BIODIVERSITY MONITORING, EVALUATION AND REPORTING FRAMEWORK
A CITY THAT CARES FOR THE ENVIRONMENT

Environmental sustainability is the basis of all Future Melbourne goals. It requires current generations to choose how they meet their needs without compromising the ability of future generations to be able to do the same.

Acknowledgement of Traditional Owners

The City of Melbourne respectfully acknowledges the Traditional Owners of the land, the Boon Wurrung and Woiwurrung (Wurundjeri) people of the Kulin Nation and pays respect to their Elders, past and present.
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Cover Image: Citizen Scientists. Photo Credit: Shannon Reddaway

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1.0 EXECUTIVE SUMMARY

The City of Melbourne is committed to achieving healthy ecosystems for both people and biodiversity. The Nature in the City Strategy 2017 sets out a series of goals, priorities and actions to deliver this commitment over the next 10 years. Underpinning this aspiration is a commitment to adopt best practice ecological management and use an evidence-based and adaptive management approach in decision making. Fundamental to this approach is the need for a strategic and co-ordinated framework to guide nature-based research and monitoring in the City of Melbourne. This Biodiversity Monitoring, Evaluation and Reporting Framework (BMERF) is a living document that guides all aspects of the research and monitoring process – from the decision to undertake research, trials or monitoring, through to design, implementation, analysis and reporting and updating of management practices. This framework also specifies six specific areas of monitoring that directly address the success of the Nature in the City Strategy.

Research, monitoring and trials are not all the same thing, although there are many similarities and common themes. In this BMERF, monitoring specifically relates to the repeated measurement of an attribute or condition over time, whilst research aims to answer a specific question. Research can range from literature searching through to lab- or field-based experiments with a scientific study design. Monitoring is typically research because it aims to answer a specific question, however, research is only monitoring when measurements or assessments are conducted over time. An example of monitoring that is not research is surveillance monitoring, where data is collected through time in case something changes. Trials are a specific form of research where we test something, often a new product, in order to assess its suitability or performance, such as the survival or growth rate of a new species of tree in the city. If the trial involves repeated measurements of a condition over time, it is also monitoring.

There are a series of steps to planning, conducting, evaluating and reporting on research and monitoring that should always be considered when developing a new project or deciding to continue with an existing one. By following the steps outlined in this BMERF, the City of Melbourne can be confident that the findings of the research and monitoring they undertake will be reliable, useful and able to inform decision-making.

The Nature in the City Strategy has six priority areas of focus across three goals and 23 actions to be delivered by 2027. How will the City of Melbourne know if it has succeeded in improving biodiversity and achieving healthy ecosystems? Section 5 of the BMERF details six monitoring objectives that will be assessed by the City of Melbourne over the next 10 years.

When the Nature in the City Strategy was endorsed in 2017, the City of Melbourne did not have sufficient baseline data to develop meaningful quantitative targets. In this BMERF, we propose a series of targets for management as well as identify areas of future work to refine the targets for the Nature in the City Strategy by 2027. The approaches and partnerships outlined in this document are ambitious, achievable and developed from ecological theory.

This document is intended to be a live document that will be revised through an adaptive management approach as the targets are refined and agreed upon over time. Importantly, the targets, once set, will not be changed until the Nature in the City Strategy is reviewed in 2027.
The City of Melbourne is home to a wide variety of natural and created habitats with over 1800 species of birds, mammals, insects, fish, amphibians, reptiles, and aquatic invertebrates. The extent and health of nature in our city is extremely important to the City of Melbourne and to our residents, workers and visitors alike. The vision of the 2017 Nature in the City Strategy is to ‘... support diverse, resilient, and healthy ecosystems that improve the environment and well-being of our community, providing the foundation for a liveable city’. The Nature in the City Strategy has six priorities across three goals that are to be implemented over a ten-year period, as seen on the following page.

How will the City of Melbourne know if it has achieved these ambitious goals and priorities? The City of Melbourne recognises the importance of monitoring and evaluation and has produced this framework to guide the development, design and evaluation and reporting of biodiversity-related research and monitoring. This framework also helps to satisfy the evaluation component of the first action in the Nature in the City Strategy, namely ‘to establish a comprehensive baseline of species, vegetation communities, and habitats to inform decision-making, guide management actions and evaluate success.’ This BMERF is the tool that the City of Melbourne will use to provide strategies and approaches to collect data to inform decision making, guide management actions and evaluate the success of the Nature in the City Strategy.
2.1 Vision

The City of Melbourne will support diverse, resilient, and healthy ecosystems that improve the environment and wellbeing of our community, providing the foundation for a liveable city.

Goals

1. Create a more diverse, connected, and resilient natural environment
2. Connect people to nature
3. Demonstrate leadership in urban ecology and conservation of biodiversity

Priorities

1. Improve ecosystem health and biodiversity.
   **Target:**
   There is a net increase in biodiversity, habitats, and ecosystem health within the City of Melbourne by 2027.

2. Develop a more ecologically connected urban landscape.
   **Target:**
   By 2027, City of Melbourne will be a more ecologically-connected city than in 2017.

3. Increase the contribution of the private realm in supporting biodiversity conservation and ecosystem health within the municipality.
   **Target:**
   By 2027, the private realm is playing a significant role in supporting nature in the city.

4. Connect more people to nature to improve social resilience, health, and wellbeing.
   **Target:**
   By 2027, more residents, workers, and visitors encounter, value, and understand nature in the city more than they did in 2017.

5. Explore opportunities to use cultural and practical ‘Caring for Country’ principles to integrate people with nature.
   **Target:**
   By 2027, the City of Melbourne will, in collaboration with Traditional Owners and the local Aboriginal community, have integrated, celebrated, and promoted ‘Caring for Country’ approaches.

6. Demonstrate local and global leadership in conserving biodiversity and creating and sustaining healthy urban ecosystems.
   **Target:**
   Deliver flagship biodiversity and urban ecology projects that are recognised locally and internationally as innovative and outstanding examples of enhancing nature in the city.
2.2 Purpose, scope and audience

The purpose of this framework is to enable the City of Melbourne and partners to:

- Determine whether the outcomes in the Nature in the City Strategy are being achieved by setting more specific targets and refining those over time.
- Determine whether the processes and activities established to achieve the goals of the Nature in the City Strategy are efficient and effective.
- Adopt an adaptive management approach to all urban ecology actions to ensure the outputs and outcomes specified in the Nature in the City Strategy are achieved.
- Decide if and when research or monitoring is required.
- Design and undertake scientifically robust research, monitoring and trials.

This framework describes how the City of Melbourne will monitor and report on activities, processes, outputs and outcomes to deliver the aspirations of the Nature in the City Strategy. The principles of this framework can be applied to any program that aims to monitor and evaluate changes in an attribute or condition over time, trial the suitability of a new product, or to assess the effectiveness of management. More specifically, this framework is focused on guiding the Nature in the City Strategy and evaluating the effectiveness of our biodiversity management actions. The primary audience for this document includes City of Melbourne employees and contractors, researchers, consultants, and community members with an interest in the conservation of biodiversity in the city. The principles and considerations outlined in this framework can also be applied to other areas of the City of Melbourne that are responsible for research, monitoring, trials and evaluating the success of programs and strategies.
3.0 BACKGROUND AND CONTEXT

Urban ecology is a new area of practice and experimentation for the City of Melbourne, and indeed for many cities globally. While there is a growing body of knowledge of the theory of urban ecology and the importance of biodiversity conservation in urban areas, there is still much to learn, especially about the practice of urban ecology. There are also many new ideas and approaches being tested and adopted in many work areas across the City of Melbourne. In some cases, the effectiveness of these new approaches is unknown and they need thorough testing before widespread adoption. The City of Melbourne aspires to be a global leader in urban ecology and innovation and needs a reliable evidence-base to evaluate the effectiveness of our actions and to keep track of our biodiversity and habitats.

Local governments are fortunate in that they have an opportunity to learn by doing, provided they are able to collect enough appropriate data, analyse these data in a scientifically robust way and report it to relevant audiences.

Most local governments, however, do not have adequate expertise or resources available to undertake comprehensive trials or evaluate how well their management actions contribute to the improvement of biodiversity for a number of reasons, including:

- Most, but not all, local government employees do not have the training or expertise to design scientifically-robust research and monitoring.
- Biodiversity research and monitoring can be expensive and resources for this are often limited and constrained to annual reporting cycles.
- Local government areas are not research agencies so this work is neither their goal nor their priority.
- Local government areas in city regions are often too small in area to have sufficient locations for multiple study sites or trial locations.
- Some monitoring is long-term, and fluctuating staff, budgets and priorities within local government can result in programs being re-prioritised, with monitoring often being discontinued in favour of other actions.

3.1 What is biodiversity?

“Biodiversity is the variety of all life forms on earth; it is the different plants, animals and micro-organisms; their genes; and the terrestrial, marine and freshwater ecosystems of which they are a part” (Australia’s Biodiversity Conservation Strategy 2010–2030).

Australia has a unique and diverse assemblage of plant and animal communities and ecosystems, however, these are under threat from numerous natural and human disturbances with urbanisation and global climate change two of the biggest threats. Urban areas are already extensively cleared and modified and home to many non-indigenous and exotic species of plants and animals, some of which are weeds and pests. A significant challenge for land managers of urban environments is to manage and protect native biodiversity, whilst recognising the important role that non-native species of plants may play in supporting wildlife and making cities liveable for people.
Box 1: What is research, and what is monitoring? Aren't they the same thing…? And where do ‘trials’ fit into this BMERF?

The terms research and monitoring are often used interchangeably, but they are quite different.

Research is defined here as the systematic collection and analysis of information or data to increase our understanding of a topic or issue, usually to answer a specific question. In contrast, monitoring is the repeated measuring over time of the condition of a variable of interest. Monitoring is research when measurements are taken over time to answer a specific question. Much research, however, would not qualify as monitoring because repeated measurements are not being taken over time. For example, research to determine how many species of bird occur in a park during winter is not monitoring, because the survey is a snapshot in time. If the question was about changes to the number of bird species in a park from season to season or year to year, it becomes monitoring because the number of bird species in the park are counted over time.

Trials are a form of research because they are testing the suitability or performance of a new or modified management approach or product. For example, trials are set up to answer a specific question, such as testing the suitability of new species of tree in the city.

Research and monitoring are often designed using similar approaches which are outlined in Section 4. For example, high-quality research and monitoring both need a good, clear question, a well-formulated study design, appropriate methods, a statistically robust analysis of the findings and an effective method to report the findings to the relevant audience.

There are three main types of monitoring that are relevant to the work of the City of Melbourne (after Lindenmayer and Likens 2010):

1) **Curiosity-driven or passive monitoring** generally has little purpose or experimental design and is often done out of curiosity or inquisitiveness. While the monitoring may have an underlying question, it usually lacks a clear hypothesis that can be tested and rarely investigates the effectiveness of management.

2) **Mandated monitoring** is conducted because someone, usually in government, has decided that it should be. Examples include monitoring of weather, pollution levels or the number of species present in an area. In most cases, mandated monitoring can identify a pattern in the data, but is rarely able to elucidate the cause of such patterns in the data. Furthermore, many of the questions that are answered using this type of data are identified by potential users after the data has been collected.

A second form of mandated monitoring relates to reporting on activities – e.g. the City of Melbourne has a goal to plant 3000 trees per year. The City of Melbourne must monitor the number of trees that are planted each year to ensure the goal of 3000 trees per annum is reached.

3) **Question-driven monitoring** is focused on answering specific questions that are of relevance to managers or researchers. Question-driven monitoring essentially evaluates the outcomes of experiments, typically where there is uncertainty about the outcome of a management action. Trials are a form of question-driven monitoring. Question-driven monitoring will usually be based on a conceptual model or hypothesis, typically something like ‘if we do action A, we expect response B to occur’ and the monitoring is carefully designed to test this hypothesis.
Given that resources are typically limited, it is often difficult to decide when it is worth monitoring, or when those resources would be better spent on actions. Monitoring is valuable if it answers a question that achieves one or more of the following:

- Helps to improve management practices so that better outcomes are achieved.
- Optimises management to save time and money.
- Gains knowledge that verifies or justifies action(s).
- Gains knowledge that can be shared with the community or other relevant institutions to improve their understanding and actions.
- Identifies an issue, or the cause of an issue, that would otherwise be unknown.

Once a decision has been made that monitoring is required or worthwhile, the value of the monitoring depends entirely on how well it is conducted. Effective biodiversity monitoring can be challenging and is often done very poorly. This results in:

- Money being wasted on monitoring that does not achieve its objective.
- The data that is collected is often unreliable or insufficient to be able to answer the questions that were posed at the outset. In a best-case scenario the data may be used to answer other questions, however, this is often not the case.
- Worst-case is that the monitoring is done so poorly that the results suggest the species is surviving or habitat condition is improving, when in reality it is doing the opposite. This could then be interpreted incorrectly by a biodiversity manager.

This BMERF is simply a formalised approach to monitoring that:

- Provides a strategic framework to determine if monitoring is actually required.
- Ensures all monitoring is conducted to the highest possible standard by asking a checklist of questions that all monitoring projects should consider.
- Increases the reliability of data and strength of conclusions by providing best-practice guidance on study designs and methods.
- Ensures a consistency in methods across different monitoring projects that are used to measure the attribute of interest.
- Provides guidelines for reporting and dissemination of the findings.

This framework guides three main types of biodiversity monitoring, namely (1) general state of the environment reporting (surveillance monitoring – e.g. is biodiversity increasing, decreasing or remaining stable?); (2) evaluating the effect of a specific management action or intervention (including trials) on specific components of biodiversity (e.g. to what extent does the addition of native mistletoe plants on plane trees increase bird species diversity?); and (3) evaluating the success of the Nature in the City Strategy. This framework document provides guidance to enable the City of Melbourne to maximise the benefits of monitoring to achieve these three scopes.

**Box 2: Biodiversity monitoring? Or a framework for all monitoring of outcomes in local government?**

This framework is primarily written to enable the City of Melbourne to evaluate the effectiveness of their actions at improving biodiversity within Melbourne. In most areas of this framework, however, it is possible to substitute the word *biodiversity* with whatever your work area is focusing on. The framework applies equally well to assessing the outcomes of:

- Trials to evaluate the suitability of new species of trees within urban Melbourne.
- Tree planting to cool streets.
- Changes to the amount of water that is absorbed into the soil after Water Sensitive Urban Design (WSUD) interventions.
- Climate adaptation actions on frequency or severity of flooding.
3.2 Adaptive management approach

An important consideration in research and monitoring is to understand how the information you gather will likely inform decision-making and management. For example, you should definitely have a well-considered question that you want answered before you begin to develop a monitoring program. Ideally, you would also have a solid understanding of how the results of the monitoring will modify management. It is often difficult to predict exactly how management might change, because the results of monitoring are unknown, but at the very least, there should be an expectation that management might need to change. In other words, the monitoring or research should be part of an adaptive management cycle (see Figure 1). If you can’t place your research or monitoring into a framework such as this, it would ideally be modified and reworked to fit within this framework.

Adaptive management simply describes a formalised approach to management, monitoring and evaluation and the inclusion of a feedback loop to update management practice. At its core, it is the expectation that the effectiveness of management will be evaluated, and that management practices in the future may change in response to the outcomes of the monitoring. A primary benefit of the adaptive management approach is that monitoring is properly integrated into the management and is adequately resourced and supported.
4.0 KEY INGREDIENTS FOR A COMPREHENSIVE MONITORING PROGRAM

This section of the framework identifies and describes a series of considerations that should be addressed when (i) deciding whether to do monitoring (or research or conducting a trial); (ii) designing a new monitoring program; or (iii) evaluating whether to continue with an existing monitoring program. The topics in this section are given as a list which suggests a linear or step by step approach, when in reality many will be addressed iteratively, requiring frequent re-evaluation during the design phase of the research or monitoring (see Figure 2). The various steps shown in Figure 2 are described in more detail in sections 4.1 to 4.13.
**Biodiversity Monitoring, Evaluation and Reporting Framework**

1. **Develop conceptual and/or mathematical model of the system**
   This model summaries how the ecological system works, including detail of key internal and external drivers and interactions, management constraints and explicit acknowledgement of any uncertainties.

2. **Define on-ground management objectives**
   Clearly formulate and articulate the specific management objectives to enhance nature in the city, specifying the target species, time frame, and location(s).

3. **Describe on-ground management actions**
   Develop and describe the on-ground management actions to enhance nature in the city.

4. **Develop and describe the aims of monitoring**
   Clearly articulate the objectives of monitoring – what are you trying to learn and how will you use the information.

5. **Select species to monitor and set spatial and temporal scales of monitoring**
   Select species that are close as possible to the goals of management.

6. **Select methods and experimental design**
   Select methods that match the spatial and temporal scale of the system you are aiming to monitor. Survey methods for a range of ecological questions are continually improving and new approaches should be considered.

7. **Assess sensitivity and feasibility**
   Determine how much precision, accuracy, replication, and labour are required to confidently assess the monitoring aims. Evaluate how much can be achieved for a given budget.

8. **Design monitoring**
   Depending on study design - collect any “before” data.

9. **Implement on-ground management action**

10. **Implement monitoring**

**Outcome #1**

**Outcome #2**

**Interpret & understand**
Regularly collate and analyse data and update understanding. Undertake quality control of data collection, storage, and accessibility procedures.

**No monitoring necessary or feasible**
If the system is well known or sufficient data has been collected, (further) monitoring may not be necessary.

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**Figure 2. A decision flowchart to inform whether monitoring is to be part of management actions to enhance nature in the city, by defining and describing (i) a model of the ecosystem (shown in dark green), (ii) the management action (light green) and (iii) the monitoring (white). The iterative process to design monitoring (shown in circles) is explicit, allowing for revision of monitoring aims, methods, study design etc, and the ability to choose to not undertake monitoring if the goals are unfeasible. The details of each step are further outlined in Section 4.1 to 4.13. Diagram after Watson et al. (2017).**
4.1 Develop a conceptual model

The first step is to carefully develop a conceptual model that describes how the ecosystem or process operates, including: an assessment of the key internal and external drivers; the interactions; and any uncertainties, such as how confident you are that the management action will achieve the desired outcome. Conceptual models can take a variety of forms, ranging from a brief series of dot points or flow chart that summarise how you think the system operates, to complex mathematical models that rigorously quantify the nature of the relationships among different variables. Neither extreme or anywhere else on this continuum is more or less correct - the key outcome is to explicitly attempt to summarise the relationships among management actions and likely outcomes, highlight where uncertainty exists and thus, identify where research and monitoring may be required.

Conceptual models can be built from a variety of data sources, including expert opinion, extensive literature review and preliminary field trials.

It is important to also identify and articulate the reason for monitoring as this has a massive influence on all aspects of the project, including the management action itself, the study design, resource requirements, priority of competing resource demands, and governance to name a few.

4.2 Do I really need to do monitoring?

Unfortunately, monitoring is frequently added to projects because it is perceived as ‘the right thing to do’ even when there is no clear purpose for the monitoring. This often results in trivial or meaningless monitoring programs. In addition, monitoring programs without a clear justification or rationale are often poorly planned, under-resourced and rarely have a meaningful impact on management.

There are a number of primary reasons for doing monitoring at the City of Melbourne:

1) Assess progress towards achieving set goals, which may be an output (e.g. plant 3000 trees annually or increase understorey vegetation habitat by 20 per cent by 2027), or an outcome (e.g. increase biodiversity in the City of Melbourne).

2) Quantify the effectiveness of management (e.g. does the installation of nest boxes or chainsaw hollows within a specific park or across the municipality result in more hollow-dependent birds?).

3) Assess the suitability (e.g. survival and growth rate) of novel tree, shrub or ground-layer plant species for harsh urban environments.

4) Keep track of biodiversity levels within the City of Melbourne (e.g. how many species of bird occur in Melbourne?).

Box 3: Outputs and outcomes

Outputs and outcomes are not the same thing. Outputs can be defined as the things we produce, build or develop, typically evident in very short timeframes. Outcomes are usually evident in the mid- to long-term and can be defined as the consequences of the things we produce, build or develop. For example, planting out 1 hectare of understorey vegetation is the output of a program, and the increase in the number of skinks found in and around that vegetation is the outcome. Similarly, planting 3000 trees per year and achieving an average canopy cover of 40 per cent are outputs, and the reason for these programs, such as reducing temperature by 2°C and increased liveability, is the outcome.
The importance of questioning the need to do monitoring is so critical that it should be asked again. Monitoring should only be done if one or more of the following conditions are met:

1) There is a mandated need or requirement to monitor the output or outcome of certain management actions (includes for example, meeting Key Performance Indicators or benchmarking against other cities).

2) There is sufficient uncertainty about the outcome of a particular management action that we need to learn more about, which may be part of an adaptive management cycle (see Figure 1) or to answer a more theoretical question. Trials are small-scale experiments that are conducted because of the high level of uncertainty about the suitability of a new method, product or species.

3) The cost of the action is sufficiently high that we don’t want to waste money. It is easier to demonstrate the converse here: We believe (and experts we consulted agree) it is highly likely that skinks will become more abundant in a park if large rocks are added, however, we are not completely confident. But, because the rocks are very cheap to have delivered and installed, we do not think it is worth the cost to intensively monitor the response of skinks to habitat provision. In essence, it is a cheap, low-risk project where the cost of monitoring would far exceed the cost of habitat management and it is considered very unlikely that the rocks will have a negative impact on the skinks.

4.3 Decided to do monitoring? Now you need to establish governance

The governance of a monitoring program is critical to its success – without it, there is an elevated risk of it being poorly undertaken or not completed at all. Governance in this context relates to:

- Who is responsible for managing and delivering the monitoring project?
- Who is responsible for actually doing the different components, such as developing the study design, collecting and analysing the data, reporting, etc?
- Have sufficient funds and other resources (e.g. vehicles, equipment, staff time) been secured for an adequate amount of time to answer the question?
- What quality assurance/control processes are in place to ensure that each component is done effectively?

The governance of a project may need to evolve as the monitoring program grows and changes. Keep in mind, however, that the most successful monitoring programs are invariably characterised by the presence of a champion who pushes through hurdles and obstacles, keeps people motivated and has an ongoing, long-term commitment to the project. Without these champions, or when such champions leave, long-term monitoring projects often flounder and cease to exist. Therefore, any changes to the project governance should avoid undermining the champion. Furthermore, monitoring projects that are well-embedded within the City of Melbourne’s strategies and plans are more likely to persist following the departure of current champions.

4.4 Take the time to carefully formulate the right questions

Getting the question right is really important. Don’t rush this phase, as it sets the basis for the entire program. Often the question that is adopted for the monitoring is very different to what was initially proposed. This occurs because question development is an iterative process – if subsequent steps in the study design demonstrate that the questions initially posed cannot be answered within the budget or number of sites available, the question will need to be re-thought. Similarly, new information may become evident at any stage of the process, causing a rethink of the question or redesign of the monitoring.

There are multiple formal and informal ways to formulate the question(s), and formal approaches, such as program logic and Structured Decision Making have the benefit of being repeatable and transparent. We do not have the capacity to go into the full details of formal decision-making here, but we used a Structured Decision Making process in mid-2017 to identify indicators to evaluate the success of the Nature in the City Strategy (see Section 5 and Appendix 1).

Clarify whether your questions relate to outcomes or outputs, as this will change the focus of your questions (see Box 3).

Sometimes questions for monitoring can be directly or indirectly derived from the objectives of a management project or strategy. Ideally, such management objectives are phrased using the SMART acronym – Specific, Measurable, Achievable, Realistic, and Time-framed. If the objectives have been so defined, then the scope of the subsequent monitoring can be closely aligned to the SMART objective. For example, it is relatively straightforward to develop a monitoring program that assesses the extent to which the biodiversity management objectives of a park redevelopment have been achieved when the SMART objective is ‘to increase biodiversity levels by 20 per cent within 10 years’. It is still unclear which specific biodiversity elements (e.g. birds, fungi, or plants, etc) should be monitored, but it is significantly better than an objective which is simply to ‘increase biodiversity’.
4.5 Identifying, defining and testing the variables to measure

Whatever the question, you will need to identify some variable to measure and compare, either over time and/or against a control or different treatments. The thing you are most interested in knowing should ideally be the thing you actually measure. Where it is not possible to directly measure the variable of interest, an indicator can be used to ‘indicate’ or represent the variable of interest. For example, it may not be possible to fully measure ecosystem health and all of its components, but some studies have suggested that diversity and abundance of ant species are good ‘indicators’ of ecosystem health. Where an indicator is being used, it may help to use a formal process, such as program logic, to ensure the indicator makes sense. The variables to measure can be identified through a range of processes, including expert opinion, literature review and field trials.

Key performance indicators or the variable you measure should ideally be:

-Sensitive or responsive to the management action within a relevant timeframe. For example, there is little value in monitoring the increased survival rate or clutch size of a hollow-nesting bird occupying naturally-occurring tree hollows in new tree plantings if it takes at least 100 years for those trees to form hollows.

-Simple and cost-effective to measure.

-Able to be measured accurately and consistently over time and by different people.

4.6 The study design matters: a case study

Monitoring is not as simple as just measuring a parameter and assuming that any changes are relevant to the aims of monitoring. The following fictional case study illustrates the importance of the experimental design when evaluating the effectiveness of an intervention. Experimental design is equally important when undertaking other types of research or monitoring.

An open space manager was given permission to trial the addition of logs on the ground as a means of increasing biodiversity, specifically, invertebrates that shelter within and feed on decomposing wood. A large log was placed at a park in 2018, and being a good manager, she measured the number of log-dwelling bugs at the park before (2017) and 12 months after installing the log (2019), and found that the number of bugs after installation was much higher. Very excitedly, the manager told everyone about the results, and she became famous. The news of this discovery made its way to a bug expert, who unbeknownst to everyone, had been studying bug numbers at numerous parks across the city for many years. His long-term monitoring showed that in 2017, bug numbers were at an all-time low across the city (possibly because of a drought and the widespread use of a now-banned insecticide) and that populations across the city had rebounded in 2019 due to favourable weather and the cessation of use of the toxic chemical. In this scenario, the increase in the number of bugs in the second survey was not demonstrative of a true management response, because there was no comparable data from any control or reference sites. Unfortunately, the money that was spent on a consultant to survey bugs was wasted, and the City has since decided that no more logs are to be placed in parks.

A better study would have used a replicated Before-After Control-Impact (BACI) experimental design, where data is collected Before and After an intervention or treatment (i.e. installing logs) at sites that are Controls (i.e. no treatment) and sites that are Impacted (i.e. those receiving logs) (see Figure 3). It is not always possible to use a BACI design for every experiment, and there are a range of alternatives with different levels of inferential strength (i.e. the ability to detect a significant effect) that can be used (Figure 3b – 3e). In general, always try to use a BACI design, and work through the alternatives in sequential order from BACI, BA, CI, and I if BACI is not feasible. Ideally, you should also discuss your project with an ecological statistician for expert advice because a relatively small amount of money spent now in planning could save tens or hundreds of thousands of dollars later.
The replication relates to the number of sites, with (say) five parks receiving logs and five not. The same measurements were taken at control and impact sites, before and after the addition of logs, and bug numbers increased by 20 per cent at control sites (presumably due to the breaking of the drought and cessation of insecticide use) but at impact sites (where logs were added), bug numbers increased by 50 per cent. The unequivocal conclusion now is that adding logs increased bug numbers by 30 per cent more than the breaking of the drought and cessation of insecticide use did, and the City has now rolled out the placement of logs at all its parks because of the overwhelming success of the trial. In a replicated BACI design, it is possible to isolate the cause of any changes and test the extent to which it is responsible for the change.

Replication of sites is a key consideration – the ideal number of replicates depends on the size of the effect expected and how variable the change across sites is likely to be. Continuing with the logs and bug scenario: let us assume that logs are so good, such that, bug numbers increase by a large amount that far exceeds the background changes (being the natural increase due to rainfall and stopping insecticide use), and all sites with logs similarly increase. In this case, five impact sites and five control sites may well be enough. However, if the increase is very minor (such as just a handful more bugs) and/or there is high variability among sites (some sites increase a lot and others not at all), then many more replicates are required to be able to detect that change. A formal ‘power analysis’ is a helpful approach to calculate how much replication is required in order to detect a difference if it exists, and should be based on pre-existing data (if available) or by conducting a pilot study. It just so happens that the manager collaborated with some researchers and they conducted some pilot studies and performed a power analysis. They calculated that they needed 100 parks with logs and 100 parks without logs to be very confident of detecting an effect if one existed. The researcher also did a literature review and the overwhelming response of >50 studies from around the world were that logs in parks in urban areas resulted in a consistently large increase in the number of bugs in parks. The park manager therefore decided that monitoring bug numbers was not justified because (i) it was very expensive and (ii) there was little uncertainty that adding logs would increase bug numbers. The money saved was instead used to place more logs in parks across the city.

Finally, the study design should also consider biases and confounding variables that can distort the conclusions that are drawn. For example, a truckload of logs suddenly became available from a nearby construction project, and because there were no storage facilities, they were installed immediately. Being winter, the contractor was unable to drive off the track, and all logs were positioned within 7 m (the reach of his crane) of the track. When the next load of logs was delivered during summer, a different contractor was used, and they had a tractor and placed logs further away. There are numerous potential biases that may have been introduced into this project and hence, the subsequent monitoring, including:

1) The logs delivered during winter were placed near a track which followed a ridgeline, and thus all were positioned high in the landscape. In contrast, the logs delivered in summer were closer to the creek, which naturally supports more bugs and a different suite of bugs.

2) The logs in summer and the logs in winter came from different projects and were from different tree species, with different levels of suitability for bugs.

While both of these confounding variables can be accounted for, it is easy to see how these unintended biases may significantly affect the interpretation of the results, if the monitoring team are unaware of these issues. One way to account for these is to use a stratified and/or random sampling approach, where sites are classified into groupings of importance (e.g. topographical position) and then sites to be sampled are selected at random from the total potential pool of sites. This approach ensures an even spread of sites amongst potentially important factors and minimises the chance that the researcher introduces a bias into the selection of sites. While random sampling is a useful approach to reduce bias, it often relies on a large sample size because a small random sample, by chance, may be located in similar or uncharacteristic areas. An alternative is to use stratified or stratified-random samples, to help guide the site selection to more sensible locations, that can be strategically selected by an expert (stratified) or randomised within strategically selected areas (stratified-random).
Figure 3a - 3e depicts the different potential study designs that could be used for an experiment, in this case the hypothetical test of the effect of the addition of logs on the number of beetles in the park.

The study designs are listed in decreasing order of preference - if possible, always attempt a replicated BACI design when doing an experiment, followed by a BA, CI, I study design. ‘Control’ sites and ‘Impact’ sites are as similar to each other as possible, with the only substantive difference being the addition of logs at the impact site. ‘Before’ and ‘After’ refers to measurements taken before and after applying the treatment or impact, which in this example is the addition of logs.

In all cases, the variable of interest is the number of bugs in the park, which are measured in the same way at all site types and study designs. A white cross indicates that the combination of stage and treatment is not part of the illustrated study design. Replication (i.e. multiple sites being measured) has not been shown, however, in all study designs, replication is recommended in order to reduce the effects of site to site variation.

Figure 3a – Before-After Control-Impact (BACI) study design, where measurements are taken before and after the logs are added to the sites, which occurred at the time indicated by the green arrow. This is usually the optimal study design because the inclusion of a control ensures that any background changes can be taken into account and before and after samples ensures changes can be related to the addition of logs. Replication with multiple impact and control sites minimises the effect of site to site variability.
Figure 3b – Before-After study design, where measurements are taken at impact sites before and after the logs are added (which occurred at the time indicated by the green arrow), but no measurements are taken at control sites. Ideally, the impact sites are replicated to ensure adequate sample sizes. This is the second most powerful study design, provided there is enough replication to separate the effects of site to site variability and changes due to the treatment (i.e. addition of logs). It is not ideal, because any large-scale changes that coincide with the addition of logs (e.g. breaking of a drought) may affect all sites, and mask the effect of the specific treatment.
Figure 3c – Control-Impact (CI) study design, where measurements are taken at control and impact sites only after the logs are added, and no ‘before’ measurements are taken. Ideally, the impact and control sites are replicated to ensure adequate sample sizes. This is the third most powerful study design, provided there is enough replication to separate the effects of site to site variation in the variable of interest. This design is also sometimes referred to as a ‘space for time’ substation, because it is not possible to go back in time to collect before data. Frequent examples of this type of study include projects where the impact of something that has already occurred is studied retrospectively.
Figure 3d – After-only study design, where measurements are taken at impact sites and only after the logs are added, and no ‘before’ measurements are taken. Ideally, the after impact sites are replicated to ensure adequate sample sizes. This is the least powerful study design because there is no baseline or control to which the ‘after-log’ results can be compared.
Figure 3e – Gradient approach to studying the effect of a management intervention, in this case increasing the density of logs within parks. The question in this trial is not ‘do logs increase the number of bugs?’ but rather ‘what is the relationship between the abundance of logs in the park and number of bugs?’

Figure 3a – 3e. Infographic illustrating the different potential study designs that could be used for an experiment, in this case the hypothetical test of the effect of the addition of logs on the number of beetles in the park.
There are two approaches to replication (i.e. the number of sites within each treatment), namely taking measurements at different sites (left column) or at multiple plots within the same park (above). Ideally, each plot should be independent from each other and positioned sufficiently far apart that actions at one site do not affect the next site.
4.7 Timing and duration of the monitoring

It is important to carefully identify when you will start the monitoring, the frequency of monitoring bouts and the overall duration of the study. If the bugs occupying logs prefer rotting wood, then there is little point in doing the ‘after’ sampling before the wood begins to rot. Similarly, taking multiple samples a year may not be necessary if the population size doesn’t change much among seasons. And finally, if the likely change is expected to occur very slowly, it may be necessary to monitor infrequently but for a long period of time.

It is worth noting that experiments in the natural environment are often difficult to design and the study design will often be a compromise that attempts to balance cost, field constraints and maximum inferential strength.

4.8 Data collection and analysis

There are usually multiple ways to collect the data that you need, and the method(s) selected will be a trade-off among cost, accuracy, repeatability and technical skill. In some situations, it may not be possible to collect the data you actually want. Keeping in mind the issues described in Section 4.5, the data collected and the method of collection should be:

1) As simple as possible, thereby reducing the likelihood of mistakes or undocumented changes to the method.

2) Repeatable, so that if multiple people are involved over time, they each would get the same result if measuring the same thing, at the same time. This point is particularly relevant in projects involving large numbers of citizen scientists.

3) Reliable – does the data collected actually measure or indicate the variable of interest?

4) How much training is required to be able to collect the data? If only high-level specialists can collect the data, then the long-term prospects for the project are reduced because only specialists, who are often expensive, must be involved. Any budget cut may result in the expensive specialist being dropped.

5) Consistent over time. Any changes to the method should be avoided if possible and any changes must be clearly documented. If the method ‘drifts’ over time or if major changes are made without calibration, the data will not be comparable over time. If methods must be changed, a calibration phase is essential to test how consistent the old and new methods are and whether a correction factor must be applied to ensure they are comparable.

6) Repeated – because it is important to actually take the measurements in a consistent manner and as specified in the project plan. Repeated measuring can be tedious and boring, and there is a tendency for staff to cut corners or skip monitoring sessions because it seems unnecessary. However – collecting data is like making many small deposits of money into the bank – at the time each deposit may seem insignificant and a waste of time but the value gradually builds as more and more data is collected.

7) The data collection method must be clearly and carefully documented and stored with the data to ensure that in the future, the data can be re-analysed correctly.

8) The data should actually be analysed, including at regular or significant milestones and at the end of the project, and not just ‘eyeballed’ to get the gist of what is being monitored. Sometimes, analysis consists of cursory inspection of the data, or even worse a cursory inspection of the field site, and the conclusion that everything is just as expected is made. Data collection and analysis must be rigorous and disciplined.

The method of data analysis should be considered when selecting the data to be collected. If data analysis is not your strength, you should consult with an expert. In all cases, you should be striving to collect robust data sets and analysing them in the most scientifically correct manner.

Returning to the logs and bugs scenario, one might conclude that logs are good for bugs if the average number of bugs at treatment sites is 22 and 20 at sites without logs. However, closer inspection of the variability in the number of bugs at each site would show that the actual number per site ranged between 3 and 47 where logs were added and between 4 and 50 bugs at sites without logs. Based on this simple example, it is apparent that the average number of bugs is not that meaningful and more complex data analysis is required.

It is beyond the scope of this framework to provide guidance on the statistical analysis approach and method that should be adopted for each monitoring project. We recommend engaging with an experienced ecological statistician to co-develop the data to be collected and the analysis method.

4.9 Don’t overlook the nuts and bolts of budgets, staffing, equipment

Sometimes, the smallest items can complicate or derail a monitoring project, and an attention to detail during the planning stage will help to minimise this risk.

All relevant aspects should be considered, including:

- Do you have sufficient confirmed funds for the duration of the project or are you likely to secure the additional funds that you need?
- If you don’t have sufficient funds every year, will the project design allow for a variable timing of data collection?
• Can you get the equipment you need, when and where you need it?
• Do you need any specialist staff or skills, and if so, where can you obtain them?
• Do you need any ethics approvals or special permits? Have you taken into account how long it may take to get these approvals?
• Do you have a champion to guide and/or support the project?

4.10 Procuring and doing your research and monitoring

There are numerous models for undertaking the monitoring and different projects are more suited to one approach than another. Different procurement models include:

• Engaging a consultant to design and deliver the project or aspects of the project, either through a competitive bidding process or by requesting a quote from a specific supplier. Whichever procurement model is adopted, ensure the selection criteria are adequately weighted for research and monitoring expertise, and potentially other key aspects, such as data analysis. Intellectual property (IP) is usually owned by the agency or group who are commissioning the project.
• Enter into a research partnership with a relevant supplier, such as a consultant or individual/group from a university or consortium of a range of partners. Research partnerships imply mutual benefits to each party, and thus may be procured at lower cost. For this approach, the research and monitoring must also be academically rigorous and be publishable in the refereed scientific literature. Unfortunately, not all monitoring we do will reach this standard and this procurement model is likely only applicable to certain projects. IP is usually ‘shared’ by all parties collaborating on the research.
• City of Melbourne employees do all or some of the monitoring, evaluation and reporting, which is of course dependent on skill sets and budget within council.
• City of Melbourne employees supervise and conduct the monitoring, evaluation and reporting and engage citizen scientists to assist to varying degrees. Citizen science projects are excellent tools to engage the community and are currently going through a massive period of growth and popularity. Not all projects, however, are suitable to citizen scientists, such as ‘boring’, repetitive or menial tasks, those that take place at inconvenient times or places and those that require high-level skill sets. Nevertheless, the number and diversity of successful citizen science projects is growing as citizens become better trained and new methods are developed to accommodate the diversity of skill sets in the community.

4.11 Evaluation, reporting and communications

The adage in academia that ‘research isn’t finished until it is published’ also holds true in monitoring conducted by local government. It is important that the data is evaluated, reported on and used regularly and frequently to inform management. Ethically, we also have a responsibility to ensure tax-payer funds are well-spent and seeing a monitoring project through to completion is important. However, if you are evaluating an existing monitoring program and if it is it is clear that the program is not achieving its aims, it should be modified or terminated.

Monitoring projects should be designed to deliver findings and (interim) recommendations throughout its lifespan for three primary reasons. The first is that timely advice, even qualified as ‘preliminary’, has the potential to improve management actions as soon as management advice becomes available. The second reason for regular reporting is that managers will see value from the monitoring as it guides management and thereby continue to support the program. Finally, if a monitoring program is discontinued, all data collected to date is not ‘wasted’ because at least some of it will have been evaluated and reported.

The results of monitoring should always be made freely available to the community via an appropriate data-sharing platform, unless the monitoring or aspects of the data are sensitive or confidential in nature. This approach to data-sharing will maximise the value of the data for learning because it allows others to access and re-analyse the data at no extra cost to us. In addition, it allows the community, who funded the research and monitoring via their rates and taxes, to access the data and independently assess our performance. An agreement between the researchers and council which outlines the data-sharing arrangements should be prepared prior to commencing the work, including consideration of:

• The time period after project completion as to when the data is made public, and giving researchers sufficient time after finishing the project within which to publish the results.
• Outlining whether IP is equally shared or owned by one party and commercialisation of any project products or IP.
• Any expectations for co-authorship or co-badging of publications or other outputs.
• Any expectations around whether other parties need to approve the content of any publications, and the nature of that approval, such as by whom, written or verbal and the period of notice that must be provided.

Most researcher centres will have a legal team who negotiate these details, and sometimes it can take many months to finalise these arrangements.
4.12 When is monitoring finished?

While not ideal, most monitoring programs finish when money runs out or when interest and enthusiasm in the program declines or ends. Other monitoring programs are shut down when champions leave or when it is discovered that the monitoring is not providing answers to the questions that need answering. Ideally, monitoring should cease when we have answered the specific question(s) that were established at the beginning or answered the revised questions that were reformulated during the monitoring.

4.13 Data storage

It is very frustrating to know that monitoring was conducted some years ago but not being able to locate the report or data sets. These historic data sets may provide the answers to a current question or provide some baseline data against which new comparisons can be made, thereby potentially saving time and money. For this reason, data should be stored on an open-data platform, provided there is some certainty that the portal itself will be maintained and remain accessible into the future. Other data storage platforms exist, such as the Atlas of Living Australia (ALA) and the Victorian Biodiversity Atlas (VBA). In many cases, submitting records to these databases is a condition of the permit required to undertake flora and fauna surveys that are granted by relevant government departments. Consider holding the final payment until the partner can confirm the submission of raw data to these databases. It is council’s responsibility to ensure the final report is securely archived and linked with the raw data so future users can easily access both.

Ideally, the data will also be integrated into databases and data sets used by the City of Melbourne, such as asset management software. This will add to the cost-effectiveness of the monitoring program, because the data collected can answer the specific monitoring question(s) as well as be of everyday use for management. For example, hollows in trees may be mapped as an asset and their size, shape and patterns of use can be recorded. Recording data in this way also ensures it can be used on a daily basis, thereby increasing its value for the City of Melbourne and providing justification for continued monitoring.
5.0 EVALUATING THE SUCCESS OF THE NATURE IN THE CITY STRATEGY

This section of the BMERF outlines how the City of Melbourne will evaluate the health of the natural environment for biodiversity by measuring the condition of our species, vegetation communities and habitats (i.e. Action 1 in the 2017 Nature in the City Strategy). It also focuses on people’s connection to nature, as it relates to their pro-environmental actions, as well as the role of the City of Melbourne as local and global leaders in urban ecology. This BMERF does not focus on environmental health for people, such as the effects of noise, light or chemical pollution on people’s health and wellbeing.

5.1 Fundamental strategy objectives and monitoring objectives

The program logic for the Nature in the City Strategy describes the relationships among the three goals, six priorities and 23 actions of the Nature in the City Strategy. City of Melbourne staff reviewed the goals, priorities and actions of the Nature in the City Strategy, and other relevant strategies and plans, and synthesised these into groupings with similar themes. These were then analysed and organised into a series of conceptual models (Figures 5a - d) to identify the fundamental objectives of the Nature in the City Strategy, which express the underlying basis for our nature in the city work. Furthermore, this process distils the Goals, Priorities and Actions of Nature in the City into a small number of fundamental objectives from which monitoring and evaluation objectives were derived. More detail of this process is provided in Appendix 1.

The conceptual models (Figures 5a - d) portray how the actions of the Nature in the City Strategy and the means objectives achieve the fundamental objectives of the Nature in the City Strategy. Means objectives are essentially intermediate steps or actions that allow us to ultimately achieve one or more fundamental objectives. For example, the reason we want more nature (first cell in Figure 5a) is because we want to increase health and wellbeing of the community, which is a fundamental objective. Other reasons we want more nature (also Figure 5a) ultimately lead to increased biodiversity and increased ecosystem health, via intermediate means objectives such as attracting more people, increasing liveability, increased economic viability, etc. Targets (i.e. Priorities of the Nature in the City Strategy) and the Goals of the Nature in the City Strategy are noted within the cells. Improving knowledge of indigenous practices and demonstrating local and international leadership were initially identified as a means objective, but are specified here as fundamental objectives because they are strategic priorities directing the City of Melbourne.

Using these conceptual models, monitoring programs can be designed to answer questions of how to best achieve a Strategy means or fundamental objective through specific actions, or to demonstrate an outcome of actions, e.g. data to demonstrate increased connectivity. The fundamental objectives and monitoring objectives in the Nature in the City Strategy are outlined in Table 1 and 2, respectively.
Figure 5a

More nature of all types in both the public and private realm

Attract people who actively and positively contribute to city life

Increase vibrancy and liveability

Increase economic viability

Connect people to nature (Goal and Target)

Increase appreciation of nature (Target)

Increased local support for NitC actions

Increased money and ability to act

Increased public maintenance of nature (Target) (this might also include greening in private realm)

Increased social license for CoM to act

Increased money and ability to act

More native biodiversity and increased ecosystem health (both are targets)

Increased health and well-being of the community (both are targets)

Figure 5b

Deliver flagship projects (Target)

Demonstrate local and international leadership and reputation (Goal)

Contribute to making CoM a SMART city

Increase local support for ecological actions

Increase money and ability to act

More native biodiversity (Target)

Increase local capacity for new products or expertise, drive innovation, and provide demonstration sites

Increase tourism

Increased economic viability

Increase productivity

Increase vibrancy and liveability

Attract diverse, creative, entrepreneurial and innovative people

Increase health and well-being of the community (both are targets)
Figure 5a – 5d. Conceptual models for Nature in the City, as revealed through a structured decision making process. Actions in the Nature in the City Strategy are shown in grey, means objectives shown in light green, and fundamental objectives to be monitored shown in white. Targets (i.e. Priorities of the Nature in the City Strategy) and the Goals of the Nature in the City Strategy are noted within the cells. Improving knowledge of indigenous practices and demonstrating local and international leadership were initially identified as a means objective, but are specified here as fundamental objectives because they are strategic priorities directing the City of Melbourne (white cells outlined with light green).
### Table 1 - The fundamental objectives in the Nature in the City Strategy.

<table>
<thead>
<tr>
<th>FUNDAMENTAL OBJECTIVES</th>
<th>DEFINITION/IMPORTANT ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase native biodiversity</td>
<td>Increase native biodiversity within the City of Melbourne. Ensure no loss of current native species that occur in the City of Melbourne.</td>
</tr>
<tr>
<td>Increase the health of the natural environment</td>
<td>Improve ecosystem health via the structure, function and composition of all components of the ecosystem (i.e. more than simply the extent of native vegetation).</td>
</tr>
<tr>
<td>Increase the physical health of the community</td>
<td>The Strategy aims to connect more people to nature to improve their physical health, because activity in nature and greenspace improves the physical health of City of Melbourne residents and visitors.</td>
</tr>
<tr>
<td>Increase the wellbeing of the community</td>
<td>The Strategy aims to connect more people to nature to improve social health, wellbeing and resilience. Wellbeing relates to mental and spiritual wellbeing of City of Melbourne residents and visitors, as reflected by their satisfaction or happiness in nature or greenspace.</td>
</tr>
<tr>
<td>Increase adoption of Caring for Country principles</td>
<td>The City of Melbourne wants to apply Caring for Country as a way of learning from sustainable practices used by the Traditional Owners of the land, the Boon Wurrung and Woiwurrung (Wurundjeri) peoples of the Kulin Nation, whilst acknowledging and celebrating Aboriginal culture.</td>
</tr>
<tr>
<td>Increase local and global leadership in urban ecology</td>
<td>Increasing local and global leadership is a strategic objective for the City of Melbourne, in order to ensure the City of Melbourne is a local and global leader in successful and innovative management and conservation of biodiversity.</td>
</tr>
</tbody>
</table>

### Table 2 - The monitoring objectives in the Nature in the City Strategy.

<table>
<thead>
<tr>
<th>MONITORING OBJECTIVES</th>
<th>DEFINITION/IMPORTANT ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record change in native biodiversity as a result of CoM actions</td>
<td>The Strategy aims to increase native biodiversity within the City of Melbourne. Monitoring is required to measure the change in key groups of biodiversity (e.g. invertebrates, plants, birds, mammals) to detect if and how large an increase occurs.</td>
</tr>
<tr>
<td>Record changes in the health of the natural environment as a result of CoM actions</td>
<td>The Strategy aims to improve ecosystem health via the structure, function and composition of all components of the ecosystem (i.e. more than simply the extent of native vegetation). Monitoring will measure changes in ecosystem health in response to actions across the City of Melbourne.</td>
</tr>
<tr>
<td>Record change in the physical health of the community</td>
<td>The Strategy aims to increase the physical health of the community by increasing their levels of physical activity in nature and greenspace. Monitoring will measure metrics of physical health of residents and visitors.</td>
</tr>
<tr>
<td>Record change in the wellbeing of the community</td>
<td>The Strategy aims to connect more people to nature to improve social health, wellbeing and resilience. Monitoring will measure the mental and spiritual wellbeing of City of Melbourne residents and visitors, as reflected by their satisfaction or happiness in nature or greenspace.</td>
</tr>
<tr>
<td>Record change in the adoption of Caring for Country principles</td>
<td>Caring for Country is a way of incorporating sustainable practices used by the Traditional Owners of the land into everyday practices. Monitoring will measure changes in the level of knowledge and adoption of caring for country principles and practices within City of Melbourne.</td>
</tr>
<tr>
<td>Record change in our local and global leadership in urban ecology</td>
<td>The City of Melbourne aspires to be a local and global leader in urban ecology and our monitoring will assess the extent to which we are achieving this leadership role.</td>
</tr>
</tbody>
</table>
5.2 Performance measures and targets for the Nature in the City Strategy

Performance measures are specific metrics that allow the impact of management or monitoring to be evaluated. Good performance measures are clear and concise, unambiguous, understandable, direct and operational. The current performance measures for each of the monitoring objectives are specified in Table 3.

The performance measures will be refined and updated in future versions of this BMERF as further investigations and planning are completed. For example, the City of Melbourne are working to benchmark the degree of connectedness to nature of the community as well as investigating the use of species-area relationships to provide species richness targets for parks in the City of Melbourne area. It is too early to develop specific targets for these two objectives before baselines are established and robust methods for setting targets established.

Table 3 - Fundamental strategy and monitoring objectives, targets and performance measures to evaluate success of Nature in the City.

<table>
<thead>
<tr>
<th>FUNDAMENTAL OBJECTIVE OF NATURE IN THE CITY STRATEGY</th>
<th>STRATEGY TARGET - BY 2027 (MONITORING REQUIRED TO DETERMINE IF THESE TARGETS HAVE BEEN ACHIEVED)</th>
<th>MONITORING JUSTIFICATION, METHOD AND FURTHER EXPLANATION</th>
<th>ADDITIONAL WORK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase native biodiversity</td>
<td>• No loss of native species from the City of Melbourne municipality.</td>
<td>• Birds and insects are reliable indicators of biodiversity and standardised survey techniques available.</td>
<td>• Investigate the feasibility of developing species-richness targets for greenspace using the species-area relationship. The species-area relationship is a well-accepted ecological theory but its application to developing species richness targets for greenspace in urban environments is novel.</td>
</tr>
<tr>
<td></td>
<td>• Increase the species richness of native birds and insects within greenspace (excluding sports fields).</td>
<td>• Annually compile publically-available data on species occurrence and analyse for trends, ensuring sufficient survey effort across space and time.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increase area of understorey habitat across the City of Melbourne municipality by 20 per cent.</td>
<td>• Undertake regular targeted bird and insect surveys using standardised techniques where available data insufficient.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increase area of biodiversity plantings across the City of Melbourne municipality.</td>
<td>• Undertake annual mapping of extent of understorey vegetation and biodiversity plantings.</td>
<td></td>
</tr>
<tr>
<td>Increase health of the natural environment</td>
<td>• Increase the percentage of sites or assets with ‘healthy’ vegetation and habitat.</td>
<td>• Undertake annual assessments of site health through existing Quality Assessment Audits.</td>
<td>• Identify and test additional ecologically-relevant criteria to include in the assessment and include these in future Quality Assessment Audits.</td>
</tr>
</tbody>
</table>
### FUNDAMENTAL OBJECTIVE OF NATURE IN THE CITY STRATEGY

#### STRATEGY TARGET - BY 2027 (MONITORING REQUIRED TO DETERMINE IF THESE TARGETS HAVE BEEN ACHIEVED)

<table>
<thead>
<tr>
<th>Objective</th>
<th>Target Details</th>
<th>Monitoring Justification, Method and Further Explanation</th>
<th>Additional Work</th>
</tr>
</thead>
</table>
| **Increase the physical health of the community** | • Increase the proportion of City of Melbourne residents and visitors visiting green space in the City of Melbourne municipality each week for a minimum of 30 mins in a single visit.  
• Increase the proportion of residents and visitors in the City of Melbourne participating at least once a year in active, outdoor biodiversity monitoring activities. | • There is evidence that visiting greenspace is correlated with benefits to physical health, and weekly visits to green spaces of > 30 mins in duration could reduce prevalence of some health issues (Shanahan et al. 2016).  
• Rate of increase of both targets to exceed rate of population growth. | • Establish baselines of both targets prior to setting a 2027 target.  
• Explore opportunities with relevant partners to quantify baselines and track progress. |
| **Increase well-being of the community**       | • Increase the percentage of people involved in nature-related monitoring activities who rate such activities with a ‘very high’ satisfaction score, measuring belief that their contribution matters to management or learning of nature. | • Targeted surveys of participants involved in specific activities.  
• Assess community levels of connection to nature, using standardised approach. | • Embed survey protocols within Citizen Forester program, and other community monitoring activities.  
• Develop targets and measures for connection to nature.  
• Quantify baseline prior to setting specific targets. |
| **Increase local and global leadership**       | • Increase relevant metrics quantifying access to the Urban Nature website (http://www.melbourne.vic.gov.au/urbannature). | • Metrics that quantify access of the Urban Nature website and downloads of ‘nature’ open data sources is a simple proxy and website analytics are a good measure of that. | • Work with internal stakeholders to develop and access relevant IT analytics, such as # and country of origin of hits, time spent per visit, # downloads, etc. |
| **Increase adoption of Caring for Country principles** | • Increase the proportion of the population (visitors and residents, indigenous and non-indigenous) with knowledge of Caring for Country and how it can be used to inform management of nature. | • No data or survey instrument currently available.  
• Caring for Country principles still being developed by the City of Melbourne. | • Work with Aboriginal Melbourne at the City of Melbourne to co-develop metrics. |

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Table 3 - Cont’d
6.0 RESEARCH, MONITORING AND TRIALS: CASE STUDIES IN THE CITY OF MELBOURNE

The case studies in this section demonstrate how the framework described in Sections 4 and 5 have variously been applied, with each case study highlighting different aspects of planning, conducting and reporting on research.

6.1 Mistletoe in plane trees

Until the adoption of the Nature in the City Strategy, Melbourne’s urban forest has been primarily managed for amenity, shade and risk reduction. With a new focus on enhancing biodiversity, the City of Melbourne have identified a range of opportunities for novel interventions to our urban forest to enhance the value for biodiversity. One of the first interventions, conducted in mid-2017, was the inoculation of 27 London Plane trees (Platanus x acerifolia) along selected streets of Melbourne with creeping mistletoe (Muellerina eucalyptoides). Until then, mistletoe had been considered a pest to be removed from trees because they were understood to be parasites that kill their host. Mistletoe, however, is a keystone species in natural forests, providing a rich source of food, shelter and other resources for a host of wildlife species.

There was significant concern that establishing and propagating mistletoe in Melbourne’s urban forest might have negative consequences, including the failure or death of branches or even entire trees. This was compounded by not knowing whether mistletoe would actually achieve the anticipated biodiversity outcomes within the highly urbanised City of Melbourne, because no-one had tried this before.

How should City of Melbourne embark on novel, ambitious ‘restoration’ projects such as the mistletoe project, whilst maintaining the health of the urban forest and assessing the biodiversity benefits?

The first step in the project was to undertake a comprehensive review of the scientific and grey literature on everything related to mistletoe in urban areas and the propagation of mistletoe seeds. The City of Melbourne lacked the necessary expertise in mistletoe ecology and engaged Professor David Watson from Charles Sturt University to assist. The City of Melbourne commissioned David Watson to undertake the comprehensive literature review and recommend a series of next steps, focusing on (i) which species of mistletoe and host tree to target; (ii) timing and methods of seed collection and inoculation; and (iii) the likely impacts of mistletoe on tree health. This literature review is currently being revised for submission to a scientific journal. The literature review also included an experimental study design to evaluate the follow questions:

1) What is the rate of germination and establishment of mistletoe on London Plane trees in central Melbourne?
2) To what extent does mistletoe affect tree health and survival?
3) Does mistletoe increase the richness or abundance of birds and butterflies?

A Before-After Control-Impact (BACI) experiment was developed, with mistletoe seeds to be wiped on pencil-sized branches of 27 London Plane trees, at the cardinal points within the tree canopy. A monitoring program was developed, with data on tree health and use by birds and butterflies collected before mistletoe establishment and to be conducted annually after establishment. Data on survival and growth stage of each seed will also be assessed annually. Data was collected at trees to be inoculated with mistletoe (i.e. ‘impact’ trees) as well as London Plane trees of similar size (as shown by diameter at breast height - DBH) and location (along streets) nearby but without mistletoe (i.e. ‘control’ trees). In this project, the individual London Plane trees are the experimental unit, thereby allowing for literally hundreds of treatment and control trees to choose from. We excluded trees within the Hoddle Grid, trees with a DBH < 40 cm, and trees that required traffic management to access them with a travel tower.

An integral component of this project was the collaborative partnership we formed with David Watson from Charles Sturt University. As an international expert in the ecology of mistletoe, David has an ongoing interest in the project, ensuring our understanding of mistletoe ecology was accurate and our experiment and monitoring was scientifically robust. We are currently seeking opportunities to expand the project with additional partners and research funding from government and philanthropic sources.

6.2 Are tree hollows limiting hollow-dependent biodiversity in the City of Melbourne?

A vast number of species of wildlife in Australia require tree hollows for shelter and raising young. A significant issue in many landscapes globally is the decline of large old trees, and an associated reduction in the abundance and diversity of tree hollows, because in Australian forests, hollows typically begin developing in trees at least 100 – 120 years of age. Urban areas in particular are typified by relatively low densities of large trees and low abundances of tree hollows because such trees are often removed due to the risk they pose to people and property. Consequently, the loss of large trees is considered a threatening process for conservation of biodiversity, and is officially recognised as such in Victorian forests under the state Flora and Fauna Guarantee Act (1988).
The second action of the Nature in the City Strategy is to identify and mitigate threats that impact nature in our city, and since 2017, the City of Melbourne are seeking opportunities to retain and create tree hollows for wildlife. We identified numerous knowledge gaps that were limiting our ability to implement hollow retention and creation and evaluate the success of our efforts:

1) Which species of wildlife within the City of Melbourne use hollows and are the populations of any limited by the number of hollows?
2) Which technique of hollow creation (nest box, installed hollow log or carved hollow) is more effective?
3) Where within the City of Melbourne should we create or retain more hollows?
4) Where are tree hollows located within the City of Melbourne and what are the characteristics (e.g. size, position in tree and location of tree) of each tree and hollow?

To answer the first question, in 2017 we commissioned BirdLife Australia to conduct a literature review of the species of birds and bats that occur within the City of Melbourne and describe all that is known of the characteristics of the hollows they utilise. From this information we identified some target species and the dimensions of hollows we intend to create.

In Spring 2017, the City of Melbourne conducted our first HollowBlitz with members of the community, where we surveyed trees within Fawkner Park, Fitzroy Gardens, a portion of Royal Park, the Stock Reserve in Kensington and Carlton Gardens and recorded signs of hollow use by nesting birds. Systematic surveys of hollows in all our trees will be undertaken over time whenever trees are assessed and when the urban forest database is updated.

Monitoring the effects of tree hollow creation and retention is difficult because there are questions at a number of levels. The simplest level of monitoring could be to focus on patterns of the use of specific hollows by wildlife and record the condition of the hollow over time and any maintenance conducted. Comparisons can be made among rates of use and characteristics of the hollow, such as hollow type (nest box, hollow log, chainsaw hollow, natural cavity), height and position within tree, aspect, tree species, type of park, etc. At this level of study, it is probably feasible to generate sufficient replication of a small number of different treatments to enable a robust analysis of the data to answer a simple question.

In contrast, the next level of monitoring is much more complicated because it might aim to determine how the community of birds, bats or other hollow-dependent wildlife changes (e.g. species richness, abundance) as the density of hollows increases. This is significantly more complicated because the park becomes the unit of experimentation and monitoring, and there are insufficient parks in the City of Melbourne to have adequate replication of both control sites and treatment sites. Furthermore, if the question is about the effect of additional hollows on successful reproduction of birds, there are other factors, such as food availability, that should be considered and factored into the experimental design. Such a study is not impossible, it may just require collaboration with other local governments to increase the pool of potential study sites and simplifying the question to ensure it can be thoroughly addressed. To that end, the Cities of Melbourne and Bayside have co-developed a ‘hollow creation framework’ to guide:

- the creation of hollows of specific sizes
- the data to be recorded for each hollow
- type and frequency of monitoring
- data storage and sharing

Importantly, this type of monitoring is intuitively simple (just go and survey birds in a few parks after creating hollows) but such thoughtless monitoring will almost definitely not be able to assess how successful the hollow-creation program is because there is no experimental design, insufficient replication and no control sites.

6.3 Mangroves planting trial at Docklands

For a number of years, there have been discussions at the City of Melbourne to introduce Grey Mangroves (Avicennia marina var. australasica) to certain tidal areas in the municipality. Areas around the Melbourne suburb, Docklands and the Moonee Ponds Creek have been identified as potentially suitable areas for establishment of mangroves considering the success of mangroves at the Stony Creek Backwash and areas of the Yarra River near Westgate Park. In May and June 2017, 118 Grey Mangrove seedlings were planted in Docklands, Melbourne by Ecology Australia. These plantings were monitored every week for the month of June 2017 by Ecology Australia. When monitoring took place it involved assessing the survival of the plants by measuring the number that remained at the site, the height of the plants, and any other general site notes. The rationale behind monitoring was to track survival of mangroves and ultimately the ‘success’ of the project, however, it had deeper roots in enhancing biodiversity across the city and evaluating if mangroves can be affordable and quick carbon sink alternatives.

Monitoring by Ecology Australia ended after this period, and it was decided the City of Melbourne would internally monitor this mangrove planting trial at Docklands at monthly intervals for the next six months. There was a large quantity of both natural (logs, sticks, rocks) and artificial (bottles, packaging, furniture) debris at the site, which significantly impacted seedling survival through physical abrasion. Therefore, at each monitoring event, information around the quantity and type of litter was recorded in
addition to a count of survival, such as the number of mangroves remaining at the site. This monitoring data demonstrated a link between litter quantity and mangrove survival, and as such, a line barrier was installed in September 2017 with the aim to block litter accumulating on the site. This was also paired with weekly litter removal by Serco and other contractors. Whilst litter on site appeared to decline slightly, the number of mangroves surviving still declined. At the end of the monitoring period, 41 mangroves were remaining.

There are currently investigations into the future of the mangroves planting trial at Docklands. Monitoring in this instance has allowed the Urban Forest and Ecology Team to track this project and the declines of mangroves at this site, identify management issues at the site, and will allow for possible repeatability if this was to be repeated in future years.

6.4 Habitat enhancement at the Wildlife Reserve on Dynon Road

Large rocks are an important habitat component for reptiles as they provide basking substrates and shelter. The Wildlife Reserve on Dynon Road has been revegetated and is dominated by garden beds with trees and shrubs and areas of turf. Complexity of the ground layer is lacking, and numerous logs have been added over the past few years. In early 2018, large rocks were added to the park to provide habitat for reptiles, primarily skinks. The question was raised about the need for monitoring and whether we needed to evaluate the effect of adding rocks on skinks.

The City of Melbourne staff evaluated whether monitoring was required and feasible and asked the following questions:

1) How confident are we that adding rocks will benefit skinks? The scientific literature confirmed that rocks are important habitat for skinks and that they will use them for basking and for shelter. There is no doubt that adding rocks will improve the quality of the habitat for skinks at the site.

2) How big is the skink population at the Wildlife Reserve? There are no records of skinks at the reserve from any government database, either the Victorian Biodiversity Atlas or the Atlas of Living Australia. However, the absence of records is more likely because no-one has looked, rather than a true absence. For this example, we have assumed that skinks occur at the reserve.

3) Can the rocks be placed in an experimental manner to enable reliable monitoring? The Wildlife Reserve is quite small and there is only sufficient space for four piles of rocks, and areas without rocks or different-sized piles of rock are not feasible options. Furthermore, because the reserve is so small, the piles of rock are not independent, which means that the skinks around one pile of rocks will be influenced by the nearby other pile of rocks.

4) What sort of monitoring would be required? The key question for this project revolves around whether the population of skinks increases with the addition of rocks. Surveys to assess skink numbers are labour intensive and involve the capture, marking and recapture of individual skinks over time to enable a reliable estimate of population size to be calculated.

5) Is a cost-effective monitoring option available? The surveys to estimate the size of the population of skinks would likely take multiple weeks annually and need to be conducted over a number of years. The City of Melbourne does not have the resources available or specialised expertise to conduct these surveys in-house, and thus would require the services of an ecological consultant. The rocks cost less than $1000 to install, and thus the cost to undertake the monitoring significantly outweighed the cost to install, and thus is not justified. Furthermore, there is little uncertainty associated with the outcome, and the risks associated with failure are so small, that there is no imperative to conduct monitoring.

6) The conclusion? Monitoring the effectiveness of placing rocks at the Wildlife Reserve was not justified because the City of Melbourne was quite sure it would be effective, the monitoring costs would be very high, there was insufficient scope for a robust study design and the risks associated with failure were very small.
6.5 Trials to select new tree species for Melbourne’s future urban forest

Melbourne’s climate is changing due to the urban heat-island effect and global climate change. The City of Melbourne has recognised that we need to increase the diversity of our urban forest to provide resilience and reduce the threat of altered climates on the survival of trees in our urban forest.

In 2016, The City of Melbourne commissioned Dr Dave Kendal and Jess Baumann to assess the suitability of 2000 species of trees for the future climate. Over a third of the species and one-fifth of trees currently growing in Melbourne were moderately or extremely vulnerable to existing temperatures, with significant increases in vulnerability under moderate and extreme climate-change scenarios.

In order to prepare for Melbourne's likely future climate, the City of Melbourne needs to identify and plant trees that will survive and thrive in the harsh urban conditions expected over the next 100 years. City of Melbourne are developing an approach to guide the design and methods of trials to measure the performance of species of trees that are new to Melbourne. The following parameters, to name just a few, are being considered:

- General planting location (e.g. park, street or residential area)
- Specific planting location (e.g. CBD or residential street, large park vs pocket park)
- Orientation of the street
- Solar radiation (e.g. full sun, partial shade)
- Degree of irrigation (e.g. on demand, passive, WSUD)
- Position of tree (e.g. in a nature strip, cut out, median)
- Soil volume

It is apparent that many factors affect the survival, growth and performance of trees in the city and it is not feasible to rigorously test all combinations of parameters within the logistic and financial constraints that councils operate under. Therefore, City of Melbourne have engaged a consultant to identify both the most important parameters to consider when designing the trials and the specific attributes to measure, such as growth rates, health and survival.
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REFERENCES


APPENDIX 1. STRUCTURED DECISION MAKING PROCESS 2017: FULL PROBLEM STATEMENT

Completed by Libby Rumpff, the University of Melbourne:

The City of Melbourne municipality is a diverse socio-ecological area that includes the city centre and a group of inner city suburbs, covering an area of 37.6 square kilometres. In April 2017, the City of Melbourne endorsed their Nature in the City Strategy (hereafter the ‘Strategy’), which provides a guide for the City of Melbourne to achieve a vision of ‘diverse, resilient and healthy ecosystem’ in the municipality through the management of biodiversity. Within the Strategy, it is stated that the development of a Biodiversity Monitoring Framework is a critical step that will allow the City of Melbourne to understand and report on the success of implementation programs to the broader community and stakeholders, develop targets, and inform decision-making.

The Urban Forest and Ecology Team within the Urban Sustainability Branch makes decisions about which projects to develop and monitor to meet the goals and priorities specified in the Strategy. The decision around funding of biodiversity projects and monitoring relates to the entire municipality and includes, private and public land, roads, roofs, walls, parks, green space, wetlands and waterways – both the natural and built environment.

The Urban Forest and Ecology Team within the City of Melbourne see several impediments to their ability to determine how biodiversity-related projects, research and monitoring should be organised and prioritised.

1) In relation to how and when projects are implemented to meet the goals and priorities of the Strategy, there is recognition that decision-making by the Urban Forest and Ecology Team is often reactionary and opportunistic. This is due to several factors: i) It is difficult to have long-term planning due to lack of hard targets, vague implementation times frames and budget uncertainty; ii) Developing justified long term plans is hampered by uncertainty around social, financial and ecological outcomes of management actions; iii) The annual time frame for budgetary commitments impedes the Urban Forest and Ecology Team’s ability to implement best management actions to ensure long-term success (i.e. both to achieve and maintain outcomes).

2) Decisions about which projects to implement, and when, are not necessarily within the control of the Urban Forest and Ecology Team. Projects may be first proposed by the Urban Forest and Ecology Team, and endorsement is granted by different levels of management, depending on the scale and cost of the project, ranging from Team Leader (David Callow as at May 2018) through to the Director of the City, Strategy and Place Group (Claire Ferres Miles as at May 2018). The City of Melbourne Councillors can also influence priorities and decisions, as driven by community expectations. The Parks, Property and Waterways Branch and the City Design Studio Branch play a key role in determining which projects can be implemented, based on the maintenance budget available and design aesthetic.

3) Similarly, there is currently an ad hoc approach to deciding whether monitoring is undertaken to evaluate these projects. Some monitoring is currently undertaken, however, this often targets the measuring of outputs (short-term results associated with the implementation of an activity e.g. area planted), not outcomes (results related to the performance of an activity in relation to objectives e.g. ‘condition’ of area planted). Informing future staff and the community about what has been done, and what was achieved is difficult because there is no central repository to store and use the data. Last, it is recognised that there is a lack of guidance and expertise for City of Melbourne staff to support decisions about how and where to implement a targeted monitoring program that can inform Strategy objectives.

As such, the Urban Forest and Ecology Team aims to develop a clear and transparent process for evaluating the effectiveness of both their management and monitoring, in relation to the objectives of the Strategy. This is to move towards having a justified, long-term action plan that supports development of targets and implementation of the Strategy. This process is designed to: i) provide a clear definition of both Strategy and monitoring program objectives; ii) start developing measures and targets such that these objectives can be evaluated; iii) create a list of potential alternative management and monitoring plans (in addition to the status quo) that could implemented;
iv) evaluate the performance or effectiveness of each of these plans in relation the objectives; and v) provide a transparent methodology for evaluating trade-offs between objectives to arrive at a preferred alternative (if possible). This process can be refined as new information becomes available and applied to other areas of the City of Melbourne to guide decision making.

There are multiple timeframes over which decisions about how to manage and monitor will be made and evaluated. The Strategy provides a plan for 10 years of management actions, with projects scheduled annually, and budgets are typically completed annually. The Urban Forest and Ecology Team must deliver on these actions and are accountable to them (but there is scope for deciding on the specifics of each project). Reporting occurs annually. Despite the shorter-term funding and management planning cycles, however, some biodiversity outcomes will be evaluated over longer time frames (e.g., potentially up to 50 years).

There are many actions that originate across multiple branches within the City of Melbourne that influence the City of Melbourne’s ability to meet the goals and priorities of the Nature in the City Strategy and this evaluation process must speak to that. Other stakeholders impacted by decisions made by the Team include: Open Space Planners (strategic park planning), Landscape Architects (park and street design and species selection) and the Parks, Property and Waterways Branch (maintenance of Parks), the rest of the Urban Sustainability Branch – e.g. Climate Resilience team (Climate Change Adaptation Strategy), Green infrastructure, etc. We aim for this to be an integrated process to improve the City of Melbourne’s ability to meet goals and priorities. Other stakeholders include land holders and land managers, Parks Victoria, Melbourne Water, Vic Roads, Vic Track and Development Victoria.

It is important to note that the Strategy works alongside other existing City of Melbourne strategies and projects, such as the Open Space Strategy, and the Urban Forest Strategy etc (City of Melbourne 2017), and that the legal context to be considered includes the Environment Protection and Biodiversity Conservation Act 1999, the Flora and Fauna Guarantee Act 1988, and the RAMSAR Convention.
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