SHORT COMMUNICATION

Non-native pollen found in short-tailed bat (*Mystacina tuberculata*) guano from the central North Island

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Abstract: We analysed pollen in short-tailed bat guano samples from Rangataua Forest and from guano and pollen found in bat holding bags used in the Kaimanawa Range, central North Island. Fifty seven percent of the pollen from Rangataua was from a previously unrecorded source and was tentatively identified as *Trachycarpus fortunei* (Chinese windmill palm). The significant remaining pollen was identified as *Collospermum* (15%) and *Nothofagus* (14%) from Rangataua, and *Collospermum* (90%) and *Nothofagus* (6%) from Kaimanawa. While the presence of *Collospermum* from both sites is consistent with previous work, pollen from *T. fortunei*, an exotic palm growing near Rangataua Forest, has not previously been found in association with short-tailed bats. Despite nocturnal surveillance with automated bat detectors and infra-red video cameras, we failed to confirm bat visitation to these palms. *Nothofagus* is wind-pollinated and pollen extracted from samples taken from both sites is probably wind-borne contamination. A collation of data from all available studies on the pollen found associated with short-tailed bats throughout New Zealand reveals that flowers from just four plant groups appear to be regularly used by bats: *Collospermum* spp., *Knightia excelsa*, *Metrosideros* spp. and, apparently, *T. fortunei*.

Keywords: *Mystacina tuberculata*; pollen; guano; *Trachycarpus fortunei*.

Introduction

The lesser short-tailed bat (*Mystacina tuberculata*) is endemic to New Zealand and since the probable extinction of the greater short-tailed bat (*M. robusta*) in the 1960s, is the only remaining member of the Mystacinidae. *M. tuberculata* has the most diverse diet of any bat species. Although it is primarily insectivorous, it also eats nectar, pollen and fruit (Lloyd, 2001). Most evidence for flower visiting comes from pollen either ingested or carried on the fur (Daniel 1976, 1979; Arkins *et al*., 1999; Sedgley 2001). So far, only data from the far north and the far south of New Zealand has been available. In only one case has there been a direct observation of bats on flowers. Ecroyd (1993, 1996) demonstrated by using video and photographs that the short-tailed bat feeds on *Dactylanthus taylorii* in Pureora Forest. Arkins *et al.* (1999) recorded increase flight activity patterns of short-tailed bats in the vicinity of flowering pohutakawa trees (*Metrosideros excelsa*) on Little Barrier Island but no direct observations were made on the flowers. In this paper, we extend the previous studies by describing pollen found in guano roosts from the Rangataua Forest near Ohakune, and from pollen and faecal samples taken directly from bats caught in the Kaimanawa ecological district, both in the central North Island.

Methods

Guano was collected from two sites. Eleven colonial short-tailed bat roost sites were sampled within the Rangataua Forest Conservation Area, Central Plateau, North Island, New Zealand, between February 1995 and December 1997. Guano samples and swabs from the inside of 10 bags used to hold individual bats caught in the Kaimanawa Range during January 1999 were also collected. The forest throughout most of these two areas is dominated by southern beeches *Nothofagus fusca* and *N. menziesii*. At lower altitudes a variety of hardwoods and podocarps, especially rimu (*Dacrydium cupressinum*) are also present and at higher altitudes (>1100 m a.s.l.) and on poorly drained soils, a monotypic forest of *N. solandri* is dominant.

A sheet of plastic mesh (1.5 mm mesh size) was placed on the ground at the base of each bat roost in Rangataua Forest and guano that dropped onto the sheet was collected, usually after one or two days but occasionally after periods as long as one week. Guano was frozen for storage until a sample, measuring approximately 1.5 mm^3, was thawed and acetolysed using a method modified from Faegri and Iversen (1989). From the acetolysed sample (approximately 0.5 mL), sub-samples were either slide-mounted in silicone oil (approximately 0.05 mL) or put onto a haemocytometer (0.0009 mL) to be counted immediately. Both slide and haemocytometer sub-samples were checked under a compound microscope. Pollen identification and relative counts were obtained from permanent slide-mounted sub-samples, while temporary haemocytometer sub-samples allowed us to estimate accurately what proportion of guano consisted of commonly found pollen. Guano found inside bags used to catch bats in Kaimanawa ranges was acetolysed and slide-mounted in silicone oil, while a 5 mm^3 cube of fuchsin jelly was used to swab and stain any other pollen from inside catch bags before melting and mounting onto slides (Beattie, 1971). All pollen was then identified and counted.

The guano from Rangataua contained pollen from a previously unrecorded source, tentatively identified as an exotic palm. To confirm this, pollen was collected from *Trachycarpus fortunei* (Chinese windmill palm), an exotic palm found locally in gardens of nearby townships, and matched with material found in the guano samples. We then searched the area within 15 km of Rangataua forest roosts for the palm, and undertook nocturnal surveillance at five flowering palms on 17 December 2002 and seven flowering palms on 3, 17 and 18 December 2003 to test whether the palms were visited by bats. We used two automated bat systems to detect bats visiting flowers: (1) automatic bat detector units (ABMs) incorporating a bat detector and a tape recorder to record echolocation calls of foraging bats, and (2) infra-red sensitive camera and video-recorder systems to attempt to record bats visiting the palm flowers.

Results

Pollen from 17 plant species was identified from 43 guano samples collected from Rangataua forest (Table 1). Fifty-seven percent of the pollen was from a previously unrecorded and almost certainly not native species (Matt McGlone, Landcare Research, Lincoln, N.Z., pers. comm.). This pollen is similar in appearance to the pollen collected from *Trachycarpus fortunei* flowers. Grains from both sources are of similar size, are bean-shaped and monocolpate (Figure 1 a & b), but pollen in the guano had oxidized and often split open so the grains were not identical and so an exact match was not possible (Dallas Mildenhall, Institute of Geological and Nuclear Sciences, Lower Hutt, NZ. pers. comm.). This type of pollen was found in 26 of the 43 samples and in samples from all but one of the eleven bat roosts. In a sample of bat guano collected on 11 December 1997 from one roost, 85% of the pollen grains and 0.01% of the total volume of guano was of this type; assuming pollen grains in guano are 20 μm in diameter and approximately spherical. We found 15 mature *T. fortunei* palms growing in gardens on

A

B

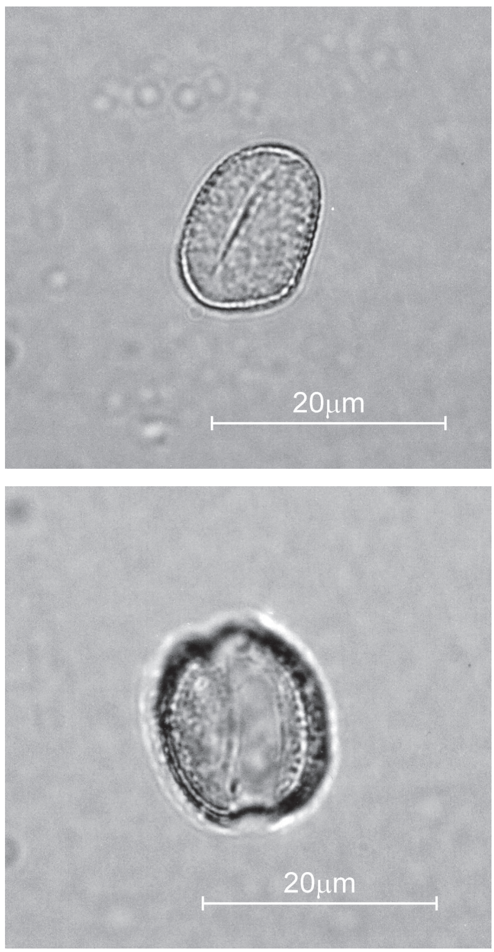

Figure 1. Acetolysed pollen grains from (a) *Trachycarpus fortunei* and (b) bat guano.

Table 1. Number of pollen grains identified in short-tailed bat guano samples collected from roosts in Rangataua Forest and from guano and pollen found in 10 bat holding bags used in Kaimanawa Range.

	Rangataua 1995			Rangataua 1996				Rangataua 1997				Total	Kaimanawa January 1999	
	Jan-Mar	Apr-Jun	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sept	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sept	Oct-Dec		Guano	Swab
Animal-pollinated														
Astelia		1					1					2		
Collospermum microspermum		3	6	28			6	274	1		18	336	202	723
Asteraceae				2					1		2	5		
Dactylanthus taylorii								1				1		
Metrosideros								1				1		1
Nestegis			2				3	4				9	1	
Pittosporum								3				3		
Pseudopanax								1	1		3	5		
Pseudowintera							1					1		
Schefflera			3				1	8			4	16		
"*Trachycarpus fortunei*"		39	141	18		4	58	73			947	1280		
Wind-pollinated														
Asplenium (Monolete fern spores)				1	2	1	2	1	2	2		15	26	1
Cyathea		1	1	1					1		2	6		
Poaceae		1	2	9	1	5	2	22			4	46		7
Nothofagus (fusca group)		27	39	58	7	34	39	36	5		64	309	5	53
Nothofagus (menziesii group)														1
Podocarpaceae	2	7	5	3	5	15	12	12			5	66		3
Trilete fern spores		5	3		1			2	5		8	24		
Others		5	12	2	2	8	3	7	1	3	60	103	1	28
Number of samples analysed	1	1	4	5	1	2	3	5	1	1	6	43	5	8
Total number of pollen grains	2	89	215	123	17	68	127	446	17	3	1132	2239	209	817

residential properties in Rangataua and Ohakune (within 10 km of roost sites) but no palms outside these townships. However, no bats were recorded on ABMs or the infra-red video cameras set up to monitor palms in gardens in either Rangataua or Ohakune.

Significant amounts of *Collospermum* (15%) and *Nothofagus* (14%) pollen were also found (Table 1), but pollen from *Nothofagus*, being a wind-pollinated species, is likely to be a wind-borne contaminant. Small amounts of pollen from other wind-pollinated species of the families Podocarpaceae and Poaceae were found as well as monolete (*Asplenium*), trilete and *Cyathea* spores. Pollen from each of the remaining species identified made up less than 1% of pollen found but included a number of other animal-pollinated species. Pollen collected from guano or swabbed from inside bat holding bags used in the Kaimanawa ranges consisted of *Collospermum* (90%) and *Nothofagus* (6%) (Table 1). Other mainly wind-pollinated species were also found but again made up less than 1% of pollen found.

Discussion

At Rangataua, the occurrence of large amounts of pollen attributable to *T. fortunei*—57% of all pollen found in bat guano and occurring in 10 out of 11 roost sites sampled—is an intriguing new discovery. *T. fortunei* is native to China, where it grows in cold mountainous regions, but it also thrives in temperate regions including Tasmania and the British Isles (Jones, 1995). It has been recognized as a potential problem weed in New Zealand (Owen, 1996) and although it has not yet naturalized in the Central North Island (Nick Singers, Department of Conservation, Turangi, pers. comm.), it has in other areas (Healy and Edgar, 1980), including Little Barrier Island (which also has short-tailed bats), where it is now actively controlled. At Rangataua Forest, *T. fortunei*, was found growing in private gardens within 10 km of roost sites, but at Kaimanawa no *T. fortunei* grew near bat collection sites.

Despite our failure to record bats visiting flowering *T. fortunei*, the pollen extracted from guano closely resembles that collected from *T. fortunei* flowers. Furthermore, anecdotal evidence from residents who describe bat activity around palms in private gardens supports our identification. High-pitched squeaks and rustling have been heard coming from a *T. fortunei* palm after dark at one resident's property. Another resident claims to have seen bats flying near their palm. In addition to this, recent evidence from overseas demonstrates that bats pollinate the Central American understorey palm *Calyptrogyne ghiesbreghtiana* (Tschapka 2003), and Daniel (1976) found trace

Table 2. Summary of dominant pollen (% of total) found in association with *Mystacina tuberculata*[1].

Location	Season	Type	*Collospermum* spp.	*Knightia excelsa*	*Metrosideros* spp.	"*Trachycarpus fortunei*"
Omahuta forest, Northland (Daniel 1976, 1979)	Autumn (1975)	Guano (1 roost)	6	13	73	
		Stomach samples (4 bats)	21	15	37	
	Autumn (1977)	Fur samples (Vaseline smears ,4 bats)	92		5	
	Summer (1977)	Fur samples (Vaseline smears, 5 bats)	5	62		
Little Barrier Island (Arkins 1999)	Summer (1995)	Fur samples (adhesive tape swabs, 29 bats)[2]	26	24	50	
Rangataua Forest (this study)	Autumn (1995–1997)	Guano samples (3 roosts)	3			32
	Winter (1995–1997)	Guano samples (3 roosts)				6
	Spring (1995–1997)	Guano samples (11 roosts)	2			78
	Summer (1995–1997)	Guano samples (11 roosts)	53		>1	16
Kaimanawa range (this study)	Summer (1999)	Swabs from 10 catch bags	88		>1	
		Guano from 10 catch bags	97			
Stewart Island (Daniel 1976)	Unknown	3 stomach samples			54	
Codfish Island (Sedgeley 2001)	Winter	Fur samples			no count	

[1]Does not include wind-pollinated pollen or spores.
[2]Data represent proportion of bats that pollen was collected off i.e. no pollen count data was available

amounts of nikau palm (*Rhopalostylis sapida*) pollen in bat guano from Northland. In our study, the disparity between the large amount of pollen in bat guano identified as *T. fortunei* and the small number of *T. fortunei* palms found in the Rangataua area is also intriguing. The large amounts of *T. fortunei* pollen found in samples collected during April in one year are anomalous, as field observations indicate peak *T. fortunei* flowering is relatively synchronous over a 2–3 week period during December. A possible explanation is that old bat guano stuck to the insides of the roost, fell at a later date, contaminating our samples. This could also explain the regular appearance of *Nothofagus* in samples collected outside its flowering season.

The large amounts of *T. fortunei* pollen we found in short-tailed bat guano, and the large proportion of pollen grains that appeared to have been broken open, indicate the bats may be obtaining nutrition directly from the pollen and not just consuming it incidentally while feeding on nectar or flowers. Short-tailed bats are noted as opportunistic foragers (Arkins *et al*., 1999) and the inclusion of an exotic plant species in their diet may not be surprising. In captivity they are willing to take nectar and pollen from a variety of flowers including native and exotic species (Lloyd, 2001). Although large populations of short-tailed bats are restricted to extensive areas of old-growth forest, lower numbers of bats can usually be found nearby in a variety of other habitats (Lloyd, 2001) and it is not surprising they visit gardens outside of Rangataua Forest. In addition, localised abundant food resources such as flowering pohutakawa or *Dactylanthus taylorii* are known to attract high numbers of short-tailed bats from long distances (Lloyd, 2001). The palms we found are in gardens less than 2 km from the forest margin and within the 10-km nightly foraging range (O'Donnell *et al*., 1999; Lloyd, 2001) of the roosts. There is additional anecdotal evidence suggesting short-tailed bats forage opportunistically in the gardens of Rangataua township. A domestic cat was found carrying a short-tailed bat that had been feeding on raspberries (John Luff, Department of Conservation, Ohakune, pers. comm.). However, further research is required to confirm that short-tailed bats from Rangataua Forest are regularly visiting and feeding on flowering *T. fortunei,* and we suggest further investigation into the role of exotic species as food sources for *M. tuberculata*.

With the data presented here, pollen samples from bats roosts or directly from bats are now available from most of the remaining populations of short-tailed bats in New Zealand (Lloyd, 2001) (Table 2). Excluding wind-borne contaminants, samples from stomachs, guano and fur swabs and from catch bags from all the major short-tailed bat population centres from the far north of New Zealand to the far south have identified a small set of plant species that form the bulk of the pollen identified. These include *Metrosideros* spp., the perching lilies *Collospermum* spp., rewarewa (*Knightia excelsa*) and now apparently *T. fortunei.* As noted by Godley (1979) and Newstrom and Robertson (2005), these species, including *T. fortunei,* have several floral features in common, notably dense inflorescences, and freely exposed pollen and nectar. However, it is not clear why the list should be so small, since many New Zealand plants share these features (Newstrom and Robertson, 2005) and include some of abundant trees like kamahi (*Weinmannia racemosa*) which is common in the Ohakune region. We did recover *some* pollen from other animal-pollinated families and genera—Asteraceae, *Schefflera, Nestegis, Pittosporum, Pseudowintera,* and one grain of *Dactylanthus*—and Daniel (1976) found a similar range of forest plants including *Freycinetia*, *Fuchsia*, *Carpodetus*, and *Weinmannia* but in all these cases only trace quantities were recovered and may be contaminants, and in any case do not appear to form a major part of the diet of these bats.

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