How much search effort is enough? Detection probabilities for possum scat detection dogs

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Emma Feenstra

Fauna Consulting

Al Glen

Bioeconomy Science Institute Maiangi Taiao

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Prepared for: Department of Conservation

Reviewed by:
Dean Anderson
Group Principal Researcher
Bioeconomy Science Institute

Approved for release by:
Duane Peltzer
Portfolio Leader – Managing Invasive Species
Bioeconomy Science Institute

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Summary

Project and client

- Wildlife detection dogs are widely used by researchers and wildlife managers to detect animals or animal sign, such as scats (droppings).
- As part of the Predator Free 2050 initiative, scat detection dogs are used to detect remaining possums (*Trichosurus vulpecula*) after their population has been reduced to low density.
- Predator Free 2050 Ltd[1] contracted Manaaki Whenua – Landcare Research (now Bioeconomy Science Institute) to estimate the detection probability for possum scat detection dogs searching in areas where the possum population has been reduced to low density.

Objectives

The objectives of this project were to:

- estimate the detection probability for possum scat detection dogs searching areas with low population densities of possums
- estimate the amount of search effort required to reach 80%, 90% or 95% probability of detection, given the presence of possums at very low or moderately low density
- investigate the influence of temperature, rainfall, wind speed, and wind direction on detection probability.
- test for variation in detection probability between two possum scat detection dogs.

Methods

- In consultation with the dog handlers and Predator Free Taranaki staff, we chose one study area where possums were believed to be at very low density and one area where possums were believed to be at moderately low density (based on previous trapping and monitoring). We emphasise that the density of possums in both areas was much lower than would likely be encountered in areas where no possum control has taken place.
- Surveys were conducted by two possum scat detection dogs and two handlers, who regularly conduct possum searches in the Predator Free Taranaki project area.
- We divided each study area into 15 ha grid cells, based on the estimated average home range size of possums in the area. These cells were used as the management units within which search effort was allocated and accumulated. Although possums were known to be present in both study areas, their presence or absence in each individual grid cell was unknown.
- Before surveys began we conducted a pilot study in which we established 31 search routes of 600–1,400 m, each within a single 15 ha grid cell. The dog handlers established fixed search routes that targeted areas they considered likely possum habitat within each cell.
- Sixteen search routes were established in the moderately low density area and 15 in the very low density area.

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[1] Predator Free 2050 Ltd was disestablished in 2025 and its functions moved to the Department of Conservation.

- All scats found by the dog teams during the pilot study and subsequent surveys were removed. This eliminated the possibility that dogs would remember where they had previously detected scats and be biased towards detecting the same scats in repeat surveys. It also decreased the likelihood of finding old scats that could have been deposited by possums no longer present in the area. As a result, our estimates of detection probability may be lower than in areas where scats have not previously been removed.
- The route walked by the handler was recorded using a GPS, while the dog worked off leash, allowing it to search on either side of the search route as desired. The handler walked the same route on each subsequent survey.
- After the pilot study each search route was searched on four occasions, with 6–11 days between repeat surveys.
- Faecal pellets ≤2 m apart were classed as a single scat.
- Detection/non-detection at the search route level (1 = one or more scats detected, 0 = none detected) was modelled using a binomial generalised linear mixed model (GLMM) with a complementary log-log link. Search-route length was included as an offset so that detection probability scaled with search effort under an encounter rate formulation.
- Encounter rates per kilometre were derived from model-predicted 1 km detection probabilities and used to determine the search effort required to reach specified detection probability thresholds in different density classes.
- For interpretation at the management unit scale, the cumulative probability of detecting at least one possum scat was calculated for each grid cell using the total kilometres searched within that cell across repeat surveys. This represents the probability of detection given the surveyed route and total search effort within that cell, assuming the encounter rate along the route is representative of the wider grid cell.

Results

- A total of 403 possum scat detections were recorded: 59 in very low density and 349 in moderately low density grid cells.
- Estimated detection probability for a 1 km search route was 0.99 (95% CI: 0.85–1.0) in moderately low density grid cells, and 0.28 (95% CI: 0.13–0.55) in very low density cells.
- In moderately low density grid cells a single 1 km survey was sufficient to achieve ≥95% probability of detecting possum scat, if present.
- In very low density cells substantially greater effort was required; approximately 10 km of cumulative search effort was needed to achieve ≥95% probability of detection.
- Within the range of weather conditions encountered there was no evidence of a relationship between weather variables and scat detection rate.
- Overall detection probability did not differ significantly between dogs; however, one dog detected a significantly higher proportion of fresh scats than the other.

Conclusions

- Detection probability for possum scat detection dogs is strongly dependent on possum density. In moderately low density populations, high detection probabilities are achievable with relatively little search effort. Where population density is very low, substantially greater search effort is required to achieve the same detection probability.
- Survey effort must therefore scale with expected possum density if high probabilities of detection are required, as short search routes or limited survey replication are unlikely to achieve high detection probabilities in very low density populations.
- Variation between dogs was evident in the type of scat detected (fresh versus not fresh), but overall detection probability was driven primarily by possum density rather than dog identity.
- Within the range of environmental conditions encountered during this study, weather variables did not appear to influence scat detection rates, although this should be interpreted cautiously given the limited range of conditions encountered.

Recommendations

1 Scale survey effort to expected possum density and the desired detection probability.

In moderately low density areas a single search route of approximately 600 m will generally be sufficient to achieve ≥95% detection probability, with shorter search routes requiring an additional replicate. In very low density areas plan for approximately 10 km of cumulative search effort to achieve ≥95% detection probability. In this study, effort was accumulated within grid cells, but the same cumulative detection framework can be applied to any survey design that accumulates search effort.

2 Design grid cells and search routes based on possum home-range scale and habitat availability.

Grid cells should be approximately home-range sized, while ensuring that each cell contains enough suitable habitat to support a ≥1 km search route, where possible. Where this is not achievable, smaller cells can be retained to maintain spatial resolution, with higher detection probabilities achieved through additional repeat surveys rather than increasing cell size. Because detection probability accumulates with search effort, equivalent detection probabilities can be achieved through different combinations of search route length and survey replication.

3 Account for variability among dog-handler teams in low density contexts.

Consider using multiple dog-handler teams or rotating teams among a subset of search areas to reduce reliance on individual search styles or scat-age biases and improve robustness of inference, particularly in very low density areas where detections are infrequent and results may depend strongly on the performance of a single dog team.

4 Use cumulative detection frameworks as the primary planning tool, and combine methods when possible.

Apply cumulative detection calculations to determine the minimum combination of search route length and repeat surveys required to meet a target threshold of detection probability. In very low density areas, detection probability can be increased by combining scat detection dogs with complementary surveillance methods (e.g. camera traps) deployed strategically within key habitat patches.

5 Use decision-support tools to scale detection probabilities to broader surveillance objectives if required.

The detection probability estimates reported here can also inform broader decision support tools used for surveillance planning. For example, applications such as JESS (Just Enough Surveillance Sensitivity) can be used to explore how cumulative search effort translates to surveillance sensitivity at larger spatial scales, provided that detection probability is re-estimated or appropriately adjusted for local habitat structure, search design, and management objectives. As detection probability may vary (e.g. due to differences in habitat or performance of dog-handler teams), site-specific pilot surveys should be used to estimate local detection probabilities before applying cumulative detection calculations in new contexts.

1 Introduction

Wildlife detection dogs are widely used by researchers and wildlife managers to detect animals, or animal sign such as scats (droppings) (Bennett et al. 2020, 2022; Glen et al. 2024). As part of the Predator Free 2050 initiative, scat detection dogs are used to detect remaining possums (*Trichosurus vulpecula*) after their population has been reduced to low density.

If no possums or scats are detected this does not necessarily mean that possums are absent. However, managers can use ‘proof of absence’ models to declare success of an eradication. Detection probability (the likelihood the species will be detected, if present) is one of the parameters required for these models (Anderson et al. 2013; Samaniego-Herrera et al. 2013; Kim et al. 2020).

Predator Free 2050 Ltd (now Department of Conservation) contracted Manaaki Whenua – Landcare Research (now Bioeconomy Science Institute) to estimate detection probability for possum scat detection dogs searching in areas where the possum population has been reduced to low density.

2 Objectives

The objectives of this project were to:

- estimate the detection probability for possum scat detection dogs searching areas with low population densities of possums
- estimate the amount of search effort required to reach 80%, 90% or 95% probability of detection, given the presence of possums at very low or moderately low density
- investigate the influence of temperature, rainfall, wind speed and wind direction on detection probability
- test for variation in detection probability between two possum scat detection dogs.

3 Methods

3.1 Study areas

We conducted our study on pastoral land with patches of native vegetation in the Taranaki region, North Island, New Zealand. The Predator Free Taranaki project aims to control invasive predators (including possums) over 700,000 ha on the ring plain surrounding Taranaki Mounga. Taranaki Regional Council is rolling out predator control across the ring plain over 10 years, starting in 2018 (Glen & Peace 2020).

In consultation with Predator Free Taranaki staff we chose one study area with intensive possum control where previous monitoring indicated that possums were at very low density, and one area where possum control had been less intensive and monitoring data indicated a moderately low density of remaining possums. The very low density area (39°10’46”S; 173°53’54”E) comprised approximately 250 ha of farmland north-west of Taranaki Mounga, where intensive possum control had been undertaken for more than 6 years. The moderately low density area (39°21’25”S;

174°09’12”E) was east of Taranaki Mounga, and comprised around 260 ha of farmland where possum control had been ongoing for 3 years (Glen & Peace 2021).

We emphasise that the density of possums in both areas was much lower than would likely be encountered in areas where no possum control has taken place. The two areas were separated by 20 km, ensuring spatial independence. No possum control was planned in either area over the period of our surveys. However, a landholder trapped one possum in the very low density area during the study period.

3.2 Possum scat surveys

Scat searches were conducted by two possum scat detection dogs and two handlers, who regularly conduct possum searches in the Predator Free Taranaki project area (Hoegh Hunting Ltd). The dogs were Peggy, a 7-year-old female German shorthaired pointer × Vizsla with 5 years’ working experience on possum scat and other targets, and Beau, a 2.5-year-old male Labrador × Vizsla with 1 year of working experience on possum scat.

We divided each study area into 15 ha grid cells, based on the estimated average home-range size of possums on nearby farmland (7 ± 11 ha; O'Malley 2023). Search routes were established during a pilot study from 6–10 May 2025 that confirmed possum presence in the study areas but not within every grid cell. Search routes were 600–1,400 m long, non-linear, and targeted areas the dog handlers considered likely possum habitat. We established 16 search routes in the moderately low density area and 15 in the very low density area, with each route located within a single grid cell.

After the pilot study the dog teams conducted four surveys along each search route between 19 May and 26 June 2025. Using the same search route on each repeated visit allowed detection probability to be estimated for a fixed search route, and confidence of detection to be accumulated through repeated surveys within a defined management unit. An alternative approach would be to survey different search routes within a cell on each visit, which would increase spatial coverage but would also introduce additional heterogeneity in detection probability associated with route placement and habitat variation.

Because our study design involved repeated surveys along the same search routes there was a possibility the dogs might recall where they had located scats on previous visits. To reduce this potential bias all scats found during the pilot study and each subsequent survey were removed. This also reduced the likelihood of finding old scats, which could have been deposited by possums no longer present in the area. As a result, our estimates of detection probability may be lower than in areas where scats have accumulated over longer periods.

The route walked by the handler was recorded using a GPS, while the dog worked off leash and searched freely around the search route. The handler walked the same route on each subsequent survey, and stayed as close as possible to the marked route unless they moved off to check an indication. On a correct indication of possum scat, the dog was rewarded with a short period of play before being asked to search on. Generally, the same dog team conducted all four scat surveys in any given cell. However, two cells in the very low density area were searched by both dog teams on separate occasions.

Because possums can deposit several faecal pellets during a single defaecation, pellets ≤2 m apart were classed as a single scat. Scats were recorded as ‘fresh’ if they had external mucus or a strong odour (Feenstra 2024), or ‘not fresh’ if they lacked those characteristics. The amount of scat was noted as <10, 10–20 or >20 pellets. These factors could be informative both for the presence and abundance of possums and for the performance of detection dogs. Search routes and scat waypoints were recorded on GPS, providing total search route length and number of detections per search route.

During each scat survey weather variables were recorded, including current rainfall (light, medium, heavy), wind direction and strength (scale of 1–5), and ambient temperature. Scat surveys within a cell were an average of 8.8 days apart (SD = 1.7, range 6–11 days). The interval between surveys allowed for the accumulation of possum scats. Each survey period took 4–5 days, during which time each cell was surveyed once. The order in which cells were searched was randomly assigned in each survey period.

3.3 Detection probabilities

We modelled the probability that a search route had ≥1 possum scat detection using a binomial generalised linear mixed model (GLMM) with a complementary log-log link. Search-route length (km) was included as a log(length) offset so that detection probability scaled with search effort as an encounter-rate process. Fixed effects were possum density (moderately low vs very low), dog, and survey number (1–4). Cell identity was included as a random intercept to account for repeated surveys within each 15 ha cell. The response variable was search-route detection (1 = one or more scats detected, 0 = none).

Our approach was similar to previous studies that have used detection probability to guide survey effort (e.g. Squires et al. 2012), but was adapted for a scat-based detection system. Models were fitted in R (version 4.5.1; R Core Team 2025) using the *lme4* package (Bates et al. 2014). Predictions were obtained from the fixed effects (i.e. population-level predictions not conditional on cell-level random effects) using the *emmeans* package (Lenth et al. 2018).

The probability of detecting at least one scat over a search route of length *L* (km) was:

$$P(L) = 1 - e^{-\lambda L}$$

where λ is the encounter rate per kilometre. We obtained the predicted detection probability for a 1 km search route and derived the corresponding encounter rate per kilometre as

$$\lambda = -\log(1 - p_{1km})$$

where p_{1km} is the model-predicted probability of detecting at least one scat over 1 km.

Detection probability was then scaled to total search effort *E* (km), where *E* represents any combination of search route length and repeat surveys (e.g. $E = L \times N$):

$$P(E) = 1 - e^{-\lambda E}$$

For each grid cell, *E* was calculated as the sum of all search-route lengths across surveys, representing the total search effort within that cell. The probability of detecting at least one scat within a cell, given the surveyed route and applied search effort, was calculated using the same cumulative detection equation:

$$P_{cell} = 1 - e^{-\lambda E}$$

Cells with detections were classified as confirmed presence. For cells without detections, P_{cell} represents the probability of detecting possum scat, if present, given the cumulative search effort applied along the surveyed route within that cell. Cells without detections were categorised according to the estimated detection probability as high (≥0.95), moderate (0.80–0.95), or low (<0.80).

3.4 Scat characteristics

We first summarised the freshness and number of pellets for all scats (fresh vs not fresh; small, medium, or large pellet groups) across dogs, survey rounds, and density classes. Freshness was recorded as a binary variable in the field and used directly in the analyses.

3.5 Comparison between dogs

To evaluate whether the two dogs differed in scat detection rates, we modelled the number of scats detected per survey using a negative binomial GLMM with a log link and an offset for search route (km). Fixed effects were dog, density class, the dog × density interaction, and survey number. Survey number was included to account for potential changes in scat availability across repeated surveys due to the removal of scats in previous rounds. A random intercept for cell was included to account for non-independence among repeated surveys within the same cell. The model tested whether detection rates differed between dogs overall, and whether any dog-specific differences varied between moderately low and very low density areas.

To test whether the two dogs differed in the freshness of scats they detected, we fitted a binomial GLMM with a logit link, using individual scat detections (fresh = 1, not fresh = 0) as the response. Each scat detection was treated as a separate observation. Fixed effects were dog and density class. A random intercept for search route was included to account for non-independence among multiple scats detected within the same survey. Survey number and search route length were not included as covariates because search effort was balanced between dogs across survey rounds and density classes, and exploratory analyses indicated that including these terms did not materially change the estimated dog effect. All models were fitted in R using the *lme4* package (Bates et al. 2014).

4 Results

The dog teams completed 123 surveys: 60 in very low density and 63 in moderately low density cells. This equated to 106 km across the four rounds of surveys, with search route length per survey similar between density classes. In very low density cells, search routes averaged 0.88 km (median 0.83 km; range 0.60–1.42 km), and in moderately low density cells they averaged 0.84 km (median 0.80 km; range 0.66–1.22 km). Each cell had four surveys, except for one moderately low density cell, which had three surveys.

There were a total of 403 detections: 59 in the very low density and 349 in the moderately low density area. The number of scat detections differed strongly between density classes. The very low density area had a mean of 3.6 detections within each grid cell (SD = 5.99, range 0–19), whereas the moderately low density area averaged 21.8 detections within each grid cell (SD = 11.7, range 5–50). Over the entire study period possum scat was detected in 9 of the 15 very low density grid cells (60%) and in all 16 moderately low density grid cells (100%). The average number of scats per kilometre was lower in the very low density grid cells (mean = 1, median = 0, SD = 2.1) than in the moderately low density cells (mean = 6.9, median = 6.9, SD = 4.9) (Figure 1).

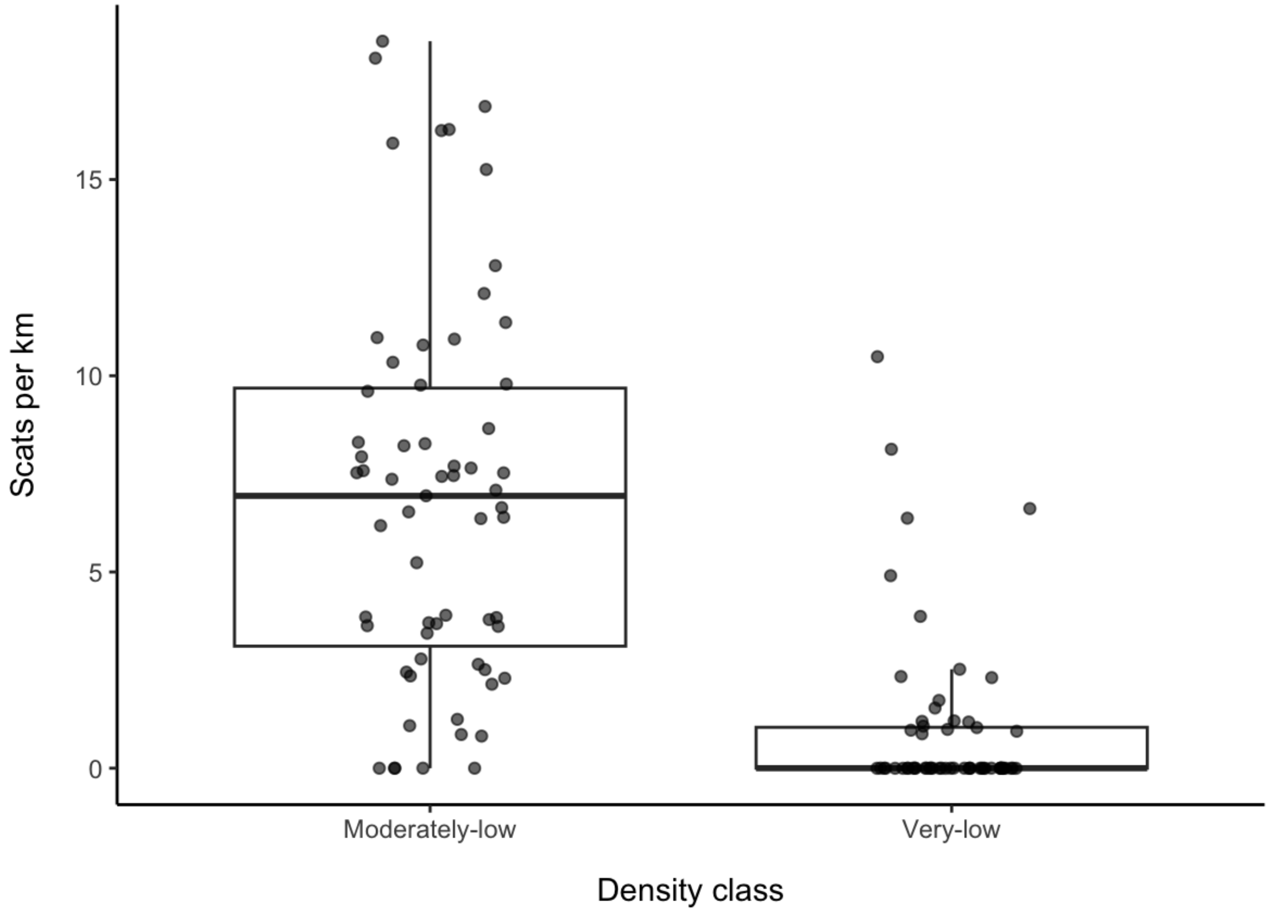

Figure 1. Number of scats encountered per kilometre in moderately low and very low density grid cells. Boxplots show the distribution across surveys, with individual survey values shown as jittered points.

4.1 Detection probabilities

Estimated detection probability for a 1 km survey route differed between density classes (Figure 2). In moderately low density areas the predicted probability of detecting at least one scat on a 1 km search route was 0.99 (95% CI: 0.85–1.00). In very low density areas the probability of detecting at least one scat was 0.28 (95% CI: 0.13–0.55).

In the GLMM, density class had a significant effect on detection probability (β = –2.92 ± 0.82 SE, *P* < 0.001). Neither dog (β = –0.84 ± 0.55 SE, *P* = 0.13) nor survey number (β = –0.06 ± 0.15 SE, *P* = 0.66) had significant effects. The random cell effect (SD = 1.10) indicated moderate spatial variation in detection rates among cells, not explained by the fixed effects (density, dog, survey number).

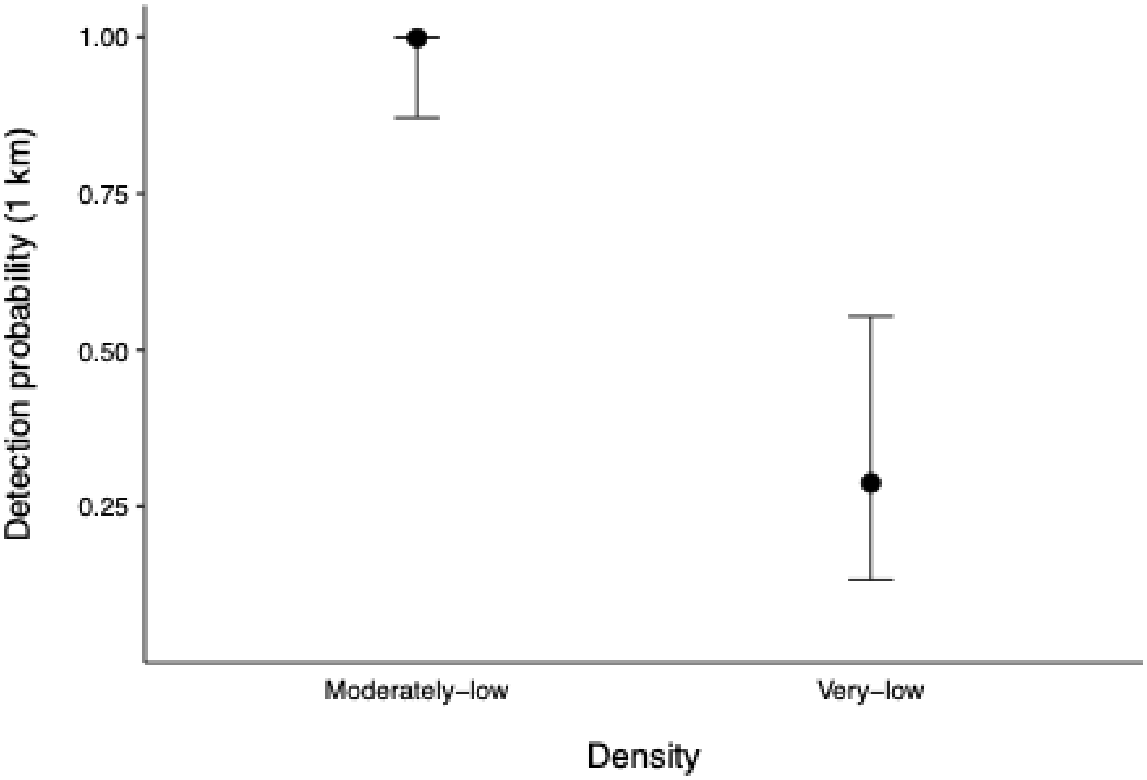

Figure 2. Estimated probability of detecting at least one possum scat on a 1 km search route in moderately low and very low density grid cells, with 95% confidence intervals derived from the binomial GLMM.

Using the estimated detection probabilities, we calculated the survey effort required to achieve 80%, 90%, and 95% probability of detecting at least one possum scat for different search-route lengths (Table 1). In moderately low density areas all detection thresholds were reached with a single survey across the range of survey-route lengths considered (0.6–2.0 km).

In very low density areas substantially more effort was required. Short search routes (<1 km) required more than 10 repeat surveys to reach 95% detection probability. For search routes of 1.5–2 km, three to seven surveys were required depending on the target detection probability (80–95%).

In moderately low density areas the median total search effort was 3.2 km per cell, and possum scat presence was confirmed in every cell. Given the estimated detection probability for a 1 km search route (0.99), a single survey was sufficient to achieve ≥95% detection probability, if possum scat was present. The effort applied in moderately low density areas therefore exceeded that required to achieve high detection probability.

In very low density areas the median total search effort was 3.5 km per cell, and possum scat presence was confirmed in 9 of 15 cells. This level of effort corresponded to an estimated detection probability of 0.69 and did not reach the 80% detection threshold shown in Table 1, given the cumulative search effort applied within each cell. Achieving 95% detection probability would require approximately 10 km of cumulative search effort per cell.

Table 1. Number of survey replicates required to achieve a cumulative detection probability of 80%, 90% or 95% across a range of search-route lengths in moderately low and very low density grid cells

Density	Length (km)	80%	90%	95%
Moderately low	0.6	1	1	1
	0.8	1	1	1
	1	1	1	1
Very low	0.6	9	12	16
	0.8	7	9	12
	1	5	7	10
	1.2	5	6	8
	1.5	4	5	7
	2	3	4	5

Among the six very low density cells with no detections, estimated detection probability ranged from 0.60 to 0.75 (Figure 3), with wide uncertainty (95% CI: 0.34-0.96), reflecting variation in total search effort (kilometres searched per cell). As expected, detection probability increased with effort: the cell with the highest estimated probability (L24) had 4.23 km of search effort, whereas the cell with the lowest (L30) had 2.75 km.

Weather variables (rain intensity, temperature, wind strength and wind direction) showed no relationship with scat encounter rates in exploratory analyses. Variation in scats per kilometre overlapped broadly across all rain and wind categories, and there were no patterns that suggested a meaningful influence of weather on detection rates. Consequently, weather variables were not included in the models. Anecdotal observation indicated that scats were not necessarily destroyed or washed away by rain. During the pilot surveys over 30 scats, including scats recorded as ‘not fresh’ according to our criteria, were detected in 4.9 km of surveys conducted 1 day after heavy rain.

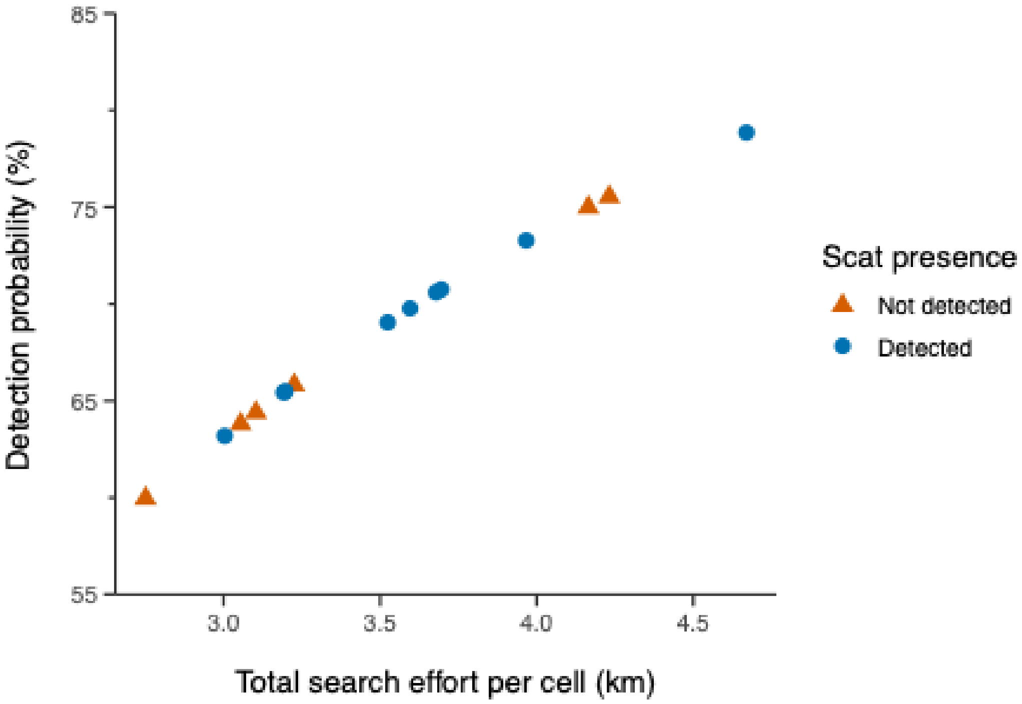

Figure 3. Relationship between cumulative search effort per very low density grid cell and the modelled probability of detecting at least one possum scat. Points indicate cell-level detection probability based on the GLMM; cells with and without scat detections (blue circle = detected, orange triangle = not detected) are shown separately.

4.2 Scat characteristics

Of the 403 scat detections recorded, 399 were classified by freshness and pellet count. Small numbers of pellets (<10) comprised the majority of detections in both classes (>85%). Of the 399 classified detections, 33% were fresh and 67% not fresh.

4.3 Comparison between dogs

Search effort was distributed consistently across survey rounds for both dogs. Beau completed 17–20 surveys per round (23–27% of his total effort in each round), and Peggy completed 11–13 surveys per round (22–26% per round). Search effort by each dog was similar across the different-density cells, although Beau participated in more scat surveys than Peggy (Table 2).

Table 2. Search effort completed by each dog across moderately low and very low density grid cells, showing the number and proportion of search routes surveyed and total kilometres searched within each density class

Dog	Density	Total search routes	Proportion of search routes	Total km
Beau	Moderately low	39	0.53	32.15
Peggy	Moderately low	24	0.48	20.82
Beau	Very low	34	0.47	30.37
Peggy	Very low	26	0.52	22.68

Both dogs detected more scats per kilometre in moderately low density areas than in very low density areas. In very low density areas Beau detected more scats per kilometre than Peggy (Figure 4).

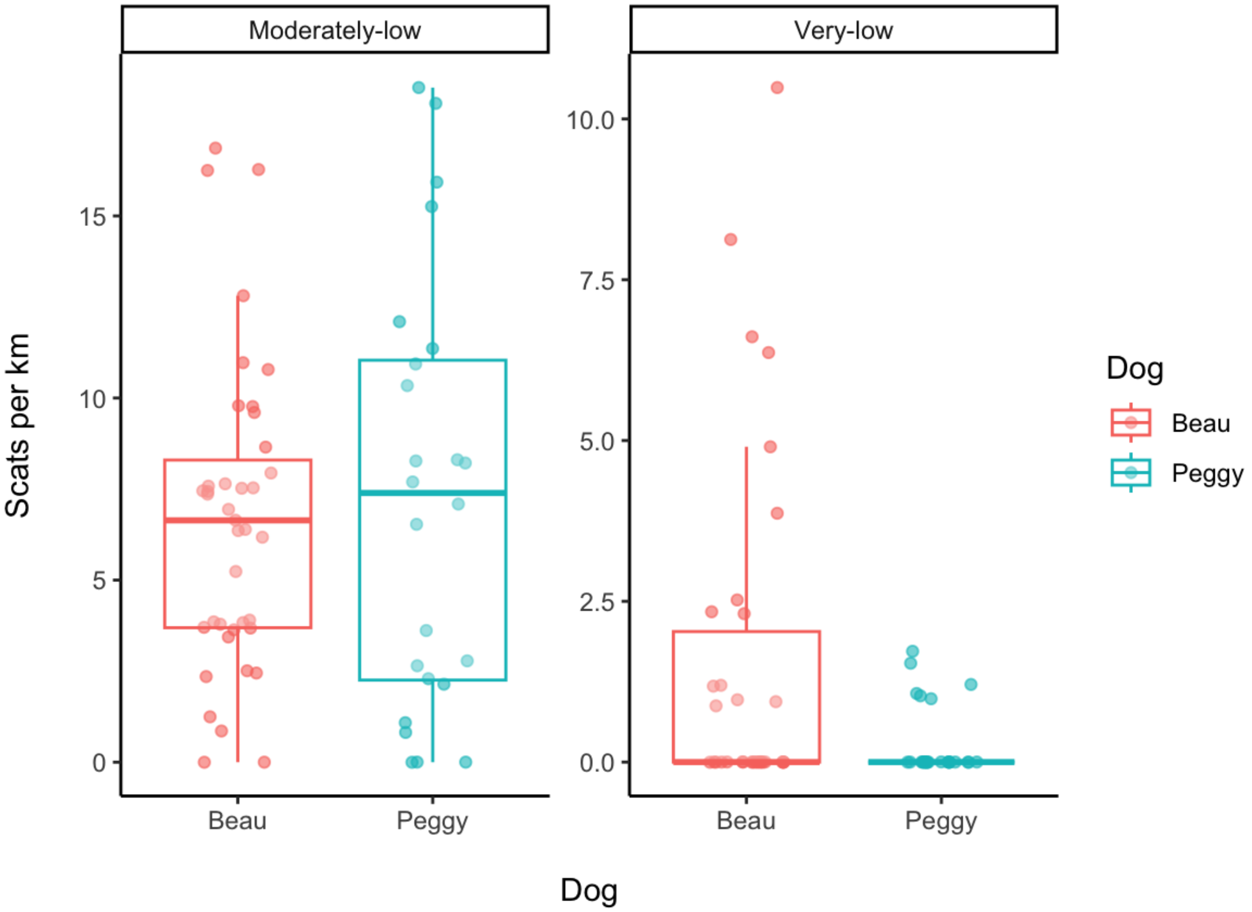

Figure 4. Number of scats per kilometre detected by each dog in moderately low and very low density areas. Boxplots summarise survey-level detection rates, and jittered points show individual surveys.

Peggy's detection rate appeared to decline slightly more than Beau's in very low density areas, although this interaction was not statistically significant (β = –1.26 ± 0.77 SE, *P* = 0.10). Both dogs completed a similar number of surveys with zero detections (Beau *n* = 22, Peggy *n* = 23). However, because Peggy completed fewer surveys overall, zero-detection surveys comprised a higher proportion of her total effort (Beau 30%, Peggy 46%).

Peggy also had a higher proportion of zero-detection surveys in each density class than Beau (moderately low density areas: Peggy 13% vs Beau 5%; very low density areas: Peggy 77% vs Beau 59%). Whether this reflects true absence of scats or differences in dog performance cannot be determined. Only two very low density cells were surveyed by both dogs: Beau completed one survey in each and Peggy completed three. All of these surveys yielded zero detections. These cells therefore provide no basis for direct comparison of dog performance, and are consistent with the low encounter rates observed throughout the very low density area.

Peggy detected a higher proportion of fresh scats (57%; 84/147) than Beau (19%; 48/252). The GLMM indicated a significant relationship between dog and scat freshness ($\beta = 1.81 \pm 0.39$ SE, $z = 4.65$, $P < 0.001$) corresponding to an odds ratio of 6.1. On the probability scale, Beau's predicted probability of detecting fresh scat was 17–20% whereas Peggy's was 55–60%. The inclusion of possum density did not alter this effect, indicating that density did not explain the observed difference.

Peggy detected a higher proportion of fresh scats than Beau in every survey round, and this difference increased over time. Beau's fresh-scat proportions increased from 8% in survey 1 to 23–30% in surveys 3–4, whereas Peggy's increased from 33% in survey 1 to 60% in survey 3 and 78% in survey 4. This pattern closely tracked the overall increase in fresh scat availability and suggests a stronger tendency for Peggy to detect fresh scats.

5 Conclusions

This study showed that detection probability differed strongly between the two study areas classified as moderately low versus very low density. Estimated detection probability per kilometre was very high in moderately low density areas and substantially lower in very low density areas. In moderately low density areas ≥95% detection probability was typically achieved with approximately 1 km of search effort. In very low density areas achieving the same detection probability would require approximately 10 km of cumulative search effort. These results show that short search routes and limited replication are unlikely to achieve high detection probability in very low density contexts. Survey design should scale effort to expected density if high detection probability is required.

Within the range of conditions encountered in this study we found no evidence that weather variables influenced scat detection rates. However, our surveys took place within a narrow range of weather conditions, with moderate temperatures and wind speeds, and limited rainfall. The absence of a detectable effect should therefore be interpreted cautiously. Our results are similar to those of Hassler et al. (2024), who found no effect of weather conditions on detection probability for a detection dog searching for scats of American mink (*Neogale vison*).

Although some differences were apparent between individual dogs, detection probability was primarily influenced by possum density rather than dog identity. The detection probability estimates presented here therefore represent an average operational expectation across dog teams, while recognising that individual dog performance may vary in specific contexts.

Using known numbers of experimentally placed scats, Sweetapple and Peace (2025) estimated detection probabilities of 0.22–0.28 for possum scat detection dogs searching contiguous forest at Māhia Peninsula, Hawke's Bay. Their estimates reflect the recoverability of placed scats from single-pass searches within an effective search swathe, rather than encounter rates of naturally occurring scats accumulated across repeated visits. Despite these and other methodological differences, the similarity in magnitude to our estimated per-kilometre detection probability in very low density cells (0.28) suggests broadly comparable detection performance under low density conditions.

However, because detection probability is conditional on search design, habitat structure, and spatial scale, the two estimates should be interpreted as broadly consistent rather than directly comparable. Whereas the Māhia study was designed to inform landscape-scale proof-of-absence surveys, our study focused on probability of detection within localised management cells in fragmented farmland, where per-kilometre estimates reflect targeted searches through likely possum habitat.

Overall, this work provides an empirically grounded basis for designing possum scat detection dog surveys that explicitly link search effort to desired thresholds of detection probability. The results support the use of cumulative detection frameworks to guide surveillance design, and emphasise the need for realistic expectations of effort in very low density populations.

6 Recommendations

1 Scale survey effort to expected possum density and the desired detection probability.

In moderately low density areas a single search route of approximately 600 m will generally be sufficient to achieve ≥95% detection probability, with shorter search routes requiring an additional replicate. In very low density areas plan for approximately 10 km of cumulative search effort to achieve ≥95% detection probability. In this study effort was accumulated within grid cells, but the same cumulative detection framework can be applied to any survey design that accumulates search effort.

2 Design grid cells and search routes based on possum home-range scale and habitat availability.

Grid cells should be approximately home-range sized, while ensuring that each cell contains enough suitable habitat to support a ≥1 km search route, where possible. Where this is not achievable, smaller cells can be retained to maintain spatial resolution, with higher detection probabilities achieved through additional repeat surveys rather than increasing cell size. Because detection probability accumulates with search effort, equivalent detection probabilities can be achieved through different combinations of search-route length and survey replication.

3 Account for variability among dog-handler teams in low density contexts.

Consider using multiple dog-handler teams or rotating teams among a subset of search areas to reduce reliance on individual search styles or scat-age biases and improve robustness of inference, particularly in very low density areas where detections are infrequent and results may depend strongly on the performance of a single dog team.

4 Use cumulative detection frameworks as the primary planning tool and combine methods when possible.

Apply cumulative detection calculations to determine the minimum combination of search route length and repeat surveys required to meet a target threshold of detection probability. In very low density areas detection probability can be increased by combining scat detection dogs with complementary surveillance methods (e.g. camera traps) deployed strategically within key habitat patches (Gormley et al. 2021).

5 Use decision support tools to scale detection probabilities to broader surveillance objectives if required.

The detection probability estimates reported here can also inform broader decision support tools used for surveillance planning. For example, applications such as JESS (Just Enough Surveillance Sensitivity) (Gormley 2024) can be used to explore how cumulative search effort translates to surveillance sensitivity at larger spatial scales, provided that detection probability is re-estimated or appropriately adjusted for local habitat structure, search design, and management objectives. Sweetapple and Peace (2025) provide an example of this approach for possum scat detection dogs in contiguous forest.

Detection probability may vary (e.g. due to differences in habitat or performance of dog-handler teams), so site-specific pilot surveys should be used to estimate local detection probabilities before applying cumulative detection calculations in new contexts.

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Appendix – Applying the cumulative detection framework: a guide

Our study provides a general framework for estimating the efficiency of scat-detection dogs and the search effort required to confidently infer presence or absence of possums within management units. The analytical workflow is transferable to other landscapes, dog teams, and target species, provided that practitioners collect a short pilot data set to estimate local detection probability. Below, we outline the approach that can be applied elsewhere.

1 Define an ecologically meaningful spatial unit

Select a grid-cell size that reflects the typical home-range scale of the target species. Cell size does not directly influence the detection model, but it determines the spatial resolution at which presence or absence is inferred.

2 Conduct pilot searches to estimate single-search detection probability

Collect search-route-level detection data and model the probability of detecting one or more signs (e.g. scat, track, audio cue) per unit effort using an appropriate GLMM or occupancy-style model. This provides the per-kilometre (or per-survey) detection probability, p_1, that forms the basis for cumulative detection calculations.

3 Scale detection probability to search effort using the MacArdle–Reed framework

Convert the single-search detection probability (p_1) into a cumulative detection probability using:

$$P(N, L) = 1 - (1 - p_1)^{N \cdot L_{km}}$$

to predict the probability of detecting the target species for any combination of search route length and number of search replicates.

4 Determine the search effort required to infer absence with high confidence

Use the cumulative detection equation (step 3) to determine the minimum combination of search length and number of replicates required to reach management-relevant confidence levels (e.g. 80%, 90%, 95%). This step supports search design by showing how much effort is needed to reliably detect possums under different density scenarios.

5 Evaluate presence/absence confidence at the cell level

Combine the actual search effort applied within each cell (total kilometres searched across all search routes) with the per-kilometre detection probability to calculate cell-specific detection confidence. This translates search-route-level detection into cell-level inference, enabling practitioners to judge whether the existing effort was sufficient to confirm presence or to meet absence thresholds.

6 Apply decision thresholds for inferring presence or absence

Use the cell-specific cumulative detection confidence (step 5) to assign presence or absence at the grid-cell scale. Presence is confirmed whenever scat or other sign is detected. Absence should only be inferred when cumulative detection confidence exceeds a predefined management threshold (e.g. 80% or 95%), recognising that higher thresholds require substantially more search effort. Selecting an appropriate confidence level depends on management goals, tolerance for missed individuals, and operational feasibility.

7 Use the framework to guide surveillance at new sites

Once a site-specific estimate of the per-kilometre detection probability (p_1) has been obtained, the same workflow can be used to support surveillance planning. Specifically, the cumulative detection framework allows practitioners to:

- determine how many surveys are required to reach a chosen confidence threshold for inferring absence
- optimise search effort to maximise the probability of detection
- standardise and compare dog-team performance across habitats or operational settings
- prioritise management areas using confidence-based metrics rather than raw detection counts.