

National Recovery Plan for the Mahogany Glider (*Petaurus gracilis*)



May 2020



Australian Government
Department of Agriculture,
Water and the Environment



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Citation

Jackson, S.M. & Diggins, J. (2020) National Recovery Plan for the Mahogany Glider (*Petaurus gracilis*). Australian Government, Canberra and Queensland Department of Environment and Science, Brisbane.

An electronic version of this recovery plan is available on the Department of Agriculture, Water and the Environment website through the Species Profile and Threats Database :

<http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl>

Acknowledgements

The authors and the Department of Agriculture, Water and the Environment (the Department) would like to acknowledge the Mahogany Glider Recovery Team, who contributed to the development of this recovery plan. Bernie Dominiak also reviewed and improved an earlier version of this plan. Maps were produced by the Environmental Resources Information Network, Department of Agriculture, Water and the Environment, in collaboration with Stephen Jackson.

Image credit

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Contents

1	SUMMARY	1
1.1	Taxonomy	1
1.2	Conservation Status	1
1.3	Distribution and habitat	1
1.4	Habitat critical to survival.....	1
1.5	Threats.....	1
1.6	Recovery plan objectives.....	2
1.7	Criteria for success	2
2	INTRODUCTION	3
2.1	About this recovery plan	3
2.2	Conservation status.....	3
2.3	Recovery plan preparation and consultation	3
2.4	Mahogany Glider Recovery Team	3
3	BACKGROUND.....	4
3.1	Taxonomy and description	4
3.2	Biology and ecology relevant to recovery	4
3.2.1	Longevity	4
3.2.2	Diet	5
3.2.3	Movement patterns and habitat use	5
3.2.4	Breeding	6
3.2.5	Gliding.....	6
3.2.6	Behaviour	6
3.3	Distribution.....	7
3.4	Population	7
3.5	Habitat	7
3.6	Habitat critical to survival.....	11
3.7	Important subpopulations.....	11
4	THREATS	14
4.1	Historical causes of decline	14
4.2	Current known threatening processes.....	14
4.2.1	Habitat loss and fragmentation.....	14
4.2.2	Inappropriate fire regimes leading to habitat degradation and alteration.....	15
4.2.3	Inappropriate grazing management.....	17
4.2.4	Weed invasion	17
4.2.5	Small population.....	18
4.2.6	Roads and easement corridors.....	18
4.2.7	Barbed wire fencing	19
4.2.8	Extreme environmental events	19
4.3	Potential threatening processes	19
4.3.1	Climate change	19
4.3.2	Feral predation	20
4.3.3	Myrtle Rust Disease.....	20
5	EXISTING CONSERVATION MEASURES	20
6	RECOVERY PROGRAM.....	21
6.1	Recovery strategy.....	21
6.2	Objectives, performance criteria and actions	21
6.2.1	Long-term recovery objective	21
6.2.2	Objectives and recovery success criteria of this recovery plan.....	21
6.2.3	Objectives and actions for the lifetime of this recovery plan	22

7	RECOVERY PLAN IMPLEMENTATION	27
7.1	Implementation schedule, costs and governance	27
7.2	Monitoring, evaluation, reporting and review	32
7.3	Potential benefits and impacts associated with implementation.....	32
7.3.1	Broader biodiversity benefits	32
7.3.2	Social and economic considerations	34
7.4	Affected interests	34
7.5	Role and interest of Indigenous people	35
8	MANAGEMENT PRACTICES AND GUIDANCE FOR DECISION MAKERS.....	35
8.1	Interaction with existing plans, policies and programs.....	35
8.2	Guidance for decision makers	36
8.3	Management practices.....	37
8.3.1	Reducing habitat loss and fragmentation	37
8.3.2	Addressing road/rail and easement threats.....	38
8.3.3	Fire management and appropriate fire regimes	39
8.3.4	Intensive grazing and weed invasion	39
8.3.5	Fencing	40
8.3.6	Extreme environmental events	40
8.3.7	Captive breeding, display, rehabilitation and release.....	40
9	REFERENCES.....	42
	APPENDIX 1: EVALUATION OF PREVIOUS RECOVERY PLAN	47
	APPENDIX 2: SUMMARY OF PRIORITY CORRIDORS.....	49

ACRONYMS

CCRC	Cassowary Coast Regional Council
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAF	Queensland Department of Agriculture and Fisheries
DES	Queensland Department of Environment and Science
DNRME	Queensland Department of Natural Resources, Mines and Energy
DAWE	Commonwealth Department of Agriculture, Water and the Environment
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
FNQROC	Far North Queensland Regional Organisation of Councils
HQ	Hancock's Queensland
HSC	Hinchinbrook Shire Council
IUCN	International Union for Conservation of Nature
LDMG	Local Disaster Management Group
MCU	Material Change of Use
MNES	Matters of National Environmental Significance
NCA	<i>Nature Conservation Act 1992</i>
NGO	Non-government organisation
MGRT	Mahogany Glider Recovery Team
QFES	Queensland Fire & Emergency Services
QRFS	Queensland Rural Fire Service
QR	Queensland Rail
TMR	Department of Transport and Main Roads
WPSQ	Wildlife Preservation Society Queensland

1 SUMMARY

1.1 Taxonomy

Mahogany Glider

Petaurus gracilis (De Vis, 1883)

Family: Petauridae

1.2 Conservation Status

Environment Protection and Biodiversity Conservation Act 1999: Endangered.

Nature Conservation Act 1992 (Queensland): Endangered.

IUCN Status 2012: Endangered. B1ab(iii) ver 3.1 (Burnett *et al.*, 2008).

1.3 Distribution and habitat

The Mahogany Glider occurs in a narrow band of open, wet sclerophyll woodlands between Ollera Creek (40 km south of Ingham) and the Hull River near Tully (a north–south distance of 120 km), in North Queensland, Australia. Throughout its distribution the Mahogany Glider occurs primarily at elevations below 100 m elevation where its presence is not uniform due to the presence of different vegetation types that are used differentially. The distribution of the Mahogany Glider also appears to be influenced by a blend of woodland vegetation that has historically been shaped and maintained by fire. The habitat requirements of the Mahogany Glider are most correlated with a variety of trees from the families Myrtaceae and Mimosaceae, as well as a reduced middle and upper canopy cover.

1.4 Habitat critical to survival

Habitat critical to the survival of the Mahogany Glider includes that within its known distribution (Fig. 1) and consists of the following:

- Any habitat where the species is likely to occur within its known distribution;
- Any newly discovered locations that extend the likely range of the Mahogany Glider; and
- Key areas that include those identified as subpopulations (Fig. 1b).

1.5 Threats

The Mahogany Glider faces a number of threats including:

- 1) habitat loss;
- 2) fragmentation of the remaining habitat as a result of illegal clearing and legal clearing for housing blocks, fencelines, firebreaks, and easements such as powerlines and roads (including the associated mortality);
- 3) inappropriate fire regimes, leading to habitat degradation through rainforest expansion and sclerophyll thickening;
- 4) intensive grazing leading to a lack of recruitment of native vegetation;
- 5) weed invasion leading to habitat degradation;
- 6) mortality from barbed wire fencing;
- 7) extreme climatic events, including tropical cyclones, and severe wildfires.

1.6 Recovery plan objectives

Long-term objective

Increase the extent, quality and connectivity of habitat occupied to the Mahogany Glider, and manage it appropriately so that the species' chances of long-term survival in the wild has increased.

Specific objectives

- 1) Habitat critical to the survival of the Mahogany Glider is secured, enhanced and managed to support the recovery of Mahogany Glider populations.
- 2) An integrated monitoring program that identifies trends in Mahogany Glider populations and the effectiveness of management and research actions is established.
- 3) The Mahogany Glider Recovery Team (MGRT) is collaborative and effectively coordinates the implementation of this recovery plan.
- 4) The community values, and is actively engaged in, the conservation of the Mahogany Glider.
- 5) Emergency triggers and response protocols are developed and are informing planning decisions.

1.7 Criteria for success

The Mahogany Glider recovery plan will be deemed successful if, within 10 years, most of the following have been achieved or are in progress:

- 1) There is an increase in the extent of high-quality habitat (i.e. mixed open forest and mixed open woodland) that is managed for Mahogany Glider recovery.
- 2) The population trajectory has improved.
- 3) Genetic diversity is maintained.
- 4) The area occupied by Mahogany Gliders has increased.
- 5) Connectivity has been restored within five priority corridors.
- 6) Infrastructure and maintenance guidelines have been implemented in all linear and transport easements.
- 7) Appropriate grazing and fire management regimes have been adopted by landholders who are actively engaged in improving habitat quality across all subpopulations.
- 8) Emergency triggers and response protocols inform planning decisions as needed.
- 9) Increased community recognition of, support for, and participation in recovery program.
- 10) Recovery program is effectively coordinated with all partners collaborating and contributing towards the effective delivery of the recovery plan.

2 INTRODUCTION

2.1 About this recovery plan

This National Recovery Plan for the Mahogany Glider (*Petaurus gracilis*) considers the conservation requirements of this species across its range. In doing this it identifies the actions required to stop its decline, support its recovery, and maximise its chances of long-term survival in the wild.

This recovery plan replaces the previous 'National recovery plan for the Mahogany Glider *Petaurus gracilis*' (Parsons & Latch, 2006). The overall objective of the previous recovery plan was to secure and improve the conservation status of the Mahogany Glider through an integrated program of habitat protection and improvement, threat abatement, and public awareness and involvement. A review of the previous recovery plan was undertaken in 2013 (summary in Appendix 1). The review showed there was some progress in establishing collaborative multi-agency projects, developing a framework for implementation of ongoing programs, networking with relevant stakeholders and monitoring of some subpopulations. However, none of the recovery objectives of the previous recovery plan were completely met due to limited progress in implementing the identified actions. Factors responsible included: 1) a lack of resources (particularly funding), 2) a lack of habitat mapping for condition and extent, and 3) unforeseen impacts of extreme weather events. The objectives and actions outlined in this recovery plan aim to address these issues as far as practicable and will build upon the recovery work undertaken to date.

2.2 Conservation status

The Mahogany Glider is listed as Endangered under both the Queensland *Nature Conservation Act 1992* (NCA) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). It is also listed as Endangered under the IUCN Red List of Threatened Species (Burnett *et al.*, 2016). The Mahogany Glider is currently not listed on any international agreements. This recovery plan is consistent with Australia's international obligations.

2.3 Recovery plan preparation and consultation

The development of this recovery plan for the Mahogany Glider has been facilitated by the Mahogany Glider Recovery Team (MGRT) through extensive consultation and collaboration with a broad range of partners. The consultation process included several meetings that brought together key species experts, regional NRM bodies and conservation managers from a range of different organisations, local, state and federal governments, and numerous other partners. The aims of this process were to identify: 1) ongoing threats to the Mahogany Glider, 2) identify knowledge gaps, and 3) potential management options. Workshop participants included representatives from DoEE, DES, CCRC, WPSQ, Terrain NRM, NQ Dry Tropics, researchers, Girringun Aboriginal Corporation, HQ plantations and TMR.

2.4 Mahogany Glider Recovery Team

The MGRT was formed in 1995 and since this time has had oversight of the development and coordination of the recovery program for the Mahogany Glider. The MGRT has the responsibility of providing advice, coordinating and directing the implementation of the actions outlined in this recovery plan, and reviewing and updating the recovery plan as required. The MGRT is nationally registered with the Department of Agriculture, Water and the Environment.

Recognising that membership may change over time, the membership of the MGRT consists of individuals with relevant expertise, including representatives from:

- Department of Agriculture, Water and the Environment (DAWE).
- Department of Environment and Science (DES).
- Department of Transport and Main Roads (TMR).
- Terrain Natural Resource Management.
- North Queensland Dry Tropics (NQDT).
- Cassowary Coast Regional Council (CCRC).
- Girringun Aboriginal Corporation.
- Wildlife Protection Society of Queensland.
- Non-Government Organisations (NGOs).
- Community groups.
- Researchers.
- Powerlink.
- Energy Queensland (Formerly Ergon).

3 BACKGROUND

3.1 Taxonomy and description

The Mahogany Glider was initially described as *Belideus gracilis* by De Vis (1883a, 1883b) from a specimen collected “North of Cardwell”, north Queensland, Australia. The taxonomy of this species was unstable soon after the scientific name was published because it is unknown if a single type specimen was formally nominated by De Vis (1883a; 1883b). As a result, it was thought to be the same species as the Squirrel Glider (*Petaurus norfolcensis*) as early as 1888 (Thomas, 1888). Subsequent authors typically considered it as either a subspecies of the Squirrel Glider, or a junior synonym of it, and no further specimens were recorded between 1886 and its rediscovery in 1989. As a result of biochemical studies by Colgan and Flannery (1992), and his own detailed morphological assessment, Van Dyck (1991; 1993) elevated the Mahogany Glider to species rank, which has been adopted by subsequent authors. Though studies have subsequently highlighted the genetic similarity of the Mahogany Glider to the Squirrel Glider (e.g. Malekian *et al.*, 2010), they are clearly distinct from each other morphologically and is broadly recognised as a valid species (Jackson & Thorington, 2012; Burbidge *et al.*, 2014; Jackson, 2015; Jackson & Groves, 2015).

The Mahogany Glider is a medium sized arboreal marsupial that can be readily distinguished from the Squirrel Glider in having a much heavier body mass, with an average body mass of 365g for females and 407g for males, compared to only 230g for the later species. The external morphology is also distinctive as the Mahogany Glider is approximately 625mm in length compared to the Squirrel Glider that is 480mm in length (Jackson, 2008; 2013; van der Ree & Suckling, 2008). The shape of the tail is also distinctive, as the Mahogany Glider has a relatively long thin tail while the Squirrel Glider has longer fur at the base of the tail. Cranially the Mahogany Glider has a larger zygomatic width, snout height and basicranial length and narrower interorbital width than the Squirrel Glider (Van Dyck, 1993).

3.2 Biology and ecology relevant to recovery

3.2.1 Longevity

The life expectancy of a Mahogany Glider in the wild is estimated to be approximately five to six years of age (Jackson, 2000a; 2008).

3.2.2 Diet

The diet of the Mahogany Glider is similar to that of other petaurid gliders and includes primarily nectar, pollen, tree sap, lerps, honeydew and invertebrates. However, the proportion of dietary items differs considerably between species (Jackson, 2001; Goldingay & Jackson, 2004).

The primary genera of trees utilised to obtain nectar and pollen include *Corymbia*, *Eucalyptus* and *Melaleuca* of the family Myrtaceae (Van Dyck, 1993; Jackson, 2001). The only rainforest species known to be utilised for nectar and pollen include the Cadargi (*Corymbia torrelliana*) and Euodia (*Melicope elleryana*) on the edge of rainforest and in riparian forest (Van Dyck, 1993; Jackson, 1998; 2001). The importance of pollen as a source of protein in the diet was confirmed by several studies that discovered that between 30 and 99 percent of the contents of pollen grains consumed are digested (Dettman *et al.*, 1995; Jackson, 2001).

Other important food items include sap from the tree White Siris (*Albizia procera*) and Hickory Wattle (*Acacia mangium*), and arils from the seed pods of the Thick-podded Salwood (*Acacia crassicarpa*), Red Wattle (*A. flavescens*) and Hickory Wattle (*A. mangium*). A variety of insects are also eaten, as well as lerps (coverings or testa excreted by the nymphs of psyllids, under which they shelter and feed); honeydew (sugary waste excreted by psyllids on the leaves and other parts of the plant on which they feed); and fruit from mistletoes of the family Loranthaceae (Van Dyck, 1993; Jackson, 2001). Nectar and sap from the flower spikes of Johnson's Grass Tree (*Xanthorrhoea johnsonii*) are important when these are available (Van Dyck, 1993). The diet of the Mahogany Glider relies on complex seasonal cycles of food availability requiring a high diversity of plants, with each species having distinct periods when it provides food during the year (Jackson, 2001).

3.2.3 Movement patterns and habitat use

The home-range of the Mahogany Glider is on average 19 ha for males and 20 ha for females in contiguous habitat, while male and female pairs occupy a combined area of approximately 23 ha. Observations of the home-range in fragmented habitat has recorded this to be as low as 11 ha for males and 7 ha for females, with a combined home-range of male and female pairs being 12 ha (Jackson, 2000b). Paired male and female home-ranges overlap with each other by approximately 86 percent, compared with only 11 percent for non-paired individuals. This finding suggests that this species is socially monogamous (Jackson, 2000b). The density of mahogany gliders averages only 0.24 individuals/ha in contiguous forest and 0.16 individuals/ha in fragmented habitat (Jackson, 2000a). These densities appear to reflect their large home-ranges and the limited overlap with non-paired animals and are typically lower than sugar and squirrel gliders, but not as low as observed in the yellow-bellied glider (Goldingay & Jackson, 2004).

In traversing their home-ranges, the Mahogany Glider is highly mobile, traveling an average distance of 1,500 m (range 600–3,400 m) each night (Jackson, 2000b). The distance travelled at different times of the year shows significant differences, with individuals traveling longer distances during late dry season to wet season and shorter distances during the early to middle dry season (Jackson, 2000b). Observations of the movements and diet of the Mahogany Glider (Jackson, 1998; 2000b) clearly show that rainforest and mangroves are rarely utilised or traversed.

The home-ranges of Mahogany Gliders appear to be actively defended, with both sexes being observed to travel around a foraging loop at least every second or third night, which appears to serve two functions:

- 1) maintaining the defence of the home-range, and
- 2) serving to locate trees that will soon be in flower or fruiting, so that when current feed trees finish flowering or fruiting, the glider can move to a new food source (Jackson, 1998).

Mahogany Gliders typically forage by themselves (Jackson, 2000b). Where connectivity exists across a transport corridor, small fragments of mature vegetation on the opposite side of the corridor may be utilised as supplemental habitat for foraging (Asari *et al.*, 2010). As a result, removal of small areas of connected habitat in such circumstances may reduce the ability of individuals to occupy an area.

Throughout their home-range, individual Mahogany Gliders have been observed to utilise between 3 and 9 dens each, with a total of 6 to 16 dens being used by socially monogamous pairs (Jackson, 2000b). The dens are typically located within trees of the family Myrtaceae, with the most common species utilised including Clarkson's Bloodwood (*Corymbia clarksoniana*), Poplar Gums (*Eucalyptus platyphylla*), and Forest Red Gum (*Eucalyptus tereticornis*) (Jackson, 2000b). Other species that have been used occasionally include the Pink Bloodwood (*Corymbia intermedia*), Moreton Bay Ash (*Corymbia tessellaris*), Red Mahogany (*Eucalyptus pellita*), Swamp Mahogany (*Lophostemon suaveolens*), Cloudy Tea-tree (*Melaleuca dealbata*), Long-leafed Paperbark (*Melaleuca leucadendra*), and Broad-leafed Teatree (*Melaleuca viridiflora*) (Jackson, 2000b). Dens are mostly occupied within living trees, though dead trees are occasionally used. The height of den trees varies greatly, ranging from 6.5 to 61.6 m, with nest entrances being 7 to 33 m above the ground (Jackson, 2000b). The aspect of the den and canopy cover appear to be important factors in determining den temperature, as den entrances that face north and have greater canopy cover are up to 7°C cooler than those that face south or have little cover (Isaac *et al.*, 2008).

3.2.4 Breeding

The Mahogany Glider has a distinct breeding season that occurs in the drier months between April and October, during which, one or two young are born (Jackson, 2000a). Field studies suggest that all adult females breed each year, with an average litter size of 1.55 and a natality rate (number of young per year) of 2.09. Typically, only one litter is raised per year, although a second litter may be raised if the first one is lost before leaving the pouch, or potentially if breeding occurs early in the year (Jackson, 2000a). The young are weaned at four to five months of age during the wet season, when there is more insect food available and sexual maturity occurs at 12 to 18 months of age; they are estimated to live until approximately five to six years of age (Jackson, 2000a; 2008; Booth *et al.*, 2019).

3.2.5 Gliding

The Mahogany Glider traverses its home-range by gliding between trees, using a well-developed gliding membrane (or patagium) that extends along each side of the body from the fifth finger of each manus to each ankle (Jackson, 2000d; Jackson & Schouten, 2012). Using this gliding membrane, individuals have been observed to glide an average of 30 m per glide, although the longest glide recorded is 60 m (Jackson, 2000c).

Direct observations of Mahogany Gliders have found them able to glide over gaps in their habitat including tracks, roads and powerline corridors, as long as the trees on each side of the gap are tall enough to allow a complete glide and landing (Jackson & Schouten, 2012). Other observations suggest that males are more likely to cross gaps in their habitat than females (Asari *et al.*, 2010).

3.2.6 Behaviour

The Mahogany Glider is nocturnal and the amount of time spent active each night throughout the year ranges from 8.0 to 10.1 hrs (or 63 percent to 80 percent of the night), which does not change significantly between the wet and dry seasons. Throughout the night they typically have only one continuous period of activity, although individuals have been observed to return to their dens during the night for a mean of 85 minutes (range 28-124 minutes), with mean entrance and exit times at 22:59 hours and 00:25 hours, respectively (Jackson & Johnson, 2002).

Although Mahogany Gliders typically occur as pairs, solitary animals also occur that appear to be primarily males, suggesting that the adult population is slightly male biased (Jackson, 2000a). Individual animals within socially monogamous pairs generally forage apart and do not den together every night, as they may spend at least one to two days at a time in separate dens in different parts of their home-range. As a result, there are opportunities for extra-pair mating, which has been observed (Van Dyck, 1993).

Mahogany Gliders are relatively quiet as they forage and traverse over their home-range and rarely vocalise. Calls are typically limited to only one or two calling episodes per night that usually consist of a single or small number of calls, although calling bouts have been observed to continue for up to nine and half minutes (Van Dyck, 1993; Jackson & Johnson, 2002). Observations suggest that both sexes vocalise and when undertaking their calls usually make a deep, nasal, course grunt “na-when, na-when” that is most often made between 22:00 and 01:00 hours.

3.3 Distribution

The Mahogany Glider is only known to occur in a narrow band of open, wet sclerophyll woodlands between Ollera Creek (40 km south of Ingham) and the Hull River near Tully (a north–south distance of 120 km, in north Queensland, Australia (Parsons & Latch, 2006; DERM, 2009; Jackson, 2008) (see Fig. 1). Bioclimatic (BIOCLIM) modelling has suggested that the limited distribution is associated with areas with higher than average annual temperature, smaller temperature range, higher temperatures throughout the year, higher annual precipitation, higher seasonality of precipitation, higher seasonality of moisture index, and higher precipitation in the wettest quarter and warmest quarter when compared with the predicted distribution of the Squirrel Glider (Jackson & Claridge, 1999). The BIOCLIM modelling also predicted the distribution of the Mahogany Glider may occur above 500m elevation in some areas within its known range and potentially on nearby Hinchinbrook Island and the Palm Islands (Jackson & Claridge, 1999; Thorsborne & Thorsborne, 1988). Despite the BIOCLIM prediction in elevation this species is primarily known to occur at elevations below 100 m (Jackson *et al.*, 2011). The distribution of the Mahogany Glider also appears to be influenced by a woodland blend of vegetation that has historically been shaped and maintained by fire (Van Dyck, 1993).

3.4 Population

Mahogany Glider habitat has been reduced by approximately 50 percent as a result of broadscale clearing for agriculture, with the remaining habitat being highly fragmented and containing only five primary subpopulations, three secondary populations and two range limit subpopulations remaining (Jackson *et al.*, 2011; 2020; Fig. 1). The total estimated population of the Mahogany Glider is estimated to be 1500-2000 individuals (Burbidge *et al.*, 2014).

3.5 Habitat

The presence of the Mahogany Glider throughout its distribution is not uniform. One study that endeavoured to determine the habitat requirements of the Mahogany Glider in the Porters Creek/Mullers Creek area used trapping and vegetation structure data. This research revealed their presence was correlated with the tree species *Corymbia clarksoniana*, *Eucalyptus platyphylla*, *Lophostemon suaveolens* and *Melaleuca dealbata*. It also correlated with a reduced middle and upper canopy cover and the absence of *Acacia mangium* and *Corymbia intermedia* (which typically occur in more closed habitat along creek lines). These results contrasted with the habitat preferences of Sugar Gliders (*Petaurus breviceps*) in the same study area, which were most correlated with a large number of stems. Sugar Gliders showed a preference for a more closed canopy, and the presence of *A. mangium*, *C. intermedia*, rain-forest species, and a dense middle and upper canopy cover (Jackson, 2000d). Direct observations also suggest that Mahogany Gliders do not tolerate the smaller Sugar

Gliders if they are in the same tree, as these will be chased away. It appears that Mahogany Gliders and Sugar Gliders (though sympatric with each other) typically partition the available habitat, with the more open habitat being utilised by the larger species, while the smaller species utilises more closed habitat (Jackson, 2000b; 2000d).

An assessment of the finer scale distribution of the Mahogany Glider within its known distributional limits was undertaken using information from Van Dyck (1993) and Jackson (2000d; 2001). This was done by allocating all 179 vegetation communities found within the predicted distribution of the glider into one of five habitat types (Table 1). The allocation of vegetation communities considered the diversity of tree species present, the forest structure, and the likely frequency of usage by the glider based on its dietary and den site requirements (Van Dyck, 1993; Jackson, 2000b; 2000d; 2001). This research created maps illustrating the location and extent of the historical and current habitat likely to be utilised by the Mahogany Glider (see Fig. 1). It also revealed that 51 870 ha consists of the most structurally diverse habitat type “Mixed Open Forest” and 55 760 ha is the more open and less diverse “Mixed Woodland”. A further 29 988 ha of the remaining habitat consists of “Monotypic Stands” that contain only one or two species of trees that are used by the Mahogany Glider for food and shelter. These include stands of Poplar Gums (*Eucalyptus platyphylla*), Broad-leaved Paperbark (*Melaleuca viridiflora*), or Broad-leaved Paperbark (*Melaleuca quinquenervia*). A further 3,504 ha were categorised as “emergent” trees such as *Corymbia torelliana*, which are suitable for Mahogany Gliders, but occur in habitat dominated by unsuitable species such as rainforest (Jackson *et al.*, 2011).

Table 1. Mahogany Glider habitat types and descriptions. Adapted from Jackson *et al.* (2011).

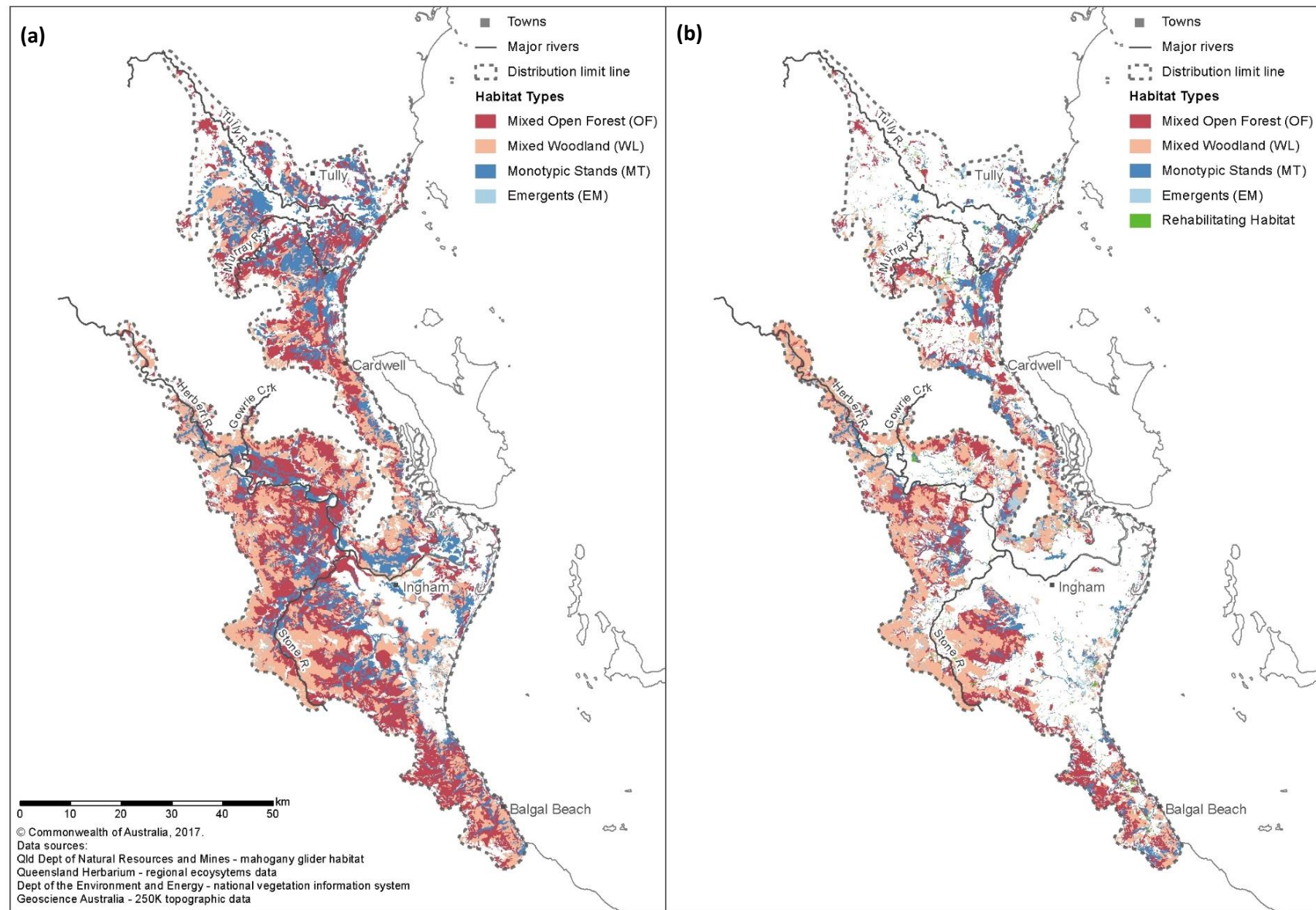
Habitat Type	Description
Mixed Open Forest (OF)	Mahogany Gliders living in a large area of this habitat type may require only occasional access to other habitat types for feeding and/or dispersal. This habitat type is often highly fragmented by clearing and can be difficult to burn once a rainforest understorey has established (Van Dyck, 1993; Jackson, 2001).
Mixed Woodland (WL)	This habitat type occurs mainly on low hills and/or in drier parts of the range of the glider and is likely to be important on a seasonal basis, with access to OF and possibly Monotypic Stands (MT) and Emergents (EM) habitat desirable to supplement the diet throughout the year. This habitat type contains at least three of the species of trees that provide food and shelter for the Mahogany Glider found in OF above, but appears not to have the complete variety required to provide a year-round food supply. This type contains den sites and provides important seasonal food requirements. It includes mainly woodlands and some open forests, with a mix of Myrtaceae, <i>Acacia</i> and sometimes <i>Albizia procera</i> .
Monotypic Stands (MT)	This type is likely to be important on a seasonal basis, with OF and possibly WL and EM necessary to supplement the diet throughout the year. These areas are primarily on plains that are seasonally waterlogged, and are characterised by seasonally abundant quantities of nectar and pollen for the glider. Monotypic stands contain only one or two species that are used by the Mahogany Glider for food and shelter, such as stands of <i>Eucalyptus platyphylla</i> , <i>Melaleuca viridiflora</i> or <i>Melaleuca quinquenervia</i> .
Emergents (EM)	These are likely to be used on an occasional basis, with OF and possibly WL and MT necessary to supplement the diet throughout the year, or may support dens within live emergents near the rainforest edge. In some situations, this category may provide food resources at certain times that are crucial for survival, especially for subpopulations living in habitat that is highly fragmented due to clearing. The invasion of these habitats by rainforest species is so far advanced that their control by fire is difficult or impossible. Efforts must be made to maintain, consolidate and/or link this habitat with OF habitat. Emergents are classified as habitat dominated by unsuitable species but that contains a minor element of suitable species (for example, rainforest with <i>Corymbia torelliana</i> emergents that are utilised by the Mahogany Glider).

Poorly
known
(PK)

These are other areas of native vegetation within which no suitable food plant species are thought to be present. These areas include mangroves, rainforest without emergent sclerophyll species, and treeless vegetation such as grasslands and sedgelands. These communities may contain resources used by the glider, but their nature and significance are currently unknown. These areas are treated as non-habitat for the glider and were excluded from further analysis.

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Figure 1 - Historic distribution of Mahogany Glider habitat before broad scale clearing (a), and current distribution of Mahogany Glider habitat (b).
Adapted from Jackson *et al.* (2011).



3.6 Habitat critical to survival

The key threats to the Mahogany Glider associated with habitat loss and the increasing fragmentation of the remaining habitat strongly indicate that all available habitat should be considered critical to its survival (see Fig. 1b). This includes 'Essential Habitat' as defined under the Queensland *Vegetation Management Act 1999* (VMA) and all other vegetation, both remnant and non-remnant located within corridors linking 'Essential Habitat'.

Limited observations suggest the Mahogany Glider can live within fragmented habitat as long as it is sufficiently wide (about 60 m), and contains sufficient number of food trees to provide a year-round supply of food (Jackson, 2000b). Creeklines may also be useful as they often include a relatively denser population of tree species, including *Corymbia intermedia*, *C. tessellaris*, *Eucalyptus tereticornis*, *Lophostemon suaveolens*, *Melaleuca dealbata*, and *M. leucadendra*. Despite this food availability within corridors there are a number of disadvantages that include:

- 1) the occurrence and spread of rainforest resulting in medium to long-term loss of habitat;
- 2) potentially higher predation due to increased exposure to predators such as pythons and owls;
- 3) the lower number of individuals of each tree species (even though tree species diversity is high), increasing competition for food and dens due to the smaller area available;
- 4) the denser canopy cover from rainforest species and acacias such as *Acacia flavescens*, which is abundant in disturbed habitat (such as along corridor edges) and favours Sugar Gliders (Jackson, 2000d);
- 5) the lower recruitment of food and den species due to denser canopy cover and competition from rain-forest species and weeds; and
- 6) the lower overall availability of dens.

Therefore, on balance, the long-term persistence of Mahogany Gliders within corridors appears questionable, even in areas with fairly wide corridors. Consequently, corridors may be viewed as areas that allow movement between two larger fragments of habitat (Jackson, 2000d), rather than as refugia.

Despite the disadvantages and limitations of corridors as habitat, their continued existence and maintenance is critical to the future survival of Mahogany Glider subpopulations. Therefore, areas of suitable habitat that contribute to priority wildlife corridors (Fig. 2) should also be considered as habitat critical to the survival of the species.

3.7 Important subpopulations

Ten subpopulations have been identified and mapped that include (Jackson *et al.*, 2018a; 2020; Fig. 2):

- five primary subpopulations in areas that each contain remnant vegetation with more than 8000 ha that may contain minimum viable populations of at least 800 animals (Jackson, 1999);
- three secondary subpopulations in areas with a higher degree of fragmentation so the glider is at greater risk of local extinction (Jackson, 1999); and
- two smaller subpopulations identified at the driest limits of the species' range, where no sightings have been recorded as yet but suitable habitat occurs so they may occur there (Jackson *et al.*, 2020).

The five primary subpopulations each have relatively good internal habitat connectivity with an average of 60 recorded sightings per subpopulation. The subpopulations are isolated from each other by cleared habitat that exceeds 100m. The identified primary subpopulations (Jackson *et al.*, 2018a; 2020), from north to south, are:

- 1) Girramay: North of Meunga Creek, habitat becomes greatly fragmented, and habitat represented on the foothills of Mount Carruchan and the Cardwell Range is only narrow and dissected by pine plantations.
- 2) Cardwell Lowlands: Extends south from Cardwell and the Elphinstone Range to the Cardwell Gap, Mt Cudmore, where habitat is largely restricted to the foothills of the Cardwell Range.
- 3) Broadwater: Extends from Mt Cudmore west towards the Herbert River Gorge, terminating at Yamanie Creek.
- 4) Lannercost – Henrietta: Bounded by clearing associated with the Stone and Herbert Rivers.
- 5) Wharps Holding - Paluma Range: Extends from Ollera Creek, the southernmost record of the glider, to the Stone River, where clearing along the river separates this subpopulation from the Lannercost – Henrietta subpopulation.

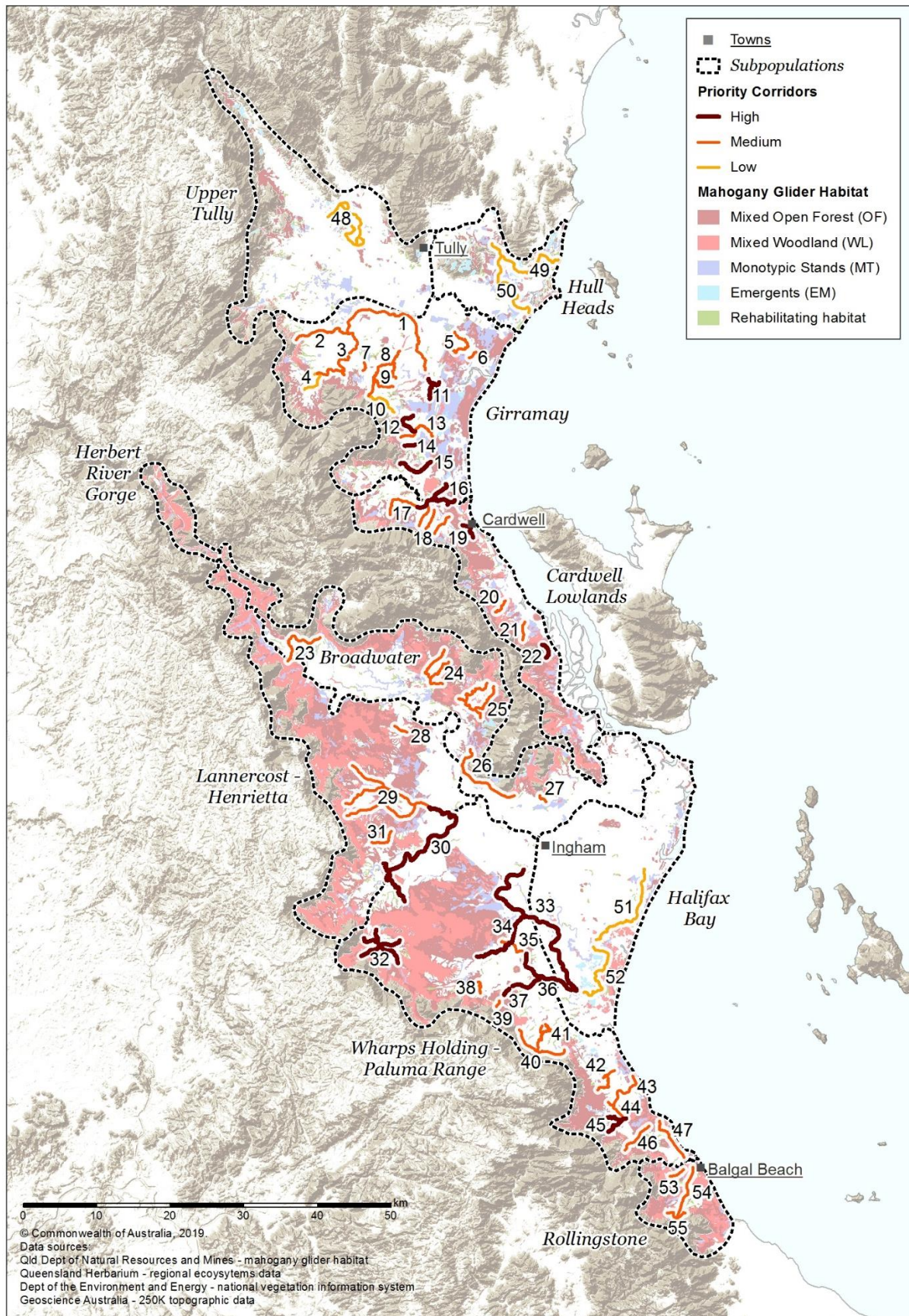
The three secondary subpopulations have a greater degree of habitat fragmentation than primary subpopulations, with little remaining internal connectivity. Consequently, their Mahogany Glider populations are unlikely to be viable in the longer term without an increase in connectivity. Strategic corridor and habitat plantings would greatly increase the viability of these subpopulations, and the value of these areas for the survival and persistence of the Mahogany Glider. These secondary subpopulations are:

- 6) Upper Tully: Covers the balance of the northern-most habitat, west of the highway and north of the Tully River, towards Tully River Gorge.
- 7) Hull Heads: Extends north of the Tully River, where rainforest starts to dominate the lowlands under a higher rainfall gradient and suitable glider habitat extends along the coast only as far north as Mission Beach, west to the foothill of Mount Mackay and bounded by the Bruce Highway.
- 8) Halifax Bay: Extends east of the Pacific Highway near Ingham, between Cattle Creek and the Herbert River.

In the south and west of the Mahogany Glider's distribution, the climate becomes drier and the habitat becomes more marginal (and the Squirrel Glider becomes more prevalent). Two range limit areas were identified within the modelled distribution where the habitat is relatively intact, but there have been no sightings of the Mahogany Glider despite considerable search effort. These areas may become populated by the glider if the adjacent subpopulation expands. The two range limit areas are:

- 9) Herbert River Gorge: Occurs within the confines of the Herbert River Gorge, where suitable habitat becomes relatively discontinuous and potentially less suitable, due to a rain-shadow effect, and the narrow steep topography of the gorge.
- 10) Rollingstone: Occurs in the far south, beyond Ollera Creek, there is extensive lowland habitat on the coastal plain that appears suitable but there have been no sightings of the Mahogany Glider over a number of searches.

Figure 2. Subpopulations and priority corridors (numbered 1-55) for the Mahogany Glider (see Appendix 2 for details). Taken from Jackson *et al.* (2020).



4 THREATS

4.1 Historical causes of decline

Historically, the major cause of decline of the Mahogany Glider was habitat loss as a result of large-scale clearing of lowland open woodlands for agriculture (including sugar cane, bananas, pineapples and aquaculture), roads and residential developments (Jackson *et al.*, 2011). The extent of Mahogany Glider habitat has decreased from an estimated 276 880 ha, before broad scale clearing began, to 141 122 ha by 2007 (a total reduction of approximately 50 percent) (Jackson *et al.*, 2011; see Fig. 1). The Mahogany Glider is now restricted to the foothills of the ranges and pockets of fragmented habitat in coastal and lowland areas throughout the extent of its range (Jackson *et al.*, 2011).

4.2 Current known threatening processes

4.2.1 Habitat loss and fragmentation

While broadscale clearing of habitat has largely abated, incremental loss of habitat still occurs particularly through changes in land use. For example, subdivisions of freehold and leasehold properties resulting in reduction in overall parcel size typically results in intensification of land use including:

- clearing of vegetation for more intensive types of agricultural activity;
- clearing of vegetation for the construction of new residential and management buildings;
- clearing of vegetation for new roads, tracks, fire breaks and fence lines,
- clearing of vegetation for new electricity supply lines and telecommunication cabling to new residential and management infrastructure;
- the erection of new boundary and internal fences.

The continued loss of habitat exacerbates the reduction in the total area and condition of Mahogany Glider habitat, creates new linear barriers, and reduces the movement of Mahogany Gliders through the landscape. New barbed wire fences add further to the threat of entrapment posed by existing barbed wire fences as a significant cause of death for this species.

It is also recognised that Material Change of Use (MCU) applications can be associated with a change of land use to a more intensive use including more intense agricultural use, subdivision and rural and urban residential developments. MCU's typically lead to impacts similar to those highlighted for Lot Reconfigurations.

The remaining habitat of the Mahogany Glider is highly fragmented with mapping studies suggesting there are 998 habitat fragments. Of these fragments, only five are greater than 8000 hectares, which is the minimum area required to maintain a stable population (Jackson, 1999; Jackson *et al.*, 2020). Consequently, there is a critical need to connect these fragments with corridors to allow the movement of animals and increase their effective population size (Jackson, 1998; 1999; Jackson *et al.*, 2020). Therefore, future conservation actions must ensure that the remaining fragments of habitat are managed appropriately to ensure they are large enough to maintain viable populations of gliders and adequately connected to adjacent fragments of habitat. The importance of maintaining large areas of continuous habitat and linking isolated fragments is highlighted by a population viability assessment of this species. This research suggests that an area of up to 8,000 ha containing approximately 800 individuals is needed to maintain a stable population (Jackson, 1999).

The Mahogany Glider is an arboreal species that does not readily come to the ground where they are prone to predation from cats and dogs, or being hit by cars. Gaps in habitat that are greater than the maximum glide distance (based on the height of the trees at the edge of the fragment) result in animals being unable to disperse between patches of adjacent suitable habitat and increasing their

genetic isolation (Jackson, 2000c; 2000e). As a result, the remaining Mahogany Glider populations are susceptible to localised decline and extinction due to inbreeding depression, loss of genetic diversity and the fixation of deleterious alleles (Lynch *et al.*, 1995; Lande, 1998; Frankham, 2005; Charlesworth and Willis 2009). Isolated populations are also susceptible to catastrophes, disease, and environmental and demographic stochasticity (Bennett, 1990; Simberloff *et al.*, 1992; Lindenmayer & Possingham, 1994).

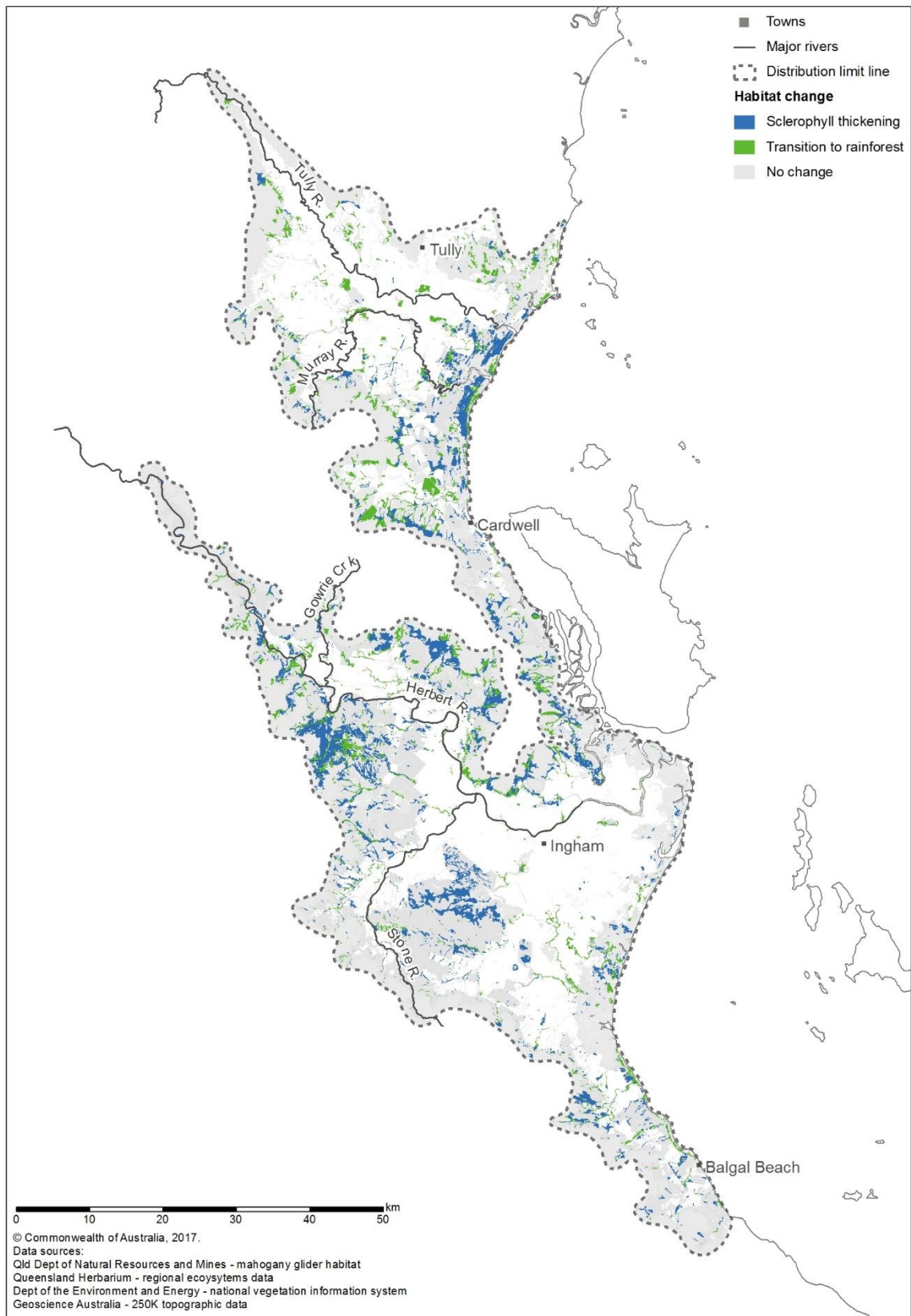
Only 30% of the remaining Mahogany Glider habitat is located on protected estates such as National Parks (Jackson *et al.*, 2011). There are also only 20 fragments of habitat that contain more than 100 ha of Mahogany Glider habitat, so an active program of corridor establishment and management is required to facilitate the movement of this species throughout its distribution (Jackson *et al.*, 2020).

4.2.2 Inappropriate fire regimes leading to habitat degradation and alteration

The Mahogany Glider does not readily utilise rainforest or mangrove habitat for food or shelter, and actively selects more open habitat where longer glides are favoured. Therefore, changes to the structure and composition of their habitat can have a substantial impact. Throughout the distribution of this species, their habitat is under significant threat from degradation due to the widespread transition to closed forest (where rainforest develops within a sclerophyll community) and sclerophyll thickening (where saplings of local sclerophyllous species form a thick secondary tree layer) due to reduced fire frequency (Harrington & Sanderson, 1994; Jackson *et al.*, 2011; see Fig. 3).

Of the remaining Mixed Open Forest habitat, 45 percent is considered to be decreasing in its suitability for the Mahogany Glider as a result of sclerophyll thickening or transition to rainforest. In addition, 26 percent of Mixed Woodland habitat, 33 percent of Monotypic Stands habitat and 8 percent of Emergent habitat are undergoing degradation. Across its distribution, at least 66 percent of the remaining suitable habitat appears to be undergoing degradation, severely reducing the amount of habitat available to this species (Jackson *et al.*, 2011). Once rainforest becomes established, it is difficult to reverse because it becomes pyrophobic (fire repellent), and fire frequency declines dramatically (Ash, 1988; Stanton, 1992; Harrington & Sanderson, 1994). Pioneer rainforest species also have fire-survival strategies, such as being able to re-coppice. Therefore, these species can aid in the transition to a secondary, more entrenched form of closed forest/rainforest transition under gradually reduced fire intervals (Jackson *et al.*, 2011).

Figure 3. Current distribution of the Mahogany Glider showing the remaining habitat under threat from sclerophyll thickening and transition to rainforest. Adapted from Jackson *et al.* (2011).



4.2.3 Inappropriate grazing management

Although the habitat where Mahogany Gliders live can potentially tolerate a degree of grazing, inappropriate grazing management can result in the degradation of understory species composition. Inappropriate grazing management does this by inhibiting plant recruitment through removal or damage of young plants which alters the canopy structure and promotes woody thickening. Weed invasion associated with poor grazing land management practices in different parts of the glider's distribution is also having a significant impact on the quality of habitat in some areas. It is clear that a combination of weed invasion and inappropriate grazing can threaten the structure and ecological integrity of the remaining fragments of habitat.

Weeds of concern within habitat of the Mahogany Glider associated with poor grazing management include Siam Weed (*Chromolaena odorata*) and Sicklepod (*Senna obtusifolia*). However, weeds of concern such as Lantana (*Lantana camara*), and similar disturbance associated weeds, have been observed to considerably transform habitat by reducing native understorey species composition, cover, and tree recruitment, which impacts both food tree and den tree availability (Jackson, 1998; Parsons & Latch, 2006; Table 2). The weeds listed below, and various others, possess a strong ability to colonise disturbed sites and can be exacerbated through grazing pressure. In the long term, the invasion of these species has the potential to decrease Mahogany Glider habitat integrity on a wide scale.

4.2.4 Weed invasion

Weed invasion poses a significant threat to Mahogany Glider habitat and is likely to be exacerbated by disturbance of either the ground layer or the tree canopy. Many of the weed species listed in Table 2 are associated with grazing disturbances and are already widespread throughout the distribution of the Mahogany Glider. Examples of the impacts include:

- Vine species such as Matchbox Vine (*Entada rheedii*) and Elephant Ear Vine (*Argyreia nervosa*) impact Mahogany Glider habitat by smothering trees, which typically reduces the recruitment of trees beneficial to the glider, expedites the transition to rainforest, and makes the remaining den and food trees increasingly difficult to access.
- High biomass grasses such as Guinea Grass (*Megathyrsus maximum*) and Elephant Grass (*Pennisetum purpureum*) alter the understorey composition by preventing beneficial tree recruitment and altering fire behaviour.
- Significant cyclones alter the structure of the glider's habitat as the disturbance provides an opportunity for many weed species to outcompete the native vegetation, which impacts the native species recovery and can negatively alter the habitat structure.

Weed management throughout Mahogany Glider habitat is essential in maintaining the viability of habitat for this species.

Table 2. Additional exotic plants of potential concern within the distribution of the Mahogany Glider. Taken from Jackson *et al.* (2018a).

Scientific Name	Common Name	Family	Plant Type	Ref.
<i>Thunbergia alata</i>	Orange Thunbergia	Acanthaceae	Vine	1
<i>Thunbergia fragrans</i>	White Thunbergia	Acanthaceae	Vine	2
<i>Thunbergia grandiflora</i>	Blue Thunbergia	Acanthaceae	Vine	3
<i>Ageratum houstonianum</i>	Billgoat Weed	Asteraceae	Herb	1
<i>Chromolaena odorata</i>	Siam Weed	Asteraceae	Herb	1
<i>Tridax procumbens</i>	Tridax Daisy	Asteraceae	Herb	1
<i>Allamanda carthartica</i>	Yellow Allamanda	Apocynaceae	Vine	3
<i>Senna obtusifolia</i>	Sicklepod	Caesalpinaceae	Shrub	1
<i>Argyreia nervosa</i>	Elephant Ear Vine	Convolvulaceae	Vine	4

<i>Ipomoea indica</i>	Blue Morning Glory	Convolvulaceae	Vine	3
<i>Ipomoea triloba</i>	Pink Convolvulus	Convolvulaceae	Vine	3
<i>Calopogonium mucunoides</i>	Calopo	Fabaceae	Vine	2
<i>Centrosema pubescens</i>	Centro	Fabaceae	Vine	1,3
<i>Clitoria laurifolia</i>	Butterfly Pea	Fabaceae	Vine	3
<i>Crotalaria goreensis</i>	Pea Rattlepod	Fabaceae	Herb	1
<i>Crotalaria pallida</i>	Pea Rattlepod	Fabaceae	Herb	1
<i>Entada rheedii</i>	Matchbox Vine	Fabaceae	Vine	4
<i>Macroptilium atropurpureum</i>	Siratro	Fabaceae	Vine	1,3
<i>Neonotonia wightii</i>	Pea Flower	Fabaceae	Vine	3
<i>Hyptis capitata</i>	Knobwood	Lamiaceae	Herb	1
<i>Mimosa pudica</i>	Sensitive Weed	Mimosaceae	Herb	1
<i>Passiflora subpeltata</i>	White Passion Fruit	Passifloraceae	Vine	3
<i>Passiflora foetida</i>	Stinking Passion Flower	Passifloraceae	Vine	1,3
<i>Passiflora suberosa</i>	Corky Passion Vine	Passifloraceae	Vine	1,3
<i>Rivina humilis</i>	Coral Berry	Phytolaccaceae	Shrub	1
<i>Chrysopogon aciculatis</i>	Mackie's Pest	Poaceae	Grass	1
<i>Megathyrsus maximum</i>	Guinea Grass	Poaceae	Grass	1
<i>Pennisetum purpureum</i>	Elephant Grass	Poaceae	Grass	1
<i>Urochloa mosambicensis</i>	Sabi Grass	Poaceae	Grass	1
<i>Urochloa mutica</i>	Paragrass	Poaceae	Grass	1
<i>Lantana camara</i>	Lantana	Verbenaceae	Shrub	1,4
<i>Stachytarpheta jamaicensis</i>	Snakeweed	Verbenaceae	Herb	1
<i>Stachytarpheta urticifolia</i>	Snakeweed	Verbenaceae	Herb	1

Potential invasive weeds

<i>Mikania micrantha</i>	Mikania Vine	Asteraceae	Vine	2
<i>Coccinea grandis</i>	Ivy Gourd	Cucurbitaceae	Vine	2
<i>Andropogon gayanus</i>	Gamba Grass	Poaceae	Grass	2
<i>Azadirachta indica</i>	Neem	Meliaceae	Tree	2
<i>Pennisetum pedicellatum unispiculum</i>	Kyasuma Grass	Poaceae	Grass	2

References: 1) Kemp & Cumming pers. comm.; 2) Calvert, 1996; 3) Jackson pers. obs; 4) Jacqui Diggins pers. obs.

4.2.5 Small population

The highly fragmented nature of the remaining Mahogany Glider habitat has resulted in numerous small isolated fragments that contain small numbers of Mahogany Gliders. The population viability studies undertaken on this species suggest that populations less than 800 individuals (within an estimated 8000 hectares) have an increasingly high probability of extinction as they get smaller (Jackson, 1999). These deleterious impacts include inbreeding that can result in a reduced genetic diversity causing inbreeding depression, and greater susceptibility to stochastic events such as cyclones (Caughley, 1994; Jackson, 1999).

4.2.6 Roads and easement corridors

The limited available information suggests that roads pose a potentially significant threat to the Mahogany Glider, with 15 road fatalities recorded between 1991 and 2005 (Smith, 1996; Parsons, 2005). Of the road kills recorded, almost all occurred on the Bruce Highway and appear to have been juveniles, suggesting that the width and volume of traffic on a road may be a barrier to dispersal (Parsons & Latch, 2006). Although the maximum recorded glide distance is 60 m (Jackson, 2000c), gaps in habitat across roads should ideally not be greater than the average glide distance of 30 m. In an attempt to mitigate road casualties, glider poles have been established in some areas to improve gliders' ability to cross safely. Roads also have a less direct (but potentially more damaging) impact by dissecting habitat and reducing connectivity. Female gliders appear to be less likely to cross over roads than males (Asari *et al.*, 2010).

4.2.7 Barbed wire fencing

Evidence suggests that barbed wire fences (usually used to contain livestock) are a major contributor of fatality and injury of the Mahogany Glider as a result of entanglement (Jackson, 2000c; Parsons, 2005). Mortality occurs when the patagium of the gliders become entangled on the top barbed wire strand, causing them to become entwined. The glider then usually dies of dehydration after several days (Parsons & Latch, 2006). The impact of fences appears to be greatest in highly fragmented areas, where animals must regularly cross barbed wire fences to cross gaps in their habitat (van der Ree, 1999; Booth, 2006). Fences located on the edge of large gaps in habitat (i.e. more than 20 m) pose the greatest risk of entanglement because the gliders are more likely to land lower down when travelling across these gaps (Parsons & Latch, 2006).

4.2.8 Extreme environmental events

Extreme weather events such as tropical cyclones, severe wildfires, floods and storm surges pose a significant threat to the distribution of the Mahogany Glider. Due to the species' small and localised distribution, a single extreme weather event has the potential to impact upon the entire extent of Mahogany Glider habitat.

The most important extreme weather events are tropical cyclones that occur regularly in northern Australia, with an average of one every two years along the north east coast of Queensland (Winter, 2011). For example, cyclones Winifred (category 2-3, 1 February 1986, Innisfail), Larry (category 4, 20 March 2006, Innisfail) and Yasi (category 5, 3 February 2011, Mission Beach) each caused major widespread damage across the distribution of the Mahogany Glider (Turton, 2008; Winter, 2011). Of these cyclones, Yasi was the most destructive within the distribution of the Mahogany Glider, as it produced wind gusts up to 285 km/hr and rainfall of over 400 mm in the Innisfail and Tully areas. This cyclone caused prolonged flooding and saltwater intrusion into Mahogany Glider-associated melaleuca wetlands. Within the distribution of the Mahogany Glider, this cyclone caused damage to 80 to 100 percent of the canopy throughout the northern part of the species distribution (north of the Cardwell Gap), where the high wind speeds resulted in canopy stripping, tree limb loss and tree topple (Winter, 2011). Due to the current level of fragmentation of remaining habitat, the species is particularly vulnerable to the impacts of tropical cyclones and their associated strong winds, largely due to the high forest edge to area ratios and associated edge effects (Turton, 2012; Jackson *et al.*, 2020).

4.3 Potential threatening processes

4.3.1 Climate change

Climate change is likely to impact upon the survival of the Mahogany Glider in the future due to the predicted increase in extreme climatic events such as tropical cyclones, heavier precipitation and flooding within the Wet Tropics (Easterling *et al.*, 2000; Walsh & Ryan, 2000; Hennessy *et al.*, 2006). Within a Wet Tropics there is also predicted to be an increase in average temperatures, more frequent and longer heatwaves, and an increase in the intensity of extreme rainfall events causing severe flooding (Hilbert *et al.*, 2014). A key strategy to mitigate this threat will be to build resilience into the woodlands and forests upon which Mahogany Gliders rely. These strategies would increase connectivity between lowland fragments and refuge areas, reduce woody weeds and sclerophyll thickening, and increase the overall quality of Mahogany Glider habitat across the entire extent of their range.

4.3.2 Feral predation

Feral predation from feral cats and dogs appears to be limited, with only one cat and one dog attack being reported to date (Lyon 1993; Parsons 2005). Nevertheless, the probability of such attacks may increase with increasing urban expansion and habitat fragmentation, as animals increasingly come closer to the ground to cross narrow gaps in habitat.

4.3.3 Myrtle Rust Disease

Myrtle Rust (*Puccinia psidii*) is a fungus of plants in the family Myrtaceae and was first detected in Australia in 2010 (Carnegie *et al.*, 2016; Carnegie & Pegg, 2018). The spread of Myrtle Rust is a concern as it could impact most species critical to the survival of the Mahogany Glider. Myrtle Rust infection can cause defoliation, twig mortality and abortion of flowers and fruits, so has the potential to reduce food availability for Mahogany Gliders. It has been recorded as occurring in Girringun National Park since June 2012, although its spread through the glider's range has been slower than originally anticipated. The projected extent, rate of establishment and the potential impact on the Mahogany Glider of this fungus is currently unknown.

5 EXISTING CONSERVATION MEASURES

A number of key conservation measures have been undertaken over the life of the last Mahogany Glider recovery plan (Parsons & Latch 2006) and include:

- Fifteen private land owners have been engaged in developing land management practices that balance conservation needs with other land uses. This has resulted in:
 - 5.9 ha of habitat revegetation,
 - 72.4 ha of woody weed control in remnant habitat,
 - replacement of 13.8 km of barbed-wire fencing with plain wire,
 - improved grazing regimes and ongoing engagement with landholders,
 - Improved weed control and fire management on some farms,
 - Installation of glide poles.
- Installation of 11 new glider pole crossings to assist the movement of gliders between habitat fragmented by linear infrastructure.
- Implementation of 95ha of appropriate fire regimes conducted within remnant habitat located on Unallocated State Land (USL).
- Habitat recovery burns have been implemented at key sites.
- These practices include weed control, fire management, revegetation, wildlife-friendly fencing and installation of glide poles.
- Mapping
 - the pre-clearing and current vegetation to determine the loss of habitat since broadscale clearing commenced (Jackson *et al.*, 2011),
 - habitat that is under threat from rainforest expansion and sclerophyll thickening (Jackson *et al.*, 2011),
 - the current Mahogany Glider subpopulations (Jackson *et al.*, 2018a; 2020),
 - the location of 55 priority locations where Mahogany Glider corridors need to be established or maintained have been identified (Jackson *et al.*, 2018a; 2020).
- Development of a Mahogany Glider captive breeding manual to maximise the effective captive management of the species (Jackson *et al.*, 2018b).
- Development of growth curves and identification of developmental milestones of the Mahogany Glider have been produced (Booth *et al.*, 2019).
- Community engagement has been undertaken in the form of school visits, community talks, presentations, media and events.

- Indigenous participation has been facilitated and promoted through training and assistance provided to Giringun, specifically to develop a monitoring program in the Ellerbeck area.
- Recovery program is coordinated by the NMGRT.

6 RECOVERY PROGRAM

6.1 Recovery strategy

The recovery of the Mahogany Glider is a long-term endeavour. Building on the previous plan, actions over the life of this recovery plan will further enhance habitat protection, quality and connectivity and improve the glider's population trajectory. This will be a significant foundation on which to further promote the on-going recovery effort needed to meet the recovery program's long-term recovery goal.

The key to the effective implementation of this recovery plan will be to engage local communities in the recovery program, raise awareness, facilitate participation and build local ownership of recovery effort. This plan will have a priority focus on the five primary populations and increasing their connectivity with the secondary and range limit populations. Actions will respond to on-ground threats, primarily habitat loss and fragmentation, inappropriate fire regimes, intensive grazing and weed invasion. Recovery of the species will be supported and facilitated by the maintenance of an effective and collaborative recovery team, improvement in our knowledge of the distribution and status of the population, and the effectiveness of the management actions.

6.2 Objectives, performance criteria and actions

6.2.1 Long-term recovery objective

The long-term objective of this recovery plan is to increase the extent, quality and connectivity of the habitat for the Mahogany Glider to maximise its chances of long-term survival in the wild.

6.2.2 Objectives and recovery success criteria of this recovery plan

The objectives and recovery success criteria of this plan include:

- 1) Habitat critical to the survival of the Mahogany Glider is secured, enhanced and managed to support recovery of Mahogany Glider populations.
- 2) An integrated monitoring program that reports on Mahogany Glider population trends and effectiveness of management and research actions is established.
- 3) The Mahogany Glider Recovery Team is collaborative and effectively coordinates the implementation of the recovery plan.
- 4) The community values, and is actively engaged in, the conservation of the Mahogany Glider.
- 5) Emergency triggers and response protocols are developed and are informing planning decisions.

The recovery plan will be deemed successful if within 10 years the following have been achieved:

- 1) There is an increase in the extent of high-quality habitat (i.e. mixed open forest and mixed open woodland) that is managed for Mahogany Glider recovery.
- 2) The population trajectory has improved.
- 3) Genetic diversity is maintained.
- 4) The area occupied by Mahogany Gliders has increased.

- 5) Connectivity has been restored within five priority corridors.
- 6) Infrastructure and maintenance guidelines have been implemented in all linear and transport easements.
- 7) Appropriate grazing and fire management regimes have been adopted by landholders who are actively engaged in improving habitat quality across all subpopulations.
- 8) Emergency triggers and response protocols to assess the feasibility and risks associated with a captive breeding and/or translocation program are in place .
- 9) Increased community recognition of, and support for, participation in recovery program.
- 10) Recovery program is effectively coordinated with all partners collaborating and contributing towards the effective delivery of the recovery plan.

6.2.3 Objectives and actions for the lifetime of this recovery plan

Objective 1: Habitat critical to the survival of the Mahogany Glider is secured, enhanced and managed to support recovery of Mahogany Glider populations

Rationale: Improved protection, enhancement and connectivity of habitat will enhance security of populations, allow for dispersal to suitable habitat and mitigate the threat of habitat clearance and degradation as well as the impacts of severe disturbances, such as cyclones.

Action	Performance Measure
<p>1.1 Improve grazing management practices and associated threats within each of the remaining Mahogany Glider subpopulations.</p> <ul style="list-style-type: none"> • Develop and implement a targeted grazing extension and incentives program, to increase the adoption of appropriate grazing management practices which balance profitability and conservation throughout 500 ha of Mahogany Glider habitat. • Removal of barbed-wire top strand fencing (and replace with plain wire) in high risk entanglement areas located within grazing properties. • Reduce woody weeds associated with intensive grazing practices and located within remnant Mahogany Glider habitat. • Develop and disseminate 'Best Practice' guidelines for grazing in Mahogany Glider habitat including managing weeds, fire, fencing and stock density. • Develop a strategy and implement a peer-to-peer program to maintain ongoing support for landholders managing Mahogany Glider habitat. 	<ul style="list-style-type: none"> • A targeted grazing extension and incentives program has been developed and implemented. The program has resulted in the implementation of appropriate grazing regimes (500 ha), woody weed control (200 ha) and the removal of barbed-wire fencing threats (100 km) within the each of the remaining Mahogany Glider subpopulations. • Guidelines for best management practice for grazing in Mahogany Glider habitat have been developed and implemented by relevant stakeholders. • A landholder peer-to-peer support network has been established and actively assists landholders to adopt the 'Best Practice' guidelines for grazing in Mahogany Glider habitat.

<p>1.2 Implement and maintain appropriate fire regimes within Mahogany Glider habitat located outside National Parks in each of the remaining Mahogany Glider subpopulations to promote suitable habitat and reduce rainforest expansion, sclerophyll thickening, and weed invasion.</p>	<ul style="list-style-type: none"> • Develop best practice management guidelines, using the best available science, that outline the most appropriate fire regimes to reduce woody weeds, rainforest expansion and sclerophyll thickening. • Appropriate fire management has been implemented throughout 500 ha habitat located outside of National Parks.
<p>1.3 Maintain the extent and management of Mahogany Glider habitat within National Parks by controlling priority weeds, removing barbed-wire fencing adjacent to estates, maintaining appropriate fire regimes and revegetating areas if required.</p>	<ul style="list-style-type: none"> • A reduction of high threat weeds (300 ha), maintenance of appropriate fire regimes (25,000 ha) and removal of 200 km of barbed-wire boundary fencing has occurred within National Parks.
<p>1.4 Improve connectivity, condition and extent of five priority corridors as identified in the Mahogany Glider's priorities corridor report (Jackson <i>et al.</i>, 2020).</p> <ul style="list-style-type: none"> • Develop and implement a program to assist landholders to improve the extent and/or management of five priority corridors by implementing revegetation and reducing high threat weeds associated with riparian corridors. • Reduce existing habitat fragmentation arising from linear infrastructure within five priority corridors through the installation of glide pole arrays or alternative methods. 	<ul style="list-style-type: none"> • Revegetation of 25 ha has occurred within five of the priority corridors. • Weeds (50 ha) associated with riparian corridors have been controlled within five of the priority corridors. • Glide pole arrays have been installed to address (five) corridor gaps resulting from linear infrastructure within priority corridors.
<p>1.5 Enhance security of Mahogany Glider habitat through the development of statutory planning instruments, and guidelines and other voluntary habitat protection mechanisms.</p> <p>Develop guidelines for infrastructure upgrades and management and incorporate into road, rail and powerline planning, construction and maintenance guidelines to minimise habitat fragmentation, degradation and Mahogany Glider mortality associated with transport and easement corridors.</p> <p>Investigate, develop and implement mechanisms for protection of Mahogany Glider habitat on freehold tenures.</p> <p>Specific impact assessment and restrictions for Lot Reconfiguration applications are</p>	<ul style="list-style-type: none"> • Guidelines for infrastructure upgrades and management have been developed. • Road, rail and powerline organisations have adopted guidelines for infrastructure upgrades and management. • Mechanisms for protection of habitat on freehold tenures have been developed and promoted to landholders.

developed to address the incremental impacts arising from land subdivision.

Specific impact assessment and restrictions for Material Change of Use applications are developed to address the incremental impacts arising from changes in land use over Mahogany Glider habitat.

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| <p>1.6 Develop best management practice guidelines for efficient and low-cost revegetation of Mahogany Glider habitat, using the best available science, and disseminate to relevant stakeholders.</p> | <ul style="list-style-type: none"> Guidelines for best management practice options for revegetation of Mahogany Glider habitat have been developed and implemented by relevant stakeholders. |
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Objective 2: An integrated monitoring program that reports on Mahogany Glider population trends and effectiveness of management and research actions is established.

Rationale: It is critical to ensure that monitoring is undertaken appropriately to provide consistent data over time that clearly measures the health of Mahogany Glider populations and habitat, and the effectiveness of recovery efforts. Evaluating and reporting on the outcomes of monitoring programs are key to informing stakeholders and enabling the adaptation of management actions, as required.

Action	Performance Measure
<p>2.1 Design and implement an integrated monitoring program which reports on Mahogany Glider population trend and allows for ongoing data collection by community groups and NGOs.</p>	<ul style="list-style-type: none"> A long-term population monitoring program has been designed and implemented. Population size and trend of the Mahogany Glider has been assessed and is reported.
<p>2.2 Assess the effectiveness of on-ground actions at increasing local population densities and/or extent.</p> <ul style="list-style-type: none"> Update and maintain the Mahogany Glider sightings and actions database (maintained by Terrain), ensure all contributors have received adequate training and data is regularly shared with DES (for upload to WildNet) and DoEE. Monitor and assess the effectiveness of fire management actions at reducing sclerophyll thickening. Monitor and assess the effectiveness of on ground grazing management actions that address threats associated with inappropriate grazing including woody weeds and habitat degradation. Report regularly on the actions delivered and the relevance of 	<ul style="list-style-type: none"> All relevant contributors receive training and are actively using relevant databases. Sightings are maintained up to date in the WildNet database. All recovery plan actions have been recorded and on ground actions mapped in the MGRT database and reported on annually to DES, DoEE and the community. Mahogany glider population response to fire management actions has been assessed to inform adaptive management actions. The effectiveness of grazing management actions at reducing woody weeds and improving habitat condition has been monitored, assessed and results used to inform management actions. A formal review of this recovery plan has been completed and the recovery plan has been adapted as necessary at the five-year review.

	actions identified in this recovery plan, including a formal review at five years, and adapt as required.	
2.3	Determine the genetic characteristics of the Mahogany Glider population to sufficiently inform management within and between sub populations.	<ul style="list-style-type: none"> Information on genetic characteristics informs planning and management actions.
2.4	Assess the effectiveness of corridors and crossings structures in maintaining genetic diversity amongst Mahogany Glider populations	<ul style="list-style-type: none"> The effectiveness of corridors and crossings structures in maintaining mahogany glider genetic diversity has been assessed and results used to inform this recovery plan.
2.5	Reassess the conservation status of the Mahogany Glider	<ul style="list-style-type: none"> Conservation status of the species has been reassessed at the five-year review of the recovery plan.

Objective 3: The Mahogany Glider Recovery Team is collaborative and effectively coordinates the implementation of this recovery plan.

Rationale: The conservation of the Mahogany Glider has been a major and enduring concern for significant sections of the community, and its conservation has involved a wide range of people from industries, conservation groups, agencies and others over many years. An active and representative recovery team is in place and has been successfully implementing this recovery plan, as resources permitted. The species' recovery is dependent upon this ongoing local coordination and implementation which is provided by the Mahogany Glider Recovery Team and their effectiveness is reliant upon local participation, collaboration and resources.

Action	Performance Measure
3.1 Coordinate the effective implementation of the recovery plan through the recovery team.	<ul style="list-style-type: none"> Recovery team has coordinated the implementation of this plan. Regular recovery team meetings held, with all members actively involved in coordinating the implementation of this plan (3 meetings per year).
3.2 Seek funding opportunities to adequately resource implementation of the recovery plan. <ul style="list-style-type: none"> Establish appropriate governance and protocols for securing and managing funds associated with offsets, donations or other forms of non-project specific funds. Investigate options for philanthropic, government and/or corporate investment in this recovery plan. This may include project sponsorship, innovative market solutions or public donations. 	<ul style="list-style-type: none"> An appropriate governance structure and protocol for securing and managing funds associated with offsets, donations or other forms of non-project specific funds has been developed. A fundraising strategy to secure philanthropic, government and/or corporate investment in the recovery plan has been developed.

Objective 4: The community values, and is actively engaged in, the conservation of the Mahogany Glider.

Rationale: A key to the effective implementation of this plan will be to engage local communities in the recovery program, raise awareness, facilitate participation and build local ownership of recovery effort. This objective recognises the need for actions to build on the knowledge, experience and

capacity of local communities and local land managers. In particular, the skills, expertise, experience, connection to Country and capacity of Traditional Owners and Aboriginal land managers are crucial to the protection and recovery of the Mahogany Glider.

Action	Performance Measure
4.1 Establish a network of local leaders from across sectors to develop and implement a shared strategy for influencing attitudes and behaviours and building local value and action for Mahogany Glider habitat and the environment.	<ul style="list-style-type: none"> • A community engagement and influence strategy has been developed and implemented by representatives from different sectors of the local community.
4.2 Continue to build, enhance and facilitate engagement of, and participation by, Aboriginal groups in Mahogany Glider recovery.	<ul style="list-style-type: none"> • Implementation of this plan appropriately involves Aboriginal groups in a manner and to the extent sought by them. • Traditional cultural knowledge informs planning and management where appropriate and where negotiated.
4.3 Increase public awareness and involvement in Mahogany Glider recovery. <ul style="list-style-type: none"> • Engage with schools to increase student awareness and involvement in Mahogany Glider conservation. • Engage community groups, volunteers, tourists in Mahogany Glider conservation. 	<ul style="list-style-type: none"> • Annual engagement occurs with at least 1 local school involving at least 10 students each year. • Annually, 20 new people volunteer in activities which contribute to Mahogany Glider conservation.
4.4 Develop and maintain up to date and publicly available communication and education products.	<ul style="list-style-type: none"> • The Mahogany Glider Recovery Plan Storymap: A planning and educational tool (Terrain NRM, 2015) is maintained up to date and used to raise awareness. • Communication and education products are developed and disseminated.

Objective 5: Emergency triggers and response protocols are developed and are informing planning decisions.

Rationale: Emergencies come in many forms and by definition are serious, unexpected and require immediate action. The identification of triggers that identify what will constitute an ‘emergency’ and the response protocols (including possible interventions) must be developed to ensure immediate action can be taken when necessary. A clear rationale for when a captive breeding and/or translocation program of Mahogany Gliders is required, along with the expected costs and benefits.

Action	Performance Measure
5.1 Identify key trigger events (e.g. future widespread fires) and thresholds in monitoring results that would catalyse	<ul style="list-style-type: none"> • Triggers and thresholds are identified and associated guidelines (that include actions

emergency response (and identify such emergency response options).	for emergency response) are developed within five years.
5.2 Establish appropriate governance and protocols to be able to respond to emergency events, such as a significant cyclone event.	<ul style="list-style-type: none"> • Appropriate governance and protocols have been established to identify and respond to emergency events, such as a significant cyclone event. • Develop a post-cyclone recovery strategy for the Mahogany Glider. That may include providing feeding stations and den boxes.
5.3 Review existing and/or develop new natural disaster recovery processes and a best management practice for habitat rehabilitation plan and disseminate to relevant stakeholders.	<ul style="list-style-type: none"> • Natural disaster recovery processes have been developed/reviewed and implemented as required.
5.4 Assess the conservation benefits, feasibility and risks of establishing a captive breeding and translocation program, and establish a response protocol if needed. <ul style="list-style-type: none"> • Assess the feasibility and risks of possible combinations of captive breeding and translocation (temporary vs insurance population vs none) to identify the most appropriate long-term strategy if required. • Develop protocols and guidelines for captive breeding and translocation consistent with IUCN guidelines, if required, and disseminate guidelines to stakeholders. 	<ul style="list-style-type: none"> • An assessment is completed that identifies the circumstances where translocation may be valuable within the known range of the glider, and the risks, costs, and benefits of translocation options have been evaluated. • An assessment is completed that identifies the circumstances where captive breeding and release may be valuable.

7 RECOVERY PLAN IMPLEMENTATION

7.1 Implementation schedule, costs and governance

Implementation of this recovery plan will require commitment and effective coordination and collaboration between key stakeholders and partners. The MGRT will be the key governance mechanism to coordinate recovery effort, ensure appropriate progress in and report on implementation, share and review information, and identify funding opportunities. The MGRT will be consistent with the Australian Government recovery team governance guidelines (DoEE, 2017). Potential implementation partners are identified for every action (Table 3) and broadly include local, state and commonwealth governments, industry, non-government organisations (NGOs), natural resource management groups, Aboriginal communities and landholders.

The implementation costs in Table 3 are indicative only and are based on estimates from comparable actions undertaken or underway as part of the ongoing Mahogany Glider conservation effort. Currently, it is not practical to provide meaningful costing figures for actions beyond year five. Significant investment in actions, particularly in the first three years, is required to establish the

foundation for ongoing conservation effort and will provide more realistic indications of ongoing implementation costs. Indicative costs for actions beyond the fifth year will therefore be developed as these initial actions are implemented and will inform the five-year review.

Implementation responsibilities and arrangements involving potential partners will be subject to negotiation once the recovery plan is in place. A detailed implementation plan is to be developed by agreed implementation partners, through which agreement is reached on partner contributions to the implementation of actions. Annual budgets should be identified, coordinated and secured by the implementation partners, with timing and reporting processes consistent with the proposed timeframes and the priority indicators. This implementation plan will identify and commit responsible partners to agreed actions and be facilitated by the recovery team.

Implementing this recovery plan is subject to budgetary, and other resource opportunities and constraints, affecting the key stakeholders. Where possible, the cost of implementing this recovery plan should be incorporated into the core business expenditure of the affected organisations and through additional funds obtained for the explicit purpose of implementing this recovery plan.

Priorities assigned to actions (Table 3) should be interpreted as follows:

Priority indicators for actions

Priority 1:	Taking prompt action is critical in order to mitigate the key threats to the mahogany glider and stabilise the population.
Priority 2:	Action would provide a more informed basis for the long-term management and recovery of the mahogany glider.
Priority 3:	Action is desirable and enhances broader engagement and while not critical to the immediate recovery of the mahogany glider will provide for longer recovery.

More details concerning proposed actions can be found in Section 8, Management Practices.

Table 3. Indicative time frames, priorities and estimated costs (\$000s) of recovery actions over the first five years of implementation

Actions	Priority	Potential Implementation partners	Indicative cost (\$000s) and timing					
			Year 1	Year 2	Year 3	Year 4	Year 5	Total
1.1 Improve grazing management practices and associated threats within the each of the remaining Mahogany Glider subpopulations.	1	Terrain NRM, NQ Dry Tropics, CCRC, HSC, landholders.	100	350	350	300	250	1350
1.2 Implement and maintain appropriate fire regimes within 500ha of Mahogany Glider habitat located outside National Parks in each of the remaining Mahogany Glider subpopulations.	1	DNRME, Terrain NRM, Girringun, CCRC, QFES/QFRS.	300	200	200	200	200	1100
1.3 Maintain the extent and management of Mahogany Glider habitat within National Parks by controlling priority weeds (300 ha), removing barbed-wire fencing adjacent to estates (200 km), maintaining appropriate fire regimes (25,000 ha) and revegetating areas if required.	1	DES, landholders & Girringun	250	250	250	250	250	1,250
1.4 Improve connectivity, condition and extent of five priority corridors as identified in the Mahogany Gliders priorities corridor report.	1	Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, HSC, TMR, Powerlink, NGOs, landholders.	180	275	300	350	300	1,035
1.5 Enhance security of Mahogany Glider habitat through the development of statutory planning instruments, guidelines and other voluntary habitat protection mechanisms.	2	Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, HSC, NGOs.	0	70	50	0	0	120
1.6 Develop best management practice guidelines for efficient and low-cost revegetation of Mahogany Glider habitat, using the best available science, and disseminate to relevant stakeholders.	3	Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, HSC, TMR, JCU.	25	25	0	0	0	50
2.1 Design and implement an integrated monitoring program which reports on Mahogany Glider population trend and allows for ongoing data collection by community groups and NGOs.	1	JCU, DES, Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, HSC, TMR.	60	80	80	80	150	450

Actions	Priority	Potential Implementation partners	Indicative cost (\$000s) and timing					
			Year 1	Year 2	Year 3	Year 4	Year 5	Total
2.2 Assess the effectiveness of on-ground actions at increasing local population densities and/or extent.	2	DES, Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, HSC, TMR, Powerlink, NGOs, QFES/QFRS, DNRME.	50	70	100	100	70	390
2.3 Determine the genetic characteristics of the mahogany glider population to sufficiently inform management within and between sub populations.	2	DES, Terrain NRM, NQ Dry Tropics, JCU, WPSQ, Girringun, TMR, DNRME.	60	120	120	0	0	300
2.4 Assess the effectiveness of corridors and crossing structures in maintain genetic diversity amongst mahogany glider populations.	2	JCU, DES, Terrain NRM, NQ Dry Tropics, WPSQ, Girringun		80	100	50	0	230
2.5 Reassess the conservation status of the Mahogany Glider.	2	DES, Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, HSC, TMR.	0	0	0	0	40	40
3.1 Coordinate the effective implementation of the recovery plan through the recovery team.	1	DES, Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, HSC, TMR, Powerlink.	10	10	10	10	10	50
3.2 Seek funding opportunities to adequately resource implementation of the recovery plan.	1	Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, NGOs.	10	5	5			25
4.1 Establish a network of local leaders from across sectors to develop and implement a shared strategy for influencing attitudes and behaviours and building local value and action for Mahogany Glider habitat and the environment.	2	Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, NGOs.	40	40	20	20	20	140
4.2 Continue to build, enhance and facilitate engagement of, and participation by, Aboriginal groups in Mahogany Glider recovery.	2	Terrain NRM, NQ Dry Tropics, DES, Girringun	50	50	50	50	50	250

Actions	Priority	Potential Implementation partners	Indicative cost (\$000s) and timing					
			Year 1	Year 2	Year 3	Year 4	Year 5	Total
4.3 Increase public awareness and involvement in Mahogany Glider recovery.	3	DES, Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, HSC, TMR, Powerlink, NGOs, DNRME.	50	50	50	50	50	250
4.4 Develop and maintain up to date and publicly available, communication and education products.	3	DES, Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC.	20	15	15	15	15	80
5.1 Identify key trigger events (e.g. future widespread fires) and thresholds in monitoring results that would catalyse emergency response (and identify such emergency response options).	2	JCU, DES, Terrain NRM, NQ Dry Tropics.	50	50	0	0	0	100
5.2 Establish appropriate governance and protocols to be able to respond to emergency events, such as a significant cyclone event.	2	DES, Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, HSC, TMR, Powerlink, NGOs, QFES/QFRS, DNRME.	0	20	20	0	0	40
5.3 Review existing and/or develop new natural disaster recovery processes and a best management practice for habitat rehabilitation, and disseminate to relevant stakeholders.	3	DES, Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC, HSC, TMR, Powerlink, NGOs, QFES/QFRS, DNRME.	0	0		30	30	60
5.4 Assess the conservation benefits, feasibility and risks of establishing a captive breeding and translocation program, and establish a response protocol if needed.	3	JCU, DES, Terrain NRM, NQ Dry Tropics, WPSQ, Girringun, CCRC.	0	0	0	0	50	50

CCRC = Cassowary Coast Regional Council; (AG); **DES** = Department of Environment and Science (Qld); **DNRME** = Department of Natural Resources, Mines and Energy (Qld); **Ergon** = Ergon Energy; **Girringun** = Girringun Aboriginal Corporation; **HQP** = Hancocks Queensland's Plantations; **LDMG** = Local Disaster Management Group; **NGOs** = Non-Governmental Organisations; **NQ Dry Tropics** = North Queensland Dry Tropics; **Powerlink** = Powerlink Queensland; **QFES** = Queensland Fire and Emergency Services; **QFRS** = Queensland Rural Fire Service; **Terrain NRM** = Terrain Natural Resource Management; **TMR** = Department of Transport and Main Roads (Qld); **WPSQ** = Wildlife Preservation Society Queensland.

7.2 Monitoring, evaluation, reporting and review

Monitoring of this plan will require ongoing assessment of the implementation and success of all actions, with regular reporting to and by the recovery team. Reporting and review should be consistent with Australian Government recovery team reporting guidelines (DoEE, 2017).

This recovery plan should be reviewed no later than five years from when it was endorsed and made publicly available. The review will be coordinated by the MGRT in consultation with relevant partners and other stakeholders. This review will be used to help inform the need for any adaptation required within this Plan, to identify and resolve any unexpected impediments, and to re-assess priorities for actions. The review will determine the performance of this Plan and assess whether:

- it continues unchanged, is varied to remove completed actions, or varied to include new conservation priorities, or
- a recovery plan is no longer necessary for the species, as conservation advice will suffice, or
- a listing status review of the Mahogany Glider under legislation is undertaken.

This recovery plan recognises a need for some flexibility and adaptation due to some substantial uncertainties. These include knowledge aspects of the species' biology the likelihood of success of some management actions, and the likelihood of somewhat unpredictable episodes of acute and severe threat. Adaptation within this plan should be guided by the regular reporting described above, and should generally fit within its broad framework. Any such needed adaptation in this plan should be overseen by the MGRT.

7.3 Potential benefits and impacts associated with implementation

7.3.1 Broader biodiversity benefits

The southern Wet Tropics coastal lowland forests contain threatened species and regional ecosystems that are linked to Mahogany Glider recovery (Table 4). Measures to protect Mahogany Glider habitat and to mitigate threats will also help to protect many other threatened species and ecosystems. The recovery of Mahogany Glider populations also focuses attention on regional land management issues such as wildlife corridors, clearing, habitat fragmentation and rehabilitation projects.

Table 4. Threatened species and ecosystems associated with Mahogany Glider habitat (derived from Parsons & Latch 2006).

Common Name	Scientific Name	Conservation status	
Fauna		NCA ¹	EPBC ²
Apollo Jewel Butterfly	<i>Hypochrysops apollo</i>	E	
Lesser Sooty Owl	<i>Tyto tenebricosa</i>	NT	
Southern Cassowary	<i>Casuarius johnsonii</i>	E	E
Spectacled Flying Fox	<i>Pteropus conspicillatus</i>	LC	V
Ghost Bat	<i>Macroderma gigas</i>	V	
Greater Large-eared Horseshoe-bat	<i>Rhinolophus robertsi</i> (Syn <i>Rhinolophus philippinensis</i>)	E	E

Diadem Leaf-nosed Bat	<i>Hipposideros diadema reginae</i>	NT	
Bare-rumped Sheath-tailed Bat	<i>Saccolaimus nudiclunatus</i>	E	CE
Flora			
Cabbage Palm	<i>Livistona drudei</i>	V	
Ant Plant	<i>Myrmecodia beccarii</i>	V	V
Bearded Orchid	<i>Calochilus psednus</i>	E	E
Cardwell Midge Orchid	<i>Genoplesium tectum</i>	E	E
Swamp Orchid	<i>Phaius tancarvilleae</i>	E	E
Green Corduroy Orchid	<i>Eulophia bicallosa</i>	NT	
Rumph's Habenaria	<i>Habenaria rumphii</i>	NT	
Yellow Habenaria	<i>Habenaria xanthantha</i>	NT	
Pink Kunai Orchid	<i>Pachystoma pubescens</i>	NT	
Lance-Leaved Sundew	<i>Drosera adalae</i>	NT	

Ecological Community	Description	EPBC Act status ²
Broad leaf tea tree	Broad leaf tea-tree (<i>Melaleuca viridiflora</i>) woodlands in high rainfall coastal north Queensland	E

Regional Ecosystems	Description	VMA status ³
RE 7.2.4	<i>Eucalyptus</i> spp. (often <i>E. pellita</i> or <i>Corymbia intermedia</i>) open forest and/or <i>Lophostemon suaveolens</i> open forest on swampy sand plains and Pleistocene beach ridges.	OC
RE 7.3.6	<i>Melaleuca dealbata</i> +/- <i>Melaleuca leucadendra</i> open forest, on poorly drained alluvial plains.	E
RE 7.3.7	<i>Eucalyptus pellita</i> and <i>Corymbia intermedia</i> open forest to woodland (or vine forest with emergent <i>E. pellita</i> and <i>C. intermedia</i>), on poorly drained alluvial plains.	E
RE 7.3.12	Mixed eucalypt open forest to woodland, dominated by <i>Eucalyptus tereticornis</i> and <i>Corymbia tessellaris</i> +/- <i>Melaleuca dealbata</i> , (or vine forest with these species as emergents). Lowland alluvial plains.	E
RE 7.3.19	<i>Corymbia intermedia</i> or <i>C. tessellaris</i> +/- <i>Eucalyptus tereticornis</i> open forest (or vine forest with these species as emergents) on well-drained alluvium.	OC
RE 7.3.20	<i>Corymbia intermedia</i> and <i>Syncarpia glomulifera</i> , or <i>C. intermedia</i> and <i>Eucalyptus pellita</i> , or <i>S. glomulifera</i> and <i>Allocasuarina</i> spp., or <i>E. cloeziana</i> , or <i>C. torelliana</i> open forest (or vine forest with these emergents) on alluvial fans at the base of ranges.	OC

RE 7.3.21	<i>Eucalyptus portuensis</i> +/- <i>Corymbia intermedia</i> open forest to woodland on alluvium on alluvial fans at the base of ranges.	OC
RE 7.3.25	<i>Melaleuca leucadendra</i> +/- vine forest species open forest to closed forest on alluvium fringing streams.	OC
RE 7.3.26	<i>Casuarina cunninghamiana</i> woodland to open forest on alluvium fringing streams.	E
RE 7.3.39	<i>Eucalyptus tereticornis</i> +/- <i>E. platyphylla</i> +/- <i>Corymbia intermedia</i> +/- <i>Lophostemon suaveolens</i> open woodland to open forest, and associated sedgelands and grasslands on broad drainage depressions of uplands.	OC
RE 7.3.40	<i>Eucalyptus tereticornis</i> open forest on well-drained alluvial plains of lowlands.	E
RE 7.3.44	<i>Eucalyptus leptophleba</i> , <i>Corymbia clarksoniana</i> open forest to woodland, on alluvium, in near-coastal areas with moderate rainfall.	E
RE 7.3.46	<i>Lophostemon suaveolens</i> open forest to woodland on alluvial plains.	E

Queensland Nature Conservation (Wildlife) Regulation 2006; 2) Commonwealth Environment Protection and Biodiversity Conservation Act 1999; 3) Queensland Vegetation Management Act 1999. E = Endangered; V = Vulnerable; NT = Near threatened; LC = Least concern; OC = Of concern.

7.3.2 Social and economic considerations

The implementation of this recovery plan is unlikely to cause significant adverse social and economic impacts. Habitat issues and likely impact on landholders have been considered in the Coastal Bioregions Regional Vegetation Management Codes for Broadscale Clearing and for Ongoing Clearing Purposes developed under the *Vegetation Management Act 1999*. The use of economic incentives for landholders to retain and manage Mahogany Glider habitat for conservation purposes is subject to funding or establishment of landholder initiative programs.

7.4 Affected interests

There are a range of land management uses within or adjacent to Mahogany Glider habitat. These include protected area estate, improved pasture and other forms of grazing, sugarcane, Caribbean pine plantations, bananas, pineapples, aquaculture and semi-rural development.

Although its distribution is restricted to the southern Wet Tropics coastal lowlands, the Mahogany Glider lives on land tenures owned or managed by various authorities and landholders, including:

- Queensland Department of Environment and Science (DES).
- Queensland Department of Natural Resources, Mines and Energy (DNRME).
- Queensland Department of Agriculture and Fisheries (DAF).
- Queensland Transport and Main Roads (TMR).
- Queensland Rail.
- Powerlink and Ergon Energy.
- Hinchinbrook and Cardwell Shires.
- Hancock's Queensland Plantations
- Aboriginal communities, councils and representative bodies.
- Private landholders and lessees.

In addition, there are a number of conservation and land management agencies that invest considerable cooperative expertise into recovery efforts towards the Mahogany Glider, including:

- Terrain Natural Resource Management (Terrain NRM).
- Peak conservation groups including the Wildlife Preservation Society Queensland (WPSQ), Tully Branch.
- Girringun Aboriginal Corporation and Girringun Ranger program.
- Scientific research organisations, including CSIRO and universities.

This recovery plan recognises the multiple land uses and values within the Mahogany Glider's distribution so, wherever possible, recovery actions are designed to advance the aspirations of all interested parties. The MGRT comprises representatives of groups with an active interest in the conservation of this species. All actions are designed to include land managers and/or landholders, including Traditional Owners, on any land directly affected by the actions.

7.5 Role and interest of Indigenous people

Implementation of this recovery plan incorporates the roles and interests of Aboriginal people in the Mahogany Glider's conservation. Aboriginal communities have been and will continue to be involved in collaborative efforts supporting Mahogany Glider recovery. Girringun Aboriginal Corporation is represented on the recovery team and the Girringun Ranger program plays an active role in conservation efforts and population monitoring including the setting of camera traps and the analysis of the images collected. Girringun represents the traditional owners in the southern Wet Tropics, including the five tribal groups on whose country Mahogany Gliders are found.

Aboriginal participation in all aspects of Mahogany Glider recovery can result in mutually beneficial sharing of knowledge, greatly enhancing conservation of the species. Some Aboriginal people want to be actively involved in the management and protection of the Mahogany Glider and its habitat through co-management arrangements, research, population monitoring and leading projects on country to both protect glider habitat and improve the health of country. Traditional cultural knowledge of the Mahogany Glider and its habitat should be, where appropriate and negotiated, considered in recovery plan projects.

8 MANAGEMENT PRACTICES AND GUIDANCE FOR DECISION MAKERS

8.1 Interaction with existing plans, policies and programs.

This recovery plan is influenced by, responds to, complements and/or overlaps a range of other strategies and plans, operating from national to property level, and with contrasting specificity of focus. This plan refers to many of these directly or has the potential to interact with them and, in most instances, does not intend to restate relevant actions or information contained in them. This plan does, however, seek to identify common approaches and actions between these existing plans and programs to provide an integrated and efficient approach to the management of threatened species across the distribution of Mahogany Glider. Activities defined in this plan will be brought to the attention of planners responsible for the development of future plans of management (in general, or for specific management issues, such as fire) for affected areas and regions, such that they can be explicitly included, or encompassed within broader activities, in such plans.

Management practices (policies, plans, strategies) that have a complementary role in supporting recovery of the Mahogany Glider include, but aren't limited to, the following:

National

- National recovery plan for the southern cassowary *Casuarius johnsonii* (2007)
- Approved Conservation Advice for Broad Leaf Tea-tree (*Melaleuca viridiflora*) Woodlands in High Rainfall Coastal North Queensland (2012).

- National recovery plan for the bare-rumped sheath-tail bat *Saccolaimus nudiclunatus* (2007).
- Approved Conservation Advice for *Myrmecodia beccarii* (2008).
- Threat abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi* (2014).
- Far North Queensland, Local Government, Regional Pest Management Strategy, 2010- 2015 (2010)

State

- Queensland Coastal Plan (2011)
- State Policy for Vegetation Management: Version 3 (2013)

Regional and Local

- Wet Tropics Plan for People and Country (2016)
- Wet Tropics Conservation Strategy: the conservation, rehabilitation and transmission to future generations of the Wet Tropics World Heritage Area (2004)
- Far North Queensland, Local Government, Regional Pest Management Strategy, 2010- 2015.
- Caring for Country and Culture - The Wet Tropics Aboriginal Cultural and Natural Resource Management Plan (2005).
- Townsville, Hinchinbrook and Cassowary Coast Local Government Area Biosecurity Management Plans
- Townsville, Hinchinbrook and Cassowary Coast local government planning schemes
- Girringun Region Indigenous Protected Areas Plan 2013-2023.

8.2 Guidance for decision makers

The EPBC Act *Significant Impact Guidelines 1.1 – Matters of National Environmental Significance* (Department of the Environment, 2013) sets out criteria under which an action may have a significant impact on an endangered species, such as the Mahogany Glider. Under these criteria, a proponent should consider carefully any actions that may impact the Mahogany Glider, which include:

- Clearing of vegetation, remnant or non-remnant, within any corridor that results in a loss of connectivity.
- Removal of known or potential den trees. A den tree is one that has hollows in which a Mahogany Glider seeks refuge in the day. Trees hollows used by Mahogany Gliders typically occur in living or dead tree of the family Myrtaceae that have a diameter at breast height (DBH, ~1.3m from the ground) of ≥ 20 cm (Jackson, 2000b).
- Loss or fragmentation of habitat associated with the conversion of tenure from leasehold to freehold, rural to rural/residential and/or other land tenures.
- Loss or fragmentation of habitat associated with Material Change of Use (MCU) applications.
- Loss or fragmentation of critical habitat and/or den trees associated with post-natural disaster clean-up.
- Inadequate management of remaining habitat through insufficient habitat management activities, such as inappropriate fire and weed management.

For example, an action may be considered to be significant if it disrupts the breeding cycle of a population. In addressing this potential impact, a proponent should consider the timing of the action, noting that it may be difficult to avoid the breeding season, considering the timing of the wet season (December to April). A proponent should also note that female gliders appear to be less likely to cross over roads than males (Asari *et al.*, 2010), and that fragmentation of habitat may therefore influence

the breeding cycle. Efforts should be made to maintain connectivity during construction, even if disruption is only temporary.

An action that results in the creation of gaps that exceed the average maximum glide distance (30 m) may, depending on the location, also result in a significant impact by fragmenting an existing population into two or more populations. This is particularly the case with actions that require clearing within priority wildlife corridors, as identified in the Mahogany Glider Recovery Plan Storymap (Terrain NRM, 2015; Fig. 2).

The section on Management Practices (Section 8, below) also provides information on measures to avoid or mitigate actions that may have a significant impact on the Mahogany Glider.

8.3 Management practices

8.3.1 Reducing habitat loss and fragmentation

The retention and effective management of the remaining Mahogany Glider habitat is critically important in ensuring the long-term viability of this species (Jackson, 2000e). An important part of this process has been to identify and prioritise wildlife corridors for protection, management and restoration (Jackson *et al.*, 2020). The function of corridors is to provide continuity between populations by maintaining or restoring natural linkages between isolated habitats (Bennett 1990). Corridors do this by assisting in the movement of animals throughout their range, which promotes gene flow between otherwise isolated populations, facilitates movement from degraded, and altered habitat. These environmental changes may become increasingly important in the face of climate change and increases the availability of food and den sites.

The areas that are considered the greatest priority for management and restoration are recognised as 'corridors', while others areas that are considered of secondarily important and can be part of the next phase of active management are referred to as 'linkages'. Linkages provide minor connectivity within populations and longer-term supplementary connections. Ultimately a managed network of habitat corridors and linkages across the landscape needs to be established. Figure 2 shows mapping of priority corridors and rates these corridors as very high, high, medium or low priority (Appendix 2).

Population and habitat mapping, coupled with on-ground assessment, were used to identify the strategic locations for corridors and linkages and determine which ones need to be enhanced, restored or created to enable the movement of Mahogany Gliders within and between populations. Where these corridors exist they may need to be widened, extended or have additional plantings added. Other areas will require restoration of habitat and/or the installation of glider poles or rope bridges, which have proven successful in facilitating glider movement between otherwise isolated fragments of habitat (Bennett, 1990; Ball & Goldingay, 2008; Goldingay *et al.*, 2004; 2011; 2013; Weston *et al.*, 2011).

In collaboration with landholders, restoration and management strategies will be developed for the highest priority corridors and adjacent habitat areas. Vegetation mapping and a series of corridor specific, landholder workshops will be conducted to further refine the threats and threat abatement actions required for each corridor. These strategies need to be reviewed every two years to assess the effectiveness of the restoration and/or management plans for priority corridors and habitat refuge areas that have been implemented in the previous years.

Corridor management and restoration on private property will primarily be achieved through incentives for landholders to undertake revegetation, installation of wildlife-friendly fencing, and implementation of appropriate fire regimes and weed reduction activities. Part of this process will involve working with landholders to reintroduce trees suitable for the Mahogany Glider (Table 6).

Corridors should ideally be in the form of habitat, however, in some cases it may be more appropriate (especially in the short-term) to install glider poles or rope bridges.

Where new development and infrastructure may occur, the best management strategy is one of avoidance, particularly avoiding removal of habitat and potential launch trees (also see section 8.4 Addressing road and easement threats).

When re-establishing wildlife corridors for Mahogany Gliders, it is important that the species composition of the plants is most beneficial to the Mahogany Glider (Table 6). Optimal habitat for the Mahogany Glider (Jackson, 1998; 2000d; 2000e) appears to consist of:

- 1) At least one species of bloodwood (e.g. *Corymbia clarksoniana* or *C. intermedia*),
- 2) At least two species of eucalypts including Poplar Gum (*Eucalyptus platyphylla*), Forest Red Gum (*E. tereticornis*), Red Mahogany (*E. pellita*) and/or Cadargi (*E. torelliana*).
- 3) One of two species of melaleucas including Cloudy tea Tree (*Melaleuca dealbata*), Long-leafed Paperbark (*Melaleuca leucadendra*), Broad-leafed Tea-tree (*M. viridiflora*) or Broad-leafed Paperbark (*M. quinquenervia*),
- 4) Two or more species of *Acacia* including Brown Salwood (*A. crassicaarpa*), *A. flavescens* and Brown Wattle (*A. mangium*),
- 5) *Albizia procera*, and
- 6) Johnson's Grass Tree (*Xanthorrhoea johnsoni*).

Table 5. List of plant species recommended for planting along corridors. * known food tree species. Taken from Jackson (1998).

Scientific Name	Common Name	Flowering Time	Ref.
<i>Acacia crassicaarpa</i> *	Brown Salwood	October-December (arils)	1,2,3
<i>Acacia flavescens</i> *	Wattle	October-November (arils)	1
<i>Acacia mangium</i> *	Wattle	October-January (arils)	1
<i>Albizia procera</i> *	Albizia	All year –sap	1
<i>Corymbia clarksoniana</i> *	Clarkson's Bloodwood	March-May	1,2,3,4
<i>Corymbia dallachiana</i>	Bloodwood	November-April	2,4
<i>Corymbia intermedia</i> *	Pink Bloodwood	November-April	1,2,3,5,6
<i>Corymbia tessellaris</i> *	Moreton Bay Ash	November-January	1,2,3,4,6
<i>Corymbia torelliana</i> *	Cadargi	July-November	1,4,6
<i>Eucalyptus portuensis</i>	Yellow Stringybark	October-February	1,2
<i>Eucalyptus drepanophylla</i>	Narrow-leaved Ironbark	November-July	1
<i>Eucalyptus pellita</i> *	Red Mahogany	January-March	1,3
<i>Eucalyptus platyphylla</i> *	Poplar Gum	September-October	1
<i>Eucalyptus tereticornis</i> *	Blue Gum	June-September	1,3
<i>Melaleuca dealbata</i> *	Cloudy Tea-tree	September-November	1,2,3
<i>Melaleuca leucadendra</i> *	Long-leafed Paperbark	June-July	1,2
<i>Melaleuca nervosa</i>	Paperbark / Tea-tree	May-September	2,7,8
<i>Melaleuca quinquenervia</i>	Coastal Tea-tree	May-July	2
<i>Melaleuca viridiflora</i> *	Broad-leafed Tea-tree	Jan.-Feb and May-Jul.	1

1 Pers. Obs.; 2 James Cook University, Townsville plant records; 3 Van Dyck, 1993; 4 Hill & Johnson, 1995; 5 Williams, 1979; 6 Brooker & Kleinig, 1994; 7 Tweddel, 1982; 8 Williams, 1984.

8.3.2 Addressing road/rail and easement threats

The width of roads and easements, such as powerlines, present dispersal barriers to Mahogany Gliders, particularly where the width exceeds the average glide distance of 30 m (Parsons & Latch 2006). Mahogany Glider conservation must be central to planning, construction, maintenance and

upgrading of transport and easement corridors, and where appropriate, all launch trees should be protected to maintain connectivity.

Priority launch trees are those with lateral branches > 20 m above the ground on each side of roads, railways, fencelines and easements including powerlines. Gaps between trees on each side of roads, railways, fencelines and easements should ideally not exceed 30m. Where it is not possible to avoid clearing a launch tree and mitigation is required, methods such as the installation of glide poles and/or rope bridges must be undertaken in accordance with best practice, to ensure connectivity is maintained. Glide poles should be installed at locations where wide roads (tree to tree gap > 30 m) intersect with Mahogany Glider corridors and linkages, and at known road kill sites, to facilitate movement across these gaps in habitat. Maintenance of transport and easement corridors also poses a risk to the condition of adjacent habitat as management actions can introduce and promote weeds of concern to adjacent vegetation and the continued, unplanned expansion of easement widths resulting from overspray during maintenance works can create new dispersal barriers if easements exceed a width of 30m.

8.3.3 Fire management and appropriate fire regimes

Significant areas of Mahogany Glider habitat are under threat from woody weed thickening, rainforest incursion and sclerophyll thickening due to altered fire regimes. These areas require the implementation of an active and ongoing fire management program that aims to restore the integrity of the sclerophyll forests.

Informed on-ground action is required to address rainforest incursion and sclerophyll thickening. Studies need to be undertaken to identify the most appropriate fire regimes to manage Mahogany Glider habitat. Studies need to consider appropriate fire regimes for controlling woody weed invasion, reducing rainforest expansion and sclerophyll thickening, and managing habitat within conservation areas and within areas subject to grazing. This research needs to identify the appropriate timing, frequency and intensity of fires required to address each of these threats, for each of the habitat types identified in Jackson *et al.*, 2011 (see also section 6.23; Action 1.2).

Using the best available science, guidelines need to be collaboratively developed for best management practice using fire. The guidelines should consider a balance between Mahogany Glider conservation needs and those of the grazing industry. Guidelines will be used to inform the development of a landholder targeted extension program, which will aim to increase the knowledge and capacity of landholders to implement appropriate fire regimes within Mahogany Glider habitat.

There is a need to assess the effectiveness of the extension program. A follow-up monitoring program needs to be developed to measure the level of adoption of appropriate fire management regimes, changes in vegetation quality and behaviour change exhibited by the participants to determine the overall success of the extension program.

8.3.4 Intensive grazing and weed invasion

A large proportion of the Mahogany Glider habitat that is under grazing management is contiguous, adjacent to protected area estate and considered optimal habitat. These areas are significantly degraded due to inappropriate grazing, fire regimes and the invasion of woody weeds. Apart from reducing the quality of Mahogany Glider habitat, these strategies are adversely impacting upon the profitability of graziers.

Best management practice guidelines for grazing in Mahogany Glider habitat need to be collaboratively developed, using best available science. The guidelines will need to consider a balance between Mahogany Glider conservation and the needs of the grazing industry. Guidelines will be used to inform the development of a management program. Management options may include extension programs coupled with incentives for the adoption of appropriate grazing regimes, revegetation and

management of high priority corridors and a reduction of listed weeds throughout high priority Mahogany Glider habitat refuge areas.

There is a need to assess the effectiveness of the management program and the overall success of the program. Therefore, a follow-up monitoring program needs to be developed to measure the level of adoption of appropriate grazing management regimes and other land conservation practices, changes in vegetation quality and behaviour change exhibited by the participants.

8.3.5 Fencing

A wildlife friendly-fencing information brochure is available, and will be promoted and distributed in the community. It describes suitable fencing designs appropriate to Mahogany Glider habitat, such as the use of a plain wire top strand, rather than barbed wire. High-risk areas will be assessed and priority sites targeted for action. Landholders will be encouraged to use a plain wire top strand when building new fences. Funding will be sought through such schemes as Nature Assist to reduce landholder costs for replacing barbed-wire top strands with plain wire in priority sites (Parsons & Latch, 2006).

To reduce the impact of barbed-wire fencing, it can be replaced with plain high-tensile fencing wire that, if tensioned correctly, can contain most stock. Alternatively, polypipe can be placed over existing barbed wire at key locations, such as adjacent to launch trees and within habitat gaps greater than 20 m.

8.3.6 Extreme environmental events

A post-cyclone recovery strategy for Mahogany Gliders needs to be developed, building upon the lessons learnt from Cyclone Yasi, to maximise the potential survival of Mahogany Glider populations after these extreme climatic events. This strategy includes preventing opportunistic habitat clearing, assessing the post-cyclone removal of damaged trees that may include den sites, and providing feeding stations and den boxes. The strategy will be developed in collaboration with government agencies, NRM bodies, researchers, disaster recovery groups and other relevant partners. Once developed, the Mahogany Glider post-cyclone recovery strategy needs to be adopted throughout all levels of government and implemented in the event of a cyclone.

8.3.7 Captive breeding, display, rehabilitation and release

A total of 19 Mahogany Gliders have required hand rearing, rehabilitation and/or continuing care due to permanent injuries, mostly involving barbed wire entanglements. Six of these animals were transferred to David Fleay Wildlife Park, where they have served as stock for a reproductive biology research project and a captive breeding program for the zoo community.

The Code of Practice – Care of Sick, Injured or Orphaned Protected Animals in Queensland (the Code), made under the NCA, guides the rehabilitation of sick, injured or orphaned protected animals in Queensland (State of Queensland 2013). The Code identifies that the main objective of wildlife rescue and rehabilitation is to relieve suffering, not to protect and preserve life at all costs. The rehabilitation and release of wildlife to the wild is the primary objective but must not be pursued at all costs or to achieve broader conservation outcomes where the animal may be subject to unreasonable suffering. Rehabilitation of Mahogany Gliders must be consistent with the Code. It is recommended that a protocol is developed for the care and rehabilitation of orphaned, injured or sick Mahogany Gliders that includes guidelines for the release of rehabilitated animals that is consistent with the Code.

Mahogany Gliders have been maintained in captivity since 1997, when they were first held by the David Fleay Wildlife Park in West Burleigh, Queensland and subsequently by several institutions including Currumbin Sanctuary, Dreamworld and the Native Wildlife Teaching and Research Facility at the Gatton campus of the University of Queensland. The Mahogany Glider has proved to be a relatively easy species to maintain in captivity, with its husbandry being similar to that required for other

petaurid gliders, especially the Squirrel Glider (Jackson, 2003; Whiteford & Booth, 2007; Vogelnest & Woods, 2008; Muller *et al.*, 2010). Several zoos and fauna parks in Queensland now house Mahogany Gliders as part of the breeding program and these act as education ambassadors. A detailed husbandry manual has been developed for this species by Jackson *et al.* (2018b) and growth and development data including growth curves for head length, ulna length, tail length and body weight have also been developed (Booth *et al.*, 2019).

There are various issues associated with long-term breeding programs that include:

- 1) sourcing a viable population of unrelated stock when establishing the captive colony;
- 2) maintaining high genetic diversity in captivity over the long term;
- 3) genetic adaptation to the captive environment;
- 4) domestication of captive animals;
- 5) disease outbreaks;
- 6) poor success in reintroductions;
- 7) high costs of maintaining captive populations, and
- 8) maintaining administrative continuity (Snyder *et al.*, 1996; Lynch & O'Hely, 2001; Frankham, 2008).

Any breeding program that proposes to release gliders needs to minimise the number of generations in captivity, in order to minimise the behavioural, genetic and phenotypic adaptation to captivity (*sensu* Frankham, 2008).

Currently, a captive breeding program for Mahogany Gliders is not recommended as a conservation outcome. There is no broad scale threat to the Mahogany Glider that would trigger the rapid and continual decline of the species, and there has been a limited loss in available habitat in recent years.

However, in an effort to ensure that prompt action can be taken in the event of a future broad scale threat emerging, triggers to inform the need to establish a captive breeding program need to be established. Any Mahogany Gliders that come into care and cannot be released, but do not require to be euthanised in accordance with the Code, must be referred to DES and will be considered for placement in the captive zoo population, to maintain the existing genetic diversity.

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APPENDIX 1: EVALUATION OF PREVIOUS RECOVERY PLAN

The overall objective of the 'Recovery Plan for the Mahogany Glider *Petaurus gracilis*' (Parsons & Latch 2006) was to secure and improve the conservation status of the Mahogany Glider through an integrated program of habitat protection and improvement, threat abatement and public awareness. Under the previous plan, there was some progress in establishing collaborative multi-agency projects, developing a framework for implementation of ongoing programs, networking with relevant stakeholders and monitoring of some populations. However, none of the recovery objectives of the previous plan have been completely achieved. Limited progress in meeting specific actions has been due to one, or a combination, of factors, including a lack of resources (particularly funding) and a lack of habitat mapping for condition and extent, along with extreme weather events.

A summary of actions implemented against each of the specific objectives under the 'Recovery Plan for the Mahogany Glider *Petaurus gracilis*' (Parsons & Latch 2006) are identified.

Specific Objective 1. Identify and prioritise areas of Mahogany Glider habitat for protection, management and recovery.

- Habitat maps have been updated to include pre-clearing habitat, habitat types based on Regional Ecosystems, areas where rainforest expansion and sclerophyll thickening are occurring and levels of transition in the Wet Tropics bioregion.
- Conservation areas for management actions have been identified and prioritised to some degree. Relevant Regional Ecosystems have been designated as one of four different usage types for clarity.
- Habitat corridors for protection, restoration and management have been identified and prioritised. Delays in this work have been experienced due to various organisational restructures.
- Strategies to conserve habitat on private land have been identified and commenced. These strategies need to be further coordinated through conservation and catchment planning.

Specific Objective 2. Improve Mahogany Glider habitat by managing grazing, fire and weeds.

- Habitats threatened by encroaching rainforest have been identified and assessed, and are available as a GIS overlay.
- Habitat recovery burns have been implemented at key sites, however, these burns do not currently match the level and rate of thickening and encroachment.
- Weed control has been challenging as weeds have expanded considerably in some areas. Some control works have been undertaken by public agencies and private landowners.
- Fifteen private land owners have been engaged in developing land management practices that balance conservation needs with other land uses. These practices have weed control, fire management, revegetation, wildlife-friendly fencing and installation of glide poles, as appropriate.

Specific Objective 3. Respond to and manage problems with easement corridors, barbed-wire fences and injured gliders.

- Threats arising from transport and easement corridors have not been reduced to any real extent, however, crossing poles are increasingly being installed/proposed as part of works.
- Wildlife-friendly fencing has been implemented on a small scale (41 km of this fencing has been installed across seven properties), however, this requires further support from public agencies.
- Care, rehabilitation and release protocols need to be formalised by relevant parties.

Specific Objective 4. Monitor Mahogany Glider populations and their habitat.

- Distribution limits are well defined for the species, however, populations and habitat monitoring has been limited due to lack of support from public agencies.
- Decreased rainforest expansion and sclerophyll thickening, along with road widening, have weakened connectivity along key corridors.
- Several papers have been published on species populations and habitat, however, improvements in co-ordination are required.

Specific Objective 5. Improve understanding of Mahogany Glider ecology and threats to its survival.

- Some improvement has been made in understanding ecology and threats, however, more is needed, especially in relation to corridor use, and the dispersal and movement of the species at the landscape scale.
- Work is required to understand the genetic structure of the species and appropriate fire regimes.

Specific Objective 6. Ensure recovery plan is operating with high levels of community participation.

- Community engagement has been undertaken in the form of school visits, community talks, presentations, media and events.
- Indigenous participation has been facilitated and promoted through training and assistance provided to Girringun, specifically to develop a monitoring program in the Ellerbeck area.
- Work is required to co-ordinate implementation of the recovery plan more effectively.

APPENDIX 2: SUMMARY OF PRIORITY CORRIDORS

Summary of corridors assessed within each of the 10 subpopulations. See Figure 2 for the location of subpopulations and corridors. Derived from Jackson *et al.* (2018).

Corridor No.	Subpopulation	Location	Priority	Total Length (km)	Gaps >30 m	Combined Gap Length (m)
1	Girramay	Murray River - lower	High	19.64	9	1,109
2	Girramay	Murray River - west	High	8.16	1	98
3	Girramay	Murray River - upper	High	14.06	9	679
4	Girramay	Murray River - Jumbun	Medium	4.13	3	805
5	Girramay	Barrett's Lagoon	High	5.61	3	544
6	Girramay	Bedfords	High	1.25	0	0
7	Girramay	Corduroy Creek - west	High	1.22	1	53
8	Girramay	Corduroy Creek	High	8.69	2	423
9	Girramay	Bilyana	High	6.38	4	311
10	Girramay	Appleyard	Medium	4.82	2	247
11	Girramay	Kennedy	Very High	4.93	2	369
12	Girramay	Deep Creek	Very High	4.22	0	0
13	Girramay	Dallachy Creek	High	5.99	3	256
14	Girramay	Dallachy Airstrip	Very High	1.49	2	999
15	Girramay	Whitfield Creek	Very High	5.25	0	0
16	Girramay and Cardwell Lowlands	Meunga - Lily Creek	Very High	9.95	7	1,028
17	Cardwell Lowlands	Ellerbeck west	High	5.9	0	0
18	Cardwell Lowlands	7 Sisters	High	9.61	3	191
19	Cardwell Lowlands	Cardwell Township	Very High	2.71	4	1,556
20	Cardwell Lowlands	Newman - Blady Grass Creeks	High	2.25	3	103
21	Cardwell Lowlands	Blady Grass Creek	High	2.46	1	89
22	Cardwell Lowlands	Conn Creek Spur	Very High	2.33	1	57
23	Broadwater	Gowrie	High	8.5	6	598
24	Broadwater	Elphinstone	High	11.65	1	206
25	Broadwater	Dalrymple	High	15.23	0	0
26	Broadwater	Mount Hawkins Foothills	High	12.1	3	169

27	Broadwater	Ripple Creek	High	1.46	1	49
28	Lannercost-Henrietta	Mount Farquarson (George Creek)	High	1.91	0	0
29	Lannercost-Henrietta	Lannercost State Forest (Lannercost Creek)	High	30.46	2	90
30	Lannercost-Henrietta and Wharps Holding-Paluma Range	Stone River (Venable Crossing - Sandy Creek)	Very High	28.26	20	1,898
31	Lannercost-Henrietta	Stone River - west	High	3.77	1	56
32	Wharps Holding-Paluma Range	Upper Stone River	Very High	15.06	5	301
33	Wharps Holding-Paluma Range and Halifax Bay	Toobanna - Cattle Creek	Very High	27.71	3	1,540
34	Wharps Holding-Paluma Range	Helen's Hill - Wharps	Very High	10.57	10	4,376
35	Wharps Holding-Paluma Range	Helen's Hill - Mt Poverty	High	3.74	4	1,043
36	Wharps Holding-Paluma Range and Halifax Bay	Helen's Hill (Leichhardt Creek)	Very High	14.38	0	0
37	Wharps Holding-Paluma Range	Helen's Hill (Waterview Creek)	Very High	1.15	0	0
38	Wharps Holding-Paluma Range	Allendale Creek	High	2.14	2	327
39	Wharps Holding-Paluma Range	Jourama Falls	High	0.91	0	0
40	Wharps Holding-Paluma Range	Bambaroo Foothills	High	8.35	3	206
41	Wharps Holding-Paluma Range	Bambaroo School	High	6.79	6	1,860
42	Wharps Holding-Paluma Range	Byabra Creek	High	5.37	5	778
43	Wharps Holding-Paluma Range	Moongobulla Area (Crystal Creek)	High	9.5	1	30
44	Wharps Holding-Paluma Range	Mutarnee Creek	High	2.11	1	115
45	Wharps Holding-Paluma Range	Moongobulla area (Little Crystal Creek)	Very High	5.51	2	183
46	Wharps Holding-Paluma Range	Moongobulla (Ollera Creek)	High	4.86	0	0
47	Wharps Holding-Paluma Range	Moongobulla Area (coastal link)	High	6.49	1	57
48	Upper Tully	Dingo Pocket	Low	19.65	15	2,306

49	Hull Heads	Mission Beach	Low	11.36	5	683
50	Hull Heads	Hull River	Low	14.61	5	227
51	Halifax Bay	Orient (Mungulla)	Medium	14.31	13	1,888
52	Halifax Bay	Orient	Medium	12.04	11	747
53	Rollingstone	Moongobulla Area (Hencamp Creek)	High	2.14	0	0
54	Rollingstone	Moongobulla Area (Rollingstone Creek)	High	7.41	0	0
55	Rollingstone	Moongobulla Area (upper Rollingstone Creek)	High	3.38	1	131
Average				8.25	3.40	523.29