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SCIENCE FOR CONSERVATION: 19

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Part 11: Detection and monitoring of short-tailed bats using *Dactylanthus*

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Foreword

Dactylanthus taylorii is New Zealand's only fully parasitic flowering plant. It is the most southerly occurring member of the largely tropical family Balanophoraceae, and the only species in the genus. A study, funded by the Department of Conservation, of the ecology of this unusual plant has shown that the possum and the kiore pose a critical threat to its survival, eating the flowers and thus preventing seed production.

The dull-coloured, bowl-shaped inflorescences appear to be for pollination by a relatively large, nocturnal animal, and contain a very large quantity of strongly scented nectar which is attractive to possums and rats. Monitoring of the flowers using a time-lapse video camera with infra-red lighting has provided convincing evidence of pollination by the short-tailed bat, *Mystacina tubcrculata,* also attracted to the nectar. These discoveries raised the possibility of developing a possum or bat lure from the chemicals found in the nectar.

Part I Development of possum lures from *Dactylanthus* nectar

Abstract

Chemical analysis of the nectar of *Dactylanthus* taylorii flowers revealed variation between the nectar from male and female flowers with some unusual compounds present. Squalene was a major component of the nectar from some of the male inflorescences. A synthetic nectar based on the volatile compounds, sugars, and hydrocarbons found in the nectar of male *Dactylanthus* inflorescences was formulated and tested as a possum lure. This synthetic nectar was attractive to some possums, ship rats *(Rattus rattus)* and kiore *(Rattus exulans).* Cinnamon was more effective than the synthetic nectar as a possum lure in one experiment comparing the two lures for trapping possums.

1. Introduction

The brush-tailed possum (*Trichosurus vulpecula) is* a very serious pest in New Zealand, causing severe damage to native species and ecosystems. Possums also contribute significantly to the spread of bovine tuberculosis and reduce agricultural and forestry production. New Zealand is the only country with a possum problem and is the world's largest user of 1080 poison (sodium monofluoroacetate), and possibly of sodium cyanide and phosphorus for vertebrate pest control (Parliamentary Commissioner for the Environment 1994).

Possums can detect 1080, the most widely used poison (Morgan 1985), and constant use of this poison may result in a selected population of 1080-shy possums. Attractive flavours or lures can be added to mask the smell or taste of 1080 and will improve the effectiveness of aerial or ground control operations with little extra cost. Lures or baits are required with most types of possum traps and there is also an urgent need for an effective mask for sodium cyanide, a poison commonly used for ground control of possums.

Possums are highly attracted to the flowers of the native parasitic plant *Dactylanthus taylorii,* completely browsing virtually all inflorescences at sites where plants are accessible. These bat-pollinated flowers produce large quantities of nectar which is strongly scented (Ecroyd 1993) and easily located by possums. The thoroughness with which possums located *Dactylanthus* flowers suggested that the nectar might contain ingredients with potential as a possum lure and preliminary investigations showed that it was feasible to create a synthetic nectar. Chemical analysis of the natural nectar (Appendix 1) has

shown that it is composed of an unusual combination of substances including squalene, a substance found in the scent mark of tamarins, Saguinus species, (Belcher *et al. 1988).*

Most of the substances previously trialed as possum lures are common food items such as carrots, apples, cinnamon and orange and raspberry essence (Morgan *1985).* Producing a synthetic lure based on a naturally occurring nectar that is known to be attractive to possums is a new and alternative approach to finding an effective lure.

2. Objective

To develop a possum lure using substances found in Dactylanthus nectar.

3. Methods

3.1 CHEMISTRY

Dactylanthus nectar was collected from male plants on the Mamaku Plateau and the volatile compounds were isolated from the nectar by steam distillation and extraction into dichloromethane using micro Likens-Nikerson apparatus. This extract was then analysed by gas chromatography using a *25* mm x *0.2* mm *HP 5* fused silica capillary column. The sugars were analysed using thin layer chromatography. The volatile compounds, sugars and hydrocarbons found in the nectar of male inflorescences were purchased or synthesised and combined at appropriate concentrations to form a synthetic nectar closely imitating the natural nectar. To do this, the synthetic nectar concentrate (Appendix *2)* was made up at 1% weight/volume of the volatile components in a sugar syrup. The following season, nectar was collected from Pureora from both male and female flowers and analysed as before.

3.2 TESTING THE ACCEPTABILITY TO POSSUMS OF THE SYNTHETIC NECTAR

Two ml of the synthetic nectar was put into a small, shallow, open container at each of six native forest sites in the central North Island and each site was monitored with time-lapse video equipment and infra-red lighting for a minimum of one night.

3.3 COMPARATIVE TESTS OF THE REACTION OF POSSUMS TO THE SYNTHETIC NECTAR, CINNAMON AND SQUALENE

The second stage of testing involved comparing the reaction of possums to the synthetic nectar with their reaction to cinnamon. The lures were prepared using similar concentrations in a sugar solution, and 2 ml of each was applied to a small pad of material and enclosed in wire mesh. The lures were placed approximately 3 m apart on the edge of native forest near Rotorua and monitored for eight nights with video cameras. A solution of 0.5% squalene in a sugar solution was also tested using this method, with the squalene replacing the cinnamon.

3.4 SYNTHETIC NECTAR COMPARED WITH CINNAMON AS A LURE FOR TRAPPING POSSUMS

The synthetic nectar mixed with soya bean oil, cinnamon with soya bean oil and pure soya bean oil were compared as possum lures. An experienced possum trapper used Lanes-ace traps in an area of exotic forest near Rotorua. This type of forest was chosen to decrease the risk of trapping short-tailed bats. The synthetic nectar was used at a concentration 10 times stronger than that of natural nectar and the cinnamon was made up at the same concentration of volatiles as the synthetic nectar. One ml of each lure was placed on a small folded piece of dark brown cloth (c. 2.5 sq. cm) and nailed to a tree just above the trap. The traps were hidden with leaf litter. Sixty traps in groups of three were used for three nights, with the traps within each group two to four metres apart and forming a triangle. The placement of the three lures at each site was varied systematically. All traps were washed before use and after each capture. Traps were not placed on possum runs or trails and a new site was used after each capture. If no catch occurred, the lures were freshened with an extra '/z ml and left for a second night. If this did not result in a capture, a new site was chosen.

The trapping was repeated in a similar area with the traps set 50 m apart instead of in groups.

4. Results

4.1 CHEMISTRY

Natural *Dactylanthus* nectar is a concentrated sugar solution, principally consisting of sucrose with some fructose and glucose. The composition of the steam volatile fraction of the Dactylanthus nectar is listed in Appendices 1, 3 &

4. The major compound identified in this fraction in the initial analysis, using nectar collected from male flowers at the Mamaku Plateau, was squalene. In the nectar volatiles fraction there were small quantities of a large number of low volatility lipids, such as the saturated and unsaturated C21 to C31 hydrocarbons, and the polyunsaturated fatty acid benzyl esters, of C18 to C24. Palmitic acid, and its ethyl and benzyl esters were also found in the nectar.

The volatile highly odoriferous compounds were mainly the ethyl esters of benzoic, salicylic and cinnamic acids, and it is these compounds which impart the very sweet odour to the nectar. Benzyl and phenylethyl alcohols add to this, while the terpene derivatives, nerol, geraniol, nerol oxide and the pentenyl alcohols contribute their own floral and citrus notes. Allyl methyl sulphide would provide an onion or garlic odour to the nectar, but this was difficult to discern in samples of fresh nectar. Ethyl cinnamate, one of the compounds present in cinnamon, was also a minor component in the Dactylanthus nectar.

The subsequent analysis of nectar from male and female flowers from Pureora produced a different balance of components, with far less squalene present. The contaminants shown in the tables (Appendices 3, 4) were probably associated with contamination by plasticisers. Comparison of the male and female nectar from Pureora shows that the female has 15 times more alcohols, and overall has more hydrocarbons and hydrocarbon components than the male nectar. The male nectar has twice as much squalene and more components corresponding to highly fragrant or flavour components (Appendices 1, 3, & 4).

4.2 TESTING THE ACCEPTABILITY TO POSSUMS OF THE SYNTHETIC NECTAR

Ship rats were frequently filmed consuming the synthetic nectar when it was accessible and to prevent this the nectar was placed above the ground on a small table just within reach of possums.

At some sites possums were filmed arriving in the early evening, going directly towards the synthetic nectar from about three metres away (Fig. 1), then enthusiastically consuming every drop of it and searching thoroughly to ensure nothing was missed. However, on a few occasions at some sites, possums were within the area being monitored but did not approach the synthetic nectar.

4.3 COMPARATIVE TESTS OF THE REACTION OF POSSUMS TO THE SYNTHETIC NECTAR, CINNAMON AND SQUALENE

On some nights the video failed to record for the full evening due to battery failure, and wet weather deterred possums from moving about on several nights. The results are summarised in Table 1. The synthetic nectar, squalene solution, and cinnamon, attracted some possums but other possums ignored the lures.

FIG. 1. A POSSUM GOING STRAIGHT TO THE SYNTHETIC *DACTYLANTHUS* NECTAR AND IGNORING THE *DACTYLANTHUS* PLANT IN FLOWER (UNDER CAGE).

TABLE 1. BEHAVIOUR OF POSSUMS TOWARDS SYNTHETIC *DACTYLANTHUS* NECTAR AND CINNAMON AND SQUALENE.

LURE	VISIT BUT NO CLOSE INTEREST	INTEREST SHOWN	NO. OF NIGHTS
Synthetic nectar	8	9	7
Cinnamon	4	15	6
Squalene	4	3	4

There were no significant differences in the behaviour of the possums towards the 3 lures ($p = 0.145$, using Fisher's Exact Test).

4.4 SYNTHETIC *DACTYLANTHUS* NECTAR COMPARED WITH CINNAMON AS A LURE FOR TRAPPING POSSUMS

When the possum traps were grouped, there was very little difference in the numbers of possums caught using the different lures but significant differences (Tables 2 & 3) were obtained by placing the traps about 50 m apart instead of 2-4 m.

There were no significant differences in the number of possums caught using any of the 3 lures ($p = 0.94$, using Fisher's Exact Test).

TABLE 2. RESULTS OF TRAPPING POSSUMS WITH SYNTHETIC *DACTYLANTHUS* NECTAR AND CINNAMON - TRAPS GROUPED.

LURE	NO. OF POSSUMS CAUGHT (INCL. SPRUNG TRAPS)	NO. OF TRAPS SPRUNG BY UNKNOWN CAUSES	TOTAL NO. OF TRAP NIGHTS
Synthetic nectar	18	4	85
Cinnamon	18	3	85
Soya bean oil	16	5	85

TABLE 3. RESULTS OF TRAPPING POSSUMS WITH SYNTHETIC *DACTYLANTHUS* NECTAR AND CINNAMON - TRAPS NOT GROUPED.

LURE	NO. OF POSSUMS CAUGHT (INCL. SPRUNG TRAPS)	NO. OF TRAPS SPRUNG BY UNKNOWN CAUSES	TOTAL NO. OF TRAP NIGHTS
Synthetic nectar	16	1	57
Cinnamon	30	1	57
Soya bean oil	17	0	58

There was a significant difference between the number of possums caught using cinnamon and those caught using other lures ($p = 0.011$, using Fisher's Exact Test).

5. Discussion

We can only speculate on the differences in composition between the initial analysis of male nectar from the Mamaku Plateau, from which the synthetic nectar composition was derived, and the more recent analysis of nectar from Pureora, in which male and female nectar were compared. *Dactylanthus* now occurs in isolated populations which may have developed divergently in some aspects, such as nectar composition. The nectar, because it includes volatile (and unstable) components, will be continuously changing from the time of its production, eventually becoming rancid if remaining in the open. Thus, the age of the flower when the nectar was collected would be significant. Also, the time and conditions involved between collection and chilling or freezing of the samples may have varied, allowing different development of the components.

The synthetic *Dactylanthus* nectar is very attractive to some possums but even in the initial tests some possums preferred to keep some distance away. This could have been due to human scent, a wariness towards new objects within

their territory or other factors. Very few lures will attract every possum, because the behaviour and reaction of possums towards lures is variable and complex.

As squalene is found in the scent marks of tamarins, there is a remote possibility of it occurring in that of possums but a search of two extensive bibliographies (Morgan and Sinclair 1983; Livingstone and Van Ginkel 1993) failed to find any references detailing the chemistry of possum scent marking. The scent marks of possums should be analysed to investigate the potential of the components as possum lures or deterrents, if such an analysis has not already been carried out. A mustelid predator odour (3,3-dimethyl-1,2dithiolane) was the most effective possum browsing repellent in a recent experiment (Morgan and Woolhouse 1993).

It was surprising that soya bean oil on its own proved just as effective as cinnamon and the synthetic nectar in one trial and that different results were obtained by moving the traps further apart. One possible explanation is that cinnamon was attracting the possums from a greater distance than the other lures but when the traps were closer together, the possums went to the nearest trap. However, others testing possum lures at Ruakura have also found their results difficult to explain and somewhat inconsistent (C. Todd, pers. comm.).

Synthetic *Dactylanthus* nectar would be expensive to produce compared to other possum lures currently used and it would need to be as good as, or better than cinnamon for it to be worthwhile conducting further tests with it. The results of the second test using trapping suggest that cinnamon is a better lure.

The synthetic *Dactylanthus* nectar mixture tested is attractive to some possums, ship rats and kiore but not very effective as a lure for the short-tailed bat, *Mystacina tuberculata* (Ecroyd *et al.* 1994). It could be worthwhile conducting further tests with squalene and some of the other major components of the natural *Dactylanthus* nectar and perhaps mixing them with other lures. For any new possum lure to be acceptable, it must not only prove effective at attracting possums but it must also be unattractive to birds and other non-target species.

6. Conclusions

Dactylanthus nectar is chemically complex with differences between the nectar of male and female inflorescences. It is possible to synthesize an artificial nectar closely imitating the natural nectar.

The synthetic *Dactylanthus* nectar mixture as tested is attractive to some possums, kiore and ship rats but in the trials was overall less attractive to possums than cinnamon, and it is more expensive to produce than currently used lures. Testing of possum lures should be conducted using at least two different methods and is probably best undertaken by a team of scientists covering a broad range of expertise from chemistry to the olfactory system and animal behaviour. However, it could be worthwhile conducting further tests with some of the more important compounds found in the *Dactylanthus* nectar such as squalene.

7. Recommendations

- Some of the major compounds found in *Dactylanthus* nectar, such as squalene, should be tested as lures for possums, either on their own or mixed with other lures.
- The compounds found in the scent marks of possums should be tested as possum lures or deterrents.
- At least two different methods should be used to test possum lures, and ideally testing should be undertaken by a team of scientists covering a broad range of expertise including chemistry, the olfactory system and animal behaviour.

8. Acknowledgements

The Science and Research Division of the Department of Conservation and the Project Crimson Trust provided the basic funding for this project with the New Zealand Lottery Grants Board providing funding for the chemicals and equipment. Barry Spring-Rice and Phil Cummins assisted with the field work, Mark Kimberley assisted with the statistical analysis and Brian Crookes helped with the video equipment. Barbara Knowles and Elizabeth Miller provided useful comments on the manuscript.

Part II Detection and monitoring of short-tailed bats using *Dactylanthus*

Abstract

A new population of the Volcanic Plateau subspecies of the lesser short-tailed bat, the only surviving species in an endemic family of bats, was found at Pureora in 1992 by monitoring flowering *Dactylanthus* plants. There was sufficient evidence to conclude that the short-tailed bat was the principal pollinator of the *Dactylanthus* flowers. Chemical analysis of the nectar revealed some unusual compounds, including one found in the scent mark of other animals. It is difficult to locate new colonies of the short-tailed bat and a synthetic nectar based on the volatile compounds, sugars, and hydrocarbons found in the nectar of male *Dactylanthus* inflorescences was formulated as a lure.

Although short-tailed bats have been filmed landing near the artificial nectar, it has not proven sufficiently attractive to these bats to warrant its use as a bat lure. Natural nectar was also collected, and placed in an artificial container at sites known to be frequently visited by short-tailed bats but no wild bats landed near it. Captive bats however, accepted the natural nectar.

Short-tailed bats have been recorded at sites with flowering *Dactylanthus* plants at Pureora in 1992, 1993 and 1994 and it is suggested that more colonies of this threatened bat species could possibly be found at other sites by monitoring *Dactylanthus* plants in flower with bat detectors and tape recorders.

1. Introduction

Bats are New Zealand's only native terrestrial mammals. Only two species of bats are currently known to exist in New Zealand, the lesser short-tailed bat *(Mystacina tuberculata)* and the long-tailed bat *(Chalinolobus tuberculatus).* The insectivorous long-tailed bat belongs to the family Vespertilionidae with about 320 other species and is probably descended from bats blown across the Tasman Sea about a million years ago (Higham 1992). The lesser short-tailed bat is the sole surviving member of the endemic family Mystacinidae and is thought to be distantly related to the neotropical superfamily Phyllostomoidea. It is a relic of the Gondwanaland fauna and the Mystacina/Phyllostomoid lineages are estimated to have separated about 35 million years ago (Pierson *et al.* 1986). The lesser short-tailed bat weighs 12-15 g, with a wingspan of 28-29 cm

(Daniel 1990). A larger species, the greater short-tailed bat *(Mystacina robusta)* has been considered extinct since 1965 after ship rats *(Rattus rattus)* established and irrupted on its last refuge, Big South Cape Island (Daniel and Williams 1984).

The short-tailed bat is unusually well adapted to feeding on the ground, reflecting the lack of terrestrial mammalian predators in New Zealand. With comparatively strong hind legs and a unique way of folding its wings into pouches, it is more agile on the ground than many other species of bat. The short-tailed bat feeds on a variety of foods, including fruits and nectar as well as insects (Daniel 1976).

The lesser short-tailed bat is currently listed as vulnerable (Williams and Given 1981) and is found only on Little Barrier Island, Codfish Island, and a few mainland North Island sites. It has not been reported from the South Island since 1977. Three subspecies of the lesser short-tailed bat have been recognised; the kauri forest short-tailed bat (M. *tuberculata aupourica),* Volcanic Plateau short-tailed bat (M. *t. rhycobia)* and the southern short-tailed bat (M. *t. tuberculata).* The Volcanic Plateau short-tailed bat has recently been confirmed as present in north Taranaki, Matemataeonga, Pureora Forest Park, and the lower southern flanks of Mt Ruapehu (Molloy 1994).

The lesser short-tailed bat is in the Department of Conservation's "Category A" - list of highest priority species for conservation action (Molloy and Davis 1992). A priority in the Department of Conservation's draft Bat Recovery Plan (Molloy 1994) is to "develop survey and monitoring techniques." For the nocturnal short-tailed bat in particular, techniques had not been well developed for locating new populations.

Lesser short-tailed bats were filmed visiting *Dactylanthus taylorii* flowers in Pureora Forest in 1992, with up to 40 visits in just one night (Ecroyd 1993). Photographs of the bat with a large quantity of pollen on its face, the colour and structure of the *Dactylanthus* inflorescence, the type of scent and the large quantity of nectar present, provide strong evidence that the short-tailed bat is (or was) the principal pollinator of this species. Since the monitoring of flowering *Dactylanthus* sites had been effective in locating short-tailed bats at one site, it seemed likely that other *Dactylanthus* sites could also be used to locate short-tailed bats.

Investigations into the chemical composition of the *Dactylanthus* nectar have shown that it is feasible to create a synthetic lure. Such a lure could be effective as a bat attractant for sites where there are no *Dactylanthus* plants present and for locating bats when *Dactylanthus is* not in flower.

2. Objective

To develop an effective and inexpensive method for detecting and monitoring short-tailed bats.

3. Methods

Dactylanthus nectar was collected from male plants on the Mamaku Plateau and the volatile compounds were isolated from the nectar by steam distillation and extraction into dichloromethane using micro Likens-Nikerson apparatus. This extract was then analysed by gas chromatography using a 25 mm x 0.2 mm HP 5 fused silica capillary column. The sugars were analysed using thin layer chromatography. The volatile compounds, sugars and hydrocarbons found in the nectar of male inflorescences were purchased or synthesised and combined at appropriate concentrations to form a synthetic nectar closely imitating the natural nectar (Appendix 2). The following season, nectar was collected from Pureora from both male and female flowers and analysed as before.

Sites with *Dactylanthus taylorii* present were selected in Tongariro/Taupo, and Waikato Conservancies, including the site at Pureora known to be visited by short-tailed bats. The *Dactylanthus* plants were protected from possums with wire netting prior to being monitored.

Sites at Ohakune and Rangataua known to be frequented by short-tailed bats (J. Luff pers. comm.) were used to test the bats' response to synthetic and natural nectar. At these sites 1-2 ml of the synthetic or the extracted natural nectar was put into a small, shallow, open container. To prevent possums and rats gaining access to the nectar it was placed on a small table attached to the top of a metal stake. An empty container was used as a control. A container of nectar was also placed directly on the branch of a tree and monitored to test whether the presence of the table was affecting the response by the bats to the nectar.

The sites were monitored using time-lapse video equipment with low powered LED infra-red lighting and bat detectors linked to tape recorders. The Batbox III bat detectors were set at 27 kHz to record short-tailed bats. They were powered by a 12 volt sealed lead-acid battery with a 9 volt converter and connected to a Sony TCM-38V voice-activated tape recorder. The bat detector and tape recorder were housed in a two litre plastic container (O'Donnell and Sedgeley 1994) which was then strapped to a small tree.

The Sony TCM-38V tape recorders have an automatic gain system which means that they increase sensitivity until they start recording the background static from the bat detector. To overcome this they had to be set with the volume control on "2" and with the volume control on the bat detector set at about "10 o'clock".

Synthetic nectar was supplied to Brian Lloyd to use on Codfish Island where short-tailed bats were being studied and synthetic and natural nectar to Jay McCartney, an M.Sc. student, to trial with captive short-tailed bats at the Wellington Zoo.

4. Results

Natural *Dactylanthus* nectar is a concentrated sugar solution, principally consisting of sucrose with some fructose and glucose. The composition of the steam volatile fraction of the *Dactylanthus* nectar is listed in Appendices 1, 3 & 4. The major compound identified in this fraction in the initial analysis, using nectar collected from male flowers at the Mamaku Plateau, was squalene. In the nectar volatiles fraction there were small quantities of a large number of low volatility lipids, such as the saturated and unsaturated C21 to C31 hydrocarbons, and the polyunsaturated fatty acid benzyl esters, of C18 to C24. Palmitic acid, and its ethyl and benzyl esters were also found in the nectar.

The volatile highly odoriferous compounds were mainly the ethyl esters of benzoic, salicylic and cinnamic acids, and it is these compounds which impart the very sweet odour to the nectar. Benzyl and phenylethyl alcohols add to this, while the terpene derivatives, nerol, geraniol, nerol oxide and the pentenyl alcohols contribute their own floral and citrus notes. Allyl methyl sulphide would provide an onion or garlic odour quality to the nectar, but this was difficult to discern in samples of fresh nectar.

The subsequent analysis of nectar from male and female flowers from Pureora produced a different balance of components, with far less squalene present. Comparison of the male and female nectar from Pureora shows that the female nectar has 15 times more alcohols, and overall has more hydrocarbons and hydrocarbon components than the male nectar. The male nectar has twice as much squalene and more components in the region corresponding to highly fragrant or flavour components.

Short-tailed bats were located in 1992, 1993 and 1994 at four sites spread over 3 km of native forest in Pureora Forest Park by monitoring flowering *Dactylanthus* with video equipment and the bat detectors (Table 1). They were recorded on five out of seven nights of monitoring in 1992, on two out of six nights in 1993, and on four out of 18 nights in 1994. On two nights, two bats were filmed near the plants at the same time.

There were no definite recordings of bats at any other monitored *Dactylanthus* sites in the Tongariro/Taupo, Bay of Plenty or Waikato Conservancies. Sites at Mamaku, Moerangi, One Hundred Acre Bush, Pihanga, Mangamingi Stream (Kakaramea), Taurewa and Erua (three sites) were monitored for at least four nights in 1994 and most sites were monitored for two nights in 1993.

At Waitaanga Saddle on 23 February 1994, Department of Conservation staff from Wanganui Conservancy recorded bats at 27 kHz, less than a 100 metres from *Dactylanthus* plants which were not yet in flower. Bat-like clicks were also recorded on 24 February 1994 at 27 kHz on the Mangorei Track, Pouakai Range, Egmont National Park near non-flowering *Dactylanthus* plants. A second tape recorder placed only a few hundred metres away near a *Dactylanthus* plant with a single inflorescence failed to record any bats on the same evening.

TABLE 1: RECORDINGS OF SHORT-TAILED BATS AT *DACTYLANTHUS* SITES AT PUREORA

LOCATION	GRID REF.	DATE
opposite DoC HQ.	*330956*	*7.4.92*
Totara Walk	*331956*	*8-9.4.92*
Totara Walk	*331956*	*18.4.92*
Totara Walk	*331956*	*4.5.92*
Totara Walk	*331956*	*12.5.92*
western end of village	*324951*	*29-30.3.93*
western end of village	*324951*	*30-31.3.93*
western end of village	*324951*	*4.3.94*
Plains Road	*342965*	*23.3.94*
Kotukunui Road	*319947*	*26-27.3.94*
Kotukunui Road	*319947*	*27-28.3.94*

At Pureora, with the synthetic nectar as an attractant, a short-tailed bat was recorded landing on a table once in ten nights of monitoring. The amount of synthetic nectar decreased significantly on this one night. The synthetic nectar was, on this occasion, placed close to flowering *Dactylanthus* plants which the bats had been visiting.

The sites used for testing the synthetic nectar at Ohakune and Rangataua were known to be good sites for short-tailed bats (J. Luff pers. comm.) and bat passes were recorded on the tape recorder about once every twenty minutes although they were not often visible on the video. On one night, a bat was filmed landing on the table and going very close to the synthetic nectar. There was no noticeable decrease in the amount of nectar but the remains of a cockroach and other insect fragments were later found on the table. Bats were also filmed flying near the synthetic nectar on two nights but were not recorded near the natural nectar and there was no evidence of bats going near a table used as a control.

Insect fragments and bat droppings, probably those of the short-tailed bat, were found inside the base of a hollow tree just off the Ohakune Mountain Road. A very cleanly cut leg of a wets, *Gymnoplectron longipes*, "probably chewed by bats" (G. Ramsey pers. comm.), was identified from the insect fragments found in this tree.

On Codfish Island only kiore *(Rattus exulans)* were attracted to the synthetic nectar (B. Lloyd pers. comm.). The captive bats in Wellington Zoo showed no interest in the synthetic nectar but accepted the natural nectar although they sometimes preferred the honey water (J. McCartney pers. comm.).

In other trials possums and ship rats have been frequently recorded consuming the synthetic *Dactylanthus* nectar and the results of this work will be the subject of a separate report.

5. Discusssion

Little is known about the sensitivity of the olfactory system in short-tailed bats. However, studies of other microchiropteran species have shown that their olfactory system can perform quite well in locating food and that they have considerable olfactory sensitivity (Schmidt 1987). In a study of Egyptian fruit bats, it was found that they could distinguish the aroma of artificial banana flavouring from natural banana aroma and localise as little as 50 mg of banana (Mohres and Kulzer 1956). Schmidt (1987) concluded that the bat species so far examined using physiological experiments "have an entirely competent olfactory organ, capable of a performance not inferior to that of other small mammals known to depend heavily on olfaction". The short-tailed bat probably has a highly sensitive olfactory system and is capable of discerning the location of small quantities of food from its odour.

Dactylanthus nectar has a comparatively simple top note odour profile providing a very sweet smell, a type known to be attractive to flower pollinating bats (Baker 1961). The lipid components in the nectar, a chemical class to which some bats are known to be sensitive (Schmidt 1987), could also provide the pollinators with essential fatty acids as part of their diet (Baker and Baker 1982) in addition to the glucose, fructose and sucrose in the nectar. The polyunsaturated fatty acids are presented as benzyl esters rather than the usual glyceryl esters and this may be a factor in attracting bats. Squalene, a major component of the sample initially analysed, is a polyene known from flowers (Aoki and Suga 1977) and roots (Ueyama and Furukawa 1987) but also found in the scent mark of tamarins, Saguinus spp. (Belcher *et al.* 1988). It has bactericidal and anti-tumour activities and is also an immunostimulant (Harborne and Baxter 1993).

We can only speculate on the differences in composition between the initial analysis of male nectar from the Mamaku Plateau, from which the synthetic nectar composition was derived, and the more recent analysis of nectar from Pureora, in which male and female nectar were compared. *Dactylanthus* now occurs in isolated populations which may have developed divergently in some aspects, such as nectar composition. The nectar, because it includes volatile (and unstable) components, will be continuously changing from the time of its production, eventually becoming rancid if remaining in the open. Thus, the age of the flower when the nectar was collected would be significant. Thirdly the time and conditions involved between collection and chilling or freezing of the samples may have varied, allowing different development of the components.

When *Dactylanthus* plants are in flower they are constantly producing nectar at the rate of about 0.5 ml per inflorescence per day, and hence there is a large quantity of nectar present and a strong odour - many times greater than that

from 1-2 ml of nectar placed in an artificial container. This is a possible explanation for the difference between the attraction of the actual flowering plants and the natural nectar in an artificial container.

The natural and synthetic nectars need to be stored at cool temperatures to prevent the sugars fermenting and are difficult to store without some change in composition. The synthetic nectar is expensive to produce in small quantities.

Short-tailed bats have been filmed close to the synthetic nectar on three occasions over fourteen nights. These visits close to the nectar have not been frequent when compared to the rate at which bats were recorded in the vicinity by the tape recorders and the visits were not necessarily due to the nectar. The results from trials with the captive bats at Wellington Zoo showed that the natural nectar was more acceptable than the synthetic nectar. However in field trials the extracted natural nectar in an artificial container was no more successful than the synthetic nectar at attracting bats. Since the natural nectar was not effective when presented in this manner other mixtures of synthetic nectar, based on the female flowers for example, would probably be no more effective.

The fact that short-tailed bats landed on the table on at least two occasions suggests that they were not averse to using artificial structures and it could be quite feasible to provide supplementary feed for these bats if this was ever considered necessary. It could also be worth putting out meal worms or other food attractive to these bats as part of a bat survey technique. This could encourage the bats to go closer to the recording equipment and would be worthwhile, for example, if there was difficulty in obtaining clear recordings on which to base an identification.

Dactylanthus plants in flower can be effective at attracting short-tailed bats. Nearly all the visits in 1992 were to one site at Pureora with particularly good inflorescences flowering - probably the only *Dactylanthus* plants in flower within the range of these bats. When a bat has no other choice of *Dactylanthus* plants in flower within its feeding range, the chances of recording it at that site will probably be increased. Prior to the monitoring, some of the plants were protected with mesh that was probably too fine for the bats to go through but, on the first night the mesh was changed to 50 x 50 mm, the bats (and rats) visited the flowers. In 1992 the bat was sometimes disturbed by a camera flash but, after flying away, it returned within a few minutes.

It is worth noting that, over a three year period, the trend is towards fewer sightings of short-tailed bats at Pureora for the number of nights of monitoring. Further monitoring is needed to determine whether this is due to a declining bat population but there are many other possible explanations. For example, there were more plants protected and flowering in 1994 than 1992 and the chances of monitoring the particular plants currently being used by the bats may have decreased due to this.

The video system worked well for monitoring sites where there was a defined area of less than 10 m^2 to monitor. The LED infra-red lighting needed to be 1-2 m from the subject. More powerful laser light sources are available but they are expensive and may cause eye damage to the animals being monitored.

The bat detector linked to the tape recorder has the advantages of being more portable, cheaper and easier to use than the video but there can be difficulties in identifying the noises recorded and tapes will only record 90 minutes of sound. At 27 kHz there are many sounds other than those made by bats which can trigger the voice activated tape recorder. The Sony TCM-38V tape recorder has the advantage of displaying the time of recording in days, hours and minutes which is more accurate and simpler than using a separate talking clock. The main disadvantage experienced with the TCM-38V was that it has an automatic gain system which means that it automatically increased the sensitivity at which it started recording until it started to record the background static generated by the bat detector. The static would be recorded for a few minutes until the sensitivity automatically decreased again. As a result a 90 minute tape rarely lasted a full night and there was usually a full 90 minutes of tape to check through. The volume controls on the detector were set at "10 o'clock" and the tape recorder volume control on "2" to reduce this problem but this may reduce the range at which bats can be detected. Brian Lloyd (pers. comm.) tried the Sony TC-38V and did not consider it appropriate for this work. He recommends other recorders for example the Sanyo TRC 1196 which is no longer available.

The Pouakai Range site needs to be investigated further and the tape checked thoroughly to verify this record. If proven correct this would be a first for Egmont National Park.

6. Conclusions

Dactylanthus nectar is chemically complex with differences between the nectar of male and female inflorescences.

Monitoring flowering *Dactylanthus* plants was effective in locating short-tailed bats at Pureora and other sites with *Dactylanthus* plants in flower should be monitored for short-tailed bats. The natural nectar, when extracted from the flowers, and used in small quantities, and the synthetic nectar were not sufficiently attractive to be effective as lures for short-tailed bats. Bats were able to distinguish between the synthetic and natural nectar and were much less attracted to the synthetic nectar than to the flowering plants.

The Batbox III bat detector linked to a tape recorder is a relatively cheap, simple and effective system for recording bats and is probably the best option currently available for locating further colonies of short-tailed bats. If a Sony TCM-38V tape recorder is used then the volume controls on the tape recorder and the detector need to be set at a low level.

7. Recommendations

- Monitoring of short-tailed bats should be continued at Pureora. Other sites with *Dactylanthus* plants in flower should be monitored for short-tailed bats and high priority should be given to sites on the Pouakai Range.
- Because a high degree of variation was found between the samples of nectar analysed, testing other mixtures of synthetic *Dactylanthus* nectar as a lure for short-tailed bats may provide a more attractive product.
- The Batbox III linked to a voice activated tape recorder is recommended for detecting bats. If the Sony TCM-38V model of tape recorder is used volume controls must be set at low or the automatic gain system disconnected.
- To assist in clearly recording their echolocating calls, other types of food attractive to short-tailed bats, such as meal worms, should be tested as a means of attracting bats towards a recording system.

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10. Appendices

10.1 COMPOSITION OF THE STEAM VOLATILE FRACTION OF *DACTYLANTHUS TAYLORII* NECTAR FROM MALE INFLORESCENCES AT MAMAKU PLATEAU

COMPOUND	RETENTION TIME (MIN)	AREA (%)#
2-Methylbut-3-en-2-ol	9.1	0.2
3-(Methylthio)-prop-l-ene (allyl methyl sulphide)	9.7	0.6
3-Methylbut-3-en-l-ol	10.9	0.1
2-Methylbut-2-en-l-ol	11.4	tr
Furan-2-carboxaldehyde	14.8	tr
Nerol oxide	15.5	2.2
Caryophyllene	19.0	1.9
Ethyl benzoate	21.5	3.7
Nerol	25.5	0.9
Ethyl salicylate	25.6	0.5
Geraniol	26.8	0.9
Benzyl alcohol	27.5	1.1
Phenyl ethanol	28.5	0.5
Heneicosane	33.6	7.8
Ethyl cinnamate	34.1	0.8
Ethyl hexadecanoate	37.1	0.6
Tricosane	38.6	14.1
Tricosene (Z)	38.8	0.9
Tricosene (E)	39.0	1.1
Phenylacetaldehyde	40.3	0.6
Tetracosane	40.5	tr
Benzyl hexadecanoate	41.0	0.8
Pentacosane	42.8	5.6

Pentacosene (Z)	43.2	0.7
Pentacosene (E)	43.4	0.9
Benzyl octadecatrienoate'	44.7	2.2
Hexacosane	44.9	0.3
Benzyl octadecatetraenoate'	45.3	0.7
Heptacosane	46.8	2.9
Heptacosene (Z)	47.1	0.5
Heptacosene (E)	47.3	0.5
Octacosane	49.0	0.1
Benzyl eicosatrienoate'	49.5	1.1
Hexadecanoic acid	51.2	5.1
Nonacosane	51.5	1.2
Nonacosene (Z)	51.6	0.2
Nonacosene (E)	51.7	0.2
Hexadecenoic acid	51.8	1.4
Benzyl docosadienoate`	53.8	1.3
Squalene	54.2	26.5
Hentriacontane	55.4	0.9
Benzyl tridecatrienoate'	58.4	1.0
Benzyl tridecatetraenoate'	59.6	3.9

Area %, uncorrected for relative response factors.

tr trace <0.1%

Position of the double bonds is not known. Benzyl esters identified from their mass spectra, viz., mass/charge 108 benzyl alcohol radical ion, 71, 85 saturated, 69,81 di-unsaturated and 67,79 tri-unsaturated alkanoate fragments.

10.2 COMPOSITION OF THE SYNTHETIC *DACTYLANTHUS* " NECTAR" CONCENTRATE BASED ON THE MALE NECTAR FROM MAMAKU PLATEAU.

COMPONENT	WEIGHT (g.)	AREA (%)#
Allyl methyl sulphide	0.02	0.07
2-methylbut-3-en-2-ol	0.08	0.23
3-methylbut-3-en-l-ol	0.04	0.11
Palmitoleic acid	0.56	1.61
Palmitic acid	0.20	0.58
Benzyl alcohol	0.44	1.26
Phenylacetaldehyde	0.24	0.69
Phenyl ethyl alcohol	0.20	0.57
Ethyl benzoate	1.48	4.24
Nerol	1.24	3.56
Geraniol	0.36	1.03
Ethyl salicylate	0.20	0.57
Caryophyllene	0.76	2.18
Ethyl cinnamate	0.32	0.92
Ethyl palmitate	0.24	0.69
Benzyl palmitate	0.32	0.92
Benzyl linolenate	4.40	12.62
Squalene	10.60	30.40
Wax C21-C31	13.16	37.74

Area %, uncorrected for relative response factors.

A synthetic nectar, similar in composition to a natural nectar, was prepared at 1% w/v of the volatile components (excluding wax) of the synthetic nectar concentrate, in a sugar syrup comprised of sucrose, glucose and fructose (3.3% w/v of each in water).

10.3 COMPOSITION OF THE STEAM VOLATILE FRACTION OF *DACTYLANTHUS TAYLORII* NECTAR FROM MALE INFLORESCENCES AT PUREORA.

COMPOUND	RETENTION TIME (MIN)	AREA (%)'''
2-Butanone, 3-hydroxy (contaminant)	4.54	.
1-Butanol, 3-methyl	5.06	3.94
1-Butanol, 2-methyl	5.15	1.33
2-Buten-I-ol, 3-methyl	6.35	7.60
2-Butanol, 2-methyl	6.70	0.83
2,3-Butanediol (contaminant)	6.88	.
Monoterpene alcohol	7.27	1.87
2-Pentanol, 4-methyl	7.42	5.26
Xylene (contaminant)	9.94	-
Butanoic acid, 3-hydroxy-, ethyl ester	12.89	1.53
delta3-Carene (internal standard)	16.05	4.52
1-Hexanol, 2-ethyl (contaminant)	16.87	-
Benzenemethanol	17.08	4.54
Nerol oxide	22.06	17.10
Napthalene (internal standard)	23.22	4.22
Benzaldehyde, 4-methyl	24.50	6.74
Nerol	24.91	1.71
trans Geraniol	25.87	1.35
Benzoic **acid, 2-hydroxy-ethyl ester (ethyl salicylate)**	26.55	2.85
plasticiser (contaminant)	30.23	-
unknown	30.86	0.49
Sesquiterpene alcohol	36.08	2.03
1,2-Benzenedicarboxylic acid, dibutyl ester (contaminant)	47.69	-
Heneicosane	50.94	1.14

11-Tricosane	55.12	0.80
Tricosane	55.52	1.95
Pentacosane	60.37	0.86
Phthalate (contaminant)	62.05	-
Perhydrosqualene (internal standard)	65.82	14.55
Squalene	71.86	12.80

Area %, uncorrected for relative response factors.

10.4 COMPOSITION OF THE STEAM VOLATILE FRACTION OF *DACTYLANTHUS TAYLORII* NECTAR FROM FEMALE INFLORESCENCES AT PUREORA.

COMPOUND	RETENTION TIME (MIN)	AREA (%)"
2-Butanone, 3-hydroxy (contaminant)	4.52	.
1-Butanol, 3-methyl	5.05	22.43
1-Butanol, 2-methyl	5.15	12.86
2-Buten-1-0l, 3-methyl	6.35	5.64
2,3-Butanediol (isomer) (contaminant)	6.52	.
2,3-Butanediol (isomer) (contaminant)	6.87	.
Monoterpene alcohol	7.24	1.27
2-Pentanol, 4-methyl	7.43	2.12
1-Pentanol, 3-methyl	7.54	1.45
2-Butanoic acid, ethyl ester, (E)-	9.02	2.21
Butanoic acid, 3-hydroxy-, ethyl ester	12.81	3.48
delta3-Carene (internal standard)	16.05	3.08
1-Hexanol, 2-ethyl (contaminant)	16.88	-
Benzeneethanol	20.40	3.44
Nerol oxide	22.06	5.58
Benzoic acid, ethyl ester (ethyl benzoate)	22.71	6.87
Napthalene (internal standard)	23.22	2.87
Benzoic acid, 2-hydroxy-ethyl ester (ethyl salicylate)	26.55	2.13
1,2-Benzenedicarboxylic acid, dibutyl ester (contaminant)	47.70	-
Heneicosane	50.94	1.38
Tricosene, (Z)	55.12	1.40
Tricosane	55.53	2.91
9-Pentacosane	59.89	2.03
Pentacosane	60.37	0.85

COMPOUND	RETENTION TIME (MIN)	AREA (%)'''
Phthalate (contaminant)	62.05	-
Perhydrosqualene (internal standard)	65.83	8.84
Heptacosene	66.97	1.26
Squalene	71.86	4.71
Nonacosene	73.24	1.21

Area %, uncorrected for relative response factors.