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Fruit flies (Diptera, Tephritidae) and their associations with native host plants in a remnant area of the highly endangered Atlantic Rain Forest in the State of Espírito Santo, Brazil

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Abstract

The results presented in this paper refer to a host survey, lasting approximately three and a half years (February 2003–July 2006), undertaken in the Vale do Rio Doce Natural Reserve, a remnant area of the highly endangered Atlantic Rain Forest located in Linhares County, State of Espírito Santo, Brazil. A total of 330 fruit samples were collected from native plants, representing 248 species and 51 plant families. Myrtaceae was the most diverse family with 54 sampled species. Twenty-eight plant species, from ten families, are hosts of ten *Anastrepha* species and of *Ceratitis capitata* (Wiedemann). Among 33 associations between host plants and fruit flies, 20 constitute new records, including the records of host plants for *A. fumipennis* Lima and *A. nascimentoi* Zucchi. The findings were discussed in the light of their implications for rain forest conservation efforts and the study of evolutionary relationships between fruit flies and their hosts.

Keywords: insecta, *Anastrepha*, *Ceratitis capitata*, host plants, natural reserve

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Introduction

Anastrepha Schiner (Diptera, Tephritidae) is the most economically important genus of Tephritidae in the Americas. Simultaneously, *Anastrepha* species have revealed remarkable ecological and behavioral characteristics (Aluja, 1994). Currently, there are 213 valid species endemic to the New World, these being restricted to both tropical and subtropical environments. A high number of host plants have already been recorded for *Anastrepha* species (143 genera in 54 families) (Norrbom, 2004). Nevertheless, this number greatly decreases on excluding pest-species and exotic plants. There are few records of native host plants, since collections have been concentrated on commercial fruits, most of which are introduced (Norrbom & Kim, 1988). These authors highlighted the importance of extensive collections of native plants, since the unknown hosts of many *Anastrepha* species are native, thus, contributing towards a better understanding of their biology. Fruit flies have been extensively studied in the tropics as pests in agricultural areas, but have rarely been assayed in forests with native vegetation. Little attention has been attributed to the natural history and behavior of fruit flies in nature, therefore underestimating the complexity of fruit fly biology and ecology (Aluja, 1999). Much of the information required

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for a better understanding of fruit fly biology, ecology and evolution is obtainable from areas with undisturbed native vegetation. Thus, finding these few remaining areas has become a notable challenge (Aluja *et al*., 2003). Consequently, studies on native host plants in forest reserves have recently been intensified, with the result that these host plant/fruit fly associations have assumed importance for comprehending host plant use patterns, as well as the ecological and evolutionary processes of these insects. Aluja *et al*. (2003) pointed out that the food habits of primitive species, such as *A. cordata*, revealed through studies conducted in a preserved area of a tropical forest in Veracruz, Mexico (Hernández-Ortiz & Pérez-Alonso, 1993) gave rise to hypotheses on the evolution of oviposition behavior in *Anastrepha* species (Aluja *et al*., 1999; Díaz-Fleischer *et al*., 1999). Furthermore, associations of *Anastrepha* species with host plants and the interactions between species were defined in the tropical rainforest biosphere reserve of Montes Azules, Mexico. This information provided support for inferences on the ecological and evolutionary processes of these insects and on pest management in the tropics (Aluja *et al*., 2003). In locations undergoing different stages of environmental conservation in Argentina, the status of native and exotic fruits as hosts of *A. fraterculus* and *Ceratitis capitata* was verified. Thus, resource-use patterns, infestation and population distribution could be determined (Ovruski *et al*., 2003; Ovruski *et al*., 2005; Segura *et al*., 2006) there. In northeastern Argentina, *A. fraterculus* was predominant on native plant species, whereas *C. capitata* was so on those introduced, demonstrating that it is well-adapted to these disturbed environments (Ovruski *et al*., 2003). In a host plant survey undertaken in the 'cerrado' of the state of Mato Grosso do Sul, Brazil, *C. capitata* denoted higher infestation in guava samples, collected in urban areas, than did *A. fraterculus* and *A. sororcula* (Uchôa-Fernandes *et al*., 2002). In areas where the pest-insect is an invasive species, this has frequently occurred in association with exotic plants (Selivon, 2000).

Among tephritids, *C. capitata*, the Mediterranean fruit fly (medfly) is considered to be the most polyphagous species with the highest adaptation capacity, since it infests 374 plant species (Liquido *et al*., 1998) of which 33% are exotic (Copeland *et al*., 2002). In several regions of Kenya, fruits were sampled to study the relationship of *C. capitata* to native plant hosts in its original home range. Medflies were predominantly reared from fruits of indigenous plant species, of which approximately 80% were new host records (Copeland *et al*., 2002). These authors also pointed out the need for studying the medfly's natural history within its original home-range.

In a tropical forest of Papua New Guinea, the associations between frugivorous Dacinae species and host plants, their abundance and the number infesting several plant species were defined (Novotny *et al*., 2005).

Atlantic Rainforest fragments can be found in the State of Espírito Santo, Brazil. These, with a high rate of endemism and diversity, constitute a priority biome for biological conservation due to its highly endangered flora and fauna, which places it fourth in rank among 25 biodiversity hotspots world-wide (Myers *et al*., 2000). Therefore, it has become highly interesting to undertake a study so as to check the associations between fruit fly species and native host plants and to more specifically observe whether there is a pattern-relationship with plant-species groups, further comparing this with already published information as well as with behavior in relation to phytophagy in remnant Atlantic Rain Forest areas such as the Vale do Rio Doce Natural Reserve.

Materials and methods

Study area: location and characterization

Fruit collections were accomplished in the Vale do Rio Doce Natural Reserve (VRDNR), a fragment of the Atlantic Rain Forest located between geographic coordinates 19°06′–19°18′ south and 39°45′–40°19′ west in the county of Linhares, Espírito Santo State. The vegetation in VRDNR corresponds to secondary Dense Ombrophilous Forest (Souza *et al*., 2002) located on the surface of Tertiary mesas in the Barreira formation (lowland forest – *mata de tabuleiro*), which is characterized by a series of low elevation hills (28–65 m high) and flat-bottom valleys (Vicens *et al*., 1998). The altitude of the fruit sampling area ranged from 48 to 60 m above sea level. According to Köppen's classification, the climate is Aw, humid tropical, with a mean annual rainfall of 1403 mm, a mean maximum temperature of 25.2°C, a mean minimum temperature of 19.1°C and a mean relative humidity of 84.3% (Souza *et al*., 2002).

Collection of fruit

Fruits from native plants (recently fallen or picked from trees) were collected weekly, according to the fruiting season of each species, during the period from February 2003 to July 2006. Sampled fruits were washed and counted, and the total mass of the sample was defined. Fruits were then placed in plastic pots containing a layer of autoclaved and sifted sand, so as to provide a pupation substratum. Puparia were kept in cages to allow adults to emerge.

Identification of insects and plants

K. Uramoto and R.A. Zucchi identified the *Anastrepha* species based on females. Nevertheless, in samples where only one species occurred, or where male characteristics permitted specific identification, males were also identified. As the *fraterculus* complex is formed by several cryptic species (Hernández-Ortiz *et al*., 2004; Selivon *et al*., 2005), the name *A. fraterculus* is being used herein in its *sensu lato*. Voucher specimens were deposited in the collection of Escola Superior de Agricultura Luiz de Queiroz (Entomologia), Universidade de São Paulo, São Paulo, Brazil.

Plants were identified by VRDNR botanists; and, in samples from which fruit flies were reared, those parts of the plant important for identification at the species level were dried and deposited in the VRDNR herbarium. Non-scientific plant names were referred to as vernacular names, since only names by which the plants were locally known were used (Frank, 2001).

Data analysis

Infestation indices were calculated in two different ways: (i) by dividing the total number of puparia obtained in a given sample by the number of fruits in the sample (puparia.fruit^{-1}); or (ii) by dividing the total number of

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puparia by the total mass (g) of fruits in the sample (puparia.g^{-1}).

Results

From 330 samples, 11,479 individual fruits were collected (39,810 g), representing 248 species in 51 plant families (table 1). The number of sampled species varied in the diverse families. Approximately 40% of the families sampled were represented by one or two species. Myrtaceae was the most diversified, with 54 species sampled (fig. 1). Emergence of fruit flies was detected in only 33 samples (10% of the total collected). The sampling and rearing of endophytic larvae is very laborious, since such sampling includes indiscriminate collecting of both infested and non-infested plant parts, as herbivore infestation cannot be easily recognized (Novotny *et al*., 2005).

In ten plant families, 28 species were established as being natural hosts of ten *Anastrepha* species (*A. antunesi* Lima (one species), *A. bahiensis* Lima (two species), *A. bondari* Lima (one species), *A. distincta* Greene (two species), *A. fraterculus* (Wiedemann) (14 species), *A. fumipennis* Lima (one species), *A. nascimentoi* Zucchi (one species), *A. obliqua* (Macquart) (five species), *A. serpentina* (Wiedemann) (four species) and *A. zenildae* Zucchi (one species)) and of *Ceratitis capitata* (Wiedemann) (one species) (tables 2 and 3). Twenty of the 33 associations were recorded for the first time (table 3). New associations with host plants were detected for the following fruit fly species: *A. antunesi*, *A. bahiensis*, *A. bondari*, *A. distincta*, *A. fumipennis*, *A. nascimentoi* and *A. zenildae* (one record each), *A. obliqua* (two records), *A. serpentina* (three records) and *A. fraterculus* (eight records) (table 3). In the 33 samples where fruit fly emergence occurred, the individual mass of the fruit was generally low. Fruit from 20 samples weighed, on average, less than 10 g (only one weighed more than 100 g). Infestation indices were lower than 0.5 puparia.g^{-1}, except for one sample of *Eugenia platyphylla* (table 4).

Discussion

Records of new hosts were obtained from several studies conducted in areas containing preserved native vegetation (Hernández-Ortiz & Pérez-Alonso, 1993; Copeland *et al*., 2002; Aluja *et al*., 2003). In this study and among the new hosts, the host-plant records were acquired for *A. fumipennis* on *Geissospermum laeve* (Vell.) Ball. (Apocynaceae) and *A. nascimentoi* on *Cathedra bahiensis* Sleumer (Olacaceae). Although *A. nascimentoi* is not classified in any species group, it may belong in the *spatulata* group, which is mainly associated with Euphorbiaceae and Olacaceae (Norrbom *et al*., 1999). Therefore, this finding has contributed to reinforcing the idea that host-plant associations of *Anastrepha* appear to be correlated with phylogenetic relationships within the genus (Norrbom *et al*., 1999). Furthermore, host information can be useful for studies on the biology and ecology of these insects. Nevertheless, the hosts of over 50% of the 213 *Anastrepha* species remain unknown.

The *fraterculus* species group, which is considered to be the most derived group (Norrbom *et al*., 1999), was represented by six species (*A. antunesi*, *A. bahiensis*, *A. distincta*, *A. fraterculus*, *A. obliqua* and *A. zenildae*) all of which were associated with plant families belonging to the plant group Rosids, namely Leguminosae (Mimosoidea), Moraceae, Rhamnaceae, Melastomataceae, Myrtaceae and Anacardiaceae, except *A. fraterculus*, which also infested a species of Annonaceae, one of the primitive families of Angiosperm (Judd *et al*., 2002).

A. fraterculus is the most polyphagous species of *Anastrepha*, infesting species of 37 plant families (Norrbom,

Table 1. Plant family and species collected in the Vale do Rio Doce Natural Reserve, Linhares, ES, February 2003–July 2006.

Families/Species
Anacardiaceae
Astronium graveolens Jacq.
Spondias venulosa Mart. ex Engl.
Spondias cf. macrocarpa Engl.
Tapiriba guianensis Aubl.
Thyrsodium schomburgkianum Benth.
Annonaceae
Annona cacans Warm
Oxandra sp.
Rollinia laurifolia Schltdl.
Unonopsis aff. stipitata Diels
Xylopia laevigata (Mart.) R.E. Fries
Xylopia sericea A. St. Hil.
Apocynaceae
Aspidosperma cylindrocarpon Mull. Arg.
Aspidosperma pyricollum Mull. Arg.
Geissospermum laeve (Vell.) Baill.
Himatanthus phagedaenica (Mart.) Woodson
Rauvolfia mattfeldiana Markgraf.
Arecaceae
Aiphanes aculeata Willd.
Desmoncus orthacanthos Mart.
Syagrus schizophylla (Mart.) Glassman
Bignoniaceae
Tabebuia arianeae A.H. Gentry
Tabebuia heptapylla (Vell.) Toledo
Tabebuia ochracea (Cham.) Standl.
Tabebuia roseo- alba (Ridley) Sandwith
Bombacaceae
Bombacopsis stenopetala (Casar.) A. Robyns
Eriotheca candolleana (K. Schum.) A. Robyns
Pseudobombax grandiflorum (Cav.) A. Robyns
Boraginaceae
Cordia lomatoloba I.M. Johnston
Cordia sellowiana Cham.
Cordia spp. (3 species)
Burseraceae
Crepidospermum atlanticum Daly
Protium aff. wearmingianum March.
Protium cf. glaziovii Swart
Protium heptaphyllum (Aubl.) Marchand
Protium heptaphyllum (Aubl.) March. subsp. *heptaphyllum*
Trattinnickia mensalis Dally

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Table 1 Continued.

Families/Species

Caricaceae
Jacaratia heptaphylla (Vell.)
Jacaratia spinosa Aubl. A.D.C.

Caryocaraceae
Caryocar edule Casar

Cecropiaceae
Cecropia pachystachya Trécul.

Celastraceae
Maytenus cestrifolia Reissek

Chrysobalanaceae
Hirtella corymbosa Cham. & Schltdl.
Licania kunthiana Hook. f.
Licania littoralis Warm.
*Licania salzmanni (*Hook.) Fritsch.
Parinari parvifolia Sandw.

Clusiaceae
Clusia spiritu-sanctensis G. Mariz & B. Weinberg
Kielmeyera membranacea Casar.
Kielmeyera occhioniana Saddi
Rheedia brasiliensis (Mart.) Planch. & Triana
Rheedia gardneriana Planch. & Triana
Tovomita brevistaminea Engl.
Vismia sp.

Combretaceae
Buchenavia rabelloana Mattos

Ebenaceae
Diospyros weddellii Hiern.

Erythroxylaceae
Erythroxylon pulchrum A. St. Hil.

Euphorbiaceae
Glycydendron amazonicum Ducke
Margaritaria nobilis Linn.

Flacourtiaceae
Banara brasiliensis (Schott) Benth.
Carpotroche brasiliensis Endl.
Casearia ulmifolia Cambess.
Casearia commersoniana Cambess.
Casearia oblongifolia Cambess.
Casearia spp. (3 species)

Hippocrateaceae
Cheiloclinium cognatum (Miers) A.C. Smith

Humiriaceae
Humiria balsamifera var. *parvifolia* (A. Juss.) Cuatrec
Vantanea bahiaensis Cuatrec.

Lauraceae
Beilschmiedia sp.
Licaria bahiana Kurz.
Ocotea cernua (Nees) Mez
Ocotea conferta Coe Teixeira
Ocotea notata (Nees) Mez
Ocotea spectabilis (Meisn.) Mez
Rhodostemonodaphne capixabensis Baitello & Coe-Teixeira

Lecythidaceae
Cariniana legalis (Mart.) Kuntze
Couroupita guianensis Aubl.

Leg. Caesalpinioideae
Amburana cearensis (Fr. All.) A.C. Smith
Apuleia leiocarpa Macbr.
Cassia ferruginea (Schrad.) ex DC.
Chamaecrista aspleniifolia H.S. Irwin & Barneby
Copaifera sp.
Dialium guianense (Aubl.) Sandwith
Dimorphandra sp.
Phyllocarpus riedelii Tul.
Sclerolobium striatum Dwyer
Senna macranthera (Collad.) Irwin & Barneby

Leg. Faboideae
Bowdichia virgiloides Kunth
Exostyles venusta Schott ex Spreng.
Lonchocarpus guillemineanus Malme
Myrocarpus frondosus Allemao
Ormosia arborea (Vell.) Harms
Poecilanthe falcata (Vell.) Heringer
Swartzia cf. acutifolia Vog.
Swartzia apetala Raddi
Swartzia apetala var. *glabra* (Vogel) R.S. Cowan
Swartzia linharensis Mansano
Sweetia fruticosa Spreng.

Leg. Mimosoideae
Acacia langsdorffii Benth.
Albizia polycephala (H.B. & K.) Killip
Inga aff. cylindrica (Vell.) Mart.
Inga laurina (Sw.) Willd.
Inga striata Benth.
Inga subnuda Salzm. ex Benth.
Inga thibaudiana DC.
Parapiptadenia pterosperma (Benth.) Brenan
Pseudopiptadenia contorta (DC.) G.P. Lewis & M.P. Lima

Loganiaceae
Strychnos cf. hirsuta Spruce ex Benth.

Malpighiaceae
Byrsonima cacaophila W.R. Anderson
Byrsonima seriacea DC.
Byrsonima stipulacea A. Juss.

Melastomataceae
Miconia cf. cinnamomifolia (DC.) Naudin
Miconia holosericea (L.) Triana
Miconia hypoleuca (Benth.) Triana
Miconia splendens (Sw.) Griseb.
Mouriri doriana Saldanha in Mart.
Mouriri glazioviana Cogn. in Mart.
Mouriria arborea Gardner

Meliaceae
Guarea penningtoniana M.E. Morales
Trichilia casaretti C.DC.
Trichilia lepisota (Harms) Mart.
Trichilia aff. surumuensis C.DC.
Thichilia sp.

Menispermaceae
Abuta selloana Eichler

Monimiaceae
Siparuna arianeae V. Pereira

Moraceae
Brosimum glaucum Tamb. Taub.
Clarisia racemosa Ruiz & Pav.
Ficus crocata Mart. ex Miq.
Ficus enormis Mart. ex Miq.
Ficus gomelleira Klunth & Bouche
Ficus mariae C.C. Berg, Emygdio & Carauta
Ficus nynphaeifolia Mill.
Ficus pertusa Bory ex Miq.
Helicostylis tomentosa Rusby
Naucleopsis oblongifolia (Kuhlm.) Carauta
Sorocea guilleminiana Gaudich.

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Table 1 Continued.

Families/Species

Myristicaceae
Virola gardneri (A.DC.) Warb.

Myrtaceae
Calyptranthes spp. (2 species)
Campomanesia espiritosantensis Landrum
Campomanesia lineatifolia Ruiz et Pav.
Eugenia adstringens Cambess
Eugenia bahiensis DC.
Eugenia beaurepaireana (Kiaersk.) C.D. Legrand
Eugenia bimarginata DC.
Eugenia brasiliensis Lam.
Eugenia excelsa O. Berg
Eugenia fluminensis O. Berg
Eugenia gemminiflora O. Berg
Eugenia involucrata DC.
Eugenia ligustrina (Sw.) Willd.
Eugenia cf. Olivacea O. Berg
Eugenia aff. oxyphylla O. Berg
Eugenia piauhiensis O. Berg
Eugenia platyphylla O. Berg
Eugenia platysema O. Berg
Eugenia stictosepala Kiaersk.
Eugenia stipitata Mc Vaugh
Eugenia sulcata Spring. ex Mart.
Eugenia cf. tinguyensis Cambess.
Eugenia vernicosa O. Berg
Eugenia spp. (9 species)
Gomidesia martiana O. Berg
Lecythis lanceolata Poir.
Marlierea acuminatissima (Berg) Legrand.
Marlierea aff. clausseniana Kiaersk.
Marlierea obscura O. Berg
Marlierea silvatica (Gardner) Kiaersk.
Marlierea sp.
Myrcia fallax DC.
Myrcia follii Barroso et. Peixoto
Myrcia aff. guyanensis DC.
Myrcia nigropunctata (Berg) N.J.E. Silveira
Myrcia sp.
Myrciaria floribunda O. Berg
Myrciaria jaboticaba (Vell.) O. Berg
Myrciaria sp.
Plinia renatiana Barroso et Peixoto
Plinia strigipes (Berg) Sobral O. Berg
Psidium guineense Sw.
Psidium aff. macrospermum O. Berg
Psidium myrtoides O. Berg
Psidium sp.

Nyctaginaceae
Guapira cf. subferruginosa (Mart. ex Schum.) Lundell

Olacaceae
Cathedra bahiensis Sleumer
Liriosma sp.
Schoepfia obliquifolia Turcz.

Passifloraceae
Passiflora riparia Mart.

Polygonaceae
Coccoloba warmingii Meisn.
Ruprechtia laurifolia (Cham. & Schltdl.) Mey.

Rhamnaceae
Rhammidium glabrum Reissek
Ziziphus glaziovii Warm.
Ziziphus platyphylla Reissek

Rubiaceae
Anthocephalus cadamba Miq.
Coussarea contracta (Walp.) Benth. & Hook.
Duroia sp.
Melanopsidium nigrum Colla
Posoqueria latifolia (Rudge) Roem. & Schult.
Psychotria carthagenensis Jacq.
Randia armata D.C.
Simira eliezeriana Peixoto
Simira glaziovii (K. Shum.) Steyernark

Rutaceae
Metrodorea maracasana Kaastra
Rauia sp.
Zanthoxylum cf. juniperinum Poeppig

Sapindaceae
Allophylus petiolulatus Radlk.
Cupania cf. scrobiculata L.C. Rich.
Cupania emarginata Cambess.
Dilodendron elegans (Radlk.) Gentry & Steyerm.
Matayba discolor Radlk.
Matayba guianensis Aubl.
Talisia intermedia Radlk.

Sapotaceae
Chrysophyllum cainito L.
Chrysophyllum lucentifolium Cronquist.
subsp. *lucentifolium*
Lucuma butyrocarpa Kuhlmann
Manilkara bella Monach.
Manilkara salzmannii (A.DC.) H.J. Lam
Manilkara subsericea (Mart.) Dubard.
Micropholis gardneriana (A.DC.) Pierre
Mimusops sp.
Pouteria bangii (Rusby) T.D. Pennington
Pouteria coelomatica Rizzini
Pouteria cuspidata (A.DC.) Baehni
Pouteria macrophylla (Lam.) Eyma
Pouteria psammophila (Mart.) Radlk.
Pouteria sp.

Simaroubaceae
Simaba subcymosa A. St. Hil. & Tul.

Sterculiaceae
Pterygota brasiliensis Fr. All.
Sterculia elata Ducke
Sterculia speciosa K. Schum.

Styracaceae
Styrax glabratum Schott

Theophrastaceae
Clavija caloneura Mart. & Miq.

Thymelaeaceae
Daphnopsis sp.

Verbenaceae
Vitex cf. montevidensis Cham.

Vochysiaceae
Qualea magna Kuhlm.
Qualea megalocarpa Stafleu
Vochysia angelica M.C. Vianna & Fontella
Erisma arietinum Kawasaki

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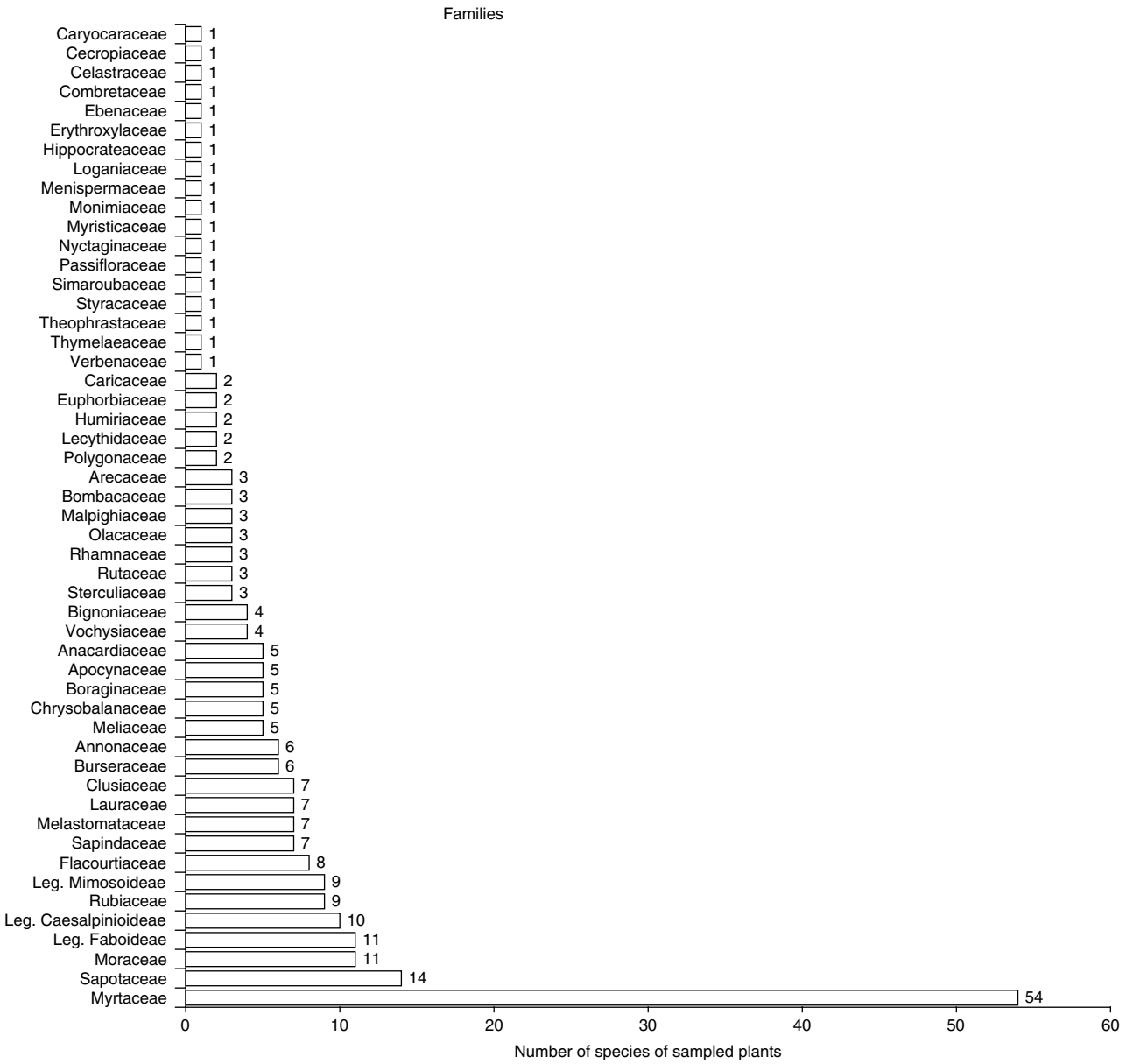

Fig. 1. Number of species of each plant family sampled in the Vale do Rio Doce Natural Reserve, Linhares, ES, February 2003–July 2006.

2004). In this study, it was noted that fruits of *Mouriri glazioviana* Cogn. (Melastomataceae) were infested by *A. fraterculus*. Melastomataceae species had never before been recorded as *A. fraterculus* hosts, thus, revealing that the host range for this species, even as regards host family, could possibly expand as further host plant surveys proceed, especially in forest areas. As *Anastrepha fraterculus* is being considered herein in its *sensu lato*, this finding could be one more indication in clarifying the species of this complex. In Angiosperm phylogeny, Melastomataceae is a close family to Myrtaceae (Judd *et al*., 2002), whereby it is possible that the fruit of both plant families possess similar characteristics, which can attract this fruit fly species. Fourteen species of three plant families (Annonaceae, Melastomataceae and Myrtaceae) were observed to be attacked by *A. fraterculus*, including 12 Myrtaceae species of which six belong to the genus *Eugenia*. Therefore, *A. fraterculus* infested the highest diversity of plants, confirming its polyphagous nature (table 2). Nevertheless, care is needed when referring to *A. fraterculus* in this context, as it is formed by a complex of cryptic species, some of which may be monophagous or oligophagous. According to fruiting phenology when infested by the *A. fraterculus* complex, it may be inferred that host succession occurred since this fly infested fruits from different plant species throughout the year (table 2).

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Table 2. Fruit fly species obtained from native fruit and their collecting periods in the Vale do Rio Doce Natural Reserve, Linhares, ES, February 2003–July 2006.

Fruit flies species	Host plants		
	Families	Species	Sampling periods
Anastrepha antunesi Lima	Anacardiaceae	*Spondias cf. macrocarpa* Engl.	Aug '03
Anastrepha bahiensis Lima	Moraceae	*Helicostylis tomentosa* (Poep. et Endl.) Rusby	Jan '04, Feb '05
	Myrtaceae	*Eugenia platyphylla* O. Berg	Dec '03
Anastrepha bondari Lima	Moraceae	*Naucleopsis oblongifolia* (Kuhlm.) Carauta	Feb '04, Feb '05
Anastrepha distincta Greene	Leg. Mimosoideae	*Inga aff. cylindrica* (Vell.) Mart.	Nov '03
		Inga laurina (Sw.) Willd.	Jun '06
Anastrepha fraterculus (Wied.)	Annonaceae	*Rollinia laurifolia* Schltdl.	Dec '05, Jan '06, Mar '05
	Melastomataceae	*Mouriri glazioviana* Cogn.	May '05
	Myrtaceae	*Eugenia gemminiflora* Berg	Jan '04
		Campomanesia espiritosantensis Landrum	Feb '04
		Campomanesia lineatifolia Ruiz et Pav.	Feb '05
		Eugenia involucrata DC.	Mar '04
		Psidium guineense Sw.	Mar '04, Nov '05
		Psidium myrtoides O. Berg	Apr '05
		Eugenia stipitata Mc Vaugh	Apr '04
		Eugenia platysema Berg	May '04, Jul '04
		Myrcia aff. clausseniana (Berg) Barroso et Peixoto	Jun '04
		Plinia strigipes O. Berg	Nov '03, Jun '04, Oct '05
		Eugenia brasiliensis Lam.	Nov '03
		Eugenia platyphylla O. Berg	Dec '03
Anastrepha fumipennis Lima	Apocynaceae	*Geissospermum laeve* (Vell.) Baill.	Mar '03, Feb '04, Feb '06
Anastrepha nascimentoi Zucchi	Olacaceae	*Cathedra bahiensis* Sleumer	Jan '04
Anastrepha obliqua (Macquart)	Anacardiaceae	*Spondias venulosa* Mart. ex Engl.	Mar '03, Apr '04
		Thyrsodium schomburgkianum Benth.	Nov '03
	Myrtaceae	*Eugenia brasiliensis* Lam.	Nov '03
		Eugenia platyphylla O. Berg	Dec '03
		Psidium guineense Sw.	Mar '04, Nov '05
Anastrepha serpentina (Wied.)	Moraceae	*Ficus gomelleira* Klunth & Bouche	Apr '03, Mar '04, Dec '05
	Sapotaceae	*Chrysophyllum cainito* L.	Oct '05
		Manilkara bella Monach.	Feb '03, Oct '04, Mar '06
		Pouteria psammophila (Mart.) Radlk.	Mar '04
Anastrepha zenildae Zucchi	Rhamnaceae	*Ziziphus platyphylla* Reissek	May '06
Ceratitis capitata (Wied.)	Myrtaceae	*Psidium guineense* Sw.	Mar '04, Nov '05

Five associations were defined between *A. obliqua* and plant species, two from the Anacardiaceae species and three from the Myrtaceae. This indicates a more oligophagous than poliphagous behavior, as has already been observed in disturbed environments.

A. bahiensis infested fruit of both the Moraceae and the Myrtaceae. Although these two plant families have already been registered as host, in the present study a new association with *Eugenia platyphylla* O. Berg (Myrtaceae) was detected.

A. distincta was associated with two *Inga* species (Leguminosae – Mimosoidea), this plant family probably being its primary host.

A new host record was obtained for *A. antunesi* on *Spondias cf. macrocarpa* Engl. (Anacardiaceae).

There are records of Rhamnaceae species being infested by only *A. fraterculus* and *A. zenildae* (see Norrbom, 2004), suggesting specificity of Rhamnaceae species with *A. zenildae* and possibly being its primitive host. Probably the record of *A. fraterculus* on Rhamnaceae species is a misidentification, seeing as the two species of flies are morphologically close to one another.

Three associations were determined between *A. serpentina* and Sapotaceae species (*Ziziphus platyphylla* Reissek, *Chrysophyllum cainito* L. and *Manilkara bella* Monach.) in addition to one Moraceae species (*Ficus gomelleira* Klunth & Bouche), constituting the first record with this plant family. Both plant families are latex-bearing, thus it appears that *A. serpentina* mainly associates with latex-bearing plant species.

A. bondari was obtained from the fruits of *Naucleopsis oblongifolia* (Kuhlm.) Carauta (Moraceae). Until now, only one species of *Helicostylis* has been cited as a host for *A. bondari* among the Moraceae genera. Therefore, *Naucleopsis* represents the second genus in this family with a species thus attacked.

C. capitata was only associated with *Psidium guineense* Sw. (Myrtaceae). Possibly this fly infests fruits of plants grown in commercial orchards located near the reserve, only using native fruits by accident. In a trap survey conducted in VRDNR (Uramoto, unpublished data), no *C. capitata* specimen was captured during a period of five years. Furthermore, in a study conducted in northeastern Argentina, *C. capitata* was predominant in introduced fruits, the population of adults being more abundant in disturbed environments, such as urban or rural zones and commercial orchards (Ovruski *et al*., 2003). In Brazil, it has been encountered in urban zones on *Terminalia catappa* L. (Malavasi *et al*., 2000).

Simultaneous infestations of the same host in VRDNR were observed in only three samples among 33; *Eugenia*

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Table 3. Total number and sex ratio of fruit fly specimens obtained from native fruit in the Vale do Rio Doce Natural Reserve, Linhares, ES, February 2003–July 2006.

Host plants			Fruit fly species sex ratio (♀/♂)
Families	Species	Vernacular names	
Anacardiaceae	*Spondias venulosa*	Cajá	*A. obliqua* (32/26)
	Spondias cf. macrocarpa	Cajá-mirim	*A. antunesi*[a] (34/29)
	Thyrsodium schomburgkianum	Acarana	*A. obliqua*[a] (2/0)
Annonaceae	*Rollinia laurifolia*	Pinha-da-mata	*A. fraterculus*[a] (1/0)
Apocynaceae	*Geissospermum laeve*	Pau-pereira	*A. fumipennis*[a] (26/27)
Leg. Mimosoideae	*Inga aff. cylindrica*	Ingá-ferro	*A. distincta*[a] (3/1)
	Inga laurina	Ingá-chato	*A. distincta* (5/0)
Melastomataceae	*Mouriri glazioviana*	Cabelo-de-negro	*A. fraterculus*[a] (5/1)
Moraceae	*Ficus gomelleira*	Mata-pau	*A. serpentina*[a] (10/7)
	Helicostylis tomentosa	Jaquinha	*A. bahiensis* (2/4)
	Naucleopsis oblongifolia	Bainha-de-espada	*A. bondari*[a] (17/12)
Myrtaceae	*Campomanesia espiritosantensis*	Araçá-miúdo	*A. fraterculus*[a] (2/4)
	Campomanesia lineatifolia	Gabiroba-gengibre	*A. fraterculus* (3/10)
	Eugenia brasiliensis	Pepeu	*A. fraterculus* (8/10)
			A. obliqua (4/0)
	Eugenia gemminiflora	Henrique	*A. fraterculus*[a] (1/3)
	Eugenia involucrata	Araçá	*A. fraterculus* (7/8)
	Eugenia platyphylla	Batinga-casca-grossa	*A. bahiensis*[a] (5/−)
			A. fraterculus[a] (14/−)
			A. obliqua[a] (1/−)
			Anastrepha sp. (20 ♂)
	Eugenia platysema	Pitanga-da-mata	*A. fraterculus*[a] (1/1)
	Eugenia stipitata	Araçá-boi	*A. fraterculus* (3/3)
	Myrcia aff. clausseniana	Coração-alado	*A. fraterculus*[a] (2/0)
	Plinia strigipes	Cambucá	*A. fraterculus* (1/0)
	Psidium guineense	Araçá-da-praia	*A. fraterculus* (2/2)
			A. obliqua (10/2)
			C. capitata (1/1)
	Psidium myrtoides	Araçá-de-pedro	*A. fraterculus*[a] (3/0)
Olacaceae	*Cathedra bahiensis*	Baleira	*A. nascimentoi*[a] (2/3)
Rhamnaceae	*Ziziphus platyphylla*	Juazeiro	*A. zenildae*[a] (4/2)
Sapotaceae	*Chrysophyllum cainito*	Abiu-roxo	*A. serpentina* (99/62)
	Manilkara bella	Parajú	*A. serpentina*[a] (4/8)
	Pouteria psammophila	Leiteiro-branco	*A. serpentina*[a] (3/2)

a, new associations with host plants; −, unidentified.

platyphylla was simultaneously infested by *A. bahiensis*, *A. fraterculus*, and *A. obliqua*, *Psidium guineense* by *A. fraterculus*, *A. obliqua* and *C. capitata*, and *Eugenia brasiliensis* by *A. fraterculus* and *A. obliqua*. Nevertheless, monophagous and oligophagous species were predominant in the reserve. In preserved tropical forests, this tendency has been noted to be common, as observed in studies undertaken in forest remnants in Mexico (Hernández-Ortiz & Pérez-Alonso, 1993; Aluja *et al*., 2003).

The individual mass of most infested fruit was low, confirming that the association between fruit flies and their native hosts is extremely important, and even those apparently insignificant in size must be evaluated (Aluja, 1999).

The results obtained in this study, such as new associations between host plants and fruit flies, as well as the discovery of host plants for *A. fumipennis* Lima and *A. nascimentoi* Zucchi, prove how important it is to undertake research in areas with preserved native vegetation. Thus, it is highly desirable to continue the fruit plant survey in this reserve, as well as in other fragments of the Atlantic Rain Forest, since the present area represents only 7.5% of its original extent (Myers *et al*., 2000). Therefore, the preservation of these areas is of inestimable value, mainly for the conservation of specialist fruit fly species and their host plants. Furthermore, their detection may represent an indicator of environmental quality. Terrestrial invertebrate richness and abundance can provide information contributing to biodiversity conservation and management and conservation planning programs for forestry reserves (Pyle *et al*., 1981).

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Table 4. Infestation indices in fruit species collected in the Vale do Rio Doce Natural Reserve, Linhares, ES, February 2003–July 2006.

Plant species	Fruits			Total number of puparia	Infestation indices	
	Sample mass	Individual mass	Total number in sample		puparia fruit^{-1}	puparia g^{-1}
	Total (g)	Mean (g)	*N*	*N*		
Spondias venulosa	616.00	34.20	18.00	106.00	5.89	0.17
	184.35	30.73	6.00	32.00	5.33	0.17
Spondias cf. macrocarpa	176.00	8.00	22.00	82.00	3.73	0.47
Thyrsodium schomburgkianum	132.76	3.49	38.00	6.00	0.16	0.05
Rollinia laurifolia	117.36	13.04	9.00	1.00	0.11	0.01
Geissospermum laeve	165.36	41.34	4.00	53.00	13.25	0.32
Inga aff. cylindrica	108.06	9.00	12.00	4.00	0.33	0.04
Inga laurina	150.32	16.70	9.00	5.00	0.56	0.03
Mouriri glazioviana	66.82	5.14	13.00	6.00	0.46	0.09
Ficus gomelleira	209.52	7.48	28.00	19.00	0.68	0.09
Helicostylis tomentosa	61.69	1.21	51.00	8.00	0.16	0.13
Naucleopsis oblongifolia	149.88	37.47	4.00	29.00	7.25	0.19
Campomanesia espiritosantensis	34.1	3.79	9.00	6.00	0.67	0.18
Campomanesia lineatifolia	46.75	5.84	8.00	13.00	1.63	0.28
Eugenia brasiliensis	104.08	2.54	41.00	20.00	0.49	0.19
	88.36	2.45	36.00	10.00	0.28	0.11
Eugenia gemminiflora	368.00	40.89	9.00	16.00	1.78	0.04
Eugenia involucrata	179.4	6.19	29.00	27.00	0.93	0.15
Eugenia platyphylla	40.16	2.36	17.00	6.00	0.35	0.15
	66.82	2.09	32.00	56.00	1.75	0.84
	57.18	2.60	22.00	21.00	0.95	0.37
Eugenia platysema	60.29	6.70	9.00	2.00	0.22	0.03
Eugenia stipitata	55.5	55.50	1.00	6.00	6.00	0.11
Myrcia aff. clausseniana	14.27	0.75	19.00	2.00	0.11	0.14
Plinia strigipes	26.76	2.06	13.00	1.00	0.08	0.04
Psidium guineense	101.23	14.46	7.00	18.00	2.57	0.18
Psidium myrtoides	18.9	1.45	13.00	3.00	0.23	0.16
Cathedra bahiensis	80.39	13.40	6.00	5.00	0.83	0.06
Ziziphus platyphylla	78.00	5.20	15.00	6.00	0.67	0.08
Chrysophyllum cainito	482.24	160.75	3.00	213.00	71.00	0.44
Manilkara bella	549.17	32.30	17.00	8.00	0.47	0.01
	302.25	21.59	14.00	4.00	0.29	0.01
Pouteria psammophila	138.08	9.86	14.00	38.00	2.71	0.28

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