

POPULATION SURVEY OF NATIVE AND EXOTIC BLOWFLY SPECIESIN WESTERN SÃO PAULO STATE, BRAZIL

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INTRODUÇÃO

Among the most common blowfly species, members of the genus Chrysomya have been intensely studied thanks to their introduction into the New World (Guimarães et al., 1978; 1979). Chrysomya albiceps, C. rufifacies, C. megacephala, and C. putoria were introduced to the Americas around 35 years ago, and this biological invasion has significantly influenced the native fauna (Baumgartner & Greenberg 1984). In Brazil, only C. rufifacies has not yet become established, but the other species have colonized many areas of South America (Guimarães et al., 1979) and have displaced native species (Prado & Guimarães 1982; Silva et al., . 2003). These species are important mechanical disease vectors and causes of myiasis, and are also used in criminal investigations to estimate the post - mortem interval (Guimarães & Papavero 1999; Byrd & Castner 2010).

Abundance in blowflies has usually been estimated by using traps and investigations focused on succession in pig carcasses (Souza & Linhares 1997). In Brazil, few systematic studies have investigated the abundance of necrophagous flies in different localities, in order to compare the characteristics of areas, such as urban, wild, and farm areas, especially in locations where the environmental conditions differ in terms of altitude and temperature (Serbino & Godoy 2007) and mainly with different degrees of urbanization. Urban development has been cited as the main cause of local extinctions, principally of native species (McKinney 2002). In spite of this, the impact of this kind of disturbance has been little studied in native species (Marzluff 2005). In urban areas where there are recent introductions of exotic species, the effects on the native fauna are probably much more pronounced. However, both aspects have been little studied in insect populations.

OBJETIVOS

The objective of this study was to investigate the abundance of native and exotic blowflies during 12 months in three municipalities with different urban profiles. In addition, we analyzed the synchrony between blowfly species based on the time - series dynamics, and evaluated the correlation between the species abundance and environmental factors. The population aggregation level of blowflies was also evaluated in three municipalities.

MATERIAL E MÉTODOS

Flies were collected monthly during one year in the urban areas of the three municipalities, Bauru $(21^{\circ}30'23''S \text{ and } 48^{\circ}50'00''W)$, Piratininga $(22^{\circ}24'00''S \text{ and } 49^{\circ}08'00''W)$, and Agudos $(22^{\circ}53'20''S \text{ and } 47^{\circ}04'39''W)$. Traps were made from plastic drinking bottles (2000 mL) similar to the design proposed by Hwang and Turner (2005), each with a hole in its bottom.

Decaying chicken liver and fish were placed in the bottles as bait. Three traps were set in trees, in each municipality. During the first week of each month, the insects were removed and identified to family and species. The bait was periodically replaced to guarantee its attractiveness. The temperature and humidity were recorded daily for each municipality. A Shapiro - Wilk test was applied to check the normality of the data (Shapiro & Wilk 1965). One - way Anova was employed to compare the differences in abundance among areas, families, and species (Gotelli & Ellison 2004). The function peak of Edgeworth - Cramer (Dondi 1982) was employed to investigate the population oscillation patterns as well as their peak patterns. The Pearson coefficient was employed to analyze the correlation between temperature and fly abundance, humidity and fly abundance, and between the most abundant species.

The frequency distribution of flies in traps was fitted to the Negative binomial and Poisson distributions, in order to determine whether the number of adults found among traps was clumped or random. The k parameter in the Negative binomial distribution was estimated by the maximum likelihood method (Ludwig & Reynolds 1988). The fits of the Negative binomial and Poisson distributions were tested by the Pearson 2 statistic (Ludwig & Reynolds 1988). In the Negative binomial distribution, the null hypothesis was that the frequency distribution of adults exhibited a clumped distribution pattern. The parameter k is a measure of the degree of clumping, and tends toward zero at maximum clumping. In the Poisson distribution, the null hypothesis was that the number of adults found follows a random distribution.

RESULTADOS

The abundance of calliphorid species (Fig. 1, Tables 1 - 3) did not differ among the three municipalities (F = 2.24, p = 0.12), but individuals of the family Calliphoridae were much more abundant than the other families in all three municipalities (p ; 0.001, Tables 4 - 6). The abundance among species was significantly different in Agudos (F = 6.76, p = 0.00075) and Piratininga (F = 3.71, p = 0.0096), but not in Bauru (F = 1, P = 0.37). Chrysomya megacephala was the most abundant species in the three municipalities, followed by C. albiceps, C. putoria, and L. eximia, except in Piratininga.

In Bauru, *L. cuprina* was also found, and in Piratininga, *L. sericata* was also captured. These results were expected, because blowfly species are easily attracted by the baits used in this study, and can be explained, at least in part, by the manner in which they exploit food resources under competition. *Chrysomya megacephala*is an excellent interspecific competitor (Rosa *et al.*, . 2004) compared to *C. albiceps*, a species which needs its predator habit to compensate for its weak performance as a competitor (Faria *et al.*, . 1999; Rosa *et al.*, . 2004). The other species are similar to *C. mega*- *cephala*, with none exhibiting the same behavior shown by C. *albiceps* (Godoy 2007).

The observed patterns of abundance and species distribution are similar to the results of calliphorid surveys from other Brazilian localities such as Campinas, Rio de Janeiro, Curitiba, and some municipalities in the state of Goias (Souza & Linhares 1997; Carvalho etal., 2004). The Brazilian fauna of Calliphoridae has been impacted by the invasion of the *Chrusomua* species 35 years ago (Guimarães et al., 1978; 1979), with native species such as C. macellaria being displaced (Prado & Guimarães 1982). The introduction of Chrysomya species has particularly affected the native fauna because of essentially two types of interactions, competition for food and intraguild predation (Faria et al., 1999; Rosa et al., 2004). Chrysomya species usually have a flexible food habit, which allows them to exploit different substrates, such as animal carcasses, feces, and decomposing organic products (Smith 1986). Nevertheless, the substrates are generally not enough to support large numbers of insects, frequently inducing the populations to compete for food (Godov et. al., 1993; Rosa et al., 2004).

Perhaps the most interesting behavior among the exotic blowflies is the predatory habit of *C. albiceps*, which probably adopts this as a strategy to compensate for its poor performance as a competitor (Rosa *et al.*, 2004): in the presence of other species, it changes its behavior, becoming an intraguild predator (Faria *et al.*, 1999; 2007). This kind of interaction is characterized by predation among competitors exploiting the same food resource (Polis *et al.*, 1989).

Although invasions by *Chrysomya* species have occurred in several parts of the world (Serbino & Godoy 2007), the scenario observed in Brazil differs from other countries with respect to different effects of the exotic species on their native faunas. Studies in other countries show the particularities of this effect on the current faunal composition, where other species such as members of *Calliphora* exploit the same resources used by the *Chrysomya* species (Centeno *et al.*, . 2002). Perhaps these differences attenuate the interaction, making the faunal composition different in the several localities in response to the manner in which the species interact.

Specimens of Sarcophagidae, Muscidae, and Faniidae were also captured during the collecting period (Tables 4 - 6). Anthomyidae was found only in Agudos, Foridae only in Bauru, and Tephritidae in Piratininga. It is possible that the variation in the diversity of the fly families can be explained by differences in the municipalities. Bauru is a larger city than Agudos and Piratininga, with approximately 360,000 inhabitants, against 34,000 and 11,000 in the other two cities, respectively. In Bauru, more domestic waste is produced, mainly decomposing organic products, attracting more species of Foridae and Muscidae than the other municipalities. Among dipteran families, the species of Calliphoridae were the most abundant. This result is probably due to the wide niche occupied by these species with respect to food source, compared to other species (Smith 1986).

The time series analyzed for the two most abundant species, C. megacephala and C. albiceps, and modelled by the peak of the Edgeworth - Cramer function (Dondi 1982), resulted in a series with similar oscillation patterns, characterized by a bimodal fluctuation trend, for the two species in the three municipalities (Figs. 2 - 5). Oscillatory patterns are common in blowfly populations (Gurney & Nisbet 1998). Long - term laboratory studies were developed with the sheep blowfly Lucilia cuprina by Nicholson (1954; 1957) to investigate the effects of resource limitation at different life stages. His research resulted in a time series characterized by quasi - cycles, and has been widely cited in theoretical studies (Gurney et al., 1980; Gurney & Nisbet 1998). It is possible that the variation found by Nicholson (1954; 1957) is related to the variation between values of demographic parameters (Saker 2008). Variable environments can play an important role in ecological dynamic systems, reflected in the sensitivity of demographic parameters (Godoy et al., 1996; Saker 2008). Sometimes frequent changes of climate impose their periods upon oscillations (Saker 2008).

Cycles in *Chrysomya* species have been discussed in previous studies that analyzed ecological patterns of population dynamics by using a density - dependent population growth mathematical model (Godoy et al., 2001). The studies suggest that *Chrysomya* species may exhibit limited cycles as a result of intraspecific competition for food, and the periodicity and spectrum of the cycles are strongly dependent on demographic parameters such as fecundity and survival (Reis et al., 1996; Godoy *et al.*, 2001). In spite of the different design of the current study compared to previous laboratory experiments performed with a mathematical model (Godoy et al., 2001), the presence of a bimodal pattern as indicated by the Edgeworth - Cramer model suggests a trend of oscillation for these species, which could be explained by the sensitivity of demographic parameters to different environmental influences from the municipalities.

We applied the Pearson correlation (r) to investigate if the fluctuations of *C. megacephala* and *C. albiceps*, the most abundant blowfly species, were correlated with each other. The results indicated that the two species are correlated in the three municipalities, with correlation coefficients of 0.49, 0.83, and 0.94 for Agudos, Bauru, and Piratininga respectively (p ; 0.05). The coefficients found in Bauru and Piratininga are close to each other and distant from the coefficient observed in Agudos. It is possible that the different vegetation profiles of Bauru and Piratininga are associated with this result. Bauru and Piratininga have a typical vegetation characterized by savanna (Cerradão) surrounding their urban areas. Agudos has plantings of *Pinus* spp. and *Eucalyptus* spp., with extensive open areas (Fabricante 2003).

The Pearson correlation (r) between C. megacephala abundance and temperature in Agudos was 0.3 (p ; (0.05); with respect to precipitation, the correlation was not significant. For C. albiceps, the correlation between abundance and temperature was 0.19 (p; 0.05), and between abundance and precipitation was 0.54 (p ; (0.05). In Bauru, the correlation between abundance of C. megacephala and temperature was 0.38 (p; 0.05). Precipitation and C. megacephala abundance showed a correlation of 0.28 (p; 0.05). For *C. albiceps*, the correlation with temperature was 0.36, and with precipitation was 0.27 (p; 0.05). In Piratininga, the correlation between C. megacephala abundance and temperature was 0.28 (p ; 0.05); the precipitation showed no significant correlation with abundance. For C. albiceps the correlation between abundance and temperature was 0.19, and precipitation showed no significant correlation with its abundance.

A similarly low correlation between climate factors and the abundance of blowflies was also observed in Malaysia, where the number of specimens of *Chrysomya bezziana* was not associated with weather conditions at the time of trapping, but was positively correlated with the total rainfall (Mahon *et al.*, . 2004). Our findings seem to show a typical necrophagous - dipteran time - series pattern in western São Paulo state, since the study by Serbino & Godoy (2007) in the municipality of Botucatu, in the same region, showed very similar correlations.

The frequency distribution analysis revealed that C. megacephala, C. albiceps, C. putoria, and L. eximia exhibited a cluster pattern described by the Binomial negative distribution; however, the aggregation level, given by the K parameter estimates, differed among the species (Table 7). Chrysomya putoria exhibited the most - clumped pattern among the calliphorid species. These results suggest that the distribution pattern of flies is clumped in the three municipalities. The studies performed in Botucatu, 80 km from Bauru, also yielded similar results (Serbino & Godoy 2007). However, the results for Botucatu indicated two distribution patterns, clumped and random, given respectively by the Binomial negative and Poisson distributions (Serbino & Godoy 2007). The pattern of distribution observed in the current study is expected in the species, because blowflies usually tend to search for substrates previously visited by other individuals of the same family (Serbino & Godoy 2007). Aggregation in blowflies has been investigated (Cruickshank & Wall 2002), and is understood as a strategy to increase egg crowding, promoting proteolytic enzyme production by the larvae after they hatch (Smith 1986).

Aggregation in blowflies has been investigated much more in immatures (Godoy *et al.*, . 1995, 1996; Reis *et al.*, . 1999; Andrade *et al.*, . 2002; Reigada & Godoy 2005). For adult flies, the studies have shown that this behavior is probably associated with the aggregation requirements of future larvae. Blowfly larvae need to be together because some specific enzymes necessary for predigestion are only produced by a large number of larvae (Goodbrood & Goff 1990; Cruickshank & Wall 2002).

CONCLUSÃO

In conclusion, species of the genus *Chrysomya* maintain their status as efficient colonizers in Brazil, with populations exhibiting trends toward peaks and confirming a potential to occasionally show periodic oscillations, as shown in previous, theoretical studies by Godoy *et al.*, (2001). There is a strong association of the patterns of population dynamics among the main exotic species surveyed, and moderate correlations with environmental factors. The spatial distribution of Calliphoridae species tends to be aggregated, and perhaps their dispersal depends especially on the urban profiles of the municipalities.

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