Acta Biológica Catarinense
2016 Jul-Dez;3(2):121-37

Richness of insect galls on shrub-tree restinga of a coastal plain of southern Brazil

Riqueza de galhas de insetos em restinga arbustivo-arbórea de uma planície costeira do sul do Brasil

Ígor Abba **ARRIOLA**[1] & João Carlos Ferreira de **MELO JÚNIOR**[2,3]

Recebido: 7 out. 2016
Aceito: 3 nov. 2016

ABSTRACT
The *restingas* are coastal ecosystems over the sandy Quaternary plains. Their vegetation present flora and structure conditioned mainly by edaphic factors. They vary from grasslands, shrub lands up to woody forests. Their environmental conditions, such as water stress and high solar irradiance, may be associated to a high richness of galling. This study aims to identify the insect-plant interactions of the gall type, in a shrub-tree *restinga* formation at the Acaraí State Park, situated in São Francisco do Sul, Santa Catarina State. The survey was conducted in four plots of 250 x 5 m (5,000 m^2) of the PELD/PPBio module, with a sample effort of 32 hours. There were found 56 morphospecies of galls in 31 species of host plants. Lauraceae, Myrtaceae, Melastomataceae, Nyctaginaceae and Calophyllaceae showed the highest number of interactions. *Guapira opposita* (Nyctaginaceae) and *Calophyllum brasiliense* (Calophyllaceae) were the major super-hosts. There was a predominance of isolated globoid galls on leaves, induced by Diptera – Cecidomyiidae. Galls on stems were less abundant. The focus of this inventory was restricted to the aerial parts of the plants, which limited the galls records on roots, for which there were records only in adventitious roots of the epiphyte *Philodendron surinamense*. The richness of galls seems to be proportional to the richness of plant species in this *restinga* formation.
Keywords: Cecidomyiidae; coastal vegetation; plant-insect interaction; super-hosts.

RESUMO
As restingas são ecossistemas costeiros que ocupam as planícies quaternárias arenosas. Sua vegetação apresenta flora e estrutura condicionada por fatores edáficos em maior grau. Variam de formações herbáceas, arbustivas, arbustivo-arbóreas a florestas. Suas características ambientais estressantes, como a baixa disponibilidade hídrica e a alta radiação solar, propiciam uma elevada riqueza de insetos galhadores. O objetivo deste estudo foi reconhecer as interações inseto-planta, do tipo galha, na formação arbustivo-arbórea da restinga do Parque Estadual Acaraí, situado em São Francisco do Sul, Santa Catarina. O levantamento foi realizado em quatro parcelas de 250 x 5 m (5.000 m^2) do módulo PELD/PPBio, com esforço amostral de 32 horas. Encontraram-se 56 morfoespécies de galhas em 31 espécies de plantas hospedeiras. As famílias com maior número de interações foram Lauraceae, Myrtaceae, Melastomataceae, Nyctaginaceae e Calophyllaceae. As espécies *Guapira opposita* (Nyctaginaceae) e *Calophyllum brasiliense* (Calophyllaceae) foram as principais super-hospedeiras. Houve predominância de galhas globoides isoladas em folhas, induzidas por Diptera – Cecidomyiidae. Galhas em caules foram menos abundantes. O foco do inventário restringiu-se às partes aéreas das plantas, o que limitou o registro de galhas em raízes, sendo registradas apenas em raízes adventícias da epífita *Philodendron surinamense*. A riqueza de galhas parece ser proporcional à riqueza de espécies vegetais nessa formação de restinga.
Palavras-chave: Cecidomyiidae; interação inseto-planta; super-hospedeiras; vegetação costeira.

1 Acadêmico do curso de Bacharelado em Ciências Biológicas – Meio Ambiente e Biodiversidade, Universidade da Região de Joinville (Univille), Joinville, SC, Brasil.
2 Laboratório de Anatomia e Ecologia Vegetal, Departamento de Ciências Biológicas, Univille, Rua Paulo Malschitzki, n. 10, CEP 89219-710, Joinville, SC, Brasil.
3 Autor para correspondência: jcmelo_wood@hotmail.com.

INTRODUCTION

The *restingas*, ecosystems in the domain of the Atlantic Forest, show in their composition mosaics of distinct plant communities that vary according to the edaphic gradient. They range from herbaceous and shrubby formations on sandy soils to forests associated with hydromorphic and/ or organic soils, whose canopy can reach 15-20 m in height (SCARANO, 2002; MELO JÚNIOR & BOEGER, 2015). The shrub-tree formations fit in the *restingas* as vegetation installed on sandy soils of low fertility and more distant from the sea, being composed of plants with habits mainly shrubby and arboreal and 2-5 m height (MELO JÚNIOR & BOEGER, 2016). In addition to these characteristics, other environmental factors considered to be adverse, such as high salinity, soil acidity, water scarcity, high incidence of winds and solar irradiation, render *restingas* extremely fragile environments as regards their conservation (ROCHA, 2003).

The characteristics of the *restinga* environments make these local ecosystems propitious to the concentration of a great richness of galling insects, which are endophytic herbivores inducing neoplasias in vegetal tissues, characterized by hypertrophy and/ or cell hyperplasia (MANI, 1964; SHORTHOUSE *et al.*, 2005). Through this interaction, these insects obtain shelter, food and protection against adverse environmental conditions and natural enemies (FERNANDES & PRICE, 1988; PRICE *et al.,* 1987; PRICE, 2005). In these relationships, the specificity of insect-plant systems generates phenotypes capable of indicating taxonomically the organisms involved (ISAIAS *et al.,* 2013; 2014), even when there are different interactions induced on the same host species, the so-called "super host plants" (ARAÚJO *et al*., 2013). This diversity of gall phenotypes may be used as an indicator of the local richness of galling insects (FLOATE *et al.*, 1996; CARNEIRO *et al.*, 2009), as well as of the diversity of organisms of other associated trophic levels (MAIA, 2001; STONE & SCHONROGGE, 2003).

Studies done in the southeastern region of Brazil have shown the richness of entomogenic galls in *restingas* (Bregonci *et al.,* 2010; MAIA *et al.*, 2008; MAIA *et al.*, 2014; RODRIGUES *et al.*, 2014) and have described a large diversity of galling insects (MAIA, 1995, 2001, 2007). In general, there are few studies with a focus on richness of gall-inducing insect in the coastal region of southern Brazil, except the articles of Mendonça Jr. *et al*. (2010), performed in *restingas* of Rio Grande do Sul, and Arriola *et al.* (2016), in *restinga* formations occurring on dunes in the northeastern portion of the state of Santa Catarina.

In addition, anthropogenic pressures such as urbanization of coastal lines, construction of roads, trampling and car traffic over the vegetation of *restinga,* garbage disposal and other actions, make these environments a significantly threatened portion of the rain forest (ROCHA, 2003; THOMAZI *et al*., 2013), opposing to their importance as a kind of vegetation that controls the effects of erosive processes of coastal regions and as an ecosystem that maintains the local biodiversity (KUKI *et al.,* 2008).

Thus, the present study aims to contribute to the knowledge about the richness of insect galls of southern Brazil *restingas*, employing the concept of “morphospecies” used by Portugal-Santana and Isaias (2014), as a tool for the record of these interactions in the shrub-tree restinga physiognomy of the Acaraí State Park (PEA), in São Francisco do Sul, Santa Catarina State, Brazil.

MATERIAL AND METHODS

The study area comprises a *restinga* remnant located in the municipality of São Francisco do Sul, in the coastal plain of Santa Catarina State, Brazil (48º33 ‘W – 26º17’ S). Considered as a priority area for biodiversity conservation (PROBIO, 2003), the PEA region was transformed into a conservation unit in 2005 and covers a total area of 6,667 ha (FATMA, 2008; figure 1).

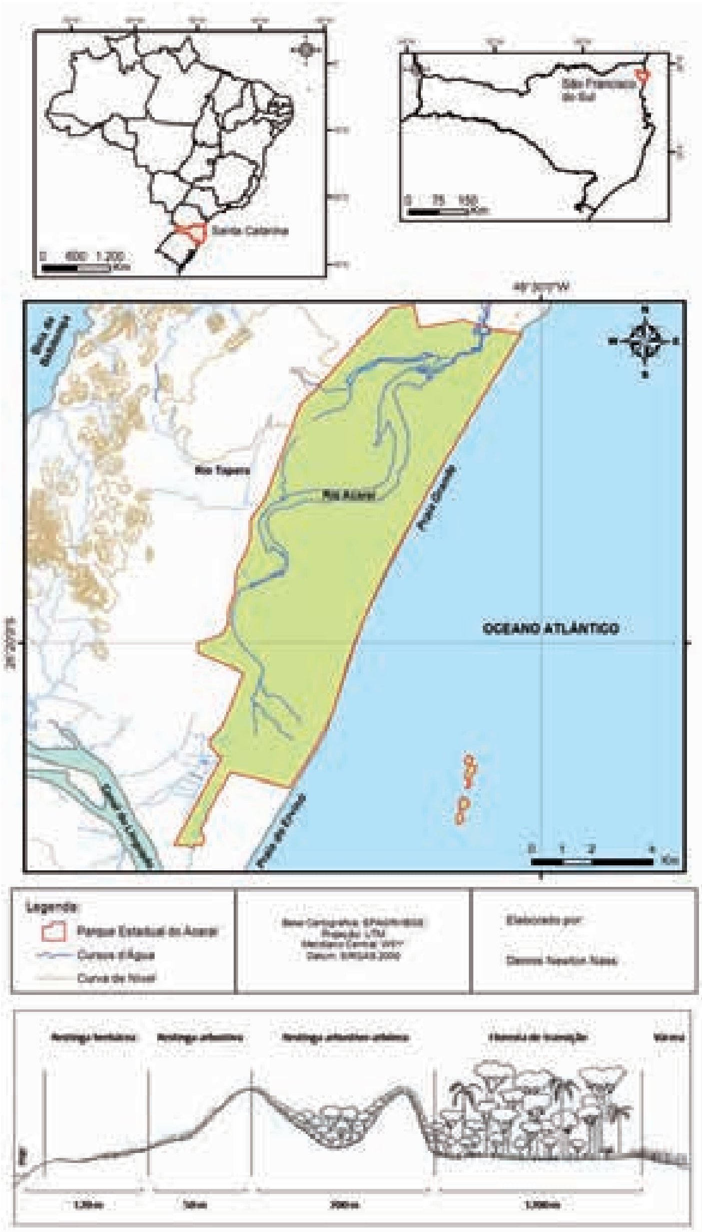


Figure 1 – *Restinga* of Parque Estadual Acaraí and yours formations, São Francisco do Sul municipality, Santa Catarina, Brazil.

The PEA is characterized by the presence of *restingas*, which vary as herbaceous formations (figure 1B) in the post-beach region and dunes, shrubs, shrubs-trees (figure 2) and transitional forests, as well as other less expressive formations such as floodplains, mangroves and submontane forest (FATMA, 2008).

The local flora covers 319 species, distributed in 215 genera and 82 families.

Among these, the most representative families in number of species are: Asteraceae (35), Fabaceae (30), Myrtaceae (20), Rubiaceae (18) and Poaceae (13) (MELO JÚNIOR & BOEGER, 2015). The climate of the region is classified as Cfa de Köppen (subtropical climate, with hot summer), influenced by the maritime humidity, with annual average temperature of 20.3ºC and relative humidity of 1.874 mm/ year (KNIE, 2002). Soil is classified as a ferrihumiluvic spodossol in the shrub-arboreal formation of *restinga* (OLIVEIRA & VIEIRA, 2008).

Figure 2 – Vegetation of shrub-tree *restinga* of Parque Estadual Acaraí (São Francisco do Sul municipality, Santa Catarina, Brazil). Credits: João Carlos F. de Melo Júnior.

Samplings were carried out in four plots of 1,250 m^2 each (250 x 5 m), inserted in the Long-Term Ecological Research Module (PELD, PPBio-MA) installed in the PEA, totaling a sample area of 5,000 m^2. The plants of each plot were inspected during 8 hours in search of galls, totalizing 32 sample hours, a pattern similar to the standardization of sample hours used by Maia *et al.* (2008) in *restingas* of the southeastern region. Branches of the plants ($n \geq 5$) with galls were collected and stored in plastic bags. Host plants were identified through the list of PEA flora species (MELO JÚNIOR & BOEGER, 2015) and classified by the APG IV system (2016). The vouchers were registered in the Herbarium of the University of the Region of Joinville (JOI). Galls were described according to the standardization of nomenclature for neotropical galls proposed by Isaias *et al*. (2013), and photographed with a Samsung ES68 digital camera. The identification of the gallers was based on the *restinga* galls review of the southeastern region of Brazil (MAIA, 2013) and on the world catalog of Diptera: Cecidomyiidae (GAGNÉ & JASCHHOF, 2014).

RESULTS

The present work registered a total of 56 gall morphospecies in 31 plant species from 21 botanical families (table 1, figures 3 to 58).

These morphospecies were classified into seven gall morphotypes, of which the most abundant was the globule with 37.5% of occurrences, followed by lenticular (26.79%) and fusiform (23.21%). The least frequent morphotypes were conical (5.36%), rosette (3.57%), foliar winding and nailing (1.79% each). Galls occurring in isolation were more frequent (87.5% of cases) than the coalescing morphotypes (12.5%). Galls morphotypes occurred predominantly in leaves (71.43%), occurring with a lower incidence in stems (25%). Galls in roots were also observed (3.57%) but, due to the focus of work in the aerial parts of the plants, they show a low proportion of records. The galls varied in color, with predominantly green morphotypes (67.86%), followed by brown (23.21%), yellow (5.36%), white and red (1.79% each). Galls exhibiting ornamentation/ pubescence occurred in about 22% of the morphotypes found. The most representative botanical families in gall morphotypes were: Lauraceae (10), Myrtaceae

(7), Melastomataceae (4), Nyctaginaceae (4) and Calophyllaceae (4). The species diagnosed as the main local super host were *Calophyllum brasiliense* Cambess. (Calophyllaceae) and *Guapira opposita* (Vell.) Reitz (Nyctaginaceae), each hosting four distinct morphotypes of galls. The galling insects were identified at least at the order level in about 60% of the cases. The Diptera: Cecidomyiidae *taxon* was the most representative, with 48.21% of occurrences. Other less representative groups were Hemiptera (7.14%), Lepidoptera (3.57%) and Coleoptera (1.79%). The remaining 40% remained undetermined.

Table 1 – Characterization of gall morphotypes and their respective host-plants occurring in the shrub-tree *restinga* of Parque Estadual Acaraí, São Francisco do Sul municipality, Santa Catarina, Brazil.

Family	Plant species	Morphotoye	Host organ / Oviposition site	Color	Pubescence	Gall-inducer*	Figure
Anacardiaceae	*Schinus terebinthifolius* Raddi	extralaminar lenticular	leaf / median vein	green	no	*Calophya terebinthifolii* Burckhardt & Basset, 2000 (Psylloidae, Hemiptera)	3
Annonaceae	*Guatteria australis* A.St.-Hil.	fusiform	stem	brown	yes	Unknown	4
		globoid	leaf / secondary vein	green	no	Unknown	5
		lenticular	leaf / secondary vein	green	no	Unknown	6
Araceae	*Philodendron surinamense* (Miq.) Schott.	fusiform	root / adventitious root grampiform	green	no	Unknown	7
		fusiform to coalescent	root / adventitious root	green	no	Cecidomyiidae (Diptera)	8
		lenticular extralaminar	leaf / secondary vein	green	no	Unknown	9
Asteraceae	*Mikania trinervis* Hook. & Arn.	conical	leaf / median vein	green	no	*Liodiplosis cylindrica* Gagné, 2001 (Cecidomyiidae, Diptera)	10
		globoid	leaf / median vein-petiole	green	no	*Liodiplosis* sp. (Cecidomyiidae, Diptera)	11
		globoid to coalescent	stem	green / red	no	*Mikaniadiplosis* sp. (Cecidomyiidae, Diptera)	12

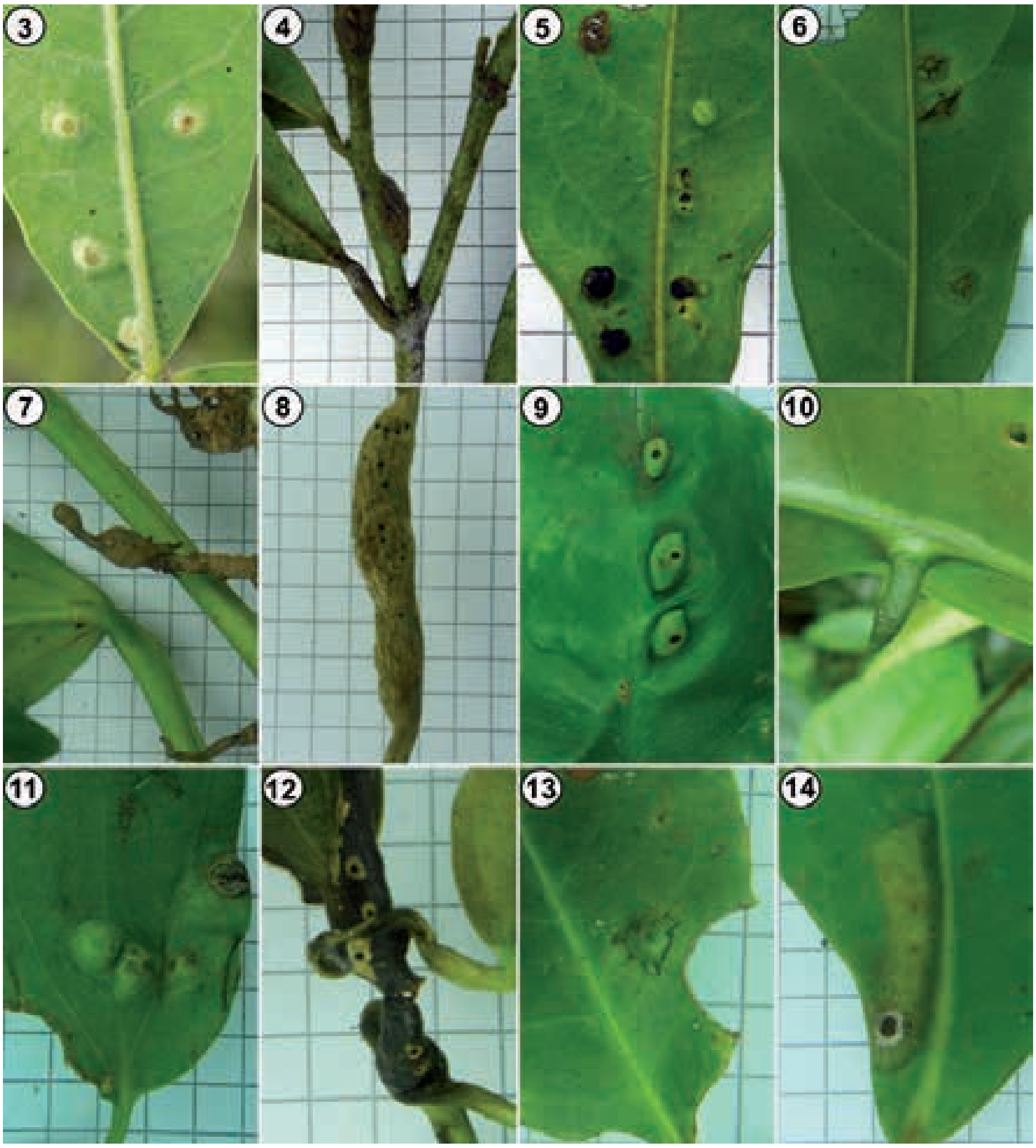
Family	Plant species	Morphotyoe	Host organ / Oviposition site	Color	Pubescence	Gall-inducer*	Figure
Calophyllaceae	*Calophyllum brasiliense* Cambess.	leaf rolling	leaf / leaf lamina	green	no	Cecidomyiidae (Diptera)	15
		fusiform	leaf / leaf lamina	green	no	*Lopesia linearis* Maia, 2003 (Cecidomyiidae, Diptera)	16
		globoid to coalescent	stem	brown	no	*Lopesia caulinaris* Maia, 2003 (Cecidomyiidae, Diptera)	17
		intralaminar lenticular	leaf / leaf lamina	green	no	*Lopesia ellipitica* Maia, 2003 (Cecidomyiidae, Diptera)	18
Celastraceae	*Maytenus glazioviana* Loes.	lenticular	leaf / secondary vein	green	no	*Mayteniella robusta* Maia, 2001 (Cecidomyiidae, Diptera)	13
Clusiaceae	*Clusia criuva* Cambess.	fusiform intralaminar	leaf / leaf lamina	green	no	Lepidoptera	14
Fabaceae	*Andira fraxinifolia* Benth.	fusiform	leaf / leaf lamina	green	yes	*Lopesia* sp. (Cecidomyiidae, Diptera)	19
		globoid	leaf / secondary vein	yellow	no	*Asphondyliina* sp. (Cecidomyiidae, Diptera)	20
	Dalbergia frutescens (Vell.) Britton	clavate	leaf / secondary vein	green	yes	*Lopesia grandis* Maia, 2001 (Cecidomyiidae, Diptera)	21
Lauraceae	*Aiouea saligna* Meisn.	lenticular	leaf / leaf lamina	green	no	Unknown	22
	Endlicheria paniculata (Spreng.) J.F.Macbr.	fusiform, isolated or coalescent	stem	brown	no	Unknown	23
	Nectandra grandiflora Nees	globoid	leaf / leaf lamina	brown	yes	Unknown	27
	Nectandra oppositifolia Nees	lenticular	leaf / leaf lamina	green	no	Unknown	28

Family	Plant species	Morphotyoe	Host organ / Oviposition site	Color	Pubescence	Gall-inducer*	Figure
Lauraceae	*Nectandra membanacea* (Sw.) Griseb.	conical	leaf / median vein	green	yes	Unknown	24
		globoid	leaf / secondary vein	green	no	Unknown	25
		globoid	leaf / secondary vein	brown	yes	Unknown	26
	Ocotea catharinensis Mez	globoid	leaf / median vein-secundária	red	no	*Neolasioptera* sp. (Cecidomyiidae, Diptera)	29
	Ocotea pulchella (Nees & Mart.) Mez	intralaminar lenticular	leaf / secondary vein	green	no	Coccidae (Hemiptera)	30
		rosette	stem / meristem	green	no	*Clinodiplosis* sp. (Cecidomyiidae, Diptera)	31
Malvaceae	*Pavonia* sp.	globoid	leaf / median and secondary vein	green	yes	Cecidomyiidae (Diptera)	32
Melastomataceae	*Miconia pussiliflora* (DC.) Naudin.	fusiform	stem	brown	no	Unknown	33
		fusiform	leaf / median vein	green	no	Unknown	34
	Tibouchina pulchra Cogn.	globoid to coalescent	stem	brown	no	Lepidoptera	35
		fusiform	leaf / median vein	green	yes	Curculionidae (Coleoptera)	36
Meliaceae	*Guarea macrophylla* Vahl	fusiform	stem	brown	no	Cecidomyiidae (Diptera)	39
		fusiform	leaf / median vein	green	yes	*Neolasioptera* sp. (Cecidomyiidae, Diptera)	40
		globoid	leaf / leaf lamina	green / yellow	yes	*Sphaeromyia flava* Maia, 2007 (Cecidomyiidae, Diptera)	41
Myrtaceae	Myrtaceae sp. 01	lenticular	leaf / secondary vein	green	no	Unknown	42
	Myrcia pulchra (O.Berg) Kiaersk.	globoid	stem	brown	no	Unknown	43
		lenticular	leaf / lewaf lamina	yellow	yes	Unknown	44
		lenticular	leaf / secondary vein	branca	no	Unknown	45

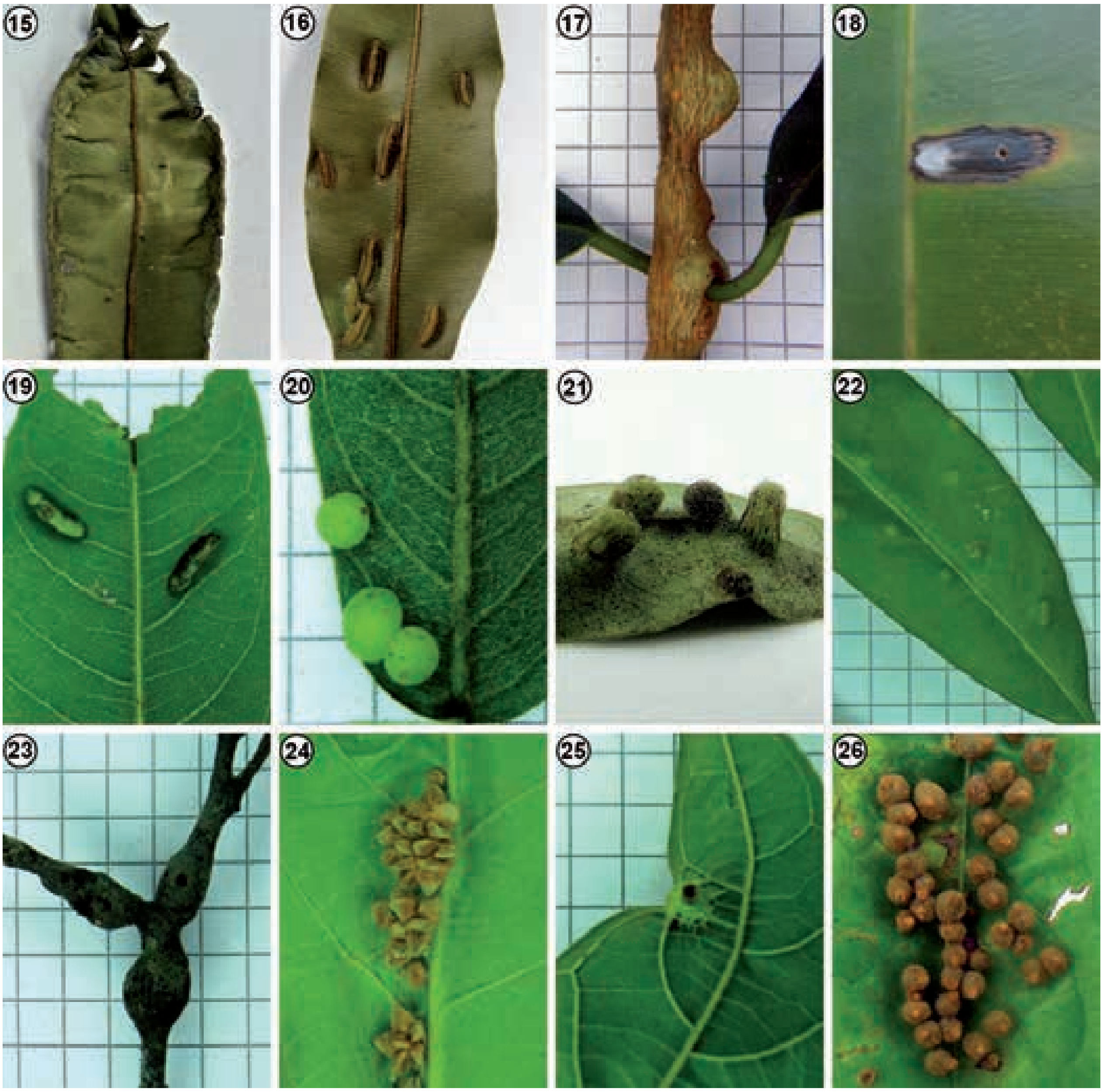
Family	Plant species	Morphotyoe	Host organ / Oviposition site	Color	Pubescence	Gall-inducer*	Figure
Myrtaceae	*Psidium cattleianum* Sabine	globoid extralaminar	leaf / secondary vein	yellow	no	*Nothotrioza cattleiani* Burckhardt, 2013 (Psylloidae, Hemiptera)	46
		intralaminar globoid with apical projection	leaf / median and secondary vein	green	no	*Tectococcus ovatus* Hempel., 1900 (Eriococcidae, Hemiptera)	47
		lenticular	leaf / leaf lamina	green	no	Cecidomyiidae (Diptera)	48
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz	fusiform	stem	brown	no	*Proasphondylia formosa* Maia, 1993 (Cecidomyiidae, Diptera)	51
		globoid, predom. coalescent	stem	brown	no	*Proasphondylia guapirae* Maia & Couri, 1993 (Cecidomyiidae, Diptera)	52
		lenticular	leaf / leaf lamina	green	no	*Bruggmannia elongata* Maia & Couri, 1993 (Cecidomyiidae, Diptera)	53
		rosette	stem / meristem	green	no	*Pisphondylia braziliensis* Couri & Maia, 1992 (Cecidomyiidae, Diptera)	54
Orchidaceae	*Vanilla chamissonis* Klotzsch	globoid	leaf / leaf lamina	green	no	Unknown	37
Piperaceae	*Piper solmsianum* C.DC.	globoid	leaf / secondary vein	green	yes	Cecidomyiidae (Diptera)	38
Rubiaceae	*Psychotria carthagenensis* Jacq.	conical	leaf / median and secondary vein	green	no	Cecidomyiidae (Diptera)	49
Sapindaceae	*Paullinia trigonia* Vell.	globoid	leaf / leaf lamina	green	no	Cecidomyiidae (Diptera)	50
Sapotaceae	*Pouteria beaurepairei* (Glaz. & Raunk.) Baehni	globoid	stem	brown	no	Unknown	55
Smilacaceae	*Smilax campestris* Griseb.	lenticular	leaf / leaf lamina	green / black	no	*Smilasioptera* sp. (Cecidomyiidae, (Diptera)	56

Family	Plant species	Morphotyoe	Host organ / Oviposition site	Color	Pubescence	Gall-inducer*	Figure
Solanaceae	*Solanum pseudoquina* A.St.-Hil.	globoid, coalescent	stem / meristem	brown	no	Unknown	57
		lenticular	leaf / leaf lamina	green	no	Unknown	58

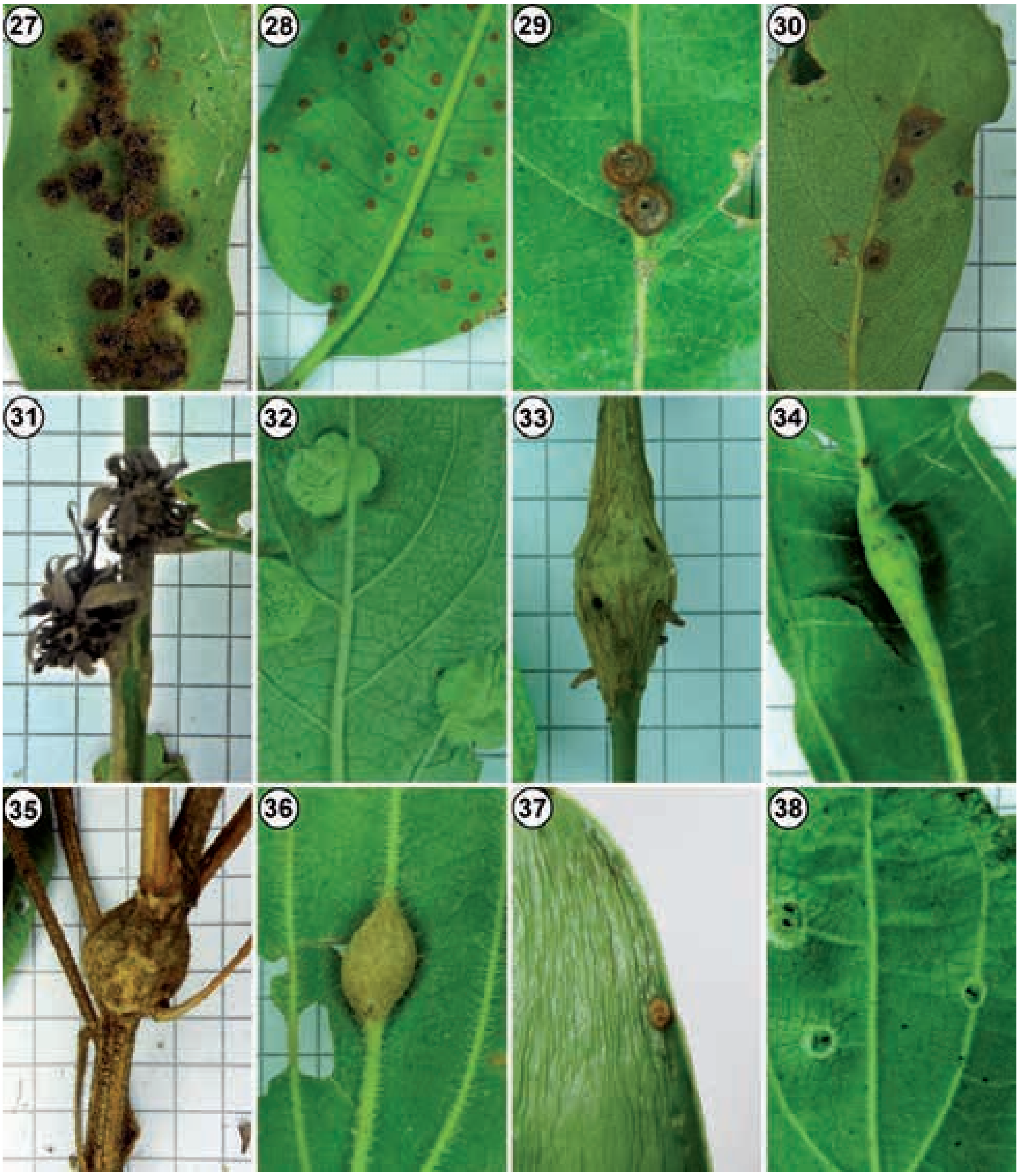
* Based on Maia (2013) and Gagné & Jaschhof (2014)



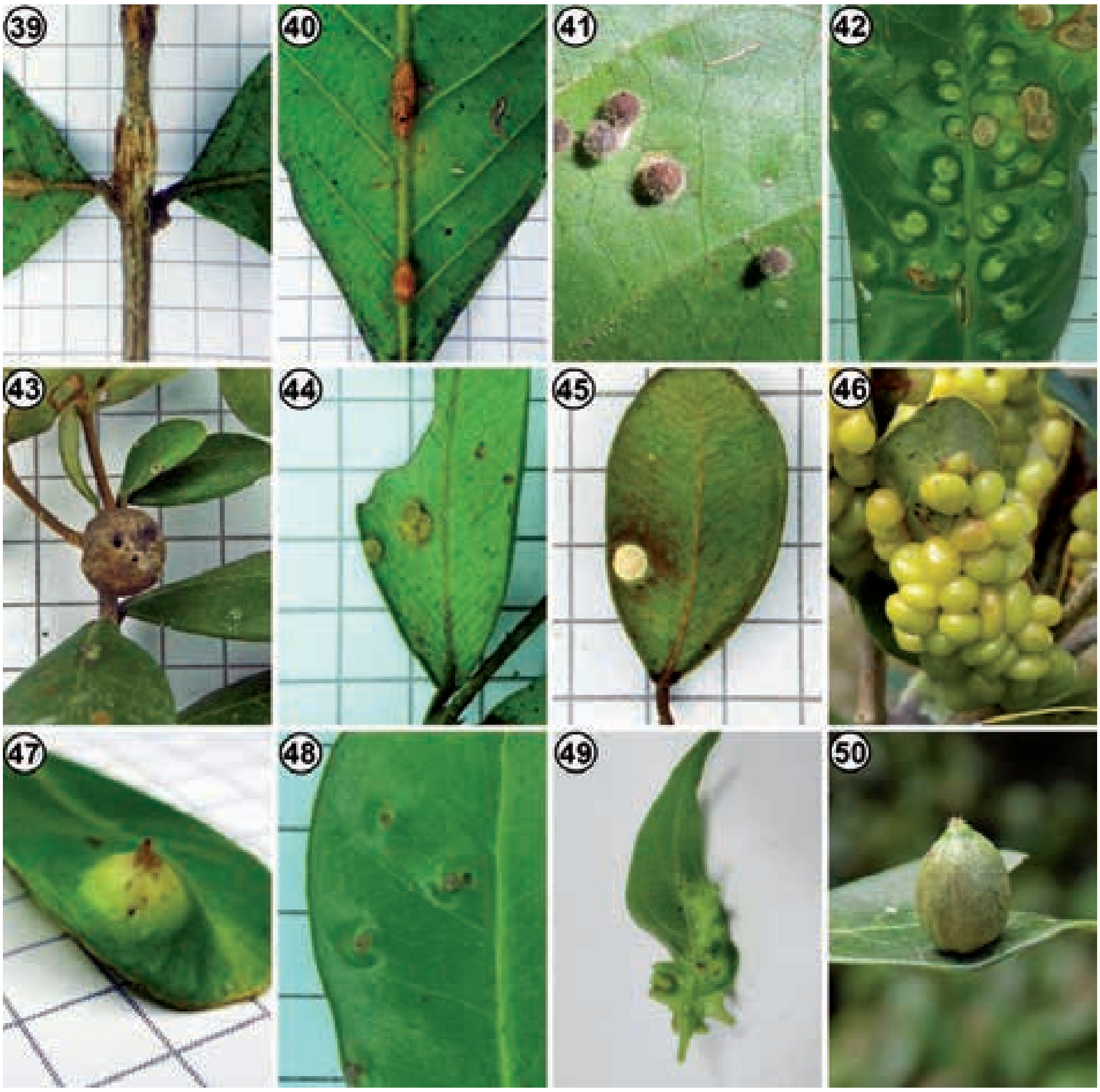
Figures 3-14 – Galls of shrub-tree *restinga* of Parque Estadual Acaraí, São Francisco do Sul municpality, Santa Catarina, Brazil. 3) *Schinus terebinthifolius* (Anacardiaceae): Extralaminar lenticular. 4-6) *Guatteria australis* (Annonaceae): (4) Fusiform on stem; (5) Globoid on leaf; (6) Lenticular on leaf. 7-9) *Philodendron surinamense* (Araceae): (7) Fusiform on adventitious root grampiform; (8) Coalescent fusiform on adventitious root; (9) Extralaminar lenticular. 10-12) *Mikania trinervis* (Asteraceae): 10) Conical; 11) Globoid on leaf; 12) Coalescent globoid on stem. 13) *Maytenus glazioviana* (Celastraceae): Lenticular. 14) *Clusia criuva* (Clusiaceae): Intralaminar fusiform.



Figures 15-26 – Galls of shrub-tree *restinga* of Parque Estadual Acaraí, São Francisco do Sul municpality, Santa Catarina, Brazil. 15-18) *Calophyllum brasiliense* (Calophyllaceae): (15) Leaf rolling; (16) Fusiform on leaf; (17) Globoid on stem; (18) Intralaminar lenticular. 19-20) *Andira fraxinifolia* (Fabaceae): (19) Fusiform on stem; 20) Globoid on leaf. 21) *Dalbergia frutescens* (Fabaceae): Clavate. 22) *Aiouea saligna* (Lauraceae): Lenticular. 23) *Endlicheria paniculata* (Lauraceae): Fusiform on stem. 24-26) *Nectandra membranacea* (Lauraceae): (24) Conical; (25) Green globoid; (26) Brown globoid.



Figures 27-38 – Galls of shrub-tree *restinga* of Parque Estadual Acaraí, São Francisco do Sul municpality, Santa Catarina, Brazil. 27) *Nectandra grandifolia* (Lauraceae): Globoid. 28) *Nectandra oppositifolia* (Lauraceae): Lenticular. 29) *Ocotea catharinensis* (Lauraceae): Globoid. 30-31) *Ocotea pulchella* (Lauraceae): (30) Intralaminar lenticular; (31) Rosette. 32) *Pavonia* sp. (Malvaceae): Globoid. 33-34) *Miconia pussiliflora* (Melastomataceae): (33) Fusiform on stem; (34) Fusiform on leaf. 35-36) *Tibouchina pulchra* (Melastomataceae): (35) Globoid on stem; (36) Fusiform on leaf. 37) *Vanilla chamissonis* (Orchidaceae): Globoid. 38) *Piper solmsianum* (Piperaceae): Globoid.



Figures 39-50 – Galls of shrub-tree *restinga* of Parque Estadual Acaraí, São Francisco do Sul municpality, Santa Catarina, Brazil. 39-41) *Guarea macrophylla* (Meliaceae): (39) Fusiform on stem; (40) Fusiform on leaf; (41) Globoid. 42) Myrtaceae sp. 01: Lenticular. 43-45) *Myrcia pulchra* (Myrtaceae): (43) Globoid on stem; (44) Yellow lenticular; (45) White lenticular. 46-48) *Psidium cattleianum* (Myrtaceae): (46) Extralaminar globoide; (47) Intralaminar globoide, with apical projection; (48) Lenticular. 49) *Psychotria carthagenensis* (Rubiaceae): Conical. 50) *Paullinia trigonia* (Sapindaceae): Globoid.

pattern of globular, lenticular and fusiform gall morphotypes of this *restinga* is in agreement with the patterns found in other r*estingas* of the Southeast region (MAIA, 2013), corroborating the neutrality of this environment in relation to its morphogenetic effects on the formation of galls (ARRIOLA *et al.*, 2015). It is a consensus in literature that the morphotypes are conditioned by the plastic capacity of the plant tissue and by the genetic interaction between insect-plant, and there is no environmental variable that determines the morphotypes (STONE & SCHONROGGE, 2003; FORMIGA *et al.*, 2015).

The occurrence of isolated gall morphotypes was greater than that of coalescing galls, the latter occurring exclusively in stems and roots. Isolated galls on leaves appear to be a guarantee for the development of the galler since there is a considerable reduction of the impact of the gall on the morphophysiological characteristics of the parasitized leaf. However, coalescent galls or the massive occurrence of galls on the same leaf can cause, by the leaf deformation, the reduction of the specific leaf area and an early leaf senescence (CONSTANTINO *et al.*, 2009).

The leaf, as the most frequent host organ, is considered the part of the plant that most houses galling insects in the flora in general (ISAIAS *et al.*, 2013, 2014). The lower frequency of galls in stems, as well as the smaller variety of morphotypes occurring in this organ, may be associated with the lower plastic response potential of the tissues to the stimulation of the galler (FORMIGA *et al.*, 2015). Galls in roots were recorded only in the epiphytic species *Philodendron surinamense* (Araceae), occurring in adventitious roots. In general, root-induced insect galls are poorly recorded, although they occur in roots of epiphytic species of other families such as Orchidaceae and Polypodiaceae (TANOUE *et al.*, 2004; MAIA & SANTOS, 2015). Underground roots aggregate gallers from other organisms, such as bacteria and nematodes (MANI, 1964) and are often the focus of agronomic science studies.

As to the coloration and ornamentation of the galls, the distinction in relation to the surrounding plant tissues confers alert signaling characteristics as protection against herbivory (IMBAR *et al.*, 2010). Thus, the predominance of green coloration (67.86%) indicates the variation in the accumulation of pigments during the senescence process of the gall, occurring the greater accumulation of chlorophyll in galls in later stages of development (DIAS *et al.*, 2013).

Superhosts families and species are those capable of harboring three or more gall morphotypes, indicating their ability to react to the stimulus of more than one inducer, which contributes to the increase of galling insects diversity in an ecosystem (ARAÚJO *et al*., 2013). In the present study, the super-host species added around 16% of the total number of galls found, demonstrating their importance for the diversity of galling insects. Similarly, studies performed by Arriola *et al*. (2015, 2016) also indicated the species *Guapira opposita* (Nyctaginaceae) and *Calophyllum brasiliense* (Calophyllaceae) as important super host galls in the PEA flora.

The predominant group of inductors in this study was the Cecidomyiidae family (Diptera), which corroborates the assumption that it is the largest and most specialized group of forming galls herbivores (MAIA, 2013; GAGNÉ & JASCHHOF, 2014). The indeterminate taxa, which represented 40% of the total observed, can be considered, due to these species-specific interactions, to be new species of inductors to be described and known by science (ESPÍRITO-SANTO & FERNANDES, 2007; CARNEIRO *et al.*, 2009).

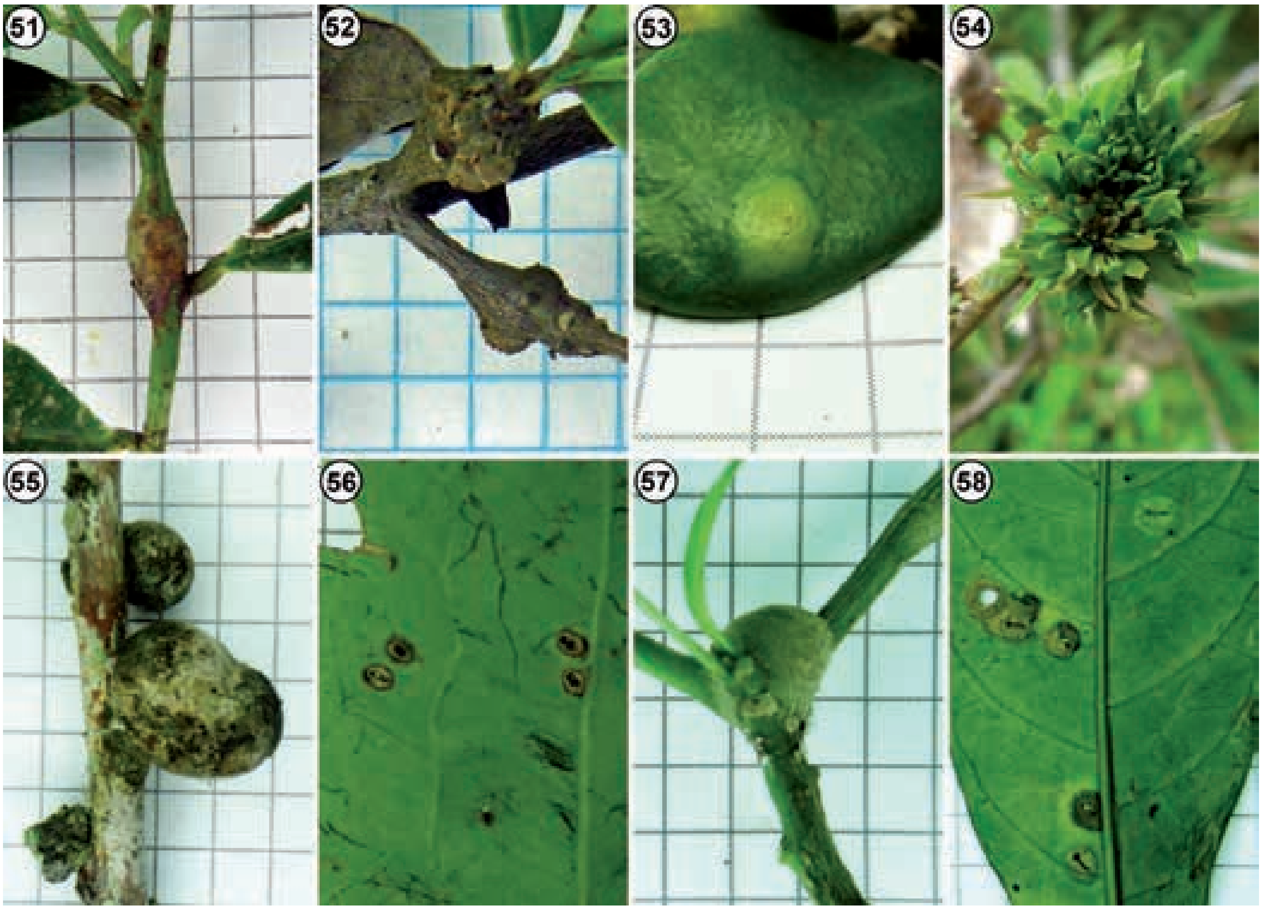
This first galls inventory focused on the shrub-arboreal vegetation of the PEA *restinga* showed the increasing diversity of specialized herbivory interactions (insect-plant) when compared to the inventories made in herbaceous vegetation of *restinga* (MENDONÇA JR. *et al.*, 2010, ARAÚJO, 2011; ARRIOLA *et al.*, 2015), as well as contributed to the design of research protocols linked to long-term ecological works developed within the PPBio Mata Atlântica network.

REFERENCES

APG IV – Angiosperm Phylogeny Group. An update of the Angiosperm Phylogeny Group classification for the ordens and families of flowering plants: APG IV. Biological Journal of the Linnean Society. 2016; 181:1-20.

Araújo, Walter Santos. Can host plant richness be used as a surrogate for galling insect diversity? Tropical Conservation Science. 2011; 4:420-427.

Araújo, Walter Santos; Cláudia Scareli-Santos; Frederico Augusto Guimarães Guilherme & Pablo Cuevas-Reyes. Comparing galling insect richness among Neotropical savannas: effects of plant richness, vegetation structure and super-host presence. Biodiversity and Conservation. 2013; 22:1083-1094.



Figures 51-58 – Galls of shrub-tree *restinga* of Parque Estadual Acaraí, São Francisco do Sul municpality, Santa Catarina, Brazil. 51-54) *Guapira opposita* (Nyctaginaceae): (51) Fusiform on stem; (52) Globoid on stem; (53) Lenticular; (54) Rosette; (55) *Pouteria beaurepairei* (Sapotaceae): Globoid on stem. 56) *Smilax campestris* (Smilacaceae): Lenticular. 57-58) *Solanum pseudoquina* (Solanaceae): (57) Globoid on stem; (58) Lenticular.

DISCUSSION

The flora of the shrub-tree physiognomy of the PEA restinga is composed of 110 species, distributed in 81 genera and 47 families (MELO JÚNIOR & BOEGER, 2015), of which 31 plant species, 28% of the floristic diversity of this formation accumulate a wealth of 56 morphospecies of galls. The families that added the most gall (51.8%) in the formation of restinga studied also stand out in the flora of the PEA as those with the greatest species richness, or with species of greater representativeness in the community structure of the restinga formations of this park (MELO JÚNIOR & BOEGER, 2015). In this way, the greater diversity presented or the greater abundance of a given taxon can be positively related to the supply of host plants (MENDONÇA JR., 2007; ARAÚJO, 2011). In the herbaceous formation of the PEA, 15 morphospecies of gall were recorded, occurring in 8 species of host plants (ARRIOLA *et al.,* 2015), a number considerably lower than that recorded in this study. This difference between gill richness formations can be explained by the difference in the local floristic richness, corroborating the hypotheses that relate the greatest plant richness to the greatest wealth of galling insects (MENDONÇA JR., 2007; ARAÚJO, 2011).

The globular morphotype occurred in 37.5% of the galls recorded in this *restinga* formation, standing out as the most common morphotype of Brazilian flora (ISAIAS *et al.,* 2013, 2014). In addition to this, the lenticular morphotype, one of the main morphotypes of local galls (ARRIOLA *et al*., 2015), and the fusiform, a predominant morphotype in stems (FORMIGA *et al.*, 2015), were prominent in this *restinga* formation. Other less frequent morphotypes in Brazilian biomes were also recorded, such as the conical, rosette, foliar winding and nailing (ISAIAS *et al.,* 2013, 2014). In general, the dominance

Arriola, Ígor Abba; João Carlos Ferreira de Melo Júnior & Rosy Mary dos Santos Isaias. Questioning the envirommental stress hypothesis for gall diversity of restinga vegetation on dunes. Revista de Biología Tropical. 2015; 63(4):959-970.

Arriola, Ígor Abba; João Carlos Ferreira de Melo Júnior; Rosy Mary dos Santos Isaias; Denise Monique Dubet da Silva Mouga & Elaine Cotrim Costa. Where host plant goes, galls go too: new records of the Neotropical galling Cecidomyiidae (Diptera) associated with *Calophyllum brasiliense* Cambess. (Calophyllaceae). Check List. 2016; 12(4):1924. doi: 10.15560/12.4.1924.

Bregonci, Juliana de Menezes; Polyana Vieira Polycarpo & Valéria Cid Maia. Galhas de insetos do Parque Estadual Paulo César Vinha (Guarapari, ES, Brasil). Biota Neotropica. 2010; 10(1):265-274. [Acesso em: 5 out. 2016]. Disponível em: http://www.biotaneotropica.org.br/v10n1/pt/fullpaper?bn01410012010+pt.

Carneiro, Marco Antônio Alves; Cristina S. A. Branco; Carlos E. D. Braga; Emmanuel D. Almada; Marina B. M. Costa; Valéria Cid Maia & Geraldo Wilson Fernandes. Are gall midge species (Diptera, Cecidomyiidae) host-plant specialists? Revista Brasileira de Entomologia. 2009; 53(3):365-378.

Constantino, Pedro de Araujo Lima; Ricardo Ferreira Monteiro & Machelle D. Wilson. Gall midge attack intensity and host-plant response in a Neotropical coastal ecosystem. Revista Brasileira de Entomologia. 2009; 53(3):391-397.

Dias, Graciela Gonçalves; Gilson Rudinei Pires Moreira; Bruno Garcia Ferreira & Rosy Mary dos Santos Isaias. Why do the galls induced by *Calophya duvauae* Scott on *Schinus polygamus* (Cav.) Cabrera (Anacardiaceae) change colors? Biochemical Systematics and Ecology. 2013; 48:111-122.

Embrapa – Empresa Brasileira de Pesquisa Agropecuária. Sistema brasileiro de classificação de solos. 3. ed. Brasília; 2013.

Espírito-Santo, Mário Marcos & Geraldo Wilson Fernandes. How many species of gall-inducing insects are there on earth, and where are they? Annals of the Entomological Society of America. 2007; 100:95-99.

Fatma – Fundação do Meio Ambiente. Plano de manejo do Parque Estadual do Acaraí. Plano Básico vol. I/III. (vol. 1). São Francisco do Sul; 2008.

Fernandes, Geraldo Wilson & Peter W Price. Biogeographical gradients in galling species richness. Test of hypotheses. Oecologia. 1988; 7:161-167.

Floate, Kevin Douglas; Geraldo Wilson Fernandes & J. A. Nilsson. Distinguishing intrapopulacional categories of plants by their insect faunas: galls on rabbitbrush. Oecologia. 1996; 135:442-450.

Formiga, Anete Teixeira; Fernando Augusto de Oliveira e Silveira, Geraldo Wilson Fernandes & Rosy Mary dos Santos Isaias. Phenotypic plasticity and similarity among gall morphotypes on a superhost, *Baccharis reticularia* (Asteraceae). Plant Biology. 2015; 17(2):512-521. doi:10.1111/plb.12232.

Gagné, Raymond J. & Mathias Jaschhof. Catalog of the Cecidomyiidae (Diptera) of the world. 3. ed. Digital version 2. 2014. 493 p. [Acesso em: 5 out. 2016]. Disponível em: http://www.ars.usda.gov/SP2UserFiles/Place/80420580/Gagne_2014_World_Cecidomyiidae_Catalog_3rd_Edition.pdf.

Imbar, Moshe; Ido Zhaki; Avi Koplovich; I. Lupo; Nissim Silanikove; Tzach Glasser; Yoram Gerchman; Avi Perevolotsky & Simcha Lev-Yadum. Why do many galls have conspicuous colors? A new hypothesis. Arthropod Plant Interact. 2010; 4:1-6.

Isaias, Rosy Mary dos Santos; Renê Gonçalves da Silva Carneiro; Dênis Coelho de Oliveira & Jean Carlos Santos. Illustrated and annoted checklist of Brazilian gall morphotypes. *Neotropical Entomology*. 2013; 42:230-239.

Isaias, Rosy Mary dos Santos; Renê Gonçalves da Silva Carneiro; Jean Carlos Santos & Dênis Coelho de Oliveira. Gall morphotypes in the neotropics and the need to standardize them. In: Fernandes, Geraldo Wilson & Jean Carlos Santos. Neotropical insect galls. New York: Springer Verlag; 2014. p. 51-67.

Jardim Botânico do Rio de Janeiro. Lista de espécies da flora do Brasil. 2016. [Acesso em: 5 out. 2016]. Disponível em: http://floradobrasil.jbrj.gov.br/.

Knie, Joachin L. W. Atlas ambiental da região de Joinville: complexo hídrico da Baía da Babitonga. Florianópolis: Fatma/GTZ; 2002.

Kuki, Kacilda Naomi; Marco Antônio Oliva; Eduardo Gusmão Pereira; Alan Carlos Costa & José Cambraia. Effects of simulated deposition of acid mist and iron ore particulate matter on photosynthesis and the generation of oxidative stress in *Schinus terebinthifolius* Raddi and *Sophora tomentosa* L. Science of the Total Environment. 2008; 403:207-214.

Maia, Valéria Cid. Dois gêneros novos de Cecidomyiidae (Diptera) associados a Myrtaceae, na restinga da Barra de Maricá, Rio de Janeiro, Brasil. Revista Brasileira de Zoologia. 1995; 12(3):567-574. doi: http://dx.doi.org/10.1590/S0101- 81751995000300012.

Maia, Valéria Cid. Galhas de insetos em restingas da região sudeste do Brasil com novos registros. Biota Neotropica. 2013; 13(1). [Acesso em: 5 out. 2016]. Disponível em: http://www.biotaneotropica.org.br/v13n1/pt/abstract?inventory+bn01613012013.

Maia, Valéria Cid. New genera and species of gall midges (Diptera, Cecidomyiidae) associated with *Guarea macrophylla* (Meliaceae). Revista Brasileira de Zoologia. 2007; 24(3):449-456. doi: http://dx.doi.org/10.1590/S0101-81752007000200024.

Maia, Valéria Cid. New genera and species of gall midges (Diptera, Cecidomyiidae) from three restingas of Rio de Janeiro State, Brazil. Revista Brasileira de Zoologia. 2001; 18(Supl. 1):1-32.

Maia, Valéria Cid; Leandro *Jorge Telles Cardoso & João Marcelo Alvarenga Braga*. Insect galls from Atlantic Forest areas of Santa Teresa, Espírito Santo, Brazil: characterization and occurrence. Boletim do Museu de Biologia Mello Leitão. 2014; (33):47-129.

Maia, Valéria Cid; Mara Angelina Galvão Magenta & Suzana Ehlin Martins. Ocorrência e caracterização de galhas de insetos em áreas de restinga de Bertioga (São Paulo, Brasil). Biota Neotropica. 2008; 8(1). [Acesso em: 5 out. 2016]. Disponível em: http://www.biotaneotropica.org.br/v8n1/pt/abstract?inventory+bn02408012008.

Maia, Valéria Cid & Marcelo Guerra Santos. Record of insects in two fern species of the genus Microgramma (Polypodiaceae) in the Atlantic Rain Forest, Rio de Janeiro state, Brazil. Brazilian Journal of Biology. 2015; 75(4, Supl. 1):253-254.

Mani, Mahadeva Subramania. Ecology of plant galls. The Hague: Springer Science; 1964. 434 p. doi: http://dx.doi.org/10.1007/978-94-017-6230-4.

Melo Júnior, João Carlos Ferreira de & Maria Regina Torres Boeger. Leaf traits and plastic potential of plant species in a light-edaphic gradient from a restinga in southern Brazil. Acta Biologica Colombiana. 2016; 21:51-62.

Melo Júnior, João Carlos Ferreira de & Maria Regina Torres Boeger. Riqueza, estrutura e interações edáficas em um gradiente de restinga do Parque Estadual do Acaraí, estado de Santa Catarina, Brasil. Hoehnea. 2015; 42:207-232.

Mendonça Jr., Milton de Souza. Plant diversity and galling arthropod diversity searching for taxonomic patterns in an animal-plant interaction in the Neotropics. Boletín de la Sociedad Argentina de Botánica. 2007; 42:347-357.

Mendonça Jr., Milton de Souza; Hosana M. F. Piccardi; Simone M. Jahnke & Ricardo V. Dalbem. Galling arthropod diversity in adjacent swamp forests and restinga vegetation in Rio Grande do Sul, Brazil. Neotropical Entomology. 2010; 39(4):513-518.

Oliveira, Fabiano Antonio de & Celso Voos Vieira. Proposal of semi-detailed geomorphological map of northeastern Santa Catarina State, Brazil. Anais. International Meeting and Field Trip Environmental Analysis and Geomorphological Mapping for a Sustainable Development. Roma, p. 13-15. 2008.

Portugal-Santana, André & Rosy Mary dos Santos Isaias. Galling insects are bioindicators of environmental quality in a conservation unit. Acta Botanica Brasilica. 2014; 28(4):594-608.

Price, Peter W. Adaptative radiation of gall-inducing insects. Basic and Applied Ecology. 2005; 6:413-421.

Price, Peter W.; Geraldo Wilson Fernandes & Gail L. Waring. Adaptive nature of insect galls. Environmental Entomology. 1987; 16:15-24.

Probio. Áreas prioritárias para a conservação, utilização sustentável e repartição de benefícios da biodiversidade brasileira. Brasília: MMA; 2003.

Rocha, Carlos Frederico Duarte. A biodiversidade nos grandes remanescentes florestais do estado do Rio de Janeiro e nas restingas da Mata Atlântica. São Carlos: RiMa, 2003. 160 p.

Rodrigues, Alene Ramos; Valéria Cid Maia & Márcia Souto Couri. Insect galls of restinga areas of Ilha da Marambaia, Rio de Janeiro, Brazil. Revista Brasileria de Entomologia. 2014; 58(2):173-197. doi: 10.1590/S0085-56262014000200010.

Scarano, Fábio Rubio. Structure, function and floristic relantioships of plants communities in stressful habitats marginal to Brazilian Atlantic Rainforest. Annals of Botany. 2002; 90(4):517-524.

Shorthouse, Joseph D.; David Wool & Anantanarayanan Raman. Gall-inducing insects – nature's most sophisticated herbivores. Basic and Applied Ecology. 2005; 6:407-411.

Stone, Graham N. & Karsten Schonrogge. The adaptive significance of insect gall morphology. Trends in Ecology and Evolution. 2003; 86:512-522.

Tanoue, Makoto; Jane Elizabeth Kraus & Fábio de Barros. Galhas radiculares em algumas *Cattleya* brasileiras. In: Barros, Fábio de & Gilberto Barbante Kerbauy (Orgs.). Orquidologia sul-americana: uma compilação científica. São Paulo: Secretaria de Estado do Meio Ambiente, Instituto de Botânica; 2004. p. 43-48.

Thomazi, Rafael D.; Rafael T. Rocha; Mariana V. Oliveira; Anderson S. Bruno & Ary G. Silva. Um panorama da vegetação das restingas do Espírito Santo no contexto do litoral brasileiro. Natureza on line. 2013; 11(1):1-6.