Frugivorous Flies (Diptera: Tephritidae, Lonchaeidae) Associated with Fruit Production on Ilha de Santana, Brazilian Amazon

Authors: Almeida, Rafael do Rosário, Cruz, Kennedy Rodrigues, Sousa, Maria do Socorro Miranda de, Costa-Neto, Salustiano Vilar da, Jesus-Barros, Cristiane Ramos de, et al.

Source: Florida Entomologist, 99(3) : 426-436

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.099.0313

Frugivorous flies (Diptera: Tephritidae, Lonchaeidae) associated with fruit production on Ilha de Santana, Brazilian Amazon

Rafael do Rosário Almeida[1], Kennedy Rodrigues Cruz[2], Maria do Socorro Miranda de Sousa[3], Salustiano Vilar da Costa-Neto[4], Cristiane Ramos de Jesus-Barros[5], Adilson Lopes Lima[5], and Ricardo Adaime[1,3,5,]*

Abstract

We conducted a survey of the species of frugivorous flies (Tephritidae and Lonchaeidae), their hosts, and their parasitoids found on Ilha de Santana, Amapá State, Brazilian Amazon. We also assessed host plant use by *Bactrocera carambolae* Drew & Hancock. Fruits were collected from various plant species, at 30 d intervals, from Jan to Jul 2015. In total, 149 fruit samples were collected (3,142 fruits, 76.3 kg), belonging to 20 plant species (9 native and 11 introduced) in 13 botanical families. Infestation by fruit flies was observed in 86 samples (11 species in 8 botanical families). Specimens of 5 species of Tephritidae and 4 species of Lonchaeidae fruit flies were obtained, as well as 3 species of braconid parasitoids. The most important fruit fly species on Ilha de Santana are: *B. carambolae*, for being a species of quarantine importance; and *Anastrepha obliqua* (Macquart) and *Anastrepha striata* Schiner, for infesting plant species of local socioeconomic importance. *Averrhoa carambola* (Oxalidaceae), *Eugenia uniflora* (Myrtaceae), *Malpighia emarginata* (Moc. & Sesse) ex DC. (Malpighiaceae), and *Psidium guajava* (Myrtaceae) are the host plants responsible for sustaining the population of *B. carambolae*.

Key Words: *Bactrocera carambolae*; *Anastrepha*; *Neosilba*; *Doryctobracon*

Resumo

Este trabalho teve por objetivo identificar as espécies de moscas frugívoras (Tephritidae e Lonchaeidae), seus hospedeiros e parasitoides na Ilha de Santana, estado do Amapá, Amazônia brasileira. Adicionalmente, objetivou estudar a exploração hospedeira por *Bactrocera carambolae* Drew & Hancock. Foram realizadas coletas de frutos de diversas espécies vegetais, a cada 30 dias, no período de janeiro a julho de 2015. Foram coletadas 149 amostras de frutos (3.142 frutos, 76,3 Kg), pertencentes a 20 espécies vegetais (9 nativas e 11 introduzidas) de 13 famílias botânicas. Houve infestação por moscas frugívoras em 86 amostras (11 espécies de 8 famílias botânicas). Foram obtidos espécimes de cinco espécies de Tephritidae, quatro de Lonchaeidae e três de parasitoides Braconidae. As espécies de moscas frugívoras mais importantes na Ilha de Santana são: *B. carambolae*, devido sua expressão quarentenária; e *Anastrepha obliqua* (Macquart) e *Anastrepha striata* Schiner, pelo fato de infestarem espécies vegetais de importância socioeconômica local. Os hospedeiros *Averrhoa carambola* (Oxalidaceae), *Eugenia uniflora* (Myrtaceae), *Malpighia emarginata* (Malpighiaceae) e *Psidium guajava* (Myrtaceae) são responsáveis pela manutenção da população de *B. carambolae*.

Palavras Chave: *Bactrocera carambolae*; *Anastrepha*; *Neosilba*; *Doryctobracon*

Tephritidae and Lonchaeidae are the principal families of Diptera whose larvae use the flesh of fruits or parts of plants as substrates for their development. Tephritidae are among the major groups of phytophagous insects of worldwide economic importance (Aluja 1994). Their larvae develop on fruits of various species of fruit-bearing trees, making them unsuitable for sale and consumption (Aluja & Mangan 2008). In addition, some species can make export impossible due to quarantine restrictions imposed by importing countries where a specific pest is not already present (Malavasi 2000).

Tephritidae that have economic importance are most frequently studied (Aluja & Norrbom 2000). *Anastrepha* Schiner is viewed as the genus of highest economic importance to the Americas (Uchôa & Nicácio 2010). In Brazil, 6 species are particularly important: *Anastrepha striata* Schiner, *Anastrepha obliqua* (Macquart), *Anastrepha fraterculus* (Wiedemann), *Anastrepha grandis* (Macquart), *Anastrepha pseudoparallela* (Loew), and *Anastrepha zenildae* Zucchi (Uramoto & Zucchi 2009). Two exotic introduced species also occur in the country: *Ceratitis capitata* (Wiedemann), known as the Mediterranean fruit fly,

[1]Universidade Federal do Amapá, Programa de Pós-graduação em Biodiversidade Tropical, Macapá, Amapá, 68902-280, Brazil; E-mail: agrorafael_ra@yahoo.com.br (R. R. A.), ricardo.adaime@embrapa.br (R. A.)

[2]Faculdade de Macapá, Macapá, Amapá, 68906-801, Brazil; E-mail: kennedy.cruz@colaborador.embrapa.br (K. R. C.)

[3]Universidade Federal do Amapá, Programa de Pós-graduação em Desenvolvimento Regional, Macapá, Amapá, 68902-280, Brazil; E-mail: socorro-ap@hotmail.com (M. S. M. S.)

[4]Instituto de Pesquisas Científicas e Tecnológicas do Amapá, Macapá, Amapá, 68900-000, Brazil; E-mail: salucostaneto@gmail.com (S. V. C.-N.)

[5]Embrapa Amapá, Macapá, Amapá, 68903-419, Brazil; E-mail: cristiane.jesus@embrapa.br (C. R. J.-B.), adilson.lopes@embrapa.br (A. L. L.)

*Corresponding author; E-mail: ricardo.adaime@embrapa.br (R. A.)

and *Bactrocera carambolae* Drew & Hancock, the carambola fruit fly (Zucchi 2001).

Bactrocera carambolae is considered a quarantine pest present in Brazil, and though limited to the states of Amapá and Roraima (Brazil 2013), it is subject to rigorous official control (Lemos et al. 2014). *Bactrocera carambolae* is the biggest phytosanitary barrier to Brazilian fruit agribusiness exports, because the main buyers of Brazilian fruit establish restrictions against acquiring products from countries where the pest is present. The Brazilian government, through its Ministry of Agriculture, Livestock and Food Supply, established a National Program for Eradication of the Carambola Fruit Fly, aiming to eliminate the pest from the states of Amapá and Roraima and maintain the "*B. carambolae*-free" status of other Brazilian states (Godoy et al. 2011).

As frugivorous dipterans whose larvae can damage fruit and vegetables, Lonchaeidae have been reported as primary pests of various crops in Brazil, with species of economic importance being found in the genera *Dasiops* Rondani and *Neosilba* McAlpine (Uchôa 2012). Some recent studies on Lonchaeidae have been conducted in Brazil, driven by advances in taxonomic knowledge about Brazilian lonchaeids (Lemos et al. 2015). However, the scarcity of studies on lonchaeid taxonomy, biology, and ecology has been hindering the development of strategies to manage these insects (Strikis et al. 2011).

In the state of Amapá, located in the Brazilian Amazon, studies on frugivorous flies and their natural enemies were started only recently. However, especially in the past 10 yr, knowledge about species that occur in Amapá, their hosts, and their parasitoids has grown significantly. On the other hand, some localities within the state remain poorly studied, including Ilha de Santana. The island belongs to the municipality of Santana and is characterized by small rural properties where fruit trees are grown, mainly for the production of fruit concentrates. The only existing survey of fruit flies on Ilha de Santana was conducted between Jan and Jul 2005 (Silva et al. 2007). The authors collected 44 samples of 13 plant species (4,177 fruits, 78.7 kg) and obtained specimens of *A. obliqua* on fruits of *Spondias mombin* Jacq. (Anacardiaceae), *A. striata* on fruits of *Psidium guajava* L. (Myrtaceae), and *Anastrepha leptozona* Hendel on fruits of *Pouteria caimito* (Ruiz & Pav.) Radik. (Sapotaceae). Three species of parasitoids were also obtained: *Doryctobracon areolatus* (Szépligeti), *Opius bellus* Gahan, and *Asobara anastrephae* (Muesebeck) (Hymenoptera: Braconidae).

We conducted research to expand our knowledge of the frugivorous flies (Tephritidae and Lonchaeidae), their hosts, and their parasitoids found on Ilha de Santana, Amapá State, Brazilian Amazon. We also assessed host plant use by *B. carambolae*.

Materials and Methods

SITE CHARACTERISTICS

The study was conducted on Ilha de Santana, municipality of Santana, state of Amapá, Brazil (Fig. 1). The island occupies an area of approximately 2,005 ha and is situated on the banks of the Norte Canal, facing the city of Santana, between the geographic coordinates 00.0666667°S and 00.1000000°S, and 00.0666667°W and 51.2083333°W (Valente et al. 1998).

The predominant climate in the area is Amw' under the Köppen classification system, characterized as a tropical wet climate with a well-defined dry season, with mean temperatures never dropping below 18 °C and annual fluctuations seldom exceeding 5 °C. Annual precipitation ranges from 1,300 to 1,900 mm, with well-defined rainy and dry seasons (Dec to Mar and Aug to Nov, respectively). The predominant soils are Yellow Latosol and Haplic Gleysol. Yellow Acrisol, Fluvic Neosol, and Indiscriminate Hydromorphic Soils are also present (Valente et al. 1998).

The island is located 600 to 800 m from the Port of Santana. Access is obtained using small boats. The predominant activity on the island is small-scale family agriculture, with fruit growing as the most representative activity. Products are sold once a week, mainly in the form of fruit concentrate, in public farmers' markets in the municipalities of Macapá and Santana.

SAMPLING PROCEDURES

Monthly sampling of fleshy fruits from various plant species was performed from Jan to Jul 2015, a period in which there is high availability of fruiting plants in the region. To quantify the rate of infestation by fruit flies and the percentage of parasitism, we applied the grouped samples method described by Silva et al. (2011a). Each sample was determined by the availability of fruits. For each plant species with a high availability of fruits, a sample consisted of approximately 20 medium-sized fruits or 50 small fruits (partially or fully ripe fruits, collected directly from the tree or recently fallen to the ground). When there was not a sufficient amount of fruits, we collected whatever was available on the trees. The geographic coordinates of the sampling sites were recorded with a GPS device. In the field, the fruits were counted and stored in properly tagged plastic bottles that were wrapped in organza bags and closed with rubber bands. Later, the bottles were placed on plastic trays and transported by river to the Port of Santana, then by road to the Plant Protection Laboratory at Embrapa Amapá, in the city of Macapá, where the fruits were stored.

ACQUISITION OF PUPARIA AND ADULT INSECTS

In the laboratory, the fruits were weighed and transferred to plastic trays containing a thin layer of sterilized, moistened vermiculite. The trays were covered with organza fabric fastened in place with rubber bands. The material on the trays was examined every 3 d. Recovered puparia were removed and transferred to transparent plastic jars (8 cm diameter) containing a thin layer of moistened vermiculite. The bottles were covered with organza fastened in place with a vented lid, then placed in climate-controlled chambers under controlled temperature (27 ± 0.5 °C), relative humidity (70 ± 10%) and photoperiod (12:12 h L:D). They were checked daily for puparia. Adult insects that emerged (fruit flies and parasitoids) were killed and stored in glass vials containing 70% ethanol, duly tagged for subsequent identification.

IDENTIFICATION OF INSECTS

Specimens of *Anastrepha* were identified using the illustrated identification key published by Zucchi et al. (2011). Only females were used for identification, which was performed by examination of everted aculei, using a stereomicroscope and optical microscope (40×). Other characteristics were also observed, including wing pattern, mesonotum, mediotergite, and subscutellum. Confirmation of *B. carambolae* identity was based on the identification key published by Drew & Hancock (1994). To identify parasitoids (Hymenoptera: Braconidae), we used the work of Canal & Zucchi (2000) and Marinho et al. (2011). *Neosilba* specimens were identified according to McAlpine & Steyskal (1982) and Strikis (2011).

IDENTIFICATION OF BOTANICAL MATERIAL

To identify the forest plant species, we collected branches containing their reproductive structures (flowers and fruits), which were later processed into herbarium specimens using the mounting and preser-

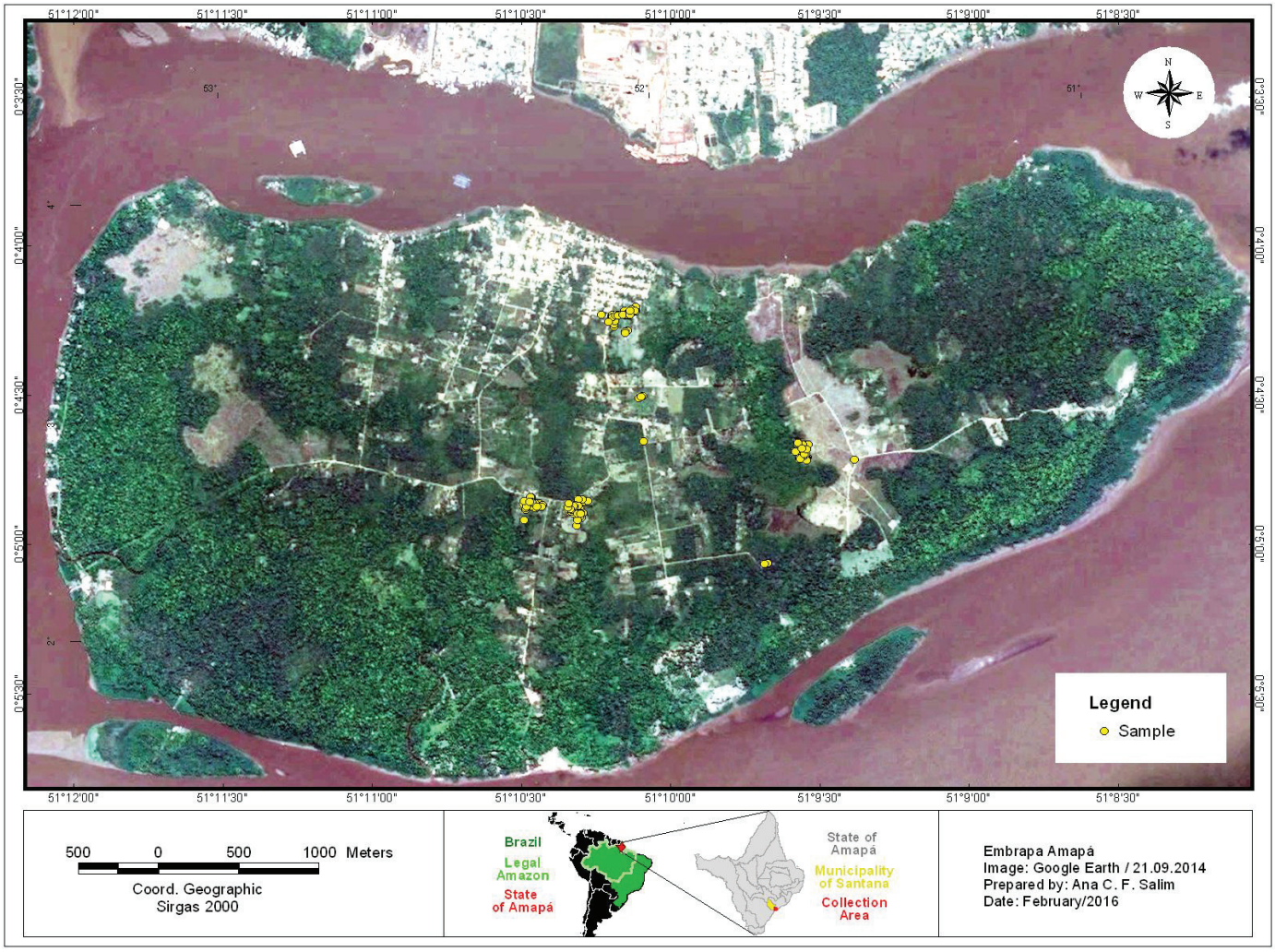

Fig. 1. Sampling sites of fruits on Ilha de Santana, state of Amapá, Brazil (Jan to Jul 2015).

vation techniques described by Fidalgo & Bononi (1984). The plant species were identified using identification keys and specialized literature, as well as comparison with specimens available at the Herbário Amapaense (HAMAB), the herbarium at the Amapá Institute for Scientific and Technological Research (IEPA) in Macapá, Amapá, Brazil.

DATA ANALYSES

The following data were calculated: 1) infestation index = number of puparia obtained/weight (kg) of fruit collected; 2) emergence = (number of emerged flies + number of emerged parasitoids)/total number of puparia × 100; and 3) percentage of parasitism = (number of parasitoids emerged/number of puparia) × 100.

Results

In total, 149 fruit samples were collected (3,142 fruits, 76.3 kg), belonging to 20 plant species (9 native and 11 introduced) in 13 botanical families. Infestation by fruit flies was observed in 86 samples (11 species in 8 botanical families). The sampled host plants were: *Averrhoa carambola* L. (Oxalidaceae), *Capsicum baccatum* L. (Solanaceae), *Eugenia uniflora* L. (Myrtaceae), *Inga edulis* Mart. (Fabaceae), *Licania* sp. (Chrysobalanaceae), *Malpighia emarginata* (Moc. & Sesse) ex DC. (Malpighiaceae), *Mangifera indica* L. (Anacardiaceae), *Passiflora* sp. (Passifloraceae), *P. guajava*, *Spondias mombin* Jacq. (Anacardiaceae), and *Syzygium cumini* (L.) Skeels (Myrtaceae) (Table 1).

We obtained 4,046 puparia, from which emerged specimens of Tephritidae (5 species), Lonchaeidae (4 species), and Braconidae (3 species). Emergence ranged from 14.3% (on *M. indica*) to 100% (on *Passiflora* sp.), and was higher than 50% on 8 plant species. The highest infestation rates were obtained on *S. mombin* (174.1 puparia per kg of fruit), *S. cumini* (106.4), *P. guajava* (142.0), and *E. uniflora* (125.6). The host plants infested by the largest numbers of fruit flies were *M. emarginata* and *S. mombin* (Tables 1 and 2).

TEPHRITIDAE

The species of Tephritidae obtained were: *A. striata*, *A. obliqua*, *A. fraterculus*, *Anastrepha antunesi* Lima, and *B. carambolae* (Table 1). *Anastrepha striata* occurred on 2 hosts (*M. emarginata* and *P. guajava*) and *A. obliqua* occurred on 3 (*S. mombin*, *M. emarginata*, and *S. cumini*). *Anastrepha antunesi* and *A. fraterculus* occurred exclusively on *S. mombin* (Table 2). *Bactrocera carambolae* occurred on 8 of the 11 plant species infested by fruit flies: *A. carambola*, *E. uniflora*, *Licania* sp., *M. emarginata*, *M. indica*, *P. guajava*, *S. mombin*, and *S. cumini* (Tables 1, 2, and 3).

Table 1. Rates of infestation of various plant species by fruit flies on Ilha de Santana, Amapá, Brazil (Jan to Jul 2015).

Families Scientific names Common names [Portuguese]	Origin N/I	Samples C/I	Fruits (*n*)	Mass (kg)	Puparia (*n*)	Infestation (PP/kg)	Emergence (%)	Tephritidae (*n*)	Lonchaeidae (*n*)	Hymenoptera (*n*)	%P
Anacardiaceae											
Spondias mombin L. Taperebá	N	11/11	387	4.9	853	174.1	67.9	Ao(99♀), Af(2♀), Aa(1♀), 108♂ + Bc(1)	—	Da(327), Ob(37), Ua(4)	43.1
Spondias purpurea L. Seriguela	I	1/0	20	0.2	—	—	—	—	—	—	—
Mangifera indica L. Manga	I	11/1	80	14.4	7	0.5	14.3	Bc(1)	—	—	—
Apocynaceae											
Hancornia speciosa Gomes Mangaba	N	1/0	20	0.5	—	—	—	—	—	—	—
Chrysobalanaceae *Licania* sp.	N	3/2	81	0.9	7	7.8	71.4	Bc(2)	—	Da(2), ni(1)	42.8
Fabaceae											
Inga edulis Mart. Ingá—cipó	N	1/1	11	0.7	2	2.9	50.0	—	Nz(1♂)	—	—
Lauraceae											
Persea americana Mill. Abacate	I	3/0	11	2.0	—	—	—	—	—	—	—
Malpighiaceae											
Malpighia emarginata D.C Acerola	I	27/22	1,205	5.5	293	53.3	58.0	Ao(6♀), As(1♀), 5♂ + Bc(144)	Npd(5♂,2♀),Npz(2♂,3♀), Nz(1♂)	Da(1)	0.3
Byrsonima crassifolia (L.) Kunth Muruci	N	4/0	98	0.2	—	—	—	—	—	—	—
Melastomataceae											
Bellucia grossularioides (L.) Triana Goiaba—de—anta	N	1/0	33	0.3	—	—	—	—	—	—	—
Myrtaceae											
Syzygium cumini (L.) Skeels Ameixa roxa	I	3/3	147	1.1	117	106.4	21.4	Ao(3♀), 2♂ + Bc(10)	—	Da(10)	8.5
Psidium guajava L. Goiaba	I	34/34	396	16.8	2,386	142.0	67.6	As(689♀), 765♂ + Bc(154)	Nz(2♂, 1♀)	Da(1)	0.04
Eugenia uniflora L. Pitanga	N	9/5	305	1.6	201	125.6	46.3	Bc(93)	—	—	—
Oxalidaceae											
Averrhoa carambola L. Carambola	I	6/4	60	4.6	167	36.3	74.9	Bc(125)	—	—	—
Averrhoa bilimbi L. Limão—caiena	I	1/0	20	0.7	—	—	—	—	—	—	—
Passifloraceae											
Passiflora sp. Maracujá	N	13/1	55	8.1	1	0.1	100	—	Ng(1♂)	—	—
Rubiaceae											
Morinda citrifolia L. Noni	I	8/0	80	6.6	—	—	—	—	—	—	—

N: native; I: introduced; C: collected; I: infested; *n*: number; PP: puparia; %P: percentage of parasitism; Aa: *Anastrepha antunesi*; Ao: *Anastrepha obliqua*; Af: *Anastrepha fraterculus*; As: *Anastrepha striata*; Bc: *Bactrocera carambolae* (♀, ♂); Ng: *Neosilba glaberrima*; Npd:*Neosilba pendula*; Npz: *Neosilba pseudozadolicha*; Nz: *Neosilba zadolicha*; Da: *Doryctobracon areolatus* (♀, ♂); Ob: *Opius bellus* (♀, ♂); Ua: *Utetes anastrephae* (♀, ♂); ni: not identified.

Table 1. (Continued) Rates of infestation of various plant species by fruit flies on Ilha de Santana, Amapá, Brazil (Jan to Jul 2015).

Families Scientific names Common names [Portuguese]	Origin N/I	Samples C/I	Fruits (*n*)	Mass (kg)	Puparia (*n*)	Infestation (PP/kg)	Emergence (%)	Tephritidae (*n*)	Lonchaeidae (*n*)	Hymenoptera (*n*)	%P
Rutaceae											
Citrus aurantium L. Orange	I	5/0	45	5.5	—	—	—	—	—	—	—
Citrus limon (L.) Osbeck Limão	I	4/0	62	1.4	—	—	—	—	—	—	—
Solanaceae											
Capsicum baccatum L Pimenta—dedo—de—moça	N	3/2	26	0.3	12	40.0	58.3	—	Ng(1♂, 1♀), Nz(5♂)	—	—
TOTAL	—	149/86	3,142	76.3	4,046	—	—	As(690♀), Ao(108♀), Af(2♀), Aa(1♀), 880♂ + Bc(530)	Nz(9♂, 1♀), Npd(5♂, 2♀), Npz(2♂, 3♀), Ng(2♂, 1♀)	Da(341), Ob(37), Ua(4), ni(1)	13.2

N: native; I: introduced; C: collected; I: infested; *n*: number; PP: puparia; %P: percentage of parasitism; Aa: *Anastrepha antunesi*; Ao: *Anastrepha obliqua*; Af: *Anastrepha fraterculus*; As: *Anastrepha striata*; Bc: *Bactrocera carambolae* (♀, ♂); Ng: *Neosilba glaberrima*; Npd:*Neosilba pendula*; Npz: *Neosilba pseudozadolicha*; Nz: *Neosilba zadolicha*; Da: *Doryctobracon areolatus* (♀, ♂); Ob: *Opius bellus* (♀, ♂); Ua: *Utetes anastrephae* (♀, ♂); ni: not identified.

Anastrepha accounted for 75.2% of all fruit flies obtained in this study, followed by *Bactrocera* (23.7%) (Table 3). The highest abundance of fruit flies occurred on *P. guajava*, with 1,611 specimens, 90.2% of them consisting of *A. striata*, 9.6% of *B. carambolae*, and 0.2% of the lonchaeid *Neosilba zadolicha* McAlpine & Steyskal.

LONCHAEIDAE

The genus *Neosilba* accounted for only 1.1% of all fruit flies obtained in this study (Table 3). The species obtained were: *N. zadolicha*, *Neosilba pendula* (Bezzi), *Neosilba pseudozadolicha* Strikis, and *Neosilba glaberrima* (Wiedemann) (Tables 1 and 2). Five hosts were recorded for lonchaeids: *C. baccatum*, *M. emarginata*, *I. edulis*, *Passiflora* sp., and *P. guajava* (Tables 1 and 2). *Malpighia emarginata* was infested by 3 species (*N. pendula*, *N. pseudozadolicha*, and *N. zadolicha*) (Tables 1 and 2). *Neosilba glaberrima* and *N. zadolicha* infested 2 and 4 plant species, respectively. Infestation by Lonchaeidae was observed in at least 1 plant species in the months of Jan to Apr and Jul (Table 2)**.**

PARASITOIDS

Three species of Braconidae (Hymenoptera) were obtained from fruits of *S. mombin*, *Licania* sp., *M. emarginata*, *S. cumini*, and *P. guajava*: *D. areolatus*, *O. bellus*, and *Utetes anastrephae* (Viereck). The most abundant species was *D. areolatus*, accounting for 89.0% of all parasitoids obtained (Table 1). The highest percentages of parasitism were observed on *S. mombin* (43.1%) and *Licania* sp. (42.6%) (Table 1).

HOST PLANT USE BY *B. CARAMBOLAE*

In all months of sampling, infestation by *B. carambolae* was observed on at least 2 plant species, peaking at 5 species in Apr. *Eugenia uniflora* and *P. guajava* were found to be infested in 5 of the 7 mo of sampling, and *M. emarginata* was infested in 6 mo (Table 2).

Bactrocera carambolae was the only species to infest *A. carambola*, *E. uniflora*, *Licania* sp., and *M. indica* (Tables 1, 2, and 3). On *M. emarginata*, it corresponded to 80.9% of all Tephritidae obtained (Table 3). On the other hand, on *P. guajava,* specimens of *B. carambolae* accounted for only 9.6% of all Tephritidae obtained, and the prevalent species was *A. striata*. On *S. mombin*, *B. carambolae* represented only 0.5% of Tephritidae obtained.

The sampling events were performed in 5 rural establishments (designated here as E_1 to E_5), as well as 3 isolated collection points (P_1 to P_3) located on the sides of secondary roads. *Bactrocera carambolae* was obtained from 48 samples collected in all of the sampled rural establishments, as well as 1 of the isolated collection points (Table 4).

Discussion

TEPHRITIDAE

This research identified 3 new reports of fruit flies, in addition to those previously reported by Silva et al. (2007): *A. fraterculus*, *A. antunesi*, and *B. carambolae* (Table 1). Therefore, to date, 6 species of fruit flies are known to occur on Ilha de Santana: *A. antunesi*, *A. fraterculus*, *A. leptozona*, *A. obliqua*, *A. striata*, and *B. carambolae*.

Anastrepha striata was the predominant species. This species exhibits a marked preference for *P. guajava*, a plant species with high availability of fruits during the sampled period. All 34 samples of *P. guajava* collected in this study (396 fruits, 16.8 kg) were infested with *A. striata* (Table 3). This dominance of *A. striata* can therefore be explained by the abundance of fruits of *P. guajava*, its main host

Table 2. Fruit flies obtained from host plants sampled in each month of sampling on Ilha de Santana, Amapá, Brazil (Jan to Jul 2015).

	Sampling months[1]						
Hosts	Jan	Feb	Mar	Apr	May	Jun	Jul
Averrhoa carambola	*B. carambolae*	*B. carambolae*	*B. carambolae*				
Capsicum baccatum				*N. zadolicha*[3]			*N. glaberrima*[3] *N. zadolicha*
Eugenia uniflora[2]		*B. carambolae*		*B. carambolae*	*B. carambolae*	*B. carambolae*	*B. carambolae*
Inga edulis			*N. zadolicha*				
Licania sp.[2]				*B. carambolae*			
Malpighia emarginata	*B. carambolae* *N. pseudozadolicha*[3] *N. pendula*[4]	*B. carambolae* *A. obliqua* *A. striata* *N. pendula* *N. zadolicha*[3]	*B. carambolae* *A. obliqua*	*B. carambolae* *N. pseudozadolicha*	*B. carambolae* *A. obliqua*		*B. carambolae*
Mangifera indica				*B. carambolae*			
Passiflora sp.	*N. glaberrima*[3]						
Psidium guajava	*A. striata*	*A. striata*	*B. carambolae* *A. striata* *N. zadolicha*	*B. carambolae* *A. striata*	*B. carambolae* *A. striata*	*B. carambolae* *A. striata*	*B. carambolae* *A. striata*
Spondias mombin	*A. obliqua*	*A. obliqua* *A. antunesi* *A. fraterculus*	*A. obliqua* *B. carambolae*	*A. obliqua*	*A. obliqua*		
Syzygium cumini[2]					*B. carambolae* *A. obliqua*		

[1] Area in gray indicates that the plant species was collected in the corresponding month.
[2] New host for *Bactrocera carambolae* in Brazil.
[3] New association between host plant and *Neosilba* species in the Brazilian Amazon.
[4] New association between host plant and *Neosilba* species in the state of Amapá.

Table 3. Specimens of *Anastrepha* spp., *Bactrocera carambolae*, and *Neosilba* spp. obtained from plant species on Ilha de Santana, Amapá, Brazil (Jan to Jul 2015).

		Anastrepha spp.			*Bactrocera carambolae*			*Neosilba* spp.			Total
Hosts	SC	SI	♂+♀	%	SI	♂+♀	%	SI	♂+♀	%	♂+♀
Averrhoa carambola	6	—	—	—	4	125	100	—	—	—	125
Capsicum baccatum	3	—	—	—	—	—	—	2	7	100	7
Eugenia uniflora	9	—	—	—	5	93	100	—	—	—	93
Inga edulis	1	—	—	—	—	—	—	1	1	100	1
Licania sp.	3	—	—	—	1	2	100	—	—	—	2
Malpighia emarginata	27	7	12	6.7	19	144	80.9	6	22	12.4	178
Mangifera indica	11	—	—	—	1	1	100	1	—	—	1
Passiflora sp.	13	—	—	—	—	—	—	1	1	100	1
Psidium guajava	34	34	1,454	90.2	14	154	9.6	1	3	0.2	1,611
Spondias mombin	11	10	210	99.5	1	1	0.5	—	—	—	211
Syzygium cumini	3	3	5	33.3	3	10	66.7	—	—	—	15
Total	121	54	1,681	75.2	48	530	23.7	9	34	1.1	2,245

SC: sample collected, SI: sample infested

at many localities in South America, including the Brazilian Amazon (Aluja 1994; Silva et al. 2011b; Marsaro Júnior et al. 2013). In addition, *A. striata* is the most abundant and widely distributed tephritid species in the state of Amapá, and is also the most polyphagous (infesting 25 host plants in 16 botanical families) (Silva et al. 2011c; Jesus-Barros et al. 2012).

Anastrepha obliqua has been particularly associated with *S. mombin*. In surveys conducted in the state of Amapá, *A. obliqua* was predominant on this host (Silva et al. 2007, 2011d; Deus et al. 2009, 2013). In this work, the mean infestation index was 173.2 puparia per kg, lower than the highest index reported for this host in the state of Amapá, i.e., 385.1 puparia per kg in samples obtained at Serra do Navio (Deus et al. 2013). These results show the importance of *A. obliqua* as a pest of *S. mombin* in the state of Amapá (Silva & Ronchi-Teles 2000; Deus & Adaime 2013; Deus et al. 2016), especially as the fruit is very well-liked by the local population, who purchase it as concentrate to be made into juice.

This is the first report of *A. obliqua* associated with *S. cumini* in Brazil. On the other hand, *A. obliqua* has already been associated with *M. emarginata* in the states of Amapá, Pará, and Roraima (Ohashi et al. 1997; Amorim et al. 2004; Marsaro Júnior et al. 2011; Lemos 2014). *Anastrepha antunesi* and *A. fraterculus* had already been associated with *S. mombin* in the state of Amapá (Deus & Adaime 2013).

Bactrocera carambolae was obtained from 8 plant species, with *E. uniflora*, *S. cumini,* and *Licania* sp. representing new reports of host plants for the species in Brazil. The other plant species had already been reported to be hosts of *B. carambolae* in Amapá (Silva et al. 2004; Lemos et al. 2010, 2014).

LONCHAEIDAE

All Lonchaeidae obtained in this study are first reports for Ilha de Santana. *Neosilba glaberrima* and *N. zadolicha* infested the highest number of hosts (Tables 1 and 3), confirming the results obtained by Strikis et al. (2011) and Lemos et al. (2015), which indicated that these are the most polyphagous species of Lonchaeidae in the Amazon region. They are also among the species of highest economic importance for South America (Uchôa 2012).

In the Brazilian Amazon, *N. pendula* had already been reported on *M. emarginata* in the states of Pará and Roraima (Pereira & Adaime 2016). Araújo & Zucchi (2002) reported the species as an important primary invader of *M. emarginata* fruits in the state of Rio Grande do Norte.

No specimens of Lonchaeidae were obtained from *S. mombin*. This result was repeated during the sampling performed by Lemos et al. (2015) in 3 municipalities of Amapá (14 samples, containing 210 fruits in total).

Five samples of 4 plant species were infested exclusively by species of *Neosilba*: *N. glaberrima* on *P. edulis* (1 sample), *N. pendula* on *M. emarginata* (1 sample), *N. zadolicha* on *I. edulis* (1 sample), and *N. zadolicha* and *N. glaberrima* on *C. baccatum* (2 samples). This finding may indicate that these lonchaeid species are primary pests of the plant species in question. In addition, Uchôa (2012) mentioned that for some plant species of economic importance in South America, lonchaeids may be more abundant and important as pests than tephritids.

This work makes new associations between species of *Neosilba* and host plants in the Brazilian Amazon: *N. glaberrima* on *Passiflora* sp. and *C. baccatum*; *N. pseudozadolicha* on *M. emarginata*; and *N. zadolicha* on *M. emarginata* and *C. baccatum* (Table 2).

PARASITOIDS

This work adds 1 species of parasitoid (*U. anastrephae*) not reported by Silva et al. (2007) on Ilha de Santana. Therefore, to date, 4 species of parasitoids have been reported at this locality: *A. anastrephae*, *D. areolatus*, *O. bellus*, and *U. anastrephae*.

The higher abundance of *D. areolatus* found in this work is consistent with the notion that this is the most abundant and disseminated species of native parasitoid of *Anastrepha* in Latin America, including in Brazil (López et al. 1999; Ovruski et al. 2005; Marinho et al. 2011). The longer ovipositor of *D. areolatus* (3.8 mm) allows it to infest larvae of fruit flies in fruits of various sizes, enabling it to outperform other parasitoids (Aluja et al. 2013).

The highest percentages of parasitism were observed on *S. mombin* (43.1%) and *Licania* sp. (42.6%), which are native plants in the sampled region (Table 1). Overall, native plants in the wild harbor significantly more parasitoids per fruit than cultivated plants (López et al. 1999; Aluja et al. 2003).

All 3 species of parasitoids obtained in this work were present on *S. mombin*. This plant species has been reported as an important reservoir of parasitoids in the state of Amapá (Sousa 2015). Considering that 11 samples of *S. mombin* were collected (4.9 kg of fruits) and that 368 specimens of parasitoids were obtained from these samples, this means that 75.1 parasitoids were obtained per kilogram of fruit. The greatest number of parasitoids obtained to date from *S. mombin* in the Brazilian Amazon was 165 parasitoids per kg of fruit, in the state

Table 4. Occurrence of *Bactrocera carambolae* (samples collected/samples infested) on plant species sampled on Ilha de Santana, Amapá, Brazil (Jan to Jul 2015).

Location[a]	Hosts	Jan	Feb	Mar	Apr	May	Jun	Jul	Total	%
E_1	*Averrhoa carambola*	1/1	1/1	1/1	1/0	—	—	—	4/3	75.0
	Citrus aurantium	1/0	—	—	—	—	1/0	—	2/0	0
	Eugenia uniflora	—	1/1	1/0	1/1	1/1	1/1	2/1	7/5	71.4
	Malpighia emarginata	2/2	2/2	—	1/1	1/1	1/0	1/1	8/7	87.5
	Mangifera indica	1/0	1/0	1/0	—	—	—	—	3/0	0
	Psidium guajava	1/0	2/0	1/1	2/1	1/0	1/1	—	8/3	37.5
	Spondias mombin	1/0	1/0	—	—	—	—	—	2/0	0
	Subtotal	7/3	8/4	4/2	5/3	3/2	4/2	3/2	34/18	52.9
E_2	*Byrsonima crassifolia*	1/0	1/0	1/0	—	1/0	—	—	4/0	0
	Citrus limon	—	1/0	1/0	—	—	—	—	2/0	0
	Eugenia uniflora	—	1/0	—	—	—	—	1/0	2/0	0
	Malpighia emarginata	2/1	2/2	2/2	—	1/1	1/0	1/1	9/7	77.7
	Passiflora sp.	1/0	1/0	1/0	—	1/0	—	—	4/0	0
	Psidium guajava	2/0	2/0	3/2	1/1	1/0	2/0	2/0	13/3	23.1
	Spondias mombin	—	1/0	—	—	—	—	—	1/0	0
	Subtotal	6/1	9/2	8/4	1/1	4/1	3/0	4/1	35/10	31.0
E_3	*Averrhoa carambola*	—	1/1	1/0	—	—	—	—	2/1	50.0
	Capsicum baccatum	—	—	—	1/0	—	1/0	1/0	3/0	0
	Citrus limon	—	—	1/0	—	—	—	—	1/0	0
	Inga edulis	—	—	1/0	—	—	—	—	1/0	0
	Malpighia emarginata	1/1	1/0	—	—	—	1/0	1/1	4/2	50.0
	Mangifera indica	—	1/0	2/0	2/1	—	—	—	5/1	20.0
	Morinda citrifolia	—	1/0	1/0	1/0	—	—	—	3/0	0
	Passiflora sp.	—	1/0	1/0	1/0	—	1/0	1/0	5/0	0
	Psidium guajava	1/0	1/0	1/1	2/1	2/2	1/1	1/0	9/5	55.6
	Spondias mombin	1/0	1/0	1/1	—	—	—	—	3/1	33.3
	Subtotal	3/1	7/1	9/2	7/2	2/2	4/1	4/1	36/10	27.8
E_4	*Averrhoa bilimbi*	—	1/0	—	—	—	—	—	1/0	0
	Citrus aurantium	1/0	1/0	1/0	—	—	—	—	3/0	0
	Citrus limon	—	—	—	1/0	—	—	—	1/0	0
	Malpighia emarginata	1/0	1/0	1/0	1/1	1/1	—	—	5/2	40.0
	Mangifera indica	—	1/0	1/0	1/0	—	—	—	3/0	0
	Morinda citrifolia	1/0	1/0	1/0	1/0	—	1/0	—	5/0	0
	Passiflora sp.	—	1/0	1/0	1/0	—	1/0	—	4/0	0
	Persea americana	1/0	1/0	—	—	—	1/0	—	3/0	0
	Psidium guajava	—	—	—	2/2	1/0	—	—	3/2	66.7
	Spondias mombin	1/0	1/0	1/0	1/0	1/0	—	—	5/0	0
	Spondias purpurea	—	—	1/0	—	—	—	—	1/0	0
	Subtotal	5/0	8/0	7/0	8/3	3/1	3/0	—	34/4	11.8
E_5	*Malpighia emarginata*	—	—	—	—	1/1	—	—	1/1	100
	Psidium guajava	—	—	—	—	1/1	—	—	1/1	100
	Syzygium cumini	—	—	—	—	3/3	—	—	3/3	100
	Subtotal	—	—	—	—	5/5			5/5	100
P_1	*Licania* sp.	—	—	—	1/1	1/0	—	1/0	3/1	33.3
P_2	*Bellucia grossularioides*	—	—	—	—	—	—	1/0	1/0	0
P_3	*Hancornia speciosa*	—	—	—	—	—	—	1/0	1/0	0
	Overall Total	21	32	28	22	18	14	14	149/48	32.2

[a] E = Rural establishment = E_1 to E_5; P = Isolated collection point = P_1 to P_3.

of Roraima (Marsaro Júnior et al. 2011). However, these are low values if compared with those reported by López et al. (1999) in Mexico (207 parasitoids per kg of fruit).

Two of the 3 samples of *Licania* sp. fruits were infested by fruit flies (presence of puparia). Four puparia were obtained from 1 sample, from which emerged 2 specimens of *B. carambolae*. Only parasitoids emerged from the other sample (2 specimens of *D. areolatus* and 1 unknown specimen). This finding merits special attention, as it suggests that at least 1 parasitoid species may be infesting larvae of *B. carambolae*. However, this cannot yet be positively affirmed. Should this be confirmed by an additional study, it will be the first report of a natural parasitoid of *B. carambolae* in Brazil, given that, up to the present time, no native parasitoid has been reported for this species (Adaime et al. 2014a). Lemos (2014) individually observed 1,262 puparia of *B. carambolae* in Amapá, originating from 9 plant species, without obtaining any parasitoid specimens. In Suriname and French Guyana, there is

also no indication of native parasitoids specifically attacking larvae of *B. carambolae* (Sauers-Müller 2005; Vayssières et al. 2013). However, Vayssières et al. (2013) considered the hypothesis that parasitoids do attack immatures of *Bactrocera*, but do not successfully develop due to poor adaptation to this host or the immune response of its larvae. According to their observations, the only species of parasitoid to emerge from pupae of *B. carambolae* was *Diachasmimorpha longicaudata* (Ashmead) (Hymenoptera: Braconidae), which was introduced to the region in the year 2000.

We did not detect any parasitoids in Lonchaeidae in this work, although species of Eucoilinae (Figitidae) have already been reported in association with frugivorous larvae of *Neosilba* in Brazil (Uchôa 2012).

HOST PLANT USE BY *B. CARAMBOLAE*

Among the 8 plant species identified as hosts of *B. carambolae* in this study, 5 (*S. mombin*, *M. indica*, *M. emarginata*, *P. guajava*, and *A. carambola*) were also sampled on Ilha de Santana by Silva et al. (2007), without being infested by the pest. The authors collected 5 samples of *A. carambola* (416 fruits, 9.2 kg) and 9 samples of *M. emarginata* (2,741 fruits, 14.4 kg) but did not obtain any puparia. This suggests that the composition of fruit fly species at this locality has changed in the 10 yr interval between the 2 surveys.

Bactrocera carambolae infested 70.4% of the samples of *M. emarginata* (19 out of 27 samples), 66.7% of the samples of *A. carambola* (4 out of 6 samples), 55.5% of the samples of *E. uniflora* (5 out of 9 samples), and 41.2% of the samples of *P. guajava* (14 out of 34 samples) (Table 3).

Analyzing the percentages of occurrence of *B. carambolae* when compared with other fruit flies (Table 3), we can assume the pest to prefer hosts that are not infested by other species. This is clearly illustrated by noting that *B. carambolae* was the only species to infest *A. carambola*, *E. uniflora*, *Licania* sp., and *M. indica* in this study. In addition, when *B. carambolae* infests hosts that are strongly associated with a given species of fruit fly, such as *S. mombin* with *A. obliqua*, or *P. guajava* with *A. striata*, its percentage of occurrence is very low.

Averrhoa carambola, *E. uniflora*, *M. emarginata*, and *P. guajava* are responsible for sustaining the population of *B. carambolae* in the sampled areas (Tables 2 and 4). In the case of *A. carambola*, the availability of fruits and consequent infestation occurred in the initial months of the year. In the case of the other plant species mentioned, particularly *M. emarginata*, fruits were available throughout the sampling period.

Bactrocera carambolae was found at all 5 sampled rural establishments and at 1 of the 3 isolated collection points (Table 4). The percentage of samples infested by *B. carambolae* at each establishment or isolated collection point ranged from 11.8% (E_4) to 100% (E_5). The number of samples infested by the pest varied according to sampling month, peaking in Apr and May, with 10 and 11 samples infested, respectively (Table 4).

On *M. indica* (unidentified genetic material, not grafted), although 11 samples were collected (80 fruits, 14.4 kg), only 7 puparia were obtained, originating from a single sample collected in Apr in establishment E_3 (Table 4) and from which emerged only a single specimen of *B. carambolae*. Lemos (2014) also sampled fruits of *M. indica* (50 fruits, unidentified genetic material, not grafted) in 3 municipalities in Amapá without observing any infestation. On the other hand, Lemos et al. (2014) obtained 22 puparia and 19 adults of *B. carambolae* from a single fruit of *M. indica* (Tommy Atkins cultivar), reporting an infestation rate of 28.5 puparia per kg. This relationship merits further investigation, as the origins of the genetic materials cultivated in the region are unknown, as is their potential resistance to *B. carambolae*. The low rate of tephritid infestation on *M. indica* can be at least partly explained by the density of laticiferous ducts present on the epicarp and mesocarp of the fruit, which has a toxic effect on eggs and larvae, as shown by Joel (1980, 1981) for *C. capitata* and by Adaime et al. (2014b) for *A. obliqua* and *Anastrepha ludens* (Loew). These topics should therefore be studied further, especially considering that *M. indica* is widely used for urban landscaping in Macapá and Santana, municipalities that contain over 70% of the population of the state of Amapá. If their genetic materials are susceptible to infestation by the carambola fruit fly, these trees used in urban landscaping could be responsible for sustaining elevated populations of the pest.

Finally, it should be noted that *B. carambolae* seems to be adapting to infest native hosts in the Amazon, such as *Licania* sp. Lemos et al. (2014) highlighted this same fact, mentioning infestations on *Eugenia stipitata* McVaugh (Myrtaceae) and *Pouteria macrophylla* (Lam.) Eyma (Sapotaceae) in the state of Amapá. In both reports, although *B. carambolae* infested native plants, the fact that they were not located in completely unaltered environments should be taken into account.

In conclusion, the most important species of fruit flies on Ilha de Santana are: *B. carambolae*, for being a species of quarantine importance; and *A. obliqua* and *A. striata*, for infesting plant species of local socioeconomic importance (*S. mombin* and *P. guajava*, respectively). Species of *Neosilba*, though potential pests, are not abundant at the sampled locality. In addition, we can conclude that *A. carambola*, *E. uniflora*, *M. emarginata*, and *P. guajava* are responsible for sustaining the population of *B. carambolae* in the sampled areas.

Acknowledgments

We extend our thanks to agricultural technician Marcelo Luiz de Oliveira at Embrapa Amapá for support during the fruit sampling expeditions. We thank Pedro Carlos Strikis for Lonchaeidae identification. We acknowledge the Brazilian Council for Scientific and Technological Development–CNPq for the Research Productivity Fellowship granted to R. Adaime.

References Cited

Adaime R, Jesus-Barros CR, Lima AL. 2014a. Pesquisas com a mosca-da-carambola no Brasil: estado da arte e perspectivas futuras, http://ainfo.cnptia.embrapa.br/digital/bitstream/item/119878/1/CPAF-AP-2014-Pesquisas-com-mosca-da-carambola.pdf *In* Anais do XXV Congresso Brasileiro de Entomologia. SEB/Embrapa Arroz e Feijão/UFG, Goiânia, Goiás, Brazil.

Adaime R, Birke A, Guillén L, Ortega F, Velázquez O, Angeles G, Aluja M. 2014b. Effect of mango breeding on laticiferous duct density and sap content/pressure and its consequences on infestation by two polyphagous fruit flies (Diptera: Tephritidae), p. 147. *In* Abstract Book of 15th International Symposium on Insect–Plant Relationships, University of Neuchâtel, Neuchâtel, Switzerland.

Aluja M. 1994. Bionomics and management of *Anastrepha*. Annual Review of Entomology 39: 155–178.

Aluja, M, Mangan RL. 2008. Fruit fly (Diptera: Tephritidae) host status determination: critical conceptual, methodological, and regulatory considerations. Annual Review of Entomology 53: 473–502.

Aluja M, Norrbom AL. 2000. Fruit Flies (Tephritidae): Phylogeny and Evolution of Behavior. CRC Press, Boca Raton, Florida.

Aluja M, Rull J, Sivinski J, Norrbom AL, Wharton RA, Macías-Ordóñez R, DíazFleischer F, López M. 2003. Fruit flies of the genus *Anastrepha* (Diptera: Tephritidae) and associated native parasitoids (Hymenoptera) in the tropical rainforest biosphere reserve of Montes Azules, Chiapas, Mexico. Environmental Entomology 32: 1377–1385.

Aluja M, Ovruski SM, Sivinski J, Córdova-Garcia G, Schliserman P, Núñez-Campero S, Ordano M. 2013. Inter-specific competition and competition-free space in the tephritid parasitoids *Utetes anastrephae* and *Doryctobracon areolatus* (Hymenoptera: Braconidae: Opiinae). Ecological Entomology 38: 485–496.

Amorim JEL, Silva NM, Ronchi-Teles B. 2004. Diversidade de espécies de *Anastrepha* (Diptera: Tephritidae), seus parasitóides e hospedeiros em quintais agroflorestais no Estado de Roraima, p. 651 *In* Anais do XX Congresso Brasileiro de Entomologia. Sociedade Entomológica do Brasil, Gramado, Rio Grande do Sul, Brazil.

Araújo EL, Zucchi RA. 2002. Hospedeiros e níveis de infestação de *Neosilba pendula* (Bezzi) (Diptera: Lonchaeidae) na região de Mossoró/Assu, RN. Arquivos do Instituto Biológico 69: 91–94.

Brazil. 2013. Instrução Normativa N.º 59, de 18 de dezembro de 2013. Diário Oficial [da] República Federativa do Brasil, Brasília, DF, 19 dez. 2013, Seção 1: 91– 92.

Canal NA, Zucchi RA. 2000. Parasitoides – Braconidae, pp. 119–126 *In* Malavasi A, Zucchi RA [eds.], Moscas-das-frutas de importância econômica no Brasil: conhecimento básico e aplicado. Holos, Ribeirão Preto, São Paulo, Brazil.

Deus EG, Adaime R. 2013. Dez anos de pesquisas sobre moscas-das-frutas (Diptera:Tephritidae) no estado do Amapá: avanços obtidos e desafios futuros. Biota Amazônia 3: 157–168.

Deus EG, Silva RA, Nascimento DB, Marinho CF, Zucchi RA. 2009. Hospedeiros e parasitóides de espécies de *Anastrepha* (Diptera, Tephritidae) em dois municípios do Estado do Amapá. Revista de Agricultura 84: 194–203.

Deus EG, Pinheiro LS, Lima CR, Sousa MSM, Guimarães JA, Strikis PC, Adaime R. 2013. Wild hosts of frugivorous dipterans (Tephritidae and Lonchaeidae) and associated parasitoids in the Brazilian Amazon. Florida Entomologist 96: 1621–1625.

Deus EG, Sousa MSM, Adaime R. 2016. Taperebá, pp. 260–265 *In* Silva NM, Adaime R, Zucchi RA [eds.], Pragas Agrícolas e Florestais na Amazônia. Embrapa, Brasília, Distrito Federal, Brazil.

Drew RAI, Hancock DL. 1994. The *Bactrocera dorsalis* complex of fruit flies (Diptera: Dacinae) in Asia. Bulletin of Entomological Research, Supplement Series 2: 1–68.

Fidalgo O, Bononi VLR. 1984. Técnicas de coleta**,** preservação e herborização de material botânico*.* Instituto de Botânica, São Paulo, Brazil.

Godoy MJS, Pacheco WSP, Portal RR, Pires Filho JM, Moraes LMM. 2011. Programa Nacional de Erradicação da Mosca-da-Carambola, pp. 134–158 *In* Silva RA, Lemos WP, Zucchi RA [eds.], Moscas-das-frutas na Amazônia brasileira: diversidade, hospedeiros e inimigos naturais. Embrapa Amapá, Macapá, Amapá, Brazil.

Jesus-Barros CR, Adaime R, Oliveira MN, Silva WR, Costa-Neto SV, Souza-Filho MF. 2012. *Anastrepha* (Diptera: Tephritidae) species, their hosts and parasitoids (Hymenoptera: Braconidae) in five municipalities of the state of Amapá, Brazil. Florida Entomologist 95: 694–705.

Joel DM. 1980. Resin ducts in the mango fruits: a defense system. Journal of Experimental Botany 30: 1707–1718.

Joel DM. 1981. The duct systems of the base and stalk of the mango fruit. Botanical Gazette 142: 329–333.

Lemos LN. 2014. Moscas-das-frutas (Diptera: Tephritidae e Lonchaeidae) em sistemas de cultivo e entorno no Estado do Amapá, Brasil. 78 pp. Thesis (Ph.D.), Fundação Universidade Federal do Amapá, Programa de Pós-Graduação em Biodiversidade Tropical, Brazil.

Lemos LN, Lima CR, Deus EG, Silva RA, Godoy MJS. 2010. Novos registros de hospedeiros para *Bactrocera carambolae* (Diptera: Tephritidae) no Estado do Amapá, Brasil. *In* Anais do XXIII Congresso Brasileiro de Entomologia. EMPARN/Sociedade Brasileira de Entomologia. Natal, Rio Grande do Norte, Brazil. 1 CD ROM.

Lemos LN, Adaime R, Jesus-Barros CR, Deus EG. 2014. New hosts of *Bactrocera carambolae* (Diptera: Tephritidae) in Brazil. Florida Entomologist 97: 841–847.

Lemos LN, Lima CR, Adaime R, Costa-Neto R, Jesus CR, Strikis PC. 2015. New findings on Lonchaeidae (Diptera: Tephritoidea) in the Brazilian Amazon. Florida Entomologist 98: 1227–1237.

López M, Aluja M, Sivinski J. 1999. Hymenopterous larval-pupal and pupal parasitoids of *Anastrepha* flies (Diptera: Tephritidae) in Mexico. Biological Control 15: 119–129.

Malavasi A. 2000. Áreas-Livres ou de baixa prevalência, pp. 175–181 *In* Malavasi A, Zucchi RA [eds.], Moscas-das-frutas de importância econômica no Brasil: conhecimento básico e aplicado. Holos, Ribeirão Preto, Piracicaba, São Paulo, Brazil.

Marinho CF, Silva RA, Zucchi RA. 2011. Chave de identificação de Braconidae (Alysiinae e Opiinae) parasitoides de larvas frugívoras na região Amazônica, pp. 91–101 *In* Silva RA, Lemos WP, Zucchi RA [eds.], Moscas-das-frutas na Amazônia brasileira: diversidade, hospedeiros e inimigos naturais. Embrapa Amapá, Macapá, Amapá, Brazil.

Marsaro Júnior AL, Adaime R, Ronchi-Teles B, Lima CR, Pereira PRVS. 2011. *Anastrepha* species (Diptera: Tephritidae), their hosts and parasitoids in the extreme north of Brazil. Biota Neotropica 11: 117–124.

Marsaro Junior AL, Deus EG, Ronchi-Teles B, Adaime R, Silva Junior RJ. 2013. Species of *Anastrepha* (Diptera: Tephritidae) captured in a guava orchard (*Psidium guajava* L., Myrtaceae) in Boa Vista, Roraima, Brazil. Brazilian Journal of Biology 73: 879–886.

McAlpine JF, Steyskal GC. 1982. A revision of *Neosilba* McAlpine with a key to the world genera of Lonchaeidae (Diptera). The Canadian Entomologist 114: 105–137.

Ohashi OS, Dohara R, Zucchi RA, Canal NA. 1997. Ocorrência de *Anastrepha obliqua* (Macquart, 1835) (Dip, Tephritidae) em acerola (*Malpighia punicifolia* L.) no Estado do Pará. Anais da Sociedade Entomológica do Brasil 26: 389–390.

Ovruski SM, Wharton R, Schliserman P, Aluja M. 2005. Abundance of *Anastrepha fraterculus* (Diptera: Tephritidae) and its associated native parasitoids (Hymenoptera) in feral guavas growing in the endangered northernmost Yungas forests of Argentina with an update on the taxonomic status of Opiinae parasitoid previously reported in this country. Environmental Entomology 34: 807–818.

Pereira JF, Adaime R. 2016. Lonchaeidae from Brazilian Amazon. Available at: http://lonchaeidae.cpafap.embrapa.br (updated 7 Jan 2016; last accessed 8 Jan 2016).

Sauers- Müller A van. 2005. Host plants of the carambola fruit fly, *Bactrocera carambolae* Drew & Hancock (Diptera: Tephritidae), in Suriname, South America. Neotropical Entomology 34: 203–214.

Silva NM, Ronchi-Teles B. 2000. Amapá, Amazonas, Pará, Rondônia e Roraima, pp. 203–209 *In* Malavasi A, Zucchi RA [eds.], Moscas-das-frutas de importância econômica no Brasil: conhecimento básico e aplicado. Holos, Ribeirão Preto, São Paulo, Brazil.

Silva RA, Jordão AL, Sá LAN, Oliveira MRV. 2004. Mosca-da-carambola: uma ameaça à fruticultura brasileira. Macapá: Embrapa Amapá. Circular técnica, 31.

Silva RA, Xavier SLO, Souza Filho MF, Silva WR, Nascimento DB, Deus EG. 2007. Frutíferas hospedeiras e parasitoides (Hym. Braconidae) no Ilha de Santana, Estado do Amapá, Brasil. Arquivos do Instituto Biológico 74: 153–156.

Silva RA, Deus EG, Raga A, Pereira JDB, Souza-Filho MF, Costa Neto SV. 2011a. Monitoramento de moscas-das-frutas na Amazônia: amostragem de frutos e uso de armadilhas, pp. 33–47 *In* Silva RA, Lemos WP, Zucchi RA [eds.], Moscas-das-frutas na Amazônia brasileira: diversidade, hospedeiros e inimigos naturais. Embrapa Amapá, Macapá, Amapá, Brazil.

Silva RA, Lemos WP, Zucchi RA [eds.]. 2011b. Moscas-das-frutas na Amazônia Brasileira: Diversidade, Hospedeiros e Inimigos Naturais. Embrapa Amapá, Macapá, Amapá, Brazil.

Silva RA, Deus EG, Pereira JDB, Jesus CR, Souza-Filho MF, Zucchi RA. 2011c. Conhecimento sobre moscas-das-frutas no Estado do Amapá, pp. 223–236 *In* Silva RA, Lemos WP, Zucchi RA [eds.], Moscas-das-frutas na Amazônia Brasileira: Diversidade, Hospedeiros e Inimigos Naturais. Embrapa Amapá, Macapá, Amapá, Brazil.

Silva RA, Lima AL, Xavier SLO, Silva WR, Marinho CF, Zucchi RA. 2011d. *Anastrepha* species (Diptera: Tephritidae), their hosts and parasitoids in southern Amapá State, Brazil. Biota Neotropica 11: 431–436.

Sousa MSM. 2015. Moscas-das-frutas associadas a fruteiras de importância socioeconômica no estado do Amapá. 66 pp. Dissertation (M.Sc.), Fundação Universidade Federal do Amapá, Programa de Pós-Graduação em Desenvolvimento Regional, Brazil.

Strikis PC. 2011. Description of 11 new species of genus *Neosilba* (Diptera: Lonchaeidae) from Brazil, its hosts and geographical distribution. Trends in Entomology 7: 67–79.

Strikis PC, Deus EG, Silva RA, Pereira JDB, Jesus CR, Marsaro Júnior AL. 2011. Conhecimento sobre Lonchaeidae na Amazônia brasileira, pp. 205–215 *In* Silva RA, Lemos WP, Zucchi RA [eds.], Moscas-das-frutas na Amazônia Brasileira: Diversidade, Hospedeiros e Inimigos Naturais. Embrapa Amapá, Macapá, Amapá, Brazil.

Uchôa MA. 2012. Fruit flies (Diptera: Tephritoidea): biology, host plants, natural enemies, and the implications to their natural control, pp. 271–300 *In* Larramendy ML, Soloneski S [eds.], Integrated Pest Management and Pest Control: Current and Future Tactics. InTech, Rijeka, Croatia.

Uchôa MA, Nicácio JN. 2010. New records of Neotropical fruit flies (Tephritidae), lance flies (Lonchaeidae) (Diptera: Tephritoidea), and their host plants in the South Pantanal and adjacent areas, Brazil. Annals of the Entomological Society of America 103: 723–733.

Uramoto K, Zucchi RA. 2009. Taxonomia de espécies de *Anastrepha* (Diptera: Tephritidae), pp. 7–11 *In* Malavasi A, Virgínio J [eds.], Biologia, Monitoramento e Controle: V Curso Internacional de Capacitação em Moscas-das-frutas. Moscamed, Juazeiro, Bahia, Brazil.

Valente MA, Oliveira Júnior RC, Rodrigues TE, Santos PL, Silva JML, Cardoso Júnior EQ. 1998. Solos da ilha de Santana, município de Santana, Estado

do Amapá. Belém: Embrapa- CPATU. 34 p. (Embrapa-CPATU. Documentos, 138).

Vayssières JF, Cayol JP, Caplong P, Séguret J, Midgarden D, Sauers-Muller A van, Zucchi R, Uramoto K, Malavasi A. 2013. Diversity of fruit fly (Diptera: Tephritidae) species in French Guiana: their main host plants and associated parasitoids during the period 1994–2003 and prospects for management. Fruits 68: 219–243.

Zucchi RA. 2001. Mosca-do-mediterrâneo, *Ceratitis capitata* (Diptera: Tephritidae) pp. 15–22 *In* Vilela EF, Zucchi RA, Cantor F [eds.], Histórico e Impacto das Pragas Introduzidas no Brasil. Holos, Ribeirão Preto, São Paulo, Brazil.

Zucchi RA, Uramoto K, Souza-Filho MF. 2011. Chave ilustrada para as espécies de *Anastrepha* da região Amazônica, pp. 71–90 *In* Silva RA, Lemos WP, Zucchi RA [eds.], Moscas-das-frutas na Amazônia Brasileira: Diversidade, Hospedeiros e Inimigos Naturais. Embrapa Amapá, Macapá, Amapá, Brazil.