Notes on the biology of the conspicuous mud dauber wasp, *Chalybion japonicum* (Gribodo, 1883) (Sphecidae) a major predator of spiders in Hong Kong.

Christophe Barthélémy
Sai Kung Country Park, Hong Kong,
E-mail: chb99@netvigator.com

ABSTRACT

The nesting biology of *Chalybion japonicum* was studied using nest traps in Hong Kong. It was revealed that (i) this wasp was very versatile in nesting site selection, (ii) it constructed few cells per nests (83% of the nests studied had one or two cells only), (iii) there was a variability in prey selection related to the seasonal abundance of prey, (iv) that nearly 40% of all brood died during development either from fungal infection or parasitism and (v) that this mud dauber was bivoltine in Hong Kong.

Key words: *Chalybion japonicum*; Sphecidae; Araneidae; nest-traps; parasitism.

INTRODUCTION

This paper describes the nesting biology of the common mud dauber wasp *Chalybion japonicum* in Hong Kong. Observations were carried out in 2010 using nest traps that were dissected and nesting behaviour was recorded *in-situ*.
The genus (sub-genus) was revised by Hensen (1988) who provided a grouping of the various species; *C. japonicum* was placed in the *C. bengalense* Group. Members of this genus have generally distinctive metallic hues of blue or green, only one member being black.
Chalybion japonicum is widely distributed from the Korean Peninsula, Japan, Taiwan and South East Asia (Yamane *et al* 1999).

MATERIALS & METHODS

The nesting behaviour of *Chalybion japonicum* was studied using nest traps that consisted of hollow bamboo canes of various length and diameters that were cut so that one end was closed by a nodal septum. Clusters of seven cut canes were bundled together and hung from roof beams in the author's office in Sai Kung Country Park, Hong Kong.

A total of 64 traps were set in April, May and June 2010 in the same location. The April and May traps were 155-185mm long (mean = 164.8; n = 50) with diameters of 6-10mm (mean = 7.6; n = 50), while the June traps were 165-230mm long (mean = 203.9; n = 14) with diameters of 6-10.5mm (mean = 7.5; n = 14). Upon collection, after completion of the nest by the wasp the traps were opened, prey, brood content and nest associates recorded and the traps then placed individually in Ziploc® bags for brood emergence.

Ten freshly completed nests totalling 12 cells were opened daily, the brood was measured, prey numbers and species determined and daily prey consumption measured until the larvae pupated, after which the nests were left undisturbed until emergence of adults. The daily growth was documented photographically.

Measurements were taken on scaled photographic enlargements for brood and with a precision stainless steel calliper for nest dimensions, cell partition and cocoon wall thickness.
Spider prey where identified by Dickson Wong Chi Chun, Hong Kong, based on my photographic records.

Additionally, I carried out *in-situ* observation of nest construction and prey provisioning on four traps, totalling 6hrs 08mns of observation.

OBSERVATIONS & DISCUSSION

Nest & brood description

Nest architecture

Chalybion japonicum was extremely versatile with regards to nesting site selection, beyond the frequent usage of my obvious traps, the wasp selected any site that would present itself with a more or less tubular shape, whether it be the screw recesses in electrical appliances, cells of a nest of *Polistes gigas*, left on a table top, the cells constructed by *Sceliphron deforme* the previous year (Fig. 1) or even interstices between rafters and joists of the roof. It was also observed opening fresh *Sceliphron deforme* cells, empty the content, prey and brood alike and then furnish it with its own prey and brood.

The nests contained few cells generally, 39% of the nests were composed of one cell, 44% had two cells,14% had three cells and 3% had 4 cells, regardless of the tube length or diameter. As was noted by Iwata (1976) the wasp does not utilize fully the cavity at hand, leaving considerable empty space either in the cell or beyond it, as opposed to many other tube-renting wasps in the family which optimise space utilisation.

The nests could be characterised by the following: (i) the innermost cells did not necessarily start from the bottom of the trap, but could be initiated anywhere along its length, (ii) there were no intercalary cells, (iii) the outermost cell anterior partition formed the nest closure and (iv) when the first cell was initiated against the nodal septum the wasp generally did not add a plug of cell material at the posterior end of the cell. Figure 2 gives an illustration of a typical nest at opening.

The cell partitions were composed of a clayish material with inclusions of sand grains, in all cases the posterior side of the cell partitions had a rough finish while the anterior surface was smooth. A great variety of forms of closures where observed, from a simple clay partition maximum 3mm thick, with or without adjunction of a finishing layer, to complex multipartitions constructions, separated with narrow empty space and thick nest plugs, with or without a finishing layer. In 14% of the cases *C. japonicum* applied an additional layer of white material - likely uric acid from reptile faeces (*Gekko* spp) - on the last cell partition on both uni- and multi-cellular nests; in another 14% it would apply patches or even layers of a grey/black material likely to be faecal matter and in 14% it applied a layer of transparent resinous material (from an unknown plant source) to the same. Iwata (1964) noted that the usage of white material was an obligate behaviour on all nests of the specimens he observed in Thailand and that such was the case for uni-cellular nests in Japan (Iwata, 1976); however, as shown here this behaviour was more facultative in Hong Kong with a large degree of variability. The use of white material has been recorded for several other species in the genus (*C. bengalense* and *C. zimmermanni*) (Jayakar and Spurway 1963; Ward 1971). Iwata (1976) observed the wasp collecting gum from peach trees and applying it to the nest closure.

The nests had no vestibular cell, although one trap presented a succession of three partitions after the single cell. It may be possible that this was the consequence of an attempt by the original wasp or even another one to add additional cells to the cavity. All but two traps had no posterior partition to the first cell and two other traps had some cell partition material applied on or very close to the nodal septum of the hollow cane.

When multi-cellular nest were built the first cells were longer than the second which were longer than the third. The first cells were 22-190mm in length (mean = 104mm; n = 64), the second cells were 23-84mm (mean = 44mm; n = 38), the third cells were 26-116mm (mean = 33mm; n = 11) and the fourth cells were 19-32mm (mean = 25.5; n = 2).

Prey and oviposition

The vast majority (90%) of prey were in the Araneidae family,7.8% in Tetragnathidae (all represented by four species of *Leucauge*), 2% in Theridiidae and 0.2% in Uloboridae. In fact the majority of all prey were represented by two genera in Araneidae, 49% in *Neoscona* spp and 33% in *Cyclosa* spp. Males and females were provided although females represented 79% and males 21% of all prey taken. There were between 5 and 18 prey items per cell (mean = 10.5; n = 47). *C. japonicum* is a major predator of small spiders. Between the 12 April 2011 and 10 May 2011 the first adults (from overwintering pupa) took 251 prey items distributed over 21 recorded nests (12 prey items per nest) and between the 29 May 2010 and 17 July 2010 the daughters took 234 prey items on seven nests (33.5 prey items per nest).

A generational variation was noted in the major species of prey taken. The first active females of the year took a majority of *Neoscona* spp., while their daughters took a majority of *Cyclosa* spp. with *Neoscona* spp. completely absent from the prey records. This absence may be explained by two independent factors: the exhaustion of the prey stock after intensive hunting by the first generation, and/or the end of the seasonal presence of the spider species from mid to end of June onwards . David A. Landes (Landes *et al* 1987) noted that *C. californicum* in the Southern USA clearly selected prey according to their seasonal abundance and this may well be the case with *C. japonicum* in Hong Kong. The difference in prey number presented above may be explained by the distinctive seasonal prey preference between the first active females and their daughters: *Neoscona* spp. are generally larger than *Cyclosa* spp.; at least in the prey record and the nesting female would require more prey matter to sustain its brood.

The egg was attached dorso-laterally close to the abdomen and cephalothoracic junction of the prey, the anal end approximately median to the host body (Figure 4). On the 32 cells for which the position of the egg was ascertained four were found to be laid on the first prey, seven on the second, five on the third, four on the fourth, one on the fifth, three on the sixth, three on the seventh, three on the eighth and one each on the ninth and thirteenth prey. This clearly shows that *C. japonicum* lays its eggs after provisioning the cells as is the case with many apoid wasps, but there was no particular determinism in the egg position.

On five nests for which prey and sex of brood was determined it was noted that the mother provided fewer prey for males than for females (Table 1).

Trap ref.	No. of prey Male cell	No. of prey Female cell
PSO-100. A7	4	7
PSO-101.A5	6	8
PSO-102.A3	9	12
PSO-102.A5	7	14
PSO-104.A2	7	9

Table 1: Prey item count relative to the sex of the brood

Brood and brood development

Brood development was monitored at 24 hour intervals on 10 traps totalling 12 cells, until the brood reached pupation period (Figure 3).

The egg was creamy in colour slightly arched, with hemispherical ends and a more or less constant diameter of 0.8-0.94mm (mean = 0.86mm; n = 29), it was 2.9-3.6mm long (mean = 3.20mm; n = 27). It hatched in approximately four days after oviposition (mean = 3.80 days; n = 12). The first instar larvae remained attached to the prey and fed ventrally on the prey abdomen until it was emptied; it then reached for other food items moving about in the cell. At first the larvae only consumed the abdomens of the prey leaving cephalothoraxes and appendages, however, when all prey had been fed upon the larva consumed what was left, leaving nothing save for a few hard chitinous elements such as the chelicerae. The larvae fed continuously for about 7 days (mean = 6.80 days; n = 10). In the first four days, the number of prey consumed daily increased and on the fourth or fifth day it suddenly decreased. The daily mean larval growth and prey consumption is expressed graphically in Figure 4. When feeding was completed the larvae groomed themselves, removing foreign objects such as prey setae and hard chitinous parts from their bodies. On the first day after completion of feeding the larvae would spin lose strands of silk in an apparent random fashion binding them to the cell walls; they then proceeded at the construction of the cocoon proper within the tangle of the loose strands, this time spinning a dense film of fine silk forming a continuous layer for about two days. It took 3-4 days (mean = 3 days; n = 10) to complete a cocoon and start pupation. The silk of the cocoon was at first creamy-white and gradually darkened in three days to become dark brownish-red, barely translucent. It was fragile and easily torn. The cocoons were oblong, with a basal hard and dark capsule and were 17.50 - 25.20mm long (mean = 21.20mm; n = 24) with a maximum diameter of 4.50 – 6.70mm (mean = 5.60mm; n = 24) the wall thickness was 0.08mm thick.

Pupation time was measured untill emergence from the nest and lasted 39-42 days (mean = 40.80 days; n = 9). However, from casual observations it seems that after breaching the cocoon the wasp remained inside the trap/nest for a day at maximum and then emerged.

As a rule males emerged before the females, and females cells were always constructed before (posteriorly) to that of male, although in one instance the mother constructed a male cell before the female one.

Voltinism

Observations on nesting patterns revealed that *C. japonicum* had two generations per year. The first generation emerged from overwintering brood in May and the second emerged in June. Two distinct ovipositioning activity periods were noted, the first in May and the second from end of June to Mid-July. The larvae entered a long diapause in July, overwintering as pre-pupal larvae until end of April of the following year when pupation started.

Sex ratio

Sex ratio was obtained on 37 active cells and was determined to be 25 females for 12 males or an approximate ratio of 2:1.

Natural enemies, *nest associates and brood death*

A number of enemies and associates were reared from cells of *C. japonicum*. Twenty-eight cells out of 105 (27%) were parasitised. The most common enemy was a cleptoparasitic phorid fly which was present in 19 cells, seven cells were infested by *Melittobia* sp (Chalcidoidea, Eulophidae), one cell was parasitised by a cleptoparasitic miltogramine fly and the brood in one cell seemed to have been destroyed by an infestation of small Psocoptera.

and fresh prey was noted on several nests (Figure 5), this indicates that the fly gains access to the cell while it is being built, it remains trapped inside at cell closure, and is then at leisure to lay eggs both on the prey and the cell walls. The wasp egg is likely consumed by the adult fly as no eggs were ever found when the parasite was still at egg stage. The maggots never consumed the entire food store and left a great volume of prey matter.

On the other hand *Melittobia* sp. attacked only mature larvae, pre-pupae and pupae, therefore the Chalcidid must have gained access much after the nest and its closure had been completed.

Small Psocoptera were found in 10 nests. They were present from the beginning untill much after brood emergence. They seemed to feed on debris in the nest rather than on the wasp brood save for the single case mentioned above.

Mites were recorded in two instances on the brood and later on the adult wasp when it was collected at emergence.

The brood died for reasons not related to parasitism in 12 out of 112 active cells (11.7%). Fungal infection was present in nine of these cells and is the presumed cause of mortality, although in some instances despite the presence of mould on the prey, the brood developed, pupated and emerged. When combined with parasitism the total brood failure reached approximately 39%. O'Neil (2001) provides a summary of brood mortality for a few species of Sphecidae and in particular for four species of *Sceliphron*, a close relative to *Chalybion*. This ranges from 36% to 43% which coincides with the brood mortality observed in this study.

***In-situ* observations**

In-situ observation totalling over six hours of activity on four traps was carried out in May-June 2010. Behaviours were time recorded. Five major activities were identified: (i) cell material foraging: (ii) prey foraging; (iii) applying cell material; (iv) placing prey and (v) other activities, referred to as unknown. Table 2 details the time spent on each of the above activities, Table 3 provides the duration of each activities for the construction of one cell and Figure 6 graphically illustrates the nesting activities sequences.

Work started soon after sunrise around 0700h locally (in May) and stopped before sunset around 1800h, the wasp sheltering for the night away from the nesting site.
On a cell the wasp spent 60% of her time foraging for prey, 28% foraging for cell material, 9% applying this material to the cell partition, 0.5% placing prey in the cell and 2.5% as unknown time spent. To construct and provision one cell the wasp took on average 3hrs50min and could therefore construct a 2-3 cell nest in one day. The cells were never closed by a temporary plug when the wasp left for foraging.

Activity	Time Spent (s)	Max (s)	Mini (s)	Mean (s)	Mean (mns)	e =
Material Foraging	7470.00	960.00	60.00	339.55	5.66	22
Prey Foraging	11580.00	1350.00	270.00	723.75	12.06	16
Applying material	2475.00	265.00	25.00	112.50	1.88	22
Placing prey	190.00	25.00	5.00	14.62	0.24	13
Empty	360.00			360.00	6.00	1
Total	22075.00					

Table 2: Recorded activities, time budget.

Activity	Time Spent (s)	Time spent (mns)	%
Material Foraging	3840.00	64.00	27.61
Prey Foraging	8405.74	140.10	60.44
Applying material	1230.00	20.50	8.84
Placing prey	72.00	1.20	0.52
Empty	360.00	6.00	2.59
Total	13907.74		100.00

Table 3: Activities durations for the construction of one cell.

Nest construction

The cell partition material was formed into a small pellet and was carried solely with the mouth parts, mandibles and possibly palpi/bristles (?). One wasp, using bundle PSO-104, procured the mud from an old *Sceliphron deforme* nest, approximately 1m away, a fact that had been observed with *C. californicum* and *C. zimmermanni* on nests of *Sceliphron* (Bohart & Menke 1976). The use of a dry source of material requires water to render it plastic, therefore it can be confirmed for *C. japonicum* (Bohart and Menke 1976) that water is procured first and then applied to a source of dry mud. When the material was applied inside the nest, the wasp produced a stridulating noise similar to that of other Sphecoidea, caused by the contraction of the longitudinal wing muscles of the thorax.

Upon completion of a cell partition the wasp always lingered at the nest entrance (2-10s), grooming and often re-entering the trap (up to five times) as if inspecting the workmanship.

In some cases when provisioning was incomplete at the end of the day the wasp would leave the cell open for the night resuming work the following day.

In several instances although the terminal partition had been constructed, it was re-worked upon several days after the nest had been completed, with the addition of a layer of white material, assuming it were the same wasps. Also, in two instances it was observed that wasps could breach the terminal partition of a completed nest, extract some of content of the last cell – never more than 1-2 prey items, and later reseal the nest. Usurpation of nests of *S. deforme* was a common occurrence, the two species co-existing in the same locale. *C. japonicum* re-used either breached cells or simply breached an occupied cell, extracted the content, either pupa, larva or prey and furnished it with its own prey and egg, sealing the cell upon completion of provisioning. Not having marked live specimens and despite the incident related above, it was unclear if *C. japonicum* showed defined intraspecific nesting site usurpation. Species in the genus have a tendency towards interspecific nest usurpation such a *C. californicum* upon nests of *Sceliphron* spp. (Bohart and Menke, 1976) and this was confirmed with the present study by *C. japonicum* upon nests of *S. deforme* although from casual observations it seems that *C. japonicum* may prefer pre-existing cavities over old nests.

Prey transportation and provisioning

The mode of transportation varied according to the prey size. While in general all prey were of similar size, occasionally the wasp would carry exceptionally small items (*Cyclosa* sp1). Large prey were carried venter up, the front legs seized by the mandibles and the body held with the wasp fore-legs. Small prey were carried similarly but held only by the mandibles, un-assisted by the forelegs.

The wasp entered the nest head first, dragging the prey under her body and always exited metasoma first being unable to rotate herself within the cavity.

On several occasions the wasp delivered additional stings to the prey before entering the trap, as if it had assessed that the item was insufficiently paralysed, behaviour that might have been confused with oviposition by Yamamoto (1942).As with cell partition construction, the wasp always lingered at the nest entrance upon completion of prey provisioning, often re-entering the tube for some kind of inspection.

Interactions with conspecifics

Chalybion spp are known to form “sleeping” aggregations (Bohart and Menke 1976) and this was observed for *C. japonicum* in one instance where males and females aggregated on a loose hanging piece of rope (Figure 7).

The wasp was fiercely defensive of her nesting site and individuals would actively grapple and chase away intruding con-specifics that came to close to their nest.

Mating

Mating was witnessed in May 2010. A Ficus tree covered in Honey suckle overlooked by my office was a favourite resting/foraging(?) ground for many of the specimens that nested in the office. Here I saw several females being swarmed by males; the encounter lasted for about 10 seconds.

Conclusion

The observations that were made seem to conform to what is known about the biology of this wasp. However, it was noted that not all nest plugs were finished by a layer of white material contrary to the assertion by Bohart and Menke (1976) that “all” species save for *C. californicum* do so.

The variability of prey choice from one generation to the other warrants further analysis in order to ascertain the life cycles and abundance of the chosen prey.

Acknowledgments

I am grateful to Alexander V. Antropov, Senior Scientist and Curator of Hymenoptera collections Zoological Museum of Moscow State University, Moscow, Russia for the comments and suggestions made to the original manuscript.Graham Reels provided a thorough proof-reading of the original manuscript and helped with its clarity.

References

Bohart, R.M. & Menke, A.S., 1976. *Sphecid wasps of the world*. A Generic Revision. University of California Press, 695pp.

Hensen, R.V. 1988. Revision of the nominate subgenus Chalybion Dahlbom (Hymenoptera, Sphecidae). *Tijdschrift Voor Entomologie* 131:13-63.

Iwata, K., 1964. Bionomics of non-social wasps in Japan. *Nature and Life in Southeast Asia* 3:323-383.

Iwata, K., 1976. *Evolution of Instinct. The Comparative Ethology of Hymenoptera*. Smithsonian Institution & National Science Foundation, Washington, D.C., translated from Japanese. 535pp.

Landes. A.D., Obin, M.S., Cady, A.B and Hunt, J.H. 1987. Seasonal and Latitudinal Variation in Spider Prey of the Mud Dauber *Chalybion californicum* (Hymenoptera, Sphecidae). *Journal of Arachnology* 15:249-256.

Jayakar, S.D. & Spurway, H.1963. Use of Vertebrate Faeces by the Sphecoid Wasp *Chalybion bengalense* Dahlb. *Journal of the Bombay Natural History Society* 60(3): 748-749.

O’Neil, K.M. 2001. *Solitary Wasps. Behavior and Natural History*. Comstock Publishing Associates. 406pp.

Yamamoto, D.1942. Habits of *Sceliphron (Chalybion) inflexum* Sickmann. *Kontyu* 16:69-75.

Yamane, S., Ikudome, S., Terayama, M. 1999. *Identification Guide to the Aculeata of the Nansei Islands, Japan*. Hokkaido University Press, Sapporo. 831pp.

Figures

Figure 1: Nesting site versatility in *C. japonicum*. Top left: re-usage of cell of *Sceliphron deforme*. Top right: screw recess as a nesting site. Bottom: Cells constructed in an old comb of *Polistes gigas*.

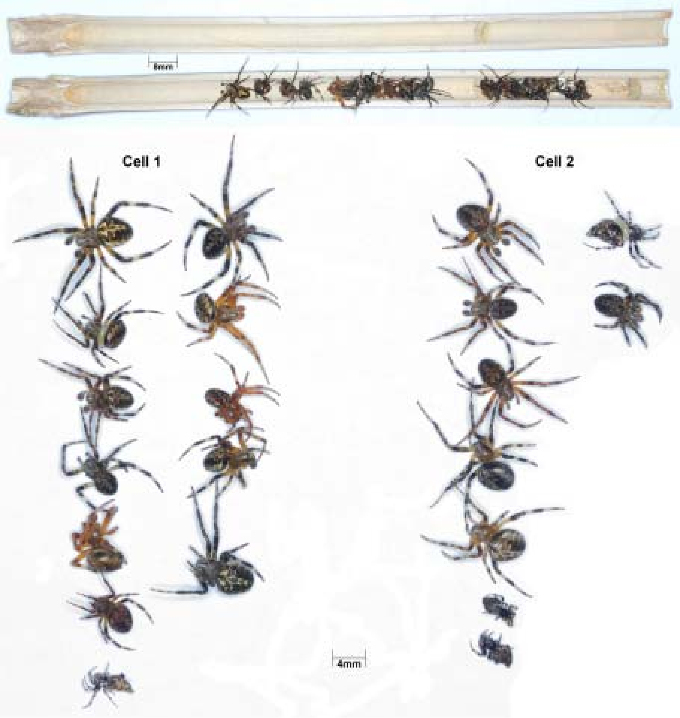

Figure 2: Typical nest content a opening. Top: trap PSO-102.A3 composed of two cells. Bottom: the prey and brood content of the same trap (photo author).

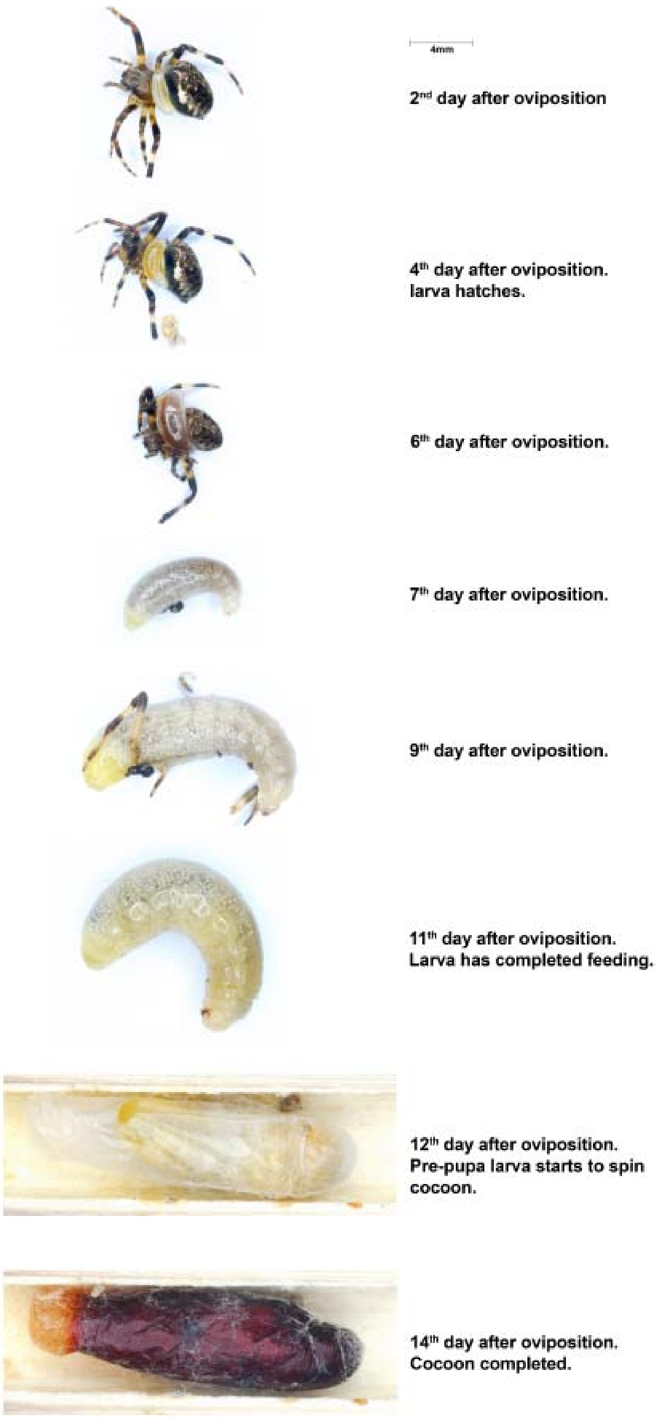

Figure 3: Brood development

Figure 7: Aggregation of males and females *C. japonicum*.

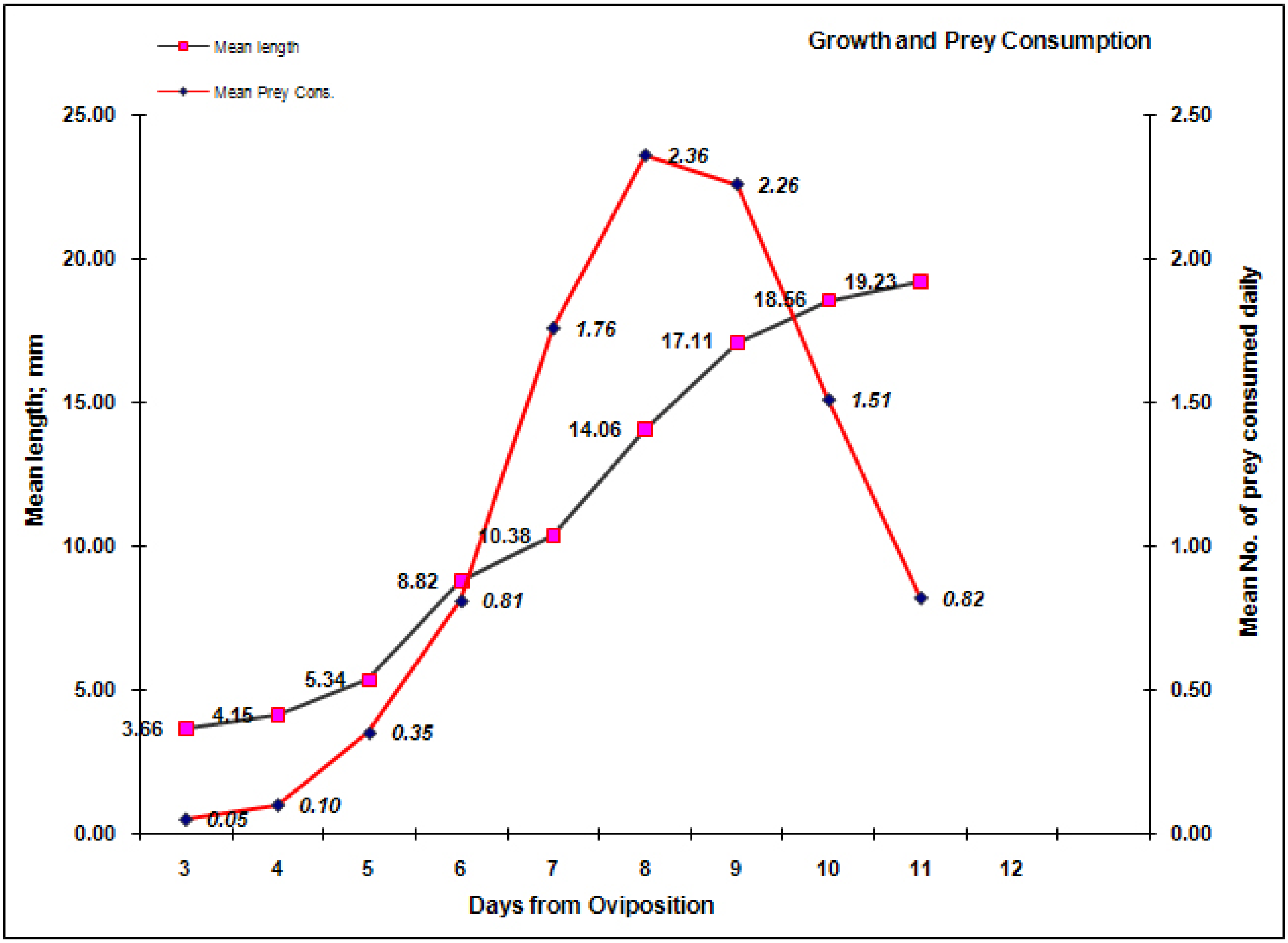

Figure 4: Prey consumption and brood growth.

Figure 5: Phoridae cleptoparasitism captured at trap opening (photo author).

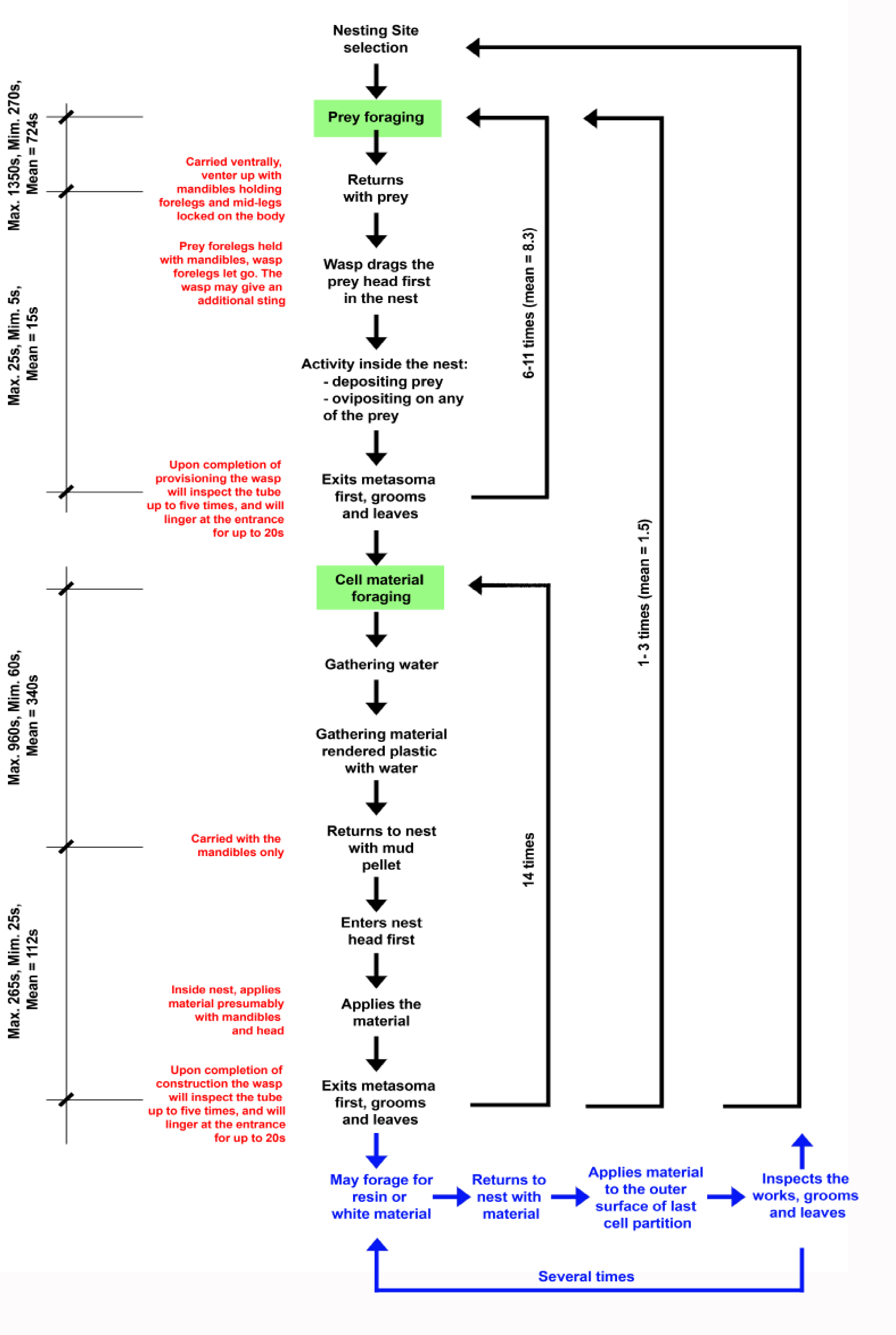

Figure 6: Nesting activities sequences