INTRODUCTION

The cherimoya (*Annona cherimola* Mill.) is an annonaceous fruit tree that originated in the highlands of South America (Morton, 1987) and is now common in many countries, including Spain, Italy, Israel, and the United States. This species has protogynous dichogamy. Therefore, autogamy is generally impossible under natural conditions, though it is self-compatible. As is usual in archaic angiosperms of the order Magnoliales, annonaceous plants including the cherimoya rely on species other than bees for pollination (Gottsberger, 1977, 1988). Thus, hand pollination is widely applied to ensure adequate harvests (Richardson and Anderson, 1996). However, because this method is labor and cost intensive, pollination agents have been sought.

Surveys of flower visitors to cherimoya have revealed that species of sap beetles (Coleoptera: Nitidulidae) are important flower visitors and likely pollinators (Gazit et al., 1982; George et al., 1989; Nagel et al., 1989; Nadel and Peña, 1994). Nitidulid beetles are not the only candidates for pollination agents. A series of recent studies on the pollination of cherimoya has suggested that some species in the genus *Orius* (Heteroptera: Anthocoridae), as well as staphylinid beetles, are major flower visitors in Italy, and that the former, at least, pollinate efficiently (Caleca et al., 1996, 1998; Palmeri and Longo, 1997). In Florida, 13 species of flower visitors, in addition to seven nitidulid species, have been recorded (Nagel et al., 1989). Such large variations among flower visitor communities suggest that the first step to using natural pollinators is to understand the faunae of indigenous flower visitors in a given area.

Pollination by bees is a relatively recent occurrence in the angiosperm phylogeny. Therefore, many plants, including important crops, rely on

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**Flower visitors to cherimoya, *Annona cherimola* (Magnoliales: Annonaceae) in Japan**

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**Abstract**

The cherimoya is an orchard tree that is not pollinated by bees. To identify likely pollinators, and to describe community diversity, we surveyed flower visitors at four sites in Wakayama and Mie prefectures, and found 569 individuals from 31 species of arthropods. Two of these species were arachnids and the others were insects. The most abundant species in terms of per capita density was *Mimemodes monstrosus* (Rhizophagidae), followed by species in the genus *Phloeonomus* (Staphylinidae) and *Cortinicara gibbosa* (Lathridiidae). Two nitidulid species, *Carpophilus marginellus* and *Haptoncus ocularis*, were also common. Among them, *M. monstrosus*, *C. marginellus* and *H. ocularis*, especially the former two, were regarded as good candidates for pollinators. All of the dominant species were beetles. *C. gibbosa* was most abundant early in the flowering season, whereas *Phloeonomus* sp. showed two peaks, in late May and late July. Species richness, $S'$ (45), ranged from 5.4 to 9.0, while heterogeneity measures, $1-D$ and $\exp H'$, ranged from 0.59 to 0.78 and from 3.5 to 5.9, respectively. The index of similarity, $C_s$, varied from 0.04 to 0.76, whereas the rank correlation coefficient, $\tau$, between each site varied from $-0.32$ to 0.23. The contents and diversities of flower visitor communities appeared to be affected by the surrounding environment and management strategy of the orchards.

**Key words:** Beetle pollination; cherimoya; Nitidulidae; flower visitor assemblage; diversity

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pollinators other than bees; that is, few adequate pollinators from the original wild pollinator fauna are used in agricultural systems (Westerkamp and Gottsberger, 2000). To establish an alternative pollination system using original pollinators is therefore one of the key issues in agricultural science. In addition, the use of bees beyond their natural distribution area can cause serious conservation problems, such as a decrease in natural pollinators in the surrounding areas and the introduction of parasitic organisms that are associated with the bees (Schaffer et al., 1983; Kato et al., 1999; Goka et al., 2001; Cunningham et al., 2002; Hansen et al., 2002; Hingston, 2004a). Therefore, establishing an alternative pollination system in *Annona* spp. (e.g., using native insect species of the area) offers a good model for future crop production.

Establishing a pollination system with indigenous insects requires a good understanding of the nature of the flower visitor community, though only a few of the flower visitors are pollinators (Nilsson, 1988; Waser et al., 1996; Hingston et al., 2004a, b). In addition, effective pollinators vary spatially and temporally (Schemske and Horvitz, 1984; Young, 1988; Waser et al., 1996; Ollerton, 1998). Therefore, identifying effective pollinators of a plant is possible only when flower visitors are monitored over the long term in various places. Moreover, it is important to clarify the community structure of flower visitors because pollinators may suffer from detrimental effects such as predation and competition by non-pollinating insects (Schaffer et al., 1983; Hingston et al., 2004a).

Flower visitor assemblages of crops are frequently affected by the flora of nearby areas because they serve as sources of visitors (Cunningham et al., 2002). For instance, a primary forest with a high diversity of flowering plants supplies diverse flower visitors to adjacent plantations (Klein et al., 2003). Other factors such as pesticide application also affect the assemblage. Therefore, comparing flower visitor diversities among different environments with different managements may reveal the cause of diversity in flower visitor communities in cherimoya and assist in identifying prerequisites for the use of pollinators. Furthermore, it offers basic data on flower visitors to newly introduced crops, changing their diversity and abundance over a longer time scale, as is known to occur in herbivores (Strong et al., 1984; Andow and Imura, 1994).

Cherimoya has recently been introduced into the main island of Japan. Commercial cultivation started in 1986, in Wakayama Prefecture. Initially, no flower visitors were recorded. More recently, however, small insects have been observed frequently in flowers during the process of hand pollination. In contrast to other annona-growing areas, Japanese growers use plastic greenhouses to reduce frost damage. Therefore, the use of pollinators may become possible by mass-release and/or adequate management of insects in these greenhouses. The aim of this study is to describe the faunal community in the flowers of cherimoya in order to identify likely pollinators in Japan, and to examine the diversity of the flower visitor communities within and between study sites to identify likely causes of differences in the communities.

**MATERIALS AND METHODS**

In its original habitat, the floral differentiation of cherimoya occurs year round. However, in Japan, trees are usually pruned from February to March and the full flowering period occurs in May and June. This cultivation calendar is planned to avoid high-temperature stress on pollen and stigma in greenhouses during the summer (Higuchi and Utsunomiya, 1999; Rosell et al., 1999).

Flowers of *Annona* spp. are light green, similar in color to the foliage, and the petals are ca. 3 cm long and ca. 5 mm wide. At the female stage, the tips of the petals open slightly and small insects such as nitidulid beetles can enter this crevice by force and hide in the aperture. During this stage, the flower secretes nectar and emits a sweet odor. One day after the female stage, the flower enters the male stage, where the petals open fully and the insects inside can no longer hide.

We surveyed flower visitors to cherimoya at four different locations (Table 1). In 1998, the survey was conducted on 14 d between 29 May and 25 July, at the Fruit Tree Experiment Station, Kibi, Wakayama Prefecture. This site was located at 135°13'E, 34°02'N, and the altitude was ca. 100 m above sea level. As is usual at official experimental stations, weeds were controlled by herbicide, and a pesticide (acephate) was sprayed once during the study period. In 1999, the survey was conducted on 10 d between 2 July and 9 August at a private com-
mercial orchard in Shimotsu, Wakayama Prefecture (135°14'E, 34°07'N, altitude: ca. 450 m), and on 40 d between 10 June and 20 September at Mie University Experimental Farm in Tsu, Mie Prefecture (136°31'E, 34°44'N, altitude: 0 m). In 2000, the study sites were the same as in 1999, and the survey was conducted on 4 d between 22 June and 9 August in Wakayama Prefecture and on 60 d between 22 May and 4 October in Mie Prefecture. In 2001, the survey was conducted at Kokawa, Wakayama Prefecture (135°24'E, 34°17'N, altitude: ca. 100 m) on 8 d between 17 May and 27 August. No spray was used at the latter three sites during the study. Except for the Mie site, trees were grown under plastic greenhouse conditions, although the plastic films were removed from the sides for air ventilation.

From 1998 to 2000, both female- and male-stage flowers were examined for visitors. As there was no clear difference in flower visitor composition between the two stages, we surveyed only female-stage flowers in 2001.

In 2001, seasonal fluctuations of visitors were also monitored to determine if likely candidate pollinators changed seasonally. We conducted a complete census where possible. However, when the number of flowers exceeded our capacity to survey (i.e., more than ca. 500), we estimated the mean number of visitors with standard error by applying a stratified sampling method (Kuno, 1986), regarding each flower as a quadrat and each tree as a discrete sampling unit counting arbitrarily 10 flowers selected from each of 75 trees. Although the maximum number of flowers examined in this way would be 750, the actual number was less than 500 because some trees had less than 10 flowers.

All flower visitors were identified at the species level where possible. Following identification, the indices used were, \( S' \) (45) (Morisita, 1996), \( 1-D' \) (Simpson, 1949), and \( \exp H' \) (MacArthur, 1965). \( S'(n) \) is the expected number of species when \( n \) individuals are obtained at a given location. \( 1-D' \) is sensitive to the number of individuals of the dominant species, especially of the most common one (Peet, 1974). Here, we used an unbiased estimate of Simpson's \( D \) for a limited number of samples (Pielou, 1969). \( H' \) is sensitive to the number of non-dominant species (Peet, 1974). We used \( e \) as the base of logarithms for the calculation of \( H' \). The similarity of the community was examined by Kendall's rank correlation coefficient, \( \tau \), and Morisita's index of similarity, \( C_{\lambda} \) (Morisita, 1959).

**RESULTS**

We found 569 individual flower visitors from 31 species of arthropods, at the four study sites (Table 2). Of these, two species (three individuals) were arachnids, while the rest were insects. The mean number of individuals per 100 flowers, shown in Table 2, was largest for *Mimemodes monstrosus* (Rhizophagidae), followed by *Phloeonomus* sp. (Staphilidae) and *C. gibbosa* (Lathriidae). *M. monstrosus* was most abundant at Shimotsu and Tsu. *Carpophilus marginellus* and *Haptoncus ochlaris* (Nitidulidae) were also common.

These dominant species were all beetles, and overall we observed 20 species of coleopteran visitors. In addition, one anthocorid true bug was found, but no *Orius* species visited the flowers at the four sites. We observed seven species of Nitidulidae, the most common family in terms of species abundance. Three species of staphylinids were found, among which Aleocharinae sp. and *Sepedophilus pumilus* had only one individual each, while *Phloeonomus* sp. had 160 individuals. No bees or butterflies were found throughout this study.

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Facility</th>
<th>Pesticide use</th>
<th>Area (m²)</th>
<th>No. of trees</th>
<th>No. of flowers examined</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>Kibi, Wakayama</td>
<td>Fruit Tree Experiment Station</td>
<td>Yes</td>
<td>1,000</td>
<td>100</td>
<td>1,025</td>
</tr>
<tr>
<td>1999</td>
<td>Tsu, Mie</td>
<td>Experimental Farm, Mie Univ.</td>
<td>No</td>
<td>50</td>
<td>28</td>
<td>277</td>
</tr>
<tr>
<td>2000</td>
<td>Shimotsu, Wakayama</td>
<td>Commercial orchard</td>
<td>No</td>
<td>1,000</td>
<td>90</td>
<td>98</td>
</tr>
<tr>
<td>2001</td>
<td>Kokawa, Wakayama</td>
<td>Commercial orchard</td>
<td>No</td>
<td>1,000</td>
<td>75</td>
<td>3,097</td>
</tr>
</tbody>
</table>
The seasonal fluctuations of the two principal visitors at Kokawa are shown in Fig. 1. The flowering period started in mid-May and ended in late August, and in the early stage of the flowering period, *C. gibbosa* was most abundant. *Phloeonomus* sp. showed two peaks in late May and late July. Other species were not found frequently, so the fluctuations are not shown.

The species richness, $S'$ (45), was large in two commercial greenhouses and small in the other two (Table 3). $1-D$ was larger at Tsu and Shimotsu, and smallest at Kokawa. These results indicate that the ratio of dominant species, especially of the most common one, was smaller at the first two sites. On the other hand, exp $H'$ was largest at Shimotsu, where each of the second to fifth ranked species consisted of more than 10% of all, and smallest at Kibi, where two dominant species consisted of more than 53% and 27% of all visitors, respectively. $t$-tests between each combination of $H'$ (Zar, 1999), followed by a Dunn-Šidák correction, showed that the difference between the above two

### Table 2. List of flower visitors to *Annona cherimola* in Wakayama and Mie prefectures, with number of captured individuals/100 flowers at each site

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Species</th>
<th>No. individuals/100 flowers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kibi</td>
</tr>
<tr>
<td><strong>Acarina</strong></td>
<td>Oribatulidae</td>
<td><em>Oribatula sakamorii</em> Aoki</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Araneae</strong></td>
<td></td>
<td>Unidentified (nymph)</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Anthicidae</td>
<td><em>Pseudoleptaleus valgipes</em> (Lewis)</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Anthribidae</td>
<td><em>Araecerus coffeeae</em> (Fabricius)</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Cucujidae</td>
<td><em>Xyloastes hilleri</em> (Reitter)</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Lathridiidae</td>
<td><em>Cortinicara gibbosa</em> (Herbst)</td>
<td>5.17</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Lathridiidae</td>
<td><em>Stephostethus chinensis</em> (Reitter)</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Mycetophagidae</td>
<td><em>Litargus antennatus</em> Miyatake</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Nitidulidae</td>
<td><em>Carpophilus marginellus</em> Motschulsky</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Nitidulidae</td>
<td><em>Carpophilus pilosellus</em> Motschulsky</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Nitidulidae</td>
<td><em>Carpophilus sibiricus</em> Reitter</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Nitidulidae</td>
<td><em>Epuraea kaszabi</em> Kirejshuk</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Nitidulidae</td>
<td><em>Haptoncus fallax</em> Grouvelle</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Nitidulidae</td>
<td><em>Haptoncus impunctatus</em> Gillogly</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Nitidulidae</td>
<td><em>Haptoncus ocellaris</em> (Fairmaire)</td>
<td>1.37</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Rhizophagidae</td>
<td><em>Memnomodes monstruosus</em> (Reitter)</td>
<td>1.66</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Scolytidae</td>
<td>hypothenus sp.</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Scolytidae</td>
<td><em>Anispis luteola</em> Marsuel</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Silvanidae</td>
<td><em>Psammococcus triguttatus</em> (Reitter)</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Staphylinidae</td>
<td><em>Aleocharinae</em> sp.</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Staphylinidae</td>
<td><em>Phloeonomus</em> sp.</td>
<td>10.05</td>
</tr>
<tr>
<td><strong>Coleoptera</strong></td>
<td>Staphylinidae</td>
<td><em>Sopedophilus pumilus</em> (Sharp)</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Dermaptera</strong></td>
<td>Anisolabididae</td>
<td><em>Gonolabbus marginalis</em> Dohrn</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Hemiptera</strong></td>
<td>Anthocoridae</td>
<td><em>Amphiareus morimotai</em> (Hiura)</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Hemiptera</strong></td>
<td>Flatidae</td>
<td><em>Geisha distinctissima</em> (Walker)</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Hemiptera</strong></td>
<td>Myridae</td>
<td><em>Campylomma</em> sp. (female)</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Hemiptera</strong></td>
<td>Unidentified (nymph)</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Lepidoptera</strong></td>
<td>Noctuidae</td>
<td>Unidentified</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Psocoptera</strong></td>
<td>unclassified (nymph)</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Thysanoptera</strong></td>
<td>Phlaeothripidae</td>
<td><em>Phlaeothripinae</em> sp.</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Thysanoptera</strong></td>
<td>Thripidae</td>
<td><em>Thripinae</em> sp.</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Acarina and Araneae belong to the class Arachnida. Others belong to the class Insecta. Abbreviations for the study sites, Kibi, Shim, Tsu, and Koka represents Kibi Town, Shimotsu Town, Tsu City and Kokawa Town, respectively (see Table 1 for details).
sites was significant \((p<0.05)\).

The \(C_\lambda\) index was smallest for the combination of Tsu and Kokawa \((0.040)\), and largest for Tsu and Shimotsu \((0.756)\) (Table 4). Theoretically, this index varies from 0 (completely different) to 1 (completely the same). Therefore, communities at Tsu and Shimotsu are similar whereas other combinations, especially those at Tsu and Kokawa, are largely different. The rank correlation coefficient, \(\tau\), between sites varied from \(-0.324\) to 0.231 (Table 4). None of the correlation coefficients of any of the combinations were significantly different from zero.

**DISCUSSION**

The sampling year, date, and frequency were different among the four sites. Therefore, despite the consideration of seasonal fluctuation pattern and the expression of insect density as the per capita number, comparisons of the communities have some limitations. Keeping this in mind, the most abundant species was *M. monstrosus*. Like other species of this family, it is a natural enemy of bark beetles (Hisamatsu, 1985; King et al., 1991; Schroeder, 1996). This ca. 3 mm long species was found at all four of the study sites. Thus, if this species functions as a pollinator, we expect it to consistently work in a variety of environments within Japan’s main islands. Our preliminary study revealed that this species has a strong tendency to enter the female-stage flowers with a lot of pollen on its body and survive there long enough to move to the next flower. In addition, the entomophagous nature of this species is more advantageous than herbivorous or frugivorous species because of its low potential of becoming a pest. On the other hand, this species was found mainly later in the flowering season, when the air temperature was higher than the adequate temperature for pollination (Higuchi et al., 1998; Higuchi and Utsunomiya, 1999; Rosell et al., 1999). Therefore, mass-rearing and release in the earlier period are required. Rearing of rhizophagid beetles as natural enemies of the bark beetle requires live insects as prey (Evans and Fielding, 1994; Herard and Mercadier, 1996). If the rearing of *M. monstrosus* requires a similar technique, the application of this insect as a pollinator may be costly.

*Phloeonomus* sp. was the second-most abundant species observed in this study. Because we could not identify it to species, no biological information is available from literature regarding this ca. 2 mm long insect. Our preliminary experiment, in which beetles with pollen on their bodies were confined to the female-stage flower, suggested that this species does not qualify as a good pollinator because no mature seeds were obtained by this procedure (unpublished data). The fact that this species...
occurred mainly in late May also suggests that it does not serve as a pollinator.

*C. gibbosa* was also common except for at Tsu. The body length of this species is less than 2 mm, which allows easy entry into female-stage flowers through the crevice. The peak of seasonal fluctuation of this species was in late May. Flowers of the very early days in a season (in this case, during May) do not usually set fruits, suggesting that the use of *C. gibbosa* would be difficult under natural conditions. In addition, species in this family are thought to exploit mold hyphae (Hisamatsu and Tanaka, 1985; Takada and Nakamura, 2002). Therefore, *C. gibbosa* would stay in withered flowers, without leaving male-stage flowers. Thus, this species would not serve as an effective pollinator even if mass-rearing and release were performed.

*C. marginellus*, a cosmopolitan nitidulid of ca. 3 mm in length, was found at three of the four study sites. This species was also found in another study on flower visitors of atemoya, a hybrid of *A. cherimola* and *A. squamosa* (Nadel and Peña, 1994). *Carpophilus* is one of the most common groups of flower visitors to *Annona* spp. (Gazit et al., 1982; George et al., 1989; Nadel and Peña, 1994), and Peña et al. (1999) showed that *Carpophilus* spp. attracted by pheromone bait stations to an orchard significantly increased the fruit set of the atemoya. Although the observed density in the flowers was insufficiently high, we developed a mass-rearing system for this species (unpublished). For this reason, the species is the best candidate for a pollinator of *Annona* spp. in Japan. The only demerit is that this species is a pest of stored food and sometimes orchard fruits (James et al., 2000). Usually cherimoya orchards are not adjacent to grain storage facilities. Additionally, we have not observed this species attacking fresh cherimoya fruits. However, careful planning is required prior to the mass-rearing and release of this species.

*H. ocularis*, a common species from Pacific to African regions (Gillogly, 1982), is rather small (ca. 2 mm) and thus can easily enter female-stage flowers. It was found at all four sites early in the season, when the air temperature was adequate for pollination. In addition, a congener of this species was found to frequently visit the flowers of *Annona* spp. in Israel (Gazit et al., 1982). Although the density was low, we established a mass-rearing system for this species as well. Therefore, this is another pollinator candidate. Further study by mass-release experiment might be fruitful. However, compared with *M. monstrosus* and *C. marginellus*, *H. ocularis* survives for a shorter period in the cherimoya flower (unpublished data). In addition, this frugivorous species causes contamination problems during the harvesting process of the Japanese prune. This is one of the most important agricultural products of Wakayama Prefecture, in which three of the four study sites were located. Therefore, consideration of such undesired results is required even for this species. We found five other nitidulid species. Similarly to the former two species, it is necessary to minimize their harmful influence on other fruit trees, as well as stored foods, to use these beetles as pollinators.

*S* (45) was larger in the two commercial greenhouses at Shimotsu and Kokawa, indicating that these two sites harbor a diverse fauna in terms of species richness. On the other hand, 1- *D* was larger at Tsu and Shimotsu, and smallest at Kokawa. This difference came from the fact that *C. gibbosa* and *Phloeonomus* sp. accounted for almost 80% and 82% of the flower visitors at Kokawa and at Kibi, respectively, whereas at Shimotsu and Tsu these two species were rare or completely absent. Exp *H'* was noticeably larger at Shimotsu than at Kibi, indicating that the number of non-dominant species was large at Shimotsu and small at Kibi (Table 3). Klein et al. (2003) showed diversity in terms of species richness, as well as abundance of flower-visiting bees positively correlated with the fruit set in coffee. If natural flower visitor assemblage, instead of mass-released pollinators, were to be used in cherimoya, the site-to-site difference in flower visitor diversity should be considered as a possible source of variation in the fruit set.

No *τ* among the study sites was significantly different from zero. In addition, *C* 2 showed dissimilarity among the sites (Table 4). Such dissimilarity suggests that the flower visitor community strongly reflects the insect community of the surrounding area, which varies from site to site. Namely, the two sites in commercial greenhouses were in the middle of orchards of various types of fruit, where many species of frugivorous insects inhabit. On the contrary, the other two sites were surrounded by a monoculture orange orchard or urban landscape. In addition, uses of herbicide and pesticide at the Kibi site would have negatively affected the diversity of
insects in the greenhouse. Therefore, at the two commercial greenhouse sites, flowers have a greater chance of receiving visitation from many species, leading to different diversities of flower visitor communities among the sites. Such opportunistic relations between flowers and visitors might be attributable to the short history of interaction between the insects and the plant. In the natural distribution area of cherimoya, a more or less specialized and efficient pollination system would have developed between Annona spp. and beetles (Gottsberger, 1989a, b, 1990; Jurgens et al., 2000). However, outside of its natural habitat, this plant has lost its original pollinators and the flower fragrance attracts mainly frugivorous insects of the area. This is the case globally, because studies hitherto have revealed that flower visitor communities varied among study sites in different countries (Gazit et al., 1982; George et al., 1989; Nadel and Peña, 1994; Caleca, 1996, 1998, Lopez and Uquillas, 1997). Our study revealed that many insects that are not known to exploit fruits or flowers visit cherimoya flowers. Understanding whether they were attracted by the flower fragrance accidentally or they routinely use flowers of any species in their lifecycle would lead to further understanding of pollination by beetles as well as by true bugs.

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