

Sap-feeding and crepuscular adults of a hoverfly (Diptera, Syrphidae)

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(Abstract, captions of tables and figs are written in English: R.)

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Introduction

Among nine species of *Volucella* living in Japan, *Volucella suzukii* Matsumura, 1916 is known to be one of the relatively rare species. So far their capture has been recorded only in Honshū (the Main Island) and Shikoku Island. The recorded places in Honshū are the Prefectures of Yamaguchi (Ōhara 1984 b), Hiroshima (Ōhara, 1985 a, 1985 b) Okayama (Kondō 1999), Mie, Saitama, Ibaragi, Chiba (Matsu'ura & Koike, 1999; Matsu'ura et al, 2003; Matsu'ura & Koike 2003), Ōsaka (Sugahara & Katsura 2000, Saitō & Katsura 2004), Kyoto (Ōishi 1998, 2002) and Nara (Isobe 2003). As for Shikoku Island, there are some records of the capture of adults in Odamiyama in Ehime Prefecture (Ōhara & Yamamoto 2000): Ōhara witnessed a male adult resting on a leaf of *Clerodendrum* directly under a *Quercus acutissima* in Jōroku-chō, Tokushima-City (unpublished); and he also gathered about 30 larvae of this species living in the earth under the nest of *Vespa mandarinia* in the bank of an orange orchard in Hokkedani, Tokushima City in December 1999. He failed to raise these larvae, so he was unable to get hold of the adult insects; but this case shows clearly that this species also lives in Tokushima Prefecture (in Shikoku). Moreover, our data in this paper confirm that they also live in Kagawa Prefecture (Shikoku).

The larvae of *Volucella jeddona* are known as cleaners, who live in the nests of *Vespula* and *Vespa*, feeding off excrement, the leftovers of larval food and dead larvae. The larvae of *Volucella pellucens tabanoides*, *Volucella nigricans* and *Volucella linearis* were found living together in the nest of *Vespa* (Ōhara 1984 [– *linearis* called *nitobei* in this paper]); and also the eggs, larvae and adults of *Volucella suzukii* Matsumura were found in the nests of *Vespa simillima* Smith, *Vespa crabro flavofasciata* Cameron and *Vespa mandarinia* (Ōhara 1984, 1985a, b; Matsu'ura & Koike 1999; Sugahara & Katsura 2000; Matsu'ura et al 2003; Saitō & Katsura 2004). In addition to this, there is the case of female adults of *Volucella jeddona* ovipositing in an external capsule of the

nest of *Bombus ardens* (Matsuura & Koike 2003). This shows that they (*Volucella*) may feed off the excrement and the dead bodies of *Bombus*.

In 1986 Myles observed that the female adults of *Volucella isabellina* living in North America oviposited on the early stage of rotting cacti. This case was quite different from *Volucella* in ---- [*I cannot read the name of the place*: R]. However, by now, we have come to know that the group feeding on cacti is a different genus (*Copestylum*). The phenomenon of *Volucella jeddona* ovipositing on plants is hitherto unknown in Japan.

Most adult *Syrphidae* are widely known as flower-visiting and pollinating insects like beetles (eg *Cetonia* (*Eucetonia*) *pilifera*), *Bombus* and *Lepidoptera*. However, there is no known record of *Volucella suzukii* Matsumura visiting flowers. Concerning adult *Volucella suzukii* we have the following records:

1. some adults found in the nest of *Vespa*
2. a male adult, flying in the early morning (Ōishi 1998)
3. two male adults flying towards the lamplight in the evening (Isobe 2003)
4. a male adult, settling on the back of a bamboo leaf (Katsura 2003)
5. 34 adults (13 female, one male, others of undet sex), being attracted to a trap made for capturing *Vespa* situated in flat woodland (Makino & Sueyoshi 2004).

From the above observations we presumed that the adults were active in the evening and feeding on tree sap, but the actual conditions were hitherto unknown. Here we report our research that has discovered that adult *Volucella suzukii* feed on tree sap and are active in the evening in extremely dim light.

Before we proceed to the main report we thank Mr Ishiguro Naohito in the Laboratory of Entomology, the Faculty of Agriculture, Kagawa University for his cooperation in our field research.

Research area & methods

With Ichikawa as the main researcher, this research forms part of a study of insects feeding on the sap of *Quercus acutissima*. The *Quercus acutissima* tree which we studied was chest-high [circa 1.2-1.3 m by Japanese standards] with trunk diameter 61 cm in 1995. From May to October every year from 1999 to 2005, we confirmed that the sap was exuding from a number of parts where the bark had come off.

We observed an adult insect flying around a bamboo field about 11:30 am on 22 July 1998; and two adult insects which flew to where the tree-sap was exuding at night on 28 July 1999. They were all *Volucella suzukii* Matsumura. After this confirmation, we focussed on the adults on tree sap both in the daytime and evening.

Even though we did not focus on *Volucella suzukii* exclusively from July 1999 to July 2005, we recorded the place and time of its arrival while we were studying other insects. The weather on the days when we confirmed the arrival of *Volucella suzukii* on the *Quercus acuttissima* tree was fine except on 28 July 1999, when it was rather cloudy. We used torchlight to see the tree after sunset.

We observed that part of the tree where the sap was exuding (up to 2.6 m high) from 18:00 until 20:00 for 6 days (1, 4, 10, 11, 12 and 19 August, 2005). We checked several parts every minute. Especially for the eastern side of the tree, which became difficult to see just before sunset, we used a torch to observe the insects. We measured the temperature and illuminance using HMP36, HmI31 Vaisala for the temperature and T-1H Minolta for the light from 18:00 till 20:00 hours. We also measured the illuminance on the lawn on the western side of the tree, where there were neither trees nor artificial lights.

Results

From July 1999 to July 2005

Table 1 shows the records of the place and time (including duration) when we discovered adult *Volucella suzukii* on the tree surface where sap was exuding, from July 1999 to July 2005. At 19:25, soon after we started our examination (19:20 on 28 July 1999), we found two male *Volucella suzukii* touching the exuding sap with extended proboscis. We concluded they were feeding on the sap. Just after we found them, we captured them with an insect net, so there were no data on the activities of these two insects afterwards. We further studied the part where the sap was exuding by torchlight until 20:00, but we were unable to find any more insects other than these two.

At 19:26 on 3 August in the same year just after we started our observation (19:00), we saw an adult *Volucella suzukii* fly to the exuding sap and start to feed. We started observing at 19:00 on 31 July 2000. At 19:18 we found 6 adults of *Volucella suzukii* on the two parts of the tree where sap was exuding, and their surroundings. We confirmed that they were feeding. After that we turned off the torch at about 19:20, and then turned it on again at 19:30 but were unable to find them again, neither at the place where we found them first nor where the sap was exuding. On the 15 August starting at 19:00, we found one adult feeding at 19:10. On 9 and 10 August 2003, we started nocturnal observation at 19:00. On 9 August one adult flew over and was feeding, then at 19:17 another came and started feeding. At 19:19 these two had disappeared. After that, one adult came at 19:23 and fed, but this had also disappeared by 19:30. On the 10th Aug we began at 19:00, and confirmed that one adult came and stayed until 19:20. On 26 July 2005 at 19:31 we found one adult settling where the sap was exuding and

feeding, but it stopped and flew away at 19:35.

We confirmed that a total of 15 adult insects came to the sap of *Quercus acutissima*. They were all found in the narrow time span between 12 and 24 minutes after sunset. Among these insects, we recorded the exact time of leaving of only one, on 26 July 2005. However, all the insects flew away between 2 and 12 minutes after their arrival, except one on 3 August 1999 (no datum) and another on 3 August 2000. We conclude that the period when adult insects come to *Quercus acutissima* and feed on sap was within 31 minutes at most after sunset.

August 2005

We were unable to confirm any adult *Volucella suzukii* flying to the trunk of *Quercus acutissima* during the observation time from 18:00 to 20:00 on 10, 11, 12 and 19 August, but three adults (two on 1 August and one on 4 August) flew to the trunk on two occasions. On neither occasion did we observe them arrive before sunset. These three came in the narrow time-span between 15-16 minutes after sunset.

As we show in Fig 1, adult *Volucella suzukii* were all feeding on tree sap, settling around the part where the sap was exuding. Fig 2 shows the durations of their stay (one on 1 and two on 4 August) (grey part on fig 2) on *Quercus acutissima* along with the sunset time on each day (arrow), illuminance and temperature. Both days were fine, and the lowering of the temperature after sunset on 1 August was faster than that of 4 August, but the reduction in illuminance was more or less the same on both days. That is to say the illuminance was 248 lux on 1 August and 308 lux on 4 August. After sunset (19:06, 1 August and 19:04, 4 August) the illuminance rapidly declined but there remained some afterglow (0.1 lux at 19:50 on 1 August, and 19:40 on 4 August): it became 0 lux at 20:00 on 1 August and 19:50 on 4 August. The time when two adults came on 1 August was at 19:21 and 19:22, the former stayed until 19:22 and the latter until 19:27. So the duration of stay by one or both insects was from 19:21 to 19:29. The illuminance at that time was between 9.0 lux (19:20) and 1.2 lux (19:30). The illuminance at the time when one adult came and stayed on from 19:18 to 19:21 on 4 August was 12.3 lux at 19:20 and 1.5 lux at 19:30. Thus we think the illuminance when they stay was between 1.5 and ± 20 lux.

Observations

It is clear that adult *Volucella suzukii* feed on sap, since a total of 18 individuals that came to the tree trunk of *Quercus acutissima* were feeding on tree sap. So far there has been no study on this species visiting flowers. It is therefore improbable that they feed on both tree sap and flower nectar. However, we cannot rule out the possibility of them going for flowers that open in the early morning, or those which produce more nectar in

the early morning, since we have not seen them active during daytime. There is also the example of adults flying around in the early morning (Ōishi 1998). On the American continent there is the genus *Copestylum*, close to *Volucella*, previously thought to be a subgenus of *Volucella*. *Copestylum vesicularia* in Indiana (USA), called *Volucella* at the time of recording, is known to visit *Cephalanthus occidentalis* (Rubiaceae) in the evening (Waldbauer, 1963). From this example, we may be able to understand whether they are specialised solely in sap feeding, or both sap and nectar feeding, by studying whether between late July and late August adult *Volucella suzukii* visit flowers in the early morning and evening.

The fact that adult *Volucella suzukii* were captured in the evening (Isobe, 2003; Katsura, 2003) shows that it is possible that they are nocturnal. As we wrote in the Methods, we found one male flying during the daytime on 22 July 1998. However, there has been no other observation of activity during daytime, so we presume that we might have disturbed it while it was settled on the tree, and possibly that it flew off confused. In this research we have not found any proof that they are diurnal. However, as a result of this study which we carried out from early evening till night, we made clear the outline of the timespan of their activity. That is to say, in order to feed on tree sap, at least, active adults fly within 15 minutes after sunset to sapping tree trunks of *Quercus acutissima*, finishing feeding and flying away after about 5 minutes.

At first glance such adults seem to be nocturnal, as they are active after sunset; but the observations on 1 and 4 August 2005 show that they are crepuscular. From everyday experience we know that there is still some afterglow after sunset. As the data of low level of illuminance on 1 and 4 August indicate, it gets dark (the standard illuminance of night) 30 minutes after sunset in fine weather. We do not know how long they have been flying, and it is difficult to measure the exact timespan of their activities. But we presume that they come 15 minutes after sunset, feed for about 5 minutes and fly away at about 20 minutes after sunset. If they return to the undersides of the leaves (where they remain) near the tree, the time they take is negligible, and even if they have to fly far there are still 20 minutes until actual night. Thus we presume that the adults are active using eyesight which functions in crepuscular light at low levels.

Copestylum vesicularia also seems to have eyesight similar to *Volucella suzukii*. Waldbauer (1963) found that these insects were visiting flowers in the evening, and therefore watched them on 26 July 1961 when visits started 25 minutes before sunset and reached a peak after sunset – one was even captured 30 minutes after sunset (Waldbauer 1963). With more illuminance the timespan of their activity is longer than that of *Volucella suzukii*, but it seems that their activity in the darker light is about the same. At present we know that they belong to different genera, but before they were thought to be close relatives. Hardly any records exist of these syrphids feeding on

nectar at the time of writing, so it is interesting that the timespan of their activities is similar. *Bombus* is also known to be crepuscular, but seems to use polarized light for navigation in returning to the nest. *Bombus terrestris* can return home directly in a straight line by sensing polarized light from the sky (zenith) using their dorsal ocelli. This is proved by an experiment. Even with their dorsal ocelli covered with red plastic paint to prevent their use during twilight (about 1/5 illuminance, 0.2~0.5 lux), they were able to return home without using landmarks (Wellington 1974). Since it is clear that *Apis mellifera* use polarized light (von Frisch 1949, 1967), it is widely known that arthropods including insects use polarized light. Therefore *Volucella suzukii* is not completely nocturnal, but is active using the polarised light at twilight.

We would like to study the activities of adult *Volucella suzukii* including their feeding activity by obtaining more accurate and detailed records of their behaviour, such as flying to the tree sap, duration of stay and feeding.

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