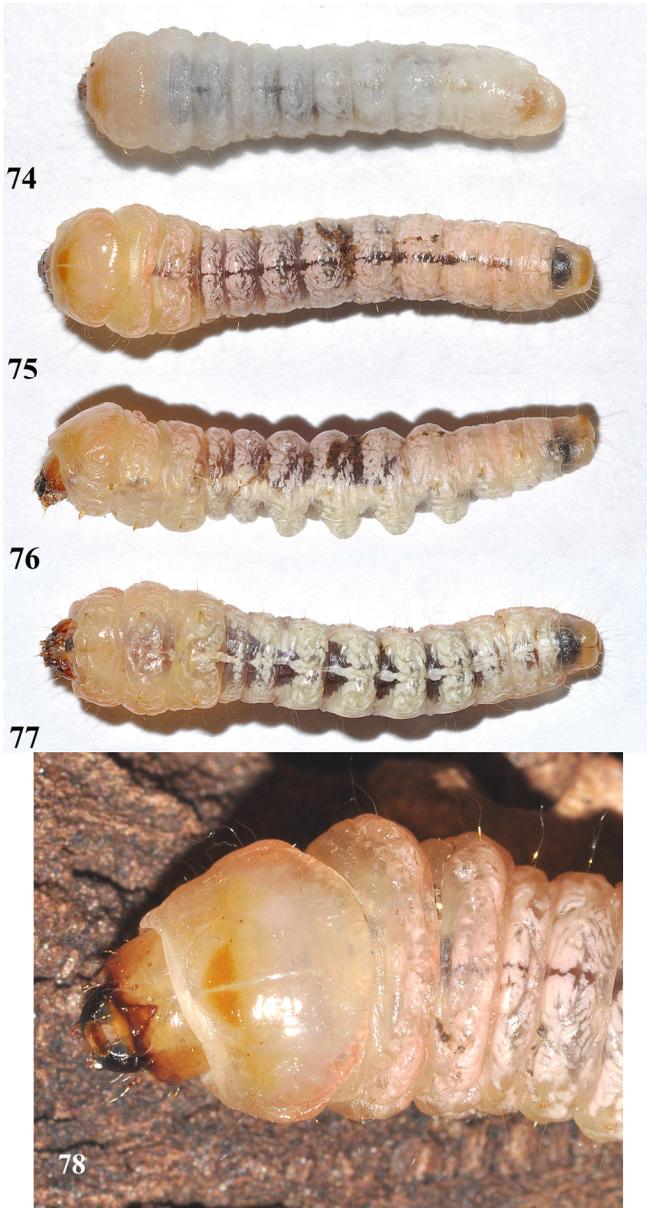
markings were seen on fat-like platelets under the skin (Fig. 78). It possessed a large, smooth and shiny, orange-yellow dorsal pro-thoracic plate on thoracic segment (TS) 1, the edges of the plate were darker and there were a pair of separated dark orange-red triangular markings on the front edge of the plate. The head was brown, smooth and shiny with black mandibles, the anal segment was pale brown peripherally, with a large dorsal dark brown half-circle anal plate at the anterior-dorsal margin. Scattered, moderately long, fine dark setae were present on the body and head, slightly longer on the anal segment. No attempt was made to map the setae distribution. Generally of slightly flattened, posteriorly tapered, cylindrical shape, typical for *Synemon* (c.f. *S. magnifica* in Common and Edwards 1981), the thoracic segments enlarged and the abdominal segments with rudimentary legs generally unsuitable for traction. The dorsal anterior and mid segments often have a roughened elliptical patch (Fig.73), presumably used for either gripping or compacting their tunnels. There was no reliable morphological character that could be used to separate this larva from that of *S. parthenoides*, except perhaps for the seemingly different arrangement of the 'fat platelets', which requires more study.



Figs 72-73. *S. discalis* mature larva 20 mm on *G. lanigera* from Kalanbi.

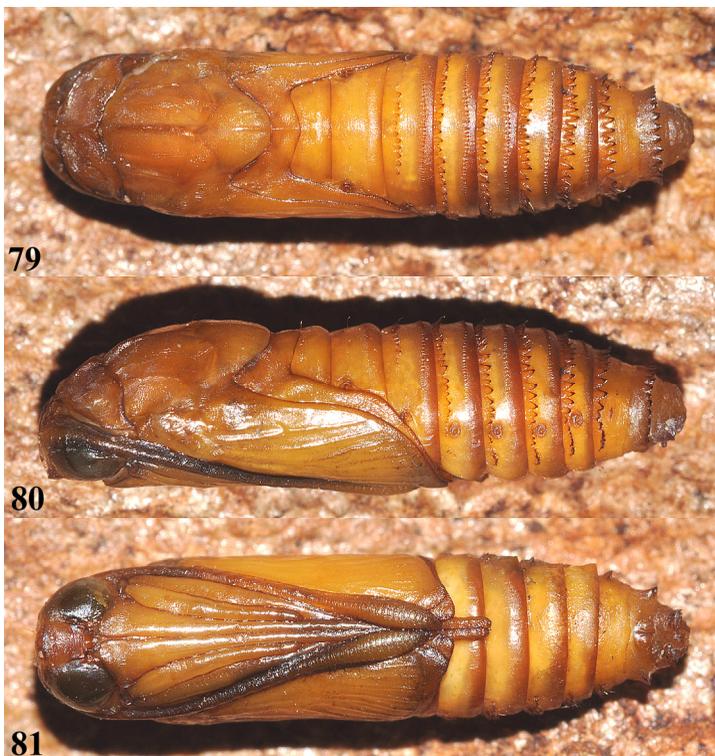
Larvae from the Southeast were observed at the base of the hostplant (culm) below ground level, but not in the root zone. They created a smooth shelter cavity to suit their size, but no silk was used. They are very sensitive to light and will hide if exposed. Based on the size of larvae observed at varying times of the year, and the experience with *S. parthenoides* larvae, we believe the larvae take two years to complete their growth.

Larval predators. Similar possible predators observed in the vicinity of *S. parthenoides* larvae have also been observed with larvae of *S. discalis*.



Figs 74-78. *S. discalis*, larvae ex Southeast, SA: (74) immature 9 mm 25.ii.2011 ex *S. breviculmis*; (75-77) mature 21 mm, 25.ii.2011 ex *G. lanigera*; (78) mature larva (21 mm) from *G. lanigera*, close-up of anterodorsal portion 25.ii.2011, showing head, prothoracic plate, dorsal elliptical ridges, setae.

Pupae (Figs. 79-82). No pupae or pupal exuviae of *Synemon* were found by RG on Eyre Peninsula. A suspected pupa of *S. discalis* was found by AS in a small *S. deformis* plant in the Mt Rescue CP on 19.x.2011. The pupa occurred head-upwards in the culm, 1.5 cm below ground level in a 'made to size' cavity. A silked tunnel (or 'cocoon', as used by *S. parthenoides*) was not noted. The pupa was male, brown 14.5 x 3.6 mm (Figs 79-82), cylindrical and although smaller, was essentially identical to the 'pupae' (pupa exuviae) of *S. parthenoides* (Figs 27-31). The *S. discalis* pupa was critically injured during extraction and so could not be used to confirm the identification of the adult by way of ecdysis. It is apparent from the work of Douglas (2008) and Edwards (in Douglas 2008), and from our observations, that *S. discalis* larvae do not leave the hostplant like *S. parthenoides* to pupate, and the construction of a silken tunnel or cocoon is also not obligatory. The flattened spines on the pupal abdomen (Fig. 82) are strong (similar to *S. parthenoides*) and constructed such that any movement that they might allow the pupa would primarily be in a forward (head) direction. A cremaster was not present on the pupa.



Figs 79-81. *S. discalis* pupa from *Schoenus deformis*, (m) 14.5 mm 9.x.2011.



Fig. 82. *S. discalis* pupa, closeup of posterior-dorsal spines.

Adult biology. Typically, males tend to stay close to the hostplants, preferring open spaces, either by flying above the plants or by basking or resting on clear ground, car tracks or plant debris nearby. They tend to fly closer to the ground than other species in the group, possibly because their hostplants are normally smaller than *Lepidosperma* spp. They are not known to actively patrol on hill and dune tops, but will utilise them if their host is nearby. While in flight males can detect females on the ground from a few metres and immediately divert to where the pheromones are coming from. Adults fly rapidly when disturbed, resembling the flight of skippers. When disturbed, females tend to fly a distance between 10-30 m in one direction before settling. Males have a tendency for a part return flight. Their normal flight tends to be in a fast, irregular zig-zag fashion. Both sexes react to intrusions by other sun moths or insects with females simply flying away, while males engage in 'dogfights' before resettling. Adults fly in full sun; however in hot conditions they will fly under high cloud. Their flight is seemingly fast and active and their exceptional vision (similar to other *Synemon*) is such that they easily evade most intrusions, responding to approaches from roughly 3-5 metres.

Adults become active around 1000 h. Males are active before females, which usually become active around midday, with the greatest number of individuals flying from midday until 1400 h. Males tend to check hostplants for females early and, if they cannot find any, then tend to fly off to other areas or rest on cleared ground. Females, as with other species in the group, tend to fly close to the ground in search of suitable hostplants, sensing the presence of the plants while in flight, we believe by both sight (initially) and later by chemical cues. Once selected, females typically land on the higher outer part of the plant, then walk down head first to the base. When performing this, the wings are held upright with regular slow, flapping

movements. At the base she turns upright and the wing movements stop, then she descends backwards to ground level and deeply probes the ground or sides of the plant with her ovipositor before oviposition. Presumably only one egg is laid, based on the time expended, but minimal effort was made by us to try and find the egg(s), due to their small size and well camouflaged location. When oviposition concludes, the female will fly on and repeat the process some 2-3 m away. The time taken to lay eggs is about one minute. We have not seen adult *S. discalis* nectaring on flowers even though the proboscis is fully developed. Douglas (2008) observed males nectaring on *Dampiera rosmarinifolia* in northwestern Victoria.

Comments. The morphological and biological information on the cryptic *Synemon* species discussed in this paper show there are differences between them that can be used to taxonomically differentiate them. *Synemon discalis* adults, when in good condition, clearly differ from those of other SA group members by their collective wing and male genitalia morphologies. The wing pattern has a diagnostic difference and there is a diagnostic difference in the male genitalia, *i.e.* the lack of an expanded phallobase. The overall similarity of the wing patterns and male genitalia indicate that the three species are congeneric, while the collective character differences indicate that they (plus one subspecies) are taxonomically distinct.

The presence of *S. discalis* on Eyre Peninsula suggests that the species has considerable dispersal ability, especially given its presence throughout temperate SA and northwestern Vic and possibly also in WA.

Interestingly, even though the male genitalia of *S. discalis* and *S. parthenoides* are very similar, and yet dissimilar to those of the *S. collecta* Swinhoe species group (Grund 2011), Kallies *et al.* (2008) nested the *discalis-parthenoides* clade within the latter species group in their phylogenetic analysis.

Acknowledgements

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