An exploratory faunal survey of New Zealand temperate rainforest epiphytes

Olivia R. Henwood, Catherine L. Kirby*, Brian T. Cutting

*Corresponding author's email: c.kirby@waikato.ac.nz
Environmental Research Institute, The University of Waikato, Private Bag 3105, Hamilton 3240, New Zealand.

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Abstract

Epiphyte communities and their corresponding faunal assemblages were quantified on the canopy trees *Agathis australis* and *Metrosideros robusta*. A diverse community of native fauna that included invertebrates, reptiles and birds was associated with the nest epiphytes *Collospermum hastatum* and *Astelia solandri* as well as mats of small, mantling epiphytic plants. The first record of the copepod *Attheyella lewisae* in epiphyte phytotelmata is reported as well as the second New Zealand report of geckos in epiphytes. Alongside 1,003 video sightings and 794 collected specimens from only four host trees, these records signal the significant potential of canopy studies to reveal unknown communities and relationships in New Zealand's forest canopies. The study of epiphyte-fauna associations in New Zealand and elsewhere is constrained by complications inherent with accessing forest canopies. Canopy video cameras and substrate sampling were successfully employed in the first all-taxa exploratory survey of epiphyte communities in a temperate rainforest in northern New Zealand. An evaluation of different research methods indicates that a range of surveying techniques should be employed to sample diversity and abundance of different microhabitats.

Key words: epiphyte; fauna; invertebrate; reptile; canopy; habitat

Introduction

New Zealand's temperate rainforests have prominent, diverse epiphyte populations (Oliver 1930; Zotz 2005) which, as in tropical forests, are important for contributions to forest biomass, biodiversity and function (Lowman & Wittman 1996; Nieder et al. 2001; Burns & Dawson 2005; Affeld et al. 2009). Previous studies on New Zealand epiphytes have investigated plant taxonomy, biology, and host associations (e.g. Oliver 1930; Bryan et al. 2011; Wyse & Burns 2011; Clarkson et al. 2012), however, interactions between epiphyte communities and higher trophic levels are understudied (Affeld et al. 2009). Knowledge of epiphyte-fauna interactions can aid understanding of the link between epiphytic habitat and the diversity of invertebrates (Affeld 2009). It could also reveal ecological requirements of native fauna, providing important insight for conservation and restoration decisions.

Epiphytes provide habitat, structural complexity, and resources that increase the faunal carrying capacity of tropical rainforests (Nadkarni & Matelson 1989; Benzing 1990). The limited available literature indicates that a similar epiphyte-fauna relationship is likely occurring in New Zealand's forest canopies. Some studies have focused on invertebrate fauna in epiphytes (e.g. McWilliam & Death 1998; Derraik 2005; Affeld et al. 2009) but most epiphyte-fauna findings have been incidental to the primary research goals or purely anecdotal. A review of New Zealand literature for this study found a range of references describing the use of epiphytes, particularly the nest epiphyte *Collospermum hastatum*, by native fauna. *Collospermum hastatum*, a tank epiphyte in the family Asteliaceae, provides flowers or fruit for most of the year and impounds water and detritus that form canopy soil at the base of rounded leaves (Cockayne 1910; Burns & Dawson 2005). This species is important as a food source for short-tailed bats (*Mystacina tuberculata*), kōkako (*Callaeas cinereus*), and mōhua (*Mohoua ochrocephala*) (Daniel 1976; Powlesland 1987; Oppel & Beaven 2004); as nesting habitat for the North Island saddleback (*Philesturnus rufusater*), kererū (*Hemiphaga novaeseelandiae*), and the New Zealand falcon (*Falco novaeseelandiae*) (Blackburn 1966; Mander et al. 1998; Barea et al. 1997); as breeding sites for Diptera (e.g. Derraik et al. 2003; Derraik 2005; Derraik & Heath 2005); and as habitat for Archey's frog (*Leiopelma archeyi*) (P. Stewart, pers. comm. 2012).

This study investigated the faunal species present in epiphyte communities with the hypothesis that epiphytic flora provide habitat and resources for a range of native faunal species in northern New Zealand forests. The feasibility of different research techniques (continuous video recording, timed visual searches and organic matter samples) for canopy studies was also explored. Technological advances have increased the efficacy of using video cameras for canopy research (Seymour & Batke 2012), and recent New Zealand studies have successfully surveyed fauna-flora interactions (e.g. Pattemore & Wilcove 2012). It was expected that, in order to capture a range of faunal activity, continuous video footage would need to be complemented by visual searches and organic matter samples.

Methods

Study Site

This study was undertaken from 19 March to 10 April 2013 at Ark in the Park (173°60'E 59°15'N) in the Waitākere Ranges Regional Park, approximately 30 kilometres west of Auckland City. Study sites were located along the Fenceline Track, and accessed from the Dam Road to the Waitākere Reservoir. Ark in the Park is a community conservation project based in 2,300 hectares of intensively pest controlled temperate rainforest (Forest and Bird 2013). The climate is strongly influenced by the close proximity to the coast, which generates a high mean annual rainfall of 2,000 millimetres and a mean annual temperature of 15°C (CliFlo (2013): Auckland, Anawhata Road Junction Station). Kauri (*Agathis australis*) forest dominates on the ridgelines, in association with northern rātā (*Metrosideros robusta*), rimu (*Dacrydium cupressinum*), rewarewa (*Knightia excelsa*) and miro (*Prumnopitys ferruginea*). Understorey species include *Coprosma* species, silver fern (*Cyathea dealbata*), hangehange (*Geniostoma ligustrifolium*) and nīkau (*Rhopalostylis sapida*). The temperate rainforest accommodates a diverse suite of epiphytes, including ferns, lilies/nests, orchids, vines and shrubs (Cranwell-Smith 2006).

Characterising epiphytic canopy habitats

For the purposes of this investigation, the diverse microhabitats of epiphytic canopy communities were broadly classified into the following types; (1) epiphyte-associated organic matter - organic material in and around the base of nest epiphytes (*Collospermum* and *Astelia* species); (2) phytotelm - a body of water within epiphytes, commonly at the base of nest epiphyte leaves; or (3) epiphyte mat - a mantle of low stature epiphytes, commonly including mosses and ferns. For the purposes of this survey, "epiphytes" refers to both epiphyte and vine species (e.g. *Metrosideros* species).

Cameras

Three camera mounting locations were selected from a range of trees that Ark in the Park volunteers had already rigged for climbing. Climbers only ascend these trees a few times a year and were therefore not considered to disturb the fauna or flora. The trees had not been climbed for several months prior to this study. One camera was installed in *A. australis*, while the remaining two were set up in two different *M. robusta* trees. Video recording systems included Miracleon cameras and Lawmate digital video recorders (DVR). These were installed near epiphytes that could be accessed using a double rope tree climbing system. Each camera was mounted on a tripod and strapped to a branch. Cameras were orientated towards a nearby epiphyte with the focal length and distance adjusted using a small LCD screen as a viewfinder. A cable was connected from the camera to the battery and DVR which were located at the base of the tree. The 640x480 and 720x480 resolution settings were used as they afforded acceptable image clarity and ample duration of recording. Both day and night time filming were trialled, but only night time footage was used because there were much higher levels of activity at night. One epiphyte mat and two *C. hastatum* nests with surrounding organic matter were successfully filmed (Table 1). A total of 204.5 hours of continuous

Table 1. Summary of the three camera setups including host tree species, epiphyte species, camera height and host diameter at breast height (d.b.h.)

	Camera 1	Camera 2	Camera 3
Host tree species	*A. australis*	*M. robusta*	*M. robusta*
Epiphyte species	*C. hastatum*	Epiphyte mat	*C. hastatum*
Camera height (m)	10	15	20
Host d.b.h. (cm)	159	208	218

footage over 23 nights (19 March – 10 April) was used for the study. The number of nights per camera varied (Table 2). The epiphyte flora of each host tree was surveyed from both the ground and the canopy to compile a comprehensive species list.

The time of recorded sightings and the taxonomic group of fauna were recorded. Taxonomic groups were: spider, wētā, cockroach, moth, stick insect, cranefly, beetle, slug, gecko or unidentified. Further taxonomic identification of these organisms was not possible from the recorded footage.

Invertebrate sampling

Epiphytes and their associated habitats were sampled for invertebrates on 8-9 April 2013. The three trees used for video surveying and one additional *M. robusta* tree were used for invertebrate sampling. Collections focused on nest epiphytes (*Astelia solandri* and *Collospermum hastatum*) that were not used for video surveys, and were reasonably accessible using established climbing techniques. Three methods were trialled for invertebrate sampling: collection of epiphyte-associated organic matter, collection of water from phytotelmata, and timed visual searches for herbivores and predators on epiphyte foliage.

For epiphyte-associated organic matter samples, as close as possible to 1 L of material was collected from within epiphyte nests, or trapped at the base of epiphyte mats. When possible, samples were taken from multiple, distinct epiphyte mats on a single tree. Collected material was dried with berlese funnels with 0.1 cm mesh and 60 watt lightbulbs positioned approximately 30 cm from the sample material. As samples dried, small invertebrate specimens dropped through the mesh into 70% ethanol. After 3 weeks of drying, a visual search of the remaining material ensured that any specimens that did not fall through the mesh were collected. Various available keys were used to sort specimens into taxonomic groups, and external morphology was used to assign apparent morphospecies.

When phytotelmata were encountered, water samples were collected using an eyedropper to extract water from between nest epiphyte leaves. Only eight phytotelmata were encountered, and the volume of water available for sampling from each varied dramatically, presumably in part due to a lack of recent rainfall at the time of sampling. Three *Astelia* were sampled on one *M. robusta* tree, and two *Collospermum* were sampled from another. Phytotelmata were sampled from two *Collospermum* in a kauri tree, as well as from one *Collospermum* growing terrestrially directly beneath the same kauri tree. As no other trees were observed growing above this ground-level *Collospermum*, it was assumed that litter and water falling into this plant would be similar to matter in phytotelmata in the *A. australis* tree itself. Specimens were preserved by adding 90% ethanol to collected water until a concentration of approximately 70% ethanol was achieved. Specimens were sorted into taxonomic groups, and an aquatic invertebrate specialist identified some specimens to species (I. Duggan, pers. comm. 2013). Fifteen five-minute timed visual surveys of epiphytes were conducted, but these produced very few specimens.

Simpson's Index of Diversity (1-D) (Simpson 1949) was calculated for each sample of epiphyte-associated organic matter. Abundance (total number of all specimens collected) was also calculated for each sample, and was divided by the sample mass to calculate the relative density of organisms in each sample. Because of constraints with access to climbable trees for this project, analysis of invertebrate data from this project is limited to qualitative comparisons.

Results

Cameras

A total of 1,003 faunal sightings were recorded over 23 nights (204.5 hours of continuous footage), with a mean of 44 faunal sightings per camera per night. The one epiphyte mat recorded included *Cardiomanes reniforme*, *Earina* spp., *Hymenophyllum* spp., and a single small *Astelia solandri*. The most frequently recorded taxonomic groups were spiders (249), moths (179), cockroaches (172) and wētā (156). There was also a large number of unidentified fauna (149) (Table 2).

A gecko was sighted on two nights (21

Table 2. Summary of night time faunal sightings in each host tree

	Camera 1	Camera 2	Camera 3	Total
Number of nights recorded	6	10	7	23
Taxonomic group	**Total number of sightings per host tree**			
spider	104	71	74	249
moth	82	92	5	179
cockroach	6	157	9	172
wētā	20	60	76	156
unidentified	38	59	52	149
cranefly	12	15	39	66
gecko	14	0	0	14
black beetle	2	9	2	13
stick insect	0	3	0	3
slug	2	0	0	2
Total	280	466	257	1003
Mean number of sightings per night	47	47	37	44

and 23 March) within one *C. hastatum* nest, located on *A. australis* at 10 metres (camera 1). Species identification and differentiation in the sightings was difficult but it is speculated that this was a single forest gecko (*Mokopirirakau granulatus*) that visited the same site multiple times (J. Thoresen, pers. comm. 2013). On each night there were numerous sightings over a period of approximately thirty minutes. The movement was very slow and appeared to be exploratory. It is therefore speculated that the gecko in both sightings was hunting. An abandoned bird's nest, most likely belonging to a tūī (*Prosthemadera novaeseelandiae*) (J. Innes, pers. comm. 2013), was found in a *C. hastatum* clump near a camera setup. The nest was located in *M. robusta* approximately three metres off the ground.

A total of 24 vascular epiphytic species were recorded on the three host trees surveyed (Appendix 3). *A. australis* hosted nine species (Camera 1), while the two *M. robusta* were host to 19 (Camera 2) and 16 (Camera 3) species. The climbing species found in *M. robusta* were absent from *A. australis*.

Invertebrate sampling

Invertebrate sampling produced a diverse collection of specimens from a broad range of taxonomic groups. Epiphyte-associated organic matter samples produced 701 invertebrate specimens (Appendix 1) and phytotelmata samples produced 93 specimens (Appendix 2). Overall abundance was strongly correlated with sample mass ($p < 0.01$, $R^2 = 0.77$) and Simpson's Index of Diversity was greater than 0.7 for all but one sample (Table 3). Several arthropod taxa were represented by multiple specimens in epiphyte-associated organic matter samples from one tree, but were absent from other trees sampled. Polyxenid millipedes (n = 8) were collected in two samples from one *M. robusta* only. Immature coccid scale insects (n = 14) were collected in 5 different samples in all three *M. robusta* sampled but were absent from the one *A. australis* sampled. Two groups identified in phytotelmata samples were also only present in samples from the one *A. australis* tree sampled. Ostracods (n = 4) and the copepod *Attheyella lewisae* (n = 17) were only encountered in *C.*

Table 3. The abundance, density (abundance/sample mass) and Simpson's index of diversity (1-D) of invertebrates found in epiphyte-associated organic matter samples

Tree ID	Epiphyte genus	Sample height (m)	Abundance	Dry sample mass (g)	Density	Simpson's Index of Diversity (1-D)
M. robusta 2	*Astelia*	11	42	45.8	0.92	0.89
M. robusta 2	*Astelia*	8	26	27.7	0.94	0.94
M. robusta 1	*Astelia*	8	73	30.9	2.36	0.89
M. robusta 2	*Collospermum*	5	87	41.9	6.69	0.75
A. australis 1	*Astelia*	11	347	71	4.89	0.78
M. robusta 3	*Collospermum*	16	116	45.4	2.56	0.48
M. robusta 3	*Collospermum*	15	2	18.7	0.11	1
M. robusta 3	*Collospermum*	2.5	8	9.2	0.87	0.96

hastatum growing on *A. australis*. Very few specimens were collected from timed visual searches, therefore this data was not analysed.

Discussion

This study provides an insight into the importance of temperate rainforest epiphytes for invertebrates, reptiles and birds in New Zealand. Video footage, invertebrate sampling and visual surveys yielded 1,003 sightings of invertebrates and reptiles, 794 invertebrate specimens, and evidence of bird nesting. This abundance of organisms in epiphytic communities is striking given the low-intensity, exploratory sampling design used, and the focus on only four host trees. These results mirror the abundance and diversity of organisms found by Affeld et al. (2009) in one host tree, and highlight the value of epiphytes to fauna in New Zealand forests.

New information on the ecology and distribution of native species was also discovered. The copepod *Attheyella lewisae* found in canopy phytotelmata is a new record of this species in this habitat (I. Duggan, pers. comm. 2013). Other members of the genus *Attheyella* are known to inhabit phytotelmata in tropical forests elsewhere (Reid 2001) but this species was previously only known to inhabit mossy banks along streams (Chapman et al. 2011). The filming of a gecko in *Collospermum hastatum* is only the second published record of geckos occupying epiphytes; the first was goldstripe geckos (*Woodworthia chrysosireticus*) in Taranaki nest epiphytes (Megren 2012).

The ability to draw statistical comparisons from these data was constrained by small sample sizes and access to only a few safely climbable study trees. However, it is noted that several invertebrate taxa were sampled from either *M. robusta* or *A. australis*, but not both. Due to the lack of replication in samples from *A. australis*, it is not possible to determine whether these patterns were due to host tree species or some other variable associated with the single *A. australis* tree sampled.

Evaluation of canopy research methods

The non-intrusive cameras were simple to use in the tree canopy with the appropriate tree-climbing methods. They allowed the investigation of understudied communities without a continuous personnel presence in the canopy. Furthermore, the use of cameras allowed for the observation of species that may have been frightened off by the presence of direct observers or destructive sampling. Processing the continuous footage from the canopy cameras was time-consuming and returned a relatively high proportion of faunal sightings that could not be identified (14%). Higher resolution cameras may reduce the unidentified proportion for larger organisms such as gecko and wētā, but are unlikely to aid identification of small invertebrates. The daytime footage had very low levels of activity so only night footage was watched for this study. This bias may create a discrepancy in the data sets because invertebrate samples were collected during the day. The use of a camera-trap/motion-detecting setup is advisable in the future to survey large fauna, such as birds and reptiles, but would need to be complimented by invertebrate sampling to identify smaller organisms that do not trigger camera sensors and cannot be reliably identified from images.

The study period coincided with a drought that saw 22.8 - 27.7% less rainfall in December, February and March than the average from 2000-2012 and 91.7% less rain than the average for January 2000-2012 (CliFlo (2013): Auckland, Henderson, Riverpark Station). It is likely that these conditions affected the results of this study, particularly for any small and soft-bodied canopy invertebrates. The exploratory design of this study limited sample size, but showed that sampling of epiphyte-associated organic matter and phytotelmata is more effective than visual invertebrate surveys. The results presented here suggest that sampling of these three microhabitats can provide information on invertebrate assemblages when removal of epiphytes (e.g. Affeld et al. 2009) is not feasible.

It is possible, however, that these methods substantially undersample species that live within epiphytes themselves. Ants (Formicidae) were a predominant group sampled by Affeld et al. (2009). However, in the present study, organic matter sampling only yielded one ant specimen, and it is not clear whether this discrepancy is a reflection of sampling bias, or simply because ant populations are scarce in the region, as suggested by Ramsay (2006).

Conclusions and recommendations for future studies

This exploratory survey of fauna in New Zealand epiphytes has provided insight on methodology that can overcome the challenges of canopy study. It has identified a range of faunal species inhabiting or using native epiphytes with indications of population variability that warrant further investigation. We speculate that greater sampling will identify variation in faunal diversity and abundance across different host tree species and epiphyte assemblages. It is recommended that future studies survey a range of host trees, epiphyte assemblages, and microhabitats; and employ multiple sampling methods (*e.g.* substrate sampling, cameras, and observations) to gain a better understanding of the fauna-flora associations.

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Appendix 1

Specimens from invertebrate sampling of epiphyte-associated organic matter

Tree species	***Agathis australis***	***Metrosideros robusta***	***Metrosideros robusta***
Epiphyte genus	*Astelia*	*Astelia*	*Collospermum*
Arachnida	271	65	159
Acari			
Bdellidae sp.1		1	2
Oribatida. sp.1	112	7	5
Oribatida. sp.2	14	22	94
Indet. sp.1	102	16	42
Indet. sp.2	41	3	5
Indet. sp.3	2		
Indet. sp.4		1	
Aranae			
Lycosidae sp.1		4	1
Linyphiidae sp.1		2	
Salticidae sp.1		1	
Stiphidiidae sp.1			1
Tetragnathidae sp.1			1
Pseudoscorpionida			
Indet. sp.1		8	8
Chilopoda	2		
Geophilomorpha sp.1	2		
Diplopoda	3	2	8
Julida sp.1		1	
Polyxenida sp.1		1	7
Indet. sp.1	3		1
Entognatha	49	27	17
Entomobryidae sp.1		14	4
Isotomidae sp.1	43		8
Hypogastruidae sp.1	4	13	5
Sminthuridae sp.1	2		
Gastropoda		18	6
snail		18	6

Appendix 1 Continued

Tree species	*Agathis australis*	*Metrosideros robusta*	*Metrosideros robusta*
Epiphyte genus	*Astelia*	*Astelia*	*Collospermum*
Insecta	14	27	16
Blattodea			
Blattidae	1		
Coleoptera			
Indet. sp.1	3	1	3
Indet. sp.2	1		
Curculionidae sp.1		2	3
Curculionidae sp.2			1
Staphylinidae sp.1	2		
Diptera			
Indet. sp.1	2		
Sciaridae		1	1
Hemiptera			
Coccidae (immature)		12	2
Hymenoptera			
Formicidae	1		
Lepidoptera			
Lepidoptera (immature)		7	2
Psocoptera			
Caeciliusidae	3		2
Psocidae		2	
Thysanoptera			
Phlaeothripidae		1	
Thripidae	1	1	2
Malacostraca	8	2	7
Isopoda	8	2	7

Appendix 2

Specimens from invertebrate sampling of epiphyte phytotelmata

Tree Species	***Agathis australis***	***Metrosideros robusta***	***Metrosideros robusta***
Epiphite genus	*Astelia*	*Astelia*	*Collospermum*
Annelida		2	
Oligochaete		2	
Arachnida	20	7	4
Acari			
indet. sp.1	20	7	3
indet. sp.2			1
Crustacea	4		
Ostracoda	4		
Entognatha	1		
Collembola	1		
Insecta	14	9	14
Coleoptera			
Scirtidae	9	7	2
Diptera			
Aphrophila	1		
Culicidae		1	4
indet. sp	4		8
Malacostraca			1
Isopoda			1
Maxillopoda	17		
Harpacticoida - *Attheyella lewisae*	17		

Appendix 3

Vascular epiphytic species recorded on the three host trees surveyed

	Camera 1	Camera 2	Camera 3
Host species	*A. australis*	*M. robusta*	*M. robusta*
d.b.h. (cm)	159	208	218
Height (m)	30	35	30
Epiphyte species	*Asplenium flaccidum*	*Asplenium oblongifolium*	*Asplenium flaccidum*
	Asplenium polyodon	*Asplenium polyodon*	*Astelia solandri*
	Collospermum hastatum	*Astelia solandri*	*Cardiomanes reniforme*
	Earina autumnalis	*Cardiomanes reniforme*	*Collospermum hastatum*
	Earina mucronata	*Collospermum hastatum*	*Coprosma grandifolia*
	Geniostoma ligustrifolium	*Coprosma lucida*	*Earina autumnalis*
	Ichthyostomum pygmaeum	*Coprosma robusta*	*Earina mucronata*
	Microsorum pustulatum	*Earina autumnalis*	*Freycinetia banksii*
	Winika cunninghamii	*Earina mucronata*	*Griselinia lucida*
		Freycinetia banksii	*Hymenophyllum sp.*
		Hymenophyllum sp.	*Phlegmariurus varius*
		Phlegmariurus varius	*Ichthyostomum pygmaeum*
		Ichthyostomum pygmaeum	*Metrosideros perforata*
		Leucopogon fasciculatus	*Microsorum pustulatum*
		Metrosideros perforata	*Tmesipteris sp.*
		Microsorum pustulatum	*Winika cunninghamii*
		Myrsine australis	
		Pseudopanax colensoi	