SHORT COMMUNICATION

Strongly biased sex ratio in cuckoo wasp *Chrysura hirsuta* (Hymenoptera: Chrysididae), a parasitoid of the mason bee *Osmia orientalis*

Tomoyuki YOKOI¹, Takuto HIROOKA²,⁵, Takeshi TERADA³,⁵, Shusaku SUGIMOTO⁴,⁵, Mayumi TAMARU⁵, Sachiko SATOH⁵ and Ikuo KANDORI⁵

¹Laboratory of Insect Ecology, Graduate School of Environmental Sciences, Okayama University, Okayama, ²Entomological Laboratory, Faculty of Agriculture, Kyushu University, Fukuoka, ³Entomological Laboratory, Graduate School of Agriculture, Kagoshima University, Kagoshima, ⁴Graduate School of Agriculture, University of the Ryukyus, Okinawa and ⁵Laboratory of Entomology, Faculty of Agriculture, Kinki University, Nara, Japan

Abstract

We examined the rate of parasitism and sex ratio of the cuckoo wasp *Chrysura hirsuta* (Gerstaecker) (Hymenoptera: Chrysididae) that emerged from nests of the mason bee *Osmia orientalis* Benoist (Hymenoptera: Megachilidae) in Nara, Japan. Nests of *O. orientalis* were found in empty shells of two snail species, *Satsuma japonica* (Pfeiffer) and *Euhadra amaliae* (Kobelt). The percentage of parasitism by cuckoo wasps per all collected cocoons tended to be high (20–50%) even though interannual variation and the average number of cocoons per nest did not differ across snail shell species within each year. Our results from three years of observation, combined with previous reports, showed that the adult sex ratio of *C. hirsuta* was strongly female-biased, which suggests that the species reproduces by thelytokous parthenogenesis.

Key words: Megachilidae, nest, parasitism, snail shell, thelytokous parthenogenesis.

Host preference and offspring sex ratio are important factors for understanding the basic life cycle and behavior of chrysidid wasps. All known cuckoo wasps are either parasitoids or cleptoparasites of a broad range of insects. Almost all of the species in the subfamily Chrysidinae are nest parasites of bees or wasps although the tribe chrysidini attacks not only megachilid bees but also wasps of Eumenidae and even *Monema flavescens* Walker (Lepidoptera: Limacodidae) (Kimsey & Bohart 1990; Terayama et al. 2010). In Chrysidini, *Chrysura hirsuta* (Gerstaecker) is a known parasitoid of megachilid bees in Europe (Berland & Bernard 1938). In Japan, the bee genus *Osmia* (Hymenoptera: Megachilidae) comprises eight species (Ikudome 2010; Murakami & Ikudome 2011) following the addition of a new species to the previously described seven species (Maeta 1978; Maeta & Miyanaga 1999). However, *C. hirsuta* only parasitizes *Osmia orientalis* Benoist (Maeta 1978, 1980). *Osmia orientalis* nests in empty snail shells and other *Osmia* bees nest in pre-existing cavities in dead wood (Shibuya 1939; Maeta 1978, 1980).

Certain aspects of the basic life history and parasitic behavior of *C. hirsuta* have been reported (Shibuya 1939; Matsumoto 2009; Yokoi et al. 2010). *Osmia orientalis* females oviposit in cells in the empty shells of several snail species. *Chrysura hirsuta* females then sneak into the nest and lay eggs in each cell while the female *O. orientalis* is absent. The first instar larva waits for the host to pupate following its last larval instar, and then begins sucking the host’s blood (Shibuya 1939; Matsumoto 2009). Two or more *C. hirsuta* females will lay eggs in one host cell although only one individual will emerge as an adult from each cocoon (Shibuya 1939). Thus, strong resource competition occurs among larvae as they use a single host. Although data regarding the parasitism rate of *C. hirsuta* has previously been reported (Shibuya 1939; Iwata 1978), the adult sex ratio

Correspondence: Tomoyuki Yokoi, Laboratory of Insect Ecology, Graduate School of Environmental Sciences, Okayama University, 1-1-1 Tsushima-naka, Kita-ku, Okayama 700-8530, Japan.
Email: yokoi@cc.okayama-u.ac.jp
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of $C. \text{hirsuta}$ individuals that emerge from each shell is unknown. In this study, we conducted field research to investigate the adult sex ratio of $C. \text{hirsuta}$ and the rate of parasitism on $O. \text{orientalis}$.

We conducted field work on the Nara campus of Kinki University, Nakamachi, Nara, Japan (34°40′N, 135°43′E). On the campus, many insect pollinators visit native and introduced plant species throughout the year (Yokoi et al. 2008). We collected empty snail shells at three locations on the campus in March 2008. After identifying the snail species, we checked them for empty cocoons or adults of $O. \text{orientalis}$ and $C. \text{hirsuta}$. We found empty shells of three land snail species: $\text{Satsuma japonica}$ (Pfeiffer), $Euhadra \text{amaliae}$ (Kobelt) and $\text{Acusta despecta sieboldiana}$ (Pfeiffer).

We conducted a field experiment by placing empty snail shells on the campus from April to May, 2008 and 2009. To provide nesting opportunities for $O. \text{orientalis}$ and $C. \text{hirsuta}$, we used empty shells from two snail species, $\text{Satsuma japonica}$ and $E. \text{amaliae}$, which we had previously collected on the campus in March and washed. We re-collected the experimental snail shells in June and kept them at a constant temperature until December. We then checked the number of $O. \text{orientalis}$ and $C. \text{hirsuta}$ cocoons in each shell. Detailed sampling methods can be found in Kandori et al. (2010). Sex discrimination of $C. \text{hirsuta}$ was conducted by examining the shape of the tip of the abdomen and assessing the presence of an ovipositor.

Except for March 2008, we found cocoons of both $O. \text{orientalis}$ and $C. \text{hirsuta}$ in nested shells of the two land snail species (Table 1). The nesting rate of $O. \text{orientalis}$ was higher in the larger shells of $E. \text{amaliae}$ than in the smaller shells of $\text{Satsuma japonica}$. We confirmed that a single $C. \text{hirsuta}$ adult was present in each $O. \text{orientalis}$ cell. The percentage of parasitism by $C. \text{hirsuta}$ per nested shells varied across years. However, the average number of $C. \text{hirsuta}$ cocoons did not differ between shell species within each year. The percentage of parasitism by cuckoo wasp per all collected cocoons was lower in 2009 than in 2008. The cuckoo wasp sex ratio was strongly female-biased in every year (Table 1). We did not find any males in nested shells, nor could we confirm the species within cells because of death or developmental failure. Other samples of $C. \text{hirsuta}$ that were collected in other districts in Japan also included only females (Table 2).

Our investigation revealed that parasitism by $C. \text{hirsuta}$ was consistently high at this study site. Iwata (1978) also briefly reported on parasitism by $C. \text{hirsuta}$; the percentage of parasitized shells was 31.3% (5/16) and 13.2% (14/106) of the $O. \text{orientalis}$ cocoons collected were parasitized. We suggest that host-specific parasitism causes a high rate of parasitism by $C. \text{hirsuta}$. Very little is known about sex ratios in $\text{Chrysura}$ populations or any other chrysidid species. In North America, the sex ratio of $\text{Chrysura kyrae}$ Krombein, a parasitoid of $Osmia lignaria lignaria$ Say, is female-biased (Krombein 1963; Maeta 1988). However, the presence of $K. \text{kyrae}$ males was confirmed but $C. \text{hirsuta}$ males were not found. We hypothesize that $C. \text{hirsuta}$ reproduces by thelytokous parthenogenesis in Japan, caused by either a genetic mechanism or through host manipulation by symbiotic bacteria. Although the species also lives in Europe, there are, to our knowledge, no studies regarding sex ratio. Genetic analysis is needed to investigate the mechanisms creating the strong female bias.
Table 2  Distribution and sex records for *Chrysura hirsuta* in Japan

<table>
<thead>
<tr>
<th>Number and sex of individuals collected</th>
<th>District</th>
<th>Collection site</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 female</td>
<td>Tohoku</td>
<td>Tamugimata-Touge, Yamagata Pref.</td>
<td>Itami (1981)</td>
</tr>
<tr>
<td>1 female</td>
<td></td>
<td>Tachikawa-cho, Yamagata Pref.</td>
<td></td>
</tr>
<tr>
<td>2 females</td>
<td>Kanto</td>
<td>Nikko, Tochigi Pref.</td>
<td>Fukuda (1968)</td>
</tr>
<tr>
<td>1 female</td>
<td></td>
<td>Utsunomiya, Tochigi Pref.</td>
<td></td>
</tr>
<tr>
<td>1 female</td>
<td></td>
<td>Toba, Tochigi Pref.</td>
<td></td>
</tr>
<tr>
<td>1 female</td>
<td>Chubu</td>
<td>Takagi-cho, Aichi Pref.</td>
<td>Yamada (1971)</td>
</tr>
<tr>
<td>1 female</td>
<td>Shikoku</td>
<td>Hiragi, Kagawa Pref.</td>
<td>Iwata (1978)</td>
</tr>
<tr>
<td>1 female</td>
<td>Chugoku</td>
<td>Niimi city, Okayama Pref.</td>
<td>Matsumoto (2009)</td>
</tr>
<tr>
<td>1 female</td>
<td></td>
<td>Mirasaka-cho, Hiroshima Pref.</td>
<td>Nakamura &amp; Haneda (1997)</td>
</tr>
<tr>
<td>1 female</td>
<td></td>
<td>Kuchiwa-cho, Hiroshima Pref.</td>
<td></td>
</tr>
</tbody>
</table>

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