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## Short Communication

# Egg Sacs of the Orb-weaving Genus *Cyclosa* (Araneae: Araneidae) Targeted by Ovipositing Lacewings (Neuroptera: Chrysopidae)

**Timothy C. Hawes***

*Akarn Teeranee, Soi 35, Pahonyothin Road, Khet Jatujak, Bangkok, Thailand*

**ABSTRACT:** The first evidence of non-mantispid Neuroptera (Chrysopidae) specializing on spider egg sacs for oviposition is reported from Thailand. Prior to this observation, specialization on spiders by neuropterans was believed to be confined exclusively to the Mantispidae, larvae of which are currently only known to locate their prey by active searching and/or phoresy on adult spiders. Observations of the targeting of *Cyclosa* egg sacs by ovipositing Chrysopidae are described.

**KEY WORDS:** *Cyclosa*, Mantispinae, Neuroptera, orb-weaver, oviposition

## INTRODUCTION

Spiders of the genus *Cyclosa* are relatively small-sized orb-weavers with a widespread distribution that spans both New and Old Worlds and encompasses both temperate and tropical biomes (WSC, 2018). They are a well-studied genus both because of their relative abundance and because they are a model group for the study of the construction and use of stabilimenta (web decorations). Web decorations assume a variety of morphologies that vary between species and across ontogenetic stages; typically, silk decorations are only utilized by juveniles, while adults construct their decorations out of detritus, prey remains and molt exuviae. Probably all species lay their eggs in a silk sac. Most species place this egg sac outside the orb web, but *C. mulmeinensis* is a notable exception, incorporating it into its stabilimentum.

In Southeast Asia a number of *Cyclosa* species have been used to test and examine hypotheses that explore the functional significance of these web decorations (e.g. Tseng and Tso, 2009; Tan and Li, 2009; Tan *et al.* 2010). Species records from Thailand are still sparse and will no doubt be added to in future years - but see Chotwong and Tanikawa (2013) and Petcharad *et al.* (2014) for recent additions. Overall, the potential species list for Thailand can be expected to share many commonalities with the genus lists provided by Song *et al.* (1999) and Tanikawa (2007).

Interspecific interactions of *Cyclosa* spiders have until now been looked at almost exclusively in terms of predator-prey interactions – in particular, how they capture insect prey and how they use their stabilimenta to hide themselves from predators. The interactions reported here are of a slightly different type and with a group of insects whose relations with spiders are much more

*Corresponding author.
E-mail: timothyhawes@hotmail.com

poorly known.

The insect order Neuroptera Linnaeus 1758 are 'net-winged' insects known for the predatory lifestyles of their larvae. While adults may or may not be predatory, almost all larvae are predacious and are equipped with specialization mandibles of different types for piercing and sucking. Such lifestyles are often facilitated by the oviposition sites chosen by females to lay their stalked egg rows. Most larval predation is targeted at other insects, and lacewings – in particular, the Chrysopidae - are often researched and reared in the context of pest management, particularly with regard to aphids (Aphididae) (Tauber *et al.*, 2009).

However, one group has evolved to specialize exclusively on spiders. Larvae of the subfamily Mantispinae (Mantispoidea: Mantispidae) locate the webs of spiders either by wandering or by phoresy on female spiders (Redborg, 1998). As a mode of predation - or 'semi'-parasitism (Killbrew, 1981) – it is probably one of the most curiously specialized associations in the Arthropoda. It was first discovered by 'serendipitous' (Redborg, 1981) discoveries of larvae in spider egg sacs hatchings made by a number of investigators in the 19th and early 20th century. Brauer (1869) is generally considered to have demonstrated that spider eggs are the obligate food of larvae of the family. Subsequent biologists have expanded the list of associates and explored some of the intricacies of the relationship – Redborg and Macleod (1984) demonstrated, for example, that phoretic larvae feed on the hemolymph of their spider transporters. An overview of the known biology of the Mantispidae was provided by Redborg (1998).

This paper reports the first observations of non-mantispid Neuroptera targeting spiders for larval prey. It also provides the first direct and unambiguous evidence of ovipositional behavior by Neuroptera as a means of targeting spiders. Although there have previously been reports of insects laying eggs on spider webs in order to protect them from predators (Nafus and Schreiner, 2008), this is probably the first report of insects using oviposition on and next to webs as a means to facilitate predation. Previous studies of mantispids have either emphasized the role played by larvae in locating spiders or have only been able to note an association between oviposition sites and spider occurrence (La Salle, 1986; Redborg, 1998).

## MATERIALS AND METHODS

Observations were made in the vicinity of Huay Yai, Banglamung, in the central-eastern province of Chonburi, Thailand. Whilst carrying out natural history surveys and observations (e.g. Hawes, 2015, 2016, 2018) the occurrence of neuropteran egg stalks was noted in direct association with the webs of *Cyclosa* spiders. The habitat consisted primarily of mixed secondary woodland, scrub, and grassy clearings interspersed between small fruit orchards and agricultural fields (mostly growing pineapple). Webs examined and noted here were all made within an area of c. 1km$^2$. Observations 1 and 3 were made at the verge of a rural road with a cleared and managed perimeter of short grass and trees with secondary woodland behind it. Observation 2 was made in the same area described by Hawes (2018), just above ground-level in the low canopy of a coconut tree at the edge of an orchard and about 500 m from the rural road. Photographs and notes were made of the associations, and egg stalks were taken home to hatch (further details below). Independent observations of *Cyclosa* egg sac targeting and of larvae predating (one *in situ*, one *ex situ*) spiderlings were made. Three sets of observations are described; all observations

were made between February and March 2013. A fourth observation of a batch of egg stalks found laid on the tip of a grass stem about 15 cm from the bridge line of a *Cyclosa* 'insulana-type' web is not included, as the proximity, while probably spider-associated, was not considered specific enough. An additional set of three further associations of stalks with empty (non-*Cyclosa*) spider webs were made, but these are not described here on the basis of their ambiguity (it was not possible to exclude the possibility that the egg stalks were laid after web abandonment).

Although it is likely that many species – probably including the one noted here – in Thailand, have yet to be described, the larvae of Neuroptera have distinctive morphologies at the Family level (Tauber *et al.*, 2009). Thus, it was possible to definitively rule out a mantispid association by general morphology of the mandibles (Redborg, personal communication). Further taxonomic specification of the chrysopid was not possible on the basis of available material but the functional significance of even this basic level of differentiation is that it effectively rewrites our previous understanding of the exclusivity of Mantispidae-spider relations. *Cyclosa mulmeinensis* was identified with reference to Roberts (1983) and Koh (1991). The latter paper provides prior record of the occurrence of *C. mulmeinensis* in Thailand. The two other webs of *Cyclosa* are noted to be of the 'insulana' type (elongate abdomens; patchwork opisthosomal colouration; vertical, relatively uncompacted trash-lines) – but noting Tanikawa's (1992) remarks on what is probably an overly misidentified species, the spiders are given only generic designation here ('*Cyclosa* sp.'). The samples were not collected but subsequent collections (Hawes, unpublished data) have examined the genitalia of a number of *Cyclosa* from Thailand, confirming the *C. mulmeinensis* identification and the variety of 'insulana' types. Further taxonomic work will be needed to untangle the latter group.

## RESULTS

*Observation 1*. 27 February 2014. Neuropteran egg stalks were found laid on the bridge line of a *C. mulmeinensis* web with egg sacs inlaid as 'balls' into the central stabilimentum (Fig. 1). Egg stalks were collected and hatched (Fig. 2) on 1 March 2014. Larvae were identified to be of the Family Chrysopidae. Larvae were predaceous and trash-carrying, after a few days only one was left, with a trash 'backpack' of the skins of the siblings it had cannibalized. An egg sac from another *Cyclosa* sp. had been collected and hatched on 3 March 2014. The remaining chrysopid larva readily attacked and ate the spiderlings that emerged from this egg sac when offered them singly (Fig. 2c). However, spiderlings were capable of silk-deployment so the larva was not always successful. Due to an insufficient familiarity with mantispid biology at the time of the observations, the larvae were not tested with an unhatched spider egg sac (but see observation 3 below).

*Observation 2*. 11 March 2014. Neuropteran egg stalks were found laid directly next to the egg sac of a *Cyclosa* sp. (Fig. 3). This species of *Cyclosa* lays its eggs outside the web. The web was hung in the shelter of a coconut palm frond and the egg fixed onto the 'finger' of one of these fronds. The proximity of the egg stalks and the *Cyclosa* egg sac was unambiguous.

*Observation 3*. 20 March 2014. Another *Cyclosa* sp. web was found strung across the lower branches of a tree with its egg sac fixed to one of the branches. A relatively large trash-'backpack' carrying neuropteran larva – later determined to be a sub-adult – was observed attacking the egg sac. The egg sac and larva were collected. The larva was left with the egg sac and subsequently molted and metamorphosed into an adult (Fig. 4). Inspection of the adult readily confirmed that it lacked the raptorial forelimbs characteristic of the 'praying mantis-like' Mantispidae.

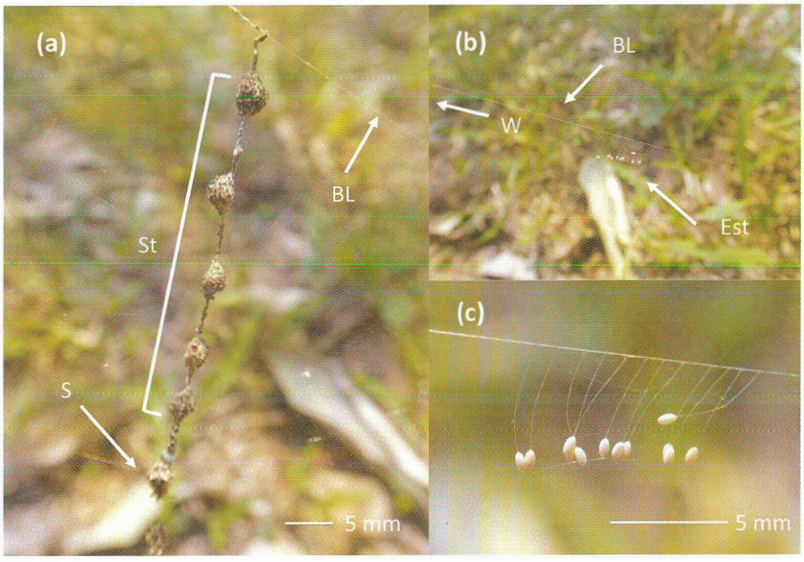



**Figure 1.** Neuropteran egg sac oviposited onto bridge line of *Cyclosa mulmeinensis*: (a) *C. mulmeinensis* (S) web with egg sacs disguised in ball-decoy stabilimentum (St), with bridge line (BL) indicated; (b) neuropteran egg stalks (Est) on the bridge line (BL), with direction of orb web indicated (W); and (c) close-up of the egg stalks.

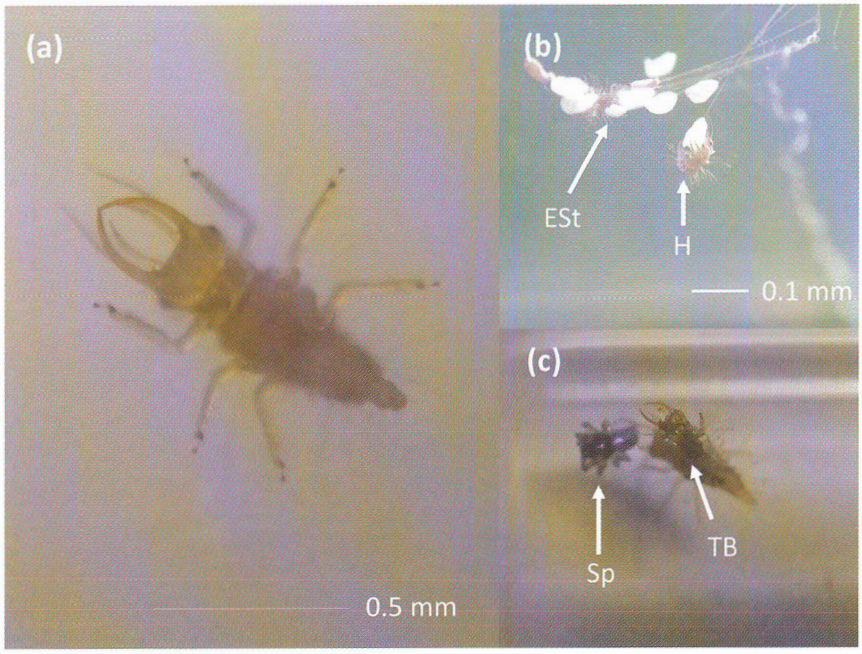



**Figure 2.** (a) Habitus of chrysopid larva (dorsal view); (b) egg stalks (Est) with recently hatched chrysopid larvae (H); and (c) chrysopid larva with 'trash backpack' (TB) made from remains of previously cannabilized siblings, preparing to predate *Cyclosa* spiderling (Sp).




**Figure 3.** Neuropteran egg stalks (Est) laid onto coconut palm frond immediately next to *Cyclosa* sp. egg sac (ES), inset shows the same with digital calipers for scale.

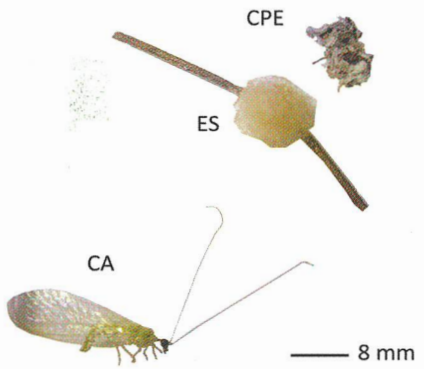



**Figure 4.** Chrysopid adult (CA) metamorphosed from larval form collected as it attacked *Cyclosa* egg sac; with egg sac (ES) and chrysopid pupal exuvium (CPE) next to adult.

## DISCUSSION

The technical specialization demonstrated by these observations indicate that spiders would have to be included as a prey group not immune to the predatory-linked oviposition strategies of the Neuroptera concerned. Indeed, not only do they show that non-mantispid Neuroptera may prey on spider egg sacs, but the degree of association exhibited by oviposition behaviors, in particular, exceeds (in terms of the precision of oviposition) any that has so far been reported for the spider-specializing Mantispidae. This does not rule out a generalist approach to oviposition site: Chrysopidae typically lay their egg stalks as multiple batches and those laid next to and on webs represent just single batches of egg stalks. Nonetheless, the site choice shows both anatomical precision (note in particular: the stalks on the wind-exposed bridge line of *C. mulmeinensis*) and a recognition of the identity and suitability of *Cyclosa* egg sacs as a larval food source.

The ovipositional behavior of egg sac predating Mantispidae remains one of the biggest enigmas of their specialized feeding habits. Redborg (1998), for example, concludes his review of their biology by noting that, 'Although there surely must be some selective behavior on the part of females, none has yet been demonstrated.' The observations described here may not answer this question directly, but they do demonstrate the potential for such 'selective behavior'.

It would be premature to interpret these observations as meaning that spider-exclusive specialization is not confined to the Mantispidae – however, these observations do reveal that Chrysopidae, as represented by the species here, have the ability to target spiders in their oviposition with an extreme degree of precision. In particular, laying egg stalks on spider silk lines has never been noted before. If these are the actions of a prey-'generalist', they reveal the extent to which it is capable of specialized site selection and egg deposition.

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