First characterization of a taxonomically well-resolved trophic network composed by host plants and gall midges (Diptera: Cecidomyiidae) in the Neotropical region

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Abstract. In the present study we described the structure of a trophic network composed by gall-midge species (Diptera: Cecidomyiidae) and their host plants in the Restinga of Barra de Maricá (Maricá, Rio de Janeiro, Brazil). Species data were retrieved from literature and different topological descriptors (links per species, connectance, and modularity of interactions) were used. All gall-midge species were monophages, with connectance of 2.8% of the 2,016 possible interactions. The network of host plants and gall midges had low number of links per species and high modularity, which indicates high specificity and specialization of plant-galling interactions in the area. This is the first characterization of a trophic network with good taxonomic resolution for the Neotropical gall midges.

Keywords. Atlantic Forest; Cecidomyiidae; Diptera; Plant-galling interactions; Specificity.

INTRODUCTION

Cecidomyiidae (Diptera) is the most diverse group of gall-inducing insects in the world, with more than 6,500 described species (Gagné & Jaschhof, 2017). Nevertheless, the Neotropical fauna comprises only about 8% of the known species, a very low percentage, considering that in this region there are some megadiverse countries (Fernandes & Santos, 2014). The Brazilian fauna includes about 50% of the described Neotropical species (Gagné, 1994; Gagné & Jaschhof, 2017), most of them from the Atlantic Forest. This situation reflects the scarcity of taxonomical studies about gall midges (Araújo et al., 2019a), which makes it difficult to understand biological and ecological processes involving these insects and their host plants.

In the present study, we described for the first time a taxonomically well-resolved network composed by host plants and gall midges at the Restinga of Barra de Maricá, municipality of Maricá, State of Rio de Janeiro, Southeastern Brazil. Restinga or coastal shrub zone is one of the most endangered vegetal physiognomy of the Brazilian Atlantic Forest due to anthropic action (Santos et al., 2017). For explore the network structure we used different topological descriptors (links per species, connectance, modularity, and robustness of interactions) commonly indicated to describe the architecture of binary bipartite networks (review in Dormann et al., 2009).

MATERIAL AND METHODS

Data compilation

Maia studied the Restinga of Barra de Maricá for several years, from 1992 to 2011, during which this author and collaborators recorded a great amount of insect galls and their host plants, and described many gall midge species. In the present study, we compiled these data and arranged them in a database containing the gall-midge species and their host plants in order to building a list of plant-galling interactions (Table 1). All data used were previously published (Appendix 1). Only plants and gall midges identified at specific level were used in the compilation. All botanical names were updated using the database Flora do Brasil (2020) and nomenclature of gall midges was verified using Gagné & Jaschhof (2017).
Table 1. Checklist of host plants and gall midges recorded in the Restinga of Barra de Maricá (Maricá, RJ, Brazil).

| Host species | Gall midge species |
|--------------|--------------------|
| Bornien verticillata (L.) G. Mey. | Asphondylia borniae Rubsaamen, 1905 |
| Byrsonima sericea DC. | Bruegmannella byrsonorma (Maia & Cout, 1992) |
| Byrsonima sericea DC. | Dasineura byrsonorma Maia, 2010 |
| Clusia fluminensis Planch. et Triana | Parasipistoius clusiae Maia, 2001 |
| Clusia lanceolata Cambess. | Clusia myia nitida Maia, 1996 |
| Couepia ovalifolia (Schout.) Benth. ex Hook.f. | Dasineura couepiae Maia, 2001 |
| Couepia ovalifolia (Schout.) Benth. ex Hook.f. | Lapesia marginalis Maia, 2001 |
| Dalbergia ecostaphylum (L.) Taub. | Lapesia grandis Maia, 2001 |
| Erythroxylum ovalifolium Peyer. | Dasineura ovalifolii Maia & Fernandes, 2011 |
| Erythroxylum ovalifolium Peyer. | Lapesia erythrophyi Rodrigues & Maia, 2010 |
| Eugenia astringens Cambess. | Dasineura globosia Maia, 1995 |
| Eugenia astringens Cambess. | Dasineura margini Maia, 2005 |
| Eugenia astringens Cambess. | Stephanomyia natudoflorum Maia, 1993 |
| Eugenia copacabambensis Klaers. | Stephanomyia espinis Maia, 1993 |
| Eugenia copacabambensis Klaers. | Stephanomyia tetetoblo Maia, 1993 |
| Eugenia unifolia L. | Clododiplosis profusa Maia, 2001 |
| Eugenia unifolia L. | Eugeniamyia triangularis Maia, 2011 |
| Eugenia unifolia L. | Neolasioptron eugeniae Maia, 1993 |
| Fredericia anjogueata (Vell.) L.G. Lohmann | Arrabadasania serrata Maia, 2001 |
| Guapira opposita (Vell.) Reitz | Bruegmannia acarudota Maia, 2004 |
| Guapira opposita (Vell.) Reitz | Bruegmannia elongata Maia & Cout, 1993 |
| Guapira opposita (Vell.) Reitz | Bruegmannia monteros Maia & Cout, 1993 |
| Guapira opposita (Vell.) Reitz | Bruegmannia robusta Maia & Cout, 1993 |
| Guapira opposita (Vell.) Reitz | Psophodina brasiliensis Cout & Maia, 1992 |
| Guapira opposita (Vell.) Reitz | Prasodiplosis funifera Maia, 1993 |
| Guapira opposita (Vell.) Reitz | Prasodiplosis guapiac Maia, 1993 |
| Heteropterys nitida (Lam.) DC. | Clododiplosis florios Novo-Guedes & Maia, 2008 |
| Hylocereus setaceus (Salis-Dyck) R.Bauer | Neolasioptron cenr (Rubsaamen, 1905) |
| Jacquiermonta holosericea (Weinm.) O’Donell | Schizomyia santorii Maia & Araújo, 2009 |
| Lantana camara L. | Schizotetradiplosis lanatae (Rubsaamen, 1916) |
| Manilkara subsericea (Mart.) Dubard | Manilkaramyia robactis Maia, 2001 |
| Melissia officinalis L. | Clododiplosis melissa Maia, 1994 |
| Micromandra vaculinata (Langsd. & Fich.) Copel. | Primadiplosis microgramma Maia, 2011 |
| Microstachys camicula (Vahl) Griseb. | Clododiplosis conia Oliveira & Maia, 2008 |
| Microstachys camicula (Vahl) Griseb. | Schizomyia spheric Maia & Oliveira, 2007 |
| Monteverdia obtusifolia (Mart.) Bailral | Bruegmannalia monteiros Maia & Cout, 1992 |
| Monteverdia obtusifolia (Mart.) Bailral | Maytenella distincta Maia, 2001 |
| Myrcia ovata Cambess. | Myrciamyia maricaensis Maia, 1996 |
| Myrcia floribunda (H.West ex Willd.) O. Berg | Dasineura myrica Maia, 1995 |
| Myrcia floribunda (H.West ex Willd.) O. Berg | Miycariumyia bisulva Maia, 1994 |
| Neomantodes obscura (DC.) N.Silveira | Neomantodes robusta Maia, 1995 |
| Neomantodes obscura (DC.) N.Silveira | Stephanomyia mine Maia, 1993 |
| Paulinia weinmanniifolia Mart. | Clododiplosis costa Maia, 2005 |
| Paulinia weinmanniifolia Mart. | Pauliniamyia amipla Maia, 2001 |
| Peplonia astenii (Vell.) Fontella & E.A. Schwartz | Asphondylia peplonea Maia, 2001 |
| Pouetia caimito (Ruiz & Pacr.) Radkl. | Youngomyia pouetii Maia, 2001 |
| Pouetia venosa (Mart.) Baehni | Lapesia singularis Maia, 2010 |
| Protium brasiliense (Spreng.) Engl. | Lapesia maricaensis Rodrigues & Maia, 2010 |
| Psychotria dichosea (Mart.) Mart. | Costadiplosis maricaensis Viecente & Maia, 2009 |
| Senna bicapsularis (L.) Rothb. | Asphondylia senor Maia & Cout, 1992 |
| Smitax rufulescens Griseb. | Smilaxoecia candelari Mohn, 1975 |
| Struthanthus tubiflorus Eichler | Asphondylia maricaensis Maia & Cout, 1992 |
| Tetrapteryx phyllooids (Spreng.) Nied. | Schizomyia maricaensis Souza & Maia, 2007 |
| Varronia curassavica Jacq. | Asphondylia caricae Mohn, 1959 |
| Varronia curassavica Jacq. | Cordamia globosa Maia, 1996 |
| Ximenia americana L. | Asphondylia communinis Maia & Cout, 1992 |

The Restinga of Barra de Maricá is located in the municipality of Maricá, Rio de Janeiro, Brazil (22°52’-22°54’S and 42°48’-42°54’W). This restinga has 8 km of extension and 844.16 ha of total area (Santos et al., 2017). The climate of the Maricá region is classified as hot tropical, super humid, with a dry season (Alves et al., 2013). The region has an average annual temperature of 23.2°C and the average annual precipitation is 1,230.8 mm (Santos et al., 2017). It comprises several microenvironment and vegetal formations, which characterize this complex ecosystem with a very diverse flora (Oliveira & Silva, 1989).

Data analyses

The structure of interactions between host plants and gall midges was evaluated using three topological descriptors: connectance, number of links per species, modularity, and robustness. Connectance (C) is the proportion of observed interactions compared to the possible interactions in the network ranging of 0 (totally specialized) to 1 (totally connected) (Dormann et al., 2009). Number of links per species (L) is the sum of links divided by number of species. Modularity (M) is a measure of the occurrence of densely connected modules within the network (Dormann et al., 2009), ranging between 0 (when the network is not modular) and 1 (when a network is very modular). Robustness (R) is a measure of the resistance level of the network to coextinctions (Dormann et al., 2009), measured as the exponent of the curve generated by the proportion of remaining species of gall midges in function of the proportion of primary random extinctions of host plant species. The significance of observed values of each network descriptor was calculated using null models (Dormann et al., 2009). All network analyses were performed using bipartite package (Dormann et al., 2008) in the R software version 3.6.1 (R Core Team, 2020).

RESULTS

In total, we recorded 56 species of 27 genera of gall midges and 36 species of 29 genera and 24 families of host plants (Table 1). The richest gall-midge genera were Asphondylia Loew, 1850 and Dasineura Rondani, 1840, each with six species. All gall midge species recorded are gall-inducers, except Clododiplosis florica Novo-Guedes & Maia, 2008 that is a free-living herbivore. All gall-midge species were monophagous, inducing galls on only one plant species (Table 1).

The host plants Guapira opposita (Vell.) Reitz (Nyctaginaceae), Eugenia astringens Cambess. and Eugenia uniflora L. sheltered more gall midges, with seven, three and three species, respectively (Table 1). The most important host family was Myrtaceae with six plant species and 13 gall-midge species. The genus Eugenia L. (Myrtaceae) stands out for having three species of host plants and eight species of gall midges.

The plant-galling network comprised 56 interactions (Fig. 1), corresponding to only 2.8% of the 2,016 possi-
ble interactions. The observed connectance (C = 0.028) was lower than expected from null model values (Null C = 0.032 ± 0.001, p < 0.001). Similarly, the observed number of links per species (L = 0.608) also was lower than expected by chance (Null L = 0.710 ± 0.020, p < 0.001). The observed modularity for plant-galling network was very high (M = 0.958), but did not differ from null model values (Null M = 0.959 ± 0.001, p > 0.05). Robustness observed was relatively low (R = 1.343), but was higher than expected by chance (Null R = 1.334 ± 0.232, p < 0.001).

**DISCUSSION**

We found a high specialization of interactions between host plants and gall midges in the present study, confirming previous studies (Carneiro et al., 2009; Araújo et al., 2019b). All species of gall midges were recorded on a single host plant species (i.e., monophagous species). The percentage of specialist species recorded in our study is higher than found by Carneiro et al. (2009) which recorded 92% of monophagous gall midges for Brazil. In other study, Araújo et al. (2019b) recorded that 79% of gall-midge species were monophages in the Slovakian region. These results suggest a lower specialization of gall midges in temperate environments when compared to the Neotropical region, which have more specific gallers in their host plants, as observed for the Restinga of Barra de Maricá. It is important to note that there are differences in the duration and frequency of sampling between the present study and the others mentioned. Our network was sampled for a much longer period of time than any previously published study (almost two decades), which enhances the sampling of rarer interactions, and consequently increases the specialization of the network. However, this fact reinforces the relevance of the observed patterns, because even with such a long sampling, only species-specific plant-galling interactions were registered.

The structure of the network formed by the gall midges and their host plants proved to be highly specialized. The connectance observed in the present study (2.8%) was low as compared to other plant-phytophagous networks (review in Araújo et al., 2015). However, comparing with other networks of galling arthropods, the value observed here was higher than observed by Araújo et al. (2017) (2.3%) but lower to that observed by Araújo & Kollar (2019) (5.4%), which sampled networks in temperate forests. Our plant-galling network also showed a low number of links per species (0.608) and a high modularity (0.958), corroborating the pattern observed in other galling networks (Araújo et al., 2017). Our results provide evidence that supports the high specificity and specialization of plant-galling interactions (Araújo et al., 2019b). Furthermore, our results show that the network of host plants and gall midges is few robust to coextinctions. This result is due to the high specificity of the plant-galling interactions, since each species of plant lost, represents the loss of at least one species of gall midge (Araújo et al., 2017).

Main genera of gall midges recorded in our study were Dasineura and Asphondylia. The genus Dasineura is the richest in Cecidomyiidae family with 476 described species (Gagné & Jaschhof, 2017). For the Neotropical region, only 39 species in this genus are described, 10 species from Brazil (Maia & Silva, 2013). In the present study,
Dasineura induced galls mainly on Myrtaceae (but also on Chrysobalanaceae, Erythroxylaceae, and Malpighiaceae). The genus Asphondyliella is cosmopolitan and includes 272 gall-inducing species in the 100 and 100 in the Neotropical region (Gagné & Jaschhof, 2017). In Brazil, Flor & Maia (2017) listed 58 species of Asphondyliella, being 20 already known and 38 are still undetermined. In the Restinga of Maricá, Asphondyliella induced galls on host plants of six families (Asclepiadaceae, Boraginaceae, Fabaceae, Loranthaceae, Olacaceae, and Rubiaceae). These two genera are characterized by highly specialized galling species, most of which are monophagous (Carneiro et al., 2009), which contributed to the low connectivity of the plant-galling network.

Myrtaceae was the plant family that sheltered more gall-midge species (13 species) and presented important host plants (in terms of the number of interactions), such as Eugenia astringens, and Eugenia uniflora (three gall midge species each). Myrtaceae are one of the most diverse families of Angiospermae, with thousands of species, being important in several Neotropical ecosystems (Wilson et al., 2001). Eugenia, with about 1,000 species, is one of the most diverse genera of Myrtaceae, distributed mainly in the Central and South Americas (Merwe et al., 2004), being the genus with the greatest number of species at restingas in the State of Rio de Janeiro (Araújo & Henriques, 1984). The great number of gall midges associated to Myrtaceae plants contributed to the high modularity of the plant-galling network, since the family forms a compartment of interactions within the network. Similarly, Guapira opposita, which was the host plant species that sheltered more gall-midge species with seven species, it also contributed to the formation of a module within the network. This species is one of the most expressive plants in Quaternary coastal plains of the Atlantic Coast of Southern Brazil, very frequent at restingas, where it is widespread and one of the dominant species (Reitz, 1970).

The frequency and abundance of these plant taxa can explain the great diversity of gall-inducers associated with them. In fact, Myrtaceae have been cited in several gall inventories at restinga areas as super host family, not only in the State of Rio Janeiro, as Maricá and Carapebus (Maia, 2001), Grumari (Oliveira & Maia, 2005), Ilha da Marambaia (Rodrigues et al., 2014), Ilha Grande (Maia & Oliveira, 2010), Região dos Lagos (Carvalho-Fernandes et al., 2016), but also in Espirito-Santo (in Guarapari) (Bregonci et al., 2010), São Paulo (in Bertioga) (Maia et al., 2008), and Santa Catarina (in Babinbonga and São Francisco do Sul) (Melo-Júnior et al., 2018; Arriola et al., 2015). The frequent presence of Myrtaceae in gall inventories at Brazilian restinga is an indication of the importance of this family for the structuring of plant-galling communities in these ecosystems. Similarly, Guapira opposita is cited as super host species in almost all inventories at restinga (review in Maia, 2013), except in Grumari and Guarapari. Recent evidence suggests that the presence of super host taxa can modify the structure of plant-galling networks in Neotropical environments, increasing the diversity and connectivity of interactions (Araújo et al., 2019c). In addition, the presence of super host species can impact the robustness of the network, because although it increases the robustness for random extinctions, the presence of closely connected species makes the network more vulnerable to directional attack (Iyer et al., 2013). These evidences suggest that Guapira opposita may have a great importance in structuring plant-galling networks in restingas, but more data are needed to measure its real role.

There is a large Linear gap in the knowledge of Neotropical cecidomyiids (Araújo et al., 2019a), which is one of the main limitations for the advancement of studies on the biology and ecology of gall-midge interactions with other species. In the present study, by using a taxonomically well-defined trophic assemblage, we elucidated for the first time the structure of a network involving host plants and gall midges in the Neotropical region. Our results show highly specialized patterns both for the interactions of gall midges with their plants. The low connectivity and high modularity observed for plant-galling interactions indicates a high level of ecological and phylogenetic restrictions for the structuring of interactions within the network, which demonstrates that eventual losses of species or interactions can be hardly substituted. Thus, this high level of specificity reinforces the important of conserving this threatened ecosystem, as each restinga area has a peculiar flora and consequently a unique assemblage of host plants and gall-midge species.

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AUTHORS’ CONTRIBUTIONS

W.S.A.: Conceptualization, Formal analysis, Writing – original draft, Visualization, Investigation, Writing – review & editing. V.C.M.: Conceptualization, Methodology, Data curation, Writing – original draft, Visualization, Investigation, Writing – review & editing. All the authors actively participated in the discussion of the results, they reviewed and approved the final version of the paper. Authors declare there are no conflicts of interest.

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Araújo, W.S. & Maia, V.C.: Trophic network of host plants and gall midges

Araújo, W.S. & Kollár, J. 2019. First characterization of a highly specialized ecological network composed by gall-inducing mites and their host plants. International Journal of Aacology, 45(4): 223-226.
APPENDIX S1

List of published data compiled in the present study.

RESTINGA OF THE BARRA DE MARICÁ (APA)

1) **Host plant:** Fridericia conjugata (Vell.) L.G. Lohmann (Bignoniaceae) (= Arrabidaea conjugata) (native to Brazil)
   **Galler:** Arrabiadaeamyia serrata Maia 2001a
   **Parasitoid:** Eurytoma sp. 1 (Eurytomidae)
   **Refs.:** Maia 2001a, b, Maia & Azevedo 2009

2) **Host plant:** Borreria verticillata (L.) G. Mey. (Rubiaceae) (native to Brazil)
   **Galler:** Asphondylia borreriae Rübsaamen 1905
   **Parasitoids:** Horismenus sp. (Eulophidae), Eupelmidae, Rileya sp. 7 (Eurytomidae)
   **Refs.:** Rübsaamen 1905, Maia 2001b, Maia & Azevedo 2009

3) **Host plant:** Ximenia americana L. (Olacaceae) (native to Brazil)
   **Galler:** Asphondylia communis Maia & Couri 1992
   **Parasitoids:** Encyrtidae, Eupelmidae
   **Refs.:** Maia & Couri 1992, Maia 2001b, Maia & Azevedo 2009

4) **Host plant:** Varronia curassavica Jacq. (= Cordia curassavica DC. = Cordia curassavica (Jacq.) Roem. & Schult.) (Boraginaceae) (native to Brazil)
   **Galler:** Asphondylia cordiae Möhn 1959
   **Parasitoid:** Eurytoma sp. 2 (Eurytomidae)
   **Refs.:** Möhn 1959, Maia 2001b, Maia & Azevedo 2009

Galler: Cordiamyia globosa Maia 1996a
   **Parasitoids:** Cirrospilus sp. 1, Galeopsomyia sp. 1 (Eulophidae), Synopeas sp. (Platygastridae), Lyrcus sp. (Pteromalidae), Dimeromicrus ceccidomyiae, Torymoides sp.; Torymus sp. (Torymidae)
   **Refs.:** Maia 1996a, Maia 2001b, Maia & Azevedo 2009

5) **Host plant:** Struthanthus taubatensis Eichler (= S. maricensis Rizzini ex Profice (Loranthaceae) (endemic to Brazil)
   **Galler:** Asphondylia maricensis Maia & Couri 1992
   **Parasitoids:** Eurytomidae, Platygaster sp. (Platygastridae)
   **Refs.:** Maia & Couri 1992, Maia 2001b, Maia & Azevedo 2009

6) **Host plant:** Peplonia asteria (Vell.) Fontella & E.A. Schwarz (Asclepiadaceae) (endemic to Atlantic Forest)
   **Galler:** Asphondylia peploniae Maia 2001a
   **Parasitoids:** Eupelmidae, Rileya sp. 1 (Eurytomidae), Torymidae
   **Refs.:** Maia 2001a, b, Maia & Azevedo 2009

7) **Host plant:** Senna bicapsularis (L.) Roxb. (Fabaceae) (exotic)
   **Galler:** Asphondylia sennae Maia & Couri 1992
   **Parasitoids:** No parasitoids.
   **Refs.:** Maia & Couri 1992

8) **Host plant:** Guapira opposita (Vell.) Reitz (Nyctaginaceae) (native to Brazil)
   **Galler:** Brugmannia acuata Maia 2004
   **Parasitoids:** Galeopsomyia sp. 1 (Eulophidae), Eupelmidae, Eurytoma sp. 9, Rileya sp. 3 (Eurytomidae), Torymidae
   **Refs.:** Maia 2001b, Maia 2004, Maia & Azevedo 2009

   **Galler:** Brugmannia elongata Maia & Couri 1993
   **Parasitoids:** Eupelmidae, Galeopsomyia sp. 1, Chrysotomymia sp., Cirsospilus sp. (Eulophidae), Rileya sp. 3, Eurytoma sp. 9 (Eurytomidae), Platygaster sp. (Platygastridae)
   **Refs.:** Maia & Couri 1993, Maia 2001b, Maia & Azevedo 2009

   **Galler:** Brugmannia monteiri Maia & Couri 1993
   **Parasitoids:** No parasitoids.
   **Refs.:** Maia & Couri 1993

   **Galler:** Brugmannia robusta Maia & Couri 1993
   **Parasitoids:** Eupelmidae, Galeopsomyia sp. 1, Chrysotomymia sp. (Eulophidae), Eurytoma sp. 3 (Eurytomidae), Platygaster sp. (Platygastridae)
   **Refs.:** Maia & Couri 1993, Maia 2001b, Maia & Azevedo 2009

   **Galler:** Brugmannia brasiliensis Couri & Maia 1992
   **Parasitoids:** No parasitoids.
   **Refs.:** Couri & Maia 1992, Maia 2001b

   **Galler:** Proasphondylia formosa Maia 1994a
   **Parasitoids:** No parasitoids.
   **Refs.:** Maia 1994a, Maia & Azevedo 2009

   **Galler:** Proasphondylia guapirea Maia 1994a
| No. | Host Plant                          | Galler                                      | Parasitoids                                                                 |
|-----|------------------------------------|---------------------------------------------|----------------------------------------------------------------------------|
| 9   | Host plant: Byrsonima sericea DC.  | Galler: Bruggmanniella byroninanae          | Eupelmidae, Rileya sp. 3, 5, 7 (Eurytomidae), Platygastrida                 |
|     | (Malpighiaceae) (native to Brazil) | Refs.: Maia 1994a, Maia 2001b, Maia & Azevedo 2009 | Refs.: Maia & Couri 1992, Maia 2001b, Maia & Azevedo 2009                  |
| 10  | Host plant: Monteverdia obtusifolia | Galler: Bruggmanniella maytenune            | Encyrtidae, Eupelmidae, Eurytomidae, Torymidae                             |
|     | (Mart.) Biral (= Maytenus obtusifolia | Refs.: Maia & Couri 1992, Maia 2001b, Maia & Azevedo 2009 | Refs.: Maia & Couri 1992, Maia 2001a, b, Maia & Azevedo 2009               |
|     | (Celastraceae) (endemic to Brazil) |                               | Eulophidae                                                                  |
| 11  | Host plant: Paulinia weinmanniiholana | Galler: Pauliniamyia ampla                 | No parasitoids.                                                             |
|     | Mart. (Sapindaceae) (endemic to Atlantic Forest) | Refs.: Maia 2001a, b, Maia & Azevedo 2009 | Refs.: Maia 2001a, b, Maia & Azevedo 2009                                  |
| 12  | Host plant: Eugenia uniflora L.    | Galler: Clinodiplosis florcola              | Chrysonotomyia sp., gen. nov. 2 sp. nov. 1, Aprostocetus sp. 1 (Euphidae), Eupelmidae, Rileya sp. 8 (Eurytomidae), Eupelmidae, Eurytoma sp. 8 (Eurytomidae), Eupelmidae, Eurytomidae, Platygastrida, Pteromalidae, Dimeromicrus cecidomyiae (Torymidae) |
|     | (Myrtaceae) (native to Brazil)      | Refs.: Maia 2001a, Maia & Azevedo 2009      | Refs.: Maia 2001a, Maia & Azevedo 2009                                     |
| 13  | Host plant: Clusia lanceolata Cambess. | Galler: Clinodiplosis profusa             | 14) Host plant: Erythroxylum ovalifolium Peyr. (Erythroxylaceae) (endemic to Atlantic Forest) |
|     | (Clusiaceae) (endemic to Atlantic Forest) | Refs.: Maia 2001a, Maia & Azevedo 2009      | Galler: Dasineura ovalifoliae Fernandes & Maia 2011                         |
|     |                                    |                               | Eupelmidae, Mymaridae, Pteromalidae, Torymidae, gen. nov. 6 sp. nov. 1 (Euphidae) |
| 14  | Host plant: Erythroxylum ovalifolium Peyr. | Refs.: Maia 2001a, Maia & Azevedo 2009      | Refs.: Maia 2001b, Fernandes & Maia 2011, Maia & Azevedo 2009               |
|     | (Erythroxylaceae) (endemic to Atlantic Forest) | Galler: Lopesia erythroxyl Rodrigues & Maia 2010 | Refs.: Maia 2001b, Rodrigues & Maia 2010, Maia & Azevedo 2009               |
|     |                                    |                               | Eupelmidae, Eurytoma sp. 6 (Eurytomidae), Mymaridae, Pteromalidae, gen. nov. 6 sp. nov. 3 (Euphidae) |
|     |                                    |                               | Parasitoids: No parasitoids.                                                |
| 15  | Host plant: Eugenia uniflora L.    | Galler: Cynadosia profusa                 | Parasitoids: No parasitoids.                                                |
|     | (Myrtaceae) (native to Brazil)      | Refs.: Maia 2001a, Maia & Azevedo 2009      | Refs.: Maia 2001a, Maia & Azevedo 2009                                      |
| 16  | Host plant: Clusia lanceolata Cambess. | Galler: Cynadosia profusa                 | Parasitoids: No parasitoids.                                                |
|     | (Clusiaceae) (endemic to Atlantic Forest) | Refs.: Maia 2001a, Maia & Azevedo 2009      | Refs.: Maia 1993, Maia 2001b, Maia & Azevedo 2009                          |
17) **Host plant:** Melissa officinalis L. (Lamiaceae) (exotic)
   **Galler:** Clinodiplosis melissae Maia 1994b
   **Parasitoids:** No parasitoids.
   **Refs.:** Maia 1994b

18) **Host plant:** Psittacanthus dichroos (Mart.) Mart. (Loranthaceae) (endemic to Brazil)
   **Galler:** Costadiplosis maricaensis Viceconte & Maia 2009
   **Parasitoids:** Aprostocetus sp.1 (Eulophidae), Pteromalidae
   **Refs.:** Maia 2001b, Viceconte & Maia 2009, Maia & Azevedo 2009

19) **Host plant:** Couepia ovalifolia (Schott) Benth. ex Hook.f. (Chrysobalanaceae) (endemic to Atlantic Forest)
   **Galler:** Dasineura couepiae Maia 2001a
   **Parasitoids:** Aphelinidae, Braconidae, Eulophidae, Eupelmidae, Torymidae
   **Refs.:** Maia 2001a, b, Maia & Azevedo 2009

20) **Host plant:** Stephomyia marginalis Maia 2001a
   **Parasitoids:** Eupelmidae, Pteromalidae, Torymidae
   **Refs.:** Maia 2001a, b, Maia & Azevedo 2009

21) **Host plant:** Eugenia astringens Cambess. (= Eugenia rotundifolia Casar) (Myrtaceae) (endemic to Atlantic Forest)
   **Galler:** Dasineura globosa Maia 1996b
   **Parasitoids:** Eulophidae, Platygaster sp. (Platygastridae), Torymidae
   **Refs.:** Maia 1996b, Maia 2001b, Maia & Azevedo 2009

22) **Host plant:** Myrcia floribunda (H. West ex Willd.) O. Berg (Myrtaceae) (native to Brazil)
   **Galler:** Dasineura myrciariae Maia 1996
   **Parasitoids:** Dimeromicrus cecidomyiae (Torymidae)
   **Refs.:** Maia 1996b, Maia 2001b, Maia & Azevedo 2009

23) **Host plant:** Dalbergia ecastophyllum (L.) Taub. (Fabaceae) (native to Brazil)
   **Galler:** Lopesia grandis Maia 2001a
   **Parasitoid:** Torymidae
   **Refs.:** Maia 2001a, b, Maia & Azevedo 2009

24) **Host plant:** Neomitranthes obscura (DC.) N. Silveira (Myrtaceae) (endemic to Atlantic Forest)
   **Galler:** Neomitranthella robusta Maia 1996c
   **Parasitoids:** Quadrastichus sp., Tetrastichinae (gen. nov.) (Eulophidae)
   **Refs.:** Maia 1996c, Maia 2001b, Maia & Azevedo 2009

25) **Host plant:** Pouteria venosa (Mart.) Baehni (Sapotaceae) (native to Brazil)
   **Galler:** Lopesia singularis Maia 2001a
   **Parasitoids:** Tetrastichinae (gen. nov.) (Eulophidae), Eupelmidae, Eurytomidae, Platygastridae, Torymidae
   **Refs.:** Maia 2001a, b, Maia & Azevedo 2009

26) **Host plant:** Manilkara subsericea (Mart.) Dubard (Sapotaceae) (endemic to Atlantic Forest)
   **Galler:** Manilkaramyia notabilis Maia 2001a
   **Parasitoids:** No parasitoids.
   **Refs.:** Maia 2001a, b

27) **Host plant:** Myrcia ovata Cambess. (Myrtaceae) (endemic to Atlantic Forest)
   **Galler:** Myrciamyia maricaensis Maia 1996c
   **Parasitoids:** gen. nov. 1 sp. nov. 1, gen. nov. 3 sp. nov. 1, Aprostocetus sp. 3 (Eulophidae)
   **Refs.:** Maia 1996c, Maia 2001b, Maia & Azevedo 2009
28) **Host plant:** *Hylocereus setaceus* (Salm-Dyck) R. Bauer (= *Selenicereus setaceus* (Salm-Dyck) Berg (Cactaceae) (native to Brazil))
   **Galler:** *Neolasioptera cerei* (Rübsaamen 1905):
   **Parasitoids:** No parasitoids.
   **Refs.:** Rübsaamen 1905, Maia 2001b

29) **Host plant:** *Clusia fluminensis* Planch. & Triana (Clusiaceae) (endemic to Atlantic Forest)
   **Galler:** *Parazalepidota clusiae* Maia 2001a
   **Parasitoid:** *Rileya* sp. 2 (Eurytomidae)
   **Refs.:** Maia 2001a, b, Maia & Azevedo 2009

30) **Host plant:** *Microgramma vacciniifolia* (Langsd. & Fisch.) Copel. (Polypodiaceae) (native to Brazil)
   **Galler:** *Primadiplosis microgramma* Maia 2011
   **Parasitoids:** Eulophidae, Torymidae
   **Refs.:** Maia 2011, Maia & Santos 2015

31) **Host plant:** *Lantana camara* L. (Verbenaceae) (naturalised)
   **Galler:** *Schismatodiplosis lantanae* (Rübsaamen 1908)
   **Parasitoids:** Eulophidae, Platygastridae, Pteromalidae, Scelionidae
   **Refs.:** Rübsaamen 1908, Maia 2001b, Maia & Azevedo 2009

32) **Host plant:** *Tetrapterys phlomoides* (Spreng.) Nied. (Malpighiaceae) (native to Brazil)
   **Galler:** *Schizomyia maricaensis* Sousa & Maia 2007
   **Parasitoids:** No parasitoids.
   **Refs.:** Maia 2001b, Sousa & Maia 2007

33) **Host plant:** *Jacquemontia holosericea* (Weinm.) O’Donell (Convolvulaceae) (native to Brazil)
   **Galler:** *Schizomyia santosi* Maia & Araújo 2009
   **Parasitoids:** No parasitoids.
   **Refs.:** Maia 2001b, Maia & Azevedo 2009

34) **Host plant:** *Smilax rufescens* Griseb. (Smilacaceae) (endemic to Brazil)
   **Galler:** *Smilasioptera candelariae* Möhn 1975
   **Parasitoids:** *Pentastichus* sp. 3 (Eulophidae), Eupelmidae
   **Refs.:** Möhn 1975, Maia 2001b, Maia & Azevedo 2009

35) **Host plant:** *Eugenia copacabanensis* Klaersk. (Myrtaceae) (endemic to Atlantic Forest)
   **Galler:** *Stephomyia espiralis* Maia 1994c
   **Parasitoid:** Tetrastichinae (gen. nov.) (Eulophidae)
   **Refs.:** Maia 1994c, Maia 2001b, Maia & Azevedo 2009

36) **Host plant:** *Pouteria caimito* (Ruiz & Pav.) Radlk (= *Pouteria caimito* var. *laurifolia*) (Sapotaceae) (native to Brazil)
   **Galler:** *Youngomyia pouteriae* Maia 2001a
   **Parasitoids:** Xanthobium sp. (Eulophidae), Eupelmidae, Dimeromicrus ceccidomyiae (Torymidae)
   **Refs.:** Maia 2001a, b, Maia & Azevedo 2009

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**RESTINGA OF THE ITAIPUAÇU**

1) **Host plant:** *Fridericia conjugata* (Vell.) L.G. Lohmann (Bignoniaceae) (= *Arrabidaea conjugata*) (native to Brazil)
   **Galler:** *Arrabiadamyia serrata* Maia 2001a
   **Parasitoid:** *Eurytoma* sp. 1 (Eurytomidae)
   **Refs.:** Maia 2001a, b, Maia & Azevedo 2009

2) **Host plant:** *Ximenia americana* L. (Olacaceae) (native to Brazil)
   **Galler:** *Asphondylia communis* Maia & Couri 1992
   **Parasitoids:** Encyrtidae, Eupelmidae
   **Refs.:** Maia & Couri 1992, Maia 2001b, Maia & Azevedo 2009

3) **Host plant:** *Varronia curassavica* Jacq. (= *Cordia verbenaecae* DC. = *Cordia curassavica* (Jacq.) Roem. & Schult.) (Boraginaceae) (native to Brazil)
   **Galler:** *Asphondylia cordiae* Möhn 1959
   **Parasitoid:** *Eurytoma* sp. 2 (Eurytomidae)
   **Refs.:** Möhn 1959, Maia 2001b, Maia & Azevedo 2009

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4) **Host plant:** Struthanthus taubatensis Eichler (= *S. maricensis* Rizzini ex Profice (Loranthaceae)) (endemic to Brazil)
   **Galler:** Eurytomidae, Platygaster sp. (Platygastridae)
   **Refs.:** Maia & Couri 1992, Maia 2001b, Maia & Azevedo 2009

5) **Host plant:** Peplonia asteria (Vell.) Fontella & E.A. Schwarz (Asclepiadaceae) (endemic to Atlantic Forest)
   **Galler:** Asphondylia peploniae Maia 2001a
   **Parasitoids:** Eulophidae, Rileya sp. 1 (Eurytomidae), Torymidae
   **Refs.:** Maia 2001a, b, Maia & Azevedo 2009

6) **Host plant:** Guapira opposita (Vell.) Reitz (Nyctaginaceae) (native to Brazil)
   **Galler:** Bruggmannia elongata Maia & Couri 1993
   **Parasitoids:** Eupelmidae, Galeopsomyia sp. 1, Chrysotomyia sp., Cirrospilus sp. (Eulophidae), Rileya sp. 3, Eurytoma sp. 9, Platygastridae
   **Refs.:** Maia & Couri 1993, Maia 2001b, Maia & Azevedo 2009

7) **Host plant:** Byrsonima sericea DC. (Malpighiaceae) (native to Brazil)
   **Galler:** Dasineura byrsonimae Maia 2010
   **Parasitoids:** Mymaridae, Eulophidae
   **Refs.:** Maia 2001b, Maia 2010, Maia & Azevedo 2009

8) **Host plant:** Heteropterys nitida (Lam.) DC. (Malpighiaceae) (native to Brazil)
   **Free-living herbivore:** Clinodiplosis floricola Novo-Guedes & Maia 2008
   **Parasitoid:** Aprostocetus sp. 1 (Eulophidae)
   **Refs.:** Maia 2001b, Novo-Guedes & Maia 2008, Maia & Azevedo 2009
14) **Host plant:** *Clusia lanceolata* Cambess. (Clusiaceae) (endemic to Atlantic Forest)  
**Galler:** *Clusia* sp. (Clusiaceae)  
**Parasitoids:** *Encarsia* sp. (Aphelinidae), Eulophidae, Eupelmidae, *Eurytoma* sp. 5 (Eurytomidae), *Inostemma* sp., *Platygaster* sp. (Platygastridae), Pteromalidae  
**Refs.:** Maia 1997, Maia 2001b, Maia & Azevedo 2009

15) **Host plant:** *Eugenia astringens* Cambess. (={*Eugenia rotundifolia*} Casar) (Myrtaceae) (endemic to Atlantic Forest)  
**Galler:** *Dasineura* globosa Maia 1996b  
**Parasitoids:** Eulophidae, *Platygaster* sp. (Platygastridae), *Torymidae*  
**Refs.:** Maia 1996b, Maia 2001b, Maia & Azevedo 2009

16) **Host plant:** *Myrciaria floribunda* (H. West ex Willd.) O. Berg (Myrtaceae) (native to Brazil)  
**Galler:** *Dasineura myricariae* Maia 1996  
**Parasitoids:** *Dimeromicros cecidomyiae* (Torymidae)  
**Refs.:** Maia 1996b, Maia 2001b, Maia & Azevedo 2009

17) **Host plant:** *Pouteria venosa* (Mart.) Baehni (Sapotaceae) (native to Brazil)  
**Galler:** *Lopsea singularis* Maia 2001a  
**Parasitoids:** Tetrastichinae (gen. nov.), *Eupelmidae*, *Eurytomidae*, Platygastridae, *Torymidae*  
**Refs.:** Maia 2001a, b, Maia & Azevedo 2009

18) **Host plant:** *Hylodera setaeus* (Salm-Dyck) R. Bauer (={*Selenicereus setaeus*} Salm-Dyck) *Berg* (Cactaceae) (native to Brazil)  
**Galler:** *Neolasionoptera cerei* (Rübsaamen 1905)  
**Parasitoids:** No parasitoids.  
**Refs.:** Rübsaamen 1905, Maia 2001b

19) **Host plant:** *Jacquemontia holosericea* (Weinm.) O’Donell (Convolvulaceae) (native to Brazil)  
**Galler:** *Schizomyia santosii* Maia & Araújo 2009  
**Parasitoids:** No parasitoids.  
**Refs.:** Maia 2001b, Maia & Araújo 2009

20) **Host plant:** *Smilax rufescens* Griseb. (Smilacaceae) (endemic to Brazil)  
**Galler:** *Smilasioptera candelariae* Möhn 1975  
**Parasitoids:** *Pentastichus* sp. 3 (Eulophidae), Eupelmidae  
**Refs.:** Möhn 1975, Maia 2001b, Maia & Azevedo 2009

21) **Host plant:** *Pouteria cainito* (Ruiz & Pav.) Radkl (={*Pouteria cainito*} var. *laurifolia*) (Sapotaceae) (native to Brazil)  
**Galler:** *Youngomyia pouteri* Maia 2001c  
**Parasitoids:** *Xanthobium* sp. (Eupelmidae), *Eupelmidae*, *Platygastridae*, *Dimeromicros cecidomyiae* (Torymidae)  
**Refs.:** Maia 2001a, c, Maia & Azevedo 2009

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