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Long-term monitoring plan of Squirrel Glider populations in Thurgoona-Wirlinga: Final Report.

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ROYAL BOTANIC GARDENS VICTORIA

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Executive summary

Squirrel Gliders are widely distributed across Thurgoona-Wirlinga, occurring in patches and linear strips of woodland along roads and streams, within relatively young environmental plantings and scattered trees. Several studies and numerous surveys have been conducted on Squirrel Gliders within the region, including those commissioned by the Albury Conservation Company, community groups and government monitoring programs, impact assessments and university research projects. While these have all been informative in their own right, a coordinated approach is needed to better understand the impacts of future urbanisation and the effectiveness of management actions on Squirrel Glider populations.

The Albury Conservation Company recognised the need for a long-term monitoring program to better understand the current and future status and distribution of Squirrel Glider populations across Thurgoona-Wirlinga, and help management best respond to future landscape change. Key aims include:

- Determine the **current distribution** of Squirrel Gliders in the study area
- Track **changes in the presence and distribution** of Squirrel Gliders across the landscape **over time**
- Provide information on the **important habitat features** influencing the presence of Squirrel Gliders
- **Engage the community** in the protection and enhancement of Squirrel Glider populations by providing avenues to participate in monitoring and restoration works
- Maintain a strong base program with potential to **incorporate complementary research projects** as funding and opportunities become available.

We recommend that a simple, baseline program be established to detect changes in the occupancy, distribution and abundance of Squirrel Gliders across the Thurgoona-Wirlinga. The recommended monitoring program consists of:

- Camera traps being the primary survey method to determine occupancy and distribution of Squirrel Gliders at sampling sites.
- Other survey techniques, such as stagwatching, nest-box surveys and spotlighting are complimentary techniques but are not recommended as the core survey method. A summary of the pros and cons of different survey techniques is given in Appendix 3.
- Squirrel Gliders are to be surveyed at 80–100 sites with existing trees or sites to be revegetated with trees set at approximately 1 km intervals in a grid across the landscape. The grid locations ensure an unbiased and random sample of sites across the study area. However, if necessary, the grid points can be adjusted slightly to avoid cleared areas or an over-representation of certain site types (e.g. roadsides, waterways, large or small patches etc).
- The actual selection of sites will occur during the implementation stage of the program when site visits are conducted and the number of sites of different types can be assessed.
- Sites should include a range of patch sizes, qualities and surrounding landscape uses
- One camera will be set per site for a minimum of seven nights, preferably twice per year (Spring and Autumn). If two surveys per year cannot be conducted, the Autumn survey should remain.
- Conduct detailed habitat assessments at each site during the first round of surveys to determine site type, vegetation type, habitat quality and nature

of the surrounding landscape. Detailed habitat assessments should be repeated at five-yearly intervals, with rapid (< 5 min) assessments conducted at each survey.

- The implementation of the monitoring plan is to be co-ordinated and guided by a Project Ecologist/s, and implemented in partnership with the local community as ‘citizen scientists’.
- Citizen-scientists to inspect camera footage through an online platform (e.g. Zooniverse).
- The monitoring plan has been developed to be responsive and adaptive in order take advantage of funding opportunities, student research projects and other events as they arise. However, by stipulating a set of consistent methods, the long-term reliability of the monitoring data can be maintained.

We recommend that ACC appoint a project ecologist to implement the monitoiring program, including: selection of sites and ensuring all site types are represented; arranging site access; seeking funds to support the program; setting up survey image storage/identification protocols; and commencing recruitment of volunteer citizen scientists. Importantly, the project ecologist will also be responsible for co-ordinating and running the field surveys.

Introduction and scope

The Australian Research Centre for Urban Ecology was commissioned by the Albury Conservation Company (ACC) to develop a long-term monitoring program for Squirrel Gliders in Thurgoona-Wirlinga. This document outlines the monitoring plan (hereafter “the plan”) that has been developed following an initial discussion paper and consultation with the Albury Conservation Company and stakeholder workshop in August 2016.

The plan consists of two sections. Section 1 provides background information on the Thurgoona-Wirlinga region, the ecology and conservation status of Squirrel Gliders, and the factors that spurred the need for a coordinated monitoring program. In Section 2, we detail the goals and methods of the monitoring program.

As well as the monitoring plan, we have also created a Squirrel Glider ‘knowledge base’. The knowledge base aims to capture the extent of the current understanding of Squirrel Gliders across Thurgoona-Wirlinga, and collate information from the numerous surveys, research programs and conservation efforts that have occurred within the region. This will include a summary report, as well as a GIS database, detailing the location and effort of surveys to date, the distribution and abundance of the Squirrel Glider population and any existing conservation actions for the species within the region, and the extent of proposed urban developments. We have included a summary of the existing data in Appendix 1.

Section 1: Background

1.1 Monitoring programs to guide conservation efforts

Conserving wildlife within human-dominated landscapes is a key goal of many conservation management programs globally. These landscapes often consist of islands of habitat in a 'matrix' of human activity. The matrix that surrounds patches can change dramatically over time, with potentially profound effects on the persistence of species and communities across the landscape (Driscoll et al. 2013). Rapid urban growth on the fringes of cities and towns is a key driver of landscape change (Ramalho & Hobbs 2012). As agricultural land is converted to urban developments, animals are presented with a vastly different matrix, in which roads, light and noise, buildings and manicured gardens replace crops or grazing land. Whether a species finds the new matrix helpful or hostile depends on their ability and willingness to traverse gaps in preferred habitat, their tolerance for disturbance, or ability to exploit novel resources (Garden et al. 2006). It is therefore critical that we understand the way in which changing the matrix type affects species persistence within the landscape. Long-term monitoring programs that track the response of wildlife to landscape change over time, investigate multiple species and multiple landscapes will greatly improve our understanding and management of species in within human-dominated landscapes (Fischer et al. 2005; Holland et al. 2012).

1.2 Squirrel Glider management in human-modified landscapes

Squirrel Gliders (Box 1) are highly susceptible to the negative effects of landscape change, which has led to the decline of the species throughout the southern-most parts of its range. Importantly, the Squirrel Glider is threatened with extinction in both NSW and Victoria under relevant legislation, and the population in the Wagga Wagga local government area is listed as an endangered population. Given the widespread nature of threats to Squirrel Gliders across the south-west slopes of NSW, this endangered status should probably also apply to the Thurgoona-Wirlinga region. Their dependence on tree hollows for shelter and nesting, and their limited ability to cross large gaps in tree cover mean that they are particularly vulnerable to habitat loss and fragmentation. However, Squirrel Gliders persist and in some case thrive within agricultural and urban landscapes if sufficient habitat resources are available and threats are minimised. For example, numerous studies have found Squirrel Gliders occurring in linear roadside remnants, small patches of vegetation on farmland or in suburban areas (e.g. van der Ree 2002; Claridge & van der Ree 2004; Crane et al. 2014; Francis et al. 2015). The population density of gliders within linear roadside strips can often exceed those observed in continuous forest.

Box 1: Squirrel Glider ecology

The Squirrel Glider is a medium sized (190–300 g) arboreal marsupial often found in remnant and roadside patches of *Eucalyptus* woodland in south-eastern Australia. Squirrel Gliders are nocturnal and feed mainly on arboreal insects, but their diet can vary seasonally to include nectar, pollen, and sap. The average home range of a Squirrel Glider ranges from 1.5–6 ha but depends largely on the shape and quality of the available habitat (Quin 1995; van der Ree & Bennett 2003; Sharpe & Goldingay 2007). Squirrel Gliders primarily move through their home range by gliding from tree to tree. The average glide length is 30–40 m, with a maximum glide length of approximately 70 m, depending on the tree height (van der Ree et al. 2004). Squirrel Gliders rarely move across the ground, but when they do they are easily preyed upon by predators such as owls, foxes and cats. As such, gliders are negatively affected by habitat fragmentation, particularly large gaps between trees.

Squirrel Gliders live in social groups of related individuals that defend a local territory. Social groups typically consist of an adult male, an adult female and their offspring or siblings and can include up to eight individuals. Multiple family groups may inhabit a single patch, depending on the size and configuration of the patch, and the availability of feeding and nesting resources. Squirrel Gliders nest, or den, communally in tree hollows, typically utilising multiple den trees within their home range. Hollow bearing trees are therefore a critical resource, without which Squirrel Gliders are unable to shelter and raise young. Female Squirrel Gliders usually give birth to one or two young between April and November and may produce a second litter within a season if sufficient resources are available. The average population density ranges from 0.50 to 1.5 individuals per hectare depending on habitat quality (van der Ree 2002). Squirrel Glider populations can fluctuate over time in response to food availability, particularly when populations depend on flowering trees as a primary food resource. For example, high adult mortality during periods of low flower production caused an abrupt decline in the density of a Squirrel Glider population on the north coast of NSW (Sharpe & Goldingay 2010).

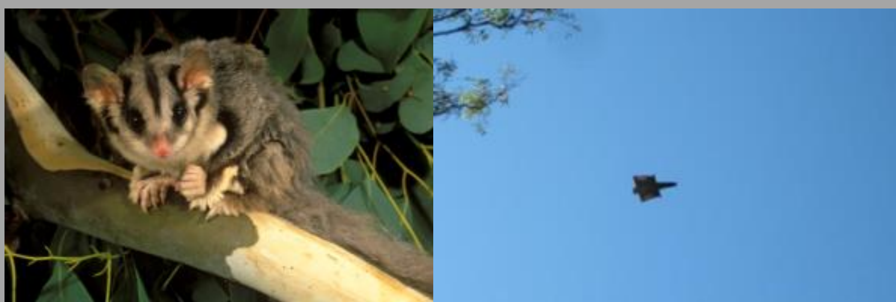

Figure 1. The Squirrel Glider, and in mid glide after being released from trap (right). Images courtesy of Lochman Transparencies (left) and Kylie Soanes (right).

A high degree of connectivity among habitat patches and the prevalence of critical habitat resources (e.g. hollows and food trees) can allow Squirrel Gliders to remain and even thrive in heavily modified landscapes. Well-connected habitats allow individuals to move throughout the landscape to access resources that are patchily distributed or seasonally available. Connectivity also allows for dispersal among patches, ensuring that animals can avoid natural disturbances (e.g. fire, disease) and vacant patches can be recolonised when local extinctions occur. As such, common management actions include the provision of habitat resources (e.g. plantings and nest boxes) and connectivity (e.g. corridors and crossing structures). Indeed in many areas, the linear strips of woodland comprise important and valuable habitat for Squirrel Gliders. However, relative success of different management strategies is unclear and questions of 'how much is enough?' remain largely unanswered, so predicting the response of Squirrel Glider populations to management at a local scale is often difficult. Long-term monitoring programs can help improve the state of knowledge in a systematic way, measuring the current status of populations and their response to change.

1.3 Squirrel Glider conservation in Thurgoona-Wirlinga

Squirrel Gliders are widely distributed across Thurgoona-Wirlinga, occurring in patches of remnant woodland, roadsides and environmental plantings across the landscape. Their persistence in the region is largely attributed to the retention of remnant patches of mature woodland, and the extensive network of "forward tree planting" that was undertaken during the 1960s-70s (Davidson et al. 2004). The Thurgoona-Wirlinga population is likely connected to several neighbouring Squirrel Glider populations including Albury, Mullengandra, Burrumbuttock and Baranduda. However the precise meta-population dynamics and viability of populations in this region is unknown.

Squirrel Gliders are a local faunal icon and an important part of the natural heritage of Thurgoona-Wirlinga. There is strong community support for conservation actions and engagement through a number of groups including (but not limited to) the Albury Conservation Company, Nature Conservation Trust and the Slopes to Summit partnership. Community members are involved in planting and restoring habitat, creating corridors between habitat patches and many even have nest boxes in their backyards. The Squirrel Glider is an important part of the community's engagement with the local environment and the impetus of many government funded environmental restoration projects (e.g. Saving Our Species, Environmental Trust).

The Squirrel Glider is not the only threatened species of wildlife in the area, nor the only species that locals appreciate. Other woodland-dependent species occur across the region, including Sugar Gliders, Brush-tailed Phascogale, woodland dependent birds including Regent Honeyeater and numerous amphibians and reptiles. It is expected that many management actions for Squirrel Gliders will benefit many other species as well. Similarly, the monitoring program as defined here, or with slight modifications, will also detect other species of wildlife.

The Thurgoona-Wirlinga region is currently undergoing major landscape change, transforming from a predominantly semi-rural community to a more intensely suburbanised landscape (Figure 2). This will include additional residential developments, new and wider roads, as well as facilities such as schools and shopping centres (RPS 2013). Without careful planning and ongoing management, this development will likely result in the loss and further fragmentation and degradation of Squirrel Glider habitat within Thurgoona-Wirlinga. The urban expansion may affect the natural heritage of the area as well as the efficacy of past and future conservation actions. Current planning documents highlight a proposed conservation network, including urban reserves and corridors for environmental management (Figure 2). The degree to which this will sufficiently preserve Squirrel Glider populations amid changing adjacent land-use is uncertain, and will depend upon:

- the extent and spatial configuration of the habitat,
- the quality of habitat,
- resources provided by the urban matrix
- the negative influence of these new land-uses (threats/degradation)
- future conservation management practises on glider survival and habitat suitability.

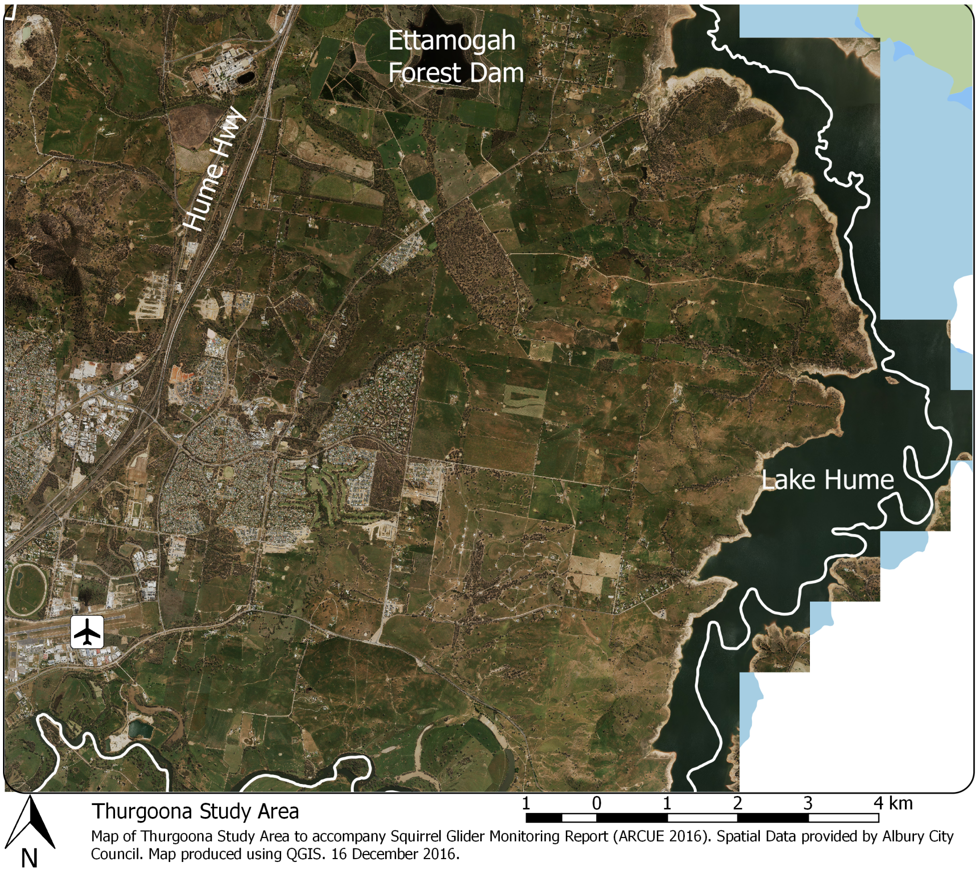

Figure 2a. Map of Thurgoona-Wirlinga showing existing woodland cover, major roads and residential areas.

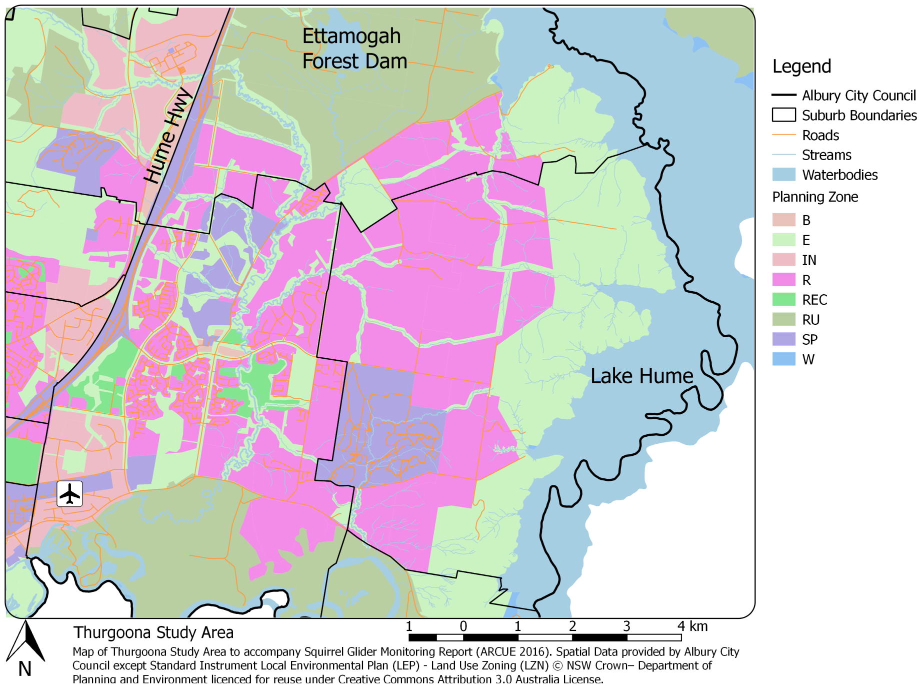

Figure 2b. Map of Thurgoona-Wirlinga showing current broad land-use planning zones: B- Business, E- Environment, IN- Industrial, R- Residential, RE- Recreation, RU- Rural, SP- Special, W- Waterways.

Several studies have been conducted on Squirrel Gliders within the region, including those commissioned by the Albury Conservation Company, community groups and government monitoring programs, impact assessments and university research projects. These studies, conducted over the past 10 years, give a preliminary overview of the spread of Squirrel Gliders throughout the landscape (Figure 3). Each of these studies has largely been conducted in isolation, driven by their own particular research questions. While these have all been informative in their own right, a coordinated approach is needed to understand the impacts of future urbanisation and the effectiveness of management actions on Squirrel Glider populations. There is also an urgent need to collate and interpret the results of the research to date to inform a unified way forward (see Appendix 1).

Figure 3. Distribution of Squirrel Glider surveys and records across Thurgoona-Wirlinga (red boundary) from 2003 to 2013, showing the locations where animals have been detected (dots) and those where no gliders have been detected (crossed circles).

2.1 A monitoring program to guide conservation efforts for the Squirrel Glider in Thurgoona-Wirlinga

The Albury Conservation Company recognised the need for a long-term monitoring program to better understand the current and future status and distribution of Squirrel Glider populations across Thurgoona-Wirlinga and help management best respond to future landscape change.

The keys to a successful monitoring program include:

- Using a study design with sufficient inferential strength (i.e. the ability to detect an effect if it exists)
- Measurements to be taken at appropriate spatial and temporal scales
- Using measurement indicators relevant to the effect being tested or measured
- Ensuring engagement and a sense of ownership with key stakeholders and community members, with a “local champion” to ensure the monitoring proceeds (i.e. the ACC and/or project ecologist)
- goals that are closely aligned to management actions

By adhering to these principles, we can avoid many of the common pitfalls that cause the vast majority of ecological monitoring programs to fail (see Legg & Nagy 2006; Field et al. 2007; Lindenmayer & Likens 2010 for more details)

This monitoring plan has been developed following extensive research as well as consultation with local stakeholders and is guided by existing knowledge of Squirrel Gliders within the region.

The overarching intent is that the monitoring program be scientifically rigorous, providing information for local management *as well as* contributing to the broader understanding of the ecology of Squirrel Gliders and other threatened species in human-modified landscapes. However, the objectives of this monitoring program are not limited to scientific and management outcomes. Increasingly, the ability of a monitoring program to engage and motivate community members is as important as scientific rigour, and this has been fundamental to the development of this plan. The success of monitoring programs often depends on community support, particularly if funding is scarce and the program relies on the contribution of volunteers. If the community are not engaged and informed, the program is unlikely to survive beyond a few years. We believe this monitoring program maximises community engagement, ensures that the information collected is both of sufficient quality to guide management decisions, as well as be publishable in scientific journals. There is also potential for this monitoring plan to serve as a blueprint for other similar landscapes and species (e.g. conservation planning, community-run monitoring).

2.1.1 Goals of the Monitoring Program

The broad aims stated by the Albury Conservation Company included a need to determine the current status of Squirrel Gliders in Thurgoona-Wirlinga, and an ability to track population change over time in a way that can inform management.

Based on the current known distribution, predicted landscape change and future threats to Squirrel Glider populations in the Thurgoona-Wirlinga district, and community/other concerns we highlight the following specific goals:

- Determine the **current status** of Squirrel Gliders in Thurgoona-Wirlinga (e.g. size and spread of population)
- Provide information on the **important habitat features** influencing the presence of Squirrel Gliders

- Track **changes in the presence and distribution** of Squirrel Gliders across the landscape **over time**
- Determine the **impact of urbanisation** on Squirrel Glider populations within key 'stronghold' patches (as indicated by previous studies)
- Evaluate the **effectiveness of management** actions designed to improve the persistence of Squirrel Glider populations in 'lower quality' patches
- Obtain information on the **threats** to Squirrel Gliders that operate within the Thurgoona-Wirlinga landscape
- Provide data that will **allow analysis of the viability** of Squirrel Gliders in individual patches and the landscape as a whole, including predicted response to changes over time
- **Engage the community** in the protection, and enhancement of Squirrel Glider populations by providing avenues to participate in monitoring and restoration works
- Maintain a strong base program but be amenable to **incorporating complementary research projects** as funding and opportunities become available.

2.1.2 Identified constraints

There are several key constraints that must be taken into account when designing this monitoring program. These, along with the overarching goals, have influenced the decisions that have been made about the proposed monitoring methods.

- *Limited funding* – There is currently a lack of secure and ongoing funding to support a large-scale, long-term monitoring program. It is possible (and likely) that additional funds will be sought and obtained in future (e.g. through grants, sponsorship, studentships etc.). However, a monitoring program that is dependent on intermittent and uncertain funding is unlikely to succeed in the long-term. Therefore it is crucial that the methods selected for the core monitoring program be relatively low cost. Additional complementary works can be added to the program if and when funds are available (see Appendix 2 for example suggestions). Programs that are inexpensive, simple to implement and that encourage community engagement are more likely to last in the long term.
- *Community engagement* – a core goal of this program is to involve the local community and stakeholders in the management, monitoring and conservation of Squirrel Gliders across Thurgoona-Wirlinga. Therefore the bulk of the methods selected need to be relatively easily implemented by the community, and which offer engaging and entertaining insights into the natural world. Furthermore, many monitoring programs fail because they depend on a single 'champion' who drives the work. When this champion moves on, the program often ceases to continue. If the community feel a sense of ownership and core contribution to the monitoring program, it will be more viable in the long-term.
- *Expertise* – the limitations on funding and the desire for community engagement dictate a need for simple, easy-to-use monitoring methods that do not require extensive hours by expert field scientists.
- *Flexibility* – the program needs to be able to grow and respond to external constraints and needs without compromising the long-term goals. For example, it should be robust to missing a survey season due to unforseen circumstances (e.g. due to lack of resources). Further, it should be able to incorporate and build on existing monitoring efforts and community works (e.g. nest boxes, opportunistic records etc.).

2.2 Proposed monitoring methods for Squirrel Gliders in Thurgoona-Wirlinga

Based on the goals and constraints listed above, we recommend that a simple, baseline program be established that can detect changes in the occupancy, distribution and abundance of Squirrel Gliders across the landscape. The proposed monitoring program will determine the presence-absence (also known as 'occupancy') of Squirrel Gliders across a large number of sites in the Thurgoona-Wirlinga landscape, and determine the habitat and landscape variables that influence the species presence over time.

The monitoring program:

- Camera traps are the primary method used to determine occupancy and distribution because they provide a systematic and consistent survey method across all site types. A detailed list of the pros and cons of different survey methods is provided in Appendix 3, and is briefly summarised here:
    - Nest-boxes: may not be installed at all sites; installation likely biased to sites with trees large enough to support a nest box; absence in boxes does not mean absent at a site; and rate of occupation of boxes may decline if boxes are not consistently maintained across sites or over time.
    - Stagwatching: is reliant on obtaining sufficient volunteer observers night after night, year after year.
    - Spotlighting: can be problematic when detecting cryptic species such as Squirrel Gliders, especially for un-trained community volunteers.
    - Hairtubing: has issues around identification of hair from Sugar and Squirrel Gliders, and does not provide information on population trend.
- 80–100 sites set at approximately 1 km intervals in a grid across the landscape.
- One camera per site set for seven nights, preferably twice per year (Spring and Autumn), or Autumn if only one season of survey is feasible.
- Annual surveys are recommended, even if not all sites gets surveyed to maintain volunteer enthusiasm and profile in the community. If insufficient funds are available to survey all points annually, a rotating sub-set of sites should be surveyed annually.
- Where nest boxes exist, these shall be inspected *in addition* to the standard survey effort provided by cameras. Nest boxes can be used to access gliders in order to collect information on age-sex structure of the population, collecting DNA samples, if fitting radio-transmitters or to show volunteers animals up-close, etc. See Appendix 3 for more details.
- Detailed habitat assessments will be conducted at all sites in the first year, including:
    - Plant community type, tree and shrub species composition and abundance within a 1 ha plot centred on the mid-point of the site
    - Diameter at breast height of each tree, and relative abundance and size/type of tree hollows
    - Site type (e.g. roadside, waterway etc)
    - Characteristics of the surrounding landscape, including landuse, housing density, amount and proximity of other patches of woodland, road density etc.

- Detailed habitat assessments shall be repeated at 5-yearly intervals, with rapid (< 5 min duration) assessments conducted at each site at each survey.
- Field work will be coordinated and guided by a project ecologist, and implemented in partnership with the local community as 'citizen scientists'.
- The project ecologist will prepare an implementation guide, which will include site details (patch size, tenure, access details, site history etc), detailed survey methods (sources of cameras, installation height of cameras, safety protocols etc) and obtaining relevant permits.
- Citizen-scientists to inspect camera footage through online image storage and access platforms, such as Zooniverse.
- Data will be analysed by or under the supervision of the project ecologist, who will also prepare yearly summary reports. Rigorous data analysis is to be completed after several years of data have been collected.

This baseline program can be complemented with additional works as resources and opportunities become available in the future, or as new research questions are raised (Appendix 2). These works could include targeted research studies (e.g. student projects addressing specific research questions) or the monitoring of additional species or environmental features (e.g. bird surveys, vegetation mapping etc). This allows the scope of the monitoring program to develop over time, while still maintaining a robust, baseline measure that provides some consistency throughout the program.

2.2.1 Response variables: occupancy and distribution over time

Taking into account the goals and constraints, the most practical, feasible and informative response variables to measure will be the occupancy and relative activity of Squirrel Gliders at survey sites across the landscape. That is, for a broad number of sampling locations;

- How many sites are occupied by Squirrel Gliders at a given time?
- What factors influence the presence of gliders at a site?
- How does occurrence of gliders change over time and is this in response to changes within the patch or in the surrounding landscape? Do habitat patches close to development become unoccupied over time? Do patches that receive habitat restoration works become occupied over time?

Occupancy is relatively simple to measure using camera traps and can be supplemented by other data such as nest boxes, spotlighting or other sightings, allowing concurrent activities to feed into the long-term program. Due to the current constraints on monitoring, we stress the need for a simple and consistent baseline approach, with the addition of more time-consuming or complex methods as need or opportunity arises.

2.2.2 Monitoring method: Camera trapping

We recommend the baseline program use camera traps to monitor Squirrel Gliders throughout Thurgoona-Wirlinga. Camera traps are relatively inexpensive, simple to use and are gaining popularity amongst scientific researchers and for community-based monitoring programs. Camera traps can meet the primary goals of determining presence, absence and distribution and therefore are ideal for this program. Furthermore, recent developments in data analysis approaches mean that cameras can also provide data on relative abundance/activity, creating the potential to analyse population trends.

Each camera will be fixed to the tree trunk at approximately 3–5 m high using straps or bracket (depending on the tree). Animals will be lured to the camera by a bait station – a mixture of honey, oats and peanut butter, secured inside a tea-infuser so that animals will be attracted to investigate, but cannot remove the bait. The aim will be to maximize the likelihood of detection by selecting a 'high-quality' tree for each camera, then consistently using the same tree for subsequent surveys to minimize factors that might influence detectability over time. The project ecologist will provide written protocols and in-field workshops on selecting and permanently marking survey trees, camera placement, and the downloading, storage and inspection of images.

We recommend the use of infrared, 'covert' trail cameras that have no visible flash to minimise the impact on the animals' behavior (e.g. Reconyx Hyperfire). The cameras are capable of detecting a range of arboreal species including the Squirrel Glider, Common Brushtail and Ringtail Possums, and the Brush-tailed Phascogale. We recommend cameras be set for a minimum of seven nights at each site. This would facilitate the involvement of citizen scientists, as camera traps could be set on one weekend, and then taken down the following weekend. Though camera traps are low impact, ethics approval will likely need to be obtained for the project. Precise camera set up (e.g. settings, position etc.) should be determined in the implementation phase of the program development, and based on previous successful camera-trap programs. These details should be part of the established protocol for implementing the fieldwork.

Risk of theft and vandalism is always a concern when using camera traps, particularly in urban areas that have high human activity. A number of steps can be taken to reduce the risks. Cameras can be placed out of sight as much as possible, camouflaged, and at a height that is difficult to reach (minimum 3 m). Survey trees should not be easily climbable or able to be driven under with a vehicle, as this will deter theft. The specific location of trap sites and detailed timing of surveys should not be broadly advertised beyond the volunteer group. Ensuring that cameras are not set out for extended periods of time can also reduce the risks.

When compared to live-trapping, there is some information that camera traps cannot provide, including the specific number of individuals at a site, sex ratios, reproductive output, the survival of individual animals over time, and age structure of the population (see also Appendix 3). However, while a regular live-trapping program would yield more information on these topics, it is unlikely that it would be viable in the long-term as live-trapping or mark-recapture programs require more funding, highly-trained staff and have relatively little scope for community involvement. A program based on camera traps will provide enough information to guide management actions, engage the local community in conservation, and is more likely to last in the long-term.

In addition to the baseline monitoring program, the cameras can be used to evaluate specific management actions. For example, cameras can be periodically set in planting corridors to determine how long it takes before they are used by wildlife, or placed in yards and urban parks to determine whether gliders make use of areas that are more heavily frequented by humans (e.g. as a 'Backyard Bioblitz'). Just as for the monitoring program, we recommend these additional works be carefully designed and carried out to the highest possible scientific standards.

2.2.3 Monitoring sites

We recommend a landscape-wide monitoring grid (Figure 4) be established across Thurgoona-Wirlinga and adjacent areas.

The advantages of a grid-based approach are:

- Reduces bias in site selection, ensuring equal monitoring effort across a range of sites and across the study area.
- Enables estimation of the distribution of Squirrel Gliders across the landscape and ability to track changes over time (e.g. expanding in response to habitat restoration, or contraction in response to urban development).
- Builds on existing knowledge from highly sampled sites by including areas that are yet to be surveyed.
- Provides new information about previously unknown sites.
- Covers a range of habitat types, including urban and rural areas, different patch sizes and quality, and areas for community engagement.
- Allow for systematic sub-sampling if survey effort must be reduced due to lack of resources in the future.

We suggest a circa 12 km x 12 km grid with grid-points at 1km intervals (Figure 4). The intersections represent potential sampling sites, in which each site is a single camera. Sites that are unsuitable can be relocated to the nearest habitat within 100 – 200 m. If no suitable habitat is available within 100 – 200 m, then that point will be removed from the survey, with potential to be re-located to a site that is a high management or community engagement priority but not currently covered by the survey grid. Additional sites can be added as needed to increase representativeness in key areas of management or community interest, which should be determined during implementation. This method gives a representative view of the region, as well as the flexibility to address specific issues/locations. For example, some survey points may be lost to future development, while new points may arise in areas where revegetation works occur. The grid approach also allows for the systematic addition of complementary surveys for additional species or environmental attributes if there are opportunities to expand the scope of the monitoring program in the future.

We anticipate that after excluding inappropriate sites, the total number of survey points will be 80 to 100. Monitoring the same sites consistently from year to year strengthens the ability of the program to track changes in Squirrel Glider populations over time.

Depending on the number of cameras available, all sites may be monitored simultaneously, or over a period of several weeks as cameras are shifted among sites. For example, if using several teams of volunteers, cameras could be set at 40 to 50 sites over a weekend. This would allow all sites to be surveyed in single month (i.e. half set on weekend 1, retrieved on weekend 2, the remaining half set on weekend 3 and the retrieved on weekend 4). If only 25 cameras were available, this would take twice the amount of time.

The final site selection within the grid should consider:

- Priority areas for research and management
- Capitalising on previous research
- Improving knowledge about under-researched areas
- Future urbanisation impacts
- Stratification to include sites with a range of habitat types and/or qualities
- Access to private property/willing participation
- Future land tenure
- Risk of theft/vandalism

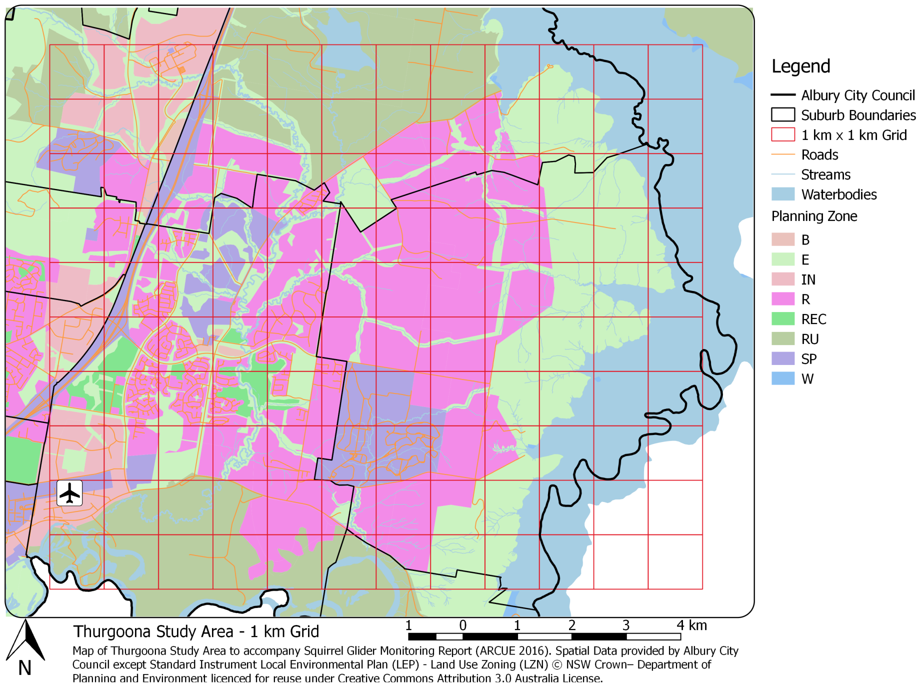

Figure 4. The survey grid for Squirrel Glider monitoring across Thurgoona-Wirlinga based on a 12km x 12km grid with sites at 1 km intervals. Each intersection represents a site and camera location. Sites that fall in unsuitable areas can be relocated to the nearest potential habitat (within ~100 – 200 m), or removed from the sampling grid. The grid can be expanded to include more survey points as required. The planning zones are defined in Figure 2b.

2.2.4 Monitoring frequency and duration

Regular and repeated surveys will allow us to track changes in the presence and abundance of Squirrel Gliders over time. We recommend camera surveys be conducted twice per year – spring and autumn – to get a full understanding of how Squirrel Gliders use the landscape. For example, Squirrel Gliders often use different parts of the landscape at different times of the year, depending on the availability of seasonal food sources. A patch may be vacant in one season and occupied the next due to the flowering of a specific tree species.

The timing of surveys should also consider volunteer availability due to other community activities and volunteer comfort. For example, attempting to do surveys in the heat of summer should be avoided due to fire risk, heat stress and potential volunteers taking holidays. The monitoring program could be boosted if it can be associated with other relevant community events, however organisers must consider volunteer burn-out.

Other field survey activities, such as detailed habitat assessments and nest-box inspections, could occur at any time of year. However, rapid habitat assessments should be conducted at the time of the survey.

2.2.5 Habitat assessments

Conducting habitat assessments at each site will allow us to better understand the influence of habitat variables on the presence and abundance of Squirrel Glider populations, and track these changes over time. Detailed habitat assessments should be undertaken at each site during the first round of survey as part of the site selection process, with rapid assessments (< 5 min per site) conducted within a 100 m radius of each survey point / camera during each survey season (e.g. number and tree species, approximate size, visible hollows or nest boxes etc.). GIS data can be combined with on ground surveys and local knowledge to track changes in the surrounding landscape over broader timescales (e.g. corridors, urban developments etc.). Local community and stakeholders can contribute further by noting landscape changes in the periods between monitoring (e.g. clearing, restoration work, fire etc.). This information can be incorporated into later analysis to determine the effect of habitat and landscape features on the persistence of Squirrel Gliders within each patch.

2.2.6 Incorporating data from other local programs

It is likely that many other local conservation actions and monitoring works can be used to complement the data from this monitoring program. For example, information from nest box surveys, 'bioblitzes' and opportunistic sightings will offer valuable additional insights about the presence of Squirrel Gliders both within the proposed monitoring network and at unsurveyed sites outside the survey area. We recommend a formal reporting system be made available so that these records can be incorporated into the existing dataset. This may be as simple as encouraging people to record observations within the Atlas of Living Australia, and then retrieving these entries on a regular basis. Any additional data that is incorporated should be clearly flagged so that there is a clear distinction between information gained from the formal camera-trap surveys, and information gleaned from other sources. If done carefully, this information can be used to improve the power and comprehensiveness of the monitoring program, as well as allow us to take imperfect detection into account when the data is analysed (e.g. if a camera fails to detect Squirrel Gliders at a site, but nest box surveys show that they are present). Importantly, these observations should be used in addition to the monitoring program, and not 'instead of' the standardised survey effort at any given site, as different survey methods have different chances of detecting animals.

2.2.7 Data entry/analysis

The largest task will likely be inspecting, cataloguing and storing the data collected by the camera traps. A camera trap program of this scale has the potential to generate 1000s of images/videos each season. However, online platforms such as Zooniverse (https://www.zooniverse.org) allow engaged citizen scientists to contribute to scientific research by accurately cataloguing large volumes of camera data. Researchers can create projects on the Zooniverse website (or other citizen scientist websites) and upload the camera trap data that needs to be inspected. Registered users from around Thurgoona, and indeed the world, are then able to log on and complete the data entry for a given project. To increase the accuracy of the data, Zooniverse uses a 'vote count' system, in which multiple users inspect each image. If there is disagreement on the identity of the species, the image is flagged and the researchers can verify it later. The platform has been successful for a wide range of projects and led to published research in scientific journals. A guide to identifying Squirrel Gliders and distinguishing them from Sugar Gliders and other arboreal mammals will be created and made available to all volunteers.

The resulting data will be analysed by the Project Ecologist(s) who will then produce a report, maps and recommendations based on each survey. This yearly report will generate basic descriptive data (e.g. number of records, location, changes from previous surveys). Detailed statistical analysis will not be completed until the project has been ongoing for several years, allowing sufficient data to accumulate to analyse occupancy, detectability and abundance.

Researchers from the Zoological Society of London (ZSL) have recently developed the 'Camera Trap Tool', a free program that helps store, organise and analyse data from long-term camera trap studies. Once the data is uploaded into the program, users can quickly obtain information on the monitoring effort, number of species detected and the spatial distribution. The program is also integrated with Google Earth, and will automatically map the camera locations and presence of species (note that the precise location of camera traps will not be publicised, to reduce risk of theft or vandalism). The ZSL have also developed protocols and guidance on the use of camera traps and management of data. This potentially allows for greater involvement of community members not just in deploying the cameras, but also entering and managing data while maintaining scientific rigour. The system can probably also be adapted to receive and store data from nest box inspections and stagwatching. If this program becomes available by the time the monitoring is implemented, we recommend including it as part of the program.

2.3 Project costs

The main up-front cost is the initial outlay for purchasing cameras, and we recommend Reconyx Hyperfire, which cost of approximately $850 each. Once the cameras are purchased, the only additional costs each year relate to deployment and data analysis (and occasional maintenance/replacement of cameras). The final number of cameras included in the program will depend on the funds available, but we expect that 25–50 will be required – these can then be rotated through the sites.

The total cost could be minimised if there are opportunities to borrow cameras from other groups. However, we recommend that if possible, the same make and model of camera be used throughout the monitoring because effectiveness (sensor sensitivity, number of images, time between trigger events etc.) can vary widely between cameras, potentially affecting the reliability of findings. Further, the ACC will be able to use the cameras for other monitoring works, or hire them to others.

If different models must be used, then there are a number of strategies to minimise the introduction of bias. If just a small number of different cameras are to be used for one survey, or if the pool of cameras varies every year, then bias should be minimised by randomly assigning cameras to sites. This will ensure that a particular site type does not always receive a certain type of camera. If a new suite of cameras are to be used for one survey or if a new model is to replace an old model of camera, time should be taken to "calibrate" the two models, so that a correction factor can be calculated. The project ecologist can assist with this if required.

Following guidance from the project ecologist, we anticipate that volunteers from the community could contribute to a large portion of this program. This includes setting camera traps, conducting on-site habitat assessments, and inspecting camera data.

Other resources that will be required include:

- Vehicles for field work
- GPS units
- Brackets to mount cameras to trees
- Batteries (for cameras and GPS units) and battery chargers
- Memory cards for cameras
- Ladders
- Bait holders (tea infusers) for each camera
- Bait (honey, oats and peanut butter)

It is likely that much of this equipment can be provided by the project ecologist or as in-kind support.

Annual cost for the project ecologist will vary depending on the specific tasks that the project ecologist is required to undertake and what tasks are undertaken by the ACC and volunteers. We recommend that the project ecologist be engaged in the initial implementation, including writing the necessary guides and protocols for volunteers and field staff as well as the proformas for accurate and consistent data collection. The project ecologist should also be engaged to co-ordinate and run the monitoring for a minimum of three years, preferably five.

2.4 Practical considerations

There are a range of practical aspects that will be important to the success of this project. The roles and responsibilities of each party will need to be determined and clearly stated in the final monitoring program.

- *Safety procedures and risk assessments:* Mounting and checking cameras, traps, nest boxes or hairtubes within trees will require working at heights and within roadside areas.
- *Project ecologist to oversee implementation:* Ongoing input from an ecologist is critical to ensure that the monitoring program continuous to be scientifically rigorous. The project ecologist should be consistent throughout the life of the program to allow long-term relationship building and consistent oversight.

- *Recruitment of volunteers for field days:* The program will involve extensive input from volunteer citizen-scientists. A plan will need to be put in place to regularly recruit volunteers to ensure that fieldwork can be completed each season. It is also important to continue engaging with volunteers after the fieldwork to encourage long-term involvement and commitment.
- *Guidance for volunteers:* Clear, detailed and easy-to-follow protocols for camera set up, habitat assessments, and species identification will be required.
- *Provision of field equipment:* could be purchased and owned by ACC, provided by the ecologist overseeing the program, or loaned from other partners. If equipment is to be borrowed, there should be some level of assurance that it will likely be available for each field season.
- *Incorporating additional works:* there is great scope to include complementary works within or alongside this monitoring program. Consultation and collaboration will be required to ensure that any additional projects are carried out without compromising integrity of long-term program and that they are best ‘bang for buck’.
- *Ethics approvals and fauna survey permits:* will be required to complete the fieldwork for this project.
- *Ongoing funding:* there is a need to secure ongoing funding that would allow the monitoring program to continue into the long-term.

Appendix 1 – Summary of existing knowledge-base of Squirrel Gliders in Thurgoona-Wirlinga

We found records of ten studies of Squirrel Gliders that were conducted within the Thurgoona-Wirlinga area (Table 1). Of these, six reports (or their associated data) could be accessed in full. We also obtained records through the Atlas of Living Australia, which were sorted, collated and crosschecked to reduce duplication. Through these reports and atlas records, we collated Squirrel Glider records from the Thurgoona-Wirlinga area into a single database. The database currently includes 109 locations where Squirrel Glider surveys have been conducted or animals have been located between 2003 and 2011. We expect this to grow as more data becomes available and can be incorporated into the database.

The records comprise trapping surveys, spotlighting surveys, camera trap surveys, nest-box records, opportunistic sightings and carcass retrievals. Where trapping surveys were conducted, the authors included information on the sex, size and reproductive output of individual gliders. Genetic samples were collected from at least 90 individuals, and are currently being analysed as part of a research project funded by the Office of Environment and Heritage.

While on the surface it may appear that much work has been done on Squirrel Gliders in the Thurgoona-Wirlinga area, the lack of a consistent, coordinated approach means the information that can be gleaned from the existing data is limited. We found it very difficult to collate records from multiple, scattered sources, and indeed, we are still in the process of verifying and consolidating records into a single database (dates, locations, coordinates, and the studies that they are associated with). Only two studies included repeat surveys to a site over multiple years: the monitoring programs by NGH environmental (4 sites) and ARCUE (1 site) in relation to the duplication of the Hume Freeway and Bypass. The lack of repeated, systematic surveys at individual sites makes it challenging to track the changes in Squirrel Glider populations over time.

Table 1. Reports generated from Squirrel Glider research projects within the Thurgoona-Wirlinga region.

Report title and publication year	Author	Year of surveys	Report available	Data available
Flora and Fauna feasibility study 'Englobo' development Thurgoona Drive/Kerr Rd	Grabham and Datson	2003	Y	N
Feasibility study for proposed development of land on the north-west corner of Vickers Road/Dallinger Rd (2003)	*Datson and Grabham*	2003	Y	Y (within ALA)
The Distribution and Status of the Squirrel Glider, Petaurus norfolcensis, in the Thurgoona Area of Albury (2003)	van der Ree	2003[#]	Y	Incomplete
Terrestrial Fauna Monitoring Program - Albury Wodonga National Highway Maintenance Program (2008–2011)	NGH	2008-2011	Y	Y
Population Viability Analysis for	*Stewart and van*	2007	Y	Y

Squirrel Gliders in the Thurgoona and Albury Ranges Region of New South Wales (2009)	der Ree			
The Influence of Urban Encroachment on Squirrel Gliders (Petaurus norfolcensis): Effects of Road Density, Light and Noise Pollution (2015)	Francis, Spooner and Matthews	2013	Y	Y
Hume Highway Duplication and Bypasses (2008–2014)	Soanes and van der Ree	2007-2013	Y	Y
Glider Project at the Lake Hume Spillway Area (year 1 of 2 year program) – surveys, nest boxes, revegetation (Woolshed Thurgoona Landcare Group)			N	N
Nest Box Inventory at the National Environment Centre – Parklands Albury Wodonga			N	N
Targeted Squirrel Glider Surveys Ettamogah Intermodal Rail Hub – Final Report (2007)	van der Ree	2007	Y	Y

Reports on sightings from 1996 to 2003.

Squirrel Gliders are widely distributed across Thurgoona-Wirlinga and several locations bordering the region (Figure 3). Records have been obtained from a variety of sources and methods, including spotlighting, live-trapping, nest-box inspections, hair tubes and opportunistic sightings. It appears that Squirrel Gliders have been detected in almost every patch where searches have been conducted, suggesting that they are locally common. Larger reserves or 'hot spot' areas include Bell's TSR, sections along Old Sydney Road, Mitchell Park, and the vegetation surrounding the Thurgoona Bypass. Some areas have received less attention in research and monitoring projects than others, and these should be priority areas for monitoring surveys to establish whether gliders are present. Wirlinga in particular is relatively unsurveyed.

Squirrel Gliders are also present in areas adjacent to the Thurgoona-Wirlinga area, including on the opposite side of the Freeway in Laverton and Albury, Mullengandra, Holbrook, Burrumbuttock and south to Baranduda and Chiltern. Maintaining connections with these areas is important to the long-term persistence of Squirrel Glider populations in each of these regions. Genetic studies are currently underway to determine the extent to which the Thurgoona-Wirlinga Squirrel Glider population is isolated from populations in nearby areas.

It is clear that Squirrel Gliders are widely distributed across the region. Unfortunately the sporadic surveying and varied nature of the existing information makes it difficult to estimate population size or trends over time. Many places were surveyed only once or with methods that do not allow accurate estimation of population size. Several patches support resident, breeding populations that have remained persistent in size over time (across 5-10 years of surveys). For example, Squirrel Gliders can be routinely captured at Bell's TSR and the roadside of the Thurgoona Drive-Hume Freeway bypass, and animals are repeatedly detected in nest boxes across the region. If this trend can be generalised to the lesser-studied patches, it is likely that the current population is stable.

Appendix 2 – Potential complementary works

As particular management questions arise, targeted studies could be used to supplement the baseline program. This may include work for student projects or community grants.

Examples of potential side-projects include:

Nest boxes for conservation

There are several interesting questions about the use of nest boxes by Squirrel Gliders that could assist managers in Thurgoona-Wirlinga. How quickly do animals take up nest boxes? Do different nest-box designs effectively exclude competitors? Are nest boxes suitable all year round? Does the placement or construction material affect suitability for gliders (e.g. temperature, weather proof, life-span)? Works could capitalise on the existing nest box monitoring programs and extensive network of nest boxes across Thurgoona-Wirlinga to address some of these issues. For example, studies could compare the information gained from the baseline camera monitoring program to that obtained from regular nest box surveys, identifying sites where Squirrel Gliders are present but not using the nest boxes. Additional camera surveys could determine if sites with nest boxes have higher activity than those without. Alternatively, cameras could be placed facing nest boxes to record all species that enter/exit, including pest species (e.g. myna, black bird) or predators such as goannas.

Population demographics

Information on population size, survival and reproductive rates are very informative for management, and could be targeted by additional works. Including mark-recapture surveys at a limited number of sites as a 'supplementary' element to the program could provide interesting insights if carefully designed to answer specific questions. For example, what is the population density in areas of high and low habitat quality? Are squirrel gliders living in areas heavily impacted by urban disturbance (light, noise etc.) following normal breeding patterns? What is the population size in key 'stronghold' patches?

Resource use in urban areas

How do Squirrel Gliders use different resources within the urban and agricultural matrix? Do they make use of paddock trees or forage within backyards and urban parks? How are they affected as scattered trees are lost over time? Cameras could be placed on urban hollow-bearing trees, including those in paddocks and backyards. Community members could be involved in 'stag watching' expeditions to see if these isolated trees are used as nesting sites for gliders or other arboreal mammals. Additional works could be carried out to further investigate seasonal patterns or set cameras at key sites before and after management interventions are undertaken.

Identify sources of mortality

What are the different sources of mortality for Squirrel Gliders within urban areas? This could include surveys of roadways and fence lines, interviews with local community members about predation or dead animals that are observed.

Wildlife crossing structures and corridors

How effective are canopy bridges, glider poles and planted corridors at facilitating connectivity across the region? GPS-telemetry could provide fine scale information on where gliders are moving throughout the region. What factors encourage Squirrel Gliders to use crossing structures? Are they crossing roads? How wide or old does a corridor need to be before it is functional? This could include additional genetic studies to complement the analyses that are currently underway and track changes in movement and gene flow over time.

Population viability analysis/connectivity analysis

Detailed analyses of population viability and habitat connectivity are incredibly valuable to management. Potential questions that can be answered include: Are certain habitat areas viable? Is there sufficient habitat to support populations in Wirlinga? Do patches need enhancement in size or quality?

However, these analyses are only as good as the data that is used to inform them, and are often based on a number of underlying assumptions about population size and habitat quality that may or may not be accurate. For example, in the absence of data on the actual distribution and abundance of Squirrel Glider populations, the previous population viability analysis conducted across Albury-Thurgoona (Stewart & van der Ree 2009) had to make assumptions based on information from other landscapes, some of which did not hold true when compared with field data. Instead, these analyses would benefit from the data generated by the monitoring program. For example, the occupancy data collected over several years of monitoring through this monitoring program would allow a rigorous analysis of patch size, landscape connectivity and viability of patches would require a spatially explicit population viability analysis based on up-to-date empirical data. This could also predict the effects of future landscape change (e.g. the predicted loss of habitat) on population viability, allowing recommendations that are more specific to Thurgoona-Wirlinga region.

Appendix 3 – Summary of potential monitoring methods for Squirrel Gliders

Spotlighting

Surveys undertaken by one or more people who walk through a site for a set period of time, searching for wildlife with a bright torch or spotlight

- Pros:
  - Low cost and low effort.
  - If conducted at a site with a known population, it can be an excellent community engagement exercise, if associated with an evening BBQ, information session etc
  - Does not generally require a high level of expertise and can be undertaken by volunteers with low levels of training
  - Detects multiple species, such as gliders, possums, and owls.
  - Can provide information on the presence and distribution of Squirrel Gliders, as well as information on behaviour.
  - Relatively non-invasive
- Cons:
  - Difficult to conduct in urban areas due to disturbance to the local community.
  - Often low detection rates, particularly when conducted with larger groups (disturbance).
  - Very hard to discern changes in population size over time
  - While not generally requiring extensive expertise, some expertise is required to consistently and accurately identify Sugar and Squirrel Gliders.
  - Different observers can have highly varying levels of detectability
  - Multiple surveys per season are typically required to confidently determine presence or population abundance. Therefore, can be time-consuming to survey a large number of sites
  - The timing of surveys (i.e. at night) and the number of surveys limits the ongoing engagement of the community.
  - Requires ethics approval and wildlife permits

Stagwatching

- An observer sits at the base of a tree with hollows (or nest box) at dusk and watches the hollow for 30 to 60 minutes without a torch, recording the presence of animals within the tree, principally as they depart their hollow.
- Pros:
  - Low cost if volunteers involved.
  - If conducted at a site with a known population, it can be an excellent community engagement exercise, if associated with an evening BBQ, information session etc
  - Does not generally require a high level of expertise and can be undertaken by volunteers with low levels of training
  - Detects multiple species, such as gliders, possums, and owls.
  - Can provide information on the presence and distribution of Squirrel Gliders, as well as information on behaviour.
  - Relatively non-invasive
  - Compared to spotlighting, the evening work takes place at dusk and does not require volunteers to commit to more than 1 to 2 hours each night.

  - It is a great experience for the volunteer when a colony of gliders leave their hollow and glide away.
- Cons:
  - Requires large numbers of volunteers, year after year, to watch sufficient trees to be able to generate sufficient data.
  - Volunteer co-ordination in the lead up and during the actual survey can be onerous.
  - Need to survey all hollow-bearing trees at a site at regular intervals in order to discern changes in population size over time
  - While not generally requiring extensive expertise, some expertise is required to consistently and accurately identify Sugar and Squirrel Gliders.
  - Different observers can have highly varying levels of detectability
  - Can be time-consuming to survey a large number of sites if they have high densities of hollow-bearing trees.
  - Will likely require ethics approval and wildlife permits

Hairtubes

- Baited PVC tubes lined with double-sided tape to collect hair samples from animals that enter them.
- Different-sized tubes detect different species.
- Pros:
  - Low cost and low effort, easy to implement
  - Can involve members of the community in installation and removal of hairtubes, and removal/preparation of hair samples from each tube.
  - Can be used to identify presence and distribution of a rage of mammal species across the landscape.
  - Non-invasive
- Cons:
  - Hair identification requires training and experience, and specialist equipment (e.g. microscope), and samples are usually identified by an external consultant at between $5 and $10 per sample.
  - Very difficult to tell the difference between Squirrel Gliders and Sugar Gliders (some say impossible).
  - Cannot be used to identify population sizes over time and not sufficient to obtain DNA from hair samples.
  - Requires ladders to mount hairtubes at a height of 3 – 5 m with associated safety risks
  - Requires ethics approval and wildlife permits

Camera traps

- Deployment of remotely triggered cameras at a height of 3 – 5 m within trees to take photos or videos of animals around a bait station.
- Pros:
  - Provides information on distribution of all species that pass in front of the camera.
  - Enables an index of population abundance to be calculated.
  - Newly developed methods are moving towards enabling population estimates even when individual animals cannot be identified.
  - Does not require expert staff to deploy and retrieve cameras. Can be conducted by citizen scientists and enhance community engagement.

  - Citizen scientists from around the world can become engaged in animal identification.
  - Non-invasive.
- Cons:
  - The initial cost can be expensive if cameras are to be purchased (but as the equipment can be re-used and/or rented to other projects it becomes less expensive over time).
  - Requires ladders to mount hairtubes at a height of 3 – 5 m with associated safety risks.
  - Cameras in urban and suburban areas may be prone to theft, but can be avoided by careful placement, camouflage paint and height above the ground.
  - Huge amounts of data (i.e. image files) will be generated and strict adherence to storage protocols must be followed to ensure data is not misplaced.
  - Sugar and Squirrel Gliders are sometimes difficult to tell apart, especially for inexperienced citizen scientists.
  - Requires ethics approval and wildlife permits.

Nest box surveys

- The inspection of nest-boxes installed in trees to determine occupation by the target species.
- Pros:
  - Nest boxes can be inspected by either by pole-mounted cameras, physical inspection or stagwatching
  - Does not require expert staff to inspect boxes. Can be conducted by citizen scientists and enhance community engagement.
  - Nest boxes can be inspected at anytime
  - A large number of nest boxes can be inspected in a relatively short period of time, especially if using pole-mounted camera.
  - Non-invasive if animals are not being removed from nest box.
  - Nest boxes are simultaneously a management action through the provision of additional hollow/denning resources
- Cons:
  - There are likely to be biases in nest box placement (e.g. placed in easy to reach locations, in areas with few hollows or on trees large enough to support a nest box).
  - Nest-boxes are not a reliable way to conclude absence at a site. A nest box may remain empty because (i) there are no gliders at the site, or (ii) they simply haven't used that nest box (e.g. perhaps there are enough hollows, or the nest box is not in the best location).
  - Does not provide information on other species that do not use Squirrel Glider nest boxes
  - Signs of glider presence (e.g. nests, chewing at box entrance) are hard to use as an indicator of change over time. For example, if we note a nest that is not 'fresh', can we tell if it is 3 months old? 1 year old? 2 years old?
  - Variation over time or space in the efficacy of nest box maintenance will influence their suitability for use by gliders, thereby biasing the survey results.
  - Requires ethics approval and wildlife permits.
  - By adding nest boxes to an area, it unnaturally affects the abundance of hollows/dens, which, depending on the monitoring question, may invalidate the data being collected.

- Data collected from nest boxes in one area or region may not be comparable with data collected by another technique elsewhere, including elsewhere within Thurgoona-Wirlinga or in other regions.

Trapping surveys

- The installation of cage or large Elliott traps in trees to capture live animals. Traps are set the evening before, and checked at dawn the following morning.
- The number of traps set and duration of trapping will affect the type and quality of data collected.
- Pros:
  - Trapping provides information on distribution, abundance, population density, survival and reproductive rates.
  - Trapping also used to obtain animals to fit tracking collars and collect genetic samples.
- Cons:
  - Requires trained experts to process animals. Citizen scientists can process animals but require training and must be under supervision of the licensed ecologist. Citizen scientists can assist with measuring, weighing, data entry etc.
  - Requires ethics approval and wildlife permits
  - Can have low detection rates.
  - More disturbance to the animals than other non-invasive survey methods, such as camera trapping, hairtubes and nest boxes.
  - High effort, as multiple traps (a minimum of approximately 10) are usually deployed at a single site.
  - Very time consuming to survey a large number of sites to simply determine presence or population trend.
  - High risk of traps being stolen or vandalised in areas frequented by people.
  - 5–7 night surveys are generally required (best-practice) to obtain reliable estimates of population size. Shorter surveys (e.g. fewer than 4 nights) risk being affected by environmental factors that influence capture rates (e.g. full moon, inclement weather) and are likely to miss a large portion of resident animals (unpublished data). To use more sophisticated mark-recapture analyses, a minimum of three repeat surveys are required at a given site.
  - While population size, survival and reproductive rates are interesting to monitor, the cost and expertise required to obtain this data will likely become prohibitive over time.
  - Animals tagged during mark-recapture surveys cannot reliably be recognised in camera images due to the low-resolution, ‘night-vision’ images (or video). They are also unlikely to be reliably recognised during non-invasive inspections of nest boxes.

Radio/GPS telemetry

- Selected animals are fitted with tracking devices, such as GPS or VHF collars. Animals are then periodically re-located, either on foot in the case of VHF or via satellite, and the movements of individuals is documented.
- Best use to answer specific questions of interest to ACC, and probably best suited to a student project.
- Pros:
  - Tracking can provide extremely detailed information on habitat selection, home range size, den use, movement paths and identification of barriers to movement.
  - With a little training, citizen scientists can be involved in radiotracking.
- Cons:

- Equipment is expensive. GPS collars that are small enough for use on gliders are >$1500 each, and multiple animals must be tracked to obtain statistically meaningful results. VHF is cheaper to purchase, but becomes expensive field staff for tracking must be paid.
- Need trained staff to fit collars and track individuals.

Genetic analysis

- DNA samples are collected from a sample of animals and analysed in the laboratory, providing a wealth of information about population size, connectivity, population dynamics, social structure and source-sink dynamics.
- Pros:
  - DNA samples can be collected from animals that are obtained for a variety of other purposes, such as trapping, nest box inspections, road-kill carcasses etc.
  - DNA samples can be stored for a number of years until sufficient samples and/or funds are obtained for analysis.
  - Analysis techniques are becoming increasingly more sophisticated and informative.
  - DNA extraction and analysis is relatively expensive, but becomes cost-effective when the amount of data and questions that can be answered is considered.
- Cons:
  - DNA samples are still best obtained from animals while in the hand (i.e. from trapping, nest boxes) - not yet available from hair samples.
  - DNA must be carefully stored, extracted in a laboratory and the resulting data analysed by trained experts.

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