Frugivorous flies (Diptera: Tephritidae, Lonchaeidae), their host plants, and associated parasitoids in the extreme north of Amapá State, Brazil

Ricardo Adaime[1,2,3,], Maria do Socorro Miranda de Sousa[2], Cristiane Ramos de Jesus-Barros[1], Ezequiel da Glória de Deus[3], José Francisco Pereira[1], Pedro Carlos Strikis[4], and Miguel Francisco de Souza-Filho[5]*

Abstract

We conducted a survey of frugivorous flies (Diptera: Tephritidae and Lonchaeidae), their host plants, and associated parasitoids in the extreme north of Amapá State, Brazil. Fruit were collected from various plant species between May 2011 and Jul 2013. In total, 218 fruit samples were collected (3,915 fruits, 115.6 kg), from 33 plant species (12 native and 21 introduced) in 22 families. Infestation by fruit flies was observed in 69 samples, representing 17 plant species in 13 families. In total, 3,480 puparia were obtained, from which emerged specimens of *Anastrepha* Schiner (6 species; Tephritidae), *Neosilba* McAlpine (4 species; Lonchaeidae), and *Bactrocera carambolae* Drew & Hancock (Tephritidae), as well as wasp parasitoids in the family Braconidae (3 species). This work adds new records of frugivorous flies in the studied area and establishes new relationships between species of frugivorous flies and host plants in the Brazilian Amazon.

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

Resumo

Este trabalho relata as espécies de moscas frugívoras (Tephritidae e Lonchaeidae), suas plantas hospedeiras e parasitoides no extremo-norte do estado do Amapá, Brasil. Foram realizadas coletas de frutos de diversas espécies vegetais, no período de maio de 2011 a julho de 2013. Foram coletadas 218 amostras de frutos (3.915 frutos, 115,6 kg), pertencentes a 33 espécies vegetais (12 nativas e 21 introduzidas) de 22 famílias. Houve infestação por moscas frugívoras em 69 amostras, representadas por 17 espécies vegetais de 13 famílias. Foram obtidos 3.480 pupários, de onde emergiram espécimes de *Anastrepha* Schiner (6 espécies; Tephritidae), *Neosilba* McAlpine (4 espécies; Lonchaeidae), *Bactrocera carambolae* Drew & Hancock (Tephritidae) e parasitoides Braconidae (3 espécies). Este trabalho acrescenta novos registros de moscas frugívoras para a área estudada e estabelece novas relações entre espécies de moscas frugívoras e hospedeiros para a Amazônia brasileira.

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

Fruit flies (Diptera: Tephritidae) are globally known as pests of fruit crops, due to the direct and indirect damage they cause to production (Aluja 1994). The family Tephritidae is comprised of over 5,000 species grouped into 500 genera. Approximately 70 species are confirmed pests, whereas others may potentially cause damage to crops (White & Elson-Harris 1992; Uchôa 2012). The *Anastrepha* Schiner species, *Ceratitis capitata* (Wiedemann) and *Bactrocera carambolae* Drew & Hancock, cause considerable damage to both commercial and non-commercial fruit trees in South America (Zucchi 2001; Vayssières et al. 2013; Lemos et al. 2014).

In recent years, particularly in Brazil, frugivorous dipterans in the family Lonchaeidae have been reported to be primary invaders of commercial plant species. *Neosilba zadolicha* McAlpine & Steyskal, *Neosilba pendula* (Bezzi), *Neosilba glaberrima* (Wiedemann), and *Neosilba perezi* Romero & Ruppel, are currently viewed as pests due to the damage they cause to fruits or other structures of different plant species (Lourenção et al. 1996; Uchôa 2012; Lemos et al. 2015).

To date, 120 species of *Anastrepha* have been reported in Brazil. Among these, only 61 have known host plants, with *Anastrepha fraterculus* (Wiedemann) (110 hosts) and *Anastrepha obliqua* (Macquart) (48 hosts) as the most polyphagous species (Zucchi 2008). *Ceratitis capitata* and *B. carambolae* are the sole representatives of their genera in Brazil (Zucchi 2001). With regards to richness of *Neosilba* McAlpine, 25 species have been reported in the country.

In the Brazilian Amazon, multiple studies on frugivorous dipterans have been conducted in the past 10 yr, advancing knowledge on

[1]Embrapa Amapá, Macapá, Amapá, 68903-419, Brazil; E-mail: ricardo.adaime@embrapa.br (R. A.), cristiane.jesus@embrapa.br (C. R. J.-B.), jose-francisco.pereira@embrapa.br (J. F. P.)
[2]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.)
[3]Universidade Federal do Amapá, Programa de Pós-graduação em Biodiversidade Tropical, Macapá, Amapá, 68902-280, Brazil; E-mail: egd_bio@hotmail.com (E. G. D.)
[4]Independent Researcher, Av. Paschoal Ardito, No. 886, Americana, São Paulo, 13473-010, Brazil; E-mail: pcstrikis@gmail.com (P. C. S.)
[5]Instituto Biológico, Caixa Postal 70, Campinas, São Paulo, 13001-970, Brazil; E-mail: miguelf@biologico.sp.gov.br (M. F. S.-F.)
*Corresponding author; E-mail: ricardo.adaime@embrapa.br (R. A.)

the biology and ecology of Tephritidae and Lonchaeidae (Silva et al. 2011). Seventy six species of *Anastrepha* and 14 species of *Neosilba* have been reported in the region to date (Adaime et al. 2016a; Pereira & Adaime 2016). Twenty-one host plants have been reported for *B. carambolae*, which has a distribution restricted to the states of Amapá and Roraima (Adaime et al. 2016b).

Although knowledge on frugivorous flies in the Amazon has increased significantly, some strategic areas in the region have not yet been duly studied. Among them is the extreme north of Amapá, Brazil, which includes the municipalities of Oiapoque and Calçoene, at the border with French Guiana. This region is extremely important to Brazil, as the flow of people and supplies crossing the border could facilitate the introduction of undesirable insect species. The introduction of the exotic species *B. carambolae* into Brazil exemplifies the vulnerability of this border area. Detected in 1989 in French Guiana, the species has been under official control in Oiapoque since 1996, when it was reported for the first time (Godoy et al. 2011).

Sugayama et al. (2015) stated that the risk of new pests being introduced through the Brazilian border is imminent. In Brazil, a constant concern exists regarding the potential introduction of *Anastrepha suspensa* (Loew), a quarantine pest that is absent in the country, but which is reported to occur in French Guiana. The introduction of this pest into Brazil would entail a closure of foreign markets, particularly for growers of mango (*Mangifera indica* L.; Anacardiaceae). Studies aiming to unveil the richness of fruit fly species and their host plants and natural enemies in this region are essential, as they will permit early detection of invading exotic species and offer supporting data for pest management.

In Oiapoque, although 20 species of *Anastrepha*, *B. carambolae*, and 5 species of parasitoids have been reported, knowledge of the associated hosts is minimal. In Calçoene, there have been reports only of *B. carambolae* and 4 species of *Anastrepha*, without any record of a parasitoid. In both municipalities, no species of Lonchaeidae have been reported to date.

Thus, we conducted a survey of frugivorous fly species (Tephritidae and Lonchaeidae), their host plants, and associated parasitoids, in the extreme north of Amapá State, Brazil.

Materials and Methods

CHARACTERIZATION OF STUDY AREA

The study area is located in the extreme north of the state of Amapá, at the Brazil–French Guiana border, and includes the municipalities of Calçoene and Oiapoque (Fig. 1). Together, these 2 municipalities occupy 25.88% of the total area of Amapá, which is 143,453.7 km^2. Natural domains in the region include dense terra firme forest, floodable areas and savannas (Weiss 2011). The predominant climate in the region, as classified by Köppen, is Af (tropical rainforest), i.e., hot and wet, with a mean temperature of 25 °C, mean annual precipitation of 2,284 mm, and 60 mm or more of precipitation on the driest month. The rainy period is observed from Dec to Jul and the dry period is from Aug to Nov (SUDAM 1984; Diniz 1986).

SAMPLING PROCEDURES

Fruit were collected in the period from May 2011 to Jul 2013. Sampling was conducted at random, with the collection of intact fruits recently fallen to the ground. Geographic coordinates of each sampling site were recorded via a global positioning system device (GPSMAP®78s; Garmin, Schaffhausen, Switzerland). Each sample, comprised of multiple fruits, was stored in a plastic container, wrapped in a fine mesh bag, labeled and subsequently transported to the Plant Protection Laboratory at Embrapa Amapá, in the city of Macapá, Brazil.

ACQUISITION OF PUPARIA AND ADULT INSECTS

In the laboratory, the fruit were counted, weighed and arranged on plastic trays over a thin layer of moistened sand. The trays were covered with fine mesh, which was fastened in place with rubber bands. The fruit and sand were examined every 3 d, and any puparia found were removed and transferred into transparent plastic vials containing a thin layer of moistened vermiculite. The vials were covered with fine mesh and a vented lid before being placed in climate-controlled chambers (27 ± 0.5 °C; 70 ± 10% relative humidity (RH); 12:12 h L:D photoperiod). Fruit flies and parasitoids that emerged were stored in glass vials containing 70% ethanol, for subsequent identification.

IDENTIFICATION OF BIOLOGICAL MATERIAL

Specimens of *Anastrepha* were identified using the illustrated identification key published by Zucchi et al. (2011a). Identification of parasitoids (Braconidae) was based on the Canal & Zucchi (2000) and Marinho et al. (2011). Specimens of *Neosilba* were identified according to McAlpine & Steyskal (1982) and Strikis (2011).

To identify species of forest plants, we collected branches containing their reproductive structures (i.e., flowers and fruits), which were later processed into herbarium specimens using the mounting and preservation techniques described by Fidalgo and Bononi (1984). Plant species were identified through identification keys and comparison with specimens available at the Amapaense Herbarium (HAMAB), the herbarium at the Amapá Institute for Scientific and Technological Research (IEPA) in Macapá, Amapá, Brazil.

DATA ANALYSES

The data obtained were analyzed based on the following calculations: 1) infestation index = puparia obtained / mass of fruits collected, 2) emergence = (number of emerged flies + number of emerged parasitoids) / total number of puparia × 100, and 3) % parasitism = (number of emerged parasitoids / number of puparia) × 100.

Results

In total, 218 fruit samples were collected, a total of 3,915 fruits weighing 115.6 kg, belonging to 33 plant species (i.e., 12 native and 21 introduced) from 22 families (Tables 1 and 2). Infestation by fruit flies was observed in 69 samples (31.7%), belonging to 17 plant species from 13 families (Tables 1 and 2).

In total, 3,480 puparia were obtained, from which emerged specimens of *Anastrepha* (6 species), *Neosilba* (4 species), *B. carambolae*, and wasp parasitoids (3 species; Braconidae).

OIAPOQUE

In total, 126 samples were collected, consisting of 2,754 fruits (84.36 kg) of 29 plant species in 18 families. Infestation by fruit flies was observed in 45 samples (13 plant species in 10 families), from which 2,667 puparia were obtained (Table 1).

The species of Tephritidae obtained were: *Anastrepha coronilli* Carrejo & González, *Anastrepha distincta* Greene, *A. fraterculus*, *Anastrepha leptozona* Hendel, *A. obliqua*, *Anastrepha striata* Schiner, and *B. carambolae* (Table 1).



Fig. 1. Fruit sampling sites in extreme north of Amapá State, Brazil (May 2011–Jul 2013).

Anastrepha obliqua was obtained from *Spondias mombin* Jacq. (Anacardiaceae) and *Averrhoa carambola* L. (Oxalidaceae). *Anastrepha striata* occurred in *Psidium guajava* L. (Myrtaceae) and *Syzygium malaccense* (L.) Merr. & L.M. Perry (Myrtaceae). *Anastrepha coronilli* was obtained from *Bellucia grossularioides* (L.) Triana (Melastomataceae), *A. distincta* from *Inga edulis* Mart. (Fabaceae), *A. leptozona* from *Pouteria caimito* (Ruiz & Pav.) Radlk. (Sapotaceae), and *A. fraterculus* from *P. guajava*. *Bactrocera carambolae* was found in fruits of 4 plant species: *A. carambola*, *Malpighia emarginata* [Moc. & Sesse] ex DC. (Malpighiaceae), *P. guajava,* and *S. malaccense* (Table 1).

Anastrepha represented 61.3% of all tephritids obtained, followed by *Bactrocera* (38.7%). The greatest abundance of tephritids was observed in *P. guajava*, with *A. striata* as the predominant species (Table 1).

Neosilba represented 15.7% of all frugivorous flies obtained in Oiapoque. The species obtained were: *Neosilba bella* Strikis & Prado, *N. glaberrima*, *Neosilba pseudozadolicha* Strikis, and *N. zadolicha* (Table 1).

Neosilba glaberrima was obtained from 5 host species. *Neosilba bella*, *N. pseudozadolicha*, and *N. zadolicha* occurred in 3 hosts (Table 1). Only females were obtained from *Byrsonima crassifolia* (L.) Kunth (Malpighiaceae), *I. edulis*, and *Moutabea chodatiana* Huber (Polygalaceae), making species identification unfeasible.

Specimens of the parasitoid *Doryctobracon areolatus* (Szépligeti) (Hymenoptera: Braconidae) were obtained from fruits of *B. grossularioides*, *P. guajava*, and *S. malaccense* infested by frugivorous flies. The highest percentage of parasitism was observed in *B. grossularioides* (11.4%) (Table 1).

CALÇOENE

In total, 92 samples were collected, consisting of 1,161 fruits (31.24 kg) of 19 plant species in 12 families. Infestation by fruit flies was observed in 24 samples (9 plant species in 7 families), from which 813 puparia were obtained (Table 2).

Table 1. Rates of infestation of various plant species by frugivorous flies (Tephritidae and Lonchaeidae) in Oiapoque, Amapá, Brazil. May 2011 to Jul 2013.

FAMILY Species	Origin in N/I	I/C	Fruits (n)	Mass (kg)	PP (n)	I (PP/kg)	E (%)	Tephritidae (n)	Lonchaeidae (n)	Hymenoptera (n)	P (%)
ANACARDIACEAE											
Anacardium occidentale L.	I	0/10	69	3.60							
Mangifera indica L.	I	2/3	11	2.81	5	1.8	0.0				
Spondias dulcis Soland. Ex Forst. fil.	I	0/3	36	2.10							
Spondias mombin Jacq.	N	2/2	76	0.90	37	41.1	75.7	Ao (12), 16 ♂			
ANNONACEAE											
Annona muricata L.	I	1/2	2	0.91	117	128.6	41.0		Nz (26), Ng (4), Np (1), 17 ♀		
APOCYNACEAE											
Ambelania acida Aubl.	N	0/2	20	0.71							
CARICACEAE											
Carica papaya L.	I	0/7	18	9.99							
CUCURBITACEAE											
Cucumis anguria L.	N	0/8	93	2.26							
Cucumis sativus L.	I	0/3	15	2.11							
Cucurbita sp.	N	0/2	2	1.83							
EUPHORBIACEAE											
Manihot esculenta Crantz	N	0/2	12	0.05							
FABACEAE											
Inga edulis Mart.	N	1/2	6	2.14	62	29.0	83.9	Ad (40), 11 ♂	1 ♀		
MALPIGHIACEAE											
Byrsonima crassifolia (L.) Kunth	N	1/5	552	0.84	1	1.2	100		1 ♀		
Malpighia emarginata [Moc. & Sesse] ex DC.	I	6/12	969	4.13	185	44.8	33.5	Bc (51)	Nb (5), Ng (2), Np (1), 3♀		
MELASTOMATACEAE											
Bellucia grossularioides (L.) Triana	N	3/3	142	1.70	88	51.8	52.3	Ac (19), 17 ♂		Da (10)	11.4
MORACEAE											
Artocarpus heterophyllus Lam.	I	0/4	4	12.54							
MYRTACEAE											
Psidium guajava L.	I	17/18	359	12.83	1,591	124.0	45.8	As (192), Af (9), 238♂ + Bc (75)	Nz (25), Nb (5), Ng (5), 44 ♀	Da (134)	8.4
Syzygium malaccense (L.) Merr. & L.M. Perry	I	3/3	58	1.34	183	136.6	45.9	As (3), 3 ♂ + Bc (77)		Da (1)	0.5
OXALIDACEAE											
Averrhoa bilimbi L.	I	0/1	11	0.16							
Averrhoa carambola L.	I	5/5	56	3.13	315	100.6	59.0	Ao (5), 5 ♂ + Bc (162)	Ng (5), Nb (1), Nz (1), 7 ♀		
PASSIFLORACEAE											
Passiflora edulis Sims (fruit)	N	0/4	20	1.32							
Passiflora edulis Sims (flower bud)	N	0/2	37	0.09							

N: native; I: introduced; I: samples infested; C: samples collected; PP: puparia; I: infestation; E: emergence; P: percentage of parasitism; Ac: *Anastrepha coronilli* Carrejo & González; Ad: *Anastrepha distincta* Greene; Af: *Anastrepha fraterculus* (Wiedemann); Al: *Anastrepha leptozona* Hendel; Ao: *Anastrepha obliqua* (Macquart); As: *Anastrepha striata* (Schiner); Bc: *Bactrocera carambolae* Drew & Hancock (♀, ♂); Nb: *Neosilba bella* Strikis & Prado; Ng: *Neosilba glaberrima* (Wiedemann); Np: *Neosilba pseudozadolicha* Strikis; Nz: *Neosilba zadolicha* McAlpine & Steyskal; Da: *Doryctobracon areolatus* (Szépligeti) (♀, ♂).

Table 1. (Continued) Rates of infestation of various plant species by frugivorous flies (Tephritidae and Lonchaeidae) in Oiapoque, Amapá, Brazil. May 2011 to Jul 2013.

FAMILY Species	Origin in N/I	I/C	Fruits (n)	Mass (kg)	PP (n)	I (PP/kg)	E (%)	Tephritidae (n)	Lonchaeidae (n)	Hymenoptera (n)	P (%)
POLYGALACEAE											
Moutabea chodatiana Huber	N	1/1	21	0.12	9	75.0	77.8		7 ♀		
RUBIACEAE											
Coffea arabica L.	I	0/1	30	0.02							
RUTACEAE											
Citrus aurantium L.	I	0/2	9	5.33							
Citrus reticulata Blanco	I	0/3	28	1.27							
Citrus sinensis (L.) Osbeck	I	1/10	69	7.86	10	1.3	100		Np (4), 6 ♀		
SAPINDACEAE											
Nephelium lappaceum L.	I	0/1	10	0.17							
SAPOTACEAE											
Pouteria caimito (Ruiz & Pav.) Radlk.	N	2/3	9	1.94	64	33.0	20.3	Al (4), 4 ♂	Ng (2), 3♀		
Solanum gilo Raddi	I	0/2	10	0.16							
Total	—	45/126	2.754	84.36	2,667	—	—	As (195 ♀), Ad (40 ♀), Ac (19 ♀), Ao (17 ♀), Af (9 ♀), Al (4 ♀), 294 ♂+ Bc (365)	Nz (52), Ng (18), Nb (11), Np (6), 89 ♀	Da (145)	—

N: native; I: introduced; I: samples infested; C: samples collected; PP: puparia; I: infestation; E: emergence; P: percentage of parasitism; Ac: *Anastrepha coronilli* Carrejo & González; Ad: *Anastrepha distincta* Greene; Af: *Anastrepha fraterculus* (Wiedemann); Al: *Anastrepha leptozona* Hendel; Ao: *Anastrepha obliqua* (Macquart); As: *Anastrepha striata* (Schiner); Bc: *Bactrocera carambolae* Drew & Hancock (♀,♂); Nb: *Neosilba bella* Strikis & Prado; Ng: *Neosilba glaberrima* (Wiedemann); Np: *Neosilba pseudozadolicha* Strikis; Nz: *Neosilba zadolicha* McAlpine & Steyskal; Da: *Doryctobracon areolatus* (Szépligeti) (♀,♂).

Table 2. Rates of infestation of various plant species by frugivorous flies (Tephritidae and Lonchaeidae) in Calçoene, Amapá, Brazil. May 2011 to Jul 2013.

FAMILY Species	Origin N/I	I/C	Fruits (n)	Mass (kg)	PP (n)	I (PP/kg)	E (%)	Tephritidae (n)	Lonchaeidae (n)	Hymenoptera (n)	P (%)
ANACARDIACEAE											
Anacardium occidentale L.	I	1/11	45	3.28	4	1.2	100		Ng (2), Np (1), 1 ♀		
Mangifera indica L.	I	0/2	5	1.32							
Spondias mombin Jacq.	N	3/3	51	0.67	41	61.2	53.7	Ao (8), 12 ♂		Ua (2)	4.9
CHRYSOBALANACEAE											
Chrysobalanus icaco L.	N	0/2	77	0.21							
COMBRETACEAE											
Terminalia catappa L.	I	0/1	20	0.31							
CUCURBITACEAE											
Cucumis anguria L.	N	1/11	131	2.49	2	0.8	100		Np (1), 1 ♀		
Cucumis sativus L.	I	0/9	32	4.32							
LAURACEAE											
Persea americana Mill.	I	1/1	5	0.39	1	2.6	100		1 ♀		
MALPIGHIACEAE											
Byrsonima crassifolia (L.) Kunth	N	0/1	30	0.05							
Malpighia emarginata [Moc. & Sesse] ex DC.	I	0/4	70	0.16							
MELASTOMATACEAE											
Bellucia grossularioides (L.) Triana	N	4/4	140	1.89	80	42.3	65.0	Ac (15), 24 ♂		Da (11), Ob (2)	16.3
MYRTACEAE											
Psidium guajava L.	I	9/10	132	4.77	525	110.0	66.9	As (160), Af (2), 173 ♂ + Bc (8)	1 ♀	Da (7)	1.3
Syzygium malaccense (L.) Merr. & L.M. Perry	I	2/2	20	0.60	81	135.0	29.6	Bc (16)	Np (3), 5 ♀		
OXALIDACEAE											
Averrhoa carambola L.	I	1/3	17	0.74	74	100.0	87.8	Bc (61)	4 ♀		
RUBIACEAE											
Coffea arabica L.	I	0/2	81	0.05							
RUTACEAE											
Citrus aurantium L.	I	0/3	14	1.79							
Citrus reticulata Blanco	I	0/3	22	2.59							
Citrus sinensis (L.) Osbeck	I	0/6	39	5.05							
SOLANACEAE											
Capsicum chinense Jacq.	I	2/14	230	0.54	5	9.3	100		Ng (1), Np(1), 3 ♀		
Total	—	24/92	1,161	31.24	813	—	—	As (160 ♀), Ac (15 ♀), Ao (8 ♀), Af (2 ♀), 209 ♂ + Bc (77)	Np (6), Ng (3), 16♀	Da (18), Ob (2), Ua (2)	—

N: native; I: introduced; I: samples infested; C: samples collected; PP: puparia; I: infestation; E: emergence; P: percentage of parasitism; Ac: *Anastrepha coronilli* Carrejo & González; Af: *Anastrepha fraterculus* (Wiedemann); Ao: *Anastrepha obliqua* (Macquart); As: *Anastrepha striata* (Schiner); Bc: *Bactrocera carambolae* Drew & Hancock (♀, ♂); Ng: *Neosilba glaberrima* (Wiedemann); Np: *Neosilba pseudozadolicha* Strikis; Da: *Doryctobracon areolatus* (Szépligeti) (♀, ♂); Ob: *Opius bellus* Gahan (♀, ♂); Ua: *Utetes anastrephae* (Viereck) (♀, ♂).

Table 3. List of frugivorous flies (Tephritidae and Lonchaeidae) and their host plants recorded in the municipality of Oiapoque, Amapá, Brazil.

Species	Sampling Method	Host	Reference
Anastrepha amita Zucchi	McPhail	—	Trindade & Uchôa (2011)
Anastrepha binodosa Stone	McPhail	—	Trindade & Uchôa (2011)
Anastrepha coronilli Carrejo & González	Fruit	*Bellucia grossularioides* (L.) Triana	Ronchi—Teles et al. (1996), Trindade & Uchôa (2011), present paper
Anastrepha dissimilis Stone	McPhail	—	Trindade & Uchôa (2011)
Anastrepha distincta Greene	McPhail	—	Trindade & Uchôa (2011)
	Fruit	*Inga edulis* Mart.	present paper
Anastrepha duckei Lima	McPhail	—	Trindade & Uchôa (2011)
Anastrepha flavipennis Greene	McPhail	—	Trindade & Uchôa (2011)
Anastrepha fraterculus (Wiedemann)	McPhail	—	Trindade & Uchôa (2011)
	Fruit	*Psidium guajava* L.	present paper
Anastrepha furcata Lima	McPhail	—	Trindade & Uchôa (2011)
Anastrepha leptozona Hendel*	Fruit	*Pouteria caimito* (Ruiz & Pav.) Radlk.	present paper
Anastrepha minensis Lima	McPhail	—	Trindade & Uchôa (2011)
Anastrepha mixta Zucchi	McPhail	—	Trindade & Uchôa (2011)
Anastrepha obliqua (Macquart)	McPhail	—	Trindade & Uchôa (2011)
	Fruit	*Averrhoa carambola* L.	present paper
	Fruit	*Spondias mombin* Jacq.	present paper
Anastrepha oiapoquensis Norrbom & Uchôa	McPhail	—	Trindade & Uchôa (2011), Norrbom & Uchôa (2011)
Anastrepha pseudoparallela (Loew)	McPhail	—	Trindade & Uchôa (2011)
Anastrepha rafaeli Norrbom & Korytkowski	McPhail	—	Trindade & Uchôa (2011)
Anastrepha siculigera Norrbom & Uchôa	McPhail	—	Trindade & Uchôa (2011)
Anastrepha sororcula Zucchi	McPhail	—	Trindade & Uchôa (2011)
Anastrepha striata Schiner	Fruit	*Psidium guajava* L.	Ronchi—Teles (2000), Creão (2003), present paper
	Fruit	*Syzygium malaccense* (L.) Merr. & L.M. Perry **	present paper
Anastrepha submunda Lima	McPhail	—	Trindade & Uchôa (2011)
Anastrepha turpiniae Stone	Fruit	*Spondias mombin* Jacq.	Creão (2003)
Bactrocera carambolae Drew & Hancock	—	—	Ronchi—Teles (2000)
	Fruit	*Averrhoa carambola* L.	Creão (2003), present paper
	Fruit	*Malpighia emarginata* [Moc. & Sesse] ex DC.	present paper
	Fruit	*Psidium guajava* L.	present paper
	Fruit	*Syzygium malaccense* (L.) Merr. & L.M. Perry	present paper
Neosilba bella Strikis & Prado*	Fruit	*Malpighia emarginata* [Moc & Sesse] ex DC.	present paper
	Fruit	*Psidium guajava* L.	present paper
	Fruit	*Averrhoa carambola* L.	present paper
Neosilba glaberrima (Wiedemann)*	Fruit	*Annona muricata* L.	present paper
	Fruit	*Averrhoa carambola* L.	present paper
	Fruit	*Malpighia emarginata* [Moc & Sesse] ex DC.	present paper
	Fruit	*Pouteria caimito* (Ruiz & Pav.) Radlk.	present paper
	Fruit	*Psidium guajava* L.	present paper
Neosilba pseudozadolicha Strikis*	Fruit	*Annona muricata* L.**	present paper
	Fruit	*Citrus sinensis* (L.) Osbeck.	present paper
	Fruit	*Malpighia emarginata* [Moc. & Sesse] ex DC.	present paper
Neosilba zadolicha McAlpine & Steyskal*	Fruit	*Annona muricata* L.	present paper
	Fruit	*Averrhoa carambola* L.	present paper
	Fruit	*Psidium guajava* L.	present paper

* First report of occurrence in this municipality.
** New association between this fly and host in the Brazilian Amazon.

The species of Tephritidae obtained were: *A. coronilli, A. fraterculus, A. obliqua, A. striata,* and *B. carambolae* (Table 2).

Anastrepha coronilli was obtained from *B. grossularioides*, *A. fraterculus* from *P. guajava*, *A. obliqua* from *S. mombin*, and *A. striata* from *P. guajava*. *Bactrocera carambolae* was found in fruits of 3 plant species: *A. carambola*, *P. guajava*, and *S. malaccense* (Table 2).

Species of *Anastrepha* represented 83.7% of all tephritids obtained, followed by *B. carambolae* (16.3%). The highest abundance of tephritids was observed in *P. guajava*, with *A. striata* as the predominant species (Table 2).

Species of *Neosilba* represented 5.0% of all frugivorous flies obtained. The species obtained were *N. glaberrima* and *N. pseudozadolicha* (Table 2).

Neosilba glaberrima was found in *Anacardium occidentale* L. (Anacardiaceae) and *Capsicum chinense* Jacq. (Solanaceae). *Neosilba pseudozadolicha* was obtained from *A. occidentale*, *C. chinense*, *Cucumis anguria* L. (Cucurbitaceae), and *S. malaccense* (Table 2). Only females were obtained from *A. carambola*, *Persea americana* Mill. (Lauraceae) and *P. guajava*, making species identification unfeasible.

Table 4. List of frugivorous flies (Tephritidae and Lonchaeidae) and their host plants reported in the municipality of Calçoene, Amapá, Brazil.

Species	Sampling Method	Host	Reference
Anastrepha coronilli Carrejo & González	Fruit	*Bellucia grossularioides* (L.) Triana	Deus et al. (2013), present paper
	Fruit	*Bellucia imperialis* Saldanha & Cogn	Deus et al. (2013)
Anastrepha fraterculus (Wiedemann)	Fruit	*Simaba guianensis* Aubl.	Deus et al. (2013)
	Fruit	*Psidium guajava* L.	present paper
Anastrepha obliqua (Macquart)*	Fruit	*Spondias mombin* Jacq.	present paper
Anastrepha parishi Stone	Fruit	*Simaba guianensis* Aubl.	Deus et al. (2013)
Anastrepha striata Schiner	Fruit	*Inga edulis* Mart.	Creão (2003)
	Fruit	*Psidium guajava* L.	Creão (2003), present paper
Bactrocera carambolae Drew & Hancock	Fruit	*Psidium guajava* L.	present paper
	Fruit	*Syzygium malaccense* (L.) Merr. & L.M. Perry	present paper
	Fruit	*Averrhoa carambola* L.	present paper
Neosilba glaberrima (Wiedemann)*	Fruit	*Anacardium occidentale* L.**	present paper
	Fruit	*Capsicum chinense* Jacq.**	present paper
Neosilba pseudozadolicha Strikis*	Fruit	*Anacardium occidentale* L.**	present paper
	Fruit	*Cucumis anguria* L.**	present paper
	Fruit	*Syzygium malaccense* (L.) Merr. & L.M. Perry	present paper
	Fruit	*Capsicum chinense* Jacq.	present paper

* First report of occurrence in this municipality.
** New association between this fly and host in the Brazilian Amazon.

Specimens of the parasitoids *D. areolatus*, *Opius bellus* Gahan, and *Utetes anastrephae* (Viereck) (Hymenoptera: Braconidae) were obtained from fruits of *B. grossularioides*, *P. guajava*, and *S. mombin* infested by frugivorous flies. The highest percentage of parasitism was observed in *B. grossularioides* (16.3%) (Table 2).

Discussion

Anastrepha striata was the predominant species in both municipalities, due to its association with *P. guajava*, an abundantly sampled plant species (Tables 1 and 2). This strong association between *A. striata* and *P. guajava* already has been reported in the Brazilian Amazon (Silva et al. 2011; Marsaro Júnior et al. 2013). *Anastrepha striata* also infested *S. malaccense* in Oiapoque, an unprecedented observation in the Brazilian Amazon.

Bactrocera carambolae was abundant, especially in Oiapoque. The species infested 4 hosts (*A. carambola*, *M. emarginata*, *P. guajava*, and *S. malaccense*) (Tables 1 and 2), all of which have already been reported in Amapá (Morais et al. 2016). *Anastrepha obliqua* was associated exclusively sampled with fruits of *S. mombin*, infesting all samples collected (Tables 1 and 2). *Anastrepha obliqua* is viewed as the main pest of this plant (Deus et al. 2016). This species also was found in *A. carambola*, an association already reported in Amapá (Zucchi et al. 2011b). *Anastrepha fraterculus* was obtained from guava fruits in both municipalities (Tables 1 and 2), always with a low abundance of specimens, confirming the results of other studies conducted in Amapá (Deus & Adaime 2013). *Anastrepha coronilli* was obtained only from fruits of *B. grossularioides*, in both municipalities (Tables 1 and 2). This association has been observed frequently in the Brazilian Amazon (Zucchi et al. 2011b). *Anastrepha leptozona* and *A. distincta* were observed only in Oiapoque (Table 1), associated with their most typical hosts in the region, namely *P. caimito* and *I. edulis*, respectively (Zucchi et al. 2011b). Among the Lonchaeidae obtained, *N. glaberrima* and *N. zadolicha* are the most polyphagous species in the Amazon region (Strikis et al. 2011; Lemos et al. 2015).

The highest infestation rates were observed in Myrtaceae host plants (Tables 1 and 2). *Psidium guajava* was infested especially by *A. striata*, and *S. malaccense* by *B. carambolae*. In Oiapoque, there was significant infestation of *Annona muricata* L. (Annonaceae), exclusively by species of *Neosilba* (Table 1).

Vayssières et al. (2013) conducted a survey using McPhail traps (1994–2003) and fruit sampling (2001–2003) in French Guiana, from the border with Brazil to the border with Suriname. The authors did not report the presence of *A. suspensa*, but obtained 21 species of *Anastrepha*, in addition to *B. carambolae*. It should be noted that all species of Tephritidae (*Anastrepha* and *Bactrocera*) obtained in the present work already have been reported in French Guiana. Also relevant is the fact that we did not detect *A. suspensa* in the studied area (extreme north of Amapá, Brazil) and all 4 hosts we reported for *B. carambolae* in Amapá are among those reported by Vayssières et al. (2013) in French Guiana.

Tables 3 and 4 show updated lists of frugivorous fly species already reported in Oiapoque and Calçoene, respectively. This work adds 5 new reports of frugivorous flies in the municipality of Oiapoque (*A. leptozona*, *N. bella*, *N. glaberrima*, *N. pseudozadolicha*, and *N. zadolicha*) and 3 in Calçoene (*A. obliqua*, *N. glaberrima*, and *N. pseudozadolicha*). In addition, 6 new associations between frugivorous fly species and their hosts were established for the Brazilian Amazon (Tables 3 and 4). This work also presents the first reports of parasitoids (*D. areolatus*, *O. bellus*, and *U. anastrephae*) in the municipality of Calçoene (Table 4).

This research contributes to the advance of knowledge on frugivorous flies, their host plants, and associated parasitoids in the extreme north of Amapá State, Brazil.

Acknowledgments

To our colleague Carlos Alberto Moraes, for support during sampling expeditions. To the Brazilian Council for Scientific and Technological Development (CNPq), for the Research Productivity Fellowships granted to R Adaime and MF de Souza-Filho. To the Ministry of Agriculture and Food Supply for authorizing publication of data pertaining to the carambola fruit fly, as provided in Normative Rule No. 52/2007.

References Cited

Adaime R, Sousa MSM, Pereira JF. 2016a. *Anastrepha* species and their hosts in the Brazilian Amazon. Amazon Network for Research on Fruit flies, last updated 3 Oct 2016, http://anastrepha.cpafap.embrapa.br (last accessed 18 Feb 2017).

Adaime R, Jesus-Barros CR, Bariani A, Lima AL, Cruz KR, Carvalho JP. 2016b. Novos registros de hospedeiros da mosca-da-carambola (*Bactrocera carambolae*) no estado do Amapá, Brasil. Comunicado Técnico 146. Embrapa Amapá, Macapá, Brazil.

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

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.

Creão MIP. 2003. Moscas-das-frutas (Diptera: Tephritidae): espécies, distribuição, medidas da fauna e seus parasitóides (Hymenoptera: Braconidae) no Estado do Amapá. MS Dissertation, Instituto Nacional de Pesquisas da Amazônia, Universidade do Amazonas, Manaus, 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, 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.

De AS Diniz TD. 1986. Caracterização climática da Amazônia Oriental. *In* Burger DM [ed.], Pesquisas sobre a utilização e conservação do solo na Amazônia Oriental. Centro de Pesquisa Agropecuária do Trópico Úmido, documento 40, EMBRAPA, Belém, Brazil.

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.

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.

Lourenção AL, Lorenzi JO, Ambrosano GMB. 1996. Comportamento de clones de mandioca em relação à infestação por *Neosilba perezi* (Romero & Rupell) (Diptera: Lonchaeidae). Scientia Agricola 53: 304–308.

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 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.

Morais EGF, Jesus-Barros CR, Adaime R, Lima AL, Navia D. 2016. Pragas de expressão quarentenária na Amazônia, pp. 521–559 *In* Silva NM, Adaime R, Zucchi RA [eds.], Pragas Agrícolas e Florestais na Amazônia. Embrapa, Brasília, Distrito Federal, Brazil.

Norrbom AL, Uchôa MA. 2011. New species and records of *Anastrepha* (Diptera: Tephritidae) from Brazil. Zootaxa 2835: 61–67.

Pereira JF, Adaime R. 2016. Lonchaeidae from Brazilian Amazon. Amazon Network for Research on Fruit flies, last updated 7 Jan 2016, http://lonchaeidae.cpafap.embrapa.br (last accessed on 18 Feb 2017)

Ronchi-Teles B. 2000. Ocorrência e flutuação populacional de espécies de moscas-das-frutas e parasitóides com ênfase para o gênero *Anastrepha* (Diptera: Tephritidae) na Amazônia Brasileira. PhD Thesis, Instituto Nacional de Pesquisas da Amazônia, Universidade do Amazonas, Manaus, Brazil.

Ronchi-Teles B, Silva NM, Norrbom AL. 1996. New records of *Anastrepha* spp. (Diptera: Tephritidae) and their host in Rondônia and Amapá States – Brazilian Amazônia, pp. 32–33 *In* Proceedings of the 2nd meeting of the Working Group on Fruit Flies of the Western Hemisphere, Viña Del Mar, Chile.

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

SUDAM (Superintendency for the Development of Amazonia). 1984. Atlas Climatológico da Amazônia Brasileira. Projecto de Hidrologia e Climatologia da Amazônia, publication number 39, Belém, Brazil.

Sugayama RL, Iede ET, Stancioli AR, Alves GA, Oliveira IM, Dias JA. 2015. Ameaças fitossanitárias, pp. 449–471 *In* Sugayama RL, Silva ML, Silva SXB, Rangel LEP [eds.], Defesa Vegetal: Fundamentos, Ferramentas, Políticas e Perspectivas. Sociedade Brasileira de Defesa Agropecuária, Belo Horizonte, Minas Gerais, Brazil.

Trindade RBR, Uchôa MA. 2011. Species of fruit flies (Diptera: Tephritidae) in a transect of the Amazonian Rainforest in Oiapoque, Amapá, Brazil. Revista Zoologia 28: 653–657.

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.

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.

Weiss BM. 2011. Plano Territorial de Desenvolvimento Rural Sustentável (PTDRS) Extremo Norte do Amapá. Programa Integrado de Ações Socioambientais da Amazônia Oriental, Macapá, Brazil, http://sit.mda.gov.br/download/ptdrs/ptdrs_qua_territorio154.pdf (last accessed 18 Feb 2017).

White IM, Elson-Harris M. 1992. Fruit Flies of Economic Significance: Their Identification and Bionomics. CAB International, Redwork Press Ltd, Melksham, UK.

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. 2008. *Anastrepha* species their host plants and parasitoids. Fruit flies (Diptera: Tephritidae) in Brazil, updated 1 Dec 2016, www.lea.esalq.usp.br/anastrepha/ (last accessed 18 Feb 2017).

Zucchi RA, Uramoto K, Souza-Filho MF. 2011a. 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.

Zucchi RA, Silva RA, Deus EG. 2011b. Espécies de *Anastrepha* e seus hospedeiros na Amazônia Brasileira, pp. 51-70 *In* Silva RA, Lemos WP, Zucchi RA [eds.], Moscas-das-frutas na Amazônia Brasileira: Diversidade, Hospedeiros e Inimigos Naturais. Embrapa Amapá, Macapá, Amapá, Brazil.