

Biotic Interactions in the Genus *Anthurium* Schott (Araceae)

by

Nathan P. Hartley

Department of Biology
Duke University

Date: _____

Approved:

Paul Manos, Supervisor

Kathleen Pryer

Michael Windham

Thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science in the Department of
Biology in the Graduate School
of Duke University

2018

ABSTRACT

Biotic Interactions in the Genus *Anthurium* Schott (Araceae)

by

Nathan P. Hartley

Department of Biology
Duke University

Date: _____

Approved:

Paul Manos, Supervisor

Kathleen Pryer

Michael Windham

An abstract of a thesis submitted in partial
fulfillment of the requirements for the degree
of Master of Science in the Department of
Biology in the Graduate School of
Duke University

2018

Copyright by
Nathan P. Hartley
2018

Abstract

The genus *Anthurium* represents one of the largest genera restricted to the neotropics and has long been recognized as one of the "megagenera" of flowering plants, in addition to claiming the bulk of diversity (~25%) in its family, the Araceae. Despite this vast and beguiling array of morphologic diversity, observations on the biotic interactions that *Anthurium* participate with other living organisms in are scant. Although these types of observations help establish foundational knowledge on the natural history of organisms and are well-known from other large clades of neotropical herbs (i.e., orchids), the few observations that have been made for *Anthurium* are scattered throughout the literature, and no attempt has been made to synthesize this information. Primary literature documents were procured largely through the Duke University Library system. A total of 316 discrete biotic interactions are referenced here, 22 of which are evidenced here as new. Previously considered to be almost entirely pollinated by euglossine bees, this review evidences a diverse assemblage of biotic interactors that complements the taxonomic, morphologic, and ecologic diversity of *Anthurium*. It is hoped that this information can provide a starting point for current and future researchers to springboard from as they continue to demystify the evolutionary forces that facilitated the diversification of this understudied megagenus.

Contents

Abstract	iv
List of Figures	viii
1. Introduction	1
1.1 The genus Anthurium.....	2
1.2 Biotic Interactions in Anthurium	4
1.2.1 Purpose of this Document.....	5
2. Materials and Methods.....	6
2.1 Literature Search.....	7
2.2 Personal Observations	8
2.3 Herbarium specimens.....	9
2.4 Other Sources	9
3. Results:.....	10
3.1 Floral interactions.....	10
3.1.1 New Observations of Floral Interactions	13
3.2 Post-Anthesis Interactions.....	18
3.2.1 New Observations of Post-Anthesis Interactions	20
3.3 Vegetative Interactions	22
3.3.1 New Observations of Vegetative Interactions.....	23
3.4 Other Notable Findings	24
4. Discussion	25

4.1 Floral Interactions.....	25
4.1.1 Floral Visitation	25
4.1.2 Floral Rewards.....	33
4.1.3 Florivory	34
4.2 Post-Anthetic Interactions.....	36
4.2.1 Fruit Consumption & Seed Dispersal.....	36
4.2.2 Other Post-Anthesis Ineractions.....	38
4.3 Vegetative Interactions	40
4.3.1 Nesting, Roosting and Mating Sites.....	40
4.3.2 Herbivory	41
4.3.3 Oviposition.....	41
4.3.4 Mycorrhizal Associations.....	42
4.4 Abiotic Phenomenon in Anthurium.....	43
4.4.1 Agamospermy.....	43
4.4.2 Anemophily.....	44
4.4.3 Vivipary	45
5. Future Directions	48
5.1 Floral Odors.....	48
5.2 Noctural Observations.....	53
6. Conclusions.....	56
Appendix 1.....	58
Appendix 2.....	74

Appendix 3.....	82
References	85

List of Figures

Figure 1: Personal observations of novel interactions with non-ant insects.....	14
Figure 2: New observations of non-ant flora interactions contributed by Alistair Hay and citizen scientist users of the iNaturalist.org database.....	16
Figure 3: Personal observation of novel floral interactions with ants	17
Figure 4: Personal observations of novel biotic interactions in post-anthetic and vegetative tissues	21
Figure 5: iNaturalist.org © observation of vivipary in a wild <i>Anthurium</i> in Colombia....	24
Figure 6: Nocturnal observations yield new records: new evidence for floral visitation by mirid bugs (Hemiptera: Miridae) in <i>Spathiphyllum</i> (Monsteroideae).....	55

1. Introduction

Biotic interactions, loosely interpreted as any exchange between organisms, represent fundamental forces that shape the growth, survival, and reproduction of individual organisms, community assemblage, and ecosystem functioning (Burslem et al. 2005). While their significance in driving neotropical plant evolution is undisputed, we are only beginning to understand how these interactions affect the fitness of the organisms involved and how these life history repercussions influence evolutionary processes at various taxonomic scales (Endara et al. 2017). It is important to note that while efforts like to those pursued by Endara et al. (2017) represent a harmonious amalgamation of natural history and big data, like most other ecological and evolutionary studies of neotropical plants, these efforts are based entirely on woody tree species. Woody trees have been—and continue to be—the principal plant growth form for which most data on neotropical plants exists (e.g., the Smithsonian Institute’s ForestGEO database is based entirely on trees). Consequently, all major ecological theories to have been produced from these massive datasets are theories that can (at best) only be applied to understand eco-evolutionary processes operating in woody trees, which in some tropical forests represent only 28% of vascular plant species and a mere 17% of all vascular plant individuals (Gentry & Dodson 1987). The need to refine the focus of neotropical research infrastructures and agendas to include more than just one form of

the neotropical flora is imperative if we ever hope to truly understand the processes that both create and maintain biodiversity in the most biodiverse ecosystems on the planet.

1.1 The genus *Anthurium*

With a minimum of 1,690 species (Croat 2015) distributed across the breadth of neotropical ecosystems, the genus *Anthurium* Schott represents one of the largest vascular plant clades endemic to the neotropics (Croat 2015; Ulloa Ulloa 2017). Having long been recognized as one of the angiosperm "megagenera" (sensu Frodin 2004), in addition to containing the bulk of species diversity in its family, the Araceae (Boyce & Croat 2011 onwards), *Anthurium* has also been shown to contribute significantly to herbaceous/epiphytic biodiversity and biomass throughout the neotropics (Kelly 1985; Ingram et al. 1996; Galeano, Suárez & Balslev 1998; Arévalo & Betancur 2004; Benavides et al. 2005; Alves & Neto 2014). Like all Araceae, *Anthurium* flowers are protogynous, wherein pistillate anthesis occurs before staminate anthesis, their pollination syndrome is zoophilous, wherein pollen is transferred by animals, and their diaspore dispersal syndrome is zoochoric, wherein seeds are embedded in fleshy berries to facilitate movement by animals. While zoophily and zoochory are considered life history hallmarks of tropical plants (Bawa 1979; Vogel & Westerkamp 1991; Correa et al. 2015), other predominant lineages of non-woody neotropical vascular plants whose biologies have been more intensively studied than *Anthurium* lack either one or both of these hallmarks (i.e., pteridophytes, orchids, and bromeliads). For these reasons, and others

elaborated upon below, *Anthurium* presents an ecologically pertinent system to investigate the processes that have shaped the evolution of non-woody neotropical plants.

Anthurium is the only New World genus of Pothoideae, an early branching subfamily of Araceae thought to have diverged from its sister genus, *Pothos* (sensu Carlsen and Croat 2013), ca. 65 Ma (Nauheimer et al. 2012). Despite the age of its lineage, most systematists agree that *Anthurium* experienced a recent and rapid radiation in the last 5 Ma (Grayum 1990; Carlsen 2011; Carlsen and Croat 2013). Regardless of the rates at which the morphological and species diversity of *Anthurium* was formed, this diversity is complemented by an equally impressive ecological diversity. For example, while some are herbaceous vines with small, leathery leaves that sprawl across the canopies of high-elevation cloud forests, others are mid-canopy hemiepiphytes in lowland rainforests with large, palmately compound leaves, some are lithophytes in seasonally dry tropical forests with large, membranaceous leaves borne on a short stem densely covered in thick roots, while others produce gigantic, variegated, velvety leaves in montane rainforests, and others are found only in the phytotelmata of terrestrial bromeliads growing on arid, sun-drenched inselbergs (Croat 1991, Mayo et al. 2000).

Despite their vast and beguiling array of morphologic and ecologic diversity, the scarcity of observations on the biotic interactions in *Anthurium* obscures our understanding of how interactions with other living organisms might have influenced

the mode and tempo of evolution in the genus, and how infraspecific populations and interspecific communities of *Anthurium* become established, structured and changed through time. While biotic interactions are adequately studied in other large clades of neotropical plants (Sun *et al.* 2015; Clark *et al.* 2015; Lagomarsino *et al.* 2017; Betts *et al.* 2015; Knudsen & Mori 1996; Gamba *et al.* 2016), most genera of Araceae that have been the focus of biotic interaction studies are thermogenic members of the unisexually-flowered subfamily Aroideae, which have evolved spatially discrete pistillate and staminate flowers along the spadix that facilitate a deceptive pollination syndrome wherein their effective pollinators are lured and temporarily trapped as a strategy for pollen movement (Meeuse 1978; Renner 2006; Chartier *et al.* 2014; Maia *et al.* 2010; Maia *et al.* 2012). Conversely, few observations exist for early-diverging lineages with bisexual flowers that lack this provocative pollination syndrome, such as *Anthurium*, and those that have been made for *Anthurium* and synthesized to some degree dealt strictly with pollinators and floral visitors (Gibernau 2003, 2011, 2016; Prieto & Cascante-Marín 2017).

1.2 Biotic Interactions in Anthurium

While no synthesis of biotic interactions in *Anthurium* has yet been produced, three efforts have been published by Marc Gibernau, of the French National Centre for Scientific Research, wherein pollinators and floral visitors of aroid inflorescences were compiled (Gibernau 2003, 2011, 2016). Of these efforts, only two reference pollinators and floral interactors of *Anthurium* (Gibernau 2003, 2011). In the first summary,

Gibernau (2003) cited six articles that evidenced pollination or floral visitation by euglossine bees, staphylinid and curculionid beetles, cecidomyiid and drosophilid flies, and hummingbirds (Williams & Dressler 1976; Madison 1979a; Croat 1980; Beath 1998; Kraemer & Schmitt 1999; and Schwerdtfeger et al. 2002). In a second addendum to aroid inflorescence visitors, Gibernau (2011) cited four additional articles pertaining to *Anthurium*, two of which represented detailed studies of curculionid beetle pollination in Costa Rica (Franz 2003 and Franz 2007), and two others which presented detailed chemical analyses that compared the euglossine bee pollination system between two sympatric *Anthurium* in French Guiana (Hentrich et al. 2007 and Hentrich et al. 2010). However, neither of these syntheses explicitly mentioned which species of *Anthurium* these interactions pertain to (although the original articles do), and the format of the table in the first synthesis made it difficult to discern how the literature cited related to each interaction listed (Gibernau 2003, 2011).

1.2.1. Purpose of this Document

In attempt to promote and facilitate future research on *Anthurium* ecology and reproductive biology, a synthesis on all known biotic interactions in *Anthurium* is presented here for researchers to springboard from as they continue to demystify the processes of gamete and diaspore dispersal and the effects interactors have on the fitnesses and life histories of individuals, populations, and species in this wide-ranging neotropical megagenus.

2. Materials and Methods

Prior to locating the primary sources that I used to generate my lists of *Anthurium* species and the organisms that interact with them, I had to decide what type of biotic interactions to include in this review. To be comprehensive, I considered all biotic interactions documented in the literature I could find, any observations I was able to make during my two field seasons, any information noted on the labels of herbarium specimens I encountered during my studies, and any information I was able to get from any other sources I found. To facilitate discussion, I decided to break these interactions down into three main categories, from perspective of the plant: **1)** floral interactors; **2)** post-anthesis interactors; and **3)** vegetative interactors. While the use of several *Anthurium* species by non-westernized human populations has been documented by various ethnobotanists in the 20th century, these interactions have already been reviewed (Plowman 1969; Duke 1972; Caballero et al. 1978; Croat 1994; Ima Omene 2012) and for that reason are excluded here. Additionally, several *Anthurium* species are common and important elements of the cut-flower and horticultural industry (*Anthurium andraeanum* Linden ex André in particular; González-Ball et al. 2017), and their microbiota have been adequately documented and described to help combat pests (Mayo et al. 1997, Table 9; Sarria-Guzmán et al. 2016; Alvarez 2018). The results of these cutting-edge, data-rich studies on *A. andraeanum* are most immediately beneficial to the horticultural industry

and for this reason are excluded herein as these interactions do not reflect natural interactions in natural *Anthurium* populations.

The goal of this review was not to classify each *Anthurium* interaction into a specific type of ecological interaction (i.e., commensal, parasitic, etc.), but instead to first broadly categorize each interaction based on which part (and phase) of the plant the interaction was observed occurring with (floral interactors, post-anthesis interactors and vegetative interactors). Within each of these broader categories, each interaction entry lists which species were involved (if known), the nature of the interaction (e.g., floral visitor, leaf consumption, etc.), the geographic location of this interaction, and the source from which this information originates. The interactions are broadly organized this way because the lack of detailed ecological studies within *Anthurium* precludes our ability to diagnose the types of ecological interactions documented herein, yet it is hoped that this synthesis provides a way for other researchers to identify potential interactions and to study them in greater detail than is available here.

2.1 Literature Search

Duke University's Library was used to locate primary literature beyond those cited by Gibernau (2003, 2011). While the use of Duke's Library diminishes the replicability of this study, I chose to use the Duke Library because I found its search engine to yield a greater amount and diversity of search results than other search engines frequently used in other meta-analysis efforts (e.g., Web of Science). As the

purpose of this thesis was to compile all known biotic interactions, I feel the use of this resource is justified as I believe it enabled me to find interactions that I would not have found had I relied only on Web of Science. For this reason, it's very likely that the literature cited herein does not represent a comprehensive take on biotic interactions in *Anthurium*, and that other search engines/facilities would yield additional primary sources that I was unable to locate. However, the primary objective of this research was to provide a synthesis for biotic interactions in *Anthurium* that expanded upon what is already known, and my use of the Duke Library enabled me to achieve this more so than I would have been able to do had I only used Web of Science for the sake of replicability. That being said, examples of words and phrases I used to search for the primary sources included: "Anthurium pollination"; "Anthurium pollinator"; "Anthurium seed dispersal"; "Anthurium interaction"; "Anthurium mycorrhizae"; and "Anthurium visitation".

2.2 Personal Observations

Personal observations were made over the course of two field seasons and used to augment the list of interactions I found in the literature. The first field season took place through the months of June, July and August in 2016, throughout various regions of Costa Rica. My second field season occurred through July and August of 2017 in various regions of Colombia, Peru, and Brazil. These observations evidenced with

photographs and are cited in the interaction appendices as “Hartley (year) personal observation” with locality data provided in the Location column.

2.3 Herbarium specimens

Two herbarium specimens I encountered in my studies had labels with notes on what organisms were interacting with the plant upon the time of collection. These specimens are cited in the interaction appendices with collector name, collection number, and herbarium where the specimen was observed. Herbarium observations were incidental and made while observing specimens for other purposes, and are by no means comprehensive as the scope of this review was not intended to be inclusive of all herbarium specimens of *Anthurium*.

2.4 Other Sources

Several observations of biotic interactions in *Anthurium* were presented at the 12th International Aroid Conference in Cali, Colombia, and these are cited with the title of the presentation in the event that these observations have not yet been published. Additionally, some researchers contacted me after the conference with personal observations based on photographic evidence that are included herein with their permission. Observations encountered on iNaturalist.org were considered sparingly and are duplicated with written permission from the original observer.

3. Results

3.1 Floral interactions

Appendix 1 presents a taxonomically explicit list of all known *Anthurium* species for which floral visitors have been documented in the published literature, supplemented with observations from my 5 months of fieldwork, notes on herbarium specimen labels, and unpublished observations by other researchers and biodiversity observers on iNaturalist.org ©. Therein, an additional 32 references are cited from the 10 referenced by Gibernau (2003, 2011) which cumulatively document a total of 207 biotic interactions involving distinct pairs of organisms, 145 of which occur with 61 known species of *Anthurium* from 14 subgeneric sections (sensu Croat & Sheffer 1983 and Carlsen & Croat 2013; Appendix 1). The 62 remaining interactions did not mention which species or section of *Anthurium* the interaction occurred with; however, 41 of these interactions (66%) had the zoological interactor identified to species. The comparatively refined taxonomy of the visitors associated with unknown species of *Anthurium* contrasts against the 51 of 145 interactions with known *Anthurium* (35%) that had their zoological interactor identified to species (Appendix 1). This perhaps an artifact of the rarity of publications interested in more than one group of organisms engaging in the interaction and the difficulty in knowing the taxonomy of two or more highly diverse and completely unrelated groups of organisms.

Of the 145 floral interactions with known *Anthurium* species, only 27 interactions (19%) were cited by their reference as being pollinator-plant interactions, the rest have either been inferred (Chouteau et al. 2008) or classified as floral visitors/interactors. Ten of these 27 pollinator interactions were made on *Anthurium sagittatum* (Sims) G.Don and *A. thrinax* Madison in French Guiana (Hentrich et al. 2007, 2010). Another eight interactions were recorded by Kraemer & Schmitt (1999) for 8 species of hummingbirds that were seen visiting and carrying the pollen of *A. sanguineum* Engl.. Six of the 9 remaining pollinator interactions were confirmed in three detailed studies conducted by Nico Franz (2003, 2007) and Florian Etl (Etl. et al. 2017), and the remaining 3 are assumed to have been observed or inferred by the melittologists cited in the pollinator interactions of *Anthurium magnificum* Linden and *A. palenquense* Croat in Table 1 (Williams & Dressler 1976; Dodson & Gentry 1978; Dressler 1982). Around the same proportion (15%) of the pollinator interactions was found for unknown species of *Anthurium* as there were for known species of *Anthurium* (Appendix 1).

Anthurium sanguineum (section *Cardiolonchium*) had the highest number of taxonomically explicit interactors (10) and two species tied for second with 8 different species of interactors: *A. buganum* (section *Calomystrium*) and *A. panduriforme* (section *Polyneurium*; Appendix 1). Sections *Cardiolonchium* and *Pachyneurium* tied for having the most species of *Anthurium* recognized (12 each), however, section *Cardiolonchium* had the with most floral interactions (43 total) followed by section *Calomystrium* with 10

identified *Anthurium* species and 25 total floral interactions. Section *Cardiolonchium* also exhibited the greatest ordinal breadth of interactions, with 9 orders of vertebrate and invertebrates observed visiting its 12 represented taxa (Appendix 1).

The most diverse genus of floral interactors in *Anthurium* is *Euglossa* (30 species in total), a group of bees long assumed to be the principal pollinators of all species of *Anthurium* (Croat 1980); however most of these euglossine bee species (19 observations, 63%) interacted with an unknown species of *Anthurium*. The distribution of interactions among different orders of animals was skewed, with 3 orders (of the 11 observed) comprising 81% of all interactions: Hymenoptera (107, 52%); Coleoptera (34, 16%); and Diptera (26, 13%; Appendix 1).

Of the 61 different species of *Anthurium* identified, 33 (54%) listed a single visiting entity (Appendix 1). The 28 remaining species of identified *Anthurium* (46%) were visited by multiple species, either different species of the same genus, or more commonly by different families in different orders of insects (Appendix 1). Despite the frequency of single visitor-interactions, only 3 sections of *Anthurium* were represented in Appendix 1 by a single species for which only one floral visitor had been observed: sections *Andiphyllum* (a drosophilid fly); section *Digitinervium* (a cecidomyiid fly); and section *Leptanthurium* (a *Nannotrigona* bee).

3.1.1 New Observations of Floral Interactions

Twenty-two new floral interactions are documented in this review with photographic evidence that was either captured by myself (Figs. 1 & 3) or generously offered by Alistair Hay and users on the citizen science database iNaturalist.org © (Fig. 2), replicated here with written consent. These 22 new interactions occurred between potentially 22 different species of insects and 16 species of *Anthurium* belonging to at least 6 different sections of *Anthurium* (*Belolonchium*, *Calomystrium*, *Cardiolonchium*, *Dactylophyllium*, *Pachyneurium* and *Polyneurium*). The 11 personal observations of non-ant visitors in Fig. 1 are comprised of 3 flies (Fig. 1: **A, B & I**); 4 bees (Fig. 1: **C, E, J & K**); and 4 beetle visitors (Fig. 1: **D, F, G & H**). The five interactions evidenced in Fig. 2 were contributed by other observers and consist of 2 butterflies (Fig. 2: **A & B**) and 3 observations from iNaturalist.org © (Fig. 2: **C-E**). The 6 remaining observations were of unidentified ant species visiting the pistillate inflorescences of 5 species of *Anthurium* (Fig. 3). Interestingly, these five observations all occurred at four discrete locations in lowland rainforests across the neotropics (Fig. 3).

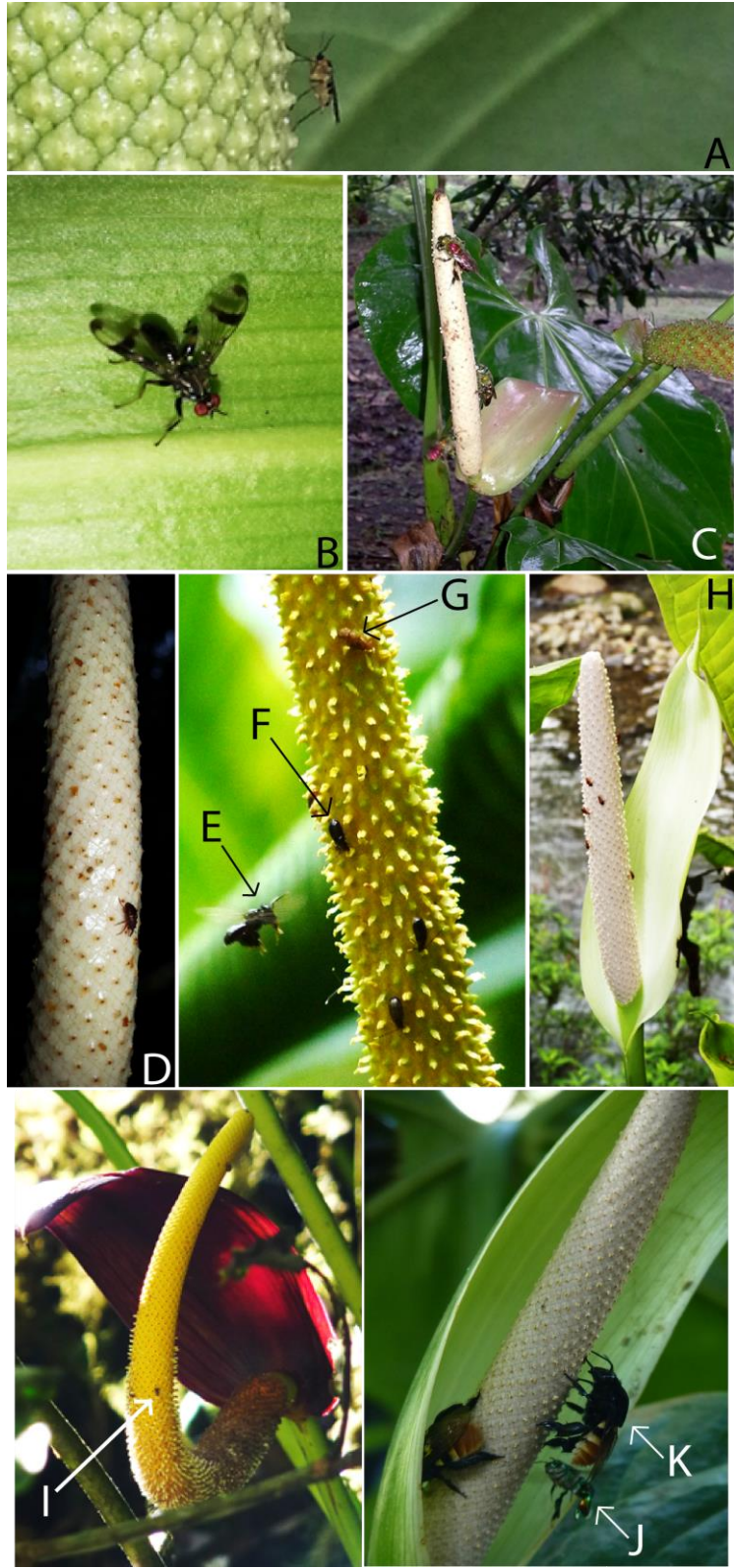


Figure 1: Eleven observations of non-ant floral visitors: **A & B:** two species of dipteran visiting the pistillate inflorescence of *Anthurium caperatum* Croat & R.A. Baker at Las Cruces Biological Station, Costa Rica [image **B** has tentatively been identified to the genus *Richardia* (Richardidiidae)]; **C** *Euglossa* sp. visiting a staminate inflorescence of *A. hoffmannii* Schott at Las Cruces Biological Station, Costa Rica; **D**) *Cyclanthura* sp. visiting a pistillate inflorescence of *A. hoffmannii* at the same locale; **E, F & G:** a species of tribe *Meliponini* bees, chrysomelid beetles and curculionid beetles, respectively, visiting the staminate inflorescence of *A. panduriforme* Schott in the Colombian Chocó; **H**) a potential chrysomelid beetle visiting a pistillate inflorescence of *A. obtusilobum* Schott in central Costa Rica; **I**) a potential dipteran visitor of an “antúrio negro” species belonging to section *Belonchium* seen in the Colombian Chocó; and **J & K:** *Euglossa* and *Eulaema* spp. visiting a staminate inflorescence of a species of section *Calomystrium* cultivated at Orquideas Amazonicas in Moyobamba, Peru.



Figure 2: Five new observations of biotic interactions graciously contributed by other aroid researchers and biodiversity observers. **A)** *Pareuptychia* sp. (Lepidoptera) visiting the pistillate inflorescence of *A. pedatum* (Kunth) Endl. ex Kunth (photo by Alistair Hay 2017, ca. Bitaco, Colombia); **B)** a species of satyriid butterfly (Satyriinae) visiting *A. vanderknaapii* Croat (photo by Alistair Hay 2017, ca. Bitaco, Colombia); **C)** dipterans visiting the pistillate inflorescence of a species in section *Cardiolonchium* ca. Mindo, Ecuador (© Rudy Gelis 2018: <https://www.inaturalist.org/observations/13681806>); **D)** large weevils copulating on a what appears to be a potentially florivored staminate inflorescence of an unknown species (© Roberto Sindaco 2018: <https://www.inaturalist.org/observations/9968039>); and **E)** mosquito visitors of a “flowering” spadix of a cultivated species of section *Pachyneurium* (© Zach Dufran 2017: <https://www.inaturalist.org/observations/5595393>).

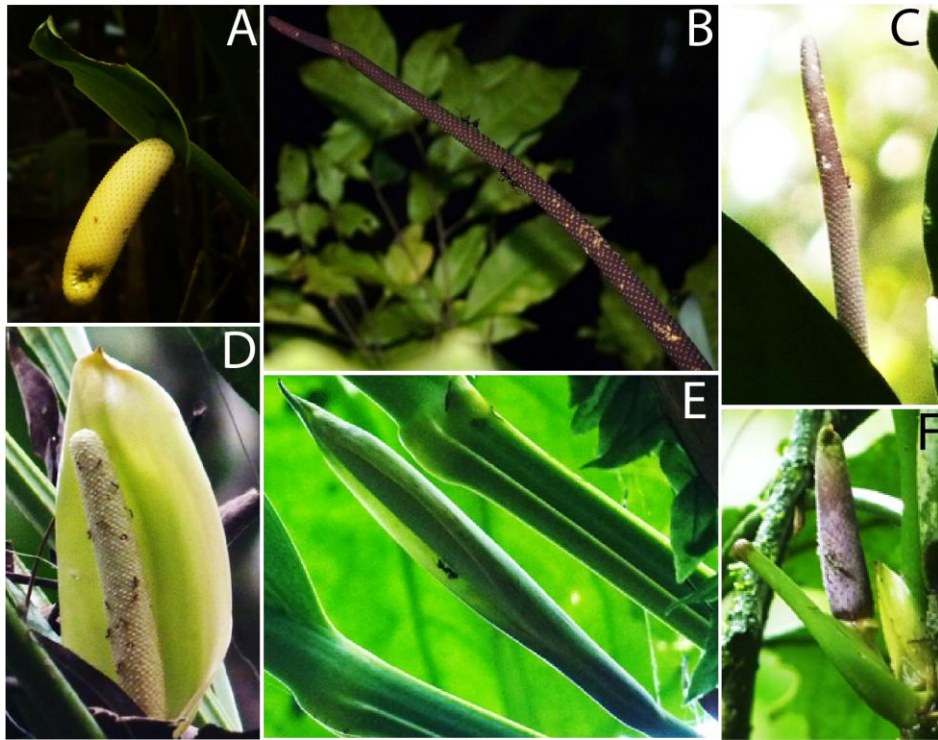


Figure 3: Six new observations of ant visitors. **A)** *Anthurium bradeanum* Croat & Grayum with several small ants visiting a pistillate spadix at La Selva Biological Station, Costa Rica, 2016; **B)** *A. tarapotense* Engl. with larger ants along the Río Huallaga outside of Tarapoto, Peru, 2017; **C)** *A. atropurpureum* with an ant at Reserva Florestal Adolpho Ducke in Amazonas, Brazil, 2017; **D)** *A. galactospadix* Croat with a multitude of ants seemingly foraging for the secretions coming out of the flowering spadix, Los Amigos Biological Station, Peru, 2017; and **E)** *A. galactospadix*, again but at an earlier point in anthesis, in a seasonally inundated forest around Tambopata Research Center, Peru, 2017; and **F)** *A. pentaphyllum* with a single, large ant visitor at La Selva Biological Station, Costa Rica, 2016.

3.2 Post-Anthesis Interactions

Unlike pollinators and floral visitors, no information has ever been synthesized for infructescence visitors, fruit consumers, or seed dispersers in *Anthurium*. Appendix 2 presents the first synthesis of this information, wherein any visitors that were observed interacting with a post-anthesis inflorescence (developing or developed infructescence) of *Anthurium* is recorded, whether the species is known or not (Appendix 2). Appendix 2 cites 41 references which documented a total of 87 post-anthesis biotic interactions, 52 of which occur with 15 known species of *Anthurium* from 8 sections of *Anthurium*. The 35 remaining interactions did not mention which species of *Anthurium* the interaction occurred with; however, 23 of these interactions (66%) had the zoological interactor identified to species. Interestingly, 35 of the 52 interactions with known *Anthurium* (67%) also had their zoological interactor identified to species, a proportion congruent with the known species of *Anthurium* with post-anthesis interactions, but a proportion much higher than what was recorded for known *Anthurium* species with known floral interactors (35%, Appendix 1) and known vegetative interactions (33%; Appendix 3).

Of the 52 post-anthesis interactions with known *Anthurium* species, only 9 interactions (17%) were assumed to not involve both fruit consumption and seed dispersal. However, of these 9 interactions, 7 are seed dispersal interactions by ants (Mayo et al. 1997; Marini-Filho 1999; Orivel & Dejean 1999; Youngsteadt et al. 2008;

Youngsteadt et al. 2010), and the remaining 2 interactions are new observations I made in my final season of field work (Appendix 2; Figure 3 A & B).

Interestingly, the three species of *Anthurium* with the most interactions observed were all species recognized for their propensities for polyploidy (Sheffer & Croat 1983), agamospermy (Madison 1979b) and tendency to occupy the forest canopy: *A. scandens* (16); *A. gracile* (10); and *A. harrisii* (7). For this reason, section *Tetraspermium* (*A. scandens* & *A. obtusum*) represents the section of *Anthurium* with the most observations of zoological taxa consuming and dispersing their seeds (20 observations; Appendix 2), followed by section *Leptanthurium* (10 observations), and section *Urospadix* (tentatively 9 observations; Appendix 2). Furthermore, in contrast to their top-ranking numbers of floral interaction observations (Appendix 1), sections *Calomystrium* and *Cardiolonchium* were the only sections of *Anthurium* represented in Appendix 2 by a single post-anthesis interactor (this considering that post-anthesis interactions have nearly half the number of sections of *Anthurium* represented by floral interactions).

As in the floral interactions, two genera tied for the highest number of zoological taxa visiting post-anthesis *Anthurium* infructescences, each with 5 species consuming fruits and dispersing seeds: the leaf-nosed bat genus *Sturnira* (Phyllostomidae) and the finch genus *Euphonia* (Fringillidae; Appendix 2). Over half of the 15 different species of *Anthurium* identified with post-anthesis interactions (8 species, 53%) were represented by a single visiting entity, with these ranging from flies, spiders, ants, birds, bats and

primates. (Appendix 2). The 6 remaining species of identified *Anthurium* (47%) were visited by multiple species (bats, birds, ants and less frequently primates). Lastly, it's perhaps worth noting that only one species (*A. scandens*) has been observed being dispersed by both birds and bats (Appendix 2). On that end, *A. gracile* is the only species known to be dispersed by birds and ants, and *A. harrisii* is the only species known to be dispersed by primates, opossums, and glass frogs (Appendix 2).

3.2.1 New Observations of Post-Anthesis Interactions

The only post-anthesis interactions not pertaining to fruit consumption and/or seed dispersal are represented by two new observations from my most recent field season (Appendix 2; Figure 4 **A** & **B**). Figure 4: **A** shows a large fly (Zoosubsection Calyptratae) visiting a post-anthesis spadix of *A. dombeyanum* in Peru that has young fruits developing, and Fig. 4: **B** shows spider webbing around the spadix of *A. atropurpureum* in Brazil. A formal post-anthesis study of biotic interactions in a natural population would be the first of its kind for *Anthurium* and would very likely shed new insights on this phase of *Anthurium* reproductive biology. While seed dispersal is a critical event in every plant's life history, and this importance is reflected by the vast majority of post-anthesis interaction listed in Appendix 2 citing seed dispersal (97%), what can end up being a long period of time between pollination and fruit maturation presents ample opportunities for biotic interactions to occur that remain unstudied.

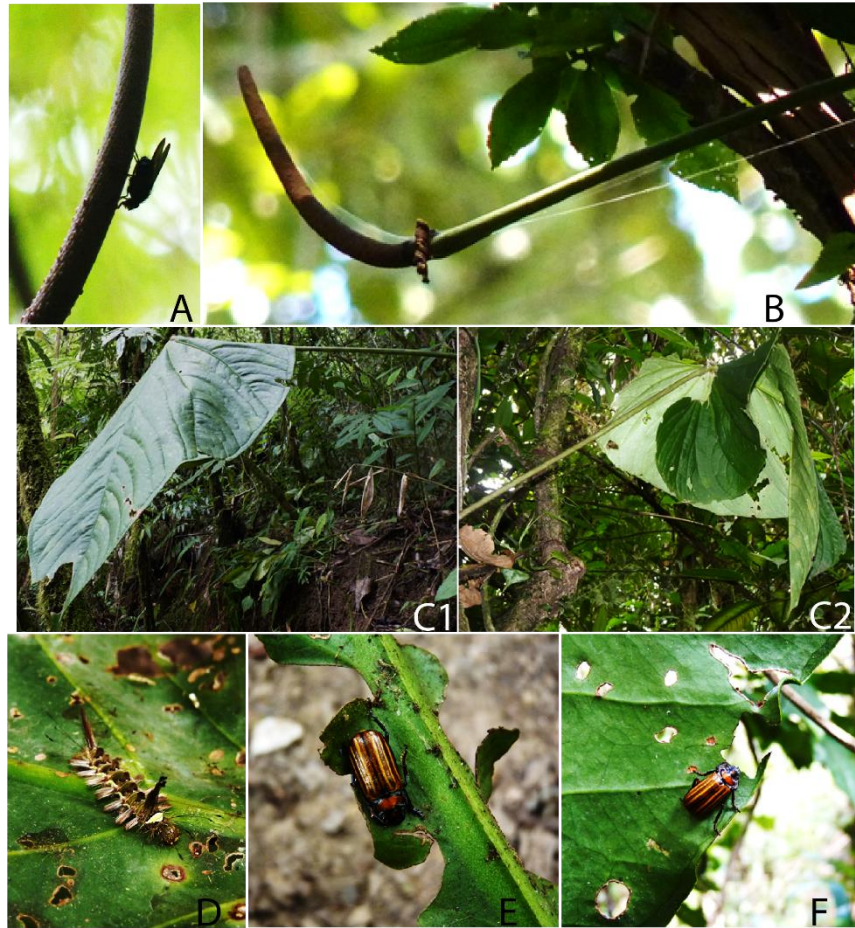


Figure 4: Two new post-anthesis interactions (**A & B**) and four discrete observations of new vegetative interactions in *Anthurium* (**C-F**). **A**) large fly (Schizophora : *Calyptratae*) visiting a young infructescence of *A. dombeyanum* Brongn. ex Schott seen at the San Pedro 1 transect along the Trocha Union in Manu National Park, Peru, 2017; **B**) cobwebs covering a post-anthesis spadix of *A. atropurpureum* R.E.Schult. & Maguire at Reserva Florestal Adolpho Ducke in Brazilian lowland rainforest, 2017; **C1 & C2**) two photos of the same leaf of an individual of *A. caperatum* Croat & R.A.Baker seen at Las Cruces Biological Station with herbivory damage indicative of bat roosting, circa San Vito, Costa Rica, 2016; **D**) the larvae of an erbid moth herbivorizing an *A. dombeyanum* in Yanachaga-Chemillén National Park, Peru, 2017; and **E & F**) two photos of two different individuals of the same scarab beetle species on two different individuals of *A. dombeyanum* in Yanachaga-Chemillén National Park, Peru, 2017.

3.3 Vegetative Interactions

With only 22 observations to date, vegetative interactions in *Anthurium* represent the category of biotic interactions considered herein with the fewest number of observations (Appendix 3). As was the case for post-anthesis interactions in *Anthurium*, no information has ever been synthesized for vegetative interactions in *Anthurium* (excluding ethnobotanical interactions; Plowman 1969; Croat 1994). Appendix 3 presents the first synthesis of this information, wherein any visitors that were observed interacting with vegetative tissues of *Anthurium* is recorded, whether the species is known or not (Appendix 3). Appendix 3 cites 18 references which documented a total of 22 vegetative interactions, 15 of which occur with 12 known species of *Anthurium* from 7 sections. The 7 remaining interactions did not mention which species of *Anthurium* the interaction occurred with; however, 6 of these interactions (85%) had the zoological interactor identified to species. Five of the 15 interactions with known *Anthurium* (33%) that had their zoological interactor identified to species, a proportion much lower than what was recorded for known *Anthurium* species with their post-anthesis interactors identified to species (67%, Appendix 2), yet similar to what was recorded for known *Anthurium* species with their floral interactors identified to species (35%, Appendix 1).

Of the 22 total vegetative interactions, 9 were related to either nesting by birds and bats or mating sites by birds and frogs (Appendix 3; Fig. 4: C), 7 observations evidenced herbivory by a variety of animals: thrips (Hara et al. 2002); tapirs (Vélez et al.

2017); woolly monkeys and spider monkeys (Dew 2005; Scherbaum & Estrada 2013); caterpillars (Green et al. 2011; Fig. 4: D); and beetles (Fig. 4: E & F). Two observations recorded oviposition by whiteflies into the leaves of cultivated plants; Paulson & Beardsley 1985; Malumphy 2011), and the 4 remaining vegetative interactions documented mycorrhizal associations with species from 4 different sections of *Anthurium* (Appendix 3).

3.3.1 New Observations of Vegetative Interactions

While ethnobotanical uses of a variety of *Anthurium* have been documented (Plowman 1969; Croat 1994), the paucity interactions of non-human animals with non-reproductive tissues presents plenty of opportunities for discovery. My field studies yielded three observations of new vegetative interactions in *Anthurium*, expanding the number of interactions with known species of *Anthurium* by 1/3 (Appendix 3; Fig 4: C–F). These new interactions include possible test roosting by new world bats on *A. caperatum* Croat & R.A. Baker (Fig. 4: C1 & C2), the second record of lepidopteran herbivory in the genus (Fig. 4: D), and the first evidence for beetle herbivory in the genus (Fig. 4: E & F).

3.4 Other Notable Findings

Photographic evidence for vivipary in *Anthurium* was encountered on the citizen science database iNaturalist.org © and the photograph is duplicated here with written permission from the observer (Fig. 5). As few observations or discussions on vivipary in *Anthurium* were encountered during this literature review, the inclusion of this observation seemed worthwhile.



Figure 5: Photographic evidence for vivipary in a natural *Anthurium* population in the Colombian Andes, encountered on the citizen science database iNaturalist.org © (<https://www.inaturalist.org/observations/10359805>). Image is duplicated here with written permission from the iNaturalist observer (© A. Meyer 2018).

4. Discussion

4.1 Floral Interactions

The 207 floral interactions in *Anthurium* presented in Appendix 1 represents a glance, at best, of the biotic interactions in *Anthurium*, however, this category of interactions, of the 3 considered herein, had the greatest number of observations.

Important contributors to the number of observations were studies that either focused on floral-visitors in Araceae (Gómez-Murillo & Cuartas-Hernández 2016) or specifically *Anthurium* (Kraemer & Schmitt 1999; Schwerdtfeger et al. 2002; Hentrich et al. 2007; Hentrich et al. 2010; and Guevara-Ibarra et al. 2017).

4.1.1 Floral Visitation

Hymenopterans are the most observed floral interactors in *Anthurium* to date with a total of 107 observations, representing over half (52%) of all observations in Appendix 1. This is perhaps unsurprising since bees have always been considered the primary pollen vectors for *Anthurium* (Williams & Dressler 1976; Croat 1980). However, only 4 of the 61 identified species of *Anthurium* in Appendix 1 were reported to be hymenopteran-pollinated, and the observations of pollination for half of these (2) are arguably anecdotal due to their lack of evidence (Williams & Dressler 1976; Dodson & Gentry 1978). Though the majority of hymenopteran interactions lacked detail beyond “visitor”, 4 observations were determined to be pollination events, another 4

observations were noted as “visitor of staminate inflorescence”, another 2 observations noted scent collection, and a final 2 observations noted pollen collection (Appendix 1).

Coleopterans were the next most observed group of floral interactors in *Anthurium* with a total of 34 observations, 6 of which were determined to be pollination events, another 4 noted “visitor of staminate inflorescence”, another 2 noted florivory, and a final observation noted “visitor of pistillate inflorescence” (Appendix 1). Diptera represented the third and final major group of floral interactors with a total of 26 observations, 7 of which noted “potential mating site”, another 4 of which noted “visitor of pistillate inflorescence”, and a final that noted a pollination event (Appendix 1). Collembolan, dermapteran, hemipteran, and thysanopteran interactions were only noted as visitations; presumably neutral interactions with little to no effects (beneficial or detrimental) to the plant.

Two points are perhaps worth mentioning here. The first is that Coleoptera, despite having less than a third of the observations as Hymenoptera, exhibited an equal diversity of floral interactions in *Anthurium* as Hymenoptera. Beetles may play a larger role significant life history events than what current circumscriptions of *Anthurium* floral biology might have us suspect (Franz 2003, 2007). The second is that unlike genera of the Aroideae whose flowers predominantly attract either scarab beetles (Scarabaeidae) and/or *Colocasiomyia* flies (Drosophilidae), coleopteran floral visitors in *Anthurium* are largely weevils (Curculionidae) and dipteran visitors are split between drosophilid and

cecidiomyiid flies (Appendix 1). Future efforts might investigate the potential significance of the taxonomic disparities between aroids and their coleopteran and dipteran floral visitors in the context of how potential differences in the behavior and morphology of the visitors reflects differences in the behavior and morphology between plants (*Anthurium* vs. Aroideae).

Snails and “small slugs” were noted by Knuth (1906) visiting the inflorescences of several cultivated *Anthurium* species. Therein he hypothesized a “malacophilous” pollination syndrome in aroids and other plants with “small flowers...crowded together at the same level” (Knuth 1906, p. 78; Appendix 1). Interestingly, in their documentation of snail pollination in the bindweed *Volvuopsis nummularium* (L.) Roberty (Convolvulaceae), Sarma et al. (2007) claim malacophily to have been documented previously in 7 other flowering plants, 3 of which were aroids: *Calla palustris* L., *Lemna minor* L., and *Philodendron pinnatifidum* (Jacq.) Schott. Sarma et al. (2007) cite two sources for these three aroid observations, though malacophily was not confirmed in either study for any of these aroids (McGregor 1976; Pammel and King 1976), for which alternative modes of reproduction are known or generally accepted (Mayo et al. 1997). While floral visitation by gastros is not uncommon in flowering plants (Suetsugu & Sueyoshi 2018), evidence for malacophily in *Anthurium* is non-existent (Gibernau 2003, 2011) and increasingly diminishing for flowering plants in general (Vislobokov 2017).

Though recognized as floral visitors, species in these three insect orders are typically not identified as pollinators in flowering plants, or suspected to be (Darwin 1876; Conran & Bradbury 2007; Gómez et al. 2014; Vislobokov et al. 2014). Of the three, thysanoptera have received the most support as pollinators in at least some Ericaceae and Monimiaceae (Williams et al. 2001; Eliyahu et al. 2015). Additional investigations into thrip and whitefly floral visitation in *Anthurium* are perhaps not necessarily warranted, but certainly not discouraged.

Two observations of hemipteran floral interactions were documented in *Anthurium* by Franz (2007) and Gómez-Murillo & Cuartas-Hernández (2016), however no mention of florivory, pollination, or any aspect of the nature of the interactions were made and the nature of these interactions remains unclear. Some Hemiptera, notably the aroid specialist *Crenidorsum aroidephagus*, a neotropical whitefly named for their detriment to the aroid horticultural industry, are pests of *Anthurium* known to oviposit on the abaxial leaf surfaces of cultivated *A. andraeanum* (Martin et al. 2001; Martin 2005; also see Paulson & Beardsley 1985). Hemiptera are also known pests in *Spathiphyllum* (Villalobos Muller et al. 2010; Li et al. 2011), potential florivores of *Dieffenbachia* (Young 1986; Etl et al. 2016), phloem feeders in *Thaumatococcus* (Francis et al. 2016), and acknowledged floral visitors in other aroid genera (*Syngonium*, Beath 1998; *Xanthosoma*, García-Robledo et al. 2005; Fig. 6). The lack of evidence in favor of hemipteran pollinator events (Young 1986; Beath 1998; Franz 2007) and known

occurrence of “host plant” interactions (interpreted as herbivory, florivory and/or oviposition) by mirid plant bugs in several aroids (Konstantinov & Knyshev 2015; Pan et al. 2015; Etl et al. 2016; Namyatova & Cassis 2016) might suggest that the Hemiptera referenced in Appendix 1 have a greater probability of representing instances of parasitism (oviposition) or florivory/herbivory than pollination events; however, more work is needed to confirm or deny the significance of these interactions in *Anthurium*.

The two butterfly (Nymphalidae) contributions by Alistair Hay (Fig. 2: **A & B**) almost doubled the number of observation of lepidopteran visitation in *Anthurium* (Hartley et al. 2017). Lepidopteran visitation now occurs more broadly throughout the genus but its significance (e.g., a role in pollination, consumption of floral rewards or floral tissues, etc.) remains unknown. Investigations into these interactions are again warranted, particularly with an emphasis on nocturnal interactions to explore the prevalence of moth visitation, as well as any pieces of evidence for potential pollination mechanisms.

One subsequent observation of hummingbird visitation in *Anthurium* has been evidenced since Kraemer & Schmitt (1999) first documented the pollination of *A. sanguineum* Engl. by in 8 species of hummingbirds (see Calderón 2017 in Appendix 1). Salaman (1996) documented visitation of a cultivated *A. andraeanum* by the violet-tailed sylph (*Agelaiocercus coelestis*), however this observation might not have been included in previous reviews of aroid visitors because the hummingbird was merely seen “resting”

on the inflorescence (Salaman 1996; Appendix 2). Similarly, the omission of Kraemer & Schmitt's (1999) observations of floral visitation in *A. sanguineum* by the tanagers *Diglossa albilatera* and *Anisognathus flavinucha* (Passeriformes: Thraupidae) from previous reviews of floral interactions (Gibernau 2003, 2011) might have been because of the lack of evidence for pollination (Kraemer & Schmitt 1999).

Though pollination in *A. sanguineum* has been proposed to occur via pollen deposition onto the bills of the various hummingbirds (Kraemer & Schmitt), details on the feeding behavior still await description in the literature. Personal communications with the iNaturalist.org © observer of the image in Fig. 2: C led to their recollection of seeing this feeding behavior exhibited by a tourmaline sunangel (*Heliangelus exortis*, Trochilidae) several times over the course of a week on single mountain in Ecuador (@rudygelis, pers. comm.). They describe how a single hummingbird “perches and runs its bill up and down the spadix, like the motion of a knife being run up and down a sharpener”, a colorful description for lack of a colorful photograph. The new observation of this phenomenon and the addition of two previously overlooked interactions have expanded the diversity of avian floral visitors in *Anthurum* to include another order and the geographic range of this phenomenon to occur within another country (Appendix 1). New observations seem likely to change our understanding of this phenomenon at this point and are encouraged to be pursued.

Though certainly more frequent visitors than shown in Figure 3, prior to my field work, no evidence or discussion of ant visitation in *Anthurium* appears to have circulated into the literature (Appendix 1). With pollination easily ruled out as a potential interaction, the nature of these visitations might otherwise seem negligible and not worth reporting (Appendix 1). Are these interactions simply “visitations” that are truly insignificant to both organisms involved?

Notes from an herbarium specimen (*Gentry et al. 61651, 1988*) of *Anthurium loretense* Croat, a species of litter-trapping *Anthurium* (section *Pachyneurium*; Croat 1991), from Loreto, Peru state that the plants are “obligately associated with *Paraponera* ant nests” (Appendix 2). Furthermore, a litter-trapping aroid *Philodendron insigne* was shown to engage in a sort of mutualism with *Odontomachus* ants in French Guiana (Gibernau et al. 2007). Therein the authors hypothesize a relationship where ants establish nests among the roots of a previously-established *P. insigne* where they then protect the plant from potential herbivores in return for sugary secretions from the plant’s extrafloral nectaries (Gibernau et al. 2007).

A similar relationship is easy to imagine for litter-trapping *Anthurium* in section *Pachyneurium*, a group for which floral visitation by ants has been observed in lowland forests across the neotropics (Fig. 3: A–E), especially in light of Gentry’s herbarium label notes. Several species of section *Pachyneurium* are known for dramatic stigmatic secretions for part of or throughout anthesis (Hartley et al. 2017). Stigmatic secretions in

ant-associated species of *Pachyneurium* could represent an alternative medium to extrafloral nectaries for reward distribution in a genus from which extrafloral nectaries have not been confirmed to occur (Mayo et al. 1997, p. 22).

As a significant proportion of *Anthurium* individuals in Amazonia are represented by species in section *Pachyneurium* (Hartley 2017, personal observation), additional investigations into the existence and extent of this relationship might prove fruitful. If any evidence supporting the existence of this type of relationship is found to exist, the idea that these plants might also be benefitting nutritionally from allochthonous organic matter brought in by ants to construct their nests in and around the roots of these epiphytes (Madison 1979b).

I observed hundreds of *Pachyneurium* throughout the Amazon in 2017 though very few were flowering and none bearing fruit. The individuals that were reliably flowering (though few and far between) were usually large individuals with “bird’s nests” filled with organic debris, growing in areas where an accumulation of canopy debris would seem ideal (Fig. 3: C, D & E). Optimistically, if germination in these plants were to occur in a less-than-ideal location for organic matter interception from the forest canopy, these litter-trapping *Anthurium* would presumably benefit from hosting ants that bring in nutrients from afar and amass them around their roots.

This hypothetical mutualism is confounded by the sixth observation of floral visitation by ants (Fig. 3: F); however, as *Anthurium pentaphyllum* is a hemiepiphyte in a

totally unrelated section (*Dactylophyllium* sensu Carlse & Croat 2013) with no apparent adaptations for ant interactions. While ant visitation may turn out to be insignificant in *Anthurium* life history and entirely stochastic, additional investigations into these interactions are highly recommended.

4.1.2 Floral Rewards

In a recent study on the evolution of pollinator interactions within the Araceae, *Anthurium* was diagnosed as engaging in a rewarding mutualism with its pollinators (Chartier et al. 2014). Therein, rewarding mutualisms in Araceae were defined as interactions wherein the plants produce pollinator rewards (e.g., stigmatic exudates, small amounts of nectar, or fragrant oils). Contrary to anecdotal claims that rewarding mutualisms are derived in Araceae (Miyake 2005), Chartier et al. (2014) explicitly inferred rewarding mutualisms to be the ancestral pollinator interaction for the family using Bayesian stochastic trait mapping. Though the authors acknowledged the limitations imposed by their sample size, one of their key findings showed that unlike in orchids where switches between deceptive and rewarding pollinator types are frequent (Johnson et al. 2103), shifts between these interaction types in Araceae are much rarer (Chartier et al. 2014). While the recent description of a novel pollination syndrome involving *Anthurium acutifolium* Engl. (Etl et al. 2017) reaffirms the presence of rewarding mutualisms in *Anthurium* floral biology, recent field observations recognizing the potential role of intersexual mimicry in *Anthurium*-pollinator interactions (Guevara-

Ibarra et al. 2017, Appendix 1; Hartley et al. 2017) warrants more field work to investigate the potential existence of alternative pollinator interaction types in *Anthurium*.

Observations on this form of floral rewards was rarely encountered during this literature review, however, a summary of the subject in *Anthurium* is discussed by Hartley et al. (2017) and are elaborated on in the Ant discussion above. Perhaps one of the most detailed studies of secretions in *Anthurium* to date was by Etl et al. (2017) who found that the exclusive and effective pollinator of a population of *A. acutifolium* in Costa Rica had specialized structures to collect oil secretions from the spadix as an inferred floral reward (Etl et al. 2017). Additional studies like this will undoubtedly lead to more novel discoveries and continue contributing to our understanding of this poorly known aspect of *Anthurium* floral biology. The potential for a mutualism to exist facultatively between ants and *Anthurium* mediated by floral secretions and nest building appears obvious and deserves immediate attention.

4.1.3 Florivory

Although florivory is a well-known and adequately studied phenomenon in genera of the Aroideae, florivory in aroids with tepals and perfect flowers is far less frequently documented. Franz (2007) observed florivory of the pollen, tepals and pistils as a part of the pollination interaction between *Anthurium formosum* Schott (section *Calomystrum*) and the weevil *Cyclanthura carinata*. Though this was the only reference

found that discussed observing this type of floral interaction, he implied the phenomenon to be an integral part of the *Anthurium*–*Cyclanthura* pollination interaction, which he concluded was likely more widespread than is currently acknowledged. This interaction, and other mentioned by Franz (2003 & 2007) but not yet observed in wild plants (e.g., oviposition) are certainly associated with the life history tradeoffs, and the outcomes of these tradeoffs are contingent upon a myriad of factors, such as whether these *Cyclanthura* herbivorize more pollen, more tepals, or more pistils (Franz 2007). Additional studies like Franz (2007) will contribute tremendously to our understanding of florivory in *Anthurium* and additional observations will likely be new.

Although no observations of oviposition by *Cyclanthura carinata* into the flowers of *A. formosum* were confirmed in his detailed study of these species' interactions, Franz (2007) determined that some female visitors "appeared to be preparing for oviposition" and concluded that *Cyclanthura* beetles are "likely to oviposit into the flowers" (Franz 2007). Figure 2: D is noteworthy in that it depicts two large curculionid beetles that were copulating on a staminate spadix that is evenly pinkish-red in color except for four dark spots, three of which were close to the weevils at the time of capture. While it seems likely that these weevils at least "florivorized" the inflorescence, the image's inability to prove florivory, let alone floral oviposition, leaves this phenomenon currently unobserved in *Anthurium* despite having been adequately observed in several genera of Aroideae by flies, beetles and wasps (Tsacas & Chassagnard 1992; Patt et. al. 1995;

Gibernau 2002; García-Robledo et al. 2004; Sultana et al. 2006; Toda & Lakim 2011, Takano et al. 2012; Maia et al. 2013; Hoe et al. 2016; Hoe et al. 2018; Wendt et al. 2018).

As with observations of floral visitation and floral rewards, observations of florivory and floral oviposition in natural *Anthurium* populations are critically needed. The possibility of floral oviposition by hemipterans deserves attention, and investigations into the intricacies and consequences of in situ *Anthurium*–*Cyclanthura* interactions might present interesting lines of research within aroid biology.

4.2 Post-Anthetic Interactions

As with the floral and vegetative interactions referenced herein, the 87 post-anthesis interactions in *Anthurium* in Appendix 2 likely represent a snapshot of the diversity of interactions that occur in post-anthetic *Anthurium* infructescences. Unfortunately, beyond fruit consumption and seed dispersal—a critical life history event for all plants—little is known about biotic interactions in *Anthurium* infructescences. Studies focused on the diets of birds and bats and seed dispersal systems were the largest contributors of post-anthetic interactions in *Anthurium* (Snow & Snow 1971; Gorchoy 1995; Loiselle 2007; Lobova et al. 2009).

4.2.1 Fruit Consumption & Seed Dispersal

Passerine birds (Passeriformes) and bats (Chiroptera) constitute the most frequently observed post-anthesis interactors (consumption & dispersal) in *Anthurium* to date (34 and 26 observations, respectively) with ants (dispersal only) coming in as a

distant third. Although observed far less frequently observed, fruit consumption and seed dispersal in *Anthurium* has been recorded in tree frogs, big-eared opossums, gracile opossums, mouse opossums, trogons, spider monkeys, woolly spider monkeys and woolly monkeys (Appendix 2).

Within passerines, manakins (Pipridae) were those most frequently observed family of consumers/dispersers (12 observations) with 8 different species dispersing 5 species of *Anthurium*, each of a different section (Appendix 2). Five different species of tanagers (Thraupidae) and finches (Fringillidae) were observed in a total 17 discrete dispersal interactions; however, these 10 bird species were only observed consuming the fruits of *A. gracile* (Rudge) Lindl. and *A. scandens* (Aubl.) Engl., two widespread species of *Anthurium* thought to be agamospermous, the former of which is also dispersed by ants (Appendix 2).

Only 6 of the 26 chiropteran observations provided species identifications for both species pairs: 6 bat species representing 3 genera of leaf-nosed bats (Phyllostomidae) were observed dispersing the fruits/seeds of 2 *Anthurium* species from 2 different sections (Appendix 2). The bat genera *Carollia* and *Sturnira* were the most observed, with six observation each nearly equaling half of the total chiropteran interactions. Of the 10 observations with the 5 species of bat-dispersed *Anthurium*, half were observations of *A. obtusum* (Engl.) Grayum in “central French Guiana” (Lobova et al. 2009).

Seed dispersal by ants (Formicidae) has been well-studied in Amazonian ant-garden plant species, and in *Anthurium gracile* (Rudge) Lindl. this interaction was shown to be mediated by chemicals produced by the seeds (Youngsteadt et al. 2008, 2010). Similar chemicals with similar effects could be found in the seeds of *Anthurium ernestii* Engl., a member of section *Pachyneurium* reported to be dispersed by ants (Ule 1905; Mayo et al. 1997). Ants are frequent visitors of anthetic inflorescences among species in section *Pachyneurium* and anecdotal observations suggest the possibility for a type of mutualism to exist between ants and various *Pachyneurium* (see Ants discussion in Floral Visitors).

Observations of fruit consumption only exist for vertebrates though the potential for insect larvae to be oviposited into the ovules, tepals, or stamens at anthesis, and for those larvae to then develop inside the infructescence and consume parts of it isn't unthinkable because of similar observations in other aroids (García-Robledo et al. 2004; Takano et al. 2012).

4.2.2 Other Post-Anthesis Interactions

The only two post-anthesis observations unrelated to fruit consumption and seed dispersal were represented by two of my field observations (Fig. 4: A & B). The visitation of a calyptrate muscoid fly to a post-anthesis spadix of *A. dombeyanum* was noted repeatedly during my short time (15 minutes) at the site (Appendix 2), but this might be completely inconsequential (Fig. 4: A). It could also represent a potential

attempt at fruit oviposition, a phenomenon apparently unknown in *Anthurium* (Appendix 2). While floral oviposition is a well-documented phenomenon (see Gibernau et al. 2002), oviposition into aroid fruit (or ovules at any point post-anthesis) appears to only be known from the Asiatic fruit fly (*Drosophila suzukii*), an invasive drosophilid with a broad potential niche that it has been recently exploring and expanding in to (Lee et al. 2015; Poyet et al. 2015). Documented in at least two aroids (the forest dwelling *Arisaema triphyllum* and *Arum maculatum*), oviposition by *D. suzukii* is presumed to occur once the fruits have begun ripening and the spathe has dehisced such that the flies can access the fruit (Lee et al. 2015; Poyet et al. 2015). To that end, Gibernau et al. (2002) observed chalcid wasps ovipositing into the ovules of *Philodendron solimoesense* through the spathe, proving that at least to some hymenopteran ovipositors of the Aroideae aren't deterred by the subfamily's characteristically (semi-)persistent around the developing fruits. Nevertheless, nothing but speculations can be made about this observation (Fig. 3) and fruit oviposition in *Anthurium* (and aroids in general) until additional observations are made.

The significance of the cobweb is debateable, if anything, the spider (unbeknownst to the *Anthurium*) might be ensnaring and consuming potential vectors, herbivores or parasites.

4.3 Vegetative Interactions

Vegetative interactors in *Anthurium* were diverse despite so few observations (22), perhaps because of the greater number of ways animals interact with vegetative plant tissues vs. reproductive tissues (Appendix 3).

4.3.1 Nesting, Roosting and Mating Sites

These interactions present the most common type of vegetative interaction, thanks to the detailed work of botanists, chiroptologists, herpetologists and ornithologists (8 total; Appendix 3). It's worth noting that tent roosting by bats in known species of *Anthurium* occur in species with prominent posterior lobes (Appendix 3). Bats are known to structurally compromise the posterior ribs of *Anthurium* such that they hang down and create a suitable roosting area (Fig. 4: C1 & C2). Though seemingly more passive than bat roosting, another interesting observation showed male individuals of *Hyalinobatrachium aureoguttatum*, a species of glass frog, perched on the leaves of an *Anthruium*, from where they vocalized, mated, and attended their clutch (Valencia-Aguilar et al. 2012).

Perhaps the most ironic interaction found involved with nesting of the sickled-winged guan (a large, beautiful bird) within several individuals of *Anthurium glaucospadix* (a large, beautiful species of "bird's nest anthurium" in section *Pachyneurium*; Londoño et al. 2007). Known colloquially as bird's nest anthurium because of the likeness between a mature *Pachyneurium* and an archetypical bird's nest,

this study showed that this common name has significance both literally and interpretatively for species in section *Pachyneurium*.

4.3.2 Herbivory

Though observations are scarce (7 total; Appendix 3), the diversity of animals that consume vegetative organs of a variety of *Anthurium* species suggests that *Anthurium* are not unlikely food items to herbivorous fauna throughout their range. Herbivory in *Anthurium* is perhaps more likely in comparison to other neotropical aroid genera (i.e., *Dieffenbachia*, *Philodendron*, *Syngonium* and *Xanthosoma*) whose vegetative tissues are imbued with latex, terpene-rich resin, and other chemicals that presumably deter herbivores, whether intentional or not (Mayo et al. 1997; Darling et al. 2007). The accounts of herbivory in Appendix 3 represent an inconsequential fragment of the total number of *Anthurium*-herbivore interactions that continually operate and collectively contribute stochasticity and complexity to the evolution and diversification of this megagenus.

4.3.3 Oviposition

While oviposition has been definitively observed in the flowers and fruit of other genera (see discussions on Floral Oviposition and Other Post-Anthesis Interactions), and has been deemed “likely” to occur in the flowers of various Costa Rican *Anthurium* (Franz 2007), the report of oviposition by *Crenidorsum aroidephagus*, an aroid herbivore

specialist (Martin 2001, 2005), into the leaves of *A. andraeanum* is an interaction known only from cultivated plants (Appendix 3).

Interestingly, Araceae are known for their production of mannose-binding lectins, a group of glycoproteins shown function as energy storage macromolecules in the corms and stems of numerous aroids (van Damme et al. 1995). The recognition of some lectins as broad-spectrum, enzyme-inhibiting, insecticides intrigued researchers to the point where transgenic tobacco (*Nicotiana tabacum* L., Solanaceae) were made with a gene associated with lectin production (*pta*) in the aroid *Pinellia ternata* (Thunb.) Makino. These transgenic tobacco were shown to significantly reduce the growth rates of hemipteran herbivores, lepidopteran herbivores, bacteria and viruses (Jin, Zhang & Daniell 2012). The apparent spectrum-wide anti-biotic activity of aroid lectins (at least *pta*) could make the study of vegetative interactions in aroids even more interesting (Darling 2007), and the case of the specialist aroid ovipositor (Martin 2001, 2005) potentially even more curious. In situ observations of vegetative oviposition in *Anthurium* are critical to begin understanding the diversity and implications of these interactions, and a comparative biochemical investigation of lectin production and function in the Araceae could prove to be a rewarding endeavor.

4.3.4 Mycorrhizal Associations

While *A. andraeanum* have been exposed to mycorrhizae in studies seeking to optimize horticultural growth (Stancato & da Silveira 2006), mycorrhizal associations in

naturally occurring *Anthurium* have scarcely been observed or discussed (Simmonds 1950; Rains et al. 2003; Appendix 3). Simmonds (1950) suggested that for at least one species of litter-trapping species, *Anthurium hookeri* Kunth, mycorrhizal associations might be facultative. The distribution of observations of mycorrhizal association in four different species from four different sections of *Anthurium* suggests that these associations, while perhaps not as strong as those in orchids, are potentially widespread throughout the genus (Appendix 3). As major contributors to neotropical epiphyte biomass and biodiversity, understanding mycorrhizal interactions in *Anthurium* would contribute to the refinement of our understanding of water and nutrient cycling in ecosystems with some of the highest turnover rates on the planet (Wang et al. 2018).

4.4 Abiotic Phenomenon in Anthurium

Not the primary focus of this study but briefly discussed below to acknowledge the various pieces of evidence that argue for their potential role in the evolution and diversification of this genus.

4.4.1 Agamospermy

Although some, if not most, species of *Anthurium* studied appear to be reliant on out-crossing events for fruit and seed development (Croat 1980; Franz 2007; Hentrich et al. 2010; Etl et al. 2017), several species, especially *A. bakeri* Hook.f., are known for their ability to self-fertilize (Croat 1980; Mayo et al. 1997). Agamospermy in flowering plants has been said to be exclusive of polyploid individuals (Noyes & Rieseberg 2000), yet

chromosomal surveys of *Anthurium* suggest that $2n=30$, the diploid number of *A. bakeri* (Sheffer & Kamemoto 1976), is the most common diploid number in the genus (Sheffer & Kamemoto 1976; Sheffer & Croat 1983). Furthermore, in his revision of the aroid genus *Monstera*, Madison (1977b) determined that the genus, despite its own taxonomic difficulties, was unlikely to suffer from agamospermy, which “bedevils [the] classification of other aroids, notably *Anthurium*” (p. 15). Self-fertilization in *Anthurium* remains an acknowledged phenomenon yet no study or review of agamospermy in *Anthurium* has ever been conducted. The role of agamospermy in the evolution of *Anthurium* is unlikely to be minor yet all we have now is anecdotal observations and speculations.

4.4.2 Anemophily

Cited by Gibernau (2003) as a potential instance of wind pollination (anemophily) in the Araceae, the article on the reproductive biology in *Anthurium scandens* (Aubl.) Engl. by Valerio & Villalobos (1980) pushed several ideas in favor of abiotic gamete and diaspore dispersal in this common and widespread species. First, they noted that gametes from different flowers of the same spadix were compatible, and inferred that the flowers between inflorescences of the same plant would also be. They also noted that diaspore dispersal by birds was not necessary because of the seed coat’s viscosity and ability to adhere to surfaces, and the seed’s ability to germinate in most neotropical settings—even within their own berries (an instance of pseudovivipary sensu

Elmqvist & 1996 if agamospermy assumed). Finally, they postulate that the large stigmatic droplets produced during pistillate anthesis might function similarly to the pollination droplets of anemophilous gymnosperms (Jin et al. 2012).

As their study plants were reportedly grown in a laboratory, it's not clear how feasible anemophily would have been in their experimental setting. Moreover, *A. scandens* presents long-standing polyploid complex (Sheffer & Croat 1983), information whose significance might have been unknown or unsuspecting at the time of study (Valerio & Villalobos 1980). Although further taxonomic work is needed in and around this taxon (Sheffer et al. 1980), the propensity for polyploidy in this species and the propensity for polyploids to be agamospermous weakens the argument for anemophily in *A. scandens* though does not rule it out.

4.4.3 Vivipary

The distribution of vivipary in the Araceae has only ever been cursorily reviewed in the published literature and has never been a subject of great study or debate (Valerio & Villalobos 1980; Elmqvist & Cox 1996; Mayo et al. 1997; Farnsworth 2000). In his discussion on vascular epiphytes, Madison (1977) attributes the occurrence of vivipary in tropical aroids to their nondormancy, stating that these plants grow continuously and germinate as conditions suit, whether having been translocated from the parental infructescence or not. While vivipary in the loose sense has been associated with a lack of dormancy, pseudovivipary, wherein asexually generated plantlets grow on the parent

plant, is common among plants occurring at high altitudes (Elmqvist & Cox 1996). It is worth noting that the photo in Fig. 5 was taken at 2500 meters above sea level in montane rainforest in the Colombian Andes and represents perhaps the first piece of evidence for vivipary in *Anthurium*.

Whether the seedlings shown in Fig. 5 are the product of true vivipary or pseudovivipary (sensu Elmqvist & Cox 1996) cannot be known; however, because agamospermy is known to occur within *Anthurium* (Madison 1979a) and the true vivipary is most common in tropical plants of shallow marine environments, we might expect the seedlings in Fig. 5 to be the product of agamospermy and subsequent germination (pseudovivipary sensu Elmqvist & Cox 1996). However, these seedlings could just as easily be example of true vivipary and this photograph could evidence our limited understanding of the diversity of plant life cycles and their reproductive strategies.

Regardless of the genetic origins behind these viviparous seedlings, vivipary immediately affects dispersal of these organisms, limiting successful dispersal events to abiotic dispersal agents (Elmqvist & Cox 1996). Studies in Cactaceae, another group of neotropical epiphytes which exhibit vivipary (Madison 1977a), have indicated that the origin of vivipary in this clade facilitates germination and survival rates while maintaining local population levels via short-distance dispersal (Cota-Sánchez 2004; Cota-Sánchez & Abreu 2007). Future investigations into *Anthurium* speciation events

and population genetics should consider the dispersal implications associated with vivipary as well as the genetic implications associated with the different forms of vivipary.

5. Future Directions

Below are short discussions on several interesting facets of *Anthurium* biology that I've given some thought to and feel deserve much more attention than they've been given to date.

5.1 Floral Odors

Although it is beyond the scope of this paper to review the species of *Anthurium* that produce floral rewards and the species that have had their oils and exudates chemically characterized, three independent studies of *Anthurium* floral biology corroborate the findings of a genus wide survey of fragrance quality and emission (Kuanprasert & Kuehnle 1999) wherein no correlation was shown to exist between floral odor, inflorescence color, or sectional classification in *Anthurium*. While these studies are all hindered by small samples sizes and limited taxonomic breadth, they reveal the potential importance of chemical volatile diversity and pollinator identity in the diversification of the genus that are worth discussing.

The first of these studies was conducted by Croat (1980) wherein characters of the flowering sequences of 23 cultivated *Anthurium* species were recorded. Here he noted the remarkable plasticity in the duration of the flowering sequence, the origin and progression of the flowering sequence along the spadix, the colors of the spadix and pollen, and floral scent (Croat 1980). Although Croat's ex situ observations were not discussed in a phylogenetic context, when considered in such a context (Carlsen & Croat

2013) it becomes clear that presumably important floral traits, such as spadix color and perceived floral odor, are uncorrelated between and within sections and therefore do not appear phylogenetically conserved. However, the ex situ nature of these observations, and the comparatively few number of them, precludes discussion here on how these floral traits might correspond to visitor pollination identity throughout the genus.

In a subsequent analysis, Schwerdtfeger et al. (2002) described the chemical composition of the floral odors emitted from eight different *Anthurium* species ex situ and compared their chemical profiles to the published profiles of other plants with known pollinators to infer which pollinators might interact with each *Anthurium* species. Interestingly, the three species with fruity floral odors and profiles enriched with lipid-derived compounds that were proposed to be pollinated by fruit flies (Drosophilidae) tentatively belong to three different sections of *Anthurium* (sensu Carlsen & Croat 2013). In contrast, of the five species proposed to be pollinated by euglossine bees (Tribe *Euglossini*), the four with chemical profiles dominated by terpenes all belong to section *Calomystrium* (*A. antioquiense* Engl., *A. armeniense* Croat, *A. huixtlense* Matuda, and *A. nymphaeifolium* K.Koch & C.D.Bouché) while the fifth, *Anthurium apoporatum* R.E.Schult. in section *Porphyrochitonium*, had a ketone-dominated profile. Although this study also suffers from a small sample size, two contrasting hypotheses are illustrated in Schwerdtfeger et al.'s (2002) survey: one in which the production of lipid-derived compounds during anthesis and potential for drosophilid pollination appears to have

evolved independently at least three times, and another in which terpene production during anthesis appears to be phylogenetically conserved in *Calomystrium*—one of the few sections retained as monophyletic in the most recent phylogenetic analysis of the genus (Carlsen & Croat 2013).

The third investigation of *Anthurium* floral odors was conducted by Hentrich *et al.* (2010) who compared the anthecologies of three sympatric aroids with bisexual spadices in French Guiana (two *Anthurium* and one *Spathiphyllum*). As pollinator interactions in *Spathiphyllum* have long been considered analogous to *Anthurium* because of their similar floral morphologies and chemistries (Williams & Dressler 1976), the overall physical similarity of their inflorescences, chemical profiles and inflorescence visitors (predominantly *Euglossini*) were perhaps to be expected (Williams Dressler 1976; Hentrich *et al.* 2010); however, interspecific differences were detected. For example, both species of *Anthurium* had a greater diversity of (potentially synapomorphic) floral chemistries identified from GC/MS analysis compared to the *Spathiphyllum*, and all three species were observed with nearly exclusive visitor assemblages despite their overlap in spatial occurrence and flowering time throughout the year (Hentrich *et al.* 2010). Pollination for each species was considered highly efficient because of the degree of visitor specificity observed for each species, even between the two *Anthurium* (Hentrich *et al.* 2010).

Despite their small sample size, the Hentrich et al. (2010) study was distinct in that it was conducted in situ, providing a relevant ecological context for their observations. Because of this, their results perhaps provide the strong set of evidence for an interspecific reproductive isolating mechanism in *Anthurium* via floral odors than any study before it, or since (Hentrich et al. 2010). It's worth noting that the two species of *Anthurium* studied here belong to two different sections (*A. sagittatum* in section *Cardiolonchium* and *A. thrinax* in section *Dactylophyllum*; sensu Croat & Sheffer 1983) and are potentially disparately related (sensu Carlsen & Croat 2013). In that context, it's not hard to surmise why these two species might have nonidentical floral chemistries, but in the context of the diversity of inflorescences, anthecologies and floral visitors known from other species in sections *Dactylophyllum* and *Cardiolonchium* (let alone the sliver of diversity represented in Appendix 1), the floral biologies of these sympatric species could appear convergent.

This pattern is partly repeated by Croat (2014) in his review of black-spathed *Anthurium* (antúrios negros). Croat (2014) mentioned the concentrated occurrence of black-spathed *Anthurium* in Colombia and highlighted that these black-spathed species were comprised of representatives from four different sections of *Anthurium* (*Belolonchium*, *Calomystrium*, *Cardiolonchium* and *Pachyneurium*). Although no discussion on this potentially distinctive example of floral convergence in *Anthurium* was provided, the similarity in spathe pigmentation and floral odor (described as “raw fish” and

“fermented oranges” in some species) reinforce the findings of Hentrich et al. (2010) wherein two or more species from two or more sections of *Anthurium* in a certain geographic region exhibit may some degree of similarity in floral chemistry and floral visitors.

Hoe et al. (2016) partially reproduced this pattern in *Homalomena* section *Cyrtocladon* despite the lack of evidence for a strong reproductive barrier between sympatric congeneric species. Here they noted that despite differences in floral odor compositions produced by their 7 focal taxa, the same insect assemblage visited the flowers of all 7 species, concluding that the production of one or two volatile organic compounds must be sufficient for luring cyclocephaline beetle pollinators (Hoe et al. 2016). Interestingly, a similar conclusion was reached in a coevolutionary study of araceous floral odors and pollinator preferences (Schiestl & Dötterl 2012). Therein Schiestl & Dötterl (2012) state that the propensity for aroids to attract scarab beetles is not an artifact of coevolution but rather of the result of floral odor convergence mediated by the scarab pollinators’ chemical preferences, which are thought to have evolved millions of years before the plants themselves (Schiestl & Dötterl 2012).

It’s worth repeating here that although no observations of floral odors were noted in his study, Franz (2007) concluded that because three different species of “largely unrelated” *Anthurium* were pollinated by the same derelomine weevil (*Cyclanthura carinata*) that their “reproductive cohesion...must be achieved by

mechanisms complementing those provided by their pollinating agents” (Franz 2007 p. 275).

While the real diversity of floral interactions in *Anthurium* and the mechanisms through which this diversity arose remain to be explored, only through additional in situ efforts like Hentrich et al. (2010) and Etl et al. (2017) will this diversity ever be recognized, understood, and known. With more visitor assemblage samples and chemical signatures from more *Anthurium* across the neotropics, and with the species involved placed in a phylogenetic context, it might then become possible to determine whether this perception of floral convergence in non-scarab-pollinated *Anthurium* communities (Schwerdtfeger et al. 2002; Hentrich et al. 2010; Croat 2014) might also reflect a sort of “pre-existing bias” by the pollinator assemblage for specific floral chemicals (Schiestl & Dötterl 2012) , or rather an artifact of biogeographic movements of plants and pollinators through time, or a combination of the two, or perhaps something else, unknown, unobserved or unimagined.

5.2 Nocturnal Observations

The argument for more nocturnal observations of biotic interactions in *Anthurium* was made by Hartley et al. (2017) and is reinforced here—for *Anthurium* and aroids in general—with a figure of a nocturnal mirid bug visitation in *Spathiphyllum wendlandii* observed at Las Cruces Biological Station (Fig. 6). Although hemipterans are known herbivores of *Spathiphyllum* (Villalobos Muller et al. 2010; Li et al. 2011), its not

clear that any hemipterans have been reported as floral interactors in *Spathiphyllum* to date (Williams & Dressler 1976; Montalvo & Ackerman 1986; Mayo et al. 1997). As was discussed for *Anthurium*, the evidence in favor of mirid plant bug visitation in aroids as parasitic/herbivorous/florivorous interactions (Konstantinov & Knyshev 2015; Pan et al. 2015; Namyatova & Cassis 2016) and against mirid interactions as pollination events in aroids (Young 1986; Beath 1998; Franz 2007; Etl et al. 2016) suggests that a florivorous interaction in Fig. 6 isn't an unlikely possibility. However, in addition to the likelihood for most nocturnal observations to contribute new information, the curious anthecological disparity discussed by Hoe et al. (2016) between night-flowering neotropical aroids and their dawn-flowering paleotropic relatives, if anything, stresses of critical need for additional nocturnal observations in neotropical aroids to continue building on our "incipient knowledge" of aroid reproductive biology (Milet-Pinheiro et al. 2017).



Figure 6: Nocturnal observation of floral visitation by a plant bug (Hemiptera: Miridae) to the pistillate inflorescence of a *Spathiphyllum* species, a potentially undocumented interaction in the genus. Seen on a planted specimen at Las Cruces Biological Station, Costa Rica. (June 2016).

6. Conclusions

The appendices found below are far from representing the real diversity of biotic interactions in *Anthurium* as a direct result of my inability to recognize or locate other numerous primary sources, herbarium specimens, in situ observations, or citizen science database observations. However, for each of the three categories of biotic interactions recognized herein, my 17 personal observations from Central and South America came to represent 5% of the 316 total biotic interactions documented. While the notion that a lot of *Anthurium* are euglossine bee pollinated has not been usurped, what has perhaps changed is an appreciation for the impressive diversity of floral, post-anthetic, and vegetative interactions, despite relatively few references and observations.

These interactions are occurring all the time, though they are being seen far less frequently, even less frequently documented in the literature. Because of this, most any new contributions are likely to enlighten our understanding the nature and diversity of biotic interactions in *Anthurium*. To that end, weevils and cecidomyiid and drosophilid flies like engage in a greater number of interactions with *Anthurium* than listed here.

The dependencies of *Anthurium* on biotic interactions for two major life history events (gamete transfer and diaspore dispersal) distinguish this genus from other groups of tropical plants that have received more attention to date. Rather than weaknesses against this genus as a model system, the dependency of *Anthurium* on biotic interactions (the hallmark of tropical plants) make this genus a prime candidate

for an evolutionary model system in neotropical herbaceous plants. It is hoped these lists will be made publicly available so that others interested in these interactions can contribute their own observations.

Appendix 1: Floral interactions in the genus *Anthurium*, determined from 42 references which documented a total of 207 floral interactions, 145 of which occur with 61 known species of *Anthurium* from 14 subgeneric sections (sensu Croat & Sheffer 1983 and Carlsen & Croat 2013). Interactions are organized first by the alphabetized sections of *Anthurium*: species cited as being in a floral interaction were placed into their taxonomic section based on the taxonomy of Croat & Sheffer 1983 and Carlsen & Croat 2013. Multiple species of *Anthurium* within each section are organized alphabetically, then higher taxonomy of the floral interactors are organized alphabetically within each species, families of floral visitors are organized alphabetically within each higher taxonomy, and finally, multiple species of floral interactors are organized alphabetically within each family of floral interactors. Priority was given to two or more references citing the same pairs of interacting species.

Section of <i>Anthurium</i>	Species of <i>Anthurium</i>	Higher Taxonomy of floral interactor	Family of floral interactor	Species of floral interactor	Interaction	Location	References (and notes)
* <i>Andiphyllum</i>	<i>A. chamulense</i> Matuda	Diptera	Drosophilidae		Visitor of cultivated plants	Cultivated at Göttingen Botanical Garden, Germany	Schwerdtfeger et al. 2002
58	<i>Anthurium</i> sp.	Diptera	c.f. Drosophilidae		Visitor	upslope of San Jose del Palmar, Chocó, Colombia	Hartley 2017 personal observation (Fig. 1: I)
	<i>A. bogotense</i> Schott	Coleoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
		Collembola				Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia
<i>Belolonchium</i>	<i>A. draconopterum</i> Sodiro	Diptera	Cecidomyiidae		Visitor, potential mating site	Ecuador	Schwerdtfeger et al. 2002
	<i>A.c.f. gualeanum</i> Engl.	Coleoptera	Curculionidae	"weevils"	Visitor	Ecuador	Madison 1979a
		Diptera	Staphylinidae	"staphylinids"	Visitor	Ecuador	Madison 1979a
			"flies"			Visitor	Ecuador
		"other insects"		Visitor	Ecuador	Madison 1979a	
	<i>A. maldonadoense</i> Croat	Coleoptera	Curculionidae	"weevils"	Visitor	Vicinity of Maldonado at 1800 m, Carchi, Ecuador	MO Herbarium Specimen: M.T. Madison

			Drosophilidae	"fruit flies"	Visitor	Vicinity of Maldonado at 1800 m, Carchi, Ecuador	4001, April 15 1977 MO Herbarium Specimen: M.T. Madison
		Diptera		"small metallic flies"	Visitor	Vicinity of Maldonado at 1800 m, Carchi, Ecuador	4001, April 15 1977 MO Herbarium Specimen: M.T. Madison
	<i>Anthurium</i> sp.	Hymenoptera	Apidae	<i>Euglossa</i> sp.	Visitor of staminate inflorescence	Cultivated at Orquideas Amazonicas plant nursery, Moyobamba, San Martín, Peru	Hartley 2017 personal observation (Fig. 1: J)
				<i>Eulaema</i> subgenus <i>Apeulaema</i>	Visitor of staminate inflorescence	Cultivated at Orquideas Amazonicas plant nursery, Moyobamba, San Martín, Peru	Hartley 2017 personal observation (Fig. 1: K)
				<i>Eulaema bennetti</i>	Visitor	Cultivated in Trinidad	Zucchi 1969 citing F.D. Bennett (MS)
	<i>A. andraeanum</i> Linden	Hymenoptera	Apidae	<i>Eulaema basicincta</i>	Visitor	Cultivated in Trinidad	Zucchi 1969 citing F.D. Bennett (MS)
				<i>Eulaema seabrai</i>	Visitor	Ubutaba, Brazil	Rocha-Filho et al. 2012
				<i>Eulaema terminata</i>	Visitor	Cultivated in Trinidad	Zucchi 1969 citing F.D. Bennett (MS)
		Aves : Apodiformes	Trochilidae	<i>Agelaiocercus coelestis</i>	Visitor, "resting" on an inflorescence	Río Nambí, Chocó, Colombia	Salaman 1996
	<i>A. atramentarium</i> Croat & Oberle	Diptera	Drosophilidae	<i>Drosophila</i> sp.	Visitor	Bitaco, Valle de Cauca, Colombia	Calderón, E. 2017. "Cultivation of native Colombian aroids at El Refugio nature reserve (Torremolinos nursery)", presented at the 12th International Aroid Society Conference in Cali, Colombia.
	<i>A. buganum</i> Engl.	Coleoptera	Curculionidae	<i>Cyclanthura</i>	Visitor of staminate inflorescence	Valle de Cauca, Colombia	Guevara-Ibarra, L., A. Marina-Torres and M. Gibernau. 2017.

	Diptera	Syrphidae	<i>Leucopodella</i> sp. <i>Apis mellifera</i>	Visitor Visitor Visitor, collecting floral scents		"Ecología de la polinización de <i>Anthurium buganum</i> (Araceae)", presented at the 12th International Aroid Society Conference in Cali, Colombia.
	Hymenoptera	Apidae	<i>Eufriesea</i> sp.	Visitor		
			<i>Nannotrigona</i> sp. <i>Augochlora</i>	Visitor Visitor		
		Halictidae	<i>Lasioglossum</i> <i>Halictus</i> sp.	Visitor Visitor		
<i>A. hoffmannii</i> Schott	Coleoptera	Curculionidae	<i>Cyclanthura</i> sp.	Visitor of pistillate inflorescence	Las Cruces Biological Station, San Vito, Costa Rica	Hartley 2016 personal observation (Fig. 1: D)
	Hymenoptera	Apidae	<i>Euglossa</i> sp.	Visitor of staminate inflorescence	Las Cruces Biological Station, San Vito, Costa Rica	Hartley 2016 personal observation (Fig. 1: C)
<i>A. formosum</i> Schott	Coleoptera	Curculionidae	<i>Cyclanthura carinata</i>	Pollinator; herbivore of floral tissues; females potentially oviposit in flowers; mating site	Las Cruces Biological Station, San Vito, Costa Rica	Franz 2003; Franz 2007
	Hymenoptera	Apidae	<i>Euglossa flammula</i>	Visitor	Las Cruces Biological Station, San Vito, Costa Rica	Beath 1998 (it's possible the visitor was meant to be " <i>Euglossa flammea</i> ")
			<i>Eulaema meriana</i>	Visitor	Las Cruces Biological Station, San Vito, Costa Rica	Beath 1998
<i>A. longistamineum</i> Engl.	Hymenoptera	Anthophila		Inferred	Cultivated at Montreal Botanical Garden, Québec, Canada	Chouteau et al. 2008
<i>A. c.f. nymphaeifolium</i> K.Koch & C.D. Bouché	Hymenoptera	Apidae	<i>Eulaema polychroma</i>	Visitor	Not specified	Ramírez et al. 2002 citing R.L. Dressler (personal observation)
<i>A. obusilobum</i> Schott	Coleoptera			Visitor	Nature Reserve of La Mesenia-Paramillo,	Gómez-Murillo & Cuartas-Hernández 2016

			c.f. Chrysomelidae	Visitor of staminate inflorescence	Antioquia, Colombia Braulio Carrillo National Park, San José, Costa Rica	Hartley 2016 personal observation (Fig. 1: H)
	Hymenoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
<i>A. peltigerum</i> Sodiro	Diptera	Drosophilidae		Visitor	Ecuador	Schwerdtfeger et al. 2002
<i>A. vanderknappii</i> Croat	Lepidoptera	Nymphalidae	Satyrinae	Visitor	Bitaco, Valle de Cauca, Colombia	Alistar Hay 2017 personal observation (Fig. 2: B)
	Coleoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
<i>A. yarumalense</i> Engl.	Hymenoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
	Thysanoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
		Thripidae	<i>Frankliniella</i> sp.	Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Cuartas-Hernández & Medel 2015
<i>Anthurium</i> sp.	Diptera			Visitor of pistillate inflorescence	ca. Mindo, Pinchincha, Ecuador	Rudy Gelis 2018 iNaturalist observation (Fig. 2: C)
<i>Cardiolonchium</i>			Superfamily Sciaroidea	Visitor of pistillate inflorescence	Las Cruces Biological Station, San Vito, Costa Rica	Hartley 2016 personal observation (Fig. 1: A)
<i>A. caperatum</i> Croat & R.A. Baker	Diptera			Visitor of pistillate inflorescence	Las Cruces Biological Station, San Vito, Costa Rica	Hartley 2016 personal observation (Fig. 1: B)
	Lepidoptera	Erebidae		Visitor of pistillate inflorescence	Las Cruces Biological Station, San Vito, Costa Rica	Hartley et al. 2017

			sp.2	Visitor of pistillate inflorescence	Las Cruces Biological Station, San Vito, Costa Rica	Hartley et al. 2017
<i>A. caramantae</i> Croat	Diptera	Drosophilidae	<i>Drosophila sp.</i>	Visitor	Bitaco, Valle de Cauca, Colombia	Calderón, E. 2017. "Cultivation of native Colombian aroids at El Refugio nature reserve (Torremolinos nursery)", presented at the 12th International Aroid Society Conference in Cali, Colombia.
<i>A. crystallinum</i> Linden & André	Hymenoptera	Apidae	<i>Euglossa tridentata</i> <i>Euglossa liopoda</i>	Visitor	Canal Zone, Panama	Williams & Dressler 1976
				Visitor	South America	Dressler 1982
<i>A. cupreum</i> Engl.	Coleoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
	Hymenoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
	Thysanoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
<i>A. magnificum</i> Linden	Hymenoptera	Apidae	<i>Euglossa cordata</i> <i>Euglossa magnipes</i>	Pollinator of cultivated plants	Cultivated in Belem, Brazil	Williams & Dressler 1976
				Pollinator of cultivated plants	Cultivated in Belem, Brazil	Williams & Dressler 1976; Dressler 1982 (identified as <i>E. magnipes</i> in Dressler 1982)
<i>A. nigrescens</i> Engl.	Coleoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
	Collembola			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016

	Dermaptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
	Diptera	Drosophilidae		Visitor	Ecuador	Schwerdtfeger et al. 2002
<i>A. ochranthum</i> K. Koch	Collembola			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
	Coleoptera	Curculionidae	<i>Cyclanthura laticola</i>	Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
				Pollinator	Ft. Sherman, Panama; La Selva Biological Station, Heredia, Costa Rica	Franz 2003; Franz 2007
	Hymenoptera	Apidae	<i>Euglossa cyanura</i>	Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
				Visitor	Barro Colorado Island, Canal Area, Panama	Croat 1980
Thysanoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016	
<i>A. queremalense</i> Croat	Aves : Apodiformes	Trochilidae	<i>Ocreatus underwoodii</i>	Visitor	Bitaco, Valle de Cauca, Colombia	Calderón, E. 2017. "Cultivation of native Colombian aroids at El Refugio nature reserve (Torremolinos nursery)", presented at the 12th International Aroid Society Conference in Cali, Colombia.
<i>A. regale</i> Linden	Hymenoptera	Apidae	<i>Euglossa analis</i>	Visitor	Cultivated in a botanical garden, Pará, Brazil	Zucchi 1969 citing Ducke 1902
			<i>Euglossa bicolor</i>	Visitor	Cultivated in a botanical garden, Pará, Brazil	Ducke 1902
			<i>Euglossa cordata</i>	Visitor	Cultivated in a botanical garden, Pará, Brazil	Ducke 1902

<i>A. sagittatum</i> (Sims) G.Don	Hymenoptera	Apidae	<i>Aglae caerulea</i>	Pollinator	French Guiana	Hentrich et al. 2007; Hentrich et al. 2010
			<i>Euglossa piliventris</i>	Pollinator	French Guiana	Hentrich et al. 2007; Hentrich et al. 2010
			<i>Euglossa viridis</i>	Pollinator	French Guiana	Hentrich et al. 2007; Hentrich et al. 2010
<i>A. sanguineum</i> Engl.	Aves: Passeriformes	Thraupidae	<i>Anisognathus flavinucha</i>	Visitor	Hato Viejo Nature Reserve, ca. Cali, Colombia	Kraemer & Schmitt 1999
			<i>Diglossa albilatera</i>	Visitor, secretion feeder	Hato Viejo Nature Reserve, ca. Cali, Colombia	Kraemer & Schmitt 1999
			<i>Adelomyia melanogenys</i>	Pollinator, secretion feeder	Hato Viejo Nature Reserve, ca. Cali, Colombia	Kraemer & Schmitt 1999
			<i>Aglaiocercus kingi</i>	Pollinator, secretion feeder	Hato Viejo Nature Reserve, ca. Cali, Colombia	Kraemer & Schmitt 1999
			<i>Boissonneaua flavescens</i>	Pollinator, secretion feeder	Hato Viejo Nature Reserve, ca. Cali, Colombia	Kraemer & Schmitt 1999
	Aves : Apodiformes	Trochilidae	<i>Coeligena coeligena</i>	Pollinator, secretion feeder	Hato Viejo Nature Reserve, ca. Cali, Colombia	Kraemer & Schmitt 1999
			<i>Coeligena torquata</i>	Pollinator, secretion feeder	Hato Viejo Nature Reserve, ca. Cali, Colombia	Kraemer & Schmitt 1999
			<i>Haplophaedia aureliae</i>	Pollinator, secretion feeder	Hato Viejo Nature Reserve, ca. Cali, Colombia	Kraemer & Schmitt 1999
			<i>Heliodoxa rubinoides</i>	Pollinator, secretion feeder	Hato Viejo Nature Reserve, ca. Cali, Colombia	Kraemer & Schmitt 1999
			<i>Urochroa bougueri</i>	Pollinator, secretion feeder	Hato Viejo Nature Reserve, ca. Cali, Colombia	Kraemer & Schmitt 1999
<i>A. versicolor</i> Engl.	Coleoptera		Visitor	Nature Reserve of La	Gómez-Murillo &	

		Collembola			Visitor	Mesenia-Paramillo, Antioquia, Colombia	Cuartas-Hernández 2016
		Thysanoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
						Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
	<i>A. clavigerum</i> Poepp.	Hymenoptera	Apidae	<i>Nannotrigona</i> sp.	Visitor, pollen collector	Amazonia, Colombia	van Dulmen 2001
	* <i>A. pedatum</i> (Kunth) Endl. ex Kunth	Lepidoptera	Nymphalidae	<i>Pareuptychia</i> sp.	Visitor	Bitaco, Valle de Cauca, Colombia	Alistar Hay 2017 personal observation (Fig. 2: A)
	<i>A. pentaphyllum</i> (Aubl.) G.Don	Hymenoptera	Formicidae		Visitor	La Selva Biological Station, Heredia, Costa Rica	Hartley 2016 personal observation (Fig. 3: F)
	<i>A. podophyllum</i> (Cham. & Schltdl.) Kunth	Lepidoptera	Nymphalidae	<i>Diaethria anna</i>	Visitor, pollen vector	Oaxaca or Veracruz, Mexico	Hartley et al. 2017
	<i>A. pseudoclavigerum</i> Croat	Diptera	Cecidomyiidae		Visitor, potential mating site	Ecuador	Schwerdtfeger et al. 2002
<i>Dactylophyllum</i>				<i>Euglossa intersecta</i>	Pollinator	Inselberg station, Nouragues Natural Reserve, Régina, French Guiana	Hentrich et al. 2010
				<i>Euglossa piliiventris</i>	Pollinator	Inselberg station, Nouragues Natural Reserve, Régina, French Guiana	Hentrich et al. 2007; Hentrich et al. 2010
	<i>A. thrinax</i> Madison	Hymenoptera	Apidae	<i>Euglossa prasina</i>	Pollinator	Inselberg station, Nouragues Natural Reserve, Régina, French Guiana	Hentrich et al. 2010
				<i>Euglossa hemichlora</i>	Pollinator	Inselberg station, Nouragues Natural Reserve, Régina, French Guiana	Hentrich et al. 2010

				<i>Euglossa mourei</i>	Pollinator	Inselberg station, Nouragues Natural Reserve, Régina, French Guiana	Hentrich et al. 2010
				<i>Eulaema bombiformis</i>	Pollinator	Inselberg station, Nouragues Natural Reserve, Régina, French Guiana	Hentrich et al. 2010
				<i>Exaerete frontalis</i>	Pollinator	Inselberg station, Nouragues Natural Reserve, Régina, French Guiana	Hentrich et al. 2010
	<i>A. triphyllum</i> (Willd. ex Schult.) Brong. ex Schott	Diptera	Cecidomyiidae		Visitor, potential mating site	Ecuador	Schwerdtfeger et al. 2002
			Drosophilidae	<i>Drosophila</i> sp.	Visitor	Ecuador	Ervik et al. 1999
	<i>Digitinervium</i>				Visitor, potential mating site	Ecuador	Schwerdtfeger et al. 2002
99	<i>Leptanthurium</i>	<i>A. gracile</i> (Rudge) Lindl.	Hymenoptera	Apidae	<i>Nannotrigona</i> sp.	Visitor, pollen collector	Amazonia, Colombia van Dulmen 2001
		<i>Anthurium</i> sp.	Diptera	Culicidae		Visitor of cultivated plant	Norman, Oklahoma, United States Zach Dufran 2017 iNaturalist observation (Fig. 2: E)
		<i>A. acutifolium</i> Engl.	Hymenoptera	Apidae	<i>Paratetrapedia chocoensis</i>	Pollinator, scented oil collector	La Gamba Biological Station, Gamba, Puntarenas, Costa Rica Etl et al. 2017
	<i>Pachyneurium</i>	<i>A. atropurpureum</i> R.E. Schult. & Maguire	Hymenoptera	Formicidae		Visitor	Reserva Florestal Adolpho Ducke, Amazonas, Brazil Hartley 2017 personal observation (Fig. 3: C)
		<i>A. bradeanum</i> Croat & Grayum	Hymenoptera	Formicidae		Visitor	La Selva Biological Station, Heredia, Costa Rica Hartley personal observation 2016 (Fig. 3: A)
		<i>A. consobrinum</i> Schott	Coleoptera	Curculionidae	<i>Cyclanthura laticola</i>	Pollinator	Ft. Sherman, Panama; La Selva Biological Station, Heredia, Costa Rica Franz 2003; Franz 2007
		<i>A. galactospadix</i> Croat	Hymenoptera	Formicidae		Visitor	Tambopata Research Center, Made de Dios, Hartley 2017 personal observation (Fig. 3: E)

					Many visitors	Peru Los Amigos Biological Station, Madre de Dios, Peru	Hartley 2017 personal observation (Fig. 3: D)
** <i>A. hookeri</i> Kunth	Diptera	Drosophilidae			Visitor of cultivated plants	Göttingen Botanical Garden, Germany	Schwerdtfeger et al. 2002
<i>A. martianum</i> K.Koch & Kolb	Gastropoda		"small slugs"		Visitor of cultivated plants	Munich Botanical Garden	Knuth 1906 citing Engler
<i>A. oxycarpum</i> Poepp.	Diptera	Cecidomyiidae			Visitor, potential mating site	Ecuador	Schwerdtfeger et al. 2002
<i>A. palenquense</i> Croat	Hymenoptera	Apidae	<i>Eulaema bomboides</i>		Pollinator	Centro Cientifico Rio Palenque, Los Rios, Ecuador	Dodson & Gentry 1978
<i>A. schlechtendalii</i> Kunth	Diptera	Drosophilidae			Visitor of cultivated plants	Göttingen Botanical Garden, Germany	Schwerdtfeger et al. 2002
	Hymenoptera	Anthophila			Inferred	Cultivated at Montreal Botanical Garden, Québec, Canada	Chouteau et al. 2008
<i>A. tarapotense</i> Engl.	Hymenoptera	Formicidae			Visitor	Catarata de Pucayaquillo, circa Tambopata, San Martín, Peru	Hartley 2017 personal observation (Fig. 3: B)
<i>A. upalaense</i> Croat & R.A.Baker	Coleoptera	Curculionidae	<i>Cyclanthura carinata</i>		Pollinator	Las Cruces Biological Station, San Vito, Costa Rica	Franz 2003; Franz 2007
<i>Polyneurium</i>	<i>A. panduriforme</i> Schott	Coleoptera	Chrysomelidae	Tribe: Luperini	Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
					Visitor of staminate inflorescence	upslope of San Jose del Palmar, Chocó, Colombia	Hartley 2017 personal observation (Fig. 1: F)
			Curculionidae		Visitor of staminate inflorescence	upslope of San Jose del Palmar, Chocó, Colombia	Hartley 2017 personal observation (Fig. 1: G)

				<i>Cyclanthura</i>	Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Cuartas-Hernández & Medel 2015
		Dermaptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
		Hymenoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
			Apidae	Tribe Meliponini	Visitor of staminate inflorescence	upslope of San Jose del Palmar, Chocó, Colombia	Hartley 2017 personal observation (Fig. 1: E)
		Thysanoptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
89 <i>Porphyrochitonium</i>	<i>A. apaporanum</i> R.E.Schult.	Hymenoptera	Apidae	<i>Euglossa mixta</i>	Visitors	circa Tena, Ecuador	Schwerdtfeger et al. 2002
				<i>Euglossa viridis</i>	Visitors	circa Tena, Ecuador	Schwerdtfeger et al. 2002
	<i>A. hacumense</i> Engl.	Hymenoptera	Apidae	<i>Euglossa cyanura</i>	Visitor	Cerro Jefe, Panama	Williams & Dressler 1976
				<i>Euglossa hyacintha</i>	Visitor	Las Cruces Biological Station, San Vito, Costa Rica	Beath 1998
	<i>A. scherzerianum</i> Schott	Gastropoda		"snails"	Visitor of cultivated plants	Not specified	Knuth 1906
<i>Semaeophyllum</i>	<i>A. tilaranense</i> Standl.	Coleoptera	Curculionidae	<i>Cyclanthura carinata</i>	Pollinator	Las Cruces Biological Station, San Vito, Costa Rica	Franz 2003; Franz 2007
	<i>A. truncicolum</i> Engl.	Diptera	Cecidomyiidae		Visitor, potential mating site	Ecuador	Schwerdtfeger et al. 2002
<i>Tetraspermium</i>	<i>A. caucanum</i> Engl.	Hemiptera			Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016

		Thysanoptera		Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
	<i>A. citrifolium</i> Sodiro	Diptera	Cecidomyiidae	Visitor, potential mating site	Ecuador	Schwerdtfeger et al. 2002
	<i>A. acaule</i> Schott	Gastropoda	"snails"	Visitor		Knuth 1906 (as <i>Anthurium lanceolatum</i> , a synonym)
	<i>A. coriaceum</i> G.Don	Gastropoda	"small slugs"	Visitor of ultivated plants	Munich Botanical Garden	Knuth 1906 citing Engler
<i>Urospadix</i>	<i>A. grandifolium</i> Kunth	Diptera	Drosophilidae	Visitor of cultivated plants	Göttingen Botanical Garden, Germany	Schwerdtfeger et al. 2002
	<i>A. harrisii</i> (Graham) G.Don	Hymenoptera	Anthophila	Inferred	Cultivated at Montreal Botanical Garden, Québec, Canada	Chouteau et al. 2008
	<i>A. longigeniculatum</i> Engl.	Hymenoptera		Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
		Coleoptera		Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
<i>Xialophyllum</i>	<i>A. microspadix</i> Schott	Collebola		Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
		Dermaptera		Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
		Hymenoptera		Visitor	Nature Reserve of La Mesenia-Paramillo, Antioquia, Colombia	Gómez-Murillo & Cuartas-Hernández 2016
Unspecified	Unspecified		Chrysomelidae	Visitor	Costa Rica	Franz 2007
Unspecified	Unspecified	Coleoptera	Curculionidae	Visitor, possible florivore	ca. Yambrasbamba District, Amazonas, Peru	Roberto Sindaco 2008 iNaturalist observation (Fig. 2: D)

Unspecified	Unspecified		<i>Cyclanthura capitulata</i>	Visitor	La Selva Biological Station, Heredia, Costa Rica	Franz 2003
Unspecified	Unspecified		<i>Cyclanthura pilosa</i>	Visitor	La Selva Biological Station, Heredia, Costa Rica	Franz 2003
Unspecified	Unspecified		<i>Cyclanthura tenuicola</i>	Visitor	Corcovado National Park, Costa Rica	Franz 2003
Unspecified	Unspecified		<i>Cyclanthura uncinata</i>	Visitor	Santa Elena Cloud Forest Reserve, Costa Rica	Franz 2003
Unspecified	Unspecified		<i>Phyllotrox ater</i>	Visitor	Not specified	Franz 2006
Unspecified	Unspecified		<i>Phyllotrox rufipes</i>	Visitor	Not specified	Franz 2006
Unspecified	Unspecified		<i>Phyllotrox variabilis</i>	Visitor	Not specified	Franz 2006
Unspecified	Unspecified	Staphylinidae		Pollinator	Not specified	Mayo et al. 1997 (pg. 48 Table 2)
Unspecified	Unspecified		c.f. Aleocharinae	Visitor	Costa Rica	Franz 2003
Unspecified	Unspecified	Diptera		Pollinator	Not specified	Madison 1979a
Unspecified	Unspecified	Hemiptera	"nymphs"	Visitor	Costa Rica	Franz 2007
Unspecified	Unspecified		"male euglossine bees"	Pollinator	Costa Rica & Panama	Dressler 1968
Unspecified	Unspecified		"male euglossine bees"	Pollinator	Not specified	Madison 1979a
Unspecified	Unspecified		"euglossine bees"	Pollinator	Not specified	Mayo et al. 1997 (pg. 48 Table 2)
Unspecified	Unspecified		"euglossine bees"	Pollinator	Not specified	Schiestl & Dotterl 2012
Unspecified	Unspecified		"small parasitoid wasp"	Visitor	Costa Rica	Franz 2007
Unspecified	Unspecified	Hymenoptera	Apidae			
Unspecified	Unspecified		<i>Eufriesea pulchra</i>	Visitor	Summit Gardens, Panama	Williams & Dressler 1976
Unspecified	Unspecified		<i>Eufriesea purpurata</i>	Visitor	Henri Pittier National Park, Aragua, Venezuela	González 1996
Unspecified	Unspecified		<i>Eufriesea venezolana</i>	Visitor, scent collector	Venezuela	Kimsey 1982 citing Williams & Dressler 1976
Unspecified	Unspecified		<i>Eufriesea venusta</i>	Visitor	Cerro Campana, Panama	Williams & Dressler 1976
Unspecified	Unspecified		<i>Euglossa asarophora</i>	Visitor	Cerro Jefe, Panama	Williams & Dressler

Unspecified	Unspecified	<i>Euglossa bicolor</i>		Cultivated in a botanical garden, Pará, Brazil	1976 Ducke 1902
Unspecified	Unspecified	<i>Euglossa championii</i>	Visitor	Rio Nambí Nature Reseve, Barbacoas, Nariño, Colombia	Ospina-Torres 2015
Unspecified	Unspecified	<i>Euglossa cordata</i>		Cultivated in a botanical garden, Pará, Brazil	Ducke 1902
Unspecified	Unspecified	<i>Euglossa dressleri</i>	Visitor	Santa Rita, Panama	Williams & Dressler 1976
Unspecified	Unspecified	<i>Euglossa flammea</i>	Visitor	University of Florida Herbarium specimen	Ramírez et al. 2002
Unspecified	Unspecified	<i>Euglossa gorgonensis</i>	Visitor	Rio Pequeni, Panama	Williams & Dressler 1976
Unspecified	Unspecified	<i>Euglossa hansonii</i>	Visitor	Santa Rita, Panama	Williams & Dressler 1976
Unspecified	Unspecified		Visitor	Cultivated in a botanical garden, Pará, Brazil	Ducke 1902
Unspecified	Unspecified	<i>Euglossa ignita</i>	Visitor	Rio Nambí Nature Reseve, Barbacoas, Nariño, Colombia	Ospina-Torres 2015
Unspecified	Unspecified		Visitor	Cordillera Escalera, Tarapoto, San Martín, Peru	Nemésio & Rasmussen 2014
Unspecified	Unspecified	<i>Euglossa igniventris</i>	Visitor	Santa Rita, Panama	Williams & Dressler 1976
Unspecified	Unspecified	<i>Euglossa maculilabris</i>	Visitor	Rio Nambí Nature Reseve, Barbacoas, Nariño, Colombia	Ospina-Torres 2015
Unspecified	Unspecified	<i>Euglossa orellana</i>	Visitor	Rio Nambí Nature Reseve, Barbacoas, Nariño, Colombia	Ospina-Torres 2015
Unspecified	Unspecified	<i>Euglossa tiputini</i>	Visitor	Yasuní Natinal Park, Napo, Ecuador	Roubik 2004 citing R.L. Dressler (personal communication)
Unspecified	Unspecified	<i>Euglossa tridentata</i>	Visitor of cultivated	Canal Zone, Panama	Williams & Dressler 1976

Unspecified	Unspecified	<i>Euglossa trinotata</i>	plants Visitor	Rio Nambí Nature Reseve, Barbacoas, Nariño, Colombia	Ospina-Torres 2015
Unspecified	Unspecified	<i>Euglossa turbinifex</i>	Visitor	Rio Nambí Nature Reseve, Barbacoas, Nariño, Colombia	Ospina-Torres 2015
Unspecified	Unspecified	<i>Euglossa variabilis</i>	Visitor	Canal Zone, Panama & Medellin, Colombia	Williams & Dressler 1976
Unspecified	Unspecified	<i>Euglossa villosiventris</i>	Visitor	Rio Nambí Nature Reseve, Barbacoas, Nariño, Colombia	Ospina-Torres 2015
Unspecified	Unspecified	<i>Euglossa viridis</i>	Visitor	Not specified	Ramírez et al. 2002 citing R.L. Dressler (personal observation)
Unspecified	Unspecified	<i>Eulaema cingulata</i>	Visitor	Cultivated in a botanical garden, Pará, Brazil	Ducke 1902 (as <i>Euglossa</i> <i>fasciata</i> , a synonym)
Unspecified	Unspecified		Visitor	Not specified	Dodson 1966
Unspecified	Unspecified	<i>Eulaema leucopyga</i>	Visitor	El Valle, Panama	Williams & Dressler 1976
Unspecified	Unspecified		Visitor	Cultivated in a botanical garden, Pará, Brazil	Ducke 1902 (as <i>Euglossa</i> <i>dimidiata</i> , a synonym)
Unspecified	Unspecified	<i>Eulaema meriana</i>	Visitor	Costa Rica Cordillera Escalera, Tarapoto, San Martín, Peru	Dodson 1966 Nemésio & Rasmussen 2014
Unspecified	Unspecified		Visitor	Cultivated in a botanical garden, Pará, Brazil	Ducke 1902 (as <i>Euglossa</i> <i>nigrita</i> , a synonym)
Unspecified	Unspecified	<i>Eulaema nigrita</i>	Visitor	Cerro Campana, Panama	Williams & Dressler 1976
Unspecified	Unspecified	<i>Eulaema peruviana</i>	Visitor	Cordillera Escalera, Tarapoto, San Martín, Peru	Nemésio & Rasmussen 2014
Unspecified	Unspecified		Visitor	Not specified	Dodson 1966
Unspecified	Unspecified	<i>Eulaema polychroma</i>	Pollinator	Medellín, Colombia and Guayaquil, Ecuador	Williams & Dressler 1976
Unspecified	Unspecified	<i>Eulaema seabrai</i>	Visitor	Not specified	Dodson 1966

Unspecified	Unspecified			Pollinator	Las Concavas, Costa Rica and Rio de Janeiro, Brazil	Williams & Dressler 1976
Unspecified	Unspecified		<i>Eulaema sororia</i>	Visitor	Rio Nambí Nature Reserve, Barbaças, Nariño, Colombia	Ospina-Torres 2015
Unspecified	Unspecified		<i>Eulaema speciosa</i>	Visitor	Not specified	Ramírez et al. 2002 citing R.L. Dressler (personal observation)
Unspecified	Unspecified		<i>Eulaema tenuifasciata</i>	Visitor	Cordillera Escalera, Tarapoto, San Martín, Peru	Nemésio & Rasmussen 2014
Unspecified	Unspecified		c.f. <i>Plebeia minima</i>	Visitor	Cultivated in a botanical garden, Pará, Brazil	Ducke 1902 (as <i>Melipona goeldiana</i> , a synonym)
Unspecified	Unspecified	Sphecidae	"sphecids wasps"	Pollinators	Not specified	Madison 1979a
Unspecified	Unspecified	Thysanoptera		Visitor	Costa Rica	Franz 2007

*Section *Andiphyllum* not yet published but based on geography and DNA sequence data (Carlsen & Croat 2013)

** Sectiona placement uncertain for this species.

Appendix 2: Post-anthesis interactions in the genus *Anthurium*, determined from 41 references which documented a total of 87 post-anthesis interactions, 52 of which occur with 15 known species of *Anthurium* from 8 sections within the genus. The layout is organized the same way as in Appendix 1 (& 3).

Section of <i>Anthurium</i>	Species of <i>Anthurium</i>	Higher Taxonomy of post-anthesis interactor	Family of post-anthesis interactor	Species of post-anthesis interactor	Interaction	Location	References (and notes)
<i>Belolonchium</i>	<i>A. brownii</i> Mast.	Aves: Passeriformes	Pipridae	<i>Manacus vitellinus vitellinus</i>	Fruit consumption, seed dispersal	Isla Orquidea, Lago Gatun, Panama	Worthington 1990
				<i>Pipra mentalis ignifera</i>	Fruit consumption, seed dispersal	Isla Orquidea, Lago Gatun, Panama	Worthington 1990
<i>Calomystrium</i>	<i>A. nymphaeifolium</i> K.Koch & C.D.Bouché	Mammalia: Chiroptera	Phyllostomidae	<i>Sturnira bidens</i>	Fruit consumption, seed dispersal	South America	Molinari & Soriano 1987
$\frac{1}{2}$ <i>Cardiolonchium</i>	<i>A. dolichostachyum</i> Sodirol	Aves: Passeriformes	Pipridae	<i>Manacus manacus</i>	Fruit consumption, seed dispersal	western Ecuador	Madison 1979a citing C.Dodson (personal communication)
<i>Dactylophyllium</i>	<i>A. clavigerum</i> Poepp.	Aves: Passeriformes	Pipridae	<i>Manacus vitellinus vitellinus</i>	Fruit consumption, seed dispersal	Isla Orquidea, Lago Gatun, Panama	Worthington 1990
				<i>Pipra mentalis ignifera</i>	Fruit consumption, seed dispersal	Isla Orquidea, Lago Gatun, Panama	Worthington 1990
	<i>A. kunthii</i> Poepp.	Mammalia: Primates	Cebidae	<i>Cebus albifrons</i>	Fruit consumption, seed dispersal	Cocha Cashu Biological Station, Manu National Park, Peru	Terborgh 1983 (pp.64)
	<i>A. thrinax</i> Madison	Mammalia: Chiroptera			Possible fruit consumption and seed dispersal	central French Guiana	Lobova et al. 2009
<i>Leptanthurium</i>	<i>A. gracile</i> (Rudge) Lindl.	Insecta: Hymenoptera	Formicidae	<i>Azteca</i> sp. <i>Camponotus</i>	Seed dispersal Seed dispersal	Amazonas, Brazil Sinnamary, French	Marini-Filho 1999 Orivel & Dejean 1999

				<i>fermorata</i>	Seed dispersal	Guiana Los Amigos Biological Station, Madre de Dios, Peru	Youngsteadt et al. 2008; Youngsteadt et al. 2010
				<i>Creमतogaster c.f. limata parabiотica</i>	Seed dispersal	Los Amigos Biological Station, Madre de Dios, Peru	Youngsteadt et al. 2008
				<i>Pachycondlyia goeldii</i>	Seed dispersal	Amazonas, Brazil	Marini-Filho 1999
					Seed dispersal	Sinnamary, French Guiana	Orivel & Dejean 1999
			Fringillidae	<i>Euphonia violacea</i>	Fruit consumption, seed dispersal	Trinidad	Snow & Snow 1971
			Pipridae	<i>Pipra mentalis ignifera</i>	Fruit consumption, seed dispersal	Isla Orquidea, Lago Gatun, Panama	Worthington 1990
		Aves: Passeriformes		<i>Ramphocelus carbo</i>	Fruit consumption, seed dispersal	Trinidad	Snow & Snow 1971
			Thraupidae	<i>Tachyphonus rufus</i>	Fruit consumption, seed dispersal	Trinidad	Snow & Snow 1971
	<i>A. atropurpureum</i> R.E.Schult. & Maguire	Arachnida: Araneae			Webbing seen on a post-anthesis inflorescence	Reserva Florestal Adolpho Ducke, Amazonas, Brazil	Hartley 2017 personal observation (Fig. 3B)
<i>Pachyneurium</i>	<i>A. dombeyanum</i> Brongn. ex Schott	Insecta: Diptera	Section Schizophora	Subsection Calyptratae	Post-anthesis visitor; spadix with immature berries scarcely emergent from the tepals	In the San Pedro 1 transect of the Trocha Union, along the road in Manu National Park, Madre de Dios, Peru	Hartley 2017 personal observation (Fig. 3A)
	<i>A. ernestii</i> Engl.	Insecta: Hymenoptera	Formicidae		Seed dispersal	Amazonia	Mayo et al. 1997 citing Ule 1905
	* <i>A. hookeri</i> Kunth	Mammalia: Chiroptera			Possible fruit consumption and seed dispersal	central French Guiana	Lobova et al. 2009
<i>Tetraspermium</i>	<i>A. obtusum</i> (Engl.)	Mammalia:	<u>Phyllostomidae</u>	<i>Artibeus obscurus</i>	Fruit	central French Guiana	Lobova et al. 2009

Grayum	Chiroptera		consumption, seed dispersal Fruit			
		<i>Carollia brevicauda</i>	consumption, seed dispersal Fruit	central French Guiana	Lobova et al. 2009	
		<i>Carollia perspicillata</i>	consumption, seed dispersal Fruit	central French Guiana	Lobova et al. 2009	
		<i>Sturnira lilium</i>	consumption, seed dispersal Fruit	central French Guiana	Lobova et al. 2009	
		<i>Sturnira tildae</i>	consumption, seed dispersal Fruit	central French Guiana	Lobova et al. 2009	
<i>A. scandens</i> (Aubl.) Engl.	Aves		Fruit consumption, seed dispersal Fruit	Los Tuxtlas, Veracruz, Mexico	Galindo-González et al. 2000	
		Cardinalidae	<i>Piranga leucoptera</i>	consumption, seed dispersal Fruit	Coatepec, Veracruz, Mexico	Cruz-Angón & Greenberg 2005
		Emberizidae	<i>Chlorospingus flavopectus</i>	consumption, seed dispersal Fruit	Coatepec, Veracruz, Mexico	Cruz-Angón & Greenberg 2005
			<i>Euphonia hirundinacea</i>	consumption, seed dispersal Fruit	Coatepec, Veracruz, Mexico	Cruz-Angón & Greenberg 2005
		Aves: Passeriformes		consumption, seed dispersal Fruit	Forests of northcentral Puerto Rico	Carlo et al. 2003
		Fringillidae	<i>Euphonia musica</i>	consumption, seed dispersal Fruit	Forests of northcentral Puerto Rico	Carlo et al. 2004
				consumption, seed dispersal Fruit	Carite State Forest, Puerto Rico	Carlo et al. 2005
				consumption, seed dispersal Fruit	Puerto Rico	Yang et al. 2013

						seed dispersal Fruit consumption, seed dispersal	Trinidad	Snow & Snow 1971
						Fruit consumption, seed dispersal	Forests of northcentral Puerto Rico	Carlo et al. 2003
						Fruit consumption, seed dispersal	Forests of northcentral Puerto Rico	Carlo et al. 2003
			Thraupidae			Fruit consumption, seed dispersal	Puerto Rico	Yang et al. 2013
						Fruit consumption, seed dispersal	Trinidad	Snow & Snow 1971
						Fruit consumption, seed dispersal	Trinidad	Snow & Snow 1971
						Fruit consumption, seed dispersal	Los Tuxtlas, Veracruz, Mexico	Galindo-González et al. 2000
		Mammalia: Chiroptera			"frugivorous bats"	Possible fruit consumption and seed dispersal	central French Guiana	Lobova et al. 2009
<i>Urospadix</i>	** <i>A. acaule</i> (Jacq.) Schott	Aves: Passeriformes	Pipridae		<i>Pipra pipra</i>	Fruit consumption, seed dispersal	Centro de Investigaciones Jenaro Herrera, Loreto Department, Peru	Gorchov et al. 1995 (<i>Anthurium acaule</i> here is likely a species of section <i>Pachyneurium</i> because <i>A.</i> <i>acaule</i> in the true sense is an Antillean entity in section ** <i>Anthurium</i>) Loiselle et al. 2007 (<i>Anthurium acaule</i> here is likely a species of section
						Fruit consumption, seed dispersal	Tiputini Biological Station, Orellana, Ecuador	

Unspecified	Unspecified		"new world passerine birds"	Fruit consumption, seed dispersal	not specified	Baker et al. 1998	
Unspecified	Unspecified			Fruit consumption, seed dispersal	Finca 'El Plastico', Heredia, Costa Rica	Stiles & Rosselli 1993	
Unspecified	Unspecified	Fringillidae	<i>Euphonia annae</i>	Fruit consumption, seed dispersal	La Selva Biological Station, Heredia, Costa Rica	Loiselle & Blake 1990	
Unspecified	Unspecified		<i>Euphonia gouldi</i>	Fruit consumption, seed dispersal	La Selva Biological Station, Heredia, Costa Rica	Loiselle et al. 2007	
Unspecified	Unspecified	Passerellidae	<i>Chlorospingus ophthalmicus</i>	Fruit consumption, seed dispersal	Monteverde, Costa Rica	Wheelright et al. 1984	
Unspecified	Unspecified		<i>Chiroxiphia linearis</i>	Fruit consumption, seed dispersal	Monteverde, Costa Rica	Wheelright et al. 1984	
Unspecified	Unspecified	Pipridae	<i>Lepidothrix coronata</i>	Fruit consumption, seed dispersal	Tiputini Biological Station, Orellana, Ecuador	Loiselle et al. 2007	
Unspecified	Unspecified		<i>Pipris erythrocephala</i>	Fruit consumption, seed dispersal	Tiputini Biological Station, Orellana, Ecuador	Loiselle et al. 2007	
Unspecified	Unspecified		<i>Pipris filicauda</i>	Fruit consumption, seed dispersal	Tiputini Biological Station, Orellana, Ecuador	Loiselle et al. 2007	
Unspecified	Unspecified	Tyrannidae	<i>Mionectes oleaginous</i>	Fruit consumption, seed dispersal	La Selva Biological Station, Heredia, Costa Rica	Loiselle et al. 2007	
Unspecified	Unspecified	Aves: Trogoniformes	Trogonidae	<i>Pharomachrus mocinno</i>	Fruit consumption, seed dispersal	Monteverde, Costa Rica	Wheelright et al. 1984
Unspecified	Unspecified	Mammalia: Chiroptera	Phyllostomidae	"bats"	Not specified	Kunz 2011	
Unspecified	Unspecified		<i>Artibeus gnomus</i>	Fruit	Centro de	Gorchov et al. 1995	

Unspecified	Unspecified		consumption, seed dispersal Fruit	Investigaciones Jenaro Herrera, Loreto, Peru	
Unspecified	Unspecified		consumption, seed dispersal Fruit	Los Tuxtlas, Veracruz, Mexico	Vazquez-Yanes et al. 1975
Unspecified	Unspecified	<i>Artibeus jamaicensis</i>	consumption, seed dispersal Fruit	southern Mexico	Orozco-Segovia & Vazquez-Yanes 1982
Unspecified	Unspecified		consumption, seed dispersal Fruit	Los Tuxtlas, Veracruz, Mexico	Estrada et al. 1984
Unspecified	Unspecified		consumption, seed dispersal Fruit	Centro de Investigaciones Jenaro Herrera, Loreto, Peru	Gorchov et al. 1995
Unspecified	Unspecified		consumption, seed dispersal Fruit	Centro de Investigaciones Janero Herrera, Loreto, Peru;	Gorchov et al. 1995
Unspecified	Unspecified	<i>Carollia brevicauda</i>	consumption, seed dispersal Fruit	Estacion Cientifica San Francisco, Zamora- Chinchipe, Ecuador	Lindner & Morawetz 2006
Unspecified	Unspecified		consumption, seed dispersal Fruit	Centro de Investigaciones Jenaro Herrera, Loreto, Peru	Gorchov et al. 1995
Unspecified	Unspecified	<i>Carollia castanea</i>	consumption, seed dispersal Fruit	Centro de Investigaciones Janero Herrera, Loreto, Peru	Gorchov et al. 1995
Unspecified	Unspecified		consumption, seed dispersal Fruit	Iwokrama Forest, Guyana	Horsley et al. 2015
Unspecified	Unspecified		consumption, seed dispersal Fruit	La Selva Biological Station, Heredia, Costa Rica	Lopez & Vaughan 2007
Unspecified	Unspecified	<i>Carollia sowelli</i>	consumption, seed dispersal Fruit	Centro de Investigaciones Jenaro Herrera, Loreto, Peru	Gorchov et al. 1995
Unspecified	Unspecified	<i>Phyllostomus hastatus</i>	consumption, seed dispersal Fruit	Estacion Cientifica San Francisco, Zamora-	Lindner & Morawetz 2006
Unspecified	Unspecified	<i>Sturnira bidens</i>	consumption,		

Unspecified	Unspecified			<i>Sturnira ludovici</i>	seed dispersal Fruit consumption, seed dispersal	Chinchipec, Ecuador Monteverde Cloud Forest Reserve, Costa Rica	Dinerstein 1986
Unspecified	Unspecified			<i>Sturnira mordax</i>	Fruit consumption, seed dispersal	Costa Rica	Howell & Burch 1974
Unspecified	Unspecified	Mammalia: Primates	Atelidae	<i>Ateles geoffroyi</i>	Fruit consumption, seed dispersal	Punta Rio Claro Wildlife Refuge, Osa Peninsula, Costa Rica	Riba-Hernández et al. 2003
Unspecified	Unspecified			<i>Lagothrix lagotricha</i>	Fruit consumption, seed dispersal	Yasuní National Park, Ecuador	Dew 2005

* Sectional placement not certain for this species.

**Likely a species of section *Pachyneurium* as *A. acaule* is an Antillean entity not known from western South America.

Appendix 3: Vegetative interactions in the genus *Anthurium*, determined from 18 references which documented a total of 22 vegetative interactions, 15 of which occur with 12 known species of *Anthurium* from 7 sections. The layout is the same as in Appendices 1 & 2.

Section of <i>Anthurium</i>	Species of <i>Anthurium</i>	Higher Taxonomy of vegetative interactor	Family of vegetative interactor	Species of vegetative interactor	Interaction	Location	Reference (and notes)
** <i>Anthurium</i>	<i>A. cordatum</i> (L.) Schott	Fungi		"mycorrhiza"	"well-developed mycorrhizae"	Trinidad, Trinidad and Tobago	Simmonds 1950
<i>Calomystrium</i>	<i>A. andraeanum</i> Linden ex André and associated hybrids	Insecta: Thysanoptera	Thripidae	<i>Chaetanaphothrips orchidii</i>	Herbivore of greenhouse plants	Hawaii, United States	Hara et al. 2002
	<i>A. ravenii</i> Croat & R.A.Baker	Mammalia: Chiroptera	Phyllostomidae	<i>Artibeus watsonii</i>	Tent roosting	Corcovado National Park, Costa Rica	Choe & Timm 1985
<i>Cardiolonchium</i>	<i>A. caperatum</i> Croat & R.A.Baker	Mammalia: Chiroptera	Phyllostomidae		Tent roosting	Corcovado National Park & Gofito Wildlife Refuge, Costa Rica	Chaverri & Kunz 2006
					Evidence for tent roosting	Las Cruces Biological Station, San Vito, Costa Rica	Hartley 2016 personal observation (Fig. 3 C1 & C2)
<i>Dactylophyllium</i>	<i>A. eminens</i> Schott	Aves: Passeriformes		<i>Superfamily: Passeroidea</i>	Lek mating site	Tiputini Biological Station, Orellana, Ecuador	Ryder et al. 2006
<i>Pachyneurium</i>	<i>A. dombeyanum</i> Brongn. ex Schott	Insecta: Coleoptera	Scarabaeidae	Tribe Dichelonychini	Herbivore of leaves	Cuenca San Alberto, Yanachaga-Chemillén National Park, Oxapampa, Pasco, Peru	Hartley 2017 personal observation (Figure 3 E & F)
		Insecta: Lepidoptera	Erebidae		Larval herbivore of leaves	Cuenca San Alberto, Yanachaga-Chemillén National Park, Oxapampa, Pasco, Peru	Hartley 2017 personal observation (Figure 3D)
	<i>A. glaucospadix</i> Croat	Aves: Galliformes	Cracidae	<i>Chamaepetes goudotii</i>	Nesting site	Santuario de Fauna y Flora Otún-Quimbaya, Risaralda, Colombia	Londoño et al. 2007
	* <i>A. hookeri</i> Kunth	Fungi		"mycorrhiza"	"sometimes"	Trinidad, Trinidad and Tobago	Simmonds 1950

					though not invariably mycorrhizal"		
	<i>A. loretense</i> Croat	Insecta: Hymenoptera	Formicidae	Paraponera sp.	"obligatey associate with Paraponera ant nests"	Explorama Lodge, Maynas, Loreto, Peru	MO herbarium specimen: A.H. Gentry et al.61651, 1988
	<i>A. schlechtendalii</i> Kunth	Mammalia: Primates	Atelidae	<i>Ateles geoffroyi</i> yucatanensis	Herbivore of mature leaves	Ya'ax'che reserve, Yucatan Peninsula, Mexico	Scherbaum & Estrada 2013
<i>Porphyrochitonium</i>	<i>A. pittieri</i> Engl.	Fungi		"arbuscular mycorrhizae"	"Vesicles and aseptate found in roots"	Monteverde Cloud Forest Preserve, Costa Rica	Rains et al. 2003
<i>Tetraspermium</i>	<i>A. scandens</i> (Aubl.) Engl.	Fungi		"mycorrhiza"	"mycorrhizae found"	Trinidad, Trinidad and Tobago	Simmonds 1950
<i>Unspecified</i>	<i>Unspecified</i>	Insecta: Hemiptera	Aleyrodidae	Crenidorsum sp.	Oviposition into stomata of cultivated plants	Oahu, Hawaii, Unites States	Paulson & Beardsley 1985
83 <i>Unspecified</i>	<i>Unspecified</i>	Insecta: Lepidoptera	Erebidae	<i>Praeamastus albipuncta</i>	Larval herbivore of leaves	circa Yanayacu Biological Station, Napo, Ecuador	Green et al. 2011
<i>Unspecified</i>	<i>Unspecified</i>	Amphibia: Anura	Centrolenidae	<i>Hyalinobatrachium aureoguttatum</i>	Males perch on the leaves for vocalizing, mating, and clutch attending	La Viborita, Buenaventura, Chocó, Colombia	Valencia-Aguilar et al. 2012
<i>Unspecified</i>	<i>Unspecified</i>	Aves: Passeriformes	Turdidae	<i>Turdus leucops</i>	Nesting site	Santuario de Fauna y Flora Otún-Quimbaya, Risaralda, Colombia	Londoño 2005
<i>Unspecified</i>	<i>Unspecified</i>	Mammalia: Chiroptera	Phyllostomidae	<i>Vampyriscus nymphaea</i>	Feeding station or tent	La Selva Biological Station, Heredia, Costa Rica	Lopez & Vaughan 2004
<i>Unspecified</i>	<i>Unspecified</i>	Mammalia: Perissodactyla	Tapiridae	<i>Tapirus terrestris</i>	Herbivore of leaves	Indigenous Reserve Nonuaya Villazula, ca. Río Caqueta Colombia	Vélez et al. 2017
<i>Unspecified</i>	<i>Unspecified</i>	Mammalia: Primates	Atelidae	<i>Lagothrix lagotricha</i>	Herbivore of buds, young	Yasuní National Park, Ecuador	Dew 2005

leaves and petioles

*Section *Andiphyllum* not yet published but based on geography and DNA sequence data (Carlsen & Croat 2013)

** Sectiona placement uncertain for this species.

References

- Alvarez, A.M. 2018. Diseases of *Anthurium*. In: McGovern, R.J. and W.H. Elmer (Eds), *Handbook of Plant Disease Management*. Springer, Cham. pp. 283–316.
- Alves, F.E. and L.M. Neto. 2014. Vascular epiphytes in a forest fragment of Serra da Mantiqueira and floristic relationships with Atlantic high altitude areas in Minas Gerais. *Brazilian Journal of Botany* 37(2): 187–196.
- Arévalo, R. and J. Betancur. 2004. Diversidad de epífitas vasculares en cuatro bosques del sector suroriental de la Serranía de Chiribiquete, Guayana, Colombiana. *Caldasia* 26(2): 359–379.
- Baker, H.G., I. Baker and S.A. Hodges. 1998. Sugar composition of nectars and fruits consumed by birds and bats in the tropics and subtropics. *Biotropica* 30(4): 559–586.
- Bawa, K. 1979. Breeding systems of trees in a tropical wet forest. *New Zealand Journal of Botany* 17: 521–524.
- Beath, D.N. 1998. Pollination ecology of the Araceae. International Aroid Society. Received from <http://www.aroid.org/pollination/beath/index.php>. Accessed 18 May 2018.
- Beattie, A.J. 1983. Distribution of ant-dispersed plants. In: Kubitzki, K. (Ed.), *Dispersal and Distribution: an international symposium*. Berlin: Verlag Paul Parey pp. 249–270.
- Benavides D., A.M., A.J. Duque M., J.F. Duivenvoorden, G.A. Vasco and R. Callejas. 2005. A first quantitative census of vascular epiphytes in rain forests of Colombian Amazonia. *Biodiversity and Conservation* 14: 739–758.
- Betts, M.G., A.S. Hadley and W.J. Kress. 2015. Pollinator recognition by a keystone tropical plant. *Proceedings of the National Academy of Science* 112(11): 3433–3438.
- Boyce, P.C. and T.B. Croat. 2011 onwards. The Überlist of Araceae, totals for published and estimated number of species in aroid genera. Received from: <http://www.aroid.org/genera/180211uberlist.pdf>. Accessed 14 Feb. 2018.
- Bunting, G.S. 1960. A revision of *Spathiphyllum* (Araceae). *Memoirs of the New York Botanical Garden* 10(3): 1–53.

- Burslem, D., M. Pinard and S. Hartley. 2005. Biotic interactions in the tropics: their role in the maintenance of species diversity. Cambridge: Cambridge University Press pp. xi.
- Caballero, J., V. Manuel Toledo, A. Argueta, E. Aguirre, P. Rojas and J. Viccon. 1978. Estudio botánico y ecológico de la region del Río Uxpanapa, Veracruz, No. 8: Flora útil o el uso tradicional de las plantas. *Biotica* 3(2): 103–144.
- Carlo, T.A., J.A. Collazo and M.J. Groom. 2003. Avian fruit preferences across a Puerto Rican forested landscape: pattern consistency and implications for seed removal. *Oecologia* 134: 119–131.
- Carlo, T.A., J.A. Collazo and M.J. Groom. 2004. Influences of fruit diversity and abundance on bird use of two shaded coffee plantations. *Biotropica* 36(4): 602–614.
- Carlo, T.A. and J.E. Aukema. 2005. Female-directed dispersal and facilitation between a tropical mistletoe and a dioecious host. *Ecology* 86(12): 3245–3251.
- Carlsen, M.M. 2011. Understanding the origin and rapid diversification of the genus *Anthurium* Schott (Araceae), integrating molecular phylogenetics, morphology and fossils. Ph.D. thesis, University of Missouri–St. Louis, St. Louis, Missouri, United States.
- Carlsen, M.M. and T.B. Croat. 2013. A molecular phylogeny of the species-rich neotropical genus *Anthurium* (Araceae) based on combined chloroplast and nuclear DNA. *Systematic Botany* 38(3): 576–588.
- Chartier, M. L. Pélozuelo, B. Buatois, J.-M. Bessièrre and M. Gibernau. 2014. Geographical variation of odour and pollinators, and test for local adaptation by reciprocal transplant of two European *Arum* species. *Functional Ecology* 27: 1367–1381.
- Chartier, M., M. Gibernau and S.S. Renner. 2014. The evolution of pollinator-plant interaction types in the Araceae. *Evolution* 68(5): 1533–1543.
- Chaverri, G. and T.H. Kunz. 2006. Roosting ecology of the tent-roosting bat *Artibeus watsoni* (Chiroptera: Phyllostomidae) in southwestern Costa Rica. *Biotropica* 38(1): 77–84.
- Choe, J.C. and R.M. Timm. 1985. Roosting site selection by *Artibeus watsoni* (Chiroptera: Phyllostomidae) on *Anthurium ravenii* (Araceae) in Costa Rica. *Journal of Tropical Ecology* 1(3): 241–247.

- Chouteau, M., M. Gibernau and D. Barabé. 2008. Relationships between floral characters, pollination mechanisms, life forms, and habitats in Araceae. *Botanical Journal of the Linnean Society* 156: 29–42.
- Chuah, C.H., L.E. Ooi, H.S. Yong and S.H. Goh. 1996. New male fruitfly attractants from spadix of *Spathiphyllum cannaefolium* (Araceae). *Biochemical Systematics and Ecology* 24(3): 189–193.
- Clark, J.L., L. Clavijo and N. Muchhala. 2015. Convergence of anti-bee pollination mechanisms in the Neotropical plant genus *Drymonia* (Gesneriaceae). *Evolutionary Ecology* 29: 355–377.
- Conran, J.G. and J.H. Bradbury. 2007. *Aspidistras*, amphipods and Oz: Niche opportunism between strangers in a strange land. *Plant Species Biology* 22: 41–48.
- Correa, D.F., E. Álvarez and P.R. Stevenson. 2015. Plant dispersal systems in Neotropical forests: availability of dispersal agents or availability of resources for constructing zoochorous fruits? *Global Ecology and Biogeography* 24: 203–214.
- Cota-Sánchez, J.H. 2004. Vivipary in the Cactaceae: its taxonomic occurrence and biological significance. *Flora* 199: 481–490.
- Cota-Sánchez, J.H. and D.D. Abreu. 2007. Vivipary and offspring survival in epiphytic cactus *Epiphyllum phyllanthus* (Cactaceae). *Journal of Experimental Botany* 58(14): 3865–3873.
- Croat, T.B. 1980. Flowering behavior of the neotropical genus *Anthurium* (Araceae). *American Journal of Botany* 67(6): 888–904.
- Croat, T.B. and R.D. Sheffer. 1983. The sectional groupings of *Anthurium* (Araceae). *Aroideana* 6(3): 85–123.
- Croat, T.B. 1991. A revision of *Anthurium* section *Pachyneurium* (Araceae). *Annals of the Missouri Botanical Garden* 78(3): 539–855.
- Croat, T.B. 1994. The use of the New World Araceae as drug plants. *Journal of Japanese Botany* 69: 185–203.
- Croat, T.B. 2014. A review of *Anthurium* species with “black” spathes. *Aroideana* 37: 95–104.
- Croat, T.B. 2015. A review of studies on neotropical Araceae. *Aroideana* 38(1): 44–54.

- Cruz-Angón, A. and R. Greenberg. 2005. Are epiphytes important for birds in coffee plantations? An experimental assessment. *Journal of Applied Ecology* 42(1): 150–159.
- Cuartas-Hernández, S. and R. Medel. 2015. Topology of plant-flower visitor networks in a tropical mountain forest: Insights on the role of altitudinal and temporal variation. *PLoS ONE* 10(10): e0141804. doi:10.1371/journal.pone.0141804.
- da Silva, H.R., M.C. de Britto-Pereira and U. Caramaschi. 1989. Frugivory and seed dispersal by *Hyla truncata*, a neotropical treefrog. *Copeia* 1989(3): 781–783.
- da Silva, H.R. and M.C. de Britto-Pereira. 2006. How much fruit do fruit-eating frogs eat? An investigation on the diet of *Xenohyla truncata* (Lissamphibia: Anura: Hylidae). *Journal of Zoology* 270: 692–698.
- Darling, D.C. 2007. Holy Aroids: circular trenching behavior by a leaf beetle in Vietnam. *Biotropica* 39(4): 555–558.
- Darwin, C. 1876. The effects of cross and self fertilization in the vegetable kingdom. John Murray; London.
- de Figueiredo, R.A. and M. Sazima. 2007. Phenology and Pollination Biology of Eight Peperomia species (Piperaceae) in semideciduous forests in southeastern Brazil. *Plant Biology* 9(2007): 136–141.
- 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.
- 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.
- Dodson, C.H. 1966. Ethology of some bees of the Tribe Euglossini (Hymenoptera: Apidae). *Journal of the Kansas Entomological Society* 39(4): 607–629.
- Dodson, C.H. and A.H. Gentry. 1978. Flora of the Rio Palenque Science Center: Los Rios Province Ecuador. *Selbyana* 4(1/6): 1–628.
- Dressler, R.L. 1968. Observations on orchids and euglossine bees in Panama and Costa Rica. *Revista de Biología Tropical* 15(1): 143–183.

- Dressler, R.L. 1982. New species of *Euglossa* IV. The *cordata* and *purpurea* species groups (Hymenoptera: Apidae). *Revista Biología Tropical* 30(2): 141–150.
- Ducke, A. 1902. Beobachtungen über Blütenbesuch, Erscheinungszeit etc. der bei Pará vorkommenden Bienen. *Allgemeine Zeitschrift für Entomologie* 7: 326.
- Duke, J.A. 1972. Isthmian Ethnobotanical Dictionary. Fulton, Maryland. pp. 6.
- Elmqvist, T. and P.A. Cox. 1996. The evolution of vivipary in flowering plants. *Oikos* 77(1): 3–9.
- Eliyahu, D., A.C. McCall, M. Lauck, A. Trakhtenbrot and J.L. Bronstein. 2015. Minute pollinators: the role of thrips (Thysanoptera) as pollinators of pointleaf manzanita, *Arctostaphylos pungens* (Ericaceae). *Journal of Pollination Ecology* 16: 64–71.
- Endara, M.-J., P.D. Coley, G. Ghabash, J.A. Nicholls, K.G. Dexter, D.A. Donoso, G.N. Stone, R.T. Pennington and T.A. Kursar. 2017. Coevolutionary arms race versus host defense chase in a tropical herbivore-plant system. *Proceedings of the National Academy of Science* 114(36): E7499–E7505.
- Ervik, F., L. Tollsten and J.T. Knudsen. 1999. Floral scent chemistry and pollination ecology in phytelephantoid palms (Arecaceae). *Plant Systematics and Evolution* 217: 279–297.
- Estrada, A., R. Coates-Estrada, C. Vasquez-Yanes and A. Orozco-Segovia. 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: 3–13.
- Etl, F., A. Berger, A. Weber, J. Schönenberger and S. Dötterl. 2016. Nocturnal plant bugs use *cis*-Jasmone to locate inflorescences of an Araceae as feeding and mating site. *Journal of Chemical Ecology* 42: 300–304.
- Etl, F., A. Franschitz, A.J.C. Aguilar, J. Schönenberger and S. Dötterl. 2017. A perfume-collecting male oil bee? Evidences of a novel pollination system involving *Anthurium acutifolium* (Araceae) and *Paratetrapedia chochoensis* (Apidae, Tapinotaspidini). *Flora* 232: 7–15.
- Farnsworth, E. 2000. The ecology and physiology of viviparous and recalcitrant seeds. *Annual Review of Ecology, Evolution and Systematics* 31: 107–138.

- Francis, A.W., I.C. Stocks, T.R. Smith, A.J. Boughton, C.M. Mannion and L.S. Osborne. Host plants and natural enemies of rugose spiraling whitefly (Hemiptera: Aleyrodidae) in Florida. *Florida Entomologist* 99(1): 150–153.
- Franz, N.M. 2003. Systematics of *Cyclanthura* gen.n., a new genus of Derelomini (Coleoptera: Curculionidae). *Insect Systematics & Evolution* 34(2): 153–198.
- Franz, N.M. 2006. Towards a phylogenetic system of derelomine flower weevils (Coleoptera: Curculionidae). *Systematic Entomology* 31: 220–287.
- Franz, N.M. 2007. Pollination of *Anthurium* (Araceae) by derelomine flower weevils (Coleoptera: Curculionidae). *Revista de Biología Tropical* 55(1): 269–277.
- Frodin, D.G. 2004. History and concepts of big plant genera. *Taxon* 53(3): 753–776.
- Galeano, G., S. Suárez, and H. Balslev. 1998. Vascular plant species count in a wet forest in the Chocó area on the Pacific coast of Colombia. *Biodiversity and Conservation* 7: 1563–1575.
- Galindo-González, J., S. Guevara and V.J. Sosa. 2000. Bat- and bird-generated seed rains at isolated trees in pastures in a tropical rainforest. *Conservation Biology* 14(6): 1693–1703.
- Gamba, D., N.R. Maguiña, C. A. Calderón-Acevedo, K. Torres and N.C. Muchhala. 2016. Seed dispersal for the unusual inflated berries of *Burmeistera* (Campanulaceae). *Neotropical Biodiversity* 3(1): 10–17.
- García-Robledo, C., G. Kattan, C. Murcia and P. Quintero-Marín. 2004. Beetle pollination and fruit predation of *Xanthosoma daguense* (Araceae) in an Andean cloud forest in Colombia. *Journal of Tropical Ecology* 20: 459–469.
- García-Robledo, C., P. Quintero-Marín and F. Mora-Kepfer. 2005. Geographic variation and succession of arthropod communities in inflorescences and infructescences of *Xanthosoma* (Araceae). *Biotropica* 37(4): 650–656.
- Gentry, A.H. and C. Dodson. 1987. Contribution of nontrees to species richness of a tropical rain forest. *Biotropica* 19(2): 149–156.
- Gibernau, M., D. Barabé, P. Cerdan and A. Dejean. 1999. Beetle pollination of *Philodendron solimoesense* (Araceae) in French Guiana. *International Journal of Plant Sciences* 160(6): 1135–1143.

- Gibernau, M., J. Albre, A. Dejean and D. Barabé. 2002. Seed predation in *Philodendron solimoesense* (Araceae) by chalcid wasps (Hymenoptera). *International Journal of Plant Sciences* 163(6): 1017–1023.
- Gibernau, M. 2003. Pollinators and visitors of aroid inflorescences. *Aroideana* 26: 73–91.
- Gibernau, M. 2011. Pollinators and visitors of aroid inflorescences: an addendum. *Aroideana* 34: 70–83.
- Gibernau, M. 2016. Pollinators and visitors of aroid inflorescences III – phylogenetic and chemical insights. *Aroideana* 39(3): 4–22.
- Gómez-Murillo, L. and S.E. Cuartas-Hernández. 2016. Patterns of diversity of flower-visitor assemblages to the understory Araceae in a tropical mountain forest in Colombia. *Journal of Insect Conservation* 20(6): 1069–1085.
- González, J.M. 1996. Fauna of the Henri Pittier National Park: Euglossini (Hymenoptera: Apidae: Bombinae). Keys and preliminary list. *Memoria de la Sociedad de Ciencias Naturales la Salle* 56(145): 45–54.
- González-Ball, R., T. Burmúdez-Rojas and M. Romero-Vargas. 2017. Floristic composition and richness of urban domestic gardens in three urban socioeconomic stratifications in the city Heredia, Costa Rica. *Urban Ecosystems* 20: 51–63.
- Gorchov, D.L., F. Cornejo, C.F. Ascorra and M. Jaramillo. 1995. Dietary overlap between frugivorous birds and bats in the Peruvian Amazon. *Oikos* 74(2): 235–250.
- Grayum, M.H. 1990. Evolution and phylogeny of the Araceae. *Annals of the Missouri Botanical Garden* 77(4): 628–697.
- Green, S.B.R., G.L. Gentry, H.F. Greeney and L.A. Dyer. 2011. Ecology, natural history, and larval descriptions of Arctiinae (Lepidoptera: Noctuoidea: Erebidae) from a cloud forest in the eastern Andes of Ecuador. *Annals of the Entomological Society of America* 104(6): 1135–1148.
- Hara, A.H., C. Jacobsen and R.Niino-DuPonte. 2002. Anthurium thrips damage to ornamentals in Hawaii. *Insect Pests* 9: 1–9
- Hartley, N.P., T. Krömer and M. Gibernau. 2017. Lepidopteran visitors of *Anthurium* inflorescences. *Aroideana* 40(1): 84–96.

- Hentrich, H., R. Kaiser and G. Gottsberger. 2007. Floral scent collection at the perfume flowers of *Anthurium rubrinervium* (Araceae) by the klepto-parasitic orchid bee *Aglae caerulea* (Euglossini). *Ecotropica* 13: 149–155.
- Hentrich, H., R. Kaiser and G. Gottsberger. 2010. Floral biology and reproductive isolation by floral scent in three sympatric aroid species in French Guiana. *Plant Biology* 12: 587–596.
- Hoe, Y.C., M. Gibernau, A.C.D. Maia and S.Y. Wong. 2016. Flowering mechanisms, pollination strategies and floral scent analyses of syntopically co-flowering *Homalomena* spp. (Araceae) on Borneo. *Plant Biology* 18: 563–576.
- Hoe, Y.C., M. Gibernau and S.Y. Wong. 2018. Diversity of pollination ecology in the *Schismatoglottis* Calyptrata Complex Clade (Araceae). *Plant Biology* 20: 563–578.
- Horsley, T.W.B., J.E. Bicknell, B.K. Lim and L.K. Ammerman. 2015. Seed dispersal by frugivorous bats in central Guyana and a description of previously unknown plant-animal interactions. *Acta Chiropterologica* 17(2): 331–336.
- Howell, D.J. and D. Burch. 1974. Food habits of some Costa Rican bats. *Revista Biología Tropical* 21(2): 281–294.
- Ingram, S.W., K. Ferrell-Ingram and N.M. Nadkarni. 1996. Floristic composition of vascular epiphytes in a neotropical cloud forest, Monteverde, Costa Rica. *Selbyana* 17(1): 88–103.
- Jackson, A.P., C.A. Machado, N. Robbins and E.A. Herre. 2008. Multi-locus phylogenetic analysis of neotropical figs does not support co-speciation with the pollinators: The importance of systematic scale in fig-wasp cophylogenetic studies. *Symbiosis* 45: 57–72.
- Jin, B., L. Zhang, Y. Lu, D. Wang, X.X. Jiang, M. Zhang and L. Wang. 2012. The mechanism of pollination drop withdrawal in *Ginkgo biloba* L. *BMC Plant Biology* 12: 59. doi:10.1186/1471-2229-12-59.
- Jin, S., X. Zhang and H. Daniell. 2012. *Pinellia ternate* agglutinin expression in chloroplasts confers broad spectrum resistance against aphid, whitefly, *Lepidopteran* insects, bacterial and viral pathogens. *Plant Biotechnology Journal* 10: 313–327.

- Johnson, S.D., N. Hobbhanh and B. Bytebier. 2013. Ancestral deceit and labile evolution of nectar production in the African orchid genus *Disa*. *Biology Letters* 9: 20130500. <http://dx.doi.org/10.1098/rsbl.2013.0500>.
- Kelly, D. L. 1985. Epiphytes and climbers of a Jamaican rain forest: vertical distribution, life forms and life histories. *Journal of Biogeography* 12(3): 223–241.
- Kimsey, L.S. 1982. Systematics of bees of the genus *Eufriesea* (Hymenoptera: Apidae). University of California Publications in Entomology Volume 95.
- Konstantinov, F.V. and A.A. Knyshov. 2015. The tribe Bryocorini (Insecta: Heteroptera: Miridae: Bryocorinae): phylogeny, description of a new genus, and adaptive radiation on ferns. *Zoological Journal of the Linnean Society* 175: 441–472.
- Knudsen, J.T., L. Tollsten, I. Groth, G. Bergstrom and R.A. Raguso. 2004. Trends in floral scent chemistry in pollination syndromes: floral scent composition in hummingbird-pollinated taxa. *Botanical Journal of the Linnean Society* 146: 191–199.
- Knudsen, J.T. and S.A. Mori. 1996. Floral scents and pollination in neotropical Lecythidaceae. *Biotropica* 28(1): 42–60.
- Knuth, P. Handbook of Flower Pollination based on Hermann Müller's work 'The Fertilisation of Flowers by Insects'. Oxford: Clarendon Press. pp. 18, 78–80.
- Kraemer, M. and U. Schmitt. 1999. Possible pollination by hummingbirds in *Anthurium sanguineum* Engl. (Araceae). *Plant Systematics and Evolution* 217(3): 333–335.
- Kuanprasert, N., A.R. Kuehnle and C.S. Tang. 1998. Floral fragrance compound of some *Anthurium* (Araceae) species and hybrids. *Phytochemistry* 40(2): 521–528.
- Kuanprasert, N. and A.R. Kuehnle. 1999. Fragrance quality, emission, and inheritance in *Anthurium* species and hybrids. *Aroideana* 22: 48–62.
- Kunz, T.H., E. Braun de Torrez, D. Bauer, T. Lobova and T.H. Fleming. 2011. Ecosystem services provided by bats. *Annals of the New York Academy of Sciences* 1223: 1–38.
- Lagomarsino, L.P., E.J. Forrestel, N. Muchhala and C.C. Davis. 2017. Repeated evolution of vertebrate pollination syndromes in a recently diverged Andean plant clade. *Evolution* 71(8): 1970–1985.
- Lee, J.C., A.J. Dreves, A.M. Cave, S. Kawai, R. Isaacs, J.C. Miller, S. van Timmeren and D.J. Bruck. 2015. Infestation of wild and ornamental noncrop fruits by *Drosophila*

- suzukii* (Diptera: Drosophilidae). *Annals of the Entomological Society of America* 108(2): 117–129.
- Li. S.-J., X. Xue, M.Z. Ahmed, S.-X. Ren, Y.-Z. Du, J.-H. Wu, A.G.S. Cuthbertson and B.-L. Qiu. 2011. Host plants and natural enemies of *Bemisia tabaci* (Hemiptera: Aleyrodidae) in China. *Insect Science* 18: 101–120.
- Lindner, A. and W. Morawetz. 2006. Seed dispersal by frugivorous bats on landslides in a montane rain forest in southern Ecuador. *Chiroptera Neotropical* 12(1): 232–237.
- Lobova, T.A., C.K. Geiselman and S.A. Mori. 2009. Seed dispersal by bats in the neotropics. New York: The New York Botanical Garden Press pp. 43 & 252.
- Loiselle, B.A. and J.G. Blake. 1990. Diets of understory fruit-eating birds in Costa Rica: seasonality and resource abundance. *Studies in Avian Biology* 13: 91–103.
- Loiselle, B.A., P.G. Blendinger, J.G. Blake and T.B. Ryder. 2007. Ecological redundancy in seed dispersal systems: a comparison between manakins (Aves: Pipridae) in two tropical forests. In: Dennis, A.J., E.W. Schupp, R.J. Green and D.A. Westcott (Eds.), *Seed Dispersal: theory and its application in a changing world*. Oxfordshire: CAB International pp.178–195.
- Londoño, G.A. 2005. A description of the nest and eggs of the pale-eyed thrush (*Platycichla leucops*), with notes on incubation behavior. *Wilson Bulletin* 117(4): 394–399.
- Londoño, G.A., M.C. Muñoz and M.M. Rios. 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.
- Lopez, J.E. and C. Vaughan. 2004. Observations on the role of frugivorous bats as seed dispersers in Costa Rican secondary humid forests. *Acta Chiropterologica* 6(1): 111–119.
- Lopez, J.E. and C. Vaughan. 2007. Food niche overlap among neotropical frugivorous bats in Costa Rica. *Revista de Biología Tropical* 55(1): 301–313.
- Low, S.L., S.Y. Wong, I.H. Ooi, M. Hesse, Y. Städler, J. Schönenberger and P.C. Boyce. 2016. Floral diversity and pollination strategies of three rheophytic Schismatoglottideae Araceae). *Plant Biology* 18: 84–97.

- Madison, M. 1977a. Vascular epiphytes: their systematic occurrence and salient features. *Selbyana* 2(1): 1–13.
- Madison, M. 1977b. A revision of *Monstera* (Araceae). *Contributions from the Gray Herbarium of Harvard University* No. 207, pp. 15.
- Madison, M. 1979a. Protection of developing seeds in neotropical Araceae. *Aroideana* 2: 52–61.
- Madison, M. 1979b. Additional observations on ant-gardens in Amazonas. *Selbyana* 5(2): 107–115.
- Maia, A.C.D., C. Schlindwein, D. Navarro and M. Gibernau. 2010. Pollination of *Philodendron acutatum* (Araceae) in the Atlantic forest of northeastern Brazil: a single scarab beetle species guarantees high fruit set. *International Journal of Plant Sciences* 171: 740–748.
- Maia, A.C.D., S. Dötterl, R. Kaiser, I. Silberbauer-Gottsberger, H. Teichert, M. Gibernau, D.M.A.F. Navarro, C. Schlindwein and G. Gottsberger. 2012. The key role of 4-methyl-5-vinylthiazole in the attraction of scarab beetle pollinators: a unique olfactory floral signal shared by Annonaceae and Araceae. *Journal of Chemical Ecology* 38: 1072–1080.
- Maia, A.C.D., M. Gibernau, A.T. Carvalho, E.G. Gonçalves and C. Schlindwein. 2013. The cowl does not make the monk: scarab beetle pollination of the Neotropical aroid *Taccarum ulei* (Araceae: Spathicarpeae). *Biological Journal of the Linnean Society* 108: 22–34.
- Malumphy, C. 2011. First records of the Neotropical whitefly, *Crenidorsum aroidephagus* Martin & Aguiar (Hemiptera: Aleyrodidae), from Malaysia, Mauritius and Singapore. *Entomologist's Monthly Journal* 147(1769–71): 250–252.
- Gómez, J.M., F. Perfectti, M. Abdelaziz, J. Lorite, A.J. Muñoz-Pajares and J. Valverde. 2014. Evolution of pollination niches in a generalist plant clade. *New Phytologist* 205: 440–453.
- Marini-Filho, O.J. 1999. Distribution, composition, and dispersal of ant gardens and tending ants in three kinds of central Amazonian habitats. *Tropical Zoology* 12: 289–296.
- Martin, J.H., A.M.F. Aguiar and P. Baufeld. 2001. *Crenidorsum aroidephagus* Martin and Aguiar sp. nov. (Sternorrhyncha: Aleyrodidae), a New World whitefly species

- now colonizing cultivated Araceae in Europe, Macaronesia and the Pacific Region. *Zootaxa* 4: 1–8.
- Martin, J.H. 2005. Whiteflies of Belize (Hemiptera: Aleyrodidae) Part 2—a review of the subfamily Aleyrodinae Westwood. *Zootaxa* 1098: 1–116.
- Mayo, S.J., J. Bogner and P.C. Boyce. 1997. The genera of Araceae. Belgium: Continental Printing.
- Mayo, S.J., L.P. Félix, J.G. Jardim and A.M. Carvalho. 2000. *Anthurium bromelicola*—a remarkable new species from northeast Brazil. *Aroideana* 23: 89–99.
- McGregor, S.E. 1976. Pollinating agents and their comparative value. In: United States Department of Agriculture (Ed.). Insect Pollination of Cultivated Crop Plants. *Agriculture Handbook*: 496: 19–23.
- Meeuse, B.J.D. 1978. The physiology of some sapromyophilous flowers. In: Richards, A.J. (Ed.), The pollination of flowers by insects. Academic Press Inc., New York, pp. 97–104.
- Milet-Pinheiro, P., E.G. Gonçalves, D.M.A.F. Navarro, L.A. Nuñez-Avellaneda and A.C.D. Maia. 2017. Floral scent chemistry and pollination in the Neotropical aroid genus *Xanthosoma* (Araceae). *Flora* 231: 1–10.
- Miyake, T. and M. Yafuso. 2005. Pollination of *Alocasia cucullata* (Araceae) by two *Colocasiomyia* flies known to be specific pollinators for *Alocasia odora*. *Plant Species Biology* 20: 201–208.
- Molinari, J. and P.J. Soriano. 1987. *Sturnira bidens*. *Mammalian Species* 276: 1–4.
- Montalvo, A.M. and J.D. Ackerman. 1986. Relative pollinator effectiveness and evolution of floral traits in *Spathiphyllum friedrichsthali* (Araceae). *American Journal of Botany* 73(12): 1665–1676.
- Namyatova, A.A. and G. Cassis. 2016. Systematic revision and phylogeny of the plant bug tribe Monaloniini (Insecta: Heteroptera: Miridae: Bryocorinae) of the world. *Zoological Journal of the Linnean Society* 176: 36–136.
- Nauheimer, L., D. Metzler and S.S. Renner. 2012. Global history of the ancient monocot family Araceae inferred with models accounting for past continental positions and previous ranges based on fossils. *New Phytologist* 195: 938–950.

- Noyes, R.D. and L.H. Rieseberg 2000. Two independent loci control agamospermy (apomixis) in the triploid flowering plant *Erigeron annuus*. *Genetics* 155: 379–390.
- Nemésio, A. and C. Rasmussen. 2014. Sampling a biodiversity hotspot: the orchid-bee fauna (Hymenoptera: Apidae) of Tarapoto, northeastern Peru, the richest and most diverse site of the neotropics. *Brazilian Journal of Biology* 74(3): S33–S44.
- Ima Omene, M.O. 2012. “Saberes Waorani y Parque Nacional Yasuní: plantas, salud y bienestar en la Amazonía del Ecuador.” *Iniciativa Yasuní ITT, Ministerio Coordinador de Patrimonio, Ministerio del Ambiente, Programa de las Naciones Unidas para el Desarrollo (PNUD) y Fondo para el Medio Ambiente Mundial (FMAM)*. Quito, Ecuador. pp. 70–71.
- Orivel, J. and A. Dejean. 1999. Selection of epiphyte seeds by ant-garden ants. *Ecoscience* 6(1): 51–55.
- Orozco-Segovia, A. and C. Vázquez Yanes. 1982. Plants and fruit bat interactions in a tropical rain forest area, southeastern Mexico. *Brenesia* 19/20: 137–149.
- Ospina-Torres, R., P.M. Montoya-Pfeiffer, A.Parra-H., V. Solarte and J.T. Otero. 2015. Interaction networks and the use of floral resources by male orchid bees (Hymenoptera: Apidae: Euglossini) in a primary rain forests of the Chocó Region (Colombia). *Revista de Biología Tropical* 63(3): 647–658.
- Pammel, L.H. and C.M. King. 1930, Honey plants of Iowa. *Iowa Geological Survey Bulletin* 7: 892–894.
- Pan, H., B. Liu, Y. Lu and K.A.G. Wyckhuys. 2015. Seasonal alteration in host range and fidelity in the polyphagous mirid bug, *Apolygus lucorum* (Heteroptera: Miridae). *PLoS ONE* 10(2): e0117153. doi:10.1371/journal.pone.0117153.
- Patt, J.M., J.C. French, C. Schal, J. Lech and T.G. Hartman. 1995. The pollination biology of tuckhoe, *Peltandra virginica* (Araceae). *American Journal of Botany* 82(10): 1230–1240.
- Paulson, G.S. and J.W. Beardsley. 1985. Whitefly (Hemiptera: Aleyrodidae) egg pedicel insertion into host plant stomata. *Annals of the Entomological Society of America* 78(4): 506–
- Passos, L. and P.S. Oliveira. 2003. Interactions between ants, fruits and seeds in a resting forest in south-eastern Brazil. *Journal of Tropical Ecology* 19: 261–270.

- Plowman, T. 1969. Folk uses of new world aroids. *Economic Botany* 23(2): 97–122.
- Poyet, M., V. le Roux, P. Gibert, A. Meirland, G. Prévost, P. Eslin and O. Chabrierie. 2015. The wide potential trophic niche of the Asiatic fruit fly *Drosophila suzukii*: The key of its invasion success in temperate Europe? *PLoS ONE* 10(11): e0142786. doi: 10.1371/journal.pone.0142785.
- Prieto, D. and A. Cascante-Marín. 2017. Pollination by nitidulid beetles in the hemi-epiphytic aroid *Monstera lantii* (Araceae: Monsteroideae). *Flora* 231: 57–64.
- Rains, K.C., N.M. Nadkarni and C.S. Bledsoe. 2003. Epiphytic and terrestrial mycorrhizas in a lower montane Costa Rican cloud forest. *Mycorrhiza* 13: 257–264.
- Ramírez, S., R.L. Dressler and M. Ospina. 2002. Abejas euglosinas (Hymenoptera: Apidae) de la región neotropical: listado de especies con notas sobre su biología. *Biota Colombiana* 3(1): 7–118.
- Renner, S.S. 2006. Rewardless flowers in the angiosperms and the role of insect cognition in their evolution. *In*: N.M. Waser and J. Ollerton, eds. *Plant-pollinator interactions: from specialization to generalization*. University of Chicago, Chicago, IL. pp. 123–144.
- Riba-Hernández, P., K.E. Stoner and P.W. Lucas. 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: 709–716.
- Rocha-Filho, L.C., C. Krug, C.I. Silva, and C.A. Garófalo. 2012. Floral resources used by Euglossini bees (Hymenoptera: Apidae) in coastal ecosystems of the Atlantic Forest. *Psyche: a journal of entomology* 2012: 13 pages: <http://dx.doi.org/10.1155/2012/934951>
- Roubik, D.W. 2004. Sibling species of *Glossura* and *Glossuropoda* in the Amazon region (Hymenoptera: Apidae: Euglossini). *Journal of the Kansas Entomological Society* 77(3): 235–253.
- Ryder, T.B., J.G. Blake and B.A. Loiselle. 2006. A test of the environmental hotspot hypothesis for lek placement in the three species of manakins (Pipridae) in Ecuador. *The Auk* 123(1): 247–258.
- Salaman, P. 1996. The uncovered treasures of the Río Nambí paradise. *World Birdwatch* 18:16–19.

- Santori, R.T., D. Astúa de Moraes and R. Cerqueira. 1996. Diet composition of *Metachirus nudicaudatus* and *Didelphis aurita* (Marsupialia, Didelphoidea) in southeastern Brazil. *Mammalia* 59(4): 511–516.
- Sarma, K., R. Tandon, K.R. Shivanna and H.Y. Mohan Ram. 2007. Snail-pollination in *Volvulus nummularium*. *Current Science* 93(6): 826–831.
- Sarria-Guzmán, Y., Y. Chávez-Romero, S. Gómez-Acata, J.A. Montes-Molina, E. Morales-Salazar, L. Dendooven and Y.E. Navarro-Noya. 2016. Bacterial communities associated with different *Anthurium andraeanum* L. plant tissues. *Microbes and Environment* 31(3): 321–328.
- Scherbaum, C. and A. Estrada. 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.
- Schiestl, F.P. and S. Dötterl. 2012. The evolution of floral scent and olfactory preferences in pollinators: coevolution or pre-existing bias? *Evolution* 66(7): 2042–2055.
- Schwerdtfeger, G.G. and R. Kaiser. 2002. Anthecology in the neotropical genus *Anthurium* (Araceae): a preliminary report. *Selbyana* 23(2): 258–267.
- Sheffer, R.D. and H. Kamemoto. 1976. Chromosome numbers in the genus *Anthurium*. *American Journal of Botany* 63(1): 74–81.
- Sheffer, R.D., W.L. Theobald and H. Kamemoto. 1980. Taxonomy of *Anthurium scandens* (Araceae). *Aroideana* 3(3): 86–93.
- Sheffer, R.D. and T.B. Croat. 1983. Chromosome numbers in the genus *Anthurium* (Araceae) II. *American Journal of Botany* 70(6): 858–871.
- Simmonds, N.W. 1950. Notes on the biology of the Araceae of Trinidad. *Journal of Ecology* 38(2): 277–291.
- Snow, B.K. and D.W. Snow. 1971. The feeding ecology of tanagers and honeycreepers in Trinidad. *The Auk* 88 (2): 291–322.
- Snow, D.W. 1981. Tropical frugivorous birds and their food plants: a world survey. *Biotropica* 13(1): 1–14.
- Stancato, G.C. and A.P.D. da Silveira. 2006. Associação de fungos micorrízicos arbusculares e cultivares micropropagadas de Antúrio. *Bragantia* 65(3): 511–516.

- Stiles, F.G. and L. Rosselli. 1993. Consumption of fruits of the Melastomataceae by birds: how diffuse is coevolution? *Vegetatio* 107/108: 57–73.
- Suetsugu, K. and M. Sueyoshi. 2018. Specialized pollination by fungus gnats in the introduced population of *Aspidistra elatior*. *Journal of Plant Research* 131: 497–503.
- Sultana, F., Y.-G. Hu, M.J. Toda, K. Takenaka and M. Yafuso. 2006. Phylogeny and classification of *Colocasiomyia* (Diptera, Drosophilidae), and its evolution of pollination mutualism with aroid plants. *Systematic Entomology* 31: 684–702.
- Sun, M., P.M. Schluter, K. Gross and F.P. Schiestl. 2015. Floral isolation is the major reproductive barrier between a pair of rewarding orchid sister species. *Journal of Evolutionary Biology* 28: 117–129.
- Takano, K.T., R. Repin, M.B. Mohamed and M.J. Toda. 2012. Pollination mutualism between *Alocas macrorrhizos* (Araceae) and two taxonomically undescribed *Colocasiomyia* species (Diptera: Drosophilidae)-in Sabah, Borneo. *Plant Biology* 14: 555–564.
- Toda, M. and M.B. Lakim. 2011. Genus *Colocasiomyia* (Drosophilidae: Diptera) in Sabah, Bornean Malaysia: High species diversity and use of host aroid inflorescences. *Entomological Science* 14: 262–270.
- Terborgh, J. 1983. *Five new world primates: a study in comparative ecology*. Princeton: Princeton University Press. pp.59–95.
- Tsacas, L. and M.T. Chassagnard. 1992. Les relations *Araceae-Drosophilidae*. *Drosophila aracea* une espèce anthophile associée à l'Aracée *Xanthosoma robustum* au Mexique (Diptera: Drosophilidae). *Annales de la Société Entomologique de France* 28(4): 421–439.
- Ule, E. 1905. Wechselbeziehungen zwischen Ameisen und Pflanzen 94: 491–497.
- Ulloa Ulloa, C., P. Acevedo-Rodríguez, S. Beck, M.J. Belgrano, R. Bernal, P.E. Berry, L. Brako, M. Celis, G. Davidse, R.C. Forzza, S.R. Gradstein, O. Hokche, B. León, S. León-Yáñez, R.E. Magill, D.A. Neill, M. Nee, P.H. Raven, H. Stimmel, M.T. Strong, J.L. Villaseñor, J.L. Zarucchi, F.O. Zuloaga and P.M. Jørgensen. 2017. An integrated assessment of the vascular plant species of the Americas. *Science* 358: 1614–1617.

- Valencia-Aguilar, A., F. Castro-Herrera and M.P. Ramírez-Pinilla. 2012. Microhabitats for oviposition and male clutch attendance in *Hyalinobatrachium aureoguttatum* (Anura: Centrolenidae). *Copeia* 4: 722–731.
- Valerio, C.E. and E. Villalobos. 1980. Polinización y eficiencia reproductiva en *Anthurium scandens* (Araceae). *Brenesia* 18: 137–146.
- van Damme, E.J.M., K. Goossens, K. Smeets, F. van Leuven, P. Verhaert and W.J. Peumans. 1995. The major tuber storage protein of Araceae species is a lectin. *Plant Physiology* 107: 1147–1158.
- van Dulmen, A. 2001. Pollination and phenology of flowers in the canopy of two contrasting rain forest types in Amazonia, Colombia. *Plant Ecology* 153: 73–85.
- Vázquez-Yanes, C., A. Orozco, G. François and L. Trejo. 1975. Observations on seed dispersal by bats in a tropical humid region in Veracruz, Mexico. *Biotropica* 7(2): 73–76.
- Vélez, J., J.M. Espelta, O. Rivera and D. Armenteras. 2017. Effects of seasonality and habitat on frugivory preferences of *Tapirus terrestris* in north-western Amazonia. *Journal of Tropical Ecology* 33: 395–406.
- Vieira, E.M. and P. Izar. 1999. Interactions between aroids and arboreal mammals in the Brazilian Atlantic Rainforest. *Plant Ecology* 145(1): 75–82.
- Villalobos Muller, W., N. Pérez Hidalgo, M.P. Mier Durante and J.M. Nieto Nafría. 2010. Aphididae (Hemiptera: Sternorrhyncha) from Costa Rica, with new records for Central America. *Boletín de la Asociación Española de Entomología* 34(1–2): 145–182.
- Vislobokov, N.A., T.V. Galinskaya, G.V. Degtjareva, C.M. Valiejo-Roman, T.H. Samigullin, A.N. Kuznetsov and D.D. Sokoloff. 2014. Pollination of Vietnamese *Aspidistra xuansonensis* (Asparagaceae) by female cecidomyiidi flies: larvae of pollinator feed on fertile pollen in anthers of anthetic bisexual flowers. *American Journal of Botany* 101(9): 1519–1531.
- Vislobokov, N.A. 2017. Flowering biology of *Aspidistra* (Asparagaceae): new data on pollination by dipteran insects. *Plant Species Biology* 32: 412–422.
- Vogel, S. and C. Westerkamp. 1991. Pollination: an integrating factor in biocoenoses. In: Seitz, A., Loeschke, V. (Eds), *Species Conservation: a population-biological approach*. Birkhauser, Basel, pp. 159–170.

- Wang, J., J. Sun, J. Xia, N. He, M. Li and S. Niu. 2018. Soil and vegetation carbon turnover times from tropical to boreal forests. *Functional Ecology* 32: 71–82.
- Wendt, L.D., E.G. Gonçalves and A.C.D. Maia. 2018. A new species of beebeomyia Curran (Diptera: Richardiidae) from Brazil, with description of immature stages and notes on their association with *Taccarum ulei* (Araceae). *Zootaxa* 4369(4): 587–599.
- Wheelright, N.T., W.A. Haber, K.G. Murray and C. Guindon. 1984. Tropical fruit-eating birds and their food plants: a survey of a Costa Rican lower montane forest. *Biotropica* 16(3): 173–192.
- Whitten, W.M., H.G. Hills and N.H. Williams. 1988. Occurrence of Ipsdienol in floral fragrances. *Phytochemistry* 27(9): 2759–2760.
- Williams, G.A., P. Adam and L.A. Mound. 2001. Thrips (Thysanoptera) pollination in Australian subtropical rainforests, with particular reference to pollination of *Wilkiea huegeliana* (Monimiaceae). *Journal of Natural History* 35(1): 1–21.
- Williams, N.H. and R.L. Dressler. 1976. Euglossine pollination of *Spathiphyllum* (Araceae). *Selbyana* 1(4): 349–356.
- Wong, S.Y., T.P. Jean, N.K. Kiaw, A.S. Othman, L.H. Boon, F.B. Ahmad and P.C. Boyce. 2013. Phylogeny of Asian Homalomena (Araceae) based on the ITS region combined with morphological and chemical data. *Systematic Botany* 38(3): 589–599.
- Worthington, A.H. 1990. Comportamiento de forrajeo de dos especies de saltarines en respuesta a la escasez de frutos. In: Leigh, E.G., A.S. Rand, and D.M. Windsor (Eds.) *Ecología de un bosque tropical: ciclos estacionales y cambios a largo plazo*. Balboa: Smithsonian Tropical Research Institute pp. 285–304.
- Yang, S., R. Albert and T.A. Carlo. 2013. Transience and constancy of interactions in a plant-frugivore network. *Ecosphere* 4(12): 1–25.
- Young, H.J. 1986. Beetle pollination of *Dieffenbachia longispatha* (Araceae). *American Journal of Botany* 73(6): 931–944.
- Youngsteadt, E., S. Nojima, C. Haberlein, S. Schulz and C. Schal. 2008. Seed odor mediates an obligate ant-plant mutualism in Amazonian rainforests. *Proceedings of the National Academy of Sciences of the United States of America* 105(12): 4571–4575.

Youngsteadt, E., P. Guerra Bustios and C. Schal. 2010. Divergent chemical cues elicit seed collecting ants in an obligate multi-species mutualism in lowland Amazonia. *PLoS ONE* 5(12): e15822. doi:10.1371/journal.pone.0015822.