Designing a track-based monitoring program to detect changes in species occupancy in the deserts of South Australia

Threatened Species Recovery Hub

National Environmental Science Programme

Arid Zone Monitoring Project

This factsheet is a summary of a detailed analysis carried out by Darren Southwell, Anja Skroblin, Katherine Moseby, Richard Southgate, Daniel Rogers, Peter Copley, David A. Roshier, Martin A. Dziminski, Reece Pedler, Naomi Indigo, Carolina Galindez-Silva, Sarah Legge. The analysis is presented in detail in a scientific manuscript (Southwell et. al 2022 – In Review).

Summary

This factsheet summarises how the Arid Zone Monitoring project (AZM) used existing 2-hectare plot data from South Australia to design a track-based monitoring program for this region. The program aimed to detect significant changes in the populations 11 priority species, including both common and rarer species. The monitoring program may be carried out by multiple people and groups, each collecting data in their local area, and collaborating to collate data, in order to examine regional trends. The same approach can be applied to design monitoring for other regions, or even for a national monitoring program.

Th approach described here is based on using existing survey data to model what drives differences in occupancy across the range of a species, and to estimate the detectability of each species. Occupancy is the proportion of sites that have sign of a species; detectability is the probability of seeing and recording sign, if the sign is there. Changes in occupancy were then simulated, and the statistical power of different monitoring designs was estimated. We used a 'spatially explicit' simulation as we aimed to predict occupancy across the whole study area, including in places that haven't been previously surveyed by AZM partners.

The work explored the outcomes of differing survey designs by changing the number of sites surveyed, the survey frequency (within and across years), and where sites were positioned in the landscape. Overall, we found that if we monitored approximately 200 sites every year (with a small subset re-surveyed twice within a year to improve detectability estimates), with those sites located to optimise detections for all species, we would detect moderate to marked declines in most priority species. Increasing the number of sites surveyed, and optimising their locations for both the rare and common species, would increase our power to detect changes. One alternative to surveying 200 sites every year, was to reduce survey frequency whilst also increasing the number of sites in the program.

As well as informing monitoring design for the South Australian case study, our work provides general guidance for designing a large-scale, regional monitoring program using track-based surveys.

Background

Biodiversity monitoring is crucial for managing threatened species (e.g. malleefowl, kowari, golden bandicoot, bilby, great desert skink), introduced species (e.g. cat, fox, camel) and species of Indigenous cultural significance (e.g. bustard, goanna, emu) in the deserts. Monitoring desert species is challenging due to the vast landscape, and because populations are often sparse with numbers that fluctuate rapidly in response to rainfall.

Track-based surveys are an effective technique for monitoring many desert species. Track-based surveys are best suited for sandy substrates, and favour species whose tracks and signs are easily to identify. The surveys involve searching for animal signs on the soil surface within an area for a set amount of time, to record animal presence. Currently, track-based surveys are carried out by many groups from the Kimberley, the Pilbara, through the western and central deserts and down into South Australia. Potentially, data collected from such surveys can be collated to contribute to regional or national monitoring of species populations.

For a monitoring program that aims to detect change in species of interest, key decisions need to be made about the number of sites, where the sites are located, and how often they sites are re-surveyed. Getting these decisions right is important, not just so the monitoring can detect the changes you are interest in, but also so that you don't waste resources by sampling many more or less sites than you need to achieve your monitoring objective.

Designing a monitoring program for South Australia

We carried out a series of spatially explicit simulations to optimise the design of future track-based monitoring in South Australia. The steps are summarised described below:

1. **We gathered information for the simulation.** We used existing data, from past surveys in South Australia, for the simulation. The existing data were collected from 550 2-ha plot sites, spread over 730,000km^2. Sites had been surveyed (once to several times) over a 13 year period (Figure 1). On average, 186 sites were surveyed each year.

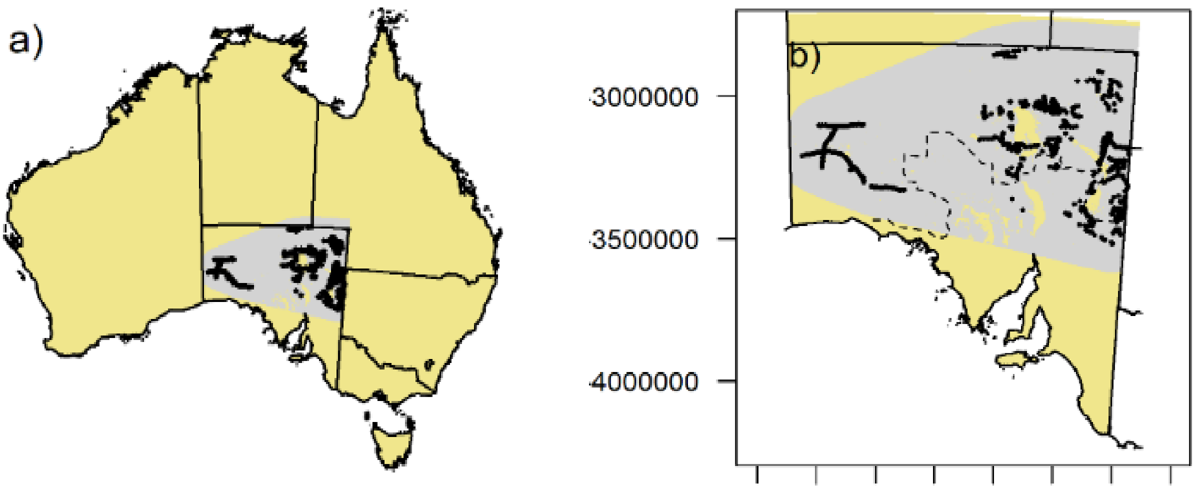

Figure 1: Location of 2-ha plot sites (black dots) in (a) Australia, and (b) South Australia (b). The grey shaded region is the study area. The black dotted line is the dog-proof fence. Salt lakes or pans, were not included in the analysis.

2. **We decided what species we wanted to monitor**. In a workshop involving government and non-government stakeholders from South Australia, 11 priority species were selected to be the focus of the monitoring program. They included:

- Introduced species with widespread distributions: camel (*Camelus dromedaries*), red fox (*Vulpes vulpes*), cat (*Felis catus*), rabbit (*Oryctolagus cuniculus*), and cow (*Bos* spp.). Monitoring these species is important for understanding the level of threat they pose, and informing management actions and outcomes.
- Native species with widespread distributions, and of cultural significance to Traditional Owners: dingo (*Canis lupus dingo*), emu (*Dromaius novaehollandiae*), large macropods (*Osphranter rufus*, *Macropus fuliginosus*), and goanna (*Varanus* spp.).
- Native species with limited distributions and conservation significance: crest-tailed mulgara (*Dasycercus cristacauda*), dusky hopping mouse (*Notomys fuscus*), great desert skink (*Liopholis kintorei*).

3. **We built species distribution models (SDMs) to inform the simulation**. We used the existing survey data from the 550 sites to build SDMs that predicted the distributions of each of the 11 priority species, based on climate, terrain, soil and vegetation data. We used different modelling approaches for each species and combined them in an 'ensemble' model, which predicts the probability of occupancy for each species, within a 1 km^2 grid cell that we overlaid on the study area. An example of the output from an SDM for the crest-tailed mulgara is in Figure 2. We also estimated single-visit detection probabilities from the existing dataset.

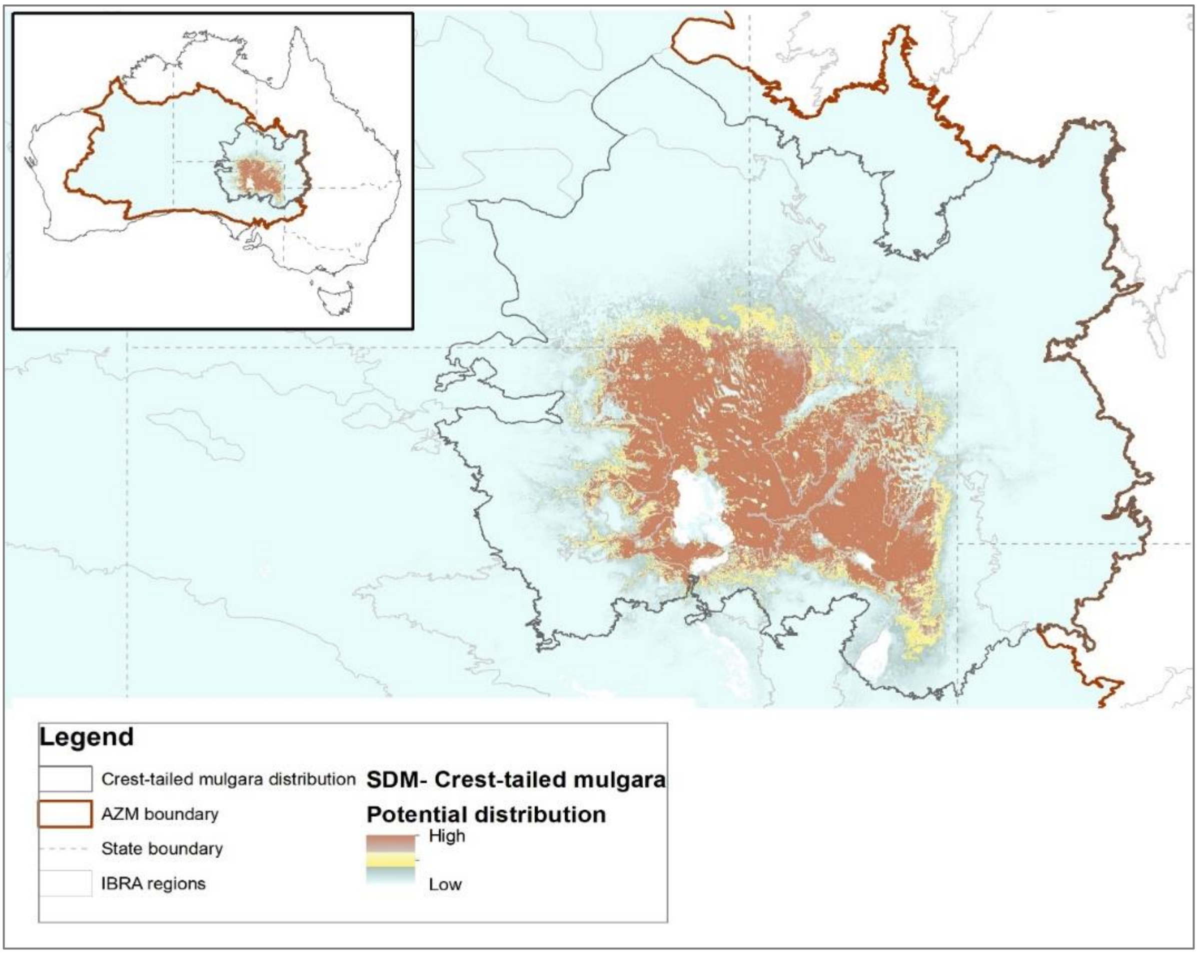

Figure 2: Map shows an example output of a species distribution model (SDM) for crest-tailed mulgara. Areas where crest-tailed mulgara are likely to be found are coloured brown. Where they are least likely to be found are coloured light blue. The known bioregional distribution of crest tailed mulgara is outlined in grey. The red outline is the AZM study boundary within Australia and encompasses the sandy-desert regions.

4. **We considered different locations for sites.** We used a spatial prioritisation tool called Zonation. Using the SDM maps as input layers for Zonation, we identified regions in the landscape with the highest predicted occupancy and representation of the 11 priority species. We then considered three different scenarios for positioning sites (Figure 3):
    - Scenario 1: Only a subset of the existing network of 2-ha plots were monitored.
    - Scenario 2: New site locations were optimised to target all 11 priority species equally.
    - Scenario 3: New site locations were optimised to target just the two species of conservation concern.

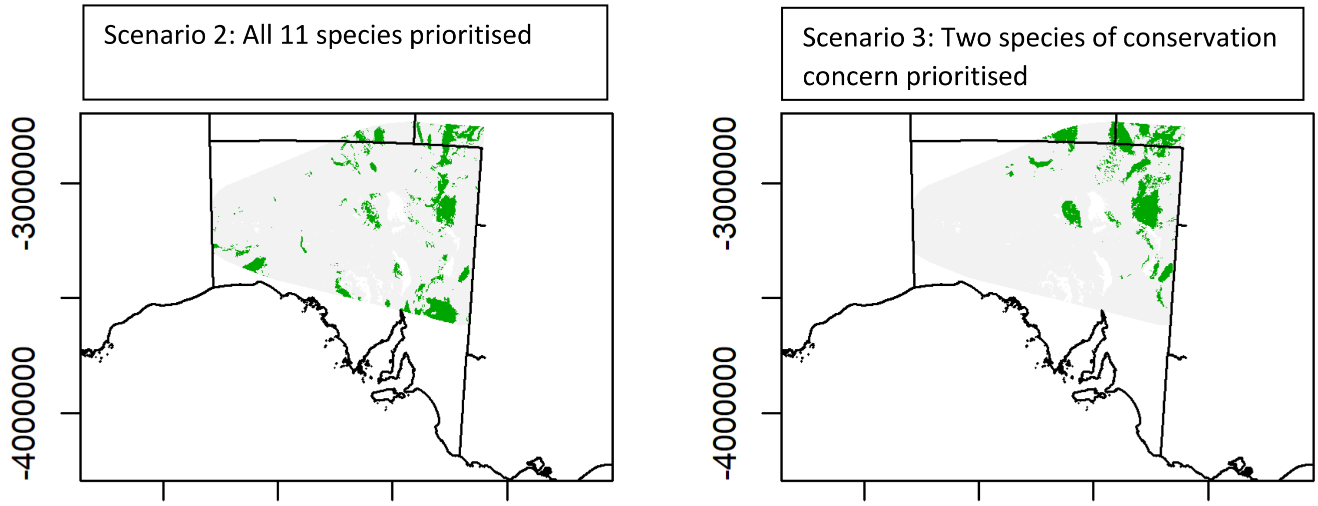

Figure 3: The areas prioritised by Zonation (green) for positioning sites, in scenario 2: when all species are weighted equally (left) and in scenario 3: when the range-restricted species, crest-tailed mulgara and dusky hopping mouse, are prioritised (right). Notice how the best places to position sites changes when the design scenario changes.

5. **We simulated future changes in occupancy.** We simulated both increases and decreases in occupancy of the 11 priority species, during each year of a future monitoring program lasting 15 years. We then simulated different sampling designs (varying the number of sites from 50 to 700, and the survey frequency from once a year to once every 5 years), in the three different location scenarios. The simulations were each run 1000 times to calculate the statistical power - the statistical power in this case is the proportion of times that the simulated change in occupancy was detected from the simulated datasets. An example of the outputs that the simulation produces is in Figure 4.

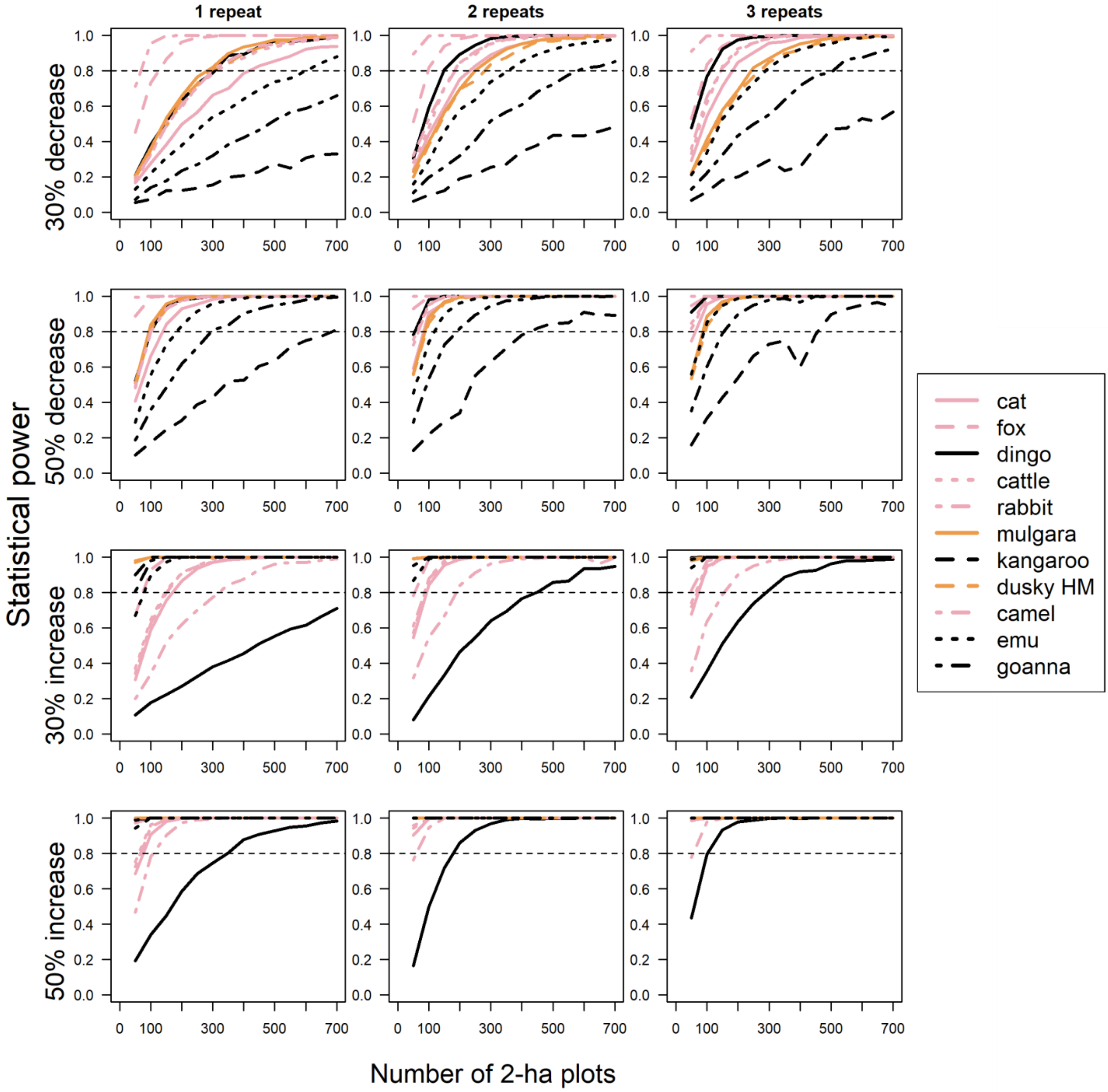

Figure 4: Statistical power (y-axis) to detect occupancy trends in 11 species over 15 years depending on the number of 2-ha plots surveyed each year (x-axis), the magnitude of change we aim to detect (30% or 50%), the direction of change (increasing or decreasing) and the number of within year repeat surveys (1-3). The dashed horizontal line represents 80% power.

Findings: General rules for monitoring design

- Increasing the number of plots surveyed increases statistical power to detect change in occupancy. Increasing the number of times a plot is surveyed in a year (e.g., from one to two) also increases statistical power, but to a lesser extent.
- Reducing the survey frequency (from annually, to once every 2, 3 or more years) reduces statistical power, but may be compensated for by increasing the number of sites that are surveyed on each occasion.
- Less survey effort is needed to detect larger changes; for example, it requires less sites or fewer surveys to detect a 50% decline compared to a 30% decline in priority species occupancy.
- It is easier to detect increasing trends than decreasing trends when the starting occupancy estimates are closer to zero than to 1, this is because an increasing effect size results in a larger value than the same effect size that is decreasing.
- A subset of sites should be re-surveyed in the same year to estimate detectability; in practice re-surveying a small proportion of sites (as low as 10%) twice, is enough.
- If species are rarely detected, it's hard to design monitoring programs that have enough statistical power. You either need to survey a very large number of sites, or you should consider a different survey technique.
- Using the ensemble SDMs and the spatial prioritisation tool (Zonation) to locate sites, rather than relying on the pre-existing network of sites, increases the power to detect change in priority species. This matters less for common and widespread species, like the camel and the cat, but is very important for rarer, range-restricted species like crest-tailed mulgara.
- It is therefore important to decide which species are the priorities for monitoring during the design stage, because this decision affects where sites should be located. If we prioritised the location of sites for the two range-restricted species (dusky hopping mouse and crest-tailed mulgara), we will lose power for some the other species, unless we increase the number of sites in other localities.

What does this mean for future monitoring in South Australia?

The analysis showed that if groups and individuals collectively monitored 200 of the pre-existing sites every year (with at least 20 re-surveyed within the year to improve detectability), which is a similar effort to that used in past years, we could detect moderate declines (i.e. at least 30%) in six of the 11 priority species; and marked declines (i.e. at least 50%) in 10 of the 11 priority species. To increase the statistical power of detecting moderate declines for most of priority species, we should increase the number of sites that are surveyed.

If groups and individuals in South Australia repositioned their track-based monitoring sites according to the spatial prioritisation, the power to detect changes would increase across all species. If the spatial prioritisation targets the two species of conservation significance, our power to detect change in these species would increase, but it would decrease for some of the other species. We could compensate for this by adding more sites to the monitoring design to make sure all species are adequately covered.

An alternative to surveying every year, could be to reduce the survey frequency, whilst increasing the number of sites in the program. The most appropriate survey frequency will depend on factors not considered in our simulation. These include logistical constraints; the status of target species (i.e. it might be more important to monitor threatened species with small populations more often); generation length of target species; and how risk averse managers are to what could happen between survey events. In addition, monitoring frequency should be synchronised, if possible, with natural peaks and troughs in populations. This is particularly important in arid Australia, where rainfall drives 'boom-bust' population cycles, but may be challenging to plan due to the irregularity and random nature of such events.

Figure 5 illustrates some of the trade-offs that need to be considered in the monitoring design. A summary of the analysis approach is in Figure 6.

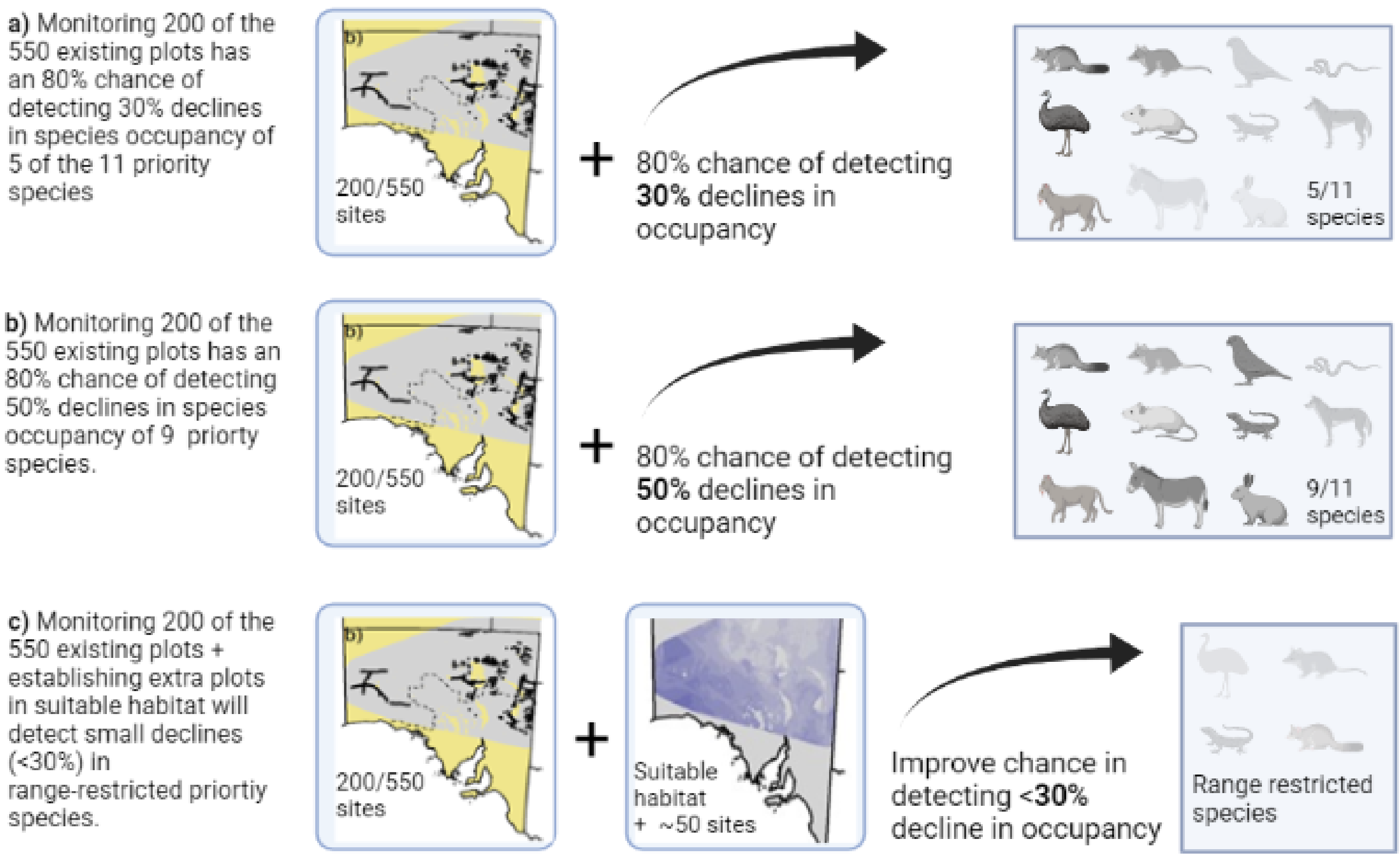

Figure 5: Examples of trade-offs in the monitoring design. Monitoring 200 of the 550 existing plots has an 80% chance of detecting 30% declines in species occupancy of 5 of the 11 species (panel a). This increased to 9 species if we relaxed our threshold to observe a 50% decline in occupancy (panel b). To detect small declines (<30%) in range-restricted species, then more of the existing 2-ha plot network should be surveyed and/or new plots should be established in areas with the highest predicted occupancy (panel c).

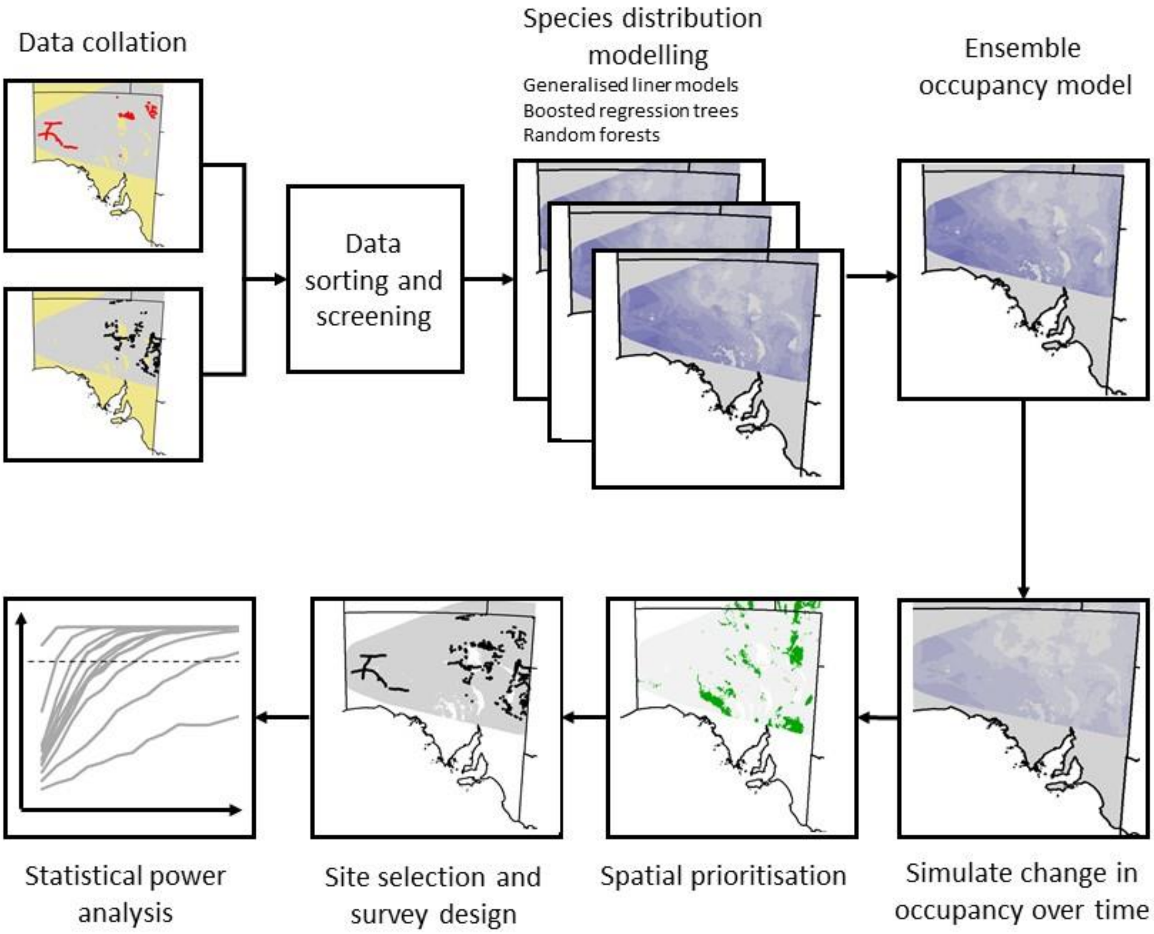

Figure 6: Spatially explicit power simulation framework. Species distribution models (SDMs) were built for each priority species. For each of three scenarios about where sites are located in the landscape (i.e., use existing sites, place sites where SDMs indicate are the best places for all species, or place sites to prioritise rare species), we then simulated changes in occupancy over time, and then applied a spatially explicit simulation tool to evaluate the likely performance of alternative monitoring designs at detecting occupancy trends over the next 15 years.

Some final considerations

We assumed the goal of monitoring was to detect trends in species occupancy, and not to understand factors driving changes in occupancy (fire or introduced species, for example). Landholders and groups might have their own, different objectives for 2-ha plot monitoring – for example, to track the effectiveness of management within their region. In this case, many plots within a small area could maximise what can be learnt about management effectiveness. If landholders are using fire to manage species, their plots could be stratified across fire histories and vegetation types within their region, so that monitoring not only meets the broader regional and national objectives of a detecting trends, but also answers local questions about management effectiveness.

There are some fundamental principles common to all good monitoring programs.

- Set clear objectives (e.g., measure the distribution or abundance of a species over time, and learning how these attributes changes with fire management).

- Position sites to overlap with the distribution or potential distribution of priority species.
- Have enough resources (funding and people) secured for the length of time needed to detect changes in desert systems.
- Design the monitoring so it has adequate statistical power to detect a change (enough samples or surveys in one area repeated over time).
- Account for imperfect detection (thinking an animal is not present, when it was) by surveying a subsample of sites (10%) twice per year.

More information

If you would like more information, the work is presented in detail in a scientific manuscript:

Darren Southwell, Anja Skroblin, Katherine Moseby, Richard Southgate, Daniel Rogers, Peter Copley, David A. Roshier, Martin A. Dziminski, Reece Pedler, Naomi Indigo, Carolina Galindez-Silva, Sarah Legge (2022) Designing a large-scale track-based monitoring program to detect changes in species distributions in arid Australia. Ecological Applications. In review.

Other useful references

Einoder, L. D., Southwell, D. M., Lahoz-Monfort, J. J., Gillespie, G. R., Fisher, A., and Wintle, B. A. (2018). Occupancy and detectability modelling of vertebrates in northern Australia using multiple sampling methods. *PLoS ONE* 13, e0203304.

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Likens, G. and Lindenmayer, D. (2018). 'Effective ecological monitoring.' (CSIRO publishing: Melbourne.)

Southwell, D. M., Einoder, L. D., Lahoz-Monfort, J. J., Fisher, A., Gillespie, G. R., and Wintle, B. A. (2019). Spatially explicit power analysis for detecting occupancy trends for multiple species. *Ecological Applications* 29, e01950.