CHAPTER 4

Atlantic Forest Fragments and Bromeliads in Pernambuco and Alagoas: Distribution, Composition, Richness and Conservation

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Above:
Flowers of *Aechmea constantinii*, a typical canopy species in the northeastern Atlantic forest.

Opposite page:
Aechmea fulgens is one of the most attractive species that live in the Atlantic forest understory of the Pernambuco Center. Populations of this species are still common, although they have disappeared from several localities where the species was once collected.

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The situation of the Atlantic forest and associated bromeliad communities in Northeast Brazil is related to the traditional sugar-cane crop. Since the onset of colonization in Brazil, this crop has had a strong influence on regional landscapes, which have been transformed into a relatively uniform matrix of cane fields, while forests have been drastically reduced to vegetation remnants of various sizes resembling chains of small islands. In this part of Brazil, sugar mills and alcohol refineries were installed on river banks in the lowlands, where water resources were abundant for this agro-industrial activity and where firewood was amply available in the surrounding forests.

Easy access to firewood favored the boilers that consumed huge quantities of wood in low-energy-conversion ovens. As of 1992, some mills still used firewood extracted from forests in these ovens (C. Almeida, pers. comm.). Intense overuse of this resource, together with forest fires that burned over huge tracts of land, had disastrous consequences for the Atlantic forest flora (Freyre, 1989).

In the 1990s, Brazil's sugar and alcohol sector was seriously affected by low sugar and alcohol prices on the international market plus the restriction of government tax incentives (Mello & Paulillo, 2005). This crisis was further aggravated by severe drought, mainly in 1993 that caused huge losses in production. Although the sugar mills of the Northeast also suffered from the

Orthophytum disjunctum and *Encholirium spectabile* are typical of the inselbergs surrounded by the Atlantic forest or by brejos de altitude. Fazenda Pelada, Quipapá, Pernambuco.

Opposite page:
The rich understory of the northeastern Atlantic forest, here represented by a large population of the endemic *Araeococcus chlorocarpus* and the huge *Hohenbergia ramageana*, is the first to suffer from ecosystem disturbance by losing the most sensitive and fragile biological components. Serra do Ouro, Murici, Alagoas.

competition and had to relinquish production leadership to mills in the state of São Paulo, sugar cane is still the main agricultural crop in the states of Pernambuco and Alagoas. However, the local sugar-cane industry has undergone a profound technological makeover, and economic survival of this activity in the region depends on irrigation of huge areas plus the construction of huge reservoirs in the headwaters of streams. Although this problem has been ignored for centuries, it is obvious today that the crisis in natural resource availability is intimately linked to the ongoing loss of vegetation cover that has led to an almost complete disappearance of the Atlantic forest.

In view of this reality, fragmentation and habitat loss are by far the most obvious and certainly the oldest ecological processes to affect Brazil's Atlantic forest, especially in the Northeast (see Chapter 2). According to Silva & Casteleti (2005), less than 5% remain today of the original 56,400 km² of Atlantic forest in northeastern Brazil. In the southern Zona da Mata of Pernambuco, most of these fragments (48%) have areas of less than 10 hectares and only 7% are over 100 hectares (Ranta *et al.,* 1998). The fragmentation process in the Atlantic forest of Pernambuco has forged ahead at an alarming rate, with grave consequences for biological and reproductive processes of populations (Schessl *et al.,* 2005). A serious problem in fragmented Atlantic forest is the

lack of consistent indicators that aid in interpreting the current situation of these remnants and in assessing the degree of environmental disturbance and the biological processes that are still in operation (Silva, 1998). By the same token, an understanding of the effects of fragmentation on biological diversity is one of the keys to success of conservation programs (Tabarelli *et al.*, 1999; Margules & Pressey, 2000).

Bromeliads are traditionally known for their species richness and great abundance in the Atlantic forest domain. They participate in a number of interactions, including interdependence relationships, with a large group of plant and animal species, from microscopic to larger sized organisms (Leme & Marigo, 1993; Benzing, 2000, Rocha *et al.*, 2004a). So they are thought to be responsible for the maintenance of a significant portion of the biological diversity in habitats where they live. By the same token, the distribution and unique abundance of bromeliads in this ecosystem may be negatively affected by the well known effects of habitat loss and fragmentation (see Chapter 3) responsible for the following: (1) reduction of bromeliad species richness and diversity (Rocha *et al.*, 2004b); (2) increased extinction risk for large groups of bromeliad species with limited geographic distributions (Smith & Downs, 1974; 1977; 1979; see Chapter 7); (3) local and regional extinction of emergent trees (Laurance *et al.*, 2000), that are a key microhabitat for several species of heliophilous bromeliads (Benzing, 2000; Dimmit, 2000); (4) habitat desiccation and the invasion of weedy species, making fragments more susceptible to fire (Gascon *et al.*, 2000) and especially affecting the bromeliads found only in the understory (Cabral, 2005); and (5) facilitating extractivism of ornamental species (Clark & Clark, 1995; Tabarelli *et al.*, 2002).

Here we analyze the floristic composition, distribution, species richness and endemism of Bromeliaceae in residual fragments of Atlantic forest in Pernambuco and Alagoas. Our analysis was based on knowledge of natural history, geographic distribution, systematics and ecology of the species of this plant family, possibly the best known group in the biogeographic unit known as the Atlantic forest.

Within this context, we tested the following hypotheses: (1) larger forest fragments hold a greater number of species; (2) the lowlands and the montane regions (including the *Brejos de altitude* or *Brejos Nordestinos*) represent two distinct biogeographic units within the Pernambuco Center of Endemism (*Centro Pernambuco*) – the lowlands are related to Amazonia, while the montane forests are related to the Atlantic forest of Southeast Brazil; and (3) floristic similarity of Bromeliaceae on inselbergs is not correlated with the geographic distance between these formations. Results show a striking richness of bromeliad species in the *Centro Pernambuco* which should promote the

An association of species rich in detail and subtleties, with bromeliads, cacti, orchids and lichens on the Sítio Palmeira inselberg, Camocim de São Félix, Pernambuco.

Opposite page:
Gardens of biodiversity can still be found in the more isolated, well-preserved areas of the Pernambuco Center; here, a rupicolous community of *Aechmea leptantha* and *Tibouchia multiflora* (Melastomataceae), components of local inselberg habitats, such as at Pedra do Cruzeiro, Frei Caneca RPPN, Jaqueira, Pernambuco.

Panoramic view of the inselberg at Serra da Naceia, the Grota do Piano slope, between Atalaia and Maribondo, in Alagoas. *Orthophytum atalaiense* and *Vriesea zonata,* two species newly described in Chapter 7, are found only at this site.

Opposite page:
A rich bromeliad community on the inselberg at Pedra do Cruzeiro, Frei Caneca RPPN, Jaqueira, Pernambuco, with dense populations of *Aechmea leptantha*, *Canistrum pickelii* and *Orthophytum disjunctum*.

effective protection of key areas that are important because of physical proximity, species richness, endemism and exclusive species sharing.

Material and Methods

Bromeliad species richness in the *Centro Pernambuco* (*sensu* Silva & Casteleti, 2005; see figure 1), especially in the area of Atlantic forest in Pernambuco and Alagoas, was estimated during 237 field expeditions from 1996 to 2006. All areas were geo-referenced by GPS, and species richness was calculated for each area. From this data base, a map was generated of species distribution and richness based on a grid of 400 km² quadrats using the software ArcView 3.1 (Esri, 1998).

The relationship between fragment size and bromeliad species richness was analyzed using Spearman rank correlation and the Lilliefors test (Sokal & Rohlf, 1995). The analyses were done using Bioestat® (Ayres *et al.*, 1998).

In order to analyze biogeographic relationships between areas based on endemic and/or exclusive species, 91 sites

Cryptanthus pickelii, rediscovered 72 years after it was first collected, forms dense populations in wet environments at the Tapacurá Ecological Station, São Lourenço da Mata, Pernambuco.

Opposite page:
Bromeliad communities are responsible for a significant increase in Atlantic forest biodiversity; *Anthurium bromelicola* (Araceae) is an endangered species that lives only in the rosettes of tank bromeliads in Pernambuco.

(table 1) were preselected of which only 26 of the most heavily sampled areas were used in the analysis. The areas were divided into three biogeographic categories: (1) lowland forests at altitudes under 500 m; (2) montane forests at altitudes over 500 m; and (3) inselbergs, or rocky outcrops (*sensu* Barthlott & Porembski, 2000) that have a unique bromeliad flora. The inselbergs were also analyzed separately due to their unique saxicolous flora with specific genera such as *Dyckia*, *Encholirium* and *Orthophytum*.

As regards geographic distribution, the bromeliad species were placed in categories based on the following sources of information: (1) analysis of a data base with 1,067 records of herbarium sheets deposited in nine regional and one international herbaria: IPA, PEUFR, UFP, UFC and US (see Holmgren *et al.*, 1990), ALCB, EAN, HST, MAC and MUFAL (see Barbosa & Barbosa, 1996); (2) monographs on the family and floristic surveys (Smith & Downs, 1974, 1977, 1979; Siqueira Filho, 2002; 2004); and (3) data from bromeliad surveys at 237 Atlantic forest sites in Pernambuco and Alagoas. Field surveys were begun in 1996, resulting in 372 herbarium records. Specimens are deposited in the Geraldo Mariz herbarium (UFP) at the Pernambuco Federal University and Herbarium Bradeanum (HB) in Rio de Janeiro. Duplicates of part of the material are deposited at the University of Vienna herbarium (WU) in Austria.

Two triangular matrices were generated from the data base, one for floristic similarity (*i.e.*, Jaccard index) and the other for geographic distance. The Mantel test was used (Zar, 1996) to test the hypothesis that there is no correlation between similarity and distance for the 12 most heavily sampled inselbergs. To test the hypothesis that northeastern Atlantic forest is composed of two biogeographic units (Andrade-Lima, 1982; Santos, 2002; Silva & Casteletti, 2005), a list of species presence/absence was generated as follows: two areas in Amazonia – the Ducke Forest Reserve (Ribeiro *et al.*, 1999) and the Guianas (Gouda, 1999); two areas in southeastern Brazil – Macaé de Cima Ecological Reserve in Rio de Janeiro (Lima & Guedes-Bruni, 1994) and Ilha do Cardoso State Park in São Paulo (Wanderley & Mollo, 1992); 13 areas of upland Atlantic forest (montane areas and northeastern *Brejos*, *sensu* Silva & Casteletti, 2005); 15 areas of lowland Atlantic forest (coastal forests, *sensu* Silva & Casteletti, 2005; see table 1). In addition, an analysis was also done on the 12 most heavily sampled areas of the 20 inselbergs that were surveyed.

Biogeographic relationships between the regions studied were evaluated using Parsimony Analysis of Endemism – PAE (Rosen, 1988), a method widely applied in biogeographic studies of the present to define regions of endemism and analyze the evolutionary history of areas. The method is analogous to cladistic analysis used in phylogenetic studies (see Silva & Oren, 1996; Santos, 2002; Silva *et al.*, 2004). The data matrix was constructed using "0" for absence and "1" for presence of the species in the selected areas, the columns representing the species (analogous to characters in phylogenetic analysis) and the lines representing the areas (corresponding to taxa in phylogenetic analysis; Silva *et al.*, 2004). A hypothetical area where all species were absent was created to root the cladogram. Some species were excluded from the PAE analysis because they are (1) found in only one locality; (2) known only from the type locality; or (3) new to science (see Chapter 7). Therefore, PAE analysis included 78 species found in at least two localities. Cladograms were generated using Winclada 0.9.99m24 (Nixon, 1999) and NONA (Goloboff, 1996), using the Parsimony Ratchet method (*Island Hooper*) (Nixon, 1999).

Results

The Atlantic forest bromeliad flora in Pernambuco and Alagoas is currently represented by 19 genera and 93 taxa of which 17 are new to science (see Chapter 7, table 2). Of the grid of 121 quadrats that cover the Atlantic forest in Pernambuco and Alagoas, 86 were sampled. The remaining quadrats have practically no forest fragments (figure 2). There was no significant relationship between species richness and fragment size.

There was a significant difference between geographic distribution patterns of bromeliad species ($X^2 = 45.663$, $df = 4$, $p < 0.001$); 45.5% of the bromeliads are endemic to the *Centro Pernambuco*, while 8.9% are found in the *Centro Pernambuco* and Bahia, 12.2% are typically Amazonia-Northeast Brazil species, 6.6% occur in the Atlantic forest of Northeast and Southeast Brazil and 26.6% are widely distributed. Of the latter, 78% have wind-dispersed plumose seeds with the capacity for long distance dispersal.

The analysis revealed that the sites most species-rich in Bromeliaceae were the Frei Caneca RPPN, in Jaqueira, with 39 species, followed by Mata de Coimbra, in Ibateguara, with 32 species, Fazenda Bitury, in Brejo da Madre de Deus, and Serra da Taquara, in Taquaritinga do Norte, both with 17 species, all located in montane or submontane areas. Lowlands generally have fewer bromeliad species than montane areas. The richest lowland areas are located on private property, such as Engenho Jindaí of the Usina Trapiche, owner of one of the largest areas of Atlantic forest in Pernambuco, and Serra da Cachoeira, which belongs to Usina Cachoeira, in Alagoas. Other species-rich lowland sites are conservation units such as the Tapacurá Ecological Station, at São Lourenço da Mata, and the Gurjaú Ecological Reserve, at Cabo de Santo Agostinho (table 1).

The most important *Brejos de altitude* (N = 17) from a floristic point of view are located at Taquaritinga do Norte and Brejo da Madre de Deus, both with 17 bromeliad species, as well as Brejo dos Cavalos, in Caruaru, with 14 species, followed by the Serra Negra Biological Reserve, between Floresta and Inajá, with 13 species. Fifteen species are found only in *Brejos de altitude*; 9 of these are endemic to the *Centro Pernambuco* and the remainder have a wider distribution pattern, occurring at other Atlantic forest sites in Brazil. *Guzmania monostachia* is found in the Amazon region, Central America and southern North America.

As regards the inselbergs (N = 20), we analyzed both inland (*Brejos de altitude*) and coastal areas. The bromeliad flora on inselbergs was exceptional and differed consistently in species composition when compared to typical forest environments. The most species-rich inselbergs were Pedra do Cruzeiro (15 species); Serra de Naceia (14 species); and Serra Lisa, in Chã Preta, and Serra do Ororubá, in Pesqueira (13 species each). Of the 41 species found on inselbergs (table 2), *Dyckia limae, D. pernambucana, Encholirium spectabile, E. pernambucanum, Orthophytum disjunctum, O. triunfense, O. atalaiense, Vriesea limae, V. freicanecana* and *V. zonata* are exclusive to this type of habitat.

As a rule, the prediction that species would be distributed in two biogeographic units relative to altitude was not confirmed (figure 3). The few, relatively well-defined clades included the lowland areas Fazenda Camarão, Reserva Ducke + Guianas, and Engenho Jindaí + Saltinho + São Bráz + Aquidabã, and the montane areas Serra Lisa + Serra da Naceia (*Brejos de altitude*), Taquaritinga do Norte + Brejo dos Cavalos, and the inselbergs. On the other hand, in the analysis of inselbergs areas only (figure 4), species distribution in the *Brejos de altitude* of Pernambuco and in Alagoas generated a clade of four areas within the limits of the Atlantic forest in Alagoas. In Pernambuco, the analysis generated a clade that included the inselbergs of the Cassange group in Brejo da Madre de Deus + Bezerros + Taquaritinga do Norte + Pedra do Cruzeiro, and a clade formed by isolated inland inselbergs (Belo Jardim and Serra do Ororubá, in Pesqueira) that are geographically close together, and, finally, the Camocim de São Félix group and the Malhada inselberg in Brejo da Madre de Deus. Geographic distance did not explain similarity between nearby inselbergs (r = -0.6239; t = -4.983; p = 1.00; 2,000 replicates).

Discussion

The Atlantic forest areas of Pernambuco and Alagoas are part of the Pernambuco Endemism Center or *Centro Pernambuco* (Pernambuco Center; *sensu* Silva & Casteleti, 2005), internationally renowned for its important biological diversity, but also with seriously threatened species on the brink of extinction (Ricketts *et al.*, 2005). Although the Pro-alcohol Program had a disastrous environmental record in the 1970s, resulting in the expansion of the agricultural frontier and the destruction of the remaining large areas of Atlantic forest in this region, relict forests still hold an important group of bromeliad species, many of which are endemic and bordering on extinction (Siqueira Filho, 2002; 2004).

The information gleaned from this study of Atlantic forest bromeliads in Pernambuco and Alagoas makes this family one of the best known biological groups of the Atlantic forest in Brazil (figure 2), together with butterflies (Brown, 1982), birds (Roda, 2003), mammals (Silva & Casteleti, 2005) and the ferns (Santiago, 2006). Research in the past ten years revealed an amazing 22 new bromeliad species (see Siqueira Filho & Leme, 2000; 2002; Leme & Siqueira Filho, 2001; Chapter 7), that is, almost two new species described per year. On the other hand, the discovery of these new species mirrors a global pattern since in last the ten years there have also been about 21,000 new plant species described for the world as a whole (Prance *et al.*, 2000). A direct consequence of this is a more conscientious and less intuitive focus on conservation as well as implementation of public policies, especially in relation to the application of financial resources which, today, are urgent, fully justified, and extremely necessary.

In terms of geographic distribution, the present study shows that the bromeliad flora of the *Centro Pernambuco* is influenced by that of Amazonia and of the Atlantic forest in Southeast Brazil, thus creating a unique, endemic, regional flora that varies significantly from the rest of the Atlantic forest in Brazil. The Amazonia/Northeast-Brazil parallelism of shrub and tree species, mentioned by Rizzini (1963) and Andrade-Lima (1966), is also observed in 11 bromeliad species.

Species occurring in a single locality were not included in the PAE analysis. The exclusion of these 31 species reflects our poor scientific knowledge of the Pernambuco Center. Our data therefore represent a sub-sample of the biogeographic region that, today, has less than 5% of its original area contained in isolated patches (Prance *et al.*, 2000). This biogeographic study of bromeliads, like Santiago's (2006) 326 fern species, revealed a lack of differentiation between lowland and montane areas, and therefore did not confirm the hypothesis of Quaternary climatic events (Bigarella & Andrade Lima, 1982) supported

Pedra do Caboclo inselberg is a site of considerable biodiversity in the Vale do Ipojuca microregion, Belo Jardim, Pernambuco.

An emerging giant in the Serra do Ouro region,
Murici, Alagoas, home to a clump of *Billbergia morellii*.

Opposite page:
Habitat of *Orthophytum atalaiense*, a species restricted to
Serra da Naceia, in Alagoas, together with *Aechmea leptantha*
and *Mandevilla dardanoi* (Apocynaceae).

by Santos (2002) for woody species involving 13 areas of the *Centro Pernambuco*. Furthermore, the area cladogram (figure 3) does not confirm the existence of two distinct forest blocks – Amazonian and Atlantic (Santos, 2002; Silva & Casteleti, 2005) – since there are no clearly defined separation events between the blocks. This is due basically to three factors: (1) in contrast to the Atlantic forest of Southeast Brazil, the bromeliad flora of Pernambuco and Alagoas does not seem to be influenced by altitude, since local mountain ranges do not exceed 1,200 m, while in Southeast Brazil they sometimes surpass 2,000 m in altitude (IBGE, 1992); (2) as with the fern flora (Santiago, 2006), forest fragments in northeastern *Brejos de altitude* and in the *Centro Pernambuco* lie quite close together if bromeliad dispersal capacity is considered and therefore, geographic distance does not constitute an effective barrier that may impede species migration; (3) the regional bromeliad flora composition, influenced by anemochoric species of *Guzmania, Racinaea* and, especially, *Tillandsia* and *Vriesea,* suggests long distance dispersal events (*sensu* Myers & Giller, 1988). These genera have mostly a broad geographic distribution, for a total of 31 species in the region.

Evidence of long distance dispersal in Bromeliaceae is cited by Givinish *et al.* (2004) for *Pitcairnia feliciana* as well as for *Maschalocephalus dinklagei* (Rapateaceae), both endemic to the African continent. According to these authors, these classic examples of African paleoendemism in the Bromeliaceae and Rapateaceae – with species absence in South America and detached from phylogenetically more closely related taxa by over 3,000 km (Jacques-Félix, 2000) – would be explained by the relatively recent arrival of these families in Africa, coming from South America by way of long distance dispersal. This dispersal would have taken place some 6 to 8 million years ago, when the continents had already been separated for over 80 million years. Another example of paleoendemism on the African continent is represented by *Rhipsalis baccifera* (Cactaceae) with populations on both the American and African continents (Porembski & Barthlott, 1999).

However, the influence of paleo-events on the current biota of the *Centro Pernambuco* and the geographic distribution of the plant families in question, considering the interaction between South America and Africa, are extremely complex and intriguing, and do not yet have a final explanation. It should be remembered that botanist Philip von Luetzelburg (1922-1923), who was familiar with large tracts of Northeast Brazil, recorded the presence of *Pitcairnia flammea*, a species related to *P. feliciana*, in Paraíba. The easternmost tip of Brazil, in Paraíba, is Ponta do Seixas in Cabo Branco. This point was therefore linked to Africa by land for a longer time. Furthermore, the recent discovery of a fossil related to the Bromeliaceae at Chapada do Araripe (Ceará) was dated some 100 to 110 million years ago (Leme *et al.,* 2005), a time when the South American and African continents were still connected by land, and this has created new perspectives for dealing with this subject.

Lowland forest remnants generally have fewer bromeliad species than montane forests (table 1). This is due in part to the fact that lowlands have historically suffered more intensely from activities related to the sugar cane crop, including repeated forest clear-cutting over the past 500 years (see preceding chapters). Even today, in small forest remnants, daily removal of firewood for domestic use and commercial use in bakeries, plus illegal extraction of timber to be used in woodworking degrades the forest environment. It is worth men-

tioning, for example, that in a three-hour search through the largest fragment of lowland Atlantic forest north of the São Francisco River, known as Mata do Matão (on land belonging to Usina Porto Rico in Campo Alegre – table 1), the first author did not find one bromeliad species. This example illustrates a typical case of the "empty forest" (Fernandez, 2005), where ecological niches in forest environments are vacant due to the extinction of organisms. Although large forest fragments generally have greater physical integrity, structural complexity and habitat heterogeneity, which would support more species than the smaller fragments (Varassin & Sazima 2000), fragment size does not always imply greater species richness because of a unique history of human occupation at the site (Siqueira Filho & Felix, 2006).

On the other hand, inselbergs are less affected by human's activities when compared to typical forested areas. In terms of vegetation physiognomy, inselbergs are similar to forest fragments, except for the rocky substrate. Most inselbergs lying within the Atlantic forest domain are not suitable for agriculture. Unlike the inselbergs of the Caatinga, use as pasture for sheep and goats is incipient here and susceptibility to fire is lower. As a result, the inselberg flora differs markedly from that of surrounding areas due to its unique edaphic and microclimatic conditions. These sites have special evolutionary and biogeographic significance for families such as the Bromeliaceae, Cactaceae and Velloziaceae that are highly diversified on inselbergs. The bromeliads have the greatest degree of speciation (Porembski *et al.,* 1998).

Protection of bromeliad species in the Atlantic forest fragments of Pernambuco and Alagoas will conserve a significant part of Atlantic forest biological diversity because of their ample functional and biological plasticity. These plants can live as forest epiphytes in the canopy and in emergent trees and many of them are threatened with extinction (Oliveira *et al.,* 2004). Furthermore, bromeliads have mutualistic relationships with a broad range of pollinators and are the main resource for hummingbirds in the Atlantic forest of Brazil (see Chapter 6). Bromeliads also provide food, shelter and reproductive sites for endangered species of the northeastern fauna such as Odonatas, *Leptagrion siqueirai* and *L. dardanoi* (Santos, 1968a; 1968b), anurans, *Phyllodytes edelmoi* and *P. gyrinaethes* (Peixoto *et al.,* 2003), and birds, *Philydor novaesi* and *Tangara fastuosa* (Barnett *et al.,* 2005).

So the small number of bromeliad populations in the fragments examined here is a cause for worry since two thirds of the species have less than six known residual populations. This low number of populations is significantly associated with restricted geographic distribution, a high degree of habitat specificity and occurrence in only a few vegetation types (see Chapter 3).

The leaves of *Hohenbergia ramageana* are the color of winein the dry Atlantic forest on shallow soils at the top of Serra da Tiririca, Murici, Alagoas.

Opposite page:
Forest devastation causes changes in the microclimate, disrupting rainfall patterns and accentuating the dry spells and lack of water – an ecologically unsustainable land-use model in the Zona da Mata of Northeast Brazil.

As a result, 61.6% of the bromeliad species are bordering on regional extinction and, specifically, the 41 species endemic to the Pernambuco Center are threatened with global extinction (Siqueira Filho & Tabarelli, 2006). By the same token, in the *Brejos de altitude* of Pernambuco, only 4% of the bromeliad species have low extinction risks, these invariably being species that easily adapt to new environments and are heliophiles, somewhat resistant to fire, self-compatible and often wind dispersed (Siqueira Filho, 2004).

The natural rarity of bromeliad species is also affected by the fragmentation process and habitat loss, since populations are generally restricted locally even in the larger fragments. In other words, one can walk for a long time on consecutive days without finding new populations of a certain species. Therefore, the susceptibility of these populations to extinction is increased when faced with common random events, such as tree falls, natural gap formation, and extractivist pressure on ornamental species (Siqueira Filho, 2003).

Pressure from plant extrativism in Pernambuco has invalidated residual populations of species such as *Guzmania lingulata* and *Vriesea ensiformis,* now well below the support capacity limit (Siqueira Filho, 2004). In more serious cases, species have become locally extinct as seen in *Guzmania monostachia*, absent today from the *Brejos de altitude* at Taquaritinga do Norte where it was last collected in 1973, as well

The arrival of heavy rains from the Serra do Vento at Pedra do Caboclo, in Belo Jardim, Pernambuco, an inselberg that still holds considerable biodiversity.

Opposite page:
Vriesea ensiformis, a typical understory species, has survived in the montane Atlantic forest of Prof. Vasconcelos Sobrinho Municipal Park, Brejos dos Cavalos, in Caruaru, Pernambuco.

Panoramic view of Atlantic forest remnants
at Engenho Ousaida, as seen from Serra da Prata,
in Catende, Pernambuco.

Opposite page:
Aechmea leptantha on the inselberg that
gave the Pedra Talhada Biological Reserve its name,
in Quebrângulo, Alagoas.

as *Billbergia morelii* and *Cryptanthus zonatus*, no longer found at Dois Irmãos State Park in the Recife metropolitan area (Siqueira Filho & Tabarelli, 2006). As a result, ecological processes are permanently interrupted.

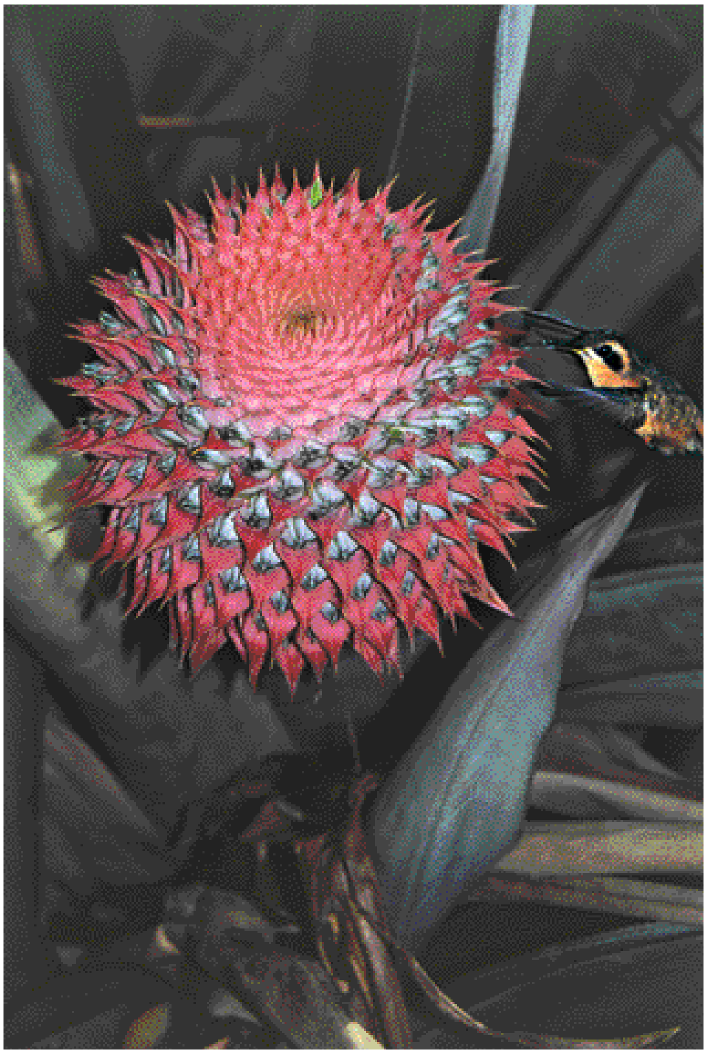
Another serious consequence of interrupted ecological processes is a dramatic increase in endangered bromeliad species. This has practically quadrupled in recent years, soaring from 15 on the 1992 IBAMA list to 58 in the recently revised *Lista da Flora Brasileira Ameaçada de Extinção* compiled by the Biodiversitas Foundation in 2005. Here, only critically endangered taxa and those threatened with extinction were taken into consideration. Among the new additions to the role of endangered species are ten endemic to the *Centro Pernambuco* of which *Cryptanthus fosterianus* is classified as officially extinct in the wild. In the absence of effective conservation measures, other species from the *Centro Pernambuco* such as *Vriesea rectifolia* and *Hohenbergia eriantha* are potential candidates for the extinct species list.

An important issue that must be given some thought is the biological simplification of Atlantic forest fragments in Pernambuco and Alagoas. Although there are theoretical models for the destructive process that leads to simplification and biological homogenization (Tabarelli & Gascon, 2005), the cascade effect of curtailed ecological processes (Murcia, 1996; Siqueira Filho & Tabarelli, 2006) may diffuse in various directions. This versatility makes it difficult to understand the cause and effect processes of destruction and biological simplification of tropical forest fragments (Laurance, 2001; see Chapter 3).

Recent studies show that the decline in native-species populations, as opposed to the explosive increase of exotic species, is not limited to fragmented sites but also extends to areas of unbroken forest (Rooney *et al.,* 2004). In general, the process of fragmentation and habitat loss affects other biological groups as well, making them vulnerable; examples are emergent trees (Oliveira *et al.,* 2004), Sphingidae (Duarte Jr. & Schlindwein, 2005; Lopes *et al.,* 2006), Coleoptera (Johnson *et al.,* 2004) and bats (Sá-Neto, 2003). It also affects the functionality of pollination processes (Murcia, 1996) and the frequency of sexual and reproductive systems (Girão, 2006), plus the composition, richness and diversity of understory epiphytes (Cabral, 2005).

Extinction of the larger animal species that inhabited forest fragments in Pernambuco and Alagoas, such as the solitary tinamou (*Tinamus solitarius*) and razor-billed curassow (*Mitu mitu*) (see Chapter 5), is now seen in plant species, not only the majestic timber trees, but also the fragile ornamental epiphytes, especially Bromeliaceae and Orchidaceae. An example is *Cattleya labiata* (Orchidaceae), one of the most intensely exploited Atlantic forest ornamental species of the past 50 years in the *Centro Pernambuco*, and this has decimated wild populations in mountainous areas, especially brejos de altitude.

If, on the one hand, perception of this phenomenon is improving due to an adverse extinction scenario, on the other, supply of these species has diminished or they are simply not available and this has changed demand. Species such as "amarelo" (*Plathymenia reticulata*, Mimosaceae), "prijuí" (*Pouteria* spp., Sapotaceae) and "sapucaia" (*Lecythis pisonis*, Lecythidaceae) were once felled for rather trivial uses such as building bridges over streams or irrigation ditches in the sugar cane fields, but today "sucupira" (*Bowdichia virgiloides*, Fabaceae), a pioneer species typical of secondary forest, is used for the same purpose. Even exotic species, such as jack-fruit (*Artocarpus sp.*, Moraceae) and mango trees (*Mangifera indica s. lato*, Anacardiaceae), are now exploited for making rustic furniture. The elimination of the larger forest trees, those with a large con-



The hummingbird, *Phaethornis ruber*, one of the most important bromeliad pollinators in the Northeast, visiting *Aechmea multiflora* flowers in a remnant forest at Usina Guaxuma, Coruripe, Alagoas.

tingent of epiphytic bromeliads, is still a common practice, the result of social disarray and serious economic management problems that affect rural populations of bankrupt municipalities in the Zona da Mata.

The advanced state of socio-environmental degradation in the *Centro Pernambuco* can be seen along the highways that run from Pernambuco to Alagoas, especially on highway BR 101. The landscape is dominated by long stretches of unproductive land where the original plant cover has been eradicated. In the past ten years, at least 20 sugar mills have closed their doors in the region (D. Bezerra, *pers. comm.*), leaving a path of environmental destruction and abandonment. And now a new threat hovers over remnants of highly disturbed secondary forest in the form of a misrepresentative movement of the landless (*Movimento dos Sem-Terra*). Often diverging from the ideals of agrarian reform, this movement is top ranked nationally in property take-over and is consuming the few natural resources that have survived an economic model based on sugar cane.

The invasion of exotic species or those typical of xeric environments is already prevalent in the northeastern Atlantic forest. The Frei Caneca RPPN flora, for example, now includes xerophilous species such as *Tillandsia polystachia* and *T. recurvata*. The former grows spontaneously in areas of hypoxerophilous Caatinga (*Agreste*) and dry forest transitions, while the latter is a typical Caatinga species. Decades ago, these species would certainly not be found in vegetation such as the dense ombrophilous forest at the Frei Caneca RPPN. Another important event is the invasion of "macambira-de-flecha" (*Encholirium spectabile*), a typical Caatinga species (Forzza, 2005), at Fazenda Pelada (Sítio da Pedra) in Quipapá, the last municipality of Atlantic forest in Pernambuco, and in *Brejos de altitude* on inselbergs like that of Fazenda Bitury in Brejo da Madre de Deus. The process of fragmentation and habitat loss, in this case, raised temperatures and reduced humidity, thus facilitating the dispersal of anemochoric species with a wide geographic distribution like the xerophilous species of *Tillandsia*.

These facts corroborate Silva & Tabarelli's (2000) statement that the fragmentation process in the northeastern Atlantic forest has brought about an overall impoverishment of the flora and promoted wind-dispersed species. In the Frei Caneca RPPN, zoochoric species' population numbers are also in decline, such as, for example, those of *Neoregelia pernambucana* and *Aechmea gustavoi*, both endangered and with current populations of less than 50 individuals (Siqueira Filho & Leme, 2000).

For these reasons, knowledge of bromeliad distribution and ecology is fundamental for the management of endangered species as well as the creation of new conservation units in Atlantic forest, especially in the *Centro Pernambuco*, even though these are late in coming. In this region, knowledge accumulated in recent years has made it possible to conserve a relevant portion of the biota, which is imperative for sustainable development in this sector of Northeast Brazil.

The Atlantic forest has been the topic of many discussions and has inspired works of huge scientific and cultural value, thus becoming one of Brazil's best known ecosystems. But this growth of knowledge is not directly proportional to the rapid rate of destruction that has practically erased this ecosystem from the map of Brazil. As was repeatedly stressed at the 8th Meeting of the Conference of the Parties to the Convention on Biological Diversity (COP8) in Curitiba, in March 2006, in spite of the technical and scientific progress of the past few decades, we are still going through the documentation phase of Atlantic forest biological diversity, as exemplified by the bromeliads of this book. Given this scenario, the well-known maxim "know in order to preserve" is still current and exacts a conservation challenge so pressing that it will require the joint effort of all levels of Brazilian society for many years.

Inselbergs at Fazenda Bitury, in Brejo da Madre de Deus, Pernambuco, have a rich, unique flora including *Vriesea limae* and *Dyckia pernambucana*.

The forest understory at Serra Negra Biological Reserve,
in Floresta, Pernambuco. Conceived by ecologist Vasconcelos Sobrinho
in the 1950s, this is the oldest biological reserve in Brazil.

Opposite page:
A rocky outcrop in the montane Atlantic forest domain is
part of the landscape at Serra Negra Biological Reserve, at Floresta
in the hinterland of Pernambuco, with a vast stretch of
caatinga in the background.

Following page:
A thicket of *Aechmea leptantha* on a rocky outcrop
at Serra Lisa, Alagoas.

Figure 1
Location of Atlantic forest fragments in Pernambuco and Alagoas and the respective vegetation types; Parsimony Analysis of Endemicity (PAE) was carried out on 78 bromeliad species.

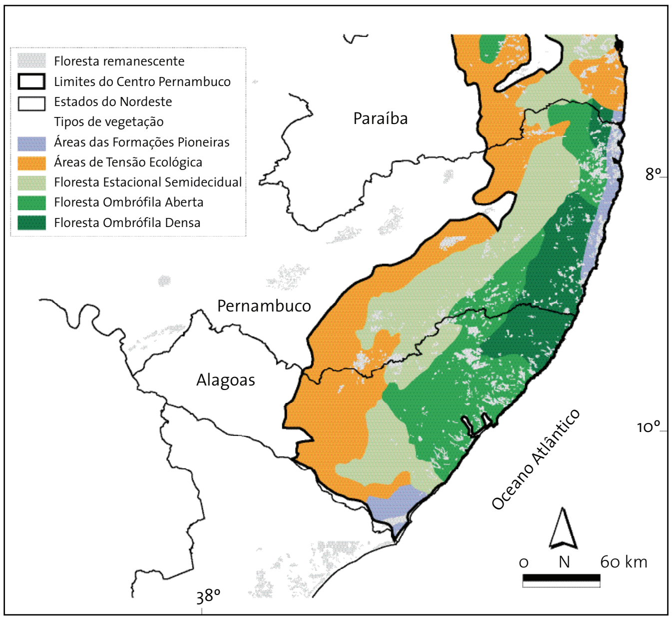


Figure 2
Bromeliad species richness in the surveyed Atlantic forest fragments of Pernambuco and Alagoas based on a grid of 400 km quadrats; forest remnants are shown in green.

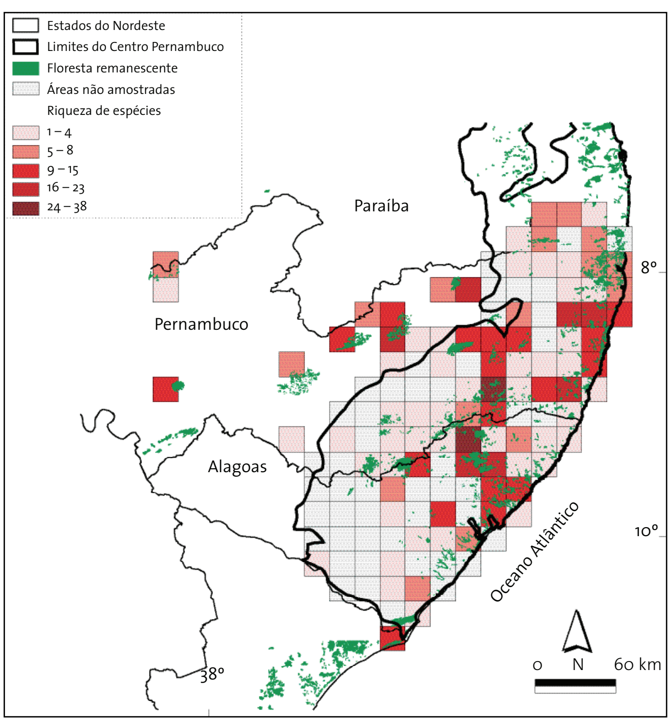


Figure 3
Consensus cladogram of the 12 most parsimonious trees for 78 bromeliad species at 26 Atlantic forest sites (C = 199, CI = 33, RI = 44) in Pernambuco and Alagoas, two sites in Amazonia and two in Atlantic forest from Southeast Brazil. "B" indicates lowland forest, "M" indicates montane forest. See Table 1 for site details.

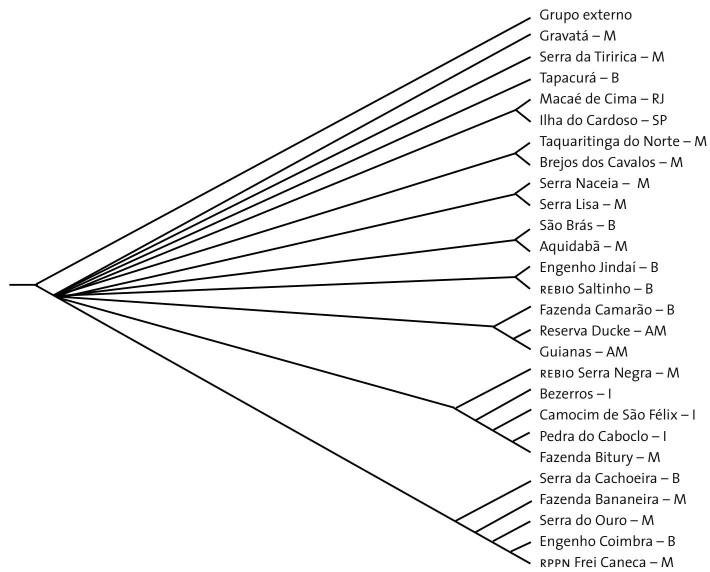


Figure 4
Reduced area cladogram of the two most parsimonious trees for 25 bromeliad species on 12 inselbergs (C = 56, CI = 44, RI = 58) of Atlantic forest in Pernambuco and Alagoas. See Table 1 for site details.

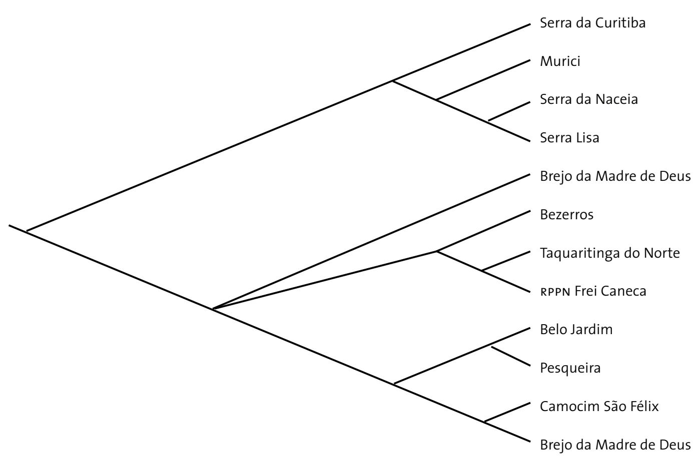


Table 1

Location of sites surveyed in the Atlantic Forest of Pernambuco and Alagoas plus respective habitats.

ST	Municipality	Site	Total spp.	Lowland	Montane	Brejos	*Inselberg*	Latitude °S	Longitude °W	Altitude (m)
AL	Paripueira	Sítio Laranjeiras	7					9°24'17"	35°30'26"	10
AL	Boca da Mata	Fazenda Daniel, Mata da Bitonha	5	1				9°36'24,2"	36°12'07,7"	208
AL	Chã Preta	Serra Lisa	13		1		1	9°13'01,0"	36°21'29,7"	841
AL	Coruripe	Usina Coruripe, Mata de Capiatã	7	1				10°03'26,4"	36°16'45,2"	23
AL	Coruripe	Usina Guaxuma, Mata da Bomba Quinze	4	1				10°01'20,8"	36°10'56,7"	<100
AL	Coruripe	Usina Guaxuma, RPPN Jacaré do Papo-Amarelo	3	1				10°03'32,8"	36°05'57,2"	<100
AL	Entre Atalaia e Marinbondo	Serra da Naceia	14		1		1	9°35'55,9"	36°11'40,7"	500
AL	Entre Flexeiras e Maceió	Usina Cachoeira, Serra da Saudinha, Fazenda Cela	10	1				9°23'38,2"	35°43'40,0"	191
AL	Ibateguara	Cerrado da Burra, Caetano e Cavalo Morto	5	1			1	8°58'44"	35°54'35,9"	481
AL	Ibateguara	Usina Serra Grande, Engenho Coimbra, Mata do Varjão	32	1				8°58'44"	35°54'35,9"	481
AL	Ibateguara	Usina Serra Grande, Mata de Aquidabã	11		1			8°58'44"	35°54'35,9"	509
AL	Marechal Deodoro	APA de Santa Rita, Sítio Campo Grande	5	1				9°37'30"	35°49'00"	<100
AL	Matriz de Camaragibe	RPPN Santuário Ecológico Serra d'Água	7	1				9°05'60"	35°34'02"	76
AL	Matriz de Camaragibe	Serra da Curitiba	5				1	9°12,5"	35°30,8"	>500
AL	Messias	Engenho Oriente, Serra da Cachoeira	5	1				9°21'11,1"	35°47'23,2"	120
AL	Murici	ESEC Murici, Fazenda Bananeira, Mata da Bananeira	16		1			9°14'17,4"	35°52'45,1"	508
AL	Murici	ESEC Murici, Fazenda Bananeira, Pedra do Bonito	8				1	9°14'26,1"	35°52'40,6"	522
AL	Murici	ESEC Murici, Mata do Assentamento Pacas	6	1				9°13'45,2"	35°53'59,8"	377
AL	Murici	ESEC Murici, Serra do Ouro, Estação da UFAL	19	1				9°14'25,3"	35°50'15,1"	468
AL	Murici	Fazenda Boa Sorte, Serra da Tiririca	10		1			9°11'26,7"	35°55'38,1"	539
AL	Murici	Fazenda Itamaracá, Mata da Pedreira	5	1				9°21'25,1"	35°51'07,6"	136
AL	Piaçabuçu	Mata da Marreca	7	1				9°26'05"	36°23'10"	<50
AL	Quebrângulo	Pedra Talhada Biological Reserve	6		1			9°15'33,1"	36°25'50,7"	582
AL	São Luís do Quitunde	RPPN Garabu	3	1				9°14'08"	35°05'04,8"	70
AL	Satuba	APA do Catolé	6	1				9°33'38,9"	35°47'44,7"	47
AL	União dos Palmares	Engenho Santo Antônio	10		1			9°02'31,0"	35°55'09,0"	508
AL	União dos Palmares	Mata da Serra do Frio	5	1				9°10'18,4"	35°59'23,7"	421
AL	Viçosa	Mata da Fazenda Bananal	5	1				9°26'38,8"	36°13'45,0"	349
PE	Água Preta	Fazenda Camarão, Mata da Cinza	10	1				8°45'35,9"	35°28'41,2"	194
PE	Amaragi	Usina União Indústria, Mata de Jaguarana	2					8°20'52,2"	35°20'54,3"	123
PE	Belo Jardim	Piaca, Vila do Socorro, Pedra da Boa Vista	3				1	8°14'20,3"	36°21'32,3"	675
PE	Belo Jardim	Serra do Olho d'Água do Tatu	4			1		8°22'32,1"	36°26'33"	>600
PE	Belo Jardim	Sítio Alegre, Pedra do Caboclo	12				1	8°14'31,6"	36°23'12,8"	1060
PE	Bezerros	Serra Negra	6			1	1	8°14'	35°45'	471
PE	Bonito	Fazenda Tudo Muito	3				1	8°30'37,6"	35°43'27,2"	789
PE	Bonito	Municipal Ecological Reserve	8			1		8°29'40"	35°41'45"	467
PE	Brejo da Madre de Deus	Sítio Amaro	6				1	8°18'38,16"	36°24'00"	>1000
PE	Brejo da Madre de Deus	Fazenda Bitury, Mata da Rita e Campos	17			1		8°12'55,9"	36°23'56,6"	1028
PE	Brejo da Madre de Deus	Fazenda Bitury, *Inselberg* da Malhada	9				1	8°11'03,3"	36°24'30,0"	1107
PE	Brejo da Madre de Deus	Fazenda Bitury, *Inselberg* do Cassange	8				1	8°11'48,9"	36°24'32,9"	1100
PE	Buenos Aires	Engenho Cavalcanti, Mata Pedra da Mesa	10	1				7°44'39,3"	35°21'18,3"	132
PE	Buíque	Catimbau National Park	7			1		8°35'01,3"	37°14'21,6"	897
PE	Cabo de Santo Agostinho	Mata da Fábrica da Pólvora Elefante	7	1				8°12'49"	34°57'57,2"	19
PE	Cabo de Santo Agostinho	Mata do Zumbi	2	1				8°18'31,6"	34°58'52,8"	63
PE	Cabo de Santo Agostinho	Gurjaú Ecological Reserve, Mata de São Brás	12	1				8°13' 48,3"	35°04'7,9"	86
PE	Camocim de São Félix	Sítio Palmeira, Pedra da Massa	10				1	8°19'42,3"	36°45'14,8"	739
PE	Camutanga	Usina Olho d'Água, Mata do Engenho Olho d'Água	4	1				7°25'15,8"	35°14'41,4"	99

Table 1 (continued)

Location of sites surveyed in the Atlantic Forest of Pernambuco and Alagoas plus respective habitats.											
ST	Municipality	Site	Total spp.	Lowland	Montane	Brejos	*Inselberg*	Latitude °S	Longitude °W	Altitude (m)
PE	Caruaru	P. V. Sobrinho Municipal Park , Brejo dos Cavalos, Mata do Abacateiro	14					18°08'58,4"	36°22'11,4"	820
PE	Catende	Usina Catende, Engenho Ousadia, Serra da Prata	3		1		1	8°37'30,6"	35°41'19,4"	628
PE	Escada	Engenho Alegria	10	1				8°344423'S	35°20965'W	151
PE	Escada	Engenho Conceição	4	1				8°24'59,3"	35°18'38,6"	175
PE	Entre Floresta e Inajá	Serra Negra Biological Reserve	13			1		8°39'18,2"	38°01'31,9"	1109
PE	Entre Rio Formoso e Sirinhaém	Usina Trapiche, Mata do Engenho Jindaí	14	1				8°37'49,5"	35°11'52,6"	35
PE	Garanhuns	Frexeiras, Sítio Vargem Grande	4					8°55'12"	36°24'31"	>500
PE	Goiana	Usina Santa Teresa, Mata do Bujari	4	1				7°35'16,8"	35°00'06,7"	23
PE	Gravatá	Caxito, Sítio Brejo Velho	11			1		8°16'42,2	35°33'05,4"	727
PE	Igarassu	Charles Darwin Ecological Refuge (= Granja São Luiz)	7					7°48'36,7"	34°56'59,2"	38
PE	Igarassu	Usina São José, Mata do Engenho d'Água	5	1				7°46'00,12"	34°58'59,88"	<100
PE	Ipojuca	Fazenda Merepe, Mata do Cupe	6	1				8°27'01,8"	34°59'15,8"	0
PE	Ipojuca	RPPN Nossa Senhora do Outeiro de Maracaípe	5	1				8°31'48"	35°01'05"	0
PE	Jaboatão dos Guararapes	Engenho Comporta, Mata da Pedreira Guarany	2	1				8°11'06,2"	34°59'19,9"	78
PE	Jaqueira	Pedra do Cruzeiro ou Espelho	15		1		1	8°43'23"	35°50'20"	700
PE	Jaqueira	RPPN Frei Caneca (= Serra do Quengo, Mata da Caranha, Cano da Barragem, Jasmim, Serra do Urubu	39		1			8°42'41,6"	35°50'30,4"	648
PE	Macaparana	Pirauá, Fazenda Fandangos	2			1		7°30'06,2"	35°29'00,4"	605
PE	Maraial	Engenho Curtume	6	1				8°48'	35°50'	260
PE	Maraial	Engenho Gigante	7	1						<300
PE	Maraial	Engenho Nabuco	4	1				8°48'00,0"	35°49'59,8"	260
PE	Maraial	Usina Catende, Engenho Flor do Bosque	10		1			8°44'18,3"	35°46'29,5"	501
PE	Paulista	Sítio Pankararu	5	1				7°55'68"	34°58'11"	157
PE	Pesqueira	Serra do Ororubá, Aldeia Pedra d'Água, Pedra do Rei	13			1	1	8°20'27"	36°46'59"	>500
PE	Poção	Fazenda Balãozinho	5			1		8°11'	36°42'	>500
PE	Quipapá	Fazenda Pelada, Sítio Pedra	4				1	8°50'03,4"	36°04'41,3"	588
PE	Recife	Dois Irmãos State Park	9	1				8°7'30"	34°52'30"	80
PE	Saloá	RPPN Fazenda Brejo	3			1		9°00'28,8"	36°47'02,4"	950
PE	São Benedito do Sul	Mata do Periperi	7	1				8°48'30'	35°57'06'	474
PE	São Caetano	RPPN Pedra do Cachorro	3				1	8°14'12,4"	36°11'33,9"	475
PE	São Lourenço da Mata	Tapacurá Ecological Station, Mata do Camocim	21	1				8°02'27,1"	35°11'46,7"	125
PE	São Vicente Férrer	Mata do Estado	4			1		7°38'	35°30'	600
PE	Sirinhaém	Usina Trapiche, Engenho Anjo, Mata do Cão	4	1				8°34'20,3"	35°05'20,5"	82
PE	Sirinhaém	Usina Trapiche, Engenho Jardim, Mata do Meio e Doletério	3	1				8°31'07,7"	35°11'01,1"	120
PE	Sirinhaém	Usina Trapiche, Engenho Ubaquinha, Mata da Laranja Cravo	5	1				8°12'36"	34°57'59,6"	<200
PE	Tamandaré	Saltinho Biological Reserve	9	1				8°43'19,7"	35°11'27"	102
PE	Taquaritinga do Norte	Serra da Taquara, Mata da Torre, Microondas or Cafundó	17			1		7°54'19"	36°01'27"	1027
PE	Taquaritinga do Norte	Sitio Queimados, Pedra da Frexeira	12			1	1	7°55'19,4"	36°01'16,6"	978
PE	Timbaúba	Usina Cruangi, Engenho Água Azul	4		1			7°35'	35°22'	600
PE	Triunfo	Mata do Carro Quebrado	5			1		7°52'43,5	38°06'14,7"	673
PE	Triunfo	Pico do Papagaio	5			1	1	7°49'22,2"	38°03'21,8"	1193
AM	Manaus	Ducke[1] Biological Reserve	14	1						
RJ	Nova Friburgo	Macaé de Cima[3] Biological Reserve	46		1					
SP	Cananéia	Ilha do Cardoso[4]	42	1						
		Guianas, Guiana Francesa and Suriname[2]	123							

1 - Ribeiro *et al* (1999), 2 - Gouda (1999), 3 - Lima & Guedes-Bruni (1994), 4 - Wanderley & Mollo (1992).

Table 2

Checklist of 88* species in 19 genera of Bromeliaceae from the Atlantic Forest of Pernambuco and Alagoas, with new species and respective geographic distribution.

Species	New Species	Pernambuco Center	Bahia	Amazônia-Northeast	Northeast-Southeast	Widespread
Aechmea aquilega				1		
Aechmea atrovittata	1	1				
Aechmea catendensis	1	1				
Aechmea cephaloides	1	1				
Aechmea eurycorymbus		1				
Aechmea froesii			1			
Aechmea fulgens		1				
Aechmea guainumbiorum	1	1				
Aechmea gustavoi			1			
Aechmea lactifera	1	1				
Aechmea leptantha		1				
Aechmea marginalis	1					
Aechmea mertensii				1		
Aechmea multiflora	1		1			
Aechmea muricata		1				
Aechmea nudicaulis var. *nordestina*	1	1				
Aechmea patentissima					1	
Aechmea pernambucentris	1	1				
Aechmea serragrandensis		1				
Aechmea constantinii		1				
Aechmea tomentosa		1				
Aechmea werdermannii		1				
Ananas bracteatus						1
Ananas comosus						1
Ananas nanus				1		
Araeococcus chlorocarpus			1			
Billbergia morelii			1			
Billbergia porteana						1
Bromelia karatas				1		
Canistrum alagoanum		1				
Canistrum aurantiacum		1				
Canistrum improcerum	1	1				
Canistrum pickelii		1				
Catopsis berteroniana						1
Catopsis sessiliflora						1
Cryptanhus alagoanus		1				
Cryptanthus burle-marxii		1				
Cryptanthus dianae		1				
Cryptanthus felixii	1	1				
Cryptanthus fosterianus		1				
Cryptanthus pickelii		1				
Cryptanthus reptans	1	1				
Cryptanthus zonatus		1				
Dyckia limae		1				

* *Aechmea chrysocoma, Hohenbergia horrida, Tillandsia catimbauensis, T. tenuifolia* var. *saxicola* and *Vriesea friburgensis* were excluded from the analysis after the study was finished.

Table 2 (continued)

Checklist of 88* species in 19 genera of Bromeliaceae from the Atlantic Forest of Pernambuco and Alagoas, with new species and respective geographic distribution.

Species	New Species	Pernambuco Center	Bahia	Amazônia-Northeast	Northeast-Southeast	Widespread
Dyckia pernambucana		1				
Encholirium pernambucanum		1				
Encholirium spectabile						1
Guzmania lingulata						1
Guzmania monostachia				1		
Hohenbergia catingae			1			
Hohenbergia ramageana						1
Hohenbergia ridleyi		1				
Hohenbergia stellata				1		
Lymania smithii			1			
Neoregelia pernambucana	1	1				
Orthophytum atalaiense	1	1				
Orthophytum disjunctum		1				
Orthophytum triunfense	1	1				
Pseudananas sagenarius						1
Racinaea spiculosa						1
Tillandsia bulbosa				1		
Tillandsia chapeuensis						1
Tillandsia gardneri						1
Tillandsia geminiflora						1
Tillandsia juncea				1		
Tillandsia kegeliana				1		
Tillandsia paraënsis				1		
Tillandsia pohliana						1
Tillandsia polystachia						1
Tillandsia recurvata						1
Tillandsia streptocarpa						1
Tillandsia stricta						1
Tillandsia tenuifolia						1
Tillandsia tricholepsis						1
Tillandsia usneoides						1
Vriesea freicanecana	1	1				
Vriesea barbosae	1	1				
Vriesea flammea					1	
Vriesea gigantea					1	
Vriesea limae	1	1				
Vriesea oleosa			1			
Vriesea procera						1
Vriesea ensiformis					1	
Vriesea rectifolia		1				
Vriesea rodigasiana					1	
Vriesea scalaris						1
Vriesea tijucana					1	
Vriesea zonata	1	1				

References

Andrade-Lima, D. 1966. Contribuição ao estudo do paralelismo da flora amazônico-nordestina. *Boletim Técnico do IPA 19*: 1-30.
Ayres, M., M. Ayres Jr., D. L. Ayres & A. S. Santos. 1998. *Bioestat: Aplicações estatísticas nas áreas das ciências biológicas e médicas*. Sociedade Civil Mamirauá, MCT-CNPq, Manaus.
Barbosa, M. C. A., & M. R. V. Barbosa. 1996. Herbários. Pp. 145-150 in E. V. S. B. Sampaio, S. J. Mayo & M. R. V. Barbosa (orgs.). *Pesquisa botânica nordestina: progresso e perspectivas*. Sociedade Botânica do Brasil, Recife.
Barnett, J. M., C. J. Carlos & S. A. Roda. 2005. Renewed Hope for the Threatened Avian Endemics of Northeastern Brazil. *Biodiversity and Conservation 14*: 2265-2274.
Barthlott, W. & S. Porembski. 2000. Why Study Inselbergs? Pp. 1-6 in S. Porembski & W. Barthlott, (eds.). *Inselbergs: Biotic Diversity of Isolated Rock Outcrops in Tropical and Temperate Regions*. Ecological Studies 146. Springer-Verlag, Alemanha.
Benzing, D. H. 2000. *Bromeliaceae: Profile of an Adaptative Radiation*. Cambridge University Press, Cambridge.
Bigarella, J. J. & D. Andrade-Lima. 1982. Paleoenvironmental Changes in Brazil. Pp. 27-40 in G. T. Prance (ed.). *Biological Diversification in the Tropics*. Columbia University Press, New York.
Brown Jr, K. S. 1982. Paleoecology and Regional Patterns of Evolution in Neotropical Forest Butterflies. Pp. 255-308 in G. T. Prance (ed.). *Biological Diversification in the Tropics*. Columbia University Press, New York.
Cabral, J. S. 2005. *Efeito de borda sobre Orchidaceae e Bromeliaceae epífitas de sub-bosque em dois diferentes habitats em um fragmento de Mata Atlântica Nordestina*. Monografia de Graduação. Universidade Federal Rural de Pernambuco, Recife.
Clark, D. A., B. B. Clark, M. R. Sandoval & C. M. V. Castro. 1995. Edaphic and Human Effects on Landscape-Scale Distributions of Tropical Rain Forest Palms. *Ecology 76*: 2581-2595.
Dimmit, M. 2000. Endangered Bromeliaceae. Pp. 609-620 in D. H. Benzing (ed.). *Bromeliaceae: Profile of an Adaptative Radiation*. Cambridge University Press, Cambridge.
Duarte Jr., J. A. & C. Schlindwein. 2005. Riqueza, abundância e sazonalidade de Sphingidae (Lepidoptera) num fragmento de Mata Atlântica de Pernambuco, Brasil. *Revista Brasileira de Zoologia 22* (3): 662-666.
Esri. 1998. *ArcView GIS 3.1.* ESRI, USA.
Fernandez, F. 2005. *O poema imperfeito – crônicas de biologia, conservação da natureza e seus heróis*. Editora da UFPR, Curitiba.
Forzza, R. C. 2005. Revisão taxonômica de *Encholirium* Mart. ex Schult. & Schult. f. (Pitcairnoideae – Bromeliaceae). *Boletim de Botânica da Universidade de São Paulo 23* (1): 1-49.
Freyre, G. 1989. *Nordeste: aspectos da influência da cana-de-açúcar sobre a vida e a paisagem do nordeste*. Record, Rio de Janeiro.
Gascon C., B. Willianson & G. A. B. Fonseca. 2000. Receding Forest Edges and Vanishing Reserves. *Science 288*: 1356-1358.
Girão, L. C. 2006. *Efeito da fragmentação e da perda de* habitat *nas freqüências de atributos florais e de síndromes de polinização em remanescentes da Floresta Atlântica nordestina*. Dissertação de Mestrado. Universidade Federal de Pernambuco, Recife.
Givinish, T. J., K. C. Millam, T. M. Evans, J. C. Hall, J. C. Pires, P. E. Berry & K. J. Sytsma. 2004. Anciente Vicariance or Recent Long-distance Dispersal? Inference about Phylogeny and South American-African Disjunctions in Rapateaceae and Bromeliaceae Based on *ndh*F Sequence Data. *International Journal of Plant Science 165* (4 suppl.): S35-S54
Goloboff, P. A. 1996. Methods for Faster Parsimoy Analysis. *Cladistics 12*: 199-220.
Gouda, E. J. 1999. Studies on the Flora of the Guianas nº 90: Checklist of Bromeliaceae of the Guianas with Notes on Critical Species. *Selbyana 20* (1): 30-39.
Holmgren, P. K., N. H. Holmgren & L. C. Barnett. 1990. *Index Herbariorum: The Herbaria of the World*. New York Botanical Garden, New York.
IBGE. 1992. *Manual técnico da vegetação brasileira*. IBGE, Rio de Janeiro.
Jacques-Félix, H. 2000. The Discovery of a Bromeliad in Africa: *Pitcairnia feliciana*. *Selbyana 21* (1-2): 118-124.
Johnson, S. D., C. L. Collin, H. J. Wissman & E. J. Halvarsson. 2004. Factors Contributing to Variation in Seed Production Among Remnant Populations of the Endangered Daisy *Gerbera aurantiaca*. *Biotropica 36* (2): 148-155.
Laurance, W. F. 2001. Fragmentation and Plant Communities: Synthesis and Implications for landscape Management. Pp. 158-168 in R. O. Bierregaard Jr., C. Gascon, T. E. Lovejoy & R. C. G. Mesquita (eds.). *Lessons from Amazonia: the Ecology and Conservation of a Fragmented Forest*. Yale University Press, New Haven.
Laurance, W. F., P. Delamônica, S. G. Laurance, H. L. Vasconcelos & T. E. Lovejoy. 2000. Rainforest Fragmentation Kills Big Trees. *Nature 404*: 836.
Leme, E. M. C, G. K. Brown, D. Dilcher, M. E. C. Bernardes-de-Oliveira, J. A. Siqueira Filho, A. M. Sales. 2005. Protoananaceae, a New Fossil Monocot Family from the Lower Cretaceous, Santana Formation, Northeastern Brazil, in *Botany 2005 – Learning from Plants*.
Leme, E. M. C. & J. A. Siqueira Filho. 2001. Studies in Bromeliaceae of Northeastern Brazil – I. *Selbyana 2*: 146-154.
Leme, E. M. C. & L. C. Marigo. 1993. *Bromélias na natureza*. Marigo Comunicação Visual, Rio de Janeiro.
Lima, M. P. M. & R. R. Guedes-Bruni. 1994. *Reserva Ecológica de Macaé de Cima: diversidade, florística e conservação em Mata Atlântica*. Jardim Botânico do Rio de Janeiro, Rio de Janeiro, 404 p.
Lopes, A.V., P. C. Medeiros, A. V. Aguiar Neto & I. C. Machado. 2006. Esfingídeos. Pp. 229-235 in K. C. Pôrto, J. S. Almeida-Cortez & M. Tabarelli (orgs.). *Diversidade biológica e conservação da Floresta Atlântica ao norte do Rio São Francisco*. Série Biodiversidade 14. MMA, Brasília, DF.
Luetzelburg, P. V. 1922-1923. *Estudo botânico do Nordeste*. Rio de Janeiro: Ministério da Viação e Obras públicas, 2v, ser. IA, 2 (57): 1-283.
Margules, C. R. & R. L. Pressey. 2000. Systematic Conservation Planning. *Nature 405*: 243-253.
Melo, F. O. & L. F. O. E. Paulillo. 2005. Metamorfoses da rede de poder sucroalcooleira paulista e os desafios da autogestão setorial. *Agricultura em São Paulo 52* (1): 41-62.
Myers, A. A. & P. S. Giller. 1988. Process, Patterns and Scale in Biogeography. Pp. 3-20 in A. A. Myers & P. S. Giller (eds.). *Analytical Biogeography: an Integrated Approach to the Study of Animal and Plant Distributions*. Chapman & Hall, Londres.
Murcia, C. 1996. Forest Fragmentation and the Pollination of Neotropical Plants. Pp. 19-36 in J. Schellas & R. Greenberg (eds.). *Forest patches in tropical landscapes*. Island Press, Washington D. C.
Nixon, K. C. 1999. The Parsimony Ratchet, a New Method for Rapid Parsimony Analysis. *Cladistic 15*: 407-414.
Oliveira, M. A., A. S. Grillo & M. Tabarelli. 2004. Forest Edge in the Brazilian Atlantic Forest: Drastic Changes in Tree Species Assemblages. *Oryx 38*: 389-394.
Peixoto, O. L., U. Caramaschi & E. M. X. Freire. 2003. Two New Species of *Phyllodytes* (Anura: Hylidae) from the State of Alagoas, Northeastern Brazil. *Herpetologica 59*: 235-246.
Porembski, S., G. Martinelli, R. Ohlemüller & W. Barthlott. 1998. Diversity and Ecology of Saxicolous Vegetation Mats on Inselbergs in the Brazilian Atlantic Forest. *Biodiversity Research 4*: 107-119.
Porembski, S. & W. Barthlott. 1999. *Pitcairnia feliciana*: The Only Indigenous African Bromeliad. *Havard Papers in Botany 4* (1): 175-184.
Prance, G. T., H. Beentje, J. Dransfield & R. Johns. 2000. The Tropical Flora Remains Undercollected. *Annals of the Missouri Botanical Garden 87*: 67-71.
Ranta, P., T. Blom, J. Niemelã, E. Joensuu & M. Siitonen. 1998. The Fragmented Atlantic Forest of Brazil: Size, Shape and Distribution of Forest Fragments. *Biodiversity and Conservation 7*: 385-403.
Ribeiro, J. E. L. S., M. J. G. Hopkins, A. Vicentini, C. A. Sothers, M. A. S. Costa, J. M. Brito, M. A. D. Souza, L. H. P Martins, L. G. Lohmann, P. A. C. L. Assunção, E. C. Pereira, C. F. Silva, M. R. Mesquita & L. C. Procópio. 1999. *Flora da Reserva Ducke: guia de identificação de uma floresta de terra-firme na Amazônia Central.* INPA/DFID, Manaus, 800 p.
Ricketts, T. H., *et al*. 2005. Pinpointing and Preventing Imminent Extinctions. *Proceedings of the National Academy of Sciences 51*: 18497-18501.
Rizzini, C. T. 1963. Nota prévia sobre a divisão fitogeográfica (florístico-sociológica) do Brasil. *Revista Brasileira de Geografia 25*: 1-64.
Rocha, C. F. D., L. C. Cogliatti-Carvalho, A. F. Nunes-Freitas, T. C. Rocha-Pêssoa, A. S. Dias, C. V. Ariani & L. N. Morgado. 2004a. Conservando uma larga porção da diversidade biológica através da conservação de Bromeliaceae. *Vidalia 2* (1): 52-68.
Rocha, C. F. D., A. F. Nunes-Freitas, L. C. Cogliatti-Carvalho & T. C. Rocha-Pêssoa. 2004b. Habitat Disturbance in the Brazilian Coastal Sand Dune Vegetation and Related Richness and Diversity of Bromeliad Species. *Vidalia 2* (2): 50-56.

Roda, S. A. 2003. *Aves do Centro de Endemismo Pernambuco: composição, biogeografia e Conservação*. Tese de Doutorado. Universidade Federal do Pará, Belém.
Rooney, T. P., S. M. Wiegmann, D. A. Rogers & D. M. Waller. 2004. Biotic Impoverishment and Homogenization in Unfragmented Forest Understory Communities. *Conservation Biology 18* (3): 787-798.
Rosen, B. R. 1988. From Fossils to Earth History: Applied Historical Biogeography. Pp. 437-481 in A. A. Myers & P. S. Giller (eds.). *Analytical biogeography*. Chapman and Hall, London.
Sá-Neto, R. J. 2003. *Efeito da fragmentação na comunidade de morcegos (Mammalia: Chiroptera) em remanescentes de Floresta Atlântica, Usina Serra Grande – Alagoas*. Dissertação de Mestrado. Universidade Federal de Pernambuco, Recife.
Santiago, A. C. P. 2006. *Pteridófitas da Floresta Atlântica ao norte do Rio São Francisco: florística, biogeografia e conservação*. Tese de Doutorado. Universidade Federal de Pernambuco, Recife.
Santos, A. M. M. 2002. *Distribuição de plantas lenhosas e relações históricas entre a Floresta Amazônica, a Floresta Atlântica costeira e os brejos de altitude do Nordeste brasileiro*. Dissertação de Mestrado. Universidade Federal de Pernambuco, Recife.
Santos, N. D. 1968a. Descrição de *Leptagrion dardanoi* sp. n. (Odonata: Coenagrionidae). *Atas Soc. Biol. 12*: 63-65.
________. 1968b. Descrição de *Leptagrion siqueirai* sp. n. (Odonata: Coenagrionidae). *Atas Soc. Biol. 12*: 137-139.
Schessl, M., L. Krause, D. Piechowski & G. Gottsberger. 2005. A fragmentação da Mata Atlântica em Pernambuco e suas conseqüências biológico-reprodutivas. Pp.143-164 in C. R. Franke, P. L. B. Rocha, W. Klein & S. L. Gomes (orgs.). *Mata Atlântica e biodiversidade*. Editora da UFBA, Salvador.
Silva, J. M. C. 1998. Integrating Biogeography and Conservation: an Example with Birds and Plants of the Cerrado Region. *Anais da Academia Brasileira de Ciências 70* (4): 881-888.
Silva, J. M. C. & D. C. Oren. 1996. Application of Parsimony Analysis of Endemicity in Amazonian Biogeography: an Example with Primates. *Biological Journal of the Linnean Society 59*: 427-437.
Silva, J. M. C. & C. H. M. Casteleti. 2005. Estado da biodiversidade da Mata Atlântica brasileira. Pp. 43-59 in C. Galindo-Leal & I. G. Câmara (eds.). *Mata Atlântica, biodiversidade, ameaças e perspectivas*. Fundação SOS Mata Atlântica, Conservação Internacional & Centro de Ciências Aplicadas à Biodiversidade, Belo Horizonte.
Silva, J. M. C., M. C. Souza & C. H. M. Castelletti. 2004. Areas of Endemism for Passerine Birds in the Atlantic Forest, South America. *Global Ecology and Biogeography 13*: 85-92.
Silva, J. M. C. & M. Tabarelli. 2000. Tree Species Impoverishment and the Future Flora of the Atlantic Forest of Northeast Brazil. *Nature 404*: 72-73.
Siqueira Filho, J. A. 2002. Bromélias em Pernambuco: diversidade e aspectos conservacionistas. Pp 219-228 in M. Tabarelli & J. M. C. Silva (orgs.). *Diagnóstico da biodiversidade de Pernambuco*. Massangana, Recife.
________. 2003. *História natural, ecologia e conservação de Bromeliaceae na floresta Atlântica Nordestina*. Tese de Doutorado. Universidade Federal de Pernambuco, Recife.
________. 2004. As bromélias nos Brejos de Altitude de Pernambuco: riqueza de espécies e *status* de conservação Pp. 99-110 in K. C. Pôrto, J. J. P. Cabral & M. Tabarelli (orgs.). *Brejos de Altitude em Pernambuco e Paraíba: história natural, ecologia e conservação*. MMA, Brasília, DF.
Siqueira Filho, J. A. & E. M. C. Leme. 2000. Suplemento: *Neoregelia* subgênero *longipetalopsis*. Pp 229-237 in E. M. C. Leme (ed.). *Nidularium: bromélias da Mata Atlântica*. Sextante, Rio de Janeiro.
________. 2002. An Addition to the Genus *Canistrum*: a New Combination for an Old Species from Pernambuco and a New Species from Alagoas, Brazil. *Journal of the Bromeliad Society 52*: 105-121.
Siqueira Filho, J. A. & L. P. Felix. 2006. Bromélias e orquídeas. Pp. 219-266 in K. C. Pôrto, J. S. Almeida-Cortez & M. Tabarelli (orgs.). *Diversidade biológica e conservação da Floresta Atlântica ao norte do Rio São Francisco*. Série Biodiversidade 14. MMA, Brasília, DF.
Siqueira Filho, J. A. & M. Tabarelli. 2006. Bromeliad Species of the Atlantic Forest of North-east Brazil: Losses of Critical Populations of Endemic Species. *Oryx 40 (2): 218-224*.
Smith, L. B. & R. J. Downs. 1974. *Pitcairnioideae (Bromeliaceae)*. Flora Neotropica Monograph 14. Hafner Press, New York.
________. 1977. *Tillandsioideae (Bromeliaceae)*. Flora Neotropica Monograph 14. Hafner Press, New York.
________. 1979. *Bromelioideae (Bromeliaceae)*. Flora Neotropica Monograph 14. The New York Botanical Garden, New York.
Sokal, R. R. & J. F. Rohlf. 1995. *Biometry*. W. H. Freeman and Company, New York.
Tabarelli, M. & C. Gascon. 2005. Lessons from Fragmentation Research: Improving Management and Policy Guidelines for Biodiversity Conservation. *Conservation Biology 19* (13): 734-739.
Tabarelli, M., J. F. Marins & J. M. C. Silva. 2002. La Biodiversidad Brasileña Amenazada. *Investigación y Ciencia 308*: 42-49.
Tabarelli, M., W. Mantovani & C. A. Peres. 1999. Effects of Habitat Fragmentation on Plant Guild Structure in the Montane Atlantic Forest of Southeastern Brazil. *Biological Conservation 91:* 119-127.
Varassin, I. G. & M. Sazima. 2000. Recursos de Bromeliaceae utilizados por beija-flores e borboletas em mata atlântica no Sudeste do Brasil. *Boletim do Museu de Biologia Mello Leitão 11/12*: 57-70.
Wanderley, M. G. L. & L. Mollo. 1992. *Flora fanerogâmica da Ilha do Cardoso (São Paulo, Brasil) – Bromeliaceae*. Instituto de Botânica, São Paulo, 3v, pp. 89-104.
Zar, J. H. 1996. *Biostatistical Analysis*. Prentice-Hall, New York.