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ANASTREPHA (DIPTERA: TEPHRITIDAE) SPECIES, THEIR HOSTS AND PARASITOIDS (HYMENOPTERA: BRACONIDAE) IN FIVE MUNICIPALITIES OF THE STATE OF AMAPÁ, BRAZIL

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Abstract

A total of 817 samples (1,094.36 kg) of potential fruit fly (Diptera:Tephritidae) hosts were collected from 70 plant species across 29 families in the state of Amapá, Brazil. Twenty-three of these plant species were infested with tephritid larvae. Twelve species of *Anastrepha* were recovered in different proportions: *Anastrepha striata* (82.65%), *Anastrepha coronilli* (6.63%), *Anastrepha obliqua* (5.47%), *Anastrepha distincta* (2.28%), *Anastrepha fraterculus* (2.10%), *Anastrepha parishi* (0.30%), *Anastrepha leptozona* (0.22%), *Anastrepha pickeli* (0.11%), *Anastrepha antunesi* (0.07%), *Anastrepha serpentina* (0.07%), *Anastrepha sororcula* (0.06%), and *Anastrepha zenildae* (0.04%). *Anastrepha striata* was recorded from the greatest number of hosts (14 plant species in 8 families). The periods of occurrence of different *Anastrepha* species were variable, but we observed that *A. striata* was constantly present in *Psidium guajava* and sporadically present in fruits of other hosts. The fruits of wild plant species showed the highest rates of infestation by fruit flies with *Pouteria* sp.1 presenting a rate of (434.29 puparia/kg), followed by *Manihot* sp. (130.43 puparia/kg) and *Inga* sp.5 (120.62 puparia/kg). All of parasitoids recovered from collection of infested fruit were Braconidae: *Doryctobracon areolatus* (95.86%), *Opius bellus* (2.76%), *Asobara anastrephae* (1.07%), and *Utetes anastrephae* (0.31%). The highest percentage of parasitism (8.45%) was observed in samples of *Spondias mombin*.

Key Words: fruit flies, *Anastrepha striata*, wild hosts, native parasitoids, Amazon

Resumo

Obteve-se 817 amostras de frutos (1.094,36 kg) potencialmente hospedeiros de moscas-das-frutas de 70 espécies vegetais incluídas em 29 famílias, destas 23 espécies apresentaram infestação por Tephritidae. Houve registro de 12 espécies de *Anastrepha*: *Anastrepha striata* (82,65%), *Anastrepha coronilli* (6,63%), *Anastrepha obliqua* (5,47%), *Anastrepha distincta* (2,28%), *Anastrepha fraterculus* (2,10%), *Anastrepha parishi* (0,30%), *Anastrepha leptozona* (0,22%), *Anastrepha pickeli* (0,11%), *Anastrepha antunesi* (0,07%), *Anastrepha serpentina* (0,07%), *Anastrepha sororcula* (0,06%) e *Anastrepha zenildae* (0,04%). *Anastrepha striata* foi a que apresentou maior número de hospedeiros (14 espécies de frutos de 8 famílias). O período de ocorrência das espécies de moscas-das-frutas foi variável, entretanto foi possível observar a presença constante de *A. striata* em *Psidium guajava* e sua ocorrência esporádica nos demais hospedeiros. Os índices de infestação mostraram que os frutos silvestres apresentam as maiores infestações por moscas-das-frutas. *Pouteria* sp.1 apresentou a maior infestação (434,29 pp/kg) seguido de *Manihot* sp. (130,43 pp/kg) e *Inga* sp.5 (120,62 pp/kg). Todos os parasitoides obtidos pertencem à família Braconidae: *Doryctobracon areolatus* (95,86%), *Opius bellus* (2,76%), *Asobara anastrephae* (1,07%) e *Utetes anastrephae* (0.31%). *Spondias mombin* foi o fruto que apresentou maior percentual de parasitismo (8,45%).

Palavras chave: moscas-das-frutas, *Anastrepha striata*, hospedeiros silvestres, parasitoides nativos, Amazônia

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Fruit flies of the genus *Anastrepha* Schiner are distributed across the Neotropical Region, where more than 250 species are known. In addition to being the most diverse genus in the neotropics, *Anastrepha* also is the economically relevant group of Tephritidae in the region (Norrbom et al. 1999; Silva et al. 2010). A total of 112 species of *Anastrepha* have been reported in Brazil, placing the country in a prominent position regarding fruit fly diversity on the American continent (Zucchi 2007, 2008).

Fruit flies have a wide variety of native and exotic hosts, as their larvae necessarily develop inside fruits or other plant parts, the occurrence of such flies is intimately associated with the availability of host fruits (Malavasi et al. 2000). Despite the importance of host plant relationship for fruit fly ecology, at least one host is known for only 47% of *Anastrepha* species in Brazil (Zucchi 2008).

Identifying the host plants of Tephritidae is a fundamental stepping stone for the adequate and efficient handling of pest species. The use of a given host by a species of tephritid may vary among populations, depending on host availability and regional fruiting phenology, and on other ecological factors that may modify the fitness of larvae on different plants, or such use may simply be the result of the existence of different hosts in different regions within the geographical range of the species (Bernays & Graham 1988; Nascimento et al. 2000; Selivon 2000; Hernandez-Ortiz & Aluja 2004). Knowing the wild hosts and infestation rates of pest species is also important in trying to control/regulate them.

The recent intensification of studies on native hosts of fruit flies in little-disturbed areas has been providing relevant information on fruit fly/host associations. These works have been fundamentally important to the clarification of host use patterns and the ecological and evolutionary processes pertinent to these insects (Uramoto et al. 2008). These studies are also important for determining interactions among different species competing for different hosts.

In the Brazilian Amazon, the available knowledge on fruit flies and their hosts expanded considerably in recent years, with 60 species of *Anastrepha* recorded thus far (Trindade & Uchôa 2011; Zucchi et al. 2011). The state of Amapá, where 33 species of *Anastrepha* have been reported to date, has been making substantial contributions to knowledge on *Anastrepha* species richness and their hosts in Amazonian ecosystems (Zucchi 2008; Trindade & Uchôa 2011); and the list of known hosts is constantly increasing (Jesus et al. 2008ab, 2010; Silva et al. 2009).

Aluja (1999) points out that native fruit flies may be at risk of extinction because of the rapid devastation of tropical forests. This makes it urgent and essential for conservation purposes to know not only the existing species of *Anastrepha*, but especially their relationship with native and/or wild hosts and tritrophic interactions among wild tephritoids, their host plants and parasitoids in these environments.

The purpose of this work was to identify the species of *Anastrepha*, their natural and introduced hosts and the associated parasitoid species in 5 municipalities of the eastern zone of the Brazilian state of Amapá.

Materials and Methods

The Brazilian state of Amapá is located in the Eastern Amazon, bordering the state of Pará to the South and West, the Atlantic Ocean to the East, French Guiana to the North, and Suriname to the Northwest (Fig. 1) (Porto 2007). Fruits were collected from urban and rural areas of the municipalities of Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba, and Tartarugalzinho in eastern Amapá (Fig. 1). The sampled region is located between latitudes N 00° 30' 14.8" and N 01° 45' 37.2" and between longitudes W 50° 41' 51.4" and 51° 14' 15.7". The climates prevailing in the region, according to the Koëppen-Geiger classification, are Aw (tropical savanna) and Am (tropical monsoon) with an average annual precipitation of 2,300 mm to 2,400 mm (Pell et al. 2007). The rainy period is from Jan to Jun, and a characteristically dry period occurs most often between Sep and Nov. The average annual temperature is 26 °C (IBGE 2011). The vegetation in this region is comprised of "Cerrado", floodplain forest, dry-land forest, and cerrado/forest and cerrado/floodplain transition forests (IEPA 2002).

Fruits of native, subspontaneous or naturalized and exotic plant species were collected at monthly intervals between Feb 2006 and Aug 2007 in urban and rural areas of each of the 5 municipalities. At each collection event, fruits of potential fruit fly hosts were sampled at random from different ecosystems. The fruits were collected directly off the plants or from the ground (if recently fallen), from plants that bore abundant numbers of maturing or ripe fruits.

The fruits were stored in coolers or cotton sacks (depending on the characteristics of each fruit), then transported to the Laboratório de Entomologia at Embrapa Amapá, in the city of Macapá. In the laboratory, fruit samples were processed to retrieve tephritid and parasitoid pupae, as per Silva et al. (2011a).

After adult emergence, tephritids and braconids were identified with identification keys (Zucchi 2000; Canal & Zucchi 2000). Voucher specimens were deposited in the Laboratório de Entomologia at Embrapa Amapá (Macapá, Amapá, Brazil).

For those plants that could not be identified in the field botanical material consisting of dried

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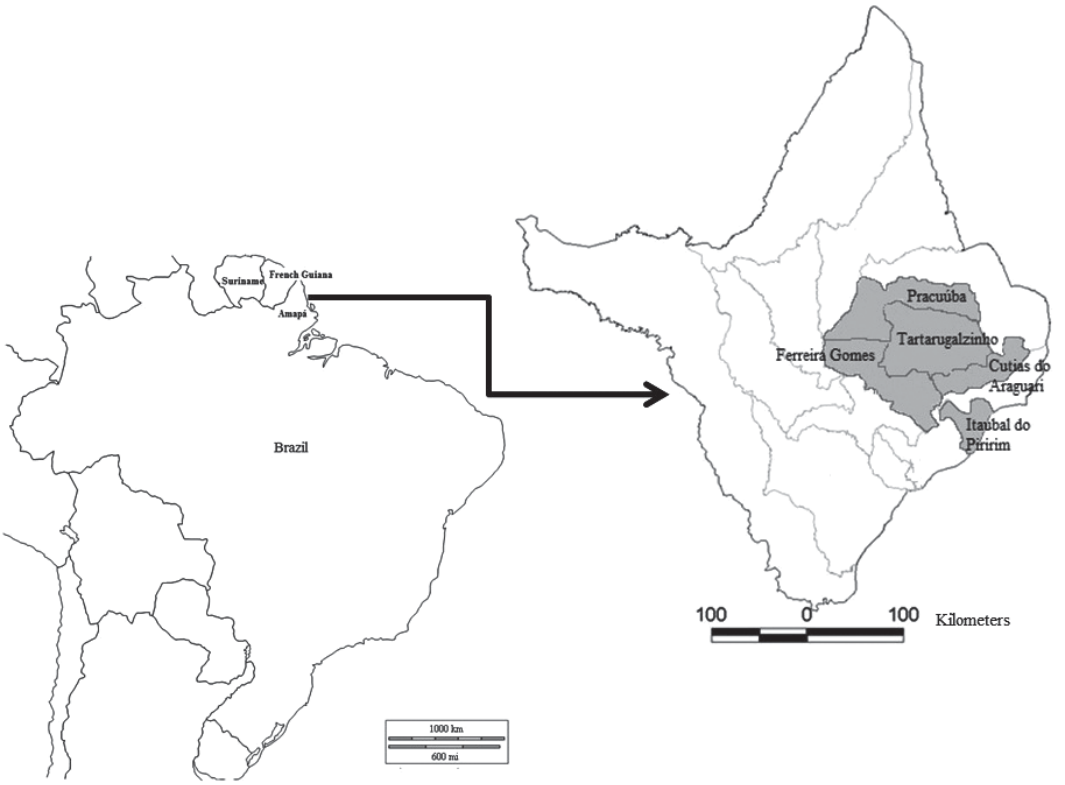


Fig. 1. Municipalities in the State of Amapá where the fruits were collected, Feb 2006 to Aug 2007.

pressed specimens was collected for later identification as per Fidalgo & Bononi (1984). Dried specimens were prepared and deposited at the Herbário Amapaense (HAMAB) of the Instituto de Pesquisas Científicas e Tecnológicas do Amapá - IEPA (Macapá, Amapá, Brazil), where they were identified and added to the institute's collection. Taxonomic names were updated to match the List of Species of the Brazilian Flora by the Rio de Janeiro Botanical Garden (Forzza et al. 2010), and plant families were classified according to APGII (2003).

The rates of infestation by fruit flies were expressed as number of puparia per fruit ($I_{pp/f}$) and number of puparia per kilogram of fruit ($I_{pp/kg}$). Percentage of parasitism was calculated as the ratio of emerged parasitoids to known number of puparia (P = number of emerged parasitoids/total number of puparia × 100).

Results and Discussion

A total of 817 samples (1,094.36 kg) of potential fruit fly hosts were collected from 70 plant species across 29 families (Table 1). Among the sampled plant species, *Psidium guajava* L.; Myrtales: Myrtaceae (guava) and *Anacardium occidentale* L; Sapindales: Anacardiaceae (cashew) are the most widely known and commonly grown in other regions of Brazil. Most other species were native (some of them found in a wild state), obtained from backyards or small rural properties where these plants are used for household consumption.

Collection efforts were most strongly focused on Fabaceae (10 species), Myrtaceae (7), and Arecaceae (7) (Fig. 2). Most of the collected families (55.2%) were represented by 3 or more plant species.

Among the sampled species, 22 were infested by *Anastrepha*, and Fabaceae was the family with the highest number of infested species, all of them in the genus *Inga*. This may be a reflection of the locations where collections took place, as *Inga* spp. are frequently found in brushwood areas and forest remnants (Cavalcante 1991) which are more easily accessible and located closer to human dwellings. Myrtaceae was second in number of collected and infested species, followed by Anacardiaceae. It should also be noted that all sampled species of Sapotaceae and Melastomataceae were infested (Fig. 2). Other studies exploring

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Table 1. Plant species sampled in the municipalities of Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba, and Tartarugalzinho in Amapá, Brazil, Feb 2006 to Aug 2007.

Family/Species	Origin*
Anacardiaceae	
Anacardium occidentale L.	N
Mangifera indica L.	SS
Spondias mombin L.	N
Spondias purpurea L.	E
Annonaceae	
Annona paludosa Aubl.	N
Annona squamosa L.	E
Annona muricata L.	E
Annona mucosa (Jacq.) Bail.	N
Apocynaceae	
Ambelania acida Aubl.	N
Couma utilis (Mart.) M. Arg.	N
Parahancornia amapa (Huber) Ducke	N
Arecaceae	
Astrocaryum vulgare L.	N
Attalea maripa (Aubl.) Mart.	N
Attalea phalerata Mart. ex Spring.	N
Bactris maraja Mart.	N
Bactris gasipaes Kunth.	N
Oenocarpus bacaba Mart.	N
Oenocarpus distichus Mart.	N
Bignoniaceae	
Jacaranda copaia (Aubl.) D. Don	N
Bromeliaceae	
Ananas ananassoides (Baker) L.B. Sm.	N
Ananas comosus (L.) Merr.	N
Burseraceae	
Protium heptaphyllum (Aubl.) March.	N
Trattinnickia burserifolia Mart.	N
Caricaceae	
Carica papaya L.	SS
Caryocaraceae	
Caryocar glabrum Pers.	N
Chrysobalanaceae	
Licania macrophylla Benth.	N
Chrysobalanus icaco L.	N
Dilleniaceae	
Doliocarpus sp.	N
Dioscoreaceae	
Dioscorea alata L.	N
Euphorbiaceae	
Manihot sp.	N
Celastraceae	
Cheiloclinium cognatum (Miers) A.C. Sm.	N
Humiriaceae	
Endopleura uchi (Huber) Cuatrec.	N
Lauraceae	
Licaria mahuba (A. Samp.) Kostern.	N
Persea americana Mill.	SS
Malpighiaceae	
Byrsonima crassifolia (L.) Kunth	N
Malpighia punicifolia L.	N
Lamiaceae	
Gmelina arborea Roxb. ex Sm.	N
Melastomataceae	
Bellucia imperialis Saldanha & Cogn.	N
Bellucia grossularioides (L.) Triana.	N
Mouriri acutiflora Naud.	N
Fabaceae	
Inga edulis Mart.	N
Inga fagifolia G. Don	N
Inga heterophylla Willd.	N
Inga velutina Willd	N
Inga sp. 1	SS
Inga sp. 2	N
Inga sp. 3	N
Inga sp. 4	N
Inga sp. 5	N
Inga sp. 6	N
Moraceae	
Artocarpus heterophyllus Lam.	SS
Ficus sp.	N
Myrtaceae	
Campomanesia xanthocarpa O. Berg.	N
Eugenia cumini (L.) Druce	SS
Eugenia luschnathiana Klotzsch ex O. Berg	SS
Eugenia malaccensis L.	N
Psidium guajava L.	N
Psidium guineense SW	N
Psidium sp. 2	N
Oxalidaceae	
Averrhoa bilimbi L.	SS
Averrhoa carambola L.	SS
Passifloraceae	
Passiflora sp. 1	N
Passiflora sp. 2	N
Rubiaceae	
Coffea arabica L.	SS
Rutaceae	
Citrus sinensis (L.) Osbeck.	SS
Citrus sp.	N
Sapotaceae	
Pouteria caimito (Ruiz & Pav.) Radlk.	N
Pouteria sp. 1	N
Pouteria sp. 2	N
Solanaceae	
Solanum paniculatum L.	N

* N = native species, E = exotic species, SS = subspontaneous.

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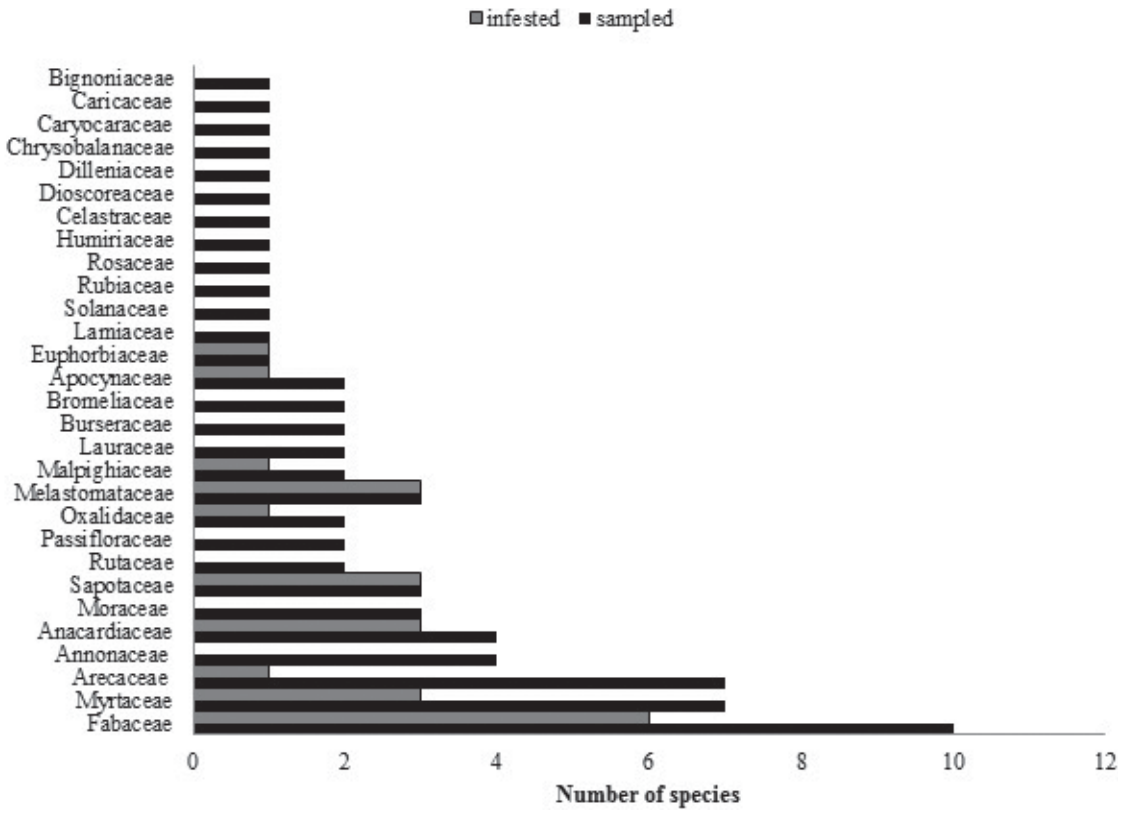


Fig. 2. Number of sampled and infested plant species, by family, in Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba, and Tartarugalzinho, Amapá, Brazil, Feb 2006 to Aug 2007.

wild fruits in Brazil have emphasized Myrtaceae as the plant family with the highest rates of infestation by Tephritidae. Uramoto et al. (2008) analyzed the associations of tephritids with native hosts in the state of Espírito Santo, where they collected fruit samples from 248 plant species (51 families). Among them, Myrtaceae was the most diversified family. Silva et al. (2010) studied the diversity of *Anastrepha* in native and exotic hosts in the state of Bahia. The authors collected fruits of 27 plant species (15 families), of which only 6 families were infested by *Anastrepha* of which the Myrtaceae had the highest infestation rate.

The tephritids obtained in this work all belonged to the genus *Anastrepha*. We did not collect any *Bactrocera carambolae* Drew & Hancock and *Ceratitis capitata* (Wiedemann). *Bactrocera carambolae* is found only in the state of Amapá where an eradication program is underway (Godoy et al. 2011). *Ceratitis capitata* has not been detected in the state (Silva et al. 2011).Twelve species of *Anastrepha* were identified (Table 2): *Anastrepha striata* Schiner (82.65%), *Anastrepha coronilli* Carrejo & González (6.63%), *Anastrepha obliqua* (Macquart) (5.47%), *Anastrepha distincta* Greene (2.28%), *Anastrepha fraterculus* (Wiedemann) (2.10%), *Anastrepha parishi* Stone (0.30%), *Anastrepha leptozona* Hendel (0.22%), *Anastrepha pickeli* Lima (0.11%), *Anastrepha antunesi* Lima (0.07%), *Anastrepha serpentina* (Wiedemann) (0.07%), *Anastrepha sororcula* Zucchi (0.06%), and *Anastrepha zenildae* Zucchi (0.04%).

Anastrepha striata had by far the highest number of hosts (14 species of fruit belonging to 8 families) (Table 2). *Anastrepha fraterculus* was observed in 5 host species (4 families). Studies conducted in the Southeast and Northeast regions of Brazil have reported *A. fraterculus* as the most polyphagous species (Uramoto et al. 2008; Silva et al. 2010). However, in the Amazon region, this species has been reported on only 10 hosts, whereas *A. striata* has a higher number of known hosts: 28 species in 16 botanical families (Zucchi et al. 2011). Deus et al. (2009), while studying fruit flies in the municipalities of Pedra Branca do Amapari and Serra do Navio in the state of Amapá, indicated that *A. striata* has the highest number of hosts and is the most abundant species in guava fruits, confirming its supremacy in North Brazil in relation to *A. fraterculus*, which is the predominant tephritid in guava in Southeast Brazil. In fact, *A. striata* is seen as the biogeographical opposite of *A. fraterculus* because it becomes gradually more common as one moves

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TABLE 2. *ANASTREPHA* SPECIES, HOSTS AND PERIOD OF OCCURRENCE IN FRUITS COLLECTED IN CUTIAS DO ARAGUARI, ITAUBAL DO PIRIRIM, FERREIRA GOMES, PRACUÚBA, AND TARTARUGALZINHO IN AMAPÁ, BRAZIL, FEB 2006 TO AUG 2007.

Host plant			Period and site of sampling*																	
			2006											2007						
Tephritidae	Family	Species	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
A. antunesi	Anacardiaceae	*S. mombin*												P							
	Melastomataceae	*B. imperialis*					C		C												
A. coronilli	Melastomataceae	*B. imperialis*					FT	CFT	T		T		T		T			F	F	CFT	CF
	Myrtaceae	*P. guajava*		T	CT		IT														
A. distincta	Fabaceae	*Inga* sp.1	T	T	T						T									F	C
		Inga sp. 4				T						F									
		Inga sp. 5												F							
		I. edulis				CFI	T	T	CI		FT	TP	CIT	CFIP	TP	FP	C				
		I. fagifolia												T							
	Myrtaceae	*P. guajava*										T	I				F				
	Oxalidaceae	*A. carambola*										I									
A. fraterculus	Anacardiaceae	*A. occidentale*											P								
		S. mombin	T	I										P		I	P				
	Malpighiaceae	*B. crassifolia*	C																		
	Melastomataceae	*M. acutiflora*													CT						
	Myrtaceae	*P. guajava*	T	T	T	CP									FPT	I	T	CIT			
A. leptozona	Sapotaceae	*Pouteria* sp. 1												F	F						
A. obliqua	Anacardiaceae	*S. mombin*	CT	CFIP	FP	CFIP								C	FPT	FIP	FP	FP			
		S. purpurea										T									
A. parishi	Melastomataceae	*B. imperialis*					T														
	Myrtaceae	*P. guajava*											P								
A. pickeli	Euphorbiaceae	*Manihot* sp.																			IT
A. serpentina	Sapotaceae	*Pouteria* sp. 2															P				
A. sororcula	Melastomataceae	*B. grossularioides*																			C
		M. acutiflora														C					
A. striata	Anacardiaceae	*A. occidentale*											P								
		S. mombin				C										P		P			
	Apocynaceae	*C. utilis*												F							
	Arecaceae	*O. bacaba*													I	P					
	Fabaceae	*Inga* sp.1		T																	
		Inga sp. 4				F															
		Inga edulis				C			I		F	P		CFT	T						
	Malpighiaceae	*B. crassifolia*												C							
	Melastomataceae	*B. grossularioides*																		F	
		B. imperialis					FT				T										
	Myrtaceae	*E. luschnathiana*										C									
		P. guajava	CFIT	CIPT	CFIT	CFIPT	CFIPT	IFP	FITP	CFIPT	CFIPT	CFIPT	CFIPT	CFIPT	CFIPT	CFIPT	CFIT	CFIPT	CFIPT	CIP	CFIT
		P. guineense													P						
	Oxalidaceae	*A. carambola*						C				C									
A. zenildae	Myrtaceae	*P. guajava*							P												

*C = Cutias do Araguari, F = Ferreira Gomes, I = Itaubal do Piririm, T = Tartarugalzinho, P = Pracuúba.

Table 3. Hosts and number of individuals of *Anastrepha* in fruits collected in Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba, and Tartarugalzinho in Amapá, Brazil, Feb 2006 to Aug 2007.

Host plant			*Anastrepha* (number of females)
Family	Species	Common name	
Anacardiaceae	*A. occidentale*	Cashew	*A. striata* (3) *A. fraterculus* (1)
	S. mombin	Hog plum	*A. striata* (33) *A. obliqua* (282) *A. fraterculus* (9) *A. antunesi* (1)
	S. purpurea	Jocote	*A. obliqua* (4)
Apocynaceae	*C. utilis*	Sorva	*A. striata* (48)
Arecaceae	*O. bacaba*	Bacaba	*A. striata* (24)
Euphorbiaceae	*Manihot* sp.	Cassava fruit	*A. pickelli* (6)
Fabaceae	*I. edulis*	Ice-cream-bean	*A. striata* (98) *A. distincta* (157)
	I. fagifolia	Sweet pea	*A. distincta* (3)
	I. velutina	"Hairy inga"	*A. striata* (8)
	Inga sp.1	Inga	*A. striata* (4) *A. distincta* (103)
	Inga sp.4	"Dwarf inga"	*A. striata* (8) *A. distincta* (70)
	Inga sp.5	Monkey inga	*A. distincta* (35)
Malpighiaceae	*B. crassifolia*	Nance	*A. striata* (1) *A. fraterculus* (5)
Melastomataceae	*B. grossularioides*	Goiaba-de-anta	*A. striata* (24) *A. coronilli* (225) *A. antunesi* (3)
	B. imperialis	Red goiaba-de-anta	*A. striata* (1) *A. sororcula* (1) *A. coronilli* (115) *A. parishi* (1)
	M. acutiflora	Mamuriballi	*A. fraterculus* (3) *A. sororcula* (2)
Myrtaceae	*E. luschnathiana*	Pitomba	*A. striata* (3)
	P. guajava	Guava	*A. striata* (4,176) *A. parishi* (15) *A. coronilli* (16) *A. fraterculus* (95) *A. distincta* (13) *A. zenildae* (2)
	P. guineense	Brazilian guava	*A. striata* (6)
Oxalidaceae	*A. carambola*	Star Fruit	*A. striata* (20) *A. distincta* (1)
Sapotaceae	*Pouteria* sp. 1	Native abiu	*A. leptozona* (12)
	Pouteria sp. 2	Wild abiu	*A. serpentina* (4)

northward along its distribution in Brazil (Malavasi et al. 2000).

Anastrepha distincta Greene was observed in 7 hosts, 5 of which belonged to *Inga* (Fabaceae), indicating that the species presents an intimate association with this plant genus (Table 2). *Anastrepha distincta* in Amapá showed a narrower spectrum of hosts than that reported in other studies, for among the 8 plant species where this tephritid has been reported in the Brazilian Amazon, 4 are Fabaceae, 2 Clusiaceae, 1 Myrtaceae, and 1 Anacardiaceae (Zucchi et al. 2011).

Some species were observed in only one host: *A. serpentina* in *Pouteria* sp.2; *A. leptozona* in *Pouteria* sp.1; *A. zenildae* in *P. guajava*, and *A. pickeli* in *Manihot* sp. (Table 2). The latter is the

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first record of a host of *A. pickeli* in the Brazilian Amazon, and this species is found in all regions of the country, where 2 host plant species have been reported to date (Zucchi 2008). However, only *A. pickeli* has been reported in the Amazon, and until now had been collected as adults with McPhail traps. *Anastrepha pickeli* belongs to the *spatulata* group, in which some species infest *Manihot* spp. and use a specialized mechanism to detoxify the glycosides present in these fruits (Selivon 2000).

The periods of occurrence of the different tephritid species were variable. *Anastrepha striata* was constantly present in *P. guajava*, with sporadic presence detected in other hosts (Table 2). It is a generalist species that occurs in 27 host species from 11 families, with a strong preference for hosts of the genus *Psidium* (Myrtaceae) (Selivon 2000; Norrbom 2005; Weems & Fasulo 2009).

Adult flies were obtained from 22 plant species, most of them wild (Table 3). *Anastrepha striata* was collected in greatest abundance (the highest number of individuals) in a single host species (4,176 specimens in *P. guajava*), followed by *A. obliqua* (282 in *Spondias mombin*), and *A. coronilli* (225 in *Bellucia grossularioides* L.) (Table 3). According to Silva et al. (2011), *A. striata* is not only the species with the highest number of hosts, it is also the most abundant and widely distributed *Anastrepha* species in the state of Amapá.

Anastrepha parishi was found in *P. guajava* and *Bellucia imperialis,* expanding its list of known hosts in Brazil after having been reported recently in fruits of *Oenocarpus bacaba* (Arecaceae) (Jesus et al. 2008a; Zucchi et al. 2011). Adaime et al. (2012) published the first host record of *A. parishi* in *Myrciaria dubia* Mc Vaugh in the state of Roraima, Brazil.

Anastrepha striata and *A. fraterculus* were found in *Anacardium occidentale* (Table 3). Cashew has already been reported as a host of *A. striata* in Amapá, *A. leptozona* in Amazonas, and *A. obliqua* in Tocantins (Jesus et al. 2008b; Zucchi et al. 2011) but this is the first report of *A. occidentale* as a host of *A. fraterculus* in Brazil.

Of all the collected fruits, 23 species were infested. In *P. caimito* was only recorded the emergence of adult braconid parasitoids but no tephritids, whereas the other infested plant species revealed the presence of both *Anastrepha* and parasitoids. All the collected samples of *Inga* sp. 4, *Inga* sp. 5, *Manihot* sp., *Pouteria* sp. 1, *Pouteria* sp. 2, and *Psidium guineense* were infested (Table 4). An analysis of infestation rates showed

Table 4. Number of samples, number of fruits, host weight, number of Tephritidae puparia, and infestation rate of fruits collected in Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba, and Tartarugalzinho in Amapá, Brazil, Feb 2006 to Aug 2007.

Hosts	Samples*			Fruits	Mass	Puparia	Infestation rate	
	C	I	%	(n)	(kg)	(n)	$I_{pp/kg}$	$I_{pp/f}$
A. occidentale	29	5	17.2	438	24.80	19	0.77	0.04
A. carambola	51	3	5.9	665	76.34	99	1.30	0.15
B. grossularioides	30	28	93.3	1,892	21.16	636	30.06	0.34
B. imperialis	32	26	81.3	2,199	32.15	1,533	47.68	0.70
B. crassifolia	7	1	14.3	3,044	6.37	7	1.10	0.00
C. utilis	5	2	40.0	163	4.12	324	78.64	1.99
E. luschnathiana	3	1	33.3	185	0.44	8	18.18	0.04
I. edulis	95	48	50.5	325	63.62	538	8.46	1.66
I. fagifolia	8	1	12.5	508	6.02	10	1.66	0.02
Inga sp. 1	17	10	58.8	313	24.75	466	18.83	1.49
Inga sp. 4	4	4	100.0	213	2.69	252	93.68	1.18
Inga sp. 5	1	1	100.0	130	0.97	117	120.62	0.90
I. velutina	6	2	33.3	115	2.92	156	53.42	1.36
Manihot sp.	3	3	100.0	126	0.23	30	130.43	0.24
M. acutiflora	2	1	50.0	225	0.59	40	67.80	0.18
O. bacaba	13	4	30.8	8,130	26.24	110	4.19	0.01
P. caimito	12	2	16.7	101	7.01	64	9.13	0.63
Pouteria sp. 1	2	2	100.0	51	0,175	76	434.29	1.49
Pouteria sp. 2	1	1	100.0	2	0.39	5	12.82	2.50
P. guajava	255	222	87.1	9,657	425.97	17,531	41.16	1.82
P. guineense	2	2	100.0	145	2.12	32	15.09	0.22
S. mombin	55	51	92.7	9,454	126.97	2,721	21.43	0.29
S. purpurea	3	1	33.3	75	0.86	26	30.23	0.35

*C: collected, I: infested, %: percentage of infested samples.

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that wild fruits were more infested by *Anastrepha* than introduced plant species. In terms of puparia/kg of fruit, *Pouteria* sp.1 was the most infested (434.29 pp/kg), followed by *Manihot* sp. (130.43 pp/kg) and *Inga* sp.5 (120.62 pp/kg). In terms of puparia/fruit, *Pouteria* sp. 2 (2.5 pp/fruit) and *C. utilis* (1.99 pp/fruit) presented the highest rates. According to Silva et al. (2011b), the highest reported infestation rates in the state of Amapá occur in native fruits of the Amazon region, where usually only 1 species of *Anastrepha* is present or predominant. We also highlight the considerable infestation rates found in guava (41.16 pp/kg and 1.82 pp/fruit), which are similar to the ones already reported in other studies in the state of Amapá (from 13.3 to 58.3 pp/kg) (Silva et al. 2011b). Araújo & Zucchi (2003) reported that guava is one of the most tephritid-infested fruits in Brazil, with infestation rates varying across different regions of the country, and influenced mainly by rainfall and host availability. Infestation ranged from 35 to 118 pp/kg in their experiment in Northeast Brazil, which caused a 78-100% loss of guava crops.

The efficient control of fruit fly populations requires the integration of several methods, including cultural, mechanical, biological, and chemical. However, some basic pre-requisites are indispensable for the successful implementation of an integrated control system for fruit flies, such as knowledge of the bio-ecology of fruit infesting populations, as well as the phenology and distribution of their host plant species and natural enemies. Nevertheless, the use of Braconidae parasitoids has been intensified in several countries of America (Ovruski et al. 2000).

The present work recorded a total of 652 specimens of parasitoids, all of them Braconidae: *Doryctobracon areolatus* (Szépligeti, 1911) (95.86%), *Opius bellus* Gahan, 1930 (2.76%), *Asobara anastrephae* (Muesebeck, 1958) (1.07%), and *Utetes anastrephae* (Viereck, 1913) (0.31%) (Fig. 3). *Doryctobracon areolatus* was the most abundant and was present in all plant species where parasitoid emergence was observed (Fig. 3). The predominance of *D. areolatus* in the state of Amapá had already been highlighted by Silva et al. (2011b). This species has been revealing itself to be an important parasitoid in Brazil and Latin America, both on account of its abundance and its widespread distribution (Canal & Zucchi 2000; Carvalho et al. 2010; Leonel Jr. et al. 1995; Ovruski et al. 2000).

Although guava presented the highest ratio of number of adult parasitoids to number of observed puparia, *S. mombin* (hog plum) was the plant species with the highest rate of parasitoid occurrence (8.45%) (Fig. 4), hog plum also contained the highest parasitoid species richness (Fig. 4b). In a study on parasitoids of tephritids in the state of Amazonas, Canal et al. (1995) also reported that the majority of parasitoids were obtained from hog plum. According to Leonel (1991), these fruits might be subject to intense parasitism because parasitoids can find host larvae with more ease in fruits of small size, thin skin and shallow flesh, such as those of hog plum. According to Sivinski et al. (1997), smaller fruit attracts parasitoids with short ovipositors because it is

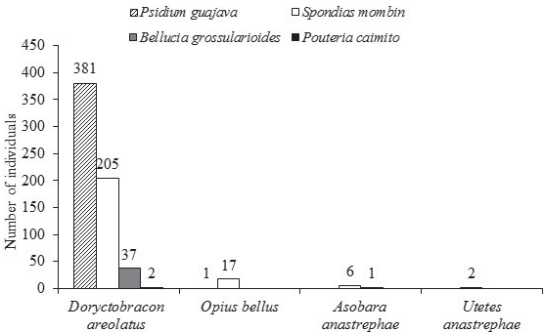


Fig. 3. Parasitoids found in plant species sampled in Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba, and Tartarugalzinho, Amapá, Brazil, Feb 2006 to Aug 2007.

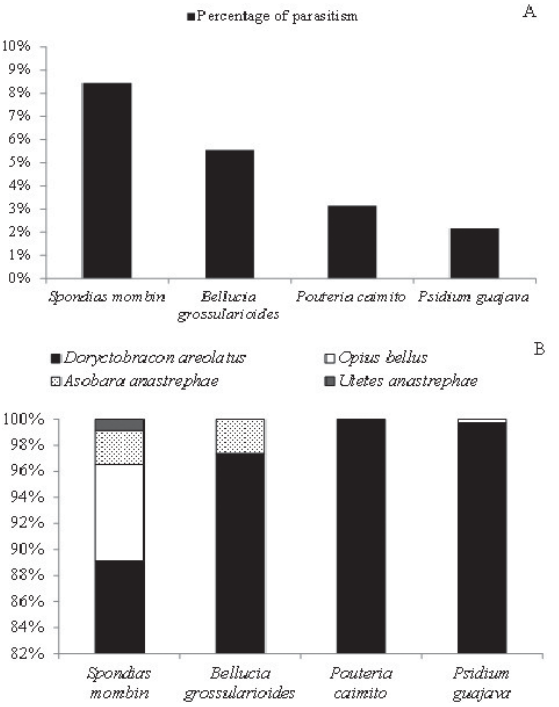


Fig. 4. Percentage of parasitism per plant species (a) and per parasitoid species (b) in *Anastrepha* individuals obtained from fruits collected in Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba, and Tartarugalzinho, Amapá, Brazi,. Feb 2006 to Aug 2007.

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Table 5. Number of parasitoids observed in *Anastrepha* species found in fruits collected in Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba, and Tartarugalzinho in Amapá, Brazil, Feb 2006 to Aug 2007.

	Doryctobracon areolatus (n)	*Opius bellus* (n)	*Asobara anastrephae* (n)	*Utetes anastrephae* (n)
A. coronilli	136	0	0	0
A. distincta	7	0	0	0
A. fraterculus	78	0	2	0
A. obliqua	95	15	1	2
A. parishi	2	0	0	0
A. striata	307	3	4	0

easier to find fly larvae, whereas parasitoids with long ovipositors are able to seek larvae in fruits of varying flesh thicknesses. This means that parasitoids with long ovipositors (>6 mm) occur on fruits of all sizes, whereas parasitoids with smaller ovipositors (<3 mm) can only infest the larvae found in small fruits. *Doryctobracon areolatus* has a long ovipositor and this characteristic is a factor explaining to its predominant position as the most common parasitoid of fruit fly larvae in the braconid's natural distribution range. Other studies in the state of Amapá have shown the importance of hog plum as a "reservoir" of parasitoids (Silva et al. 2007; Cunha et al. 2011).

A parasitoid/fruit fly association can be established when a single species of fly and a single species of parasitoid are the only ones to emerge in the same rearing container (Leonel Jr. et al. 1996). We were able to confirm that *D. areolatus* is associated with 6 species of *Anastrepha*; the parasitoids *A. anastrephae*, *O. bellus* and *U. anastrephae* were associated with 3, 2, and 1 species respectively (Table 5). For the state of Amapá records of *U. anastrephae* infesting *A. obliqua*, *D. areolatus* infesting *A. fraterculus* and *A. parishi*, and *A. anastrephae* infesting *A. fraterculus* are first-time reports.

In conclusion, based on fruit sampling in 5 municipalities in eastern Amapá, it is possible conclude that *A. striata* is the most abundant and polyphagous tephritid species in the region. The highest rates of infestation by *Anastrepha* were found in wild plant species. The highest parasitism levels occurred in fruits of *S. mombin* and *D. areolatus* was the most abundant parasitoid species.

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