Effective Monitoring of Arboreal Giant Weta (Deinacrida heteracantha and D. mahoenui; Orthoptera: Anostostomatidae) using Footprint Tracking Tunnels

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Effective monitoring of arboreal giant weta (*Deinacrida heteracantha* and *D. mahoenui*; Orthoptera: Anostostomatidae) using footprint tracking tunnels

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Abstract

There are few suitable monitoring tools for assessing the effectiveness of management for threatened insect taxa. This is especially true for cryptic arboreal species of nocturnal flightless orthopterans in the genus *Deinacrida* from New Zealand. Systematic searching of habitat during the day was compared with footprint tracking tunnels baited with peanut butter as methods for monitoring the arboreal giant weta *Deinacrida heteracantha* and *Deinacrida mahoenui* (Orthoptera: Anostostomatidae). Searching by day required more time (3h per transect) than operating tracking tunnels (1.4h). Lines of 30-35 tracking tunnels spaced 30 m apart could be quickly set to sample large areas. Searching may provide additional information including the species, age class, and sex, whereas tracking tunnels yield presence/absence data for giant weta that were larger than other anostostomatid present. Both methods provide indices of relative abundance: it is impractical in tall forest to accurately estimate absolute density whereas tracking tunnel results are related to the activity of weta. Weta activity may depend on vapour pressure deficit modulated by the temperature. For conservation and monitoring purposes, we recommend that tracking tunnels be used first to detect giant weta and only then search for them if further data is required.

Key words

monitoring tool, threatened taxa, footprint tracking tunnels, conservation

Introduction

Monitoring threatened insect taxa, especially cryptic arboreal species like nocturnal flightless orthopterans in the genus *Deinacrida*, is among the most difficult of tasks in entomological conservation management. Successful conservation relies on accurate population assessments derived from robust sampling and monitoring (Lettink & Patrick 2006; Watts *et al.* 2012). Although *Deinacrida* species are threatened taxa in New Zealand (Watts *et al.* 2008a), there is currently a lack of standard survey methods for giant weta and so current rates of their population change and range reductions are difficult to determine. Most monitoring of *Deincrida* has involved searching habitat during the day or spotlighting at night, but this is time and expert dependent and often yields little beyond establishing the presence of the animals. When densities are low, such search effort may still fail to detect them.

Footprint tracking tunnels are routinely used in New Zealand to both detect and monitor populations of smaller mammals, such as rats, mice, and stoats that were introduced into New Zealand by humans (Brown *et al.* 1996; Blackwell *et al.* 2002; Gillies & Williams 2002; Speedy *et al.* 2007). Tracking tunnels are easy to use and can be relatively efficient in terms of the time required to collect data compared to searching (Watts *et al.* 2011a). Previously, tracking tunnels have been primarily used to monitor small mammals although occasionally they have recorded other animals, including insects (*e.g.*, De Monchy 2006; Watts *et al.* 2011b). Weta, in particular, leave distinctive and easily recognised footprints on tracking tunnel cards (Watts *et al.* 2008). Despite this, tracking tunnels were only recently considered seriously as a means for monitoring weta after Watts *et al.* (2008b) showed they could be used for detecting wetapunga (*Deinacrida heteracantha*: Orthoptera: Anostostomatidae), the largest of the giant weta. Wetapunga are predominantly arboreal and yet tracking tunnels baited with peanut butter detected activity on the ground and on tree branches. Watts *et al.* (2008b) indicated that foot prints cannot distinguish between weta species of the same size but could only discriminate adults and the largest juveniles of the largest weta species from the size of their footprints. Watts *et al.* (2011b) subsequently showed that tracking rates of another giant weta, *Deinacrida rugosa*, a predominantly ground active species, reflect local population density. However, their research was conducted over a narrow environmental temperature range.

Recently, Watts *et al.* (2011a), based on archived tracking tunnel cards, showed that the tracking rates could detect population increases in weta following the eradication of mammals at Maungatautari. Here, patterns using tracking rates were supported by data from weta caught in pitfall traps. Watts *et al.* (2011a) cautioned that these changes could be behavioral rather than increases in animal numbers, because tree weta spend more time on the ground when rodents are not present (Rufaut & Gibbs 2003).

Previously, a variety of methods were used to monitor weta as listed by Stringer and Chappell (2008) but the most frequently used methods are searching at night with spotlights and using artificial refuges. Most searching, particularly for giant weta, is now done at night when weta are active. This could provide an index of the weta population although an unknown proportion may remain in their refuges or be hidden from view. Such a population index would be useful for monitoring if the effects of environmental conditions on weta activity were known; otherwise such indices should be used comparatively by searching on nights with similar conditions at the same time of year. Searching at night together with mark-recapture have been used to make local population estimations of Cook Strait giant weta but was particularly time consuming (Watts *et al.* 2011b). Tree weta are most commonly monitored nowadays by counting those in artificial refuges because it is easily accomplished. However, the results are contentious because the relationship between numbers in such refuges and those in the surrounding vegetation has not been sufficiently investigated. Bleakley *et al.* (2006) indicated that such refuge sampling could reflect local weta densities whereas Bowie *et al.* (2006) suggested that artificial refuges are unsuitable because they are unlikely to reflect the overall abundance of weta and may simply artificially increase the carrying capacity of an area, especially where there are few suitable natural refuges. There are certainly indications that some tree weta populations may be limited by the availability of refuges whereas in other situations a high proportion of suitable refuges can remain unoccupied (Field & Sandlant 2001 and references therein; Trewick & Morgan-Richards 2000). Searching suitable natural refuges has rarely been done because numerous individuals often occupy deep narrow holes so each weta must be removed in order to be counted and this may involve destroying the refuge or damaging weta (*e.g.*, Townsend *et al.* 1997; Leisnham *et al.* 2003).

In this paper we compare the effectiveness and efficiency of tracking tunnels and searching as means of monitoring threatened arboreal giant weta. We examined the relationship between tracking tunnel rates and the numbers of weta seen during day searches using two threatened giant weta species, wetapunga and the Mahoenui giant weta (*D. mahoenui*). Both species are primarily arboreal and are mostly active high in closed canopy forest which makes monitoring them by searching particularly difficult. We also documented seasonal changes in the tracking rates of *D. mahoenui* at one location to determine what time of year is best for such monitoring, and we include a preliminary analysis of how temperature and humidity might affect weta activity.

Methods

Study areas and species.—Historically, *D. mahoenui* are thought to be an arboreal species living in the epiphytes of tall tawa (*Belischmeidia tawa*) forests of the King Country and Waikato (Sherley & Hayes 1993). Their sole surviving natural population exists in a patch of gorse (*Ulex europaeus*), an exotic weed. This gorse patch was legally protected at the Mahoenui Giant Weta Scientific Reserve at Mahoenui in the King Country, New Zealand (Watts & Thornburrow 2009). The prickly foliage of the gorse provides the weta protection from mammal predators, as well as shelter and food (Sherley & Hayes 1993). Since 1989, a total of 2050 *D. mahoenui* have been transferred from this reserve to four sites containing gorse and native vegetation, and three with native vegetation protected from introduced mammals during 32 releases. Watts & Thornburrow (2009) found weta persisted at four of these sites (Mangaokewa Scenic Reserve, Mahurangi Island Scenic Reserve, Tikikaru and Warrenheip; Fig. 1). At two sites, Mahurangi Island Scenic Reserve and Warrenheip, weta appeared to be flourishing and have successfully established new populations in the absence of rats. Only one weta was found during the surveys at Mangaokewa Scenic Reserve and Tikikaru (Watts & Thornburrow 2009) but the gorse habitat at the latter site was removed in November 2008, and no weta appeared to have survived.

Wetapunga, *D. heteracantha*, were historically widespread in forest over Auckland, Northland, Waiheke Island, and Great Barrier Island (Watt 1963; Gibbs 2001), but they currently survive only on Little Barrier Island, a 3083-ha nature reserve where introduced mammalian predators have been eliminated (Fig. 1). Wetapunga have been recently translocated to Tiritiri Matangi and Motuora Islands in the Hauraki Gulf but their long-term survival there remains unknown (CJ Green, Department of Conservation, pers. comm.). Wetapunga numbers were originally thought to be declining on Little Barrier Island (Gibbs & McIntyre 1997), but are now slowly increasing following the eradication of kiore (*Rattus exulans*) in 2004 (CJ Green, unpublished data).

Tracking tunnels.—Tracking tunnels ('Black Trakka': Gotcha Traps, 2 Young Street, RD2, Warkworth, New Zealand) were spaced 30m apart and the position of each tunnel was recorded with a GPS (estimated accuracy < 5m). Pre-inked tracking cards were used with *ca* 4 g of peanut butter applied to the middle of each inked area as bait. The tunnels were set on the ground for 6 nights and cards were checked daily for footprints but the peanut butter was not replaced as it dried. Cards were scored as confirmed adult or large juvenile giant weta present (footprint evidence) or absent.

Five transects of seven tracking tunnels ($n = 35$) were each established at the Mahoenui Giant Weta Scientific Reserve, Mangaokewa Scenic Reserve, Mahurangi Island, and Warrenheip, with the tunnels being placed 1-2 m off the track. The vegetation at the Mahoenui Giant Weta Scientific Reserve is dominated by a mosaic of gorse (up to 3 m in height) and pasture grass. The vegetation searched at Mangaokewa Scenic Reserve consisted of forest up to 4 m high dominated by tawa with a understorey of treeferns (*D. fibrosa*, *C. medullaris* and *C. smithii*) and nikau palms (*Rhopalostylis sapida*). At Mahurangi Island, the vegetation is long grass with patches of bracken, gorse and large areas of regenerating native plant species such as mānuka (*Leptospermum scoparium*), karo (*Pittosporum crassifolium*) and pohutukawa (*Metrosideros excelsa*). The vegetation at Warrenheip consists of regenerating vegetation, including kānuka (*Kunzea ericoides*), treeferns, kaikomako (*Pennantia corymbosa*), and *Coprosma* species. Tunnels were set at Mahoenui Giant Weta Scientific Reserve between 3 and 9 February 2009, at Mangaokewa Scenic Reserve between 9 and 15 February 2009, at Mahurangi Island between 16 and 22 February 2009, and at Warrenheip between 23 February and 1 March 2009.

Five transects of six tracking tunnels ($n = 30$) were established at five locations in regenerating kānuka-broadleaf forest (up to 4 m in height) adjacent to Te Maraeroa Flat on Little Barrier Island. Two transects of tunnels followed the tracks originating from Te Maraeroa Flat with the tunnels being placed 1-2 m off the track. Tracks were not present at the other three locations so the transects were marked using flagging tape. The tunnels were set between 14 and 20 May 2010.

Scoring tracking cards for giant weta footprints.—Weta leave distinctive footprints on tracking tunnel cards, with each tarsus producing a row of up to four closely spaced dots that originate from contact with their inflated tarsal pulvilli pads (Watts *et al.* 2008). In addition, prints made by the protarsus, mesotarsus, and metatarsus are easily distinguished because of their relative sizes and positions. We used the length of tarsal rows of dots to confirm if footprints were made by adult or large juvenile giant weta: on Little Barrier Island, footprints greater than 4.3, 4.9 and 8.9 mm in length for protarsus, mesotarsus, and metatarsus respectively were from *D. heteracantha*, whereas elsewhere those for *D. mahoenui* were greater than 3.8, 4.4 and 7.8 mm in length for protarsus, mesotarsus, and metatarsus respectively (Watts *et al*. 2008b). Cards with such footprints were scored as giant weta. Cards with shorter weta footprints could potentially have been from juvenile giant weta or juvenile or adult tree, weta or ground weta (*Hemideina* and *Hemiandrus* species, respectively). Cards with these small footprints were scored as giant weta not present.

Visual searches.—Visual searches were carried out along the tracking tunnel transects during daylight hours at all locations. Each search extended 5 m on either side of the transect and covered ground and vegetation above to a height of approximately 2.5 m. Suitable places where weta could potentially rest were examined, such as cavities in trees or spaces between the fronds of ferns and palms. A total of 15 person-searching hours was carried out by C Watts and D Thornburrow at each study site with three person hours of search effort being spent at each transect.

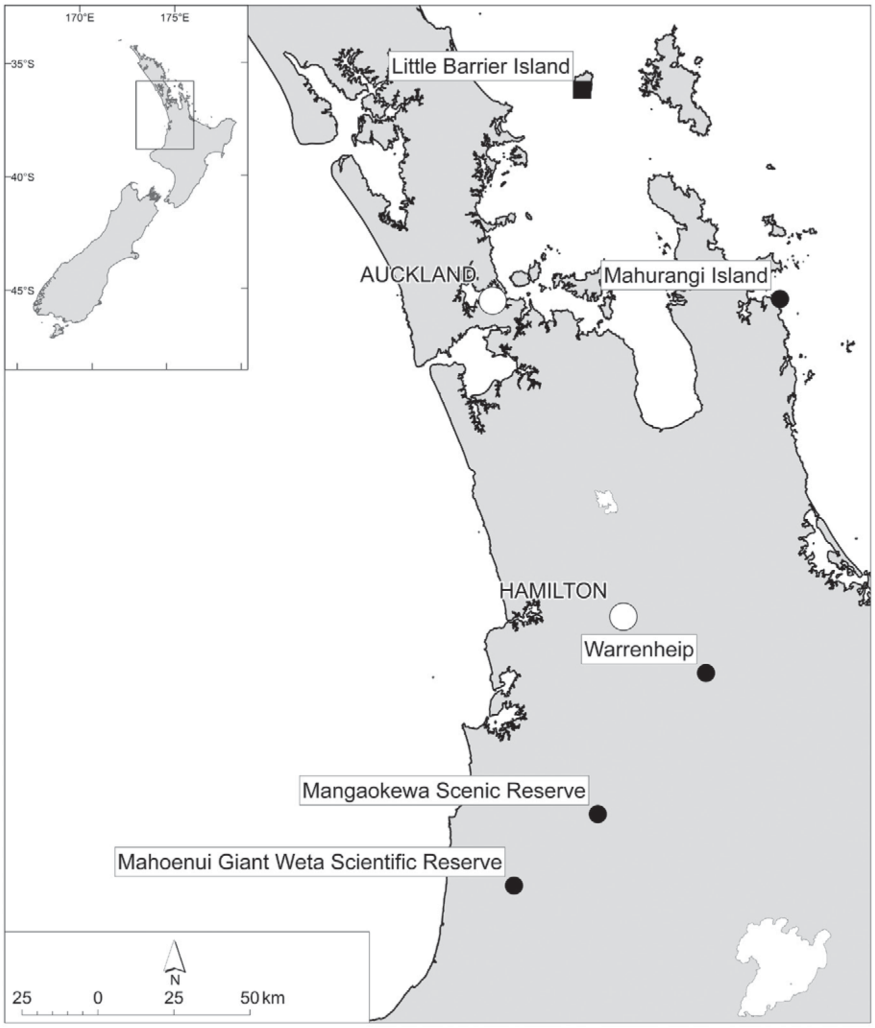

Fig. 1. Locations of *D. mahoenui* (solid circles) surveys in the Waikato and *D. heteracantha* (solid square) survey on Little Barrier Island.

Monthly tracking tunnel monitoring of Mahoenui giant weta at Warrenheip.—The transects at Warrenheip were run over 7 nights during the new moon phase each month in 2009 to determine seasonal changes in tracking rate (proportion of tracking tunnels with confirmed giant weta footprints). Tracking tunnel cards with footprints were scored as either *D. mahoenui* present or, if too small, as 'other weta' present. To assess the impact of weather conditions on weta activity, hourly measurements of meteorological data were obtained from Hamilton Airport, 22 km away, and averaged over the time the tracking tunnels were run.

Data Analysis.—All analyses were made using the statistical software R 2.15.1.

The relationship between the numbers of weta seen during visual searches and the number of giant weta footprints found in tracking tunnels along the same transects was analysed using a generalised linear regression with Poisson model to account for count data. This was applied to both weta species combined and then to the *D. mahoenui* data alone because the sample size for *D. heteracantha* was inadequate.

The effect of time (month and season) on the presence or absence of Mahoenui giant weta footprints in tracking tunnels was assessed from data collected repeatedly over 12 months at Warrenheip. Data for each of the four seasons were generated by combining the relevant monthly records where summer included December, January, and February. A generalised linear mixed model with the logistic link was employed using the lme4 package. The best model was chosen using AIC.

The effect of temperature and vapour pressure deficit (VPD) on the tracking rate was examined using presence/absence data for footprints of giant weta in the tracking tunnels from sampling at Warrenheip. The weta data are from a single site and relate to 12 temperature and 12 VPD records. The number of tracking tunnels found each month with giant weta footprints out of 35 tracking tunnels installed was modelled using a generalised linear model with binomial response. AIC was used to select the best model (Table 1). The full model is given algebraically below, where p is the probability of finding giant weta footprints.

$$\log\left(\frac{p}{1\text{-}p}\right) = \beta_0 + \beta_1 \text{ Temp} + \beta_2 \text{ VDP} + \beta_3 \text{ Temp} \times \text{VDP}$$

Table 1. Model selection for determining the relationship between time of year (month or season) and the probability of finding confirmed Mahoenui weta footprints (p) in tracking tunnels at Warrenheip Reserve. (α = a random intercept term; β = a random slope term, $(\frac{1}{TT})$indicates random intercept model and $(\frac{time}{TT})$ indicates random intercept and slope model, where TT means tracking tunnel)

Model (mixed effects)	month		season	
	df	AIC	df	AIC
M1: $\text{logit}(p) = \alpha + \beta\ \text{time}$	12	561.11	4	574.42
M2: $\text{logit}(p) = \alpha + \beta\ \text{time} + (\frac{1}{TT})$	13	497.67	5	520.91
M3: $\text{logit}(p) = \alpha + \beta\ \text{time} + (\frac{time}{TT})$	15	497.80	7	520.61

Results

Tracking tunnels.—The tracking rate varied from zero to 67% (*D. heteracantha* on Little Barrier Island) and there was considerable variation within a site. At Mangaokewa Scenic Reserve, no confirmed *D. mahoenui* weta footprints were found. None were found in three transects at the Mahoenui Giant Weta Scientific Reserve or in two transects at Warrenheip, even though these were set at the same times as others that did have giant weta footprints in them. The average tracking rate for *D. heteracantha* on Little Barrier Island was 37%±10% (±SE) and for *D. mahoenui*, 43%±8% at Warrenheip, 17% ±10% on Mahurangi Island, and 12%±7% at the Mahoenui Giant Weta Scientific Reserve.

Searching for weta.—A total of 142 adult *D. mahoenui* and 33 *D. heteracantha* were found during the surveys and of these, 80 *D. mahoenui* (56%) and 18 *D. heteracantha* (54%) were female. All giant weta were found on vegetation, and most weta were hidden in cavities or between fronds of tree ferns or palm trees. At Warrenheip, some *D. mahoenui* and occasionally *D. heteracantha* on Little Barrier Island were clearly visible on tree trunks or branches, the fronds of tree ferns or palms and amongst foliage.

The highest rate at which giant weta were found by searching was at Warrenheip where on average 4.0±0.9 (±SE) *D. mahoenui* were found per person per hour. This was followed by average sightings of 3.4±0.5 *D. mahoenui* at the Mahoenui Giant Weta Scientific Reserve, 2.2±0.4 *D. heteracantha* on Little Barrier Island, and 2.1±0.8 *D. mahoenui* on Mahurangi Island. No weta were found at Mangaokewa Scenic Reserve and so this site was omitted from any further analysis.

Relationship between numbers of weta sighted and numbers of weta detected in tracking tunnels.—The number of tracking tunnels with confirmed footprints of giant weta showed a positive relationship with the number of weta found per person-search hour at each location when the results were modeled using data from all locations where *D. mahoenui* were present, and when results were modeled from locations where both species were present (Fig. 2). This relationship changed little when only *D. mahoenui* sites were compared to combined *D. mahoenui* and *D. heteracantha* sites (Table 2). In both of the latter cases, an average of 1.3 more weta was seen by searching with each increase in tunnel tracked.

Seasonal Monitoring of D. mahoenui *at Warrenheip.*—The individual models for interpreting the relationship between the chance of finding footprints from adult *D. mahoenui* in tracking tunnels at Warrenheip during each month and season of 2009 are:

$$\log\left(\frac{p}{1\text{-}p}\right) = -0.43 - 0.0001\text{Feb} + 0.48\text{Mar} + 2.33\text{Apr} - 0.49\text{May} - 1.99\text{Jun} - 0.16\text{Jul} + 1.61\text{Aug} - 0.0004\text{Sep} + 1.14\text{Oct} - 0.00001\text{Nov} - 0.16\text{Dec} + \left(\frac{1}{TT}\right)$$

and

$$\log\left(\frac{p}{1\text{-}p}\right) = -0.45 + 0.71\text{Autumn} + 0.41\text{Spring} - 0.48\text{Winter} + \left(\frac{1}{TT}\right)$$

where p is the probability of weta footprints being found in tracking tunnels. In the above equations, $(\frac{1}{TT})$ indicates there is a random chance of finding weta footprints in tracking tunnels.

The observed tracking rate for *D. mahoenui* at Warrenheip during 2006 varied with both the month and season in which the tracking

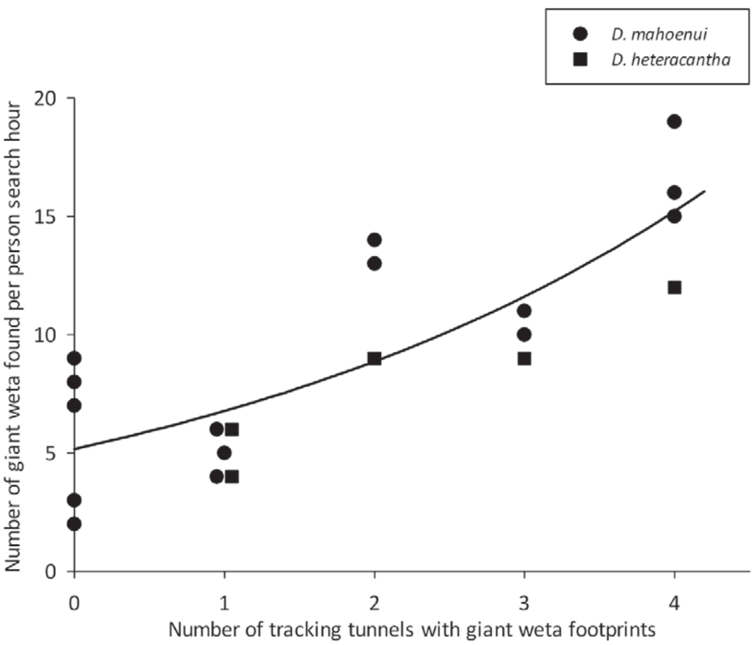

Fig. 2. Relationship between the number of adult giant weta found per person search hour and the number of tracking tunnels with confirmed giant weta footprints per transect. *D. mahoenui* = solid circles and *D. heteracantha* = solid squares. Coincident data have been offset for clarity.

Table 2. Overall relationship between the number of weta seen per hour by searching for *D. mahoenui* and for both *D. mahoenui* and *D. heteracantha* combined and the number of footprints in tracking tunnel over the transect. Values for intercept and slope are natural logarithms.

Species	Intercept	Slope (P-value)	Residual deviance	D.F.
D. mahoenui	1.643	0.270 (<<0.001)	14.5	13
D. mahoenui, D. heteracantha	1.693	0.277 (<<0.001)	17.95	18

tunnels were set. Tracking rates were similar during most months except in April, when they were at their highest; in October when they were slightly higher than most; and in June, when they were at their lowest (Fig. 3; Table 3). The tracking rate for weta changed seasonally, with the highest tracking rate in autumn and the lowest in winter (Fig. 4; Table 4).

The relationship between temperature and vapour pressure deficit on the tracking rate of D. mahoenui *at Warrenheip.*—Tracking rate varied significantly in relation to an interactive effect between temperature and VPD (Table 5). About 50% of tracking tunnels were predicted to be tracked by weta when the temperature was about 15°C and the VPD 0.25 but the chances of tracking increased when either temperature or VPD increased above these values (Fig. 5).

Discussion

The number of confirmed giant weta detected via tracking tunnels showed a positive relationship to the number found per unit search effort. This demonstrates that footprint tracking tunnels can be used to both detect giant weta and assess their relative abundance. Neither unit search effort nor tracking tunnels provide information about the absolute density of a weta population. Weta that are out of reach in the canopy can be missed during searching and tracking tunnels provide no information of how many different weta may have passed thru them. The tracking tunnel and search approaches have different advantages and disadvantages based on their relative efficiency of operation and potential for gathering additional information.

The primary requisites for using tracking tunnels for assessing populations is determining the number of tunnels necessary to detect change and this requires a preliminary study for a power analysis. However, tracking tunnels can only be used for this if the giant weta of interest is the largest species of anostostomatid weta at the location. This is the usual situation in most places in New Zealand except in north west South Island where the distribution of *Hemideina boughi*, the largest New Zealand tree weta, overlaps in the lower subalpine with a similar sized giant weta, *Deinacrida tibiospina* (Gibbs 2001). We found that operating tracking tunnels required about half the time required for searching (Table 6) whereas Watts *et al.* (2011a) spent more than five times searching with spotlights at night compared with using tracking tunnels. Overall, our experience suggested that the use of tracking tunnels is more efficient (faster and data were obtained more easily) than visual searching. A further advantage of tracking tunnels is that they can be left over several nights or easily and relatively quickly set again with new cards and bait to increase the chance of detecting weta where they are in low numbers or if few weta are found because of inactivity.

Table 3. Relationship between tracking rate and the month when the tracking tunnels were set. A generalised linear mixed model with the logistic link was used for the analysis. January is the reference category.

Month	Estimate	S.E.	z value	p
Jan	-0.434	0.465	-0.934	0.350
Feb – Jan	-0.000	0.552	0.000	1.000
Mar – Jan	0.481	0.551	0.874	0.382
Apr – Jan	2.332	0.636	3.668	<0.001
May – Jan	-0.500	0.563	-0.888	0.375
Jun – Jan	-1.986	0.671	-2.958	0.003
Jul – Jan	-0.163	0.555	-0.294	0.769
Aug – Jan	0.161	0.551	0.293	0.770
Sep – Jan	-0.0004	0.552	-0.001	0.999
Oct – Jan	1.140	0.564	2.022	0.043
Nov – Jan	-0.00001	0.552	0.000	1.000
Dec – Jan	-0.163	0.555	-0.294	0.769

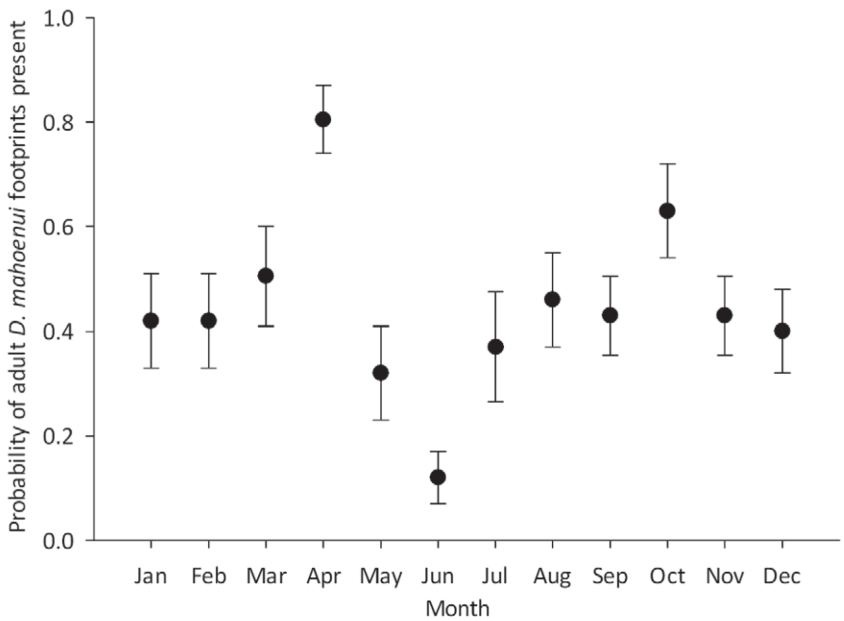

Fig. 3. Relationship between the time of year (month) and the probability of finding confirmed footprints of adult *D. mahoenui* weta in tracking tunnels at Warrenheip in 2009. Bars are ± SE.

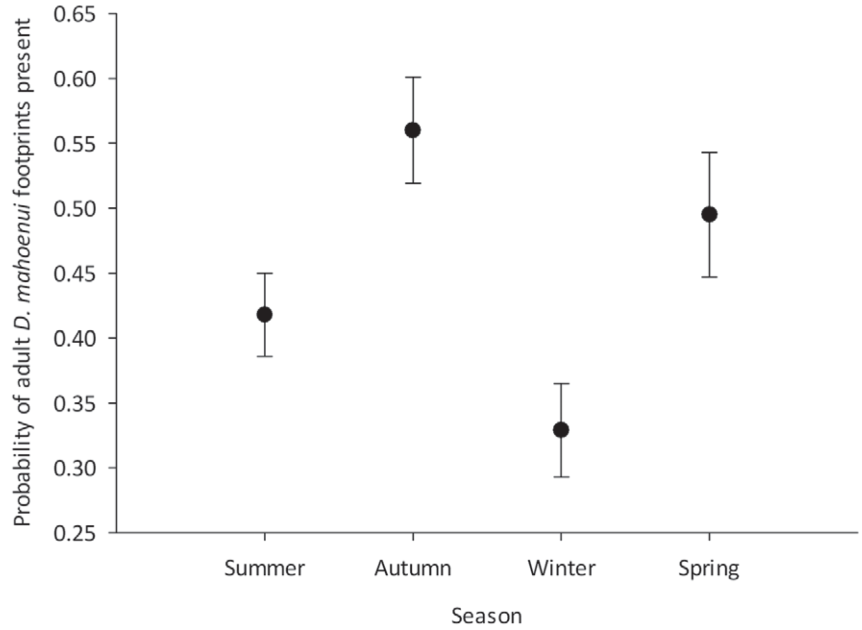

Fig. 4. Relationship between season and the presence of confirmed footprints of adult *D. mahoenui* weta in tracking tunnels at Warrenheip during 2009. Bars are ± SE.

Table 4. Relationship between tracking rate and the season when the tracking tunnels were set. A generalised linear mixed model with the logistic link was used for the analysis. Summer is the reference category.

Season	Estimate	S.E.	z-value	p
Summer	-0.4509	0.3098	-1.455	0.1456
Autumn – Summer	0.7090	0.3118	2.274	0.0229
Spring – Summer	0.4054	0.3099	1.308	0.1909
Winter – Summer	-0.4769	0.3183	-1.498	0.1340

Table 5. Relationship between temperature (Temp) and vapour pressure deficit (VPD) on tracking rate. The analysis was done with a generalised linear model with binomial response.

	df	Deviance	Residual df	Residual deviance	p(>χ)
NULL			11	40.926	
Temp	1	3.9415	10	36.985	0.047108
VPD	1	0.1807	9	36.804	0.670779
Temp:VPD	1	7.3958	8	29.408	0.006538

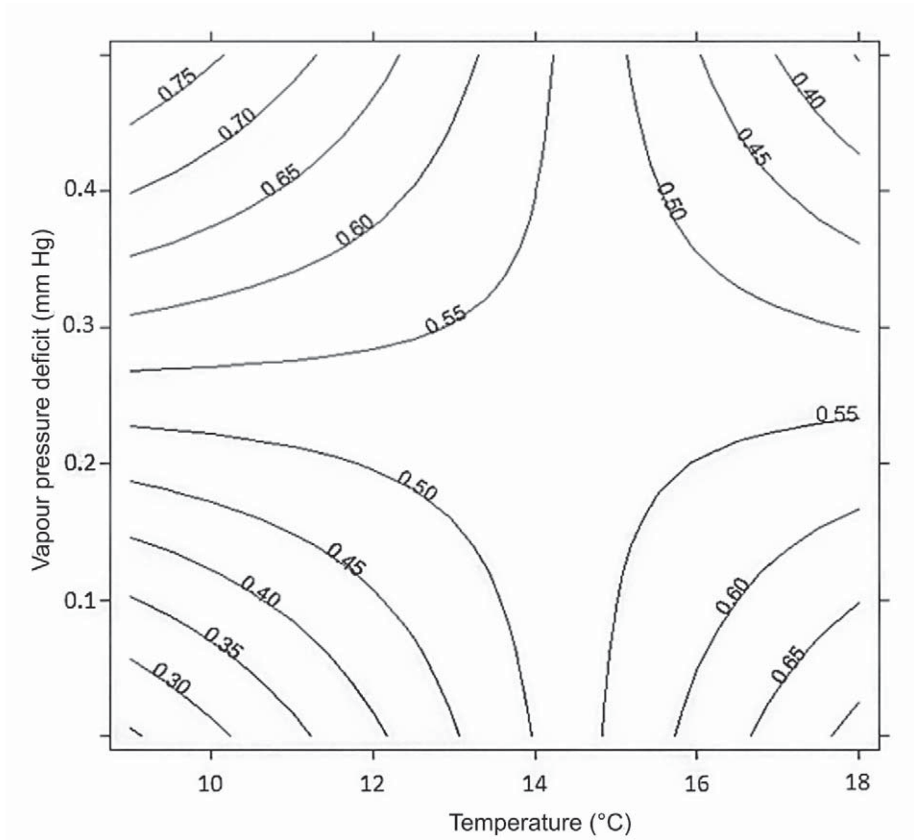

Fig. 5. Contour plot showing the predicted probability of finding confirmed footprints of *D. mahoenui* weta in tracking tunnels at Warrenheip in relation to the mean temperature and vapour pressure deficit when the tracking tunnels were set.

Table 6. Times (minutes) taken to search for giant weta during daytime and using tracking tunnels to detect them. Values are for a single transect.

Monitoring technique	Time taken to set out in field	Time taken to collect data in field	Lab analysis	Total time
Searching	-	180	-	180
Tracking tunnels	50	25	10	85

The objective of any giant weta survey will determine which technique is the more suitable. Searching likely resting places is an effective method for finding giant weta when they are abundant and it has the advantage that individuals can be examined to obtain further data such as their sex or dimensional measurements. Tracking tunnels only provide presence/absence information for the largest anostostomatid species present at a location. Their disadvantages are that tracking tunnels are dependent on weta being active, they provide no ancillary information and fail to distinguish among the smaller weta species or juvenile giant weta.

The influence of weather conditions on the detectability of weta, alluded to by Watts *et al*. (2011b), has been confirmed in this study with both ambient air temperature and vapour pressure deficit being important up to certain threshold values, while both being important at higher values. We caution that our results provide only a preliminary indication of how these weta may respond because temperature and relative humidity were recorded *ca* 22 km from the site where we worked (Warrenheip) and there was no replication at other sites. We suggest that both VPD and temperature be considered as driving variables in future assessments of weta monitoring techniques. Searching likely resting areas during the daytime when the weta are resting is independent of the weather and, although it could potentially be used to obtain an estimate of absolute abundance – as was done by Bleakley *et al.* (2006) for tree weta – this is impracticable for arboreal weta in tall forest. Searching also requires a substantial investment of time and the area that can be searches is relatively small. We have yet to investigate how the number of giant weta found per person search hour or how the number of tracking tunnels with confirmed giant weta footprints relates to the absolute density of weta. This will be difficult for *D. heteracantha* because it lives in continuous forest on Little Barrier Island and males and females can move on average 10 m and 5 m per day respectively from where they were first caught (Watts & Thornburrow 2011). Nevertheless, a preliminary attempt was made to estimate their abundance in 2010 but only 4 of the 102 marked weta were recaptured during 144 hours of searching (Watts & Thornburrow 2010). We do not yet know how *D. mahoenui* disperses in continuous vegetation but Richards (1994) found that they usually remained locally on small isolated groups of gorse (1-3 m^3) in the Mahoenui Giant Weta Scientific Reserve and only occasionally travelled up to 31 m between bushes. It may be possible to estimate absolute abundance (number per m^2) of *D. mahoenui* at the Mahoenui Giant Weta Scientific Reserve because the entire gorse habitat is accessible.

There were two locations where searching during the day and tracking rate of giant weta differed substantially from other locations. The first was at Mangaokewa Scenic Reserve where giant weta were neither seen nor their footprints found during this study. This location was included because an individual *D. mahoenui* weta had been found there during 20 person search hours by Watts & Thornburrow (2009). It seems likely that the abundance of the weta at this reserve is now either too low for them to be detected by searching or by the tracking tunnels used in this study, or that the weta no longer survive at this location.

The second location was at the Mahoenui Giant Weta Scientific Reserve. Here the tracking rates were lower than elsewhere even though the number of weta found per person hour was similar to other locations. This suggests that *D. mahoenui* may spend less time on the ground when predatory mammals are present, similar to that reported by Rufaut & Gibbs (2003) for the tree weta *Hemideina crassidens.* This tree weta roosted closer to and was more active on the ground on Nukuwaiata Island 4 years after kiore (*Rattus exulans*) were eradicated from the island. Mammalian predators were present at the Mahoenui Giant Weta Scientific Reserve whereas the other two populations were mammal-free: one was a mammal-free island (Mahurangi Island) and the other was an area enclosed by a mammal-proof fence (Warrenheip) which was subject to occasional minor mammal invasions.

When should giant weta be monitored using tracking tunnels?—Our results from Warrenheip indicate that *D. mahoenui* weta can be active on the ground throughout the year, at least on moonless nights, when the observed effects of VPD and temperature are taken into account, but these results are preliminary. These results do, however, indicate that *D. mahoenui* could potentially be monitored at most times of year although the tracking rate is likely to vary considerably. We suggest that the best time to carry out monitoring, particularly if the density of weta is low, is during autumn and possibly spring; the tracking rate in winter is likely to be too low for effective monitoring. Autumn, in particular April, is when females are most frequently found ovipositing into soil and when males of arboreal species may spend more time on the ground trying to intercept gravid females with which to mate (Ramsay 1955; Richards 1973).

Conclusions

We have shown that arboreal giant weta can be detected effectively by using footprint tracking tunnels baited with peanut butter and that this method can produce similar relative estimates of abundance to searching during the day. Tracking tunnels are easily deployed and large numbers can be set efficiently over sizable areas whereas searching during the day involves about twice as much time and covers a relatively small area. Disadvantages of using tracking tunnels are that only footprints are recorded and that juvenile giant weta cannot be distinguished from other smaller anastostomatid species that may be present. Searching, by contrast, provides opportunities to obtain additional information such as the age class and sex of individual weta. We suggest that tracking tunnels are an effective monitoring tool for detecting the presence of large threatened weta, such as arboreal giant weta. Tracking tunnels may also be suitable for relative abundance estimates but once weta have been detected, searching when weta are active will be necessary to obtain further data from individual weta.

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