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CAMPUS DE SÃO JOSÉ DO RIO PRETO

O papel do estudo de redes complexas como ferramenta para o desenvolvimento de programas de restauração ecológica

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DOUTORADO

PÓS GRADUAÇÃO EM BIOLOGIA ANIMAL

PÓS-GRADUAÇÃO

UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Campus de São José do Rio Preto

IBILCE

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2017

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Orientadora: Sandra Bos Mikich

São José do Rio Preto

2017

Almeida, Adriana de.
O papel do estudo de redes complexas como ferramenta para o desenvolvimento de programas de restauração ecológica = The use of a complex network approach for the developemnt of ecological restoration programmes / Adriana de Almeida. -- São José do Rio Preto, 2017
243 f.: il.

Orientador: Sandra Bos Mikich
Tese (doutorado) - Universidade Estadual Paulista "Júlio de Mesquita Filho", Instituto de Biociências, Letras e Ciências Exatas

1. Ecologia animal. 2. Ave - Alimentos. 3. Mamífero - Alimentos. 4. Animais frugívoros. 5. Frugivoria. 6. Interação animal-planta. 7. Sementes - Dispersão. 8. Plantas - Efeito dos elementos traços. I. Universidade Estadual Paulista "Júlio de Mesquita Filho". Instituto de Biociências, Letras e Ciências Exatas. II. Título.

CDU - 518.5

Ficha catalográfica elaborada pela Biblioteca do IBILCE
UNESP - Câmpus de São José do Rio Preto

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São José do Rio Preto, 03 de março de 2017

Agradecimentos

Meus mais sinceros agradecimentos:

- À minha orientadora, Dra. Sandra Bos Mikich, não tenho palavras para expressar toda a minha gratidão
- À Capes pelo financiamento, através das bolsas PDSE (no. 99999.012756/2013-00) e demanda social
- Aos funcionários da Seção Técnica de Pós-Graduação do Instituto de Biociências, Letras e Ciências Exatas da Universidade Estadual Paulista, por todo o suporte durante os últimos quatro anos
- Ao Programa de Pós-Graduação em Biologia Animal da Universidade Estadual Paulista, representado pela Coordenadora Dra. Eliane Gonçalves de Freitas e pelo Conselho do Programa, por garantirem a qualidade do PPGBA e toda a logística
- À Embrapa Florestas, pela disponibilização da estrutura e suporte para o desenvolvimento do meu projeto
- Aos membros da comissão avaliadora, por aceitaram o convite para avaliar a minha tese. Titulares: Profas. Dras. Isabela Galarda Varassin e Maria Cecília Martins Kierulff, e Prof. Dr. Gustavo Quevedo Romero; Suplentes: Profs. Drs. Gledson Vigiano Bianconi, Wesley Rodrigues Silva e Diogo Borges Provete.
- Aos amigos que de alguma maneira colaboraram com o meu trabalho, especialmente Lays Cherobim Parolin, por estar sempre presente
- Aos meus familiares, especialmente minha mãe Ivone, que sempre acreditou no sucesso dessa jornada e não me deixa desanimar nunca!

Acknowledgements

I am very grateful:

- To the University of Oxford, for allowing my visit during the PDSE scholarship
- To the Community Ecology Research Oxford team, especially my supervisors Owen T. Lewis and Rebecca J. Morris, I really appreciate all your support during my research, and group meeting discussions
- To Dr Eleanor M. Slade, for accepting to be part of the thesis' examiners committee, and for all your valuable comments
- To the lovely Mrs. Lie, who was very kind receiving me in her house during my stay in Oxford
- To Elizabeth Raine, for editing the entire thesis, I cannot thank you enough for all your help!

"Thoroughly conscious ignorance is the prelude to every real advance in science."

ঌ James Clerk Maxwell ॡ

Resumo

Os mutualismos planta–animal são um tipo fundamental de interações e a manutenção da biodiversidade em nosso planeta é altamente dependente deles. Nos trópicos, a maioria das espécies de plantas tem sementes dispersas por animais que consomem frutos. A região neotropical contém a maior concentração de angiospermas com frutos carnosos e de animais que consomem frutos do mundo, mas essa região rica em biodiversidade é constantemente ameaçada por impactos causados pela humanidade. Eu conduzi uma revisão em escala continental sobre a disponibilidade de dados em interação entre plantas frutíferas e animais consumidores de frutos na região neotropical. O objetivo deste estudo foi identificar as lacunas que ainda existem no conhecimento deste tipo de interação e usar estes dados para conduzir meta-análises a partir de uma perspectiva de redes. O principal propósito era verificar se o uso de análises de redes podia ser aplicado como uma ferramenta para auxiliar o desenvolvimento de planos de restauração ecológica. Eu constatei que as interações entre plantas e frugívoros na região neotropical são ainda sub amostradas tanto em termos da distribuição espacial dos estudos quanto em termos da diversidade de espécies de aves e mamíferos investigada. Eu então combinei dados de uma série de estudos que registraram o consumo por aves e mamíferos para construir 17 redes de interação. Essas redes se mostraram altamente estruturadas exibindo organização aninhada e modular e na maioria dos casos desviando significativamente da estrutura esperada em redes aleatórias. Ainda, para entender a importância de frutos e como os seus traços influenciam na dieta de dois mamíferos dispersores de sementes e usando três comunidades-foco neotropicais como estudos de caso, eu encontrei que macacos-prego (gêneros *Cebus* e *Sapajus*) e quatis (gênero *Nasua*), apesar de apresentarem estratégias tróficas gerais semelhantes, exibiram uma baixa similaridade na composição de espécies de frutos em suas dietas. Em suas dietas, eles também não apresentaram nenhuma preferência por características de frutos específicas. Macacos prego e quatis parecem, então, desempenhar papéis complementares como dispersores de sementes nessas comunidades. Isto é especialmente importante em áreas perturbadas, aonde grandes mamíferos já não ocorrem mais, porque macacos-prego e quatis tendem a persistir e se adaptar a essas áreas e podem ser os responsáveis pela manutenção e restauração da floresta através de serviços de dispersão de sementes. Por último, eu usei análises de redes para identificar espécies-chave de plantas nas 17 redes de interação entre plantas e animais frugívoros. Estas espécies têm a capacidade de suportar uma série de espécies de vertebrados e de aumentar o número de interações na rede de uma maneira geral. Assim, o uso de análises de redes para interpretar interações frutos–frugívoros em comunidades neotropicais pode ser uma ferramenta bastante útil para auxiliar planos de restauração ecológica que incluem o plantio de árvores. Considerando que a provisão deste tipo de projeto é normalmente limitada, se faz necessário selecionar espécies de plantas com o maior potencial de incrementar a estrutura da comunidade.

Palavras-chave: Aves. Dispersão de sementes. Dieta. Espécies-chave. Frugivoria. Interações animal–planta. Mamíferos. Traços das plantas.

Abstract

Plant–animal mutualisms are a central type of interactions and the maintenance of biodiversity on our planet is dependent on them. In the tropics, the majority of plant species have seeds dispersed by fruit-eating animals. The neotropical region contains the highest concentration of fruiting plants and fruit-eating animals in the world, but this biodiversity rich region is constantly threatened by human-driven impacts. I conducted a continental-scale review of the availability of data for the interactions between neotropical fruiting plants and fruit-eating mammals. The aim of this study was to identify the gaps that still exist in knowledge of this interaction type and use this data to conduct meta-analyses from a complex network perspective. The main purpose was to verify if the use of network analyses can be applied as a tool to assist the development of ecological restoration plans. I found that the interactions between plants and fruit-eating birds and mammals in the neotropical region are still undersampled both in terms of the spatial distribution of studies and in terms of bird and mammal diversity of the species investigated. I then combined data from a range of studies that reported fruit eating by birds and mammals to construct 17 interaction networks. These networks were found to be highly structured exhibiting nested and modular organization and mostly deviating significantly from the structure expected in random networks. Additionally, in order to understand the importance of fruits and how their traits influence in the diet of two mammalian seed dispersers by using three neotropical focal communities as cases studies I found that two capuchin monkeys (genera *Cebus* and *Sapajus*) and coatis (genus *Nasua*), despite having similar overall trophic strategies, exhibited a low similarity in fruit species composition in their diet. They also showed no preference for particular fruit traits in their diets. Capuchins and coatis are thus performing complementary roles as seed dispersers in these communities. This is especially important in disturbed areas, where large frugivores are already absent because capuchins and coatis can be responsible for forest maintenance and restoration through seed dispersal services. Finally, I used network analyses to identify key plant species in the 17 plant–frugivore networks. These key plants have the ability to support a wide range of vertebrate species and to increase the number of interactions in the network as a whole. Thus, the use of network analyses to interpret fruit–frugivore interactions in neotropical communities can be a useful tool to assist ecological restoration plans that include the planting of trees. Considering that projects of ecological restoration usually have a limited budget, it is necessary to select the plant species with the greatest potential to improve community structure.

Keywords: Animal–plant interactions. Birds. Diet. Frugivory. Keystone species. Mammals. Plant traits. Seed dispersal.

Summary

General Introduction

The ecological interactions between animals and plants are among the main processes that generate and maintain biodiversity in our planet (ODUM; BARRETT, 2008). They include diverse key ecological processes such as pollination, seed dispersal and ant–plant protection, spanning many environments through the world (HERRERA; PELLMYR, 2002). In the tropics, mutualisms play a central role as approximately 90% of the plants depend on animals for their reproduction through pollination and seed dispersal (JORDANO, 2000). These mutualistic relationships usually involve dozens of species that form complex networks of interdependencies and occur in a community context.

Birds and mammals are the main fruit-eating vertebrates, although few species rely exclusively on this resource (JORDANO, 2000). Plants developed several strategies in order to attract seed dispersers such as colourful or scented fruits, even though most of the attracted animals are not effective dispersers because processing fruits often kills seeds. Fruits provide a reliable source of energy and the energy gain is greater than the energy expended for seed dispersal (HOWE, 1986). Not all frugivores are seed dispersers, yet recognized seed predators may actually assist in seed dispersal under some circumstances (NORCONK; GRAFTON; CONKLIN-BRITTAIN, 1998). The consequences of these interactions include an enormous diversity and abundance of fruits suitable for consumption by several groups of vertebrates (HERRERA, 1992; JANSON, 1983; JORDANO, 1995).

The Neotropics is home to highly diverse assemblages of fruiting plants and fruit-eating vertebrates. Fruit-eating birds and mammals comprise a major fraction of the vertebrate biomass in the neotropical region, in a more pronounced fashion than in any other region of the world (TERBORGH, 1986). This geographical region encompasses a unique combination of environmental conditions that enable the existence of a variety of terrestrial ecosystems (OLSON et al., 2001). It is also home for many endemic species (DIRZO; RAVEN, 2003). Nevertheless, areas of natural forest continue to decline (KEENAN et al., 2015), and virtually all neotropical forests have been affected by hunting (REDFORD, 1992). This could have severe consequences for plant–animal interactions through all this geographical region.

The study of complex networks is an expanding field and has been applied to several areas of knowledge, such as the functioning of entire societies, the internet and biological systems (BASCOMPTE; JORDANO, 2007). Networks exist at all levels of biological organization, from gene networks interacting for mutual regulation to species interacting within communities (PROULX; PROMISLOW; PHILLIPS, 2005). The network approach in ecology has been known for a long time, mainly in relation to food webs (MELLO, 2010). But the use of tools and the theory of complex networks has more recently been actively contributing to the understanding of these interactions on larger scales, encompassing entire communities and helping to understand the "architecture of biodiversity" (BASCOMPTE; JORDANO, 2007; PROULX; PROMISLOW; PHILLIPS, 2005). Real mutualistic networks are not randomly organised. Instead, networks have been found to be highly structured around some emergent properties with important implications for the evolution, stability, and resilience to perturbations. These networks are known to be heterogenous, that is the bulk of species interact with a few species and a few species have a much higher number of interactions than would be expected by chance (BASCOMPTE; JORDANO, 2007). They also are found to exhibit a nested pattern, in which specialists interact with subsets of the species generalists interact with (BASCOMPTE; JORDANO, 2006). Mutualistic networks are known to be built on weak and asymmetric links among species (BASCOMPTE; JORDANO, 2007). It is also common that mutualistic networks organize in a modular pattern, in which groups of strongly connected species are weakly interlinked with other groups of strongly connected species (OLESEN et al., 2007). Mutualistic plant–animal interaction webs are described using bipartite graphs, which represent the relationships between two distinct trophic guilds, in this case plants and animals (JORDANO; BASCOMPTE; OLESEN, 2003).

Community level studies usually focus on a small diversity of frugivorous species, mainly seed-dispersing birds. Studies with hyper-diverse frugivore communities have the ability to clarify how species organize according to their shared phylogenetic history and trait convergence of phylogenetically unrelated species (DONATTI et al., 2011). Also, the interactions within and between different taxonomic groups are responsible for shaping species composition in different communities (BEAUDROT et al., 2013), so focusing on only one taxonomic group provides incomplete information about the processes underlying these mechanisms.

Human-driven fragmentation, conversion of vegetation and reduction of habitats through disturbance are the main causes of biodiversity loss in natural ecosystems (BROOKS et al., 2002; DOBSON; BRADSHAW; BAKER, 1997). These disturbances affect mutualistic interactions at several levels: pollination, seed dispersal, nutrient cycling (CARDINALE et al., 2012). Most studies that evaluate anthropic action in the suppression of natural habitats are conducted over short periods, so many long-term consequences can go undetected, underrepresenting the severity of the consequences of human modification (HAGEN et al., 2012). The consequences of biodiversity loss can be observed in most ecological processes within an ecosystem, namely primary productivity and the provision of ecosystem services, but also in regulatory services such as climate regulation and disease/pest control (CARDINALE et al., 2012). Ecological interactions are being lost even before species disappearance. For example, changes in the phenology of an interacting partner due to climate change can cause a temporal mismatch between species, thus interrupting their interaction (VALIENTE-BANUET et al., 2015). So, human-driven disturbances may be affecting ecosystems more severely than previously thought. This only increases the need to improve the way in which plant–frugivore interactions are studied in order to improve restoration projects in disturbed areas.

Ecological restoration can be defined as “the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed” (SER INTERNATIONAL, 2004), which means not only to restore the original composition of a degraded habitat, but also its functional diversity. Thus, biodiversity has to be understood not only as the number of species occurring in an environment, but also the interactions between them (BASCOMPTE; JORDANO, 2007). Ecological restoration should be the focus of conservation efforts because it has the potential to re-establish complex ecological interactions as well as ecological functions inherent to them, such as seed dispersal (RIBEIRO DA SILVA et al., 2015), which enables the ecosystem to become self-sustainable over time (RODRIGUES et al., 2011). Animal seed dispersal has the potential to accelerate native forest regeneration (WUNDERLE JR., 1997). Using a network perspective, it is possible to predict the consequences of habitat restoration. Network analyses allow us to explore the patterns of ecological systems that can be difficult to detect using other approaches. For example, with the aid of ecological networks knowledge it is possible to assess the robustness of networks to species extinctions, habitat loss or other anthropogenic disturbances (BASCOMPTE, 2009). Information obtained from the study of these interactions has the potential to support restoration programs, for example, by identifying the key species of plants that can lead to greater increases in biodiversity (HAGEN et al., 2012; POCOCK; EVANS; MEMMOTT, 2012). From a network perspective, it is also possible to predict the indirect effects of the addition or extinction of a species. For example, one single species can be involved in a high number of interactions and its extinction in a particular habitat could result in a great loss in ecosystem functioning; on the other hand, the deletion of a species that has only one or another connection in that habitat may not cause such a severe effect (HAGEN et al., 2012).

This thesis is organized into four chapters that investigated fruit–frugivore interactions in the Neotropics and how this information can be gathered and analysed in order to provide insightful information for the development of new restoration efforts. In the first chapter, an extensive review of the literature sought to gather the data currently available in the literature on fruit-eating birds and mammals in the Neotropics. The objective of this review was to understand how the knowledge about these interactions is distributed in terms of taxonomy and geography. We point out current gaps of knowledge and indicate the next steps for further research in the region.

In the second chapter, we used the information previously reviewed in order to build 17 highly diverse plant–frugivore networks distributed throughout the neotropical region. These combined networks can be an alternative to exhaustive, costly and time consuming fieldwork in areas that have already been focus of several studies that considered different groups of fruit-eating vertebrates individually.

Capuchin monkeys (genera *Cebus* and *Sapajus*) and coatis (genus *Nasua*) are among the most resilient animals in the Neotropics. The third chapter investigates the importance of fruit-eating by these two generalist mammals, that frequently disperse the seeds they eat, and whether their roles are complementary or redundant in three neotropical communities. In this chapter, we also investigated whether plant traits are involved in the diet composition of these two groups.

The final chapter aims to suggest practical implications of this accumulated knowledge in fruit–frugivore interactions and network analysis. We looked for key species of plants acting as connectors and hubs in the 17 neotropical fruit–frugivore networks. These species can potentially catalyse restoration projects by favouring plant–frugivore interactions in neotropical disturbed habitats.

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1 Chapter 1

Studies of fruit consumption by neotropical birds and mammals: gaps in current knowledge

Abstract

The neotropical region exhibits a high diversity of both fruiting plants and fruit-eating animals. Much research has been carried out to investigate the interactions between these two groups. Nevertheless, there is a need to improve the overall picture of the available information concerning this topic. Through compiling data from individual study sites this wealth of literature can provide additional insight into frugivorous interactions and provide recommendations for the future design of frugivory studies. This study gathered and analysed information available on interactions among neotropical plants and fruit-eating birds and mammals to answer the following questions: (1) do studies of fruit-eating animals accurately represent the geographic range and the range of species that are known to perform frugivory in the Neotropics; (2) are these studies conducted over a time period that can identify the effects of seasonal climatic change in frugivory; (3) what are the most appropriate methods for data collection on fruit-eating by vertebrates and; (4) are studies of frugivory accurately representing community level interactions between plants and animals? We found that: (1) in spite of all the research done to date, the fruit diet of most frugivorous birds and mammals is poorly known throughout the Neotropics; (2) the bulk of studies (90%) focused on mammalian species, especially primates and bats; (3) the majority (52%) of the 156 study sites investigated were surveyed only once; (4) most studies concentrated in a few sites and focused on a few groups of frugivorous species; (5) only a small portion of the areas were surveyed for the entire frugivorous community; (6) studies usually spanned 12 months or less, and thus do not account for interannual variation in fruit availability, a common feature in neotropical forests; (7) visual observation is the main method to study the diet of birds and mammals (65%), followed by the analysis of faecal samples (47%); (8) different sampling protocols may require data transformation to standardize diet information, especially when dealing with a range of taxonomic groups. Understanding the interactions associated with frugivory is important because they are responsible for plant population dynamics and for the persistence of frugivores. Data from these studies may be useful in planning restoration and species conservation programmes. Further research should focus on long-term studies and frugivory at the community level.

Keywords: Animal–Plant interactions. Aves. Diet. Frugivory. Mammalia. Seed dispersal.

1.1 Introduction

It is thought that angiosperms evolved fruits with fleshy tissue for vertebrate consumption during the Cretaceous period (REGAL, 1977). The advantages of frugivory for plants are related to the improved dispersal of propagules. Seeds dispersed from the parent plant are more likely to escape the effects of density-dependent mortality, reach favourable sites, and find non-random and well-suited places for establishment and growth (COMITA et al., 2014; CONNELL; SLATYER, 1977; HOWE; SMALLWOOD, 1982; JANZEN, 1970). Animals that feed on fruit benefit from a nutrient rich food source whilst providing this seed dispersal for the plant (JORDANO, 2000). The consequences of these interactions have resulted in an enormous diversity and abundance of modern fruits suitable for consumption by several groups of vertebrates (HERRERA, 1992; JANSON, 1983; JORDANO, 1995).

Birds and mammals are the most common fruit-eating animals in the tropics (HOWE, 1986; JORDANO, 2000). Although these animals depend to a variable extent on fruits, most vertebrates are not exclusively frugivorous and supplement their diet with various food items from vegetal and animal sources (JORDANO, 2000). This variation is probably due to the different profitability this resource provides to animal species based on their different foraging behaviours (HOWE, 1986). Plants also exhibit a variety of strategies in order to attract seed dispersers, despite the fact that the vast majority of the animals attracted are not effective dispersers, because processing fruits often kills seeds (HOWE, 1986). In this review, we considered frugivory as the consumption of pulp, seed, or the whole fruit. Thus, frugivorous animals can function both as seed dispersers and seed predators within a community, depending on the plant species they interact with (BECK, 2005; FORGET et al., 2002; JANZEN, 1971) and the food availability. In periods of food shortage, some animals can modulate the digestive tract and digest the seeds they would usually disperse (MIKICH, 2002). It is also possible that a frugivore simultaneously performs different functions for the same plant species, dispersing some seeds and predating others (JANZEN, 1982). This can occur with animals known to be seed predators, when some seeds are able to pass intact through the digestive tract, such as peccaries (BECK, 2005), or rodents, that have the habit of storing seeds in the soil in a scattered manner and away from the mother plant (JANSEN et al., 2002). Most seeds are later found by the animal, but some manage to escape from predation and establish successfully. Seed dispersers, by transporting seeds away from the parent plant, play a central role in demographic an evolutionary processes of plant populations (JORDANO, 2000; NATHAN; MULLER-LANDAU, 2000). Seed predators can also regulate plant recruitment, demography and spatial distribution, thus also influencing plant diversity (BECK, 2005; SILMAN; TERBORGH; KILTIE, 2003).

The Neotropics comprise of a variety of terrestrial ecosystems, from high seasonally dry environments to moist evergreen forests (OLSON et al., 2001). The historical conditions in the Neotropics enabled the evolution of such a diversity of frugivorous species and high levels of endemism (DIRZO; RAVEN, 2003; WIENS; DONOGHUE, 2004). One of the probable causes for this pattern of high frugivorous species richness and endemicity is because with a high diversity of plants with edible fruits, even with a seasonal variation in fruit productivity by most plant species, fruit availability remains almost constant (FLEMING; BREITWISCH; WHITESIDES, 1987; LEVEY, 1988). In the neotropical region 50% – 98% tree species produce edible fruits with seeds dispersed by vertebrates (HOWE; SMALLWOOD, 1982). Similarly, vertebrates that depend primarily on fruits for survival can represent up to 80% of the avian and mammalian biomass in some localities (TERBORGH, 1986).

Tropical forests are subject to pronounced phenological variation between seasons and/or between years, which could be explained by an adaptation to biotic and abiotic factors (CHAPMAN et al., 2005; VAN SCHAIK; TERBORGH; WRIGHT, 1993). As a result, these habitats face annual periods of fruit scarcity, which directly affects the behaviour of the fruit-eating animals. During these periods, primary consumers respond by dietary switching, seasonal breeding, changes in range use or migration (DIAZ-MARTIN et al., 2014; VAN SCHAIK; TERBORGH; WRIGHT, 1993). Sampling effort for interactions between plants and frugivores must consider these variations in fruit availability and frugivore behaviour.

Different methods are used to record the interactions between plants and fruit-eating animals. All conventional approaches to determine vertebrate feeding behaviours have limitations (LITVAITIS, 2000). The observation of the feeding behaviour through following individual animals or groups is common for primates, and usually employed in behavioural studies in which dietary data are one aspect of the wider study of a focal primate species. Thus, although it provides valuable information some food sources are not accurately sampled by this method (HAWES; CALOURO; PERES, 2013). Other direct methods used to record dietary data include observation of opportunistic feeding events while walking on trails systems or *ad libitum*, use of camera traps situated in the proximity of fruiting trees, and focal observations of targeted plant species. Indirect recording of frugivory include survey of food remains, faecal material, and stomach and gut content. Faecal samples can be collected through walking on transects, opportunistic records of animal defecation, from baited traps without capturing the animals, and by capturing the animals with the aid of traps or mist-nets (LITVAITIS, 2000). The use of these techniques can vary according to the focal species or group of species, the characteristics of the study site, and researcher preferences.

Frugivory is highly correlated with animal seed dispersal, an important ecosystem function, which is an essential process to study in order to understand long term plant population dynamics (GARCIA; MARTINEZ, 2012; JORDANO, 2000; TERBORGH, 1995). The interactions between plants and the animals that eat their fruits are among the key processes that help to understand species abundances in different communities (PERES; VAN ROOSMALEN, 2002). This knowledge, combined with the study of other ecological processes, is essential for the management of protected areas and threatened species. To maintain viable populations of endangered or declining species is important to have information about their requirements and the competitive interactions they might be subjected to (DE OLIVEIRA; LYNCH ALFARO; VEIGA, 2014). Moreover, to better understand the distribution of animal species and the composition of communities, it is essential to consider the broader community occurring at a site rather than a focal species or group (BEAUDROT et al., 2013). Despite this, the ecological processes occurring at the whole community level are still poorly explored (*but see* Donatti *et al.*, 2011; Vidal, Pires, & Guimarães Jr., 2013; Hawes & Peres, 2014; Stevenson *et al.*, 2015). In the neotropical region, there are some studies reviewing the information available on frugivoy of some animal groups such as bats (LOBOVA; GEISELMAN; MORI, 2009; PAROLIN; BIANCONI; MIKICH, 2016), birds (SNOW, 1981), peccaries (BECK, 2005), primates (BOYLE et al., 2016; DIAS; RANGEL-NEGRÍN, 2015; HAWES; CALOURO; PERES, 2013; HAWES; PERES, 2014a), and tapirs (O'FARRILL; GALETTI; CAMPOS-ARCEIZ, 2013). But there are no studies to our knowledge that compiled the information currently available for all neotropical fruit-eating bird and mammal species and addressed the methodological issues.

This study aimed to survey the information available in the literature on fruit consumption by birds and mammals in the Neotropics and to answer the following questions: (1) do studies of frugivory accurately represent the geographic range of the neotropical region, and the range of species that are known to perform frugivory in the Neotropics; (2) are these studies conducted over a time period that can identify the effects of seasonal climatic changes in frugivory; (3) what are the most common methods for data collection on fruit-eating by vertebrates and; (4) are studies of frugivory accurately representing community level interactions between plants and animals? Although we do expect to find some gaps in knowledge for species distributions and for species biotic interactions, the Wallacean and Eltonian shortfalls, respectively (HORTAL et al., 2015). Nevertheless, research on fruit-eating by neotropical birds and mammals have already provided a large amount of data, and there is a need to bring together all the generated information in order to identify the gaps in current knowledge and to determine the next steps as well as future priorities.

1.2 Material and Methods

A previous review of the diet of neotropical primates, the best studied vertebrate order in this geographical region (HAWES; CALOURO; PERES, 2013; HAWES; PERES, 2014a), was used as a starting point for data collection. We used this information in addition to our own field data, and collecting references from papers, consulting experts, and our own knowledge of the literature. We then selected 156 neotropical study sites (excluding the Caribbean islands) with data on plant–frugivore interactions (Appendix A).

For each one of these sites we performed a comprehensive search for studies about frugivory by mammals or birds in all databases of the *Web of Science*™ (http://apps.webofknowledge.com), from 1990 to 2015, in *Google Scholar* (https://scholar.google.com.br/), and an online repository of theses and dissertations (http://bancodeteses.capes.gov.br/), in addition to direct searches of references cited in the analysed studies. We performed the searches for each study site using their names both in English and in the local language, combined with the terms: 'diet' OR 'fruit' OR 'frugivor*' OR 'seed dispersal'.

In this study, we considered a frugivore as animals that eat the entire fruit, only the pulp or only the seeds (as suggested by Charles-Dominique, 1995). We only considered studies presenting lists of the plants that had fruits, pulp or seeds eaten and/or dispersed by any mammal or bird in the wild. We preferably included studies with original data, although in some cases we used secondary cited data when the original source was not available. Studies in which the diet, frugivory or seed dispersal were not actively investigated were not included in this review. Studies using the focal tree method (when the researcher registers plant-animal interactions occurring at pre-selected plants) that considered less than five plant species were not included either.

Plant–frugivore interaction data were collected for the following groups of birds: Columbiformes, Coraciiformes, Cuculiformes, Galliformes, Passeriformes, Piciformes, Psittaciformes, Struthioniformes, Trogoniformes; and mammals: Artiodactyla, Carnivora, Chiroptera, Didelphimorphia, Perissodactyla, Primates, Rodentia. These orders contain species that feed on fruits, even though some might not be considered true frugivores. For each study site, we collected the information about its geographical coordinates and listed the studies that recorded fruit-eating by birds and mammals according to the aforementioned criteria. Then, for each study, we collected the following data: frugivore order and species, sampling method of the interactions, study duration (number of months sampled), number of plant species eaten, and type of study (which could include published and unpublished work).

The taxonomy of frugivore species was verified according to the *Catalogue of Life* (http://www.catalogueoflife.org; ROSKOV et al., 2016). The taxonomy of plant species was verified according to *The Plant List* (http://www.theplantlist.org/). The number of frugivorous bird and mammal species distributed within the neotropical region was estimated based on maps and ecological data compiled by the World Conservation Union (http://iucnredlist.org/; IUCN, 2016). This data was compared to the data collected from the literature review. Maps with the distribution of study sites according to sampling effort and diversity of frugivores were built using the software *QGIS* version *2.16.0-Nødebo* (QGIS DEVELOPMENT TEAM, 2016).

1.3 Results

1.3.1 Range of investigated fruit-eating species and geographic range of studies

We compiled information from 373 studies, which reported frugivory by one or more bird and/or mammal species conducted in the 156 investigated areas (Appendix B). The identified study sites ranged from small urban forest remnants to continuous areas of conserved forests, most of which (82%) are protected public- and private-owned areas (Appendix B). Although a few sites correspond to pristine forests, the vast majority had already undergone some level of disturbance such as logging, hunting, fragmentation and habitat loss. Overall, we gathered information on 183 mammalian species and 292 bird species (Table 1.1). These studies included 278 peer reviewed papers, 21 book chapters and 74 unpublished theses and dissertations (Appendix B).

Studies reporting frugivory by mammals corresponded to 90% of the total reviewed. The most commonly studied orders were Primates and Chiroptera, accounting for 49% and 17% of the total investigations, respectively. The order Perissodactyla was the best studied (Table 1.1) with all three species investigated. It was followed by the order Primates, comprising 46% of studies of all neotropical species. Although the Class Aves has the greatest absolute number of species, only 10% of them had their frugivore diet examined compared to 27% of mammal species. (Table 1.1).

Table 1.1. Representation of frugivorous groups from studies on fruit consumption by mammals and/or birds in the Neotropics.

Class / Order	Estimated no. of frugivore species*	No. of studies with information on frugivory	No. of species with data on frugivory
Mammalia	**668**	**336**	**183 (27%)**
Perissodactyla	3	25	3 (100%)
Primates	136	183	63 (46%)
Chiroptera[1]	170	63	68 (39%)
Artiodactyla[2]	22	24	8 (36%)
Carnivora[3]	54	38	14 (26%)
Didelphimorphia	95	17	14 (15%)
Rodentia[4]	188	13	13 (7%)
Aves	**2996**	**43**	**292 (10%)**
Trogoniformes	26	5	8 (31%)
Columbiformes	64	9	14 (22%)
Galliformes	90	15	16 (18%)
Cuculiformes	27	2	4 (15%)
Coraciiformes	19	4	2 (11%)
Piciformes	251	12	23 (9%)
Psittaciformes	164	9	15 (9%)
Passeriformes	2304	28	207 (9%)
Struthioniformes	51	3	3 (6%)

*Estimation based on potential frugivorous species belonging to each order from IUCN list.
[1]Includes only species from the Family Phyllostomidae.
[2]Includes only species from the Families Cervidae and Tayassuidae.
[3]Includes only species from the Families Canidae, Mephitidae, Mustelidae and Procyonidae.
[4]Includes only species from the Families Cuniculidae, Dasyproctidae, Echimyidae, Heteromyidae and Sciuridae.

Most study sites (52%) were surveyed only once for frugivory by birds and/or mammals, while four sites (3% of the total), three of them located in Mesoamerica, were the target of ten or more studies: Barro Colorado Island (09°10’ N, 79°51’ W; Panama), Santa Rosa National Park (10°52’ N; 85°37’ W; Guanacaste, Costa Rica), Los Tuxtlas Biosphere Reserve (18°35’N, 95°04’ W; Veracruz, Mexico), and Manaus (02°23’ S, 59°56’ W; Amazonas, Brazil), with 16, 14, 11 and ten unique studies, respectively (Fig. 1.1a).

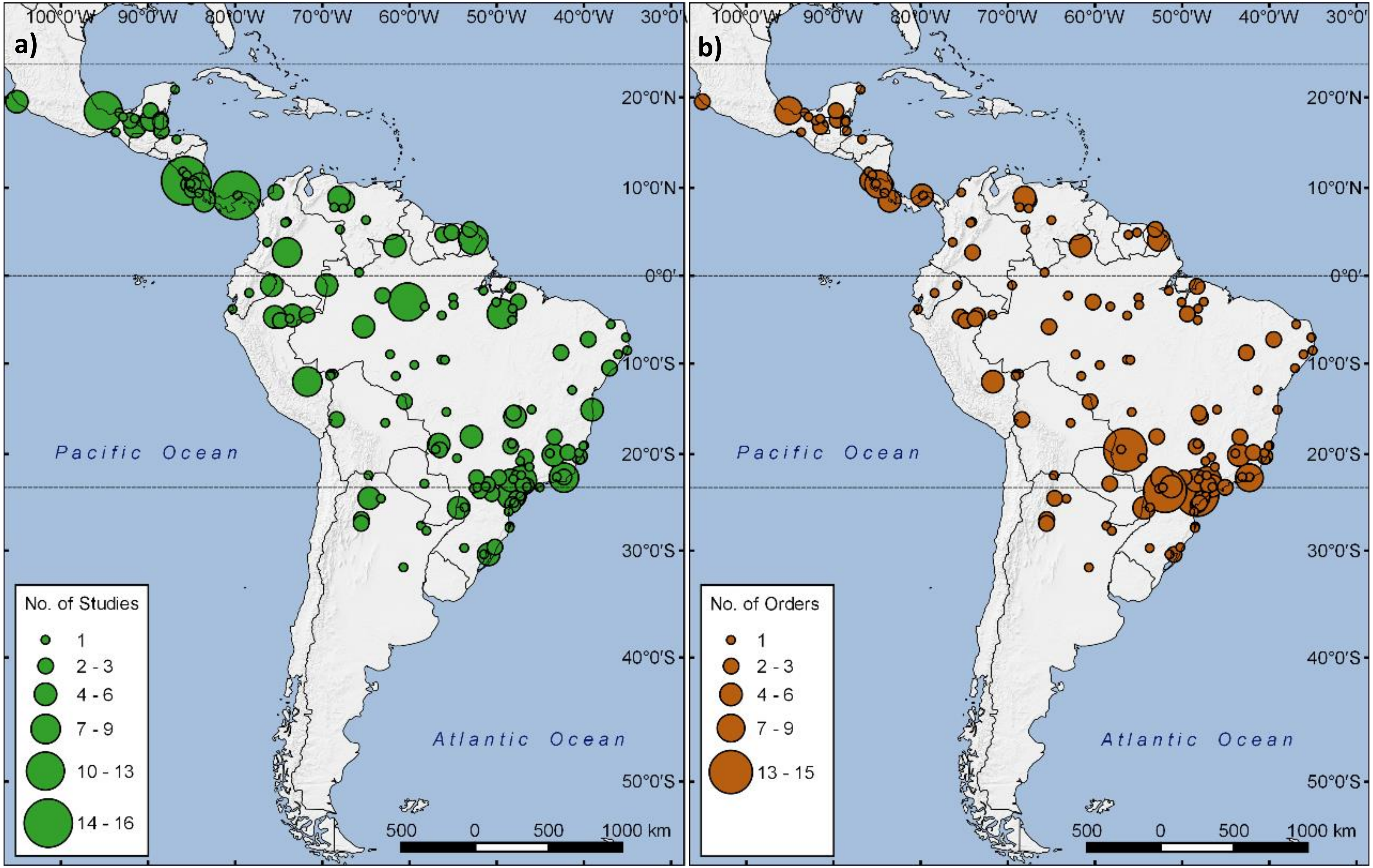

Figure 1.2. Number and distribution of studies on fruit consumption by neotropical birds and mammals (a) and diversity of taxonomic orders surveyed (b).

Most study sites (61%) surveyed frugivory by species belonging to only one bird or mammalian order. Only 13% of the study sites surveyed frugivory by species belonging to four or more different bird or mammalian orders. Three study sites can be highlighted in terms of community-wide frugivory because of high levels of frugivore diversity sampled: Intervales State Park (24°16’ S, 48°25’ W; São Paulo, Brazil), Rio Negro/Barranco Alto Farms (19°34’ S, 56°12’ W; Mato Grosso do Sul, Brazil), and Vila Rica do Espírito Santo State Park (23°54’ S, 51°58 W; Paraná, Brazil), with 15, 14 and 13 bird and mammalian orders studied, respectively (Fig. 1.1b).

1.3.2 Variation in study length

Studies of frugivory by birds and mammals in the Neotropics had a median duration of 12 months (varying from 1 to 120 months of sampling) and studies conducted during six months were also common (Fig. 1.2). Thirty-five percent of the studies were conducted during less than 12 months. As for the cumulative amount of sampling effort (accumulated across different studies), there was a wide variation among the different orders of frugivorous vertebrates: ranging from 63 months for Struthioniformes to 2,582 accumulated months for Primates (Fig. 1.3).

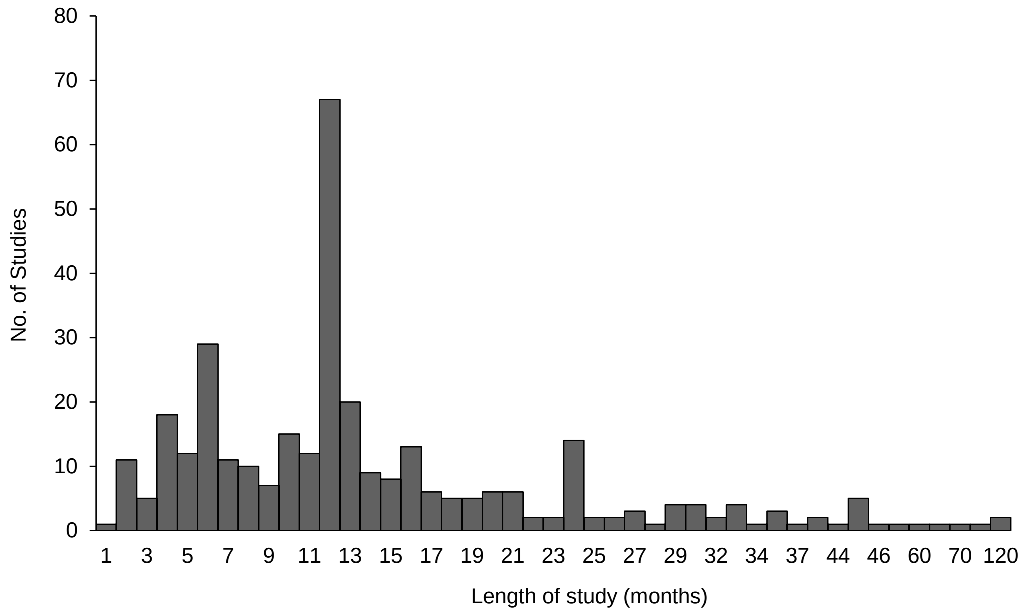

Figure 1.2. Frequency of studies of frugivory by neotropical birds and mammals.

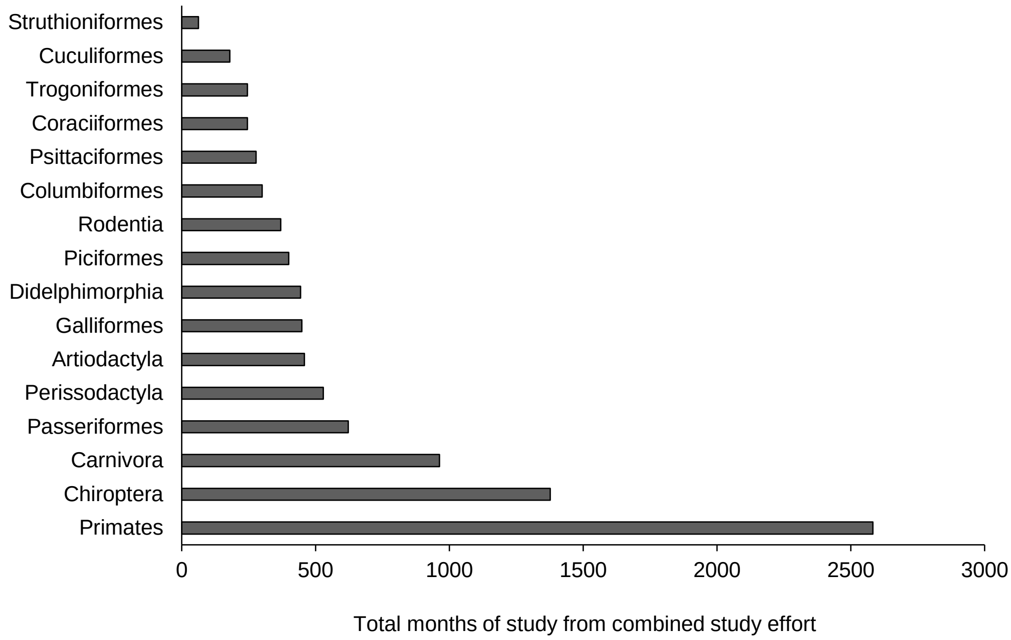

Figure 1.3. Cumulative number of months of study for different groups of neotropical frugivores.

1.3.3 Survey methods

The most common method for surveying frugivory by birds and mammals in the Neotropics was direct visual observation of fruit consumption, employed in 65% of the studies (*n* = 249). The indirect recording of fruit consumption by faecal analysis was also frequently used, employed in 47% of cases (*n* = 180). The least common method employed was sampling of stomach content (5% of the cases). In 2% of the cases the records were cited by secondary studies and it was not possible to determine the sampling methods.

1.4 Discussion

We performed a continental-scale review to assess the availability of data of interactions between fruiting plants and fruit-eating birds and mammals. Our investigation compiled studies investigating fruit-eating by neotropical birds and mammals to determine whether the amount of available studies is representative of this geographical region and of the frugivore diversity found in there. We discuss about study lengths and methodological approaches employed by the different studies. This review has the widest taxonomic focus to date on the subject and provides insightful information for further research.

1.4.1 Range of investigated fruit-eating species and geographic range of studies

We found that frugivory by vertebrates in the Neotropics is still poorly understood, considering the high diversity of frugivores occurring in this geographical region. Almost all vertebrate orders examined had less than 50% of their fruit-eating species investigated for frugivory. This undersampling is even more pronounced in Aves, where less than 31% of species had been investigated. This is worrying because fruit–frugivore interactions are particularly important for seed dispersal and seed predation dynamics (JORDANO, 2000), and also because it has been known that the recording of species interaction data is already limited by sampling problems, a phenomenon known as Eltonian shortfall of biodiversity knowledge (HORTAL et al., 2015). Plant–frugivore interactions are crucial for determining the requirements of animal species, especially for declining populations and threatened species (DE OLIVEIRA; LYNCH ALFARO; VEIGA, 2014).

Among the main trends observed in the current available data are the high concentration of studies in a few well-known sites, as well as a low diversity of frugivore orders studied in each site, even in the sites with a high concentration of studies, such as Barro Colorado Island in Panama and Santa Rosa National Park in Costa Rica. Studies that aimed to survey the diet of the entire frugivore assemblage were rare and, in this review, only three sites can be identified by the high diversity of orders addressed, all three located in Brazil. These geographical biases in research are related to variations in financial support of research throughout the neotropical region. Study sites with greater numbers of studies are the ones that have the support of international organizations and consequently have established field research stations with enough infrastructure for the development of field studies and experiments. Another explanation for the high quantity of studies in some sites is the proximity to important universities, which is the case for study sites located in southern and southeastern Brazil. The less studied areas are also the ones exposed to higher human pressure, such as the Brazilian Amazon where the main current threats include cattle ranches, soy plantations, and the continued construction of large hydroelectric dams (DE OLIVEIRA; LYNCH ALFARO; VEIGA, 2014).

Geographical gaps in the knowledge of plant–frugivore interactions can be even larger if we consider the Linnean and Wallacean shortfalls of biodiversity knowledge. The first shortfall refers to species not yet described and catalogued (HORTAL et al., 2015), that were not even considered in our estimation of the number of species. The second one is related to knowledge about the geographic distribution of species, and is closely associated with variation in surveying effort (HORTAL et al., 2015). These gaps can be also a result of funding limitations, and differences in accessibility of study sites.

One possible explanation for the observed geographical gap in the availability of studies is that ecological research based on dietary data (which include fruit–frugivore interactions) often do not make basic data available and purely descriptive studies are rarely published due to the bias towards novel research in traditional high impact journals. Also, theses and dissertations developed in Brazilian Universities were easily accessed by the authors and this may be one of the main reasons for the bias towards research performed in Brazilian study sites. Although citation of grey literature is usually avoided, it is a valuable source for information such as fruit consumption, since most of this basic data will not be published elsewhere. Thus, we suggest that a similar effort searching for grey literature should be employed in each Neotropical country in order to improve the database. In this study, data from grey literature represented 20% of the total data reviewed. Attempts to increase accessibility to these data are increasing as many leading journals have been adopting public data archiving policies. This is beneficial because it can enhance data verification, work visibility, and will allow other scientists to reuse data in order to answer novel questions and to provide better meta-analyses (WHITLOCK, 2011).

1.4.2 Variation in study length

Studies conducted over 12 months were the most common in this review and are suitable to explore all the variation in plant fruit production contained in one annual cycle. However, there is also important interannual variation in fruit production (CHAPMAN et al., 2005; SMYTHE, 1986; VAN SCHAIK; TERBORGH; WRIGHT, 1993) that can only be captured by long-term studies, which accounted for few of the studies analysed here. In the Neotropics, fruits as well as other types of resources, face a marked seasonality. There are periods of the year when the supply is very abundant and periods of severe scarcity, resulting in fruit availability being variable in space and in time (SMYTHE, 1986; TERBORGH, 1986). The phenology of plants (the timing of life cycle events) are related to the climatic conditions they are exposed to, and tropical climates are subject to annual patterns of variation. In the neotropical region, fruit production has an intimate relationship with rainfall and irradiation (MORELLATO et al., 2001; VAN SCHAIK; TERBORGH; WRIGHT, 1993), and temperature can also have a strong influence in some areas (LIEBSCH; MIKICH, 2009; MARQUES; ROPER; SALVALAGGIO, 2004). The variation in fruit availability is also directly related to the frugivore population cycles and to their reproductive success (GLANZ et al., 1983; RUSSELL, 1983; VAN SCHAIK; TERBORGH; WRIGHT, 1993).

Studies shorter than 12 months were also common. Short-term studies will usually underrepresent the fruit diets of most animals, especially if they are conducted during less than six months. Fruit availability in neotropical forests differ markedly between the wet and dry seasons (VAN SCHAIK;

TERBORGH; WRIGHT, 1993), and most vertebrates usually shift their diets during the lean season, including other plant parts and animal matter in order to compensate for fruit scarcity (TERBORGH, 1986). Although it is important to have long-term studies in order to better record the interactions occurring at a given site, study length is directly influenced by factors other than the researcher expectations. It is usually limited by the amount of funding for research, time, and resources available at the field sites. It is therefore important, for plant–frugivore networks, to run the field sampling during the periods of greater fruit abundance and availability in order to record the maximum amount of possible interactions.

1.4.3 Survey methods

In general, there is not a consensus as to which methods are most appropriate to investigate of the diet of frugivorous animals. All available techniques used to determine vertebrates' diets have their advantages and disadvantages (LITVAITIS, 2000). Also, each of the methods can vary in different studies, for example different survey efforts or different nature of reporting effort for example, which makes it difficult to compare the results (HAWES; CALOURO; PERES, 2013). Frugivorous vertebrates exhibit different forms of feeding and behaviours, which makes it difficult to use a single sampling technique to collect information about frugivory across all different groups. Some groups are more problematic to observe than others, which may result in the low sampling some groups, such as the remoteness of extant populations of some primate species or nocturnal habits. The existence of more charismatic study groups like large mammals or small birds creates a bias in research. While the low density of some frugivorous species, like large vertebrates, in the Neotropics make their study more difficult and mean they may be underrepresented (HAWES; CALOURO; PERES, 2013; VIDAL; PIRES; GUIMARÃES JR., 2013). In the neotropical region, unlike the African continent, large vertebrates tend to occur in low densities and can exhibit more elusive behaviour, so that the interactions performed by these animals are more difficult to record than the ones performed by species that are more abundant and easy to observe (VIDAL; PIRES; GUIMARÃES JR., 2013). In studies that analysed frugivory by multiple taxonomic groups (AMATUZZI, 2009; DONATTI et al., 2011; MIKICH, 2001) it was necessary to employ different methods to record fruit eating e.g., camera traps, direct observation of consumption by animals, and faecal analysis (of samples collected in trail systems or after mist nets captures).

When studying the interactions between plants and fruit-eating animals using different techniques it is necessary to standardize the sampling effort, in order to avoid sampling bias (JORDANO, 2016). Some authors suggested interesting approaches for diet determination in primates that are potentially applicable to other groups. For example, the frequency method, in which the ingested items are measured by the quantity of “feeding records” (ROBINSON, 1986). More recently, the standardization of sampling effort through the conversion of measures coming from different sampling techniques has been utilized (*e.g.* feeding bouts, group scans, opportunistic observation, stomach content analysis, faecal sampling) into quantity of hours (HAWES; CALOURO; PERES, 2013). Thus, an adequate approach for detecting interactions between plants and fruit-eating animals will vary according to each site (JORDANO, 2016).

1.5 Implications for the study of community-level interactions

The study sites analysed included a wide range of sizes and conservation levels, from big pristine forests to small fragments inserted in urban environments. However, due to the effects of hunting, there are few remaining natural areas with a completely intact biota (EMMONS, 1984; PERES; PALACIOS, 2007; REDFORD, 1992). Thus, we expect that the ecological relationships observed in the different sites are highly influenced by the types of disturbances to which they were exposed. High levels of disturbance can directly interfere with the availability of forest resources (CHIARELLO, 1999). Hunting, fragmentation and reduction of habitats can cause a decline in species numbers (CHIARELLO, 1999; GALETTI; DIRZO, 2013; SODHI; LIOW; BAZZAZ, 2004). Large frugivores are the first animals to disappear from small fragments after isolation from continuous forests and frugivorous animals are also the most threatened by hunting (HOWE; MIRITI, 2004; PERES; PALACIOS, 2007; VIDAL et al., 2014). In addition, isolation and fragmentation of forest remnants are contributing factors towards species extinctions (CHIARELLO, 1999). The absence or severe decrease of populations of seed dispersers has consequences for the entire community. For example, local extinction of large birds is associated with the reduction of the seed size of a keystone palm in the Brazilian Atlantic forest, which can have a series of negative consequences for plant recruitment and population dynamics (GALETTI et al., 2013).

Only a small quantity of sites were investigated for frugivory at the whole community level. This lack of information is concerning since it is hard to evaluate the processes influencing species diversity, abundances and distributions if we consider only a small subset of the species interacting in a particular site (BEAUDROT et al., 2013). Community level research on multiple fruit–frugivore interactions is of central importance in ecology and evolution and has recently provided insights into the effects of defaunation (VIDAL; PIRES; GUIMARÃES JR., 2013), evolution and community structuring (DONATTI et al., 2011), keystone species (MELLO et al., 2015; STEVENSON et al., 2015), and ecosystem functions and conservation (PALACIO; VALDERRAMA-ARDILA; KATTAN, 2016).

1.6 Future Research

New studies on fruit–frugivore interactions in the Neotropics should focus on the entire assembly of frugivores occurring in the focal communities. These studies should employ different sampling techniques, in order to capture the largest possible number of interactions, and be careful enough to standardize the sampling effort so the ability to quantitatively combine data sets is not lost (HAWES; CALOURO; PERES, 2013). In order to better capture these interactions, it is also recommended that those studies are conducted for longer than one annual cycle, since there is interannual variation in fruit production that can directly interfere in the dynamics of the interactions.

Future studies should also focus undersampled regions of the Neotropics – such as Central Brazil, Guyana, Brazilian Amazon, and Northeastern Brazil – as well as undersampled vertebrate groups such as birds, rodents and marsupials.

1.7 Conclusions

Frugivore diversity in the Neotropics is very high and ranges from small bats and rodents to the large 300-kg tapirs. This high diversity, however, is not reflected in studies on fruit consumption by vertebrates. The studies on frugivory available in the literature are highly concentrated to a few taxonomic groups, like primates, bats and small birds. The observed bias may be a consequence of sampling adversities for some groups, the popularity of other groups, or the low density of some frugivore species. Also, the bulk of studies reviewed here were conducted over short timespans (12 or less months), so they may be not portraying all the variation expected due to interannual differences in fruit availability. Due to the scarcity of studies that research fruit-frugivore interactions at the community level, the information already available from the literature in well studied sites could be potentially optimized through the conversion and standardization of data collected by different techniques. Gathering the data already produced on fruit–frugivore interactions during the last decades is useful for the planning of restoration and conservation programmes. Nevertheless, it is evident that more baseline studies are necessary on fruit consumption by many frugivorous species, including common ones. It is also important that this basic information becomes available in the literature, in the form of published papers, and deposited in a publicly accessible database archive.

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APPENDIX A — Name and location of 156 neotropical study sites in which were carried studies of fruit consumption by different orders of birds and mammals between the years 1900 and 2015. *Area protection category according to the IUCN: I = Scientific Reserve/Strict Nature Reserve; II = National Park/Provincial Park; IV = Nature Conservation Reserve/Managed Nature Reserve/Wildlife Sanctuary; V = Protected Landscape; VI = Resource Reserve; IX = Biosphere Reserve; NP = non-protected area.

Study sites	**Latitude**	**Longitude**	**Protection category***	**No. of studies**	**No. of studied orders**
1. Barro Colorado Island	9.16	-79.85	I	16	5
2. Santa Rosa National Park	10.81	-85.69	II	14	4
3. Los Tuxtlas Biosphere Reserve	18.56	-95.15	IX	11	7
4. Manaus	-3.01	-60.22	NP	10	2
5. Saut Parare/Nouragues Natural Reserve	4.09	-52.67	IV	9	5
6. Intervales State Park	-24.31	-48.27	II	8	15
7. La Macarena & Tinigua National Parks	2.66	-74.05	II	8	3
8. Santa Genebra Reserve	-22.82	-47.11	II	8	7
9. Manu National Park	-12.04	-71.72	II	7	4
10. Poço das Antas Biological Reserve	-22.52	-42.28	I	7	7
11. Tucuruí	-4.37	-49.4	II	7	3
12. Iguaçu and Iguazú National Parks	-25.67	-54.36	II	6	5
13. Maracá Island Ecological Reserve	3.42	-61.67	I	6	5
14. Chamela-Cuixmala Biosphere Reserve	19.53	-105.05	I	5	3
15. Fundo Pecuario Masaguaral	8.57	-67.58	II	5	3
16. Lacandona Jungle	16.83	-91.5	IX	5	3
17. Una Biological Reserve	-15.17	-39.05	I	5	1
18. Upper Urucu River	-5.83	-65.27	NP	5	2
19. Yasuní National Park	-1.1	-75.81	II	5	1
20. Central Pantanal/Nhumirim Ranch	-18.98	-56.64	II	4	3
21. Edgardia Ranch	-22.81	-48.39	II	4	4
22. El Rey National Park	-24.68	-64.62	II	4	3
23. Emas National Park	-18.12	-52.9	II	4	3
24. Gama-Cabeça de Veado Environmental Protection Area	-15.93	-47.9	V	4	2
25. Hato Piñero	8.93	-68.08	II	4	4
26. Itapuã State Park	-30.38	-50.92	II	4	3
27. La Selva Biological Station	10.42	-84.02	VI	4	3
28. Osa Peninsula	8.54	-83.57	II	4	4
29. Otún-Quimbaya Fauna and Flora Sanctuary	-4.72	-75.46	IV	4	2
30. Quebrada Blanco Biological Station	-4.56	-73.46	I	4	3
31. Caraçá Sanctuary Private Reserve	-20.1	-43.49	II	4	4
32. Tikal National Park	17.55	-89.58	II	4	2
33. Yaigojé-Apaporis/Caparú Natural National Park	-1.09	-69.51	II	4	1
34. Brasília National Park	-15.54	-48.08	II	3	2
35. Caetetus Ecological Station	-22.52	-49.76	I	3	3

Continues…

APPENDIX A — Continuation

Study sites	Latitude	Longitude	Protection category*	No. of studies	No. of studied orders
36. Carlos Botelho State Park	-24.73	-47.73	II	3	2
37. Mata do Junco Wildlife Refuge	-10.53	-37.05	IV	3	1
38. Noel Kempff Mercado National Park	-14.27	-60.57	II	3	2
39. Pacaya-Samiria National Reserve	-5.13	-74.83	I	3	3
40. Palo Verde National Park	10.39	-85.34	II	3	2
41. Piste de Saint-Elie Station	5.3	-53.07	I	3	3
42. Prof. Mello Leitão Biology Museum	-20.25	-40.5	I	3	2
43. Raleighvallen-Voltzberg Nature Reserve	4.68	-56.17	II	3	1
44. Rio Negro/Barranco Alto Farms	-19.55	-56.53	II	3	14
45. Rio Preto State Park	-18.15	-43.38	II	3	2
46. Serra da Capivara National Park	-8.78	-42.63	II	3	3
47. Tunquini Biological Station	-16.25	-68.37	I	3	3
48. Araripe National Forest	-7.28	-39.49	VI	2	2
49. Brownsberg Nature Park	4.94	-55.17	II	2	1
50. Calakmul Biosphere Reserve	18.55	-89.71	IX	2	2
51. Cantareira State Park	-23.37	-46.6	II	2	6
52. Community Baboon Sanctuary	17.55	-88.58	IV	2	1
53. Curú Wildlife Refuge	9.78	-84.93	IV	2	2
54. Doralice Woods	-23.26	-51.05	II	2	1
55. Feliciano Miguel Abdalla Private Reserve/Montes Claros Ranch	-19.83	-41.83	II	2	2
56. Guri Lake	7.77	62.88	II	2	1
57. Horco Molle Fauna and Flora Experimental Reserve	-26.87	-65.53	I	2	2
58. Japi Mountain Range	-23.28	-46.98	II	2	2
59. Jaú National Park	-2.28	-63.09	II	2	1
60. Lago Preto Conservation Concession	-4.46	-71.76	IV	2	1
61. Monkey River	16.35	-88.48	IV	2	1
62. Monte Alegre Ranch	-24.21	-50.56	NP	2	1
63. Monteverde Cloud Forest Biological Reserve	10.42	-84.83	I	2	8
64. Palenque National Park	17.49	-92.05	II	2	1
65. Panga Ecological Reserve	-19.17	-48.4	I	2	2
66. Pontal do Paranapanema	-22.53	-52.3	NP	2	4
67. Runaway Creek Nature Reserve	17.37	-88.58	IV	2	1
68. San Jacinto Mountain Range	9.5	-75.35		2	1
69. San Javier Mountain Range	-27.27	-65.55	II	2	2
70. Serra da Canastra National Park	-20.33	-46.67	II	2	1
71. State Foundation for Agricultural Research	-29.66	-50.21	I	2	1
72. Superagüi National Park	-25.35	-48.17	II	2	2
73. União Biological Reserve	-22.46	-42.28	I	2	1

74. Vila Rica do Espírito Santo State Park	-23.91	-51.96	II	2	13
75. Vitória Ranch	-2.98	-47.52	NP	1	1
76. "Ya´ax´che" Reserve	20.84	-86.9	II	1	1
77. Alter do Chão	-2.52	-55	NP	1	1
78. Amazônia National Park	-4.55	-56.3	II	1	1
79. Assu National Forest	-5.57	-36.91	VI	1	1
80. Augusto Ruschi Biological Reserve	-19.87	-40.55	I	1	1
81. Barra do Ribeiro	-30.37	-51.45	NP	1	1
82. Barreiro Rico Ranch	-22.68	-48.1	II	1	1
83. Brasilera Island	-27.5	-58.68	NP	1	1
84. Cachoeira Samuel Ecological Station	-8.97	-62.23	I	1	1
85. Campo de Instrução de Santa Maria	-29.75	-53.72	II	1	1
86. Carabajal Island	-31.65	-60.7	NP	1	1
87. Cauaxi Ranch	-3.76	-48.17	NP	1	1
88. Celmar-Imperatriz	-5.08	-48.22	NP	1	1
89. Chapada Diamantina National Park	-12.99	-41.34	II	1	1
90. Chapada dos Guimarães National Park	-15.42	-55.78	II	1	1
91. Cinturão Verde de Cianorte Municipal Park	-23.67	-52.63	II	1	1
92. Córrego do Veado Biological Reserve/Recanto das Antas Private Reserve	-19.08	-39.97	I	1	1
93. Córrego Grande Ecological Park	-27.58	-48.5	II	1	1
94. Dardanelos	-10.17	-59.45	NP	1	1
95. El Nogalar de los Toldos National Reserve	-22.27	-64.72	VI	1	1
96. El Tuparro	5.27	-67.97	II	1	1
97. Estancia Guaycolec	-23.16	-58.3	NP	1	2
98. Fazenda Pacatuba Private Reserve	-7.05	-35.16	II	1	1
99. Ferreira Penna Science Station	-1.71	-51.53	I	1	1
100. Finca La Luz	11.83	-85.98	NP	1	1
101. Finca La Pacifica	10.45	-85.13	II	1	1
102. Grande Sertão Veredas National Park	-15.15	-45.99	II	1	1
103. Gunma Ecological Park	-1.23	-48.29	II	1	2
104. Ilha Anchieta State Park	-23.54	-45.06	II	1	2
105. Ilha do Cardoso State Park	-25.17	-48	II	1	2
106. Itirapina Ecological Station	-22.25	-47.82	I	1	1
107. Jenaro Herrera Research Center	-4.92	-73.75	I	1	2
108. Juréia-Itatins Ecological Station	-24.48	-47.28	I	1	1
109. Jutaituba Ranch	-3.03	-50.06	NP	1	1
110. La Chonta Forestry Concession	-16.62	-62.79	II	1	1
111. La Sepultura Biosphere Reserve	16.2	-93.72	IX	1	1
112. La Venta Park Museum	18.33	-93.3	II	1	1
113. Lagoa do Peri Municipal Park	-27.72	-48.53	II	1	1
114. Las Quinchas Mountain Range	6.05	-74.27	I	1	1

Continues…

APPENDIX A — Continuation

Study sites	Latitude	Longitude	Protection category*	No. of studies	No. of studied orders
115. Los Colorados Biological Station	-24.72	-63.28	II	1	1
116. Lote Cristalino Private Reserve (Alta Floresta)	-9.6	-55.94	II	1	1
117. Mangabeiras Park	-19.93	-43.9	II	1	1
118. Manuel Antonio National Park	9.43	-84.15	II	1	1
119. Mariana Ranch	-11.41	-61.57	NP	1	1
120. Marista Nook	-23.55	-52.22	NP	1	1
121. Mata dos Godoy State Park	-23.45	-51.25	II	1	4
122. Mburucuyá National Park	-28.02	-58.06	II	1	1
123. Mogi Guaçu Biological Reserve	-22.27	-47.18	I	1	1
124. Nossa Senhora do Outeiro de Macaraípe Private Reserve	-8.53	-35.02	II	1	1
125. Olaria Woods	-21.38	-46.25	NP	1	1
126. Ometepe Island	11.44	-85.55	II	1	1
127. Órgãos Mountain Range	-22.45	-43.11	II	1	1
128. Pando Department, Cocamita	-11.18	-68.7	IV	1	1
129. Pando Department, Mucden	-11.2	-69.08	IV	1	1
130. Pando Department, San Sebastian	-11.4	-69.1	IV	1	1
131. Paranaíta, Mato Grosso	-9.57	-56.32	NP	1	1
132. Park of the Goeldi Museum	-1.45	-48.48	II	1	1
133. Passo do Lontra	-19.49	-57	NP	1	1
134. Paulo Cesar Vinha State Park	-20.6	-40.41	II	1	1
135. Payquerê Ranch	-25.63	-53.7	NP	1	1
136. Pico Bonito National Park	15.42	-86.73	II	1	1
137. Pico da Neblina National Park	0.37	-65.78	II	1	1
138. Prosa State Park	-20.45	-54.55	II	1	1
139. Ranchería Leona Vicario	17.7	-91.54	NP	1	1
140. Río Tabaro Valley	6.35	-65	NP	1	1
141. Sabiá Municipal Park	-18.91	-48.23	II	1	1
142. San Fernando de Apure	7.81	-68.64	NP	1	1
143. San Juan del Carare Ranch	6.15	-74.09	NP	1	1
144. Sangay National Park	-1.98	-78.4	II	1	1
145. Santa Gemma e Maggion Ranches	-20.76	-47.31	NP	1	1
146. Serra Grande Hydroelectric Power Plant	-8.97	-36.07	II	1	1
147. Soberanía National Park	9.15	-79.73	II	1	1
148. Tapajós National Forest	-3.35	-54.93	VI	1	1
149. Tietê Ecological Park	-23.5	-46.52	II	1	1
150. Tumbes National Reserve	-3.82	-80.31	IX	1	1
151. Upper Essequibo Conservation Concession	-3.53	-58.24	IV	1	1
152. Vale Natural Reserve	-19.14	-40.06	II	1	1
153. Various sites - Venezuela	7.68	-67.61	NP	1	1
154. Volta Velha Private Reserve	-26.07	-48.62	II	1	1

155. Yotoco Natural Forest Reserve	3.83	-76.33	IV	1	1
156. Yumká Park	17.87	-92.87	II	1	1

APPENDIX B — List of 373 published and unpublished studies of fruit consumption by neotropical birds and mammals with full reference, study sites (according to appendix 1), frugivore orders contemplated, no. of interacting frugivore and plant species, method of sampling (F= faecal sampling, SC= stomach content sampling, V= visual sampling), data source (original work or secondary cited data), and type of study. Frugivore Orders: Aves: Co = Columbiformes, Cu = Cuculiformes, Cr = Coraciiformes, Ga = Galliformes, Pa = Passeriformes, Pi = Piciformes, Ps = Psittaciformes, St = Struthioniformes, Tr = Trogoniformes; Mammalia: Ar = Artiodactyla, Ca = Carnivora, Ch = Chiroptera, Di = Didelphimorphia, Pe = Perissodactyla, Pr = Primates, Ro = Rodentia.

Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
1. Aguiar, L. M., Reis, N. R., Ludwig, G., & Rocha, V. J. (2003). Dieta, área de vida, vocalizações e estimativas populacionais de *Alouatta guariba* em um remanescente florestal do Norte do estado do Paraná. Neotropical Primates, 11(2), 78–86.	54	Pr	1	10	F & V	12	Original	Journal article
2. Aguiar, L. M., Moro-Rios, R. F., Silvestre, T., Silva-Pereira, J. E., Bilski, D. R., Passos, F. C., Sekiama, M. L., Rocha, V. J. (2011). Diet of brown-nosed coatis and crab-eating raccoons from a mosaic landscape with exotic plantations in southern Brazil. Studies on Neotropical Fauna and Environment, 46(3), 153–161. Retrieved from https://doi.org/10.1080/01650521.2011.640567	62	Ca	2	13	SC	NA	Original	Journal article
3. Aguiar, L. M. S., & Marinho-Filho, J. (2007). Bat frugivory in a remnant of Southeastern Brazilian Atlantic forest. Acta Chiropterologica, 9(1), 251–260. Retrieved from https://doi.org/10.3161/1733-5329(2007)9[251:BFIARO]2.0.CO;2	55	Ch	7	15	F	11	Original	Journal article
4. Altrichter, M., Carrillo, E., Sáenz, J., & Fuller, T. K. (2001). White-lipped peccary (*Tayassu pecari*, Artiodactyla: Tayassuidae) diet and fruit availability in a Costa Rican rain forest. Revista de Biología Tropical, 49(3), 1183–1192.	28	Ar	1	37	F & V	9	Original	Journal article
5. Alvarenga, C. A., & Talamoni, S. A. (2006). Foraging behaviour of the Brazilian squirrel *Sciurus aestuans* (Rodentia, Sciuridae). Acta Theriologica, 51(1), 69–74. Retrieved from https://doi.org/10.1007/BF03192657	31	Ro	1	9	V	8	Original	Journal article
6. Braza, F., Alvarez, F., & Azcarate, T. (1983). Feeding habits of the red howler monkeys (*Alouatta seniculus*) in the Llanos of Venezuela. Mammalia, 47(2), 459–473. Retrieved from https://doi.org/10.1515/mamm.1983.47.2.205	142	Pr	1	18	F, SC & V	12	Original	Journal article
7. Alves. (2008). Composição da avifauna e frugivoria por aves em um mosaico sucessional na Mata Atlântica. Dissertation (*Master*). Instituto de Biociências, Universidade Estadual Paulista. 107p.	104	Pa, Co	25	16	V	NA	Original	Dissertation
8. Alves-Costa, C. P., & Eterovick, P. C. (2007). Seed dispersal services by coatis (*Nasua nasua*, Procyonidae) and their redundancy with other frugivores in southeastern Brazil. Acta Oecologica, 32(1), 77–92. Retrieved from https://doi.org/10.1016/j.actao.2007.03.001	117	Ca	1	32	F	33	Original	Journal article

9. Amato, K. R., & Estrada, A. (2010). Seed dispersal patterns in two closely related howler monkey species (*Alouatta palliata* and *A. pigra*): A preliminary report of differences in fruit consumption, traveling behavior, and associated dung beetle assemblages. Neotropical Primates, 17(2), 59–66.	3	Pr	1	13	F & V	2	Original	Journal article
9. Amato, K. R., & Estrada, A. (2010). Seed dispersal patterns in two closely related howler monkey species (*Alouatta palliata* and *A. pigra*): A preliminary report of differences infruit consumption, traveling behavior, and associated dung beetle assemblages. Neotropical Primates, 17(2), 59–66.	64	Pr	1	25	F & V	2	Original	Journal article
10. Amato, K. R., & Garber, P. A. (2014). Nutrition and foraging strategies of the black howler monkey (*Alouatta pigra*) in Palenque National Park, Mexico. American Journal of Primatology, 76(8), 774–787. Retrieved from https://doi.org/10.1002/ajp.22268	64	Pr	1	29	V	10	Original	Journal article
11. Amatuzzi, M. C. O. (2009). Redes de interações entre plantas e frugívoros na Mata Atlântica: estrutura e fragilidade a extinções (master's dissertation). Department of Ecology, Universidade Estadual de Campinas. 121 p.	6	Co, Cr, Ga, Pa, Pi, Ps, St, Tr, Ar, Ca, Ch, Di, Pe, Pr, Ro	112	207	F & V	58	Original	Dissertation
12. Amboni, M. P. D. M. (2007). Dieta, disponibilidade alimentar e padrão de movimentação de lobo-guará, *Chrysocyon brachyurus*, no Parque Nacional da Serra da Canastra, MG (master's dissertation), Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais. 108 p.	70	Ca	1	28	F	15	Original	Dissertation
13. Andrade, T. Y., Thies, W., Rogeri, P. K., Kalko, E. K. V., & Mello, M. A. R. (2013). Hierarchical fruit selection by neotropical leaf-nosed bats (Chiroptera: Phyllostomidae). Journal of Mammalogy, 94(5), 1094–1101. Retrieved from https://doi.org/10.1644/12-MAMM-A-244.1	1	Ch	2	27	F	NA	Original	Journal article
14. Anzelc, A. (2009). The foraging and travel patterns of white-faced sakis in Brownsberg Nature Park, Suriname: Preliminary evidence for goal-directed foraging behavior. Thesis (Master of Arts). Kent State University, 194 p.	49	Pr	1	23	V	3	Original	Thesis
15. Aquino, R., & Bodmer, R. E. (2004). Plantas útiles en la alimentación de primates en la cuenca del Río Samiria, Amazonia peruana. Neotropical Primates, 12(1), 1–6.	39	Pr	9	47	V	43	Original	Journal article
16. Aquino, R. (2005). Alimentación de mamíferos de caza en los «aguajales» de la Reserva Nacional de Pacaya-Samiria (Iquitos, Perú). Revista Peruana de Biología, 12(3), 417-425.	39	Ar, Pr, Ro	13	16	V	10	Original	Journal article

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APPENDIX B — Continuation

	Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
17.	Aranguren, C. I., Gonzalez-Carcacia, J. A., Martinez, H., & Nassar, J. M. (2011). *Noctilio albiventris* (Noctilionidae), a potential seed disperser in disturbed tropical dry forest habitats. Acta Chiropterologica, 13(1), 189–194. Retrieved from https://doi.org/10.3161/150811011X578732	25	Ch	8	4	F	10	Original	Journal article
18.	Arceo, G., Mandujano, S., Gallina, S., & Perez-Jimenez, L. A. (2005). Diet diversity of white-tailed deer (*Odocoileus virginianus*) in a tropical dry forest in Mexico. Mammalia, 69(2), 159–168. Retrieved from https://doi.org/10.1515/mamm.2005.014	14	Ar	1	3	F	10	Original	Journal article
19.	Asensio, N., Cristobal-Azkarate, J., Dias, P. A. D., Vea, J. J., & Rodríguez-Luna, E. (2007). Foraging habits of *Alouatta palliata mexicana* in three forest fragments. Folia Primatologica, 78(3), 141–153. Retrieved from https://doi.org/10.1159/000099136	3	Pr	1	20	V	34	Original	Journal article
20.	Atramentowicz, M. (1988). La frugivorie opportuniste de trois marsupiaux didelphidés de Guyane. Revue d'Écologie (La Terre et La Vie), 43, 47–56.	41	Di	3	22	F & V	NA	Original	Journal article
21.	Autino, A. G., & Barquez, R. M. (1993). Patrones reproductivos y alimenticios de dos especies simpatricas del genero *Sturnira* (Chiroptera, Phyllostomidae). Mastozoología Neotropical, 1(1), 73–80.	57	Ch	2	7	F & SC	23	Original	Journal article
22.	Bachand, M., Trudel, O. C., Ansseau, C., & Almeida-Cortez, J. (2009). Dieta de *Tapirus terrestris* Linnaeus em um fragmento de Mata Atlântica do Nordeste do Brasil. Revista Brasileira de Biociências, 7(2), 188–194.	146	Pe	1	23	F & V	4	Original	Journal article
23.	Baiao, S. A. A., Correia, F., & Ferrari, S. F. (2015). Dietary differences have contrasting effects on the seed dispersal potential of the titi monkey *Callicebus coimbrai* in north-eastern Brazil. Journal of Tropical Ecology, 31(2), 175–181. Retrieved from https://doi.org/10.1017/S0266467414000649	37	Pr	1	20	F & V	4	Original	Journal article
24.	Barnett, A. A., De Castilho, C. V., Shapley, R. L., & Anicácio, A. (2005). Diet, habitat selection and natural history of *Cacajao melanocephalus ouakary* in Jaú National Park, Brazil. International Journal of Primatology, 26(4), 949–969. Retrieved from https://doi.org/10.1007/s10764-005-5331-5	59	Pr	1	26	V	3	Original	Journal article
25.	Barnett, A. A., Boyle, S. A., Pinto, L. P., Lourenço, W. C., Almeida, T., Silva, W. S., Ronchi-Teles, B., Bezerra, B. M., Ross, C., MacLarnon, A., & Spironello, W. R. (2012). Primary seed dispersal by three Neotropical seed-predating primates (*Cacajao melanocephalus ouakary*, *Chiropotes chiropotes* and *Chiropotes albinasus*). Journal of	59	Pr	1	7	V	19	Original	Journal article

	Tropical Ecology, 28(6), 543–555. Retrieved from https://doi.org/10.1017/S0266467412000600								
25.	Barnett, A. A., Boyle, S. A., Pinto, L. P., Lourenço, W. C., Almeida, T., Silva, W. S., Ronchi-Teles, B., Bezerra, B. M., Ross, C., MacLarnon, A., & Spironello, W. R. (2012). Primary seed dispersal by three Neotropical seed-predating primates (*Cacajao melanocephalus ouakary*, *Chiropotes chiropotes* and *Chiropotes albinasus*). Journal of Tropical Ecology, 28(6), 543–555. Retrieved from https://doi.org/10.1017/S0266467412000600	148	Pr	1	56	V	11	Original	Journal article
26.	Barreto, G., Hernandez, O., & Ojast, J. (1997). Diet of peccaries (*Tayassu tajacu* and *T. pecari*) in a dry forest of Venezuela. Journal of Zoology, 241(2), 279–284. Retrieved from https://doi.org/10.1111/j.1469-7998.1997.tb01958.x	25	Ar	2	18	F, SC & V	10	Original	Journal article
27.	Barros, M. A. S., Rui, A. M., & Fabian, M. E. (2013). Seasonal variation in the diet of the bat *Anoura caudifer* (Phyllostomidae: Glossophaginae) at the southern limit of its geographic range. Acta Chiropterologica, 15(1), 77–84. Retrieved from https://doi.org/10.3161/150811013X667876	71	Ch	1	6	F	12	Original	Journal article
28.	Beck, H. (2005). Seed predation and dispersal by peccaries throughout the Neotropics and its consequences: a review and synthesis. In P.-M. Forget, J. E. Lambert, P. E. Hulme, & S. B. Vander Wall (Eds.), Seed fate: Predation, Dispersal and Seedling Establishment (pp. 77–115). CABI Publishing.	3	Ar	1	8	V	NA	Original	Book chapter
28.	Beck, H. (2005). Seed predation and dispersal by peccaries throughout the Neotropics and its consequences: a review and synthesis. In P.-M. Forget, J. E. Lambert, P. E. Hulme, & S. B. Vander Wall (Eds.), Seed fate: Predation, Dispersal and Seedling Establishment (pp. 77–115). CABI Publishing.	9	Ar	2	16	F & V	NA	Original	Book chapter
28.	Beck, H. (2005). Seed predation and dispersal by peccaries throughout the Neotropics and its consequences: a review and synthesis. In P.-M. Forget, J. E. Lambert, P. E. Hulme, & S. B. Vander Wall (Eds.), Seed fate: Predation, Dispersal and Seedling Establishment (pp. 77–115). CABI Publishing.	5	Ar	2	3	V	NA	Original	Book chapter
28.	Beck, H. (2005). Seed predation and dispersal by peccaries throughout the Neotropics and its consequences: a review and synthesis. In P.-M. Forget, J. E. Lambert, P. E. Hulme, & S. B. Vander Wall (Eds.), Seed fate: Predation, Dispersal and Seedling Establishment (pp. 77–115). CABI Publishing.	2	Ar	1	14		NA	Secondary data	Book chapter
29.	Behie, A. M., & Pavelka, M. S. M. (2005). The short-term effects of a hurricane on the diet and activity of black howlers (*Alouatta pigra*) in Monkey River, Belize. Folia Primatologica, 76(1), 1–9. Retrieved from https://doi.org/10.1159/000082450	61	Pr	1	7	V	12	Original	Journal article

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APPENDIX B — Continuation

	Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
30.	Beltzer, A. H., Quiroga, M., Latino, S., & Comini, B. (2004). Feeding ecology of the Grayish Saltator *Saltator coerulescens* (Aves: Emberizidae) in the Parana river floodplain (Argentina). Orsis, 19, 91–99.	86	Pa	1	7	SC	NA	Original	Journal article
31.	Bernard, E. (2002). Diet, activity and reproduction of bat species (Mammalia, Chiroptera) in Central Amazonia, Brazil. Revista Brasileira de Zoologia. Retrieved from https://doi.org/10.1590/S0101-81752002000100016	4	Ch	21	19	F	6	Original	Journal article
32.	Berndt, A. (2005). Nutrição e ecologia nutricional de cervídeos brasileiros em cativeiro e no Parque Nacional das Emas (Doctoral thesis). Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo. 80 p.	23	Ar	1	10	V	12	Original	Thesis
33.	Bertsch, C., & Barreto, G. R. (2008). Diet of the yellow-knobbed curassow in the central Venezuelan Llanos. The Wilson Journal of Ornithology, 120(4), 767–777. Retrieved from https://doi.org/10.1676/07-172.1	25	Ga	1	31	F, SC & V	8	Original	Journal article
34.	Bianchi, R. de C., Campos, R. C., Xavier-Filho, N. L., Olifiers, N., Gompper, M. E., & Mourão, G. (2014). Intraspecific, interspecific, and seasonal differences in the diet of three mid-sized carnivores in a large neotropical wetland. Acta Theriologica, 59(1), 13–23. Retrieved from https://doi.org/10.1007/s13364-013-0137-x	20	Ca	2	18	F	27	Original	Journal article
35.	Bianchi, C. A. (2009). Notes on the ecology of the yellow-faced parrot (*Alipiopsitta xanthops*) in central Brazil. Ornitologia Neotropical, 20(4), 479–489.	23	Os	1	6	V	NA	Original	Journal article
36.	Bianconi, G. V. (2009). Morcegos frugívoros no uso do hábitat fragmentado e seu potencial para recuperação de áreas degradadas: subsídios para uma nova ferramenta voltada à conservação (Doctoral thesis). Instituto de Biociências de Rio Claro, Universidade Estadual Paulista. 97 p.	74	Ch	11	32	F	47	Original	Thesis
37.	Bisbal, F., & Ojasti, J. (1980). Nicho trofico del zorro Cerdocyon thous (Mammalia, Carnivora). Acta Biologica Venezolana, 10(4), 469–496.	153	Ca	1	18	SC	NA	Original	Journal article
38.	Bobrowiec, P. E. D. (2003). Padrão alimentar de morcegos frugívoros em áreas alteradas da Amazônia central (master's dissertation). Biologia Tropical e Recursos Naturais, Intituto Nacional de Pesquisas da Amazônia & Universidade Federal do Amazonas. 56p.	4	Ch	6	11	F	12	Original	Dissertation
39.	Bodmer, R. E. (1990). Fruit patch size and frugivory in the lowland tapir (*Tapirus terrestris*). Journal of Zoology, 222(1), 121–128. Retrieved from https://doi.org/10.1111/j.1469-7998.1990.tb04034.x	30	Pe	1	8	SC	16	Original	Journal article

40.	Bodmer, R. E. (1990). Responses of ungulates to seasonal inundations in the Amazon floodplain. Journal of Tropical Ecology, 6(2), 191–201. Retrieved from https://doi.org/10.1017/S0266467400004314	30	Ar	3	13	SC	16	Original	Journal article
41.	Bodmer, R. E. (1991). Strategies of seed dispersal and seed predation in Amazonian ungulates. Biotropica, 23(3), 255. Retrieved from https://doi.org/10.2307/2388202	30	Pe	1	16	F & SC	16	Original	Journal article
42.	Bonaccorso, F. J., & Humphrey, S. R. (1984). Fruit bat niche dynamics: their role in maintaining tropical forest diversity. In A. C. Chadwick & S. L. Sutton (Eds.), Tropical rain-forest: the Leeds Symposium (pp. 169–183). Leeds, UK: Leeds Philosphical & Literary Society.	1	Ch	7	20		NA	Secondary data	Book chapter
43.	Bonaccorso, F. J. (1979). Foraging and reproductive ecology in a panamanian bat community. Bulletin of the Florida State Museum, Biological Sciences, 24(4), 359–408.	1	Ch	13	26	F & V	17	Original	Journal article
44.	Boubli, J. P. (1999). Feeding ecology of black-headed uacaris (*Cacajao melanocephalus melanocephalus*) in Pico da Neblina National Park, Brazil. International Journal of Primatology, 20(5), 719–749. Retrieved from https://doi.org/10.1023/a:1020704819367	137	Pr	1	119	V	16	Original	Journal article
45.	Bowler, M., & Bodmer, R. E. (2011). Diet and food choice in Peruvian red uakaris (*Cacajao calvus ucayalii*): selective or opportunistic seed predation? International Journal of Primatology, 32(5), 1109–1122. Retrieved from https://doi.org/10.1007/s10764-011-9527-6	60	Pr	1	162	V	25	Original	Journal article
46.	Boyle, S. A., Zartman, C. E., Spironello, W. R., & Smith, A. T. (2012). Implications of habitat fragmentation on the diet of bearded saki monkeys in central Amazonian forest. Journal of Mammalogy, 93(4), 959–976. Retrieved from https://doi.org/10.1644/11-MAMM-A-286.1	4	Pr	1	234	V	11	Original	Journal article
47.	Bravo, S. P. S., & Sallenave, A. (2003). Foraging behavior and activity patterns of *Alouatta caraya* in the northeastern Argentinean flooded forest. International Journal of Primatology, 24(4), 825–846.	83	Pr	1	12	V	17	Original	Journal article
48.	Briones, M., & Sánchez-Cordero, V. (1999). Dietary value of fruits and seeds to spiny pocket mice (*Liomys pictus*) in a tropical deciduous forest in Mexico. Studies on Neotropical Fauna and Environment, 34(2), 65–71. Retrieved from https://doi.org/10.1076/snfe.34.2.65.2101	14	Ro	1	11	V	NA	Original	Journal article

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APPENDIX B — Continuation

Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
49. Brito, J. E. C., Gazarini, J., & Zawadzki, C. H. (2010). Abundância e frugivoria da quiropterofauna (Mammalia, chiroptera) de um fragmento no noroeste do Estado do Paraná, Brasil. Acta Scientiarum - Biological Sciences, 32(3), 265–271. Retrieved from https://doi.org/10.4025/actascibiolsci.v32i3.5351	120	Ch	5	11	F	9	Original	Journal article
50. Brown, A., Chalukian, S., & Malmierca, L. (1984). Habitat y alimentación de *Cebus apella* en el NO argentino y la disponibilidad de frutos en el dosel arboreo. Revista Del Museo Argentino de Ciencias Naturales Bernardino Rivadavia, 13(1–60), 273–280.	22	Pr	1	2	V	18	Original	Journal article
51. Brown, A. D., & Zunino, G. E. (1990). Dietary variability in Cebus apella in extreme habitats: evidence for adaptability. Folia Primatologica, 54, 187–195. Retrieved from https://doi.org/10.1159/000156443	12	Pr	1	2	V	NA	Original	Journal article
52. Buchanan-Smith, H. M. (1991). A field study on the red-bellied tamarin, *Saguinus l. labiatus*, in Bolivia. International Journal of Primatology, 12(3), 259–276. Retrieved from https://doi.org/10.1007/BF02547587	128	Pr	1	16	V	5	Original	Journal article
53. Bueno, R. S., Guevara, R., Ribeiro, M. C., Culot, L., Bufalo, F. S., & Galetti, M. (2013). Functional redundancy and complementarities of seed dispersal by the last neotropical megafrugivores. PLoS ONE, 8(2). Retrieved from https://doi.org/10.1371/journal.pone.0056252	36	Pe, Pr	2	27	F	14	Original	Journal article
54. Bueno, A. de A., Belentani, S. C. da S., & Motta-Junior, J. C. (2002). Feeding ecology of the maned wolf, *Chrysocyon brachyurus* (Illiger, 1815) (Mammalia: Canidae), in the Ecological Station of Itirapina, São Paulo state, Brazil. Biota Neotropica, 2(2), 1–9. Retrieved from https://doi.org/10.1590/S1676-06032002000200007	106	Ca	1	22	F	45	Original	Journal article
55. Cáceres, N. C., Prates, L. Z., Ghizoni-Junior, I. R., & Graipel, M. E. (2009). Frugivory by the black-eared opossum *Didelphis aurita* in the Atlantic Forest of southern Brazil: Roles of sex, season and sympatric species. Biotemas, 22(3), 203–211. Retrieved from https://doi.org/10.5007/2175-7925.2009v22n3p203	113	Di	1	8	F	6	Original	Journal article
56. Camargo, N. F. De, Cruz, R. M. S., Ribeiro, J. F., & Vieira, E. M. (2011). Frugivoria e potencial dispersão de sementes pelo marsupial Gracilinanus agilis (Didelphidae: Didelphimorphia) em áreas de Cerrado no Brasil central. Acta Botanica Brasilica, 25(3), 646–656. Retrieved from https://doi.org/10.1590/S0102-33062011000300018	24	Di	1	8	F	12	Original	Journal article

57.	Camargo, C. C. (2005). Ecologia comportamental de *Alouatta belzebul* (Linnaeus, 1766) na Amazônia oriental sob alteração antrópica de hábitat (master's dissertation). Zoologia, Museu Paraense Emílio Goeldi & Universidade Federal do Pará. 92p.	11	Pr	1	10	V	6	Original	Dissertation
58.	Campuzano, M. D. L., & Bacherer, L. A. S. (1999). Determinación de la dieta del aguara guazú (*Chrysocyon brachyurus*) durante la estación lluviosa en el parque Nacional Noel Kempff Mercado. In: T. G. Fang, O. L. Montenegro, & R. E. Bodmer (Eds.), Manejo y conservación de fauna silvestre en América Latina (pp. 397-399). Instituto de Ecología, Universidad Mayor de San Andrés.	38	Ca	1	13	F	NA	Original	Book chapter
59.	Canale, G. R., Kierulff, M. C. M., & Chivers, D. J. (2013). A critically endangered capuchin monkey (*Sapajus xanthosternos*) living in a highly fragmented hotspot. In L. K. Marsh & C. A. Chapman (Eds.), Primates in Fragments: Complexity and Resilience (pp. 299–311). New York, NY: Springer New York. Retrieved from https://doi.org/10.1007/978-1-4614-8839-2_20	17	Pr	1	10	V	16	Original	Book chapter
60.	Capece, P. I., Aliaga-Rossel, E., & Jansen, P. A. (2013). Viability of small seeds found in feces of the Central American tapir on Barro Colorado Island, Panama. Integrative Zoology, 8(1), 57–62. Retrieved from https://doi.org/10.1111/j.1749-4877.2012.00313.x	1	Pe	1	16	F	4	Original	Journal article
61.	Cardoso, N. A., Le Pendu, Y., Lapenta, M. J., & Raboy, B. E. (2011). Frugivory patterns and seed dispersal by golden-headed lion tamarins (*Leontopithecus chrysomelas*) in Una Biological Reserve, Bahia, Brazil. Mammalia, 75(4), 327–337. Retrieved from https://doi.org/10.1515/MAMM.2011.042	17	Pr	1	57	F & V	11	Original	Journal article
62.	Carrillo, E., Wong, G., & Rodriguez, M. A. (2001). Hábitos alimentarios del mapachín (*Procyon lotor*) (Carnivora: Procyonidae) en un bosque muy húmedo tropical costero de Costa Rica. Revista de Biología Tropical, 49(3–4), 1193–1197.	118	Ca	1	7	F	21	Original	Journal article
63.	Carrillo-Bilbao, G., Di Fiore, A., & Fernández-Duque, E. (2005). Dieta, forrajeo y presupuesto de tiempo en cotoncillos (*Callicebus discolor*) del Parque Nacional Yasuní en la Amazonia Ecuatoriana. Neotropical Primates, 13(2), 7–11. Retrieved from https://doi.org/10.1896/1413-4705.13.2.7	19	Pr	1	19	V	8	Original	Journal article
64.	Carvalho, F. M. V. De, Pinheiro, P. S., Fernandez, F. A. dos S., & Nessimian, J. L. (1999). Diet of small mammals in Atlantic Forest fragments in southeastern Brazil. Revista Brasileira de Zoociências, 1(1), 91–101.	10	Di, Ro	6	5	F	NA	Original	Journal article

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APPENDIX B — Continuation

	Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
65.	Carvalho, F. M. V, Fernandez, F. A. S., & Nessimian, J. L. (2005). Food habits of sympatric opossums coexisting in small Atlantic Forest fragments in Brazil. Mammalian Biology, 70(6), 366–375. Retrieved from https://doi.org/10.1016/j.mambio.2005.08.003	10	Di	2	8	F	NA	Original	Journal article
66.	Carvalho, C. T. (1961). Sobre os hábitos alimentares de Phillostomídeos (Mammalia, Chiroptera). Revista de Biología Tropical, 9(1), 53–60.	132	Ch	3	9	V	NA	Original	Journal article
67.	Carvalho-Ricardo, M. C., Uieda, W., Fonseca, R. C. B., & Rossi, M. N. (2014). Frugivory and the effects of ingestion by bats on the seed germination of three pioneering plants. Acta Oecologica, 55, 51–57. Retrieved from https://doi.org/10.1016/j.actao.2013.11.008	21	Ch	5	11	F	12	Original	Journal article
68.	Carvalho-Ricardo, M. C. (2013). Germinação de sementes e importância relativa da qualidade, disponibilidade e morfologia de frutos na dieta de *Carollia perspicillata* (Chiroptera: Phyllostomidae). Thesis (Doctorate). Instituto de Biociências, Universidade Estadual Paulista. 97p.	21	Ch	1	10	F	12	Original	Thesis
69.	Casella, J. (2006). Dieta e frugivoria por marsupiais didelfideos em uma floresta estacional semidecidual no Parque Nacional Do Iguaçu, Paraná, Brasil (master's dissertation). Ecologia E Conservação, Universidade Federal de Mato Grosso do Sul. 50p	12	Di	3	5	F	6	Original	Dissertation
70.	Caselli, C. B., & Setz, E. Z. F. (2011). Feeding ecology and activity pattern of black-fronted titi monkeys (*Callicebus nigrifrons*) in a semideciduous tropical forest of southern Brazil. Primates, 52(4), 351–359. Retrieved from https://doi.org/10.1007/s10329-011-0266-2	58	Pr	1	41	V	9	Original	Journal article
71.	Castro, A. F. S. 2012. Dispersión de semillas por murciélagos en zonas abiertas heterogeneas adyacentes a fragmentos de bosque de la Orinoquía colombiana (master's thesis). Ciencias-Biología, Universidad Nacional de Colombia. 72p.	7	Ch	20	19	F	7	Original	Thesis
72.	Catenacci, L. S., De Vleeschouwer, K. M., & Nogueira-Filho, S. L. G. (2009). Seed dispersal by golden-headed lion tamarins *Leontopithecus chrysomelas* in southern Bahian Atlantic Forest, Brazil. Biotropica, 41(6), 744–750. Retrieved from https://doi.org/10.1111/j.1744-7429.2009.00530.x	17	Pr	1	24	F	12	Original	Journal article

73.	Caywood, J. M. (1980). Ecology of Guatemalan howler monkeys (*Alouatta pigra* Lawrence). University of Montana Theses, Dissertations, Professional Papers. Paper 7254.	32	Pr	1	7	V	4	Original	Dissertation
74.	Cestari, C., & Pizo, M. A. (2013). Frugivory by the White-bearded Manakin (*Manacus manacus*, Pipridae) in restinga forest, an ecosystem associated to the Atlantic forest. Biota Neotropica, 13(2), 345–350. Retrieved from http://doi.org/10.1590/S1676-06032013000200038	108	Pa	1	57	F & V	24	Original	Journal article
75.	Chalukian, S. C., de Bustos, M. S., & Lizárraga, R. L. (2013). Diet of lowland tapir (*Tapirus terrestris*) in El Rey National Park, Salta, Argentina. Integrative Zoology, 8(1), 48–56. Retrieved from https://doi.org/10.1111/j.1749-4877.2012.12009.x	22	Pe	1	23	F & V	78	Original	Journal article
76.	Chapman, C. A., & Fedigan, L. M. (1990). Dietary differences between neighboring *Cebus capucinus* groups: local traditions, food availability or responses to food profitability? Folia Primatologica. Retrieved from https://doi.org/10.1159/000156442	2	Pr	1	19	V	18	Original	Journal article
77.	Chapman, C. (1987). Flexibility in diets of three species of Costa Rican primates. Folia Primatologica, 49(2), 90–105. Retrieved from https://doi.org/10.1159/000156311	2	Pr	2	9	V	21	Original	Journal article
78.	Chapman, C. A. (1989). Primate seed dispersal: the fate of dispersed seeds. Biotropica, 21(2), 148–154. Retrieved from https://doi.org/10.2307/2388705	2	Pr	3	26	F	26	Original	Journal article
79.	Charles-Dominique, P., & Cockle, A. (2001). Frugivory and seed dispersal by bats. In F. Bongers, P. Charles-Dominique, P.-M. Forget, & M. Théry (Eds.), Nouragues: Dynamics and plant-animal interactions in a neotropical rainforest (pp. 207–216). Springer Netherlands. Retrieved from https://doi.org/10.1007/978-94-015-9821-7_19	5	Ch	10	22	F	NA	Original	Book chapter
80.	Charles-Dominique, P. (1991). Feeding strategy and activity budget of the frugivorous bat *Carollia perspicillata* (Chiroptera: Phyllostomidae) in French Guiana. Journal of Tropical Ecology, 7(2), 243. Retrieved from https://doi.org/10.1017/S026646740000540X	41	Ch	1	10	F	17	Original	Journal article
81.	Chaves, Ó. M., Stoner, K. E., Arroyo-Rodríguez, V., & Estrada, A. (2011). Effectiveness of Spider Monkeys (*Ateles geoffroyi vellerosus*) as Seed Dispersers in Continuous and Fragmented Rain Forests in Southern Mexico. International Journal of Primatology, 32(1), 177–192. Retrieved from https://doi.org/10.1007/s10764-010-9460-0	16	Pr	1	25	F & V	15	Original	Journal article
82.	Chiarello, A. G. (1994). Diet of the brown howler monkey *Alouatta fusca* in a semi-deciduous forest fragment of southeastern Brazil. Primates, 35(1), 25–34. Retrieved from https://doi.org/10.1007/BF02381483	8	Pr	1	12	V	12	Original	Journal article

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APPENDIX B — Continuation

Study reference		Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
83.	Castro, J. M. (2010). Dieta estacional del borochi (*Chrysocyon brachyurus*) en el Parque Nacional Noel Kempff Mercado (PNK): Reserva Biológica el Refugio Huanchaca (ERH) y posibles causas de su variación temporal. (Lic. thesis). Universidad Autónoma "Gabriel Rene Moreno", Santa Cruz de La Sierra.	38	Ca	1	19	F	5	Original	Journal article
84.	Coelho Jr, A. M., Bramblett, C. A., Quick, L. B., & Bramblett, S. S. (1976). Resource availability and population density in primates: a soci-bioenergetic analysis of the energy budgets of Guatemalan howler and spider monkeys. Primates, 17, 63–80. Retrieved from https://doi.org/10.1007/BF02381567	32	Pr	2	23	V	3	Original	Journal article
85.	Corrêa, H. K. M. (2006). Ecologia de dois grupos de sagüis-brancos, *Mico argentatus* (Linnaeus 1771), em um fragmento florestal natural, Santarém-Pará (Doctoral thesis). Zoologia, Museu Paraense Emílio Goeldi e Universidade Federal do Pará. 135p.	77	Pr	1	28	V	16	Original	Thesis
86.	Correia, J. M. de S. (1997). Utilização de espécies frutíferas da Mata Atlântica na alimentação da avifauna da Reserva Biológica de Poço das Antas, RJ (master's dissertation). Instituto de Biologia, Universidade de Brasília. 92 p.	10	Co, Pa, Pi	45	13	V	15	Original	Dissertation
87.	Correia, F. B. de A. (2014). Dispersão de sementes por guigós (*Callicebus coimbrai*) e conservação da Mata do Junco, Capela/SE (master's dissertation). Desenvolvimento e Meio Ambiente, Universidade Federal de Sergipe. 73p.	37	Pr	1	25	F & V	11	Original	Dissertation
88.	Costa, E. M. de J. (2009). Preferência alimentar, dispersão de sementes e ecologia comportamental de quatis (*Nasua nasua* - Procyonidae - Carnivora) em fragmentos de cerrado, Campo Grande, Mato Grosso do Sul (Doctoral thesis). Ecologia e Conservação, Universidade Federal do Mato Grosso do Sul. 172p.	138	Ca	1	23	F & V	NA	Original	Thesis
89.	Coutinho, L. A. (2012). Variação sazonal e longitudinal na ecologia do guariba-de-mãos-ruivas, *Alouatta belzebul* (Primates, Atelidae), na fazenda Pacatuba, Paraíba (master's dissertation). Ecologia e Conservação, Universidade Federal de Sergipe. 85p.	98	Pr	1	6	F & V	7	Original	Dissertation
90.	Culot, L., Lazo, F. J. J. M., Huynen, M. C., Poncin, P., & Heymann, E. W. (2010). Seasonal variation in seed dispersal by tamarins alters seed rain in a secondary rain forest. International Journal of Primatology, 31(4), 553–569. Retrieved from https://doi.org/10.1007/s10764-010-9413-7	30	Pr	2	292	F & V	24	Original	Journal article
91.	Dalponte, J. C., & Lima, E. D. S. (1999). Disponibilidade de frutos e a dieta de *Lycalopex vetulus* (Carnivora - Canidae) em um cerrado de Mato Grosso, Brasil. Revista Brasileira	90	Ca	1	27	F	30	Original	Journal article

	de Botânica, 22, 325–332. Retrieved from https://doi.org/10.1590/S0100-84041999000500015								
92.	De Ruiter, J. R. (1986). The influence of group size on predator scanning and foraging behaviour of wedgecapped capuchin monkeys (*Cebus olivaceus*). Behaviour, 98(1), 240–258. Retrieved from https://doi.org/10.1163/156853986X00982	15	Pr	1	6	V	5	Original	Journal article
93.	Dear, F., Vaughan, C., & Polanco, A. M. (2010). Current status and conservation of the Scarlet Macaw (*Ara macao*) in the Osa Conservation Area (ACOSA), Costa Rica. Cuadernos de Investigacion UNED, 2(1), 7–21.	28	Ps	1	59	V	NA	Original	Journal article
94.	Defler, T. R., & Defler, S. B. (1996). Diet of a group of *Lagothrix Lagothricha lagothricha* in southeastern Colombia. International Journal of Primatology, 17(2), 161–190. Retrieved from https://doi.org/10.1007/BF02735446	33	Pr	1	180	V	33	Original	Journal article
95.	Defler, T. R. (1979). On the ecology and behavior of *Cebus albifrons* in eastern Colombia: I. Ecology. Primates, 20(4), 475–490. Retrieved from https://doi.org/10.1007/BF02373430	96	Pr	1	32	V	6	Original	Journal article
96.	Desbiez, A. L. J., & Lima-Borges, P. A. (2010). Density, habitat selection and observations of South American coati *Nasua nasua* in the central region of the Brazilian Pantanal wetland. Small Carnivore Conservation, 42(1), 14–18.	20	Ca	1	22	V	28	Original	Journal article
97.	Desbiez, A. L. J., Santos, S. A., Keuroghlian, A., & Bodmer, R. E. (2009). Niche partitioning among white-lipped peccaries (*Tayassu pecari*), collared peccaries (*Pecari tajacu*), and feral pigs (*Sus Scrofa*). Journal of Mammalogy, 90(1), 119–128. Retrieved from https://doi.org/10.1644/08-MAMM-A-038.1	20	Ar	2	11	F	16	Original	Journal article
98.	Dew, J. L. (2005). Foraging, food choice, and food processing by sympatric ripe-fruit specialists: *Lagothrix lagotricha poeppigii* and *Ateles belzebuth belzebuth*. International Journal of Primatology, 26(5), 1107–1135. Retrieved from https://doi.org/10.1007/s10764-005-6461-5	19	Pr	2	52	V	12	Original	Journal article
99.	Di Fiore, A. (2004). Diet and feeding ecology of woolly monkeys in a western Amazonian Rain Forest. International Journal of Primatology, 25(4), 767–801. Retrieved from https://doi.org/10.1023/B:IJOP.0000029122.99458.26	19	Pr	1	96	V	12	Original	Journal article
100.	Díaz, A. C., Barbosa C., C. E., & de la Ossa V., J. (1986). Aspectos ecologicos y etologicos de primates com enfasis em *Alouatta seniculus* (Cebidae), de la region de Coloso, Serrania San Jacinto (Sucre), costa norte de Colombia. Caldasia, 14(68/70), 709–741.	68	Pr	1	15	V	NA	Original	Journal article

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APPENDIX B — Continuation

Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
101. Dietz, J. M., Peres, C. A., & Pinder, L. (1997). Foraging ecology and use of space in wild golden lion tamarins (*Leontopithecus rosalia*). American Journal of Primatology, 41(4), 289–305. Retrieved from https://doi.org/10.1002/(SICI)1098-2345(1997)41:4<289::AID-AJP2>3.0.CO;2-T	10	Pr	1	58	V	14	Original	Journal article
102. Dinerstein, E. (1986). Reproductive ecology of fruit bats and the seasonality of fruit production in a Costa Rican cloud forest. Biotropica, 18(4), 307–318. Retrieved from https://doi.org/10.2307/2388574	63	Ch	2	31	F	16	Original	Journal article
103. Donatti, C. I., Guimarães, P. R., Galetti, M., Pizo, M. A., Marquitti, F. M. D., & Dirzo, R. (2011). Analysis of a hyper-diverse seed dispersal network: Modularity and underlying mechanisms. Ecology Letters, 14(8), 773–781. Retrieved from https://doi.org/10.1111/j.1461-0248.2011.01639.x	44	Co, Cu, Ga, Pa, Pi, Ps, St, Tr, Ar, Ca, Pe, Pr, Ro	44	44	F & V	NA	Original	Journal article
104. Downer, C. C. (2001). Observations on the diet and habitat of the mountain tapir (*Tapirus pinchaque*). Journal of Zoology, 254(3), 279–291. Retrieved from https://doi.org/10.1017/S0952836901000796	144	Pe	1	70	F & V	NA	Original	Journal article
105. Dunn, J. C., Cristóbal-Azkarate, J., & Veà, J. J. (2010). Seasonal variations in the diet and feeding effort of two groups of howlers in different sized forest fragments. International Journal of Primatology, 31(5), 887–903. Retrieved from https://doi.org/10.1007/s10764-010-9436-0	3	Pr	1	68	V	10	Original	Journal article
106. Egler, S. G. (1992). Feeding ecology of *Saguinus bicolor bicolor* (Callitrichidae: Primate) in a relict forest in Manaus, Brazilian Amazonia. Folia Primatologica, 59(2), 61–76. Retrieved from https://doi.org/10.1159/000156644	4	Pr	1	23	V	11	Original	Journal article
107. Emmert, L. (2012). Dieta e uso do habitat pelo lobo-guará (*Chrysocyon brachyurus*, Illiger, 1815) na Floresta Nacional de Brasília (master's dissertation). Departamento de Engenharia Florestal, Universidade de Brasília. 86 p.	34	Ca	1	11	F	12	Original	Dissertation
108. Encarnación, F. and Cook, A. G. 1998. Primates of the tropical forest of the Pacific coast of Peru: The Tumbes Reserved Zone. Primate Conservation 18: 15–20.	150	Pr	3	29	V	4	Original	Journal article
109. Erard, C., Théry, M., & Sabatier, D. (2007). Fruit characters in the diet of syntopic large frugivorous forest bird species in French Guiana. Revue d'Écologie (La Terre et La Vie), 62(4), 323–350.	5	Ga	2	65	SC	NA	Original	Journal article
110. Estrada, A., & Coates-Estrada, R. (1984). Fruit eating and seed dispersal by howling monkeys (*Alouatta palliata*) in the tropical rain forest of Los Tuxtlas, Mexico.	3	Pr	1	19	V	60	Original	Journal article

	American Journal of Primatology, 6(2), 77–91. Retrieved from https://doi.org/10.1002/ajp.1350060202								
111.	Estrada, A., Coates-Estrada, R., Vasquez-Yanes, C., & Orozco-Segovia, A. (1984). Comparison of frugivory by howling monkeys (*Alouatta palliata*) and bats (*Artibeus jamaicensis*) in the tropical rain forest of Los Tuxtlas, Mexico. American Journal of Primatology, 7(1), 3–13. Retrieved from https://doi.org/10.1002/ajp.1350070103	3	Ch, Pr	2	37	F & V	12	Original	Journal article
112.	Faria, D. M. (1996). Uso de recursos alimentares por morcegos filostomídeos fitófagos na Reserva de Santa Genebra, Campinas, São Paulo (master's dissertation). Instituto de Biologia, Universidade Estadual de Campinas, 86 p.	8	Ch	8	23	F	16	Original	Dissertation
113.	Faustino, T. C., & Machado, C. G. (2006). Frugivoria por aves em uma área de campo rupestre na Chapada Diamantina, BA. Revista Brasileira de Ornitologia, 14(2), 137–143.	89	Pa	9	10	V	12	Original	Journal article
114.	Felton, A. M., Felton, A., Wood, J. T., & Lindenmayer, D. B. (2008). Diet and feeding ecology of *Ateles chamek* in a Bolivian semihumid forest: the importance of *Ficus* as a staple food resource. International Journal of Primatology, 29(2), 379–403. Retrieved from https://doi.org/10.1007/s10764-008-9241-1	110	Pr	1	38	V	13	Original	Journal article
115.	Fernandes, C. C. (2013). Padrão de atividade, dieta e uso do espaço por *Callicebus personatus* (Primates, Pitheciidae) em uma área de parque urbano, município de Santa Teresa, ES (master's dissertation). Biologia Animal, Universidade Federal do Espírito Santo. 34 p.	42	Pr	1	14	V	7	Original	Dissertation
116.	Ferrol-Schute. (2008). Changes in the behavioural and feeding ecology of the red uakari monkey (*Cacajao calvus ucayalii)* at the Lago Preto Conservation Concession, Peru (master's dissertation). Durrell Institute of Conservation and Ecology, University of Kent. 64p.	60	Pr	1	11	V	4	Original	Dissertation
117.	Fleming, T. H. (1991). The relationship between body size, diet, and habitat use in frugivorous bats, genus *Carollia* (Phyllostomidae). Journal of Mammalogy, 72(3), 493–501.	2	Ch	2	5	F	NA	Original	Journal article
118.	Fleming, T. H., & Heithaus, E. R. (1986). Seasonal foraging behavior of the frugivorous bat *Carollia perspicillata*. Journal of Mammalogy, 67(4), 660–671.	2	Ch	1	11	F	4	Original	Journal article
119.	Fleming, T. H., Heithaus, E. R., & Sawyer, W. B. (1977). An experimental analysis of the food location behavior of frugivorous bats. Ecology, 58(3), 619–627. Retrieved from https://doi.org/10.2307/1939011	2	Ch	7	11	F	4	Original	Journal article

Continues…

APPENDIX B — Continuation

Study reference		Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
120.	Fleming, T. H. (1988). The short-tailed fruit bat: A study in plant-animal interactions. Chicago: University of Chicago Press.	2	Ch	1	18	F	70	Original	Book chapter
121.	Fogaça, M. D. (2014). Comportamento alimentar e propriedades físicas dos alimentos consumidos por macacos-prego (*Sapajus nigritus*), no Parque Estadual Carlos Botelho (Doctoral thesis). Psicologia Experimental, Universidade de São Paulo. 80p.	36	Pr	1	14	V	24	Original	Thesis
122.	Fortes, V. B. (2008). Ecologia e comportamento do Bugio-Ruivo (*Alouatta guariba clamitans* Cabrera, 1940) em fragmentos florestais na depressão central do Rio Grande do Sul, Brasil (Doctoral thesis). Zoologia, Pontifícia Universidade Católica do Rio Grande do Sul. 130p.	85	Pr	1	18	V	12	Original	Thesis
123.	Foster, R. B., Arce, J. B., & Wachter, T. S. (1986). Dispersal and the sequential plant communities in Amazonian Peru floodplain. In A. Estrada & T. H. Fleming (Eds.), Frugivores and Seed Dispersal (pp. 357–370). Dordrecht: Dr. W. Junk Publishers.	9	Ch	7	11		NA	Secondary data	Book chapter
124.	Fragoso, J. M. V., & Huffman, J. M. (2000). Seed-dispersal and seedling recruitment patterns by the last neotropical megafaunal element in Amazonia, the tapir. Journal of Tropical Ecology, 16(3), 369–385. Retrieved from https://doi.org/10.1017/S0266467400001462	13	Pe	1	25	F	13	Original	Journal article
125.	Fragoso, J. M. V. (1999). Perception of scale and resource partitioning by peccaries: behavioral causes and ecological implications. Journal of Mammalogy, 80, 993–1003. Retrieved from https://doi.org/10.2307/1383270	13	Ar	2	9	V	13	Original	Journal article
126.	Frazão, E. R. (1992). Dieta e estrategia de forragear de *Chiropotes satanas chiropotes* (Cebidae: Primates) na Amazônia Central Brasileira (master's dissertation). Biologia Tropical e Recursos Naturais, Instituto Nacional de Pesquisas da Amazônia & Universidade Federal do Amazonas. 116p.	4	Pr	1	148	V	12	Original	Dissertation
127.	Freese, C. H. (1977). Food habits of the white-faced capuchins *Cebus capucinus* L. (Primates: Cebidae) in Santa Rosa National Park, Costa Rica. Brenesia, 10/11, 45–56.	2	Pr	2	46	V	17	Original	Journal article
128.	Freitas, C. H. De, Setz, E. Z. F., Araújo, A. R. B., & Gobbi, N. (2008). Agricultural crops in the diet of bearded capuchin monkeys, *Cebus libidinosus* Spix (Primates: Cebidae), in forest fragments in southeast Brazil. Revista Brasileira de Zoologia, 25(1), 32–39.	145	Pr	1	47	V	13	Original	Journal article
129.	Fuentes, E., Estrada, a., Franco, B., Magaña, M., Decena, Y., Muñoz, D., & García, Y. (2003). Reporte preliminar sobre el uso de recursos alimenticios pro una tropa de	112	Pr	1	9	V	5	Original	Journal article

	monos aulladores, *Alouatta palliata*, en el Parque La Venta, Tabasco, México. Neotropical Primates, 11(1), 24–29.								
130.	Galetti, M., & Morellato, L. P. C. (1994). Diet of the large fruit-eating bat *Artibeus lituratus* in a forest fragment in Brasil. Mammalia, 58(4), 661–665.	8	Ch	1	19	F	12	Original	Journal article
131.	Galetti, M., Keuroghlian, A., Hanada, L., & Inez Morato, M. (2001). Frugivory and seed dispersal by the Lowland Tapir (*Tapirus terrestris*) in Southeast Brazil. Biotropica, 33(4), 723. Retrieved from https://doi.org/10.1646/0006-3606(2001)033[0723:FASDBT]2.0.CO;2	35	Pe	1	9	F	NA	Original	Journal article
132.	Galetti, M., Laps, R., & Pizo, M. A. (2000). Frugivory by toucans (Ramphastidae) at two altitudes in the Atlantic Forest of Brazil. Biotropica, 32(4b), 842–850.	6	Pi	4	53	V	67	Original	Journal article
133.	Galetti, M., & Pedroni, F. (1994). Seasonal diet of capuchin monkeys (*Cebus apella*) in a semideciduous forest in south-east Brazil. Journal of Tropical Ecology, 10(1), 27–39.	8	Pr	1	59	V	45	Original	Journal article
134.	Galetti, M., & Pizo, M. A. (1996). Fruit eating by birds in a forest fragment in southeastern Brazil. Ararajuba, 4(2), 71–79.	8	Ga, Pa, Pi	30	34	V	45	Original	Journal article
135.	Galetti, M. (1993). Diet of the scaly-headed parrot (*Pionus maximiliani*) in a semideciuous forest in Southeatern Brazil. Biotropica. Retrieved from https://doi.org/10.1002/jez.b.22	8	Ps	1	37	V	45	Original	Journal article
136.	Galetti, M. (1992). Sazonalidade na dieta de vertebrados frugívoros em uma floresta semidecídua no Sudeste do Brasil (master's thesis). Instituto de Biologia, Universidade Estadual de Campinas. 103 p.	8	Pr	1	21	V	45	Original	Dissertation
137.	Galindo-González, J., Guevara, S., & Sosa, V. J. (2000). Bat- and bird-generated seed rains at isolated trees in pastures in a tropical rainforest. Conservation Biology, 14(6), 1693–1703. Retrieved from https://doi.org/10.1111/j.1523-1739.2000.99072.x	3	Ch	5	6	F	12	Original	Journal article
138.	García-Amado, M. A., Rodríguez-Ferraro, A., & Bosque, C. (2011). Dieta y eficiencia digestiva del Lechosero pechiblanco *Saltator orenocensis*. Revista Venezolana de Ornitología, 1(1), 4–16.	15	Pa	1	12	V	10	Original	Journal article
139.	Gatti, A., Bianchi, R., Rosa, C. R. X., & Mendes, S. L. (2006). Diet of two sympatric carnivores, *Cerdocyon thous* and *Procyon cancrivorus*, in a restinga area of Espirito Santo State, Brazil. Journal of Tropical Ecology, 22(2), 227–230. Retrieved from https://doi.org/10.1017/S0266467405002956	134	Ca	2	11	F	27	Original	Journal article
140.	Ghilardi Jr., R., & Alho, C. J. R. (1990). Produtividade sazonal da floresta e atividade de forrageamento animal em habitat de terra firme da Amazônia. Acta Amazonica, 20, 61–76.	11	Ar, Pr, Ro	9	25	V	13	Original	Journal article

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APPENDIX B — Continuation

Study reference		Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
141.	Giannini, N. P., & Kalko, E. K. V. (2004). Trophic structure in a large assemblage of phyllostomid bats in Panama. Oikos, 105, 209–220.	1	Ch	23	48	F & V	120	Original	Journal article
142.	Giombini, M. I., Bravo, S. P., & Martínez, M. F. (2009). Seed dispersal of the palm *Syagrus romanzoffiana* by tapirs in the semi-deciduous atlantic forest of Argentina. Biotropica, 41(4), 408–413. Retrieved from https://doi.org/10.1111/j.1744-7429.2009.00526.x	12	Pe	1	3	F	4	Original	Journal article
143.	Giraldo, P., Gómez-Posada, C., Martínez, J., & Kattan, G. (2007). Resource use and seed dispersal by red howler monkeys (*Alouatta seniculus*) in a Colombian Andean Forest. Neotropical Primates, 14(2), 55–64. Retrieved from https://doi.org/10.1896/044.014.0202	29	Pr	1	13	F & V	6	Original	Journal article
144.	Glanz, W. E., Thorington Jr, R. W., Giancalone-Madden, J., & Heaney, L. R. (1983). Seasonal food use and demographic trends in *Sciurus granatensis*. In E. G. Leigh Jr., A. S. Rand, & D. M. Windsor (Eds.), The Ecology of a Tropical Forest: Seasonal Rhythms and Long-Term Changes (pp. 239–252). Oxford: Oxford University Press.	1	Ro	1	61	V	19	Original	Book chapter
145.	Gomes, A. L. S. (2008). Interação mutualística entre aves frugívoras de sub-bosque e plantas no Parque Ecológico de Gunma, Santa Bárbara do Pará (master's dissertation). Zoologia, Museu Paraense Emílio Goeldi & Universidade Federal do Pará. 79p.	103	Pa, Pi	11	12	F	NA	Original	Dissertation
146.	Gómez, A. M. S. (1999). Ecologia e comportamento de *Alouatta seniculus* em uma mata de terra firme na amazônia central (master's dissertation). Ecologia, Conservação e Manejo de Vida Silvestre, Universidade Federal de Minas Gerais. 73p.	4	Pr	1	17	F & V	7	Original	Dissertation
147.	Gómez-Posada, C. (2012). Dieta y comportamiento alimentario de un grupo de mico maicero *Cebus apella* de acuerdo a la variación en la oferta de frutos y artrópodos, en la Amazonía colombiana. Acta Amazonica, 42(3), 363–372. Retrieved from https://doi.org/10.1590/S0044-59672012000300008	33	Pr	1	92	V	12	Original	Journal article
148.	Gorchov, D. L., Cornejo, F., Ascorra, C. F., & Jaramillo, M. (1995). Dietary overlap between frugivorous birds and bats in the Peruvian Amazon. Oikos, 74(2), 235–250. Retrieved from https://doi.org/10.2307/3545653	107	Pa, Ch	18	77	F	18	Original	Journal article
149.	Goulart, F. F. (2007). Aves em quintais agroflorestais do Pontal do Paranapanema, São Paulo: epistemologia, estrutura de comunidade e frugivoria (master's dissertation).	66	Pa, Pi, Ps	5	45	V	12	Original	Dissertation

	Ecologia, Conservação e Manejo da Vida Silvestre, Universidade Federal de Minas Gerais. 86p.							
150.	Gregory, T. (2006). Comparative socioecology of sympatric, free-ranging White-Faced and Bearded Sakis in Brownsberg Nature Park, Suriname (master's dissertation). Kent State University, 88 p.	49	Pr	2	66	V	5	Original	Dissertation
151.	Griffin, N. C. (2013). The use of fallback foods in a population of Black Handed Spider Monkeys at Runaway Creek Nature Reserve, Belize (master's thesis). Anthropology, University of Calgary. 62p.	67	Pr	1	16	V	21	Original	Thesis
152.	Guillotin, M., Dubost, G., & Sabatier, D. (1994). Food choice and food competition among the three major primate species of French Guiana. Journal of Zoology, 233, 551–579.	5	Pr	3	108	SC	21	Original	Journal article
153.	Guix, J. C., Ruiz, X., & Jover, L. (2001). Resource partitioning and interspecific competition among coexisting species of Guans and Toucans in SE Brazil. Netherlands Journal of Zoology, 51(3), 285–297. Retrieved from https://doi.org/10.1163/156854201X00107	105	Ga, Pi	6	38	V	NA	Original	Journal article
154.	Handley, C. O., Wilson, D. E., & Gardner, A. L. (1991). Demography and natural history of the common fruit bat, *Artibeus jamaicensis*, on Barro Colorado Island, Panamá. Smithsonian Contributions to Zoology, (511), 1–173. Retrieved from https://doi.org/10.5479/si.00810282.511	1	Ch	13	19	F & V	NA	Original	Journal article
155.	Heithaus, E. R., & Fleming, T. H. (1978). Foraging movements of a frugivorous bat, *Carollia perspicillata* (Phyllostomatidae). Ecological Monographs, 48(2), 127–143. Retrieved from https://doi.org/10.2307/2937296	2	Ch	1	10	V	6	Original	Journal article
156.	Heithaus, E. R., Fleming, T. H., & Opler, P. A. (1975). Foraging patterns and resource utilization in seven species of bats in a seasonal tropical forest. Ecology, 56(4), 841–854.	101	Ch	4	15	F	24	Original	Journal article
157.	Herrera M, L. G., Hobson, K. A., Manzo A, A., Estrada B, D., Sanchez-Cordero, V., & Mendez C, G. (2001). The role of fruits and insects in the nutrition of frugivorous bats: Evaluating the use of stable isotope models. Biotropica, 33(3), 520–528. Retrieved from https://doi.org/10.1111/j.1744-7429.2001.tb00206.x	3	Ch	2	3	F	6	Original	Journal article
158.	Hidalgo-Mihart, M. G., Cantú-Salazar, L., López-González, C. A., Martínez-Meyer, E., & González-Romero, A. (2001). Coyote (*Canis latrans*) food habits in a tropical deciduous forest of western Mexico. The American Midland Naturalist, 146(1), 210–216.	14	Ca	1	4	F	16	Original	Journal article

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APPENDIX B — Continuation

	Study reference	Study site	Frugivore Orders¹	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
159.	Hilário, R. R., & Ferrari, S. F. (2010). Feeding ecology of a group of buffy-headed marmosets (*Callithrix flaviceps*): Fungi as a preferred resource. American Journal of Primatology, 72(6), 515–521. Retrieved from https://doi.org/10.1002/ajp.20804	80	Pr	1	12	V	12	Original	Journal article
160.	Hines, J. J. H. (2005). Ecology and taxonomy of *Ateles geoffroyi* in Parque Nacional Pico Bonito, Atlántida, Honduras. (Doctoral thesis). Australian National University. 218 p.	136	Pr	1	7	V	12	Original	Thesis
161.	Hirsch, B. T. (2009). Seasonal variation in the diet of ring-tailed coatis (*Nasua nasua*) in Iguazu, Argentina. Journal of Mammalogy, 90(1), 136–143. Retrieved from https://doi.org/10.1644/08-MAMM-A-050.1	12	Ca	1	29	V	27	Original	Journal article
162.	Hladik, A., & Hladik, C. M. (1969). Rapports trophiques entre végétation et Primates dans la forêt de Barro Colorado (Panama). Revue d'Écologie (La Terre et La Vie), 23, 25–117.	1	Pr	5	68	V	15	Original	Journal article
163.	Ikuta, K. G., & Martins, F. D. C. (2013). Interação entre aves frugívoras e plantas no Parque Estadual da Cantareira, estado de São Paulo. Atualidades Ornitológicas, 172, 33–36.	51	Co, Ga, Pa, Pi, Ps	19	7	V	6	Original	Journal article
164.	Iwanaga, S., & Ferrari, S. F. (2001). Party size and diet of syntopic atelids (*Ateles chamek* and *Lagothrix cana*) in Southwestern Brazilian Amazonia. Folia Primatologica, 72(4), 217–227.	119	Pr	2	26	V	5	Original	Journal article
165.	Izar, P. (2008). Dispersão de sementes por *Cebus nigritus* e *Brachyteles arachnoides* em área de Mata Atlântica, Parque Estadual Intervales, SP. In S. F. Ferrari & J. Rímoli (Eds.), A Primatologia no Brasil (9th ed., pp. 8–24). Aracaju: Sociedade Brasileira de Primatologia, Biologia Geral e Experimental – UFS.	6	Pr	2	63	F	32	Original	Book chapter
166.	Izawa, K. (1975). Foods and feeding behavior of monkeys in the upper Amazon basin. Primates, 16(3), 295–316. Retrieved from https://doi.org/10.1007/BF02381557	7	Pr	1	27	V	2	Original	Journal article
167.	Jácomo, A. T. A., Silveira, L., & Diniz-Filho, J. A. F. (2004). Niche separation between the maned wolf (*Chrysocyon brachyurus*), the crab-eating fox (*Dusicyon thous*) and the hoary fox (*Dusicyon vetulus*) in central Brazil. Journal of Zoology, 262, 99–106. Retrieved from https://doi.org/10.1017/S0952836903004473	23	Ca	3	14	F	36	Original	Journal article
168.	Janson, C.H. (1975). Ecology and population densities of Primates in a Peruvian rainforest (B.A. thesis). Department of Biology, Princeton University. 96 pp.	9	Pr	2	8		NA	Secondary data	Book chapter

169.	Janson, C. (1985). Aggresive competition and individual food consumption in wild brown capuchin monkeys (*Cebus apella*). Behavioral Ecology and Sociobiology, 18(2), 125–138. Retrieved from https://doi.org/10.1007/BF00299041	9	Pr	1	4	V	25	Original	Journal article
170.	Janzen, D. H. (1982). Seeds in tapir dung in santa Rosa National Park, Costa Rica. Brenesia, 19/20, 129–135.	2	Pe	1	14	F	NA	Original	Journal article
171.	Jones, E., Gallo, A., Lebbin, D. J., Pott, C., Leavelle, K. M., & Powell, L. L. (2014). Notes on the distribution, natural history, and conservation of the Yellow-billed Cotinga (*Carpodectes antoniae*). Ornitologia Neotropical, 25, 169–177.	28	Pa	1	9	V	20	Original	Journal article
172.	Julien-Laferrière, D. (1999). Foraging strategies and food partitioning in the neotropical frugivorous mammals *Caluromys philander* and *Potos flavus*. Journal of Zoology, 247(1), 71–80. Retrieved from https://doi.org/10.1111/j.1469-7998.1999.tb00194.x	41	Di, Ca	2	39	V	22	Original	Journal article
173.	Julien-Laferrière, D. (1993). Radio-tracking observations on ranging and foraging patterns by kinkajous (*Potos flavus*) in French Guiana. Journal of Tropical Ecology, 9(1), 19. Retrieved from https://doi.org/10.1017/S0266467400006908	5	Ca	1	9	V	2	Original	Journal article
174.	Julien-Laferrière, D. (2001). Frugivory and seed dispersal by kinkajous. In F. Bongers, P. Charles-Dominique, P.-M. Forget, & M. Théry (Eds.), Nouragues: Dynamics and plant-animal interactions in a neotropical rainforest (1st ed., pp. 217–226). Springer Netherlands. Retrieved from https://doi.org/10.1007/978-94-015-9821-7_20	5	Ca	1	41	F & V	7	Original	Book chapter
175.	Julliot, C. (1996). Fruit choice by red howler monkeys (*Alouatta seniculus*) in a tropical rain forest. American Journal of Primatology, 40(3), 261–282. Retrieved from https://doi.org/10.1002/(SICI)1098-2345(1996)40:3<261::AID-AJP4>3.0.CO;2-W	5	Pr	1	97	F & V	19	Original	Journal article
176.	Kaufmann, J. H. (1962). Ecology and social behavior of the coati, *Nasua narica*, of Barro Colorado Island, Panama. University of California Publications in Zoology, 60(3), 95–222.	1	Ca	1	19	V	24	Original	Journal article
177.	Kays, R. W. (1999). Food preferences of kinkajous (*Potos flavus*): A frugivorous carnivore. Journal of Mammalogy, 80, 589–599. https://doi.org/10.2307/1383303	147	Ca	1	40	F & V	12	Original	Journal article
178.	Kelm, D. H., Wiesner, K. R., & Helversen, O. von. (2008). Effects of artificial roosts for frugivorous bats on seed dispersal in a neotropical forest pasture mosaic. Conservation Biology, 22(3), 733–741. Retrieved from https://doi.org/10.1111/j.1523-1739.2008.00925.x	27	Ch	3	29	F	NA	Original	Journal article

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APPENDIX B — Continuation

Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
179. Keuroghlian, A., Eaton, D. P., & Desbiez, A. L. J. (2009). The response of a landscape species, white-lipped peccaries, to seasonal resource fluctuations in a tropical wetland, the Brazilian pantanal. International Journal of Biodiversity and Conservation, 1(4), 87–97.	44	Ar	1	30	V	23	Original	Journal article
180. Keuroghlian, A., & Eaton, D. P. (2008). Fruit availability and peccary frugivory in an isolated Atlantic forest fragment: Effects on peccary ranging behavior and habitat use. Biotropica, 40(1), 62–70. Retrieved from https://doi.org/10.1111/j.1744-7429.2007.00351.x	35	Ar	2	18	F & V	46	Original	Journal article
181. Kiltie, R. A. (1981). Stomach contents of rain forest peccaries (*Tayassu tajacu* and *T. pecari*). Biotropica, 13(3), 4–5.	9	Ar	2	5	SC	7	Original	Journal article
182. Koch, F. (2008). Dieta e comportamento de um grupo de *Alouatta guariba clamitans* Cabrera, 1940: Uma relação de causa e efeito? (master's dissertation). Zoologia, Pontifícia Universidade Católica do Rio Grande do Sul. 48 p.	81	Pr	1	15	V	12	Original	Dissertation
183. Lapenta, M. J., Procópio-de-Oliveira, P., Kierulff, M. C. M., & Motta-Junior, J. C. (2008). Frugivory and seed dispersal of golden lion tamarin (*Leontopithecus rosalia* (Linnaeus, 1766)) in a forest fragment in the Atlantic Forest, Brazil. Brazilian Journal of Biology, 68(2), 241–249.	73	Pr	1	88	F & V	12	Original	Journal article
184. Lapenta, M. J., Procópio-de-Oliveira, P., Kierulff, M. C. M., & Motta-Junior, J. C. (2003). Fruit exploitation by Golden Lion Tamarins (*Leontopithecus rosalia*) in the União Biological Reserve, Rio das Ostras, RJ - Brazil. Mammalia, 67(1), 41–46. Retrieved from https://doi.org/10.1515/mamm.2003.67.1.41	73	Pr	1	57	V	24	Original	Journal article
185. Laranjeiras, T. O. (2011). Biology and population size of the Golden Parakeet (*Guaruba guarouba*) in western Pará, Brazil, with recommendations for conservation. Revista Brasileira de Ornitologia, 19(3), 303–314.	78	Ps	1	5	V	10	Original	Journal article
186. Leiner, N. O., & Silva, W. R. (2007). Seasonal variation in the diet of the Brazilian slender opossum (*Marmosops paulensis*) in a montane Atlantic forest area, southeastern Brazil. Journal of Mammalogy, 88(1), 158–164.	6	Di	1	9	F	24	Original	Journal article
187. Leiva, M. (2010). Frugivoria e germinação de sementes após passagem pelo sistema digestivo de marsupiais em floresta estacional semidecidual (master's dissertation). Instituto de Biologia, Universidade Estadual Paulista. 53 p.	21	Di	2	11	F	12	Original	Dissertation

188.	Lessa, L. G., & Costa, F. N. (2009). Food habits and seed dispersal by *Thrichomys apereoides* (Rodentia: Echimyidae) in a brazilian Cerrado Reserve. Mastozoología Neotropical, 16(2), 459–463.	45	Ro	1	4	F	24	Original	Journal article
189.	Lessa, L. G., & da Costa, F. N. (2010). Diet and seed dispersal by five marsupials (Didelphimorphia: Didelphidae) in a Brazilian cerrado reserve. Mammalian Biology, 75(1), 10–16. Retrieved from https://doi.org/10.1016/j.mambio.2008.11.002	45	Di	5	14	F	14	Original	Journal article
190.	Lessa, L. G. (2012). Ecologia alimentar e estratégias de germinação de sementes consumidas por marsupiais (Didelphimorphia: Didelphidae) em uma área de cerrado no sudeste do Brasil (Doctoral thesis). Ecologia e Evolução, Universidade do Estado do Rio de Janeiro. 87p.	45	Di	7	22	F	24	Original	Thesis
191.	Lima, E. M. (2014). Percepção de cores e ecologia alimentar de cuxiú de Uta Hick, *Chiropotes utahickae* Hershkovitz, 1985 (Mammalia: Primates) (Doctoral thesis). Biologia Animal, Universidade de Brasília. 106p.	109	Pr	1	47	V	10	Original	Thesis
192.	Linhares, K. V. (2009). Espécies vegetais estratégicas à conservação de *Antilophia bokermanii*, ave ameaçada e endêmica da Chapada do Araripe, Ceará, Brasil: Riqueza, uso e distribuição temporal de recursos (Doctoral thesis). Biologia Vegetal, Universidade Federal de Pernambuco. 143p.	48	Pa	1	22	F & V	44	Original	Thesis
193.	Link, A., Galvis, N., Marquez, M., Guerrero, J., Solano, C., & Stevenson, P. R. (2012). Diet of the critically endangered brown spider monkey (*Ateles hybridus*) in an inter-Andean lowland rainforest in Colombia. American Journal of Primatology, 74(12), 1097–1105. Retrieved from https://doi.org/10.1002/ajp.22066	114	Pr	1	97	V	30	Original	Journal article
194.	Link, A., & Di Fiore, A. (2006). Seed dispersal by spider monkeys and its importance in the maintenance of neotropical rain-forest diversity. Journal of Tropical Ecology, 22(3), 235–246. Retrieved from https://doi.org/10.1017/S0266467405003081	19	Pr	1	41	F & V	12	Original	Journal article
195.	Loayza, A. P., Rios, R. S., & Larrea-Alcázar, D. M. (2006). Disponibilidad de recurso y dieta de murciélagos frugívoros en la Estación Biológica Tunquini, Bolivia. Ecología en Bolivia, 41(1), 7–23.	47	Ch	6	6	F	13	Original	Journal article
196.	Lobova, T. A., Geiselman, C. K., & Mori, S. A. (2009). Seed dispersal by bats in the Neotropics. New York: New York Botanical Garden Press.	5	Ch	3	4	F	9	Original	Book chapter
197.	Londoño, G. A., Munoz, M. C., & Rios, M. M. (2007). Density and natural history of the sickle-winged guan (*Chamaepetes goudotii*) in the central Andes, Colombia. The Wilson Journal of Ornithology, 119(2), 228–238. Retrieved from https://doi.org/10.1676/06-041.1	29	Ga	1	24	F & V	12	Original	Journal article

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APPENDIX B — Continuation

Study reference		Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
198.	Lopes, M. A., & Ferrari, S. F. (1994). Foraging behavior of a tamarin group (*Saguinus fuscicollis weddelli*) and interactions with marmosets (*Callithrix emiliae*). International Journal of Primatology, 15(3), 373–387. Retrieved from https://doi.org/10.1007/BF02696099	84	Pr	1	25	V	9	Original	Journal article
199.	Lopez, J. E., & Vaughan, C. (2004). Observations on the role of frugivorous bats as seed dispersers in Costa Rican secondary humid forests. Acta Chiropterologica, 6(1), 111–119. Retrieved from https://doi.org/10.3161/001.006.0109	27	Ch	8	24	F	8	Original	Journal article
200.	Lou, S., & Yurrita, C. L. (2005). Análisis de nicho alimentario en la comunidad de murciélagos frugívoros de Yaxhá, Petén, Guatemala. Acta Zoológica Mexicana, 21(1), 83–94.	32	Ch	11	21	F	11	Original	Journal article
201.	Ludwig, G., Aguiar, L. M., & Rocha, V. J. (2005). Uma avaliação da dieta, da área de vida e das estimativas populacionais de *Cebus nigritus* (Goldfuss, 1809) em um fragmento florestal no norte do estado do Paraná. Neotropical Primates, 13(3), 12–18.	54	Pr	1	18	F & V	12	Original	Journal article
202.	Ludwig, G. (2011). Padrão de atividade, hábito alimentar, área de vida e uso do espaço do mico-leão-de-cara-preta (*Leontopithecus caissara* Lorini & Persson 1990) (Primates, Callitrichidae) no Parque Nacional do Superagui, Guaraqueçaba, Estado do Paraná (Doctoral thesis). Zoologia, Universidade Federal do Paraná. 146p.	72	Pr	1	43	V	19	Original	Thesis
203.	Macedo, L., Fernandez, F. A. S., & Nessimian, J. L. (2010). Feeding ecology of the marsupial *Philander frenatus* in a fragmented landscape in Southeastern Brazil. Mammalian Biology, 75(4), 363–369. Retrieved from https://doi.org/10.1016/j.mambio.2009.06.004	10	Di	1	13	F	NA	Original	Journal article
204.	MacKinnon, K. C. (2006). Food choice by juvenile capuchin monkeys (*Cebus capucinus*) in a tropical dry forest. In A. Estrada, P. A. Garber, M. S. M. Pavelka, & L. Luecke (Eds.), New Perspectives in the Study of Mesoamerican Primates (pp. 349–365). Boston: Springer US. Retrieved from https://doi.org/10.1007/0-387-25872-8_17	2	Pr	1	63	V	12	Original	Book chapter
205.	Magalhães, T. P. (2010). Ecologia, comportamento e associações poliespecíficas do macaco-de-cheiro (*Saimiri sciureus*), Amazônia oriental (master's dissertation). Zoologia, Museu Paraense Emílio Goeldi & Universidade Federal do Pará, 56p.	11	Pr	1	19	V	6	Original	Dissertation

206.	Mantilla, G. R. (2012). Ingestão alimentar e nutricional de *Callithrix jacchus*: relação com hierarquia social e disponibilidade de alimento (master's dissertation). Ecologia, Universidade Federal do Rio Grande do Norte. 63p.	79	Pr	1	9	V	11	Original	Dissertation
207.	Marinho-Filho, J. S. (1991). The coexistence of two frugivorous bat species and the phenology of their food plants in Brazil. Journal of Tropical Ecology, 7(1), 59–67.	58	Ch	2	14	F	12	Original	Journal article
208.	Marques, A. A. B., Rylands, A. B., & Schneider, M. (2008). Seed dispersal and germination by the brown howler monkey (*Alouatta guariba clamitans* Cabrera, 1940) in an area of Atlantic Forest in Southern Brazil. In S. F. Ferrari & J. Rímoli (Eds.), A Primatologia no Brasil (9th ed., pp. 109–113). Aracaju: Sociedade Brasileira de Primatologia, Biologia Geral e Experimental – UFS.	26	Pr	1	10	F & V	12	Original	Book chapter
209.	Marsh, L. K., & Loiselle, B. A. (2003). Recruitment of black howler fruit trees in fragmented forests of northern Belize. International Journal of Primatology, 24(1), 65–86. Retrieved from https://doi.org/10.1023/A:1021446512364	52	Pr	1	25	V	12	Original	Journal article
210.	Martínez-Romero, L. E., & Mandujano, S. (1995). Hábitos alimentarios del pecarí de collar (*Pecari tajacu*) en un bosque tropical caducifolio de Jalisco, México. Acta Zoológica Mexicana, 64, 1–20.	14	Ar	1	7	F & V	6	Original	Journal article
211.	Martins, M. M., & Setz, E. Z. F. (2000). Diet of buffy-tufted-eared marmosets (*Callithrix aurita*) in a forest fragment in Southeastern Brazil. International Journal of Primatology, 21(3), 467–476.	125	Pr	1	12	V	12	Original	Journal article
212.	Martins, M. M. (2008). Fruit diet of *Alouatta guariba* and *Brachyteles arachnoides* in Southeastern Brazil: Comparison of fruit type, color, and seed size. Primates, 49(1), 1–8. Retrieved from https://doi.org/10.1007/s10329-007-0050-5	82	Pr	2	21	F & V	12	Original	Journal article
213.	Martins, W. P. (2010). Densidade populacional e ecologia de um grupo macaco-prego-de-crista (*Cebus robustus*, Kuhl, 1820) na Reserva Natural Vale (Doctoral thesis). Ecologia, Conservação e Manejo de Vida Silvestre, Universidade Federal de Minas Gerais. 118p.	152	Pr	1	63	V	10	Original	Thesis
214.	Masat, O. M. O., Chatellenaz, M. L., & Fontana, J. L. (2011). Dieta del Ñandú *Rhea americana* (Aves: Rheidae) en el Parque Nacional Mburucuyá, Argentina. Brenesia, 75–76, 83–89.	122	St	1	16	F	5	Original	Journal article
215.	McKinney, T. (2010). Social and ecological impact of anthropogenic disturbance on the sympatric white-faced capuchin (*Cebus capucinus*) and mantled howler monkey (*Alouatta palliata*) (Doctoral dissertation). Graduate Program in Anthropology, The Ohio State University. 376p.	53	Pr	2	12	V	24	Original	Dissertation

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APPENDIX B — Continuation

	Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
216.	Mello, M. A. R., Schittini, G. M., Selig, P., & Bergallo, H. G. (2004). Seasonal variation in the diet of the bat *Carollia perspicillata* (Chiroptera: Phyllostomidae) in an Atlantic Forest area in southeastern Brazil. Mammalia, 68(1), 49–55.	10	Ch	1	11	F	18	Original	Journal article
217.	Mello, M. A. R., Kalko, E. K. V, & Silva, W. R. (2008). Diet and abundance of the bat *Sturnira lilium* (Chiroptera) in a Brazilian Montane Atlantic Forest. Journal of Mammalogy, 89(2), 485–492. Retrieved from https://doi.org/10.1644/06-MAMM-A-411R.1	6	Ch	1	10	F	15	Original	Journal article
218.	Mendes-Pontes, A. R. (1997). Habitat partitioning among primates in Maraca island, Roraima, northern Brazilian Amazonia. International Journal of Primatology, 18(2), 131–157.	13	Pr	5	35	V	6	Original	Journal article
219.	Mikich, S. B. (2001). Frugivoria e dispersão de sementes em uma pequena reserva isolada do Estado do Paraná, Brasil (Doctoral thesis). Zoologia, Universidade Federal do Paraná. 160p.	74	Co, Cr, Cu, Ga, Pa, Pi, Ps, Tr, Ar, Ca, Ch, Pr, Ro	88	115	F & V	120	Original	Thesis
220.	Miller, L. E. (1998). Dietary choices in *Cebus olivaceus*: a comparison of data from Hato Piñero and Hato Masaguaral, Venezuela. Primate Conservation, 18, 42–50.	25	Pr	1	26	V	13	Original	Journal article
221.	Miranda, J. M. D., & Passos, F. C. (2004). Hábito alimentar de *Alouatta guariba* (Humboldt) (Primates, Atelidae) em Floresta de Araucária, Paraná, Brasil. Revista Brasileira de Zoologia, 21(4), 821–826. Retrieved from https://doi.org/10.1590/S0101-81752004000400016	135	Pr	1	21	F & V	12	Original	Journal article
222.	Miranda, G. H. B. (1997). Aspectos da ecologia e comportamento do mico-estrela (*Callithrix penicillata*) no cerradão e cerrado denso da Área de Proteção Ambiental (APA) do Gama e Cabeça-de-Veado /DF (master's thesis). Ecologia, Universidade de Brasília. 97p.	24	Pr	1	14	V	8	Original	Dissertation
223.	Monge, J., & Hilje, L. (2006). Hábitos alimenticios de la ardilla *Sciurus variegatoides* (Rodentia: Sciuridae) en la Península de Nicoya, Costa Rica. Revista de Biología Tropical, 54(2), 681–686.	53	Ro	1	7	SC	12	Original	Journal article
224.	Montaño-Centellas, F. A. (2012). Are males and females of the Yungas Manakin (*Chiroxiphia boliviana*) ecologically redundant as seed dispersers? Ornitologia Neotropical, 23, 185–192.	47	Pa	1	10	F	9	Original	Journal article

225.	Montuy, G. P., & Serio Silva, J. C. (2006). Comportamiento alimentario de monos aulladores negros (*Alouatta pigra* Lawrence, Cebidae) em hábitat fragmentado en Balancán, Tabasco, México. Acta Zoológica Mexicana, 22(3), 53–66.	139	Pr	1	7	V	12	Original	Journal article
226.	Moraes, P. L. R. (1992). Espécies utilizadas na alimentação no mono-carvoeiro (*Brachyteles arachnoides* E. Geoffroy, 1806) no Parque Estadual de Carlos Botelho. Revista do Instituto Florestal, 4, 1206–1208.	36	Pr	1	40	F & V	NA	Original	Journal article
227.	Morais, A. A. (2006). Dieta frugivora de *Tapirus terrestris* e deposição de fezes: contribuição para a dispersão de sementes e regeneração de florestas, Amazônia Central, AM (master's dissertation). Biologia Tropical e Recursos Naturais, Instituto Nacional de Pesquisa da Amazônia & Universidade Federal do Amazonas. 59p.	18	Pe	1	38	F	3	Original	Dissertation
228.	Morrison, D. W. (1978). Foraging ecology and energetics of the frugivorous bat *Artibeus jamaicensis*. Ecology, 59(4), 716–723.	1	Ch	1	5	V	8	Original	Journal article
229.	Moscow, D., & Vaughan, C. (1987). Troop movement and food habits of white-faced monkeys in a tropical-dry forest. Revista de Biología Tropical, 35(2), 287–297.	40	Pr	1	23	V	2	Original	Journal article
230.	Mosquera, E. A. M. (2011). Papel de los murciélagos frugívoros como dispersores de semillas en la reserva forestal natural de Yotoco, municipio de Yotoco, Colombia (master's thesis). Biología, Universidad Nacional de Colombia. 100p.	155	Ch	12	20	F	5	Original	Thesis
231.	Motta-Junior, J. C. (1991). A exploração de frutos como alimento por aves de mata ciliar numa região do Distrito Federal (master's thesis). Instituto de Biociências, Universidade Estadual Paulista. 121p.	24	Pa, Pi	28				Original	
232.	Moura, A. C. D. A., & McConkey, K. R. (2007). The capuchin, the howler, and the Caatinga: Seed dispersal by monkeys in a threatened Brazilian forest. American Journal of Primatology, 69(2), 220–226. Retrieved from https://doi.org/10.1002/ajp.20343	46	Pr	2	18	F & V	17	Original	Journal article
233.	Mourthé, Í. M. C. (2012). Influência das características físico-químicas e disponibilidade dos frutos na ecologia dos primatas em uma floresta no norte da Amazônia (Doctoral thesis). Ecologia, Instituto Nacional de Pesquisas da Amazônia. 134p.	13	Pr	4	20	V	24	Original	Thesis
234.	Munin, R. L., Fischer, E., & Gonçalves, F. (2012). Food habits and dietary overlap in a phyllostomid bat assemblage in the Pantanal of Brazil. Acta Chiropterologica, 14(1), 195–204. Retrieved from https://doi.org/10.3161/150811012X654871	44	Ch	9	10	F	22	Original	Journal article

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APPENDIX B — Continuation

Study reference		Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
235.	Muñoz, M. C., Londoño, G. A., Rios, M. M., & Kattan, G. H. (2007). Diet of the Cauca Guan: Exploitation of a novel food source in times of scarcity. Condor, 109, 841–851. Retrieved from https://doi.org/10.1650/0010-5422(2007)109{[}841:DOTCGE]2.0.CO;2	29	Ga	1	14	F & V	12	Original	Journal article
236.	Naranjo, E. J. (2009). Ecology and conservation of Baird's tapir in Mexico. Tropical Conservation Science, 2(2), 140–158. Retrieved from https://doi.org/10.1016/S1470-2045(07)70104-3	16	Pe	1	12		NA	Secondary data	Journal article
237.	Neyman, P. F. (1977). Aspects of the ecology and social organization of free-ranging cotton-top tamarins (*Saguinus oedipus*) and the conservation status of the species. In D. G. Kleiman (Ed.), The Biology and Conservation of the Callitrichidae (pp. 39–71). Washington, D.C.: Smithsonian Institution Press.	68	Pr	1	46	V	24	Original	Book chapter
238.	Norconk, M. A., & Conklin-Brittain, N. Lou. (2004). Variation on frugivory: the diet of Venezuelan white-faced sakis. International Journal of Primatology, 25(1), 1–26. Retrieved from https://doi.org/10.1023/B:IJOP.0000014642.68751.ed	56	Pr	1	36	V	12	Original	Journal article
239.	Norconk, M. A., & Kinzey, W. G. (1994). Challenge of neotropical frugivory: Travel patterns of spider monkeys and bearded sakis. American Journal of Primatology, 34(2), 171–183. Retrieved from https://doi.org/10.1002/ajp.1350340208 // Kinzey, W. G., & Norconk, M. A. (1990). Hardness as a basis of fruit choice in two sympatric primates. American Journal of Physical Anthropology, 81, 5–15.	43	Pr	2	47	V	6	Original	Journal article
240.	Norconk, M. A., & Veres, M. (2011). Physical properties of fruit and seeds ingested by primate seed predators with emphasis on sakis and bearded sakis. The Anatomical Record, 294(12), 2092–2111. Retrieved from https://doi.org/10.1002/ar.21506	56	Pr	1	65	V	5	Original	Journal article
241.	Nunes, A. (1998). Diet and feeding ecology of *Ateles belzebuth belzebuth* at Maracá Ecological Station, Roraima, Brazil. Folia Primatologica, 69(2), 61–76. Retrieved from https://doi.org/10.1159/000021573	13	Pr	1	61	V	12	Original	Journal article
242.	Olea-Wagner, A., Lorenzo, C., Naranjo, E., Ortiz, D., & León-Paniagua, L. (2007). Diversidad de frutos que consumen tres especies de murciélagos (Chiroptera: Phyllostomidae) en la selva Lacandona, Chiapas, México. Revista Mexicana de Biodiversidad, 78, 191–200.	16	Ch	3	19	F	6		Journal article
243.	Oliveira, A. C. M., & Ferrari, S. F. (2000). Seed dispersal by black-handed tamarins, *Saguinus midas niger* (Callitrichinae, Primates): implications for the regeneration of	75	Pr	1	18	V	6	Original	Journal article

	degraded forest habitats in eastern Amazonia. Journal of Tropical Ecology, 16(2000), 709–716. Retrieved from https://doi.org/10.1017/S0266467400001668								
244.	Oliveira, S. G. de, Lynch Alfaro, J. W., & Veiga, L. M. (2014). Activity budget, diet, and habitat use in the critically endangered Ka'apor capuchin monkey (*Cebus kaapori*) in Pará State, Brazil: A preliminary comparison to other capuchin monkeys. American Journal of Primatology, 76(10), 919–931. Retrieved from https://doi.org/10.1002/ajp.22277	11	Pr	1	35	V	4	Original	Journal article
245.	Olmos, F. (1993). Diet of sympatric Brazilian caatinga peccaries (*Tayassu tajacu* and *T. pecari*). Journal of Tropical Ecology, 9(2), 255. Retrieved from https://doi.org/10.1017/S0266467400007276	46	Ar	2	3	V	5	Original	Journal article
246.	Olmos, F. (1993). Notes on the food habits of Brazilian "Caatinga" carnivores. Mammalia, 57(1), 126–130.	46	Ca	2	6	F & V	6	Original	Journal article
247.	Oppenheimer in prep. *Apud* Freese, C. H., & Oppenheimer, J. R. (1981). The capuchin monkeys, genus *Cebus.* In A. F. Coimbra-Filho & R. M. M. Mittermeier (Eds.), Ecology and Behavior of Neotropical Primates (vol. 1, pp. 331–390). Rio de Janeiro: Academia Brasileira de Ciências.	1	Pr	1	31		NA	Secondary data	Book chapter
248.	Oppenheimer, J. R. (1968). Behavior and ecology of the white-faced monkey, *Cebus capucinus*, on Barro Colorado Island, C.Z. (Doctoral dissertation). University of Illinois at Urbana-Champaign, 179p.	1	Pr	1	66	V	NA	Original	Thesis
249.	Oppenheimer, J. R. (1983). *Cebus capucinus*: Home range, population dynamics, and interspecific relationships. In E. G. Leigh Jr., A. S. Rand, & D. M. Windsor (Eds.), The Ecology of a Tropical Forest: Seasonal Rhythms and Long-Term Changes (pp. 253–272). Oxford: Oxford University Press.	1	Pr	1	98	V	33	Original	Book chapter
250.	Orozco-Segovia, A., Vázquez-Yanes, C., Armella, M. A., & Correa, N. (1985). Interacciones entre una población de murciélagos de la especie *Artibeus jamaicensis* y la vegetación del área circundante en la región de los Tuxtlas, Veracruz. In A. Gomez-Pompa & R. S. Del Amo (Eds.), Investigaciones sobre la regeneración de selvas altas en Veracruz, México, II (pp. 365–377). Instituto Nacional de Investigaciones Sobre Recursos Bióticos.	3	Ch	1	29	F	12	Original	Book chapter
251.	Palacios, E., Rodríguez, A., & Defler, T. R. (1997). Diet of a group of *Callicebus torquatus lugens* (Humboldt, 1812) during the annual resource bottleneck in Amazonian Colombia. International Journal of Primatology, 18(4), 503–522. Retrieved from https://doi.org/10.1023/A:1026307121583	33	Pr	1	49	V	6	Original	Journal article

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APPENDIX B — Continuation

Study reference		**Study site**	**Frugivore Orders[1]**	**No. of Frugivore spp.**	**No. of Plant spp.**	**Method**	**Duration (months)**	**Data Source**	**Type**
252.	Palacios, E., & Rodríguez, A. (2013). Seed eating by *Callicebus lugens* at Caparú Biological Station, on the lower Apaporis River, Colombian Amazonia. In L. M. Veiga, A. A. Barnett, S. F. Ferrari, & M. A. Norconk (Eds.), Evolutionary Biology and Conservation of Titis, Sakis and Uacaris (pp. 225–231). Cambridge: Cambridge University Press. Retrieved from https://doi.org/10.1017/CBO9781139034210.026	33	Pr	1	23	V	12	Original	Journal article
253.	Palma, A. C., & Stevenson, P. R. (2010). Dispersión de semillas por monos araña en la Estación Biológica Cocha Cashu, Parque Nacional Manu, Perú. In V. Pereira-Bengoa, P. R. Stevenson, M. L. Bueno, & F. Nassar-Montoya (Eds.), Primatología en Colombia: Avances al Princípio del Milenio (pp. 19–35). Bogotá: Fundación Universitaria San Martín; Facultad de Medicina Veterinaria y Zootecnia; Asociación Colombiana de Primatología.	9	Pr	1	56	F & V	6	Original	Book chapter
254.	Palmeirim, J. M., Gorchov, D. L., & Stoleson, S. (1989). Trophic structure of a neotropical frugivore community: is there competition between birds and bats? Oecologia, 79(3), 403–411. Retrieved from https://doi.org/10.1007/BF00384321	27	Pa, Ch	14	35	F	1	Original	Journal article
255.	Parrini, R., & Pacheco, J. F. (2014). Contribuição ao conhecimento das dietas fitófagas dos dois sanhaçus (*Thraupis cyanoptera* e *Thraupis ornata*) endêmicos da Mata Atlântica. Atualidades Ornitológicas, 177(1), 40–45.	127	Pa	2	28	V	43	Original	Journal article
256.	Paschoal, M., & Galetti, M. (1995). Seasonal food use by the neotropical squirrel *Sciurus ingrami* in southeastern Brazil. Biotropica, 27(2), 268–273.	8	Ro	1	14	V	36	Original	Journal article
257.	Passos, F. C., Silva, W. R., Pedro, W. A., & Bonin, M. R. (2003). Frugivoria em morcegos (Mammalia, Chiroptera) no Parque Estadual Intervales, sudeste do Brasil. Revista Brasileira de Zoologia, 20(3), 511–517.	6	Ch	6	23	F	13	Original	Journal article
258.	Passos, F. C., & Graciolli, G. (2004). Observações da dieta de *Artibeus lituratus* (Olfers) (Chiroptera, Phyllostomidae) em duas áreas do sul do Brasil. Revista Brasileira de Zoologia, 21(3), 487–489.	72	Ch	1	2	F	4	Original	Journal article
258.	Passos, F. C., & Graciolli, G. (2004). Observações da dieta de *Artibeus lituratus* (Olfers) (Chiroptera, Phyllostomidae) em duas áreas do sul do Brasil. Revista Brasileira de Zoologia, 21(3), 487–489.	154	Ch	1	4	F	4	Original	Journal article
259.	Passos, J. G., & Passamani, M. (2003). *Artibeus lituratus* (Chiroptera, Phyllostomidae): biologia e dispersão de sementes no Parque do Museu de Biologia Prof. Mello Leitão, Santa Tereza (ES). Natureza on Line, 1(1), 1–6.	42	Ch	1	10	F	19	Original	Journal article

260.	Passos, F. C. (1999). Dieta de um grupo de mico-leão-preto, *Leontopithecus chrysopygus* (Mikan) (Mammalia, Callitrichidae), na Estação Ecológica dos Caetetus, São Paulo. Revista Brasileira de Zoologia, 16(1), 269–278. Retrieved from https://doi.org/10.1590/S0101-81751999000500019	35	Pr	1	22	V	15	Original	Journal article
261.	Pedro, W. A. (1992). Estrutura de uma taxocenose de morcegos da Reserva do Panga (Uberlândia, MG), com ênfase nas relações tróficas em Phyllostomidae (Mammalia: Chiroptera) (master's dissertation). Instituto de Biologia, Universidade Estadual de Campinas. 110p.	65	Ch	7	11	F	37	Original	Dissertation
262.	Pellanda, M., Almeida, C., Santos, M. D. F., & Hartz, S. (2010). Dieta do mão-pelada (*Procyon cancrivorus*, Procyonidae, Carnivora) no Parque Estadual de Itapuã, sul do Brasil. Neotropical Biology and Conservation, 5(3), 154–159. Retrieved from https://doi.org/10.4013/nbc.2010.53.03	26	Ca	1	11	F	12	Original	Journal article
263.	Peres, C. A. (1993). Diet and feeding ecology of saddle-back (*Saguinus fuscicollis*) and moustached (*S. mystax*) tamarins in an Amazonian terra firme forest. Journal of Zoology, 230, 567–592.	18	Pr	2	173	V	13	Original	Journal article
264.	Peres, C. A. (1993). Notes on the ecology of buffy saki monkeys (*Pithecia albicans*, Gray 1860): A canopy seed-predator. American Journal of Primatology, 31(2), 129–140. Retrieved from https://doi.org/10.1002/ajp.1350310205	18	Pr	1	68	V	20	Original	Journal article
265.	Peres, C. A. (1994). Diet and feeding ecology of gray woolly monkeys (*Lagothrix lagotricha cana*) in Central Amazonia: Comparisons with other Atelines. International Journal of Primatology, 15(3), 333–372. Retrieved from https://doi.org/10.1007/BF02696098	18	Pr	1	72	V	11	Original	Journal article
266.	Peres, C. A. (1994). Primate responses to phenological changes in an Amazonian Terra Firme Forest. Biotropica, 26(1), 98. Retrieved from https://doi.org/10.2307/2389114	18	Pr	4	14	V	NA	Original	Journal article
267.	Perez-Cortez, S. & Reyna-Hurtado, R. (2008) La dieta de los pecaries (*Pecari tajacu* y *Tayassu pecari*) en la región de Calakmul, Campeche, México. Revista Mexicana de Mastozoología 12, 17–42.	50	Ar	2	21	F, SC & V	15	Original	Journal article
268.	Naranjo Piñera, E.J. & Cruz Aldán, E. (1998) Ecología del tapir (*Tapirus bairdii*) en la reserva de la Biósfera La Sepultura, Chiapas, México. Acta Zoológica Mexicana 73, 111–125.	111	Pe	1	20	F & V	16	Original	Journal article
269.	Pinheiro, P. S., Carvalho, F. M. V., Fernandez, F. A. S., & Nessimian, J. L. (2002). Diet of the marsupial *Micoureus demerarae* in small fragments of Atlantic forest in southeasten Brazil. Studies on Neotropical Fauna and Environment, 37(3), 213–218.	10	Di	1	16	F	29	Original	Journal article

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APPENDIX B — Continuation

	Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
270.	Pinto, A. C. B., Azevedo-Ramos, C., & de Carvalho Jr., O. (2003). Activity patterns and diet of the howler monkey *Alouatta belzebul* in areas of logged and unlogged forest in Eastern Amazonia. Animal Biodiversity and Conservation, 26, 39–49.	87	Pr	1	19	V	10	Original	Journal article
271.	Pinto, D., & Ortêncio-Filho, H. (2006). Dieta de quatro espécies de filostomídeos frugívoros (Chiroptera, Mammalia) do Parque Municipal do Cinturão Verde de Cianorte, Paraná, Brasil. Chiroptera Neotropical, 12(2), 274–279.	91	Ch	4	9	F	12	Original	Journal article
272.	Pinto, L. P., & Setz, E. Z. F. (2004). Diet of *Alouatta belzebul discolor* in an amazonian rain forest of Northern Mato Grosso State, Brazil. International Journal of Primatology, 25(6), 1197–1211. Retrieved frm https://doi.org/10.1023/B:IJOP.0000043958.75534.7f	131	Pr	1	33	V	10	Original	Journal article
273.	Pires, M. M., Martins, E. G., Araújo, M. S., & Dos Reis, S. F. (2013). Between-individual variation drives the seasonal dynamics in the trophic niche of a Neotropical marsupial. Austral Ecology, 38(6), 664–671. Retrieved from https://doi.org/10.1111/aec.12011	123	Di	1	5	F	10	Original	Journal article
274.	Pires, L. P. (2010). Diversidade e frugivoria por morcegos em um remanescente de floresta semidecidual de Uberlândia, MG (master's dissertation). Ecologia e Conservação de Recursos Naturais, Universidade Federal de Uberlândia. 67p.	141	Ch	6	9	F	10	Original	Dissertation
275.	Ponce-Santizo, G., Andresen, E., Cano, E., & Cuarón, A. D. (2006). Dispersión primaria de semillas por primates y dispersión secundaria por escarabajos coprófagos en Tikal, Guatemala. Biotropica, 38(3), 390–397. Retrieved from https://doi.org/10.1111/j.1744-7429.2006.00144.x	32	Pr	2	9	F & V	5	Original	Journal article
276.	Pontes, A. R. M., & Chivers, D. J. (2002). Abundance, habitat use and conservation of the Olingo *Bassaricyon* sp. in Maracá Ecological Station, Roraima, Brazilian Amazonia. Studies on Neotropical Fauna and Environment, 37(2), 105–109. Retrieved from https://doi.org/10.1076/snfe.37.2.105.8577	13	Ca	1	4	V	2	Original	Journal article
277.	Port-Carvalho, M., & Ferrari, S. F. (2004). Occurrence and diet of the black bearded saki (*Chiropotes satanas satanas*) in the fragmented landscape of western Maranhao, Brazil. Neotropical Primates, 12(1), 17–21.	88	Pr	1	48	V	14	Original	Journal article
278.	Porter, L. M. (2001). Dietary differences among sympatric Callitrichinae in northern Bolivia: *Callimico goeldii*, *Saguinus fuscicollis* and *S. labiatus*. International Journal of Primatology, 22(6), 961–992. Retrieved from https://doi.org/10.1023/A:1012013621258	130	Pr	3	78	V	12	Original	Journal article

279.	Prates, J. C., Gayer, S. M. P., Kunz Jr., L. F., & Buss, G. (1990). Feeding habits of the brown howler monkey *Alouatta fusca clamitans* (Cabrera, 1940) (Cebidae, Alouattinae) in the Itapuã State Park. A preliminary report. Acta Biologica Leopoldensia, 12(1), 175–188.	26	Pr	1	13	V	12	Original	Journal article
280.	Puebla-Olivares, F., & Winker, K. (2004). Dieta y dispersion de semillas por dos especies de tangara (*Habia*) en dos tipos de vegetacion en Los Tuxtlas, Veracruz, Mexico. Ornitologia Neotropical, 15, 53–64.	3	Pa	2	24	F	3	Original	Journal article
281.	Queirolo, D., & Motta-Junior, J. C. (2007). Prey availability and diet of maned wolf in Serra da Canastra National Park, southeastern Brazil. Acta Theriologica, 52(4), 391–402. Retrieved from https://doi.org/10.1007/BF03194237	70	Ca	1	21	F	15	Original	Journal article
282.	Quevedo, A. E. A., Fernando Pacheco, L., Irene Roldán, A., & Sol Aguilar Ariñez, y M. (2008). Ecología de *Ateles chamek* Humboldt en un bosque húmedo montano de los Yungas Bolivianos. Neotropical Primates, 15(1), 13–21. Retrieved from https://doi.org/10.1896/044.015.0103	47	Pr	1	19	V	13	Original	Journal article
283.	Raboy, B. E., Canale, G. R., & Dietz, J. M. (2008). Ecology of *Callithrix kuhlii* and a review of eastern Brazilian marmosets. International Journal of Primatology, 29(2), 449–467. Retrieved from https://doi.org/10.1007/s10764-008-9249-6	17	Pr	1	17	V	21	Original	Journal article
284.	Raboy, B. E., & Dietz, J. M. (2004). Diet, foraging, and use of space in wild golden-headed lion tamarins. American Journal of Primatology, 63(1), 1–15. Retrieved from https://doi.org/10.1002/ajp.20032	17	Pr	1	71	V	32	Original	Journal article
285.	Raguet-Schofield, M. L. (2010). The ontogeny of feeding behavior of Nicaraguan mantled howler monkeys (*Alouatta palliata*) (Doctoral thesis). Department of Anthropology, University of Illinois at Urbana-Champaign. 274p.	126	Pr	1	18	V	13	Original	Thesis
286.	Reis, N. R. dos, & Guillaumet, J.-L. (1983). Les chauves-souris frugivores de la région de Manaus et leur rôle dans la dissémination des espèces végétales. Revue d'Écologie (La Terre et La Vie), 38, 147–169.	4	Ch	18	28	F & SC	16	Original	Journal article
287.	Reis, N. R., & Peracchi, A. L. (1987). Quirópteros da região de Manaus, Amazonas, Brasil (Mammalia, Chiroptera). Boletim do Museu Paraense Emílio Goeldi. Série Zoologia, 3, 161–182.	4	Ch	17	43	F	16	Original	Journal article
288.	Riba-Hernández, P., Stoner, K. E., & Lucas, P. W. (2003). The sugar composition of fruits in the diet of spider monkeys (*Ateles geoffroyi*) in tropical humid forest in Costa Rica. Journal of Tropical Ecology, 19(6), 709–716. Retrieved from https://doi.org/10.1017/S0266467403006102	28	Pr	1	27	V	12	Original	Journal article

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APPENDIX B — Continuation

	Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
289.	Richard, E., Juliá, J. P., & Aceñolaza, P. G. (1995). Hábitos frugívoros de la corzuela parda (*Mazama gouazoubira* Fischer, 1814) (Mammalia Cervidae), en un ambiente secundario de Yungas. Doñana Acta Vertebrata, 22(1–2), 19–28.	57	Ar	1	10	V	6	Original	Journal article
290.	Ríos, M. M., Londoño, G. A., & Muñoz, M. C. (2005). Densidad poblacional e historia natural de la Pava negra (*Aburria aburri*) en los Andes Centrales de Colombia. Ornitología Neotropical, 16, 205—217.	29	Ga	1	7	V	12	Original	Journal article
291.	Robinson, J. G., & Eisenberg, J. F. (1985). Group size and foraging habits of the Collared Peccary *Tayassu tajacu*. Journal of Mammalogy, 66(1), 153–155. Retrieved from https://doi.org/10.2307/1380972	15	Ar	1	7	V	14	Original	Journal article
292.	Robinson, J. G. (1984). Diurnal variation in foraging and diet in the Wedge-Capped Capuchin *Cebus olivaceus*. Folia Primatologica, 43(4), 216–228. Retrieved from https://doi.org/10.1159/000156183	15	Pr	1	13	V	14	Original	Journal article
293.	Rocha, V. J., Aguiar, L. M., Silva-Pereira, J. E., Moro-Rios, R. F., & Passos, F. C. (2008). Feeding habits of the crab-eating fox, *Cerdocyon thous* (Carnivora: Canidae), in a mosaic area with native and exotic vegetation in Southern Brazil. Revista Brasileira de Zoologia, 25(4), 594–600. Retrieved from https://doi.org/10.1590/S0101-81752008000400003	62	Ca	1	17	SC	NA	Original	Journal article
294.	Rocha, V. J. (2001). Ecologia de mamíferos de médio e grande portes do Parque Estadual Mata dos Godoy, Londrina (PR) (Doctoral thesis). Zoologia, Universidade Federal Do Paraná. 131p.	121	Ar, Ca, Pe, Pr	5	83	F & V	36	Original	Thesis
295.	Rocha, A. C. C. L. (2008). Dieta de três espécies de carnívoros simpátricos no Parque Nacional Grande Sertão Veredas, MG e Ecologia e Comportamento do lobo-guará (*Chrysocyon brachyurus*, Illiger, 1815) (master's dissertation). Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais. 106p.	102	Ca	2	14	F	13	Original	Dissertation
296.	Rodrigues, F. H. G. (1996). História natural e biologia comportamental do veado campeiro *Ozotoceros bezoarticus* em Cerrado do Brasil Central (master's dissertation). Instituto de Biologia, Universidade Estadual de Campinas. 89p.	23	Ar	1	15	V	12	Original	Dissertation
297.	Rodrigues, M. (1991). Ecologia alimentar de traupídeos (Aves: Thraupinae) em uma área de Mata Atlântica do estado de São Paulo (master's thesis). Instituto de Biologia, Universidade Estadual de Campinas. 84p.	6	Pa	13	11	V	13	Original	Thesis

298.	Rodríguez-Ferraro, A., Garcia-Amado, M. A., & Bosque, C. (2007). Diet, food preferences, and digestive efficiency of the Grayish Saltator, a partly folivorous passerine. Condor, 109, 824–840. Retrieved from https://doi.org/10.1650/0010-5422(2007)109[824:DFPADE]2.0.CO;2	15	Pa	1	22	V	8	Original	Journal article
299.	Rosa, G. A. B. da. (2003). Frugivoria e dispersão de sementes por aves em uma área de reflorestamento misto em Botucatu, SP (master's dissertation). Instituto de Biologia, Universidade Estadual de Campinas. 69p.	21	Co, Pa	16	31	F	12	Original	Dissertation
300.	Rougès, M., & Blake, G. (2001). Tasas de captura y dietas de aves del sotobosque en el Parque Biológico Sierra de San Javier, Tucumán. Hornero, 16(1), 7–15.	69	Co, Pa	9	5	F	4	Original	Journal article
301.	Ruggera, R. A., Álvarez, M. E., & Blendinger, P. G. (2011). Diet of the Red-faced Guan (*Penelope dabbenei*) in a montane forest in northwestern Argentina. Ornitología Neotropical, 22, 215–221.	95	Ga	1	7	F	6	Original	Journal article
302.	Ruggera, R. A., Gomez, M. D., & Blendinger, P. G. (2014). Frugivory and seed dispersal role of the Yellow-striped Brush-Finch (*Atlapetes citrinellus*), an endemic emberizid of Argentina. Emu, 114(4), 343–351. https://doi.org/10.1071/MU14033	22	Pa	1	2	V	4	Original	Journal article
302.	Ruggera, R. A., Gomez, M. D., & Blendinger, P. G. (2014). Frugivory and seed dispersal role of the Yellow-striped Brush-Finch (*Atlapetes citrinellus*), an endemic emberizid of Argentina. Emu, 114(4), 343–351. Retrieved from https://doi.org/10.1071/MU14033	69	Pa	1	16	V	4	Original	Journal article
303.	Rui, A. M. (2002). Ecologia de morcegos filostomídeos em Floresta Atlântica no extremo sul do Brasil (Doctoral thesis). Ecologia, Universidade de Brasília. 65p.	71	Ch	3	10	F	12	Original	Thesis
304.	Russell, J. K. (1983). Timing of reproduction by coatis (*Nasua narica*) in relation to fluctuations in food resources. In E. G. Leigh Jr., A. S. Rand, & D. M. Windsor (Eds.), The Ecology of a Tropical Forest: Seasonal Rhythms and Long-Term Changes (pp. 413–431). Oxford: Oxford University Press.	1	Ca	1	24	V	14	Original	Book chapter
305.	Rylands, A. B. (1981). Preliminary field observations on the marmoset, *Callithrix humeralifer intermedius* (Hershkovitz, 1977) at Dardanelos, Rio Aripuanã, Mato Grosso. Primates, 22(1), 46–59. Retrieved from https://doi.org/10.1007/BF02382556	94	Pr	1	14	V	7	Original	Journal article
306.	Aldana Saavedra, J. P. (2009). Feeding ecology and seed dispersal by *Ateles hybridus*, *Alouatta seniculus* and *Cebus albifrons* in a fragmented area at San Juan del Carare, Colombia: ecology of a monkey community in a fragment (master's thesis). CBM Swedish Biodiversity Centre, Swedish University of Agricultural Science, 60p.	143	Pr	3	20	F & V	9	Original	Thesis

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APPENDIX B — Continuation

Study reference		Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
307.	Sabbatini, G., Stammati, M., Tavares, M. C. H., & Visalberghi, E. (2008). Behavioral flexibility of a group of bearded capuchin monkeys (*Cebus libidinosus*) in the National Park of Brasília (Brazil): consequences of cohabitation with. Brazilian Journal of Biology, 68(4), 685–693.	34	Pr	1	35	V	12	Original	Journal article
308.	Sacramento, T. S. (2014). Influência da disponibilidade de alimentos sobre os comportamentos de um grupo de *Sapajus libidinosus* e análise das interações e conflitos entre humanos e macacos-prego no Parque Nacional de Brasília, DF (master's dissertation). Biologia Animal, Universidade de Brasília. 79p.	34	Pr	1	26	V	10	Original	Dissertation
309.	Salas, L. A., & Fuller, T. K. (1996). Diet of the lowland tapir (*Tapirus terrestris* L.) in the Tabaro River valley, southern Venezuela. Canadian Journal of Zoology, 74(8), 1444–1451. Retrieved from https://doi.org/10.1139/z96-159	140	Pe	1	28	F	20	Original	Journal article
310.	Sampaio, D. T. (2004). Ecologia de macaco-prego (*Cebus apella apella*) na ilha de germoplasma, usina hidrelétrica de Tucuruí-PA. (master's dissertation). Teoria E Pesquisa Do Comportamento, Universidade Federal do Pará. 61p.	11	Pr	1	24	V	6	Original	Dissertation
311.	Sánchez, M. S., Giannini, N. P., & Barquez, R. M. (2012). Bat frugivory in two subtropical rain forests of Northern Argentina: Testing hypotheses of fruit selection in the Neotropics. Mammalian Biology, 77(1), 22–31. Retrieved from https://doi.org/10.1016/j.mambio.2011.06.002	12	Ch	5	17	F	12	Original	Journal article
312.	Santana, M. M. De. (2012). Comportamento, dieta e uso do espaço em um grupo de guigó de coimbra (*Callicebus coimbrai* Kobayashi & Langguth 1999) No RVS Mata do Junco (master's dissertation). Ecologia e Conservação, Universidade Federal de Sergipe. 65p.	37	Pr	1	9	V	5	Original	Dissertation
313.	dos Santos, G. P., Galvão, C., & Young, R. J. (2012). The diet of wild black-fronted titi monkeys *Callicebus nigrifrons* during a bamboo masting year. Primates, 53(3), 265–272. Retrieved from https://doi.org/10.1007/s10329-012-0295-5	31	Pr	1	31	V	12	Original	Journal article
314.	Santos, V. A., & Beisiegel, B. D. M. (2006). A dieta de *Nasua nasua* (Linnaeus, 1766) no Parque Ecológico do Tietê, SP. Revista Brasileira de Zoociências, 8(2), 199–203.	149	Ca	1	7	F	2	Original	Journal article
315.	Scherbaum, C., & Estrada, A. (2013). Selectivity in feeding preferences and ranging patterns in spider monkeys *Ateles geoffroyi yucatanensis* of northeastern Yucatan peninsula, Mexico. Current Zoology, 59(1), 125–134.	76	Pr	1	22	V	6	Original	Journal article

316.	Seibert, J. B. (2015). Padrão de frugivoria de *Tapirus terrestris* na Mata Atlântica do norte do Espírito Santo, Brasil (master's dissertation). Biologia Animal, Universidade Federal do Espírito Santo. 43p.	92	Pe	1	26	F	29	Original	Dissertation
317.	Setz, E. Z. F. (1993). Ecologia alimentar de um grupo de parauacus (*Pithecia pithecia chrysocephala*) em um fragmento florestal na Amazônia Central (Doctoral thesis). Instituto de Biologia, Universidade Estadual de Campinas. 237p.	4	Pr	1	172	V	29	Original	Thesis
318.	Shaffer, C. A. (2013). Feeding ecology of northern bearded sakis (*Chiropotes sagulatus*) in Guyana. American Journal of Primatology, 75(6), 568–580. Retrieved from https://doi.org/10.1002/ajp.22134	151	Pr	1	30	V	11	Original	Journal article
319.	Silva, A. G. da, Gaona, O., & Medellín, R. A. (2008). Diet and trophic structure in a community of fruit-eating bats in Lacandon Forest, Mexico. Journal of Mammalogy, 89(1), 43–49. Retrieved from https://doi.org/10.1644/06-MAMM-A-300.1	16	Ch	13	17	F	7	Original	Journal article
320.	Silva, A. R. Da, Forneck, E. D., Bordignon, S. A. D. L., & Cademartori, C. V. (2014). Diet of *Didelphis albiventris* Lund, 1840 (Didelphimorphia, Didelphidae) in two periurban areas in southern Brazil. Acta Scientiarum. Biological Sciences, 36(2), 241. Retrieved from https://doi.org/10.4025/actascibiolsci.v36i2.20444	26	Di	1	6	F	21	Original	Journal article
321.	Silva, A. M., & Melo, C. de. (2011). Frugivory and seed dispersal by the Helmeted Manakin (*Antilophia galeata*) in forests of Brazilian Cerrado. Ornitología Neotropical, 22, 69–77.	65	Pa	1	16	V	11	Original	Journal article
322	Silva, J. A., & Talamoni, S. A. (2003). Diet adjustments of maned wolves, *Chrysocyon brachyurus* (Illiger) (Mammalia, Canidae), subjected to supplemental feeding in a private natural reserve, Southeastern Brazil. Revista Brasileira de Zoologia, 20(2), 339–345. Retrieved from https://doi.org/10.1590/S0101-81752003000200026	31	Ca	1	12	F	18	Original	Journal article
323.	Silva, R. F. S. da. (2013). Comportamento e dieta de *Chiropotes albinasus* (I. Geoffroy & Deville, 1848) - cuxiú-de-nariz-vermelho (master's dissertation). Zoologia, Museu Paraense Emílio Goeldi & Universidade Federal do Pará. 64p.	116	Pr	1	33	V	6	Original	Dissertation
324.	Silver, S. C., Ostro, L. E. T., Yeager, C. P., & Horwich, R. (1998). Feeding ecology of the black howler monkey (*Alouatta pigra*) in Northern Belize. American Journal of Primatology, 45(3), 263–279. Retrieved from https://doi.org/10.1002/(SICI)1098-2345(1998)45:3<263::AID-AJP3>3.0.CO;2-U	52	Pr	1	18	V	12	Original	Journal article
325.	Simmen, B., & Sabatier, D. (1996). Diets of some French Guianan primates: Food composition and food choices. International Journal of Primatology, 17(5), 661–693. Retrieved from https://doi.org/10.1007/BF02735260	5	Pr	3	153	V	6	Original	Journal article

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APPENDIX B — Continuation

	Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
326.	Smythe, N., Glanz, W. E., & Leigh Jr., E. G. (1983). Population regulation in some terrestrial frugivores. In E. G. Leigh Jr., A. S. Rand, & D. M. Windsor (Eds.), The Ecology of a Tropical Forest: Seasonal Rhythms and Long-Term Changes (pp. 227–238). Oxford: Oxford University Press.	1	Ro	2	36	V	17	Original	Book chapter
327.	Soini, P. (1992). Ecologia del Coto Mono (*Alouatta seniculus*, Cebidae) en el rio Pacaya, Reserva Nacional Pacaya-Samiria, Peru. Folia Amazónica, 4(2), 117–134.	39	Pr	1	24	V	NA	Original	Journal article
328.	Souza, L. L. De. (1999). Comportamento alimentar e dispersão de sementes por guaribas (*Alouatta belzebul*) na Estação Científica Ferreira Penna (Caxiuanã/Melgaço/Pará) (master's dissertation). Zoologia, Museu Paraense Emílio Goeldi & Universidade Federal do Pará. 168p.	99	Pr	1	39	V	13	Original	Dissertation
329.	Spironelo, W. R. (1991). Importância dos frutos de palmeiras (Palmae) na dieta de um grupo de *Cebus apella* (Cebidae, Primates) na Amazônia Central. In A. B. Rylands & A. T. Bernardes (Eds.), A Primatologia no Brasil (3rd ed., pp. 285–296). Belo Horizonte: Fundação Biodiversitas.	4	Pr	1	15	V	12	Original	Journal article
330.	Stevenson, P. R., Quiñones, M. J., & Ahumada, J. A. (1994). Ecological strategies of woolly monkeys (*Lagothrix lagotricha*) at Tinigua National Park, Colombia. American Journal of Primatology, 32, 123–140. Retrieved from https://doi.org/10.1002/ajp.1350320205	7	Pr	1	20	V	13	Original	Journal article
331.	Stevenson, P. R., Quiñones, M. J., & Ahumada, J. A. (2000). Influence of fruit availability on ecological overlap among four neotropical primates at Tinigua National Park, Colombia. Biotropica, 32(3), 533–544. Retrieved from https://doi.org/10.1646/0006-3606(2000)032 // Stevenson, P. R., Castellanos, M. C., Pizarro, J. C., & Garavito, M. (2002). Effects of seed dispersal by three ateline monkey species on seed germination at Tinigua National Park, Colombia. International Journal of Primatology, 23(6), 1187–1204. Retrieved from https://doi.org/10.1023/A:1021118618936	7	Pr	3	120	F	13	Original	Journal article
332.	Stevenson, P. R., & Link, A. (2010). Fruit preferences of *Ateles belzebuth* in Tinigua Park, Northwestern Amazonia. International Journal of Primatology, 31(3), 393–407. Retrieved from https://doi.org/10.1007/s10764-010-9392-8	7	Pr	1	28	V	24	Original	Journal article
333.	Stevenson, P. R. (2000). Seed dispersal by woolly monkeys (*Lagothrix lagothricha*) at Tinigua National Park, Colombia: Dispersal distance, germination rates, and dispersal	7	Pr	1	106	F & V	12	Original	Journal article

	quantity. American Journal of Primatology, 50(4), 275–289. Retrieved from https://doi.org/10.1002/(SICI)1098-2345(200004)50:4<275::AID-AJP4>3.0.CO;2-K								
334.	Stoner, K. E. (1996). Habitat selection and seasonal patterns of activity and foraging of mantled howling monkeys (*Alouatta palliata*) in Northeastern Costa Rica. International Journal of Primatology, 17(1), 1–30. Retrieved from https://doi.org/10.1007/BF02696156	27	Pr	1	33	V	14	Original	Journal article
335.	Strier, K. B. (1991). Diet in one group of woolly spider monkeys, or muriquis (*Brachyteles arachnoides*). American Journal of Primatology, 23(2), 113–126. Retrieved from https://doi.org/10.1002/ajp.1350230205	55	Pr	1	39	V	14	Original	Journal article
336.	Suarez, S. A. (2006). Diet and travel costs for spider monkeys in a nonseasonal, hyperdiverse environment. International Journal of Primatology, 27(2), 411–436. Retrieved from https://doi.org/10.1007/s10764-006-9023-6	19	Pr	1	238	V	12	Original	Journal article
337.	Talamoni, S. A., & Assis, M. A. C. (2009). Feeding habit of the Brazilian tapir, *Tapirus terrestris* (Perissodactyla: Tapiridae) in a vegetation transition zone in south-eastern Brazil. Zoologia, 26(2), 251–254. Retrieved from https://doi.org/10.1590/S1984-46702009000200007	31	Pe	1	10	F	12	Original	Journal article
338.	Teixeira, R. C., Corrêa, C. E., & Fischer, E. (2009). Frugivory by *Artibeus jamaicensis* (Phyllostomidae) bats in the Pantanal, Brazil. Studies on Neotropical Fauna and Environment, 44(1), 7–15. Retrieved from https://doi.org/10.1080/01650520802692283	133	Ch	1	6	F	20	Original	Journal article
339.	Thel, T. N., Teixeira, P. H. R., Lyra-Neves, R. M., Telino-Júnior, W. R., Ferreira, J. M. R., & Azevedo-Júnior, S. M. (2015). Aspects of the ecology of *Penelope superciliaris* temminck, 1815 (Aves: Cracidae) in the Araripe National Forest, Ceará, Brazil. Brazilian Journal of Biology, 75(4), 126–135. https://doi.org/10.1590/1519-6984.07314	48	Ga	1	13	F & V	12	Original	Journal article
340.	Tobler, M. W., Janovec, J. P., & Cornejo, F. (2010). Frugivory and seed dispersal by the lowland tapir *Tapirus terrestris* in the Peruvian Amazon. Biotropica, 42(2), 215–222. Retrieved from https://doi.org/10.1111/j.1744-7429.2009.00549.x	9	Pe	1	122	F	30	Original	Journal article
341.	Tófoli, C. F. de. (2006). Frugivoria e dispersão de sementes por *Tapirus terrestris* (Linnaeus, 1758) na paisagem fragmentada do Pontal do Paranapanema, São Paulo. (master's dissertation). Instituto de Biociências, Univesidade de São Paulo. 89p.	66	Pe	1	58	F & SC	24	Original	Dissertation

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APPENDIX B — Continuation

	Study reference	Study site	Frugivore Orders¹	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
342.	Trevelin, L. C., Port-Carvalho, M., Silveira, M., & Morell, E. (2007). Abundance, habitat use and diet of *Callicebus nigrifrons* Spix (Primates, Pitheciidae) in Cantareira State Park, São Paulo, Brazil. Revista Brasileira de Zoologia, 24(4), 1071–1077. Retrieved from https://doi.org/10.1590/S0101-81752007000400026	51	Pr	1	13	V	12	Original	Journal article
343.	Trolliet, F. (2010). Ecology of the Belizean black howler monkey (*Alouatta pigra*): a comparison between two populations living in a riparian forest and on coastal limestone hills (master's dissertation). Ethologie et Psychologie Animale, Université de Liège. 51p.	61	Pr	1	7	V	4	Original	Dissertation
343.	Trolliet, F. (2010). Ecology of the Belizean black howler monkey (*Alouatta pigra*): a comparison between two populations living in a riparian forest and on coastal limestone hills (master's dissertation). Ethologie et Psychologie Animale, Université de Liège. 51p.	67	Pr	1	6	V	4	Original	Dissertation
344.	Tujague, M., Bacigalupe, M., Lahitte, H., & Janson, C. (2016). Memoria espacial en monos capuchinos de Argentina: un estudio observacional en vida silvestre. Revista Argentina de Antropología Biológica, 18(1), 1–13. Retrieved from https://doi.org/10.17139/raab.2016.0018.01.01	12	Pr	1	27	V	20	Original	Journal article
345.	Valenta, K., & Fedigan, L. M. (2008). How much is a lot? Seed dispersal by white-faced capuchins and implications for disperser-based studies of seed dispersal systems. Primates, 49(3), 169–75. Retrieved from https://doi.org/10.1007/s10329-008-0087-0	2	Pr	1	39	F & V	8	Original	Journal article
346.	Valenzuela, D. (1998). Natural history of the white-nosed coati, *Nasua narica*, in a tropical dry forest of western Mexico. Revista Mexicana de Mastozoología, 3, 26–44.	14	Ca	1	16	F & V	29	Original	Journal article
347.	Valle, Y. G. del, Muñoz, D., Magaña-Alejandro, M., & Franco, B. (2001). Uso de plantas como alimento por monos aulladores, *Alouatta palliata*, em el Parque Yumká, México. Neotropical Primates, 9(3), 112–118.	156	Pr	1	5	V	6	Original	Journal article
348.	van Dorp, D. (1985). Frugivoria y dispersion de semillas por aves. In A. Gómez-Pompa & S. del Amo (Eds.), Investigaciones sobre la regeneración de selvas altas en Veracruz, México, II (pp. 333–363). Alhambra: INIREB.	3	Cr, Pa, Pi, Tr	35	4	V	7	Original	Book chapter
349.	van Roosmalen, M. G. M. (1985). Habitat preferences, diet, feeding strategy and social organization of the black spider monkey [*Ateles paniscus paniscus* Linnaeus	43	Pr	1	170	F & V	26	Original	Journal article

	1758] in Surinam. Acta Amazonica, 15(3–4), 7–238. Retrieved from https://doi.org/10.1590/1809-43921985155238								
350.	van Roosmalen, M. G. M., Mittermeier, R. A., & Fleagle, J. G. (1988). Diet of the northern bearded saki (*Chiropotes satanas chiropotes*): A neotropical seed predator. American Journal of Primatology, 14(1), 11–35. Retrieved from https://doi.org/10.1002/ajp.1350140103	43	Pr	1	81	V	30	Original	Journal article
351.	Varela, O., Cormenzana-Méndez, A., Krapovickas, L., & Bucher, E. H. (2008). Seasonal diet of the pampas fox (*Lycalopex gymnocercus*) in the chaco dry woodland, northwestern Argentina. Journal of Mammalogy, 89(4), 1012–1019. Retrieved from https://doi.org/10.1644/07-MAMM-A-125.1	115	Ca	1	12	F	12	Original	Journal article
352.	Varela, R. O., & Brown, A. D. (1995). Tapires y pecaries como dispersores de plantas de los bosques húmedos subtropicales de Argentina. In A. D. Brown & H. R. Grau (Eds.), Investigación, Conservación y Desarrollo en Selvas Subtropicales de Montana (pp. 129–140). Tucumán: Laboratorio de Investigaciones Ecológicas de las Yungas; Universidad Nacional de Tucumán.	97	Ar, Pe	3	18	F	2	Original	Journal article
353.	Vargas-Contreras, J. A., Medellín, R. A., Escalona-Segura, G., & Interián-Sosa, L. (2009). Vegetation complexity and bat-plant dispersal in Calakmul, Mexico. Journal of Natural History, 43(3–4), 219–243. Retrieved from https://doi.org/10.1080/00222930802478651	50	Ch		20	F	13	Original	Journal article
354.	Vaughan, C., & Rodriguez, M. (1986). Comparacion de los habitos alimentarios del coyote (*Canis latrans*) em dos localidades de Costa Rica. Vida Silvestre Neotropical, 1(1), 6–11.	40	Ca	1	2	F	33	Original	Journal article
355.	Veiga, L. M. (2006). Ecologia e comportamento do cuxiú-preto (*Chiropotes satanas*) na paisagem fragmentada da Amazônia oriental (Doctoral thesis). Psicologia Experimental, Universidade Federal do Pará. 207p.	11	Pr	1	40	V	12	Original	Thesis
356.	Veríssimo, K. C. da S. (2007). Área domiciliar e utilização de recursos alimentares por sagüis *Callithrix jacchus* na Reserva Particular do Patrimônio Natural - RPPN Nossa Senhora do Outeiro de Macaraípe, Ipojuca, PE (master's dissertation). Biologia Animal, Universidade Federal de Pernambuco. 72p.	124	Pr	1	15	V	6	Original	Dissertation
357.	Vieira, E. M., & Izar, P. (1999). Interactions between aroids and arboreal mammals in the Brazilian Atlantic rainforest. Plant Ecology, 145, 75–82.	6	Di, Pr	5	8	F	20	Original	Journal article

Continues…

APPENDIX B — Continuation

	Study reference	Study site	Frugivore Orders[1]	No. of Frugivore spp.	No. of Plant spp.	Method	Duration (months)	Data Source	Type
358.	Vieira, T. M. (2005). Aspectos da ecologia do cuxiú de uta hick, *Chiropotes utahickae* (Hershkovitz, 1985), com ênfase na exploração alimentar de espécies arbóreas da ilha de germoplasma, Tucuruí, PA (master's dissertation). Zoologia, Museu Paraense Emílio Goeldi & Universidade Federal do Pará. 122p.	11	Pr	1	95	F & V	6	Original	Dissertation
359.	Vilela, S. L. (1999). Aspectos ecológicos e comportamentais de dois grupos de *Callithrix penicillata* (Primates, Callitrichidae) em fisionomia de cerrado denso e cerradão e comparação entre estação seca e chuvosa, incluindo dados fenológicos, Brasília - DF (master's dissertation). Ecologia, Universidade de Brasília. 58p.	24	Pr	1	8	V	8	Original	Dissertation
360.	Vilela, S. L. (2007). Simpatria e dieta de *Callithrix penicillata* (Hershkovitz) (Callitrichidae) e *Cebus libidinosus* (Spix) (Cebidae) em matas de galeria do Distrito Federal, Brasil. Revista Brasileira de Zoologia, 24(3), 601–607.	24	Pr	2	17	V	7	Original	Journal article
361.	Wallace, R. B. (2005). Seasonal variations in diet and foraging behavior of *Ateles chamek* in a southern Amazonian Tropical Forest. International Journal of Primatology, 26(5), 1053–1075. Retrieved from https://doi.org/10.1007/s10764-005-6458-4	38	Pr	1	20	V	11	Original	Journal article
362.	Wehncke, E. V., Valdez, C. N., & Domínguez, C. A. (2004). Seed dispersal and defecation patterns of *Cebus capucinus* and *Alouatta palliata*: consequences for seed dispersal effectiveness. Journal of Tropical Ecology, 20(5), 535–543. Retrieved from https://doi.org/10.1017/S0266467404001865	40	Pr	2	30	F & V	7	Original	Journal article
363.	Wehncke, E. V., Hubbell, S. P., Foster, R. B., & Dalling, J. W. (2003). Seed dispersal patterns produced by white-faced monkeys: Implications for the dispersal limitation of neotropical tree species. Journal of Ecology, 91(4), 677–685. Retrieved from https://doi.org/10.1046/j.1365-2745.2003.00798.x	1	Pr	1	92	F & V	4	Original	Journal article
364.	Wheelwright, N. T., Haber, W. A., Murray, K. G., & Guindon, C. (1984). Tropical fruit-eating birds and their food plants: A survey of a Costa Rican lower montane forest. Biotropica, 16(3), 173–192. Retrieved from https://doi.org/10.2307/2388051	63	Co, Cr, Cu, Ga, Pa, Pi, Tr	61	170	F & V	20	Original	Journal article
365.	Williams, K. D. (1984). The Central American tapir (*Tapirus bairdii* Gill) in northwestern Costa Rica (Doctoral dissertation). Michigan State University. 86p.	2	Pe	1	29		NA	Secondary data	Thesis
366.	Williams-Guillén, K. (2003). The behavioral ecology of mantled howler monkeys (*Alouatta palliata*) living in a Nicaraguan shade coffee plantation. Dissertation (Doctorate). Department of Anthropology, New York University. 242p.	100	Pr	1	22	V	13	Original	Dissertation

367.	Yoneda, M. (1984). Ecological study of the saddle backed tamarin (*Saguinus fuscicollis*) in Northern Bolivia. Primates, 25(1), 1–12. Retrieved from https://doi.org/10.1007/BF02382290	129	Pr	1	30	V	6	Original	Journal article
368.	Yumoto, T., Kimura, K., & Nishimura, A. (1999). Estimation of the retention times and distances of seed dispersed by two monkey species, *Alouatta seniculus* and *Lagothrix lagotricha*, in a Colombian forest. Ecological Research, 14(2), 179–191. https://doi.org/10.1046/j.1440-1703.1999.00286.x	7	Pr	2	17	F & V	2	Original	Journal article
369.	Yumoto, T. (1999). Seed Dispersal by Salvin's Curassow, *Mitu salvini* (Cracidae), in a tropical forest of Colombia: direct measurements of dispersal distance. Biotropica, 31(4), 654–660. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1744-7429.1999.tb00414.x/abstract	7	Ga	1	13	F & V	2	Original	Journal article
370.	Zago, L., Miranda, J. M. D., Neto, C. D., Santos, C. V., & Passos, F. C. (2013). Dieta de *Callithrix penicillata* (E. Geoffroy, 1812) (Primates, Callitrichidae) introduzidos na Ilha de Santa Catarina. Biotemas, 26(2), 227–235. Retrieved from https://doi.org/10.5007/2175-7925.2013v26n2p227	93	Pr	1	11	V	12	Original	Journal article
371.	Zárate, D. A., Andresen, E., Estrada, A., & Serio-silva, J. C. (2014). Black howler monkey (*Alouatta pigra*) activity, foraging and seed dispersal patterns in shaded cocoa plantations versus rainforest in southern Mexico. American Journal of Primatology, 76(9), 890–899. Retrieved from https://doi.org/10.1002/ajp.22276	16	Pr	1	23	F & V	8	Original	Journal article
372.	Zortea, M., & Chiarello, A. (1994). Observations on the big fruit eating bat, *Artibeus lituratus*, in an urban reserve of Southeast Brazil. Mammalia, 58(4), 665–670.	42	Ch	1	11	F	13	Original	Journal article
373.	Zorzi, B. T. (2009). Frugivoria por *Tapirus terrestris* em três regiões do Pantanal, Brasil (master's dissertation). Ecologia E Conservação, Universidade Federal de Mato Grosso do Sul. 54p.	20	Pe	1	39	F	12	Original	Dissertation

2 Chapter 2

Combining plant–frugivore networks for describing the structure of neotropical communities

Abstract

Frugivory and seed dispersal are key processes for the maintenance of biodiversity. This is particularly true in the Neotropics, where most plant species depend on animals to disperse their seeds and most birds and mammals include fruits in their diets. We performed a continental-scale literature review to build a database of interactions between neotropical fruits and fruit-eating birds and mammals. Our objective was to evaluate the viability of combining literature data from different studies to describe the structure of highly diverse fruit–frugivore neotropical communities. We investigated sites that had been the focus of studies of at least four different avian and/or mammalian taxonomic orders and we included in our database only those conducted for at least a 6-month period in order to account for the seasonality in fruit availability. In spite of a large number of study sites investigated for frugivory (n = 156), we found a huge gap in the knowledge of community-wide fruit–frugivore interactions in the Neotropics, since most studies focused on single or a few species. Nevertheless, we were able to construct diverse plant–frugivore qualitative networks for 17 areas unevenly spread throughout the neotropical region. Using complex network analyses, we found that these networks were highly informative and non-randomly organized. Most networks were both significantly nested and modular, characteristics related to stability and resilience in biological systems. We concluded that it is possible to use merged data to build networks for sites of conservation interest. The main advantage of using this approach is to optimize resources, avoiding exhaustive, costly and time-consuming fieldwork when data is already available. Whilst bearing in mind the shortcomings of this methodology, these results can be used in studies aiming to understand the ecological processes structuring different communities in the neotropical region and to support conservation and restoration actions.

Keywords: Animal–plant interactions. Binary networks. Birds. Complex networks. Frugivory. Mammals.

2.1 Introduction

Mutualisms between plants and animals are among the main processes capable of generating and maintaining the biodiversity on our planet. They are usually represented by the association of very distinct organisms (ODUM; BARRETT, 2008). In tropical forests, about 90% of all woody plants depend on animals to complete their reproductive cycles, such as for pollination or seed dispersal (JORDANO, 2000). Similarly, up to 80% of the biomass of birds and mammals can be represented by animals that primarily depend on fruit in their diet (TERBORGH, 1986).

Frugivores can act as plant antagonists, destroying the seeds through cracking or digesting them, and as plant mutualists, discarding intact seeds with or without ingestion, into habitats suitable for seedling emergence and establishment (HOWE; SMALLWOOD, 1982; JORDANO, 2000). Both roles can be played by the same frugivorous species in relation to different plant species and even for the same plant species, as seeds of the same species can vary in their ability to remain viable after digestion (GENRICH et al., 2016). The roles that frugivores adopt can also vary between different habitats and over time because the probabilities of survival for different demographic stages of plants (seeds, seedlings, saplings, sub-adults and adults) vary with the environment (HOWE, 2016). The variation in the roles frugivores play can also be a result of food scarcity and a consequent change of the functioning of the digestive system (e.g. MIKICH, 2002).

The application of the Theory of Complex Networks (ESTRADA, 2011) for the study of ecological interactions between species has proven to be an effective approach and enables the examination of how organisms interact, the evolution of current observed patterns, and the effects of ecosystem changes (BASCOMPTE, 2010; BASCOMPTE; JORDANO, 2007; NUISMER; JORDANO; BASCOMPTE, 2013). Networks of ecological interactions are representations of interactions (links) between species (nodes or vertices) that assemble a community (network) (BLÜTHGEN et al., 2008). The network approach is able to simplify complex interactions uncovering patterns and characteristics of a species in a community (BASCOMPTE; JORDANO, 2007; JORDANO, 1987). It is also an appropriate way to test the various factors involved in the dynamics of coevolution of animals and plants, such as phylogenetic history and climatic changes, and to examine the potential effects of the extinction or addition of species in a community through simulations and statistical modelling (BASCOMPTE; JORDANO; OLESEN, 2006; GUIMARÃES JR.; JORDANO; THOMPSON, 2011; MEMMOTT; WASER; PRICE, 2004; OLESEN; ESKILDSEN; VENKATASAMY, 2002; THÉBAULT; FONTAINE, 2010; VALDOVINOS et al., 2009).

Studies of communities based on the complex network approach can also provide important information for decision makers regarding species conservation, management, and restoration (DEVOTO et al., 2012; KAISER-BUNBURY; BLÜTHGEN, 2015; TYLIANAKIS et al., 2010). Devoto et al.

(2012), for example, studied 30 quantitative plant–pollinator networks along a managed successional gradient using theoretical and empirical approaches in order to identify which species should be given restoration priority, according to different restoration targets. Kaiser-Bunbury and Blüthgen (2015) also used the study of plant–pollinator interactions to aid conservation action and improve management success by building a framework that integrates conservation practitioners and network ecologists. Network structure can also be incorporated into conservation monitoring, as suggested by Tylianakis et al. (2010).

Studies of frugivory usually focus on one frugivorous species or one group of frugivores with similar behaviour, like bats, birds or primates (as seen in chapter 1). Although such studies provide useful knowledge on particular species and can contribute with their conservation, it is essential to assess their interactions with the rest of the community in which they are found (TYLIANAKIS et al., 2010). However, few studies to date have used this approach in order to understand the observed patterns in highly diverse communities (DÁTTILO et al., 2016; FONTAINE et al., 2011; GENRICH et al., 2016). Even studies that considered only one type of interaction (i.e. plant–frugivore) still fail to consider the several groups involved in these interactions and base their conclusions on observations of only one taxonomic group (e.g. plants–birds or plants–bats). Thus, there are a few studies (e.g. DONATTI et al., 2011; HAWES; PERES, 2014; SILVA et al., 2007; STEVENSON et al., 2015) that have evaluated the interactions considering the whole community of frugivores. This scarcity of information is due, in part, to sampling limitations since different taxonomic groups usually demand different sampling techniques and it is usually not viable to sample different groups at the same time (LITVAITIS, 2000; VIDAL; PIRES; GUIMARÃES JR., 2013).

Given the amount of data collected through different studies and the need to broaden the knowledge about the interactions between plants and frugivores in highly diverse neotropical communities, this study sought to evaluate the viability of combining literature data from different studies in order to describe the structure of mutualistic fruit–frugivore communities in the neotropical region. We expected our combined qualitative interaction networks to have: (1) similar structure to empirical mutualistic networks described in the literature, concerning qualitative indices of network characterization; (2) structural indices with statistical significance, which indicates the presence of ecological factors influencing the community structure (GOTELLI; GRAVES, 1996; SEBASTIÁN-GONZÁLEZ et al., 2015); and (3) nestedness and modularity showing a positive relationship with the richness of frugivores, since networks have been found to become more structured with increased complexity (BASCOMPTE et al., 2003; BASTOLLA et al., 2009; DONATTI et al., 2011; OLESEN et al., 2007).

We believe that the combination of data already available in the literature can be used as a surrogate for the study of interaction networks in neotropical communities that today are restricted to individual studies dealing with subsets of frugivores. These combined networks will assist in community-level conservation strategies and restoration plans.

2.2 Material and methods

2.2.1 Data collection

We built a database of interactions between neotropical plant and fruit-eating birds and mammals, after a comprehensive review of the literature (chapter 1). We then searched for study sites with data on at least four different taxonomic orders of birds and/or mammals to build binary (presence–absence) fruit-frugivore interaction networks. Studies reporting fruit and seed consumption and/or seed dispersal by bird or mammals were used. The following data were collected from the selected studies: taxonomic information on plants (to the lowest taxonomic rank available in the study) and frugivores (always to species level), name and location of the study site (country and geographical coordinates), and sampling duration (in months). As we built a binary network, all interactions between a given fruit taxa and a bird/mammal species were included in our database but computed only once for each study site. Additionally, since patterns of plant–animal interactions are not constant throughout the year, especially due to seasonality in fruit availability (VAN SCHAIK; TERBORGH; WRIGHT, 1993), only studies conducted during at least one dry and one wet season (a 6-month period or more) were used to build the networks. A map with the distribution of study sites was built using the software *QGIS* version *2.16.0-Nødebo* (QGIS DEVELOPMENT TEAM, 2016).

2.2.2 Network topology

Species-rich mutualistic networks are usually organized in a nested pattern, which means that the more specialist species interact with subsets of species interacting with generalists. This type of non-random organization has been found to make communities more resilient to perturbations because the most generalist species interact cohesively among them creating a dense core of interactions (Fig. 2.1a; BASCOMPTE et al., 2003). Another commonly observed pattern inherent to mutualistic networks is modularity. This type of structure is also related to network stability and is characterized by groups of strongly connected species weakly connected to other species belonging to other groups of strongly connected species in the network (Fig. 2.1b; OLESEN et al., 2007). Both structural patterns are expected to have a positive correlation with network size (OLESEN et al., 2007).

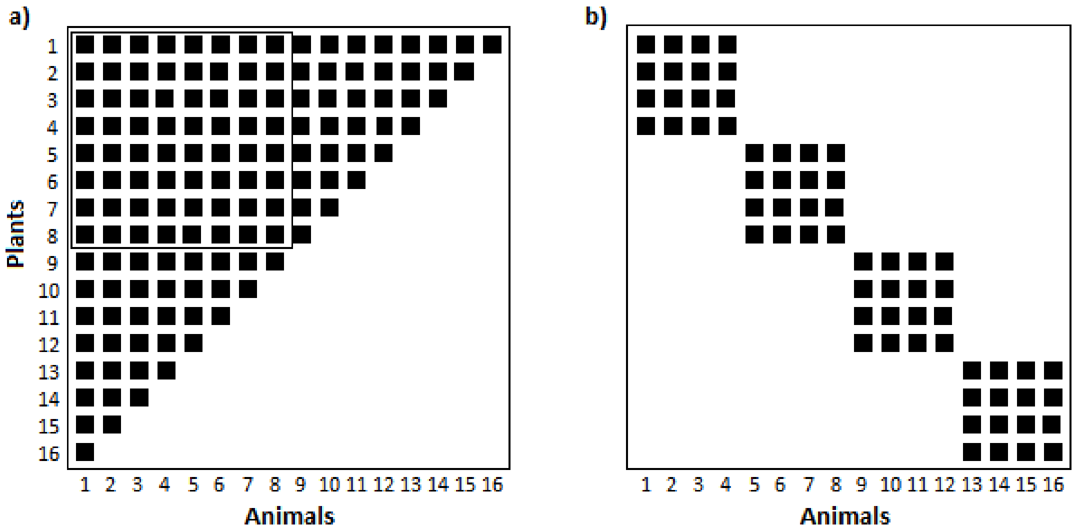

Figure 2.1. Examples of plant–animal matrices perfectly nested, with a generalist core indicated with a square line (a), and organized in modules or groups (b). Adapted from (BASCOMPTE; JORDANO, 2006).

For graph and network analyses of neotropical plant–frugivore webs, we built a binary matrix of adjacencies *Aij* for each site. Frugivorous species were arranged in *i* rows and plant taxa were arranged in *j* columns. The interactions resulting from these matrices generate representations in the form of bipartite graphs, since interactions do not occur between entities of the same trophic level (BASCOMPTE; JORDANO, 2006).

Since our networks were built from the combination of different studies, we were able to calculate qualitative measurements only. We used six indices to describe the structure of neotropical fruit–frugivore networks: network size (*S*), connectance or connectivity (*C*), mean number of links per species ($\overline{L_x}$), niche overlap, nestedness (*NODF*), and modularity (*M*).

Network size, which consists of the sum of animal and plant species, can be considered as species richness, species density or a biodiversity measure of the network, and indicates the maximum number of interactions possible (OLESEN; JORDANO, 2002). The level of generalization of the network can be measured through the connectance (JORDANO, 1987), which is equivalent to the proportion of interactions that actually exist in the network in relation to the total number of possible interactions (number of animals multiplied by the number of plants) (OLESEN; JORDANO, 2002). The mean number of links per species corresponds to the total number of links observed in the network divided by the total number of species. Niche overlap indicates the mean similarity in the pattern of interactions between species of the same trophic level, in this case the frugivores. It was determined by the *Horn* index (DORMANN et al., 2009), and can vary from 0 (no niche overlap) to 1 (total niche overlap). All these indices were determined using the *Bipartite* package version *2.04* (DORMANN et al., 2009; DORMANN; GRUBER; FRÜND, 2008) implemented in the software *R 3.1.2* (R CORE TEAM, 2014).

Nestedness is a feature intrinsic to mutualistic networks, such as pollination or seed dispersal, and it is characterized by non-random interactions between species, which has been found to make networks particularly robust (BASCOMPTE et al., 2003). A network is nested when specialists interact with a subset of species of which the generalist interact (BASCOMPTE; JORDANO, 2006). In this study, the nestedness was determined by the *NODF* index (ALMEIDA-NETO et al., 2008) using the software *ANINHADO 3.0.3* (GUIMARÃES; GUIMARÃES, 2006).

Modularity is also commonly observed in ecological networks. Modules correspond to groups of nodes that are highly connected between them that have only a few connections with other nodes belonging to other groups in the network (OLESEN et al., 2007). For its determination, we chose the Barber modularity index M_B (BARBER, 2007), which determines how many interactions a species has within its module than expected at random. This index was specifically designed for bipartite networks and proved to be the most suitable for detecting modularity in presence–absence matrices (THÉBAULT, 2013). The calculations were made using the software *MODULAR 0.21* (MARQUITTI et al., 2014). Network modules were identified using the software *NetCarto* (GUIMERÀ; AMARAL, 2005a, 2005b) and graphically designed using the software *Pajek 3.13* (BATAGELJ; MRVAR, 2013) in order to optimize the node positioning inside their modules.

2.2.3 Analyses

The patterns observed in the networks can be caused by biological processes, but can also be a byproduct of sampling intensity, sampling biases, or a result of species abundance (BLÜTHGEN et al., 2008). An efficient way for evaluating if the structural patterns are caused by these stochastic processes is to compare the observed values with values generated by null models (GOTELLI; COLWELL, 2001; GOTELLI; GRAVES, 1996).

The statistical significance of the indices C, $\overline{L}_x$, and niche overlap among frugivores was also calculated using the *Bipartite* package after comparison with values obtained from 1000 random matrices, created based on the “null model 2”: where each simulated network is the same size of each empirical network and the probability of an interaction between one animal species and one plant species is proportional to the total number of interactions (BASCOMPTE et al., 2003). The statistical significance of the index M_B was calculated using the same procedure, but with the software *MODULAR*. In order to determine if the network was more nested than expected at random because of species richness and heterogeneity of interactions, the expected value of *NODF* was compared to the value of *NODF* estimated from 100 random matrices created based on the null model *CE* of the software *ANINHADO*, equivalent to Bascompte's "null model 2" (BASCOMPTE et al., 2003).

The effect of the richness of frugivorous species on the modularity and nestedness of the networks was analysed using two linear regression models, where the values of *NODF* and M_B were the dependent variables of their respective models and the number of frugivorous species was the predictive variable in both models. Linear regression models were run with the *R commander 2.1-2* package for *R* (FOX, 2005).

2.3 Results

We were able to build 17 plant–frugivore interaction networks for the neotropical region (Table 2.1; Fig. 2.2). The study sites are mainly remnants of native vegetation protected by public or private administration. In some sites the diversity of frugivores reached up to 15 different orders (Table 2.1).

Table 2.1. Characteristics of 17 interaction networks created based on literature data for different groups of fruit-eating birds and mammals in the Neotropics.

Network name	Site	Country	Latitude	Longitude	Animal group	No. of Orders	No. of animal species	No. of plant species	Network size (A+P)	References[1]
BCI	Barro Colorado Island	Panama	9.16	-79.85	mammal	4	34	257	291	1–15
CSPR	Caraçá Sanctuary Private Reserve	Brazil	-20.10	-43.49	mammal	4	4	60	64	16–19
GCVEPA	Gama-Cabeça de Veado Environmental Protection Area	Brazil	-15.93	-47.90	bird/ mammal	4	31	57	88	20–24
HPIN	Hato Piñero	Venezuela	8.93	-68.08	bird/ mammal	4	12	64	76	25–28
INP	Iguaçu and Iguazú National Parks	Argentina /Brazil	-25.67	-54.36	mammal	4	10	60	70	29–33
ISP	Intervales State Park	Brazil	-24.31	-48.27	bird/ mammal	15	114	61	415	34–41

LTBR	Los Tuxtlas Biosphere Reserve	Mexico	18.56	-95.15	bird/ mammal	7	43	110	153	42–52
MCFBR	Monteverde Cloud Forest Biological Reserve	Costa Rica	10.42	-84.83	bird/ mammal	7	42	189	231	53–54
MGSP	Mata dos Godoy State Park	Brazil	-23.45	-51.25	mammal	4	5	71	76	55
MNP	Manu National Park	Peru	-12.04	-71.72	mammal	4	13	191	204	42; 56–61
PABR	Poço das Antas Biological Reserve	Brazil	-22.52	-42.28	bird/ mammal	7	52	89	141	62–68
PONP	Pontal do Paranapanema	Brazil	-22.53	-52.30	bird/ mammal	4	6	90	96	69–70
RNBAF	Rio Negro and Barranco Alto farms	Brazil	-19.55	-56.53	bird/ mammal	14	52	63	115	71–73
SGR	Santa Genebra Reserve	Brazil	-22.82	-47.11	bird/ mammal	7	45	113	158	74–81
SPNNR	Saut Pararé/ Nouragues Natural Reserve	French Guiana	4.09	-52.67	bird/ mammal	5	18	317	335	42; 82–89
SRNP	Santa Rosa National Park	Costa Rica	10.81	-85.69	mammal	4	16	173	189	42; 90–102
VRESSP	Vila Rica do Espírito Santo State Park	Brazil	-23.91	-51.96	bird/ mammal	12	84	124	208	103–104

[1] References used as data sources for the construction of fruit–frugivore interaction networks: 1) KAUFMANN (1962); 2) HLADIK & HLADIK (1969); 3) OPPENHEIMER (1968); 4) MORRISON (1978); 5) BONACCORSO (1979); 6) OPPENHEIMER (*apud* FREESE & OPPENHEIMER, 1981); 7) GLANZ et al. (1983); 8) OPPENHEIMER (1983); 9) RUSSELL (1983); 10) SMYTHE et al. (1983); 11) BONACCORSO & HUMPHREY (1984); 12) HANDLEY et al. (1991); 13) WEHNCKE et al. (2003); 14) GIANNINI & KALKO (2004); 15) ANDRADE et al. (2013); 16) SILVA & TALAMONI (2003); 17) ALVARENGA & TALAMONI (2006); 18) TALAMONI & ASSIS (2009); 19) SANTOS et al. (2012); 20) MOTTA-JÚNIOR (1991); 21) MIRANDA (1997); 22) VILELA (1999); 23) VILELA (2007); 24) CAMARGO et al. (2011); 25) BARRETO et al. (1997); 26) MILLER (1998); 27) BERTSCH & BARRETO (2008); 28) ARANGUREN et al. (2011); 29) BROWN & ZUNINO (1990); 30) CASELLA (2006); 31) HIRSCH (2009); 32) SÁNCHEZ et al. (2012); 33) TUJAGUE et al. (2016); 34) RODRIGUES (1991); 35) VIEIRA & IZAR (1999); 36) GALETTI et al. (2000); 37) PASSOS et al. (2003); 38) LEINER & SILVA (2007); 39) IZAR (2008); 40) MELLO et al. (2008); 41) AMATUZZI (2009); 42) BECK (2005); 43) ESTRADA & COATES-ESTRADA (1984); 44) ESTRADA et al. (1984); 45) OROZCO-SEGOVIA et al. (1985); 46) VAN DORP (1985); 47) GALINDO-GONZÁLEZ et al. (2000); 48) HERRERA et al. (2001); 49) PUEBLA-OLIVARES & WINKER (2004); 50) ASENSIO et al. (2007); 51) AMATO & ESTRADA (2010); 52) DUNN et al. (2010); 53) WHEELWRIGHT et al. (1984); 54) DINERSTEIN (1986); 55) ROCHA (2001); 56) JANSON (1975); 57) KILTIE (1981); 58) JANSON (1985); 59) FOSTER et al. (1986); 60) TOBLER et al. (2010); 61) PALMA & STEVENSON (2010); 62) CORREIA (1997); 63) DIETZ et al. (1997); 64) CARVALHO et al. (1999); 65) PINHEIRO et al. (2002); 66) MELLO et al. (2004); 67) CARVALHO et al. (2005); 68) MACEDO et al. (2010); 69) TÓFOLI (2006); 70) GOULART (2007); 71) KEUROGHLIAN et al. (2009); 72) DONATTI et al. (2011); 73) MUNIN et al. (2012); 74) GALETTI (1992); 75) GALETTI (1993); 76) CHIARELLO (1994); 77) GALETTI & MORELLATO (1994); 78) GALETTI & PEDRONI (1994); 79) PASCHOAL & GALETTI (1995); 80) FARIA (1996); 81) GALETTI & PIZO (1996); 82) JULIEN-LAFERRIÈRE (1993); 83) GUILLOTIN et al. (1994); 84) JULLIOT (1996); 85) SIMMEN & SABATIER (1996); 86) CHARLES-DOMINIQUE & COCKLE (2001); 87) JULIEN-LAFERRIÈRE (2001); 88) ERARD et al. (2007); 89) LOBOVA et al. (2009); 90) FLEMING et al. (1977); 91) FREESE (1977); 92) HEITHAUS & FLEMING (1978); 93) JANZEN (1982); 94) WILLIAMS (1984); 95) FLEMING & HEITHAUS (1986); 96) CHAPMAN (1987); 97) FLEMING (1988); 98) CHAPMAN (1989); 99) CHAPMAN & FEDIGAN (1990); 100) FLEMING (1991); 101) MACKINNON (2006); 102) VALENTA & FEDIGAN (2008); 103) MIKICH (2001); 104) BIANCONI (2009).

Figure 2.2. Location of the study sites for which plant–frugivore interaction networks were constructed based on literature data.

The mean size of the networks was $\bar{S}$ = 171, varying between S = 64 and S = 415 nodes, and included networks with four to 114 frugivorous species (Table 2.2). The indices C, $\bar{L}_x$ and niche overlap were statistically different from the null models in all 17 networks (P < 0.001). Connectance was generally low, with a mean value of C = 0.12 ± 0.08 (mean ± standard deviation), reaching a maximum value of C = 0.35 in the MGSP network (Table 2.2). The mean number of links per species was $\bar{L}_x$ = 1.94 ± 0.76, but this differed greatly between trophic levels. The mean number of links for frugivores was $\bar{L}_{HL}$ = 13.48 ± 7.24, and mean number of links for plants was $\bar{L}_{LL}$ = 2.62 ± 1.40. Niche overlap was low among frugivores, with a mean value of NO_{HL} = 0.17 ± 0.09, indicating a low common use of resources. Fifty-nine percent of networks were significantly nested (P < 0.05), and the mean value for nestedness was $NODF$ = 24.18 ± 11.08. Similarly, 71% of the networks were significantly modular (P < 0.05), and the mean observed value was M_B = 0.51 ± 0.07 (Table 2.2). The networks had an average of five modules (5.00 ± 0.94), a number that varied from four to seven (Fig. 2.3). Fifty-three percent of all networks were both significantly nested and modular (Table 2.2).

Table 2.2. Structural descriptors of 17 neotropical fruit–frugivore interaction networks. The indices calculated were: network size (S), number of frugivorous and plant species, connectance (*C*), niche overlap (*NO*), nestedness (*NODF*), modularity (M_B), mean number of links per species ($\bar{L}_x$), mean number of links per frugivorous species ($\bar{L}_{HL}$) and mean number of links per plant species ($\bar{L}_{LL}$). Significance levels in relation to the null model 2 of nestedness and modularity indices are indicated by: *, $P < 0.05$; **, $P < 0.01$; NS, non-significant.

Network name	Type	N Frugivores	N Plants	*S*	*C*	*NO*	*NODF*	M_B	$\bar{L}_x$	$\bar{L}_{HL}$	$\bar{L}_{LL}$
BCI	mammal	34	257	291	0.07	0.14	35.74**	0.50**	2.06	17.62	2.33
CSPR	mammal	4	60	64	0.27	0.04	7.29^{NS}	0.63**	1.00	16.00	1.07
GCVEPA	mixed	31	57	88	0.09	0.18	17.29^{NS}	0.48^{NS}	1.90	5.39	2.93
HPIN	mixed	12	64	76	0.13	0.14	24.17*	0.57*	1.33	8.42	1.58
INP	mammal	10	60	70	0.18	0.24	27.57^{NS}	0.54**	1.50	10.50	1.75
ISP	mixed	114	301	415	0.04	0.07	14.68**	0.43**	3.31	12.05	4.56
LTBR	mixed	43	110	153	0.05	0.31	26.33**	0.61**	1.54	5.47	2.14
MCFBR	mixed	42	189	231	0.09	0.20	26.62**	0.43**	3.03	16.67	3.70
MGSP	mammal	5	71	76	0.35	0.35	39.11^{NS}	0.40^{NS}	1.62	24.60	1.73
MNP	mammal	13	191	204	0.09	0.03	8.48^{NS}	0.57^{NS}	1.11	17.46	1.19
PABR	mixed	52	89	141	0.06	0.21	13.68^{NS}	0.52**	1.96	5.33	3.11
PONP	mixed	6	90	96	0.21	0.20	9.69^{NS}	0.55^{NS}	1.19	19.00	1.27
RNBAF	mixed	52	63	115	0.09	0.13	29.09**	0.51**	2.62	5.79	4.78
SGR	mixed	45	113	158	0.07	0.11	28.12**	0.51**	2.13	7.47	2.97
SPNNR	mixed	18	317	335	0.09	0.10	27.21**	0.52^{NS}	1.57	29.17	1.66
SRNP	mammal	16	173	189	0.11	0.21	28.97**	0.54**	1.66	19.63	1.82
VRESSP	mixed	84	124	208	0.07	0.20	47.09**	0.36**	3.51	8.69	5.89

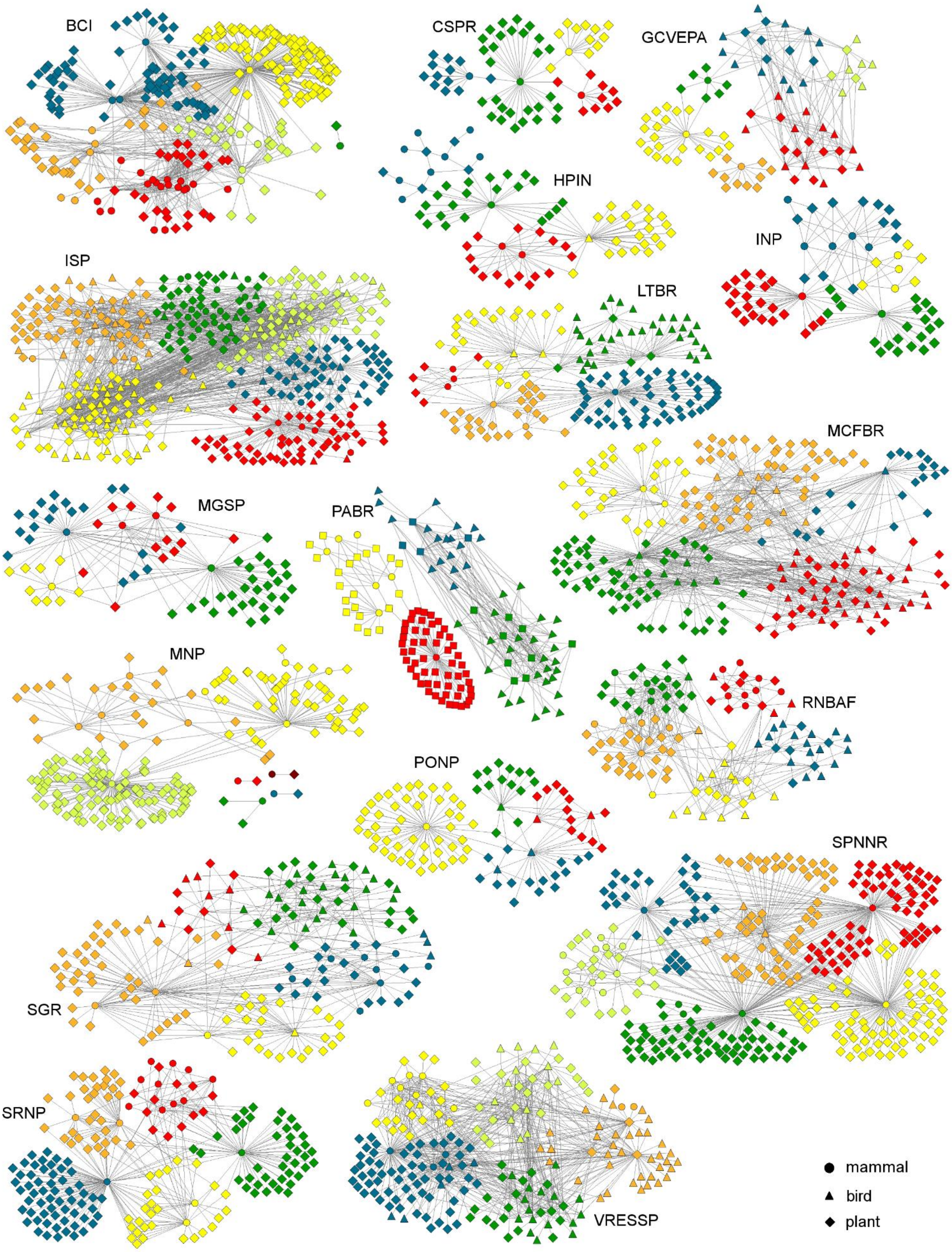

Figure 2.3. Networks of interaction (lines) among plants (diamonds) and frugivores (birds: triangles; mammals: circles) in 17 neotropical communities. Different colours represent different modules of the networks.

Contrary to what was expected, modularity exhibited a significant negative relationship with frugivorous richness (*lm*: $R^2 = 0.31$; $F = 6.61$; *d.f.* = 15; $P = 0.021$; Fig. 2.4a). Additionally, nestedness did not exhibit any significant relationship with frugivorous richness ($R^2 = 0.03$; $F = 0.53$; *d.f.* = 15; $P = 0.479$; Fig. 2.4b). Linear models conducted only with the significant values of modularity and nestedness exhibited the same patterns.

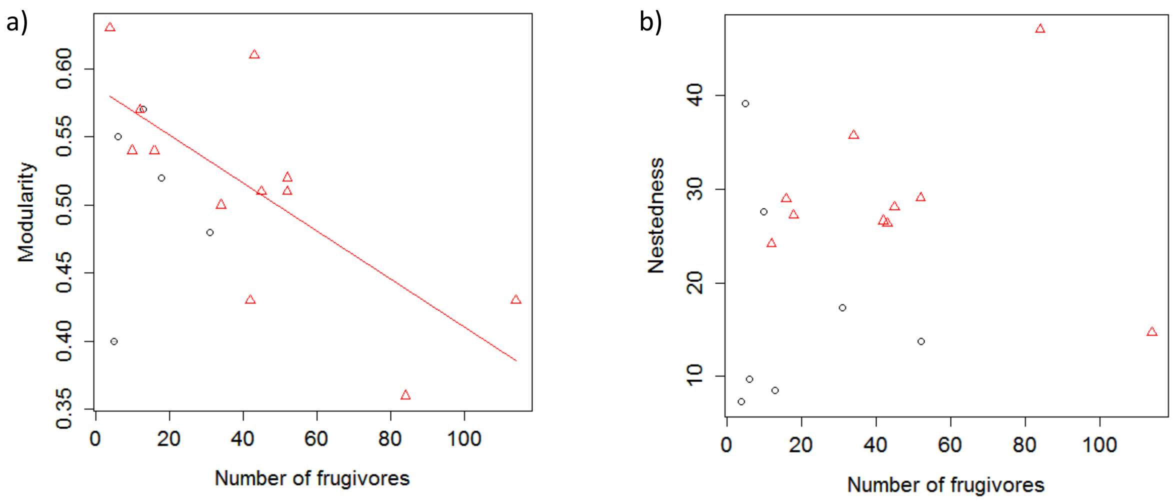

Figure 2.4. Relationships between frugivorous richness and both modularity (a) and nestedness (b) in 17 neotropical plant–frugivore interaction networks. Triangles represent networks with significant measures of modularity and nestedness, and circles represent networks with non-significant measures of modularity and nestedness.

2.4 Discussion

Our study suggests that using combined networks created after literature data for specific fruit-frugivore communities can provide valid (non-random) information on animal–plant interactions in the tropics. Yet, we face a huge spatial gap in the knowledge of community-wide fruit–frugivore interactions in the Neotropics. The 17 networks analysed in this study are not evenly distributed throughout this geographical region, but concentrated in areas such as southeastern Brazil and Central America. Highly biodiverse ecosystems such as the Amazon, Andean forests, Araucaria forest, Cerrado, and the Yungas remain poorly sampled. Although studies on the frugivorous diet of vertebrates were carried out in some of these areas, they have either focused on a few species or were conducted for less than a 6-month period, so that they were not included in our analyses.

In general, the networks studied here exhibited a similar structure to other mutualistic networks previously described in the literature, in terms of their nestedness and modularity. The nested pattern is a common trait in mutualistic networks and is caused by multiple ecological and evolutionary processes (NUISMER; JORDANO; BASCOMPTE, 2013). This structural pattern occurs because the generalists interact between them, representing the bulk of interactions in the network, and the specialists have only a few connections with generalists (BASCOMPTE et al., 2003). This complex and non-random network structuring is believed to be among the main causes for the stability of ecological systems (BASCOMPTE, 2010). Nestedness can enhance the number of coexisting species, by reducing interspecific competition (BASTOLLA et al., 2009), and increase the robustness of the network to species extinctions (MEMMOTT; WASER; PRICE, 2004), and habitat loss (FORTUNA; BASCOMPTE, 2006). Evolutionary constraints also seem to have favoured modularity – semi-independent compartments of highly connected species – in mutualistic networks. This compartmentalization is thought to be a result of morphological, functional, or phylogenetic constraints (LEWINSOHN et al., 2006). Modules in pollination and in seed dispersal networks have been found to be related with their respective syndromes (CARSTENSEN; SABATINO; MORELLATO, 2016; DANIELI-SILVA et al., 2012; DONATTI et al., 2011), that are morphological traits of flowers or fruits associated with plant visitation or fruit consumption by different taxa of vertebrates. It can also be a direct consequence of climatic seasonality (SCHLEUNING et al., 2014). Although mostly significant, modularity values in our networks were usually low. Indeed, these values have been found to be low in tropical seed-dispersal systems (SCHLEUNING et al., 2014). Modularity, as nestedness, is related with community stability and resilience because any perturbations are retained within a single module, minimizing the impact in the rest of the network (DONATTI et al., 2011; SEBASTIÁN-GONZÁLEZ et al., 2015).

Other qualitative indices of network structure also revealed a non-random organization of our 17 fruit–frugivore webs. A low average connectance is common for mutualistic networks, indicating a low generalization and high specialization, and thus low competition between species in the same trophic level (JORDANO, 1987). As connectance is correlated with the number of links in a network (BLÜTHGEN; MENZEL; BLÜTHGEN, 2006), it was expected that the mean number of links would also be low. Although, when examined separately, $\bar{L}$ showed great variation since $\bar{L}$ for animals was much higher than $\bar{L}$ for plants. This difference may be determined by the extremely asymmetrical matrix architecture of most webs, where the number of plant species greatly exceeds the number of frugivore species. This pattern could occur due to the seasonal variation in fruiting, which forces animal species to switch between fruit species during the annual cycle according to their availability. A high resource richness may be the cause of a low niche overlap between frugivores, because seed-dispersal systems are known to be the less specialised compared to other types of mutualism such as plant–ant and plant–pollinator interactions (BLÜTHGEN et al., 2007). High fruit species richness reduces the overlap between the diets of frugivores because it reduces interspecific competition (RAMOS-ROBLES; ANDRESEN; DÍAZ-CASTELAZO, 2016).

The statistical significance of the binary indices from the empirical networks we created in relation to null models confirmed the influence of biological and ecological processes in community structuring, eliminating the possibility that the observed patterns are only a result of stochastic processes (GOTELLI; GRAVES, 1996). In other empirical mutualistic networks reported in the literature, the network structure has been found to be a result of multiple processes such as species abundance, morphological trait matching, species spatio-temporal distribution, and phylogenetic relationships, and usually a combination of such processes is what dictates the interaction events between individuals (VAZQUEZ et al., 2009; VÁZQUEZ; CHACOFF; CAGNOLO, 2009).

The studied networks did not exhibit a significant relationship between size and nestedness. A positive relationship was expected since a nested structure allows greater species coexistence, even with a low number of interactions (BASCOMPTE et al., 2003; BASTOLLA et al., 2009). Nestedness can be both a result of network richness but it is also related to the complexity of the system, that is the number of links for a given number of species (BASCOMPTE et al., 2003). The 17 neotropical networks studied here exhibited a low mean number of links, a result greatly biased by the low mean number of links in the lower trophic level (plants). Modularity, in turn, exhibited a surprisingly significant, although low, negative relationship with an increase of species number, contrary to what was expected. The modular structure of networks involving frugivores and plants usually reflects species diversity (DONATTI et al., 2011; MELLO et al., 2011), but it can also be influenced by a synergy of multiple processes. Both network patterns have been found to be significant more often with an increase in size, but a high density of interactions between the generalist species can explain reductions in modularity level for some networks (OLESEN et al., 2007). Modularity is also expected to be low in networks characterized by low interaction specificity (LEWINSOHN et al., 2006), which is the case for fruit–frugivore interactions.

We acknowledge that our approach has shortcomings. The studies used here to build the networks were conducted in different periods, had different time spans, and data were collected by several methods, but we are confident that by only considering qualitative descriptors of the networks these differences do not affect our analyses. It is known that many of these factors influence the interactions between species and how they are recorded by researchers. For example, sampling quality is expected to be directly linked with sampling effort (FALCÃO; DÁTTILO; RICO-GRAY, 2016). Also, some species exhibit conflicting ecological traits, such as different phenologies or morphological mismatch, known as forbidden links, and it means that there are biological constraints limiting the interactions between two species and, irrespective of sampling effort, they will remain unobservable (JORDANO, 2016; JORDANO; BASCOMPTE; OLESEN, 2003). The metrics used to characterize networks are highly influenced by the number of observations, the sampling period, and the size of the networks (BLÜTHGEN, 2010; BLÜTHGEN; MENZEL; BLÜTHGEN, 2006; FRÜND; MCCANN; WILLIAMS, 2016). Species abundances and foraging behaviours of the animals also influence the recording of plant–animal interactions (SILVA et al., 2007). Nevertheless, even the most comprehensive study will fail in collecting all the interactions occurring in any given ecological community, but it is still possible to achieve valid conclusions by analysing major ecosystem compartments (JORDANO, 2016). Nestedness, for example, is not found to be very sensitive to sampling effort (NIELSEN; BASCOMPTE, 2007). Metrics based on binary data, although not as robust as weighted metrics, have shown to be effective for describing the macroecological structure of seed dispersal networks for example (SEBASTIÁN-GONZÁLEZ et al., 2015), and in general they present similar results to corresponding quantitative metrics (CORSO et al., 2015).

Combined interaction networks can be used to assess the structure of frugivore assemblages in neotropical systems, and as traditional interaction networks they are potentially applicable to aid conservation efforts such as determining keystone species (MELLO et al., 2015; STEVENSON et al., 2015), understanding the effects species loss (KAISER-BUNBURY et al., 2010; VIDAL; PIRES; GUIMARÃES JR., 2013), and addition of invasive species (AIZEN; MORALES; MORALES, 2008), and evaluating ecosystem functioning after restoration (RIBEIRO DA SILVA et al., 2015).

2.4.1 Conclusions

This study presented a novel way for studying the interactions between plants and frugivores, combining data already available from the literature to build complex networks of interactions with a high diversity of animal species. This approach has the advantage of avoiding costly, extensive, and time-consuming fieldwork. Despite this, the Neotropics still is poorly explored in terms of its highly diverse communities of frugivores, with gaps in important biodiverse ecosystems such as the Amazon. The combined networks presented characteristics similar to those of mutualistic networks already described in the literature. Whilst bearing in mind the shortcomings of this methodology, these results can be used in studies aiming to understand the ecological processes structuring different communities in the neotropical region, as well as to predict possible consequences of disturbances caused by the extinction of species in these systems.

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3 Chapter 3

Complementary roles of two resilient neotropical mammalian seed dispersers

Abstract

Capuchin monkeys (*Cebus* spp. and *Sapajus* spp.) and coatis (*Nasua* spp.) coexist in most neotropical forests, including small forest remnants. Both capuchins and coatis eat fruit and disperse seeds, but little is known about whether their roles in seed dispersal are redundant or complementary. We compiled 49 studies from the literature on food eating by capuchins and/or coatis, of which 19 were comprehensive enough for our analyses. We determined the relative importance of fruit eating to each species and compared their diets. Additionally, we analysed the structure of three fruit–frugivore networks containing both groups and evaluated whether fruit traits influenced the network topography. Fruits represented the largest part of capuchin and coati diets, even though coatis are classed as Carnivores. Capuchins and coatis also exhibited similar general diet parameters (niche breadth and trophic diversity). All three networks exhibited high connectance, and an overlap in the frugivore diets of capuchins and coatis ranging from 16–57%. A Multiple Correspondence Analysis, failed to detect any trait or trait combination related to food choice. In conclusion capuchins and coatis showed generalist diets but they feed on very different species of fruits, so exhibiting important complementarity as seed dispersers, and that both are likely to be essential seed dispersers in disturbed and fragmented forests.

Keywords: Animal–plant interactions. *Cebus*. Complex networks. *Nasua*. *Sapajus*.

3.1 Introduction

Plant–animal interactions are among the main processes that create and maintain biodiversity (ODUM; BARRETT, 2008). In the tropics, mutualisms such as pollination and seed dispersal play a central role, with up to 90% of plant species dependent on animals for their reproduction (HOWE; SMALLWOOD, 1982; JORDANO, 2000). Many plant species produce fruits with edible parts to attract frugivorous animals (HOWE; SMALLWOOD, 1982). These animals benefit from the interaction because the fruits act as an energy source, while the plants have their seeds carried away from parent plants, increasing their probability of recruitment (HOWE; MIRITI, 2004; JANZEN, 1971). Seed dispersal by frugivores is a key process in plant population dynamics (TERBORGH, 1995), and in highly fragmented landscapes it can increase the chances of restoration of degraded lands (DUNCAN; CHAPMAN, 2002) and gene flow among natural vegetation patches (JORDANO; GODOY, 2002).

However, medium and large-sized frugivores are becoming extinct or have extremely reduced populations in many tropical ecosystems (WRIGHT et al., 2007), mainly as a result of hunting and habitat loss (CHIARELLO, 1999; CULLEN JR; BODMER; PÁDUA, 2000; PERES; PALACIOS, 2007). This can impact ecosystem structure and dynamics due to the disruption of key interactions, including those related to seed dispersal (DONATTI et al., 2011; GALETTI et al., 2013; GALETTI; DIRZO, 2013; PERES; VAN ROOSMALEN, 2002). In this scenario, some resilient seed dispersing species may become very important because they can provide continuity to essential processes in the forest (ALVES-COSTA; ETEROVICK, 2007).

Capuchin monkeys (genera *Cebus* Erxleben and *Sapajus* Kerr, Primates: Cebidae) and coatis (genus *Nasua* Storr, Carnivora: Procyonidae) are among the residual medium-bodied frugivores that can persist in small Neotropical forest fragments (CHIARELLO, 1999). These two mammal groups are omnivores, but fruits often comprise a major part of their diets, reaching up to 89% for capuchins (GALETTI; PEDRONI, 1994; JANSON, 1985; MIKICH, 2001; MOSCOW; VAUGHAN, 1987; ROCHA, 2001), and 72% for coatis (AGUIAR et al., 2011; GOMPPER, 1996; MIKICH, 2001; RUSSELL, 1983).

Capuchin monkeys are arboreal and social primates (FREESE; OPPENHEIMER, 1981), which are widely distributed throughout the Neotropics. Species of the genus *Cebus* are found in the Amazon and Central America, while species of the genus *Sapajus* are distributed through South America, occupying a variety of habitat types, from dense rainforests and wetlands to areas of Cerrado and Caatinga (FREESE; OPPENHEIMER, 1981; IUCN, 2013).

Coatis are scansorial (they can travel and forage on the ground but are also adapted for climbing trees, where they can forage, avoid predators, sleep and breed), social mammals, although adult males are solitary (GOMPPER, 1995; GOMPPER; DECKER, 1998). The two extant species have discrete distributions: *Nasua narica* (Linnaeus, 1766) in Central America and southern North America, and *Nasua nasua* (Linnaeus, 1766) in South America, from Colombia and Venezuela to Uruguay and Argentina (IUCN, 2013).

Capuchin monkeys and coatis are relatively common to abundant in Neotropical forests (EISENBERG; THORINGTON JR., 1973; GOMPPER; DECKER, 1998), and their geographical ranges overlap. Given their potential importance as frugivores in highly disturbed habitats, where large-seeded plant species may depend on only a few frugivorous species for seed dispersal (ALVES-COSTA; ETEROVICK, 2007; VIDAL; PIRES; GUIMARÃES JR., 2013), further information on their diets and interactions will be valuable for forest conservation and restoration programmes. Due to their diets, habits and behaviour, it is expected that these two mammal groups will exhibit both similarities and dissimilarities regarding their ecological functions and interactions, even in shared habitats, which may affect the wider ecological community.

The mutualisms between animals and plants form a complex network of interactions (BASCOMPTE; JORDANO, 2007) affecting the structure and stability of a community (MARUYAMA et al., 2014; VÁZQUEZ; CHACOFF; CAGNOLO, 2009). Plant ecological traits can shape the interactions between plants and animal visitors, constraining the number and identity of interacting species (JORDANO; BASCOMPTE; OLESEN, 2003), and therefore affecting the patterns of interactions or the network structures, both for plant–pollinator (JUNKER et al., 2013; MAGLIANESI et al., 2014; MARUYAMA et al., 2014; SCHLEUNING; FRÜND; GARCÍA, 2015; VIZENTIN-BUGONI; MARUYAMA; SAZIMA, 2014) and frugivory and seed dispersal networks (DEHLING et al., 2014; GONZÁLEZ-CASTRO et al., 2015). Trait-based analyses have proven the importance of traits of interacting species for the dynamics of interactions, for example morphological matches between plants and their pollinators in pollination networks (JUNKER et al., 2013; MAGLIANESI et al., 2014). Morphological matches have also been shown to be important in determining community structure, as well as species abundances, for plant and avian–seed dispersal interactions (GONZÁLEZ-CASTRO et al., 2015). However, studies incorporating the influence of species' traits in structuring ecological networks are still scarce (KISSLING; SCHLEUNING, 2015), particularly for plant–seed dispersal systems. Furthermore, little is known about networks involving frugivore groups other than birds.

Thus, in this paper, our objectives were: (1) to determine the importance of fruits in the diets of capuchins and coatis, aiming to understand their functional role as fruit consumers (and potential seed dispersers); (2) to compare diet parameters between these two mammalian groups, and to investigate the possible causes of any differences; and (3) to identify key plant traits linked to these groups' fruit preferences. We predicted that fruits should represent a smaller part of coatis' diet when compared to capuchins', considering that the former group belongs to the Order Carnivora. Due to morphological and behavioural differences between the two groups, we expected diet breadth and diversity to differ, with capuchins favouring fruit consumption over other items, and as a result exploiting a higher fruit species diversity than coatis. We also expected plant, fruit and/or seed traits to explain the trophic interaction structure for these two taxa.

To test our predictions, we gathered data from a systematic literature review to evaluate frugivory by capuchin monkeys and coatis and their interactions with fruit plants over the Neotropical region. For three case studies, where detailed data were available on capuchin and coati feeding associations, we also investigated fruit-frugivore network structure.

3.2 Material and methods

3.2.1 Data compilation

We performed a broad review, using the *Web of Science* database (http://apps.webofknowledge.com), our own knowledge of the literature, dissertations, theses, and our own unpublished data about the diets of wild populations of capuchin monkeys and coatis. For capuchins, the search in the database was performed using the keywords [("*Cebus*" OR "*Sapajus*") AND "diet"], and all studies listed until August 2016 were analysed. For coatis, the investigation included all studies published until August 2016 that resulted from the search of the term "*Nasua*". We did not use the "diet" filter in this last search because there were already few results and we did not want to miss any relevant studies. In order to compare the diet parameters (trophic diversity and niche breadth) between the two mammalian groups, we selected diet studies that described all recognisable food items, and not just the dominant foods, conducted during ≥ 12 months, and where the relative frequencies of occurrence of the different items in their diet (e.g. fruit + seeds, non-fruit plant parts and animal matter) were reported or could be calculated. We used studies where the method could quantify the frequency of occurrence of different items as this tends to include even rare and important food sources (ROBINSON, 1986). We used original datasets whenever available, and secondary data when the original data were not accessible.

Since the taxonomy of both capuchins and plants can be controversial, we standardized their classifications. For the capuchins, we followed the proposal of Alfaro *et al.* (2012a; 2012b). For plants, scientific names and classifications were verified according to *The Plant List* database (http://www.theplantlist.org).

3.2.2 Case studies

Despite a reasonable number of studies published on the diets and/or seed dispersal of both groups (35 studies for capuchin monkeys and 16 studies for coatis) and the considerable overlap in their geographical ranges, only two study sites had the diets of both groups investigated at the same time and with the same methodology (MIKICH, 2001; ROCHA, 2001). Additionally, one study site (Barro Colorado Island, Panama) had a number of independent, detailed and consistent observational studies on the diets of capuchins and coatis (OPPENHEIMER, 1968 *apud* FREESE; OPPENHEIMER, 1981; HLADIK; HLADIK, 1969; KAUFMANN, 1962; RUSSELL, 1983), making it possible to combine data from different sources for some analyses. We acknowledge that there are some methodological limitations in combining these data into one BCI network because although the different studies were all sampled using direct observation by following habituated bands during long periods, they involved different sampling efforts, were conducted by different investigators, were not concurrent and had different durations. However, despite the data being collected over a long period, there was little change in the plant species recorded, or in the extent of forest on BCI, and therefore we decided that combining these data sets was appropriate for our purposes and would not negatively affect the results. Study duration will also influence the size of the network and the plant species recorded and therefore this needs to be taken into consideration. Our analyses therefore focused on these three case studies, where each study had the same sampling effort for capuchins and coatis within the study—although sampling effort was not consistent across studies—which we now describe in detail.

The first study system included data on *Sapajus nigritus* (Goldfuss, 1809) and *N. nasua* interacting with 101 plant species (S. B. Mikich, in prep.). This author collected the data in a protected area called Vila Rica do Espírito Santo State Park, which is located in the interior portion of the Atlantic forest of Parana state, southern Brazil, municipality of Fenix (23°54’ S, 51°58’ W; 440 m a.s.l.), hereafter named Fenix. The climate is subtropical (Cfa, according to the Köppen-Geiger classification; KOTTEK et al., 2006) with mean temperatures below 18°C during winter and above 22°C during summer; annual rainfall between 1400 and 1500 mm with twice as much rain in the summer than in the winter. The vegetation type is semi-deciduous seasonal forest in the form of a 354-ha fragment of old secondary forest (almost 400 years old and similar to primary forests according to MIKICH; SILVA, 2001) surrounded by an agricultural matrix. Although this fragment is protected, poaching occurs (ROCHA-MENDES et al., 2005), but the main threats to wildlife are the hunting by domestic dogs, and the reduced size and isolation of the fragment (MIKICH; OLIVEIRA, 2003). Due to the scarcity of top predators and the abundance of food, the population of both capuchins and coatis have increased considerably (MIKICH; OLIVEIRA, 2003; ROCHA-MENDES et al., 2005) so they are now among the most abundant mammal species within this protected area. The sampling methods were both direct observation *ad libitum* and faecal samples collected monthly between May 1990 and December 1999 along a trail system (9 km long) (MIKICH, 2001). Each visual encounter with one feeding individual or group was taken as a feeding record, as was each item or plant species found in the faecal samples, making the visual and faecal data points equivalent in this case, totalling 5,808 feeding records by capuchin monkeys and 729 by coatis.

The second study system had the same monkey and coati species found in Fenix, interacting with 50 plant species (ROCHA, 2001). It is a 680-ha protected area also located in Parana state, municipality of Londrina, called Mata dos Godoy State Park (23°27' S, 51°15' W; 700 m a.s.l.), hereafter named Godoy. The climate, vegetation type and surrounding matrix are all similar to Fenix. Godoy is a relatively well preserved area and it is connected to neighbouring forest fragments with different levels of disturbances, totalling approximately 1,800 ha of forests (ROCHA, 2001). According to Rocha (2001), capuchin monkeys and coatis are among the most commonly observed mammals in the area, which may be related to a low number of top predators. The author conducted monthly samplings between October 1993 and September 1994 and between April 1996 and March 1998. Data collection and counting of feeding records were the same employed in Fenix and totalled 241 feeding records by capuchin monkeys and 134 by coatis (ROCHA, 2001).

The third study system is based on data presented in four different studies conducted in Barro Colorado Island, Panama (9°09' N, 79°51' W; 25 m a.s.l.), merged as a single dataset, hereafter named BCI. Barro Colorado is a 1,560-ha island formed following the construction of the Panama Canal, between 1911 and 1914, when the River Chagres was dammed (CROAT, 1978). The climate is equatorial monsoon climate (Am, according to the Köppen-Geiger classification; KOTTEK et al., 2006), annual rainfall ranges from 190 to 360 mm. The vegetation type is semi-evergreen moist tropical forest (CROAT, 1978). The island is composed of late secondary forest (KNIGHT, 1975) and poaching is under control. *Cebus capucinus* (Linnaeus, 1758) and *N. narica* are among the most abundant mid-sized fruit-eating mammals in the area (WRIGHT; GOMPPER; DELEON, 1994). The first study was conducted by Kaufmann (1962) on *N. narica* between July 1958 and June 1960, when the author followed five groups of coatis during a total of 1,370 hours recording 19 consumed plant species through direct observation. The second study, conducted by Oppenheimer (1968 *apud* FREESE; OPPENHEIMER, 1981) between March 1966 and August 1967, recorded 66 plant species in the diet of *C. capucinus* through direct observation. The third study, also on the diet of *C. capucinus*, was performed between November 1966 and January 1968 by Hladik and Hladik (1969). They followed the monkeys and recorded the consumption of 45 plant species also through direct observation. The last study was conducted by Russell (1983), who recorded feeding bouts in 24 fruit species by two habituated groups of *N. narica* during 14 months (between August and September 1975, June and October 1977 and January and July 1978). The combined dataset totalled 108 distinct plant species.

3.2.3 Plant traits

Using plant identities would make it difficult to perform further comparisons among the three case studies since there is little overlap in plant species, especially with BCI, due to geographical and climatic constraints. Therefore, we used plant traits known to be important for frugivores instead, aiming to find key traits that might have been favoured by each mammal in the study sites. Plant life form, fruit type, fruit colour, fruit size, seed size, number of seeds per fruit were compiled for the 293 plant species found in the studies based on published data (CROAT, 1978; JORDANO, 1995; MIKICH; SILVA, 2001; WRIGHT et al., 2010). To perform the analyses, these traits were standardized as follows: five categories of plant life forms (climber; epiphyte; herb; shrub; and tree), seven categories of fruit types (aril; berry; drupe; fleshy aggregates; grain; pod; and samara), eight categories of fruit colours (black; brown; blue + purple; green; orange; red + burgundy; white; yellow), five categories of number of seeds per fruit (one = 1 seed; two = 2 seeds; three = 3 to 4 seeds; four = 5 to 10 seeds; and five = > 10 seeds), and five intervals of fruit sizes (one = [0, 6] mm; two =]6, 10] mm; three =]10, 20] mm; four =]20, 50] mm; and five =]50, ∞[mm) and seed sizes (one = [0, 3] mm; two =]3, 6] mm; three =]6, 10] mm; four =]10, 20] mm; and five =]20, ∞[mm).

3.2.4 Data analyses

To compare patterns in the composition and diversity of capuchin and coati diets, we calculated trophic diversity (Shannon's diversity index, *H'*) and niche breadth (Levin's index, *B*) based on the relative percentage of occurrence of the main food categories (fruits and seeds, non-fruit plant parts, and animal matter) in their diets (*see* ZHOU et al., 2011). These indexes were obtained for each study containing information on the proportion of different food items consumed. To assess differences in trophic diversity and niche breadth between capuchin and coati diets, we used *t*-tests.

Food web analyses were performed to describe the topology of the three case study communities with data on fruit consumption by both capuchins and coatis. These networks had only presence–absence data, allowing us to determine their qualitative characteristics such as the number of links (*L*), connectance (*C*) and normalised degree (*ND*)—a measure of generalisation defined as the proportion of species a particular species interacts with out of the total possible in the network (MARTÍN GONZÁLEZ; DALSGAARD; OLESEN, 2010). For each community, we calculated the Jaccard (d_J)

dissimilarity coefficient (OKSANEN et al., 2013) between species composition in the diets of capuchins and coatis.

A Multiple Correspondence Analysis (MCA) was performed to identify patterns in the plant trait data for each of the three study cases. Prior to the MCA, we performed an imputation analysis to handle missing values (JOSSE; HUSSON, 2012) in the matrices of plant traits.

All statistical analyses were carried out in the statistical computing environment *R 3.1.2* (R CORE TEAM, 2014) using packages *R commander 2.0-0* (FOX, 2005) for diet indices and t-tests, *bipartite 2.02* (DORMANN, 2011; DORMANN et al., 2009; DORMANN; GRUBER; FRÜND, 2008) for food web and graph analysis, *vegan 2.0-10* (OKSANEN et al., 2013) for the calculation of dissimilarity coefficients, *missMDA 1.7.2* (JOSSE; HUSSON, 2012) and *FactoMineR 1.27* (HUSSON et al., 2014; LÊ; JOSSE; HUSSON, 2008) for imputation and MCA.

3.3 Results

3.3.1 Overall diet

Data on the diet of wild capuchin monkeys, genera *Cebus* and *Sapajus*, were obtained from 35 studies: 29 peer-reviewed articles, three book chapters, one dissertation, one thesis, and one unpublished dataset (Appendix C). They included three *Cebus* (*C. albifrons* [Humboldt, 1812], *C. capucinus*, and *C. olivaceus* Schomburgk, 1848) and six *Sapajus* species (*S. apella* [Linnaeus, 1758], *S. cay* [Illiger, 1815], *S. libidinosus* [Spix, 1823], *S. macrocephalus* [Spix, 1823], *S. nigritus*, and *S. xanthosternos* [Wied-Neuwied, 1826]). There were 1,480 records of fruit consumption by these species involving 940 plant species. We found seven additional references related to occasional records of fruit consumption (Appendix C). Twelve out of 35 diet studies (one of which had information about two groups located in two different study sites) were conducted for ≥ 12 months and had the relative frequency of occurrence of the different items in capuchins' diet reported or with enough information to be calculated (Appendix D).

Data on the diet of wild coatis (*N. narica* and *N. nasua*) were obtained from 16 studies: 10 peer-reviewed articles, one book chapter, one dissertation, three theses and one unpublished dataset (Appendix C). There were 414 records of fruit consumption by these species, involving 272 plant species. We found seventeen additional references related to occasional records of fruit consumption (Appendix C). Ten out 16 diet studies were conducted for ≥12 months and had the relative frequency of occurrence of the different items in coatis' diet reported or with enough information to be calculated (Appendix D).

Fruits plus seeds and animal matter (comprised mainly of invertebrates) were the main food categories eaten by both capuchins and coatis (Table 3.1; Appendix D). More infrequent food categories included non-fruit plant parts, such as leaves or roots, as well as crops/human waste.

Table 3.1. Dietary composition in capuchin monkeys and coatis in the neotropical region. Values correspond to median percentages (interquartile ranges).

	capuchins	**coatis**
N*	12	10
Fruits and seeds	47 (27)	49 (37)
Non-fruit plant parts	16 (21)	2 (6)
Animal matter	27 (17)	48 (25)

* Number of studies reviewed (*see* Appendix 3).

Average trophic diversity (*H'*) and niche breadth (*B*) for capuchins were 1.14 (SD 0.25) and 2.78 (SD 0.86), respectively. The same indexes for coatis were 1.07 (SD 0.15) and 2.52 (SD 0.37), respectively. The two mammal groups did not differ significantly in *H'* (t = 0.752; df = 18.4; P = 0.462) or *B* (t = 0.965; df = 15.4; P = 0.349) (Fig. 1).

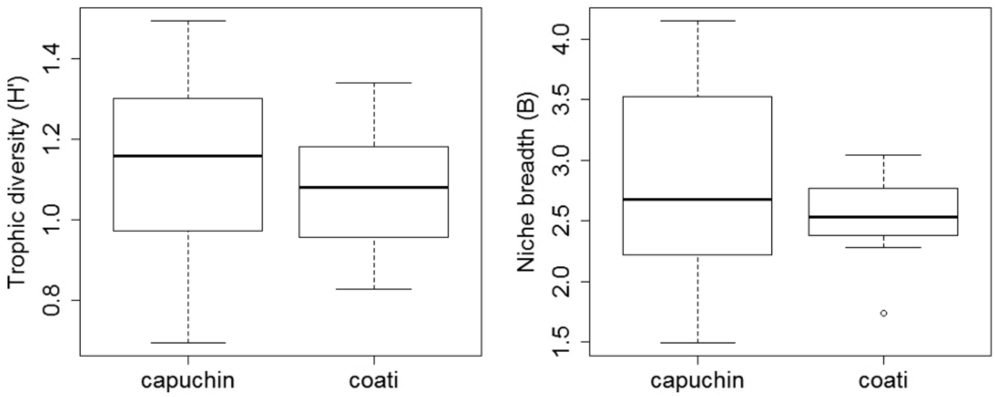

Figure 3.1. Comparisons of the mean values (± SE) of trophic diversity (left) and niche breadth (right) for capuchin monkeys and coatis.

3.3.2 Case studies

The three focal communities showed differences in their network structures (Table 3.2; and *see* Fig. 2). At Fenix, a much higher percentage of fruiting species was shared by the two mammal taxa (57%) compared to Godoy (20%) and BCI (16%). The number of links also differed considerably among communities (Table 3.2).

Table 3.2. Network indices (*L* = number of links, *C* = connectance, and *ND* = normalised degree) and the Jaccard dissimilarity index (d_J) for three neotropical communities used as case studies to evaluate the roles of the mammalian dispersers capuchin monkeys and coatis.

	L	*C*	$ND_{capuchins}$	ND_{coatis}	d_J
Fenix	159	0.79	0.90	0.34	0.43
Godoy	60	0.57	0.86	0.36	0.84
BCI	125	0.58	0.79	0.67	0.80

Fenix network showed higher number of links and connectance values, and lower dissimilarity coefficients between fruit species composition in the diets of capuchins and coatis (Table 3.2). The normalised degree for capuchins did not vary greatly in the three networks but the same index for coatis had a higher variation among Fenix networks and the other networks (Table 3.2).

3.3.3 Plant traits

We recorded a wide diversity of plant traits in the three studied communities (Fig. 2). Both mammal groups included in their diets fruits from each category of traits. The MCA did not reveal any combination of traits that might be influencing fruit choice by capuchins or coatis in our three focal communities (Fig. 3), indicating an opportunistic and generalist diet for both groups.

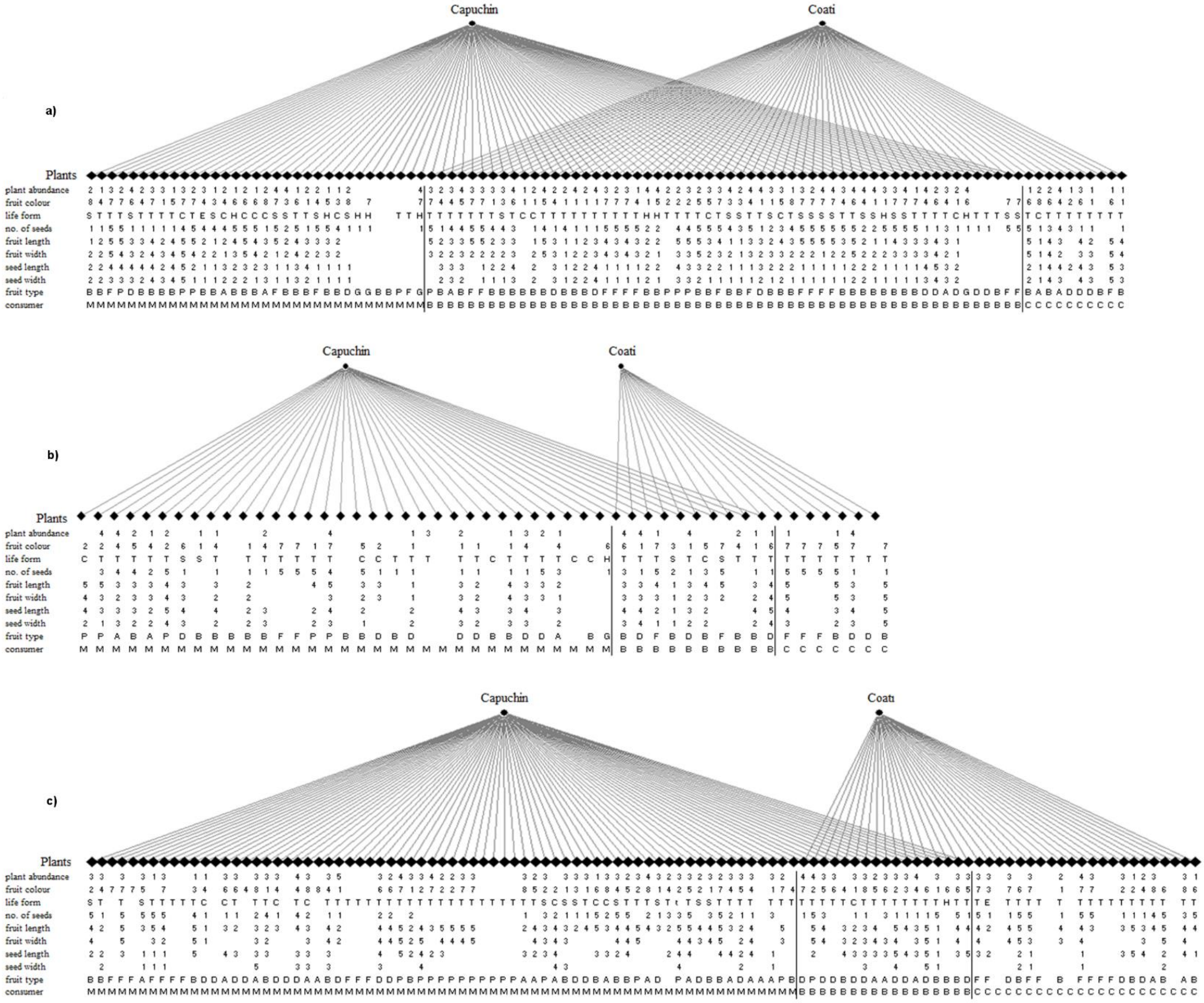

Figure 3.2. Interactions among fruit plants and two generalist mammals in three focal communities: Fenix (a); Godoy (b); and BCI (c). The diversity of plant and fruit traits is listed below the lower vertices (plants) in each community. Legend for plant and fruit traits – plant abundance: 1 = rare, 2 = intermediate, 3 = common, 4 = abundant; fruit colour: 1 = black, 2 = brown, 3 = blue/purple, 4 = red/burgundy, 5 = orange, 6 = yellow, 7 = green, 8 = white; life form: E = epiphyte, H = herb, C = climber, S = shrub, T = tree; number of seeds per fruit (no. of seeds): 1 = 1 seed, 2 = 2 seeds; 3 = 3 to 4 seeds, 4 = 5 to 10 seeds, 5 = > 10 seeds; fruit sizes: 1 = [0, 6] mm, 2 =]6, 10] mm, 3 =]10, 20] mm, 4 =]20, 50] mm, 5 =]50, ∞[mm; seed sizes: 1 = [0, 3] mm, 2 =]3, 6] mm, 3 =]6, 10] mm, 4 =]10, 20] mm, 5 =]20, ∞[mm.

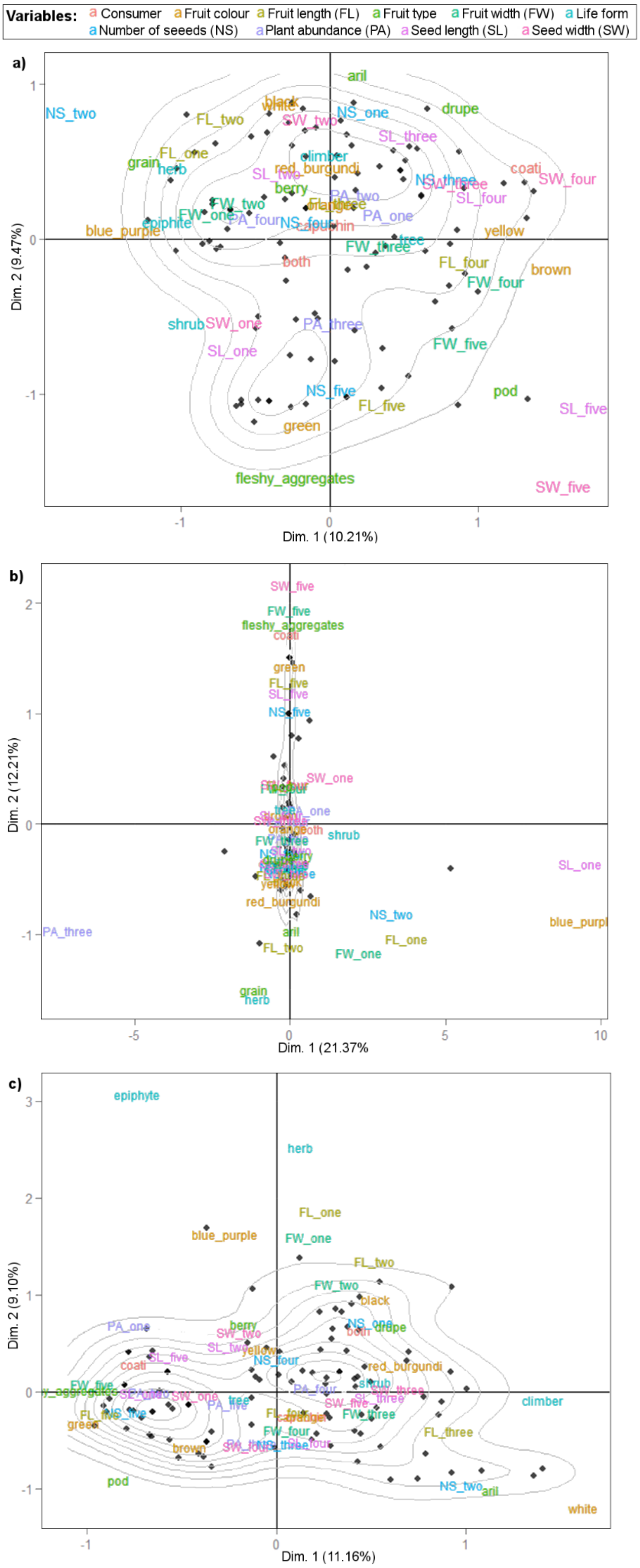

Figure 3.3. Multiple correspondence analysis representation of the individual plants (dots) and categories of plant traits in the first two axes for each focal community: Fenix (a), Godoy (b), and BCI (c).

3.4 Discussion

Fruits comprised the major part of the diet of both capuchins and coatis throughout the Neotropical region. Both groups presented similar values for niche breadth and trophic diversity, meaning that the variety of foods they ate was similar, although animal matter was more frequently recorded for coatis. Coatis ingested a smaller number of fruit species compared to capuchins in all three case studies, but numbers increased with sampling effort, suggesting that long term studies are necessary to get a comprehensive picture of the diets of these mammals. Accordingly, the communities taken as case studies differed in the number of shared plant species by coatis and capuchins, but diet overlap was higher for the system sampled for a longer period (Fenix). A novel approach using a MCA to evaluate plant ecological and morphological traits on fruit choice by capuchins and coatis failed to detect any trait or trait combination that could be directly related to food choice.

The large representation of fruits plus seeds and animal matter (mostly insects) in both capuchin and coati diets indicates a very flexible diet, which is known to be affected by seasonal availability of food types (ALVES-COSTA; FONSECA; CHRISTÓFARO, 2004; HIRSCH, 2009; MIKICH; LIEBSCH, 2014; PERES, 1994), cultivated crops (BEISIEGEL; MANTOVANI, 2006; FREITAS et al., 2008; GALETTI; PEDRONI, 1994; LUDWIG; AGUIAR; ROCHA, 2005; MIKICH, 2001; PÉREZ; PACHECO, 2006), and other anthropogenic disturbances (AGUIAR et al., 2011; FERREIRA et al., 2013; SABBATINI et al., 2008). This flexibility in diet is a possible explanation for the variation in feeding composition observed across the studies for each group.

Animal matter, especially arthropods, represented an important food source for coatis, being often chosen over fruits, although it may be more related to resource availability than to any feeding preference (ALVES-COSTA; FONSECA; CHRISTÓFARO, 2004; HIRSCH, 2009). Capuchins, on the other hand, consumed more non-fruit plant parts—as flowers, leaves and roots—than did the coatis. These monkeys have the ability to explore a wider range of different food items because of their manipulative skills and tool use (BOINSKI; QUATRONE; SWARTZ, 2000; FRAGASZY; VISALBERGHI; ROBINSON, 1990; MANNU; OTTONI, 2009; OTTONI; IZAR, 2008). Despite marked morphological and behavioural differences between the capuchins and coatis, they showed similar patterns of average trophic diversity and niche breadth, confirming the overall generalist nature of their diets (FREESE; OPPENHEIMER, 1981; GOMPPER, 1995; GOMPPER; DECKER, 1998).

To date, there are few network studies documenting interactions between fruiting plants and generalist fruit-eating mammals (BUFALO; GALETTI; CULOT, 2016; HAWES; CALOURO; PERES, 2013; PIRES et al., 2014; STEVENSON et al., 2015; VIDAL; PIRES; GUIMARÃES JR., 2013). The three networks analysed had higher connectance values when compared with other fruit-frugivore networks such as bat– or bird–fruit networks with mean *C* values of 0.30 and 0.22, respectively (MELLO et al., 2011). In fact, previous analyses of food webs found that small webs dominated by generalist omnivores tended to be those with higher connectance values (DUNNE; WILLIAMS; MARTINEZ, 2002), as in our study. The dissimilarity in fruit species composition between the diets of coatis and capuchins was high, especially in BCI and Godoy. The proportion of fruit species shared by the two taxa differed among the three communities, but most species were consumed by only one mammalian species. Although, as already stated, sampling effort, especially study duration in years, may be affecting the results.

Since capuchins and coatis have been shown to disperse the seeds of most fruit species they eat (ALVES-COSTA; ETEROVICK, 2007; MIKICH et al., 2015; VALENTA; FEDIGAN, 2008; WEHNCKE; DOMÍNGUEZ, 2007), these two groups are likely to be important seed dispersers in disturbed habitats. Considering the differences observed in their diets and reported differences in movement patterns (HIRSCH et al., 2013), they should have complementary roles in seed dispersal at the study sites (SCHLEUNING; FRÜND; GARCÍA, 2015). The normalised degree index indicates the generalisation of species (MARTÍN GONZÁLEZ; DALSGAARD; OLESEN, 2010). In all three areas capuchins achieved high normalised degree values and included a wide range of fruit species in their diets, so the vast majority of fruit species available were eaten by these primates. In turn, coatis showed high variation across communities in the quantity of fruit species eaten, in relation to the number of species available, which was highlighted by the contrasting values of normalised degree observed. Our results indicate that coatis are very flexible regarding the fruits included in their diet suggesting that fruit choice is related to availability.

Plant traits of the species eaten by capuchins and coatis at Fenix, Godoy and BCI were variable, including different plant abundances, life forms, number of seeds per fruit, seed sizes, and fruit types, colours and sizes. We did not detect any trait or trait combination closely linked to fruit choice by either coatis or capuchins. Due to their low dietary specialisation and relatively large size, capuchins and coatis appear to select a broad variety of fruit. In tropical ecosystems, frugivores have been found to have generalized roles in networks because they require a high diversity of fruit plants (DALSGAARD et al., 2017). This contrasts with more specialized temperate fruit–frugivore systems, such as plant–bird networks, where particular fruit traits (e.g. fruit size) can constrain fruit choice, simply due to beak size determining the size of seed that can be consumed (DEHLING et al., 2014). Future studies should focus on comparing mammals with contrasting levels of frugivory and diet specialization, in order to evaluate the effect of plant and fruit traits on diet composition and, consequently, on the structure of the community.

Whilst we did not find any diet restrictions caused by plant traits, capuchins and coatis have different life histories, which in turn influences their nutritional demands and diet compositions

(HIRSCH, 2009; JANSON; BALDOVINO; DI BITETTI, 2012). Additionally, differences in terms of movement patterns and foraging patterns (HIRSCH et al., 2013) may help to explain the differences observed in their frugivorous diets. Coatis are scansorial, but they forage primarily on the ground where they eat fallen fruits among other items (HIRSCH et al., 2013; RUSSELL, 1983), while capuchins are primarily arboreal and feed in the forest canopy (HIRSCH et al., 2013). Capuchins also have handling skills and tool use ability, which allows them to exploit a large range of fruits and seeds (BOINSKI; QUATRONE; SWARTZ, 2000).

Habitat loss and fragmentation can directly affect mammalian assemblages in disturbed habitats, particularly for frugivores (CHIARELLO, 1999). Coatis and capuchins can persist in relatively small and disturbed habitats, and even benefit from anthropogenic disturbances, persisting in sites where other mid-sized and large mammals cannot (ALVES-COSTA; ETEROVICK, 2007; CHIARELLO, 1999). Although there is some level of redundancy in seed dispersal by coatis and capuchins with other medium-sized mammals and large birds (ALVES-COSTA; ETEROVICK, 2007; MIKICH, 2001), there still are a considerable proportion of fruit species that rely on these animals for seed dispersal. Therefore, these two groups are likely to perform key roles in forest maintenance and restoration through seed dispersal in such habitats. Our study was unfortunately unable to directly assess the level of seed dispersal caused by capuchins and coatis, however, since capuchins and coatis can disperse the seeds of most fruit species they eat (ALVES-COSTA; ETEROVICK, 2007; MIKICH et al., 2015; VALENTA; FEDIGAN, 2008; WEHNCKE; DOMÍNGUEZ, 2007), we can infer that seed dispersal is likely to be highly correlated with fruit consumption.

Our study is an important initial attempt to investigate the interactions between capuchins, coatis, and the fruit species they eat and disperse, using a network and trait based approach. These taxa alone do not reflect the entirety of mutualistic interactions occurring in an intact forest where a large assemblage of frugivores may share and compete for the same resources. Nevertheless, taking into account the ongoing fragmentation and habitat loss throughout the Neotropical region (DIRZO; RAVEN, 2003; LAURANCE, 2007; MYERS et al., 2000; SILVA; TABARELLI, 2000), and their complementary seed dispersal services in disturbed habitats, capuchins and coatis are likely to play an essential role in Neotropical forest maintenance and recovery.

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WRIGHT, S. J.; GOMPPER, M. E.; DELEON, B. Are large predators keystone species in neotropical forests? The evidence from barro colorado island. **Oikos**, v. 71, n. 2, p. 279–294, nov. 1994.

ZHOU, Y.-B. et al. Biogeographical variation in the diet of Holarctic martens (genus *Martes*, Mammalia: Carnivora: Mustelidae): adaptive foraging in generalists. **Journal of Biogeography**, v. 38, n. 1, p. 137–147, 9 jan. 2011.

APPENDIX C – Reviewed studies of diet, seed dispersal or occasional fruit consumption by capuchin monkeys, genera *Cebus* and *Sapajus*, and coatis, genus *Nasua*.

	Reference	Focus of the Study	Mammal genera			Type of Study
			Cebus	***Sapajus***	***Nasua***	
1-	CHAPMAN, C. A.; FEDIGAN, L. M. Dietary differences between neighboring *Cebus capucinus* groups: local traditions, food availability or responses to food profitability? **Folia Primatologica**, v. 54, p. 177–186, 1990.	Diet	X			Journal article
2-	CHAPMAN, C. A. Primate seed dispersal: The fate of dispersed seeds. **Biotropica,** v. 21, n. 2, p. 148–154, 1989.	Seed dispersal	X			Journal article
3-	CUERVO-DÍAZ, A.; BARBOSA C., C. E.; DE LA OSSA V., J. Aspectos ecologicos y etologicos de primates con enfasis en *Alouatta seniculus* (Cebidae), de la region de Coloso, serrania de San Jacinto (Sucre), costa norte de Colombia. **Caldasia**, v. 14, n. 68–70, p. 709–741, 1986.	Occasional	X			Journal article
4-	CUNHA, A. A.; VIEIRA, M. V; GRELLE, C. E. V. Preliminary observations on habitat, support use and diet in two non-native primates in an urban Atlantic forest fragment: The capuchin monkey *(Cebus* sp.) and the common marmoset (*Callithrix jacchus*) in the Tijuca forest, Rio de Janeiro. **Urban Ecosystems**, v. 9, n. 4, p. 351–359, 18 out. 2006.	Diet	X			Journal article
5-	DE OLIVEIRA, S. G.; LYNCH ALFARO, J. W.; VEIGA, L. M. Activity budget, diet, and habitat use in the critically endangered Ka'apor capuchin monkey (*Cebus kaapori*) in Pará State, Brazil: A preliminary comparison to other capuchin monkeys. **American Journal of Primatology**, v. 76, n. 10, p. 919–931, out. 2014.	Diet	X			Journal article
6-	DE RUITER, J. R. The influence of group size on predator scanning and foraging behaviour of wedgecapped capuchin monkeys (*Cebus olivaceus*). **Behaviour**, v. 98, n. 1, p. 240–258, 1986.	Occasional	X			Journal article
7-	FREESE, C. H. Food habits of the white-faced capuchins *Cebus capucinus* L. (Primates: Cebidae) in Santa Rosa National Park, Costa Rica. **Brenesia**, v. 10/11, p. 45–56, 1977.	Diet	X			Journal article
8-	FREESE, C. H.; OPPENHEIMER, J. R. The capuchin monkeys, genus *Cebus.* In: COIMBRA-FILHO, A. F.; MITTERMEIER, R. M. M. (Eds.). **Ecology and Behavior of Neotropical Primates**. Rio de Janeiro: Academia Brasileira de Ciências, 1981. v. 1p. 331–390.	Diet	X	X		Book chapter
9-	HLADIK, A.; HLADIK, C. M. Rapports trophiques entre végétation et Primates dans la forêt de Barro Colorado (Panama). **Revue d'Écologie (La Terre et La Vie)**, v. 23, p. 25–117, 1969.	Diet	X			Journal article

Continues…

APPENDIX C – Continuation.

	Reference	Focus of the Study	Mammal genera			Type of Study
			Cebus	*Sapajus*	*Nasua*	
10-	IZAWA, K. Foods and feeding behavior of monkeys in the upper Amazon basin. **Primates**, v. 16, n. 3, p. 295–316, 1975.	Diet	X	X		Journal article
11-	MCKINNEY, T. The effects of provisioning and crop-raiding on the diet and foraging activities of human-commensal white-faced capuchins (*Cebus capucinus*). **American Journal of Primatology**, v. 73, n. 5, p. 439–448, maio 2011.	Diet	X			Journal article
12-	MENDES-PONTES, A. R. Habitat partitioning among primates in Maraca island, Roraima, northern Brazilian Amazonia. **International Journal of Primatology**, v. 18, n. 2, p. 131–157, 1997.	Occasional	X	X		Journal article
13-	MOSCOW, D.; VAUGHAN, C. Troop movement and food habits of white-faced monkeys in a tropical-dry forest. **Revista de Biología Tropical**, v. 35, n. 2, p. 287–297, 1987.	Diet	X			Journal article
14-	MOSDOSSY, K. N.; MELIN, A. D.; FEDIGAN, L. M. Quantifying seasonal fallback on invertebrates, pith, and bromeliad leaves by white-faced capuchin monkeys (*Cebus capucinus*) in a tropical dry forest. **American Journal of Physical Anthropology**, v. 158, n. 1, p. 67–77, set. 2015.	Diet	X			Journal article
15-	OPPENHEIMER, J. R.; OPPENHEIMER, E. C. Preliminary observations of *Cebus nigrivittatus* (Primates: Cebidae) on the Venezuelan llanos. **Folia Primatologica**, v. 19, p. 409–436, 1973.	Occasional	X			Journal article
16-	PERES, C. A. Primate responses to phenological changes in an Amazonian Terra Firme Forest. **Biotropica**, v. 26, n. 1, p. 98, mar. 1994.	Diet	X	X		Journal article
17-	RATIARISON, S.; FORGET, P.-M. Fruit availability, frugivore satiation and seed removal in 2 primate-dispersed tree species. **Integrative Zoology**, v. 6, n. 3, p. 178–194, set. 2011.	Occasional	X	X	X	Journal article
18-	ROBINSON, J. G. Seasonal variation in use of time and space by the wedge-capped capuchin monkey, *Cebus olivaceus*: implications for foraging theory. **Smithsonian Contributions to Zoology**, n. 431, p. 1–60, 1986.	Diet	X			Journal article
19-	TOMBLIN, D. C.; CRANFORD, J. A. Ecological niche differences between *Alouatta palliata* and *Cebus capucinus* comparing feeding modes, branch use, and diet. **Primates**, v. 35, n. 3, p. 265–274, 1994.	Diet	X			Journal article
20-	VALENTA, K.; FEDIGAN, L. M. How much is a lot? Seed dispersal by white-faced capuchins and implications for disperser-based studies of seed dispersal systems. **Primates**, v. 49, n. 3, p. 169–75, jul. 2008.	Seed dispersal	X			Journal article
21-	WEHNCKE, E. V. et al. Seed dispersal patterns produced by white-faced monkeys: Implications for the dispersal limitation of neotropical tree species. **Journal of Ecology**, v. 91, n. 4, p. 677–685, ago. 2003.	Seed dispersal	X			Journal article

22-	AGOSTINI, I.; VISALBERGHI, E. Social influences on the acquisition of sex-typical foraging patterns by juveniles in a group of wild tufted capuchin monkeys (*Cebus nigritus*). **American Journal of Primatology**, v. 65, n. 4, p. 335–351, abr. 2005.	Diet	X		Journal article
23-	BROWN, A. D.; ZUNINO, G. E. Dietary variability in *Cebus apella* in extreme habitats: evidence for adaptability. **Folia Primatologica**, v. 54, p. 187–195, 1990.	Diet	X		Journal article
24-	CANALE, G. R.; BERNARDO, C. S. S. Predator-prey interaction between two threatened species in a Brazilian hotspot. **Biota Neotropica**, v. 16, n. 1, p. e0059, 2016.	Diet	X		Journal article
25-	CARVALHO, D. R. J. DE. **Predação em *Pinus* spp. por *Cebus nigritus* (Goldfuss, 1809) (Primates; Cebidae) na região nordeste do Paraná - Brasil**. Universidade Federal do Paraná, 2007.	Diet	X		Dissertation
26-	CHALK, J. et al. Age-related variation in the mechanical properties of foods processed by *Sapajus libidinosus*. **American Journal of Physical Anthropology**, v. 159, n. 2, p. 199–209, fev. 2016.	Diet	X		Journal article
27-	FREITAS, C. H. DE et al. Agricultural crops in the diet of bearded capuchin monkeys, *Cebus libidinosus* Spix (Primates: Cebidae), in forest fragments in southeast Brazil. **Revista Brasileira de Zoologia**, v. 25, n. 1, p. 32–39, 2008.	Diet	X		Journal article
28-	GALETTI, M.; PEDRONI, F. Seasonal diet of capuchin monkeys (*Cebus apella*) in a semideciduous forest in south-east Brazil. **Journal of Tropical Ecology**, v. 10, n. 1, p. 27–39, 1994.	Diet	X		Journal article
29-	GUILLOTIN, M.; DUBOST, G.; SABATIER, D. Food choice and food competition among the three major primate species of French Guiana. **Journal of Zoology**, v. 233, p. 551–579, 1994.	Diet	X		Journal article
30-	IZAR, P. Dispersão de sementes por *Cebus nigritus* e *Brachyteles arachnoides* em área de Mata Atlântica, Parque Estadual Intervales, SP. In: FERRARI, S. F.; RÍMOLI, J. (Eds.). **A Primatologia no Brasil**. 9. ed. Aracaju: Sociedade Brasileira de Primatologia, Biologia Geral e Experimental – UFS, 2008. p. 8–24.	Seed dispersal	X		Book chapter
31-	JANSON, C. Aggresive competition and individual food consumption in wild brown capuchin monkeys (*Cebus apella*). **Behavioral Ecology and Sociobiology**, v. 18, n. 2, p. 125–138, 1985.	Occasional	X		Journal article
32-	LUDWIG, G.; AGUIAR, L. M.; ROCHA, V. J. Uma avaliação da dieta, da área de vida e das estimativas populacionais de *Cebus nigritus* (Goldfuss, 1809) em um fragmento florestal no norte do estado do Paraná. **Neotropical Primates**, v. 13, n. 3, p. 12–18, 2005.	Diet	X		Journal article
33-	MIKICH, S. B. **Frugivoria e dispersão de sementes em uma pequena reserva isolada do Estado do Paraná, Brasil.** Universidade Federal do Paraná, 2001.	Diet	X	X	Thesis

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APPENDIX C – Continuation.

Reference		Focus of the Study	Mammal genera			Type of Study
			Cebus	***Sapajus***	***Nasua***	
34-	MOURA, A. C. D. A.; MCCONKEY, K. R. The capuchin, the howler, and the Caatinga: Seed dispersal by monkeys in a threatened Brazilian forest. **American Journal of Primatology**, v. 69, n. 2, p. 220–226, 2007.	Seed dispersal		X		Journal article
35-	ROCHA, V. J. **Ecologia de mamíferos de médio e grande portes do Parque Estadual Mata dos Godoy, Londrina (PR).** Universidade Federal do Paraná, 2001.	Diet		X	X	Thesis
36-	SABBATINI, G. et al. Behavioral flexibility of a group of bearded capuchin monkeys (*Cebus libidinosus*) in the National Park of Brasília (Brazil): consequences of cohabitation with. **Brazilian Journal of Biology**, v. 68, n. 4, p. 685–693, 2008.	Diet		X		Journal article
37-	SCHALLER, G. B. Mammals and their biomass on a Brazilian ranch. **Arquivos de Zoologia**, v. 31, n. 1, p. 1–36, 1983.	Occasional		X	X	Journal article
38-	SIMMEN, B.; SABATIER, D. Diets of some French Guianan primates: Food composition and food choices. **International Journal of Primatology**, v. 17, n. 5, p. 661–693, 1996.	Diet		X		Journal article
39-	SPIRONELO, W. R. Importância dos frutos de palmeiras (Palmae) na dieta de um grupo de *Cebus apella* (Cebidae, Primates) na Amazônia Central. In: RYLANDS, A. B.; BERNARDES, A. T. (Eds.). **A Primatologia no Brasil**. 3. ed. Belo Horizonte: Fundação Biodiversitas, 1991. p. 285–296.	Diet		X		Book chapter
40-	STEVENSON, P. R.; QUINONES, M. J.; AHUMADA, J. A. Influence of fruit availability on ecological overlap among four neotropical primates at Tinigua National Park, Colombia. **Biotropica**, v. 32, n. 3, p. 533–544, 2000.	Diet		X		Journal article
41-	VIEIRA, E. M.; IZAR, P. Interactions between aroids and arboreal mammals in the Brazilian Atlantic rainforest. **Plant Ecology**, v. 145, p. 75–82, 1999.	Occasional		X		Journal article
42-	VILELA, S. L. Simpatria e dieta de *Callithrix penicillata* (Hershkovitz) (Callitrichidae) e *Cebus libidinosus* (Spix) (Cebidae) em matas de galeria do Distrito Federal, Brasil. **Revista Brasileira de Zoologia**, v. 24, n. 3, p. 601–607, 2007.	Diet		X		Journal article
43-	ZHANG, S.-Y.; WANG, L.-X. Fruit consumption and seed dispersal of *Ziziphus cinnamomum* (Rhamnaceae) by two sympatric primates (*Cebus apella* and *Ateles paniscus*) in French Guiana. **Biotropica**, v. 27, n. 3, p. 397–401, 1995.	Occasional		X		Journal article
44-	AGUIAR, L. M. et al. Diet of brown-nosed coatis and crab-eating raccoons from a mosaic landscape with exotic plantations in southern Brazil. **Studies on Neotropical Fauna and Environment**, v. 46, n. 3, p. 153–161, dez. 2011.	Diet			X	Journal article

45-	ALVES-COSTA, C. P.; ETEROVICK, P. C. Seed dispersal services by coatis (*Nasua nasua*, Procyonidae) and their redundancy with other frugivores in southeastern Brazil. **Acta Oecologica**, v. 32, n. 1, p. 77–92, jul. 2007.	Seed dispersal	X	Journal article
46-	AMARAL, C. **Dieta de duas espécies carnívoras simpátricas graxaim-do-mato *Cerdocyon thous* (Linnaeus, 1766) e quati *Nasua nasua* (Linnaeus, 1766) nos municipios de Tijucas do Sul e Agudos do Sul, estado do Parana**. Universidade Federal do Paraná, 2007.	Diet	X	Dissertation
47-	ASENSIO, N.; ARROYO-RODRÍGUEZ, V.; CRISTÓBAL-AZKARATE, J. Feeding encounters between a group of howler monkeys and white-nosed coatis in a small forest fragment in Los Tuxtlas, Mexico. **Journal of Tropical Ecology**, v. 23, n. 2, p. 253–255, 5 mar. 2007.	Occasional	X	Journal article
48-	BECKMAN, N. G.; MULLER-LANDAU, H. C. Differential effects of hunting on pre-dispersal seed predation and primary and secondary seed removal of two Neotropical tree species. **Biotropica**, v. 39, n. 3, p. 328–339, maio 2007.	Occasional	X	Journal article
49-	BIANCHI, R. DE C. et al. Intraspecific, interspecific, and seasonal differences in the diet of three mid-sized carnivores in a large neotropical wetland. **Acta Theriologica**, v. 59, n. 1, p. 13–23, 12 mar. 2014.	Diet	X	Journal article
50-	BISBAL E, F. J. Food habits of some neotropical carnivores in Venezuela (Mammalia, Carnivora). **Mammalia**, v. 50, n. 3, p. 329–339, 1986.	Occasional	X	Journal article
51-	BONATTI, J. **Uso e seleção de hábitat, atividade diária e comportamento de Nasua nasua (Linnaeus, 1766) (Carnivora; Procyonidae) na ilha do Campeche, Florianópolis, Santa Catarina**. Universidade Federal do Rio Grande do Sul, 2006.	Occasional	X	Dissertation
52-	CAMPOS, R. C.; STEINER, J.; ZILLIKENS, A. Bird and mammal frugivores of *Euterpe edulis* at Santa Catarina Island monitored by camera traps. **Studies on Neotropical Fauna and Environment**, v. 47, n. 2, p. 105–110, ago. 2012.	Occasional	X	Journal article
53-	COSTA, E. M. DE J. **Preferência alimentar, dispersão de sementes e ecologia comportamental de quatis (*Nasua nasua* - Procyonidae - Carnivora) em fragmentos de cerrado, Campo Grande, Mato Grosso do Sul**. Universidade Federal de Mato Grosso do Sul, 2009.	Seed dispersal	X	Thesis
54-	DA SILVA, F. R. et al. Seed dispersal and predation in the palm *Syagrus romanzoffiana* on two islands with different faunal richness, southern Brazil. **Studies on Neotropical Fauna and Environment**, v. 46, n. 3, p. 163–171, dez. 2011.	Occasional	X	Journal article
55-	DE BARROS, D.; FRENEDOZO, R. DE C. Uso do habitat, estrutura social e aspectos básicos da etologia de um grupo de quatis (*Nasua nasua* Linnaeus, 1766) (Carnivora: Procyonidae) em uma área de Mata Atlântica, São Paulo, Brasil. **Biotemas**, v. 23, n. 3, p. 175–180, 2010.	Occasional	X	Journal article

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APPENDIX C – Continuation.

Reference		Focus of the Study	Mammal genera			Type of Study
			Cebus	*Sapajus*	*Nasua*	
56-	DESBIEZ, A. L. J.; BORGES, P. A. L. Density, habitat selection and observations of South American coati *Nasua nasua* in the central region of the Brazilian Pantanal wetland. **Small Carnivore Conservation**, v. 42, n. 1, p. 14–18, 2010.	Diet			X	Journal article
57-	DONATTI, C. I. et al. Analysis of a hyper-diverse seed dispersal network: Modularity and underlying mechanisms. **Ecology Letters**, v. 14, n. 8, p. 773–781, 2011.	Seed dispersal			X	Journal article
58-	FERREIRA, G. A. et al. Diet of the coati *Nasua nasua* (Carnivora: Procyonidae) in an area of woodland inserted in an urban environment in Brazil. **Revista Chilena de Historia Natural**, v. 86, p. 95–102, 2013.	Diet			X	Journal article
59-	GARCÍA-ROBLEDO, C.; KUPREWICZ, E. K. Vertebrate fruit removal and ant seed dispersal in the Neotropical ginger *Renealmia alpinia* (Zingiberaceae). **Biotropica**, v. 41, n. 2, p. 209–214, mar. 2009.	Occasional			X	Journal article
60-	GOMPPER, M. E. Sociality and asociality in white-nosed coatis (*Nasua narica*): foraging costs and benefits. **Behavioral Ecology**, v. 7, n. 3, p. 254–263, 1996.	Occasional			X	Journal article
61-	HIRSCH, B. T. Seasonal variation in the diet of ring-tailed coatis (*Nasua nasua*) in Iguazu, Argentina. **Journal of Mammalogy**, v. 90, n. 1, p. 136–143, fev. 2009.	Diet			X	Journal article
62-	HOWE, H. F.; VANDE KERCKHOVE, G. A. Removal of wild nutmeg (*Virola surinamensis*) crops by birds. **Ecology**, v. 62, n. 4, p. 1093–1106, ago. 1981.	Occasional			X	Journal article
63-	HOWE, H. F. Monkey dispersal and waste of a neotropical fruit. **Ecology**, v. 61, n. 4, p. 944–959, 1980.	Occasional			X	Journal article
64-	KAUFMANN, J. H. Ecology and social behavior of the coati, *Nasua narica*, of Barro Colorado Island, Panama. **University of California Publications in Zoology**, v. 60, n. 3, p. 95–222, 1962.	Diet			X	Thesis
65-	KORINE, C.; KALKO, E. K. V; HERRE, E. A. Fruit characteristics and factors affecting fruit removal in a Panamanian community of strangler figs. **Oecologia**, v. 123, p. 560–568, 2000.	Occasional			X	Journal article
66-	RÍMOLI, A. O. et al. Behavior patterns of a group of black howler monkeys *Alouatta caraya* (Humboldt, 1812) in a forest fragment in Terenos, Mato Grosso do Sul: a seasonal. In: FERRARI, S. F.; RÍMOLI, J. (Eds.). **A Primatologia no Brasil - 9**. Aracaju: Sociedade Brasileira de Primatologia, Biologia Geral e Experimental – UFS, 2008. v. 9p. 179–191.	Occasional			X	Book chapter
67-	ROBERTS, J. T.; HEITHAUS, E. R. Ants rearrange the vertebrate-generated seed shadow of a Neotropical fig tree. **Ecology**, v. 67, n. 4, p. 1046–1051, 1986.	Occasional			X	Journal article

68-	ROCHA-MENDES, F. et al. Feeding ecology of carnivores (Mammalia, Carnivora) in Atlantic forest remnants, southern Brazil. **Biota Neotropica**, v. 10, n. 4, p. 21–30, 2010.	Diet		X	Journal article
69-	RUSSELL, J. K. Timing of reproduction by coatis (*Nasua narica*) in relation to fluctuations in food resources. In: LEIGH JR., E. G.; RAND, A. S.; WINDSOR, D. M. (Eds.). **The Ecology of a Tropical Forest: Seasonal Rhythms and Long-Term Changes**. Oxford: Oxford University Press, 1983. p. 413–431.	Diet		X	Book chapter
70-	SANTOS, V. A.; BEISIEGEL, B. DE M. A dieta de *Nasua nasua* (Linnaeus, 1766) no Parque Ecológico do Tietê, SP. **Revista Brasileira de Zoociências**, v. 8, n. 2, p. 199–203, 2006.	Diet		X	Journal article
71-	VALENZUELA, D. Natural history of the white-nosed coati, *Nasua narica*, in a tropical dry forest of western Mexico. **Revista Mexicana de Mastozoología**, v. 3, p. 26–44, 1998.	Diet		X	Journal article
72-	YUMOTO, T. Seed dispersal by Salvin's Curassow, *Mitu salvini* (Cracidae), in a tropical forest of Colombia: direct measurements of dispersal distance. **Biotropica**, v. 31, n. 4, p. 654–660, dez. 1999.	Occasional		X	Journal article

APPENDIX D – Relative frequency of occurrence of food items in the diets of capuchin monkeys (genera *Cebus* and *Sapajus*) and coatis (genus *Nasua*) in the neotropical region.

Mammal Species	**Sampling method**	**Fruits plus seeds**	**Non-fruit plant parts**	**Crops**	**Animal matter**	**References[1]**
C. olivaceus	visual	53	9	0	38	**18**
S. cay	visual	3	72	0	25	**23**
S. libidinosus	visual*	52	5	30	9	**27**
S. macrocephalus	visual	41	14	0	45	**40**
S. nigritus	visual	37	23	0	40	**23**
S. nigritus	visual	69	18	13	0	**28**
S. nigritus	visual/ faeces	66	6	6	23	**32**
S. nigritus	faeces	18	40	12	30	**
S. nigritus	faeces	58	6	7	29	**33**
S. nigritus	visual	20	36	20	24	**66**
S. nigritus	visual/ faeces	89	8	1	2	**35**
S. xanthosternos	visual	38	26	0	36	**24**
N. narica	visual	60	0	0	40	**60**
N. narica	faeces	46	0	0	54	**71**
N. nasua	stomach content	20	7	0	73	**44**
N. nasua	faeces	63	17	0	20	**46**
N. nasua	faeces	39	0	0	61	**49**
N. nasua	faeces	11	9	21	59	**58**
N. nasua	visual	52	0	5	43	**61**
N. nasua	faeces	66	5	3	26	**33**
N. nasua	visual/ faeces	63	4	0	34	**35**
N. nasua	faeces	9	0	5	86	**69**

* In this case 4% of food items were not identified. ** MIKICH S.B. *et al.*, unpublished
[1]References according to the appendix C.

4 Chapter 4

Identification of key plants for the restoration of degraded neotropical habitats based on network analysis of plant–frugivore interactions

Abstract

Ecological restoration of natural habitats is expected to take into account not only the original species composition of a given site, but also the ecological functions and interactions performed by these species. Network analyses of complex interactions have been found to provide insightful information to interpret community structure and the contributions of species in structuring these communities. Here, we investigated 17 neotropical fruit–frugivore systems, distributed over 12 distinct ecoregions, in order to identify plant species responsible for supporting a wide array of fruit-eating birds and mammals and for increasing the interactions between all species. Using network analyses, we compared species centrality indices and vertices universal roles as a method to detect key plant species in those 17 networks of fruit–frugivore interactions. We found that vertices universal roles were more effective in determining key plant species. Despite the fact that more basic information on fruit–frugivore interactions is needed in order to produce robust listings of key neotropical plant species, network analyses proved to be a useful tool to assist in ecological restoration plans.

Keywords: Birds. Exotic species. Extinction. Keystone species. Long-term studies. Mammals. Seed dispersal.

4.1 Introduction

Fruits are an important food item for vertebrates, especially in tropical forests, where up to 80% of avian and mammalian biomass can be represented by animals that depend primarily on fruit for food (TERBORGH, 1986). The term frugivore can be applied to both animals that search fruits to consume the edible pulp, ingesting or discarding the seeds, and also to animals that eat only the seeds (CHARLES-DOMINIQUE, 1995; JORDANO, 2000). The neotropical region has the highest diversity of frugivore vertebrates in the tropics (FLEMING; BREITWISCH; WHITESIDES, 1987), and mutualisms involving frugivory and seed dispersal are responsible for the reproduction of approximately 75% of tree species (HOWE; SMALLWOOD, 1982).

There is a high concentration of endemic species in the Neotropics and this region has undergone a remarkable loss of habitat across many ecosystems (DINERSTEIN et al., 1995; DIRZO; RAVEN, 2003). Many plants rely on mutualistic interactions that are carried out by frugivores. These can be lost through habitat fragmentation resulting in direct effects on processes such as in pollination, seed dispersal, and nutrient cycling (CARDINALE et al., 2012). Restoration aims to return habitats to their previous condition. Hence, in restoration as well as returning an ecosystem to the conditions experienced before degradation, it is also important that ecosystem functions are restored through the recovery of the complex ecological interactions related to them (CORLETT, 2016; RIBEIRO DA SILVA et al., 2015). The use of complex network theory and analyses in order to unravel the structure of interactions between species in ecological communities has been demonstrated to be a very efficient approach to understanding the observed patterns in both mutualistic relationships and in antagonistic relationships (BASCOMPTE, 2010; BASCOMPTE; JORDANO, 2007; DÁTTILO et al., 2016; GENRICH et al., 2016; POCOCK; EVANS; MEMMOTT, 2012; THÉBAULT; FONTAINE, 2010). From a network perspective, these analyses allow an understanding of the factors involved in species coevolution, the consequences of population decline and species extinctions, and also the impact of habitat restoration (BASCOMPTE; JORDANO; OLESEN, 2006; DEVOTO et al., 2012; MEMMOTT; WASER; PRICE, 2004; POCOCK; EVANS; MEMMOTT, 2012; RIBEIRO DA SILVA et al., 2015; THÉBAULT; FONTAINE, 2010).

The network approach is particularly useful when studying species-rich systems. Networks of mutualistic interactions present a defined structure which is responsible for the stability and persistence of communities with a high number of species (BASTOLLA et al., 2009). Some species are more important than others in structuring ecological communities, these can be termed as keystone species (COTTEE-JONES; WHITTAKER, 2012). The keystone concept has been broadly applied in the ecological literature using different approaches to denote a species with disproportional influence in community structuring (COTTEE-JONES; WHITTAKER, 2012). We can assess a species' relative importance in a network through some emergent properties (GUIMERÀ; AMARAL, 2005a, 2005b; MELLO et al., 2015; OLESEN et al., 2007; STEVENSON et al., 2015). The importance of a plant species in a given community is not necessarily related to the quantity of realized interactions but how these interactions are distributed. Some species are disproportionally well connected to other species and their presence can lead to significant gains in biodiversity (POCOCK; EVANS; MEMMOTT, 2012). A species' function can be related to its position within the network, in terms of centrality, as well as how this species relates with the different modules of the network (GUIMERÀ; AMARAL, 2005a; MELLO et al., 2015; OLESEN et al., 2007). The robustness of a network, or the ability of a species to persist given the extinction of an interacting partner (JORDANO; BASCOMPTE; OLESEN, 2006), is also closely related to species' roles within the network. Thus, the extinction of a module connector or a hub may cause significant impacts in network structure, as well as in the ecological and evolutionary dynamics of the system (OLESEN et al., 2007; SAAVEDRA et al., 2011; VIDAL et al., 2014). In particular, plant extinctions have a high probability of causing animals co-extinctions, especially those with narrow climatic niches (SCHLEUNING et al., 2016). In this sense, by knowing the role played by a species in protected and well preserved areas, one might expect that the planting or enrichment of similar but degraded areas with plant species having central, connector or module hub roles could catalyse its recovery, an inverse result to what its extinction would cause.

In the Neotropics, as in other tropical regions of the world, habitat loss and fragmentation is so marked that active restoration of connectivity between remaining areas is a common approach to conservation (HOWE, 2016). Tools capable of improving the existing restoration techniques can be very useful. Ecological restoration projects usually have a limited budget, so it is necessary that the selection of plant species for planting consider the species with the greatest potential to improve the structure of the community. This study aimed to identify key species that are structurally important in interaction networks that are found in different ecoregions of the Neotropics, and that have the potential to support and increase the quantity of interactions with frugivorous birds and mammals. These key species are recommended for having conservation priority, and to be favoured for planting in ecological restoration and enrichment of degraded habitats.

4.2 Methods

4.2.1 Data collection

We built a database of interactions between neotropical plant and fruit-eating birds and mammals, after a comprehensive review of the literature (chapter 1). We then searched for study sites with data on at least four different taxonomic orders of birds and/or mammals to build binary (presence–absence) fruit-frugivore interaction networks. Studies reporting fruit and seed consumption and/or seed dispersal by bird or mammals were used. The following data were collected from the selected studies: taxonomic information on plants (to the lowest taxonomic rank available in the study) and frugivores (always to species level), name and location of the study site (country and geographical coordinates), and sampling duration (in months). In some studies, the authors were not able to identify all the fruits consumed to species level, so in such cases we decided to include the plants that were identified up to genus or botanic family level as morpho species to avoid losing relevant information. Species with no such identifications (species or genus or botanical family) were not included in the database. Studies in which the diet, frugivory or seed dispersal were not actively investigated, as well as studies using the focal tree method (when the observer register plant-animal interactions occurring at pre-selected plants) focusing less than five plant species, were also not included. In order to understand the dynamics of communities and find appropriate approaches to restore the ecosystems functions lost due to habitat loss and fragmentation it is necessary to bring together as much information as possible. Thus, we decided to combine data from different studies in order to build fruit–frugivore interaction matrices for well sampled study sites. As we built a binary network, all interactions between a given fruit taxa and a bird/mammal species were included in our database but computed only once for each study site. Additionally, since patterns of plant–animal interactions are not constant throughout the year, especially due to seasonality in fruit availability (VAN SCHAIK et al., 1993), only studies conducted during at least one dry and one wet season (a 6-month period or more) were used to build the networks.

We assigned the selected study sites to their respective ecoregion, according to the classification suggested by Olsen and cols (2001). These ecoregions are, according to these authors, "relatively large units of land containing a distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land-use change" (OLSON et al., 2001:933). There are 867 distinct terrestrial ecoregions in the world, 150 of these are in the Neotropics (not including the Caribbean Islands).

We only included in the database information from studies that presented lists of the plant species that had fruits, pulp or seeds eaten and/or dispersed by any mammal or bird in the wild. The different studies that form our database used various methods for the collection of the interaction data. These include direct and indirect records of fruit consumption and different time frames that varied from 6 to 120 months. We acknowledge that the use of different methods for data collection have distinct detection probabilities of species interactions, but we expect to minimize the negative effects of these discrepancies by only considering qualitative descriptors of the networks.

The taxonomy of frugivore species was verified according to the *Catalogue of Life* (http://www.catalogueoflife.org; ROSKOV *et al.*, 2016). The taxonomy of plant species was verified according to *The Plant List* ver. 1.1 (http://www.theplantlist.org/). A map with the distribution of study sites and neotropical terrestrial ecoregions (OLSON et al., 2001) was built using the software *QGIS* version *2.16.0-Nødebo* (QGIS DEVELOPMENT TEAM, 2016).

4.2.2 Network analyses and identification of key plant species

For graph and network analyses of the structure of webs of interactions between neotropical plants and fruit-eating animals we built binary matrices of adjacencies *Aij* for each of the 17 study sites. In these matrices, plants were arranged in *i* lines and animals were arranged in *j* columns. The interactions resulting from these matrices are represented by bipartite graphs, since interactions do not occur between species from the same trophic level (BASCOMPTE; JORDANO, 2006).

A structural pattern commonly observed in mutualistic networks is modularity, which can be described as groups, or modules, of species that share much more interactions between them than with species from other modules in the network (OLESEN et al., 2007). Thus, by identifying network modules it is possible to determine functions or roles played by the different species in a network (GUIMERÀ; AMARAL, 2005a, 2005b; OLESEN et al., 2007). The position a species occupies in the interaction network is a decisive variable for determining its role in the community (JORDÁN; LIU; DAVIS, 2006; MARTÍN GONZÁLEZ; DALSGAARD; OLESEN, 2010). Some species have a disproportionately important role in communities due to both their direct and their indirect interactions, and they can be considered as key mutualists in these communities (DÁTTILO et al., 2016; POCOCK; EVANS; MEMMOTT, 2012). Connector species and module hub species, for example, are important for the maintenance of network structure and their existence has crucial effects in the dynamics of the system, especially in relation to species extinctions and persistence (OLESEN et al., 2007; VIDAL et al., 2014).

The use of the term keystone species can be controversial as different authors have been using different definitions to describe them (COTTEE-JONES; WHITTAKER, 2012). We do not intend to broaden this discussion and we chose instead to use the term “key plant species” to describe the species of plants that are structurally important in fruit–frugivore networks according to the network metrics explained below. We believe that we cannot use the term keystone as we are only considering here the frugivorous part of the diet of neotropical birds and mammals. These animals include other food items in their diets, such as insects and other plant parts, that can be equally or more important than fruits (JORDANO, 2000; TERBORGH, 1986).

In networks, species are represented as vertices linked through interactions (BLÜTHGEN et al., 2008). To find key species of plants, which are vertices important for network structure and stability, we computed binary indices at the species level using the *Bipartite* package *version 2.04* (DORMANN et al., 2009; DORMANN; GRUBER; FRÜND, 2008) implemented in the computing environment *R 3.1.2* (R CORE TEAM, 2014). The degree (*D*) and normalized degree (*ND*) are indices based in the quantity of interactions a species realizes, and they indicate its level of generalization (MARTÍN GONZÁLEZ; DALSGAARD; OLESEN, 2010). Since network size is not constant, *ND* is an appropriate measure for comparing networks. The centrality of species, besides these indices, can be also determined by the indices closeness centrality (*CC*) and betweeness centrality (*BC*). *CC* represents the mean distance from a vertex to all the other vertices in the network, whilst *BC* indicates how many times a vertex is part of the shortest path between the other vertices in the network (JORDÁN; LIU; DAVIS, 2006).

Additionally, species universal roles and network modules were identified using the software *NetCarto* (GUIMERÀ; AMARAL, 2005a, 2005b). These universal roles are a reflection of the position of a vertex in relation to the other vertices within the same module, as well as in relation to the other modules of the network. Thus, vertices can be classified as hubs or non-hubs. Non-hub vertices, in turn, are classified into four discrete universal roles: (R1) ultra-peripheral vertices, which are vertices with all their links within their module; (R2) peripheral vertices, which are vertices with most links within their module; (R3) non-hub connector vertices, which are vertices with many links to other modules; and (R4) non-hub kinless vertices, which are vertices with links homogeneously distributed among all modules. Similarly, hub vertices are classified into three discrete universal roles: (R5) provincial hubs, which are hub vertices with the vast majority of links within their module; (R6) connector hubs, which are hubs that have many links to most of the other modules; and (R7) kinless hubs, which are hubs with links homogeneously distributed among all modules (GUIMERÀ; AMARAL, 2005a, 2005b).

Species were considered as key species when they exhibited the ability to structure the community by keeping species cohesive and preventing species extinctions, which is the case for connector vertices and module hubs vertices (OLESEN et al., 2007). Species identified as R3, R4, R5, and R6 were considered key species in their communities. The influence of the frugivore richness on the amount of plant connector species in the networks was tested using a multiple linear regression model. The analysis was carried out in the statistical computing environment *R 3.1.2* (R CORE TEAM, 2014) using the package *R commander 2.0-0* (FOX, 2005).

4.3 Results

Based on the aforementioned criteria of minimum diversity of taxonomic orders, minimum study duration, and availability of the listings of interactions between plant and frugivores, we were able to build-up 17 plant–frugivore interaction networks for the neotropical region. The selected study sites are remnants of the native vegetation with different levels of disturbance, protected public- and private-owned areas, and distributed over 12 different neotropical ecosystems or ecoregions (classification proposed by OLSON et al. (2001); Fig. 4.1; Table 4.1).

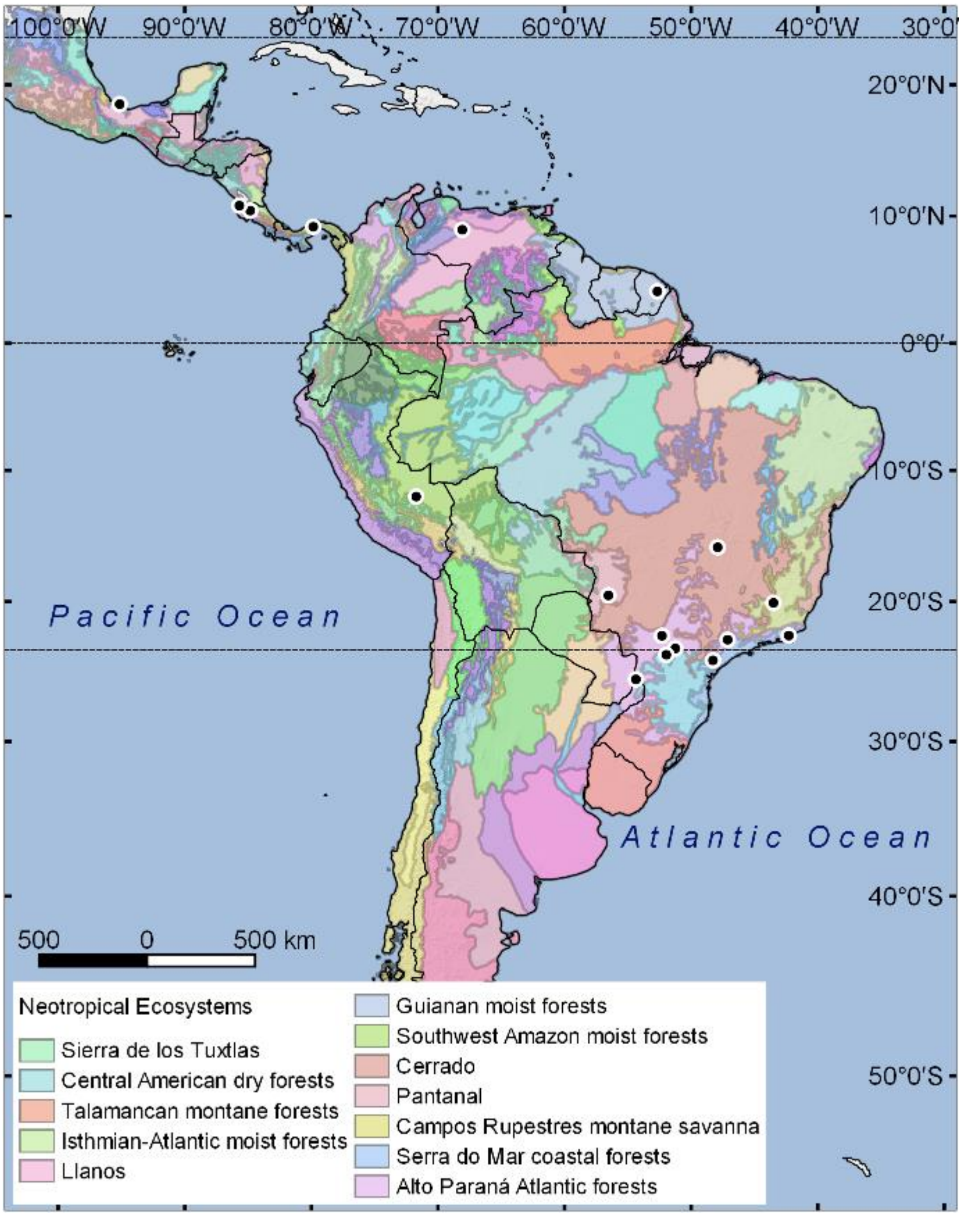

Figure 4.1. Location of 17 study sites from which we built networks of interactions between fruits and fruit-eating birds and mammals, based on data collected through a literature review. Different colours represent different terrestrial ecoregions (Olson et al. 2001) and we indicated in the legend only the ecoregions in which our study sites are inserted.

Table 4.1. Characteristics of 17 fruit–frugivore interaction networks created based on literature data for different groups of fruit-eating birds and mammals in 12 neotropical ecoregions (*sensu* OLSON et al. 2001).

Network name	Site	Country	Latitude	Longitude	Ecoregion	No. of plant species	No. of frugivore species	References[1]
BCI	Barro Colorado Island	Panama	9.16	-79.85	Isthmian-Atlantic moist forests	257	34	1–15
CSPR	Caraçá Sanctuary Private Reserve	Brazil	-20.10	-43.49	Campos Rupestres montane savanna	60	4	16–19
GCVEPA	Gama-Cabeça de Veado Environmental Protection Area	Brazil	-15.93	-47.90	Cerrado	57	31	20–24
HPIN	Hato Piñero	Venezuela	8.93	-68.08	Llanos	64	12	25–28
INP	Iguaçu and Iguazú National Parks	Argentina/ Brazil	-25.67	-54.36	Alto Paraná Atlantic forest	60	10	29–33
ISP	Intervales State Park	Brazil	-24.31	-48.27	Serra do Mar coastal forests	61	114	34–41
LTBR	Los Tuxtlas Biosphere Reserve	Mexico	18.56	-95.15	Sierra de los Tuxtlas	110	43	42–52
MCFBR	Monteverde Cloud Forest Biological Reserve	Costa Rica	10.42	-84.83	Talamancan montane forests	189	42	53–54
MGSP	Mata dos Godoy State Park	Brazil	-23.45	-51.25	Alto Paraná Atlantic forest	71	5	55
MNP	Manu National Park	Peru	-12.04	-71.72	Southwest Amazon moist forest	191	13	42; 56–61
PABR	Poço das Antas Biological Reserve	Brazil	-22.52	-42.28	Serra do Mar coastal forests	89	52	62–68
PONP	Pontal do Paranapanema	Brazil	-22.53	-52.30	Alto Paraná Atlantic forest	90	6	69–70
RNBAF	Rio Negro and Barranco Alto farms	Brazil	-19.55	-56.53	Pantanal	63	52	71–73
SGR	Santa Genebra Reserve	Brazil	-22.82	-47.11	Alto Paraná Atlantic forest	113	45	74–81
SPNNR	Saut Pararé/Nouragues Natural Reserve	French Guiana	4.09	-52.67	Guianan moist forest	317	18	42; 82–89
SRNP	Santa Rosa National Park	Costa Rica	10.81	-85.69	Central American dry forest	173	16	42; 90–102
VRESSP	Vila Rica do Espírito Santo State Park	Brazil	-23.91	-51.96	Alto Paraná Atlantic forest	208	84	103–104

[1] References used as data sources for the construction of fruit–frugivore interaction networks: 1) KAUFMANN (1962); 2) HLADIK & HLADIK (1969); 3) OPPENHEIMER (1968); 4) MORRISON (1978); 5) BONACCORSO (1979); 6) OPPENHEIMER (*apud* FREESE & OPPENHEIMER, 1981); 7) GLANZ et al. (1983); 8) OPPENHEIMER (1983); 9) RUSSELL (1983); 10) SMYTHE et al. (1983); 11) BONACCORSO & HUMPHREY (1984); 12) HANDLEY et al. (1991); 13) WEHNCKE et al. (2003); 14) GIANNINI & KALKO (2004); 15) ANDRADE et al. (2013); 16) SILVA & TALAMONI (2003); 17) ALVARENGA & TALAMONI (2006); 18) TALAMONI & ASSIS (2009); 19) SANTOS et al. (2012); 20) MOTTA-JÚNIOR (1991); 21) MIRANDA (1997); 22) VILELA (1999); 23) VILELA (2007); 24) CAMARGO et al. (2011); 25) BARRETO et al. (1997); 26) MILLER (1998); 27) BERTSCH & BARRETO (2008); 28) ARANGUREN et al. (2011); 29) BROWN & ZUNINO (1990); 30) CASELLA (2006); 31) HIRSCH (2009); 32) SÁNCHEZ et al. (2012); 33) TUJAGUE et al. (2016); 34) RODRIGUES (1991); 35) VIEIRA & IZAR (1999); 36) GALETTI et al. (2000); 37) PASSOS et al. (2003); 38) LEINER & SILVA (2007); 39) IZAR (2008); 40) MELLO et al. (2008); 41) AMATUZZI (2009); 42) BECK (2005); 43) ESTRADA & COATES-ESTRADA (1984); 44) ESTRADA et al. (1984); 45) OROZCO-SEGOVIA et al. (1985); 46) VAN DORP (1985); 47) GALINDO-GONZÁLEZ et al. (2000); 48) HERRERA et al. (2001); 49) PUEBLA-OLIVARES & WINKER (2004); 50) ASENSIO et al. (2007); 51) AMATO & ESTRADA (2010); 52) DUNN et al. (2010); 53) WHEELWRIGHT et al. (1984); 54) DINERSTEIN (1986); 55) ROCHA (2001); 56) JANSON (1975); 57) KILTIE (1981); 58) JANSON (1985); 59) FOSTER et al. (1986); 60) TOBLER et al. (2010); 61) PALMA & STEVENSON (2010); 62) CORREIA (1997); 63) DIETZ et al. (1997); 64) CARVALHO et al. (1999); 65) PINHEIRO et al. (2002); 66) MELLO et al. (2004); 67) CARVALHO et al. (2005); 68) MACEDO et al. (2010); 69) TÓFOLI (2006); 70) GOULART (2007); 71) KEUROGHLIAN et al. (2009); 72) DONATTI et al. (2011); 73) MUNIN et al. (2012); 74) GALETTI (1992); 75) GALETTI (1993); 76) CHIARELLO (1994); 77) GALETTI & MORELLATO (1994); 78) GALETTI & PEDRONI (1994); 79) PASCHOAL & GALETTI (1995); 80) FARIA (1996); 81) GALETTI & PIZO (1996); 82) JULIEN-LAFERRIÈRE (1993); 83) GUILLOTIN et al. (1994); 84) JULLIOT (1996); 85) SIMMEN & SABATIER (1996); 86) CHARLES-DOMINIQUE & COCKLE (2001); 87) JULIEN-LAFERRIÈRE (2001); 88) ERARD et al. (2007); 89) LOBOVA et al. (2009); 90) FLEMING et al. (1977); 91) FREESE (1977); 92) HEITHAUS & FLEMING (1978); 93) JANZEN (1982); 94) WILLIAMS (1984); 95) FLEMING & HEITHAUS (1986); 96) CHAPMAN (1987); 97) FLEMING (1988); 98) CHAPMAN (1989); 99) CHAPMAN & FEDIGAN (1990); 100) FLEMING (1991); 101) MACKINNON (2006); 102) VALENTA & FEDIGAN (2008); 103) MIKICH (2001); 104) BIANCONI (2009).

The 17 neotropical fruit–frugivore networks presented an average of 171 ± 101 species (mean ± SD). Overall, 230 birds, 96 mammals, and 1251 plants were analysed. Most plant species (an average of 93% ± 6%) were identified as peripheral and only six communities had plant species acting as hubs (Table 4.2). We did not identify any species as kinless hub (R7 universal role). In average, 60% (± 20%) of plants species interacted with only one animal species. This percentage was even higher (73% ± 13%) in networks with a frugivore richness of less than 20 species.

In general, plant species exhibited low indices of centrality which did not exceed an average value of 0.02 for both *BC* and *CC* (Table 4.2). Although average values for these two indices were similar in all networks, some species reached larger values of *BC*: 0.49, 0.40, 0.36, 0.34, 0.33, and 0.32 for the species *Syagrus romanzoffiana* (Arecaceae; PONP network), unidentified Myrtaceae (CSPR network), *Cecropia pachystachya* (Urticaceae), *Henriettea saldanhaei* (Melastomataceae; PABR network), *Psidium guajava* (Myrtaceae; PONP network), and *Psychotria* sp. (Rubiaceae; CSPR), respectively (Appendix E).

Table 4.2. Structural properties of fruit–frugivore interaction networks and average measures of generality or centrality (D = degree; ND = normalized degree; CC = closeness centrality; BC = betweeness centrality) and plant species universal roles (as in Guimerà and Amaral, 2005a, 2005b).

Network name	Size	No. Frugivore spp.	No. Plant spp.	Plant mean *D*	Plant mean *ND*	Plant mean *CC*	Plants mean *BC*	Plant Universal Roles (no. spp.)					
								R1	R2	R3	R4	R5	R6
BCI	291	34	257	2.33	0.07	0.00	0.00	243	11	3	0	0	0
CSPR	64	4	60	1.07	0.27	0.02	0.02	56	4	0	0	0	0
GCVEPA	88	31	57	2.93	0.09	0.02	0.02	40	15	2	0	0	0
HPIN	76	12	64	1.58	0.13	0.02	0.02	51	10	3	0	0	0
INP	70	10	60	1.75	0.18	0.02	0.02	48	10	2	0	0	0
ISP	415	114	301	4.56	0.04	0.00	0.00	154	101	45	0	0	1
LTBR	153	43	110	2.14	0.05	0.01	0.01	86	21	1	0	2	0
MCFBR	231	42	189	3.70	0.09	0.01	0.01	109	60	19	0	0	1
MGSP	76	5	71	1.73	0.35	0.01	0.01	43	17	11	0	0	0
MNP	204	13	191	1.19	0.09	0.01	0.01	179	11	1	0	0	0
PABR	141	52	89	3.11	0.06	0.01	0.01	76	11	1	0	0	1
PONP	96	6	90	1.27	0.21	0.01	0.01	81	5	4	0	0	0
RNBAF	115	52	63	4.78	0.09	0.02	0.02	34	27	1	0	0	1
SGR	158	45	113	2.97	0.07	0.01	0.01	69	35	9	0	0	0
SPNNR	335	18	317	1.66	0.09	0.00	0.00	206	74	36	1	0	0
SRNP	189	16	173	1.82	0.11	0.01	0.01	117	44	11	1	0	0
VRESSP	208	84	124	5.89	0.07	0.01	0.01	61	39	22	0	0	2

The quantity of plant species considered as key species according to their universal roles varied widely between the communities, from the CSPR network, located in the ecoregion Campos Rupestres, without any plant species acting as connector or module hub, to the ISP network located in the ecoregion Serra do Mar, that has 46 plant hub and non-hub connector species (Table 4.3). The quantity of connector plant species was directly influenced by the richness of frugivores, as it presented a significant positive relationship with frugivore richness in the communities (*lm*: $R^2 = 0.34$; $F = 7.61$; *d.f.* = 15; $P = 0.0146$).

Table 4.3. Key plant species in neotropical communities, according to the ecoregions in which they are located, determined based on 17 interaction networks between plants and fruit-eating birds and mammals. *Exotic species.

Ecoregion[1] / **Network Name[2]** / **Role[3]**	**Plant Family**	**Plant Species**
Sierra de los Tuxtlas		
LTBR		
R3	Moraceae	*Ficus* sp.
R5	Araliaceae	*Dendropanax arboreus*
R5	Moraceae	*Ficus colubrinae*
Central American dry forest		
SRNP		
R3	Anacardiaceae	*Spondias mombin*
R3	Anacardiaceae	*S. purpurea*
R3	Leguminosae	*Acacia collinsii*
R3	Leguminosae	*Albizia saman*
R3	Leguminosae	*Enterolobium cyclocarpum*
R3	Leguminosae	*Swartzia cubensis*
R3	Moraceae	*Brosimum alicastrum*
R3	Muntingiaceae	*Muntingia calabura*
R3	Piperaceae	*Piper* sp.
R3	Primulaceae	*Ardisia revoluta*
R3	Sapotaceae	*Manilkara zapota*
R4	Rhamnaceae	*Karwinskia calderonii*
Talamancan montane forests		
MCFBR		
R3	Araceae	*Anthurium* sp.
R3	Araliaceae	*Oreopanax xalapensis*
R3	Clusiaceae	*Clusia alata*
R3	Lauraceae	*Ocotea tonduzi*
R3	Malvaceae	*Malvaviscus arboreus*

R3	Marcgraviaceae	*Marcgravia brownei*
R3	Melastomataceae	*Conostegia icosandra*
R3	Moraceae	*Ficus aurea*
R3	Moraceae	*F. pertusa*
R3	Piperaceae	*Piper auritum*
R3	Primulaceae	*Ardisia palmana*
R3	Rosaceae	*Rubus rosifolius**
R3	Salicaceae	*Hasseltia floribunda*
R3	Solanaceae	*Cestrum schlechtendalii*
R3	Solanaceae	*Solanum nudum*
R3	Solanaceae	*S. umbellatum*
R3	Solanaceae	*Witheringia solanacea*
R3	Urticaceae	*Cecropia obtusifolia*
R3	Urticaceae	*Urera elata*
R6	Solanaceae	*Acnistus arborescens*
Isthmian-Atlantic moist forests		
BCI		
R3	Anacardiaceae	*Spondias mombin*
R3	Leguminosae	*Dipteryx oleifera*
R3	Malvaceae	*Quararibea asterolepis*
Llanos		
HPIN		
R3	Arecaceae	*Copernicia tectorum*
R3	Malvaceae	*Guazuma ulmifolia*
R3	Rubiaceae	*Genipa americana*.
Guianan moist forest		
SPNNR		
R3	Arecaceae	*Euterpe oleracea*
R3	Burseraceae	*Protium tenuifolium*
R3	Burseraceae	*Tetragastris altissima*
R3	Caricaceae	*Jacaratia spinosa*
R3	Celastraceae	*Cheiloclinium* sp.
R3	Cucurbitaceae	*Cayaponia* sp.
R3	Cucurbitaceae	*C. ophthalmica*
R3	Cyclanthaceae	*Ludovia lancifolia*
R3	Goupiaceae	*Goupia glabra*
R3	Lauraceae	*Ocotea* sp.
R3	Leguminosae	*Inga* sp.
R3	Malvaceae	*Theobroma subincanum*
R3	Moraceae	*Bagassa guianensis*
R3	Moraceae	*Ficus* sp.
R3	Moraceae	*F. americana*

Continues…

Table 4.3. Continuation

Ecoregion[1] / **Network Name[2]** / **Role[3]**	**Plant Family**	**Plant Species**
R3	Myristicaceae	*Iryanthera sagotiana*
R3	Myristicaceae	*Virola michelii*
R3	Myristicaceae	*Virola* sp.
R3	Olacaceae	*Minquartia guianensis*
R3	Polygalaceae	*Moutabea guianensis*
R3	Polygonaceae	*Coccoloba* sp.
R3	Rhamnaceae	*Ziziphus cinnamomum*
R3	Rubiaceae	*Psychotria carthagenensis*
R3	Rubiaceae	*Stenostomum acreanum*
R3	Sapotaceae	*Chrysophyllum lucentifolium*
R3	Sapotaceae	*Manilkara bidentata*
R3	Sapotaceae	*M. huberi*
R3	Sapotaceae	*Micropholis melinoniana*
R3	Sapotaceae	*Pouteria torta*
R3	Schlegeliaceae	*Schlegelia paraensis*
R3	Solanaceae	*Solanum* sp.
R3	Urticaceae	*Cecropia obtusa*
R3	Urticaceae	*Coussapoa angustifolia*
R3	Urticaceae	*C. latifolia*
R3	Urticaceae	*Pourouma* sp.
R3	Urticaceae	*P. villosa*
R4	Urticaceae	*Cecropia sciadophylla*
Southwest Amazon moist forest		
MNP		
R3	Anacardiaceae	*Spondias mombin*
Cerrado		
GCVEPA		
R3	Euphorbiaceae	*Alchornea glandulosa*
R3	Myristicaceae	*Virola sebifera*
Pantanal		
RNBAF		
R3	Malpighiaceae	*Byrsonima cydoniifolia*
R6	Dilleniaceae	*Doliocarpus dentatus*
Serra do Mar coastal forests		
ISP		
R3	Annonaceae	*Xylopia brasiliensis*
R3	Aquifoliaceae	*Ilex microdonta*

R3	Araceae	*Philodendron appendiculatum*
R3	Arecaceae	*Geonoma elegans*
R3	Boraginaceae	*Cordia polycephala*
R3	Cactaceae	*Rhipsalis teres*
R3	Cannabaceae	*Trema micrantha*
R3	Celastraceae	*Maytenus robusta*
R3	Clusiaceae	*Clusia* sp.
R3	Euphorbiaceae	*Alchornea glandulosa*
R3	Lauraceae	*Persea pyrifolia*
R3	Leguminosae	*Inga semialata*
R3	Marcgraviaceae	*Marcgravia polyantha*
R3	Melastomataceae	*Leandra dasytricha*
R3	Melastomataceae	*Miconia budlejoides*
R3	Melastomataceae	*M. cabussu*
R3	Melastomataceae	*M. racemifera*
R3	Meliaceae	*Cabralea canjerana*
R3	Moraceae	*Ficus* sp.
R3	Moraceae	*Ficus luschnathiana*
R3	Myristicaceae	*Virola bicuhyba*
R3	Myrtaceae	*Myrcia brasiliensis*
R3	Myrtaceae	*M. pubipetala*
R3	Myrtaceae	*Psidium* sp.
R3	Myrtaceae	*Siphoneugena densiflora*
R3	Phyllanthaceae	*Hieronyma alchorneoides*
R3	Phytolaccaceae	*Phytolacca dioica* L.
R3	Piperaceae	*Piper corintoanum**
R3	Piperaceae	*P. dilatatum*
R3	Primulaceae	*Myrsine venosa*
R3	Rosaceae	*Rubus rosaefolius*
R3	Rosaceae	*R. urticifolius*
R3	Rubiaceae	*Amaioua intermedia*
R3	Rubiaceae	*Coussarea contracta*
R3	Rubiaceae	*Psychotria leiocarpa*
R3	Rubiaceae	*P. suterella*
R3	Rubiaceae	*P. vellosiana*
R3	Rubiaceae	*Rudgea jasminoides*
R3	Sapindaceae	*Allophylus edulis*
R3	Solanaceae	*Aureliana fasciculata*
R3	Solanaceae	*Solanum inodorum*
R3	Symplocaceae	*Symplocos glanduloso-marginata*
R3	Symplocaceae	*S. variabilis*
R3	Urticaceae	*Cecropia glaziovii*
R3	Urticaceae	*Coussapoa microcarpa*
R6	Myrsinaceae	*Myrsine coriacea*

Continues…

Table 4.3. Continuation

Ecoregion[1]	**Network Name[2]** / **Role[3]**	**Plant Family**	**Plant Species**
	PABR		
	R3	Melastomataceae	*Henriettea saldanhaei*
	R6	Verbenaceae	*Citharexylum myrianthum*
Alto Paraná Atlantic forest			
	INP		
	R3	Sapotaceae	*Chrysophyllum gonocarpum*
	R3	Urticaceae	*Cecropia pachystachya*
	MGSP		
	R3	Arecaceae	*Euterpe edulis*
	R3	Arecaceae	*Syagrus romanzoffiana*
	R3	Cactaceae	*Pereskia aculeata*
	R3	Lauraceae	*Nectandra megapotamica*
	R3	Lauraceae	*Persea americana**
	R3	Melastomataceae	*Miconia pusilliflora*
	R3	Moraceae	*Ficus* sp.
	R3	Moraceae	*Maclura tinctoria*
	R3	Myrtaceae	*Campomanesia xanthocarpa*
	PONP		
	R3	Arecaceae	*S. romanzoffiana*
	R3	Leguminosae	*I. vera*
	R3	Myrtaceae	*Psidium guajava**
	R3	Urticaceae	*Cecropia pachystachya*
	SGR		
	R3	Arecaceae	*S. romanzoffiana*
	R3	Clusiaceae	*Calophyllum brasiliense*
	R3	Lauraceae	*Ocotea* sp.
	R3	Lauraceae	*O. corymbosa*
	R3	Leguminosae	*I. uruguensis*
	R3	Meliaceae	*Cabralea canjerana*
	R3	Moraceae	*Ficus luschnathiana*
	R3	Moraceae	*M. tinctoria*
	R3	Urticaceae	*Cecropia hololeuca*
	VRESSP		
	R3	Araliaceae	*Dendropanax cuneatus*
	R3	Arecaceae	*E. edulis*
	R3	Cactaceae	*Pereskia aculeata*

R3	Lauraceae	*O. silvestris*
R3	Meliaceae	*C. canjerana*
R3	Meliaceae	*Melia azedarach**
R3	Meliaceae	*Trichilia catigua*
R3	Moraceae	*Ficus* sp.
R3	Moraceae	*F. citrifolia*
R3	Moraceae	*F. insipida*
R3	Moraceae	*F. luschnathiana*
R3	Moraceae	*Maclura tinctoria*
R3	Moraceae	*Morus nigra**
R3	Myrtaceae	*Plinia peruviana*
R3	Myrtaceae	*Psidium guajava**
R3	Rubiaceae	*Palicourea macrobotrys*
R3	Salicaceae	*Prockia crucis*
R3	Solanaceae	*Cestrum amictum*
R3	Solanaceae	*C. viridiflorum*
R3	Urticaceae	*Cecropia glaziovii*
R3	Urticaceae	*C. pachystachya*
R3	Verbenaceae	*Citharexylum solanaceum*
R6	Cannabaceae	*Trema micrantha*
R6	Lauraceae	*N. megapotamica*

[1]Ecoregion according to the classification in Olson et al. (2001).
[2]For more details about the networks see Table 4.1.
[3]Vertices universal roles according to the classification proposed by Guimerà and Amaral (2005b, 2005a): R3 = non-hub connectors; R4 = non-hub kinless vertices; R5 = provincial hubs; R6 = connector hubs.

Some communities exhibited non-native plant species with exceptional importance for the frugivorous fauna that are included among the key species (Table 4.3).

4.4 Discussion

Using fruit-frugivore networks analyses, it was possible to identify key plant species in communities distributed in different ecoregions of the Neotropics, according to the characteristics of the interactions in which they are involved within and between modules in each network.

Species from the botanical families Moraceae, Urticaceae and Solanaceae (with key species occurring 20, 15 and 10 times in the different communities, respectively) were important in almost all Neotropical ecoregions. Generalist plants with high levels of soluble sugars, which is the case for species belonging to these three families, seem to be very useful for attracting frugivorous animals (HOWE, 2016). Figs (Moraceae) are particularly important in neotropical forests, since they are eaten by several vertebrate species—such as monkeys, carnivores, bats and birds of varying sizes—, and they fruit irregularly and can be available during the whole year, including periods of fruit scarcity (TERBORGH, 1986).

Most ecoregions were represented by only one study site. Species varied in importance between different communities and most key plants were not consistently important even between communities within the same ecoregion. However, in the ecoregion Alto Parana Atlantic Forest, which had five study sites, the same key plant species occurred three times. This was the case for three plant species: *Cecropia pachystachya* (Urticaceae), *Maclura tinctoria* (Moraceae) and *Syagrus romanzoffiana* (Arecaceae). This ecoregion is one of the best studied both in terms of frugivore diversity and study duration. This result is encouraging because it suggests that increasing the length or number of studies in a region will enable the accurate identification key species highlights the importance of long-term studies of fruit–frugivore interactions. The differences in key plant species in other ecoregions might also be due to methodological differences among the studies included in our database, such as the type of record and the duration of sampling, as well as other non-measured variables such as the size of the study sites, landscape traits and conservation status of these areas, differences in floristic communities, and differences in habitat productivity. This suggest that determining key species in a given community should not be extrapolated for its entire ecoregion if the length and number of studies are limited and instead each site to be restored should be thoroughly studied in order to identify the key plant species required for restoration. However, although this approach is desirable for a strong restoration plan, this is almost impracticable for most sites.

Non-native plant species were found to be key species in some communities. Key plant species such as *Persea americana* (Lauraceae), *Morus nigra* (Moraceae), *Psidium guajava* (Myrtaceae) and *Rubus rosifolius* (Rosaceae) are commonly cultivated for human consumption, and may occur close to forest remnants while not being invasive. Non-native fruit species can thus serve as an important supporting resource for frugivores, especially in periods when other fruits are scarce (HIRSCH, 2009; MIKICH, 2001). Their use for habitat restoration is controversial (CORLETT, 2016; VIVIAN-SMITH; GOSPER, 2006) but some successful restoration projects have included the planting of exotic species (RIBEIRO DA SILVA et al., 2015).

Vertices with a high diversity of connections, and that are usually between two other vertices, have the ability to propagate both extinction and stability in the network (BASCOMPTE; JORDANO, 2007). In our study, frugivore diversity was directly linked with the amount of connector plants, so networks with a low richness of frugivores, CSPR for example (with only four frugivore species), presented few or no plants acting as connectors. Although we used fruit–frugivore networks with the greatest possible diversity of frugivores in each of the communities (according to the information available from the literature), it became evident that very little information is available on this type of interaction, which makes it difficult to determine the most appropriate key species. Studies of frugivory and seed dispersal usually consider only one frugivorous species or one homogenous taxon (chapter 1). Thus, in order to create a list of key plant species for habitat recovery that is sufficiently representative of neotropical ecological communities and ecoregions, it is still necessary to generate basic studies about fruit–frugivore interactions.

Our result suggests that network analyses, which provide evidence about species functions in terms of community structure, can be used as a tool to assist the development of ecological restoration plans that include the planting of trees. However, most neotropical ecoregions still lack basic information about fruit–frugivore interactions to aid the building of robust networks and aid restoration programs.

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APPENDIX E – Values of centrality indices of plant species belonging to 17 neotropical fruit–frugivore networks.

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
BCI network						
Ficus sp.	20	0.59	0.01	0.00	0.35	2.16
Ficus insipida Willd.	15	0.44	0.04	0.00	0.60	0.61
Ficus yoponensis Desv.	15	0.44	0.02	0.00	0.44	1.05
Spondias mombin L.	13	0.38	0.06	0.00	0.77	0.38
Dipteryx oleifera Benth.	12	0.35	0.06	0.00	0.78	0.11
Ficus trigonata L.	12	0.35	0.00	0.00	0.15	1.05
Anacardium excelsum (Bertero ex Kunth) Skeels	11	0.32	0.05	0.00	0.74	-0.51
Cecropia sp.	11	0.32	0.03	0.00	0.55	0.16
Ficus obtusifolia Kunth	11	0.32	0.03	0.00	0.55	0.16
Quararibea asterolepis Pittier	11	0.32	0.05	0.00	0.76	0.38
Spondias radlkoferi Donn.Sm.	11	0.32	0.04	0.00	0.64	-0.06
Ficus dugandii Standl.	8	0.24	0.00	0.00	0.00	0.38
Brosimum alicastrum Sw.	7	0.21	0.03	0.00	0.73	-0.19
Ficus citrifolia Mill.	7	0.21	0.01	0.00	0.24	-0.06
Ficus costaricana (Liebm.) Miq.	7	0.21	0.01	0.00	0.24	-0.06
Ficus popenoei Standl.	7	0.21	0.00	0.00	0.00	0.16
Piper sp.	7	0.21	0.00	0.00	0.49	0.24
Astrocaryum standleyanum L.H.Bailey	6	0.18	0.01	0.00	0.61	0.05
Calophyllum longifolium Willd.	6	0.18	0.02	0.00	0.61	-0.73
Quararibea sp.	6	0.18	0.01	0.00	0.61	-0.73
Cecropia insignis Liebm.	5	0.15	0.02	0.00	0.56	-0.73
Ficus bullenei I.M.Johnst.	5	0.15	0.00	0.00	0.00	-0.28
Trichilia cipo (A.Juss.) C.DC.	5	0.15	0.01	0.00	0.64	-0.15
Attalea rostrata Oerst.	4	0.12	0.01	0.00	0.38	0.05
Cecropia obtusifolia Bertol.	4	0.12	0.01	0.00	0.75	-0.42
Eugenia florida DC.	4	0.12	0.00	0.00	0.38	0.05
Ficus maxima Mill.	4	0.12	0.00	0.00	0.00	-0.51
Ficus nymphaeifolia Mill.	4	0.12	0.00	0.00	0.00	-0.51
Guettarda foliacea Standl.	4	0.12	0.01	0.00	0.63	-0.95
Gustavia superba (Kunth) O.Berg	4	0.12	0.03	0.00	0.63	-0.10
Mangifera indica L.	4	0.12	0.01	0.00	0.63	-0.10
Poulsenia armata (Miq.) Standl.	4	0.12	0.01	0.00	0.38	-0.73

Protium tenuifolium (Engl.) Engl.	4	0.12	0.01	0.00	0.63	-0.10
Socratea exorrhiza (Mart.) H.Wendl.	4	0.12	0.01	0.00	0.63	-0.10
Solanum hayesii Fernald	4	0.12	0.02	0.00	0.63	-0.19
Spondias sp.	4	0.12	0.00	0.00	0.00	-0.51
Tetragastris panamensis (Engl.) Kuntze	4	0.12	0.01	0.00	0.38	0.05
Trichilia sp.	4	0.12	0.00	0.00	0.50	-0.19
Virola sebifera Aubl.	4	0.12	0.01	0.00	0.63	-0.15
Annona spraguei Saff.	3	0.09	0.01	0.00	0.67	-0.42
Apeiba membranacea Spruce ex Benth.	3	0.09	0.01	0.00	0.44	-0.10
Beilschmiedia pendula (Sw.) Hemsl.	3	0.09	0.01	0.00	0.44	-0.10
Carludovica palmata Ruiz & Pav.	3	0.09	0.00	0.00	0.00	0.03
Cecropia longipes Pittier	3	0.09	0.00	0.00	0.67	-0.41
Cecropia peltata L.	3	0.09	0.00	0.00	0.44	-0.15
Chrysophyllum argenteum Jacq.	3	0.09	0.01	0.00	0.44	-0.10
Coccoloba excelsa Benth.	3	0.09	0.01	0.00	0.44	-0.10
Coussarea impetiolaris Donn.Sm.	3	0.09	0.01	0.00	0.44	-0.10
Cupania latifolia Kunth	3	0.09	0.01	0.00	0.44	-0.10
Doliocarpus sp.	3	0.09	0.00	0.00	0.44	-0.15
Eugenia nesiotica Standl.	3	0.09	0.01	0.00	0.44	-0.10
Faramea occidentalis (L.) A.Rich.	3	0.09	0.01	0.00	0.44	-0.10
Ficus pertusa L.f.	3	0.09	0.00	0.00	0.00	-0.73
Ficus tonduzii Standl.	3	0.09	0.00	0.00	0.44	-0.95
Garcinia madruno (Kunth) Hammel	3	0.09	0.01	0.00	0.44	-0.10
Hawkesiophyton ulei (Dammer) Hunz.	3	0.09	0.00	0.00	0.44	-0.19
Hirtella triandra Sw.	3	0.09	0.01	0.00	0.44	-0.10
Maripa panamensis Hemsl.	3	0.09	0.01	0.00	0.44	-0.10
Miconia argentea (Sw.) DC.	3	0.09	0.01	0.00	0.44	-0.10
Mouriri myrtilloides (Sw.) Poir.	3	0.09	0.00	0.00	0.44	-0.15
Musa paradisiaca L.	3	0.09	0.01	0.00	0.67	-0.42
Oenocarpus mapora H.Karst.	3	0.09	0.01	0.00	0.44	-0.10
Philodendron sp.	3	0.09	0.02	0.00	0.44	-0.19
Psidium guajava L.	3	0.09	0.01	0.00	0.67	-0.42
Randia armata (Sw.) DC.	3	0.09	0.01	0.00	0.44	-0.10
Sterculia apetala (Jacq.) H.Karst.	3	0.09	0.01	0.00	0.44	-0.10
Trophis caucana (Pittier) C.C. Berg	3	0.09	0.01	0.00	0.67	-0.41

Continues…

APPENDIX E – Continuation

Plant species	Degree (*D*)	Normalised degree (*ND*)	Betweenness (*BC*)	Closeness (*CC*)	Participation coefficient (Pi)	Within-module degree (Zi)
Alseis blackiana Hemsl.	2	0.06	0.00	0.00	0.50	-0.25
Apeiba glabra Aubl.	2	0.06	0.00	0.00	0.50	-0.25
Chrysophyllum cainito L.	2	0.06	0.00	0.00	0.50	-0.42
Clusia flavida (Benth.) Pipoly	2	0.06	0.02	0.00	0.50	-0.41
Clusia odorata Seem.	2	0.06	0.00	0.00	0.50	-0.10
Connarus sp.	2	0.06	0.00	0.00	0.00	-0.10
Cordia bicolor A.DC.	2	0.06	0.00	0.00	0.50	-0.25
Cordia lasiocalyx Pittier	2	0.06	0.00	0.00	0.50	-0.25
Cupania rufescens Triana & Planch.	2	0.06	0.00	0.00	0.50	-0.25
Desmopsis panamensis (B.L.Rob.) Saff.	2	0.06	0.00	0.00	0.50	-0.25
Doliocarpus major J.F.Gmel.	2	0.06	0.00	0.00	0.50	-0.25
Ficus colubrinae Standl.	2	0.06	0.00	0.00	0.50	-0.10
Ficus paraensis (Miq.) Miq.	2	0.06	0.01	0.00	0.50	-0.10
Genipa americana L.	2	0.06	0.00	0.00	0.50	-0.41
Inga goldmanii Pittier	2	0.06	0.00	0.00	0.50	-0.42
Inga laurina (Sw.) Willd.	2	0.06	0.00	0.00	0.50	-0.25
Inga pezizifera Benth.	2	0.06	0.00	0.00	0.50	-0.25
Inga sp.	2	0.06	0.00	0.00	0.00	-0.10
Lacmellea edulis H.Karst.	2	0.06	0.00	0.00	0.50	-0.42
Lacmellea panamensis (Woodson) Markgr.	2	0.06	0.00	0.00	0.50	-0.25
Lindackeria laurina C. Presl	2	0.06	0.00	0.00	0.50	-0.25
Maquira guianensis Aubl.	2	0.06	0.00	0.00	0.50	-0.25
Ochroma pyramidale (Cav. ex Lam.) Urb.	2	0.06	0.00	0.00	0.50	-0.42
Piper aequale Vahl	2	0.06	0.00	0.00	0.00	-0.19
Piper arboreum Aubl.	2	0.06	0.00	0.00	0.00	-0.19
Piper carrilloanum C.DC.	2	0.06	0.00	0.00	0.00	-0.19
Piper cordulatum C. DC.	2	0.06	0.00	0.00	0.00	-0.19
Piper grande Vahl	2	0.06	0.00	0.00	0.00	-0.19
Piper marginatum Jacq.	2	0.06	0.00	0.00	0.00	-0.19
Piper multiplinervium C.DC.	2	0.06	0.00	0.00	0.00	-0.19
Piper reticulatum L.	2	0.06	0.00	0.00	0.00	-0.19
Platypodium elegans Vogel	2	0.06	0.00	0.00	0.50	-0.42

Pouteria sapota (Jacq.) H.E.Moore & Stearn	2	0.06	0.00	0.00	0.50	-0.25
Protium panamense (Rose) I.M.Johnst.	2	0.06	0.00	0.00	0.50	-0.25
Solanum sp.	2	0.06	0.00	0.00	0.00	-0.19
Sorocea affinis Hemsl.	2	0.06	0.00	0.00	0.50	-0.25
Talisia nervosa Radlk.	2	0.06	0.00	0.00	0.50	-0.25
Tetrathylacium johansenii Standl.	2	0.06	0.00	0.00	0.50	-0.25
Tocoyena pittieri (Standl.) Standl.	2	0.06	0.00	0.00	0.50	-0.42
Virola surinamensis (Rol. ex Rottb.) Warb.	2	0.06	0.00	0.00	0.50	-0.25
Vismia sp.	2	0.06	0.00	0.00	0.00	-0.19
Zanthoxylum sp.	2	0.06	0.00	0.00	0.50	-0.42
Zuelania guidonia (Sw.) Britton & Millsp.	2	0.06	0.00	0.00	0.50	-0.25
Abuta panamensis (Standl.) Krukoff & Barneby	1	0.03	0.00	0.00	0.00	-0.10
Abuta racemosa Triana & Planch.	1	0.03	0.00	0.00	0.00	-0.10
Aechmea tillandsioides (Mart. ex Schult. & Schult.f.) Baker	1	0.03	0.00	0.00	0.00	-0.41
Alibertia edulis (Rich.) A.Rich. ex DC.	1	0.03	0.00	0.00	0.00	-0.10
Allophylus psilospermus Radlk.	1	0.03	0.00	0.00	0.00	-0.10
Annona acuminata Saff.	1	0.03	0.00	0.00	0.00	-0.25
Annona purpurea Moc. & Sessé ex Dunal	1	0.03	0.00	0.00	0.00	-0.10
Annona sp.	1	0.03	0.00	0.00	0.00	-0.10
Anthurium brownii Mast.	1	0.03	0.00	0.00	0.00	-0.10
Anthurium clavigerum Poepp.	1	0.03	0.00	0.00	0.00	-0.25
Anthurium durandii Engl.	1	0.03	0.00	0.00	0.00	-0.10
Apeiba tibourbou Aubl.	1	0.03	0.00	0.00	0.00	-0.10
Astronium graveolens Jacq.	1	0.03	0.00	0.00	0.00	-0.25
Bactris barronis L.H.Bailey	1	0.03	0.00	0.00	0.00	-0.25
Bactris major Jacq.	1	0.03	0.00	0.00	0.00	-0.25
Brosimum sp.	1	0.03	0.00	0.00	0.00	-0.25
Capparidastrum frondosum (Jacq.) Cornejo & Iltis	1	0.03	0.00	0.00	0.00	-0.10
Capparis baducca L.	1	0.03	0.00	0.00	0.00	-0.10
Carica papaya L.	1	0.03	0.00	0.00	0.00	-0.25
Casearia guianensis (Aubl.) Urb.	1	0.03	0.00	0.00	0.00	-0.10
Cayaponia granatensis Cogn.	1	0.03	0.00	0.00	0.00	-0.10

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Ceiba pentandra (L.) Gaertn.	1	0.03	0.00	0.00	0.00	-0.25
Cestrum sp.	1	0.03	0.00	0.00	0.00	-0.10
Chamaedorea tepejilote Liebm.	1	0.03	0.00	0.00	0.00	-0.10
Chrysochlamys nicaraguensis (Oerst., Planch. & Triana) Hemsl.	1	0.03	0.00	0.00	0.00	-0.10
Chrysophyllum sp.	1	0.03	0.00	0.00	0.00	-0.25
Cissampelos tropaeolifolia DC.	1	0.03	0.00	0.00	0.00	-0.10
Citrus sp.	1	0.03	0.00	0.00	0.00	-0.42
Clitoria arborescens R.Br.	1	0.03	0.00	0.00	0.00	-0.25
Coccoloba manzinellensis Beurl.	1	0.03	0.00	0.00	0.00	-0.25
Coccoloba sp.	1	0.03	0.00	0.00	0.00	-0.10
Connarus turczaninowii Triana & Planch.	1	0.03	0.00	0.00	0.00	-0.10
Cordia laevigata Lam.	1	0.03	0.00	0.00	0.00	-0.10
Cordia sp.	1	0.03	0.00	0.00	0.00	-0.25
Coussarea curvigemma Dwyer	1	0.03	0.00	0.00	0.00	-0.10
Croton billbergianus Müll.Arg.	1	0.03	0.00	0.00	0.00	-0.25
Cupania seemannii Triana & Planch.	1	0.03	0.00	0.00	0.00	-0.10
Cupania sp.	1	0.03	0.00	0.00	0.00	-0.25
Dendropanax arboreus (L.) Decne. & Planch.	1	0.03	0.00	0.00	0.00	-0.10
Desmoncus isthmius L.H.Bailey	1	0.03	0.00	0.00	0.00	-0.10
Desmoncus sp.	1	0.03	0.00	0.00	0.00	-0.10
Dioclea wilsonii Standl.	1	0.03	0.00	0.00	0.00	-0.10
Doliocarpus dentatus (Aubl.) Standl.	1	0.03	0.00	0.00	0.00	-0.10
Doliocarpus olivaceus Sprague & R.O.Williams ex G.E.Hunter	1	0.03	0.00	0.00	0.00	-0.25
Entada rheedii Spreng.	1	0.03	0.00	0.00	0.00	-0.10
Epiphyllum phyllanthus (L.) Haw.	1	0.03	0.00	0.00	0.00	-0.10
Epiphyllum sp.	1	0.03	0.00	0.00	0.00	-0.10
Eugenia chepensis Standl.	1	0.03	0.00	0.00	0.00	-0.10
Eugenia choapamensis Standl.	1	0.03	0.00	0.00	0.00	-0.10
Eugenia galalonensis (C.Wright ex Griseb.) Krug & Urb.	1	0.03	0.00	0.00	0.00	-0.10
Eugenia oerstediana O.Berg	1	0.03	0.00	0.00	0.00	-0.10
Eugenia sp.	1	0.03	0.00	0.00	0.00	-0.41
Faramea sp.	1	0.03	0.00	0.00	0.00	-0.25

Ficus hartwegii Miq.	1	0.03	0.00	0.00	0.00	-0.10
Ficus sp.1	1	0.03	0.00	0.00	0.00	-0.25
Ficus sp.2	1	0.03	0.00	0.00	0.00	-0.25
Ficus sp.3	1	0.03	0.00	0.00	0.00	-0.10
Ficus sp.4	1	0.03	0.00	0.00	0.00	-0.10
Garcinia intermedia (Pittier) Hammel	1	0.03	0.00	0.00	0.00	-0.10
Guapira myrtiflora (Standl.) Little	1	0.03	0.00	0.00	0.00	-0.25
Guarea glabra Vahl	1	0.03	0.00	0.00	0.00	-0.25
Guarea guidonia (L.) Sleumer	1	0.03	0.00	0.00	0.00	-0.10
Guarea sp.	1	0.03	0.00	0.00	0.00	-0.25
Gurania sp.	1	0.03	0.00	0.00	0.00	0.00
Gurania suberosa Standl.	1	0.03	0.00	0.00	0.00	-0.10
Gurania tubulosa Cogn.	1	0.03	0.00	0.00	0.00	-0.10
Handroanthus guayacan (Seem.) S.O.Grose	1	0.03	0.00	0.00	0.00	-0.10
Hasseltia floribunda Kunth	1	0.03	0.00	0.00	0.00	-0.10
Heisteria concinna Standl.	1	0.03	0.00	0.00	0.00	-0.10
Herrania purpurea (Pittier) R.E. Schult.	1	0.03	0.00	0.00	0.00	-0.10
Hieronyma alchorneoides Allemão	1	0.03	0.00	0.00	0.00	-0.10
Hirtella americana L.	1	0.03	0.00	0.00	0.00	-0.25
Hura crepitans L.	1	0.03	0.00	0.00	0.00	-0.10
Hybanthus prunifolius (Humb. & Bonpl. ex Schult.) Schulze-Menz	1	0.03	0.00	0.00	0.00	-0.10
Inga cocleensis Pittier	1	0.03	0.00	0.00	0.00	-0.10
Inga mucuna Walp.	1	0.03	0.00	0.00	0.00	-0.10
Inga oerstediana Benth.	1	0.03	0.00	0.00	0.00	-0.10
Inga ruiziana G.Don	1	0.03	0.00	0.00	0.00	-0.10
Inga sapindoides Willd.	1	0.03	0.00	0.00	0.00	-0.10
Inga sp.1	1	0.03	0.00	0.00	0.00	-0.42
Inga sp.2	1	0.03	0.00	0.00	0.00	-0.10
Inga sp.3	1	0.03	0.00	0.00	0.00	-0.10
Inga sp.4	1	0.03	0.00	0.00	0.00	-0.10
Inga sp.5	1	0.03	0.00	0.00	0.00	-0.10
Jacaranda copaia (Aubl.) D.Don	1	0.03	0.00	0.00	0.00	-0.25
Lacistema aggregatum (P.J.Bergius) Rusby	1	0.03	0.00	0.00	0.00	-0.10

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Laetia procera (Poepp.) Eichler (Poepp.) Eichler	1	0.03	0.00	0.00	0.00	-0.10
Laetia thamnia L.	1	0.03	0.00	0.00	0.00	-0.10
Licania hypoleuca Benth.	1	0.03	0.00	0.00	0.00	-0.10
Luehea seemannii Triana & Planch	1	0.03	0.00	0.00	0.00	-0.10
Mabea occidentalis Benth.	1	0.03	0.00	0.00	0.00	-0.10
Maclura tinctoria (L.) D.Don ex Steud.	1	0.03	0.00	0.00	0.00	-1.17
Markea ulei (Dammer) Cuatrec.	1	0.03	0.00	0.00	0.00	-0.10
Mendoncia retusa Turrill	1	0.03	0.00	0.00	0.00	-0.25
Mendoncia sp.	1	0.03	0.00	0.00	0.00	-0.10
Miconia affinis DC.	1	0.03	0.00	0.00	0.00	-0.10
Miconia hondurensis Donn. Sm.	1	0.03	0.00	0.00	0.00	-0.10
Monstera adansonii Schott	1	0.03	0.00	0.00	0.00	-0.10
Monstera dubia (Kunth) Engl. & K.Krause	1	0.03	0.00	0.00	0.00	-0.10
Myrcia fosteri Croat	1	0.03	0.00	0.00	0.00	-0.25
Nectandra purpurea (Ruiz & Pav.) Mez	1	0.03	0.00	0.00	0.00	-0.10
Neea amplifolia Donn.Sm.	1	0.03	0.00	0.00	0.00	-0.10
Ocotea cernua (Nees) Mez	1	0.03	0.00	0.00	0.00	-0.10
Ocotea whitei Woodson	1	0.03	0.00	0.00	0.00	-0.10
Ouratea lucens (Kunth) Engl.	1	0.03	0.00	0.00	0.00	-0.10
Passiflora ambigua Hemsl.	1	0.03	0.00	0.00	0.00	-0.10
Passiflora punctata L.	1	0.03	0.00	0.00	0.00	-0.41
Passiflora seemannii Griseb.	1	0.03	0.00	0.00	0.00	-0.10
Paullinia bracteosa Radlk.	1	0.03	0.00	0.00	0.00	-0.10
Paullinia turbacensis Kunth	1	0.03	0.00	0.00	0.00	-0.10
Pentagonia macrophylla Benth.	1	0.03	0.00	0.00	0.00	-0.10
Perebea xanthochyma H.Karst.	1	0.03	0.00	0.00	0.00	-0.42
Philodendron sp.1	1	0.03	0.00	0.00	0.00	-0.10
Philodendron sp.2	1	0.03	0.00	0.00	0.00	-0.10
Philodendron sp.3	1	0.03	0.00	0.00	0.00	-0.10
Phoradendron piperoides (Kunth) Trel.	1	0.03	0.00	0.00	0.00	-0.10
Picramnia latifolia Tul.	1	0.03	0.00	0.00	0.00	-0.10
Piper colonense C.DC.	1	0.03	0.00	0.00	0.00	-0.41

Piper dilatatum Rich.	1	0.03	0.00	0.00	0.00	-0.41
Piper hispidum Sw.	1	0.03	0.00	0.00	0.00	-0.41
Posoqueria latifolia (Rudge) Schult.	1	0.03	0.00	0.00	0.00	-0.10
Pourouma bicolor Mart.	1	0.03	0.00	0.00	0.00	-0.10
Pouteria fossicola Cronquist	1	0.03	0.00	0.00	0.00	-0.10
Prioria copaifera Griseb.	1	0.03	0.00	0.00	0.00	-0.10
Protium sp.	1	0.03	0.00	0.00	0.00	-0.25
Psidium friedrichsthalianum (O.Berg) Nied.	1	0.03	0.00	0.00	0.00	-0.10
Pterocarpus rohrii Vahl	1	0.03	0.00	0.00	0.00	-0.10
Pterocarpus sp.	1	0.03	0.00	0.00	0.00	-0.25
Quassia amara L.	1	0.03	0.00	0.00	0.00	-0.10
Sapium pachystachys K.Schum. & Pittier	1	0.03	0.00	0.00	0.00	-0.10
Senna undulata (Benth.) H.S.Irwin & Barneby	1	0.03	0.00	0.00	0.00	-0.41
Simarouba amara Aubl.	1	0.03	0.00	0.00	0.00	-0.10
Siparuna pauciflora (Beurl.) A. DC.	1	0.03	0.00	0.00	0.00	-0.10
Sloanea terniflora (Moc. & Sessé ex DC.) Standl.	1	0.03	0.00	0.00	0.00	-0.10
Souroubea sympetala Gilg	1	0.03	0.00	0.00	0.00	-0.10
Swartzia simplex (Sw.) Spreng.	1	0.03	0.00	0.00	0.00	-0.25
Symphonia globulifera L.f.	1	0.03	0.00	0.00	0.00	-0.10
Syzygium malaccense (L.) Merr. & L.M.Perry	1	0.03	0.00	0.00	0.00	-0.42
Tabebuia rosea (Bertol.) Bertero ex A.DC.	1	0.03	0.00	0.00	0.00	-0.25
Tabernaemontana arborea Rose ex J.D.Sm.	1	0.03	0.00	0.00	0.00	-0.10
Thevetia ahouai (L.) A.DC.	1	0.03	0.00	0.00	0.00	-0.10
Topobea parasitica Aubl.	1	0.03	0.00	0.00	0.00	-0.10
Tovomita stylosa Hemsl.	1	0.03	0.00	0.00	0.00	-0.10
Trichilia tuberculata (Triana & Planch.) C. DC.	1	0.03	0.00	0.00	0.00	-0.10
Vismia baccifera (L.) Planch. & Triana	1	0.03	0.00	0.00	0.00	-0.41
Xylopia macrantha Triana & Planch.	1	0.03	0.00	0.00	0.00	-0.10
Zanthoxylum setulosum P.Wilson	1	0.03	0.00	0.00	0.00	-0.10
CSPR network						
Myrciaria delicatula (DC.) O.Berg	2	0.50	0.23	0.02	0.50	-0.33

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Myrtaceae	2	0.50	0.40	0.02	0.50	-0.29
Psychotria sp.	2	0.50	0.32	0.02	0.50	-0.30
Syagrus romanzoffiana (Cham.) Glassman	2	0.50	0.06	0.02	0.50	-0.33
Amaioua guianensis Aubl.	1	0.25	0.00	0.02	0.00	-0.19
Andira sp.	1	0.25	0.00	0.02	0.00	-0.19
Annona sp.	1	0.25	0.00	0.01	0.00	-0.30
Baccharis sp.	1	0.25	0.00	0.01	0.00	-0.29
Cabralea canjerana (Vell.) Mart.	1	0.25	0.00	0.02	0.00	-0.19
Carapa sp.	1	0.25	0.00	0.02	0.00	-0.19
Casearia decandra Jacq.	1	0.25	0.00	0.02	0.00	-0.19
Cecropia sp.	1	0.25	0.00	0.02	0.00	-0.19
Clusia sp.	1	0.25	0.00	0.02	0.00	-0.19
Coix lacryma-jobi L.	1	0.25	0.00	0.01	0.00	-0.29
Convolvulaceae	1	0.25	0.00	0.01	0.00	-0.29
Cupressus sp.	1	0.25	0.00	0.01	0.00	-0.33
Dasyphyllum sp.	1	0.25	0.00	0.01	0.00	-0.33
Diospyros sp.	1	0.25	0.00	0.01	0.00	-0.29
Eugenia punicifolia (Kunth) DC.	1	0.25	0.00	0.02	0.00	-0.19
Eugenia sp.	1	0.25	0.00	0.02	0.00	-0.19
Ficus sp.	1	0.25	0.00	0.02	0.00	-0.19
Guapira opposita (Vell.) Reitz	1	0.25	0.00	0.02	0.00	-0.19
Handroanthus chrysotrichus (Mart. ex DC.) Mattos	1	0.25	0.00	0.02	0.00	-0.19
Ilex integerrima Reissek	1	0.25	0.00	0.01	0.00	-0.29
Ilex sp.	1	0.25	0.00	0.01	0.00	-0.29
Inga sellowiana Benth.	1	0.25	0.00	0.02	0.00	-0.19
Lafoensia pacari A. St.-Hil.	1	0.25	0.00	0.01	0.00	-0.33
Lauraceae	1	0.25	0.00	0.02	0.00	-0.19
Leguminosae sp.1	1	0.25	0.00	0.01	0.00	-0.30
Leguminosae sp.2	1	0.25	0.00	0.01	0.00	-0.30
Marlierea clausseniana (O.Berg) Kiaersk.	1	0.25	0.00	0.02	0.00	-0.19
Melastomataceae sp.1	1	0.25	0.00	0.01	0.00	-0.30
Melastomataceae sp.2	1	0.25	0.00	0.02	0.00	-0.19
Melastomataceae sp.3	1	0.25	0.00	0.02	0.00	-0.19

Melastomataceae sp.4	1	0.25	0.00	0.02	0.00	-0.19
Melastomataceae sp.5	1	0.25	0.00	0.02	0.00	-0.19
Merostachys fischeriana Rupr. ex Döll	1	0.25	0.00	0.02	0.00	-0.19
Musa sp.	1	0.25	0.00	0.01	0.00	-0.33
Myrcia laruotteana Cambess.	1	0.25	0.00	0.02	0.00	-0.19
Passiflora speciosa Gardner	1	0.25	0.00	0.02	0.00	-0.19
Poaceae	1	0.25	0.00	0.01	0.00	-0.29
Pouteria sp.	1	0.25	0.00	0.02	0.00	-0.19
Prunus persica (L.) Batsch	1	0.25	0.00	0.01	0.00	-0.33
Psidium guajava L.	1	0.25	0.00	0.01	0.00	-0.33
Psidium myrtoides O.Berg	1	0.25	0.00	0.01	0.00	-0.30
Psidium sp.	1	0.25	0.00	0.01	0.00	-0.29
Psychotria vellosiana Benth.	1	0.25	0.00	0.02	0.00	-0.19
Rollinia sp.	1	0.25	0.00	0.01	0.00	-0.30
Roupala montana Aubl.	1	0.25	0.00	0.02	0.00	-0.19
Rubiaceae sp.1	1	0.25	0.00	0.01	0.00	-0.30
Rubiaceae sp.2	1	0.25	0.00	0.01	0.00	-0.30
Rubus brasiliensis Mart.	1	0.25	0.00	0.01	0.00	-0.33
Senna sp.	1	0.25	0.00	0.01	0.00	-0.30
Solanaceae	1	0.25	0.00	0.01	0.00	-0.30
Solanum cinnamomeum Sendtn.	1	0.25	0.00	0.02	0.00	-0.19
Solanum lycocarpum A. St.-Hil.	1	0.25	0.00	0.01	0.00	-0.29
Solanum sp.	1	0.25	0.00	0.01	0.00	-0.29
Syagrus sp.	1	0.25	0.00	0.01	0.00	-0.29
Tovomitopsis paniculata Planch. & Triana	1	0.25	0.00	0.02	0.00	-0.19
Vitex sp.	1	0.25	0.00	0.02	0.00	-0.19
GCVEPA network						
Cabralea canjerana (Vell.) Mart.	13	0.42	0.00	0.02	0.52	1.26
Miconia cuspidata Mart. ex Naudin	11	0.35	0.18	0.02	0.61	1.43
Protium spruceanum (Benth.) Engl.	11	0.35	0.00	0.02	0.30	1.63
Alchornea glandulosa Poepp.	10	0.32	0.00	0.02	0.62	2.45
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin	10	0.32	0.00	0.02	0.32	1.26
Miconia pepericarpa Mart. ex DC.	8	0.26	0.18	0.02	0.53	0.92
Solanum viscosissimum Sendtn.	8	0.26	0.00	0.02	0.47	0.92

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Virola sebifera Aubl.	8	0.26	0.00	0.02	0.63	-0.20
Amaioua guianensis Aubl.	7	0.23	0.00	0.02	0.45	0.16
Cecropia pachystachya Trécul.	7	0.23	0.00	0.02	0.24	1.43
Guatteria sellowiana Schltdl.	6	0.19	0.00	0.02	0.28	0.16
Xylopia aromatica (Lam.) Mart.	6	0.19	0.00	0.02	0.61	0.69
Paullinia carpopoda Cambess.	5	0.16	0.00	0.02	0.32	-0.21
Richeria grandis Vahl	5	0.16	0.00	0.02	0.48	-0.09
Piper tectoniifolium (Kunth) Steud.	4	0.13	0.00	0.02	0.00	-0.21
Mauritia flexuosa L.f.	2	0.06	0.00	0.02	0.00	-0.95
Miconia albicans (Sw.) Steud.	2	0.06	0.20	0.02	0.50	-0.41
Miconia ferruginata DC.	2	0.06	0.20	0.02	0.50	-0.41
Mouriri glazioviana Cogn.	2	0.06	0.00	0.02	0.00	-0.95
Psittacanthus robustus (Mart.) Marloth	2	0.06	0.00	0.01	0.00	-0.59
Sacoglottis guianensis Benth.	2	0.06	0.23	0.02	0.50	-0.32
Acinodendron pohlianum (Cogn.) Kuntze	1	0.03	0.00	0.02	0.00	-0.41
Alibertia sp.	1	0.03	0.00	0.02	0.00	-0.21
Aspidosperma sp.	1	0.03	0.00	0.01	0.00	-0.32
Aspidosperma subincanum Mart. ex A.DC.	1	0.03	0.00	0.01	0.00	-0.32
Astrocaryum sp.	1	0.03	0.00	0.01	0.00	-0.32
Blepharocalyx salicifolius (Kunth) O.Berg	1	0.03	0.00	0.02	0.00	-0.21
Brosimum gaudichaudii Trécul	1	0.03	0.00	0.02	0.00	-0.21
Cheiloclinium cognatum (Miers) A.C.Sm.	1	0.03	0.00	0.02	0.00	-0.21
Copaifera langsdorffii Desf.	1	0.03	0.00	0.01	0.00	-0.32
Cordiera concolor (Cham.) Kuntze	1	0.03	0.00	0.02	0.00	-0.21
Cryptocarya aschersoniana Mez	1	0.03	0.00	0.01	0.00	-0.32
Cupania vernalis Cambess.	1	0.03	0.00	0.02	0.00	-0.21
Duguetia furfuracea (A.St.-Hil.) Saff.	1	0.03	0.00	0.02	0.00	-0.21
Erythroxylum cuspidifolium Mart.	1	0.03	0.00	0.02	0.00	-0.21
Euterpe edulis Mart.	1	0.03	0.00	0.02	0.00	-0.21
Guapira graciliflora (Mart. ex J.A.Schmidt) Lundell	1	0.03	0.00	0.02	0.00	-0.21
Hymenaea courbaril L.	1	0.03	0.00	0.01	0.00	-0.32

Inga alba (Sw.) Willd.	1	0.03	0.00	0.02	0.00	-0.21
Inga semialata (Vell.) C.Mart.	1	0.03	0.00	0.02	0.00	-0.21
Inga sp.	1	0.03	0.00	0.02	0.00	-0.21
Licania sp.	1	0.03	0.00	0.01	0.00	-0.32
Miconia sp.	1	0.03	0.00	0.02	0.00	-0.21
Ossaea congestiflora Cogn.	1	0.03	0.00	0.02	0.00	-0.41
Passiflora sp.	1	0.03	0.00	0.02	0.00	-0.21
Persea sp.	1	0.03	0.00	0.01	0.00	-0.32
Phoradendron crassifolium (Pohl ex DC.) Eichler	1	0.03	0.00	0.02	0.00	-1.31
Phoradendron perrottetii Nutt.	1	0.03	0.00	0.02	0.00	-0.41
Schefflera macrocarpa (Cham. & Schltdl.) Frodin	1	0.03	0.00	0.02	0.00	-0.21
Simarouba versicolor A. St.-Hil.	1	0.03	0.00	0.02	0.00	-0.21
Siphoneugena densiflora O.Berg	1	0.03	0.00	0.02	0.00	-0.21
Solanaceae	1	0.03	0.00	0.02	0.00	-0.41
Swartzia sp.	1	0.03	0.00	0.01	0.00	-0.32
Syzygium cumini (L.) Skeels	1	0.03	0.00	0.02	0.00	-0.21
Tapirira guianensis Aubl.	1	0.03	0.00	0.02	0.00	-0.21
Tapura amazonica Poepp.	1	0.03	0.00	0.02	0.00	-0.21
Tibouchina candolleana Cogn.	1	0.03	0.00	0.02	0.00	-0.21
HPIN network						
Cecropia peltata L.	4	0.33	0.08	0.02	0.38	0.96
Ficus sp.	4	0.33	0.00	0.01	0.00	1.93
Genipa americana L.	4	0.33	0.15	0.02	0.63	-0.30
Guazuma ulmifolia Lam.	4	0.33	0.15	0.02	0.63	-0.30
Maclura tinctoria (L.) D.Don ex Steud.	4	0.33	0.07	0.02	0.38	0.96
Albizia saman (Jacq.) Merr.	3	0.25	0.03	0.02	0.44	-0.30
Bromelia chrysantha Jacq.	3	0.25	0.06	0.02	0.44	-0.30
Caesalpinia coriaria (Jacq.) Willd.	3	0.25	0.03	0.02	0.44	-0.30
Copernicia tectorum (Kunth) Mart.	3	0.25	0.14	0.02	0.67	-0.22
Mangifera indica L.	3	0.25	0.03	0.02	0.44	-0.30
Acacia macracantha Willd.	2	0.17	0.00	0.01	0.00	-0.30
Chamaecrista nictitans (L.) Moench	2	0.17	0.00	0.01	0.00	-0.30
Chloroleucon mangense (Jacq.) Britton & Rose	2	0.17	0.00	0.01	0.00	-0.30

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Coccoloba caracasana Meisn.	2	0.17	0.08	0.02	0.50	-0.22
Cyperaceae	2	0.17	0.00	0.01	0.00	-0.30
Euphorbiaceae	2	0.17	0.08	0.02	0.50	-0.22
Hecatostemon completus (Jacq.) Sleumer	2	0.17	0.08	0.02	0.50	-0.22
Pereskia guamacho F.A.C.Weber	2	0.17	0.00	0.01	0.00	-0.30
Piper sp.	2	0.17	0.00	0.01	0.00	0.00
Quadrella odoratissima (Jacq.) Hutch. odoratissima (Jacq.) Hutch.	2	0.17	0.02	0.02	0.50	-0.21
Sapindus saponaria L.	2	0.17	0.00	0.01	0.00	-0.30
Spondias mombin L.	2	0.17	0.00	0.01	0.00	-0.30
Acacia glomerosa Benth.	1	0.08	0.00	0.02	0.00	-0.21
Allophylus racemosus Sw.	1	0.08	0.00	0.02	0.00	-0.21
Annona jahnii Saff.	1	0.08	0.00	0.02	0.00	-0.22
Annona purpurea Moc. & Sessé ex Dunal	1	0.08	0.00	0.01	0.00	-0.55
Annona sp.	1	0.08	0.00	0.02	0.00	-0.22
Bignoniaceae sp.1	1	0.08	0.00	0.02	0.00	-0.21
Bignoniaceae sp.2	1	0.08	0.00	0.02	0.00	-0.21
Bromelia pinguin L.	1	0.08	0.00	0.02	0.00	-0.22
Cassia grandis L.f.	1	0.08	0.00	0.02	0.00	-0.22
Chloroleucon tortum (Mart.) Pittier	1	0.08	0.00	0.02	0.00	-0.22
Chomelia spinosa Jacq.	1	0.08	0.00	0.02	0.00	-0.22
Combretum fruticosum (Loefl.) Stuntz	1	0.08	0.00	0.02	0.00	-0.22
Combretum sp.	1	0.08	0.00	0.02	0.00	-0.21
Convolvulus sp.	1	0.08	0.00	0.02	0.00	-0.21
Cordia nodosa Lam.	1	0.08	0.00	0.02	0.00	-0.22
Cordia tetrandra Aubl.	1	0.08	0.00	0.02	0.00	-0.21
Echinodorus paniculatus Micheli	1	0.08	0.00	0.02	0.00	-0.21
Enterolobium cyclocarpum (Jacq.) Griseb.	1	0.08	0.00	0.02	0.00	-0.21
Ficus trigonata L.	1	0.08	0.00	0.02	0.00	-0.22
Guettarda odorata (Jacq.) Lam.	1	0.08	0.00	0.01	0.00	-0.55
Guettarda sp.	1	0.08	0.00	0.02	0.00	-0.21
Lantana camara L.	1	0.08	0.00	0.02	0.00	-0.21
Lantana trifolia L.	1	0.08	0.00	0.02	0.00	-0.21

Licania pyrifolia Griseb.	1	0.08	0.00	0.02	0.00	-0.21
Marsdenia undulata Dugand	1	0.08	0.00	0.02	0.00	-0.22
Matelea maritima (Jacq.) Woodson	1	0.08	0.00	0.02	0.00	-0.22
Melicoccus bijugatus Jacq.	1	0.08	0.00	0.02	0.00	-0.22
Mimosa pellita Willd.	1	0.08	0.00	0.02	0.00	-0.21
Olyra sp.	1	0.08	0.00	0.02	0.00	-0.22
Passiflora sp.	1	0.08	0.00	0.02	0.00	-0.21
Poaceae	1	0.08	0.00	0.02	0.00	-0.21
Schaefferia frutescens Jacq.	1	0.08	0.00	0.01	0.00	-0.55
Scleria sp.	1	0.08	0.00	0.02	0.00	-0.21
Sesbania sp.	1	0.08	0.00	0.02	0.00	-0.21
Solanum bicolor Willd. ex Roem. & Schult.	1	0.08	0.00	0.01	0.00	-0.96
Sterculia apetala (Jacq.) H.Karst.	1	0.08	0.00	0.02	0.00	-0.22
Tabernaemontana cymosa Jacq.	1	0.08	0.00	0.02	0.00	-0.21
Thalia geniculata L.	1	0.08	0.00	0.02	0.00	-0.21
Trichocentrum cebolleta (Jacq.) M.W.Chase & N.H.Williams	1	0.08	0.00	0.02	0.00	-0.22
Trophis racemosa (L.) Urb.	1	0.08	0.00	0.02	0.00	-0.22
Ziziphus cyclocardia S.F.Blake	1	0.08	0.00	0.02	0.00	-0.21
Ziziphus saeri Pittier	1	0.08	0.00	0.02	0.00	-0.22
INP network						
Cecropia pachystachya Trécul.	8	0.80	0.25	0.02	0.69	0.45
Piper sp.	6	0.60	0.10	0.02	0.61	0.45
Maclura tinctoria (L.) D.Don ex Steud.	5	0.50	0.13	0.02	0.56	-0.29
Ficus citrifolia Mill.	4	0.40	0.00	0.01	0.00	0.09
Ficus luschnathiana (Miq.) Miq.	4	0.40	0.00	0.01	0.00	0.09
Ficus sp.	4	0.40	0.06	0.02	0.38	-0.29
Piper amalago L.	4	0.40	0.00	0.01	0.00	0.09
Solanum granuloso-leprosum Dunal	4	0.40	0.00	0.01	0.00	0.09
Chrysophyllum gonocarpum (Mart. & Eichler ex Miq.) Engl.	3	0.30	0.13	0.02	0.67	-0.22
Psidium guajava L.	3	0.30	0.04	0.02	0.44	-0.67
Allophylus edulis (A.St.-Hil., A.Juss. & Cambess.) Radlk.	2	0.20	0.04	0.02	0.50	-0.21
Hovenia dulcis Thunb.	2	0.20	0.04	0.02	0.50	-0.22
Maclura sp.	2	0.20	0.00	0.01	0.00	-0.45

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Nectandra sp.	2	0.20	0.04	0.02	0.50	-0.22
Piper aduncum L.	2	0.20	0.00	0.01	0.00	-0.67
Piper gaudichaudianum (Kunth) Kunth ex Steud.	2	0.20	0.00	0.01	0.00	-0.67
Piper hispidum Sw.	2	0.20	0.00	0.01	0.00	-0.67
Sorocea bonplandii (Baill.) W.C.Burger, Lanj. & de Boer	2	0.20	0.04	0.02	0.50	-0.22
Syagrus romanzoffiana (Cham.) Glassman	2	0.20	0.04	0.02	0.50	-0.21
Trichostigma octandrum (L.) H.Walter	2	0.20	0.04	0.02	0.50	-0.21
Ananas sagenaria (Arruda) Schult. & Schult.f.	1	0.10	0.00	0.02	0.00	-0.22
Cabralea canjerana (Vell.) Mart.	1	0.10	0.00	0.02	0.00	-0.21
Campomanesia xanthocarpa (Mart.) O.Berg	1	0.10	0.00	0.02	0.00	-0.21
Carica papaya L.	1	0.10	0.00	0.02	0.00	-0.22
Casearia decandra Jacq.	1	0.10	0.00	0.02	0.00	-0.21
Casearia sylvestris Sw.	1	0.10	0.00	0.02	0.00	-0.21
Celtis iguanaea (Jacq.) Sarg.	1	0.10	0.00	0.02	0.00	-0.21
Chrysophyllum marginatum (Hook. & Arn.) Radlk.	1	0.10	0.00	0.02	0.00	-0.21
Citrus aurantium L.	1	0.10	0.00	0.02	0.00	-0.21
Citrus reticulata Blanco	1	0.10	0.00	0.02	0.00	-0.21
Citrus sp.1	1	0.10	0.00	0.02	0.00	-0.22
Citrus sp.2	1	0.10	0.00	0.02	0.00	-0.22
Citrus sp.3	1	0.10	0.00	0.02	0.00	-0.22
Coussarea contracta (Walp.) Benth. & Hook.f. ex Müll.Arg.	1	0.10	0.00	0.02	0.00	-0.21
Dicella nucifera Chodat	1	0.10	0.00	0.02	0.00	-0.21
Eriobotrya japonica (Thunb.) Lindl.	1	0.10	0.00	0.02	0.00	-0.22
Eugenia involucrata DC.	1	0.10	0.00	0.02	0.00	-0.22
Eugenia pyriformis Cambess.	1	0.10	0.00	0.02	0.00	-0.21
Eugenia sp.	1	0.10	0.00	0.02	0.00	-0.22
Ficus sp.1	1	0.10	0.00	0.02	0.00	-0.22
Ficus sp.2	1	0.10	0.00	0.02	0.00	-0.22
Guarea kunthiana A.Juss.	1	0.10	0.00	0.02	0.00	-0.21
Inga sp.	1	0.10	0.00	0.02	0.00	-0.22

Jacaratia spinosa (Aubl.) A.DC.	1	0.10	0.00	0.01	0.00	-1.34
Luehea divaricata Mart	1	0.10	0.00	0.02	0.00	-0.21
Matayba elaeagnoides Radlk.	1	0.10	0.00	0.02	0.00	-0.21
Miconia discolor DC.	1	0.10	0.00	0.02	0.00	-0.21
Miconia pusilliflora (DC.) Naudin	1	0.10	0.00	0.02	0.00	-0.22
Morus alba L.	1	0.10	0.00	0.02	0.00	-0.22
Musa sp.	1	0.10	0.00	0.02	0.00	-0.21
Myrtaceae	1	0.10	0.00	0.02	0.00	-0.22
Ocotea sp.	1	0.10	0.00	0.02	0.00	-0.21
Ossaea sp.	1	0.10	0.00	0.02	0.00	-0.22
Passiflora amethystina J.C.Mikan	1	0.10	0.00	0.01	0.00	-1.05
Philodendron bipinnatifidum Schott ex Endl.	1	0.10	0.00	0.02	0.00	-0.22
Plinia rivularis (Cambess.) Rotman	1	0.10	0.00	0.02	0.00	-0.21
Rollinia emarginata Schltdl.	1	0.10	0.00	0.02	0.00	-0.22
Rollinia sp.	1	0.10	0.00	0.02	0.00	-0.21
Solanaceae	1	0.10	0.00	0.01	0.00	-1.34
Solanum sp.	1	0.10	0.00	0.01	0.00	-1.05
ISP network						
Myrsine coriacea (Sw.) R.Br. ex Roem. & Schult.	39	0.34	0.02	0.00	0.66	2.84
Ficus luschnathiana (Miq.) Miq.	34	0.30	0.05	0.00	0.76	1.26
Cecropia glaziovii Snethl.	32	0.28	0.11	0.00	0.78	1.72
Coussapoa microcarpa (Schott) Rizzini	29	0.25	0.03	0.00	0.72	1.24
Myrsine lancifolia Mart.	29	0.25	0.01	0.00	0.55	2.44
Cupania vernalis Cambess.	26	0.23	0.01	0.00	0.49	2.24
Miconia pusilliflora (DC.) Naudin	26	0.23	0.01	0.00	0.60	1.41
Trema micrantha (L.) Blume	25	0.22	0.02	0.00	0.64	1.44
Myrcia splendens (Sw.) DC.	20	0.18	0.01	0.00	0.58	1.24
Symplocos glanduloso-marginata Hoehne	20	0.18	0.01	0.00	0.67	1.32
Euterpe edulis Mart.	19	0.17	0.02	0.00	0.54	1.24
Leandra dasytricha (A. Gray) Cogn.	19	0.17	0.02	0.00	0.68	0.58
Miconia budlejoides Triana	19	0.17	0.01	0.00	0.73	0.25
Miconia valtheri Naudin	19	0.17	0.01	0.00	0.61	0.75
Alchornea triplinervia (Spreng.) Müll.Arg.	16	0.14	0.01	0.00	0.55	0.84

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Rubus rosaefolius S.Vidal	16	0.14	0.01	0.00	0.76	0.08
Xylopia brasiliensis Spreng.	16	0.14	0.00	0.00	0.68	0.44
Psychotria vellosiana Benth.	15	0.13	0.01	0.00	0.64	0.41
Miconia racemifera (Schrank & Mart. ex DC.) Triana	14	0.12	0.01	0.00	0.70	0.08
Ossaea amygdaloides Triana	14	0.12	0.01	0.00	0.61	0.41
Schinus terebinthifolia Raddi	14	0.12	0.00	0.00	0.60	0.90
Miconia latecrenata (DC.) Naudin	13	0.11	0.00	0.00	0.38	0.75
Myrcia brasiliensis Kiaersk.	13	0.11	0.03	0.00	0.76	0.22
Virola bicuhyba (Schott) Warb.	13	0.11	0.01	0.00	0.67	0.42
Allophylus edulis (A.St.-Hil., A.Juss. & Cambess.) Radlk.	12	0.11	0.01	0.00	0.69	-0.16
Miconia theizans (Bonpl.) Cogn.	12	0.11	0.00	0.00	0.54	0.25
Marcgravia polyantha Delpino	11	0.10	0.03	0.00	0.71	-0.16
Myrcia pubipetala Miq.	11	0.10	0.03	0.00	0.64	0.48
Nectandra membranacea (Sw.) Griseb.	11	0.10	0.02	0.00	0.55	0.24
Rubus urticifolius Poir.	11	0.10	0.01	0.00	0.63	0.48
Struthanthus sp.	11	0.10	0.00	0.00	0.43	0.44
Hieronyma alchorneoides Allemão	10	0.09	0.02	0.00	0.64	0.22
Ilex brevicuspis Reissek	10	0.09	0.00	0.00	0.46	0.69
Psidium cattleianum Afzel. ex Sabine	10	0.09	0.01	0.00	0.48	0.48
Sapium glandulosum (L.) Morong	10	0.09	0.01	0.00	0.18	0.64
Struthanthus vulgaris (Vell.) Mart.	10	0.09	0.00	0.00	0.32	0.44
Tetrorchidium rubrivenium Poepp.	10	0.09	0.00	0.00	0.18	0.64
Alchornea glandulosa Poepp.	9	0.08	0.01	0.00	0.72	-0.18
Clusia criuva Cambess.	9	0.08	0.00	0.00	0.62	-0.16
Leandra sp.	9	0.08	0.00	0.00	0.49	0.08
Matayba guianensis Aubl.	9	0.08	0.02	0.00	0.49	0.04
Amaioua intermedia Mart. ex Schult. & Schult.f.	8	0.07	0.00	0.00	0.72	-0.18
Ilex microdonta Reissek	8	0.07	0.00	0.00	0.63	0.06
Leandra laevigata Cogn.	8	0.07	0.00	0.00	0.22	0.25
Leandra pilonensis Wurdack	8	0.07	0.00	0.00	0.56	-0.09
Maytenus robusta Reissek	8	0.07	0.01	0.00	0.69	0.02
Ocotea puberula (Rich.) Nees	8	0.07	0.00	0.00	0.22	0.24

Persea pyrifolia (D. Don) Spreng.	8	0.07	0.00	0.00	0.63	0.06
Philodendron appendiculatum Nadruz & Mayo	8	0.07	0.03	0.00	0.63	0.18
Phytolacca dioica L.	8	0.07	0.01	0.00	0.75	0.02
Psychotria suterella Müll.Arg.	8	0.07	0.02	0.00	0.75	-0.42
Fuchsia regia (Vand. ex Vell.) Munz	7	0.06	0.00	0.00	0.57	0.06
Miconia cinnamomifolia (DC.) Naudin	7	0.06	0.01	0.00	0.57	-0.25
Piper dilatatum Rich.	7	0.06	0.01	0.00	0.69	-0.12
Piper sp.	7	0.06	0.00	0.00	0.00	0.80
Solanum sp.1	7	0.06	0.01	0.00	0.41	0.34
Vassobia breviflora (Sendtn.) Hunz.	7	0.06	0.01	0.00	0.57	0.11
Casearia sylvestris Sw.	6	0.05	0.00	0.00	0.61	-0.56
Guapira opposita (Vell.) Reitz	6	0.05	0.00	0.00	0.61	-0.15
Leandra australis (Cham.) Cogn.	6	0.05	0.00	0.00	0.28	-0.09
Leandra regnellii (Triana) Cogn.	6	0.05	0.00	0.00	0.28	-0.09
Marlierea reitzii D.Legrand	6	0.05	0.01	0.00	0.50	0.06
Miconia brasiliensis (Spreng.) Triana	6	0.05	0.00	0.00	0.50	-0.25
Miconia discolor DC.	6	0.05	0.00	0.00	0.28	-0.09
Miconia inconspicua Miq.	6	0.05	0.00	0.00	0.44	-0.36
Ocotea corymbosa (Meisn.) Mez	6	0.05	0.00	0.00	0.28	-0.16
Piper corintoanum Yunck.	6	0.05	0.01	0.00	0.72	-0.35
Solanum variabile Mart.	6	0.05	0.01	0.00	0.61	-0.12
Tournefortia paniculata Cham.	6	0.05	0.00	0.00	0.50	-0.36
Anthurium harrisii (Graham) G.Don	5	0.04	0.00	0.00	0.00	0.33
Ficus sp.1	5	0.04	0.00	0.00	0.56	-0.12
Ficus sp.2	5	0.04	0.00	0.00	0.00	0.34
Leandra melastomoides Raddi	5	0.04	0.00	0.00	0.56	-0.42
Leandra refracta Cogn.	5	0.04	0.00	0.00	0.00	-0.09
Myrcia hebepetala DC.	5	0.04	0.00	0.00	0.56	-0.15
Myrcia sp.1	5	0.04	0.01	0.00	0.56	-0.15
Myrsine gardneriana A. DC.	5	0.04	0.00	0.00	0.32	-0.36
Myrsine venosa A. DC.	5	0.04	0.00	0.00	0.72	-0.36
Protium heptaphyllum (Aubl.) Marchand	5	0.04	0.00	0.00	0.48	-0.15
Psidium guajava L.	5	0.04	0.00	0.00	0.48	-0.15
Rudgea jasminoides (Cham.) Müll.Arg.	5	0.04	0.00	0.00	0.72	-0.59

Continues…

APPENDIX E – Continuation

Plant species	Degree (*D*)	Normalised degree (*ND*)	Betweenness (*BC*)	Closeness (*CC*)	Participation coefficient (Pi)	Within-module degree (Zi)
Schefflera angustissima (Marchal) Frodin	5	0.04	0.00	0.00	0.48	-0.56
Solanum inodorum Vell.	5	0.04	0.00	0.00	0.64	-0.36
Solanum mauritianum Scop.	5	0.04	0.00	0.00	0.56	-0.15
Solanum megalochiton Mart.	5	0.04	0.00	0.00	0.32	0.11
Solanum scuticum M.Nee	5	0.04	0.00	0.00	0.00	0.34
Solanum sp.2	5	0.04	0.00	0.00	0.00	0.34
Bicuiba oleifera (Schott) J.J.de Wilde	4	0.04	0.00	0.00	0.00	0.22
Cabralea canjerana (Vell.) Mart.	4	0.04	0.00	0.00	0.63	-0.18
Copaifera trapezifolia Hayne	4	0.04	0.00	0.00	0.38	0.02
Geonoma elegans Mart.	4	0.04	0.00	0.00	0.63	-0.76
Inga semialata (Vell.) C.Mart.	4	0.04	0.01	0.00	0.63	-0.36
Leandra barbinervis (Cham. ex Triana) Cogn.	4	0.04	0.00	0.00	0.00	-0.25
Leandra sabiaensis Brade	4	0.04	0.00	0.00	0.00	-0.25
Miconia cabussu Hoehne	4	0.04	0.00	0.00	0.63	-0.76
Miconia sp.	4	0.04	0.00	0.00	0.38	-0.56
Miconia tristis Spring	4	0.04	0.00	0.00	0.38	-0.42
Mollinedia boracensis Peixoto	4	0.04	0.00	0.00	0.38	-0.42
Morus sp.	4	0.04	0.00	0.00	0.38	-0.15
Ocotea teleiandra (Meisn.) Mez	4	0.04	0.00	0.00	0.50	-0.36
Philodendron corcovadense Kunth	4	0.04	0.00	0.00	0.00	0.18
Posoqueria latifolia (Rudge) Schult.	4	0.04	0.00	0.00	0.00	0.18
Psychotria leiocarpa Cham. & Schltdl.	4	0.04	0.00	0.00	0.63	-0.36
Rhipsalis campos-portoana Loefgr.	4	0.04	0.00	0.00	0.38	-0.42
Rhipsalis teres (Vell.) Steud.	4	0.04	0.01	0.00	0.63	-0.59
Rubus brasiliensis Mart.	4	0.04	0.00	0.00	0.38	-0.12
Solanum paranense Dusén	4	0.04	0.00	0.00	0.00	0.11
Solanum sp.3	4	0.04	0.00	0.00	0.00	0.11
Struthanthus concinnus Mart.	4	0.04	0.00	0.00	0.38	-0.56
Urera baccifera (L.) Gaudich. ex Wedd.	4	0.04	0.00	0.00	0.38	-0.42
Agonandra sp.	3	0.03	0.00	0.00	0.44	-0.12
Aureliana fasciculata (Vell.) Sendtn.	3	0.03	0.00	0.00	0.67	-0.58
Bromeliaceae sp.1	3	0.03	0.01	0.00	0.44	-0.59

Bromeliaceae sp.2	3	0.03	0.00	0.00	0.44	-0.59
Casearia decandra Jacq.	3	0.03	0.00	0.00	0.44	-0.59
Citharexylum myrianthum Cham.	3	0.03	0.00	0.00	0.00	0.02
Clusia sp.	3	0.03	0.00	0.00	0.67	-0.57
Cordia polycephala (Lam.) I.M.Johnst.	3	0.03	0.00	0.00	0.67	-0.57
Coussarea contracta (Walp.) Benth. & Hook.f. ex Müll.Arg.	3	0.03	0.01	0.00	0.67	-0.27
Cucurbitaceae	3	0.03	0.01	0.00	0.44	-0.35
Eugenia melanogyna (D.Legrand) Sobral	3	0.03	0.00	0.00	0.00	-0.15
Ficus sp.3	3	0.03	0.00	0.00	0.67	-0.39
Heteropsis oblongifolia Kunth	3	0.03	0.01	0.00	0.44	-0.12
Leandra scabra DC.	3	0.03	0.00	0.00	0.00	-0.42
Leandra xanthostachya Cogn.	3	0.03	0.00	0.00	0.00	-0.42
Miconia rigidiuscula Cogn.	3	0.03	0.00	0.00	0.00	-0.42
Miconia sellowiana Naudin	3	0.03	0.00	0.00	0.44	-0.36
Monstera adansonii Schott	3	0.03	0.00	0.00	0.00	0.03
Myrcia sp.2	3	0.03	0.00	0.00	0.44	-0.76
Myrsine umbellata Mart.	3	0.03	0.00	0.00	0.00	-0.15
Nectandra cuspidata Nees & Mart.	3	0.03	0.00	0.00	0.44	-0.36
Neomitranthes glomerata (D.Legrand) Govaerts	3	0.03	0.00	0.00	0.44	-0.36
Ocotea sp.	3	0.03	0.00	0.00	0.44	-0.18
Ocotea spixiana (Nees) Mez	3	0.03	0.00	0.00	0.44	-0.18
Paullinia uloptera Radlk.	3	0.03	0.00	0.00	0.00	-0.56
Philodendron eximium Schott	3	0.03	0.00	0.00	0.00	0.03
Piper aduncum L.	3	0.03	0.00	0.00	0.44	-0.35
Psidium sp.	3	0.03	0.00	0.00	0.67	-0.39
Psychotria malaneoides Müll.Arg.	3	0.03	0.00	0.00	0.44	-0.59
Psychotria mapourioides DC.	3	0.03	0.01	0.00	0.44	-0.18
Rollinia sericea (R.E. Fr.) R.E. Fr.	3	0.03	0.00	0.00	0.44	-0.12
Siphoneugena densiflora O.Berg	3	0.03	0.00	0.00	0.67	-0.39
Sloanea guianensis (Aubl.) Benth.	3	0.03	0.00	0.00	0.44	-0.12
Solanum rufescens Sendtn.	3	0.03	0.00	0.00	0.44	-0.35
Solanum subsylvestre L.B.Sm. & Downs	3	0.03	0.00	0.00	0.00	-0.12
Solanum swartzianum Roem. & Schult.	3	0.03	0.00	0.00	0.44	-0.35

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Symplocos variabilis Mart. ex Miq.	3	0.03	0.00	0.00	0.67	-0.27
Abuta selloana Eichler	2	0.02	0.00	0.00	0.50	-0.27
Anthurium sellowianum Kunth	2	0.02	0.00	0.00	0.50	-0.27
Campomanesia guaviroba (DC.) Kiaersk.	2	0.02	0.00	0.00	0.00	-0.35
Campomanesia neriiflora (O.Berg) Nied.	2	0.02	0.00	0.00	0.50	-0.27
Campomanesia xanthocarpa (Mart.) O.Berg	2	0.02	0.00	0.00	0.00	-0.36
Carica papaya L.	2	0.02	0.00	0.00	0.50	-0.58
Cecropia pachystachya Trécul.	2	0.02	0.00	0.00	0.00	-0.35
Chrysophyllum viride Mart. & Eichler ex Miq.	2	0.02	0.00	0.00	0.00	-0.12
Clusia parviflora Humb. & Bonpl. ex Willd.	2	0.02	0.00	0.00	0.50	-0.27
Coccocypselum geophiloides Wawra	2	0.02	0.00	0.00	0.50	-0.58
Coccocypselum hasslerianum Chodat	2	0.02	0.00	0.00	0.00	-0.36
Cryptocarya moschata Nees & Mart.	2	0.02	0.00	0.00	0.50	-0.27
Cucurbitaceae sp. 2	2	0.02	0.00	0.00	0.00	-0.35
Cupania oblongifolia Mart.	2	0.02	0.00	0.00	0.00	-0.18
Drimys brasiliensis Miers	2	0.02	0.00	0.00	0.00	-0.36
Drimys winteri J.R.Forst. & G.Forst.	2	0.02	0.00	0.00	0.00	-0.36
Eugenia magnifica Spring ex Mart.	2	0.02	0.00	0.00	0.00	-0.36
Eugenia sp.	2	0.02	0.00	0.00	0.00	-0.12
Ficus gomelleira Kunth & C.D.Bouché	2	0.02	0.00	0.00	0.00	-0.12
Ficus insipida Willd.	2	0.02	0.00	0.00	0.00	-0.12
Geonoma sp.	2	0.02	0.00	0.00	0.50	-0.39
Gomidesia sp.	2	0.02	0.00	0.00	0.50	-0.57
Hedychium coronarium J.Koenig	2	0.02	0.00	0.00	0.00	-0.59
Heisteria silvianii Schwacke	2	0.02	0.00	0.00	0.00	-0.12
Hymenaea courbaril L.	2	0.02	0.00	0.00	0.00	-0.12
Hyperbaena sp.	2	0.02	0.00	0.00	0.50	-0.27
Ixora heterodoxa Müll.Arg.	2	0.02	0.00	0.00	0.50	-0.57
Loranthaceae	2	0.02	0.00	0.00	0.00	-0.76
Matayba elaeagnoides Radlk.	2	0.02	0.00	0.00	0.00	-0.18
Maytenus sp.	2	0.02	0.00	0.00	0.50	-0.27

Melastomataceae	2	0.02	0.00	0.00	0.50	-0.57
Merostachys sp.	2	0.02	0.00	0.00	0.00	-0.18
Miconia cubatanensis Hoehne	2	0.02	0.00	0.00	0.50	-0.57
Miconia doriana Cogn.	2	0.02	0.00	0.00	0.50	-0.75
Mollinedia floribunda Tul.	2	0.02	0.00	0.00	0.50	-0.75
Myrcia sp.3	2	0.02	0.00	0.00	0.50	-0.57
Myrtaceae sp.1	2	0.02	0.00	0.00	0.00	-0.12
Myrtaceae sp.2	2	0.02	0.00	0.00	0.00	-0.12
Myrtaceae sp.3	2	0.02	0.00	0.00	0.00	-0.12
Nectandra grandiflora Nees & Mart.	2	0.02	0.00	0.00	0.50	-0.57
Ocotea aciphylla (Nees & Mart.) Mez	2	0.02	0.00	0.00	0.50	-0.27
Ocotea odorifera (Vell.) Rohwer	2	0.02	0.00	0.00	0.50	-0.39
Ouratea vaccinioides Engl.	2	0.02	0.00	0.00	0.50	-0.39
Passiflora sp.	2	0.02	0.00	0.00	0.00	-0.35
Philodendron crassinervium Lindl.	2	0.02	0.00	0.00	0.00	-0.12
Philodendron sp.	2	0.02	0.00	0.00	0.50	-0.39
Phytolacca sp.	2	0.02	0.00	0.00	0.00	-0.36
Piper gaudichaudianum (Kunth) Kunth ex Steud.	2	0.02	0.00	0.00	0.00	-0.35
Pourouma guianensis Aubl.	2	0.02	0.00	0.00	0.00	-0.12
Protium widgrenii Engl.	2	0.02	0.00	0.00	0.00	-0.18
Prunus sellowii Koehne	2	0.02	0.00	0.00	0.00	-0.18
Psittacanthus sp. 1	2	0.02	0.00	0.00	0.00	-0.76
Pterocarpus violaceus Vogel	2	0.02	0.00	0.00	0.00	-0.36
Salacia sp.	2	0.02	0.00	0.00	0.00	-0.12
Solanum americanum Mill.	2	0.02	0.00	0.00	0.00	-0.59
Solanum sanctae-katharinae Dunal	2	0.02	0.00	0.00	0.00	-0.35
Symplocos tetrandra Mart.	2	0.02	0.00	0.00	0.50	-0.57
Virola gardneri (A.DC.) Warb.	2	0.02	0.00	0.00	0.00	-0.18
Aechmea sp.	1	0.01	0.00	0.00	0.00	-0.75
Amaioua guianensis Aubl.	1	0.01	0.00	0.00	0.00	-0.39
Andira pisonis Benth.	1	0.01	0.00	0.00	0.00	-0.58
Anthurium crassinervium (Jacq.) Schott	1	0.01	0.00	0.00	0.00	-0.27
Anthurium scandens (Aubl.) Engl.	1	0.01	0.00	0.00	0.00	-0.75
Aureliana sp.	1	0.01	0.00	0.00	0.00	-0.58
Brosimum sp.	1	0.01	0.00	0.00	0.00	-0.39

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Campomanesia sp.	1	0.01	0.00	0.00	0.00	-0.58
Cayaponia sp.	1	0.01	0.00	0.00	0.00	-0.58
Celtis iguanaea (Jacq.) Sarg.	1	0.01	0.00	0.00	0.00	-0.57
Chrysophyllum flexuosum Mart.	1	0.01	0.00	0.00	0.00	-0.39
Cinnamodendron dinisii Schwacke	1	0.01	0.00	0.00	0.00	-0.27
Citrus medica L.	1	0.01	0.00	0.00	0.00	-0.57
Codonanthe cordifolia Chautems	1	0.01	0.00	0.00	0.00	-0.75
Combretum sp.	1	0.01	0.00	0.00	0.00	-0.39
Cordia silvestris Fresen.	1	0.01	0.00	0.00	0.00	-0.39
Cordiera myrciifolia (K.Schum.) Perss. & Delprete	1	0.01	0.00	0.00	0.00	-0.57
Cryptocarya aschersoniana Mez	1	0.01	0.00	0.00	0.00	-0.39
Cucumis sp.	1	0.01	0.00	0.00	0.00	-0.58
Cucurbitaceae sp. 1	1	0.01	0.00	0.00	0.00	-0.57
Cybianthus peruvianus (A.DC.) Miq.	1	0.01	0.00	0.00	0.00	-0.96
Dendropanax sp.	1	0.01	0.00	0.00	0.00	-0.39
Dichorisandra thyrsiflora J.C.Mikan	1	0.01	0.00	0.00	0.00	-0.75
Endlicheria paniculata (Spreng.) J.F.Macbr.	1	0.01	0.00	0.00	0.00	-0.27
Eugenia handroana D.Legrand	1	0.01	0.00	0.00	0.00	-0.39
Eugenia oblongata O.Berg	1	0.01	0.00	0.00	0.00	-0.39
Eugenia prasina O.Berg	1	0.01	0.00	0.00	0.00	-0.27
Ficus eximia Schott	1	0.01	0.00	0.00	0.00	-0.39
Galium hypocarpium (L.) Endl. ex Griseb.	1	0.01	0.00	0.00	0.00	-0.75
Garcinia brasiliensis Mart.	1	0.01	0.00	0.00	0.00	-0.27
Guarea macrophylla Vahl	1	0.01	0.00	0.00	0.00	-0.75
Guatteria australis A.St.-Hil.	1	0.01	0.00	0.00	0.00	-0.75
Heteropsis rigidifolia Engl.	1	0.01	0.00	0.00	0.00	-0.75
Heteropsis sp.	1	0.01	0.00	0.00	0.00	-0.96
Inga edulis Mart.	1	0.01	0.00	0.00	0.00	-0.27
Inga sessilis (Vell.) Mart.	1	0.01	0.00	0.00	0.00	-0.27
Lantana camara L.	1	0.01	0.00	0.00	0.00	-0.75
Lantana sp.	1	0.01	0.00	0.00	0.00	-0.75
Lauraceae	1	0.01	0.00	0.00	0.00	-0.96

Leandra xanthocoma (Naudin) Cogn.	1	0.01	0.00	0.00	0.00	-0.57
Margaritaria nobilis L.f.	1	0.01	0.00	0.00	0.00	-0.39
Margaritopsis astrellantha (Wernham) L.Andersson	1	0.01	0.00	0.00	0.00	-0.39
Marlierea sp.	1	0.01	0.00	0.00	0.00	-0.27
Maytenus ilicifolia Mart. ex Reissek	1	0.01	0.00	0.00	0.00	-0.39
Maytenus ligustrina Reissek	1	0.01	0.00	0.00	0.00	-0.39
Maytenus littoralis Carv.-Okano	1	0.01	0.00	0.00	0.00	-0.39
Miconia cabucu Hoehne	1	0.01	0.00	0.00	0.00	-0.39
Miconia multiflora Cogn.	1	0.01	0.00	0.00	0.00	-0.75
Mollinedia uleana Perkins	1	0.01	0.00	0.00	0.00	-0.39
Musa velutina H.Wendl. & Drude	1	0.01	0.00	0.00	0.00	-0.27
Myrcia ilheosensis Kiaersk.	1	0.01	0.00	0.00	0.00	-0.96
Myrtaceae sp.4	1	0.01	0.00	0.00	0.00	-0.27
Myrtaceae sp.5	1	0.01	0.00	0.00	0.00	-0.27
Myrtaceae sp.6	1	0.01	0.00	0.00	0.00	-0.27
Myrtaceae sp.7	1	0.01	0.00	0.00	0.00	-0.27
Myrtaceae sp.8	1	0.01	0.00	0.00	0.00	-0.27
Myrtaceae sp.9	1	0.01	0.00	0.00	0.00	-0.27
Nectandra reticulata Mez	1	0.01	0.00	0.00	0.00	-0.39
Norantea sp.	1	0.01	0.00	0.00	0.00	-0.27
Ocotea pulchella (Nees & Mart.) Mez	1	0.01	0.00	0.00	0.00	-0.57
Oreopanax sp.	1	0.01	0.00	0.00	0.00	-0.96
Ottonia sp.	1	0.01	0.00	0.00	0.00	-0.58
Philodendron obliquifolium Engl.	1	0.01	0.00	0.00	0.00	-0.27
Phoradendron crassifolium (Pohl ex DC.) Eichler	1	0.01	0.00	0.00	0.00	-0.96
Piper hoehnei Yunck.	1	0.01	0.00	0.00	0.00	-0.58
Poaceae	1	0.01	0.00	0.00	0.00	-0.75
Psittacanthus sp. 2	1	0.01	0.00	0.00	0.00	-0.96
Randia sp.	1	0.01	0.00	0.00	0.00	-0.27
Rhamnidium sp.	1	0.01	0.00	0.00	0.00	-0.27
Rhipsalis elliptica G.Lindb. ex K.Schum.	1	0.01	0.00	0.00	0.00	-0.75
Rhipsalis paradoxa (Salm-Dyck ex Pfeiff.) Salm-Dyck	1	0.01	0.00	0.00	0.00	-0.96
Rhipsalis sp.	1	0.01	0.00	0.00	0.00	-0.75

Continues…

APPENDIX E – Continuation

Plant species	Degree (*D*)	Normalised degree (*ND*)	Betweenness (*BC*)	Closeness (*CC*)	Participation coefficient (Pi)	Within-module degree (Zi)
Rollinia emarginata Schltdl.	1	0.01	0.00	0.00	0.00	-0.58
Rudgea recurva Müll.Arg.	1	0.01	0.00	0.00	0.00	-0.39
Sapotaceae	1	0.01	0.00	0.00	0.00	-0.27
Schefflera sp.	1	0.01	0.00	0.00	0.00	-0.39
Schlegelia parviflora (Oerst.) Monach.	1	0.01	0.00	0.00	0.00	-0.27
Smilax elastica Griseb.	1	0.01	0.00	0.00	0.00	-0.57
Solanum argenteum Dunal	1	0.01	0.00	0.00	0.00	-0.96
Solanum bullatum Vell.	1	0.01	0.00	0.00	0.00	-0.57
Solanum cinnamomeum Sendtn.	1	0.01	0.00	0.00	0.00	-0.58
Solanum granuloso-leprosum Dunal	1	0.01	0.00	0.00	0.00	-0.58
Solanum pseudocapsicum L.	1	0.01	0.00	0.00	0.00	-0.58
Solanum pseudoquina A. St.-Hil.	1	0.01	0.00	0.00	0.00	-0.58
Strychnos brasiliensis (Spreng.) Mart.	1	0.01	0.00	0.00	0.00	-0.58
Strychnos sp.	1	0.01	0.00	0.00	0.00	-0.27
Syagrus romanzoffiana (Cham.) Glassman	1	0.01	0.00	0.00	0.00	-0.58
Symplocos uniflora (Pohl) Benth.	1	0.01	0.00	0.00	0.00	-0.39
Tabernaemontana catharinensis A.DC.	1	0.01	0.00	0.00	0.00	-0.75
Tapirira guianensis Aubl.	1	0.01	0.00	0.00	0.00	-0.39
Tibouchina mutabilis (Vell.) Cogn.	1	0.01	0.00	0.00	0.00	-0.57
Vismia sp.	1	0.01	0.00	0.00	0.00	-0.58
Vitex sp.	1	0.01	0.00	0.00	0.00	-0.27
Zanthoxylum rhoifolium Lam.	1	0.01	0.00	0.00	0.00	-0.39
Zanthoxylum riedelianum Engl.	1	0.01	0.00	0.00	0.00	-0.96
Zingiberaceae	1	0.01	0.00	0.00	0.00	-0.27
LTBR network						
Ficus colubrinae Standl.	24	0.56	0.08	0.01	0.16	3.98
Dendropanax arboreus (L.) Decne. & Planch.	21	0.49	0.11	0.01	0.25	3.12
Cecropia obtusifolia Bertol.	19	0.44	0.16	0.01	0.56	1.84
Allophylus camptostachys Radlk.	14	0.33	0.00	0.01	0.13	2.05
Ficus sp.	6	0.14	0.16	0.01	0.67	0.00

Conostegia xalapensis (Bonpl.) D. Don ex DC.	4	0.09	0.00	0.01	0.50	-0.89
Moraceae	4	0.09	0.00	0.01	0.38	0.00
Piperaceae	4	0.09	0.00	0.01	0.38	0.00
Solanaceae	4	0.09	0.00	0.01	0.38	0.00
Brosimum alicastrum Sw.	3	0.07	0.04	0.01	0.44	-0.05
Ficus insipida Willd.	3	0.07	0.04	0.01	0.44	-0.05
Nectandra ambigens (S.F.Blake) C.K.Allen	3	0.07	0.04	0.01	0.44	-0.05
Piper hispidum Sw.	3	0.07	0.03	0.01	0.44	-0.23
Poulsenia armata (Miq.) Standl.	3	0.07	0.04	0.01	0.44	-0.05
Pseudolmedia glabrata (Liebm.) C.C.Berg	3	0.07	0.04	0.01	0.44	-0.05
Solanum sp.	3	0.07	0.03	0.01	0.44	-0.23
Trema micrantha (L.) Blume	3	0.07	0.03	0.01	0.44	-0.23
Brachistus nelsonii (Fernald) D'Arcy, J.L.Gentry & Averett	2	0.05	0.00	0.01	0.00	-0.23
Clibadium arboreum Donn.Sm.	2	0.05	0.00	0.01	0.00	-0.23
Clidemia deppeana Steud.	2	0.05	0.00	0.01	0.00	-0.23
Cynometra retusa Britton & Rose	2	0.05	0.03	0.01	0.50	-0.29
Diospyros nigra (J.F.Gmel.) Perrier	2	0.05	0.03	0.01	0.50	-0.29
Drymonia strigosa (Oerst.) Wiehler	2	0.05	0.00	0.01	0.00	-0.23
Ficus obtusifolia Kunth	2	0.05	0.03	0.01	0.50	-0.29
Hamelia longipes Standl.	2	0.05	0.00	0.01	0.00	-0.23
Lasiacis divaricata (L.) Hitchc.	2	0.05	0.00	0.01	0.00	-0.23
Manilkara sapota Van Royen	2	0.05	0.01	0.01	0.50	-0.29
Notopleura macrophylla (Ruiz & Pav.) C.M.Taylor	2	0.05	0.00	0.01	0.00	-0.23
Piper sp.	2	0.05	0.00	0.01	0.50	-1.79
Pouteria campechiana (Kunth) Baehni	2	0.05	0.03	0.01	0.50	-0.29
Psychotria limonensis K.Krause	2	0.05	0.00	0.01	0.00	-0.23
Sideroxylon capiri (A.DC.) Pittier	2	0.05	0.03	0.01	0.50	-0.29
Spondias mombin L.	2	0.05	0.03	0.01	0.50	-0.29
Urera caracasana (Jacq.) Gaudich. ex Griseb.	2	0.05	0.00	0.01	0.00	-0.23
Xiphidium caeruleum Aubl.	2	0.05	0.00	0.01	0.00	-0.23
Abuta panamensis (Standl.) Krukoff & Barneby	1	0.02	0.00	0.01	0.00	-0.14
Albizia tomentosa (Micheli) Standl.	1	0.02	0.00	0.01	0.00	-0.14

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Ampelocera hottlei (Standl.) Standl.	1	0.02	0.00	0.01	0.00	-0.14
Andira galeottiana Standl.	1	0.02	0.00	0.01	0.00	-0.14
Anthurium sp.	1	0.02	0.00	0.01	0.00	-0.29
Astrocaryum mexicanum Liebm. ex Mart.	1	0.02	0.00	0.01	0.00	-0.29
Attalea rostrata Oerst.	1	0.02	0.00	0.01	0.00	-0.14
Bursera simaruba (L.) Sarg.	1	0.02	0.00	0.01	0.00	-0.14
Calophyllum brasiliense Cambess.	1	0.02	0.00	0.01	0.00	-0.29
Castilla elastica Cerv.	1	0.02	0.00	0.01	0.00	-0.14
Cissus gossypiifolia Standl.	1	0.02	0.00	0.01	0.00	-0.14
Citharexylum affine D. Don	1	0.02	0.00	0.01	0.00	-0.14
Cordia alliodora (Ruiz & Pav.) Oken	1	0.02	0.00	0.01	0.00	-0.14
Cordia dodecandra A.DC.	1	0.02	0.00	0.01	0.00	-0.14
Cordia sp.	1	0.02	0.00	0.01	0.00	-0.14
Cordia stellifera I.M.Johnst.	1	0.02	0.00	0.01	0.00	-0.14
Costus scaber Ruiz & Pav.	1	0.02	0.00	0.01	0.00	-0.45
Costus sp.	1	0.02	0.00	0.01	0.00	-0.45
Couepia polyandra (Kunth) Rose	1	0.02	0.00	0.01	0.00	-0.14
Coussapoa purpusii Standl.	1	0.02	0.00	0.01	0.00	-0.14
Croton schiedeanus Schltdl.	1	0.02	0.00	0.01	0.00	-0.14
Cupania dentata Moc. & Sessé ex DC.	1	0.02	0.00	0.01	0.00	-0.14
Cymbopetalum baillonii R.E.Fr.	1	0.02	0.00	0.01	0.00	-0.29
Dialium guianense (Aubl.) Sandwith	1	0.02	0.00	0.01	0.00	-0.14
Diphysa macrophylla Lundell	1	0.02	0.00	0.01	0.00	-0.14
Eugenia acapulcensis Steud.	1	0.02	0.00	0.01	0.00	-0.14
Ficus americana Aubl.	1	0.02	0.00	0.01	0.00	-0.14
Ficus apollinaris Dugand	1	0.02	0.00	0.01	0.00	-0.14
Ficus aurea Nutt.	1	0.02	0.00	0.01	0.00	-0.14
Ficus cotinifolia Kunth	1	0.02	0.00	0.01	0.00	-0.14
Ficus hartwegii Miq.	1	0.02	0.00	0.01	0.00	-0.29
Ficus maxima Mill.	1	0.02	0.00	0.01	0.00	-0.14
Ficus pertusa L.f.	1	0.02	0.00	0.01	0.00	-0.14
Ficus trigonata L.	1	0.02	0.00	0.01	0.00	-0.14
Ficus yoponensis Desv.	1	0.02	0.00	0.01	0.00	-0.14

Garcinia intermedia (Pittier) Hammel	1	0.02	0.00	0.01	0.00	-0.14
Gouania lupuloides (L.) Urb.	1	0.02	0.00	0.01	0.00	-0.14
Guarea megantha A.Juss.	1	0.02	0.00	0.01	0.00	-0.14
Guazuma ulmifolia Lam.	1	0.02	0.00	0.01	0.00	-0.14
Hirtella triandra Sw.	1	0.02	0.00	0.01	0.00	-0.14
Ilex costaricensis Donn.Sm.	1	0.02	0.00	0.01	0.00	-0.14
Inga acrocephala Steud.	1	0.02	0.00	0.01	0.00	-0.14
Inga paterno Harms	1	0.02	0.00	0.01	0.00	-0.14
Licania sp.	1	0.02	0.00	0.01	0.00	-0.29
Lycianthes heteroclita (Sendtn.) Bitter	1	0.02	0.00	0.01	0.00	-0.14
Maclura tinctoria (L.) D.Don ex Steud.	1	0.02	0.00	0.01	0.00	-0.14
Manilkara zapota (L.) P.Royen	1	0.02	0.00	0.01	0.00	-0.29
Momordica charantia L.	1	0.02	0.00	0.01	0.00	-0.45
Monstera tuberculata Lundell	1	0.02	0.00	0.01	0.00	-0.14
Omphalea oleifera Hemsl.	1	0.02	0.00	0.01	0.00	-0.14
Pachira aquatica Aubl.	1	0.02	0.00	0.01	0.00	-0.14
Piper amalago L.	1	0.02	0.00	0.01	0.00	-0.29
Piper auritum Kunth	1	0.02	0.00	0.01	0.00	-0.29
Piper lapathifolium (Kunth) Steud.	1	0.02	0.00	0.01	0.00	-0.29
Piper sanctum (Miq.) Schltdl. ex C.DC.	1	0.02	0.00	0.01	0.00	-0.29
Pleuropetalum sprucei (Hook.f.) Standl.	1	0.02	0.00	0.01	0.00	-0.45
Pouteria reticulata (Engl.) Eyma subsp. Reticulata	1	0.02	0.00	0.01	0.00	-0.29
Protium copal (Schltdl. & Cham.) Engl.	1	0.02	0.00	0.01	0.00	-0.14
Psychotria simiarum Standl.	1	0.02	0.00	0.01	0.00	-0.14
Psychotria veracruzensis Lorence & Dwyer	1	0.02	0.00	0.01	0.00	-0.45
Pterocarpus rohrii Vahl	1	0.02	0.00	0.01	0.00	-0.14
Quararibea funebris (La Llave) Vischer	1	0.02	0.00	0.01	0.00	-0.29
Renealmia mexicana Klotzsch ex Petersen	1	0.02	0.00	0.01	0.00	-0.45
Robinsonella mirandae Gómez Pompa	1	0.02	0.00	0.01	0.00	-0.14
Rollinia mucosa (Jacq.) Baill.	1	0.02	0.00	0.01	0.00	-0.14
Sapium lateriflorum Hemsl.	1	0.02	0.00	0.01	0.00	-0.14

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Sideroxylon portoricense Urb.	1	0.02	0.00	0.01	0.00	-0.14
Siparuna thecaphora (Poepp. & Endl.) A.DC.	1	0.02	0.00	0.01	0.00	-0.45
Smilax sp.	1	0.02	0.00	0.01	0.00	-0.14
Spondias radlkoferi Donn.Sm.	1	0.02	0.00	0.01	0.00	-0.14
Tapirira mexicana Marchand	1	0.02	0.00	0.01	0.00	-0.14
Tournefortia hirsutissima L.	1	0.02	0.00	0.01	0.00	-0.14
Trichospermum mexicanum (DC.) Baill.	1	0.02	0.00	0.01	0.00	-0.14
Trophis mexicana (Liebm.) Bureau	1	0.02	0.00	0.01	0.00	-0.14
Turpinia occidentalis (Sw.) G.Don	1	0.02	0.00	0.01	0.00	-0.29
MCFBR network						
Acnistus arborescens (L.) Schltdl.	30	0.71	0.04	0.01	0.34	3.78
Ficus aurea Nutt.	22	0.52	0.07	0.01	0.69	0.59
Hampea appendiculata (Donn.Sm.) Standl.	20	0.48	0.03	0.01	0.53	1.44
Sapium glandulosum (L.) Morong	19	0.45	0.01	0.01	0.28	2.08
Citharexylum integerrimum (Kuntze) Moldenke	18	0.43	0.02	0.01	0.50	1.23
Ocotea tonduzii Standl.	16	0.38	0.02	0.01	0.65	0.37
Conostegia icosandra (Sw. ex Wikstr.) Urb.	15	0.36	0.06	0.01	0.74	0.08
Trema micrantha (L.) Blume	15	0.36	0.01	0.01	0.32	1.23
Hasseltia floribunda Kunth	14	0.33	0.03	0.01	0.68	0.23
Oreopanax oerstedianus Marchal	12	0.29	0.02	0.01	0.58	0.16
Urera elata (Sw.) Griseb.	12	0.29	0.01	0.01	0.65	0.02
Cecropia obtusifolia Bertol.	11	0.26	0.11	0.01	0.71	0.18
Xylosma chlorantha Donn.Sm.	11	0.26	0.00	0.01	0.17	0.80
Ardisia palmana Donn.Sm.	10	0.24	0.01	0.01	0.62	0.18
Myrsine coriacea (Sw.) R.Br. ex Roem. & Schult.	10	0.24	0.00	0.01	0.32	0.37
Solanum cordovense Sessé & Moc.	10	0.24	0.01	0.01	0.54	-0.05
Cinnamomum triplinerve (Ruiz & Pav.) Kosterm.	9	0.21	0.01	0.01	0.57	0.08
Citharexylum macradenium Greenm.	9	0.21	0.01	0.01	0.57	-0.27
Cinnamomum neurophyllum (Mez & Pittier) Kosterm.	8	0.19	0.00	0.01	0.38	0.23

Ficus pertusa L.f.	8	0.19	0.02	0.01	0.72	-0.20
Nectandra cuspidata Nees & Mart.	8	0.19	0.01	0.01	0.59	-0.06
Viburnum costaricanum Hemsl.	8	0.19	0.01	0.01	0.41	-0.05
Colubrina celtidifolia (Cham. & Schltdl.) Schltdl.	7	0.17	0.01	0.01	0.45	0.18
Guettarda crispiflora Vahl	7	0.17	0.01	0.01	0.61	-0.15
Nectandra salicina C.K.Allen	7	0.17	0.00	0.01	0.41	0.08
Symplococarpon purpusii (Brandegee) Kobuski	7	0.17	0.01	0.01	0.61	-0.15
Symplocos limoncillo Humb. & Bonpl.	7	0.17	0.00	0.01	0.24	0.23
Dendropanax sp.	6	0.14	0.01	0.01	0.61	-0.69
Guarea glabra Vahl	6	0.14	0.01	0.01	0.50	-0.48
Matayba apetala (Griseb.) Radlk.	6	0.14	0.01	0.01	0.28	-0.27
Miconia sp.	6	0.14	0.00	0.01	0.28	0.18
Rubus rosifolius Sm.	6	0.14	0.01	0.01	0.67	-0.31
Schefflera rodriguesiana Frodin	6	0.14	0.01	0.01	0.50	0.02
Witheringia solanacea L'Hér.	6	0.14	0.02	0.01	0.67	-0.15
Beilschmiedia costaricensis (Mez & Pittier) C.K.Allen	5	0.12	0.00	0.01	0.00	0.08
Clusia alata Planch. & Triana	5	0.12	0.01	0.01	0.64	-0.31
Daphnopsis americana (Mill.) J.R.Johnst.	5	0.12	0.00	0.01	0.32	-0.48
Ilex lamprophylla Standl.	5	0.12	0.00	0.00	0.56	-0.69
Lycianthes multiflora Bitter	5	0.12	0.01	0.01	0.56	-0.15
Ocotea austinii C.K.Allen	5	0.12	0.01	0.01	0.56	-0.20
Ocotea floribunda (Sw.) Mez	5	0.12	0.00	0.01	0.00	0.08
Ocotea glaucosericea Rohwer	5	0.12	0.00	0.01	0.00	0.08
Phytolacca rivinoides Kunth & C.D.Bouché	5	0.12	0.00	0.01	0.32	0.02
Solanum umbellatum Mill.	5	0.12	0.04	0.01	0.64	-0.14
Xylosma flexuosa (Kunth) Hemsl.	5	0.12	0.01	0.01	0.48	-0.15
Xylosma intermedia (Seem.) Griseb.	5	0.12	0.00	0.00	0.32	-0.48
Besleria sp.	4	0.10	0.00	0.01	0.00	0.02
Celastraceae	4	0.10	0.00	0.01	0.38	-0.69
Clibadium sp.1	4	0.10	0.01	0.01	0.38	-0.15
Conostegia rufescens Naudin	4	0.10	0.01	0.01	0.38	-0.15
Cupania glabra Sw.	4	0.10	0.00	0.01	0.38	-0.69
Dendropanax arboreus (L.) Decne. & Planch.	4	0.10	0.00	0.01	0.38	-0.20

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Gonzalagunia rosea Standl.	4	0.10	0.00	0.01	0.00	0.02
Guatteria consanguinea Klotzsch	4	0.10	0.00	0.01	0.38	-0.20
Marcgravia brownei (Triana & Planch.) Krug & Urb.	4	0.10	0.01	0.01	0.63	-0.31
Meliosma idiopoda S.F.Blake	4	0.10	0.00	0.01	0.50	-0.34
Ocotea bernoulliana Mez	4	0.10	0.00	0.01	0.00	-0.06
Ocotea sp.1	4	0.10	0.00	0.01	0.00	-0.06
Ocotea sp.2	4	0.10	0.00	0.01	0.00	-0.06
Ocotea sp.3	4	0.10	0.00	0.01	0.38	-0.20
Oreopanax xalapensis (Kunth) Decne. & Planch.	4	0.10	0.00	0.01	0.63	-0.91
Ossaea micrantha (Sw.) Macfad. ex Cogn.	4	0.10	0.00	0.00	0.00	0.02
Ossaea sp.	4	0.10	0.00	0.01	0.00	0.02
Perrottetia longistylis Rose	4	0.10	0.00	0.00	0.38	-0.69
Solanum nudum Dunal	4	0.10	0.04	0.01	0.63	-0.14
Zanthoxylum culantrillo Kunth	4	0.10	0.00	0.01	0.38	-0.69
Anthurium sp.1	3	0.07	0.01	0.01	0.67	-0.22
Ardisia compressa Kunth	3	0.07	0.01	0.01	0.44	-0.34
Beilschmiedia sp.2	3	0.07	0.00	0.01	0.00	-0.20
Blakea gracilis Hemsl.	3	0.07	0.00	0.01	0.44	-0.31
Bocconia frutescens L.	3	0.07	0.00	0.00	0.44	-0.91
Cavendishia complectens Hemsl.	3	0.07	0.00	0.01	0.44	-0.31
Cestrum schlechtendahlii G.Don	3	0.07	0.01	0.01	0.67	-0.22
Chione venosa (Sw.) Urb.	3	0.07	0.00	0.01	0.00	-0.20
Drymonia rubra C.V.Morton	3	0.07	0.02	0.00	0.44	-0.14
Lycianthes synanthera (Sendtn.) Bitter	3	0.07	0.00	0.01	0.44	-0.31
Malvaviscus arboreus Cav.	3	0.07	0.01	0.01	0.67	-0.22
Ocotea klotzschiana (Nees) Hemsl.	3	0.07	0.00	0.01	0.44	-0.34
Palicourea alajuelensis C.M.Taylor	3	0.07	0.00	0.01	0.00	-0.20
Piper auritum Kunth	3	0.07	0.03	0.01	0.67	-0.34
Psychotria elata (Sw.) Hammel	3	0.07	0.01	0.01	0.44	-0.31
Witheringia coccoloboides (Dammer) Hunz.	3	0.07	0.00	0.01	0.00	-0.15
Beilschmiedia sp.1	2	0.05	0.00	0.01	0.00	-0.34
Besleria triflora (Oerst.) Hanst.	2	0.05	0.00	0.01	0.00	-0.31

Burmeistera cyclostigmata Donn.Sm.	2	0.05	0.00	0.00	0.00	-0.14
Cavendishia sp.	2	0.05	0.00	0.00	0.50	-0.22
Cestrum racemosum Ruiz & Pav.	2	0.05	0.00	0.01	0.50	-0.22
Chamaedorea sp.	2	0.05	0.00	0.01	0.00	-0.34
Chionanthus ligustrinus (Sw.) Pers.	2	0.05	0.00	0.01	0.50	-0.48
Dendropanax gonatopodus (Donn.Sm.) A.C.Sm.	2	0.05	0.00	0.00	0.00	-0.31
Drymonia conchocalyx Hanst.	2	0.05	0.00	0.01	0.00	-0.31
Ficus yoponensis Desv.	2	0.05	0.00	0.00	0.00	-0.14
Guarea rhopalocarpa Radlk.	2	0.05	0.00	0.01	0.00	-0.34
Hamelia patens Jacq.	2	0.05	0.00	0.00	0.50	-0.22
Mappia racemosa Jacq.	2	0.05	0.00	0.01	0.00	-0.34
Nectandra sp.1	2	0.05	0.00	0.00	0.00	-0.34
Nectandra sp.2	2	0.05	0.00	0.01	0.00	-0.34
Neea amplifolia Donn.Sm.	2	0.05	0.00	0.01	0.50	-0.22
Persea sp.2	2	0.05	0.00	0.00	0.50	-0.48
Piper amalago L.	2	0.05	0.00	0.00	0.00	-0.14
Piper bisasperatum Trel.	2	0.05	0.00	0.00	0.00	-0.14
Piper dotanum Trel.	2	0.05	0.00	0.00	0.00	-0.14
Piper epigynium C. DC.	2	0.05	0.00	0.00	0.00	-0.14
Piper lanceifolium Kunth	2	0.05	0.00	0.00	0.00	-0.14
Piper sp.	2	0.05	0.02	0.01	0.50	-0.22
Pouteria exfoliata T.D.Penn.	2	0.05	0.00	0.00	0.00	-0.34
Prunus annularis Koehne	2	0.05	0.00	0.01	0.00	-0.34
Prunus cornifolia Koehne	2	0.05	0.00	0.00	0.50	-0.48
Psychotria cuspidata Bredem. ex Schult.	2	0.05	0.00	0.01	0.50	-0.22
Psychotria sp.2	2	0.05	0.00	0.01	0.50	-0.22
Saurauia montana Seem.	2	0.05	0.00	0.00	0.00	-0.14
Solanum argenteum Dunal	2	0.05	0.00	0.00	0.00	-0.14
Solanum asperolanatum Ruiz & Pav.	2	0.05	0.03	0.01	0.50	-0.34
Stemmadenia glabra Benth.	2	0.05	0.00	0.00	0.00	-0.91
Tournefortia glabra L.	2	0.05	0.00	0.01	0.50	-0.47
Anthurium sp.	1	0.02	0.00	0.00	0.00	-0.34
Anthurium sp.2	1	0.02	0.00	0.00	0.00	-0.22
Asplundia vagans Harling	1	0.02	0.00	0.00	0.00	-0.34
Besleria formosa C.V.Morton	1	0.02	0.00	0.00	0.00	-0.22

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Bunchosia odorata (Jacq.) Juss.	1	0.02	0.00	0.01	0.00	-0.48
Bunchosia sp.	1	0.02	0.00	0.01	0.00	-0.48
Casearia sylvestris Sw.	1	0.02	0.00	0.00	0.00	-0.48
Cavendishia capitulata Donn.Sm.	1	0.02	0.00	0.00	0.00	-0.47
Cavendishia melastomoides (Klotzsch) Hemsl.	1	0.02	0.00	0.00	0.00	-0.47
Cecropia angustifolia Trécul	1	0.02	0.00	0.00	0.00	-0.34
Cestrum sp.	1	0.02	0.00	0.01	0.00	-0.48
Clibadium sp.2	1	0.02	0.00	0.00	0.00	-0.47
Conostegia speciosa Naudin	1	0.02	0.00	0.00	0.00	-0.47
Conostegia xalapensis (Bonpl.) D. Don ex DC.	1	0.02	0.00	0.00	0.00	-0.22
Coussarea sp.	1	0.02	0.00	0.00	0.00	-0.48
Cucurbitaceae	1	0.02	0.00	0.01	0.00	-0.48
Dendropanax querceti Donn.Sm.	1	0.02	0.00	0.00	0.00	-0.47
Erythroxylum amplum Benth.	1	0.02	0.00	0.01	0.00	-0.48
Eugenia acapulcensis Steud.	1	0.02	0.00	0.00	0.00	-0.34
Eugenia sp.1	1	0.02	0.00	0.01	0.00	-0.48
Eugenia sp.2	1	0.02	0.00	0.00	0.00	-0.48
Faramea ovalis Standl.	1	0.02	0.00	0.00	0.00	-0.22
Gaiadendron punctatum (Ruiz & Pav.) G.Don	1	0.02	0.00	0.00	0.00	-0.47
Glossoloma tetragonum Hanst.	1	0.02	0.00	0.00	0.00	-0.47
Guapira costaricana (Standl.) Woodson	1	0.02	0.00	0.01	0.00	-0.48
Hieronyma oblonga (Tul.) Müll.Arg.	1	0.02	0.00	0.00	0.00	-0.47
Hoffmannia sp.1	1	0.02	0.00	0.01	0.00	-0.48
Hoffmannia sp.2	1	0.02	0.00	0.00	0.00	-0.47
Hoffmannia sp.3	1	0.02	0.00	0.00	0.00	-0.47
Lasiacis sp.	1	0.02	0.00	0.00	0.00	-0.22
Loranthaceae sp.1	1	0.02	0.00	0.00	0.00	-1.12
Loranthaceae sp.2	1	0.02	0.00	0.00	0.00	-1.12
Mappia sp.	1	0.02	0.00	0.00	0.00	-0.48
Maytenus sp.	1	0.02	0.00	0.00	0.00	-1.12
Melastomataceae sp.1	1	0.02	0.00	0.00	0.00	-0.47
Melastomataceae sp.2	1	0.02	0.00	0.00	0.00	-0.48

Myrtaceae	1	0.02	0.00	0.00	0.00	-0.47
Notopleura guadalupensis (DC.) C.M.Taylor	1	0.02	0.00	0.00	0.00	-0.47
Oreopanax sp.	1	0.02	0.00	0.00	0.00	-0.47
Palicourea ovalis Standl.	1	0.02	0.00	0.00	0.00	-0.47
Palicourea sp.1	1	0.02	0.00	0.00	0.00	-0.47
Palicourea sp.2	1	0.02	0.00	0.00	0.00	-0.47
Paullinia sp.	1	0.02	0.00	0.00	0.00	-1.12
Persea sp.1	1	0.02	0.00	0.00	0.00	-0.47
Persea veraguensis Meisn.	1	0.02	0.00	0.01	0.00	-0.48
Phytolacca sp.	1	0.02	0.00	0.00	0.00	-0.22
Picramnia teapensis Tul.	1	0.02	0.00	0.01	0.00	-0.48
Piper aequale Vahl	1	0.02	0.00	0.00	0.00	-0.34
Piper gibbosum C.DC.	1	0.02	0.00	0.00	0.00	-0.34
Piper glabrescens (Miq.) C.DC.	1	0.02	0.00	0.00	0.00	-0.34
Piper obliquum Ruiz & Pav.	1	0.02	0.00	0.00	0.00	-0.34
Piper phytolaccifolium Opiz	1	0.02	0.00	0.00	0.00	-0.34
Piper umbellatum L.	1	0.02	0.00	0.00	0.00	-0.34
Prunus sellowii Koehne	1	0.02	0.00	0.01	0.00	-0.48
Psychotria galeottiana (M.Martens) C.M.Taylor & Lorence	1	0.02	0.00	0.00	0.00	-0.22
Psychotria sp.1	1	0.02	0.00	0.01	0.00	-0.48
Satyria sp.	1	0.02	0.00	0.00	0.00	-0.47
Schefflera robusta (A.C.Sm.) A.C.Sm.	1	0.02	0.00	0.00	0.00	-0.47
Schultesianthus venosus (Standl. & C.V. Morton) S. Knapp	1	0.02	0.00	0.00	0.00	-0.34
Siparuna sp.	1	0.02	0.00	0.00	0.00	-1.12
Smilax sp.	1	0.02	0.00	0.01	0.00	-0.48
Solanaceae	1	0.02	0.00	0.01	0.00	-0.48
Solanum rovirosanum Donn. Sm.	1	0.02	0.00	0.00	0.00	-0.34
Solanum sp.	1	0.02	0.00	0.00	0.00	-0.34
Symplocos sp.1	1	0.02	0.00	0.00	0.00	-0.47
Symplocos sp.2	1	0.02	0.00	0.00	0.00	-0.48
Tabernaemontana sp.	1	0.02	0.00	0.00	0.00	-0.22
Tradescantia zanonia (L.) Sw.	1	0.02	0.00	0.00	0.00	-0.22
Trichilia havanensis Jacq.	1	0.02	0.00	0.00	0.00	-0.22
Trophis mexicana (Liebm.) Bureau	1	0.02	0.00	0.00	0.00	-0.22
Vitaceae	1	0.02	0.00	0.00	0.00	-0.48

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Witheringia maculata (Standl. & C.V. Morton) Hunz.	1	0.02	0.00	0.00	0.00	-0.47
Witheringia sp.	1	0.02	0.00	0.00	0.00	-1.12
Xanthosoma microrhiza	1	0.02	0.00	0.00	0.00	-0.34
MGSP network						
Syagrus romanzoffiana (Cham.) Glassman	5	1.00	0.13	0.02	0.72	-0.34
Euterpe edulis Mart.	4	0.80	0.06	0.02	0.63	-0.34
Ficus sp.	4	0.80	0.06	0.02	0.63	-0.34
Miconia pusilliflora (DC.) Naudin	4	0.80	0.06	0.02	0.63	-0.34
Nectandra megapotamica (Spreng.) Mez	4	0.80	0.06	0.02	0.63	-0.34
Pereskia aculeata Mill.	4	0.80	0.06	0.02	0.63	-0.34
Persea americana Mill.	4	0.80	0.03	0.01	0.63	-0.34
Zea mays L.	4	0.80	0.13	0.02	0.75	-0.33
Annona cacans Warm.	3	0.60	0.01	0.01	0.44	-0.34
Brachiaria plantaginea (Link) Hitchc.	3	0.60	0.02	0.01	0.67	-0.33
Campomanesia xanthocarpa (Mart.) O.Berg	3	0.60	0.06	0.02	0.67	-0.22
Chrysophyllum gonocarpum (Mart. & Eichler ex Miq.) Engl.	3	0.60	0.02	0.02	0.44	-0.34
Jacaratia spinosa (Aubl.) A.DC.	3	0.60	0.01	0.01	0.44	-0.34
Maclura tinctoria (L.) D.Don ex Steud.	3	0.60	0.05	0.02	0.67	-0.22
Melia azedarach L.	3	0.60	0.01	0.01	0.44	-0.34
Cedrela fissilis Vell.	2	0.40	0.02	0.02	0.50	-0.19
Croton floribundus Spreng.	2	0.40	0.02	0.01	0.50	-0.33
Cucurbita sp.	2	0.40	0.05	0.02	0.50	-0.22
Malpighiaceae	2	0.40	0.00	0.01	0.50	-0.22
Mendoncia coccinea Ruiz & Pav.	2	0.40	0.05	0.02	0.50	-0.22
Ocotea sp.	2	0.40	0.00	0.01	0.50	-0.22
Piper aduncum L.	2	0.40	0.01	0.01	0.50	-0.19
Plinia rivularis (Cambess.) Rotman	2	0.40	0.01	0.01	0.50	-0.19
Poaceae sp.1	2	0.40	0.02	0.01	0.50	-0.33
Psidium guajava L.	2	0.40	0.00	0.01	0.50	-0.22
Rauvolfia sellowii Müll.Arg.	2	0.40	0.01	0.01	0.50	-0.19

Solanum sp.	2	0.40	0.02	0.01	0.50	-0.33
Vitis sp.	2	0.40	0.05	0.02	0.50	-0.22
Acacia velutina DC.	1	0.20	0.00	0.01	0.00	-0.19
Alternanthera ficoidea (L.) Sm.	1	0.20	0.00	0.01	0.00	-0.22
Aspidosperma polyneuron Müll.Arg.	1	0.20	0.00	0.01	0.00	-0.19
Cabralea canjerana (Vell.) Mart.	1	0.20	0.00	0.01	0.00	-0.19
Casearia decandra Jacq.	1	0.20	0.00	0.01	0.00	-0.19
Celtis iguanaea (Jacq.) Sarg.	1	0.20	0.00	0.01	0.00	-0.19
Cestrum intermedium Sendtn.	1	0.20	0.00	0.01	0.00	-0.19
Chrysophyllum marginatum (Hook. & Arn.) Radlk.	1	0.20	0.00	0.01	0.00	-0.19
Citrus limon (L.) Osbeck	1	0.20	0.00	0.01	0.00	-0.22
Eugenia ramboi D.Legrand	1	0.20	0.00	0.01	0.00	-0.19
Eugenia uniflora L.	1	0.20	0.00	0.01	0.00	-0.19
Euphorbiaceae sp.1	1	0.20	0.00	0.01	0.00	-0.63
Euphorbiaceae sp.2	1	0.20	0.00	0.01	0.00	-0.63
Guarea kunthiana A.Juss.	1	0.20	0.00	0.01	0.00	-0.22
Guarea sp.	1	0.20	0.00	0.01	0.00	-0.33
Guazuma ulmifolia Lam.	1	0.20	0.00	0.01	0.00	-0.19
Hovenia dulcis Thunb.	1	0.20	0.00	0.01	0.00	-0.33
Hydrocotyle sp.	1	0.20	0.00	0.01	0.00	-0.22
Inga semialata (Vell.) C.Mart.	1	0.20	0.00	0.01	0.00	-0.19
Ixora sp.	1	0.20	0.00	0.01	0.00	-0.19
Lauraceae	1	0.20	0.00	0.01	0.00	-0.22
Lycianthes glandulosa (Ruiz & Pav.) Bitter	1	0.20	0.00	0.01	0.00	-0.19
Mangifera indica L.	1	0.20	0.00	0.01	0.00	-0.22
Myrciaria floribunda (H.West ex Willd.) O.Berg	1	0.20	0.00	0.01	0.00	-0.19
Myrsine umbellata Mart.	1	0.20	0.00	0.01	0.00	-0.19
Neomitranthes glomerata (D.Legrand) Govaerts	1	0.20	0.00	0.01	0.00	-0.19
Neomitranthes sp.	1	0.20	0.00	0.01	0.00	-0.19
Ocotea diospyrifolia (Meisn.) Mez	1	0.20	0.00	0.01	0.00	-0.19
Ocotea puberula (Rich.) Nees	1	0.20	0.00	0.01	0.00	-0.19
Palicourea sp.	1	0.20	0.00	0.01	0.00	-0.22
Panicum maximum Jacq.	1	0.20	0.00	0.01	0.00	-0.33
Passiflora sp.	1	0.20	0.00	0.01	0.00	-0.19

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Phyllanthus niruri L.	1	0.20	0.00	0.01	0.00	-0.22
Phytolacca thyrsiflora Fenzl ex J.A.Schmidt	1	0.20	0.00	0.01	0.00	-0.22
Plinia peruviana (Poir.) Govaerts	1	0.20	0.00	0.01	0.00	-0.19
Poaceae sp.2	1	0.20	0.00	0.01	0.00	-0.33
Prunus domestica L.	1	0.20	0.00	0.01	0.00	-0.22
Psychotria carthagenensis Jacq.	1	0.20	0.00	0.01	0.00	-0.22
Rollinia silvatica Mart.	1	0.20	0.00	0.01	0.00	-0.22
Sorocea bonplandii (Baill.) W.C.Burger, Lanj. & de Boer	1	0.20	0.00	0.01	0.00	-0.19
Styrax acuminatus Pohl	1	0.20	0.00	0.01	0.00	-0.19
Tetrorchidium rubrivenium Poepp.	1	0.20	0.00	0.01	0.00	-0.19
Tynanthus elegans Miers	1	0.20	0.00	0.01	0.00	-0.19
MNP network						
Astrocaryum murumuru Mart.	4	0.31	0.11	0.01	0.38	-0.02
Attalea sp.	4	0.31	0.01	0.00	0.00	0.26
Astrocaryum sp.	3	0.23	0.00	0.00	0.00	-0.02
Brosimum alicastrum Sw.	3	0.23	0.12	0.01	0.44	0.00
Dipteryx micrantha Harms	3	0.23	0.02	0.00	0.44	-0.30
Iriartea deltoidea Ruiz & Pav.	3	0.23	0.02	0.00	0.44	-0.30
Mauritia flexuosa L.f.	3	0.23	0.04	0.01	0.44	-0.30
Oenocarpus bataua Mart.	3	0.23	0.04	0.01	0.44	-0.30
Socratea exorrhiza (Mart.) H.Wendl.	3	0.23	0.02	0.00	0.44	-0.30
Spondias mombin L.	3	0.23	0.17	0.01	0.67	-0.58
Astrocaryum chambira Burret	2	0.15	0.00	0.00	0.00	-0.30
Brosimum sp.	2	0.15	0.00	0.00	0.00	-0.30
Clarisia racemosa Ruiz & Pav.	2	0.15	0.12	0.01	0.50	-0.16
Combretum sp.	2	0.15	0.00	0.00	0.00	-0.30
Euterpe edulis Mart.	2	0.15	0.00	0.00	0.00	-0.30
Ficus coerulescens (Rusby) Rossberg	2	0.15	0.03	0.00	0.50	-0.58
Ficus insipida Willd.	2	0.15	0.01	0.00	0.00	0.00
Ficus pertusa L.f.	2	0.15	0.01	0.00	0.00	0.00
Ficus sp.	2	0.15	0.00	0.00	0.00	-0.30
Jacaratia digitata (Poepp. & Endl.) Solms	2	0.15	0.12	0.01	0.50	-0.16

Phytelephas macrocarpa Ruiz & Pav.	2	0.15	0.00	0.00	0.00	-0.30
Quararibea cordata (Bonpl.) Vischer	2	0.15	0.12	0.01	0.50	-0.16
Rollinia centrantha R.E. Fr.	2	0.15	0.02	0.00	0.00	0.00
Socratea sp.	2	0.15	0.00	0.00	0.00	-0.30
Acacia sp.	1	0.08	0.00	0.01	0.00	-0.09
Agonandra brasiliensis Miers ex Benth.	1	0.08	0.00	0.00	0.00	-0.16
Alibertia sp.	1	0.08	0.00	0.01	0.00	-0.09
Allophylus divaricatus Radlk.	1	0.08	0.00	0.00	0.00	-0.16
Allophylus scrobiculatus (Poepp.) Radlk.	1	0.08	0.00	0.00	0.00	-0.16
Annona neglecta R.E.Fr.	1	0.08	0.00	0.00	0.00	-0.16
Annona sp. 1	1	0.08	0.00	0.01	0.00	-0.09
Annona sp. 2	1	0.08	0.00	0.01	0.00	-0.09
Annonaceae	1	0.08	0.00	0.01	0.00	-0.09
Anomospermum chloranthum Diels	1	0.08	0.00	0.00	0.00	-0.16
Anomospermum reticulatum (Mart.) Eichler	1	0.08	0.00	0.01	0.00	-0.09
Attalea butyracea (Mutis ex L.f.) Wess.Boer	1	0.08	0.00	0.00	0.00	-0.58
Attalea cephalotus Poepp. ex Mart.	1	0.08	0.00	0.00	0.00	-0.16
Bactris hirta Mart.	1	0.08	0.00	0.01	0.00	-0.09
Bertholletia excelsa Bonpl.	1	0.08	0.00	0.00	0.00	-0.58
Brosimum lactescens (S.Moore) C.C.Berg	1	0.08	0.00	0.00	0.00	-0.16
Buchenavia grandis Ducke	1	0.08	0.00	0.00	0.00	-0.16
Byrsonima sp.	1	0.08	0.00	0.01	0.00	-0.09
Calatola sp.	1	0.08	0.00	0.01	0.00	-0.09
Casearia sp.1	1	0.08	0.00	0.01	0.00	-0.09
Casearia sp.2	1	0.08	0.00	0.01	0.00	-0.09
Cecropia membranacea Trécul	1	0.08	0.00	0.00	0.00	0.00
Cecropia sciadophylla Mart.	1	0.08	0.00	0.00	0.00	-0.16
Cecropia sp.1	1	0.08	0.00	0.01	0.00	-0.09
Cecropia sp.2	1	0.08	0.00	0.01	0.00	-0.09
Cecropia sp.3	1	0.08	0.00	0.01	0.00	-0.09
Cecropia sp.4	1	0.08	0.00	0.01	0.00	-0.09
Cecropia sp.5	1	0.08	0.00	0.01	0.00	-0.09
Ceiba pentandra (L.) Gaertn.	1	0.08	0.00	0.01	0.00	-0.09
Celtis iguanaea (Jacq.) Sarg.	1	0.08	0.00	0.00	0.00	-0.16

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Celtis schippii Standl.	1	0.08	0.00	0.00	0.00	-0.16
Cestrum sp.	1	0.08	0.00	0.01	0.00	-0.09
Clarisia biflora Ruiz & Pav.	1	0.08	0.00	0.00	0.00	-0.71
Clusia sp.1	1	0.08	0.00	0.01	0.00	-0.09
Clusia sp.2	1	0.08	0.00	0.01	0.00	-0.09
Coccoloba sp.	1	0.08	0.00	0.00	0.00	-0.16
Couroupita guianensis Aubl.	1	0.08	0.00	0.01	0.00	-0.09
Cremastosperma leiophyllum (Diels) R.E.Fr.	1	0.08	0.00	0.00	0.00	-0.16
Cyperaceae sp. 1	1	0.08	0.00	0.01	0.00	-0.09
Cyperaceae sp. 2	1	0.08	0.00	0.01	0.00	-0.09
Cyperaceae sp. 3	1	0.08	0.00	0.01	0.00	-0.09
Duguetia quitarensis Benth.	1	0.08	0.00	0.00	0.00	-0.16
Duguetia riparia Huber	1	0.08	0.00	0.01	0.00	-0.09
Enterolobium cyclocarpum (Jacq.) Griseb.	1	0.08	0.00	0.00	0.00	-0.58
Epiphyllum sp.	1	0.08	0.00	0.00	0.00	-0.58
Eugenia florida DC.	1	0.08	0.00	0.01	0.00	-0.09
Euterpe precatoria Mart.	1	0.08	0.00	0.00	0.00	-0.16
Ficus benjamina L.	1	0.08	0.00	0.00	0.00	-0.16
Ficus maxima Mill.	1	0.08	0.00	0.00	0.00	-0.16
Ficus paraensis (Miq.) Miq.	1	0.08	0.00	0.00	0.00	0.00
Ficus sp.1	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.2	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.3	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.4	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.5	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.6	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.7	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.8	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.9	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.10	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.11	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.12	1	0.08	0.00	0.01	0.00	-0.09
Ficus sp.13	1	0.08	0.00	0.01	0.00	-0.09

Ficus sp.14	1	0.08	0.00	0.01	0.00	-0.09
Fusaea longifolia (Aubl.) Saff.	1	0.08	0.00	0.01	0.00	-0.09
Genipa americana L.	1	0.08	0.00	0.01	0.00	-0.09
Guazuma ulmifolia Lam.	1	0.08	0.00	0.01	0.00	-0.09
Hebepetalum humiriifolia (Planch.) Benth.	1	0.08	0.00	0.01	0.00	-0.09
Helicostylis tomentosa (Poepp. & Endl.) J.F.Macbr.	1	0.08	0.00	0.01	0.00	-0.09
Heteropsis spruceana Schott	1	0.08	0.00	0.01	0.00	-0.09
Hirtella racemosa Lam.	1	0.08	0.00	0.01	0.00	-0.09
Hirtella sp.	1	0.08	0.00	0.01	0.00	-0.09
Hymenaea oblongifolia Huber	1	0.08	0.00	0.01	0.00	-0.09
Hyperbaena domingensis (DC.) Benth.	1	0.08	0.00	0.00	0.00	-0.16
Inga edulis Mart.	1	0.08	0.00	0.00	0.00	-0.16
Inga sp.	1	0.08	0.00	0.00	0.00	-0.16
Iriartea sp.	1	0.08	0.00	0.00	0.00	-0.58
Iryanthera juruensis Warb.	1	0.08	0.00	0.00	0.00	-0.16
Leguminosae	1	0.08	0.00	0.01	0.00	-0.09
Macoubea guianensis Aubl.	1	0.08	0.00	0.01	0.00	-0.09
Malvaceae	1	0.08	0.00	0.01	0.00	-0.09
Manilkara sp.	1	0.08	0.00	0.00	0.00	0.00
Matayba sp.	1	0.08	0.00	0.00	0.00	-0.16
Miconia sp.1	1	0.08	0.00	0.00	0.00	-0.58
Miconia sp.2	1	0.08	0.00	0.01	0.00	-0.09
Miconia sp.3	1	0.08	0.00	0.01	0.00	-0.09
Miconia sp.4	1	0.08	0.00	0.01	0.00	-0.09
Miconia sp.5	1	0.08	0.00	0.01	0.00	-0.09
Micropholis melinoniana Pierre	1	0.08	0.00	0.00	0.00	-0.16
Mimosa sp.	1	0.08	0.00	0.01	0.00	-0.09
Moutabea aculeata (Ruiz & Pav.) Poepp. & Endl.	1	0.08	0.00	0.01	0.00	-0.09
Myrcia sp.	1	0.08	0.00	0.00	0.00	-0.16
Ochroma pyramidale (Cav. ex Lam.) Urb.	1	0.08	0.00	0.01	0.00	-0.09
Ocotea longifolia Kunth	1	0.08	0.00	0.00	0.00	-0.16
Ocotea oblonga (Meisn.) Mez	1	0.08	0.00	0.00	0.00	-0.16
Oenocarpus mapora H.Karst.	1	0.08	0.00	0.01	0.00	-0.09
Olyra sp.	1	0.08	0.00	0.01	0.00	-0.09

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Onychopetalum periquino (Rusby) D.M. Johnson & N.A. Murray	1	0.08	0.00	0.01	0.00	-0.09
Ormosia sp.	1	0.08	0.00	0.01	0.00	-0.09
Otoba parvifolia (Markgr.) A.H.Gentry	1	0.08	0.00	0.00	0.00	-0.16
Oxandra acuminata Diels	1	0.08	0.00	0.00	0.00	-0.16
Oxandra xylopioides Diels	1	0.08	0.00	0.01	0.00	-0.09
Pachira aquatica Aubl.	1	0.08	0.00	0.01	0.00	-0.09
Pacouria boliviensis (Markgr.) A.Chev.	1	0.08	0.00	0.00	0.00	-0.16
Palicourea sp.1	1	0.08	0.00	0.01	0.00	-0.09
Palicourea sp.2	1	0.08	0.00	0.01	0.00	-0.09
Palicourea sp.3	1	0.08	0.00	0.01	0.00	-0.09
Palicourea sp.4	1	0.08	0.00	0.01	0.00	-0.09
Palicourea sp.5	1	0.08	0.00	0.01	0.00	-0.09
Palicourea sp.6	1	0.08	0.00	0.01	0.00	-0.09
Parkia pendula (Willd.) Walp.	1	0.08	0.00	0.01	0.00	-0.09
Passiflora nitida Kunth	1	0.08	0.00	0.00	0.00	-0.16
Perebea sp.1	1	0.08	0.00	0.01	0.00	-0.09
Perebea sp.2	1	0.08	0.00	0.01	0.00	-0.09
Perebea sp.3	1	0.08	0.00	0.01	0.00	-0.09
Perebea sp.4	1	0.08	0.00	0.01	0.00	-0.09
Perebea sp.5	1	0.08	0.00	0.01	0.00	-0.09
Piper arboreum Aubl.	1	0.08	0.00	0.00	0.00	-0.71
Porcelia nitidifolia Ruiz & Pav.	1	0.08	0.00	0.01	0.00	-0.09
Pourouma minor Benoist	1	0.08	0.00	0.01	0.00	-0.09
Pouteria putamen-ovi T.D.Penn.	1	0.08	0.00	0.01	0.00	-0.09
Pouteria sp.1	1	0.08	0.00	0.01	0.00	-0.09
Pouteria sp.2	1	0.08	0.00	0.01	0.00	-0.09
Pouteria sp.3	1	0.08	0.00	0.01	0.00	-0.09
Pouteria sp.4	1	0.08	0.00	0.01	0.00	-0.09
Protium amazonicum (Cuatrec.) Daly	1	0.08	0.00	0.01	0.00	-0.09
Protium sp.1	1	0.08	0.00	0.00	0.00	-0.16
Protium sp.2	1	0.08	0.00	0.01	0.00	-0.09
Protium sp.3	1	0.08	0.00	0.01	0.00	-0.09

Pseudosenefeldera inclinata (Müll.Arg.) Esser	1	0.08	0.00	0.01	0.00	-0.09
Psidium sp.	1	0.08	0.00	0.01	0.00	-0.09
Psychotria sp.1	1	0.08	0.00	0.01	0.00	-0.09
Psychotria sp.2	1	0.08	0.00	0.01	0.00	-0.09
Psychotria sp.3	1	0.08	0.00	0.01	0.00	-0.09
Psychotria sp.4	1	0.08	0.00	0.01	0.00	-0.09
Psychotria sp.5	1	0.08	0.00	0.01	0.00	-0.09
Psychotria sp.6	1	0.08	0.00	0.01	0.00	-0.09
Psychotria sp.7	1	0.08	0.00	0.01	0.00	-0.09
Psychotria sp.8	1	0.08	0.00	0.01	0.00	-0.09
Richeria grandis Vahl	1	0.08	0.00	0.00	0.00	-0.16
Rinorea sp.1	1	0.08	0.00	0.01	0.00	-0.09
Rinorea sp.2	1	0.08	0.00	0.01	0.00	-0.09
Rinoreocarpus ulei (Melch.) Ducke	1	0.08	0.00	0.01	0.00	-0.09
Rollinia sp.1	1	0.08	0.00	0.01	0.00	-0.09
Rollinia sp.2	1	0.08	0.00	0.01	0.00	-0.09
Rollinia sp.3	1	0.08	0.00	0.01	0.00	-0.09
Rubiaceae sp.1	1	0.08	0.00	0.01	0.00	-0.09
Rubiaceae sp.2	1	0.08	0.00	0.01	0.00	-0.09
Sapindaceae	1	0.08	0.00	0.01	0.00	-0.09
Sapium marmieri Huber	1	0.08	0.00	0.00	0.00	-0.16
Sapotaceae	1	0.08	0.00	0.00	0.00	-0.16
Sarcaulus sp.1	1	0.08	0.00	0.01	0.00	-0.09
Sarcaulus sp.2	1	0.08	0.00	0.01	0.00	-0.09
Scleria macrophylla J.Presl & C.Presl	1	0.08	0.00	0.01	0.00	-0.09
Senna sp.	1	0.08	0.00	0.01	0.00	-0.09
Simarouba amara Aubl.	1	0.08	0.00	0.01	0.00	-0.09
Sloanea guianensis (Aubl.) Benth.	1	0.08	0.00	0.00	0.00	-0.16
Sloanea obtusifolia (Moric.) K.Schum.	1	0.08	0.00	0.00	0.00	-0.16
Sorocea briquetii J.F. Macbr.	1	0.08	0.00	0.00	0.00	-0.16
Strychnos asperula Sprague & Sandwith	1	0.08	0.00	0.00	0.00	-0.58
Theobroma cacao L.	1	0.08	0.00	0.00	0.00	-0.16
Unonopsis guatterioides (A.DC.) R.E.Fr.	1	0.08	0.00	0.00	0.00	-0.16
Virola calophylla (Spruce) Warb.	1	0.08	0.00	0.00	0.00	-0.16

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Vismia sp.	1	0.08	0.00	0.01	0.00	-0.09
Xylopia cuspidata Diels	1	0.08	0.00	0.00	0.00	-0.16
Xylopia ligustrifolia Dunal	1	0.08	0.00	0.00	0.00	-0.16
Ziziphus cinnamomum Triana & Planch.	1	0.08	0.00	0.00	0.00	-0.16
PABR network						
Guarea guidonia (L.) Sleumer	21	0.40	0.01	0.01	0.41	2.07
Citharexylum myrianthum Cham.	18	0.35	0.01	0.01	0.40	3.12
Miconia albicans (Sw.) Steud.	18	0.35	0.01	0.01	0.50	1.87
Myrsine coriacea (Sw.) R.Br. ex Roem. & Schult.	18	0.35	0.01	0.01	0.28	2.07
Miconia prasina (Sw.) DC.	17	0.33	0.01	0.01	0.36	1.61
Xylopia sericea A.St.-Hil.	17	0.33	0.01	0.01	0.21	2.07
Aegiphila sellowiana Cham.	16	0.31	0.01	0.01	0.22	1.84
Cupania oblongifolia Mart.	15	0.29	0.00	0.01	0.44	2.18
Miconia cinnamomifolia (DC.) Naudin	14	0.27	0.01	0.01	0.24	1.38
Trema micrantha (L.) Blume	11	0.21	0.01	0.01	0.00	1.15
Myrcia splendens (Sw.) DC.	10	0.19	0.01	0.01	0.18	0.69
Cecropia sp.	5	0.10	0.03	0.01	0.00	0.87
Piper mollicomum (Kunth) Kunth ex Steud.	5	0.10	0.04	0.01	0.00	0.87
Piper sp.	5	0.10	0.04	0.01	0.00	0.87
Alchornea triplinervia (Spreng.) Müll.Arg.	4	0.08	0.00	0.01	0.00	-0.46
Henriettea saldanhaei Cogn.	4	0.08	0.34	0.01	0.63	-0.62
Cecropia pachystachya Trécul.	3	0.06	0.36	0.01	0.44	-0.29
Cecropia hololeuca Miq.	2	0.04	0.13	0.01	0.50	-0.67
Ficus sp.1	2	0.04	0.00	0.01	0.00	-0.29
Ficus sp.2	2	0.04	0.00	0.01	0.00	-0.29
Inga leptantha Benth.	1	0.02	0.00	0.01	0.00	-0.13
Miconia sp.	2	0.04	0.00	0.01	0.00	-0.29
Abuta selloana Eichler	1	0.02	0.00	0.01	0.00	-0.13
Arecaceae	1	0.02	0.00	0.01	0.00	-0.13
Astrocaryum aculeatissimum (Schott) Burret	1	0.02	0.00	0.01	0.00	-0.13

Bactris sp.	1	0.02	0.00	0.01	0.00	-0.13
Campomanesia sp.	1	0.02	0.00	0.01	0.00	-0.13
Catunaregam spinosa (Thunb.) Tirveng.	1	0.02	0.00	0.01	0.00	-0.13
Celtis sp.	1	0.02	0.00	0.01	0.00	-0.13
Chrysophyllum sp.	1	0.02	0.00	0.01	0.00	-0.13
Cissus sp.	1	0.02	0.00	0.01	0.00	-0.13
Clidemia biserrata DC.	1	0.02	0.00	0.01	0.00	-0.13
Clidemia bullosa DC.	1	0.02	0.00	0.01	0.00	-0.13
Cordia sellowiana Cham.	1	0.02	0.00	0.01	0.00	-0.13
Cordia sp.	1	0.02	0.00	0.01	0.00	-0.13
Coussarea sp.	1	0.02	0.00	0.01	0.00	-0.13
Cucurbitaceae	1	0.02	0.00	0.01	0.00	-0.67
Diospyros hispida A.DC.	1	0.02	0.00	0.01	0.00	-0.13
Eugenia fusca O.Berg	1	0.02	0.00	0.01	0.00	-0.13
Eugenia sp.	1	0.02	0.00	0.01	0.00	-0.13
Euterpe edulis Mart.	1	0.02	0.00	0.01	0.00	-0.13
Ficus clusiifolia Schott	1	0.02	0.00	0.01	0.00	-0.13
Ficus obtusiuscula (Miq.) Miq.	1	0.02	0.00	0.01	0.00	-0.13
Ficus sp.	1	0.02	0.00	0.01	0.00	-0.67
Genipa americana L.	1	0.02	0.00	0.01	0.00	-0.13
Geonoma cuneata H.Wendl. ex Spruce	1	0.02	0.00	0.01	0.00	-0.13
Inga edulis Mart.	1	0.02	0.00	0.01	0.00	-0.13
Inga ruiziana G.Don	1	0.02	0.00	0.01	0.00	-0.13
Inga thibaudiana DC.	1	0.02	0.00	0.01	0.00	-0.13
Jacaratia spinosa (Aubl.) A.DC.	1	0.02	0.00	0.01	0.00	-0.13
Marlierea racemosa (Vell.) Kiaersk.	1	0.02	0.00	0.01	0.00	-0.13
Miconia calvescens DC.	1	0.02	0.00	0.01	0.00	-0.13
Miconia candolleana Triana	1	0.02	0.00	0.01	0.00	-0.13
Miconia hypoleuca (Benth.) Triana	1	0.02	0.00	0.01	0.00	-0.13
Miconia ibaguensis (Bonpl.) Triana	1	0.02	0.00	0.01	0.00	-0.13
Mimusops sp.	1	0.02	0.00	0.01	0.00	-0.13
Monstera sp.	1	0.02	0.00	0.01	0.00	-0.13
Musa balbisiana Colla	1	0.02	0.00	0.01	0.00	-0.13
Musa paradisiaca L.	1	0.02	0.00	0.01	0.00	-0.13
Myrcia sp.	1	0.02	0.00	0.01	0.00	-0.13

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Myrtaceae	1	0.02	0.00	0.01	0.00	-0.13
Passiflora sp.	1	0.02	0.00	0.01	0.00	-0.67
Paullinia carpopoda Cambess.	1	0.02	0.00	0.01	0.00	-0.13
Piper arboreum Aubl.	1	0.02	0.00	0.01	0.00	-0.67
Piper caldense C. DC.	1	0.02	0.00	0.01	0.00	-0.67
Piper cernuum Vell.	1	0.02	0.00	0.01	0.00	-0.67
Piper divaricatum G.Mey.	1	0.02	0.00	0.01	0.00	-0.67
Piper vicosanum Yunck.	1	0.02	0.00	0.01	0.00	-0.67
Plinia edulis (Vell.) Sobral	1	0.02	0.00	0.01	0.00	-0.13
Polygonaceae	1	0.02	0.00	0.01	0.00	-0.67
Pouteria ramiflora (Mart.) Radlk.	1	0.02	0.00	0.01	0.00	-0.13
Pouteria sp.1	1	0.02	0.00	0.01	0.00	-0.13
Pouteria sp.2	1	0.02	0.00	0.01	0.00	-0.13
Pradosia lactescens (Vell.) Radlk.	1	0.02	0.00	0.01	0.00	-0.13
Psidium guineense Sw.	1	0.02	0.00	0.01	0.00	-0.13
Psidium sp.	1	0.02	0.00	0.01	0.00	-0.13
Rubiaceae	1	0.02	0.00	0.01	0.00	-0.13
Sabicea cinerea Aubl.	1	0.02	0.00	0.01	0.00	-0.13
Siparuna guianensis Aubl.	1	0.02	0.00	0.01	0.00	-0.13
Solanaceae	1	0.02	0.00	0.01	0.00	-0.67
Solanum sp.1	1	0.02	0.00	0.01	0.00	-0.67
Solanum sp.2	1	0.02	0.00	0.01	0.00	-0.67
Solanum sp.3	1	0.02	0.00	0.01	0.00	-0.67
Syzygium glomeratum (Lam.) DC.	1	0.02	0.00	0.01	0.00	-0.13
Syzygium jambos (L.) Alston	1	0.02	0.00	0.01	0.00	-0.13
Thoracocarpus bissectus (Vell.) Harling	1	0.02	0.00	0.01	0.00	-0.13
Tovomita sp.	1	0.02	0.00	0.01	0.00	-0.13
Virola theiodora (Spruce ex Benth.) Warb.	1	0.02	0.00	0.01	0.00	-0.13
Vitex polygama Cham.	1	0.02	0.00	0.01	0.00	-0.13
PONP network						
Syagrus romanzoffiana (Cham.) Glassman	5	0.83	0.49	0.02	0.72	-0.04
Cecropia pachystachya Trécul.	4	0.67	0.04	0.01	0.63	-0.17

Inga vera Willd.	4	0.67	0.04	0.01	0.63	-0.17
Melia azedarach L.	4	0.67	0.02	0.01	0.50	-0.17
Morus nigra L.	3	0.50	0.01	0.01	0.44	-0.17
Psidium guajava L.	3	0.50	0.33	0.01	0.67	-0.27
Hymenaea courbaril L.	2	0.33	0.04	0.01	0.50	-0.41
Mangifera indica L.	2	0.33	0.00	0.01	0.50	-0.57
Pouteria ramiflora (Mart.) Radlk.	2	0.33	0.00	0.01	0.00	-0.04
Protium heptaphyllum (Aubl.) Marchand	2	0.33	0.02	0.01	0.50	-0.27
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin	2	0.33	0.00	0.01	0.00	-0.17
Syzygium cumini (L.) Skeels	2	0.33	0.00	0.01	0.50	-0.57
Terminalia catappa L.	2	0.33	0.00	0.01	0.00	-0.04
Acacia mangium Willd.	1	0.17	0.00	0.01	0.00	-0.27
Acrocomia aculeata (Jacq.) Lodd. ex Mart.	1	0.17	0.00	0.01	0.00	-0.14
Aegiphila sellowiana Cham.	1	0.17	0.00	0.01	0.00	-0.27
Alchornea sp.	1	0.17	0.00	0.01	0.00	-0.14
Annona cacans Warm.	1	0.17	0.00	0.01	0.00	-0.14
Arecaceae	1	0.17	0.00	0.01	0.00	-0.14
Bromelia balansae Mez	1	0.17	0.00	0.01	0.00	-0.14
Carica papaya L.	1	0.17	0.00	0.01	0.00	-0.57
Casearia sp.	1	0.17	0.00	0.01	0.00	-0.14
Casearia sylvestris Sw.	1	0.17	0.00	0.01	0.00	-0.27
Cassia ferruginea (Schrad.) DC.	1	0.17	0.00	0.01	0.00	-0.14
Cecropia glaziovii Snethl.	1	0.17	0.00	0.01	0.00	-0.57
Cedrela sp.	1	0.17	0.00	0.01	0.00	-0.41
Citharexylum myrianthum Cham.	1	0.17	0.00	0.01	0.00	-0.14
Colubrina glandulosa G.Perkins	1	0.17	0.00	0.01	0.00	-0.14
Compositae	1	0.17	0.00	0.01	0.00	-0.14
Cordia ecalyculata Vell.	1	0.17	0.00	0.01	0.00	-0.57
Cordia sp.	1	0.17	0.00	0.01	0.00	-0.14
Croton floribundus Spreng.	1	0.17	0.00	0.01	0.00	-0.41
Cyperaceae	1	0.17	0.00	0.01	0.00	-0.14
Delonix regia (Hook.) Raf.	1	0.17	0.00	0.01	0.00	-0.41
Enterolobium contortisiliquum (Vell.) Morong	1	0.17	0.00	0.01	0.00	-0.14
Eugenia gracillima Kiaersk.	1	0.17	0.00	0.01	0.00	-0.27

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Eugenia sp.1	1	0.17	0.00	0.01	0.00	-0.14
Eugenia sp.2	1	0.17	0.00	0.01	0.00	-0.14
Eugenia sp.3	1	0.17	0.00	0.01	0.00	-0.14
Euphorbiaceae sp.1	1	0.17	0.00	0.01	0.00	-0.14
Euphorbiaceae sp.2	1	0.17	0.00	0.01	0.00	-0.14
Ficus enormis (Miq.) Miq.	1	0.17	0.00	0.01	0.00	-0.41
Ficus sp.	1	0.17	0.00	0.01	0.00	-0.14
Genipa americana L.	1	0.17	0.00	0.01	0.00	-0.14
Gliricidia sepium (Jacq.) Walp.	1	0.17	0.00	0.01	0.00	-0.41
Gomidesia sp.	1	0.17	0.00	0.01	0.00	-0.14
Guarea guidonia (L.) Sleumer	1	0.17	0.00	0.01	0.00	-0.57
Handroanthus albus (Cham.) Mattos	1	0.17	0.00	0.01	0.00	-0.41
Handroanthus impetiginosus (Mart. ex DC.) Mattos	1	0.17	0.00	0.01	0.00	-0.41
Heteropterys sp.	1	0.17	0.00	0.01	0.00	-0.27
Ilex paraguariensis A.St.-Hil.	1	0.17	0.00	0.01	0.00	-0.14
Ilex sp.	1	0.17	0.00	0.01	0.00	-0.14
Jacaratia spinosa (Aubl.) A.DC.	1	0.17	0.00	0.01	0.00	-0.14
Leguminosae	1	0.17	0.00	0.01	0.00	-0.14
Machaerium scleroxylon Tul.	1	0.17	0.00	0.01	0.00	-0.41
Malpighiaceae	1	0.17	0.00	0.01	0.00	-0.14
Matayba elaeagnoides Radlk.	1	0.17	0.00	0.01	0.00	-0.27
Myrcia sp.	1	0.17	0.00	0.01	0.00	-0.14
Myrciaria floribunda (H.West ex Willd.) O.Berg	1	0.17	0.00	0.01	0.00	-0.27
Myrsinaceae	1	0.17	0.00	0.01	0.00	-0.14
Myrtaceae sp.1	1	0.17	0.00	0.01	0.00	-0.14
Myrtaceae sp.2	1	0.17	0.00	0.01	0.00	-0.14
Myrtaceae sp.3	1	0.17	0.00	0.01	0.00	-0.14
Parapiptadenia rigida (Benth.) Brenan	1	0.17	0.00	0.01	0.00	-0.41
Peltophorum dubium (Spreng.) Taub.	1	0.17	0.00	0.01	0.00	-0.41
Piptadenia sp.	1	0.17	0.00	0.01	0.00	-0.27
Plinia cauliflora (Mart.) Kausel	1	0.17	0.00	0.01	0.00	-0.27
Poaceae sp.1	1	0.17	0.00	0.01	0.00	-0.14

Poaceae sp.2	1	0.17	0.00	0.01	0.00	-0.14
Poaceae sp.3	1	0.17	0.00	0.01	0.00	-0.14
Poaceae sp.4	1	0.17	0.00	0.01	0.00	-0.14
Poaceae sp.5	1	0.17	0.00	0.01	0.00	-0.14
Polygonaceae sp.1	1	0.17	0.00	0.01	0.00	-0.14
Polygonaceae sp.2	1	0.17	0.00	0.01	0.00	-0.14
Polygonaceae sp.3	1	0.17	0.00	0.01	0.00	-0.14
Psidium sp.1	1	0.17	0.00	0.01	0.00	-0.14
Psidium sp.2	1	0.17	0.00	0.01	0.00	-0.14
Psidium sp.3	1	0.17	0.00	0.01	0.00	-0.14
Psychotria sp.	1	0.17	0.00	0.01	0.00	-0.14
Rapanea sp.	1	0.17	0.00	0.01	0.00	-0.14
Senna sp.	1	0.17	0.00	0.01	0.00	-0.14
Serjania mansiana Mart.	1	0.17	0.00	0.01	0.00	-0.27
Solanaceae sp.1	1	0.17	0.00	0.01	0.00	-0.14
Solanaceae sp.2	1	0.17	0.00	0.01	0.00	-0.14
Spondias mombin L.	1	0.17	0.00	0.01	0.00	-0.27
Spondias purpurea L.	1	0.17	0.00	0.01	0.00	-0.57
Vochysiaceae	1	0.17	0.00	0.01	0.00	-0.14
Zanthoxylum sp.	1	0.17	0.00	0.01	0.00	-0.14
Zea mays L.	1	0.17	0.00	0.01	0.00	-0.27
Zeyheria tuberculosa (Vell.) Bureau ex Verl.	1	0.17	0.00	0.01	0.00	-0.41
RNBAF network						
Genipa americana L.	15	0.29	0.07	0.02	0.58	2.05
Cecropia pachystachya Trécul.	15	0.29	0.28	0.01	0.55	1.92
Doliocarpus dentatus (Aubl.) Standl.	15	0.29	0.01	0.01	0.52	3.04
Byrsonima cydoniifolia A.Juss.	12	0.23	0.09	0.02	0.63	0.40
Ficus pertusa L.f.	13	0.25	0.04	0.02	0.56	1.63
Ocotea diospyrifolia (Meisn.) Mez	11	0.21	0.12	0.02	0.56	1.62
Hancornia speciosa Gomes	9	0.17	0.01	0.02	0.49	-0.07
Psidium nutans O.Berg	10	0.19	0.09	0.02	0.58	-0.07
Copernicia alba Morong	9	0.17	0.10	0.02	0.57	0.34
Curatella americana L.	8	0.15	0.01	0.01	0.38	0.77
Ficus crocata (Miq.) Mart. ex Miq.	8	0.15	0.00	0.01	0.00	1.92
Guazuma ulmifolia Lam.	8	0.15	0.01	0.02	0.50	0.18

Continues…

APPENDIX E – Continuation

Plant species	Degree (*D*)	Normalised degree (*ND*)	Betweenness (*BC*)	Closeness (*CC*)	Participation coefficient (Pi)	Within-module degree (Zi)
Melicoccus lepidopetalus Radlk.	8	0.15	0.01	0.02	0.59	0.18
Zanthoxylum rigidum Humb. & Bonpl. ex Willd.	8	0.15	0.00	0.01	0.22	2.10
Attalea phalerata Mart. ex Spreng.	7	0.13	0.01	0.02	0.41	-0.07
Cordiera sessilis (Vell.) Kuntze	7	0.13	0.01	0.02	0.49	-0.34
Protium heptaphyllum (Aubl.) Marchand	7	0.13	0.02	0.02	0.24	0.77
Vitex cymosa Bertero ex Spreng.	7	0.13	0.01	0.02	0.57	-0.34
Acrocomia aculeata (Jacq.) Lodd. ex Mart.	6	0.12	0.01	0.02	0.44	-0.34
Agonandra brasiliensis Miers ex Benth.	5	0.10	0.01	0.02	0.32	-0.34
Ficus gomelleira Kunth & C.D.Bouché	6	0.12	0.01	0.02	0.44	0.18
Garcinia brasiliensis Mart.	6	0.12	0.01	0.02	0.50	-0.05
Mouriri elliptica Mart.	5	0.10	0.00	0.02	0.32	0.18
Piper tuberculatum Jacq.	6	0.12	0.00	0.01	0.00	1.03
Couepia uiti (Mart. & Zucc.) Benth. ex Hook.f.	5	0.10	0.00	0.02	0.00	-0.07
Diospyros hispida A.DC.	5	0.10	0.01	0.02	0.32	-0.34
Rhamnidium elaeocarpum Reissek	5	0.10	0.00	0.01	0.00	0.34
Annona dioica A.St.-Hil.	4	0.08	0.01	0.02	0.38	-0.61
Bactris glaucescens Drude	4	0.08	0.01	0.02	0.38	-0.61
Dipteryx alata Vogel	4	0.08	0.00	0.02	0.00	-0.34
Enterolobium contortisiliquum (Vell.) Morong	4	0.08	0.00	0.02	0.00	0.18
Ficus obtusifolia Kunth	4	0.08	0.00	0.01	0.00	0.15
Sterculia apetala (Jacq.) H.Karst.	4	0.08	0.01	0.01	0.38	-0.51
Dulacia egleri (Rangel) Sleumer	3	0.06	0.00	0.02	0.00	-0.05
Piper aduncum L.	3	0.06	0.00	0.01	0.00	-0.29
Pouteria gardneri (Mart. & Eichler ex Miq.) Baehni	3	0.06	0.00	0.01	0.00	-0.61
Pouteria ramiflora (Mart.) Radlk.	3	0.06	0.00	0.01	0.00	-0.61
Psittacanthus calyculatus (DC.) G.Don	3	0.06	0.00	0.01	0.00	0.21
Salacia elliptica (Mart.) G.Don	3	0.06	0.00	0.02	0.44	-0.88
Swartzia jororii Harms	3	0.06	0.00	0.01	0.44	-0.26
Byrsonima verbascifolia (L.) DC.	2	0.04	0.00	0.01	0.00	-0.88
Caryocar brasiliense A.St.-Hil.	2	0.04	0.00	0.02	0.00	-0.28

Eugenia dysenterica DC.	2	0.04	0.00	0.02	0.00	-0.28
Ficus insipida Willd.	2	0.04	0.00	0.01	0.00	-0.74
Hymenaea stigonocarpa Hayne	2	0.04	0.00	0.02	0.50	-0.51
Maclura tinctoria (L.) D.Don ex Steud.	2	0.04	0.00	0.01	0.00	-0.74
Syagrus flexuosa (Mart.) Becc.	2	0.04	0.00	0.01	0.00	-0.88
Albizia saman (Jacq.) Merr.	1	0.02	0.00	0.02	0.00	-0.51
Alibertia edulis (Rich.) A.Rich. ex DC.	1	0.02	0.00	0.02	0.00	-0.51
Andira sp.	1	0.02	0.00	0.02	0.00	-0.51
Bromelia balansae Mez	1	0.02	0.00	0.02	0.00	-0.51
Chomelia obtusa Cham. & Schltdl.	1	0.02	0.00	0.02	0.00	-0.51
Inga laurina (Sw.) Willd.	1	0.02	0.00	0.02	0.00	-0.51
Licania parvifolia Huber	1	0.02	0.00	0.02	0.00	-0.51
Pouteria sp.	1	0.02	0.00	0.02	0.00	-0.51
Psidium guajava L.	1	0.02	0.00	0.02	0.00	-0.51
Psidium guineense Sw.	1	0.02	0.00	0.02	0.00	-0.51
Psittacanthus cordatus (Hoffmanns. ex Schult. f.) Blume	1	0.02	0.00	0.01	0.00	-0.73
Sapindus saponaria L.	1	0.02	0.00	0.02	0.00	-0.51
Strychnos pseudoquina A. St.-Hil.	1	0.02	0.00	0.02	0.00	-0.51
Syzygium cumini (L.) Skeels	1	0.02	0.00	0.02	0.00	-0.51
Talisia esculenta (A. St.-Hil.) Radlk.	1	0.02	0.00	0.02	0.00	-0.51
Tocoyena formosa (Cham. & Schltdl.) K.Schum.	1	0.02	0.00	0.02	0.00	-1.15
SGR network						
Trema micrantha (L.) Blume	16	0.36	0.01	0.01	0.22	2.39
Cecropia pachystachya Trécul.	14	0.31	0.09	0.01	0.46	1.34
Ficus luschnathiana (Miq.) Miq.	14	0.31	0.05	0.01	0.66	0.91
Chamissoa altissima (Jacq.) Kunth	11	0.24	0.00	0.01	0.00	1.60
Pera glabrata (Schott) Poepp. ex Baill.	11	0.24	0.05	0.01	0.17	1.34
Ocotea corymbosa (Meisn.) Mez	10	0.22	0.07	0.01	0.70	0.87
Cabralea canjerana (Vell.) Mart.	9	0.20	0.05	0.01	0.67	0.87
Ficus enormis (Miq.) Miq.	8	0.18	0.03	0.01	0.53	0.60
Trichilia claussenii C. DC.	8	0.18	0.00	0.01	0.00	0.82
Urera baccifera (L.) Gaudich. ex Wedd.	8	0.18	0.04	0.01	0.22	0.55
Citharexylum myrianthum Cham.	7	0.16	0.01	0.01	0.45	0.03

Continues…

APPENDIX E – Continuation

Plant species	Degree (*D*)	Normalised degree (*ND*)	Betweenness (*BC*)	Closeness (*CC*)	Participation coefficient (Pi)	Within-module degree (Zi)
Dendropanax cuneatus (DC.) Decne. & Planch.	7	0.16	0.04	0.01	0.24	0.29
Magnolia ovata (A.St.-Hil.) Spreng.	7	0.16	0.00	0.01	0.49	0.19
Solanum granuloso-leprosum Dunal	7	0.16	0.02	0.01	0.24	0.91
Pereskia aculeata Mill.	6	0.13	0.07	0.01	0.61	-0.49
Cecropia hololeuca Miq.	5	0.11	0.04	0.01	0.64	-0.33
Copaifera langsdorffii Desf.	5	0.11	0.02	0.01	0.32	0.26
Ficus eximia Schott	5	0.11	0.04	0.01	0.56	0.08
Maclura tinctoria (L.) D.Don ex Steud.	5	0.11	0.02	0.01	0.64	-0.33
Myrcia hebepetala DC.	5	0.11	0.00	0.01	0.00	0.03
Piper sp.	5	0.11	0.02	0.01	0.56	-0.02
Zanthoxylum fagara (L.) Sarg.	5	0.11	0.00	0.01	0.00	0.03
Ficus sp.	4	0.09	0.00	0.01	0.00	0.29
Momordica charantia L.	4	0.09	0.00	0.01	0.00	-0.23
Ocotea sp.	4	0.09	0.00	0.01	0.63	-0.48
Syagrus romanzoffiana (Cham.) Glassman	4	0.09	0.02	0.01	0.63	-0.10
Calophyllum brasiliense Cambess.	3	0.07	0.02	0.01	0.67	-0.27
Celtis iguanaea (Jacq.) Sarg.	3	0.07	0.01	0.01	0.44	-0.10
Cestrum sp.	3	0.07	0.00	0.01	0.00	-0.49
Cordia ecalyculata Vell.	3	0.07	0.01	0.01	0.44	-0.10
Dicella bracteosa (A.Juss.) Griseb.	3	0.07	0.02	0.01	0.44	-0.02
Diclidanthera laurifolia Mart.	3	0.07	0.01	0.01	0.44	-0.10
Inga affinis DC.	3	0.07	0.02	0.01	0.44	-0.10
Inga luschnathiana Benth.	3	0.07	0.02	0.01	0.44	-0.10
Inga uruguensis Hook. & Arn.	3	0.07	0.03	0.01	0.67	-0.27
Piper arboreum Aubl.	3	0.07	0.00	0.01	0.00	-0.02
Rubus sp.	3	0.07	0.00	0.01	0.00	-0.49
Solanum pseudoquina A. St.-Hil.	3	0.07	0.01	0.01	0.44	-0.33
Xylopia brasiliensis Spreng.	3	0.07	0.01	0.01	0.44	-0.48
Annona cacans Warm.	2	0.04	0.00	0.01	0.00	-0.10
Aspidosperma polyneuron Müll.Arg.	2	0.04	0.01	0.01	0.50	-0.27
Chrysophyllum gonocarpum (Mart. & Eichler ex Miq.) Engl.	2	0.04	0.00	0.01	0.50	-0.27
Chrysophyllum marginatum (Hook. & Arn.) Radlk.	2	0.04	0.01	0.01	0.50	-0.27

Cordia sp.	2	0.04	0.02	0.01	0.50	-0.27
Croton floribundus Spreng.	2	0.04	0.00	0.01	0.00	-0.02
Cryptocarya moschata Nees & Mart.	2	0.04	0.00	0.01	0.00	-0.10
Cuspidaria convoluta (Vell.) A.H.Gentry	2	0.04	0.00	0.01	0.00	-0.10
Dalechampia pentaphylla Lam.	2	0.04	0.00	0.01	0.00	-0.02
Esenbeckia leiocarpa Engl.	2	0.04	0.01	0.01	0.50	-0.27
Euterpe edulis Mart.	2	0.04	0.01	0.01	0.50	-0.64
Ficus insipida Willd.	2	0.04	0.00	0.01	0.00	-0.33
Hymenaea courbaril L.	2	0.04	0.01	0.01	0.50	-0.27
Metrodorea stipularis Mart.	2	0.04	0.01	0.01	0.50	-0.27
Miconia elegans Cogn.	2	0.04	0.00	0.01	0.00	-0.76
Miconia sp.	2	0.04	0.01	0.01	0.50	-0.27
Muntingia calabura L.	2	0.04	0.00	0.01	0.00	-0.33
Palicourea sp.	2	0.04	0.00	0.01	0.00	-0.76
Paullinia sp.	2	0.04	0.00	0.01	0.00	-0.48
Persea major (Meisn.) L.E.Kopp	2	0.04	0.00	0.01	0.00	-0.48
Piper amalago L.	2	0.04	0.00	0.01	0.00	-0.33
Piptadenia gonoacantha (Mart.) J.F.Macbr.	2	0.04	0.01	0.01	0.50	-0.27
Plinia cauliflora (Mart.) Kausel	2	0.04	0.01	0.01	0.50	-0.64
Protium heptaphyllum (Aubl.) Marchand	2	0.04	0.00	0.01	0.00	-0.76
Psidium guajava L.	2	0.04	0.01	0.01	0.50	-0.64
Pyrostegia venusta (Ker Gawl.) Miers	2	0.04	0.00	0.01	0.00	-0.10
Serjania sp.	2	0.04	0.00	0.01	0.00	-0.10
Terminalia catappa L.	2	0.04	0.00	0.01	0.50	-0.27
Zea mays L.	2	0.04	0.01	0.01	0.50	-0.27
Acacia polyphylla DC.	1	0.02	0.00	0.01	0.00	-0.27
Actinostemon klotzschii (Didr.) Pax	1	0.02	0.00	0.01	0.00	-0.27
Adenocalymma bracteatum (Cham.) DC.	1	0.02	0.00	0.01	0.00	-0.27
Amphilophium crucigerum (L.) L.G.Lohmann	1	0.02	0.00	0.01	0.00	-0.27
Anguria sp.	1	0.02	0.00	0.01	0.00	-0.27
Astronium graveolens Jacq.	1	0.02	0.00	0.01	0.00	-0.27
Banisteriopsis muricata (Cav.) Cuatrec.	1	0.02	0.00	0.01	0.00	-0.27
Cariniana legalis (Mart.) Kuntze	1	0.02	0.00	0.01	0.00	-0.27

Continues…

APPENDIX E – Continuation

Plant species	Degree (*D*)	Normalised degree (*ND*)	Betweenness (*BC*)	Closeness (*CC*)	Participation coefficient (Pi)	Within-module degree (Zi)
Cassia ferruginea (Schrad.) DC.	1	0.02	0.00	0.01	0.00	-0.27
Celtis tala Gillies ex Planch.	1	0.02	0.00	0.01	0.00	-0.27
Coffea arabica L.	1	0.02	0.00	0.01	0.00	-0.27
Colubrina glandulosa G.Perkins	1	0.02	0.00	0.01	0.00	-0.27
Croton salutaris Casar.	1	0.02	0.00	0.01	0.00	-0.27
Eriobotrya japonica (Thunb.) Lindl.	1	0.02	0.00	0.01	0.00	-0.64
Eugenia ligustrina (Sw.) Willd.	1	0.02	0.00	0.01	0.00	-0.27
Fridericia triplinervia (Mart. ex DC.) L.G.Lohmann	1	0.02	0.00	0.01	0.00	-0.27
Guazuma ulmifolia Lam.	1	0.02	0.00	0.01	0.00	-0.27
Holocalyx balansae Micheli	1	0.02	0.00	0.01	0.00	-0.64
Lantana sp.	1	0.02	0.00	0.01	0.00	-1.02
Lonchocarpus guillemineanus (Tul.) Malme	1	0.02	0.00	0.01	0.00	-0.27
Luehea divaricata Mart	1	0.02	0.00	0.01	0.00	-0.27
Machaerium aculeatum Raddi	1	0.02	0.00	0.01	0.00	-0.27
Machaerium nyctitans (Vell.) Benth.	1	0.02	0.00	0.01	0.00	-0.27
Mangifera indica L.	1	0.02	0.00	0.01	0.00	-0.64
Maytenus ilicifolia Mart. ex Reissek	1	0.02	0.00	0.01	0.00	-1.02
Mendoncia coccinea Ruiz & Pav.	1	0.02	0.00	0.01	0.00	-0.27
Miconia discolor DC.	1	0.02	0.00	0.01	0.00	-1.02
Miconia inaequidens (DC.) Naudin	1	0.02	0.00	0.01	0.00	-0.27
Ocotea diospyrifolia (Meisn.) Mez	1	0.02	0.00	0.01	0.00	-0.27
Pachystroma longifolium (Nees) I.M.Johnst.	1	0.02	0.00	0.01	0.00	-0.27
Passiflora sp.	1	0.02	0.00	0.01	0.00	-0.27
Paullinia pinnata L.	1	0.02	0.00	0.01	0.00	-0.27
Paullinia rhomboidea Radlk.	1	0.02	0.00	0.01	0.00	-1.02
Platypodium elegans Vogel	1	0.02	0.00	0.01	0.00	-0.27
Rhamnidium elaeocarpum Reissek	1	0.02	0.00	0.01	0.00	-0.27
Rhipsalis sp.	1	0.02	0.00	0.01	0.00	-1.02
Sarcaulus brasiliensis (A.DC.) Eyma	1	0.02	0.00	0.01	0.00	-0.27
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin	1	0.02	0.00	0.01	0.00	-0.27
Sebastiania sp.	1	0.02	0.00	0.01	0.00	-0.27
Solanum aculeatissimum Jacq.	1	0.02	0.00	0.01	0.00	-0.27

Solanum argenteum Dunal	1	0.02	0.00	0.01	0.00	-0.27
Stizophyllum perforatum (Cham.) Miers	1	0.02	0.00	0.01	0.00	-0.27
Syzygium jambos (L.) Alston	1	0.02	0.00	0.01	0.00	-0.64
Zanthoxylum sp.	1	0.02	0.00	0.01	0.00	-0.27
Zeyheria tuberculosa (Vell.) Bureau ex Verl.	1	0.02	0.00	0.01	0.00	-0.27
SPNNR network						
Cecropia obtusa Trécul	9	0.50	0.05	0.00	0.64	0.72
Ficus sp.	8	0.44	0.04	0.00	0.69	0.38
Cecropia sciadophylla Mart.	6	0.33	0.06	0.00	0.83	-0.61
Ziziphus cinnamomum Triana & Planch.	6	0.33	0.03	0.00	0.78	-0.06
Coussapoa latifolia Aubl.	5	0.28	0.03	0.00	0.72	-0.06
Philodendron sp.	5	0.28	0.00	0.00	0.00	0.72
Asplundia sp.	4	0.22	0.00	0.00	0.00	0.38
Cayaponia ophthalmica R.E.Schult.	4	0.22	0.02	0.00	0.75	-0.20
Cheiloclinium sp.	4	0.22	0.01	0.00	0.75	-0.17
Chrysophyllum lucentifolium Cronquist	4	0.22	0.02	0.00	0.75	-0.17
Euterpe oleracea Mart.	4	0.22	0.01	0.00	0.63	-0.06
Evodianthus funifer (Poit.) Lindm.	4	0.22	0.00	0.00	0.00	0.38
Goupia glabra Aubl.	4	0.22	0.02	0.00	0.75	-0.20
Minquartia guianensis Aubl.	4	0.22	0.02	0.00	0.63	-0.06
Pourouma sp.	4	0.22	0.02	0.00	0.75	-0.20
Psychotria carthagenensis Jacq.	4	0.22	0.02	0.00	0.75	-0.20
Schlegelia paraensis Ducke	4	0.22	0.03	0.00	0.63	-0.28
Solanum sp.	4	0.22	0.04	0.00	0.63	-0.28
Virola michelii Heckel	4	0.22	0.02	0.00	0.75	-0.17
Anthurium obtusum (Engl.) Grayum	3	0.17	0.00	0.00	0.00	0.05
Bagassa guianensis Aubl.	3	0.17	0.01	0.00	0.67	-0.12
Brosimum parinarioides Ducke	3	0.17	0.01	0.00	0.44	-0.06
Cayaponia sp.1	3	0.17	0.01	0.00	0.67	-0.17
Coccoloba sp.	3	0.17	0.01	0.00	0.67	-0.12
Coussapoa angustifolia Aubl.	3	0.17	0.01	0.00	0.67	-0.17
Eugenia coffeifolia DC.	3	0.17	0.01	0.00	0.44	-0.06
Ficus americana Aubl.	3	0.17	0.01	0.00	0.67	-0.17

Continues…

APPENDIX E – Continuation

Plant species	Degree (*D*)	Normalised degree (*ND*)	Betweenness (*BC*)	Closeness (*CC*)	Participation coefficient (Pi)	Within-module degree (Zi)
Inga sp.1	3	0.17	0.00	0.00	0.44	-0.06
Inga sp.2	3	0.17	0.01	0.00	0.67	-0.12
Iryanthera sagotiana (Benth.) Warb.	3	0.17	0.01	0.00	0.67	-0.20
Jacaratia spinosa (Aubl.) A.DC.	3	0.17	0.01	0.00	0.67	-0.12
Ludovia lancifolia Brongn.	3	0.17	0.01	0.00	0.67	-0.12
Manilkara bidentata (A.DC.) A.Chev.	3	0.17	0.01	0.00	0.67	-0.12
Manilkara huberi (Ducke) Standl.	3	0.17	0.01	0.00	0.67	-0.17
Micropholis melinoniana Pierre	3	0.17	0.01	0.00	0.67	-0.12
Moutabea guianensis Aubl.	3	0.17	0.01	0.00	0.67	-0.17
Ocotea sp.	3	0.17	0.01	0.00	0.67	-0.20
Pourouma villosa Trécul	3	0.17	0.01	0.00	0.67	-0.12
Pouteria torta (Mart.) Radlk.	3	0.17	0.01	0.00	0.67	-0.12
Protium tenuifolium (Engl.) Engl.	3	0.17	0.01	0.00	0.67	-0.20
Sacoglottis guianensis Benth.	3	0.17	0.01	0.00	0.44	-0.06
Stenostomum acreanum (K.Krause) Achille & Delprete	3	0.17	0.01	0.00	0.67	-0.20
Symphonia globulifera L.f.	3	0.17	0.01	0.00	0.44	-0.28
Tetragastris altissima (Aubl.) Swart	3	0.17	0.01	0.00	0.67	-0.20
Theobroma subincanum Mart.	3	0.17	0.01	0.00	0.67	-0.12
Virola sp.	3	0.17	0.01	0.00	0.67	-0.17
Vouacapoua americana Aubl.	3	0.17	0.02	0.00	0.00	0.13
Abuta sp.	2	0.11	0.01	0.00	0.50	-0.20
Ambelania acida Aubl.	2	0.11	0.00	0.00	0.50	-0.12
Annonaceae sp.1	2	0.11	0.01	0.00	0.50	-0.12
Apeiba petoumo Aubl.	2	0.11	0.00	0.00	0.50	-0.17
Brosimum acutifolium Huber	2	0.11	0.00	0.00	0.50	-0.17
Brosimum guianense (Aubl.) Huber ex Ducke	2	0.11	0.00	0.00	0.50	-0.12
Carapa procera DC.	2	0.11	0.00	0.00	0.00	0.00
Cayaponia sp.2	2	0.11	0.00	0.00	0.50	-0.17
Chrysophyllum eximium Ducke	2	0.11	0.01	0.00	0.50	-0.12
Chrysophyllum prieurii A.DC.	2	0.11	0.00	0.00	0.50	-0.12
Cinnamodendron tenuifolium Uittien	2	0.11	0.00	0.00	0.50	-0.12
Cordia sp.1	2	0.11	0.01	0.00	0.50	-0.12
Cordia sp.2	2	0.11	0.00	0.00	0.50	-0.12

Coussapoa microcephala Trécul	2	0.11	0.00	0.00	0.00	-0.06
Cupania scrobiculata Rich.	2	0.11	0.01	0.00	0.50	-0.20
Diospyros sp.	2	0.11	0.00	0.00	0.50	-0.12
Doliocarpus sp.	2	0.11	0.00	0.00	0.50	-0.17
Drypetes variabilis Uittien	2	0.11	0.01	0.00	0.50	-0.20
Dussia discolor (Benth.) Amshoff	2	0.11	0.00	0.00	0.50	-0.20
Eperua falcata Aubl.	2	0.11	0.01	0.00	0.50	-0.12
Ficus nymphaeifolia Mill.	2	0.11	0.00	0.00	0.50	-0.12
Ficus trigona L.f.	2	0.11	0.00	0.00	0.50	-0.17
Geonoma stricta (Poit.) Kunth	2	0.11	0.00	0.00	0.00	-0.06
Guatteria sp.1	2	0.11	0.00	0.00	0.00	-0.06
Helicostylis pedunculata Benoist	2	0.11	0.00	0.00	0.50	-0.12
Helicostylis sp.	2	0.11	0.00	0.00	0.50	-0.12
Heteropsis flexuosa (Kunth) G.S.Bunting	2	0.11	0.01	0.00	0.50	-0.12
Hieronyma alchorneoides Allemão	2	0.11	0.00	0.00	0.50	-0.20
Inga huberi Ducke	2	0.11	0.00	0.00	0.50	-0.17
Inga sp.3	2	0.11	0.00	0.00	0.50	-0.12
Inga sp.4	2	0.11	0.00	0.00	0.50	-0.12
Inga sp.5	2	0.11	0.01	0.00	0.50	-0.12
Lacmellea floribunda (Poepp.) Benth. & Hook.f.	2	0.11	0.01	0.00	0.50	-0.12
Laetia procera (Poepp.) Eichler (Poepp.) Eichler	2	0.11	0.00	0.00	0.50	-0.17
Lauraceae	2	0.11	0.00	0.00	0.50	-0.12
Licania alba (Bernoulli) Cuatrec.	2	0.11	0.00	0.00	0.00	0.00
Licania membranacea Sagot ex Laness.	2	0.11	0.01	0.00	0.50	-0.61
Licania sp.	2	0.11	0.00	0.00	0.50	-0.61
Margaritopsis kappleri (Miq.) C.M.Taylor	2	0.11	0.00	0.00	0.00	-0.06
Matayba sp.	2	0.11	0.00	0.00	0.50	-0.17
Maytenus sp.	2	0.11	0.00	0.00	0.50	-0.12
Mendoncia sp.	2	0.11	0.01	0.00	0.50	-0.12
Micropholis guyanensis (A.DC.) Pierre	2	0.11	0.00	0.00	0.50	-0.12
Moutabea aculeata (Ruiz & Pav.) Poepp. & Endl.	2	0.11	0.00	0.00	0.50	-0.12
Neea sp.	2	0.11	0.00	0.00	0.50	-0.12
Ocotea floribunda (Sw.) Mez	2	0.11	0.01	0.00	0.50	-0.20

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Oreopanax capitatus (Jacq.) Decne. & Planch.	2	0.11	0.01	0.00	0.50	-0.20
Orthomene sp.	2	0.11	0.00	0.00	0.00	-0.06
Parahancornia fasciculata (Poir.) Benoist	2	0.11	0.00	0.00	0.50	-0.12
Paullinia capreolata (Aubl.) Radlk.	2	0.11	0.00	0.00	0.50	-0.17
Paullinia sp.	2	0.11	0.00	0.00	0.50	-0.12
Piper sp.	2	0.11	0.00	0.00	0.00	-0.28
Pourouma bicolor Mart.	2	0.11	0.00	0.00	0.50	-0.17
Pourouma mollis Trécul	2	0.11	0.01	0.00	0.50	-0.12
Pourouma tomentosa Mart. ex Miq.	2	0.11	0.01	0.00	0.50	-0.12
Pouteria ambelaniifolia (Sandwith) T.D.Penn.	2	0.11	0.00	0.00	0.50	-0.12
Pouteria bilocularis (H.J.P.Winkl.) Baehni	2	0.11	0.01	0.00	0.50	-0.20
Pouteria egregia Sandwith	2	0.11	0.00	0.00	0.50	-0.12
Pouteria filipes Eyma	2	0.11	0.01	0.00	0.50	-0.12
Pouteria guianensis Aubl.	2	0.11	0.00	0.00	0.50	-0.12
Pouteria hispida Eyma	2	0.11	0.00	0.00	0.50	-0.17
Pouteria laevigata (Mart.) Radlk.	2	0.11	0.00	0.00	0.50	-0.12
Pouteria sp.	2	0.11	0.00	0.00	0.50	-0.12
Protium sp.	2	0.11	0.00	0.00	0.50	-0.17
Psychotria bahiensis DC.	2	0.11	0.00	0.00	0.00	-0.06
Psychotria oblonga (DC.) Steyerm.	2	0.11	0.00	0.00	0.00	-0.06
Sacoglottis cydonioides Cuatrec.	2	0.11	0.00	0.00	0.50	-0.20
Salacia sp.1	2	0.11	0.00	0.00	0.50	-0.17
Salacia sp.2	2	0.11	0.00	0.00	0.50	-0.12
Siparuna sp.	2	0.11	0.00	0.00	0.50	-0.17
Sterculia frondosa Rich.	2	0.11	0.00	0.00	0.50	-0.12
Strychnos sp.1	2	0.11	0.00	0.00	0.50	-0.12
Tapirira guianensis Aubl.	2	0.11	0.01	0.00	0.50	-0.12
Tapirira obtusa (Benth.) J.D.Mitch.	2	0.11	0.00	0.00	0.50	-0.12
Tetragastris panamensis (Engl.) Kuntze	2	0.11	0.00	0.00	0.50	-0.12
Tetragastris sp.	2	0.11	0.00	0.00	0.50	-0.20
Thoracocarpus bissectus (Vell.) Harling	2	0.11	0.00	0.00	0.00	-0.28

Trichilia septentrionalis C.DC.	2	0.11	0.01	0.00	0.50	-0.20
Unonopsis guatterioides (A.DC.) R.E.Fr.	2	0.11	0.01	0.00	0.50	-0.20
Virola surinamensis (Rol. ex Rottb.) Warb.	2	0.11	0.00	0.00	0.50	-0.17
Abuta grandifolia (Mart.) Sandwith	1	0.06	0.00	0.00	0.00	-0.20
Abuta imene (Mart.) Eichler	1	0.06	0.00	0.00	0.00	-0.17
Aechmea sp.	1	0.06	0.00	0.00	0.00	-0.61
Alchorneopsis floribunda (Benth.) Müll.Arg.	1	0.06	0.00	0.00	0.00	-0.14
Annona haematantha Miq.	1	0.06	0.00	0.00	0.00	-0.14
Annona sp.	1	0.06	0.00	0.00	0.00	-0.12
Annonaceae sp.2	1	0.06	0.00	0.00	0.00	-0.14
Annonaceae sp.3	1	0.06	0.00	0.00	0.00	-0.12
Anomospermum chloranthum Diels	1	0.06	0.00	0.00	0.00	-0.12
Anomospermum sp.	1	0.06	0.00	0.00	0.00	-0.12
Apeiba glabra Aubl.	1	0.06	0.00	0.00	0.00	-0.17
Apocynaceae	1	0.06	0.00	0.00	0.00	-0.12
Araceae	1	0.06	0.00	0.00	0.00	-0.12
Attalea maripa (Aubl.) Mart.	1	0.06	0.00	0.00	0.00	-0.12
Bactris acanthocarpoides Barb.Rodr.	1	0.06	0.00	0.00	0.00	-0.20
Bactris gastoniana Barb.Rodr.	1	0.06	0.00	0.00	0.00	-0.20
Bignoniaceae	1	0.06	0.00	0.00	0.00	-0.12
Brosimum rubescens Taub.	1	0.06	0.00	0.00	0.00	-0.20
Buchenavia sp.	1	0.06	0.00	0.00	0.00	-0.14
Buchenavia tetraphylla (Aubl.) R.A.Howard	1	0.06	0.00	0.00	0.00	-0.14
Byrsonima sp.	1	0.06	0.00	0.00	0.00	-0.61
Calathea elliptica (Roscoe) K.Schum.	1	0.06	0.00	0.00	0.00	-0.20
Caryocar glabrum (Aubl.) Pers.	1	0.06	0.00	0.00	0.00	-0.14
Cassia sp.	1	0.06	0.00	0.00	0.00	-0.12
Cayaponia sp.3	1	0.06	0.00	0.00	0.00	-0.14
Celastraceae	1	0.06	0.00	0.00	0.00	-0.14
Cheiloclinium cognatum (Miers) A.C.Sm.	1	0.06	0.00	0.00	0.00	-0.12
Cheiloclinium sp.1	1	0.06	0.00	0.00	0.00	-0.14
Cheiloclinium sp.2	1	0.06	0.00	0.00	0.00	-0.14
Chrysophyllum cuneifolium (Rudge) A.DC.	1	0.06	0.00	0.00	0.00	-0.12

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Chrysophyllum pomiferum (Eyma) T.D.Penn.	1	0.06	0.00	0.00	0.00	-0.14
Chrysophyllum sanguinolentum (Pierre) Baehni	1	0.06	0.00	0.00	0.00	-0.12
Chrysophyllum sp.	1	0.06	0.00	0.00	0.00	-0.14
Cissus sp.	1	0.06	0.00	0.00	0.00	-0.20
Clusia sp.	1	0.06	0.00	0.00	0.00	-0.17
Coccoloba excelsa Benth.	1	0.06	0.00	0.00	0.00	-0.14
Connarus sp.	1	0.06	0.00	0.00	0.00	-0.20
Cordia lomatoloba I.M.Johnst.	1	0.06	0.00	0.00	0.00	-0.14
Cordia sp.3	1	0.06	0.00	0.00	0.00	-0.12
Cordia sp.4	1	0.06	0.00	0.00	0.00	-0.12
Couratari guianensis Aubl.	1	0.06	0.00	0.00	0.00	-0.12
Coussapoa sp.	1	0.06	0.00	0.00	0.00	-0.61
Coussarea albescens (DC.) Müll.Arg.	1	0.06	0.00	0.00	0.00	-0.12
Cupania sp.	1	0.06	0.00	0.00	0.00	-0.20
Davilla kunthii A.St.-Hil.	1	0.06	0.00	0.00	0.00	-0.12
Davilla sp.	1	0.06	0.00	0.00	0.00	-0.14
Dendrobangia boliviana Rusby	1	0.06	0.00	0.00	0.00	-0.14
Dicranostyles sp. 1	1	0.06	0.00	0.00	0.00	-0.12
Dicranostyles sp. 2	1	0.06	0.00	0.00	0.00	-0.12
Dimorphandra pullei Amshoff	1	0.06	0.00	0.00	0.00	-0.12
Dipteryx sp.	1	0.06	0.00	0.00	0.00	-0.12
Doliocarpus paraensis Sleumer	1	0.06	0.00	0.00	0.00	-0.14
Drypetes fanshawei Sandwith	1	0.06	0.00	0.00	0.00	-0.20
Duguetia sp.	1	0.06	0.00	0.00	0.00	-0.20
Duguetia surinamensis R.E.Fr.	1	0.06	0.00	0.00	0.00	-0.12
Ecclinusa guianensis Eyma	1	0.06	0.00	0.00	0.00	-0.14
Ecclinusa lanceolata (Mart. & Eichler ex Miq.) Pierre	1	0.06	0.00	0.00	0.00	-0.14
Elvasia sp.	1	0.06	0.00	0.00	0.00	-0.14
Eperua rubiginosa Miq.	1	0.06	0.00	0.00	0.00	-0.14
Ephedranthus guianensis R.E.Fr.	1	0.06	0.00	0.00	0.00	-0.20
Euphorbiaceae	1	0.06	0.00	0.00	0.00	-0.12
Ficus amazonica (Miq.) Miq.	1	0.06	0.00	0.00	0.00	-0.14
Ficus broadwayi Urb.	1	0.06	0.00	0.00	0.00	-0.14

Ficus gomelleira Kunth & C.D.Bouché	1	0.06	0.00	0.00	0.00	-0.14
Ficus leiophylla C.C.Berg	1	0.06	0.00	0.00	0.00	-0.12
Ficus pertusa L.f.	1	0.06	0.00	0.00	0.00	-0.14
Galipea sp.	1	0.06	0.00	0.00	0.00	-0.12
Garcinia benthamiana (Planch. & Triana) Pipoly	1	0.06	0.00	0.00	0.00	-0.12
Gnetum paniculatum Spruce ex Benth.	1	0.06	0.00	0.00	0.00	-0.14
Gnetum sp.	1	0.06	0.00	0.00	0.00	-0.14
Guarea gomma Pulle	1	0.06	0.00	0.00	0.00	-0.20
Guarea guidonia (L.) Sleumer	1	0.06	0.00	0.00	0.00	-0.20
Guarea kunthiana A.Juss.	1	0.06	0.00	0.00	0.00	-0.20
Guarea silvatica C.DC.	1	0.06	0.00	0.00	0.00	-0.12
Guatteria sp.2	1	0.06	0.00	0.00	0.00	-0.12
Guatteria sp.3	1	0.06	0.00	0.00	0.00	-0.20
Herrania kanukuensis R.E. Schult.	1	0.06	0.00	0.00	0.00	-0.12
Inga alata Benoist	1	0.06	0.00	0.00	0.00	-0.12
Inga alba (Sw.) Willd.	1	0.06	0.00	0.00	0.00	-0.12
Inga brachyrhachis Harms	1	0.06	0.00	0.00	0.00	-0.17
Inga cinnamomea Benth.	1	0.06	0.00	0.00	0.00	-0.17
Inga edulis Mart.	1	0.06	0.00	0.00	0.00	-0.12
Inga jenmanii Sandwith	1	0.06	0.00	0.00	0.00	-0.12
Inga leiocalycina Benth.	1	0.06	0.00	0.00	0.00	-0.12
Inga paraensis Ducke	1	0.06	0.00	0.00	0.00	-0.12
Inga pezizifera Benth.	1	0.06	0.00	0.00	0.00	-0.12
Inga retinocarpa Poncy	1	0.06	0.00	0.00	0.00	-0.12
Inga sp.5	1	0.06	0.00	0.00	0.00	-0.12
Inga sp.6	1	0.06	0.00	0.00	0.00	-0.12
Inga sp.7	1	0.06	0.00	0.00	0.00	-0.12
Isertia coccinea (Aubl.) J.F.Gmel.	1	0.06	0.00	0.00	0.00	-0.12
Lacmellea aculeata (Ducke) Monach.	1	0.06	0.00	0.00	0.00	-0.14
Lacunaria crenata (Tul.) A.C.Sm.	1	0.06	0.00	0.00	0.00	-0.12
Lacunaria jenmanii (Oliv.) Ducke	1	0.06	0.00	0.00	0.00	-0.12
Lecythis sp.	1	0.06	0.00	0.00	0.00	-0.12
Leguminosae	1	0.06	0.00	0.00	0.00	-0.12
Leonia glycycarpa Ruiz & Pav.	1	0.06	0.00	0.00	0.00	-0.12

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Licania canescens Benoist	1	0.06	0.00	0.00	0.00	-0.61
Licania sp.1	1	0.06	0.00	0.00	0.00	-0.14
Licania sp.2	1	0.06	0.00	0.00	0.00	-0.14
Malpighiaceae	1	0.06	0.00	0.00	0.00	-0.12
Manilkara sp.	1	0.06	0.00	0.00	0.00	-0.12
Maquira guianensis Aubl.	1	0.06	0.00	0.00	0.00	-0.14
Marcgravia sp.	1	0.06	0.00	0.00	0.00	-0.12
Margaritopsis guianensis (Bremek.) C.M.Taylor	1	0.06	0.00	0.00	0.00	-0.20
Maripa scandens Aubl.	1	0.06	0.00	0.00	0.00	-0.12
Miconia sp.	1	0.06	0.00	0.00	0.00	-0.12
Micrandra elata (Didr.) Müll.Arg.	1	0.06	0.00	0.00	0.00	-0.12
Micropholis cayennensis T.D.Penn.	1	0.06	0.00	0.00	0.00	-0.14
Micropholis egensis (A.DC.) Pierre	1	0.06	0.00	0.00	0.00	-0.12
Micropholis longipedicellata Aubrév.	1	0.06	0.00	0.00	0.00	-0.12
Micropholis mensalis (Baehni) Aubrév.	1	0.06	0.00	0.00	0.00	-0.14
Micropholis obscura T.D.Penn.	1	0.06	0.00	0.00	0.00	-0.14
Micropholis sp.	1	0.06	0.00	0.00	0.00	-0.14
Micropholis venulosa (Mart. & Eichler ex Miq.) Pierre	1	0.06	0.00	0.00	0.00	-0.12
Mollinedia sp.	1	0.06	0.00	0.00	0.00	-0.17
Mouriri crassifolia Sagot	1	0.06	0.00	0.00	0.00	-0.14
Mouriri huberi Cogn.	1	0.06	0.00	0.00	0.00	-0.17
Naucleopsis guianensis (Mildbr.) C.C. Berg	1	0.06	0.00	0.00	0.00	-0.20
Nyctaginaceae	1	0.06	0.00	0.00	0.00	-0.14
Ocotea tomentella Sandwith	1	0.06	0.00	0.00	0.00	-0.12
Oenocarpus bacaba Mart.	1	0.06	0.00	0.00	0.00	-0.12
Oenocarpus bataua Mart.	1	0.06	0.00	0.00	0.00	-0.12
Orthomene schomburgkii (Miers) Barneby & Krukoff	1	0.06	0.00	0.00	0.00	-0.12
Osteophloeum platyspermum (Spruce ex A.DC.) Warb.	1	0.06	0.00	0.00	0.00	-0.12
Parkia sp.	1	0.06	0.00	0.00	0.00	-0.14
Parkia ulei (Harms) Kuhlm.	1	0.06	0.00	0.00	0.00	-0.20
Passiflora crenata Feuillet & Cremers	1	0.06	0.00	0.00	0.00	-0.12

Passiflora garckei Mast.	1	0.06	0.00	0.00	0.00	-0.17
Passiflora sp.	1	0.06	0.00	0.00	0.00	-0.12
Perebea guianensis Aubl.	1	0.06	0.00	0.00	0.00	-0.14
Philodendron linnaei Kunth	1	0.06	0.00	0.00	0.00	-0.14
Phoradendron piperoides (Kunth) Trel.	1	0.06	0.00	0.00	0.00	-0.14
Piper hispidum Sw.	1	0.06	0.00	0.00	0.00	-0.61
Poraqueiba guianensis Aubl.	1	0.06	0.00	0.00	0.00	-0.20
Posoqueria latifolia (Rudge) Schult.	1	0.06	0.00	0.00	0.00	-0.12
Posoqueria sp.	1	0.06	0.00	0.00	0.00	-0.12
Pourouma melinonii Benoist	1	0.06	0.00	0.00	0.00	-0.14
Pourouma minor Benoist	1	0.06	0.00	0.00	0.00	-0.14
Pouteria congestifolia Pilz	1	0.06	0.00	0.00	0.00	-0.14
Pouteria deliciosa T.D.Penn.	1	0.06	0.00	0.00	0.00	-0.12
Pouteria franciscana Baehni	1	0.06	0.00	0.00	0.00	-0.12
Pouteria sp.1	1	0.06	0.00	0.00	0.00	-0.14
Pouteria sp.2	1	0.06	0.00	0.00	0.00	-0.14
Pouteria sp.3	1	0.06	0.00	0.00	0.00	-0.14
Pouteria sp.4	1	0.06	0.00	0.00	0.00	-0.14
Pradosia ptychandra (Eyma) T.D.Penn.	1	0.06	0.00	0.00	0.00	-0.12
Protium araguense Cuatrec.	1	0.06	0.00	0.00	0.00	-0.61
Protium sagotianum Marchand	1	0.06	0.00	0.00	0.00	-0.14
Protium subserratum (Engl.) Engl.	1	0.06	0.00	0.00	0.00	-0.20
Psychotria anceps Kunth	1	0.06	0.00	0.00	0.00	-0.17
Psychotria sp.	1	0.06	0.00	0.00	0.00	-0.20
Quararibea sp.	1	0.06	0.00	0.00	0.00	-0.12
Quiina obovata Tul.	1	0.06	0.00	0.00	0.00	-0.14
Rhodospatha spp.	1	0.06	0.00	0.00	0.00	-0.61
Salacia cordata (Miers) Mennega	1	0.06	0.00	0.00	0.00	-0.14
Salacia multiflora (Lam.) DC.	1	0.06	0.00	0.00	0.00	-0.14
Salacia sp.3	1	0.06	0.00	0.00	0.00	-0.12
Salacia sp.4	1	0.06	0.00	0.00	0.00	-0.12
Salacia sp.5	1	0.06	0.00	0.00	0.00	-0.14
Salacia sp.6	1	0.06	0.00	0.00	0.00	-0.12
Schefflera decaphylla (Seem.) Harms	1	0.06	0.00	0.00	0.00	-0.14
Schefflera sp.	1	0.06	0.00	0.00	0.00	-0.14

Continues…

APPENDIX E – Continuation

Plant species	Degree (*D*)	Normalised degree (*ND*)	Betweenness (*BC*)	Closeness (*CC*)	Participation coefficient (Pi)	Within-module degree (Zi)
Securidaca sp.	1	0.06	0.00	0.00	0.00	-0.12
Senna quinquangulata (Rich.) H.S.Irwin & Barneby	1	0.06	0.00	0.00	0.00	-0.61
Smilax sp.	1	0.06	0.00	0.00	0.00	-0.20
Spondias mombin L.	1	0.06	0.00	0.00	0.00	-0.14
Stelestylis surinamensis Harling	1	0.06	0.00	0.00	0.00	-0.12
Sterculia excelsa Mart.	1	0.06	0.00	0.00	0.00	-0.12
Sterculia pruriens (Aubl.) K.Schum.	1	0.06	0.00	0.00	0.00	-0.12
Sterculia sp.	1	0.06	0.00	0.00	0.00	-0.12
Strychnos erichsonii M.R.Schomb. ex Progel	1	0.06	0.00	0.00	0.00	-0.17
Strychnos guianensis (Aubl.) Mart.	1	0.06	0.00	0.00	0.00	-0.12
Strychnos sp.2	1	0.06	0.00	0.00	0.00	-0.14
Strychnos sp.3	1	0.06	0.00	0.00	0.00	-0.12
Styrax guyanensis A.DC.	1	0.06	0.00	0.00	0.00	-0.12
Swartzia sp.1	1	0.06	0.00	0.00	0.00	-0.12
Swartzia sp.2	1	0.06	0.00	0.00	0.00	-0.12
Talisia sp.	1	0.06	0.00	0.00	0.00	-0.14
Tontelea scandens Aubl.	1	0.06	0.00	0.00	0.00	-0.12
Trattinnickia sp.	1	0.06	0.00	0.00	0.00	-0.12
Trichilia pallida Sw.	1	0.06	0.00	0.00	0.00	-0.12
Trymatococcus oligandrus (Benoist) Lanj.	1	0.06	0.00	0.00	0.00	-0.14
Violaceae sp. 1	1	0.06	0.00	0.00	0.00	-0.12
Violaceae sp. 2	1	0.06	0.00	0.00	0.00	-0.12
Virola venosa (Benth.) Warb.	1	0.06	0.00	0.00	0.00	-0.17
Vismia sp.	1	0.06	0.00	0.00	0.00	-0.61
Vitex fanshawii	1	0.06	0.00	0.00	0.00	-0.14
Vitex sp.	1	0.06	0.00	0.00	0.00	-0.12
Xylopia nitida Dunal	1	0.06	0.00	0.00	0.00	-0.20
SRNP network						
Cecropia peltata L.	11	0.69	0.05	0.01	0.45	1.09
Maclura tinctoria (L.) D.Don ex Steud.	10	0.63	0.05	0.01	0.48	0.71
Ficus sp.	9	0.56	0.05	0.01	0.62	-0.03

Muntingia calabura L.	8	0.50	0.05	0.01	0.66	-0.41
Solanum hazenii Britton	8	0.50	0.00	0.01	0.22	0.71
Ficus cotinifolia Kunth	6	0.38	0.01	0.01	0.50	-0.41
Piper arboreum Aubl.	6	0.38	0.00	0.01	0.28	-0.03
Ficus crassinervia Desf. ex Willd.	5	0.31	0.00	0.01	0.32	-0.41
Karwinskia calderonii Standl.	5	0.31	0.08	0.01	0.80	-0.30
Manilkara zapota (L.) P.Royen	5	0.31	0.09	0.01	0.72	-0.08
Piper amalago L.	5	0.31	0.00	0.01	0.32	-0.41
Piper jacquemontianum Kunth	5	0.31	0.00	0.01	0.32	-0.41
Albizia saman (Jacq.) Merr.	4	0.25	0.02	0.01	0.63	-0.08
Brosimum alicastrum Sw.	4	0.25	0.05	0.01	0.63	-0.06
Enterolobium cyclocarpum (Jacq.) Griseb.	4	0.25	0.02	0.01	0.63	-0.08
Piper sp.	4	0.25	0.04	0.01	0.63	-1.15
Spondias mombin L.	4	0.25	0.08	0.01	0.75	-0.30
Acacia collinsii Saff.	3	0.19	0.04	0.01	0.67	-0.15
Ardisia revoluta Kunth	3	0.19	0.02	0.01	0.67	-0.30
Bursera graveolens (Kunth) Triana & Planch.	3	0.19	0.01	0.01	0.44	-0.06
Genipa americana L.	3	0.19	0.01	0.01	0.44	-0.06
Guazuma ulmifolia Lam.	3	0.19	0.02	0.01	0.44	-0.08
Hirtella racemosa Lam.	3	0.19	0.01	0.01	0.44	-0.06
Hymenaea courbaril L.	3	0.19	0.02	0.01	0.44	-0.08
Manilkara chicle (Pittier) Gilly	3	0.19	0.01	0.01	0.44	-0.06
Piper tuberculatum Jacq.	3	0.19	0.00	0.01	0.44	-1.15
Quercus oleoides Schltdl. & Cham.	3	0.19	0.02	0.01	0.44	-0.08
Sideroxylon capiri (A.DC.) Pittier	3	0.19	0.01	0.01	0.44	-0.06
Spondias purpurea L.	3	0.19	0.07	0.01	0.67	-0.28
Swartzia cubensis (Britton & Wilson) Standl.	3	0.19	0.01	0.01	0.67	-0.30
Alibertia edulis (Rich.) A.Rich. ex DC.	2	0.13	0.01	0.01	0.50	-0.28
Allophylus racemosus Sw.	2	0.13	0.04	0.01	0.50	-0.15
Aralia excelsa (Griseb.) J.Wen	2	0.13	0.00	0.01	0.50	-0.30
Bromelia pinguin L.	2	0.13	0.01	0.01	0.50	-0.28
Bursera simaruba (L.) Sarg.	2	0.13	0.01	0.01	0.50	-0.28
Caesalpinia coriaria (Jacq.) Willd.	2	0.13	0.00	0.00	0.00	-0.08
Casearia arguta Kunth	2	0.13	0.00	0.01	0.50	-0.30
Cecropia sp.	2	0.13	0.00	0.01	0.50	-0.15

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Clidemia octona (Bonpl.) L.O.Williams	2	0.13	0.00	0.01	0.50	-0.15
Cochlospermum vitifolium (Willd.) Spreng.	2	0.13	0.01	0.01	0.50	-0.28
Crescentia alata Kunth	2	0.13	0.00	0.00	0.00	-0.08
Cupania guatemalensis (Turcz.) Radlk.	2	0.13	0.00	0.01	0.50	-0.30
Dilodendron costaricense (Radlk.) A.H.Gentry & Steyerm.	2	0.13	0.00	0.01	0.50	-0.30
Garcinia intermedia (Pittier) Hammel	2	0.13	0.00	0.01	0.50	-0.30
Handroanthus ochraceus (Cham.) Mattos	2	0.13	0.00	0.01	0.50	-0.30
Luehea candida (Moc. & Sessé ex DC.) Mart.	2	0.13	0.00	0.01	0.50	-0.30
Maclura sp.	2	0.13	0.00	0.01	0.50	-0.15
Margaritaria nobilis L.f.	2	0.13	0.01	0.01	0.50	-0.28
Ocotea veraguensis (Meisn.) Mez	2	0.13	0.00	0.01	0.50	-0.30
Passiflora sp.	2	0.13	0.00	0.01	0.50	-0.30
Piper marginatum Jacq.	2	0.13	0.00	0.01	0.50	-0.15
Piper pseudofuligineum C.DC.	2	0.13	0.00	0.01	0.50	-0.15
Psidium guajava L.	2	0.13	0.04	0.01	0.50	-0.15
Raphia taedigera (Mart.) Mart.	2	0.13	0.00	0.00	0.00	-0.08
Simarouba amara Aubl.	2	0.13	0.01	0.01	0.50	-0.28
Sloanea terniflora (Moc. & Sessé ex DC.) Standl.	2	0.13	0.00	0.01	0.50	-0.30
Solanum sp.	2	0.13	0.00	0.01	0.50	-0.15
Vismia baccifera (L.) Planch. & Triana	2	0.13	0.01	0.01	0.50	-0.30
Zuelania guidonia (Sw.) Britton & Millsp.	2	0.13	0.00	0.01	0.50	-0.30
Acnistus arborescens (L.) Schltdl.	1	0.06	0.00	0.01	0.00	-0.15
Agonandra macrocarpa L.O.Williams	1	0.06	0.00	0.00	0.00	-0.30
Albizia adinocephala (Donn.Sm.) Record	1	0.06	0.00	0.01	0.00	-0.13
Alvaradoa amorphoides Liebm.	1	0.06	0.00	0.00	0.00	-0.30
Amphilophium crucigerum (L.) L.G.Lohmann	1	0.06	0.00	0.01	0.00	-0.13
Annona purpurea Moc. & Sessé ex Dunal	1	0.06	0.00	0.01	0.00	-0.13

Annona reticulata L.	1	0.06	0.00	0.01	0.00	-0.13
Annona sp.	1	0.06	0.00	0.01	0.00	-0.13
Apeiba tibourbou Aubl.	1	0.06	0.00	0.01	0.00	-0.13
Asclepias curassavica L.	1	0.06	0.00	0.01	0.00	-0.13
Attalea rostrata Oerst.	1	0.06	0.00	0.00	0.00	-0.28
Averrhoa carambola L.	1	0.06	0.00	0.00	0.00	-0.28
Bauhinia ungulata L.	1	0.06	0.00	0.00	0.00	-0.28
Bonellia macrocarpa (Cav.) B.Ståhl & Källersjö	1	0.06	0.00	0.01	0.00	-0.13
Bonellia nervosa (C.Presl) B.Ståhl & Källersjö	1	0.06	0.00	0.01	0.00	-0.13
Bunchosia sp.	1	0.06	0.00	0.01	0.00	-0.13
Byrsonima crassifolia (L.) Kunth	1	0.06	0.00	0.01	0.00	-0.13
Calycophyllum candidissimum (Vahl) DC.	1	0.06	0.00	0.01	0.00	-0.13
Carica papaya L.	1	0.06	0.00	0.01	0.00	-0.15
Carludovica palmata Ruiz & Pav.	1	0.06	0.00	0.01	0.00	-0.15
Casearia sylvestris Sw.	1	0.06	0.00	0.01	0.00	-0.13
Castilla elastica Cerv.	1	0.06	0.00	0.00	0.00	-0.30
Cecropia insignis Liebm.	1	0.06	0.00	0.01	0.00	-0.15
Cedrela odorata L.	1	0.06	0.00	0.01	0.00	-0.13
Chloroleucon mangense (Jacq.) Britton & Rose	1	0.06	0.00	0.00	0.00	-0.28
Chomelia spinosa Jacq.	1	0.06	0.00	0.01	0.00	-0.13
Chrysophyllum cainito L.	1	0.06	0.00	0.01	0.00	-0.15
Cissus alata Jacq.	1	0.06	0.00	0.01	0.00	-0.13
Coccoloba uvifera (L.) L.	1	0.06	0.00	0.01	0.00	-0.15
Coccoloba venosa L.	1	0.06	0.00	0.00	0.00	-0.30
Cochlospermum sp.	1	0.06	0.00	0.00	0.00	-0.28
Coffea sp.	1	0.06	0.00	0.01	0.00	-0.15
Combretum farinosum Kunth	1	0.06	0.00	0.01	0.00	-0.13
Cordia alliodora (Ruiz & Pav.) Oken	1	0.06	0.00	0.01	0.00	-0.13
Cordia guanacastensis Standl.	1	0.06	0.00	0.00	0.00	-0.28
Cordia panamensis L.Riley	1	0.06	0.00	0.01	0.00	-0.13
Croton sp.	1	0.06	0.00	0.01	0.00	-0.13
Curatella americana L.	1	0.06	0.00	0.01	0.00	-0.13
Dipteryx odorata (Aubl.) Willd.	1	0.06	0.00	0.01	0.00	-0.15
Dipteryx oleifera Benth.	1	0.06	0.00	0.01	0.00	-0.15

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Euphorbia sp.	1	0.06	0.00	0.01	0.00	-0.13
Euphorbiaceae	1	0.06	0.00	0.01	0.00	-0.13
Ficus benjamina L.	1	0.06	0.00	0.01	0.00	-0.15
Ficus insipida Willd.	1	0.06	0.00	0.00	0.00	-0.28
Gliricidia sepium (Jacq.) Walp.	1	0.06	0.00	0.01	0.00	-0.13
Guettarda deamii Standl.	1	0.06	0.00	0.01	0.00	-0.13
Guettarda macrosperma Donn.Sm.	1	0.06	0.00	0.01	0.00	-0.13
Gymnanthes lucida Sw.	1	0.06	0.00	0.01	0.00	-0.13
Hamelia mateus	1	0.06	0.00	0.01	0.00	-0.13
Hawkesiophyton ulei (Dammer) Hunz.	1	0.06	0.00	0.01	0.00	-0.15
Heisteria sp.	1	0.06	0.00	0.01	0.00	-0.15
Hura crepitans L.	1	0.06	0.00	0.01	0.00	-0.13
Inga vera Willd.	1	0.06	0.00	0.01	0.00	-0.13
Lasiacis nigra Davidse	1	0.06	0.00	0.01	0.00	-0.13
Lasiacis ruscifolia (Kunth) Hitchc. ex Chase	1	0.06	0.00	0.01	0.00	-0.13
Lasiacis sp.	1	0.06	0.00	0.01	0.00	-0.13
Licania arborea Seem.	1	0.06	0.00	0.01	0.00	-0.15
Lonchocarpus costaricensis (Donn.Sm.) Pittier	1	0.06	0.00	0.00	0.00	-0.30
Luehea speciosa Willd.	1	0.06	0.00	0.01	0.00	-0.13
Malvaviscus arboreus Cav.	1	0.06	0.00	0.01	0.00	-0.13
Mangifera indica L.	1	0.06	0.00	0.01	0.00	-0.15
Manilkara bidentata (A.DC.) A.Chev.	1	0.06	0.00	0.01	0.00	-0.15
Margaritopsis microdon (DC.) C.M.Taylor	1	0.06	0.00	0.00	0.00	-0.28
Melicoccus bijugatus Jacq.	1	0.06	0.00	0.01	0.00	-0.15
Miconia argentea (Sw.) DC.	1	0.06	0.00	0.01	0.00	-0.13
Mouriri myrtilloides (Sw.) Poir.	1	0.06	0.00	0.01	0.00	-0.13
Mucuna pruriens (L.) DC.	1	0.06	0.00	0.01	0.00	-0.13
Musa paradisiaca L.	1	0.06	0.00	0.00	0.00	-0.28
Musa sp.	1	0.06	0.00	0.01	0.00	-0.15
Paullinia cururu L.	1	0.06	0.00	0.01	0.00	-0.13
Pimenta racemosa (Mill.) J.W.Moore	1	0.06	0.00	0.01	0.00	-0.15
Piper aequale Vahl	1	0.06	0.00	0.01	0.00	-0.15

Piper auritum Kunth	1	0.06	0.00	0.01	0.00	-0.13
Piper cordulatum C. DC.	1	0.06	0.00	0.01	0.00	-0.15
Piper glabrescens (Miq.) C.DC.	1	0.06	0.00	0.01	0.00	-0.15
Piper reticulatum L.	1	0.06	0.00	0.01	0.00	-0.15
Poaceae sp.1	1	0.06	0.00	0.01	0.00	-0.13
Poaceae sp.2	1	0.06	0.00	0.01	0.00	-0.13
Prockia crucis P.Browne ex L.	1	0.06	0.00	0.01	0.00	-0.13
Prosopis juliflora (Sw.) DC.	1	0.06	0.00	0.00	0.00	-0.28
Psidium guineense Sw.	1	0.06	0.00	0.01	0.00	-0.13
Psychotria horizontalis Sw.	1	0.06	0.00	0.01	0.00	-0.13
Psychotria nervosa Sw.	1	0.06	0.00	0.00	0.00	-0.28
Quararibea asterolepis Pittier	1	0.06	0.00	0.01	0.00	-0.15
Randia armata (Sw.) DC.	1	0.06	0.00	0.00	0.00	-0.28
Randia echinocarpa Moc. & Sessé ex DC.	1	0.06	0.00	0.01	0.00	-0.13
Randia monantha Benth.	1	0.06	0.00	0.01	0.00	-0.13
Randia thurberi S.Watson	1	0.06	0.00	0.01	0.00	-0.13
Sapindus saponaria L.	1	0.06	0.00	0.01	0.00	-0.15
Senna bicapsularis (L.) Roxb.	1	0.06	0.00	0.00	0.00	-0.28
Senna undulata (Benth.) H.S.Irwin & Barneby	1	0.06	0.00	0.01	0.00	-0.15
Solanum hayesii Fernald	1	0.06	0.00	0.01	0.00	-0.15
Solanum hirtum Vahl	1	0.06	0.00	0.01	0.00	-0.15
Solanum ochraceo-ferrugineum Fernald	1	0.06	0.00	0.01	0.00	-0.15
Solanum rudepannum Dunal	1	0.06	0.00	0.01	0.00	-0.15
Spondias radlkoferi Donn.Sm.	1	0.06	0.00	0.00	0.00	-0.28
Spondias sp.	1	0.06	0.00	0.00	0.00	-0.30
Sterculia apetala (Jacq.) H.Karst.	1	0.06	0.00	0.01	0.00	-0.13
Symphonia globulifera L.f.	1	0.06	0.00	0.00	0.00	-0.28
Syzygium jambos (L.) Alston	1	0.06	0.00	0.01	0.00	-0.15
Syzygium malaccense (L.) Merr. & L.M.Perry	1	0.06	0.00	0.01	0.00	-0.15
Tabebuia ochracea A.H. Gentry	1	0.06	0.00	0.01	0.00	-0.13
Tabernaemontana donnell-smithii Rose ex J.D.Sm.	1	0.06	0.00	0.01	0.00	-0.13
Tabernaemontana odontadeniiflora A.O.Simões & M.E.Endress	1	0.06	0.00	0.01	0.00	-0.13
Terminalia catappa L.	1	0.06	0.00	0.01	0.00	-0.15

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Tillandsia streptophylla Scheidw. ex E.Morren	1	0.06	0.00	0.01	0.00	-0.13
Trema micrantha (L.) Blume	1	0.06	0.00	0.01	0.00	-0.13
Trichilia martiana C.DC.	1	0.06	0.00	0.01	0.00	-0.13
Trichilia sp.1	1	0.06	0.00	0.01	0.00	-0.13
Trichilia sp.2	1	0.06	0.00	0.01	0.00	-0.13
Trophis racemosa (L.) Urb.	1	0.06	0.00	0.01	0.00	-0.13
Virola sp.	1	0.06	0.00	0.00	0.00	-0.28
Vismia sp.	1	0.06	0.00	0.01	0.00	-0.15
Ziziphus guatemalensis Hemsl.	1	0.06	0.00	0.00	0.00	-0.28
VRESSP network						
Trema micrantha (L.) Blume	51	0.61	0.02	0.01	0.59	5.49
Cecropia pachystachya Trécul.	38	0.45	0.06	0.01	0.75	2.47
Morus nigra L.	35	0.42	0.08	0.01	0.73	1.87
Nectandra megapotamica (Spreng.) Mez	32	0.38	0.05	0.01	0.66	3.45
Euterpe edulis Mart.	21	0.25	0.03	0.01	0.69	1.70
Dendropanax cuneatus (DC.) Decne. & Planch.	20	0.24	0.04	0.01	0.71	1.06
Cabralea canjerana (Vell.) Mart.	19	0.23	0.02	0.01	0.68	1.06
Cecropia glaziovii Snethl.	18	0.21	0.02	0.01	0.75	-0.02
Maclura tinctoria (L.) D.Don ex Steud.	18	0.21	0.03	0.01	0.77	-0.24
Cestrum amictum Schltdl.	15	0.18	0.02	0.01	0.72	0.75
Ficus citrifolia Mill.	15	0.18	0.02	0.01	0.68	-0.02
Ficus insipida Willd.	13	0.15	0.02	0.01	0.69	-0.02
Ficus eximia Schott	12	0.14	0.01	0.01	0.49	0.21
Ficus luschnathiana (Miq.) Miq.	12	0.14	0.01	0.01	0.79	-0.68
Schefflera morototoni (Aubl.) Maguire, Steyerm. & Frodin	12	0.14	0.01	0.01	0.60	1.06
Alchornea triplinervia (Spreng.) Müll.Arg.	10	0.12	0.01	0.01	0.46	0.76
Citharexylum solanaceum Cham.	10	0.12	0.01	0.01	0.64	0.17
Ocotea silvestris Vattimo	10	0.12	0.01	0.01	0.66	0.43
Pereskia aculeata Mill.	10	0.12	0.01	0.01	0.62	0.43
Piper hispidum Sw.	10	0.12	0.02	0.01	0.54	-0.02

Campomanesia xanthocarpa (Mart.) O.Berg	9	0.11	0.02	0.01	0.49	0.24
Cordia axillaris I.M.Johnst.	9	0.11	0.01	0.01	0.49	0.46
Piper gaudichaudianum (Kunth) Kunth ex Steud.	9	0.11	0.01	0.01	0.35	0.21
Piper sp.	9	0.11	0.01	0.01	0.57	-0.24
Eugenia florida DC.	8	0.10	0.02	0.01	0.59	-0.13
Ficus sp.	8	0.10	0.01	0.01	0.66	-0.20
Piper amalago L.	8	0.10	0.01	0.01	0.47	-0.24
Psidium guajava L.	8	0.10	0.01	0.01	0.69	-0.43
Trichilia catigua A.Juss.	8	0.10	0.01	0.01	0.66	-0.43
Alchornea glandulosa Poepp.	7	0.08	0.01	0.01	0.57	-0.13
Cestrum viridiflorum Hook.	7	0.08	0.03	0.01	0.65	-0.20
Eriobotrya japonica (Thunb.) Lindl.	7	0.08	0.01	0.01	0.61	-0.13
Ocotea sp.	7	0.08	0.01	0.01	0.45	0.11
Solanum granuloso-leprosum Dunal	7	0.08	0.01	0.01	0.49	-0.46
Chrysophyllum gonocarpum (Mart. & Eichler ex Miq.) Engl.	6	0.07	0.01	0.01	0.28	0.11
Cissus verticillata (L.) Nicolson & C.E.Jarvis	6	0.07	0.01	0.01	0.50	-0.20
Lycianthes glandulosa (Ruiz & Pav.) Bitter	6	0.07	0.01	0.01	0.28	0.11
Melia azedarach L.	6	0.07	0.00	0.01	0.67	-0.20
Miconia discolor DC.	6	0.07	0.02	0.01	0.50	-0.02
Miconia pusilliflora (DC.) Naudin	6	0.07	0.02	0.01	0.50	-0.43
Piper diospyrifolium Kunth	6	0.07	0.00	0.01	0.28	-0.24
Psychotria carthagenensis Jacq.	6	0.07	0.03	0.01	0.50	-0.02
Solanum caavurana Vell.	6	0.07	0.01	0.01	0.50	-0.68
Geophila macropoda (Ruiz & Pav.) DC.	5	0.06	0.02	0.01	0.32	-0.02
Holocalyx balansae Micheli	5	0.06	0.01	0.01	0.48	-0.20
Inga affinis DC.	5	0.06	0.01	0.01	0.32	-0.02
Inga striata Benth.	5	0.06	0.01	0.01	0.32	-0.02
Jacaratia spinosa (Aubl.) A.DC.	5	0.06	0.01	0.01	0.00	0.11
Palicourea macrobotrys (Ruiz & Pav.) Schult.	5	0.06	0.01	0.01	0.64	-0.73
Piper crassinervium Kunth	5	0.06	0.01	0.01	0.48	-0.68
Solanum americanum Mill.	5	0.06	0.01	0.01	0.56	-0.15
Solanum sp.	5	0.06	0.00	0.01	0.32	-0.46

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Trichostigma octandrum (L.) H.Walter	5	0.06	0.01	0.01	0.48	-0.15
Allophylus edulis (A.St.-Hil., A.Juss. & Cambess.) Radlk.	4	0.05	0.02	0.01	0.38	-0.15
Geophila repens (L.) I.M.Johnst.	4	0.05	0.01	0.01	0.00	-0.02
Guarea kunthiana A.Juss.	4	0.05	0.01	0.01	0.50	-0.52
Phytolacca dioica L.	4	0.05	0.01	0.01	0.38	-0.15
Plinia peruviana (Poir.) Govaerts	4	0.05	0.00	0.01	0.63	-0.28
Prockia crucis P.Browne ex L.	4	0.05	0.00	0.01	0.63	-0.28
Solanum argenteum Dunal	4	0.05	0.01	0.01	0.50	-0.90
Syagrus romanzoffiana (Cham.) Glassman	4	0.05	0.01	0.01	0.00	-0.02
Zea mays L.	4	0.05	0.01	0.01	0.00	-0.02
Acacia polyphylla DC.	3	0.04	0.00	0.01	0.00	-0.15
Annona cacans Warm.	3	0.04	0.00	0.01	0.00	-0.15
Cissus gongylodes (Baker) Burch. ex Baker	3	0.04	0.00	0.01	0.00	-0.15
Citrus sinensis (L.) Osbeck	3	0.04	0.00	0.01	0.00	-0.15
Cordia ecalyculata Vell.	3	0.04	0.01	0.01	0.00	-0.15
Dicella nucifera Chodat	3	0.04	0.00	0.01	0.00	-0.15
Eugenia sp.	3	0.04	0.01	0.01	0.00	-0.15
Passiflora edulis Sims	3	0.04	0.00	0.01	0.00	-0.68
Poaceae	3	0.04	0.00	0.01	0.00	-0.15
Prunus sellowii Koehne	3	0.04	0.00	0.01	0.00	-0.15
Psychotria leiocarpa Cham. & Schltdl.	3	0.04	0.01	0.01	0.44	-0.28
Sorocea bonplandii (Baill.) W.C.Burger, Lanj. & de Boer	3	0.04	0.01	0.01	0.00	-0.15
Celtis iguanaea (Jacq.) Sarg.	2	0.02	0.00	0.01	0.00	-0.28
Chamissoa altissima (Jacq.) Kunth	2	0.02	0.00	0.01	0.50	-0.83
Chrysophyllum marginatum (Hook. & Arn.) Radlk.	2	0.02	0.00	0.01	0.00	-0.28
Eugenia ramboi D.Legrand	2	0.02	0.00	0.01	0.00	-0.28
Inga semialata (Vell.) C.Mart.	2	0.02	0.00	0.01	0.00	-0.28
Passiflora alata Curtis	2	0.02	0.00	0.01	0.00	-0.28
Psychotria myriantha Müll.Arg.	2	0.02	0.00	0.01	0.00	-0.28
Rauvolfia sellowii Müll.Arg.	2	0.02	0.01	0.01	0.50	-0.83
Rubus urticifolius Poir.	2	0.02	0.00	0.01	0.50	-1.03

Trichilia elegans A.Juss.	2	0.02	0.00	0.01	0.00	-0.52
Trichilia pallida Sw.	2	0.02	0.00	0.01	0.50	-1.03
Zanthoxylum sp.	2	0.02	0.00	0.01	0.00	-0.52
Achatocarpus praecox Griseb.	1	0.01	0.00	0.01	0.00	-0.41
Aegiphila brachiata Vell.	1	0.01	0.00	0.01	0.00	-0.83
Aegiphila mediterranea Vell.	1	0.01	0.00	0.01	0.00	-0.83
Allophylus guaraniticus (A.St.-Hil.) Radlk.	1	0.01	0.00	0.01	0.00	-0.41
Araucaria angustifolia (Bertol.) Kuntze	1	0.01	0.00	0.01	0.00	-0.41
Artocarpus integer (Thunb.) Merr.	1	0.01	0.00	0.01	0.00	-0.41
Bauhinia forficata Link	1	0.01	0.00	0.01	0.00	-0.41
Carica papaya L.	1	0.01	0.00	0.01	0.00	-0.41
Cordia polycephala (Lam.) I.M.Johnst.	1	0.01	0.00	0.01	0.00	-1.03
Davilla elliptica A.St.-Hil.	1	0.01	0.00	0.01	0.00	-0.41
Endlicheria paniculata (Spreng.) J.F.Macbr.	1	0.01	0.00	0.01	0.00	-0.41
Eugenia handroi (Mattos) Mattos	1	0.01	0.00	0.01	0.00	-0.41
Eugenia moraviana O.Berg	1	0.01	0.00	0.01	0.00	-0.41
Eugenia pyriformis Cambess.	1	0.01	0.00	0.01	0.00	-0.41
Fevillea trilobata L.	1	0.01	0.00	0.01	0.00	-0.41
Galium hypocarpium (L.) Endl. ex Griseb.	1	0.01	0.00	0.01	0.00	-1.03
Guarea macrophylla Vahl	1	0.01	0.00	0.01	0.00	-0.83
Hamelia patens Jacq.	1	0.01	0.00	0.01	0.00	-0.83
Hovenia dulcis Thunb.	1	0.01	0.00	0.01	0.00	-0.41
Jacaranda micrantha Cham.	1	0.01	0.00	0.01	0.00	-0.41
Lepismium cruciforme (Vell.) Miq.	1	0.01	0.00	0.01	0.00	-0.41
Lepismium sp.	1	0.01	0.00	0.00	0.00	-0.34
Miconia collatata Wurdack	1	0.01	0.00	0.01	0.00	-0.41
Momordica charantia L.	1	0.01	0.00	0.01	0.00	-0.41
Musa rosea Baker	1	0.01	0.00	0.01	0.00	-0.41
Ottonia sp.	1	0.01	0.00	0.01	0.00	-1.12
Passiflora amethystina J.C.Mikan	1	0.01	0.00	0.01	0.00	-0.41
Paullinia meliifolia Juss.	1	0.01	0.00	0.01	0.00	-0.41
Persea americana Mill.	1	0.01	0.00	0.01	0.00	-1.03
Phoradendron crassifolium (Pohl ex DC.) Eichler	1	0.01	0.00	0.01	0.00	-1.03

Continues…

APPENDIX E – Continuation

Plant species	**Degree (*D*)**	**Normalised degree (*ND*)**	**Betweenness (*BC*)**	**Closeness (*CC*)**	**Participation coefficient (Pi)**	**Within-module degree (Zi)**
Piper lindbergii C. DC.	1	0.01	0.00	0.01	0.00	-1.12
Randia armata (Sw.) DC.	1	0.01	0.00	0.01	0.00	-0.41
Schinus terebinthifolia Raddi	1	0.01	0.00	0.01	0.00	-1.03
Solanum atropurpureum Schrank	1	0.01	0.00	0.01	0.00	-0.41
Solanum hirtellum (Spreng.) Hassl.	1	0.01	0.00	0.01	0.00	-0.41
Trichilia pallens C.DC.	1	0.01	0.00	0.01	0.00	-0.83
Triticum sp.	1	0.01	0.00	0.01	0.00	-0.41
Urera baccifera (L.) Gaudich. ex Wedd.	1	0.01	0.00	0.01	0.00	-0.41

5 Concluding remarks

- The high diversity of neotropical frugivores is not reflected in studies on fruit-eating by vertebrates, which are highly concentrated in a few taxonomic groups, like primates, bats and small birds.

- To date, only a few studies have examined frugivory at the community wide level in the Neotropics, and few study sites investigated the detailed diets of a high diversity of frugivorous species.

- Most studies of fruit-eating by neotropical vertebrates do not take into account interannual variation in fruit availability as they were conducted during one annual cycle or less.

- New studies of fruit–frugivore interactions in the Neotropics should focus on the entire assembly of frugivores occurring in focal communities, and on undersampled regions of the Neotropics, as well as undersampled vertebrate groups such as birds, rodents and marsupials.

- By combining data available from the literature about fruit-eating by birds and mammals from well-studied study sites it is possible to build qualitative fruit–frugivore interaction networks that are a valid addition to current methods of assessing community structure and composition.

- This approach has the advantage of avoiding costly, extensive and time-consuming fieldwork required for the investigation of interactions between plants and animals of diverse taxonomic groups.

- The combined networks presented characteristics similar to those of mutualistic networks already described in the literature, and have the potential to be further analysed in order to answer relevant ecological questions.

- Two generalist neotropical mammalian taxa, capuchin monkeys and coatis, depend highly on fruits to complement their diets. Both groups have the ability to disperse most seeds they ingest.

- By analysing three fruit–frugivore networks containing both groups, we found that these mammals are providing complementary roles as seed dispersers in different neotropical communities. Due to their high ecological flexibility, capuchin monkeys and coatis may be responsible for forest maintenance and recovery through seed dispersal throughout their ranges, especially in disturbed and fragmented forests.

- Using a multivariate analysis in three neotropical communities we failed to detect any plant trait or trait combination able to explain fruit choice by these animals.

- Using qualitative networks of fruit–frugivore interactions built using data from a literature review it is possible to detect key species of plants performing central or connector roles in their communities.

- These key plant species should be favoured in conservation and restoration plans, because they have the potential to enhance the number of interactions between plants and frugivores.

- Most neotropical ecoregions still lack robust information about fruit–frugivore interactions involving a more realistic diversity of frugivore species occurring in the communities. The collection of basic information is valuable to improve restoration projects.

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São José do Rio Preto, _03__/__04_/_2017

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