Manaaki Whenua
Landcare Research

Power analysis for biodiversity monitoring in Cape to City

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Power analysis for biodiversity monitoring in Cape to City

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Summary

Project and client

- Manaaki Whenua – Landcare Research was commissioned by Hawke’s Bay Regional Council (HBRC) to conduct a power analysis to assist with the design of their lizard and invertebrate monitoring in the Cape to City area.

Objectives

- To conduct a power analysis to assess whether the current biodiversity monitoring programme in the Cape to City area can confidently detect changes in the abundance and/or occurrence of the various animal groups monitored.
- To assess the power to detect such changes under scenarios of increased sampling effort.

Methods

- We used artificial cover object (ACO), wētā house and tracking tunnel data collected during spring and summer from 2015 to 2019 within the Cape to City footprint, and in an adjacent non-treatment area (with no predator control).
- Using these data, we conducted a power analysis to determine the magnitude of change in the abundance and/or occurrence of different animal groups that can be confidently detected with the current monitoring design.
- For those groups for which there is currently insufficient statistical power to confidently detect the magnitudes of change simulated, we assessed the statistical power of an extended monitoring design, which included either increasing the number of years monitored, the number of lines monitored, or both.

Results

- There is currently enough power to detect small changes (≥20%) in the probability of occurrence of all invertebrates combined using ACOs, and to detect medium changes (≥60%) in their abundance using wētā houses. There is also sufficient power to detect medium changes (≥40%) in the probability of occurrence of invertebrates excluding spiders and wētā using wētā houses. The current sampling does not provide sufficient power to detect any of the changes assessed in the probability of occurrence or abundance of wētā, spiders or geckos.
- If monitoring continues for 1 more year, the current design would have sufficient power to detect medium changes (≥40%) in spider abundance using wētā houses.
- Increasing the number of lines monitored using wētā houses from 44 to 100, and monitoring for 3 years or more, would allow for large changes (≥100%) in the probability of occurrence of wētā using wētā houses to be confidently detected.
- If monitoring continues for 3 more years, the current design would have sufficient power to detect medium changes (≥60%) in the probability of occurrence of geckos using tracking tunnels. None of the extended designs simulated would confidently detect changes of the magnitude assessed in the abundance of geckos.
- A brief summary of the results is presented in Table S1.

Table S1. A brief summary of the results of power analyses by target group, monitoring method and measure of abundance. ES = effect size, N = abundance, O = occupancy. A thumbs-up indicates that the threshold of 80% power to detect a given effect size can be achieved either with the current monitoring design or with one of the extended designs we simulated. A thumbs-down indicates that the threshold of 80% power cannot be achieved with any of the extended monitoring designs we simulated. A dash indicates that such an analysis was not performed, whereas NA indicates that the analysis is not appropriate (e.g. geckos do not use wētā houses)

Group	ACOs		Wētā houses		Tunnels
	N	O	N	O	O
Geckos	👎	👎	NA	NA	👍 60% ES with ≥6 years
All invertebrates combined	NA	👍 20% ES with current design	👍 60% ES with current design 40% ES with 100 lines & ≥4 years	–	NA
Wētā	NA	NA	👍 100% ES with 100 lines & ≥6 years	👍 100% ES with 100 lines & ≥3 years	NA
Spiders	NA	NA	👍 40% ES with ≥4 years	–	NA
Other invertebrates	NA	NA	👍 100% ES with 100 lines & ≥3 years	👍 40% ES with current design	NA

Recommendations

- Although small changes (≤20%) in abundance cannot be confidently detected, the use of multiple types of devices and measures of abundance ensure that at least one method provides sufficient power to confidently detect medium to large changes for each group of interest.
- We recommend that HBRC continue monitoring biodiversity assets in Cape to City for a minimum of 6 years using the current sample of lines.
- If more resources become available, we would recommend that the number of lines be increased from 44 to 100 for wētā houses. These additional wētā houses could be installed along existing lines that currently have ACOs (85 lines) or tracking tunnels (125 lines).
- We recommend that ACOs be discontinued as these have low power to detect changes in lizard abundance. The savings made by ceasing ACO monitoring could be put towards increasing the number of wētā houses.

1 Introduction

The Cape to City initiative involves controlling invasive predators in a rural/peri-urban landscape spanning a large area between Cape Sanctuary and Hastings. A principal aim is to restore native biodiversity. Predator control is being conducted by Hawke's Bay Regional Council (HBRC). The response of native birds is being monitored by an ecological consultant (J. McLennan), while monitoring of native lizards and invertebrates is being conducted by Manaaki Whenua – Landcare Research.

Given the aim of restoring native biodiversity, HBRC wants to determine whether the current biodiversity sampling effort can confidently detect changes in the occurrence and/or abundance of the animal groups monitored.

2 Objectives

- To conduct a power analysis to assess whether the current biodiversity monitoring programme in the Cape to City area can confidently detect changes in the abundance and/or occurrence of the various animal groups monitored.
- To assess the power to detect such changes under scenarios of increased sampling effort.

3 Background

Predator control was rolled out sequentially over the 26,000 ha of the Cape to City initiative in 2016 and 2017. To assess biodiversity responses to the reduction in predator abundance, biodiversity monitoring lines were established between November 2015 and January 2016. Lines were established both within the Cape to City area and in an adjacent non-treatment area (with no predator control) for comparison (Figure 1). The monitoring lines consisted of the following devices for detecting wildlife:

- tracking tunnels for lizards and invertebrates
- tree wraps (Bell 2009) for arboreal lizards
- artificial cover objects (ACOs) for terrestrial lizards
- frass funnels (Sweetapple & Barron 2016) for tree canopy invertebrates
- wētā houses for other arboreal invertebrates

Most monitoring lines included two or more types of monitoring device, with five devices of each type per monitoring line. A detailed description of the placement and number of monitoring devices per line can be found in Norbury & McLennan 2015. All monitoring lines were checked for the first time in summer 2015/16 in order to sample native biodiversity in the treatment and non-treatment areas before predator control began, and then every subsequent spring and summer.

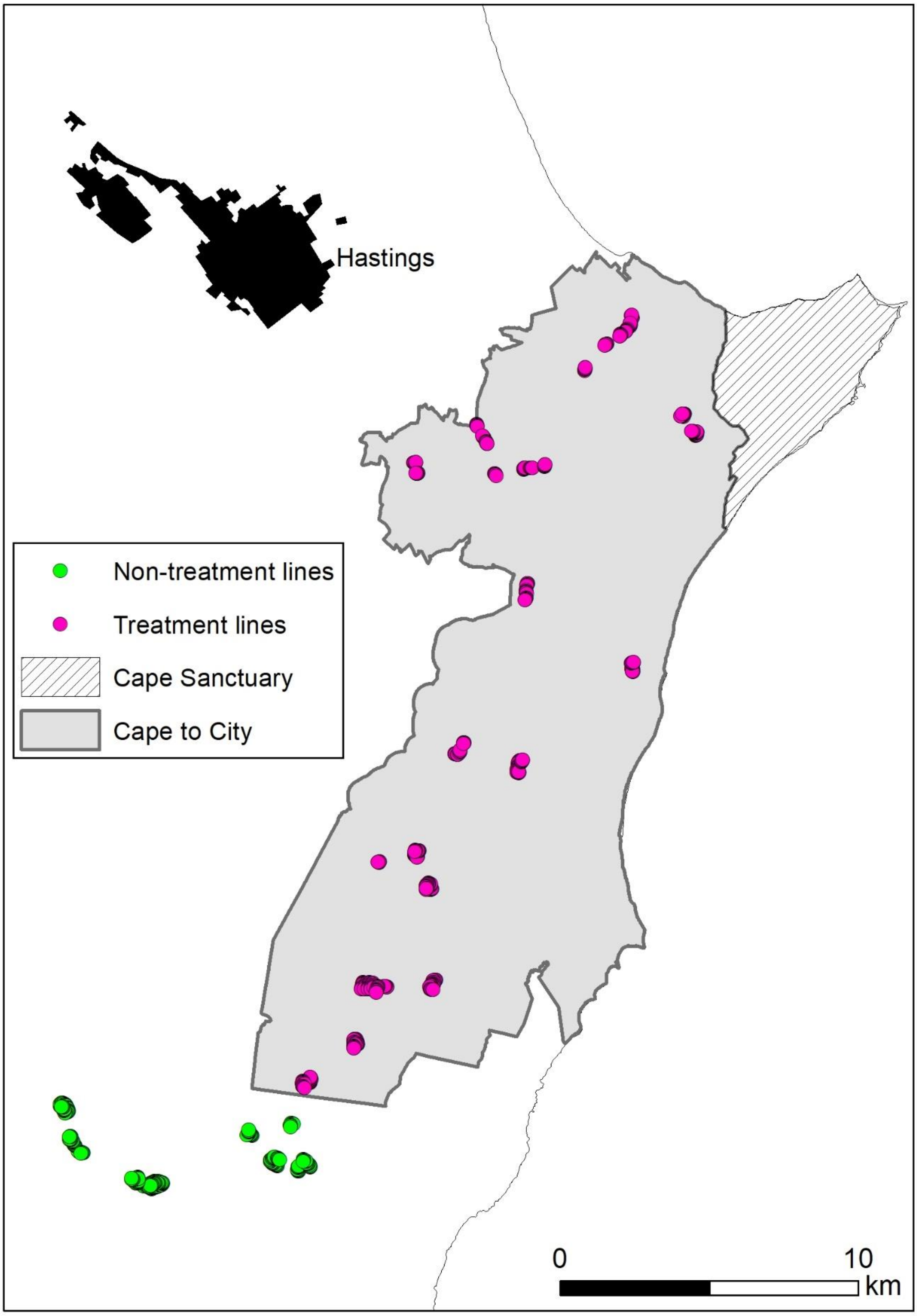

Figure 1. Map showing the locations of monitoring lines used by Manaaki Whenua – Landcare Research in the Cape to City Area.

4 Methods

We analysed three data sets separately: ACOs, wētā houses, and tracking tunnels. Each data set had been collected over 3 years (2015–2018) and two seasons (spring and summer) in the treatment and non-treatment areas.

Statistical power is the ability of an analysis to detect a significant difference between groups, when one is present. Its calculation depends on three interrelated components: (i) sample size, (ii) the chance of incorrectly concluding there is an effect when there isn't one (called α) and (iii) effect size. For each data set, statistical power was first determined for four effect sizes under the current sampling design (i.e. current sample size for each monitoring device type). For ACOs and wētā houses, the effect size was an increase of 20%, 40%, 60% or 100% in the mean abundance, or in the probability of occurrence, of each animal group in the treatment area compared with the non-treatment area. The animal groups were geckos, wētā, spiders, other invertebrates (any invertebrates not including wētā or spiders), and all invertebrates (wētā + spiders + other invertebrates). We set $\alpha = 0.05$ in all analyses.

Each group was analysed separately. For tracking tunnels, the effect size was an increase of 20%, 40%, 60% or 100% in the probability of occurrence of geckos in the treatment area compared with the non-treatment area. We specified a Poisson family for analyses involving mean abundance, and a binomial family for analyses involving presence/absence data (i.e. to estimate probability of occurrence). Skink abundance (from ACOs) or occurrence (from tracking tunnels) was not analysed because of the paucity of data.

Power was then estimated for an increase in the number of years monitored (currently 3 years) or the number of lines (currently 85 lines in total for ACOs, 44 lines for wētā houses, and 125 lines for tracking tunnels). If power under those scenarios was still insufficient, an increase in both the number of years and lines was also trialled.

Power analyses were conducted using the package simr (Green & MacLeod 2016) in R version 3.5.1 (R Core Team 2018). In all analyses, the nested nature of the data (devices nested within lines, and repeated measures conducted on the same lines over the years) was modelled by including appropriate random effects in the regression models used to describe the temporal and treatment trends, as suggested by Green and MacLeod (2016). For all device types and target groups we assessed the power of the full nested design (devices within lines); however, in some cases power was very low because of the overabundance of zero values. In those cases, we assessed power for a sampling design where devices were pooled within each line.

In the results section, for all device types and target groups, we first present whether a significant difference between treatments has been detected in the dependent variable (*in red italics*), and if so, we report the effect size that was detected with the current sampling design. We do this because a non-significant difference between treatments could arise from (1) a real lack of difference between treatments, or (2) a sample size too small to detect the desired effect size. We then present the results of power analyses to be able to differentiate these two possibilities.

5 Results

5.1 ACOs

5.1.1 Gecko abundance, pooling devices within lines (pooled data)

Currently there is no significant difference between treatments.

There is currently insufficient power to detect any of the differences assessed in the mean abundance of geckos between treatment and non-treatment using the ACO data. Neither increasing the number of lines, nor the number of years, nor both achieves the typically accepted threshold of 80% power (Figure 2).

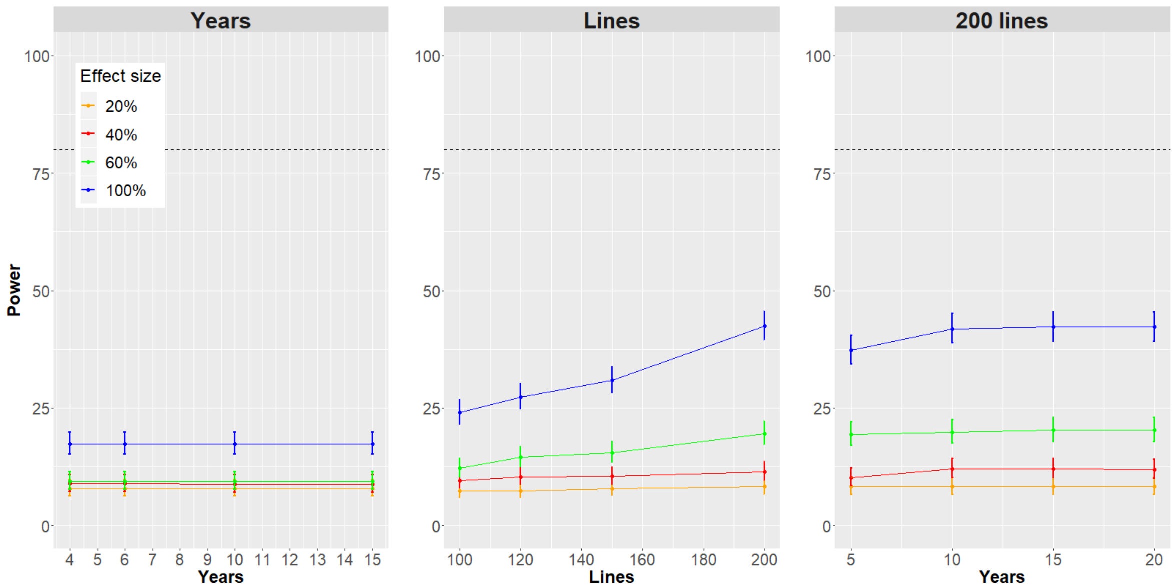

Figure 2. Power (with 95% confidence intervals) to estimate changes in gecko abundance using ACOs. Power estimates were calculated to detect increases of 20%, 40%, 60% and 100% in the mean abundance of geckos by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (100–200) or the number of years surveyed (5–20) on 200 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.1.2 Gecko presence/absence, accounting for devices within lines (unpooled data)

Currently there is no significant difference between treatments.

There is currently insufficient power to detect any of the differences assessed in the probability of occurrence of geckos between treatment and non-treatment using the ACO data. Neither increasing the number of lines, nor the number of years, nor both achieves the typically accepted threshold of 80% power.

5.1.3 Gecko presence/absence, pooling devices within lines (pooled data)

Currently there is no significant difference between treatments.

There is currently insufficient power to detect any of the differences assessed in the probability of occurrence of geckos between treatment and non-treatment using the ACO data (Figure 3). Neither increasing the number of lines, nor the number of years, nor both achieves the typically accepted threshold of 80% power.

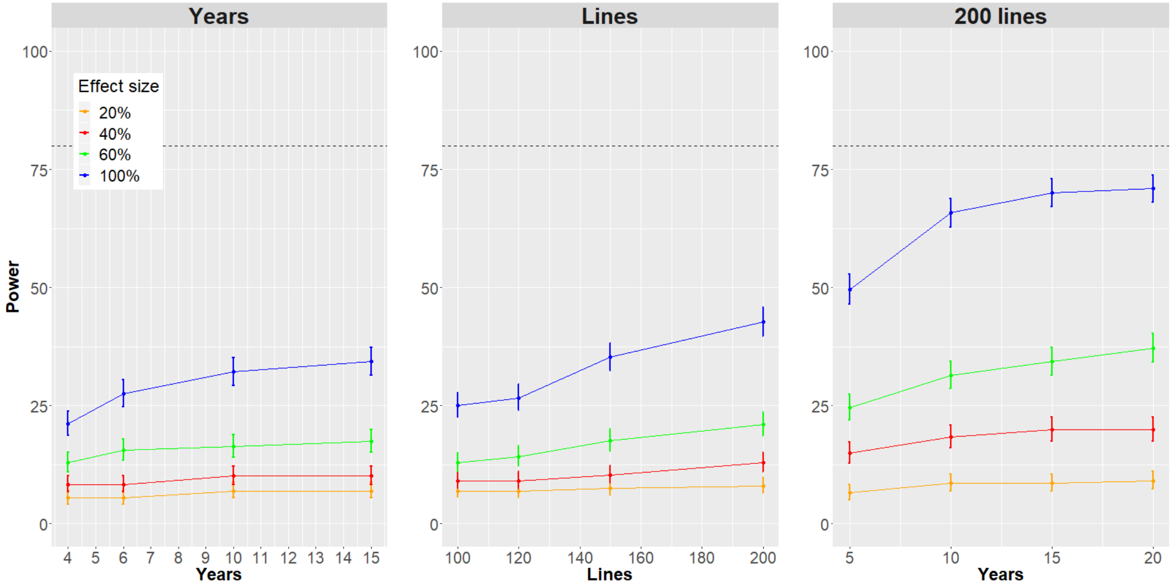

Figure 3. Power (with 95% confidence intervals) to estimate changes in the probability of occurrence of geckos using ACOs. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the probability of occurrence of geckos by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (100–200) or the number of years surveyed (5–20) on 200 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.1.4 Invertebrates presence/absence, accounting for devices within lines (unpooled data)

Currently there is no significant difference between treatments.

With the current design there is sufficient power to detect increases of ≥100% in the probability of occurrence of invertebrates in the treatment compared to non-treatment sites. Increasing the number of monitoring lines from 85 to 110 would allow for increases of ≥60% to be confidently detected (Figure 4). If the number of lines is increased to 200, then increases of 40% in the probability of occurrence of invertebrates could be detected at a slightly smaller confidence level (76% power)

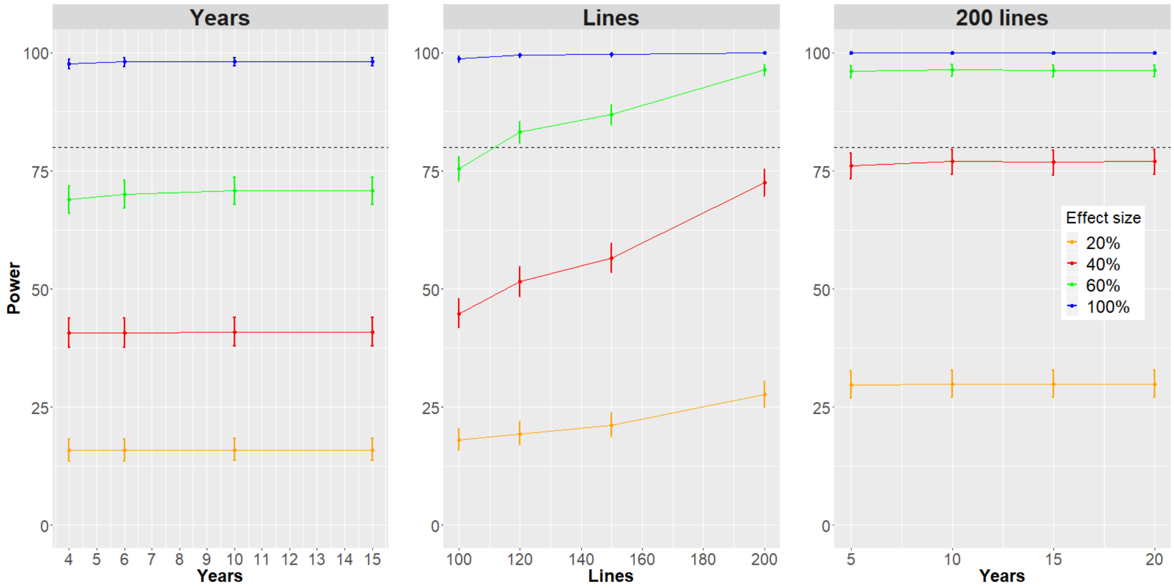

Figure 4. Power (with 95% confidence intervals) to estimate changes in the probability of occurrence of invertebrates using ACOs. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the probability of occurrence of invertebrates by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (100–200) or the number of years surveyed (5–20) on 200 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.1.5 Invertebrates presence/absence, pooling devices within lines (pooled data)

Currently there is a significant difference between treatments, with a lower probability of occurrence of invertebrates in treatment compared to non-treatment during spring (30% difference) and summer (15% difference).

The current design provides sufficient power to detect increases of ≥20% in the probability of occurrence of invertebrates in treatment compared to non-treatment sites using ACOs.

5.2 Wētā houses

5.2.1 Wētā abundance, accounting for devices within lines (unpooled data)

There is currently a significant difference between treatments, with an effect size of 188% higher abundance in treatment compared to non-treatment.

However, the current design has low power (<30%) to detect changes of smaller magnitude (≤100%).

5.2.2 Wētā abundance, pooling devices within lines (pooled data)

There is currently a significant difference between treatments, with an effect size of 197% higher wētā abundance in treatment compared to non-treatment.

There is currently insufficient power to detect any of the differences assessed in the mean abundance of wētā between treatment and non-treatment sites using the wētā house data. Increasing the number of lines from 44 to 100 and monitoring for ≥6 years would allow for the largest change (100% difference between treatment and non-treatment sites) to be confidently detected (Figure 5).

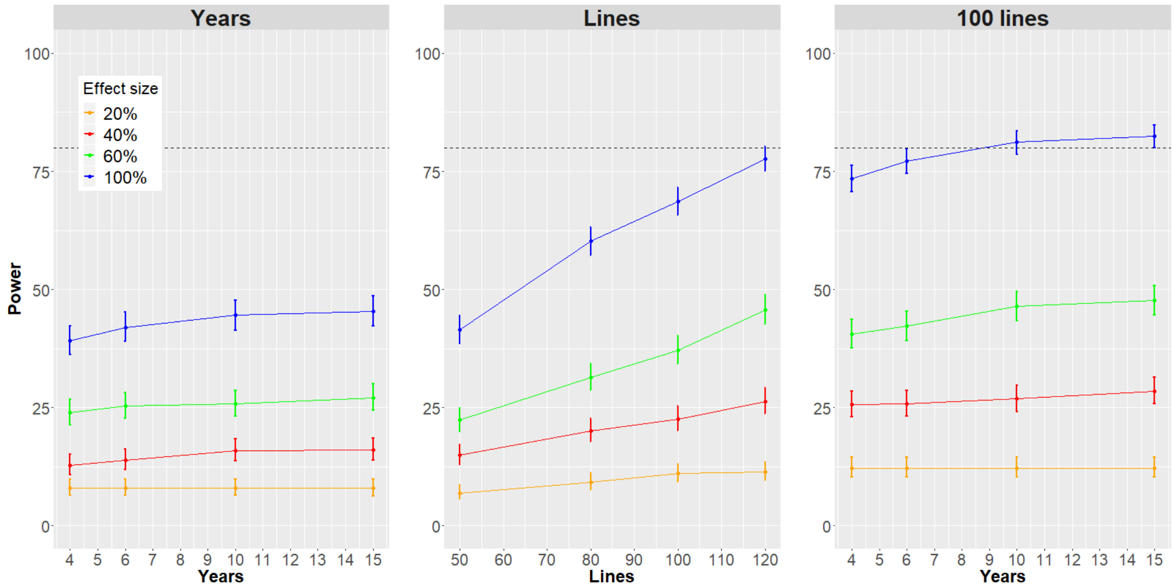

Figure 5. Power (with 95% confidence intervals) to estimate changes in the mean abundance of wētā using wētā houses. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the mean abundance of wētā by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (50–120) or the number of years surveyed (4–15) on 100 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.2.3 Wētā presence/absence, accounting for devices within lines (unpooled data)

There is currently a significant difference between treatments: the current effect size is 198% higher probability of occurrence of wētā in treatment compared to non-treatment sites.

The current design has low power (<10%) to detect increases of ≤100% in the probability of occurrence of wētā in treatment compared to non-treatment sites. Neither increasing the number of lines, nor the number of years, nor both achieves the typically accepted threshold of 80% power (Figure 6).

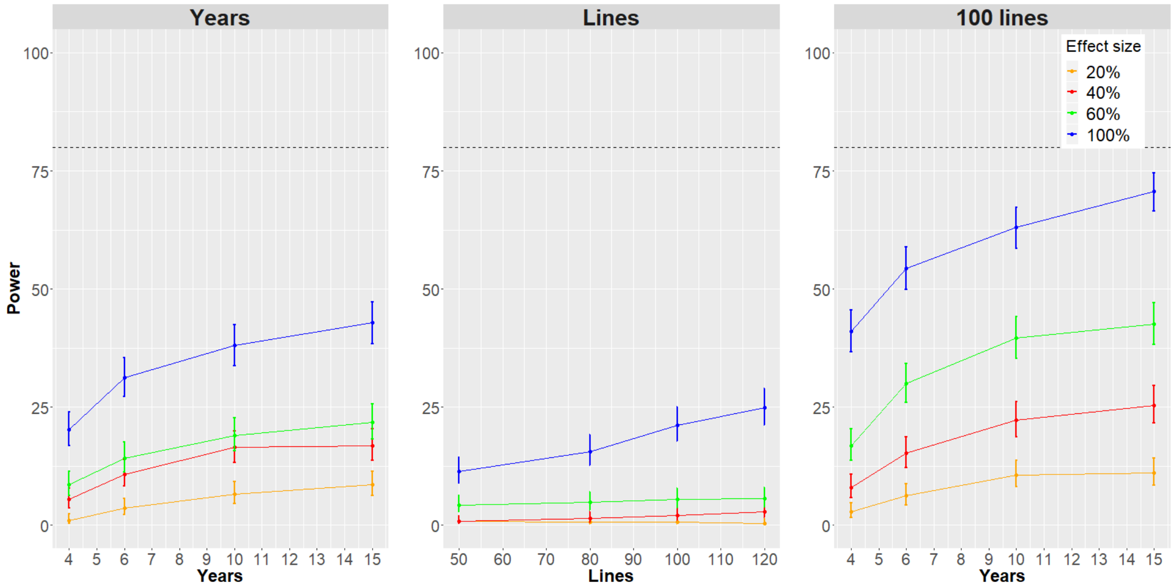

Figure 6. Power (with 95% confidence intervals) to estimate changes in the probability of occurrence of wētā using unpooled data from wētā houses. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the probability of occurrence of wētā by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (50–120) or the number of years surveyed (4–15) on 100 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.2.4 Wētā presence/absence, pooling devices within lines (pooled data)

There is currently a non-significant difference between treatments: the current effect size is 87% higher probability of occurrence of wētā in treatment compared to non-treatment sites.

Increasing the number of lines from 44 to 100 would allow for the largest change (100% difference between treatment and non-treatment) to be confidently detected (Figure 7).

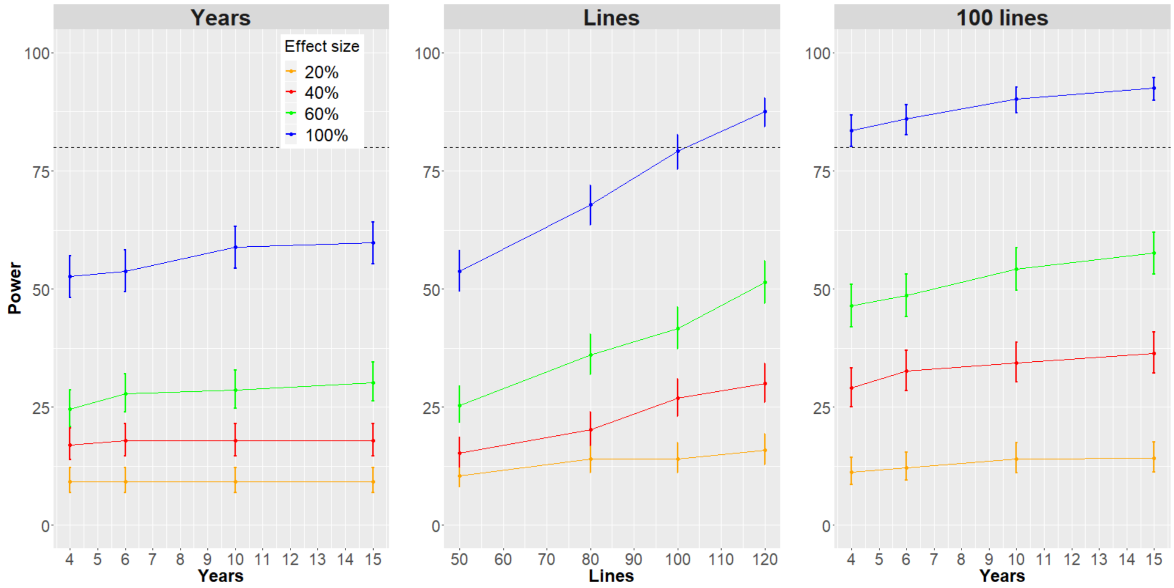

Figure 7. Power (with 95% confidence intervals) to estimate changes in the probability of occurrence of wētā using pooled data from wētā houses. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the probability of occurrence of wētā by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (50–120) or the number of years surveyed (4–15) on 100 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.2.5 Spider abundance, accounting for devices within lines (unpooled data)

There is currently a non-significant difference between treatments: the current effect size is 25% lower abundance in treatment compared to non-treatment sites.

The current design has low power (<33%) to detect increases of ≤100% in the abundance of spiders in treatment compared to non-treatment sites.

5.2.6 Spider abundance, pooling devices within lines (pooled data)

There is currently a non-significant difference between treatments: the current non-significant effect size is 23% lower abundance in treatment compared to non-treatment sites.

The current design provides sufficient power to detect increases of ≥40% in the mean abundance of spiders in treatment compared to non-treatment sites, provided monitoring continues for 1 more year (Figure 8).

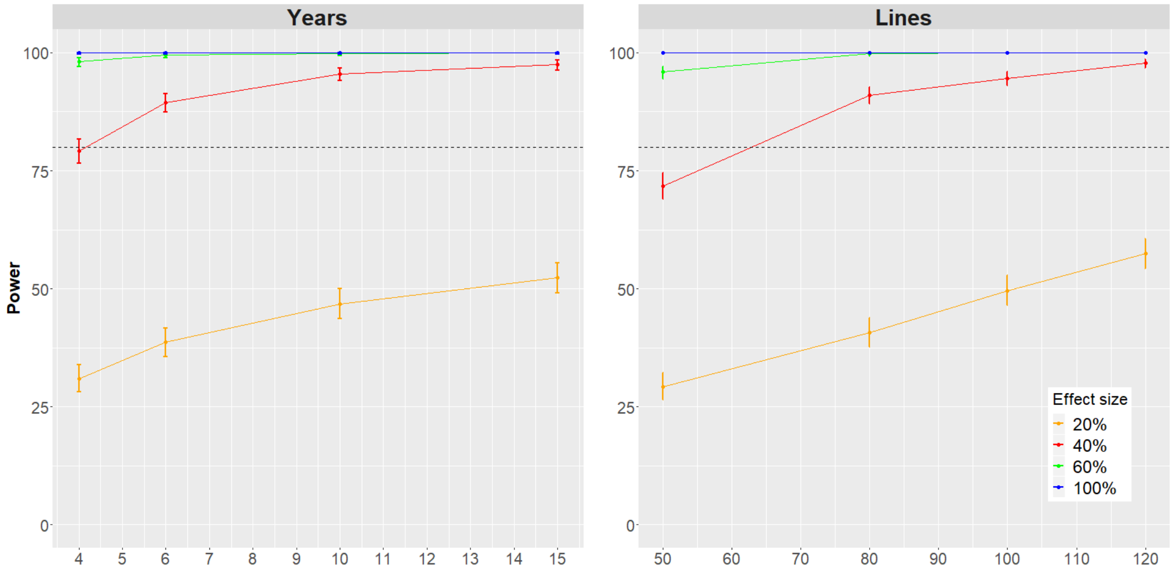

Figure 8. Power (with 95% confidence intervals) to estimate changes in the mean abundance of spiders using data from wētā houses. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the mean abundance of spiders by simulating changes in the number of years surveyed (4–15) and the number of lines surveyed (50–120). The dashed line indicates the minimum target of 80% power to detect a given change.

5.2.7 Other invertebrates' abundance, accounting for devices within lines (unpooled data)

There is currently a significant difference between treatments, with an effect size of 122% higher abundance in treatment compared to non-treatment sites.

The current design has low power (<20%) to detect increases of ≤100% in the abundance of other invertebrates in treatment compared to non-treatment sites.

5.2.8 Other invertebrates' abundance, pooling devices within lines (pooled data)

There is currently a significant difference between treatments, with an effect size of 215% higher abundance in treatment compared to non-treatment sites.

There is currently insufficient power to detect any of the differences assessed in the mean abundance of other invertebrates between treatment and non-treatment sites using the wētā house data. Increasing the number of lines from 44 to 100 and monitoring for ≥4 years would allow for the largest change (100% difference between treatment and non-treatment sites) to be confidently detected (Figure 9).

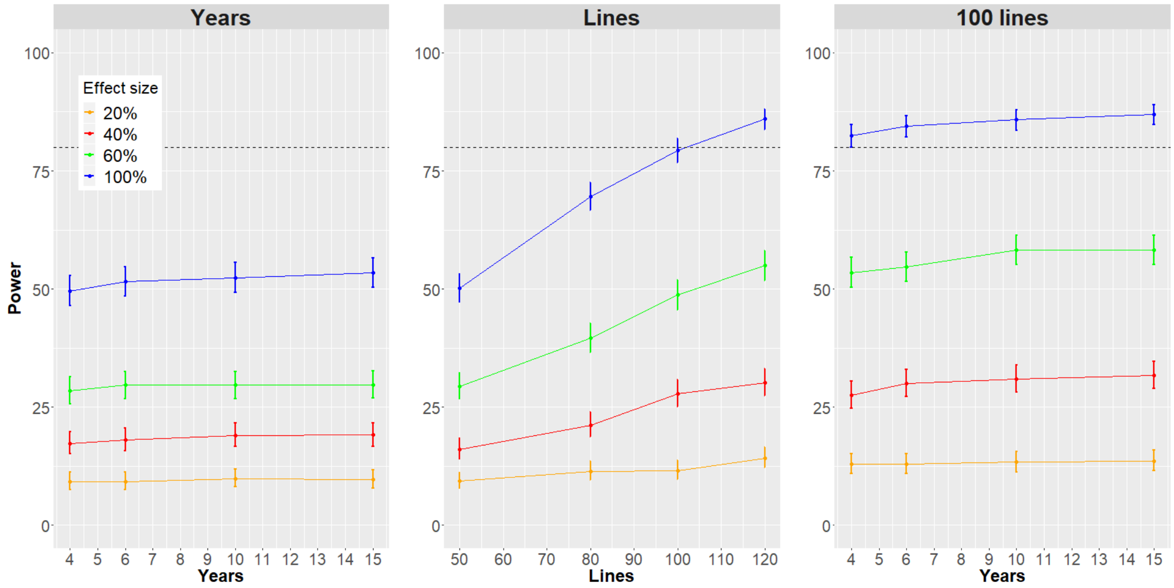

Figure 9. Power (with 95% confidence intervals) to estimate changes in the mean abundance of other invertebrates using pooled data from wētā houses. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the mean abundance of other invertebrates by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (50–120), or the number of years surveyed (4–15) on 100 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.2.9 Other invertebrates' presence/absence, accounting for devices within lines (unpooled data)

There is currently a significant difference between treatments, with an effect size of 85% higher probability of occurrence in treatment compared to non-treatment sites.

Based on our simulations, the current design has sufficient power to detect increases of ≥100% in the probability of occurrence of other invertebrates in treatment compared to non-treatment sites (Figure 10). Increasing the sample size from 44 to 100 lines would allow for increases of ≥60% to be confidently detected.

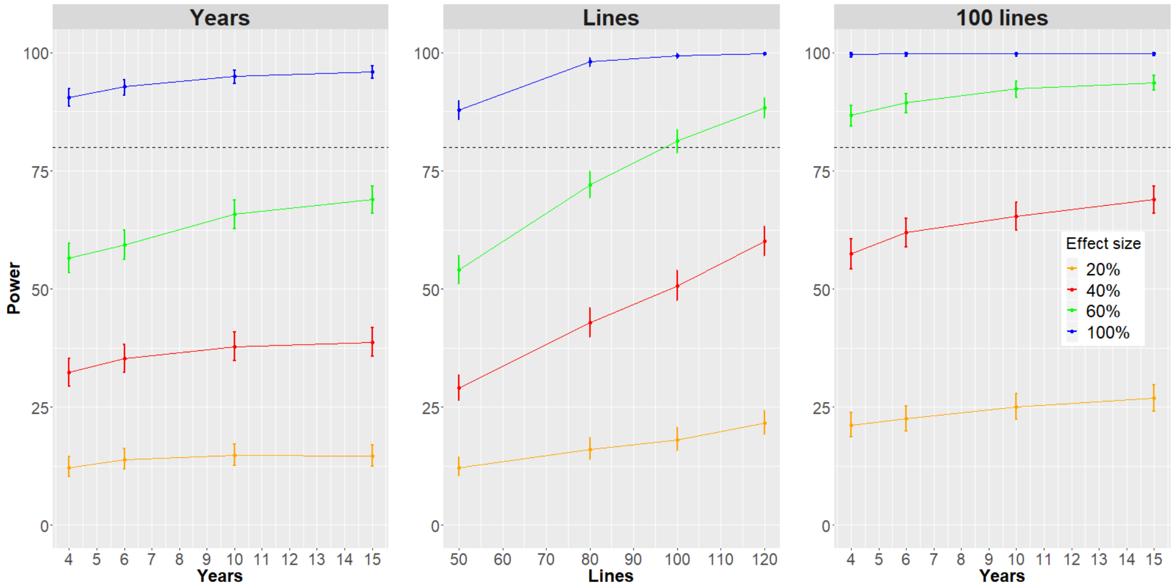

Figure 10. Power (with 95% confidence intervals) to estimate changes in the probability of occurrence of other invertebrates using unpooled data from wētā houses. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the probability of occurrence of other invertebrates by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (50–120), or the number of years surveyed (4–15) on 100 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.2.10 Other invertebrates' presence/absence, pooling devices within lines (pooled data)

There is currently a non-significant difference between treatments, with an effect size of 25% higher probability of occurrence in treatment compared to non-treatment sites.

Based on our simulations, the current design has sufficient power to detect increases of ≥40% in the probability of occurrence of other invertebrates in treatment compared to non-treatment sites. Increasing the sample size from 44 to 100 lines would allow for increases of 20% to be confidently detected so long as monitoring is conducted for a total of 6 years (Figure 11).

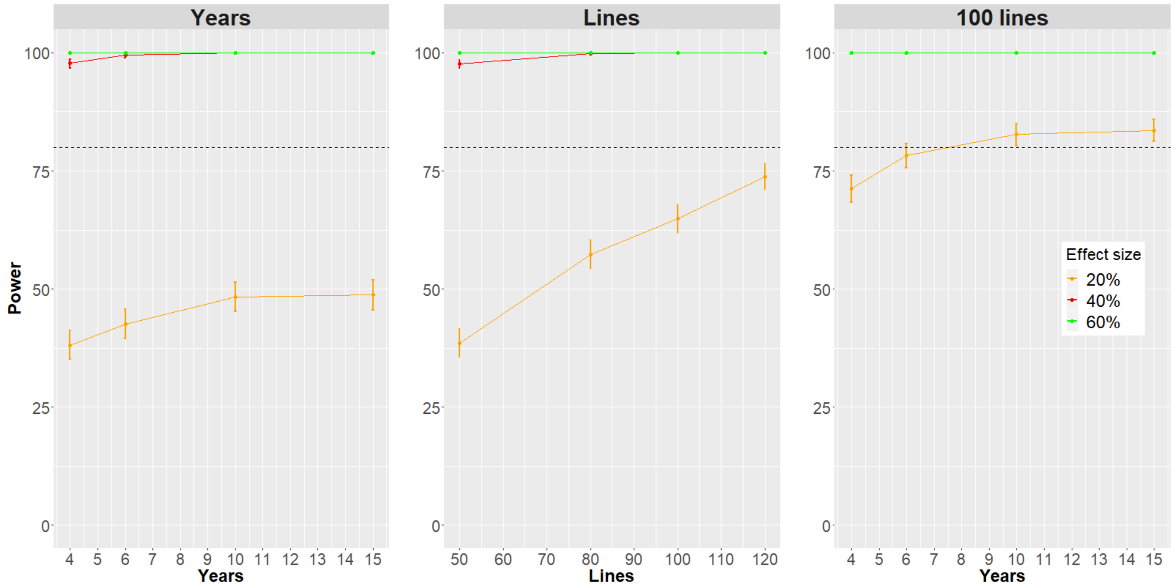

Figure 11. Power (with 95% confidence intervals) to estimate changes in the probability of occurrence of other invertebrates using pooled data from wētā houses. Power estimates were calculated to detect increases of 20%, 40%, and 60% in the probability of occurrence of other invertebrates by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (50–120), or the number of years surveyed (4–15) on 100 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.2.11 All invertebrates' abundance (wētā, spiders, other invertebrates), accounting for devices within lines (unpooled data)

There is currently a significant difference between treatments, with an effect size of 98% higher abundance in treatment compared to non-treatment sites.

Based on our simulations, the current design has sufficient power to detect increases of ≥60% in the abundance of all invertebrates in treatment compared to non-treatment sites. Increasing the sample size from 44 to 100 lines would allow for increases of ≥40% to be confidently detected (Figure 12).

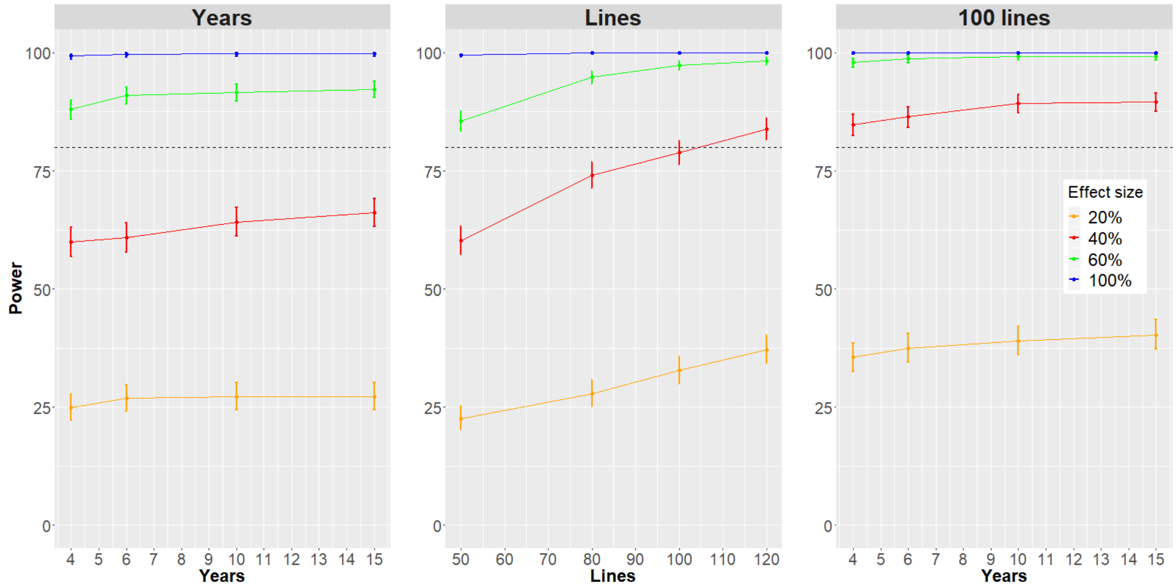

Figure 12. Power (with 95% confidence intervals) to estimate changes in the mean abundance of all invertebrates using unpooled data from wētā houses. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the mean abundance of all invertebrates by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (50–120), or the number of years surveyed (4–15) on 100 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.2.12 All invertebrates' abundance (wētā, spiders, other invertebrates), pooling devices within lines (pooled data)

There is currently a significant difference between treatments, with an effect size of 85% higher abundance in treatment compared to non-treatment sites.

Based on our simulations, the current design has sufficient power to detect increases of ≥100% in the abundance of all invertebrates in treatment compared to non-treatment sites. Increasing the sample size from 44 to 100 lines would allow for increases of ≥40% to be confidently detected so long as monitoring is conducted for a total of 4 years (Figure 13).

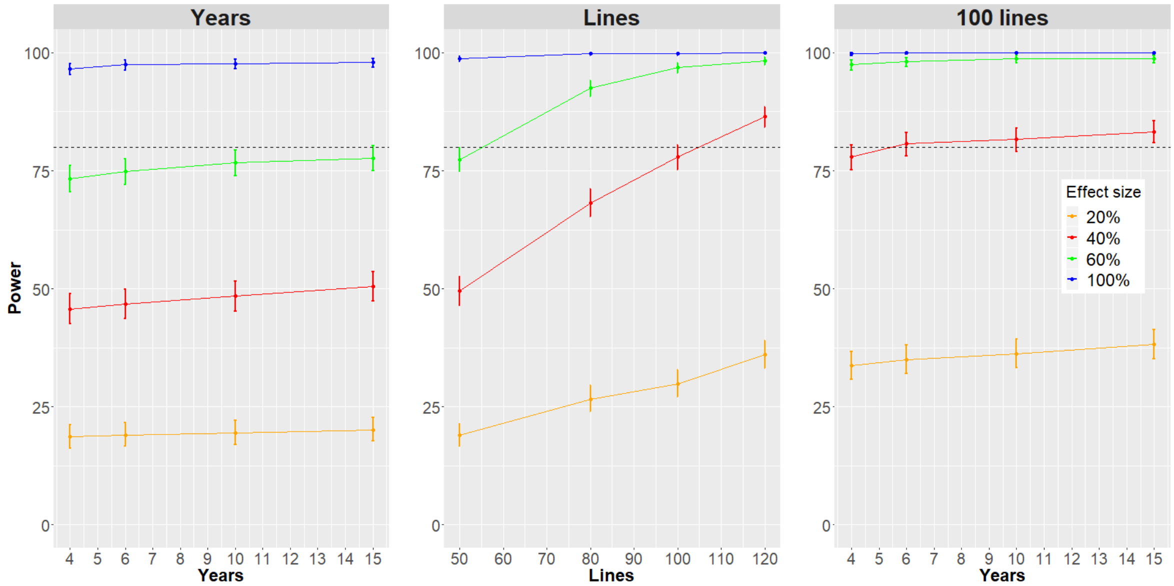

Figure 13. Power (with 95% confidence intervals) to estimate changes in the mean abundance of all invertebrates using pooled data from wētā houses. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the mean abundance of all invertebrates by simulating changes in the number of years surveyed (4–15), the number of lines surveyed (50–120), or the number of years surveyed (4–15) on 100 lines. The dashed line indicates the minimum target of 80% power to detect a given change.

5.3 Tracking tunnels

5.3.1 Gecko presence/absence, accounting for devices within lines (unpooled data)

There is currently a marginally significant (P = 0.07) difference between treatments, with an effect size of 363% higher probability of gecko occurrence in treatment compared to non-treatment sites.

The current design has low power (<10%) to detect increases of ≤100% in the probability of occurrence of geckos in treatment compared to non-treatment sites.

5.3.2 Gecko presence/absence, pooling devices within lines (pooled data)

There is currently a significant difference between treatments, with an effect size of 200% higher probability of gecko occurrence in treatment compared to non-treatment sites.

The current design has low power (<30%) to detect increases ≤100% in the probability of occurrence of geckos in treatment compared to non-treatment sites. However, the current design provides sufficient power to detect increases of ≥100% provided monitoring continues for 1 more year (Figure 14), and even increases of ≥60% if monitoring continues for 3 more years (for a total of 6 years).

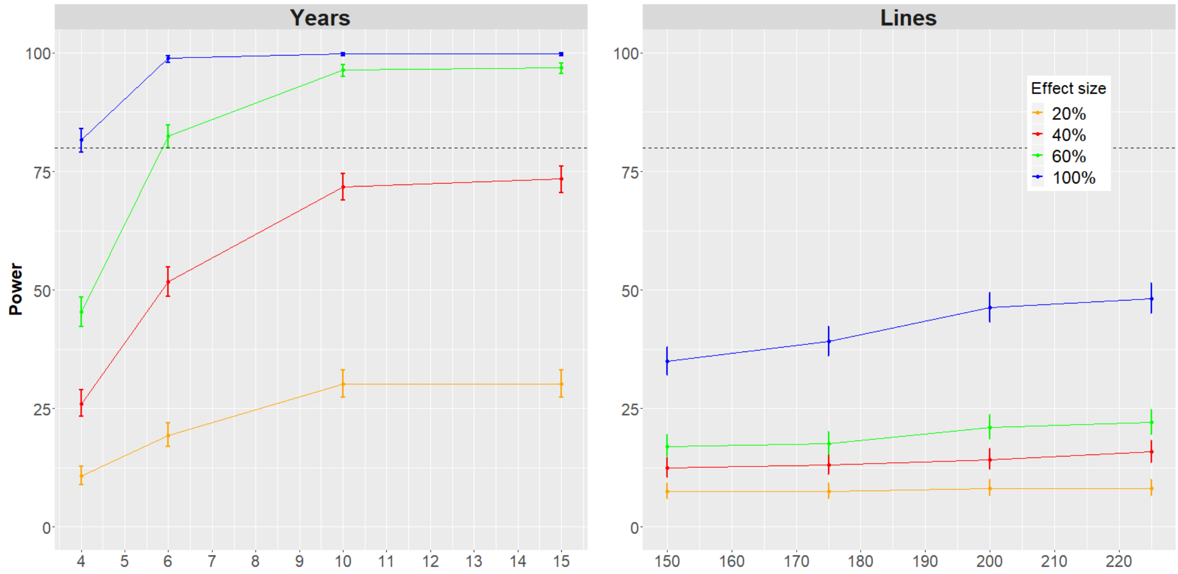

Figure 14. Power (with 95% confidence intervals) to estimate changes in the probability of occurrence of geckos using pooled data from tracking tunnels. Power estimates were calculated to detect increases of 20%, 40%, 60%, and 100% in the probability of occurrence of geckos by simulating changes in the number of years surveyed (4–15) or the number of lines surveyed (150–230). The dashed line indicates the minimum target of 80% power to detect a given change.

6 Conclusions

A detailed summary of all the results from these power analyses is presented in Table 1, and a brief summary by target group and survey method is presented in Table 2.

There is currently enough power to detect small changes (≥20%) in the probability of occurrence of all invertebrates (wētā + spiders + other invertebrates) using ACOs, and to detect medium changes (≥60%) in their abundance using wētā houses. There is also sufficient power to detect medium changes (≥40%) in the probability of occurrence of other invertebrates (any invertebrates not including wētā or spiders) using wētā houses. The current design does not provide sufficient power to detect any of the changes assessed in the probability of occurrence or abundance of wētā, spiders or geckos.

If monitoring continues for 1 more year, the current sample size would provide sufficient power to detect medium changes (≥40%) in the abundance of spiders using wētā houses. Increasing the number of lines monitored from 44 to 100 and monitoring for ≥3 years would allow for large changes (≥100%) in the probability of occurrence of wētā using wētā houses to be detected confidently; if monitoring were to continue for 6 years then large changes (≥100%) in wētā abundance could be confidently detected. If monitoring continues for 3 more years (for a total of 6 years), the current sample size would have sufficient power to detect medium changes (≥60%) in the probability of occurrence of geckos using tracking tunnels. None of the extended designs simulated would allow the confident detection of changes of the magnitude assessed in the abundance of geckos.

Table 1. Detailed summary of power analyses conducted on three data sets and various animal groups in the Cape to City area. A dash in a cell indicates that such analysis was not performed

Data set	Target Group	Measure[1]	Data[2]	Achieves 80% power? Current design	Increase years	Increase lines	Increase lines and years
ACOs	Geckos	N	NP	–	–	–	–
			P	Insufficient	Insufficient	Insufficient	Insufficient
		O	NP	Insufficient	Insufficient	Insufficient	Insufficient
			P	Insufficient	Insufficient	Insufficient	Insufficient
	All inverts	O	NP	ES ≥100%	ES ≥100%	110 lines & ≥3 years would detect ES ≥60%	200 lines & ≥5 years would detect ES ≥40%
			P	ES ≥20%	–	–	–
Wētā houses	Wētā	N	NP	Insufficient	–	–	–
			P	Insufficient	Insufficient	Insufficient	100 lines & ≥6 years would detect ES ≥100%
		O	NP	Insufficient	Insufficient	Insufficient	Insufficient
			P	Insufficient	Insufficient	100 lines & ≥3 years would detect ES ≥100%	100 lines & ≥3 years would detect ES ≥100%
	Spiders	N	NP	Insufficient	–	–	–
			P	Insufficient	4 years would detect ES ≥40%	≥60 lines & ≥3 years would detect ES ≥40%	–
	Other inverts	N	NP	Insufficient	–	–	–
			P	Insufficient	Insufficient	≥100 lines & ≥3 years would detect ES ≥100%	100 lines & ≥3 years would detect ES ≥100%
		O	NP	ES ≥100%	ES ≥100%	100 lines & ≥3 years would detect ES≥60%	100 lines & ≥3 years would detect ES ≥60%
			P	ES ≥40%	ES ≥40%	ES ≥40%	100 lines & ≥6 years would detect ES ≥20%
	All inverts	N	NP	ES ≥60%	ES ≥60%	100 lines & ≥3 years would detect ES ≥40%	100 lines & ≥3 years would detect ES ≥40%
			P	ES ≥100%	≥10 years would detect ES≥60%	≥50 lines & ≥3 years would detect ES ≥60%	100 lines and ≥4 years would detect ES≥40%
Tunnels	Geckos	O	NP	Insufficient	–	–	–
			P	Insufficient	≥4 years would detect ES ≥100%, ≥6 years would detect ES ≥60%	Insufficient	–

[1] N = abundance, O = occupancy.

[2] NP = devices that have not been pooled within lines; P = devices that have been pooled within lines

Table 2. Brief summary of results of power analyses by target group, monitoring method and measure of abundance. ES = effect size, N = abundance, O = occupancy. A thumbs-up indicates that the threshold of 80% power to detect a given effect size can be achieved either with the current monitoring design or with one of the extended designs we simulated. A thumbs-down indicates that the threshold of 80% power cannot be achieved with any of the extended monitoring designs we simulated. A dash indicates that such analysis was not performed, whereas NA indicates that the analysis is not appropriate (e.g. geckos do not use wētā houses).

Group	**ACOs**		**Wētā houses**		**Tunnels**
	N	**O**	**N**	**O**	**O**
Geckos	👎	👎	NA	NA	👍 60% ES with ≥6 years
All invertebrates combined	NA	👍 20% ES with current design	👍 60% ES with current design; 40% ES with 100 lines & ≥4 years	–	NA
Wētā	NA	NA	👍 100% ES with 100 lines & ≥6 years	👍 100% ES with 100 lines & ≥3 years	NA
Spiders	NA	NA	👍 40% ES with ≥4 years	–	NA
Other invertebrates	NA	NA	👍 100% ES with 100 lines & ≥3 years	👍 40% ES with current design	NA

The current sampling design provides low power to detect small changes (≤20%) in the abundance of all the groups analysed. This cannot be overcome by increasing the number of lines or years monitored, at least not within the range of values that we simulated. It is possible that even larger sample sizes than the ones we simulated would provide sufficient power to detect small changes in abundance, but this might be prohibitively expensive or logistically impractical. Further, detecting such small changes might not be of importance from a biological or management perspective because they might not represent a large enough change to indicate viable populations. It is important for managers to decide *a priori* what level of positive response in the asset (i.e. the effect size) would be deemed successful; this can then be used to guide the level of sampling required.

7 Recommendations

- Although small changes (≤20%) in abundance cannot be confidently detected, the use of multiple types of devices and measures of abundance ensures that at least one method provides sufficient power to confidently detect medium to large changes for each group of interest.
- We recommend that HBRC continue monitoring biodiversity assets in Cape to City for a minimum of 6 years using the current sample of lines.
- If more resources become available, we would recommend that the number of lines be increased from 44 to 100 for wētā houses. These additional wētā houses could be installed along existing lines that currently have ACOs (85 lines) or tracking tunnels (125 lines).
- We recommend that ACOs be discontinued as these have low power to detect changes in lizard abundance. The savings made by ceasing ACO monitoring could be put towards increasing the number of wētā houses.

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