Levels of parasitism of *Xenos myrapetru*s (Strepsiptera, Stylopidae) and its seasonal changes in the swarm-founding wasp, *Polybia paulista* (Hymenoptera, Vespidae)

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**ABSTRACT**

Social insects face strong selection from parasites because the conditions of group living often favor the transmission of infection among nestmates. Yet, we lacked detailed information on the effect of parasite infection in the host species. Workers of *Polybia* species, Neotropical swarm-founding wasps, are commonly infected by strepsipteran parasites, possibly *Xenos myrapetru*s (Troisi). Previous studies showed in two *Polybia* species that workers infected by the strepsiptera were smaller than uninfected workers. However, the effect of seasonality on infection rates throughout a year or between wet and dry seasons has not been examined. We compared rates of strepsiptera infection in workers of *Polybia paulista* between wet and dry seasons or among months. Infection rates by the strepsiptera in workers are generally low throughout a year, but different between the seasons. However, there is no particular tendency on seasonal differences of workers infected by the strepsiptera. Population dynamics of the parasites and temperature variation can have effects on the differences.

Parasites induce significant physiological, behavioral and morphological effects on their hosts. Also, the coevolution of parasites and their hosts often leads to drastic changes in the life history of the host species, e.g. [1]. Although numerous social insect studies have described parasite faunae, host-parasite interactions and immune defense [2,3], we have limited available studies on the parasites of social wasps. Most of the studies on social wasps deal with the effect of parasitoids belonging to Hymenoptera, Lepidoptera and Diptera [4]. These ectoparasitoids, which oviposit on cell walls, typically attach to pupal hosts and consume them, after which they pupate and leave. Although the parasitoids of *Polistes* wasps have received less attention in the last few decades [5], the abundance and ecological impact of the obligatory endoparasites, Strepsiptera have been investigated at length in paper wasps [6–13]. Cervo et al. [14] hypothesized that the rapid spread of the introduced species *Polistes dominulus* in North America may be due to the lack of parasitization by strepsipterans. Hughes et al. [6,7] reported the prevalence of the strepsiptera in some adult and immature *Polistes* wasps. Manfredini et al. [12] examined susceptibility toward the strepsiptera at both the individual (immune defense) and colony level, i.e. hygienic behavior (removal of diseased individuals by nestmates) in *P. dominul*a. Kudô et al. [15] made morphological comparisons between uninfected workers and workers infected by strepsipterans in *Polybia paulista*, and showed that workers infected by Strepsiptera were smaller than uninfected workers. Here, we examine seasonal changes in rates of strepsiptera infection in workers at individual and colony levels in a swarm-founding wasp, *P. paulista*. First, we collected workers from several colonies at regular intervals throughout a year and compared rates of strepsiptera infection between wet and dry seasons or among months. Next, we collected colonies of this species in wet and dry seasons and compared rates of strepsiptera infection between seasons. Every 2 months between November 2000 and November 2001, we collected wasps with insect nets from a total of 10 colonies at campus of Universidade de Sào Paulo (USP) in Ribeirão Preto city (21°11' S, 47° 48’ W), after these nests were partially destroyed. In each colony, collections were carried out until the colony was destroyed by unknown predators (abscending swarming) or exhibited swarm emigration (reproductive swarming or emigration swarming). The number of wasps in each colony collected by sampling month is summarized in Table 1. In our study locality, *P. paulista* exhibits colony activity throughout the year, but the activity is commonly higher between October and April (hereafter referred to as "wet season") than between May and September (hereafter referred to as "dry season") [16,17]. Our sampling was carried out four times during the wet season and three times during the dry season (Table 1). On average, 233.7 ± 33.9 wasps (±SE,
range: 20–168 wasps) from 4.1 ± 0.7 colonies were collected in each sampling month and immersed in 99% ethanol for later dissection.

We collected 11 colonies in August 2012 (dry season) and 12 colonies in January–March 2013 (wet season) (3 colonies in January, 4 in February, and 5 in March) on the campus of USP and its adjacent area. All wasps were immersed in 99% ethanol for later dissection.

The abdomen was dissected from all wasps collected in 2000 and 2001 (N = 1636) under a binocular microscope (Olympus, SZ-61), whereas the abdomen was dissected from 100 randomly selected wasps from each of 23 colonies collected in 2012 and 2013 (N = 2300). The following three development types were recognized in the ovary: type A with filamentous ovarioles bearing no visible or slightly developed oocytes; type B with at least some mature or nearly mature oocytes; and type C with well-developed and longer ovarioles each bearing from two to several mature oocytes. Since only type C females contained sperm in the spermatheca, females with ovaries A, B and C were characterized as workers, intermediates and queens, respectively. By dissection of the abdomen, we found strepsipteran larvae or puparia in the host wasps.

The number of queens, intermediates and workers collected in 2000 and 2001 were 7, 19 and 1610, respectively. No queens or intermediates were parasitized by the strepsiptera. The proportion of parasitized workers was constantly low throughout the year examined except for November 2001 (Figure 1). The proportion of infected workers during the wet season (3.33%) was significantly larger than that during the dry season (0.56%) (Fisher’s exact test, P < 0.001) due to high proportion of parasitized workers in November 2001.

In 11 colonies collected in the dry season (2012), 26 of 998 workers (2.61%) (mean ± SE: 2.66 ± 0.86% per colony) were parasitized by the strepsiptera, but no queens (N = 17) or intermediates (N = 85) were parasitized. In 12 colonies collected in the wet season (2013), 12 of 1144 workers (1.05%) (mean ± SE: 1.06 ± 0.46% per colony) were parasitized by the strepsiptera, but no queens (N = 34) or intermediates (N = 22) were parasitized. The proportion of infected workers during the dry season (2.61%) was significantly larger than that during the dry season (1.05%) (Fisher’s exact test, P < 0.01). At the colony level, however, the mean proportion of infected workers did not significantly differ between the seasons (Mann–Whitney U-test, z = 1.349, P = 0.18).

Kudô et al. [15] showed in P. paulista that 1–2% workers were parasitized by the strepsiptera during the wet season in three out of four colonies examined. The rates of strepsiptera infection were nearly comparable to our study (approximately 1–3% in this study). Kudô et al. [17] further showed in another

![Table 1. The number of wasps collected for dissection to examine seasonal change in infection rates by gregarine.](image)

| Nest | November | January | March | May | July | September | November |
|------|----------|---------|-------|-----|------|-----------|----------|
| 7    | 34       | 100     |       |     |      |           |          |
| 10   | 88       | 102     | 50    |     |      |           |          |
| 11   | 20       | 20      | 39    | 24  |      |           |          |
| 34   | 36       | 32      | 21    | 21  |      |           |          |
| 44   | 73       |         | 85    | 78  | 20   |           |          |
| 47   |          |         | 26    | 28  |      |           |          |
| 48   |          |         | 168   | 100 |      |           |          |
| 51   |          |         | 40    | 103 | 88   |           |          |
| 52   |          |         | 40    | 104 | 51   |           |          |
| 53   |          |         | 25    | 20  |      |           |          |
| Total| 108      | 192     | 294   | 324 | 332  | 247       | 139      |
| Average ± SE | 54.0 ± 34.0 | 48.0 ± 18.3 | 58.8 ± 12.4 | 64.8 ± 28.4 | 47.4 ± 11.3 | 61.8 ± 24.1 | 69.5 ± 18.5 |

![Figure 1. Monthly changes in proportion of workers infected by gregarines throughout a year (November 2000–November 2001).](image)
swarm-founding wasp Polybia occidentalis that mean proportion of workers infected by the strepsiptera was 1.8% during the wet season. These results consistently showed that a small proportion of workers were parasitized by the strepsiptera. Similarly, proportions of workers parasitized by undescribed gregarines (Phylum: Apicomplexa, Subclass: Gregarinasina) were generally low during wet seasons in P. paulistana (1.8%) (Kudô et al. in preparation) and P. occidentalis (1.5%) [17]. This study showed that in the swarm-founding wasp P. paulistana infection rates by strepsiptera in workers were generally low throughout a year, but different between the seasons. However, there is no particular tendency on seasonal differences of workers parasitized by the strepsiptera. Population dynamics of the parasites and temperature variation can have effects on the differences.

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