Lake Macquarie

Squirrel Glider

Planning and Management
Guidelines 2015

Lake Macquarie City Council November 2015

Acknowledgements

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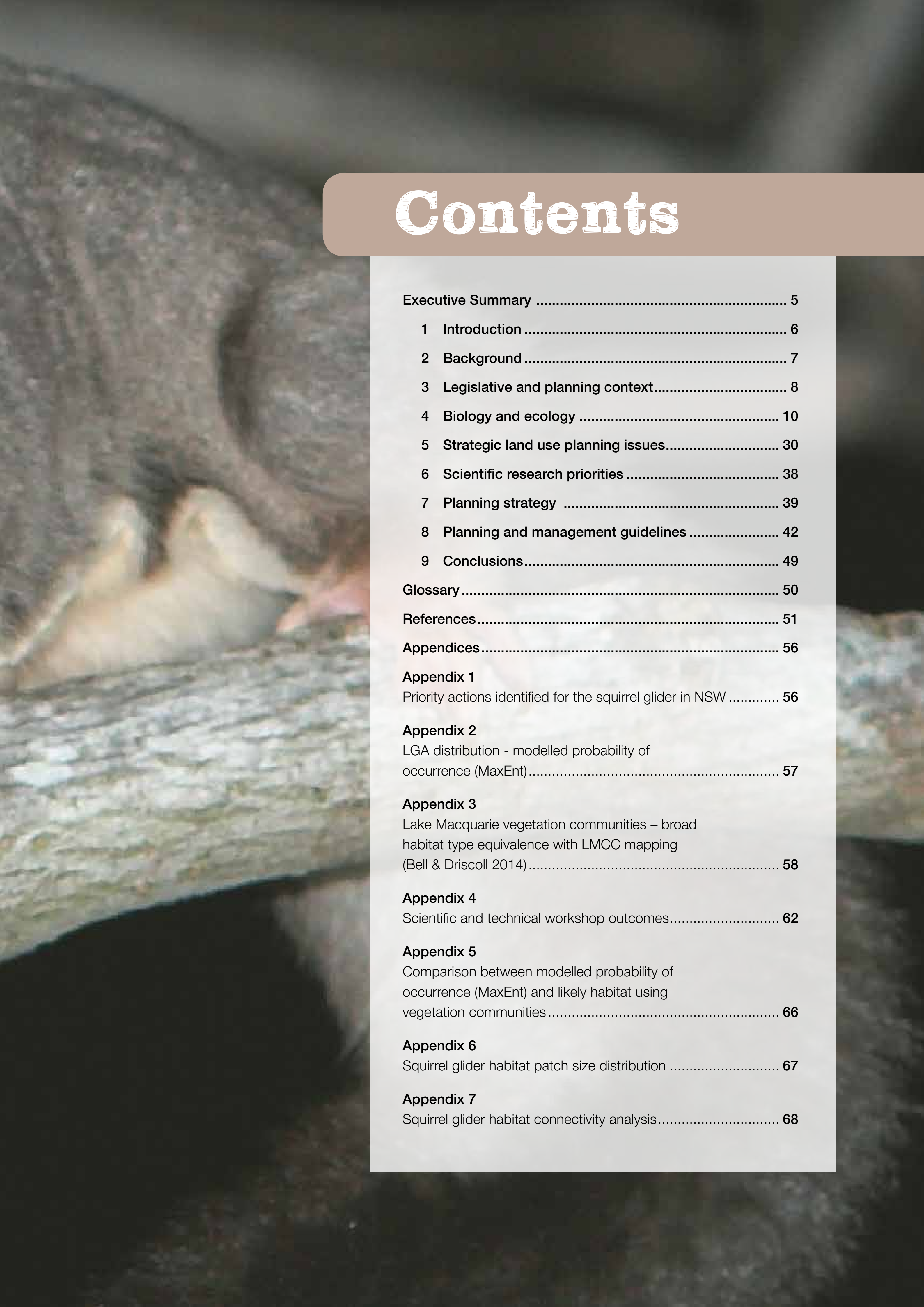

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Photo: NSW Office of Environment & Heritage

Executive summary

The squirrel glider *Petaurus norfolcensis* is a small, nocturnal, tree dependent gliding marsupial listed as a threatened species in NSW legislation. Many development projects and activities impacting on native vegetation in the Lake Macquarie Local Government Area (LGA) potentially affect the species.

The squirrel glider is distributed in forests and woodlands along Australia's east coast, with a concentration of records in Lake Macquarie and the Lower Hunter. As a listed threatened species, the impacts of development proposals on this species are required to be assessed.

These guidelines compile information about squirrel gliders to inform conservation, strategic land use planning and land management. One objective of the guidelines is to compile current knowledge for the species into one reference document to inform local planning and management and to guide future scientific research programs.

A strategic review of long term land use within the Lake Macquarie LGA indicates that around 24% of likely squirrel glider habitat has the potential to be affected by development to 2030. Only around 8% of likely habitat is protected in conservation reserves.

The guidelines inform future land use planning and management, and give more certainty to government and the development industry in relation to requirements applying when proposed development impacts on squirrel gliders.

Proposals to be incorporated in future strategic planning include:

1. Objectives for land use strategies and policies.
2. Guidelines for assessing the significance of impacts on squirrel gliders.
3. Areas to be investigated for future conservation reserves.
4. Guidelines for land managers.
5. Future scientific research priorities to inform planning and management.

The Guidelines have been prepared by Lake Macquarie City Council following consultation with the NSW Office of Environment and Heritage and the input of an expert scientific and technical workshop.

left: Squirrel gliders mainly feed on nectar, pollen, gum and insects.

1. Introduction

The Lake Macquarie Squirrel Glider Planning and Management Guidelines support strategic planning, impact assessment and management for the squirrel glider in the Lake Macquarie LGA, near Newcastle NSW. The squirrel glider is a small possum-like, arboreal marsupial with a head and body length of about 20 cm and a gliding membrane between the elbow and ankle. The species generally occurs in dry woodland.

Photo: Alex Bonnazzi.

Squirrel glider landing on dead tree.

This report specifically relates to the Lake Macquarie LGA, and:

1. Compiles and summarises current scientific knowledge and presents this in an accessible form for land use decision-making.
2. Identifies strategic land use planning considerations requiring integration with conservation planning in the medium to long term.
3. Includes measures to protect squirrel glider populations in strategic land use planning processes and documents (such as regional and local plans, policies and strategies).
4. Provides land management guidelines for public and private landowners with squirrel glider habitat on their property.

Information in this document (especially sections 7 and 8) should be used as a reference for strategic planning and development assessment where potential impacts on squirrel gliders may occur.

The Guidelines were prepared by Lake Macquarie City Council (LMCC) and are the result of a process of data compilation and review, and a scientific/technical workshop with researchers and specialists on the biology of the squirrel glider as well as local and state government agency representatives.

2. Background

The squirrel glider *Petaurus norfolcensis* is a small, nocturnal, tree dependent gliding marsupial listed as a threatened (vulnerable) species in the NSW *Threatened Species Conservation Act 1995* (TSC Act). It is distributed in forests and woodlands along Australia's east coast, with a concentration of records in Lake Macquarie and the Lower Hunter. As a listed threatened species, an assessment of the impacts of development proposals on this species is required under relevant legislation.

Within the Lake Macquarie LGA the squirrel glider is widely distributed and forms part of a larger metapopulation, the full extent of which is unclear. It is frequently recorded in ecological surveys for development proposals and its habitat co-incides with locations subject to significant urban development pressure. Under some circumstances, the species appears capable of surviving in bushland fragments within these urban areas.

Although the biology of the squirrel glider is reasonably well understood at the species and site scale, key issues affecting long term population viability and habitat connectivity requirements require landscape scale analysis. Field surveys and studies of squirrel glider within the Lake Macquarie LGA and nearby areas over the last two decades, have led to knowledge of occurrence being concentrated in development areas, with over 300 unique records with an accuracy of <100m. There has been no systematic survey for squirrel gliders in the area and the distribution and density of population is poorly understood.

These Guidelines compile and review all available information for the squirrel glider in the LGA to provide a basis for future planning and scientific research.

Squirrel gliders favour woodland vegetation with flowering banksias.

3. Legislative and planning context

Species, populations and ecological communities are listed in the TSC Act based on their vulnerability to extinction. The squirrel glider was listed as vulnerable in 1991, meaning it is likely to become endangered in NSW unless threats cease.

The NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) requires impacts on listed threatened species to be considered as part of planning and development approval processes. Lake Macquarie City Council (LMCC) is the local planning and consent authority for its area and has responsibilities under both the TSC Act and EP&A Act. When considering a development application LMCC must consider whether there are likely to be significant impacts on listed threatened species from the proposed development. The preparation of planning guidelines is an effective way to assist LMCC in carrying out its responsibilities. As a landowner and manager, LMCC also has responsibilities for actions that may affect the species.

The Guidelines will inform local and state based decision-making processes affecting the squirrel glider and its habitat within the Lake Macquarie LGA. They supplement the NSW Threatened Species Priorities Action Statement (DECC 2007), the NSW Office of Environment & Heritage (OEH) Saving our Species program, and the Lower Hunter Regional Conservation Plan (DECC 2009) at the local level.

Under the review of the Priorities Action Statement (OEH 2013) the squirrel glider is identified as a landscape managed species. These species are typically distributed widely and are most vulnerable to the threat of habitat loss or degradation. The security of these species depends more on the total extent and condition of habitat available than particular management actions, and these species are largely managed through existing legislation, policies and programs. The Priorities Action Statement actions identified for the squirrel glider are outlined in Appendix 1, none of these are specific to Lake Macquarie LGA.

The Lower Hunter Regional Conservation Plan (DECC 2009) recognises that *"the squirrel glider population in the Lower Hunter is of state significance as the area supports extensive, high quality coastal habitat",* but does not provide a species specific context for squirrel glider conservation at the local level. This 25-year plan focuses on the conservation of forest ecosystems and vegetation communities and is currently under review. It applied the regional conservation criteria and targets for vegetation communities known as the 'JANIS criteria' as agreed by the NSW and Australian governments (Commonwealth of Australia 1997). The targets apply to the reservation and protection of land for conservation based on the general principle of 15% reservation of the pre-1750 distribution of each forest ecosystem, with greater reservation for vulnerable forest ecosystems where the area of clearing approaches 70% in the bioregion and threatening processes continue. While the plan recognises that dry forest and woodland ecosystems within the region are important for many threatened species including the squirrel glider, and are poorly conserved, there are no planning guidelines for key issues identified such as habitat linkages or conservation reserve requirements.

Currently, the assessment of significance of impacts of development on squirrel glider is primarily assessed on a case by case basis for individual development applications by taking account of the matters for consideration in Section 5A of the EP&A Act. This is primarily to determine whether there will be a significant impact, and therefore whether a species impact statement is required to be prepared.

LMCC has previously undertaken some squirrel glider studies and reviews to inform area wide development plans in key development areas. These studies are:

- Eleebana Squirrel Glider Study (SWC Wetland and Ecological Management Consultancy 1996);
- Squirrel glider impact assessments for developments at Glendale, Coal Point and Morisset (Smith, 2005A, Smith 2005B and Smith, 2005C);
- Squirrel Glider Review for the Morisset Structure Plan (Fallding & Smith 2008);
- Wyee Squirrel Glider Review (LMCC 2008); and
- Broad LGA wide fauna habitat assessment for a range of species including squirrel gliders (Forest Fauna Surveys 2014).

These studies highlighted the importance of effective strategic planning to ensure conservation of habitat and viable populations of gliders in areas fragmented by existing and future development. Mapping of priority squirrel glider habitat conservation areas was suggested, together with protection of corridor linkages (Smith 2005A). Further ecological survey work was suggested to identify critical habitat for the purposes of the *TSC Act*, update strategic mapping, and to confirm population densities and identified corridor linkages, particularly proposed road corridor crossing locations and design requirements.


Photo: Janet Purcell

Gliders llive in the tree canopy.

4. Biology and ecology

An understanding of the biological and ecological characteristics of a species is important for informing future planning and management actions. Both landscape scale and site scale ecological characteristics need to be taken into account.

The general biology of the squirrel glider is reasonably well understood and important characteristics are summarised in Table 1 which focuses on matters relevant to the species within the Lake Macquarie LGA. Specific biological and ecological characteristics with implications for planning and impact assessment are discussed later in this section.

Table 1

Summary of important squirrel glider characteristics

Characteristic	Review & comment
LIFE CYCLE	
Reproduction	Gliders nest in tree hollows and live in family groups, typically comprising a mature male, one or more adult females, and their offspring for the season. They typically live for 3 - 4 yrs (Murray 2007 pers. comm.; Sharpe & Goldingay 2010) and have an average adult weight of about 200g. Reproduction peaks in late Autumn and Winter. Variability in available food resources can alter timing of reproduction (Millis & Bradley 2001; Goldingay, Sharpe, Beyer & Dobson 2006; Sharpe & Goldingay 2010).
Behaviour (including home range)	Gliders are nocturnal, emerging at dusk and gliding to preferred feeding sites. They are rarely observed on the ground. They live in social groups of two to nine individuals in leaf lined nests in tree hollows generally within a 5 - 15 ha home range (van der Ree & Bennett 2003; Sharpe & Goldingay 2007; Goldingay et al. 2010). Home range varies according to habitat quality, especially presence of feed trees and habitat trees with suitable hollows. Multiple nest sites are used within their home range and may be changed frequently (van der Ree 2000). Home range varies according to habitat quality and may vary seasonally (van der Ree & Bennett 2003). Nightly ranges are generally 300 – 500 m. Home ranges of 12 – 15 ha were found at Tea Gardens, NSW (Goldingay, Sharpe & Dobson 2010; Smith 2002). A home range of 6 to 7 ha was calculated for Eleebana in Lake Macquarie LGA (SWC 1996).
HABITAT	
Habitat requirements	Squirrel glider occurrence is highly localised and dependent on availability of suitable foraging habitat with tree hollows. Colonies require multiple den trees within their home ranges. High population density is only achievable in habitats with abundant hollow bearing trees (>4 habitat trees/ha) and abundant food trees (Smith and Murray 2003; van der Ree 2000; Sharpe & Goldingay 2010). Dead trees (stags) are an important habitat component and are used when available (Rowston 1998; Ball, Goldingay & Wake 2011; Beyer, Goldingay & Sharpe 2008). Although sugar gliders are generally not present at locations where squirrel gliders occur (Smith 2002), the ecology of both species is similar and they appear to co-exist at many locations within Lake Macquarie LGA.
Tree hollows	Tree hollows utilised can have entrance sizes of 2.5 – 12 cm diameter, although hollows with entrances ≤ 5 cm wide are used most frequently (Beyer et al. 2008). Gliders select small entrances (about 3 - 5 cm entrance diameter) to exclude competitors and predators. Most foraging is within about 400 m of dens.
Dietary requirements	Squirrel gliders eat nectar from flowers, pollen and sugary plant and insect exudates. They require winter flowering eucalypts, understorey shrubs, or winter gum producing acacias. In addition to pollen and nectar, arthropods are an important food source (Sharpe & Goldingay 1998; Dobson, Goldingay & Sharpe 2005; Ball et al. 2009). Red Bloodwood trees *(Corymbia gummifera)* are important in providing sap in the Lake Macquarie LGA.
Environmental conditions	All but two squirrel glider (accurate and unique) records in Lake Macquarie LGA are from land with an elevation below 100 m.

Characteristic	Review & comment
HABITAT	
Vegetation community associations	Found in a range of dry and moist sclerophyll forest, swamp forest, and woodland vegetation communities dominated by: (1) winter flowering eucalypts or flowering banksias, (Quin et al. 2004; Sharpe 2004; Sharpe & Goldingay 2010), or (2) summer flowering eucalypts with an understorey of acacia species that provide edible gum exudates in winter (eg *A. irrorata, A. parramattensis, and A. longifolia)* (Smith and Murray, 2003). Important vegetation communities in Lake Macquarie LGA for squirrel gliders are those containing Spotted Gum *(Corymbia maculata),* Scribbly Gum *(E. haemastoma)*, Swamp Mahogany *(E. robusta)* and Red Bloodwood *(Corymbia gummifera)*. The majority of LGA records are in dry sclerophyll forest with banksia understorey (Forest Fauna Surveys 2014). Broad habitat types with known squirrel glider populations are Dry Sclerophyll Forest, Dry Sclerophyll Forest – Banksia, Spotted Gum Forest, and Swamp Mahogany Forest (Forest Fauna Surveys 2014). The ecological role of squirrel glider in pollination and maintaining plant species and vegetation communities is unknown but can be inferred as important from work on sugar gliders.
POPULATION	
Distribution	The squirrel glider is sparsely distributed along Australia's east coast from Victoria to North Queensland, generally extending inland up to about 300 km (NSW Office of Environment and Heritage, 2014A). Lake Macquarie is in the centre of the north - south distribution. Possible confusion between the squirrel glider and the sugar glider means that some records of occurrence may be misidentifications and not reliable (NSW Scientific Committee 2008).
Conservation status	The squirrel glider *Petaurus norfolcensis* is listed as a threatened (Vulnerable) species on the NSW TSC Act. It is also listed as threatened in Victoria and South Australia but not listed in Queensland or under the Commonwealth *Environment Protection and Biodiversity Act 1999*. Within the Lake Macquarie LGA approximately 40% of its estimated potential habitat has been lost since 1750. It is poorly protected within conservation reserves, mainly occurring on private land.
Minimum habitat size	The minimum habitat patch size that will be occupied by squirrel gliders is strongly influenced by habitat quality. Squirrel gliders occupy very small patches if habitat quality is high, and much larger habitat patch sizes in lower quality habitat. However, the probability of a patch being occupied by squirrel gliders decreases with remnant size. Modelling predicts that density and occurrence begins to decline when patch size falls below 100 ha depending on time since isolation, remnant shape, and distance to nearby habitat. In Wyong, the largest known remnant of suitable habitat without squirrel gliders is 30 ha. Habitat patches of less than 4 ha are considered unsuitable for permanent occupancy. Small habitat patches of 4 ha to 30ha, are considered at high risk of local extinction. Minor habitat patches of 30 ha to 100 ha, are considered at moderate to low risk in the short-term, and high risk in the long-term; and major habitat patches, 100 ha to 1,000 ha are considered at no risk in the short-term, (50 yrs to 100 yrs), and low to moderate risk in the long term (Smith 2002).
Population density	Average population density varies with habitat quality from 0.5 to1.6 animals/ha (Sharpe & Goldingay 2010). Factors affecting density include habitat quality and disturbance effects (eg severe wildfire, and density of suitable den trees). Density estimates are given for some vegetation communities by Smith (2002) in the Lower Hunter Central Coast Regional Environmental Management Strategy (LHCCREMS, 2003). Estimated densities (based on vegetation communities) in Lake Macquarie LGA are from 0.3 – 0.4 individuals/ha. Yearly variation in flowering rates can alter population densities by around 50% (Goldingay, Sharpe, Beyer & Dobson 2006).
Population viability	A remnant patch of habitat would need to exceed 400 ha to ensure continued survival of a viable population (Goldingay, Sharpe, Beyer & Dobson 2006). Smith (2002) estimated that remnant habitat patches in Wyong LGA greater than 250 ha, or populations of more than 90 individuals should have close to a 100% probability of surviving in the short term (about 40-60 years). Larger minimum habitat areas or population sizes are likely to be required to ensure that populations are viable for longer time periods, with minimum populations of around 1,000-2,000 individuals required to sustain glider populations over the long term. This would require conservation reserves with about 2,500-5,000 hectares of habitat. This is not to say that populations in smaller fragments are not viable.

Characteristic	Review & comment
HABITAT	
Genetics	Separation of populations can be determined over 5 to 7 years using genetic studies. A period of at least 30 years separation is required to show significant genetic differentiation of squirrel glider subpopulations, coupled with loss of genetic diversity and increased inbreeding may occur within 30 years of habitat isolation (Goldingay et al. 2013).
MOVEMENT	
Maximum travel distance	Squirrel gliders will generally move up to 1 km in a night, with the longest reported distance travelled by a Glider in one night through suitable habitat being about 1.9 km (Sharpe & Goldingay 2007). The maximum distance that squirrel gliders will move through unsuitable habitat is not known (van der Ree & Bennet 2003). Averaged maximum distances moved by female and male squirrel gliders within a night were found to be 1,174 m and 1,043 m respectively (Sharpe & Goldingay 2007).
Gliding distance	The glide angle averages 28.5 degrees (Goldingay & Taylor 2009), with horizontal glide distance varying with launch height. As a general rule, the average gap crossing distance between trees is 1.8 times launch height minus 2 m (assuming that the landing point is a minimum of 2 m above ground). Therefore, gliding distance = (launch height - 2) x 1.8.
Gap crossing ability	Squirrel gliders are reluctant to come to the ground to cross gaps and crossing width depends on tree height on either side of the gap (van der Ree 2000). The probability of small habitat patches separated by road or clearing gaps being occupied by squirrel gliders in Wyong district is: • 50% for gaps of 35 m, • 20% for gaps of 100 m, and • close to zero for gaps >250m wide (Smith 2002). For practical purposes, road gaps >35 m wide are considered a potential barrier to crossing. To achieve movement across a tree-gap of 20 m (two-lane road) or 43 m (four-lane road) in a single glide, tree height would need to be at least 13 m and 25 m respectively (Goldingay & Taylor 2009). A road canopy gap of at least 50 m appears to be almost complete barrier to glide crossings (van der Ree et al. 2010). A decline in squirrel glider population near roads with high traffic volumes has been observed, although they occupy habitat near roads (McCall et al. 2010).
DISTURBANCE & THREATS	
Threats	The main threats are loss and degradation of habitat, habitat fragmentation and resulting population fragmentation, road kill, frequent fire, predation, collision with barbed wire fencing, weed invasion, and removal of dead wood and dead trees (NSW Scientific Committee 2008).
Bush fire response	The most significant impact of bush fire is change to vegetation structure and loss of hollow bearing den trees. Effects of fire vary with habitat type. Habitats with winter flowering or gum producing understorey plants (Banksia, Acacia) are likely to be most affected and may only carry peak glider densities 10 or more years after fire (Smith & Murray 2003).
Predation	Owls, goannas, cats and foxes (Smith 2002) prey on squirrel gliders. Predation is likely to cause periodic extinction in small patches. Cat predation is likely to be a problem near urban areas.
Translocation response	There is no literature documenting translocation of squirrel gliders. Translocation of mammal species has generally been unsuccessful though continued research may improve outcomes.

Notes:

1. The summary information in Table 1 primarily refers to squirrel glider characteristics within the Lake Macquarie LGA and may not apply across the full range of its Australian distribution.
2. Some of the information was compiled by Matthew Kennedy, and Table 1 was reviewed by the scientific and technical workshop.
3. Some characteristics identified may vary across the distributional range of the squirrel glider.

Many studies have been undertaken to understand the ecology of the squirrel glider across its range from Western Victoria, coastal NSW and Queensland. Published information focuses on the ecology of the species, impacts of habitat fragmentation, gliding ability and gap crossing, diet, den tree selection, home range, and habitat requirements.

Most studies have been undertaken in fragmented landscapes, especially in Victoria and in urbanised areas around south-east Queensland. There is substantial species information available for particular sites and can be applied generally throughout its range.

Key research topics described in the scientific literature are:

- The effect of habitat fragmentation on squirrel glider populations.
- Den and hollow characteristics and behaviour.
- Crossing of barriers, especially the effectiveness of glide poles to facilitate movement.
- Food resources and diet, and effect of changes in plant flowering on population.

Fragmentation of habitat has a large effect on the species, as gaps in tree cover between adjacent sites form barriers the species cannot cross. Research has been undertaken to evaluate the performance of erected glide poles along roadsides, along land bridges across roads and in open areas between sites. The information being published on glide poles shows squirrel gliders will utilise these devices for crossing gaps over roads (Taylor and Goldingay, 2012, Taylor and Goldingay, 2013) and between vegetation remnants (Ball and Goldingay, 2008). Glide poles are a tool for reconnection of some disconnected habitats for the squirrel glider.

Studies into the dietary requirements of the squirrel glider have been undertaken across the species range. Food resources and their utilisation vary between sites, reflecting different habitat types and condition. Sugary exudates (such as nectar, sap, honeydew and gum) are eaten for energy including scarring the bark of certain eucalypts and feeding on the sugary sap that flows. Insects and pollen provide protein. Squirrel gliders most commonly occur where there is a reliable supply of nectar and pollen in winter because insects and exudates are scarce and energy requirements are high (Smith 2002).

Changes in flowering patterns from year to year can greatly affect the squirrel glider population (Sharpe and Goldingay, 2010), densities and dynamics. Variations in annual flowering patterns and availability of other food sources can have major implications with potentially serious and detrimental consequences for long-term sustainability of squirrel glider populations. Large trees also play a role in the preservation and persistence of this species, providing more flowering mass, a higher frequency of hollows and an important means of dispersal.

Planning for the species is dependent on the level of scientific understanding and applying this effectively in land use decision-making. Important matters relating to the ecology of squirrel gliders that land use planning can influence include:

- the spatial location of future development and infrastructure,
- vegetation clearing and habitat fragmentation, and
- the identification and protection of conservation areas and connecting habitat.

Although many aspects of the biology and ecology of the squirrel glider are well understood, important scientific questions remain which are important at planning and management scales. These are population issues, habitat requirements, movement and connectivity requirements. The following sections outline the available data for Lake Macquarie LGA for these issues, and provide the basis for determining future strategic planning and management.

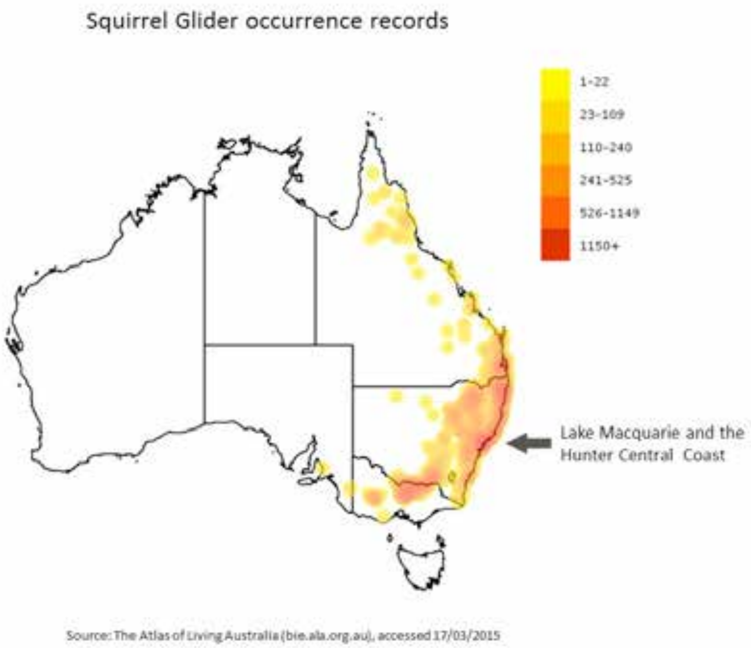
4.1 Population

Understanding the spatial distribution of the existing population and its context is important for strategic planning, and for evaluating future development and conservation options. This is a factor relevant at site, landscape and regional scales. Understanding the populations and their response to habitat loss is a key factor in conserving biodiversity.

Map 1 shows the national distribution of the squirrel glider including its distribution in Eastern Australia. The records are concentrated in the centre of its geographic range, particularly in the Lake Macquarie/Wyong area and in north-east NSW to south-east Queensland. Smith (2002) considered the population within the Lake Macquarie – Wyong area to be of state and national significance because it represents the highest concentration of Wildlife Atlas records in NSW and is estimated to be of a large size (i.e. approximately 5000 individuals).

Map 1

Australian distribution of records



Records of the presence of squirrel gliders within Lake Macquarie LGA were compiled and evaluated and broad habitat type was identified, giving 433 occurrence records (Forest Fauna Surveys 2014). The records are from both the NSW Wildlife Atlas and the Lake Macquarie Threatened Species Database, which includes records from surveys of development sites. All records were then reviewed in terms of their spatial accuracy and reliability, and unreliable records were eliminated.

Within the Lake Macquarie LGA, there are 392 reliable squirrel glider records from 1993 to the present that indicate the population and its distribution. These records can be used in models to predict habitat suitability and potentially to determine likely populations and their viability.

The following are key issues to consider in interpreting these records.

1. Records show species presence and do not confirm species absence.
2. Absence records for squirrel gliders are unreliable. An absence record means only that the survey did not record the species, not that the species does not occur on the site.
3. They are primarily in areas where field surveys are concentrated, and are overwhelmingly on proposed development sites and/or in the vicinity of roads.
4. Some areas of potential habitat have not been surveyed at all. Survey bias could be corrected with systematic surveys.
5. There is a possibility that some records prior to about 2000 may have confused squirrel gliders with sugar gliders because the two species can be difficult to differentiate (especially if spotlighting) and co-exist in many locations.
6. No surveys have included genetic analysis that could indicate separation of populations over time and inform estimates of population viability.
7. Considerable additional survey effort would be required to determine with confidence the number, distribution and home range of local populations and/or metapopulations within the LGA.

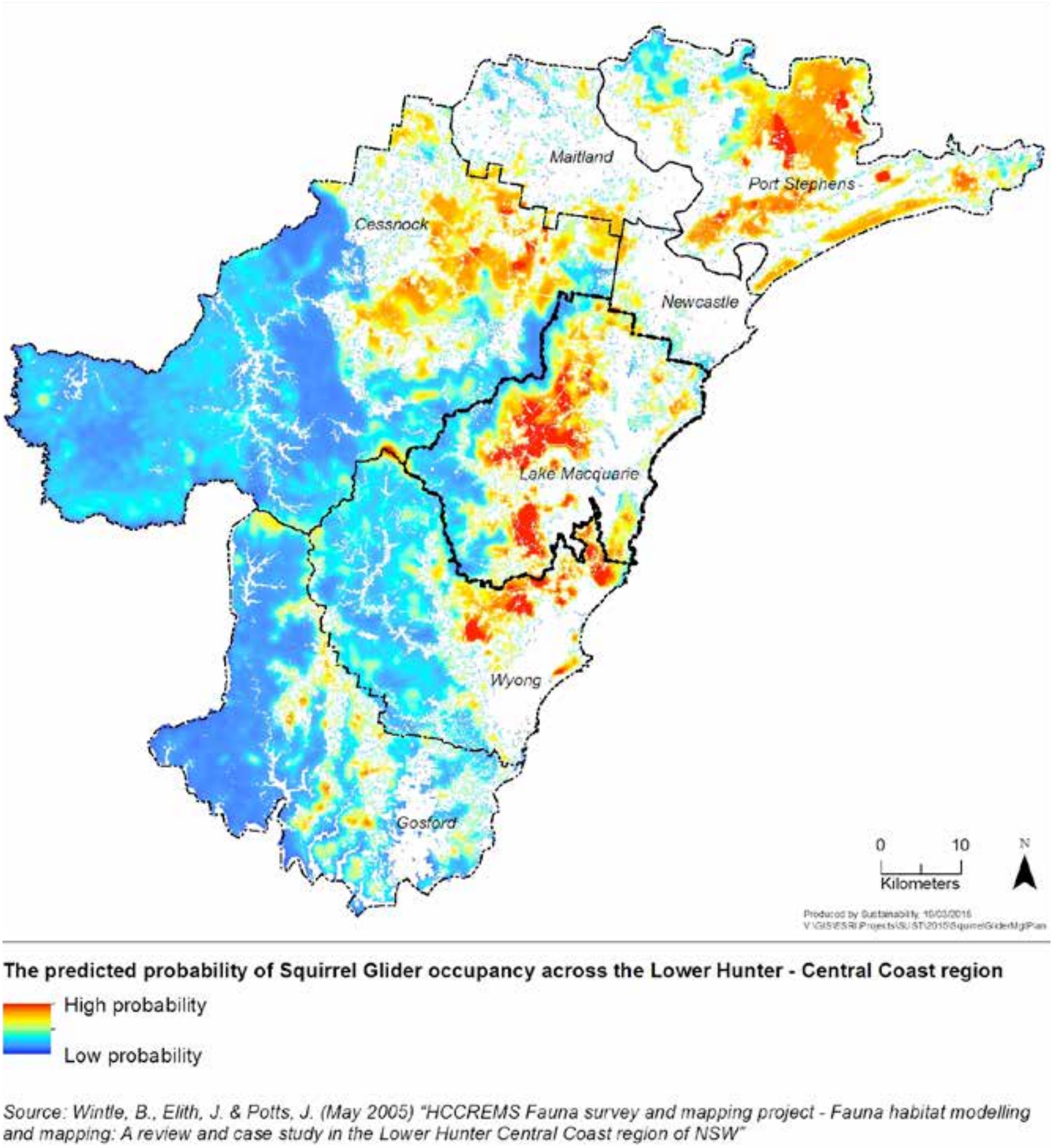
Species distribution models (SDM) have been used to predict the likelihood of occurrence of squirrel glider habitat. Map 2 shows the predicted probability of occurrence of squirrel glider habitat across the Lower Hunter Region (Wintle et al. 2005) and 2015 modelling for the Hunter Region is also being undertaken by the University of Melbourne. These models use species presence records and a range of environmental variables to determine relative habitat suitability probabilities.


Photo: Michael Murray

Incision marks on Red Bloodwood *(Corymbia gummifera)*

Map 2

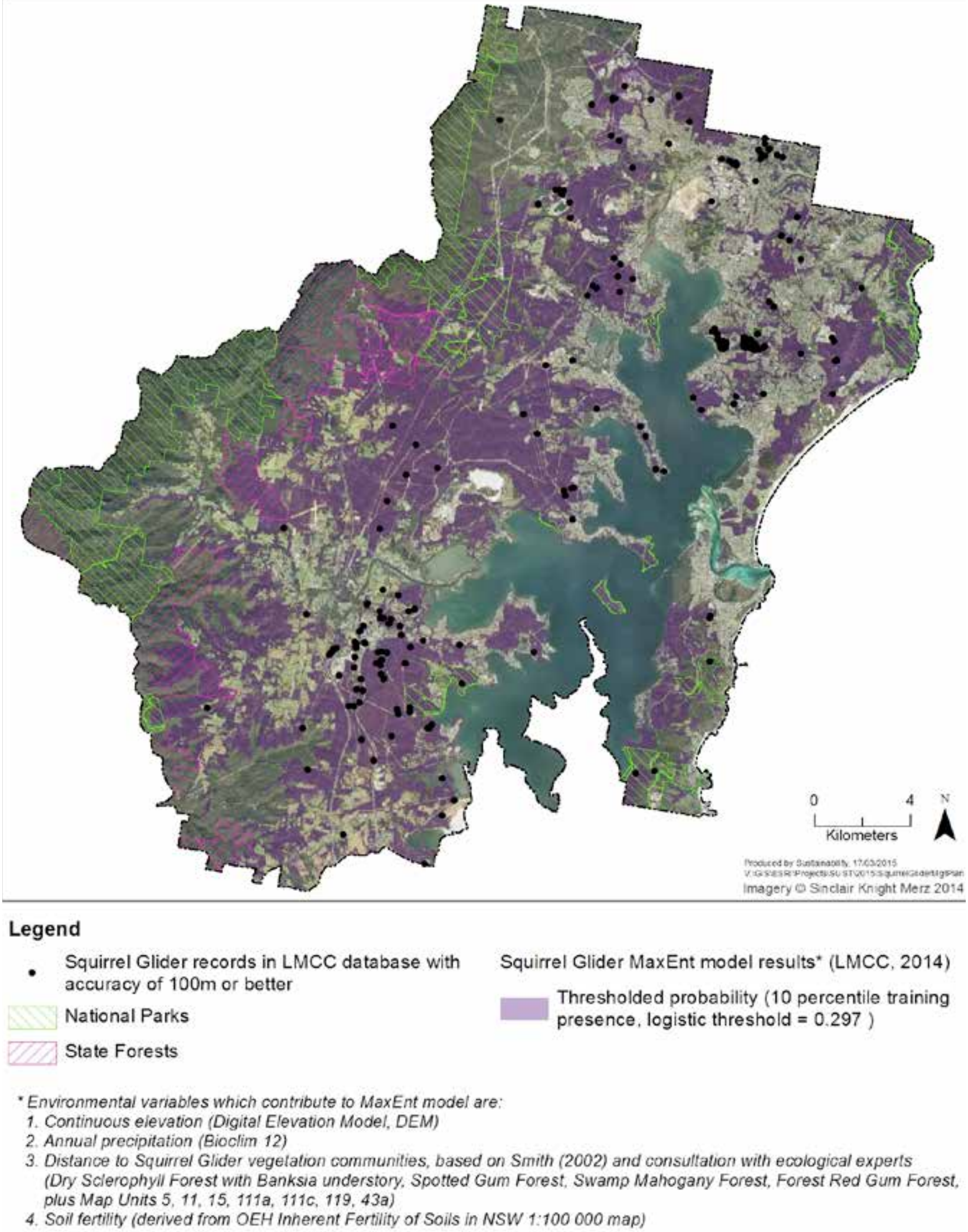
Regional modelled predicted occurrence of habitat (2005)



LMCC used MaxEnt to model the probability of occurrence of squirrel glider habitat using squirrel glider records and a range of environmental variables. Records of occurrence are concentrated in certain areas, and are primarily a result of ecological surveys associated with development proposals. The methodology used in this analysis is described in McDonald & Economos (2015). Variables that made the highest contribution to the predicted habitat in the model were elevation, rainfall and vegetation communities important for squirrel gliders. Map 3 shows the location of squirrel glider records and the results of a threshold analysis using MaxEnt modelling to give a predicted habitat distribution map for the LGA. This is derived from the relative probability of habitat occurrence map in Appendix 2.

Map 3

Predicted LGA distribution based on threshold probability of occurrence of squirrel glider habitat (MaxEnt model)



The predicted habitat distribution in Map 3 identifies approximately 23,500 ha of suitable habitat within the LGA. There are also extensive areas of suitable squirrel glider habitat within Wyong LGA and contiguous with native vegetation in Lake Macquarie LGA.

It is also important to note that squirrel glider and sugar glider records overlap within the LGA. These two species probably competitively occupy the same habitat and records show a general trend for sugar gliders to occur in wetter and higher elevation land to the west of the LGA. This pattern of distribution and the possibility of incorrect identification suggests that the two species need to be surveyed and reported concurrently.

Although the predicted distribution shows extensive areas of squirrel glider habitat, especially on the western side of Lake Macquarie, there is extensive fragmentation of habitat and all viable populations should be considered to be important populations. Conservation of the species in a number of different patches and locations is important, especially for surviving catastrophic disturbance events.

Importantly, the Lower Hunter councils have a large proportion of the NSW population of squirrel gliders, and Lake Macquarie LGA contains a very significant population.

4.2 Squirrel glider habitat requirements

The availability and quality of habitat affects the distribution of the population and determines the breeding success of individuals as part of a larger population. Understanding habitat is therefore important at local and site scales.

Section 5A of the EP&A Act requires that an assessment to be made of whether a proposed action is likely to significantly affect threatened species habitat. For planning, it is therefore important to understand and define squirrel glider habitat, the extent of its removal and fragmentation, and the importance of the habitat to the survival of the species, and viability of populations relative to habitat patch size.

Understanding habitat requirements is also important in determining population density, likely presence and absence, and to identify areas that may be suitable for conservation and/or for the provision of biodiversity offsets. Habitat characteristics such as home range, distance travelled, gap crossing ability, and use of hollows and dens are applicable across the full range of the squirrel glider. See the scientific workshop report in Appendix 4.

For an individual site, it is useful to know things such as the number of trees used by individuals, spatial distribution and arrangement, and the frequency of den use over time. These characteristics and population size will often be dependent on plant flowering patterns, as a substantial part of the squirrel glider diet is nectar and pollen.

Squirrel glider distribution is determined by two key characteristics, (1) habitat suitability and (2) habitat size and spatial arrangement.

1. Habitat suitability
   This is highly localised and dependent on the availability of suitable foraging habitat with tree hollows.

2. Habitat size and spatial arrangement
   The major threat to the continuing presence of squirrel gliders is habitat clearing and fragmentation, resulting in smaller habitat patches and increased isolation. Surveys in Wyong by Smith (2002) have shown that density and probability of occurrence in remnants, increases significantly with
   - increasing remnant size,
   - decreasing distance to the nearest remnant, and
   - increasing size of the nearest remnant.

Density and occurrence is also related to the presence of corridor links with adjoining remnants, and the width of habitat either side of roads and other linear barriers.

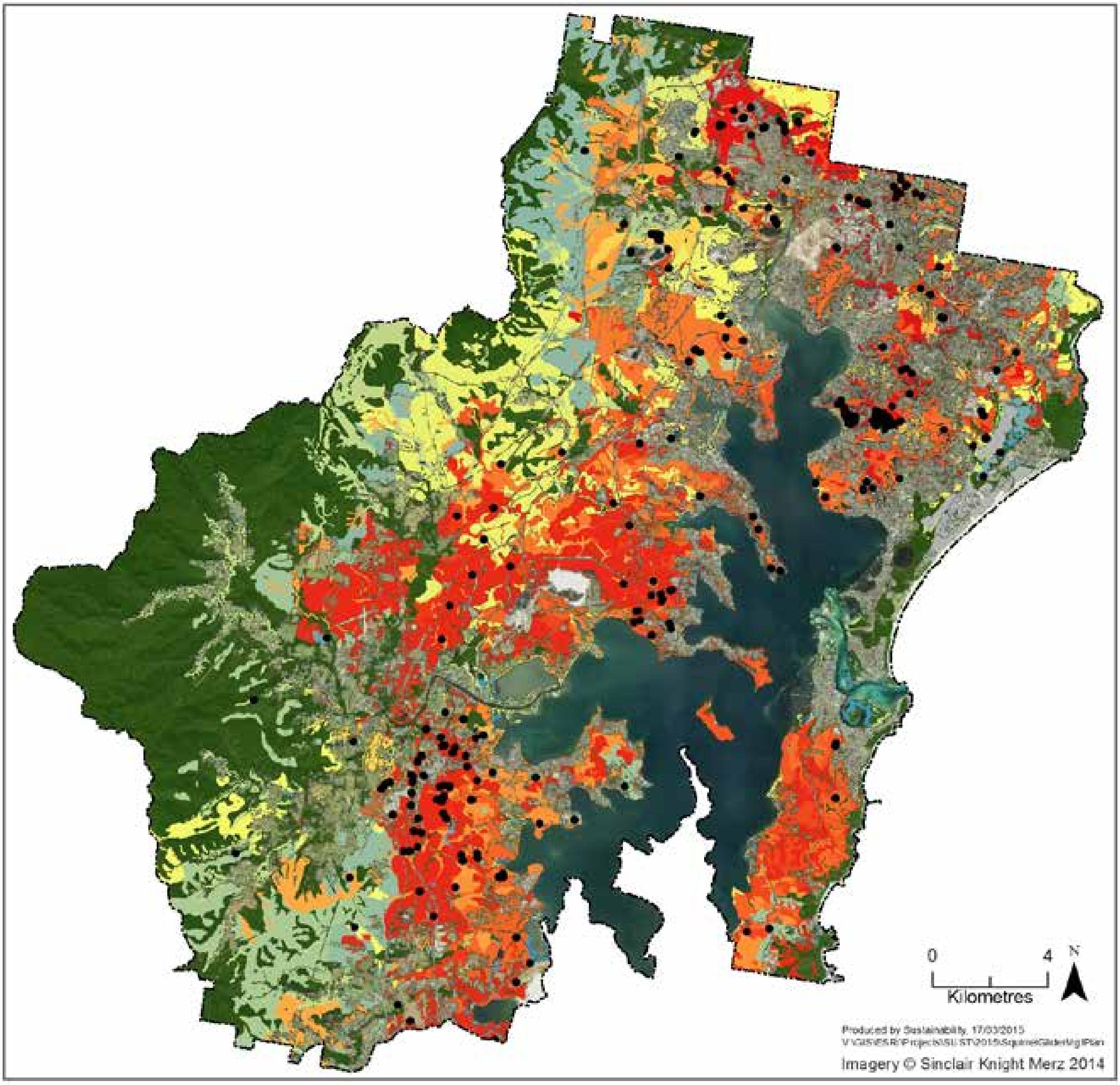
Squirrel glider records across the Lake Macquarie LGA, have been categorised according to both vegetation communities and the broad habitat types occurring within the LGA (Forest Fauna Surveys 2014). These habitat types were based on LMCC native vegetation community mapping (Bell & Driscoll 2014) and used to inform predictive modelling. Vegetation mapping approximates habitat, being based on vegetation structure and plant species composition.

The distribution of vegetation communities across the LGA and the species records of occurrence are shown in Map 4. Records exist in a total of 36 different communities, although the majority of records are from only 6 communities. Names of vegetation communities and the equivalence of communities with broad habitat types are shown in Appendix 3.

Hollow used by squirrel gliders in den tree.

Map 4

LMCC vegetation communities and number of squirrel glider records



LMCC Vegetation Map Unit & Community (Bell & Driscoll, 2014) and number of squirrel glider (SG) records in LMCC fauna database within accuracy distance (where 100m or better) from vegetation community

- 30e - Coastal Plains Stringybark - Apple Forest, 92 records
- 31 - Coastal Plains Scribbly Gum Woodland, 56 records
- 37 - Swamp Mahogany - Paperbark Forest, 37 records
- 11 - Coastal Sheltered Apple-Peppermint Forest, 31 records
- 15h - Lake Macquarie Spotted Gum Forest, 25 records
- 111a - Lake Macquarie Snappy Gum Forest, 12 records
- 12 - Hunter Valley Moist Forest, 9 records
- 30h - Sugarloaf Lowlands Bloodwood - Apple Forest, 8 records
- 38 - Foreshore Redgum-Rough-barked Apple Forest, 7 records
- 31j - Snappy Gum Ridgetop Heathy Forest, 6 records
- 42 - Red Mahogany - Apple Paperbark Forest, 6 records
- 17o - Hinterland Spotted Gum - Red Ironbark Forest, 5 records
- 15i - Lake Macquarie Ironbark Forest, 4 records
- 30j - Sugarloaf Lowlands Bloodwood-Apple-Scribbly Gum Forest, 4 records
- 38a - Floodplain Redgum-Rough-barked Apple Forest, 4 records
- 38c - Foreshore Redgum-Ironbark Forest, 3 records
- 43a - Estuarine Paperbark Scrub Forest, 3 records
- 119 - Kahibah Snappy Gum Forest, 2 records
- 15 - Coastal Foothills Spotted Gum - Ironbark Forest, 2 records
- 30f - Freemans Peppermint-Apple-Bloodwood Forest, 2 records
- 30i - West Wallsend Stringybark Forest, 2 records
- 37j - Dune Swale Swamp Forest, 2 records
- 40 - Swamp Oak - Rushland Forest, 2 records
- 5 - Alluvial Tall Moist Forest, 2 records
- 111c - Killingworth Snappy Gum Forest, 1 record
- 15n - Jilliby Spotted Gum-Ferguson's Ironbark-Mahogany Forest, 1 record
- 30 - Coastal Plains Smooth-barked Apple Woodland, 1 record
- 30a - Buttonderry Footslopes Forest, 1 record
- 30b - Sugarloaf Uplands Bloodwood - Apple Forest, 1 record
- 31k - Narrabeen Dune Forest, 1 record
- 33 - Coastal Sand Apple-Blackbutt Forest, 1 record
- 37a - Alluvial Paperbark Sedge Forest, 1 record
- 43c - Paperbark Clay Heath, 1 record
- 44m - Coastal Plains Wet Heath, 1 record
- 47 - Mangrove - Estuarine Complex, 1 record
- XsM - Mining Rehabilitation (Coastal Tea-Tree/ Bitou/ Acacia), 1 record
- Vegetation communities which do not contain accurate SG records

Potential squirrel glider habitat known to occur within the LGA is based on woodland and forest habitat categories developed by Forest Fauna Surveys (2014) using vegetation mapping provided by Bell and Driscoll (2014). The number of records for broad habitat types within the LGA are shown in Table 2, which also shows the priority ranking of habitat types. Each broad habitat type comprises a number of mapped vegetation communities (Appendix 3). By reviewing the description of these communities and their species composition, a squirrel glider habitat map based on vegetation communities can be produced. While an estimate of potential habitat is shown, it is not certain that the squirrel glider occurs over the full area of habitat identified as suitable, or that the species occurs at a consistent density.

Table 2

Broad habitat types in LGA and records of occurrence

Broad habitat type	Area of habitat in city (hectares)	Number of squirrel glider records (<100m accurate)	% total records
Dry Sclerophyll Forest / Banksia understorey	14691	163	41.6
Dry Sclerophyll Forest	7084	45	11.5
Swamp Mahogany Forest	2218	33	8.4
Spotted Gum Ironbark Forest	7178	29	7.4
Wet Sclerophyll Forest	4464	10	2.6
Forest Red Gum Forest	1378	10	2.6
Swamp Oak / Melaleuca Forest	615	4	1.0
Wet Heath	91	1	0.3
Mangrove / Saltmarsh	232	1	0.3
Dry Heath / Scrub	310	1	0.3
Coastal Scrub	706	1	0.3
Beach	9	0	0.0
Littoral Rainforest	21	0	0.0
Rainforest	3505	0	0.0
Riparian Forest	442	0	0.0
Wetland / Sedge	166	0	0.0
Total records in habitat	**n/a**	**298**	**76.0**
Not assigned (not mapped as vegetation)	**n/a**	**94**	**24.0**
Total	**43116**	**392**	**100.0**

From Forest Fauna Surveys 2014

Rank 1 is red, Rank 2 is orange, and yellow is Rank 3 which is not regarded as habitat.

The spatial data available show that it is feasible to use vegetation community mapping to indicate the likelihood of occurrence of suitable habitat. However, this provides no indication of the actual presence or absence, or the quality of the habitat. One limitation of the available data is understanding of the presence of old growth habitat characterised by a relatively higher proportion of large mature, and dead trees and therefore hollows. Although there are some exceptions, trees with a diameter at breast height of approximately 40cm are of an age to form hollows for squirrel gliders (Michael Murray pers. comm.).

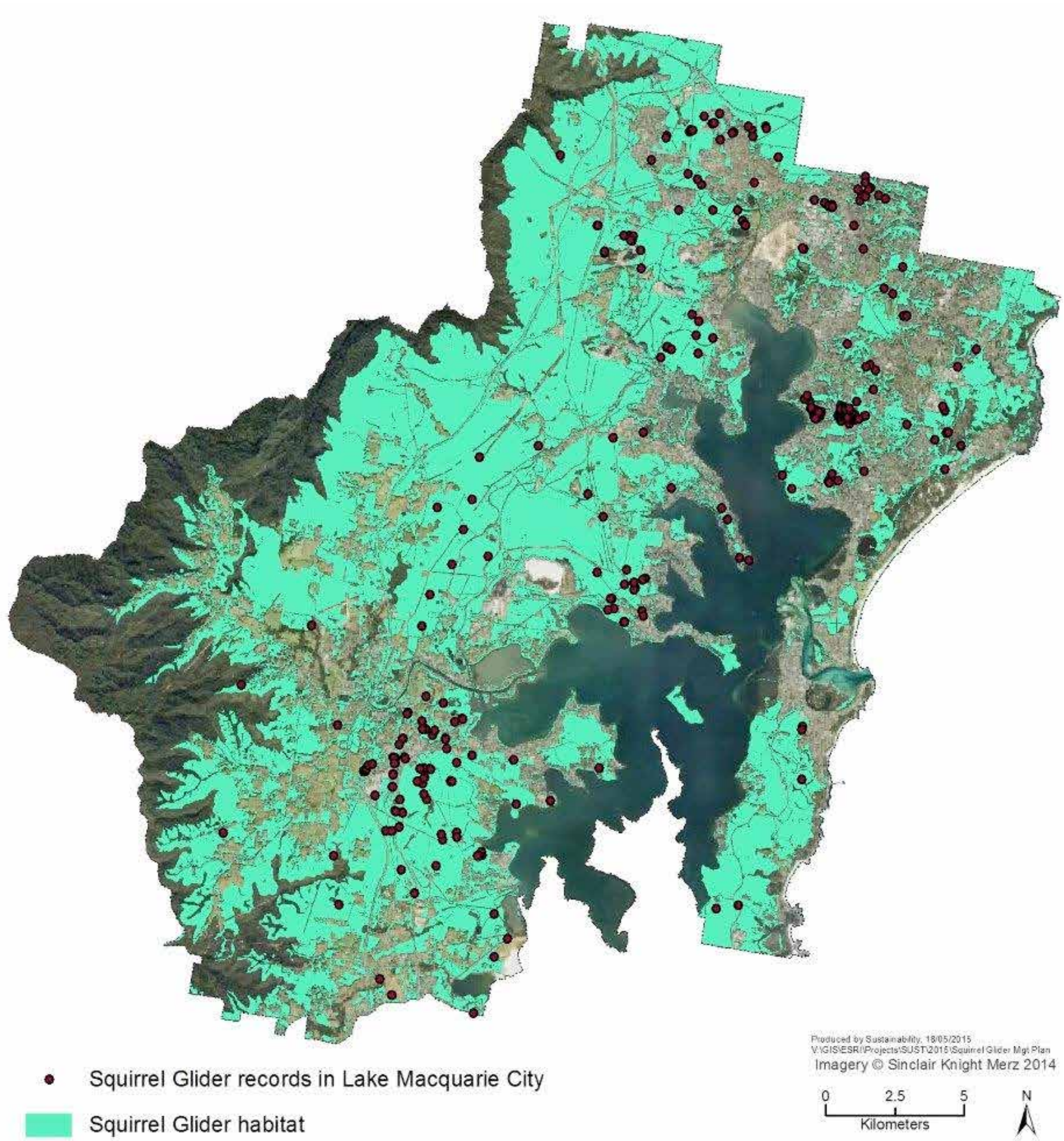
Using vegetation mapping and descriptions in conjunction with the distribution of records, and by excluding unsuitable habitat, a map of likely squirrel glider habitat has been prepared as shown in Map 5. This shows that there is an area of approximately 30,000 ha of squirrel glider habitat within the LGA. The extent of likely habitat within the LGA has been determined by applying the following method:

1. Identify and review all squirrel glider records from the LGA, eliminating those records of limited accuracy or reliability.
2. Determine the number of presence records within each vegetation community identified in the Lake Macquarie Vegetation Community Mapping (Bell & Driscoll 2014).
3. Vegetation communities were used to map squirrel glider habitat suitability in conjunction with elevation. Vegetation communities were identified as habitat where there was at least one reliable record of presence in that community, and/ or where the winter flowering plant species known to be used by squirrel gliders were present within that community. Land above 100 m elevation was excluded as habitat.
4. The habitat map was compared with models of predicted probability of occurrence at the regional and local scales to identify inconsistencies (Appendix 5).

Squirrel Glider gliding from dead tree.

Map 5

Likely LGA squirrel glider habitat based on vegetation communities and altitude



In addition to the vegetation communities, specific habitat characteristics are important indicators of suitable squirrel glider habitat, especially known food plants which are listed in Table 3. Where these species are identified on a site, it is more likely that the site supports habitat for squirrel gliders. The priority broad habitat types in Table 2 and associated vegetation communities include many known food plants.

Table 3

Important known squirrel glider food plants in Lake Macquarie LGA (from Smith 2002)

Food Plants		Food type & seasonal importance
Eucalyptus	*siderophloia*	nectar winter
	tereticornis	nectar winter
	pilularis	nectar winter
	robusta	nectar winter
Corymbia	*maculata*	nectar winter
	gummifera	sap, nectar summer
Melaleuca	*quinquenervia*	nectar autumn, insect bark feed
Acacia	*Irrorata subsp. irrorata*	gum
	Longifolia subsp. longifolia	gum
Banksia	*Integrifolia subsp. integrifolia*	nectar and pollen winter
	oblongifolia	nectar and pollen summer
	serrata	nectar and pollen summer autumn
	spinulosa var. collina	nectar and pollen winter
Xanthorrhoea	*spp.*	nectar, gum

Note: Other local species should be investigated for inclusion on this list, including the winter flowering acacias A. myrtifolia, A. prominens and A. ulicifolia, and a range of other species also occurring within vegetation communities identified as likely squirrel glider habitat including A. implexa, A. parramattensis, A. myrtifolia, A. prominens, A. ulicifolia, M. styphelioides, M. linariifolia and M. nodosa.

The map of likely LGA squirrel glider habitat based on the Lake Macquarie vegetation community mapping (Map 5) has been compared with the species distribution modelling which shows that the two approaches largely co-incide as shown in Appendix 5. The main differences occur in the:

- north west of the LGA where vegetation communities suggest more extensive squirrel glider distribution in the foothills and Mt Sugarloaf area and there are no species records, and
- east of the LGA where the habitat model includes more coastal and heath vegetation.

The results of this analysis suggest that the Lake Macquarie vegetation community mapping is a solid basis to use for determining squirrel glider habitat for planning purposes. Since it is less abstract than modelling and is readily applicable in the field, this is the preferred method for predicting/mapping squirrel glider habitat. The method for predicting squirrel glider habitat should be reviewed over time as further surveys are undertaken.

When compared with the OEH plant community (and biometric) vegetation types (PCTs), there is not a good correlation between, the 66 vegetation communities where squirrel glider records occur and suitable habitat exists, and the 30 PCTs occupying the same area. This indicates that the Biobanking Assessment Methodology applying PCTs is not a reliable approach in Lake Macquarie LGA for either identifying suitable squirrel glider habitat or in determining biodiversity offsets, if the assessment is based on ecosystem credits rather than species credits. Importantly, OEH PCTs are much broader in their spatial extent and floristics than the Lake Macquarie Vegetation Community Map Units used, meaning that the PCTs do not adequately represent squirrel glider habitat.

Smith (2002) developed an algorithm for calculating "effective remnant size" that was found to be the best predictor of squirrel glider occurrence in remnants. Effective remnant size equals the size of a remnant (>4 ha) plus the size of all adjacent remnants, separated by gaps of a specified isolation class that presents no barrier or impediment to squirrel glider movement, less the area of unsuitable habitat within the combined area. Gaps that presented no impediment to glide crossing were defined in Smith (2002) as any road or clearing gaps <100 m wide with forest vegetation on either side of the gap for a distance of at least 250 m, as determined from air photos.

The density and number of squirrel gliders within the Lake Macquarie LGA is difficult to determine, as adequate systematic survey has not been undertaken. Estimated densities of squirrel gliders in the Wyong/Lake Macquarie area, based on Smiths (2002) algorithm, are shown in Table 4. These identify densities for different LHCCREMS (2003) vegetation community Map Units which are broadly comparable with the Lake Macquarie Vegetation Mapping Map Units (Bell & Driscoll 2014).

Habitat tree with hollow for nesting.

Table 4
Squirrel glider population density estimates for vegetation communities (from Forest Fauna Surveys 2014, derived from Smith, 2002)

Vegetation community name (LHCCREMS 2003)	Estimated squirrel glider (density/ha)
Coastal Sheltered Apple – Peppermint Forest (Map Unit 11)	0.30
Coastal foothills Spotted Gum - Ironbark Forest (Map Unit 15)	0.45
Coastal Plains Smooth-Barked Apple Woodland (Map Unit 30)	0.37
Coastal plains Scribbly Gum woodland (Map Unit 31)	0.37
Riparian Melaleuca Swamp Woodland (Map Unit 42)	0.38

Note: Density also varies according to the type of understorey vegetation (Smith 2002). Map Units vary in their equivalence to Bell & Driscoll Map Units, but are broadly comparable.

4.3 Movement and habitat connectivity

Movement and habitat connectivity is closely related to habitat patch size and spatial arrangement. Importantly, canopy gaps greater than the length of a single glide are potentially a barrier to the movement of gliding marsupials. Therefore, gap crossing is important for maintaining population, and an important consideration in assessing impacts of development which will either reduce the size of habitat patches, or remove connectivity between these patches.

The review of literature indicates that squirrel glider population viability in smaller habitat patch sizes is highly dependent on maintaining habitat connectivity, and especially the ability of the species to utilise corridors and to cross roads and barriers. Habitat connectivity is required for both:

(1) regular movement of individual animals for feeding and breeding within a home range, and population dispersal, and

(2) infrequent and occasional movement of an animal to facilitate the flow of genetic material between populations to prevent in-breeding.

The former requires continuous habitat connectivity, while the latter requires habitat connectivity over longer time scales, and is primarily relevant to the viability of small, isolated populations. Both must be considered in planning and impact assessment.

The Morisset Squirrel Glider Review (Fallding & Smith 2008) was undertaken to review land use options for identified urban development areas, and proposed planning measures to maintain local populations and maintain connectivity. It divided up habitat fragments according to size classes (major, minor and small fragments) based on a single gap separation of >35m, which is based on an estimated maximum squirrel glider glide distance. Fragments with an area <4ha were assumed to be too small to support a permanent resident population, and a maximum travel distance of 1km was recommended between patches of >4ha in size. Population estimates were made based on squirrel glider densities for different vegetation types using Smith (2002)

data from Wyong LGA. This approach led to land use planning principles for inclusion in development planning, and the same methodology was also used in Wyee (LMCC 2008).

Analyses have been undertaken to understand the fragmentation of native vegetation in the LGA and habitat connectivity for squirrel gliders. The methodology used is summarised as follows:

1. Habitat patch size analysis was undertaken using mapped native vegetation identified as likely squirrel glider habitat (Map 5). The current distribution of habitat patches across the LGA was grouped by patch size ranges with 4–10 ha being the minimum habitat patch size range and 35m gap crossing width used in Fallding & Smith (2008). Appendix 6 illustrates the results of the patch size analysis.
2. Priority corridor linkages between habitat patches were determined. A Graphab analysis was undertaken for habitat thresholds of both 4 ha and 10 ha with a gap crossing distance of 35m to determine habitat components and least cost paths for connecting the habitat. Other connectivity parameters used were consistent with Fallding & Smith (2008).
3. A separate analysis was also undertaken to investigate the ability of squirrel gliders to cross major movement barriers through the LGA, being the M1 Pacific Motorway and the Great Northern Railway Line. This takes into account the height of trees, road width, and topographic considerations, to identify potential crossing points and feasible locations for maintaining long term connectivity.

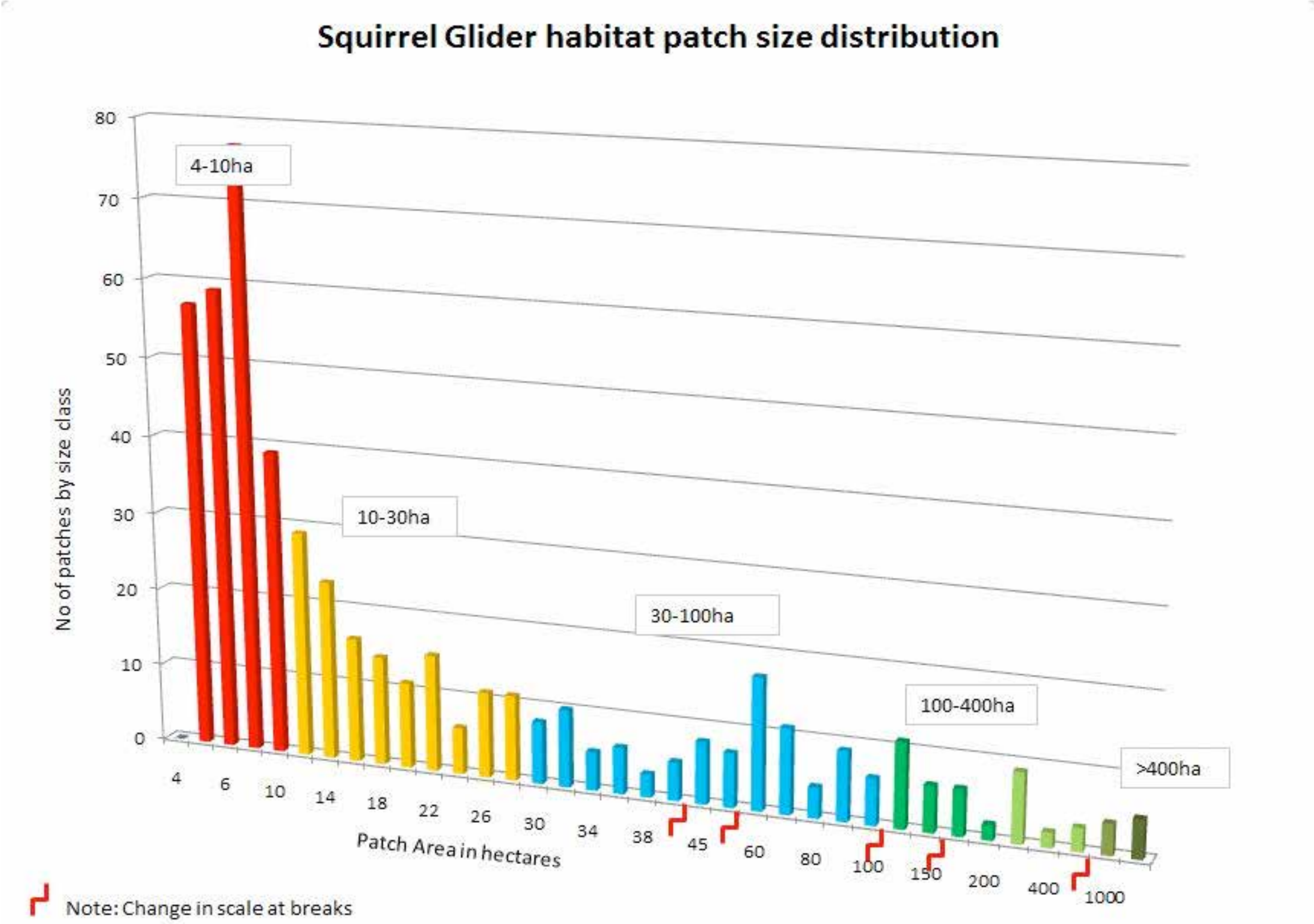
The habitat patch size analysis results are shown in Figure 1, with 5% of habitat being in the range 4 - <10 ha (in 232 patches), 9% of habitat in 10 - <30 ha (in 144 patches), 18% of habitat in 30 - <100 ha (in 91 patches), 23% of habitat in 100 – <400 ha (in 36 patches), and 45% of habitat in 12 patches over 400 ha in size. The spatial distribution of habitat patches is shown in Appendix 6. This shows that the majority of patches are less than 30 ha, although a large proportion of the total area of habitat is in a small number of large patches. The small patches are unlikely to retain squirrel glider populations in the long term unless habitat connectivity can be retained.

Note that Graphab is a least cost path graph network modelling analysis. It highlights gap areas important for connectivity. Areas which are isolated (ie separate components) have been identified and assist in determining whether to restore connectivity in these locations. In some areas the land use and distance is such that no realistic restoration can be contemplated and populations within these compartments can be considered isolated. In other locations such as at Morisset and Coal Point, detailed analysis on site indicates that restoration measures could be effective in connecting components that are currently regarded as isolated.

Photo: Martin Fallding

Banksias provide an important food resource.

Figure 1


Squirrel Glider habitat patch size distribution
No of patches by size class
80
70
60
50
40
30
20
10
0
4-10ha
10-30ha
30-100ha
100-400ha
>400ha
4
6
10
14
18
22
26
30
34
38
45
60
80
100
150
200
400
1000
Patch Area in hectares
Note: Change in scale at breaks

The patch size analysis (Appendix 6) can be used to prioritise areas for squirrel glider conservation, and is also important for understanding the landscape scale context when assessing the impact of individual development proposals. This highlights the importance of native vegetation west of Lake Macquarie for securing long term population viability for the species as the largest patches occur here.

The habitat connectivity analysis shows that squirrel glider habitat is reasonably well connected across the LGA. The maps of the analysis are shown in Appendix 7 together with an explanation of the methodology used. Applying minimum patch thresholds of both 4 ha and 10 ha gives an indication of the sensitivity of the results to varying patch size. There are 54 separate habitat components (ie groups of connected of patches) in the 4ha analysis and 32 components in the 10 ha analysis. The output of both the 4 and 10 ha analysis confirm that there appear to be five large areas (components) supporting separate populations across the LGA with characteristics which can be summarised as follows:

1. *North – east* – highly fragmented, with a habitat area of 1,767 ha, a generally small habitat patch size, and some existing conservation reserves.
2. *Wallarah Peninsula* – 1,675 ha of relatively contiguous habitat in large patches with some fragmentation by roads, linked to habitat to the south in Wyong LGA and one small conservation reserve.
3. *Morisset/Wyee* – A variety of habitat patch sizes comprising an area of 2,423 ha, with potential corridor links to Wyong LGA habitat to the south, and no conservation reserve.
4. *West Lake Macquarie* – A large habitat area of 9,749 ha, mostly in patches over 400 ha with reasonable corridor links with no existing conservation reserves. The M1 Pacific Motorway forms a barrier limiting population connectivity to the west.
5. *Sugarloaf to Mandalong* – Foothills and valley sides west of the M1 Pacific Motorway. Habitat of 9,221 ha is fragmented by agricultural land use particularly along the major creekline valleys.

Note that the number of components in the connectivity analysis suggests that there may be additional smaller habitat areas supporting isolated populations however, these should be confirmed using more detailed examination and site survey.

The analysis also shows that there are key barriers within the LGA where connectivity represents a significant long term issue. It highlights that connectivity operates at both the landscape scale, and also at the scale of individual trees. Connectivity is primarily affected by linear infrastructure being major roads, the railway line, and electricity easements. Habitat elements such as roadside vegetation and trees in median strips are important for allowing connectivity across major barriers.

The analysis also provides a basis for applying habitat connectivity parameters to be incorporated into future planning and development processes. The results show that habitat and connectivity modelling can inform planning principles and guidelines for the squirrel glider across the LGA in land use plans. The results also support further investigation of population density and viability analysis across the LGA over the medium to long term.


Photo: Martin Falding

Woodland vegetation in Lake Macquarie LGA.

5. Strategic land use planning issues

This section considers important issues for strategic conservation and development planning, and how knowledge of the biological and ecological characteristics of squirrel gliders can be integrated into planning and development processes. The data presented in Section 4 have been used to prepare information to support strategic planning within the LGA, in particular to:

1. Identify likely squirrel glider habitat and its spatial distribution for strategic land use planning purposes.
2. Propose strategic planning objectives and parameters.
3. Estimate the potential size range of squirrel glider populations.
4. Identify major barriers between populations and key connectivity links.

Photo: Martin Fallding

Large trees along roads allow gliders to cross.

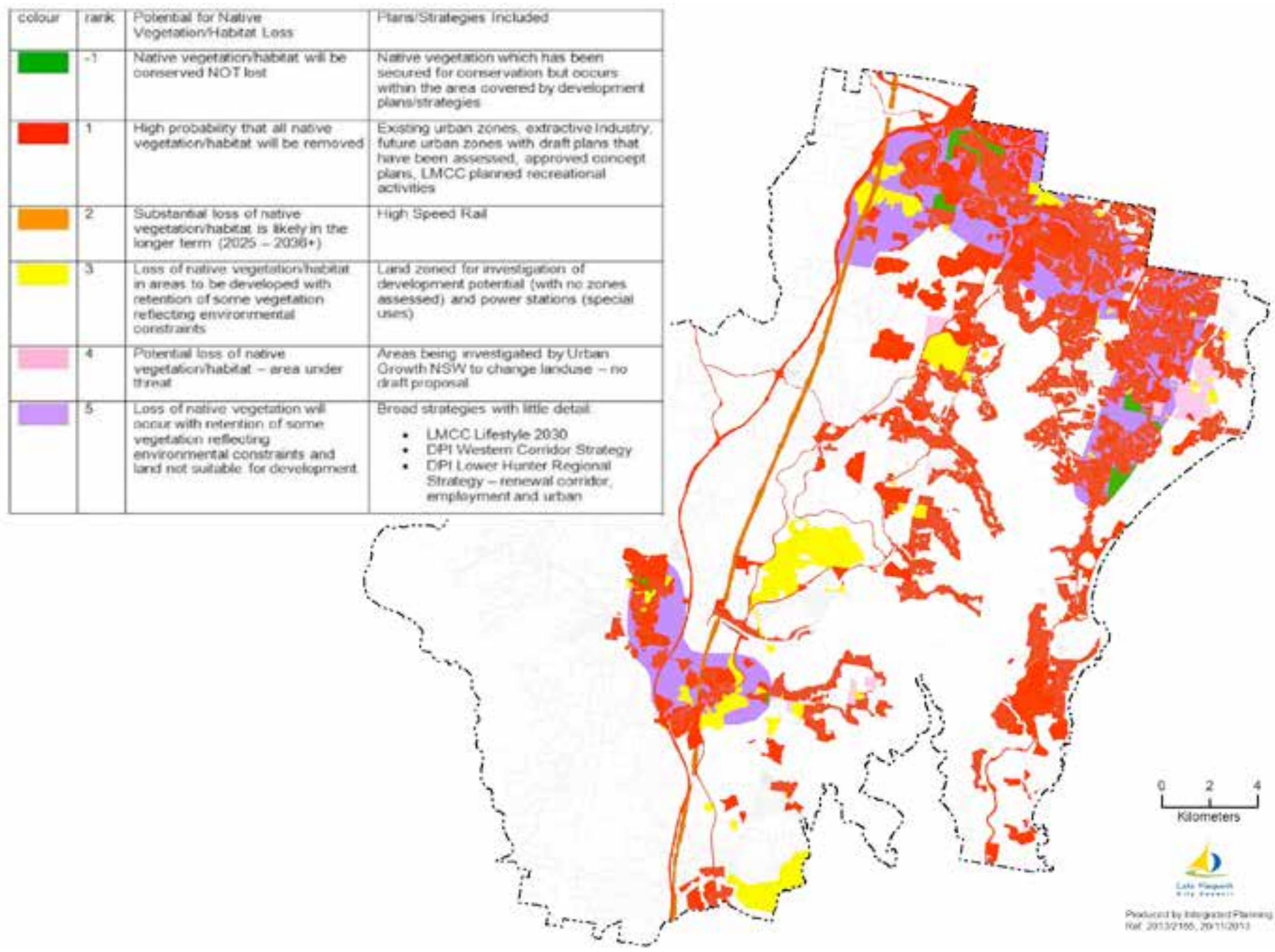
Based on the extent of development foreshadowed in relevant land use planning documents for Lake Macquarie LGA and the Lower Hunter Region, squirrel glider habitat is expected to be affected by urban development over the next 25+ years. The area affected is shown on Map 6 and the extent is summarised in Table 5 along with areas dedicated for conservation. Relevant strategic land use planning documents taken into account in reviewing potential future impacts on squirrel gliders include:

- the Lower Hunter Regional Conservation Plan (DECCW 2009),
- Lower Hunter Regional Strategy (NSW Department of Planning 2006),
- Newcastle – Lake Macquarie Western Corridor Planning Strategy (NSW Planning 2010),
- Lake Macquarie City Lifestyle 2030 Strategy (LMCC 2013), and
- Lake Macquarie Local Environmental Plan 2014.

The North Wyong Shire Structure Plan (NSW Department of Planning and Infrastructure 2012) is also important as this affects both the extent of loss of squirrel glider population in the North Wyong area and the potential to retain habitat connectivity between the populations in the south of Lake Macquarie LGA.

Map 6

Indicative future urban development and land use change in Lake Macquarie LGA to 2030



Based on current strategic planning documents (shown in Map 6), about 24% of mapped squirrel glider habitat in Lake Macquarie LGA (shown in Map 5) is subject to potential future urban development by 2030, being a total area of about 7,325 ha as shown in Table 5. Only about 8% of mapped habitat is in secure conservation reserves. This indicates the potential for further loss of habitat patches and native vegetation linkages, the majority of which are on private land.

The extensive area of future development expected to 2030 and potentially occurring in the longer term, highlights the desirability of effectively planning concurrently for conservation and development. While there are some proposed reserves which would potentially protect squirrel glider habitat, the future management of private land currently zoned for conservation is crucial for the long term protection of populations of squirrel gliders, as well as 1,772 ha of LMCC owned land.

Table 5

Indicative future urban development to 2030 In Lake Macquarie LGA

Land use category / status	Likely squirrel glider habitat (ha)*	Proportion of likely squirrel glider habitat within LGA (%)
Lake Macquarie LGA	30,317	100
Potential future urban development land to 2030	7,325	24
National Park and Nature Reserves	2,468	8.1
State Forest	2,476	8.2
Conservation zoned land (E2)	14,519	48
Proposed Lake Macquarie Coastal Wetlands Park	109	0.4
Proposed Awaba Conservation Area	2,036	6.7
Council owned bushland	1,772	5.8

* Using likely squirrel glider habitat as shown in Map 5

Key issues affecting squirrel glider populations in Lake Macquarie LGA over the long term are:

1. Native vegetation clearing for new urban development, together with direct and indirect impacts arising such as construction of infrastructure.
2. Vegetation clearing on rural land leading to reduced habitat patch size and fragmentation.
3. Loss of large mature trees, and lack of replacement (especially in terms of providing hollows and reducing gap crossing ability).
4. Climate change affecting vegetation, and therefore habitat suitability.
5. Widening of roads and increased traffic leading to barriers that cannot be crossed.
6. Bush fires leading to loss of habitat trees, impacts on food resources, and local extinction, and loss of the ability to establish replacement populations through migration.

7. Reduction in population sizes in small habitat patches to below a viable level, leading to inbreeding or localised extinction.
8. Predation by feral animals.

Land use planning measures are able to significantly impact on the extent to which these issues will affect squirrel glider populations over time. Potential planning approaches include:

1. Defining and mapping current squirrel glider habitat and populations within the LGA.
2. Determining the significance of the Lake Macquarie LGA populations in the context of the regional, NSW and national distribution.
3. Reviewing the adequacy of the existing conservation reserve system and securing appropriate areas of habitat for long term protection.
4. Determining criteria to apply in strategic land use planning and planning instruments for squirrel glider conservation, including considerations for cumulative impact assessment.
5. Determining the framework for assessing the potential impact of future project land use change, development options and proposals, including planning and development guidelines to limit habitat fragmentation, and the location of key connectivity links to be retained.
6. Identifying opportunities for ensuring habitat connectivity between populations is restored where lost.
7. Ensuring appropriate ecological survey guidelines are applied to accurately record presence/absence of occurrence.
8. Undertaking further scientific research and surveys to support planning and management.

Significant issues for future strategic planning are discussed below, including habitat suitability and populations, conservation requirements, survey and data issues, impact assessment, biodiversity offsets and planning implementation mechanisms.

5.1 Squirrel glider habitat and populations in Lake Macquarie LGA

To meet the legislative requirement to assess the significance of the impact of a development on listed threatened species, the impact on a “viable local population” must be considered as well as whether that population of the species is likely to be placed at risk of extinction.

As outlined in Section 4, it is possible to estimate the extent of likely squirrel glider habitat in Lake Macquarie LGA with reasonable accuracy for strategic planning purposes. Using the habitat mapping (i.e. the preferred method), there is estimated to be around 30,000 ha of likely squirrel glider habitat. This likely extent of squirrel glider habitat is confirmed with the MaxEnt model predicting around 23,000 ha of squirrel glider habitat. Together with the connectivity analysis, these estimates can be used to determine the number of squirrel glider populations within the LGA, their approximate size and conservation importance.

Both habitat probability modelling and likely habitat based on vegetation communities can be used to determine the approximate area of habitat, number and size of patches. Maximum population estimates can then be derived using density estimates shown in Table 4. The habitat in the south of the LGA is contiguous with vegetation in Wyong LGA, contributing to a larger, interconnected population. Using this method, the total estimated squirrel glider population in the LGA is potentially in the approximate range of 6,000 to 10,000 individuals, the majority being distributed in five populations as outlined in Table 6.

Table 6

Squirrel glider populations in Lake Macquarie LGA

Population name	Characteristics
North – east	This population is highly fragmented, with extensive areas of urban development, no habitat patches of more than 400 ha, and many patches ranging between 4 and 30 ha in size. Includes Glenrock State Conservation Area, and Tingira Heights Nature Reserves, plus areas suggested for conservation in the Lake Macquarie Coastal Wetlands Park. There is potential for limited connectivity with habitat in the Newcastle LGA and where possible this should be enhanced as there are known Squirrel Glider populations to the north in Jesmond Bushland and Blackbutt Reserve. The area of likely habitat is 1,767 ha, with a potential maximum population of possibly 300 - 600 squirrel gliders.
Wallarah Peninsula	Although there are significant areas of urban development, native vegetation is relatively contiguous, and habitat patches are mostly in the range 100 – 400 ha. Part of this population is protected in the 178 ha Wallarah National Park and other conservation reserves are proposed. The habitat is well connected to squirrel glider populations in the North Wyong area. With estimated habitat area of 1,675 ha, there could be a potential population of around 300 - 600 squirrel gliders.
Morisset/Wyee	Contains one area of over 400 ha of high quality habitat with potential for a conservation reserve, with linked habitat in smaller patches through urban development areas. The estimated habitat area is 2,423 ha, with a potential population of around 400 - 800 squirrel gliders. Habitat is tenuously linked to squirrel glider populations in the North Wyong area and to the West Lake Macquarie population. Existing links to Wyong LGA and the western populations should be retained and enhanced.
West Lake Macquarie	This area of habitat is the largest and least fragmented in the LGA, with most habitat in large patches of over 400 ha. Species records in this area are limited. Includes part of Sugarloaf SCA and further opportunities exist for conservation reserves to be established to protect part of this population, including the proposed Awaba Conservation Area. . The estimated habitat area is 9,749 ha, with a potential population of around 3,000 to 5,000 squirrel gliders. The western boundary is the M1 Pacific Motorway and there is connection to the Newcastle City LGA to the north, however, this connection is likely to be significantly impacted by State government approved development.
Sugarloaf to Mandalong	A habitat area of 9,221 ha, west of the M1 Pacific Motorway which forms a barrier to the east, and mostly in patches over 400 ha but a large perimeter. Includes part of Sugarloaf SCA and bounded by agricultural development. Very little survey has been conducted in this area. With so few records, any population estimates are likely to be inaccurate, but could be in the range 1,000 – 3,000.

Note: These populations have been identified at a broad scale based on an analysis of habitat for the purpose of reviewing the potential for maintaining squirrel gliders in the long term. Further investigation is required to determine whether the identified areas comprise one population, metapopulations or a number of genetically separate populations.

Based on Smith (2002) the population of the combined population including both North Wyong and Lake Macquarie LGAs could be be around 10,000 – 15,000 individuals.

Based on the literature review and the scientific and technical workshop, specific planning parameters for Lake Macquarie LGA can be used for planning and development unless these are demonstrated to require updating as a result of more recent local research:

1. Home range – Estimated at 5 to 10 ha.
2. Maximum gap distance allowing regular crossing – Estimated at 35 m.
3. Density of occurrence – Likely to be 0.3 to 0.4 animals/ha, but is expected to vary widely according to habitat quality, and lower in and adjacent to urban areas.
4. Minimum habitat patch size – Estimated at 4 ha.
5. Minimum viable conservation area – Estimated at 400 ha.
6. Maximum travel distance between habitat – Estimated to be 1 km.
7. Desirable conservation reserve size – 2,500 to 5,000 ha.

While these parameters are assumed to be uniform across the LGA, in reality they are expected to vary continuously, but provide an important basis for planning future development. Together with corridor linkage requirements, these parameters provide an important basis for securing populations in the LGA over the long term.

5.2 Conservation issues

A very low proportion of squirrel glider habitat is conserved in secure reserves with most of the population on private land. This is of concern as the regional conservation targets in the Lower Hunter Regional Conservation Plan (DECC 2009) are not met for the squirrel glider or its habitat.

Determining preferred locations for conservation reserves and including these in a secure tenure is a priority if squirrel glider conservation in the LGA is to be assured. The amount, location and type of high priority conservation habitat required in reserves to facilitate retention of the squirrel glider across its current distribution within the LGA (e.g. the amount and location of old growth forest, den sites, corridors and/or home range extent) should be subject to further review. It is suggested that a squirrel glider conservation reserve system with two areas each of at least 400 – 1000 ha on the west of Lake Macquarie is required to provide a sufficient basis for a conservation reserve system for the species.

A separate issue for conservation is the consideration of the feasibility of maintaining squirrel glider populations in urban areas in the long term. Gliders currently known to exist in some urban locations such as Coal Point where there are small Council reserves and extensive native tree cover. With the expected change in presence of native vegetation in such locations over time, the already small glider populations will be under threat. Separate planning guidelines may be required for the squirrel glider in urban settings, when compared with rural areas or land currently zoned for conservation purposes, and this may require further scientific surveys.

5.3 Survey requirements and data issues

Current survey requirements focus on detecting the presence of squirrel gliders. There is a case for updating field survey requirements, given the limited number of reliable records within the LGA, and the need to ensure that squirrel gliders are correctly identified and differentiated from sugar gliders.

More data are also desirable in relation to species absence, population density, population viability and the effectiveness of species movement across roads and between habitat patches.

5.4 Determining significant impacts

The NSW Government has prepared guidelines for the assessment of significance including definitions of terms (NSW DECC 2007). Local mapping showing the distribution of records, habitat probability modelling, and likely habitat based on vegetation communities (Maps 3 & 5) assist in providing the context for decisions on the significance of impacts on a local population.

The assessment of significance is largely dependent on determining the extent of the viable local population, and any population occurring on a site is generally considered to be a viable population. More locally specific guidelines can assist in providing the context for the assessment of significant impacts, and providing consistent guidance in relation to what impacts on squirrel gliders are expected to be significant within the LGA.

It is appropriate to consider the significance of the population at different scales in terms of the landscape scale, the LGA, and separate populations within the LGA. At the landscape scale, the LGA population is connected with the squirrel glider population in the north of Wyong LGA which may account for around 20 – 30% of the Lake Macquarie LGA population. Significance of development impacts is probably related to loss of major habitat connectivity, and reduction in habitat fragments to sizes of less than 400 ha. Within the LGA, any further loss of habitat or connectivity in the north-east population is expected to be significant, while in the others the impact will depend on the size and location of the development proposal.

Factors that may affect the determination of what constitutes a 'viable local population' include its area of occupancy, landscape context and connectivity, potential for fragmentation of the population into two or more populations, habitat critical to the survival of the population, and the species breeding requirements.

In the future, it is expected that genetic information may become available which will enable clarification of whether populations in separate habitat patches are functionally connected or not, and also could indicate the period of separation. Scientific study has shown that indications of genetic separation of a population are evident over a period of 5 – 7 years, although a period of about 30 years is likely to be able to confirm this. This will inform judgements about the significance of impacts.

5.5 Biodiversity offset requirements

Measures to offset the biodiversity impacts of developments are normally required, and consideration has been given to the most effective measures to offset loss of squirrel glider habitat and populations. LMCC has sought consistent approaches to biodiversity offsetting which can effectively compensate for losses arising from development within the LGA.

Biodiversity offsetting relies on adequate field survey of squirrel gliders and their habitat. The Lake Macquarie Flora and Fauna Survey Guidelines (LMCC 2013) has LGA wide specific requirements for biodiversity surveys to ensure that adequate information is provided to properly assess impacts and determine offsets. The NSW Biobanking Assessment Methodology currently assesses squirrel gliders using ecosystem credits. However, due to the variability in the density of hollows and the complexity of identifying patch sizes and fragmentation, and corridor linkages, the squirrel glider can be more effectively considered in Lake Macquarie LGA using species credits, and a review of the current approach is recommended.

Adequate areas occur within Lake Macquarie LGA for offsetting the impacts of local development proposals. Preferred locations for offset areas can be identified using the information outlined in Section 4, in particular assessing habitat patch size, connectivity and habitat quality. In addition, other effective measures may include retention of native and habitat connectivity within development areas in areas with suitable size and shape, protection, rehabilitation and enhancement of corridor linkages, together with associated complementary measures which may include installation of replacement or supplementary habitat such as plantings, nest boxes, crossing structures and the like.

5.6 Strategic planning approaches and implementation

Strategic planning for squirrel gliders should focus on implementing an appropriate land use planning framework which balances development and conservation needs. It is appropriate for different planning approaches for the squirrel glider populations in the north-east and south-east of the LGA, and west of Lake Macquarie. A high priority should be the identification of areas for squirrel glider conservation reserves.

Measures which are compatible with squirrel glider conservation should be incorporated in updates to the Lower Hunter Regional Strategy, and Lower Hunter Regional Conservation Plan, the Lake Macquarie Local Environmental Plan 2014, and other relevant land use planning strategies and policies.

Specific planning measures and development controls need to differentiate between urban areas where squirrel gliders are present, and rural and conservation lands where development is less intense and habitat patches are larger and are better connected to other patches.

Implementation of management measures can complement the land use planning framework, especially in the management of habitat on Council reserves, and community monitoring programs or other community projects.

Photo: Ann Whitelaw

Glider caught on barbed wire fence.

6. Scientific research priorities

Although the biology and ecology of the squirrel glider has been reasonably well studied across its range, detailed knowledge of local habitat characteristics and the population dynamics of the species are not well known. Some species characteristics may vary across its range of distribution and it is important to confirm some estimates such as home ranges and population density for the Lake Macquarie LGA.

Researching genetic characteristics also can assist in determining variability of populations across its distributional range, which can define local populations and their viability, and hence planning and management actions.

The following scientific research priorities are proposed to support planning and management for squirrel gliders in the Lake Macquarie LGA:

Systematic field survey program

1. A systematic field survey program across the LGA to (1) collect presence/absence data and improve habitat modelling, (2) determine population densities, and (3) sample genetic material to provide benchmark data for determining population change and gene flow, and consequent population viability. The program would be in selected priority areas, including West Lake Macquarie and the proposed Awaba Conservation Area, Glenrock State Conservation Area and Jewells Wetland and connected habitat in the north east of the LGA, remnant vegetation around Morisset, connected areas west of the M1 Motorway, and in the north west of the LGA focusing on Spotted Gum/Ironbark Dry Sclerophyll Forest with Banksia understorey and connecting habitat across the M1 Motorway.

Movement and gap crossing

2. Evidence of gap crossing would be beneficial in designing connectivity between patches of habitat across the LGA and especially across roads, and refining connectivity modelling parameters. This would assist in determining management practices that may assist in avoiding and mitigating impacts and specifying habitat corridor requirements and improving road design and crossing structures for re-connection of fragmented habitat.

Bush fire response

3. Review squirrel glider resilience to bush fires and habitat disturbance.

Nest boxes and replacement habitat

4. Reviewing effectiveness of nest boxes as compensatory habitat.

Urban squirrel gliders

5. Squirrel glider behaviour in urban areas should be observed (eg radio tracking) to determine the likelihood of species persistence in these areas (short and medium term) and key habitat characteristics. Research could answer questions as to the extent to which urban impacts can be tolerated, particularly in proximity to den trees, preferred foraging habitat, connectivity corridors, old growth forest fragments and impacts from domestic animals.


Photo: Tom Hicks

Nest boxes may supplement natural habitat.

7. Planning Strategy

This section outlines the proposed strategy for planning and managing squirrel gliders within Lake Macquarie LGA. It provides information to be incorporated within or used in updates of current planning documents, including the Lower Hunter Regional Strategy, Lake Macquarie Lifestyle 2030 Strategy, Lake Macquarie Development Control Plan 2014, and local environmental studies to support draft local environmental plan proposals.

The species is widespread in the LGA and there will be an inevitable loss of individual animals as a result of development and human impacts. The main strategic planning questions are; to what extent populations of squirrel gliders can be retained where there is continuing development pressure, and the extent to which the losses are acceptable.

The objectives included in Table 7 below outline conservation and land use planning objectives and measures that should be applied. Detailed guidelines for implementing the strategic objectives are outlined in Section 8.

Table 7 Planning and management objectives for squirrel gliders

Strategic planning
Maintain the viability of the species across its range within the LGA in the long term (100+ years), by retaining a viable, connected populations in each of the 5 broad squirrel glider populations identified in Table 6. The West Lake Macquarie population is the highest priority to retain with the benchmark for determining what constitutes acceptable loss being retention of a minimum of 5,000 ha of connected habitat where squirrel gliders are known to be present.
Identify areas of the LGA with important populations where no loss of squirrel glider habitat or connectivity is acceptable.
Improve the species conservation status within the LGA by identifying and permanently reserving two or more suitable areas for conservation reserves suitable for maintaining at least 400 to 1,000 ha of connected squirrel glider habitat.
Ensure at least 50% of likely squirrel glider habitat identified on Map 5 is zoned for conservation as its primary use under relevant planning instruments (eg E1 or E2) in the long term.
Implement measures to protect habitat corridors in the LGA to maintain squirrel glider connectivity at the local and regional level in conjunction with adjoining LGAs.
Identify and protect identified areas where crossing the M1 Pacific Motorway is theoretically possible and implement 3 x squirrel glider crossings at suitable locations across this road.
Liaise with Wyong Council and seek to reach agreement on common policy and planning arrangements for squirrel gliders applicable to both LGAs.
Development assessment & management
Apply consistent ecological survey methods for squirrel gliders across the LGA and Lower Hunter Region.
Development proposals in Lake Macquarie LGA affecting squirrel glider habitat will be assessed having regard to the planning and management guidelines (specifically Table 8).
Development likely to result in an adverse impact on identified important squirrel glider populations will not be supported unless this can be adequately offset within the LGA.
Include measures to protect and appropriately manage squirrel gliders in management plans for Council owned land.
Consider cumulative and indirect effects of development on squirrel gliders in development assessment processes, including avoiding or minimising fragmentation and impacts arising from feral animal predation.

Scientific research
Support scientific research to inform planning and management with priorities as outlined in Section 6.
Undertake systematic long term surveys to determine squirrel glider presence and population dynamics within LMCC's Awaba Biodiversity Conservation Area.
Co-operate with the NSW Rural Fire Service to develop burning prescriptions and responses to protect squirrel gliders in bushland areas subject to frequent fires.
Review whether the squirrel glider or populations in Lake Macquarie LGA should be identified as endangered populations under the TSC Act and whether the species warrants listing under the Commonwealth EPBC Act.

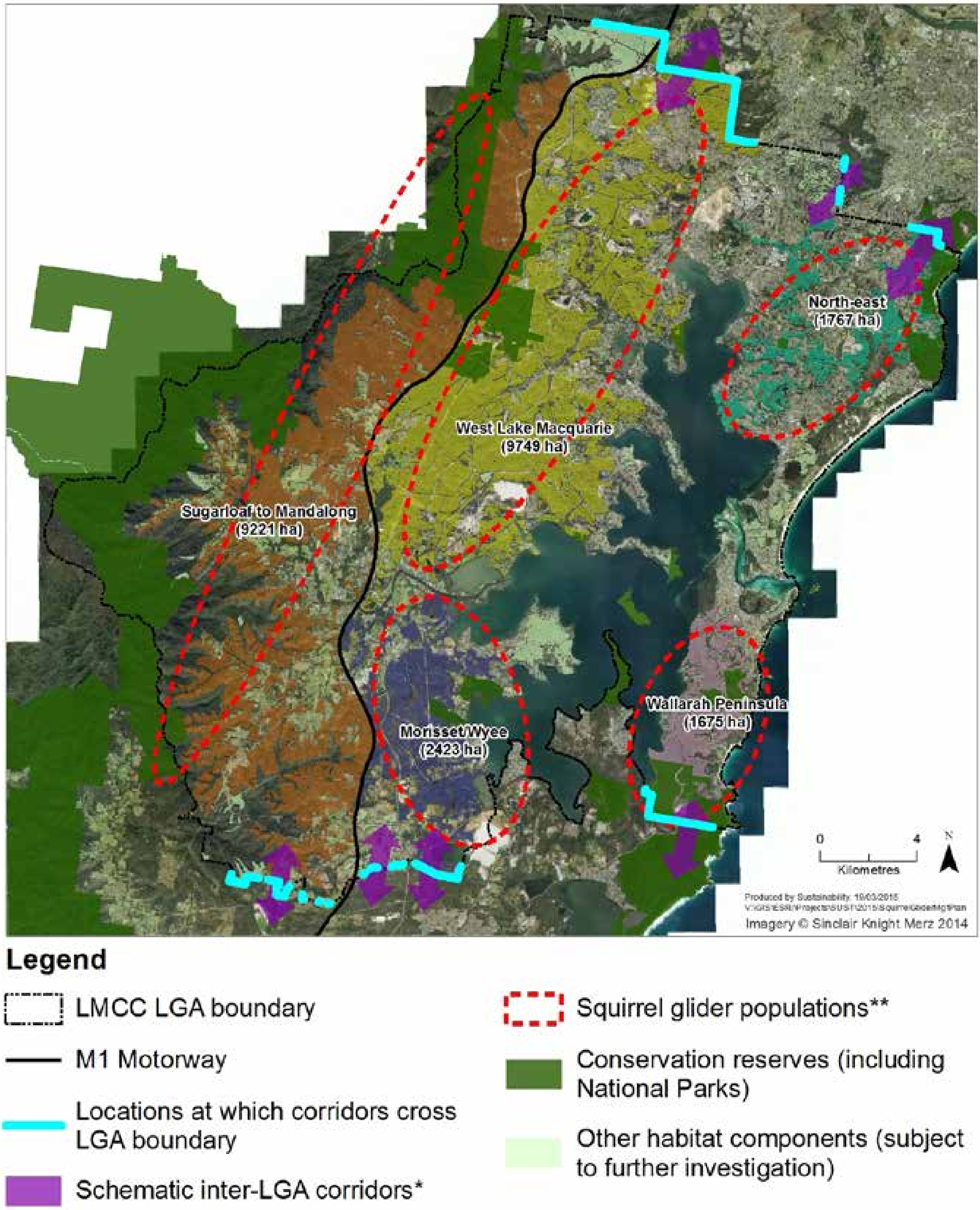
The objectives in Table 7 should be considered for incorporation in planning provisions such as strategic planning or zone objectives, and in consequential plan provisions and associated maps.

Map 7 identifies likely squirrel glider habitat, populations, and key habitat linkages for Lake Macquarie LGA at the broad strategic level. This should be complemented by more detailed, local area planning for squirrel gliders such as has been done for Morisset and Wyee.

Large trees with hollows provide important food and resources.

Map 7

Squirrel glider strategic planning map



* Refer to Council's Native Vegetation and Corridors Map for exact locations

** Areas are based on likely squirrel glider habitat in patches >4 hectares

8. Planning and management guidelines

This section provides guidelines for considering squirrel glider conservation requirements in future land use planning and management processes. These planning and management guidelines provide information to support existing planning and assessment and are intended to be included in future updates to policy documents.

Guidelines for planning and management are outlined in the tables below. These differentiate between guidelines for strategic land use planning (Table 8), and guidelines for the ongoing management of land (Table 9). These Guidelines are specific to Lake Macquarie LGA, but will also be relevant to broader state and local government policy and practice in NSW.

Table 8

Planning guidelines for squirrel gliders

Planning issue	Guideline
Local population	A local population (for the purposes of determining significant impacts) comprises the squirrel gliders occupying the site, plus connected habitat area up to a maximum of 50 ha, and the habitat linkages allowing for regular movement.
Viable population	A viable population is a population (or metapopulation) with a 95% probability of persistence over 100 years. For planning purposes within Lake Macquarie LGA, the squirrel glider populations shown on Map 7 are viable. For the purposes of the EP&A Act test of significance a local population is assumed to be a viable population in the absence of genetic data and analysis demonstrating that this is not the case. Determining population viability is important for conservation purposes to determine whether adequate sized habitat fragments are retained.
Important population	Important populations will be considered in assessing the impact of development proposals. Five squirrel glider populations are identified as important within Lake Macquarie LGA and have strategic priority for maintaining populations in the long term as shown on Map 7. Consideration may be given to seeking the listing of an important population as an endangered population under the *Threatened Species Conservation Act 1995* where evidence suggests that it is at sufficient risk of extinction.
Minimum area of habitat	For planning purposes within the Lake Macquarie LGA, the minimum area of habitat likely to be permanently occupied by squirrel gliders is 4 – 6 ha of contiguous habitat (not including connecting corridors) if well connected to adjoining habitat patches or ≥30 ha if poorly connected to other habitat.
Squirrel glider habitat	Squirrel glider habitat in Lake Macquarie includes any of the following: A: The following priority broad habitat types: • Dry Sclerophyll Forest • Dry Sclerophyll Forest – Banksia • Spotted Gum Forest • Swamp Mahogany Forest. B: The vegetation communities below 100 m elevation and identified on Map 5 using the Lake Macquarie Vegetation Mapping (Bell & Driscoll 2014) are likely to provide suitable squirrel glider habitat. C: Areas that support hollow bearing trees with hollows of small and medium size and/or trees with a DBH of 40 cm. D: Areas where accurate records of squirrel gliders exist. Land is not considered to be squirrel glider habitat if it is, or is part of a patch of native vegetation of less than 4 ha in size that is isolated from other patches of native vegetation by a gap of greater than 250 m or a gap that can be demonstrated to be impossible for gliders to cross.

Planning issue	Guideline
Applicable conservation standard	No net loss of important populations within Lake Macquarie LGA, and maintaining an area of greater than 50% of pre-1750 squirrel glider habitat.
Conservation reserve requirements	The minimum conservation reserve size to secure a squirrel glider population in the long term is 400 ha.
Biodiversity offset requirements	If development impacts cannot be avoided or mitigated, a suitable biodiversity offset is to be provided to compensate for the impact in perpetuity. Suitable offsets include: • Suitable squirrel glider habitat at a replacement ratio of 2:1, and • At least an equivalent number of natural hollows of suitable size for squirrel gliders. Nest boxes are generally not an acceptable offset, but may be used as an ameliorative measure during construction, or an offset where replaced by natural hollows during the effective nest box lifetime. The general principle is that 50% of nest boxes are to be installed prior to construction, and 50% after the completion of works. Within Lake Macquarie LGA, the Biobanking Assessment Methodology does not provide a sufficient basis for adequately assessing development impacts on squirrel gliders if this species is treated as an ecosystem credit.
Corridors & connectivity	Squirrel glider habitat patches are assumed to be regularly biologically connected if they are linked by suitable native vegetation and not separated by a distance of more than 1km. The wider the corridor the more effectively it will function. Movement corridors should be not more than 1km long without incorporating a habitat patch of >4ha in size (minimum patch size occupied by a squirrel glider). Habitat links and corridors for squirrel gliders should have a desirable width of greater than 150 m and a minimum width of 30 – 40 m of native vegetation, that may be either suitable glider habitat, and contain vegetation of a structure and height that allows for movement. Notwithstanding this, narrower strips of vegetation can be important for connectivity and movement. Individual trees (especially large and mature trees) may be important for providing connectivity across roads and other barriers and gaps, and need to be assessed and retained where possible.
Assessing corridors & key strategic linkages	Councils Native Vegetation and Corridor maps and the Graphab analysis Appendix 6 identify corridors and potential connectivity however, each case needs to be assessed in relation to corridor length, habitat and patch size, and by site survey to assess functionality. Key strategic corridor linkages are areas of native vegetation or trees important for, and capable of, providing habitat for the movement of squirrel gliders including: • Vegetation linking conservation reserves to other habitat patches, and • Direct vegetation links between squirrel glider habitat patches having areas of 400 ha or greater, and • Links across major linear infrastructure barriers such as roads or cleared electricity easements, and/or • Vegetation links defined on Map 7. Isolated populations may require restoration or re- establishment of native vegetation to provide connectivity depending on feasibility.
Habitat tree protection	A buffer of native vegetation 20 – 30 m width is to be maintained around habitat trees occupied or used by squirrel gliders that are to be retained. Trees larger than 40cm DBH are likely to be important for habitat. Retain 75% - 80% of habitat trees with small to medium hollows, and retain 70% of trees larger than 40cm DBH.

Planning issue	Guideline
Survey requirements (Apply on land identified on the map as likely squirrel glider habitat)	Site field surveys are to determine presence and/or absence of both squirrel gliders and sugar gliders with a 95% level of certainty. Surveys in areas of >4 ha where gliders are present must also provide data suitable for estimating population density and size. Trap surveys for a minimum of 5 consecutive nights are normally required to confirm presence, or 7 nights to infer the site may not be currently used by gliders. Bodyweight data is to be recorded as well as sex and growth stage. Collection of genetic material for future analysis is suggested. To confirm the absence of squirrel gliders, it is desirable to undertake trapping on at least two separate occasions for at least 5 - 7 consecutive nights with the period between surveys being a minimum of 1 month as well as spot light surveys of flowering plants. It should not be assumed that gliders do not use a site without long term monitoring. Spotlighting alone does not provide sufficient certainty for identification, and multiple survey methods may be needed. Photographs of trapped animals are desirable to confirm identification, in conjunction with weight and length measurements. Habitat survey and mapping is required to document and assess habitat quality (especially the presence of winter flowering species and banksias). Record and map the habitat trees, tree and hollow size and number of tree hollows. Important trees for connectivity and other relevant habitat elements are to be recorded and mapped. Field surveys can be undertaken at any time of year. Plant species, flowering stage, and food resources available at the time of survey are to be documented. To prevent individuals being trapped for more than two consecutive nights, trap nights should be adjusted to comply with animal ethics and welfare guidelines. Pre- and post-development habitat patch size and connectivity analysis is to be undertaken. In addition to trapping and spotlighting, supplementary survey techniques that can be utilised are: • Installation of nest boxes – for longer term surveys such as rezoning proposals. • Camera traps – used alone or in conjunction with other techniques. • Radio tracking – where habitat connectivity is important on small sites, and in the vicinity of roads and urban areas. • Stag watching - used to determine possible den sites. Full survey results and the spatial location of records are to be provided to the NSW Wildlife Atlas and LMCC.
Road design and traffic speeds	Squirrel gliders may be killed while crossing roads. In the vicinity of identified important populations and identified native vegetation corridors, road design shall consider incorporating measures to facilitate squirrel glider road crossing, and desirably traffic speed shall be limited to 80km /hr unless other suitable arrangements are in place to ameliorate impacts.
Determining the significance of development impacts (TSC Act) *(Impact assessment needs to determine existing and retained patch sizes and number of den trees)*	Where field surveys have been undertaken in accordance with these guidelines, a significant impact is expected to occur where squirrel gliders are present (or assumed to be present) if: • An area of squirrel glider habitat of more than 4 ha will be cleared, and/or • More than 1 ha of habitat will be cleared and the habitat patch size will be reduced to less than 4 ha, and/or • There is a greater than 5% loss of a habitat patches with an area of more than 10 ha, and/or • There will be a reduction in effectiveness of a key strategic corridor linkage connecting habitat patches, and/or • Habitat connectivity to a habitat patch will be lost, or narrowed to a width that is not suitable for maintaining in the long term. In addition to the above, for the population in the north east of Lake Macquarie LGA any loss of habitat greater than 1,000 square metres or 10 trees is likely to have a significant impact on squirrel gliders and a reduction of habitat patch size below 4 ha would be significant. Where area specific planning guidelines for squirrel gliders have been prepared (including Morisset and Wyee) locally specific principles guiding the determination of significance may be applied.

Land management practices affect squirrel gliders and Table 9 provides guidance on how to manage habitat and populations. Management actions depend on the location of the land, its habitat quality and condition, context in relation to populations, and the extent to which a site needs to be actively managed.

Management should have regard to the planning objectives outlined in Section 7. Where land use plans identify that native vegetation is to be retained (eg conservation zonings) land management should have an objective to retain bushland in a natural condition and to actively manage the land to support the retention of important ecological values and processes, such as squirrel glider populations. Where land use plans have not been finalised or development has not been approved, then existing ecological values must be retained and managed.

Squirrel glider killed by feral cat.

Matters that need to be considered when managing land include:

- Relevant land use plans, or restrictions on development.
- Development consent conditions or requirements (eg protection of habitat or rehabilitation of land).
- Bush fire asset protection requirements.
- Bushfire regimes (fire frequency and intensity) required to maintain suitable habitat structure and composition for the species.
- Management plans applying to the land such as vegetation management plans, rehabilitation plans or plans of management for public land.
- Legislative provisions that may restrict vegetation clearing or use of the land or impose management obligations (eg noxious weed control).
- The nature and impact of adjoining land uses or activities.
- Legal restrictions on land such as easements or covenants.
- Pest and disease management.

Land management is an important consideration later in the process of development after plans have been determined, and is especially important at the construction stage. Management issues should be taken into account in planning and development approval. Specific guidelines for management actions which may affect squirrel gliders are outlined in Table 9. These guidelines should be considered when determining planning and development consent and ongoing management requirements. Many of these actions are consistent with guidelines for managing other threatened species and should form part of integrated management programs.

Table 9

Management guidelines for squirrel gliders

Management action	Guideline
Preparing a management plan	Public lands and other land for conservation (eg Biobanking or biodiversity offset sites) normally require the preparation of management plans meeting legislative requirements. The preparation of such management plans should be in accordance with Council guidelines, identify the likely presence of squirrel glider habitat, and implement measures compatible with the conservation of the species.
Protecting assets from bush fires	Habitat trees in bush fire asset protection zones should be retained where possible, but are regarded as lost for the purposes of impact assessment. Hollow bearing trees with hollows with entrances 4-6 cm wide (suitable for squirrel glider) within bush fire asset protection zones should be protected, and provided with appropriate buffers and connecting native vegetation. In carrying out bush fire hazard reduction and asset protection activities, hollow bearing trees (including dead trees) are to be protected from fire.
Bush fire regimes	Hot fires are expected to damage habitat trees and cause higher animal fatalities and should be avoided. Frequent fire in squirrel glider habitat is also to be avoided. Many of the preferred squirrel glider food plants also require a specific fire regime to enable seeding and reproduction, and this is a key consideration for maintaining suitable habitat in the long term. Optimum habitat suitability generally does not occur until the understorey has been left unburnt for 10 or more years. Control burns in squirrel glider habitat should: • occur in a mosaic pattern ensuring sufficient accessible habitat is left unburnt. • be low intensity and maintained below 3 metres in height. • occur in early Autumn (not late winter when females have pouch young). • be conducted so as to maintain connectivity and glider movement.
Road widening	Road widening proposals should consider whether roadside native vegetation is likely to be squirrel glider habitat and whether any trees proposed to be removed or disturbed form part of a connecting corridor or road crossing point. Field surveys may be required to determine whether or not this is the case. Roadside vegetation (especially trees) should be retained where it is safe to do so. Removal of connectivity as a result of road widening may require construction of a replacement crossing structure (eg glide poles).
Controlling weeds	Weeds that have the capacity to transform the native vegetation structure must be controlled (especially those affecting acacia and banksia species). Ensure spraying is weed selective and does not impact on native shrubs, particularly acacia and banksia species.
Maintaining electricity and water easements	When wide easements exist (ie >50 m wide) install/maintain crossing points which might support tall understorey or low trees underneath power lines at >1 per km over the length of the easement or install poles to facilitate movement. Tree height and clearing width along easements should be checked to determine whether gliders have the ability to cross from one side to the other.
Grazing or clearing native vegetation	Any changes to native vegetation species composition and structure may affect squirrel glider habitat. Areas of high quality habitat should be identified, and any loss of habitat in these areas due to clearing or grazing should be limited and subject to biodiversity offset arrangements. Removal of understorey native vegetation should not be undertaken where squirrel glider conservation is a priority.
Providing replacement habitat & nest boxes	Detailed site surveys are required prior to installation of any replacement habitat or nest boxes to identify the existing availability of hollows. Where natural hollow density is low (<10 hollows per 5 ha), then installation of boxes may be approriate. RTA guidelines suggest box spacing of 60 – 100m for squirrel gliders (NSW Roads and Traffic Authority 2011). Where nest boxes are to be installed, rear entry nest boxes are preferred, with a height of 3 – 6 m above ground to allow easier periodic inspection and maintenance. One nest box on rough barked trees is preferred, generally with a south orientation. Boxes should be securely attached with wire to allow tree growth. Relocation of natural hollows should be considered where these are to be removed from a site. Nest boxes are not considered a suitable biodiversity offset due to their limited life.

Management action	Guideline
Glide poles & rope bridges	Glider poles may facilitate movement across roads or other barriers, and are applicable in areas where the gap is >50 m wide, particularly for large, significant patches divided by major roadways or where corridors have been compromised by works. Glider poles should only be used where appropriate, with a suitable pole height and spacing. Design specifications for glide poles and bridges have been prepared by NSW Roads and Maritime Services and may be suitable for use.
Fencing	Barbed wire fences should not be used in squirrel glider habitat areas. Where such fences exist, they should be replaced with plain wire fences.
Translocation of individual animals	Experience with other mammals has shown that translocation is expensive and generally unsuccessful. Translocation of squirrel gliders is not supported and should not be undertaken within the Lake Macquarie LGA. Translocation is only to be considered as a last resort if an important strategic habitat patch becomes extinct and an appropriate translocation plan and program is implemented.
Tree clearing protocol	Smith (2002) recommended the following tree clearing protocols in areas with known squirrel glider populations: 1. All occupied squirrel glider habitat trees in the area to be cleared will be identified (by survey) and marked. 2. Marked habitat trees and corridors of retained trees linking marked habitat trees with the nearest uncleared (secure) habitat areas will be left standing after initial vegetation clearing for a period of at least 3 weeks (to encourage gliders to disperse into adjacent uncleared habitat). 3. After the three week waiting period standing habitat trees and corridors may be felled commencing with the trees most distant from secure habitat. It is preferable for habitat trees to be cleared within 1 hour of dusk to facilitate dispersal. 4. Clearing should be undertaken in the Spring to Autumn period to facilitate survival of displaced animals. 5. If habitat trees are in short supply (< 4 suitable trees per hectare) artificial nest sites (nest boxes) should be installed in adjacent (secure) habitat before clearing. 6. If no secure habitat exists nearby to areas to be cleared, land owners should seek advice from the NSW National Parks and Wildlife Service before proceeding with clearing.
Managing squirrel glider records & data	Records of the presence and absence of squirrel gliders within the LGA are to be maintained and updated together with the reliability of identification, using flora and fauna survey reports undertaken for planning and development proposals, as well as scientific research. Data will be collated in the LMCC database. Where squirrel glider genetic material is collected, this can be banked with the Australian Museum DWA laboratory.
Management in urban areas	Squirrel glider populations have the ability to remain in urban areas where native canopy trees are retained, together with habitat connectivity to areas of native vegetation, suitable hollows and understorey food plants. Companion animal (primarily cat) controls would reduce predation of squirrel gliders and should be considered. Provision of nest boxes suitable for squirrel gliders may benefit the species, but is not a suitable substitute for natural hollows in the long term. Nest boxes require ongoing monitoring and maintenance. They may also benefit other native or introduced species.
Management in agricultural landscapes	Isolated paddock trees are used for foraging and denning by squirrel gliders and should be retained where gliders are present to facilitate their movement to suitable habitat. Barbed wire fences should be avoided adjacent to native vegetation and corridor linkages where squirrel gliders are known.
Guidelines for habitat augmentation in a conservation or offset area	Where habitat is being restored in a conservation area or Council reserve, consideration should be given to using known squirrel glider food plants for rehabilitation.

In addition to the actions to be implemented by LMCC, some actions are suggested for the consideration of other agencies. Modifications to the current application of the Biobanking Assessment Methodology by the NSW Office of Environment and Heritage are suggested as follows:

1. Within the LGA, squirrel gliders should be regarded as a species credit species.
2. Lake Macquarie Vegetation Mapping (Bell & Driscoll 2014) vegetation communities should be used in the methodology in preference to PCTs, because they are a more accurate representation of squirrel glider habitat and occurrence for the purpose of development assessment and determining biodiversity offset requirements.
3. A rule in the methodology should be considered to provide for the retention of minimum areas of 4 ha of squirrel glider habitat and connected native vegetation to other habitat patches.

It is also proposed that NSW Roads and Maritime Services investigate and undertake feasibility studies into the installation of squirrel glider crossings across major roads within the LGA, especially the M1 Pacific Motorway, especially in the mapped habitat identified in Map 7 and at locations identified in Appendix 7.

In the proposed review of the NSW biodiversity legislation, consideration should be given to improving the clarity of the definition of a local population and a viable population for the purposes of assessing the impacts of development, given the importance of this issue to the determination of what constitutes a significant impact, and the consequent effect on future squirrel glider populations within the LGA.

Cross boundary collaboration with adjoining local government areas is also important to maintain regional squirrel glider populations, and it is suggested that Wyong Council be approached to develop a combined approach to the protection of squirrel glider habitat and connectivity in the north of the Wyong LGA.

9. Conclusions

These planning and management guidelines outline current knowledge of the biology and ecology of squirrel gliders and will inform decision-making in relation to the species within Lake Macquarie LGA.

Although these guidelines apply specifically to Lake Macquarie LGA, the measures proposed may be relevant in other locations across the range of the species. They may also be useful to other organisations and landowners making decisions affecting squirrel glider management.

Squirrel glider habitat is expected to be subject to continuing development impacts over the next 50 years and beyond, and these guidelines outline the possible scale of impacts and the conservation measures that are available.

Key measures included in the guidelines will:

1. Update the survey methodology for squirrel gliders.
2. Provide clarification as to what constitutes a significant impact for the purposes of development assessment.
3. Provide a locally specific set of objectives for strategic planning.
4. Implement a consistent and locally relevant set of principles and practices for development assessment.
5. Provide directions for future scientific research to inform planning and management.

Additional scientific research to improve species knowledge will contribute to improved planning and management certainty in the future. It is expected that the guidelines will be reviewed and updated as further information becomes available.

Applying the planning objectives and guidelines in ongoing strategic planning and implementation actions is essential if the important squirrel glider populations in Lake Macquarie LGA are to be retained in the long term.

Protecting roadside vegetation allows gliders to cross roads.

Glossary

DBH means diameter at breast height, and is used for identifying tree size.

Habitat is an area or place occupied by a species, population or ecological community. It may be occupied permanently, periodically or occasionally.

Habitat corridor /habitat linkages is an area of native vegetation that enables migration, colonisation and interbreeding of plants and animals between two or more larger areas of habitat. Habitat corridors may consist of a sequence of discontinuous areas of habitat (such as feeding trees, wetlands and roadside vegetation) as long as any gaps can be crossed.

Important population is a concept used for planning and management and refers to populations that have been identified to be important for conservation of the species in the long term. These are determined using relevant criteria.

LGA means local government area.

JANIS refers to the Joint National Forest Policy Statement Implementation sub- committee nationally agreed criteria (Commonwealth of Australia 1997).

Local population means a population spatially segregated from other local populations, and occupying a suitable, discrete habitat patch. Local populations form part of a metapopulation. Sometimes the terms "population" and "local population" are used interchangeably. For the purposes of these guidelines and the *EP&A Act* a local population is defined as comprising the squirrel gliders occupying the site, plus connected habitat area up to a maximum of 50 ha, and the habitat linkages allowing regular movement.

Metapopulation (also referred to as a regional population) means a group of populations of the same species between which genetic material can potentially be transferred as a result of recurrent extinction/ recolonisation patterns. Metapopulations often occur in fragmented habitats.

OEH means NSW Office of Environment and Heritage.

Population means an occurrence of the species in a particular area, normally a reproductive community of individuals sharing a common gene pool.

Site population means the number of individuals found at any site.

Viable local population is a term referred to in Section 5A of the *EP&A Act* and refers to the ability of a population to persist and to avoid extinction. Quantification of species habitat requirements can enable estimation of minimum viable populations over certain time periods and may allow reserve and connectivity requirements to be determined.

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Appendices

Appendix 1

Priority Actions identified for the squirrel glider in NSW

(NSW Environment and Heritage (2014B)

Action title	Priority
Conduct surveys on the Far South Coast, from Murramarong National Park south to Eden, to determine population size and extent and connectivity of populations (surveys should incorporate potential habitat on public as well as private land).	Low
Model and predict the distribution of squirrel gliders across the south west slopes.	Low
Delineate boundaries of population to identify the extent to which populations are interconnected (to determine propensity to move across cleared land).	Medium
Ensure the largest hollow bearing trees (including dead trees) are given highest priority for retention in PVP assessments and other environmental planning instruments, or other land assessment tools.	Medium
Control feral horses at relevant sites to promote retention and growth of mid- storey shrubs.	Medium
Prepare EIA guidelines which address the retention of hollow bearing trees maintaining diversity of age groups, species diversity. Give priority to largest hollow bearing trees.	Low
Investigate the effectiveness of logging prescriptions.	Low
Prepare a recovery plan for the squirrel glider.	Low
Conduct surveys and assessments of less known sites to confirm presence of species and negotiate, develop and implement conservation management agreements for high priority sites.	High

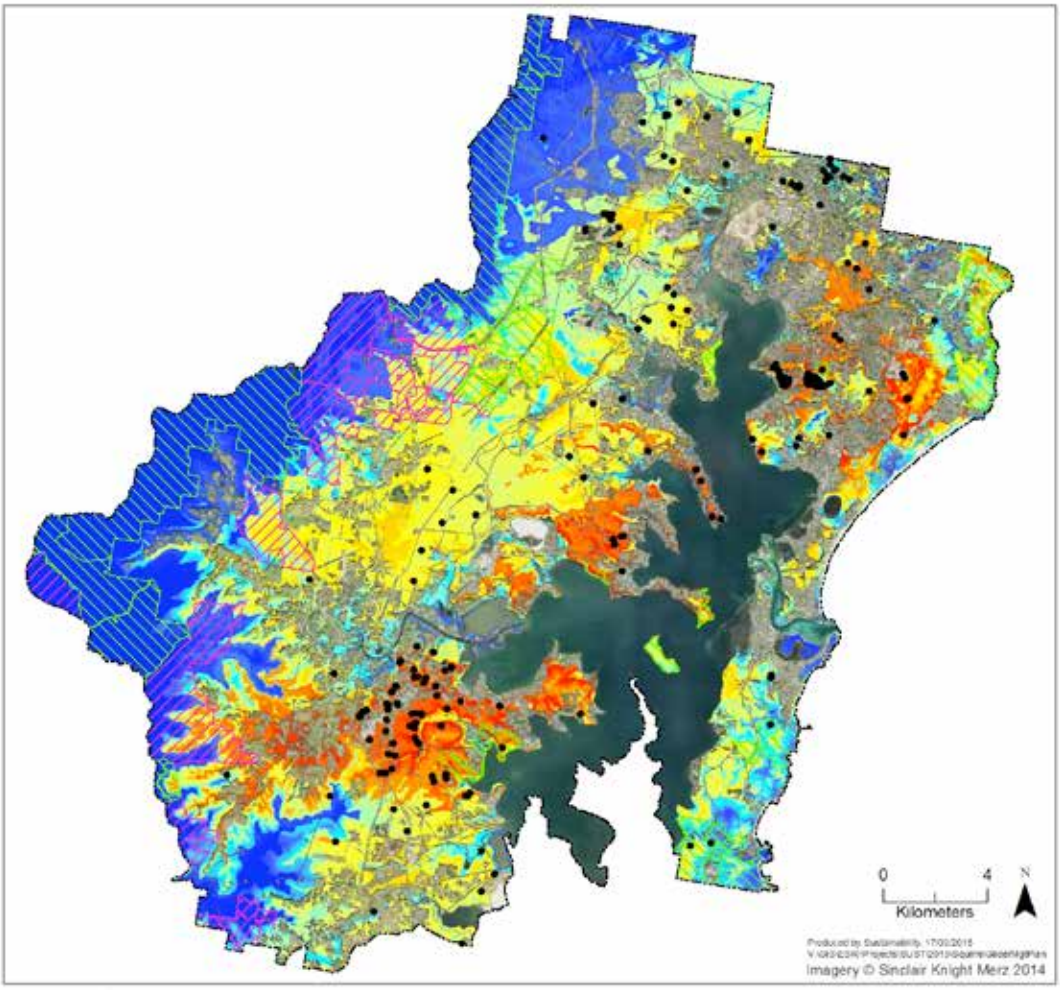
Note: The Priority Actions are under review and proposed changes have been exhibited.


Photo: Robbie Economos

Squirrel glider road crossing point.

Appendix 2

LGA distribution modelled probability of occurrence (LMCC 2015)



Legend

- • Squirrel Glider records in LMCC database with accuracy of 100m or better
- National Parks
- State Forests

Squirrel Glider MaxEnt model results* (LMCC, 2014)

- High probability
- Low probability

** Environmental variables which contribute to MaxEnt model are:*

1. *Continuous elevation (Digital Elevation Model, DEM)*
2. *Annual precipitation (Bioclim 12)*
3. *Distance to Squirrel Glider vegetation communities, based on Smith (2002) and consultation with ecological experts (Dry Sclerophyll Forest with Banksia understory, Spotted Gum Forest, Swamp Mahogany Forest, Forest Red Gum Forest, plus Map Units 5, 11, 15, 111a, 111c, 119, 43a)*
4. *Soil fertility (derived from OEH Inherent Fertility of Soils in NSW 1:100 000 map)*

Appendix 3

Broad habitat type equivalence with Lake Macquarie vegetation communities (Bell & Driscoll 2014)

Broad Habitat Type	Bell & Driscoll 2014 Map Units	Bell and Driscoll (draft 2014) Map Unit Name
Wet Sclerophyll Forest	5	Alluvial Tall Moist Forest
	6	Coastal Narrabeen Moist Forest
	6a	Coastal Narrabeen Bluegum Ridge Forest
	9a	Coastal Ranges Mesic Blackbutt Forest
	9e	Coastal Ranges Mesic Peppermint Forest
	9i	Coastal Ranges Mesic Stringybark - Mahogany Forest
	12	Hunter Valley Moist Forest (12)*
	15k	Coastal Foothills Moist Grey Gum- Mahogany Forest*
	39	Apple-Palm Gully Forest
Dry Sclerophyll Forest	9	Coastal Ranges Open Forest
	9b	Coastal Ranges Dry Blackbutt Forest
	9d	Coastal Ranges Dry Spotted Gum - Blackbutt Forest
	9f	Coastal Ranges Dry Peppermint - Blackbutt Forest
	9h	Coastal Ranges Dry Tallowwood - Blackbutt Forest
	9l	Coastal Ranges Mesic Blackbutt- Tallowwood Forest
	11	Coastal Sheltered Apple - Peppermint Forest
	21a	Hunter Range Dry Escarpment Apple Forest
	21d	Hunter Range Dry Ironbark - Grey Gum Forest
	21e	Hunter Range Dry Mahogany - Grey Gum Forest
	21f	Hunter Range Dry Mahogany - Apple Forest
	21g	Hunter Range Dry Stringybark - Blackbutt Forest
	22	Coastal Narrabeen Shrub Forest
	22e	Coastal Narrabeen Dry Bloodwood - Apple - Mahogany Forest
	26h	Watagans Remnant Hawkesbury Forest
	33d	Awabakal Sand Mantled Blackbutt Forest
	111a	Lake Macquarie Snappy Gum Forest
	111c	Killingworth Snappy Gum Forest
	112	Narrabeen Wallarah Sheltered Grassy Forest
	119	Kahibah Snappy Gum Forest
	123	Cooranbong Blackbutt Tall Forest

* Note: Since drafting this report MUs 12 and 15k have been allocated more correctly to Spotted Gum Forest (+/- Ironbark)

Broad Habitat Type	Bell & Driscoll 2014 Map Units	Bell and Driscoll (draft 2014) Map Unit Name
Dry Sclerophyll Forest - Banksia	15i	Lake Macquarie Ironbark Forest
	25a	Narrabeen Peppermint - Apple Forest
	30	Coastal Plains Smooth-barked Apple Woodland
	30a	Buttonderry Footslopes Forest
	30b	Sugarloaf Uplands Bloodwood - Apple Forest
	30e	Coastal Plains Stringybark - Apple Forest
Dry Sclerophyll Forest - Banksia continued	30f	Freemans Peppermint - Apple - Bloodwood Forest
	30h	Sugarloaf Lowlands Bloodwood - Apple Forest
	30i	West Wallsend Stringybark Forest
	30j	Suglarloaf Lowlands Bloodwood - Apple - Scribbly Gum Forest
	31	Coastal Plains Scribbly Gum Woodland
	31?	Narrabeen Doyalson Coastal Woodland
	31j	Snappy Gum Ridgetop Heathy Forest
	31k	Narrabeen Dune Forest
	33	Coastal Sand Apple - Blackbutt Forest
	33a	Coastal Sand Apple-Blackbutt Forest (redefined)
	122	Cockle Creek Dune Forest
Spotted Gum Forest (+/- Ironbark)	12a	Hunter Valley Moist Spotted Gum - Blackbutt Forest
	12b	Hunter Valley Moist Spotted Gum – Turpentine Forest
	12c	Hunter Valley Moist Spotted Gum - Ironbark Forest
	12d	Hunter Valley Moist Spotted Gum - Ferusons Forest
	15	Coastal Foothill Spotted Gum - Ironbark Forest
	15d	Coastal Foothill Spotted Gum - Ironbark Forest (Kurri Kurri)
	15h	Lake Macquarie Spotted Gum Forest
	15l	Sugarloaf Uplands Dry Spotted Gum - Ironbark Forest
	15m	Jilliby Spotted Gum-Northern Ironbark-Mahogany Forest
	15n	Jilliby Spotted Gum-Ferguson's Ironbark - Mahogany Forest
	17o	Hinterland Spotted Gum - Red Ironbark Forest
Swamp Mahogany Forest	33c	Pelican Bangalay Forest
	37	Swamp Mahogany - Paperbark Forest
	37a	Alluvial Paperbark Sedge Forest
	37e	Coastal Sand Swamp Forest
	37f	Swamp Mahogany - Livistonia Swamp Forest
	37g	Swamp Mahogany - Tallowwood Swamp Forest
	37j	Dune Swale Swamp Forest
	42	Red Mahogany-Apple Paperbark Forest
	43	Wyong Paperbark Swamp Forest

Broad Habitat Type	Bell & Driscoll 2014 Map Units	Bell and Driscoll (draft 2014) Map Unit Name
Forest Red Gum Forest	37d	Alluvial Floodplain Cabbage Gum Forest
	38	Foreshore Redgum-Rough-barked Apple Forest
	38a	Floodplain Redgum-Rough-barked Apple Forest
	38c	Foreshore Redgum-Ironbark Forest
	43f	Forest Red Gum Paperbark Scrub- Forest
Swamp Oak / Melaleuca Forest	40	Swamp Oak - Rushland Forest
	40d	Lake Macquarie Headland Swamp Oak Forest
	42a	Narrabeen Alluvial Paperbark Thicket
	43a	Estuarine Paperbark Scrub Forest
	43e	White Stringybark Paperbark Scrub- Forest
	100a	Swamp Paperbark Thicket (Floodplain Alluvials)
	108b	Paperbark Depression Forest (M. styphelioides)
	110a	Red Ironbark - Paperbark Forest
	110b	Depression Paperbark Thicket
Dry Heath / Scrub	31h	Coastal Plains Dry Heath
	31i	Coastal Sandstone Laterite Heath
	34	Coastal Sand Wallum Woodland Heath
	34a	Coastal Sand Wallum - Heath
	34b	Coastal Sand-Mantled Clay Heath
	34c	Coastal Sandplain Dry Heath
Dry Heath / Scrub cont.	36c	Tomago Clay Wallum Scrub
	43c	Paperbark Clay Heath
	48	Coastal Clay Heath
	n/a	Closed Heath on Aeolian Sand
Wet Heath	44	Coastal Wet Sand Cyperoid Heath
	44a	Munmorah Grasstree Wet Heath
	44g	Coastal Sand Bottlebrush Wet Heath
	44l	Munmorah Impeded Sand Sedgeland
	44m	Coastal Plains Wet Heath
	54	Hawkesbury Hanging Swamps
Coastal Scrub	50	Coastal Sand Scrub
	50a	Coastal Sand Foredune Scrub
	50b	Coastal Sand Banksia Scrub
	51	Coastal Headland Complex
	51a	Coastal Headland Grassland
	51b	Coastal Headland Shrubland
	51c	Coastal Headland Low Forest
	51d	Coastal Headland Paperbark Scrub
	XsM	Xs - Mining Rehabilitation (Coastal Tea-Tree/ Bitou/ Acacia)

Broad Habitat Type	Bell & Driscoll 2014 Map Units	Bell and Driscoll (draft 2014) Map Unit Name
Wetland / Sedge	40a	Phragmites Rushland
	40c	Estuarine Juncus Rushland
	45	Lepironia Swamp
	46	Freshwater Wetland Complex
	46a	Freshwater Typha Wetland
	46f	Freshwater Philydrum Sedgeland
	46h	Freshwater Cladium Sedgeland
	46i	Freshwater Gahnia Sedgeland
Mangrove / Saltmarsh	47	Mangrove - Estuarine Complex
	47a	Saltmarsh
Littoral Rainforest	4	Littoral Rainforest
Rainforest	1	Coastal Wet Gully Forest
	1a	Coastal Warm Temperate - Subtropical Rainforest
	1g	Permian Gully Rainforest
	3e	Lake Macquarie Dry Rainforest
	46c	Freshwater Carex Rainforest Sedgeland
Riparian Forest	5a	Alluvial Bluegum-Paperbark Forest
	5b	Alluvial Bluegum-Apple Moist Forest
	5e	Alluvial Bluegum-Spotted Gum Moist Forest
	5h	Alluvial Riparian Blackbutt Forest
	11a	Riparian Paperbark - Peppermint Forest
	11c	Awaba Peppermint - Black Wattle Riparian Forest
	42c	Wyee Turpentine - Red Mahogany - Apple Riparian Forest
	114	Mesic Paperbark Thicket
Beach	53	Beach Spinifex
Unspecified	P	Plantation
	R	Revegetation
	XX	XX - Exotic Plantings
	U	Unclassified vegetation

Appendix 4

Scientific and Technical Workshop summary and outcome report

Notes of Scientific Workshop Monday 30 March 2015 - Lake Macquarie Squirrel Glider Planning and Management Guidelines

Background

A full day scientific workshop was held at Lake Macquarie City Council offices on Monday 30

March 2015 to provide review and input into the draft Lake Macquarie Squirrel Glider Planning and Management Guidelines. The Squirrel Glider is listed as threatened under the NSW Threatened Species Conservation Act 1995 and is widespread in the area.

The workshop aimed to review current scientific understanding for the Squirrel Glider, and the specific implications for future planning and management within the Lake Macquarie Local Government Area (LGA). Preliminary draft Squirrel Glider Planning and Management Guidelines were circulated to participants prior to the workshop.

Attendance

The workshop was attended by:

Rodney van der Ree, University of Melbourne
Ross Goldingay, Southern Cross University
Rod Kavanagh, Niche Environment and Heritage
Michael Murray, Forest Fauna Surveys
Rochelle Lawson, Wyong Council
Rebecca Goodenough, Cessnock Council
Mathew Bell, Great Lakes Council
Karen Thumm, Office of Environment and Heritage
Steve Lewer, Office of Environment and Heritage
Josie Stokes, Roads and Maritime Services
Robbie Economos, Lake Macquarie City Council
Martin Fallding, Lake Macquarie City Council
Mandy McDonald, Lake Macquarie City Council
Vanessa Owen, Lake Macquarie City Council
Sarah Warner, Lake Macquarie City Council
Symon Walpole, Lake Macquarie City Council (part)
Matthew Kennedy, University of Newcastle
John Clulow, University of Newcastle (part)

Presentations

Martin Fallding provided an overview of the draft Squirrel Glider Planning and Management Guidelines and outlined their intent and structure. He noted that the main content requiring review at the workshop related to the summary of scientific knowledge for the species, and the structure and content of the Planning and Management Guidelines. He also outlined the process of preparation of the Guidelines.

A number of short presentations were made at the beginning of the workshop as summarised below:

- Ross Goldingay reviewed his extensive experience in relation to urban fragmentation in Brisbane, and the conclusions reached about opportunities for gene flow in fragmented vegetation.
- Rodney van der Ree outlined the experience at Albury and along the Hume Highway, and density and home ranges. He highlighted debates about the use versus effectiveness of connectivity and road crossings, noting that Squirrel Gliders used road verges as habitat.
- Rod Kavanagh highlighted the importance of accurate records and for recording absence of the species. He noted that the Lake Macquarie local government area is a 'hot spot' for the species and that being poorly conserved in national parks, conservation is primarily a private land management issue. He outlined experience in urban areas at Forster where Squirrel Gliders only occur in small, apparently genetically isolated patches.
- Martin Fallding provided a summary of the conclusions of the Morisset Squirrel Glider Review in 2008 which were applied also by Lake Macquarie City Council in Wyee. Four hectare habitat patches were considered the minimum habitat area, with connecting corridors of suitable vegetation no longer than 1 km to maintain connectivity, and a maximum gap crossing width of 35 metres based on tree heights and glide angle.
- Robbie Economos and Vanessa Owen outlined a case study of a current development application at Whitebridge where the assessment of Squirrel Glider habitat and connectivity is an important consideration, and determination of the significance of impact is required.
- Mandy MacDonald presented the outcomes of Lake Macquarie City Council Squirrel Glider modelling using MaxEnt software.

Martin Fallding presented the proposed framework for summarising the characteristics of Squirrel Gliders (Table 1), and asked workshop participants to complete relevant sections of this summary. This is important to provide a common understanding of the key aspects of their biology which can be applied for planning purposes. Martin also provided copies of the planning guidelines (Table 5) and management guidelines (Table 6) for participants to include their ideas and comments.

Key issues discussed

The workshop then considered key issues underpinning the guidelines. Matters discussed included the following:

Population distribution

The uneven concentration of records of occurrence of Squirrel Gliders across the LGA means that habitat modeling may need to be reviewed to make it more reliable by spreading records used for modeling further apart.

In particular, further survey work should be undertaken to determine absence of the species, especially west of the M1 Pacific Motorway.

Records of Squirrel Gliders occur only on land below 100m elevation, and this elevation is also the most important predictor in habitat modeling.

It is reasonable to identify the Squirrel Gliders in the north east of the LGA as a separate population. The viability of this population will depend on the level of management, with 10 ha patches probably not being viable. To maintain the population in the long term it is possible that some re-introduction of animals may be required.

The Squirrel Gliders west of Lake Macquarie appear to be in connected habitat and should be strategically identified as important for conservation.

In Brisbane, a minimum area of 400ha of suitable habitat is considered to be required to maintain a long term viable population, at a density of around 0.5 animals/ha. There is a large variation in density assessments.

Population viability analysis techniques are primarily used to evaluate and compare options and outcomes. To be applied in Lake Macquarie, a lot more data on occurrence and absence would be required.

The population within the Lower Hunter (four Councils plus Great Lakes) is still of national significance, because of the size of the population, density of records, and the extent of habitat.

Key conclusions are:

- All viable populations should be considered to be important populations.
- Species conservation in a number of different patches is important, especially for surviving catastrophic disturbance events.
- The Lower Hunter councils have a large proportion of the NSW population of Squirrel Gliders.
- Lake Macquarie LGA contains a very significant population of Squirrel Gliders, especially when combined with the north of Wyong LGA.

Significance of impacts

It is difficult to apply numerical standards to determine the significance of impacts. However, it is possible to make general statements that any impact on a strategic corridor linkage would be important, and that a greater than 10% loss of habitat patches with an area of greater than 10 ha would be significant.

In the north east of the LGA, any loss of total habitat is expected to be significant, and any reduction of patch size below 4 ha would be significant.

In terms of determining significant impacts and local populations, there was discussion agreeing that the patch size of the subject site occurs in needs to be defined, the % patch size being retained, the number of den trees being cleared, and number of den trees being retained (as displaced gliders are unlikely to persist if forced to move into another gilder's home range).

Survey guidelines

Survey requirements depend on the reason for the survey. Consideration should be given to whether information on presence is required only, or whether the object is to estimate population density and size.

It is also important to review the presence of Sugar Gliders concurrently with Squirrel Glider surveys as both species commonly occupy the same area.

Council's current requirement of 3-4 nights trapping is not sufficient. Because of trap shyness, surveys are needed over 5 – 7 nights and may need to use multiple methods (traps, cameras, spotlighting). Ross Goldingay suggests requiring at least 2 periods of at least 3 nights, with at least 1 month between survey periods. Nest boxes are a good survey method and can be left out for some months. Pipe traps are very effective and baited cameras can also be used, but protocols for camera use are required.

Absence surveys are important. To be reliable, such surveys need to use traps, bodyweight data must be recorded, and whether male or female, adult or juvenile. Spotlighting data should be eliminated to determine absence as it is not reliable for identification.

Rodney van der Ree uses cage traps (20 x 20 x 50 cm) with an internal drop down door, nailed to tree trunks, and traps for at least 5 nights with traps at spacing of 100 – 150 m. To determine presence/absence traps are left out for at least 7 nights until no new animals are captured.

It is important to consider the application of the Biobanking assessment methodology to Squirrel Gliders. Currently this is an ecosystem credit species. However, a recommendation should be made to the Office of Environment and Heritage that Squirrel Gliders should be considered a species credit species for important populations such as found in Lake Macquarie LGA. This requires a change in current practice.

There should be more survey effort given to determining habitat (especially winter flowering species and

Banksias), surrounding development, and habitat connectivity.

There are some difficulties in differentiating Squirrel Gliders from Sugar Gliders. Capture and weight are the best. Spotlighting is less reliable and it is necessary to target Eucalypts in flower. Gliders will not enter traps if there is abundant blossom and are trap shy, so the traps must be there for longer. Photos should also be taken for confirmation.

It is easy to miss Squirrel Gliders in survey and no need to avoid winter surveys.

For rezoning proposals it may be feasible to install nest boxes and monitor Gliders by micro- chipping.

Habitat

It is worth giving further consideration to using Lake Macquarie vegetation community mapping as the basis for determining Squirrel Glider habitat for planning purposes. However, systematic presence/absence surveys should be undertaken to confirm the accuracy of this approach.

There was discussion about the bias of records in the City towards more populated areas experiencing development pressure. The habitat predicted by the MaxEnt model was considered reasonable if suitable thresholded habitat was present. The model was not considered robust enough to use the heat map i.e. to predict varying levels of habitat suitability.

Swamp mahogany dominated wet sclerophyll forest appears to be the most important vegetation community for Squirrel Gliders in Lake Macquarie LGA. It is reasonable to assume presence of Squirrel Gliders based on the occurrence of preferred habitat (such as swamp sclerophyll forest, spotted gum forest, bloodwood/scribbly gum). In Lake Macquarie important species and communities are:

Banksia
Spotted Gum
Spotted Gum Ironbark Forest
Swamp Mahogany
Scribbly Gum
Angophora
Corymbia gummifera

Even if Squirrel Gliders are not present, habitat may be important for connectivity either in the short or long term.

In Victoria, Squirrel Gliders are known to occupy 95% cleared landscapes, occupy habitat in

20m strips, and to travel up to 160m into private backyards.

Hollows and nest boxes

Probably only about 10% of natural hollows are actually utilised by Squirrel Gliders. Gliders only need 1 or 2 hollow bearing trees but will use several, denning in more trees if they are available. They move between den trees to protect territory within their home range, possibly to reduce parasite loads, and to be close to food sources. It is useful to determine the number of habitat trees within the home range, which generally varies between 5 – 8 ha of contiguous native vegetation, with 14 – 15 ha at Tea Gardens and about 6 ha at Eleebana.

Providing nest boxes is an important survey technique, as well as a management action for providing additional habitat. It is important to distinguish between using nest boxes as a mitigation measure and their use as an offset measure.

Rear entry nest boxes are preferred, being specific for arboreal mammals. This appears to prevent use of the nest box by certain bird species. Hollow Log Homes http://hollowloghomes.com produce quality boxes with a reasonable lifespan of 5 – 10 years.

Nest boxes for Squirrel Gliders should be placed about 3m above ground for ease of access and maintenance, with an orientation on the south or south east side of trees. Boxes should be wired to trees, not nailed.

RMS applies guidelines for impact mitigation of construction projects requiring 1:1 replacement of hollows with 50% erected before construction and 50% following completion of works. Next boxes can only be regarded as an offset if they are maintained in perpetuity.

Buffer distances

Buffer distances to Squirrel Glider den trees are primarily to protect the tree, by preventing root compaction and give animals using the trees some cover. The distance will depend on the height of the tree. A radius of 20m-30m around trees was considered adequate.

Bushfire impacts

It is important to protect habitat trees with hollows during bush fire hazard reduction activities. Fire should also be excluded from riparian areas where possible.

The biggest impact on fire is expected to be the effect on the structure of the vegetation and increases in the rate of collapse of hollow bearing trees. Hazard reduction burns should protect standing habitat trees even if they are dead.

Fires disrupt flowering species for 1 – 2 years and it takes 3 – 5 years for Banksias to recover.

A bush fire at Crescent Head led to a 50% population decline in Squirrel Glider numbers.

After a hot burn in bushland at Jesmond in Newcastle, Squirrel Gliders returned after 7 years.

Connectivity and gap crossings

It is important to distinguish between providing genetic connectivity across gaps and barriers and providing for regular animal crossing.

Trees in road median strips are needed for crossing wide roads.

Protection of individual large old trees that give connectivity across roads is very important. Gap crossing ability is dependent on tree height.

Rope bridges allow additional species to cross roads when compared with gliding poles. Gliders still use the rope crossings. The cross-beam on a pole should be in the direction of the glide.

Keeping shrubs on, and maintaining natural connectivity across electricity easements is important.

Roads and Maritime Services (RMS) only provides crossing structures as part of new construction projects. Otherwise action is only taken in response to road kill, and there is a need to identify hotspots and demonstrate the impacts and need for a structure.

RMS has standard drawings for the construction of crossing structures.

Genetic issues

Separation of populations can be determined over 5 – 7 years using genetic studies. However, it takes 30 – 50 years to show significant genetic differences.

In trap surveys, it would be useful to collect genetic material for future analysis. This could be stored by the University of Newcastle.

Translocation

There is no literature documenting translocation of Squirrel Gliders, and translocation of animals is generally not supported. Experience with translocation shows that this is unlikely to be successful, very expensive, and there are very poor survival rates. There are many complex issues that need to be considered.

However, the view was expressed that it cannot be ruled out for a specific conservation purpose such as (1) genetic restocking to maintain population viability or (2) relocation for a development proposal, where the receiving area formerly contained gliders but they are no longer present.

Other management issues

Barbed wire fencing needs to be avoided and removed from Glider habitat.

Shrubs at creek crossings should be maintained in transmission easements. Whilst transmission easements are not considered a significant barrier, vegetation would assist crossing and provide cover. Gliders are more vulnerable if they are on the ground.

Presence of cats appears to be an issue in urban areas.

Scientific research questions

Climate change impacts on Squirrel Gliders are unknown, but probably the most significant impact will be on changes in vegetation. However, climate change raises more uncertainties than can be dealt with.

It is important to research the population density for all vegetation communities that have not been systematically surveyed.

It would be appropriate to review the population threat level within the Lake Macquarie local government area and the amount of population decline, and thus whether the population warrants listing as endangered under the Threatened Species Conservation Act 1995.

Conclusions

Martin Fallding invited workshop participants to provide comments on the draft Lake Macquarie Squirrel Glider Planning and Management Guidelines that had been circulated.

Martin advised that a summary of the workshop outcomes will be circulated to participants for review, together with the updated summary of the scientific characteristics.

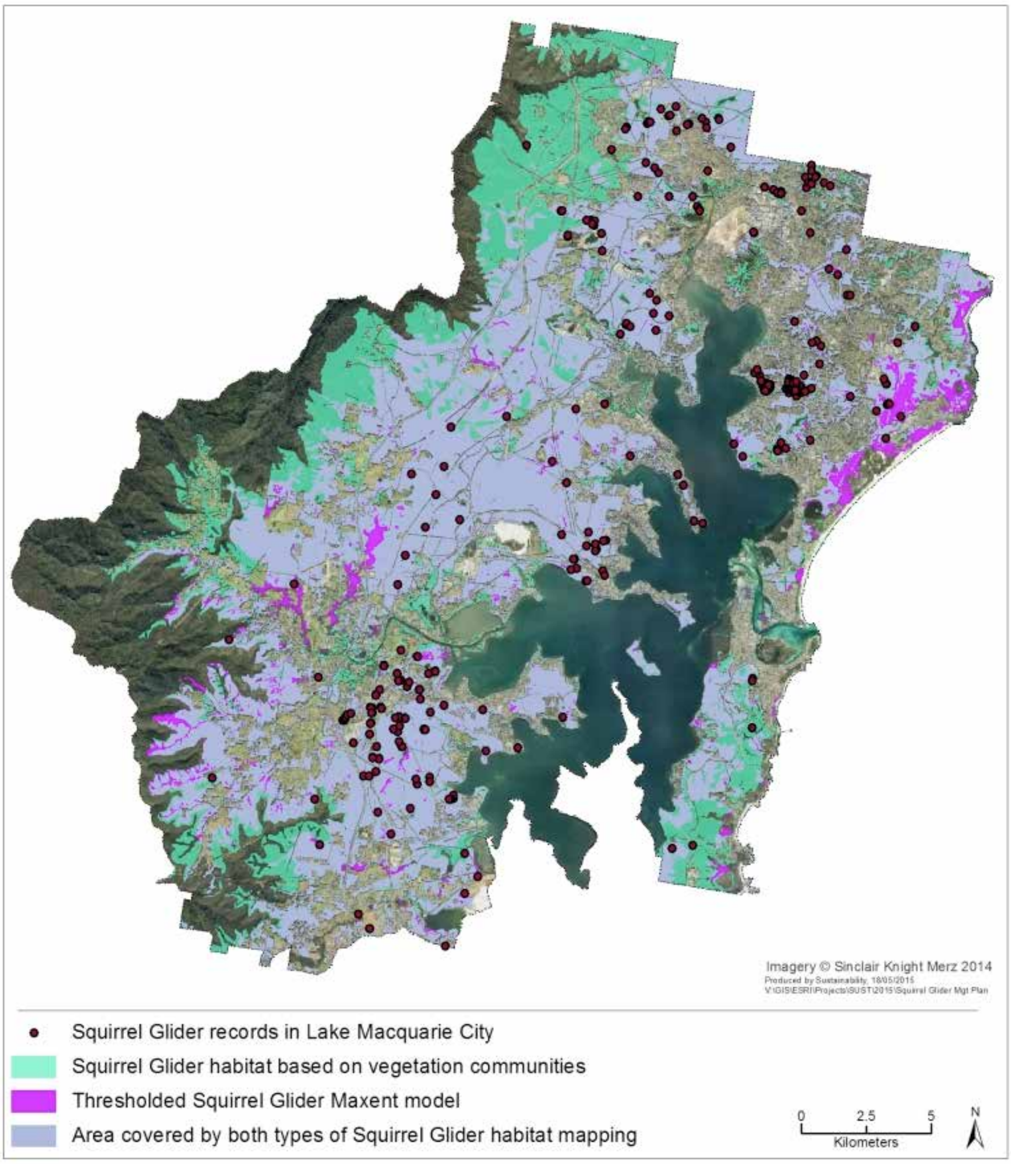
Workshop participants were thanked for their attendance and participation.

Martin Fallding
24 April 2015

Appendix 5

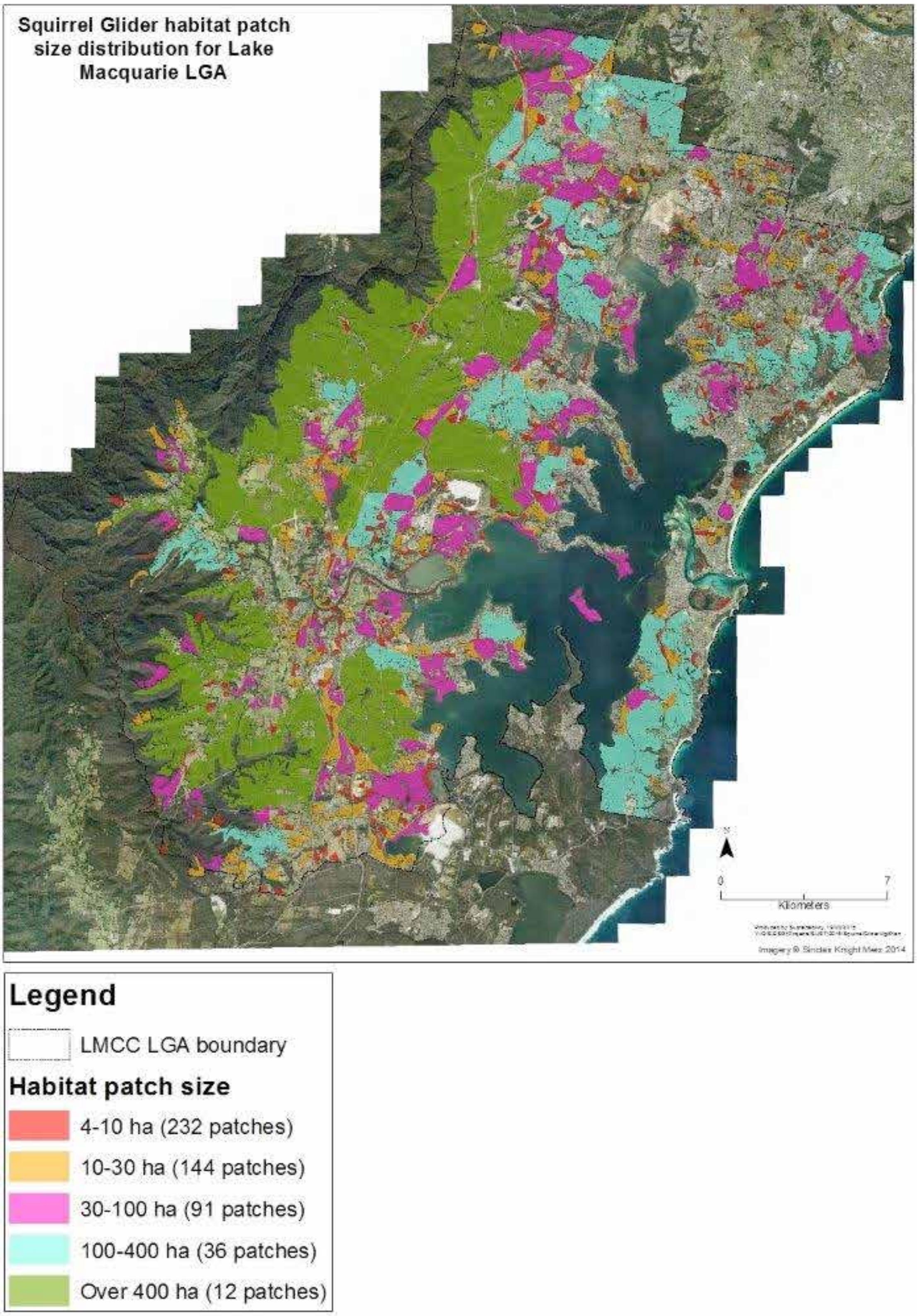
Comparison between modelled probability of occurrence (MaxEnt) and likely habitat using vegetation communities

Squirrel glider habitat vs MaxEnt – an overview of the similarities and differences between the habitat map (veg communities plus elevation <100m) and the thresholded MaxEnt map. Green shows the additional area brought in by the new habitat map and pink shows the areas included by Maxent but excluded by the new map. The purple-green shows the overlap between the two.



Appendix 6

Squirrel glider habitat patch size distribution
Map A6.1 Habitat patch sizes >4 ha



Appendix 7

Squirrel glider habitat connectivity analysis

This appendix outlines the methodology, results and limitations of investigation of habitat fragmentation and potential squirrel glider connectivity in the Lake Macquarie Local Government Area (LGA).

A7.1 Least cost paths and squirrel glider habitat components

A connectivity analysis was undertaken for the squirrel glider in Lake Macquarie LGA to assist in examining fragmentation and connectivity of Squirrel Glider habitat as well as to identify areas that may be important for squirrel glider movement.

A multi-criteria connectivity planning framework, called General Approach to Planning Connectivity from Local Scales to Regional (GAP CLoSR) (Lechner and Lefroy 2014) had previously been applied to Lake Macquarie LGA. By using average movement parameters for a number of species, overall connectivity for all species in the LGA was examined with least cost movement paths being identified. Economos and Redmond (2015) documents in detail the method, outputs and limitations of application of GAP CLoSR to the LGA. Such a general analysis does not necessarily cater for the needs of individual species, particularly gliders that have a maximum glide distance that is dependent on tree height or the height of the launch structure.

This analysis involved the use of GAP CLoSR for a specific species, the squirrel glider, using patch size and movement parameters specific to this species rather than general parameters used in the previous analysis.

Two data layers are required for GAP CLoSR: native vegetation extant and landuse. Both these layers had been developed as part of the general analysis undertaken for the LGA (Economos & Redmond 2015).

In this case, likely squirrel glider habitat (as described in Map 5 Section 4.2) was used, rather than the native vegetation extant, to ensure that outputs would focus on the connectivity between patches of habitat important for squirrel gliders. A digital height model (DHM prepared as outlined in Attachment 1 Step 5) was used to remove grid cells (i.e. 5 m x 5 m cell of vegetation) with a maximum height of less than 5 metres (m) as it is assumed that vegetation of less than this height would not contribute to glider movement.

Graphab is software for modelling ecological networks using landscape graphs and least-cost paths. Graphab is used as part of GAP CLoSR. A Graphab analysis was undertaken using parameters specific to the squirrel glider. These were habitat area (habitat patch sizes) of both 4 hectares (ha) and 10 ha with a gap crossing distance of 35m. Other connectivity parameters used were consistent with Fallding & Smith (2008). That is, the maximum distance that will be travelled across gaps of 35m and through vegetation that is not a habitat patch is 1 kilometre (km).

The Graphab analysis outputs were used to determine habitat components and least cost paths for connecting the habitat. The Graphab outputs shown in Maps A7.1 and A7.2 (for 4 ha and 10 ha respectively) indicate relative fragmentation across the LGA, and importantly identify groups of habitat patches (habitat components). These habitat components are isolated from each other by a distance of more than 35 m between habitat vegetation and/or are separated by a least cost path distance of more than 1 km from other components. (The 1 km being adjusted for the underlying landuse resistance to movement).

It is important to acknowledge that there may be able to be some glider movement from one habitat patch to another, using vegetation that is not habitat and that this method is very sensitive to the way habitat (or vegetation) is mapped. The presence of gliding structures such as power poles and gliding poles at Wyee have not been included in the analysis. It is therefore necessary to confirm the likelihood of movement with field survey (mapping of launch points and radio tracking and genetic analysis).

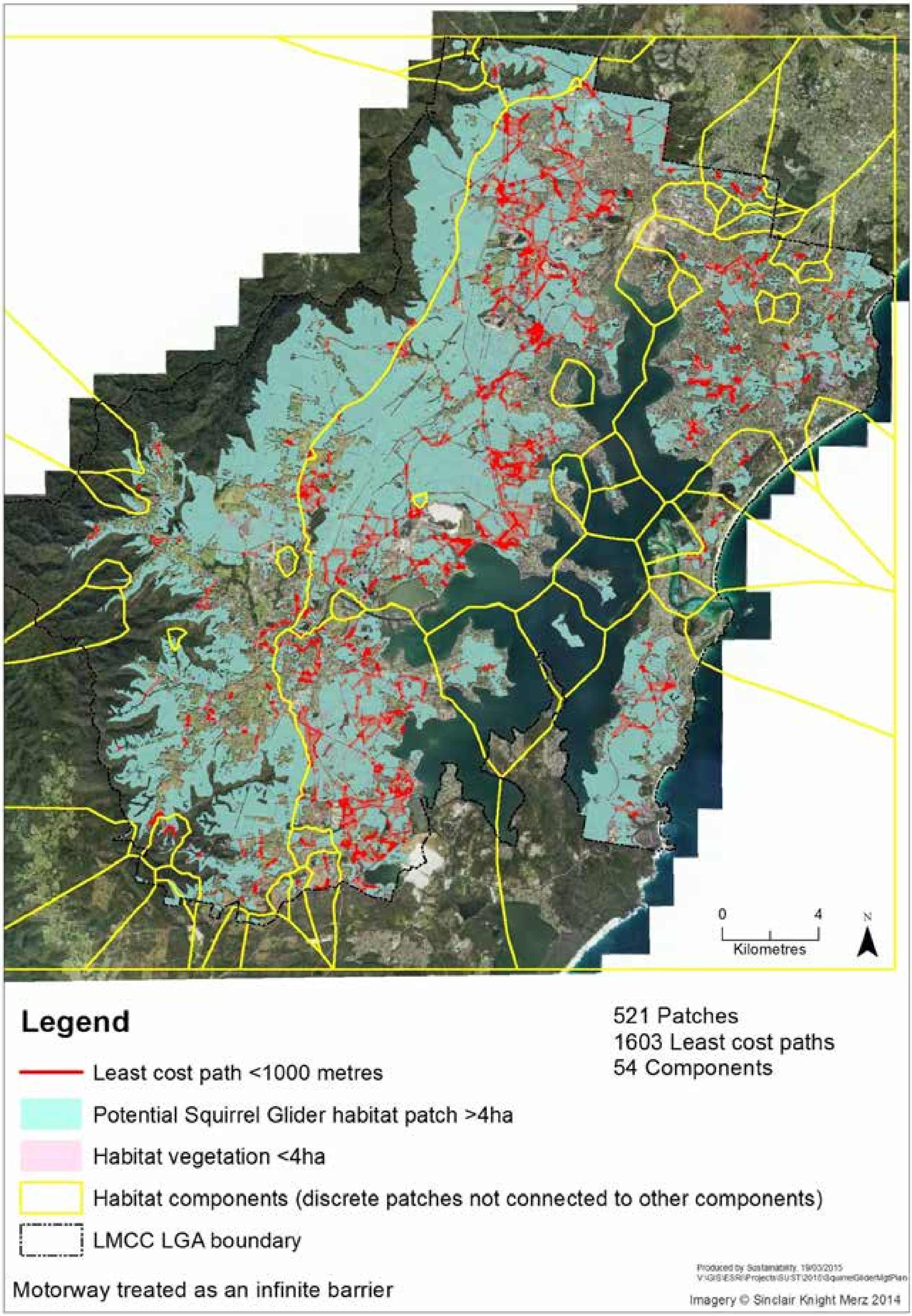
In this analysis, the M1 Pacific Motorway (M1) (also known as the Freeway) was treated as a complete (infinite) barrier i.e. it is assumed it cannot be crossed by squirrel gliders. The Great Northern Railway (the Railway) was treated as crossable using the crossings that were determined in the generalised mapping for the LGA.

The ability of squirrel gliders to cross the M1 and the Railway were individually subject to further analysis in Section A7.2.

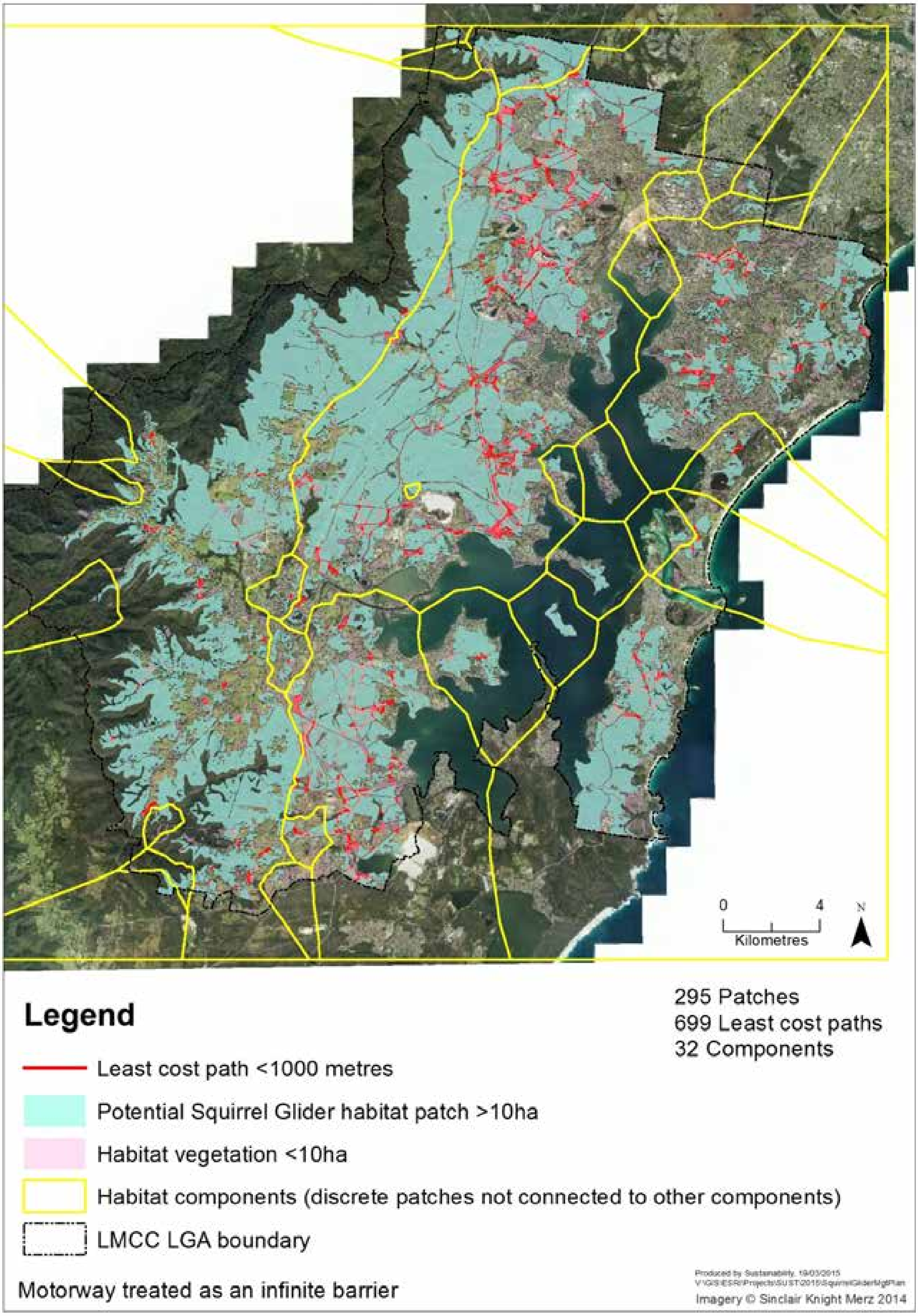
Crossings of the Railway (from the general species Graphab analysis) are mainly culverts and creek lines. The analysis below indicates that these crossings do not support vegetation that is high enough for gliders to glide across the Railway. Treating the Railway as an infinite barrier would result in an increased number of components. Alternatively, a further GAP CLoSR analysis would use the crossing points identified in Section A7.2 below.

Both the 4 ha and 10 ha analysis (Maps A7.1 and 7.2 respectively) show five large broadly similar components that have been used in the guidelines to represent populations.

Map A7.1 Connectivity analysis for >4ha native habitat patches



Map A7.2 Connectivity analysis for >10ha native habitat patches



A 7.2 Ability of squirrel gliders to cross major barriers the M1 Pacific Motorway and the Great Northern Railway

Spatial analysis was undertaken to determine if and where it was possible for squirrel gliders to cross two major barriers to fauna movement that run through the LGA. The M1 and the Railway run in roughly a north-south direction fragmenting native vegetation into patches and restricting fauna movement in an east-west direction. Neither of these transport corridors includes any purpose built structures to facilitate fauna movement across them.

The aim of this analysis was to identify areas of native vegetation adjacent to the M1 and the Railway that could be important in maintaining connectivity on a landscape scale with a view to ensuring that this potential connectivity be retained and enhanced into the future.

The detailed method including steps used in this analysis is outlined in Attachment 1 - Steps to analyse squirrel glider crossing points for the M1 Motorway and the Great Northern Railway.

If theoretically, squirrel gliders could cross these barriers, then the areas of vegetation highlighted are probably important for other mobile species as well particularly birds and bats.

Map A7.3 and Map A7.4 show the identified potential crossing points for both the M1 and Railway respectively. Tables A7.1 and A7.2 detail the number of crossing points and the way they are grouped in general locations for the M1 and Railway respectively.

Table A7.1 Summaries the possible crossing points for the M1 Pacific Motorway

Complete Crossing	Direction	M1	Comments
One glide	East to West	9	Clustered in two locations: · Dora Creek · Stockton Creek
	West to East	0	
Two glides using median	East to west only	237	Clustered roughly in the following locations · South of the Hunter Expressway interchange (Cameron Park) · Slatey Creek · Wyee
	West to East only	288	Clustered roughly in the following locations · West Wallsend · North of Cooranbong · South of Cooranbong · Morisset · Cobra Creek
	Both Directions		Clustered roughly in the following locations · North of the Hunter Expressway interchange · Burkes Creek (Killingworth) · Jigadee Creek · South of Jigadee Creek to North of Dora Creek · Dora Creek to Morisset · South of Morisset · Wyee Creek

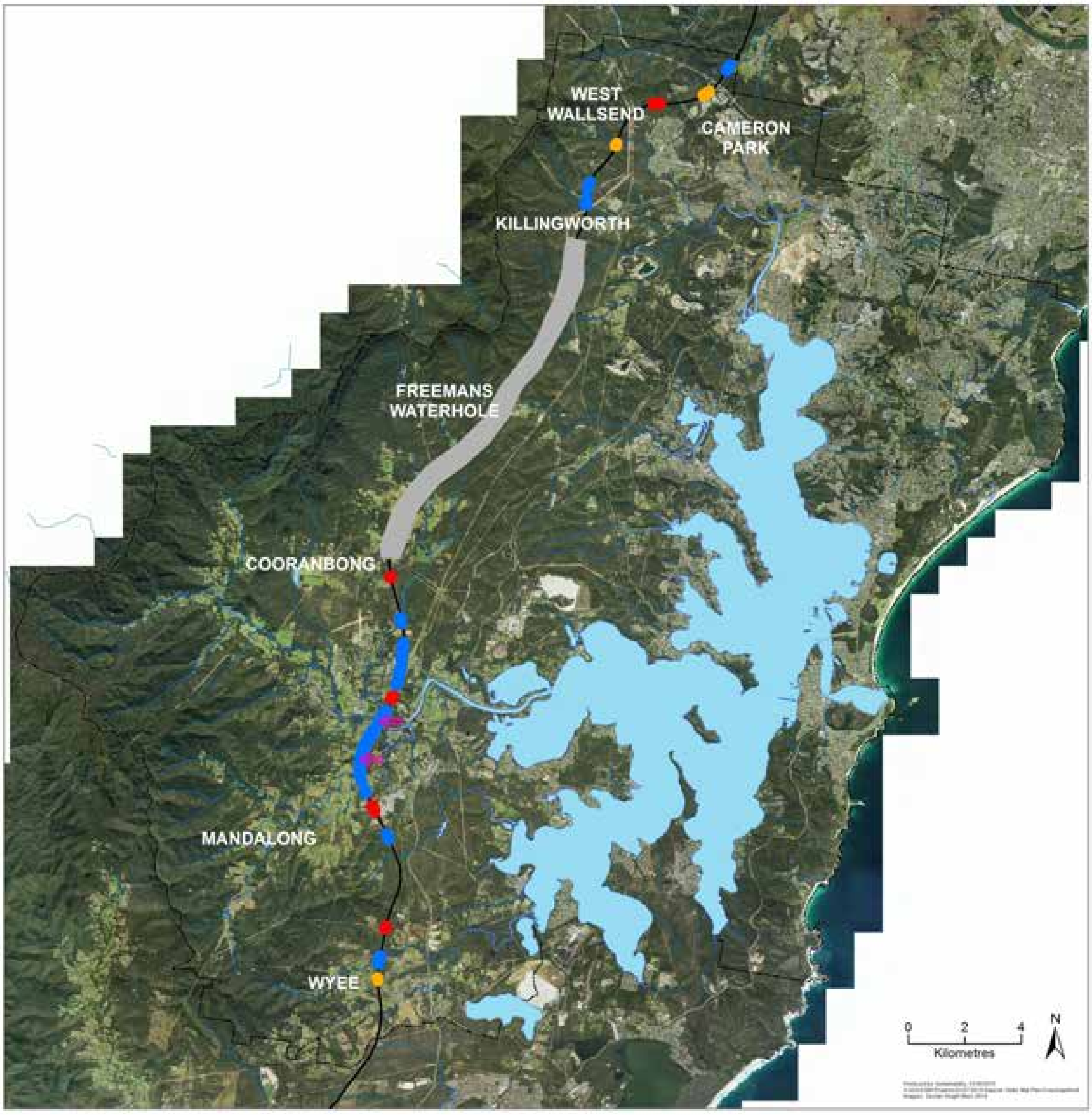
Table A7.1 shows that there are limited locations where the M1 can potentially be crossed by squirrel gliders and this requires the use of vegetation in the median for the vast majority of crossing points. It also shows that the M1 can be crossed in an east west direction in one glide, only at two locations (made up of nine points), Dora and Stockton Creeks.

Table A7.2 Summaries the possible crossing points for the Great Northern Railway

Complete Crossing	Direction	Railway	Comments
One glide	East to West Only	474	Clustered roughly in the following locations: · Tickhole tunnel · Cardiff · Fassifern · Stoney Creek · Muddy Lake · Morisset Golf Course · Morisset Hospital · North Wyee
	West to East Only	532	Clustered roughly in the following locations: · Cardiff Railway Workshop · Booragul Rail Loop · Fassifern · Stoney Creek · Eraring · Dora Creek · Morisset North · Morisset Golf Course · Morisset Hospital
	Both Directions (ie east to west and west to east within 100 metres of each other)	282 west 340 east	Clustered roughly in around 10 locations · Tickhole tunnel · Cardiff · Five Islands · Booragul Rail Loop · Fassifern · Eraring · Muddy Lake · Dora Creek · Morisset North · North Wyee

Table A7.2 shows that there are many more locations where the Railway could potentially be crossed in one glide. Crossing the railway is likely to be somewhat more probable than the M1 because of the gaps between trains.

Map A7.3 Barrier crossing analysis for the M1 Motorway



Legend

— M1 Motorway

⇐ East to West across Motorway possible in one flight

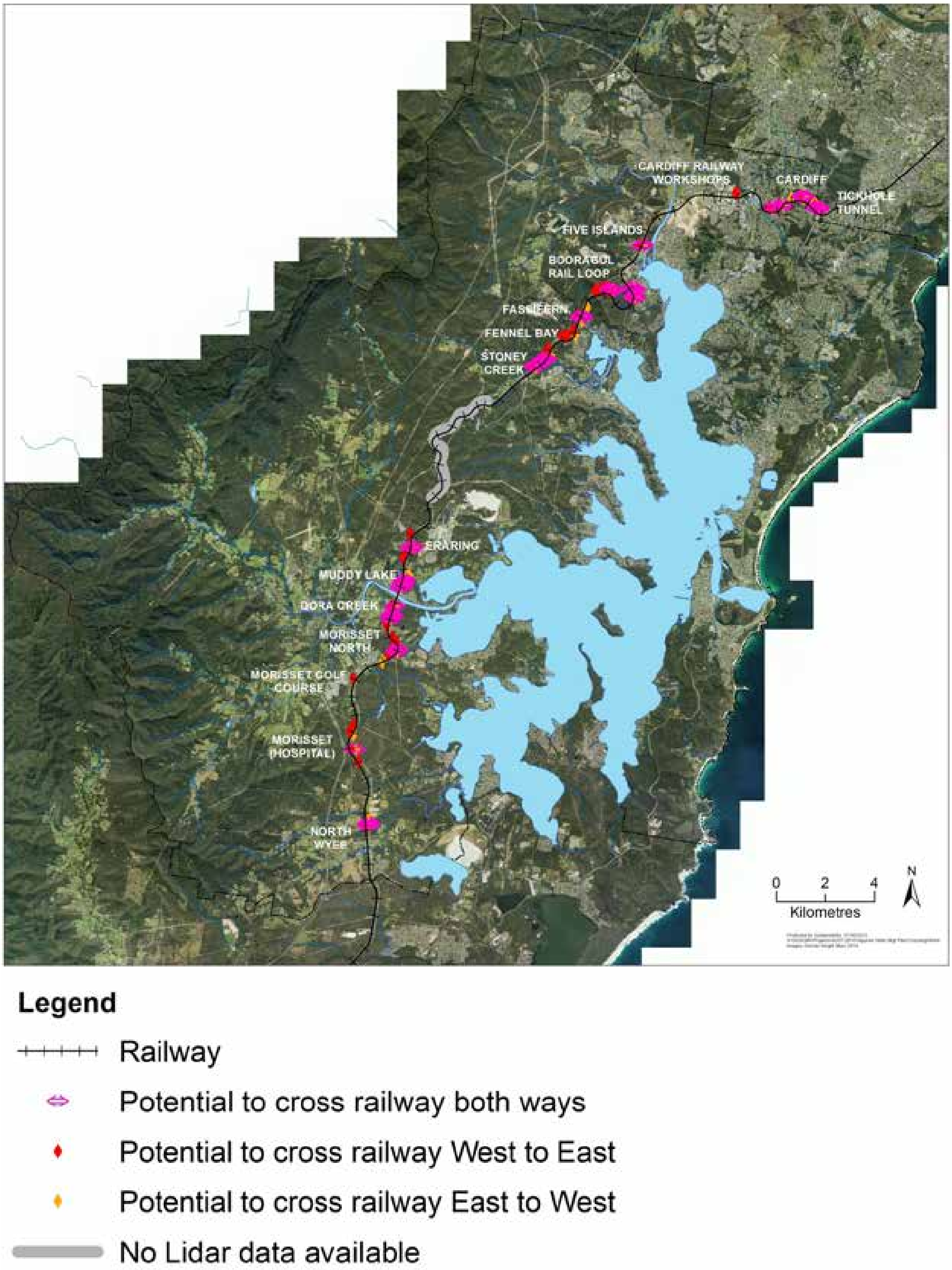
Potential using centre vegetation to cross Motorway East to West

Potential using centre vegetation to cross Motorway West to East

Potential using centre vegetation to cross Motorway in both directions

No Lidar data available

Map A7.4 Barrier Crossing for the Great Northern Railway



A7.3 Limitations of connectivity and barrier crossing analysis

The analyses in A7.1 and A 7.2 are largely theoretical and have a number of limitations.

Only the glide distance has been factored into the analyses. There has been no analysis of whether there are actually suitable structures such as tree branches and trunks for launch and landing. The existence of these would need to be identified on site.

The glide distance calculation used for the M1 and the Railway crossing analysis, presumes that gliders land on the ground at the end of the glide (either in the vegetation on the opposite side of the M1 or the Railway or on the ground in the median of the M1). That is the "-2" in the calculation Glide Distance = Height x 1.8 – 2, has been ignored. This would mean gliding across the M1 carriageways at a height that would increase the risk of collision with vehicles.

The DHM uses the highest canopy point (which could be the top of the highest tree) within a 5 m grid to represent height/launching point. Any lateral branch used as a launch point is likely to be at a lower level than the very top of the tree. The extent to which this error might be balanced out by LiDAR data representing branches below the top of the tree rather than at the top of the tree is unknown.

The LiDAR used to generate the DHM (representing canopy height) layer was captured in 2007. There are likely to be a number of changes in tree height in eight years.

Approximately 13 km of M1 and 6 km of the Railway are not covered by LiDAR and therefore have not been analysed.

Only the distance across the barriers is assessed in this analysis. The M1 and Railway present more hazardous challenges for fauna than the mere crossing distance. The M1 has very high volume traffic for 24 hours a day and collision with vehicles is likely. The railway has a range of aerial and ground obstruction that would restrict gliding. This analysis should not be used to assume that gliders do cross but rather acknowledge the potential is there for such crossing, albeit it very high risk.

The connectivity analysis (Graphab in particular) is very sensitive to how vegetation has been mapped and how barriers are treated. Separate components arise when the M1 and Railway are treated as infinite barriers (i.e. barriers that cannot be crossed). Economos and Redmond (2015) discuss further the limitations of GAP CLoSR. In this analysis, the vegetation used was not all native vegetation but only likely squirrel glider habitat so there is likely to be other vegetation that is important for movement. A least cost path method only identifies one connection between habitat patches. There may also be other important connections.

It is therefore important to manually check separate components and confirm on site that movement from one component to another is not possible before basing important decisions on this. Having said this, the analysis is sufficient to identify five broad populations.

A7.4 Potential uses of the Analysis

Given the limitations outlined above, the barrier crossing analysis is considered sufficient to identify areas of vegetation beside the M1 and the Railway that are potentially important for movement but the analysis not sufficient to infer that movement occurs. A conservative approach is therefore required in using this for decision making.

Populations on either side of the M1 should be considered as separate unless further site-specific investigations are undertaken to demonstrate that crossing this barrier is possible and occurs.

Areas of vegetation that have been identified in this analysis as having the potential to be important in connectivity should be retained and enhanced until detailed site specific investigations are undertaken to demonstrate that these areas cannot function to support movement of relevant species.

The areas that are potentially important for barrier crossing (movement) would be suitable locations to investigate encouraging greater height in vegetation adjacent to the M1 carriageways and within the median as well as adjacent to the Railway. The vegetation in these areas should be maintained and enhanced, as it will be used by a variety of mobile species.

This barrier crossing analysis could also be used to identify areas where structures would be useful to assist movement across these major barriers. In many locations, movement into the median of the M1 appears possible and movement out of the median back to the same side appears possible but a complete crossing cannot occur in the same direction.

The connectivity analysis highlights areas (least cost paths) that may be devoid of squirrel glider habitat that could be important for glider movement. The 4 ha Graphab analysis, Map 7.1, (rather than the 10 ha analysis, Map 7.2) should be used for this purpose as it identifies more least cost pathways. This should be used in conjunction with other corridor information and mapping as only one path is identified in the least cost path analysis.

A detailed review of the components and the vegetation between them highlights areas where works (such as structures or revegetation) could significantly improve connectivity by reducing the number of components. In some areas the land use and distance is such that no realistic restoration can be contemplated and populations within these components can be considered isolated. In other locations such as at Morisset and Coal Point, detailed analysis on site indicates small pockets of unmapped vegetation may allow movement and that restoration measures could be effective in connecting components that have been identified by the analysis as being isolated.

The components identified by both the 4 and 10 ha analysis appear to be consistent in identifying five larger separated populations across the LGA. The number of isolated components could increase if the Railway is treated as a barrier that cannot be crossed.

A7.5 Conclusion

Areas where there is vegetation that could potentially facilitate squirrel gliders crossing the two major (transport infrastructure) barriers in the LGA have been identified.

The M1 is considered a particularly formidable barrier to movement. Map 7A.3 demonstrates that there are locations where tree height and ground level would theoretically allow a glide across it either with or without the median vegetation. However, given the heavy traffic particularly at night, the M1 should be treated as a barrier that cannot be crossed until it is demonstrated to the contrary. The areas of vegetation identified as being potentially important for crossing these barriers and the corridors connecting them to other patches of native vegetation should be retained and enhanced unless it is demonstrated (using site specific survey, radio tracking genetic studies etc.) that they do not facilitate movement across these barriers.

Further investigation should be conducted before inferences can be made about populations of fauna on either side of the transport barriers (the M1 and the Railway). It should be presumed that they are separate populations in the absence of genetic studies and radio tracking that may show crossings actually occur. Similar studies should be required before approval is granted to disturb or remove vegetation:

- within the identified potential crossing areas, and
- connecting other native vegetation patches to the identified potential crossing areas.

Broad habitat components that support five large separated populations have been identified by the connectivity analysis.

Further investigations should be undertaken to ascertain

- the potential to reconnect before populations in some of the separate components are presumed to be isolated, particular for the Morisset Peninsula and Coal Point, and
- native vegetation connections that lead to the identified potential crossing points.

A7.6 References

Economos R. and Redmond L. (2015) *Native vegetation corridor refinement report*. Prepared for Lake Macquarie City Council February 2015. (prepared through the Lake Macquarie Regional Sustainability Project Grant funded by the Department of the Environment)

Lechner A. and Lefroy EC. (2014) *General approach to planning connectivity from Local Scales to Regional (GAP CLoSR): combining multi-criteria analysis and connectivity science to enhance conservation outcomes at the regional scale in the Lower Hunter*, University of Tasmania (prepared by the Landscapes and Policy Hub under the National Environmental Research Program).

ATTACHMENT 1 - STEPS TO ANALYSE SQUIRREL GLIDER CROSSING POINTS FOR THE PACIFIC MOTORWAY (M1) AND GREAT NORTHERN RAILWAY

M1 MOTORWAY

Step 1 - Vegetation Mapping

The 2012 LMCC Native Vegetation Mapping extant along freeway was overlain with more recent aerial photography (2014). The layer was edited where required by adding slivers of vegetation previously not mapped and centre vegetation where previously not mapped and where this vegetation was obviously trees. These areas could reflect native vegetation that has regrown since 2012 or trees that were missed. Vegetation that had been cleared since 2012 review was removed.

Step 2 - Buffers

The outer edge of each freeway carriageway was buffered for a distance of 100 metres. Vegetation on either side of the freeway was clipped to this distance to reduce the dataset sizes for analysis.

The buffer distance of 100 metres was determined by looking at the width of the carriageways and the maximum distance that a glider could glide from the tallest tree in the LGA. Since each carriageway is 12 metres wide, the distance from any centre vegetation to the furthest tree in both directions after the clipping is 112 metres. The tallest tree in the LGA from the LiDAR coverage is 57 metres. The tallest tree along the M1 is actually only 38 metres. Based on the gliding equation of (1.8 x tree height) - 2, the furthest possible glide distance from a height of 57 metres is 100 metres, which would not reach the centre vegetation because the buffer distance plus the carriageway equals 112 metres. Therefore, by including all vegetation to a distance of 100 metres from the outer edge of the carriageway any possible glide to the centre vegetation is well covered.

Step 3

The boundaries to the vegetation polygons were dissolved to remove boundaries between adjoining polygons and all of these were labelled as vegetation with no distinction between bushland & partly cleared polygons) File – BaseEditedFreewayVegClippedDissolved

Step 4

A location relative to the M1 was assigned within the attribute table to each polygon – West, Centre or East. **File – BaseEditedFreewayVegClippedDissolved**. This layer was clipped by the extent of the LidDAR 2007 coverage as the LiDAR data was used in further steps for the glide analysis File – **BaseEditedFreewayVegClippedDissolvedLidarArea** (Freeway Vegetation (1))

NOTE: LiDAR 2007 coverage does not extend the full length of the freeway. There approximately 13 kilometres of the M1 (in the centre of the LGA) that is not covered.

Step 5 - Digital Height Model

LiDAR digital height model (DHM) (LMCC Digital Height Model (DHM)) was created from 2007 LiDAR to produce a layer representing the maximum height of vegetation. This was calculated in 5m cells by taking the maximum LiDAR values for that cell from the average ground value, thus giving the height of the object in that cell (**Lidar_DHM_5m_NN.tif**)(LiDAR raster (2)).

Issues: LiDAR quality is poor and is not classified other than ground/non ground in separate LAS files, both point clouds contained noise, birds and ground classification errors. LAS files were 'cleaned' within time constraints.

Method:

- ArcGIS 10.2 was used to create lasd (LAS mosaic dataset) from LAS files a non-ground lasd and ground lasd (as supplied from NSW Department of Planning via Geoscience Australia, captured 2007).
- Missing tiles were replaced with ascii file versions (txt2las)
- Point cloud data was cleaned focusing on vegetated areas. This process removed extraneous noise values (e.g. power easement towers and flocks of birds) to better reflect true height values in relation to ground heights
- A maximum value natural neighbour 5m raster was created from the non-ground dataset (DSM)
- An average value natural neighbour 5m raster was created from the ground dataset (DEM)
- The raster calculator was used to take the max value raster from the average ground raster (DSM-DEM=DHM)
- The negative values from the DHM were reset to zero (outside vegetation extent lake/ocean areas)
- DHM to was clipped to the LiDAR extent (DHM) and vegetation extent (vegetation_DHM)

All data in MGA Zone 56 meters and all rasters have the same extent.Nodata value = -3.40282306074e+038

Step 6 - Vegetation Height

Extracting Vegetation Height Values Using LiDAR DHM using **Lidar_DHM_5m_NN.tif** (LiDAR raster (2))

- Freeway vegetation (1) was exported to raster (5m cell size), setting the "processing extent" and "snap to raster" in "environments" to be the same as the LiDAR raster (2). File – FwayVeg5m (Veg value of 1) (Vegetation raster 3)
- From LiDAR raster (2) used "Set Null" (Spatial Analyst tool) to create a raster with DHM values covering only where there was vegetation present in the Vegetation raster (3) file. (Tool instructions – Input – FwayVeg5m, Expression – "VALUE"<>1, False raster – LidarDHM5m_NN)
File – fwyveg5mLdr (M1 vegetation raster LiDAR values (4))
- M1 vegetation raster LiDAR values (4) had decimal values and below zero values (-6.20451 – 37.72). To simplify analysis this file was reclassified to make whole integer values ranging from zero to 38. i.e. <0 = 0, 0-1=1, 0-2=2 etc. File – fwyvg5mldrRcl (M1 vegetation raster LiDAR values reclassified (5))

Step 7

Separate polygon shape files and raster files (5m cell size) were created for each group of vegetation based on their location as assigned in step 4 (West, Centre and East) from Freeway Vegetation (1) :
Rasters – **fwayvegEast, fwayvegWest, fwyvegCntre** (Vegetation values of 1)
Polygons – **BaseEasternVeg, BaseWesternVeg, BaseCentreVeg**

"Set Null" tool was used in a similar way to the method used in step 6, to extract height values for eastern, western and centre vegetation rasters. For example, for western vegetation:

(Instructions - Input – fwayvegWest, Expression – "VALUE"<>1, False raster – fwyvg5mldrRcl)

Resultant output raster **files** were – **vegeastlidar, vegwestlidar, vegcentrelidar**. These files represent mapped vegetation on each side of the freeway to a distance of 100 metres from the edge of the carriageway and between carriageways, with each 5 metre grid cell having a integer height value from the LiDAR coverage, representing the highest vegetation point in that 5 metre grid cell.

Step 8 - Glide Analysis

Analysis of glide East to West, and West to East, in one flight, ignoring use of centre vegetation.

"Raster to Point" conversion was run to create point files where each grid cell produced a point which was assigned the related grid cell height value.
vegeastlidar – raster to point – **vegeastpoints**
vegwestlidar – raster to point – **vegwestpoints**

Two fields in the point tables were created; these were "Height" (which was then populated from the grid code) and "FlightMax".

FlightMax field calculated using – Height x 1.8 – to give maximum flight distance, the subtraction of two (-2) was ignored in the equation because

- Vegetation is likely to have grown somewhat since 2007 LiDAR
- Gliders will land on the ground and scramble up vegetation from the base

"Near" analysis (Toolbox analysis tool) was used to find the distance to the closest polygon feature in **BaseEasternVeg, BaseWesternVeg**, on opposite side of the freeway for each respective point file **vegeastpoints** and **vegwestpoints**. That is, for **vegeastpoints** the closest feature in polygon file **BaseWesternVeg** was calculated and for **vegwestpoints** the closest feature in polygon file **BaseEasternVeg** was calculated. The output of this analysis gives the distance in metres, populates a field in the point file table with this distance, and identifies that closest feature.

Selected from **vegeastpoints** and **vegwestpoints** those points where "FlightMax" >= "NEAR_DIST" - that is the distance to the closest feature found using the "near" analysis. Every point was labelled either with a "Yes", if a glide across entire M1 to vegetation on the other side was possible or "No" if such a glide was not possible. No points were found where glide was possible the entire way from West to East and nine points were found where a glide was possible from East to West.

Data was copied from NEAR_DIST and NEAR_ID fields to new fields – NRIDEast, NRDistEast (in the vegwestpoints file) and NRIDWest, NRDistWest (in the vegeastpointsfile) otherwise new data would override these results when running a further "Near" analysis using the centre vegetation.

Step 9

Analysis of glide across M1 in (one) direction using the Centre vegetation i.e. East to centre, then centre to west OR West to Centre, then Centre to East.

"Raster to Point" conversion was run to create a point files where each grid cell produced a point that was assigned the related grid cell height value.
Vegcntrelidar – raster to point – **vegcentrepoints**

Two fields in the point table were created; these were "Height" (which was then populated from the grid code) and "FlightMax". Did field calculation in FlightMax field – Height x 1.8 – to give maximum glide distance.

Ran "Near" analysis for both scenarios, centre to west, and centre to east to determine if and where glide was possible from the centre vegetation of the freeway outwards. That is, for **vegcentrepoints** the closest feature in polygon file **BaseWesternVeg** was calculated and again for **vegcentrepoints** the closest feature in polygon file **BaseEasternVeg** was calculated. Attribute fields in **vegcentrepoints** were populated with the results of nearest polygon ID and distance in metres – NrIDWest, NrDistWest, NrIDEast, NrDistEast.

Selected from **vegcentrepoints** those points where "FlightMax" >= "NEAR_DIST" for each directional scenario. Points were then labelled with the results of this selection. Centre to West (Cntre2West) (yes or no), Centre to East (Cntre2East) (yes or no), Both directions possible (BothWayOut) (yes or no).

"Near" analysis was then run to determine where glide was possible from outside the carriageways to the centre vegetation.

Using **vegwestpoints** "Near" analysis was run to the polygons in **BaseCentreVeg**. Populated fields NRIDCentre, NrDistCntr, with the "Near" analysis results, created a field West2Cntre and using a selection where "FlightMax" >= "NEAR_DIST" points were labelled "Yes" or "No" depending on whether glide was possible.

Using **vegeastpoints** "Near" analysis was run to the polygons in **BaseCentreVeg**
Populated fields NRIDCentre, NrDistCntr, with the "Near" analysis results, created a field East2Cntre and using a selection where "FlightMax" >= "NEAR_DIST" points were labelled "Yes" or "No" depending on whether glide was possible.

To identify areas where there was a high potential for gliders to use the centre vegetation to cross the following series of "selection" processes was used:

Example depicting analysis from East to West using centre vegetation.

1. "Select by attribute" - From **vegeastpoints** those points where East2Cntre = Yes
2. "Select by location" - From **vegcentrepoints** those points within 100 metres of those selected in 1 (i.e. where the glide from East to Centre is possible). This identifies a pool of centre points that may be used to continue the full traverse if they are high enough to get back out.
3. "Select by attribute" – From the existing selection previously made in **vegcentrepoints** those points where Cntre2West = Yes (i.e. where the glide from Centre to West is possible).
4. Created a new field in **vegcentrepoints** (called **HighPotE2W**) that identifies potential for crossing from east to west, using the centre vegetation. All those remaining selected points are given a "Yes" value in this field; all other points are "No".
5. Repeated the process for the opposite direction (West to East) and identified relevant points in a field called **HighPotW2E**.

The final result of these steps allows any points in the centre of the M1 to be identified where there is suitably sized vegetation within 100 metres to get into the centre vegetation and potentially traverse through to that point. The point is then tall enough to allow flight out to existing vegetation on the opposite side.

Step 10 - Review of Potential Crossing Points

All areas containing points indicating that squirrel gliders can cross the M1 from one side to the other were examined using air photography and LiDAR 0.5m contours.

This included glides in both directions, either as one glide across both M1 carriageways or, in two glides using vegetation in the centre (i.e. cross one carriageway and then use the vegetation in the centre to complete the crossing of the M1).

The ground level of the launching points were checked to ensure that the height of the tree still enabled the glide to occur, if the launch height was adjusted for the level of the ground at the launch point in relation to the level of the carriageway. For example, should the launch point be located on a downward sloping batter it may be up to 4-5 metres lower than the carriageway or landing point level. Gliding across the gap was not possible in reality, because the launch height was reduced by the difference between the ground level height and the height of the landing point.

There were also some areas excluded where selected centre vegetation points were within 100 metres of trees or a tree that could provide glide into the midpoint, however significant gaps, sparseness of centre vegetation and/or either of the glides being at the extreme limit of possibility made it very unlikely.

Map A7.1 only depicts glides that were possible.

Step 11 - Crossing Zone Polygons

Points were grouped to depict areas important for gliders crossing the M1. These areas include all suspected launching points generally within 100m of the vegetation in the centre of the M1 that has been mapped as high enough to allow a glide out from the centre to the opposite side. Some of these areas have potential for movement in both directions, others are one directional.

Again, these have been visually checked using air photograph and LiDAR 0.5m contours to ensure they reflect an ability to glide e.g. presence of suitable vegetation, height and topography present realistic scenarios and no other barriers to the glide.

THE GREAT NORTHERN RAILWAY

Step 1 - Vegetation Mapping

The 2012 LMCC Native Vegetation Mapping extant along the railway was overlain with more recent aerial photography (2014). The layer was edited where required by adding small patches of vegetation, slivers previously not captured and linear rows of trees or isolated trees that for the purposes of this particular analysis could be significant. Some of this newly edited vegetation had not previously been captured by LMCC vegetation mapping, due to the small area of the polygons involved. Any vegetation cleared since the 2012 version was edited and removed. File - RailwayVeg

Step 2 - Buffers

The railway was buffered for a distance of 100 metres on both sides and the buffer used to "clip" RailwayVeg. File - RailwayVegClipped

Step 3

The boundaries to the vegetation polygons were dissolved to remove boundaries between adjoining polygons and all of these were labelled as vegetation with no distinction between Bushland & partly cleared polygons) File – RailwayVegClippedDissolved

Step 4

A location relative to the railway was assigned within the attribute table to each polygon – West or East. File – RailwayVegClippedDissolved (Railway Vegetation (1)).

Step 5 - Vegetation Height

Extracting Vegetation Height Values Using LiDAR DHM using Lidar_DHM_5m_NN.tif (LiDAR raster (2))

NOTE: LiDAR 2007 coverage does not extend the full length of the railway. Approximately 6 km of the Railway is not covered.

- Railway vegetation (1) was exported to raster (5m cell size), setting the "processing extent" and "snap to raster" in "environments" to be the same as the LiDAR raster (2). File – RwayVeg5m (Veg value of 1) (Vegetation raster (3)). From LiDAR raster (2) "Set Null" (Spatial Analyst tool) was used to create a raster with DHM values covering only where there was vegetation present in the Vegetation raster (3) file. (Tool instructions – Input – RwayVeg5m, Expression – "VALUE"<>1, False raster – LidarDHM5m_NN) File – rwyveg5mLdr (Railway vegetation raster LiDAR values (4))
- Railway vegetation raster LiDAR values (4) had decimal values and below zero values (-6.3327 – 54.636). To simplify analysis this file was reclassified to make whole integer values ranging from zero to 55. That is <0 = 0, 0-1=1, 0-2=2 etc. File – rwyvg5mldrRcl (Railway vegetation raster LiDAR values reclassified (5)).

Step 6

Separate polygon shape files and raster files (5m cell size) were created for each group of vegetation based on their location as assigned in step 4 (West and East) from Railway Vegetation (1):

Polygons – BaseEasternRailwayVeg, BaseWesternRailwayVeg

Rasters – rwayvegEast, rwayvegWest (Vegetation values of 1)

The "Set Null" tool was used in a similar way to the method used in step 5, to extract the integer height values for western and eastern vegetation rasters. For example, for western vegetation:

(Instructions - Input – rwayvegWest, Expression – "VALUE"<>1, False raster – rwyvg5mldrRcl)

The resultant output raster files were – rwyvegeastldr and rwyvegwestldr. These files represent mapped vegetation on each side of the railway to a distance of 100 metres either side, with each 5 metre grid cell having an integer height value from the LiDAR coverage, representing the highest vegetation point in that 5 metre grid cell.

Step 7 - Glide Analysis

Analysis of glide East to West, and West to East, in one flight.

"Raster to Point" conversion was run to create point files where each grid cell produced a point that was assigned the related grid cell height value.

rwyvegeastldr – raster to point – railwayvegeastpoints
rwyvegwestldr – raster to point – railwayvegwestpoints

Two fields in the point tables were created; these were "Height" (which was then populated from the grid code) and "FlightMax".

FlightMax field calculated using Height x 1.8 to give maximum flight distance, the subtraction of two (- 2) was ignored in the equation because

- Vegetation is likely to have grown somewhat since 2007 LiDAR
- Gliders will land on the ground and scramble up vegetation from the base

The "Near" analysis (Toolbox analysis tool) was used to find the distance to the closest polygon feature in BaseEasternRailwayVeg and BaseWesternRailwayVeg, on the opposite side of the railway for each respective point file railwayvegeastpoints and railwayvegwestpoints. That is, for railwayvegeastpoints, the closest feature in polygon file BaseWesternRailwayVeg was calculated and for railwayvegwestpoints, the closest feature in polygon file BaseEasternRailwayVeg was calculated. The output of this analysis gives the distance in metres, populates a field in the point file table with this distance, and identifies that closest feature.

Selected from railwayvegeastpoints and railwayvegwestpoints those points where "FlightMax" >= "NEAR_DIST" - that is the distance to the closest feature found using the "near" analysis. Every point was labelled with a "Yes", either if a glide across entire railway to vegetation on the other side was possible or "No" if such a glide was not possible.

Step 8 - Review of Potential Crossing Points

All areas containing points indicating that squirrel gliders can cross the Railway from one side to the other were examined using air photography and LiDAR 0.5m ground contours. This included glides in both directions.

As with the procedure for the M1, the ground level of launching points were checked to ensure that the height of the tree still enabled the glide to occur, if the launch height was adjusted for the ground level of the launch point, in relation to the level of the Railway.

Other potential crossing points were excluded where the launch points were located adjacent to a railway platform.

Glides that were not possible have been not been depicted on Map A7.4.

Lake Macquarie City Council