HERBIVORY AND INSECT LOADS ON EPIPHYTES, VINES, AND HOST TREES IN THE RAIN FOREST CANOPY OF FRENCH GUIANA

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INTRODUCTION

One of the major obstacles in canopy research is the obvious logistical difficulty associated with access (Wilson 1989, Moffett and Lowman 1995, Lowman and Wittman 1996). It is hypothesized that the highest diversity of invertebrates in the world and a large proportion of vascular plants live in tropical forest canopies. With the rapid rates of deforestation, the development of safe and accurate sampling techniques is urgently needed. The life cycles of forest insects are directly or indirectly dependent upon the foliage in the canopy, and a large portion of them are herbivores. In this study, we quantified the herbivory pathway within the canopy of a tropical rain forest of French Guyana.

The primary canopy access method used during this project was the placement of an inflatable canopy raft situated on the top of several adjacent trees. A hot-air dirigible was used to situate the raft, and also to serve as an independent sampling vehicle above the canopy. The canopy raft was accessible by climbing a rope from the ground. During the 1991 mission of Operation Canopée in the Biafran-Congo Basin equatorial rain forests of Cameroon, a new sampling technique was designed to overcome the limitations of reaching the uppermost canopy branches of emergent trees. A canopy sled was constructed to "sail" along the treetops, maneuvered by a dirigible. In a fashion similar to fishing boats trawling with nets in shallow waters, we conducted replicated sweeps over five-minute durations on top of the canopy. The sled sampling revealed the patchiness of insect distribution between neighboring trees, as well as to provide unique access to vines, epiphytes and the foliage of emergents (Lowman, Moffett & Rinker 1993). Using the raft and sled in conjunction with the dirigible and single rope climbing techniques, we can now reach all of the foliage throughout a stand of tall trees.

In this study, we used the same methods as in the previous Operation Canopée (Lowman et al. 1992) to compare our African surveys of 1991 with a tropical rain forest on the western side of the Atlantic Ocean. We measured herbivory on the upper canopy, mid- and understory leaves of a large array of trees within the vicinity of the raft. In addition, we surveyed the epiphytes and vines in addition to the canopy trees. Our collaborative group, from Selby Gardens and affiliated institutions, had expertise in the systematics and ecology of epiphytes and canopy trees, and in the collection and identification of insect specimens. We collected voucher specimens where possible, and provided identifications for other members of the Pro-Natura scientific team.

METHODS

1. Site

Approximately 95% of French Guiana is classified as old-growth forest. The raft site was located in silviculture Plot #16 of an area called Dispositit de Paracou, Silvolab, Guyane approximately 75 km northwest of Cayenne and 5 km from the Atlantic coast. GPS locations were: Campsite - N 5° 16.40' W 52 55 50'; Launchfield - 5 16.08' W 52 55.72; and Radeau Site C - 5 15.29' W 52 56.32'. The soils in this region were sandy, acidic, and relatively poor in nutrients. Canopy height was 30-40 m with many emergents *(e.g. Pradosia cochlearia)*. A stream ran through the vicinity of the plot, and its nutrient load may have been responsible for the relatively high number of vines in the area (Foster, personal communication). As we moved away from the stream, the vine load seemed to diminish. Vines include *Orthomene, Strychnos, Pacouria, Maripa, Machaerium, Cydista, Derris, Combretum cacoucia, and Rourea.* Many were in flower or fruit during November.

The dominant tree was *Eperua rubiginosa*. On the forestry trail into the raft site, several trees were labeled from previous studies: *Eschweilera odora, Micropholis guyanensis, Trattinnickia rhoifolia, Astrocaryum sciophilum, Ocotea rubra, Tapirira guianensis, Inga nobilis, Dendrobangia boliviana, Symphonia globulifera, Carapa procera, Mouriri acutiflora, Licania ovalifolia, Swartzia remiger, Didymopanax morototoni, Recordoxylon speciosum, Vouacapoua americana, Ragala sanguinolenta, Dicorynia guianensis, Pradosia cochlearia, Moronobea coccinea, Goupia glabra, Drypetes variabilis, Licania davillifolia,* and *Eschweilera chartacea*. Palms were not common, although both *Euterpe* and Attalea were located in the vicinity of the raft. There was good evidence of vertebrates in the area including sightings of peccary, ocelot, caiman, howler monkey, and several species of snake.

Our sampling from the raft C included the following trees (and vines, some of which have not yet been identified):

Virola melinonii (Myristicaceae) with liana (Malpighiaceae); *Couratari guianensis* (Lecythidaceae) with hemiphyte *Clusia grandiflora* (Clusiaceae), liana (Rubiaceae), liana (Malpighiaceae), and liana; *Parkia velutina* (Fabaceae) with liana *Maripa sp.*(Clusiaceae); *Enterolobium schomburgtii* (Fabaceae); *Qualea sp.* (Vochysiaceae); *Recordoxylum* (Fabaceae); *Swartzia* (Fabaceae) with liana *Maripa* sp. and hemiepiphyte *Coussapoa sp.*; unidentified Fabaceae; and *Eperua rubiginosa* (Fabaceae) with liana *Machaerium sp.* and unidentified liana of Rubiaceae.

2. Foliage surveys

We sampled populations of leaves and epiphytes for insect damage, using previously developed protocols (Lowman 1984). This involved the collection of 30 leaves of known species, leaf age, height, light, and aspect for each sample. For each sample, each leaf was measured for length, width, total area, and hole area. Leaf areas and herbivory (% leaf surface area missing) were measured using a Li-Cor Area Meter either at the field site or back at our host institutions. Leaf toughness was assessed in the field using a portable penetrometer (Lowman 1985). At least three replicate sections of three leaves of each sample of 30 leaves was assessed for toughness. Leaf mining, galls, and fungal infections were visually estimated (Lowman and Heatwole 1992). Collectively, this data set allowed us to effectively "map" the rain forest canopy with respect to herbivore activity. To make the map more accurate, we also measured the presence/absence of trees and vines both in the canopy and along the forest floor within our sampling area. We hypothesized that vines may serve as highways for herbivores and thereby result in higher levels of herbivory when vines are present in a tree crown.

We collected voucher specimens where possible or else took photographs for identification. All epiphytes, vines and host trees in the vicinity of the camp, raft, and sled were sampled.

3. Herbivore Assessment

We surveyed the populations of arthropods, including herbivores in different regions of the canopy. Sampling was conducted from the raft, in the understory, and opportunistically from the canopy sled. We used a range of different techniques, since each one effectively collected different groups of arthropods:

1. beating trays (one meter square)
2. sweep nets (including our long-handled nets for the sled) (1 sweep to approximate one meter cubed of vegetation and air)
3. epiphyte tank collections
4. nocturnal observations and collections
5. aspirators
6. mini-fogging (as described in Lowman et al 1993)

From these samples, we estimated the proportions of herbivores inhabiting this canopy region and compared that data to previous studies (e.g. Lowman 1982; Moffet, Lowman and Rinker, unpublished). We also assessed the numbers of flying versus non-flying insects captured in each survey. The relative accuracy of some of these techniques was discussed elsewhere (Lowman et al. 1996).

RESULTS TO DATE

Herbivory was measured for 61 samples, including over 1500 leaves of 30 genera of vines, hemi-epiphytes, and canopy trees (Table 1). Damage levels (expressed as percent leaf surface area missing to chewing insects) ranged from as low as 0% (e.g. Clusia grandifolia) to as high as 32.5% (e.g. Inga nobilis at 2 m, understory leaves). The average damage, as measured exclusively by holes in leaves, for this site was 4.7 % leaf area missing.

The trees with vines averaged over twice as much herbivory as the trees whose canopies had no vines (7.4 % versus 2.7 %). The vines themselves had approximately half the amount of herbivory as their host tree (4.2 % vine herbivory versus 7.4 % tree herbivory). In contrast, the epiphytes on these trees averaged only 1.5 % herbivory. Only half of our data set was analyzed at the time of this report; more detailed analyses are underway in a forthcoming publication.

The insect analyses are still in process, and only data from the first week have been examined (see Appendix). Preliminary data indicate that there were more insects in the canopy than in the understory (Table 2). Of the three methods used (beating, sweeping, and misting), the misting technique captured the highest numbers of insects. The abundance of flying insects was higher in the canopy, whereas the non-flying insects were proportionally more abundant on the forest floor. The most common orders throughout all sampling were Hymenoptera (predominantly ants), Collembola, and Thysanoptera (Table 3).

From the canopy sled, paired trees with and without lianas were sampled in quick succession (Table 4). These sled data were combined with similar surveys from the raft, where paired samples of trees with and without lianas were also sampled. Trees with lianas had greater numbers of insects than trees without lianas (Table 5). Herbivores were more abundant by 2-3 fold in trees with lianas, while the total numbers of insects were consistently greater in the tree crowns with lianas. Additional data has been collected in Panama and Peru, to test this hypothesis more rigorously.

DISCUSSION

Vines may serve to encourage higher numbers of insects to visit tree crowns for two reasons: 1. they add an additional level of complexity to the three-dimensional array of foliage and branches, thereby contributing more potential food and shelter for invertebrates; and 2. they may serve as pathways to facilitate access into tree crowns for non-flying insects. Our data are too preliminary at this stage to address this hypothesis, although the numbers of insects and also herbivory were both greater in tree crowns with lianas than those without. We hope to collect more extensive paired trees with vines versus no vines in simpler situations where the variability in phenology, micro-climate, and other factors that may confound the results are minimized.

Preliminary examination of the insect data indicates that Hymenoptera are the most abundant group throughout both ground and canopy. Thysanoptera (thrips) were very abundant in the canopy. The misting technique produced greater numbers of insects than the beating or sweeping. Non-flying arthropods were more abundant on the ground than in the canopy, while flying insects were more abundant in the canopy than on the ground. Insects were more abundant in tree crowns with lianas than crowns without lianas.

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Arthropod Collection Operation Canopeé Paracou, French Guyana

Date	Time	Location	Total	Contents	Description
18-Nov-96	10 pm	Canopy Raft C	26	1 Arachnida Acari, 2 Blattodea, 2 Coleoptera, 1 Coleoptera Curculionidae, 4 Diptera, 6 Homoptera, 7 Hymenoptera Apocrita, 1 Lepidoptera, 1 Neuroptera Planipennia Chrysopidae, 1 Orthoptera Gryllidae	light sheet for ~ 1 hour
20-Nov-96	3 pm	Lab in Camp	1	1 Coleoptera Elateridae	Spot Collection
20-Nov-96	afternoon	Ground Raft C	1	1 Gryllidae a	Spot Collection
20-Nov-96	afternoon	Canopy Raft C	74	2 Arachnida Araneida, 1 Coleoptera Curculionidae, 3 Collembola, 3 Diptera, 4 Hemiptera (1 adult, 3 nymph), 4 Homoptera (2 adult, 2 nymph), 3 Hymenoptera Formicidae, 1 Lepidoptera larva, 47 Thysanoptera, 2 Thysanura, 1 Unknown insect nymph	Insecticidal Fog, m3 Mist 1, no lianes
20-Nov-96	afternoon	Canopy Raft C	183	8 Arachnida Araneida, 5 Blattodea nymph, 2 Coleoptera Curculionidae, 1 Coleoptera nymph, 17 Collembola, 10 Diptera, 7 Hemiptera (6 adult, 1 nymph), 1 Hemiptera Pentatomidae, 7 Homoptera (1 adult, 6 nymph), 3 Hymenoptera Formicidae, 5 Hymenoptera Apocrita, 1 Orthoptera Gryllidae nymph, 110 Thysanoptera, Thysanura, 1 Unknown insect nymph	Insecticidal Fog, m3 Mist 2 , lianas
20-Nov-96	afternoon	Canopy Raft C	436	2 Arachnida Acari, 5 Arachnida Araneida, 20 Blattodea nymph, 4 Coleoptera, 1 Coleoptera Chrysomelidae, 2 Coleoptera Curculionidae, 19 Diptera, 12 Hymenoptera Formicidae, 1 Lepidoptera larva, 1 Orthoptera Acrididae nymph , 2 Orthoptera Gryllidae nymphs , 360 Thysanoptera, 1 Thysanura	Insecticidal Fog, Mist 3, m3 no lianas
20-Nov-96	afternoon	Canopy Raft C	6	5 Blattodea (1 a w/egg case), 1 Orthoptera Tettigoniidae	Insecticidal Fog, m3 Mist 4, lianas
20-Nov-96	9 pm	Dining Area in Camp	277	6 Arachnida Acari, 14 Arachnida Araneida, 3 Blattodea (1 adult, 2 nymph), 3 Coleoptera Curculionidae, 1 Coleoptera Scarabaeidae, 2 Collembola, 40 Diptera(39 adult, 1 larva), 1 Hemiptera, 1 Hemiptera Largidae, 1 Homoptera (Acanaloniidae?), 2 Homoptera nymph, 4 Hymenoptera Formicidae, 1 Lepidoptera larva, 5 Psocoptera, 190 Thysanoptera, 2 Thysanura, 1 Unknown Ant-mimic sucking insect	Spot Collection
20-Nov-96	9 pm	Dining Area in Camp	1	1 Coleoptera Cerambycidae Physopleurus tritomicros	Spot Collection
20-Nov-96	8:30 pm	Camp	1	1 Orthoptera Tettigoniidae Leptotettix falconarius a	Spot Collection
20-Nov-96	8 pm	Trail to Q16	1	1 Orthoptera Tettigoniidae Platychiton species 1	Spot Collection
20-Nov-96	day	Trail Head at road	1	1 Orthoptera Tettigoniidae nymph	Spot Collection
21-Nov-96	morning	Dirigible Field	1	1 Orthoptera Gryllidae a	Spot Collection
21-Nov-96	morning	Canopy Raft D	1	1 Orthoptera Gryllidae nymph	Spot Collection

Date	Time	Location	Total	Contents	Description
16-Nov-96	afternoon	Ground in Q16	35	Isoptera	Spot Collection; in log on ground
17-Nov-96	afternoon	Ground Raft C	35	Isoptera	nest sampling
17-Nov-96	afternoon	Ground Raft C	35	Isoptera	nest sampling
17-Nov-96	afternoon	Ground Raft C	35	Isoptera	nest sampling; has Queen
17-Nov-96	afternoon	Ground Raft C	35	Isoptera	nest sampling
17-Nov-96	afternoon	Ground Raft C	35	Isoptera	nest sampling
20-Nov-96	afternoon	Ground Raft C	35	Isoptera	nest sampling; 1 m from ground in palm
20-Nov-96	afternoon	Ground Raft D	35	Isoptera	nest sampling; 0.2 m from ground; reproductives
22-Nov-96	4:30-6 pm	Canopy Raft D	35	Isoptera	Spot Collection; flying in rain
22-Nov-96	night	Lab in Camp	35	Isoptera	Spot Collection; winged reproductives
22-Nov-96	day	Canopy Raft D	6	1 Coleoptera, 1 Coleoptera Chrysomelidae, 1 Homoptera, 1 Homoptera Cercopidae, 1 Orthoptera Gryllidae; 1 Orthoptera Tettigoniidae nymph	Spot Collection
23-Nov-96	morning	Trail to Q16	4	4 Coleoptera Carabidae	Spot Collection
23-Nov-96	morning	Trail to Q16	1	1 Coleoptera Curculionidae	Spot Collection
23-Nov-96	1 pm	Lab in Camp	1	1 Hemiptera Reduviidae	Spot Collection
20-Nov-96	day	Canopy Raft D	1	1 Odonata Anisoptera	Spot Collection
20-Nov-96	day	Canopy Raft D	1	1 Homoptera nymph	Spot Collection
21-Nov-96	morning	Dirigible Field	1	1 Mantodea nymph	Spot Collection
21-Nov-96	11 am	Trail to Q16	1	1 Hymenoptera Formicidae Paraponera clavata	Spot Collection
22-Nov-96	night	Lab in Camp	1	1 Hemiptera Reduviidae	Spot Collection
21-Nov-96	day	Ground in Q16	33	32 Arachnida Acari on 1 Coleoptera Scarabaeidae	Spot Collection
21-Nov-96	1 pm	Ground Raft D	45	44 Arachnida Acari on 1 Coleoptera Scarabaeidae Gxysternon festivum	Spot Collection
20-Nov-96	evening	Camp	2	2 Coleoptera Scarabaeidae	Spot Collection
21-Nov-96	day	???	27	26 Arachnida Acari on 1 Coleoptera Scarabaeidae Gxysternon festivum	Spot Collection
22-Nov-96	night	Ground Raft D	2	2 Coleoptera Elateridae (1 adult, 1 larva)	Spot Collection

Date	Time	Location	Total	Contents	Description
14-Nov-96	—	Canopy in O16		9 Arachnida Acari, 3 Arachnida Araneida, 1 Arachnida Psuedoscorpiones, 12 ootheca (Blattodea egg case), 32 Blattodea nymphs, 1 Coleoptera Curculionidae, 2 Coleoptera (Phalacridae?), 6 Coleoptera larva (aquatic) + 15 molts, 15 Diptera (1 adult, 14 larval), 9 Collembola, 1 Hemiptera, 15 Hymenoptera Formicidae (6 winged), 3 Hymenoptera Symphyta, 2 Thysanoptera, 1 Trichoptera nymph, 3 "worms", 1 silk cocoon (3-4 mm opened), 1 Unknown larva mot	Contents of Aechmea mertensii @ 30m in canopy: ants collected separately
20-Nov-96	day	Canopy Raft D	93	1 Arachnida Acari, 2 Arachnida Araneida, 48 Blattodea nymph, 15 Coleoptera (10 adult, 5 larva), 5 Coleoptera Curculionidae, 2 Coleoptera Scarabaeidae, 3 Collembola, 1 Diptera, 1 Hemiptera Reduviidae nymph 10 Hymenoptera Formicidae, 5 Psocoptera (winged), 5 Unknown larva (grub-like; 4 with legs, 1 no legs)	Contents of abandoned bird nest in canopy, near to Raft D, located in Socratea sp vine in tree
23-Nov-96	afternoon	Canopy Raft D	30	5 Arachnida Araneida (+1 molt), 1 Blattodea, 2 Coleoptera Curculionidae, 4 Diptera, 3 Hemiptera (2 adult, 1 nymph), 1 Homoptera nymph, 1 Hymenoptera Apocrita, 3 Lepidoptera larva, 1 Orthoptera Gryllidae nymph, 1 Psocoptera (winged) 8 Thysanoptera	Insecticidal Fog, m3 Mist 5, lianas
23-Nov-96	afternoon	Canopy Raft D	32	1 Arachnida Acari, 1 Arachnida Araneida, 1 Blattodea nymph, 1 Coleoptera, 1 Collembola, 10 Diptera, 2 Hemiptera, 15 Thysanoptera	Insecticidal Fog, m³ Mist 6, no lianas
23-Nov-96	afternoon	Canopy Raft D	17	1 Arachnida Araneida, 2 Arachnida Acari, 5 Diptera, 3 Hymenoptera Apocrita, 6 Thysanoptera	m² sheet in rain for 20 minutes collection under foliage
21-Nov-96	morning	Ground Raft D	14	1 Arachnida, 1 Crustacea Isopoda, 1 Coleoptera Staphylinidae, 4 Diptera, 2 Hymenoptera Formicidae, 4 Orthoptera Gryllidae nymph, 1 Thysanoptera	10 full sweeps
21-Nov-96	morning	Ground Raft D	8	2 Arachnida Araneida, 1 Hemiptera nymph, 1 Hymenoptera Apocrita Apoidea, 2 Hymenoptera Formicidae, 2 Orthoptera Gryllidae nymph	10 full sweeps
21-Nov-96	morning	Ground Raft D	3	1 Collembola, 2 Hymenoptera Formicidae	10 full sweeps
21-Nov-96	morning	Ground Raft D	3	1 Arachnida Araneida, 1 Coleoptera Adephaga Carabidae, 1 Diptera	10 full sweeps
21-Nov-96	morning	Ground Raft D	13	1 Arachnida Araneida, 1 Arachnida Phalangida, 1 Crustacea Isopoda (sowbug), 1 Blattodea nymph, 1 Coleoptera Staphylinidae, 2 Collembola, 1 Diptera, 1 Hymenoptera Apocrita, 1 Hymenoptera Formicidae (with fugal thread protruding from top of neck), 1 Hemiptera Reduviidae nymph, 1 Orthoptera Gryllidae nymph	10 full sweeps
21-Nov-96	morning	Ground Raft D	6	1 Arachnida Phalangida, 1 Coleoptera Polyphaga, 2 Diptera, 1 Hymenoptera Apocrita, 1 Orthoptera Gryllidae	10 full sweeps

Date	Time	Location	Total	Contents	Description
21-Nov-96	morning	Ground Raft D	8	2 Arachnida, 1 Arachnida Phalangida, 1 Crustacea Isopoda, 1 Blattodea, 1 Hemiptera nymph, 2 Orthoptera Gryllidae nymphs	10 full sweeps
21-Nov-96	morning	Ground Raft D	3	1 Arachnida Araneida, 2 Orthoptera Gryllidae (1 adult, 1 nymph),	10 full sweeps
21-Nov-96	morning	Ground Raft D	10	1 Arachnida Acari, 1 Coleoptera, 1 Collembola, 4 Diptera, 1 Hymenoptera Formicidae, 2 Orthoptera Gryllidae nymph	10 full sweeps
21-Nov-96	morning	Ground Raft D	8	1 Coleoptera, 5 Diptera, 1 Hemiptera, 1 Hymenoptera Apocrita	10 full sweeps
21-Nov-96	morning	Ground Raft D	20	5 Arachnida Araneida, 9 Collembola, 3 Diptera, 1 Hymenoptera Apocrita, 1 Lepidoptera , 1 Orthoptera Gryllidae nymph	Insecticidal Fog, m3 Mist 1
21-Nov-96 m3 Mist 2	morning	Ground Raft D	4	1 Blattodea nymph, 3 Diptera	Insecticidal Fog,
21-Nov-96	morning	Ground Raft D	14	1 Arachnida Phalangida, 6 Diptera, 3 Hymenoptera Apocrita, 1 Hymenoptera Formicidae, 1 Orthoptera Gryllidae a, 2 Psocoptera	Insecticidal Fog, m3 Mist 3
21-Nov-96	morning	Ground Raft D	19	7 Arachnida Acari, 4 Arachnida Araneida, 1 Arachnida Phalangida, 1 Coleoptera Curculionidae, 2 Coleoptera,Staphylinidae, 3 Diptera, 1 Lepidoptera	Insecticidal Fog, m3 Mist 4
21-Nov-96	morning	Ground Raft D	18	5 Arachnida Araneida, 1 Blattodea nymph, 3 Collembola, 3 Diptera, 1 Hymenoptera Apocrita, 1 Hymenoptera Formicidae, 4 Orthoptera Gryllidae nymph	Insecticidal Fog, m3 Mist 5
21-Nov-96	morning	Ground Raft D	6	2 Collembola, 3 Diptera, 1 Hymenoptera Apocrita	Insecticidal Fog, m3 Mist 6
21-Nov-96	morning	Ground Raft D	10	2 Arachnida Araneida, 1 Collembola, 1 Coleoptera, 1 Diptera, 5 Hymenoptera Formicidae	Insecticidal Fog, m3 Mist 7
21-Nov-96	morning	Ground Raft D	12	1 Arachnida Araneida, 1 Coleoptera, 1 Coleoptera Ptilodactylidae larva, 5 Diptera, 2 Hymenoptera Apocrita, 2 Hymenoptera Formicidae	Insecticidal Fog, m3 Mist 8
21-Nov-96	morning	Ground Raft D	14	1 Arachnida Araneida, 2 Arachnida Phalangida, 1 Arachnida Pseudoscorpiones, 1 Crustacea Isopoda, 1 Blattodea nymph, 1 Coleoptera Curculionidae, 1 Coleoptera Staphylinidae, 1 Collembola, 1 Diptera Culicidae, 1 Hymenoptera Apocrita, 3 Hymenoptera Formicidae	Insecticidal Fog, m3 Mist 9
21-Nov-96	morning	Ground Raft D	15	2 Arachnida Araneida, 1 Blattodea, 1 Coleoptera (Endomychidae?), 3 Diptera, 1 Hemiptera, 1 Lepidoptera, 2 Orthoptera Gryllidae (both), 4 Psocoptera	Insecticidal Fog, m3 Mist 10
21-Nov-96	morning	Sled Ride	1	1 Coleoptera	Sweep 1A
21-Nov-96	morning	Sled Ride	2	1 Diptera, 1 Homoptera	Sweep 1B
21-Nov-96	morning	Sled Ride	3	1 Diptera, 1 Hymenoptera Formicidae, 1 Unknown	Sweep 2A
21-Nov-96	morning	Sled Ride	3	1 Diptera, 1 Homoptera, 1 Hymenoptera Formicidae	Sweep 2B

Date	Time	Location	Total	Contents	Description
21-Nov-96	morning	Sled Ride	0	no insects	Sweep 3B no insects
21-Nov-96	morning	Sled Ride	3	2 Blattodea nymphs, 1 Diptera	Sweep 4A
21-Nov-96	morning	Sled Ride	0	no insects	Sweep 4B no insects
21-Nov-96	morning	Sled Ride	0	no insects	Sweep 5A no insects
21-Nov-96	morning	Sled Ride	0	no insects	Sweep 5B no insects
21-Nov-96	morning	Sled Ride	2	2 Coleoptera Curculionidae	Sweep 6A
21-Nov-96	morning	Sled Ride	1	1 Homoptera nymph	Sweep 7A
13-Nov-96	morning	Trail to O16	1	1 Coleoptera Carabidae	Spot Collection
14-Nov-96	morning	Trail to O16	1	1 Coleoptera Carabidae	Spot Collection
14-Nov-96	morning	O16	1	1 Phasmatodea Phasmatidae Phasma sp1.	Spot Collection
14-Nov-96	night	Trail P6C2	1	1 Phasmatodea Phasmatidae Phasma sp1.	Night collection
14-Nov-96	night	Trail P6C2	1	1 Phasmatodea Phasmatidae Citrina venilia?	Night collection
14-Nov-96 mating pair	night	Trail P6C2	1	2 Phasmatodea Phasmatidae Citrina venilia?	Night collection
14-Nov-96	morning	Ground Raft C	3	3 Orthoptera Tetrigidae	Ground in canopy gap
12-Nov-96	night	Trail P6C2	1	1 Orthoptera Romaleidae	Night collection; 3.5 m high
14-Nov-96	day	O16	2	2 Orthoptera Romaleidae	Ground level
12-Nov-96	night	Trail P6C2	1	1 Orthoptera Tettigonidae Schedocentrus sp.	Night collection
16-Nov-96	day	Canopy Raft C	1	1 Orthoptera Tettigonidae Eucocconotideus guianensis? a	Spot Collection
13-Nov-96	day	Canopy Raft C	1	1 Orthoptera Tettigonidae Eucocconotideus guianensis?	Spot Collection
14-Nov-96	night	Trail P6C2	1	1 Orthoptera Tettigoniidae Leptotettix falconarius	Night Collection
14-Nov-96	night	Trail P6C2	1	1 Orthoptera Tettigoniidae Platychiton species 2	Night Collection
15-Nov-96			1	1 Orthoptera Tettigoniidae Ilarissa sp.	Spot Collection
16-Nov-96	day	Canopy Raft C	1	1 Orthoptera Tettigoniidae Anaulacomera species 1	Spot Collection
14-Nov-96	night	Trail P6C2	1	1 Orthoptera Tettigoniidae Anaulacomera species 2	Night Collection
14-Nov-96	day	middle of O16	1	1 Orthoptera Tettigoniidae Anaulacomera species 3	Spot Collection
16-Nov-96	day	Canopy Raft C	1	1 Orthoptera Tettigoniidae Anaulacomera species 4	Spot Collection
14-Nov-96	day	Camp	1	1 Orthoptera Tettigoniidae Cnemidophyllum lineatum	Spot Collection
16-Nov-96	day	Canopy Raft C	1	1 Orthoptera Gryllidae	Spot Collection

Herbivory Means for Plant Species from the Canopy of French Guiana					
Genus	Species	Age	Height (m)	Light	% Herbivory
Trees with lianas (7.4 %)					
Chrysophyllum	prieurii	3	32	sun	3.70
Couratari	guianiensis	3	30	sun	29.10
Eperua	rubiginosa	3	30	sun	4.80
Parkia	velutina	3	35	sun	5.70
Pouteria	sp	3	30	sun	2.30
Swartzia	sp	3	32	sun	0.60
Virola	melinanii	3	32	sun	0.60
Virola	melinanii	3	38	sun	10.80
Virola	melinanii	2	38	sun	9.40
Trees without lianas (2.7 %)					
Eperua	rubiginosa	3	25	sun	3.60
Fabaceae	sp	3	30	sun	2.90
Pradosia	cochlealia	3	32	sun	0.50
Pradosia	cochlealia	3	32	sun	2.40
Pradosia	cochlealia	3	30	sun	0.20
Pradosia	cochlealia	3	30	sun	4.00
Protium	sp	3	30	sun	8.80
Lianas in trees (4.2 %)					
Dicranostylis	sp	3	30	sun	7.10
Dilleniaceae	sp	3	30	sun	1.00
Dolocarpus	sp	3	35	sun	0.50
Maripa	sp	3	35	sun	8.80
Maripa	convolvulacea	2	35	sun	4.40
Malpighiaceae	sp	3	38	sun	2.70
Maytenus	sp	3	30	sun	0.80
vine	sp	2	32	sun	0.10
vine	sp	3	30	sun	7.30
Epiphytes (1.5 %)					
Clusia	grandifolia	3	30	sun	0.00
Clusia	grandifolia	3	30	sun	1.00
Clusia	sp	3	30	sun	3.60
No assessment of liana presence					
Bocoa	sp	3	30	sun	1.80
Eperua	rubiginosa	3	18	shade	3.20
Eperua	rubiginosa	3	2	shade	8.40
Eschweilera	sp	3	30	sun	0.50
Eschweilera	corrugata	3	30	sun	3.00
Humeria	balsamifera	3	35	sun	2.90
Inga	sp	2	2	shade	12.90
Inga	sp	3	2	shade	32.50
Laetia	procera	3	32	sun	8.00
Lecythidaceae	sp	3	30	sun	1.70
Licania	sp	3	30	sun	1.20
Lneopsis	sp	3	30	sun	1.30
Malpighiaceae	sp	3	30	sun	1.70
Norantea	sp	3	35	sun	3.40
Olacaceae	sp	3	35	sun	1.90
Orthomene	sp	3	30	sun	9.90
Otoba	sp	3	30	sun	4.00
Pouteria	sp	3	30	sun	1.60
Pouteria	sp	3	30	sun	1.00
Qualea	sp	3	31	sun	2.00
Symphonia	globifera	3	30	sun	1.80
			Grand Mean		4.89

TABLE 2. FLYING VERSUS NON-FLYING INSECTS CAPTURED WI. DIFFERENT SAMPLING TECHNIQUES IN THE CANOPY AND ON THE FOREST FLOOR.

METHOD (per 10 m^3)	FLYING	NON-FLYING
1. Ground Beating	19 (19.2%)	80 (80.8%)
2. Ground Sweeping	47 (51.6%)	44 (48.4%)
3. Ground misting	56 (17.5%)	264 (82.5%)
TOTALS FOR GROUND	122 (23.9%)	388 (76.1%)
4. Canopy Beating	17 (12.2%)	122 (87.8%)
5. Canopy Sweeping	21 (20.6%)	1 (79.4%)
6. Canopy Misting	1562 (95.7%)	70 (4.3%)
7. Sled Sweeping	44 (64.7%)	24 (35.3%)
TOTALS FOR CANOPY	1644 (84.7%)	297 (15.3%)

Percentages of arthropod individuals belonging to various taxa collected at Site C in French Guiana in 1996. Taxa are given in order of general importance in samples overall from our 1991 Cameroon study. All taxa represented by less than 3.0% of the individuals in any sample were lumped into "Miscellaneous."

	Ground			Canopy			
				From Raft			From Sled
TAXON	*Beating***	*Sweep*	*Spray**	*Beating***	*Sweep*	*Spray**	*Sweep*
Hymenoptera	28.3	20.2	40.9/41.4	31.7	87.3	1.8/31.9	10.8
Diptera	9.1	21.3	8.8/8.9	1.4	2.0	0.7/12.8	23.1
Coleoptera	3.0	9.0	2.2/2.2	2.2	3.9	0.3/6.4	3.1
Homoptera	0.0	11.2	1.6/1.6	1.4	0.0	0.2/3.2	24.6
Collembola	22.2	5.6	16.7/16.9	1.0	0.0	0.7/12.8	0.0
Hemiptera	0.0	1.1	2.5/2.5	0.7	0.0	0.2/3.2	3.1
Orthoptera	7.1	9.0	12.6/12.7	3.6	1.0	0.1/1.2	7.7
Lepidoptera	1.0	1.1	0.9/1.0	2.9	1.0	0.1/2.1	0.0
Blattodea	2.0	0.0	3.1/3.2	0.7	0.0	0.2/4.3	0.0
Arachnids	25.3	16.9	6.9/7.0	18.0	1.0	1.2/20.2	12.3
Thysanoptera**	0.0	0.0	1.3/--	35.0	0.0	94.2/--	0.0
Miscellaneous	2.0	4.5	2.5/2.5	0.7	3.9	0.1/2.1	15.4
# OF SAMPLES	10	10	10	10	10	9	18
MEAN # OF INDIVIDUALS/SAMPLE	9.9	8.9	31.8/31.4	14.0	10.2	181.1/10.4	3.6

*First percentage includes Thysanoptera; the second percentage does not include this taxonomic order.

**Category not included in comparative African study (see Rinker, H.B., M.D. Lowman, and M.W. Moffett. 1995. "Africa from the Treetops" in *American Biology Teacher*, vol. 57, no. 7. Pp. 393-401).

17 November 1996; 0630 to 0800

Sled Sweeping = 10 continuous full sweeps from edge of sled suspended from airship at a height of 35-45 m on top of canopy, net kept wet with 3.0% Resmethrin EC26 Insect Spray[1], contents of net placed into plastic bag and later into glass vials containing 75% ethanol.

SWEEP#	COLL.	ORTHO	HO/HEMIP	COLEO	LEPID	OTHERS	NOTES
1.0A	HBR	1	2	0	0	5	6 flying, 2 nonflying; yes lianas
1.1A	HBR	1	0	0	0	0	1 flying, 0 nonflying; yes lianas
1B	MDL	0	2	0	0	3	2 flying, 3 nonflying; yes lianas
2A	HBR	0	4	0	0	2	4 flying, 2 nonflying; yes lianas
2B	MDL	0	1	0	0	1	2 flying, 0 nonflying; yes lianas
3A	HBR	0	0	0	0	0	0 flying, 0 nonflying; yes lianas
3B	MDL	1	0	0	0	8	3 flying, 6 nonflying; yes lianas
4A	HBR	0	0	0	0	3	2 flying, 1 nonflying; no lianas
4B	MDL	0	1	0	0	2	1 flying, 2 nonflying; no lianas
5A	HBR	1	0	1	0	5	5 flying, 2 nonflying; no lianas
5B	MDL	0	0	0	0	1	0 flying, 1 nonflying; no lianas
6A	HBR	0	0	0	0	3	2 flying, 1 nonflying; no lianas
6B	MDL	0	2	0	0	2	3 flying, 1 nonflying; no lianas
7A	HBR	0	0	0	0	2	2 flying, 0 nonflying; yes lianas
7B	MDL	0	0	1	0	1	2 flying, 0 nonflying; yes lianas
8A	HBR	0	0	0	0	0	0 flying, 0 nonflying; no lianas
8B	MDL	0	0	0	0	1	0 flying, 1 nonflying; no lianas
9A	HBR	1	2	0	0	2	4 flying, 1 nonflying; yes lianas
9B	MDL	0	4	0	0	2	5 flying, 1 nonflying; yes lianas

[1] Synthetic pyrethroid (EPA Reg. No. 904-424) for controlling flying/crawling insects (Pratt-Gabriel Division, Miller Chemical & Fertilizer Corporation, Hanover, Pennsylvania 17331 USA); diluted to 3.0% from 26.0%.

TABLE 5. RELATIVE ABUNDANCE OF INSECTS IN TREE CROWNS WITH VERSUS WITHOUT LIANAS

	LIANAS		NO LIANAS	
METHOD (per 10 m^3)	HERBIVORES	OTHER	HERBIVORES	OTHER
1. Canopy Sweeping	1 (1.0%)	90 (88.2%)	5 (4.9%)	6 (5.9%)
2. Canopy Misting	10 (0.6%)	825 (50.6%)	3 (0.2%)	794 (48.7%)
3. Sled Sweeping	20 (29.4%)	26 (38.2%)	5 (7.4%)	17 (25%)
Subtotal	31	941	13	817
TOTAL	972		830	