Chapter 7
Vascular Epiphytes of the Atlantic Forest: Diversity and Community Ecology

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Abstract Epiphytes are plants that germinate and root non-parasitically on other plants, without contact with the soil. They are hyper-diverse and comprise approximately 9% of all vascular plant species. We discuss here vascular epiphytes growing in the Atlantic Forest, focusing on (i) their diversity, the number of epiphyte species, and the main groups and families; (ii) their biogeography and the influence of biotic and abiotic factors on species distributions; (iii) their relationships with phorophyte trees, considering mainly trunk and crown influences on epiphyte communities; and (iv) conservation, discussing epiphyte conservation statuses and reintroductions.

Keywords Biogeography · Conservation · Endemism · Epiphytes · Phorophytes · Richness

7.1 Introduction

Epiphytes are plants that germinate and root non-parasitically on other plants, without contact with the soil (Madison 1977; Bennet 1986; Zotz 2016), obtaining most of their nutrients from atmospheric sources (Benzing 1983). The classification of plants into epiphytic life forms has been controversial, and many attempts have been made to define them (Batke et al. 2016; Benzing 1987, 1990). The currently most useful life form classification for mechanically dependent plants (Kelly 1985) divides species into six categories: holo-epiphytes, primary

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hemi-epiphytes, nomadic vines (includes secondary hemi-epiphytes), climbers (lianas and vines), stranglers, and hemi-parasites (i.e., mistletoes) (Zotz 2013). Zotz (2013, 2016) only consider holo- and primary hemi-epiphytes as epiphytes (including stranglers).

Epiphytes are hyper-diverse, comprising approximately 9% of all vascular plant species (Cascante-Marín and Nivia-Ruíz 2013; Ibisch et al. 1996; Kress 1986; Zotz 2013). They provide ecological services related to hydrology and nutrient cycling (Jarvis 2000; Stanton et al. 2014; Bruijnzeel et al. 2011) and contribute to diversity through their interactions with other biota (Benzing 1983; Yanoviak et al. 2007). A great number of invertebrate and vertebrate organisms use epiphytes as habitat or as food resources (Angelini and Silliman 2014; Lasky and Keitt 2012; Scheffers et al. 2014). Epiphytes are one of the first life forms to become extinct due to overexploitation and deforestation, the loss of large trees (their support), and changes in microclimatic conditions (Sodhi et al. 2008). Because of their arboreal lifestyles and sensitivity to environmental stress, epiphytes can be important bioindicators (Kull and Hutchings 2006; Li et al. 2015).

The South American Atlantic Forest is considered one of the most endangered ecosystems in the world (Myers et al. 2000; Mittermeier et al. 2004) and one of the main floristic centers in the Neotropics (Gentry 1982; Stehmann et al. 2009). Most of that forest (~ 95%) occurs in eastern Brazil, but it also extends into Argentina, Paraguay, and Uruguay (from 3° S to 30° S, Ribeiro et al. 2009, Stehmann et al. 2009). The biome shows wide variations in rainfall and elevation (from sea level up to >2800 m) and comprises a vast heterogeneity of habitats (Oliveira-Filho and Fontes 2000), including several vegetation types, partly reflecting environmental gradients (Oliveira-Filho et al. 2005). While forest physiognomies in the continental interior largely receive rainfall concentrated in only a single season (~1000 mm/year), coastal forests can receive as much as 4000 mm distributed relatively evenly throughout the year (Câmara 2003). The Atlantic Forest originally covered approximately 150 million hectares but now occupies only 12% of its original area, with 80% of its fragments being <50 ha, with a mean distance between them of 1.4 km (Ribeiro et al. 2009). The Atlantic Forest presents very high richness of the epiphyte species, representing more than 15% of the total vascular plant richness (2000 species, Ramos et al. 2019), being most (78%) of them endemic from this biome (Freitas et al. 2016).

We present an overview of vascular epiphyte studies in the Atlantic Forest in this chapter and discuss conservation implications and gaps in our knowledge concerning epiphyte diversity.

7.2 Vascular Epiphyte Studies

Most epiphyte assemblage studies undertaken in the Atlantic Forest have been floristic inventories that documented the most common representatives of local floras (Ramos et al. 2019). The first epiphyte inventory in Paraná State, Brazil, was made in 1950 (Hertel 1950). The most common sampling method adopted in epiphyte assemblage inventories in the Atlantic Forest has been the walk-through methodology, as proposed by Filgueiras et al. (1994). Those surveys follow a transect in a selected forest area, without quantifications of the number of individuals of each species, which makes new epiphyte inventories necessary as new epiphyte species are still being found. Lana et al. (2018), for example, studying only the Orchidaceae assemblage in a conservation area in Minas Gerais State, recently found four species that had not yet been reported in any Atlantic Forest flora. Quantitative studies are fundamental to describing patterns and understanding community ecology processes, such as those related to assemblage changes in response to environmental disturbances (Ricklefs 2007). There have been very few quantitative studies (11 studies or 12% of the data), however, of epiphyte communities in the Atlantic Forest (Ramos et al. 2019) or even in the world (Mendieta-Leiva and Zotz 2015). The quantification methodology most commonly adopted in epiphyte inventories in the Atlantic Forest involves counting the number of individuals or stands (sense Sanford 1968) (99%) (Ramos et al. 2019) – but there have been only rare studies examining them by coverage (1%) and only one quantifying biomass (Petean et al. 2018). There have also been collection biases in epiphyte assemblage inventories in the Atlantic Forest, as those inventories have been concentrated in southern and southeastern Brazil, mainly near the coast (Ramos et al. 2019). Studies examining epiphyte-tree relationships have likewise been very scarce, and few workers have presented any information about phorophytes (e.g., Chaves et al. 2016; Francisco et al. 2018).

7.3 Vascular Epiphyte Diversity

Floristic surveys in the Atlantic Forest have largely focused on tree species, although there has been increasing interest in epiphyte diversity in the Atlantic Forest [e.g., Kersten (2010), Leitman et al. (2015), Menini Neto et al. (2016), Freitas et al. (2016), and Ramos et al. (2019)]. The first estimates of Atlantic Forest vascular epiphyte richness were made by Kersten (2010), who cited 1074 species; current estimated epiphyte richness is approximately 2000 species. Our consultations of the official list of Brazilian flora (Brazilian Flora 2020 under construction) identified 2227 epiphyte species in the Atlantic Forest. Freitas et al. (2016) reported 2256 species of vascular epiphytes, while Ramos et al. (2019) reported 2080 species of vascular and avascular epiphytes. Although the species list of Freitas et al. (2016) was incorporated in the database published by Ramos et al. (2019), the latter only reported records of species with validated geographic coordinates – which may have contributed to the differences in the number of species records between Freitas et al. (2016) and Ramos et al. (2019).

7.3.1 Number of Vascular Epiphyte Species

We present here a brief description of the number behind epiphyte diversity in the Atlantic Forest. Almost 80% of the vascular epiphytes found in the Atlantic Forest are endemic (Freitas et al. 2016; Brazil Flora G 2020). That degree of epiphyte species endemism is very high when compared both to (i) other groups in the Atlantic Forest, such as total vascular plants (57%), trees (54–60%), or amphibians (60%) (Mittermeier et al. 2004, Brazilian Flora 2020 under construction), and (ii) epiphytes in other forests from Central America or north of South America (0 from 37%, Kreft 2004, Cascante-Marin and Nivia-Ruíz 2013). Species not endemic to the Atlantic Forest have disjunct distributions between the Atlantic Forest and the Amazon or Cerrado biomes (~15%), but only a few species (~5%) occur in more than two phytogeographic domains (Freitas et al. 2016, Brazilian Flora 2020 under construction). Angiosperms have a higher proportion of Atlantic Forest endemic species than ferns (Fig. 7.1). The richest families of vascular epiphytes are, in descending order, Orchidaceae, Bromeliaceae, Piperaceae, Arecaceae, Cactaceae, and Gesneriaceae (among angiosperms) and Polypodiaceae, Dryopteridaceae, Hymenophyllaceae, and Aspleniaceae (among ferns). The richest families of angiosperm epiphytes show high levels of endemism, especially Bromeliaceae and Gesneriaceae (91% and 89% endemic species, respectively).

Fontoura et al. (2012) and Menini Neto et al. (2016) reported that the southeastern and southern regions of the Atlantic Forest were the most species-rich. According to Ramos et al. (2019), the southern and southeastern regions of Brazil and southern region of Bahia State (Fig. 7.2) contain the richest known areas of epiphyte species diversity – which also coincide with areas that have experienced the highest

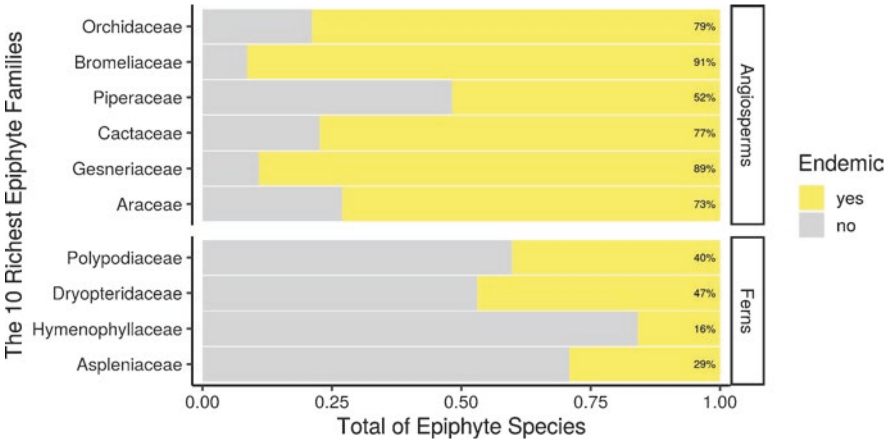

Fig. 7.1 Proportions of endemic species among the ten richest families of Atlantic Forest epiphytes. The percentage numbers indicate the percentage of endemic species within each family. The data in this figure was derived from the Brazil Flora G (2020)

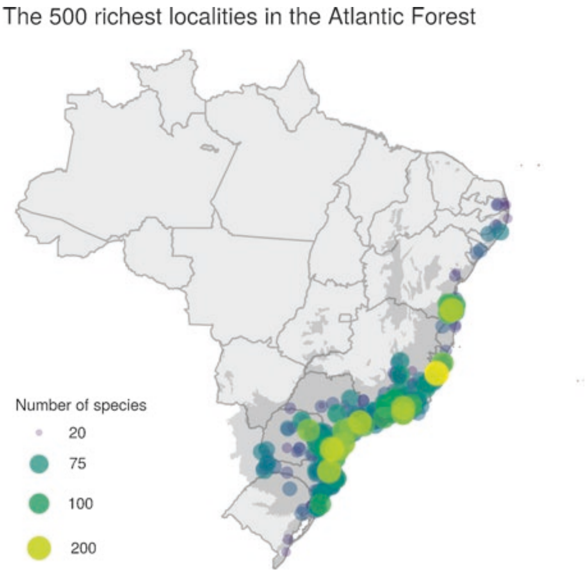

Fig. 7.2 Number of species recorded in each locality in the Atlantic Forest (Atlantic Forest domain in dark gray). Regions with the highest number of species are (1) southern Bahia State and (2) southeastern and (3) southern Brazil. (Data from Ramos et al. (2019))

sampling efforts (Kersten 2010; Ramos et al. 2019), being close to important research centers in large cities (with the exception of southern Bahia State).

The areas holding the greatest epiphyte richness are southeastern and southern Brazil, especially near central-southern Rio de Janeiro and Espírito Santo States, along the Serra do Mar mountain range (Fontoura et al. 2012; Menini Neto et al. 2016). Similarly, studies with angiosperms (Werneck et al. 2011) and some animal groups (Ferro and Melo 2011; Vasconcelos et al. 2014) reported that same pattern and also included southern Bahia State as one of the richest areas (Menini Neto et al. 2016). Many other organisms occurring in the Atlantic Forest share similar diversity patterns, such as butterflies (Brown Jr. and Freitas 2000), moths (Ferro and Melo 2011), termites (Cancello et al. 2014), and harvestmen spiders (Pinto-da-Rocha and Silva 2005).

Most Atlantic Forest epiphyte records are from Ombrophilous Forest sites (60%) (both Mixed and Dense), with fewer records from Semideciduous Forests (25%) (Ramos et al. 2019). Leitman et al. (2015) identified 38 epiphytic species indicators of Atlantic Forest vegetation types, most of them bromeliads and orchids. Seasonal Semideciduous Forest was the only vegetation type where indicator species were not identified. Epiphyte species occurring in Seasonal Semideciduous Forest represent a subset of the species occurring in Ombrophilous Forests (more humid and richer forest), which can tolerate lower precipitation rates, lower air humidity, and greater seasonality (Leitman et al. 2015). Epiphyte assemblages from Seasonal Semideciduous Forests representing subsets of Ombrophilous Forest species adapted to seasonal conditions were also reported in a local study of epiphyte assemblages (Forzza et al. 2014) and in tree assemblage studies (Oliveira-Filho and Fontes 2000). Additionally, adaptations of epiphyte species to lower temperatures could explain the high number of indicator species found in Mixed Ombrophilous Forests (Leitman et al. 2015).

7.4 Biogeography of Vascular Epiphytes

There have been few studies of epiphyte biogeography in the world, but epiphyte distributions have been observed to be influenced by both climatic conditions and vicariance events (Kessler 2001, 2002a; Kreft et al. 2004; Kessous et al. 2019; Moreno-Chacón and Saldaña 2019). Epiphyte species show wider distributions as compared to terrestrial or rupicolous species, due to their greater capacities of diaspore dispersal (Kessler 2002a). Epiphyte species, however, appear to be more susceptible to water stress and low temperatures (especially frost) as compared to terrestrial plants (Gentry and Dodson 1987; Benzing 1990; Kessler 2002b; Kreft et al. 2004), although more research is still needed in that area (Zotz 2016).

Epiphyte richness has been found to be greater in areas with high precipitation rates and low seasonality, as those plants live without soil and are highly dependent on moisture derived directly from rainfall or water vapor (Kreft et al. 2004). Precipitation is therefore an important climatic factor influencing epiphyte diversity (Gentry and Dodson 1987; Zotz 2016). Additionally, although at smaller scales, the presence of humidity derived from clouds, rivers, or streams (even temporary ones) can influence epiphyte richness (Gentry and Dodson 1987; Zotz 2016; Furtado and Menini Neto 2018). Another limiting climatic factor for epiphyte distribution is temperature (Gentry and Dodson 1987; Krömer et al. 2005; Kessler et al. 2011; Hsu et al. 2014). Low temperatures, especially frost events, appear to be the most important climatic condition limiting the latitudinal and altitudinal distributions of epiphyte species (Mayo et al. 1997; Nervo et al. 2019). Altitude can also influence vascular epiphyte richness. Several studies have shown a peak of epiphyte richness at intermediate altitudes between 1000 and 1500 m a.s.l. (Gentry and Dodson 1987; Hietz and Hietz-Seifert 1995; Küper et al. 2004; Krömer et al. 2005; Cardelus et al. 2006; Krömer et al. 2008; Hsu et al. 2014; Sanger and Kirkpatrick 2015; Ding et al. 2016).

Epiphyte richness and composition along latitudinal and altitudinal gradients in the Atlantic Forest are influenced not only by climatic conditions but also by historic events, such as river formation and Pleistocene refuges (Fontoura et al. 2012; Leitman et al. 2015; Menini Neto et al. 2016; Nervo et al. 2016; Furtado and Menini Neto 2018; Nervo et al. 2019), as is presented below in detail.

7.4.1 Latitude

Latitudinal distributions of epiphyte species in the Atlantic Forest are influenced by climatic factors, mainly precipitation (from ocean to inland) and temperature (Fontoura et al. 2012; Leitman et al. 2015; Menini Neto et al. 2016). Areas with high precipitation show high epiphyte richness, such as the “Serra do Mar,” a mountain chain in southeastern Brazil that receives orographic rains on its highest slopes, providing both horizontal and vertical precipitations (Almeida and Carneiro 1998) – and thus sustaining considerable epiphyte diversity. Areas with low precipitation and (mainly) high seasonality, on the other hand, show lower epiphyte richness, such as Seasonal Semideciduous Forests, an inland forest physiognomy (Menini Neto et al. 2016). Temperatures also affect epiphyte richness in some areas of the Atlantic Forest, especially minimum and mean annual temperatures in low latitudinal areas (Fontoura et al. 2012). Epiphyte assemblages in the Atlantic Forest are also influenced by geographical distances (Leitman et al. 2015), with epiphyte communities being very similar between neighboring areas, even those with differing environmental conditions – suggesting that seed dispersal is an important limitation (Leitman et al. 2015).

7.4.2 Elevation

There is a strong influence of altitude on the general pattern of epiphyte distribution in the Atlantic Forest (Leitman et al. 2015; Nervo et al. 2016; Furtado and Menini Neto 2018; Nervo et al. 2019), although that influence decreases with increasing latitude (Leitman et al. 2015). Fontoura et al. (2012) suggested that elevational influences were stronger at regional scales. Because most of the higher-altitude areas in the Atlantic Forest mountains are equivalent to mid-elevation peaks (between 1000 and 1500 m a.s.l.), however, some studies investigating the influence of elevation on epiphyte assemblage diversity did not show sharp reductions of species richness at the highest reaches of those gradients (Nervo et al. 2016, Furtado and Menini Neto 2018, Nervo et al. 2019), as opposed to reductions in taller mountains, such as the Andes (Krömer et al. 2005).

7.4.3 Past Events

Plant (Prance 1982; Oliveira-Filho and Fontes 2000; Ledru et al. 2007; Prata et al. 2018) and animal (Pellegrino et al. 2005; Cabanne et al. 2007; Thome et al. 2010; DaSilva and Pinto-da-Rocha 2010; DaSilva et al. 2015) species distributions in the Atlantic Forest are not homogenous but rather have two main sections that are divided by the Doce River in northeastern Espírito Santo State. The northern block comprises the northeastern region of the Atlantic Forest, while the southern block comprises the southeastern and southern forest regions – with epiphyte distribution following the same pattern (Fontoura et al. 2012; Menini Neto et al. 2016). That disjunction between the two blocks has been attributed to (i) their geomorphologic differentiation (DaSilva and Pinto-da-Rocha 2010), (ii) oceanic invasions of the Doce River region during Pleistocene interglacial periods (Suguio et al. 2005), and

(iii) the creation of forest refuges to the north of the São Francisco River during the Pleistocene era (Carnaval and Moritz 2008).

7.5 Relationships Between Epiphytes and Their Phorophytes

The relationships between epiphytes and their support plants (phorophytes) are consensually defined as commensal relationships. Epiphytes show non-random distribution patterns, which are influenced by phorophyte traits and climatic conditions. In general, the relationships between epiphytes and phorophytes in the Atlantic Forest show only low levels of specialization (Francisco et al. 2018; Francisco et al. 2019; Zotarelli et al. 2019), similar to other epiphyte/phorophyte patterns in tropical forests (e.g., Sáyago et al. 2013) – suggesting stronger associations with specific phorophyte features and not the phorophyte species themselves. Traits associated with specific phorophyte species, however, can explain variations of epiphyte diversity in specific cases [e.g., the bark-shedding species *Piptadenia gonoacantha* (Fabaceae.) harbors fewer epiphyte individuals in the Atlantic Forest as compared to other phorophytes] (Dislich and Mantovani 2016).

In terms of other phorophyte traits, larger tropical forest trees support the most epiphyte species, and just a few large trees may satisfactorily describe local epiphyte species diversity (Zotz and Bader 2011). The largest trees in the Atlantic Forest support a considerable fraction of epiphyte diversity (Schmitt and Windisch 2010; Dislich and Mantovani 2016), and a single large tree was found to bear 46% of the total local epiphyte richness (Francisco et al. 2018). Epiphyte diversity on Atlantic Forest phorophytes is not equally distributed along the tree surface, with the intermediate height of the tree harboring the highest epiphyte diversity (Kersten et al. 2009). The trunk tends to support more epiphyte richness, but with lower abundance (individuals/biomass), than the crown (Francisco et al. 2018; Petean et al. 2018); that pattern is not consistent, however, in other forest types (e.g., the Amazon Forest; Pos and Sleegers 2010). Even though some epiphytes may show preferences for specific phorophyte zones (e.g., Flores-Palacios and García-Franco 2005), that does not necessarily result in considerable differences in species compositions between Atlantic Forest zones (Machado et al. 2016).

Phorophyte traits influencing epiphyte distributions generally reflect the combined effect of several tree features, as opposed to a single isolated trait. Larger trees have more habitat available for epiphytes and are thus able to support more epiphyte coverage, while trees with more habitat heterogeneity (e.g., rugose bark) show the richest epiphyte species compositions (Batista and Santos 2016). Phorophyte habitat availability and heterogeneity can therefore better explain epiphyte distribution patterns when analyzed together. Small trees, for example, usually harbor fewer epiphytes but become excellent hosts to atmospheric bromeliads if they are also deciduous (habitat heterogeneity proxy) (Chaves et al. 2016). The decisive role of large trees in Atlantic Forest epiphyte diversity is well-established, but we know very little about the traits associated with habitat heterogeneity and even less about the effects of combined tree features. In comparisons of ecosystems analogous to the Atlantic Forest (i.e., tropical forests), bark (e.g., peeling bark, Boelter et al. 2014) and canopy characteristics (e.g., canopy structure, Fayle et al. 2006) were found to be associated with epiphyte assemblage in different ways, but have not yet been extensively examined in the Atlantic Forest.

It is possible that the unique distribution patterns of Atlantic Forest epiphytes are due to the high proportion of endemic epiphyte species found there. As such, a vast gap in our knowledge of Atlantic Forest epiphyte/phorophyte relationships exists in terms of (I) the combined effects of two or more traits and (II) traits associated with phorophyte habitat heterogeneity.

7.6 Conservation

Anthropic disturbances reducing forest cover represent the main threat to epiphyte species (Barberena et al. 2018; Cardoso et al. 2018), followed by the absence of mutualistic organisms (pollinators, seed dispersers, mycorrhiza) and collection pressure (Barros 2007). According to the CNCFlora red list of endangered species (Martinelli and Moraes 2013), only 8% (171) of the Brazilian epiphyte species (Brazil Flora G 2020) listed are considered endangered [including the categories of critically endangered (33 species), endangered (82), or vulnerable (56)]; on the other hand, only 11% of the epiphyte species are considered as of least concern. Given that the majority (~80%) of Brazilian epiphyte species are endemic to the Atlantic Forest (Freitas et al. 2016) and a considerable number are represented by less than ten records from the Atlantic Forest (Ramos et al. 2019), considerably more work will be needed to determine their conservation statuses. Our knowledge of epiphyte diversity is therefore still incipient, and data on epiphyte species distributions and local abundances are still extremely scarce. Fully 19% of all epiphyte species are represented by only a single collection, and 59% have less than ten records (Ramos et al. 2019). The combination of high endemism levels, few records, and limited data on species abundances and conservation raises concern about how little we actually know about epiphyte ecology in the Atlantic Forest.

Deforestation (due to farming and cattle raising) represents one of the greatest impacts on epiphyte assemblages. Studying the effects of forest fragmentation and land use on this plant group will be important for determining effective conservation and management actions. The few studies already undertaken to examine the impacts of anthropic land use on epiphyte assemblages in the Neotropics have shown that areas having more intense land use [especially plantations, such as shade coffee, teak, and pine (Moorhead et al. 2010, Einzmann and Zotz 2016, Alzate-Q et al. 2019), and pasture land (Köster et al. 2009, Larrea and Werner 2010, Werner et al. 2011)] demonstrate decreased richness and alterations in epiphyte assemblage composition, mainly due to altered microclimatic conditions (Werner 2011). Studies of land use or edge effects in the Atlantic Forest have shown similar patterns. Only two studies comparing the effects of land use on epiphyte assemblages in the

Atlantic Forest have been published that examined differences in epiphyte assemblages in intact forest versus shaded cocoa plantations (Pardini et al. 2009; Fernandes et al. 2015). Those studies showed that although epiphyte richness was lower in shaded cocoa plantations and their species composition differed from the forest, that type of agroforestry could still preserve important number of species. It is important, however, to highlight the fact that the richness and abundances of generalist species were higher than those of specialist/forest species in shaded cocoa plantations. There have been six studies focusing on edge effects on epiphyte assemblages in the Atlantic Forest (Bataghin et al. 2008; Bernardi and Budke 2010; Bataghin et al. 2012; Bianchi and Kersten 2014; Dias-Terceiro et al. 2015; Silva et al. 2017), and they demonstrated that the forest fragments showed impoverished epiphyte assemblages that become even poorer near forest edges. Not only did richness decrease, but there were also compositional changes, and solar radiation levels appeared to be correlated with epiphyte abundances and distribution within the fragments (Bataghin et al. 2008, Bernardi and Budke 2010, Bataghin et al. 2012, Bianchi and Kersten 2014, Dias-Terceiro et al. 2015, Silva et al. 2017).

Few local studies addressing epiphyte conservation in the Atlantic Forest have been conducted in past decades. Some of them evaluated the conservation status of species in a specific area (Cardoso et al. 2016, 2018; Barberena et al. 2018) and economic impacts on epiphyte conservation (Santos et al. 2005), while others evaluated the growth and survival of reintroduced epiphyte species in remnant or restored forest fragments (Jasper et al. 2005; Endres-Júnior et al. 2015, 2018; Duarte and Gandolfi 2013, 2017).

Epiphyte restoration or reintroduction attempts can be difficult because of (a) a lack of knowledge of a given species' conservation status and its population dynamics; (b) their complex propagation and cultivation requirements; (c) a limited knowledge of their interactions with biotic and abiotic factors in forest remnants; and (d) problems related to the maintenance of genetic diversity. The few reintroduction projects with epiphyte species conducted in Atlantic Forests have achieved high (>50%) survival rates with both adult and young individuals (Jasper et al. 2005; Dorneles and Trevelin 2011; Duarte and Gandolfi 2013, 2017; Endres-Júnior et al. 2015, 2018). Reintroduction success was affected mainly by solar radiation levels (Endres-Júnior et al. 2015, 2018), the age or biomass of the epiphyte individuals (Duarte and Gandolfi 2013; Endres-Júnior et al. 2015, 2018), the season when planted (Duarte and Gandolfi 2017), and the substrate used to attach the individual to the tree (Jasper et al. 2005; Duarte and Gandolfi 2017). Those studies did not find any effects of phorophyte tree traits on epiphyte reintroduction success. Given that epiphyte reintroduction success was species dependent, detailed studies of the biology of epiphyte species will be necessary (Jasper et al. 2005), as both abiotic and biotic conditions could affect epiphyte reintroduction in Atlantic Forests. Solar radiation, for example, positively affected *Catasetum fimbriatum* (Orchidaceae) (Dorneles and Trevelin 2011; Endres-Júnior et al. 2015, 2018) (Duarte and Gandolfi 2017) but negatively affected *Rhipsalis floccosa* (Cactaceae) (Duarte and Gandolfi 2017) epiphyte reintroductions, while herbivory negatively affected the survival of *Cattleya intermedia* (Orchidaceae) (Dorneles and Trevelin 2011, Endres-Júnior et al. 2015, 2018). Additionally, many *Tillandsia* (Bromeliaceae) species showed higher transplantation survival rates when associated with other Orchidaceae, Cactaceae, or bryophyte species (by maintaining humidity) (Jasper et al. 2005).

7.7 Concluding Remarks

We reviewed in this chapter a number of studies that examined vascular epiphyte diversity, ecology, biogeography, and conservation in the Atlantic Forest and identified some significant gaps in our knowledge. Although there have been in situ conservation and restoration efforts using Atlantic Forest epiphytes, their conservation is still incipient. Epiphyte inventories undertaken in the Atlantic Forest have a longer history than studies of their ecology and conservation, but they are still not sufficient to fully support their management or unify political efforts that could guarantee their long-term protection. The combination of high endemism levels, few records, and only limited data concerning species' abundances or conservation statuses raises concern about how little we actually know about epiphyte distribution in the Atlantic Forest.

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