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RESEARCH

Comparison of footprint tracking and pitfall trapping for detecting skinks

Marieke Lettink[1*], Jim Young[2] and Joanne M. Monks[3,4]

[1]Fauna Finders, 20 Days Road, Lyttelton 8082, Christchurch, New Zealand
[2]Vital Statistics Ltd, 91 Longhurst Tce, Christchurch 8022, New Zealand
[3]Department of Conservation, Ōtepoti/Dunedin Office, PO Box 5244, Dunedin 9058
[4]Department of Zoology, University of Otago, P O Box 56, Dunedin 9054
*Author for correspondence (Email: marieke@faunafinders.co.nz)

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Abstract: Inventory and monitoring of biodiversity requires effective sampling tools. Footprint tracking tunnels, developed in New Zealand to monitor small mammals, may also be useful for sampling lizards and other reptiles but more research is needed to verify this. To that end, we compared the detectability of terrestrial skinks using two methods: pitfall trapping and footprint tracking. In New Zealand, the former is the traditional method for sampling skinks, while the latter is routinely used to monitor populations of introduced rodents and mustelids. In January 2019, we operated paired grids containing 5 × 5 arrays of pitfall traps and standard rodent tracking tunnels on Tiwai Peninsula in Southland, South Island, and compared the daily proportions of traps and tunnels that detected skinks via captures and footprints, respectively. Overall, tracking tunnels were approximately twice as likely to detect skinks as pitfall traps. Additional research is required to: (1) test the relative efficacy of footprint tracking versus conventional detection methods on other lizard and reptile species; (2) investigate alternative tunnel designs and long-life lures; and, (3) calibrate footprint tracking rates against density estimates to assess suitability for monitoring.

Keywords: detection, monitoring, pitfall trap, reptiles, tracking tunnel, sampling tools

Introduction

Effective sampling tools are essential for accurate inventory and monitoring of biodiversity. In New Zealand, footprint tracking tunnels (King & Edgar 1977) are routinely used by the Department of Conservation (DOC) and others to detect and measure the activity of small mammals, particularly introduced rodents and mustelids (Gillies & Williams 2013). Footprints are acquired when animals walk over a pre-inked card or ink tray placed inside a tunnel that contains a suitable attractant and are identified to species or genus from their patterns and sizes. Because it is generally not possible to count or reliably distinguish individuals, the proportion of tunnels that record footprints (percentage frequency of detection or "tracking rate") is instead used to provide an index of activity for each species (Elliott et al. 2018).

Footprint tracking tunnels have also been used to detect large-bodied flightless invertebrates, particularly wētā, (Watts et al. 2008, 2011) and reptiles (skinks and geckos; Harker et al. 2017; Knox et al. 2019). Coincidental detection of lizard footprints in tracking tunnels used to index mammal populations has revealed remnant populations on offshore islands (Baling et al. 2013) and in remote locations in the South Island's alpine zone (K Sidaway, DOC, unpubl. data). Use of tracking tunnels for arboreal geckos has suggested that this technique has limited utility for lizards that live primarily above ground (e.g. Thoresen 2011, Chamberlain 2015). While identification to species level is not always possible, further research and development is warranted to assess the utility of tracking tunnels for detection and monitoring of lizard populations (Jarvie & Monks 2014).

To our knowledge, there are no published studies that have assessed the relative efficacy of footprint tracking versus conventional sampling methods for skinks. Standard methods for sampling terrestrial New Zealand skinks are live (pitfall and funnel) trapping and artificial retreats, with pitfall trapping being the traditional method with the longest history of use (Whitaker 1967; Lettink & Monks 2016). In this study, we compared the detectability of terrestrial skinks using two sampling methods: footprint tracking and pitfall trapping.

Methods

Field work was conducted in the Tiwai Spit Conservation Area (1934 ha; administered by DOC) on the Tiwai Peninsula, located near Bluff on the southern coast of the South Island, New Zealand. Dominant vegetation in this area includes bracken (*Pteridium esculentum*), flax (*Phormium tenax*), red tussock (*Chionochloa rubra*), mikimiki (*Coprosma propinqua*), matagouri (*Discaria toumatou*), tauhinu (*Ozothamnus leptophyllus*), mānuka (*Leptospermum scoparium*) and various

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mosses, herbs and grasses. The substrate is mostly pea gravel in the west, graduating to fine sand and peat in the east. The known resident lizard fauna comprises three diurnal species: Southland green skink (*Oligosoma chloronoton*), southern grass skink (*O.* aff. *polychroma* Clade 5) and cryptic skink (*O. inconspicuum*; DOC Herpetofauna Database).

Skinks were sampled at eight sites within the Conservation Area over 13 days of predominantly warm and sunny weather (14–18 and 24–31 January 2019). Sites were at least 1 km apart to maximise spatial coverage and ensure their independence with respect to skink movements, and were all located in areas known to contain skink populations (based on previous monitoring (S Crump, DOC, unpubl. data). Each site contained a 5 × 5 grid of paired pitfall traps (4-L plastic pails, 180 mm (L) × 180 mm (W) × 190 mm (H); Stowers Containment Solutions Ltd.) and tracking tunnels (Black Trakka standard tunnels, 500 mm (L) × 100 mm (W) × 100 mm (H), fitted with pre-inked tracking cards; Gotcha Traps Ltd.) at 4-m spacing. Pitfall traps had shade covers (plastic lids) staked 10–20 mm above their rims. All traps and tunnels were baited with tinned pear (refreshed as needed) and checked daily, at which time any cards that had been tracked by skinks or mammals were replaced.

Captured skinks were identified to species and uniquely numbered on the ventral surface using a non-toxic (Xylene-free) pen. Due to flooding of pitfall traps at two of the eight grids on 24 January 2019 (day 6; caused by a rising water table following rainfall), sampling ceased at these sites to prevent skinks from drowning. Data from these grids was omitted from all analyses. Trapping effort for the six remaining grids was 1650 trap-days, where one trap-day was one 24-hr period that a pitfall trap was operational for.

To enable direct comparison of skink detectability by method, we converted the data into a binary format that denoted presence (i.e. footprints or captures) versus absence for each sampling device (tunnel or pitfall) on each sampling occasion (24-hr period or trap-day). The presence or absence data are potentially correlated in both space and time. If ignored, such correlation leads to unrealistic precision when estimating the effect of one sampling method relative to the other (Valcu 2010). It is straightforward to allow for spatial and temporal correlation in a generalised additive mixed model (Wood 2016), but invariably this requires a binomial model with a logit link and then the estimated effect is an odds ratio.

Instead we fitted two generalised mixed models that allowed estimation of a prevalence ratio. First we summed presence or absence data for the 25 tunnels and 25 pitfalls in each grid on any given day. Using a grid total (the responses variable) avoids the problem of spatial correlation between sampling devices within the same grid. We viewed the grid totals as independent of each other on each sampling occasion. The temporal correlation that arises through repeated measures of grid totals over time was accommodated by using a random intercept for each grid. This allowed some grids to have higher totals on each sampling occasion than other grids, reflecting natural variations in skink densities between grids. Our mixed models had fixed effects for the day of sampling because warmer days were expected to produce higher grid totals than cooler days for both sampling methods as a result of greater skink activity. Sampling device was specified as a fixed effect in both models.

In the first generalised mixed model, we assumed that grid totals had a Poisson distribution. While this allows estimation of a prevalence ratio for the sampling method, it is not a particularly convincing model because a Poisson response has an infinite upper limit, whereas our response cannot exceed 25 (if skinks were detected in all tunnels or pitfalls in a grid). The first model afforded a check of the estimate from a second more plausible, but more complicated, model. In the second model, we converted grid totals (the response variable) to a proportion and assumed this proportion to have a beta distribution. Beta regression is often used to analyse fractional responses (rates or proportions), but typically with a logit link function. We used a log link to provide inference in terms of a prevalence ratio, a strategy used with binomial regression although such models do not always converge (Douma 2018). We fitted both models in R (R Core Team 2021), the first using the lme4 package (1.1-27.1) and the second using the mgcv package (1.8-33).

Results

Skink sampling was conducted over 13 days of favourable conditions for skink activity, in two sessions separated by 5 days of unsuitable (wet and windy) weather (Table 1). This yielded 11 sampling occasions (24-hr periods or trap-days). In total, there were 592 captures of 350 skinks in pitfall traps, at least 310 of which were cryptic skinks. There was one capture of a green skink and 39 skinks that were not identified to species; these were most likely cryptic skinks (it is possible that a small number were southern grass skinks although none were identified as such). The total number of skink detections obtained at each site was consistently higher for tracking tunnels than pitfall traps (Table 2). Daily tracking rates ranged from 0.00 to 0.96 between grids, and within each grid were consistently higher on average than the proportion of pitfall traps that captured skinks (Fig. 1).

In the mixed model for Poisson-distributed counts, the prevalence of skinks in tunnels relative to traps was 2.2 (95% confidence interval 1.9 to 2.5); in the mixed model for beta-distributed proportions, the relative prevalence was 2.0 (95% confidence interval 1.7 to 2.4). Broadly speaking then, skinks were detected in twice as many tunnels as traps.

Discussion

In this study, footprint tracking tunnels were approximately twice as likely to detect terrestrial skinks as pitfall traps. Since animals constrained in pitfall traps are temporarily unavailable for tracking, detectability of skinks in tunnels may have been under-estimated. Despite this disadvantage, the tunnels were consistently superior at detecting skinks, with greater proportions of tunnels than traps detecting skink presence at all sites. Sampling of additional species and in other habitats will be required to determine if this applies to terrestrial lizards generally, and to assess the utility of footprint tracking for lizard monitoring (as opposed to detection). We were unable to find any published studies outside of New Zealand that used footprint tracking tunnels to sample lizards or other reptiles, but tracks have proven utility for inventory and monitoring in terrain that preserves them, especially sand and snow (e.g. Foster 2012). In general, we expect footprint tracking to be more effective for actively-foraging lizard species, which move through their habitats to hunt prey using chemosensory and visual cues, compared to sit-and-wait foragers, which primarily

Table 1. Summary of weather conditions during skink sampling on Tiwai Peninsula, January 2019. Data were sourced from the weather station located at Tiwai Point (NZ Aluminium Smelter site).

Date	Sampling day	Total rainfall (mm)	Mean temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Mean wind speed (km hr^{-1})
14/01/2019	1	0.0	13.7	16.2	10.7	4.1
15/01/2019	2	0.0	14.8	18.0	10.9	4.2
16/01/2019	3	0.2	15.0	20.3	10.0	4.4
17/01/2019	4	1.6	14.3	15.8	12.4	3.5
18/01/2019	5	0.0	14.8	19.4	11.8	3.4
19/01/2019	traps closed	14.8	15.8	20.3	12.4	8.4
20/01/2019	traps closed	9.4	13.2	16.2	10.2	14.9
21/01/2019	traps closed	8.6	12.6	14.5	10.0	14.9
22/01/2019	traps closed	1.6	15.6	19.6	11.7	13.8
23/01/2019	traps closed	20.8	12.4	15.5	9.1	10.4
24/01/2019	6	0.6	12.0	14.7	9.8	9.9
25/01/2019	7	0.4	13.4	15.9	11.1	9.2
26/01/2019	8	7.0	16.6	23.4	12.5	8.7
27/01/2019	9	6.0	16.0	19.9	14.4	9.3
28/01/2019	10	1.2	16.8	19.3	14.4	8.7
29/01/2019	11	0.0	19.1	25.9	12.4	2.6
30/01/2019	12	1.8	19.8	26.2	15.2	2.9
31/01/2019	13	0.0	21.4	27.0	16.4	4.0

Table 2. Numbers of skink detections obtained from footprint tracking tunnels and pitfall traps at six sites on Tiwai Peninsula, January 2019. Each site contained 25 paired devices of each type operated concurrently for 11 sampling occasions (see text). Numbers in parentheses indicate the number of individuals caught in traps.

Site	Number of skink detections from tracking tunnels	Number of skink detections from pitfall traps	Number of skink captures in pitfall traps
1	208	136	229 (105)
2	184	78	109 (62)
3	145	67	87 (61)
4	198	75	105 (70)
5	89	22	27 (25)
6	57	25	28 (21)
Total	**881**	**403**	**585 (344)**

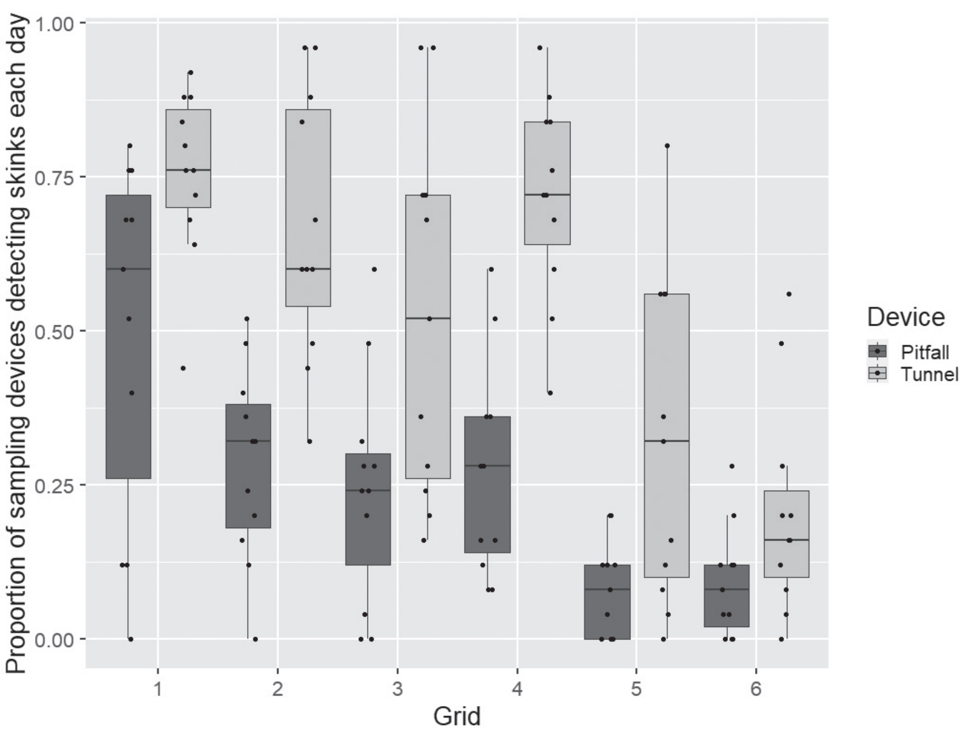

Figure 1. Daily proportions of sampling devices (footprint tracking tunnels and pitfall traps) that detected skinks on each of six paired grids, Tiwai Peninsula. Each point shows the proportion of the 25 devices of each type that detected skinks each day; the boxplot shows the median and interquartile range of these proportions over the 11 sampling occasions.

Table 3. Advantages and disadvantages of footprint tracking and pitfall trapping for sampling lizards.

Method	Advantages	Disadvantages
Footprint tracking	Easy to repeat and standardise No observer bias Non-invasive Low-maintenance Little additional work required in conservation areas that already have tracking tunnels in place to detect and/or monitor mammals Minimal/no habitat disturbance Does not require Wildlife Act Authorisation (a 'wildlife permit')	Cannot be used to count individuals Species identification may not be possible Detectability of most species unknown compared to standard methods Has not been calibrated for monitoring
Pitfall trapping	Easy to repeat and standardise No observer bias Permits species and individual identification, and collection of life-history data Suitable for monitoring	Labour-intensive Some habitat disturbance Geckos can escape Not possible in rocky terrain Risk of injury/mortality to animals in traps (e.g. predator by-catch) Not all life stages equally trappable Requires Wildlife Act Authorisation

use vision to scan their environment and tend to ambush mobile prey as it approaches (Cooper Jr 1995).

Footprint tracking has some notable advantages over pitfall trapping for lizard detection (Table 3): it requires significantly less effort to install devices, poses no risk of harm (since animals are not constrained in traps or handled) and does not require Wildlife Act Authorisation (a wildlife permit) from DOC, making it an ideal tool for citizen science projects involving community groups, private landowners and schools. Many conservation areas already have tracking tunnels in place to detect and/or monitor small mammals, and little additional work would be required to use them for lizard detection (e.g. baiting tunnels with canned pear to attract lizards and scoring cards for skink and gecko tracks in addition to those of small mammals). However, a major disadvantage of footprint tracking is that individuals cannot be counted or identified to species in most cases, particularly for skinks (Jarvie & Monks 2014). However, where only one gecko and one skink species is found in an area, the tracks can be easily distinguished and used in species-specific reporting. Furthermore, where the objective of management is increased activity, distribution and/or relative abundance of lizards as part of a functioning ecological community, species-level identification is unnecessary and tracking tunnels may serve as a useful tool in monitoring.

Pitfall trapping has been the dominant method for sampling terrestrial New Zealand lizards for 50+ years (Whitaker 1967; Lettink & Monks 2016). While effective for many species, it is labour-intensive because traps must be dug into the ground and checked at least once every 24 hr period (a legal requirement for any live-capture trap under the NZ Animal Welfare Act 1999). In contrast, footprint tracking tunnels may be left unchecked as long as desired and will remain functional until the ink has dried (at least 2 months for some commercially-available tracking cards placed in a high-rainfall, alpine environment over the austral summer (ML pers. obs.). Further research is required to determine the optimal placement period, which will vary among species as a function of their activity and density. Ultimately, the choice of sampling method will likely be determined by the aims of the study. Cost and availability of sampling devices may also be a factor (at the time-of-writing, pitfall traps and tracking tunnels were both able to be made or purchased for ≤ NZ$10 each).

Data from footprint tracking tunnels provide an index of activity rather than abundance. It is reasonable to expect a proportional relationship between the two, but this will need to be demonstrated before tracking tunnels can be used to index lizard abundance (as done for some rodent species; Brown et al. 1996; Elliott et al. 2018). Exploratory work on lizards suggests that abundance estimates from tracking tunnels can only be obtained in high-density populations (Siyam 2006). The relationship between activity and abundance will be more difficult to demonstrate for reptiles than mammals because they are ectotherms. The many factors that influence reptile activity include ambient temperature, rainfall, humidity, time-of-day, season, moon phase and preceding weather conditions (Spence-Bailey et al. 2010). Future studies in this area should therefore take account of these factors when examining patterns in the resultant data.

Based on our results, we consider footprint tracking to merit further investigation for lizards and recommend: (1) further trials of footprint tracking versus conventional detection methods on other terrestrial species; (2) investigation of alternative tunnel designs and long-life lures attractive to lizards; and, (3) calibration of footprint tracking rates against density estimates to assess suitability (accuracy and precision) for monitoring. The method is also likely to be useful for sampling other reptiles outside of New Zealand.

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Author contributions

ML and JM conceptualised the research, JY conducted the statistical analysis and all authors were involved in writing the manuscript.

References

Baling M, van Winkel D, Rixon M, Ruffell J, Ji W, Ussher G 2013. A review of reptile research and conservation management on Tiritiri Matangi Island, New Zealand. New Zealand Journal of Ecology 37(3): 272–281.

Brown KP, Moller H, Innes J, Alterio N 1996. Calibration of tunnel tracking rates to estimate relative abundance of ship rats (*Rattus rattus*) and mice (*Mus musculus*) in a New Zealand forest. New Zealand Journal of Ecology 20: 271–275.

Chamberlain E 2016. Analysing gecko monitoring data and standardising monitoring procedures at Shakespear, Tawharanui and Whakanewha Regional Parks. MSc Thesis. Massey University, Auckland. 133 p.

Cooper Jr WE 1995. Foraging mode, prey chemical discrimination, and phylogeny in lizards. Animal Behaviour 50(4): 973–85.

Douma JC & Weedon JT 2019. Analysing continuous proportions in ecology and evolution: A practical introduction to beta and Dirichlet regression. Methods in Ecology and Evolution 10(9): 1412–1430.

Elliott GP, Kemp J, Russell JC 2018. Estimating population growth rates from tracking tunnels. New Zealand Journal of Ecology 42(2): 269–72.

Foster MS 2012. Standard techniques for inventory and monitoring. pp 205 – 271 In: MacDiarmid RW, Foster MS, Guyer C, Gibbons JW, Chernoff (eds) Reptile Biodiversity: Standard Methods for Inventory and Monitoring. University of California Press.

Gillies C, Williams D 2013. DOC tracking tunnel guide v2.5.2: Using tracking tunnels to monitor rodents and mustelids. Hamilton, Department of Conservation. 14 p.

Jarvie S, Monks JM 2014. Step on it: can footprints from tracking tunnels be used to identify lizard species? NZ Journal of Zoology 41(3): 210–217.

Harker TD, Harker NF, Harker FR, Peace J, Barry M, Ludbrook MR, Ji W 2017. Analysis of footprints provides additional insights during monitoring of Duvaucel's geckos (*Hoplodactylus duvaucelii*). New Zealand Journal of Zoology 44(4): 305–318.

King CM, Edgar RL 1977. Techniques for trapping and tracking stoats (*Mustela erminea*); a review and a new system. New Zealand Journal of Zoology 4: 193–212.

Knox CD, Jewell TR, Monks JM 2019. Ecology of orange-spotted geckos (*Mokopirirakau* "Roys Peak") in Central Otago and Queenstown-Lakes districts. New Zealand Journal of Ecology 43(2): 1–9.

Lettink M, Monks JM 2016. Survey and monitoring methods for New Zealand lizards. Journal of the Royal Society of New Zealand 46(1): 16–28.

R Core Team 2021. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Siyam SM 2006. Reptile monitoring: development of an effective, passive monitoring technique. Unpublished MSc thesis. Auckland University, Auckland. 264 p.

Spence-Bailey LM, Nimmo DG, Kelly LT, Bennett AF, Clarke MF 2010. Maximising trapping efficiency in reptile surveys: the role of seasonality, weather conditions and moon phase on capture success. Wildlife Research 37(2): 104–115.

Thorensen JJ 2011. Monitoring the impacts of invasive mammals on arboreal geckos' habitat use, cell foam retreat use, and the effectiveness of different monitoring techniques. MSc Thesis. Massey University, Auckland. 161 p.

Valcu M, Kempenaers B 2010. Spatial autocorrelation: an overlooked concept in behavioral ecology. Behavioral Ecology 21(5): 902–905.

Watts CH, Thornburrow D, Green CJ, Agnew WR 2008. Tracking tunnels: a novel method for detecting a threatened New Zealand giant weta (Orthoptera: Anostostomatidae). New Zealand Journal of Ecology 32: 92–97.

Watts CH, Armstrong DP, Innes J, Thornburrow D 2011. Dramatic increases in weta (Orthoptera) following mammal eradication on Maungatautari–evidence from pitfalls and tracking tunnels. New Zealand Journal of Ecology 35(3): 261–272.

Whitaker AH 1967. Baiting pitfall traps for small lizards. Herpetologica 23: 309–311.

Wood SN, Pya N, Säfken B 2016. Smoothing parameter and model selection for general smooth models. Journal of the American Statistical Association 111(516): 1548–1563.

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