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Habitat selection by two focal species; golden-tailed gecko and glossy black-cockatoo

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Executive summary

The APLNG EIS for the coal seam gas (CSG) fields and associated infrastructure of central and southern Queensland included the habitat of 99 species of animal of special conservation significance i.e. species that are listed as threatened or near-threatened under relevant legislation. For 11 species, the study area was considered to be of high or very high importance. Two of these species, the golden-tailed gecko (*Strophurus taenicauda*) and the glossy black-cockatoo (*Calyptorhynchus lathami*), were chosen as the focus for detailed assessments to understand the potential impacts of CSG development. These two species use the landscape at widely divergent spatial scales. The intention in choosing species that differ in the scale at which the landscape is used was to cover as widely as possible the range of impacts of CSG development on animal species of conservation concern.

Assessments of both species were undertaken during 2015 in the Surat Cumulative Management Area (CMA) of southern and central Queensland. The research involved desktop (assembling available records and carrying out bioclimatic modelling) and field-based components for both species.

We found that the golden-tailed gecko is relatively widespread within the Surat CMA and it is, in places, a common arboreal gecko. It was located across patches of all sizes including in patches of small size (down to 1.11 ha). It occurred at high abundance in some of these patches. Although not a factor we knew of at the outset of our research, we found that another commonly occurring arboreal gecko the dubious dtella (*Gehyra dubia*) was negatively correlated with golden-tailed gecko abundance. Small patches in particular showed a strongly negative association between the two species.

When examining the abundance of the golden-tailed gecko, the most important of the habitat variables we collected was the average basal area of trees. As this increased, especially above 22.8 cm, this species was more likely to be present. When we considered only the small patches, the main factors influencing presence and abundance of the golden-tailed gecko were the average basal area of white cypress (*Callitris glaucophylla*) and grazing (neglible/absent). Taken together, these findings characterise the golden-tailed gecko within the Surat CMA as a species that can occupy patches of all sizes if trees, especially white cypress, of sufficient basal area are present and there is no or limited grazing. These results indicate that the golden-tailed gecko has a tolerance of fragmentation.

The glossy black-cockatoo had a clumped distribution within the Surat CMA. Our bioclimatic model showed that most of the suitable habitat for the species occurs in the south-east third of the study area with smaller areas in the central and northern regions. Our assessment of records indicates that there are 6 'hotspots' of glossy black-cockatoo occurrence within the study area. The majority of these are centred on large areas of continuous forest, mostly national parks and state forests. During field surveys and while working in the Surat CMA we obtained very few recent records of the species. Although preliminary in nature, our results lead us to suggest that the glossy black-cockatoo is scarce within extensive cleared tracts of the Surat CMA and that its patchy distribution is centred on large areas of suitable remnant (uncleared) habitat. The species is clearly capably of

accessing small, relatively remote, patches of remnant vegetation in which to feed but does not appear to be resident within these.

We developed a set of five management recommendations for the golden-tailed gecko and seven recommendations for the glossy black-cockatoo. For the gecko, we recommend the maintenance of small patches of woodland, especially those containing white cypress, and assisting movement between patches by ensuring the presence of trees and shrubs in the grassland matrix between patches. For the cockatoo, we focus on protection and restoration of mature eucalypts and large patches of feeding habitat consisting of *Casuarina and Allocasuarina*.

1 Introduction

1.1 Rationale for the Current Project

The 1,470,000 ha study area covered by the APLNG EIS for the coal seam gas (CSG) fields and associated infrastructure included the habitat of 99 species of animal of conservation significance i.e. species that are listed as threatened or near-threatened under relevant legislation. These species either are known to occur or are considered to possibly occur within the CSG development region. Of these 99 species, the Australia Pacific LNG Project EIS (2010) developed a list of 11 species for which the study area was considered to be of high or very high importance (Table 8.6, page 31, volume 2, Chapter 8 of the EIS). Two of these 11 species were chosen as the focus for further survey and research to assess in more detail the potential impacts of CSG development. This is the work that is described and analysed in the current report.

The species selected for investigation were the golden-tailed gecko (*Strophurus taenicauda*) and the glossy black-cockatoo (*Calyptorhynchus lathami*). Each species is briefly described below along with an explanation of the rationale for choosing this particular combination of species. Existing knowledge on the conservation status, systematics and ecology of each species is summarised in section 1.2.

The golden-tailed gecko is a mostly arboreal, small lizard (70 mm snout-vent length) that feeds on invertebrates and is active at night. It occupies small (< 10 ha) home ranges within continuous vegetation and smaller fragments. The gecko is considered to be a characteristic 'Brigalow Belt' species; almost its entire range occurs within the Brigalow Belt North and South IBRA regions.

In contrast, the glossy black-cockatoo is a diurnal species that is distributed widely in eastern Australia. It moves widely across the landscape and has discrete requirements for foraging habitat (*Allocasuarina* and *Casuarina* seeds) and nesting habitat (large hollows in eucalypts). The glossy black-cockatoo is one of the largest hollow-nesting birds (body length up to 48 cm) in central Queensland and, as a consequence, requires large, old hollows in mature eucalypt trees in which to nest.

Limited information is currently available on the ecology of these two species and on their responses, at a population-level, to various disturbance regimes. This situation makes it difficult to predict what impact a particular disturbance regime, such as that associated with CSG, will have on populations of these species. As a consequence, the habitat use and response to disturbance of these two species were assessed in the current study. By choosing two species that use the landscape at widely divergent spatial scales, the intention was to cover as wide as possible the range of impacts of CSG development on threatened species. Management prescriptions for habitat are developed in this report to ensure the long-term persistence of the two species with CSG development. The golden-tailed gecko assessments focussed on the influence of habitat fragmentation and edge effects on the species. In contrast, the glossy black-cockatoo assessments attempted to understand how landscape connectivity, particularly the availability of feeding and nesting resources, may influence the species.

1.2 Synopsis of the Study Species

1.2.1 Golden-tailed Gecko

The golden-tailed gecko is listed as 'near threatened' under the Queensland *Nature Conservation Act*. It is not listed as 'threatened' nationally (*Environment Protection and Biodiversity Conservation Act*).

The golden-tailed gecko is a strikingly patterned species (Figure 1). It differs from other members of the genus *Strophurus* by its lack of spines or tubercles on the body and tail, and the presence of brightly coloured tail striping (Brown et al. 2012). There are three subspecies now recognised following the description of two subspecies by Brown et al. in 2012. The subspecies differ from each other in tail patterning, eye colour, and in the size of spots on the dorsal surface. *Strophurus t. taenicauda* (hereafter Southern golden-tailed gecko) has a red to orange eye, large dorsal spots (4–12 scales in size) and a single tail stripe with either undulating margins or transverse extensions. *Strophurus t. albiocularis* (hereafter Northern golden-tailed gecko) has a pale eye, small dorsal spots (1–8 scales in size) and a single tail stripe with straight edges. The third subspecies, *Strophurus t. triaureus* (hereafter Central golden-tailed gecko) has an amber eye, small dorsal spots (1–3 scales in size) and three tail stripes: one straight-edged dorsal stripe and two undulating lateral stripes (Brown et al. 2012).

All three subspecies of the golden-tailed gecko have their range focussed on the Brigalow Belt IBRA regions of Queensland. The distribution of the Southern golden-tailed gecko comprises the south-east of the Brigalow Belt South IBRA region. The Northern golden-tailed gecko occupies the northern half of the Brigalow Belt South and the southern half of the Brigalow Belt North, whereas the Central golden-tailed gecko has a limited range in the north-east section of the Brigalow Belt South IBRA region. The species was formerly considered to be confined to Queensland; however, records of the nominate subspecies from the Pilliga Scrub region of northern New South Wales were made in 1998, extending the known range of the species by >250 km south (Brown et al. 2012).

The golden-tailed gecko is common in a variety of regional ecosystems. The Southern golden-tailed gecko occurs in a wide range of vegetation types that are typified by the presence of *Acacia harpophylla* (brigalow), *Casuarina cristata* (belah), *Allocasuarina luehmannii* (bull oak), *Eucalyptus crebra* (narrow-leaved ironbark) and *Callitris glaucophylla* (white cypress) (Brown et al. 2012). The other two subspecies are considered by Brown et al. (2012) to be predominantly inhabitants of *Eucalyptus* woodlands. In a stratified study of the impact of thinning and logging of cypress forest on vertebrates, Eyre et al. (2015) found that the Southern golden-tailed gecko belonged to a group of reptiles that were associated with unthinned and unlogged sites, and whose presence was correlated with increased densities of large live eucalypts, litter cover, dead trees and small live trees.

The golden-tailed gecko is predominately arboreal (Figure 2). Individuals are most commonly found at night on the trunks and outer branches of trees but are also sometimes observed on the ground amongst leaf-litter or ground debris. It shelters during the day beneath loose bark in standing trees, particularly under dead bark on small saplings, and in tree hollows. They have also been found in a cryptic, "stretched-out" posture on relatively exposed branches of shrubs by day.

The potential impacts of CSG development on the golden-tailed gecko include: (i) the loss of more than 5,000 ha of potential habitat, (ii) direct mortality during clearing activities, (iii) creation of barriers to movement, and (iv) enhanced access to the species' habitat for introduced predators. In addition, populations of reptiles that live within linear remnants, such as roadside strips, are particularly vulnerable to disturbances that remove vegetation and essential microhabitat features, for example, rocks, logs, dense leaf litter and fallen bark. Therefore, this species may be impacted by a range of direct and indirect activities associated with CSG development.

Figure 1 Golden-tailed gecko, northern subspecies (*Strophurus taenicauda albiocularis*).

Image Eric Vanderduys

Figure 2 Golden-tailed gecko (circled) in typical "stretched out" posture on the outer branches of a dead shrub.

Image Eric Vanderduys

1.2.2 Glossy Black Cockatoo

The glossy black-cockatoo, *Calyptorhynchus lathami*, is listed as vulnerable under the Queensland Nature Conservation Act. It is not listed as threatened nationally (*Environment Protection and Biodiversity Conservation Act*).

The glossy black-cockatoo (Figure 3) is a large bird with a body length of up to 48 cm. The species occurs in low densities throughout eastern and south-eastern Australia and on Kangaroo Island, South Australia.

Figure 3 A pair of glossy black-cockatoos feeding on the seed cones of a Casuarina tree, probably Casuarina littoralis. The female, with yellow on the head, is on the right side. Image Graeme Chapman.

Research on the glossy black-cockatoo has come from two areas of the species' range; Kangaroo Island where the threatened subspecies *C. l. halmaturinus* occurs (Pepper 1996; 1997; Garnett et al. 1999; Pepper et al. 2000; Crowley & Garnett 2001) and Goonoo State Forest in central New South Wales (Cameron 2005, 2006 a, b, 2009, Cameron and Cunningham 2006).

Glossy black-cockatoos feed almost exclusively on the seeds produced by trees in the genera *Allocasuarina* and *Casuarina*. These trees produce woody barrel-shaped seed cones, generally 20-50 mm long. These seed cones contained many small, dry, 1-winged fruits known as samaras. Each samara contains a single seed. Seed cones are retained on the tree, rather than being dispersed, and do not usually release the seeds for more than a year. As a consequence, seed-bearing cones are available to glossy black-cockatoos all year round (Pepper et al. 2000); however, seed cone production drops during low rainfall periods (Cameron 2006a).

To access the seed within the cone, a glossy black-cockatoo uses its large bill to break off a cone and, while slowly turning the cone in its foot, shreds the cone (Figure 4). The seeds are then extracted from the shredded cone with the bird's tongue (Crowley & Garnett 2001). Birds select individual trees on the basis of cone abundance and profitability (i.e. kernel intake rate as measured by the ratio of seed weight to total seed and cone weight (Cameron & Cunningham 2006). Glossy black-cockatoos spend up to 50% of their time foraging. The median size of feeding groups is 3 with a range of 1 to 5 (Cameron 2005).

In Goonoo State Forest, central New South Wales, an inland locality with broadly similar climate and vegetation to central Queensland, glossy black-cockatoos nested only in large, old eucalypts. Recorded nest hollows were located in *Eucalyptus crebra* (narrow-leaved ironbark; n = 23), *E. nubila* (= *E. fibrosa* subsp. *nubila*, blue-leaved ironbark; n = 5), and *E. blakelyi* (Blakely's red gum; n = 3) (Cameron 2006b). These nest trees were typically large, with 80% having a diameter at breast height (including bark) of 60 cm (mean, 70 cm; range, 39–96 cm). Half of the nest hollows were in dead trees (snags). None of the nest trees had more than one nest hollow. Nest hollows were vertical or near vertical spouts (n = 24), trunk cavities exposed by the loss of a large branch at a fork in the trunk (n = 6), or trunk cavities with a side entrance (n = 1). The minimum entrance diameter of these nest hollows was 15 cm.

Both nesting and feeding sites are aggregated in the landscape. For example, at Goonoo State Forest, Cameron (2006b) found 5 aggregations, supporting 26 nests and ranging in size from 2 to 11 nests. An aggregation was defined as a group of two or more nests where no nest was more than 1 km from another (Cameron 2006b). Likewise, the availability of *Allocasuarina* cones was patchy at Goonoo State Forest both in space and time (Cameron 2006a). This aggregation of resources and the specific requirements for feeding and nesting habitat result in individuals of the species moving over large areas. As an example, an observer in 2015 located a nesting pair on Macleay Island, Morton Bay, south-east Queensland, that foraged each day on North Stradbroke Island, a minimum 1-way distance of 4 km (G. Ingram unpublished data).

The glossy black-cockatoo may be threatened by clearance, fragmentation or degradation of forests in which it forages and nests (Garnett et al. 2010). An important part of the remaining population of this species occurs within the CSG development area; however, little is known about the distribution or ecology of the species in Queensland. Therefore, it is difficult to specify the likely impacts of development. The potential impacts of CSG development on the glossy black-cockatoo are: (i) the loss of about 2,700 ha of potential habitat for the species, and (ii) increased competition for tree hollows used for nesting with other hollow-dependent species displaced by clearing of habitat.

Figure 4 A glossy black-cockatoo feeding on the cone of a Casuarina. Image Graeme Chapman.

1.3 Research Objectives

Given the information summarised in 1.2 (above), research objectives were formulated for each of the two species in relation to the current project. These objectives are detailed below.

1.3.1 Golden-tailed Gecko

The objectives of the golden-tailed gecko assessments were to understand how fragmentation and edge effects influence this species and to use this information to predict how it may be impacted by the development of CSG infrastructure and the operation phase of CSG activity. In particular, a focus of the work was to determine the size and location of fragments that the species occupied and the relationship between fragment size and presence of cypress on the abundance of the golden-tailed gecko. This approach was based on published work showing that the presence of golden-tailed gecko is indicated by characteristic of unlogged and unthinned cypress forest in the study area and that its presence is correlated with increased densities of large live eucalypts, litter cover, dead trees and small live trees (see section 1.2.1 above and Eyre et al. 2015).

1.3.2 Glossy Black-Cockatoo

The objectives of the glossy black-cockatoo assessments were, first, to characterise its occurrence in the study area using existing databases. This information was used to provide understanding of what level of landscape connectivity it requires. Subsequent field surveys were undertaken to determine the frequency of occupation of the area, the spatial distribution of glossy black-cockatoo ‘hotspots’ to each and to ascertain whether the area contained both feeding and nesting habitat.

2 Methods

2.1 General Methods

Field work for both species was undertaken during 2015. The field work took place within the Surat Cumulative Management Area (CMA) of southern and central Queensland. The Surat CMA overlaps broadly with the CSG development area. Field trips were carried out in February, August, October and November; we sought to balance the advantage of including seasonal variation in our sampling with the low activity of golden-tailed geckos in the cooler winter months. Species-specific methods and approaches are detailed below.

2.2 Methods for Golden-tailed Gecko

2.2.1 Survey Methods

Golden-tailed geckos are readily detected by "eyeshine" using appropriate head torches. Therefore, we chose to survey for the species at night using active searches for active individuals without any habitat destruction i.e. we did not strip bark or search leaf-litter. We felt that this approach maximised our chances of success as opposed to other approaches such as pitfall or funnel traps or bark stripping.

We undertook time constrained searches in known or inferred habitat within the golden-tailed geckos known and inferred range. Each search during the main stratified part of the study was 45 minutes in duration and involved 3 observers each with a head torch (Led Lenser H14R, Solingen, Germany). The same 3 observers under took all the surveys.

2.2.2 Survey Design

Two field programs were carried out on the golden-tailed gecko to assess the potential impact of fragmentation and edge effects on occurrence and abundance. The two programs are detailed below.

Field program 1 – stratified survey

The first program involved searches for the species in remnant vegetation of three patch sizes; small (≤10 ha), medium (10 – 100 ha), and large (≥100 ha). Regional Ecosystem (RE) and bioclimatic modelling was undertaken to identify REs in which golden-tailed geckos may occur within a modelled highly favourable bioclimatic extent. Potentially favourable REs (Figure 5a) were considered to be those that were mapped as containing *Callitris* spp. in the RE1 column of Queensland Government's Regional Ecosystem Description Database (REDD; Queensland Herbarium 2014). Bioclimatic suitability (Figure 5b) was modelled using MAXENT (Phillips et al. 2006), based on eight climatic variables (annual mean temperature, temperature seasonality, maximum temperature of warmest month, minimum temperature of coldest month, annual precipitation, precipitation of wettest month, precipitation of driest month, precipitation seasonality) at one km^2 resolution. We carried out a desktop study to identify potentially suitable habitat areas of different sizes in order to stratify our sampling across the three patch sizes. Small and medium remnant patches had to be mapped as being surrounded by non-remnant vegetation in order to qualify. All patches had to fall within the modelled high bioclimatic suitability extent in order to qualify.

We chose 3 broad geographic areas within the range of golden-tailed gecko in which to focus our attention. These areas were: southern (approximately between Chinchilla and Miles), central (north of Roma and west of Taroom), and northern (east and southeast of Blackwater and east to Duaringa). These areas are shown in Figure 5a. The first area is within the range of the Southern golden-tailed gecko, whereas the second and third are within the range of the Northern golden-tailed gecko. The Central golden-tailed gecko was not covered in the study because its known range is entirely outside the Surat CMA. These three geographic areas have extensive operational and/or exploratory gas drilling, though there are fewer wells in the north than the central and southern areas.

The survey design was such that we examined a minimum of three replicates of each patch size in each of the three geographic areas (9 combinations of region and patch with 3 replicates of each). A full set of surveys was carried out twice; once in February 2015 and once in October 2015. Each set of surveys was carried out over 9 to 10 nights (3-4 sites surveyed per night). The order in which sites of different size were surveyed was varied each night in an effort to prevent daily weather fluctuations influencing the results.

Field program 2 – survey of small area patches

The purpose of the second field program was to understand how the size and isolation of small patches affected occurrence of golden-tailed geckos. The program involved searches for the species in patches that were designated as small (i.e. < 10 ha) in the first field program. All sites in this program were in the southern geographic region (Figure 5) i.e. within the range of the Southern golden-tailed gecko. Nine small sites were surveyed on each of two nights and an additional two small sites on one night during November 2015. Each of these sites was < 4 ha in area except for one (Chinchilla cemetery) which consisted of a few groves of trees that were continuous with the urban area of Chinchilla i.e. this site did not support a vegetation patch per se. In addition, a large site (156.1 ha) and a medium site (23.01 ha), based on the patch size groups from field program 1, were surveyed on each of two nights during this period to ensure that conditions were not influencing search success

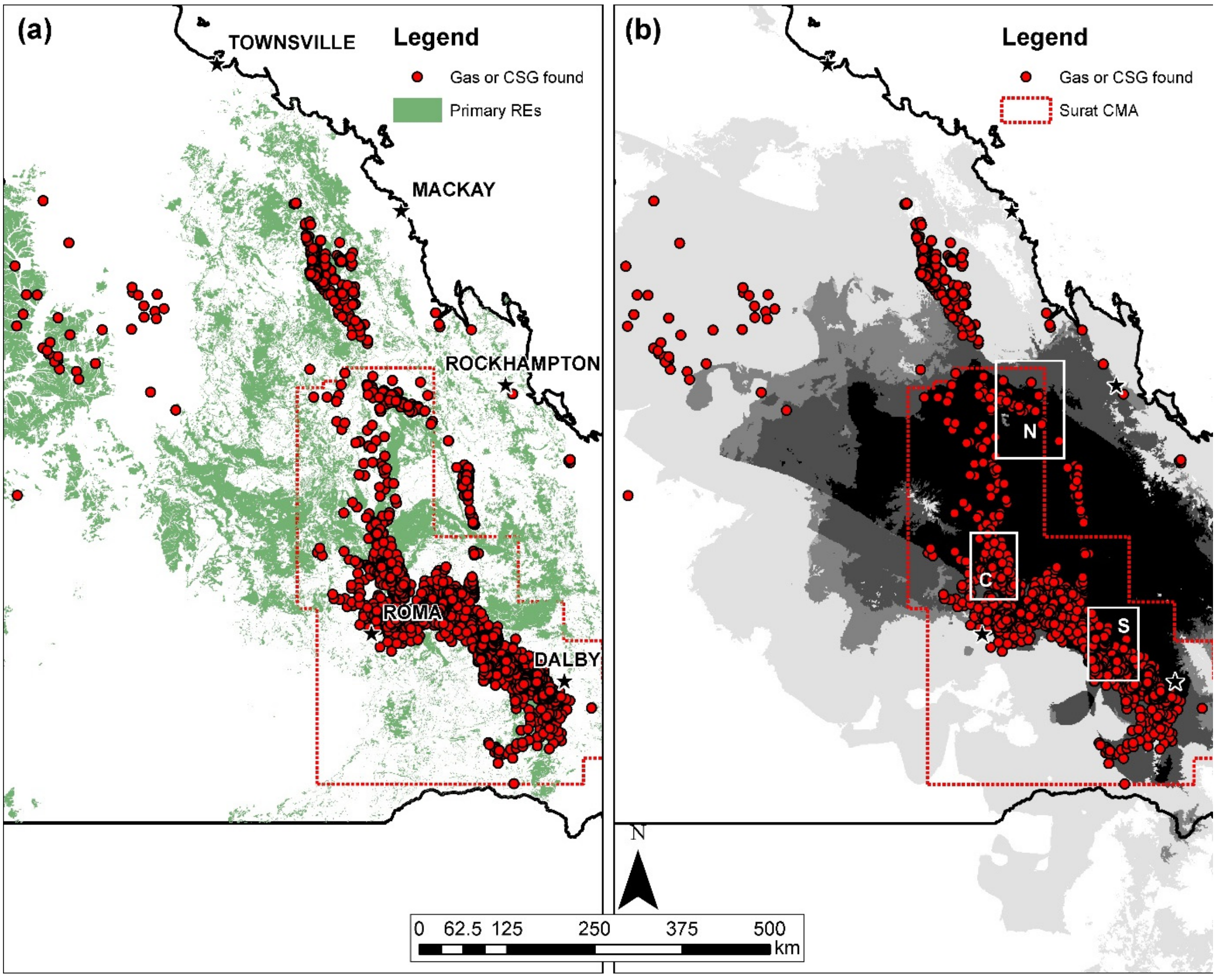

Figure 5 Maps showing (a) the location of gas wells in relation to primary REs mapped as containing *Callitris* species and (b) the separation of the Surat Cumulative Management Area (CMA) into three geographic blocks for the purposes of this study; S, south; C, central; and N, north. MAXENT-modelled bioclimatic suitability for golden-tailed geckos underlies (b), with black being high suitability through to white being unsuitable.

2.2.3 Habitat Surveys

We recorded a standardised set of habitat variables at each of the sites at which we surveyed for golden-tailed geckos. The habitat assessment was based on the methods of Neldner et al. 2012 (Table 8, p. 44) and is summarised below.

Four disturbance variables were scored on an ordinal scale. These variables and the measurement scales are listed here.

- Fire frequency. Scored as 0 (≤ 1 year since last burn), 1 (1-5 years since last burn), 2 (5-10 years since last burn) and 3 (>10 years since last burn).
- Weed extent. Ranged from 0 (not present) to 3 (widespread).
- Grazing impact. Ranged from 0 (none) to 3 (high).
- Erosion extent. Ranged from 0 (none) to 3 (high).

A 100 metre line transect was established centrally at each site and a number of vegetation structural and floristic variables were measured. These variables were; tree species richness, shrub species richness, basal area of all trees and basal area of white cypress. Basal area measurements were undertaken using the Bitterlich stick method at the 0, 50 and 100 m marks on the line transect. Averages of these three measures were used in the analyses. Five 1m2 quadrats were established along the 100 m line transects, at 25, 35, 45, 55 and 65 m and in each of these the % cover of bare ground, litter, native perennial grasses, native perennial herbs, native annuals, native shrubs, native trees, exotic herbs and shrubs, and exotic grasses was visually estimated.

In addition, the following landscape-scale spatial variables (or groups of variables) were recorded for each of the survey sites.

- Patch dimensions. This category included patch size (area in hectares), maximum length (in metres), and minimum width (in metres).
- Proximity to larger patches.
- Isolation. The length of time since the patch was isolated (only applicable to small and medium-sized patches).

2.3 Methods for Glossy Black-Cockatoo

2.3.1 Occurrence of Glossy Black-Cockatoo within the Surat Cumulative Management Area

Records of the glossy black-cockatoo were obtained from all available sources. These sources included:

- Atlas of Living Australia;
- Internal Origin Energy database (accessed on 8 January 2015);
- Internal CSIRO database (itself derived from Bird Atlas, Wildnet and a number of other sources).

The distribution of glossy black-cockatoo records was mapped within the Surat CMA at the scale of 1 km grid squares i.e. multiple records from the same 1 km grid square were removed for clarity.

2.3.2 Models of Glossy Black-Cockatoo Habitat Suitability

From Regional Ecosystem maps within the Brigalow Belt North, Brigalow Belt South, Mulga Lands, Southeast Queensland and Central Coast IBRA regions, we derived all REs where the primary RE (RE1 in REDD, see 2.2.2.1 above) contained the term *"Allocasuarina"*. *Allocasuarina* trees are the key food species for the cockatoos. Although glossy black-cockatoos feed on both *Allocasuarina* and *Casuarina* cones, various sources including Higgins (1999) and L. Gould (SEQ Catchments, pers. comm., July 2014), suggest that *Casuarina* is less important to the species than *Allocasuarina*. Seventy-eight REs were identified by this process. We buffered these mapped "*Allocasuarina* REs" by 2.5 km and selected any RE that contacted this 2.5 km buffer zone. In this way we derived a set of RE polygons that included all *Allocasuarina*, plus remnants that would be accessible to glossy black-cockatoos if they can travel a minimum of 2.5 km. This distance was chosen on the basis of discussions with L. Gould (SEQ Catchments, pers. comm., July 2014) suggesting that an unpublished draft habitat model for the species in the Southeast Queensland IBRA region buffered suitable feeding habitat by 2.5 km.

The process outlined in the paragraph above enabled a demarcation of potentially suitable habitat for the glossy black-cockatoo within the Surat CMA. We then modelled bioclimatically suitable areas for the species based upon all records from the sources listed above. We used the bioclimatically highly suitable areas to clip the RE map indicated in the previous paragraph, in the same manner used in Field program 1 – stratified survey above. This gave us a large area of potentially suitable habitat within the Surat CMA.

2.3.3 Field Searches

Glossy black-cockatoos were searched for within the Surat CMA using two approaches; a specific field-based survey and by incidental sightings. Details of the two approaches are provided below. Presence of birds was established through sightings and by the presence of the distinctive chewed *Casuarina* or *Allocasuarina* cones (referred to as 'orts') found below feeding trees (Figure 6). The detection and assessment of orts is detailed in Field based surveys section (below).

Figure 6 Chewed orts: the discarded cones that represent distinctive feeding signs of the glossy black-cockatoo found below *Allocasuarina* and *Casuarina* trees in which they have fed. The single seed has been carefully removed from each samara on the cone.

Field based surveys

We surveyed for glossy black-cockatoos in the southern and central region of the Surat CMA in August and October 2015, respectively. The area surveyed in the southern region extended roughly from Roma in the west to Pittsworth in the east, south to Surat and north to the Aberdeen camp (north of Yuleba). The central region surveys were within a 100 km radius of the town of Injune.

A total of 26 sites were visited. These sites were designated as either 'new' or 'previous record'. A 'new' site consisted of a large continuous patch of potential feed trees (*Casuarina* or *Allocasuarina*) that could be as large as 700 m in length. These new sites were located by extensive driving in a vehicle searching for potentially suitable habitat. This process was guided by the results of habitat modelling detailed in 2.3.2 (above). A 'previous record' site was one where the species had been detected before. In all cases birds had been seen feeding at these previous sites. The previous records were obtained from the data sources listed in 2.3.1. Previous sites were only inspected if the existing vegetation looked suitable as a feeding or nesting location for the glossy black-cockatoo. To ensure the suitability of sites, we focussed on locations from the Origin Energy database as these were the most recent (2010 onwards).

A site visit consisted of a detailed search of the area by 2 observers for a variable period of time that was generally >60 minutes per observer. Observers searched for birds, by sight and sound, and for signs of feeding activity. As a glossy black-cockatoo feeds on a seed cone, it partially or completely shreds the cone (Figure 4). After the seeds are obtained by the bird, the shredded cone is dropped below the feed tree (Figure 6), sometimes with branchlets that are nipped off in the feeding process. The shredded cones below feed trees are referred to as 'orts'. The presence of orts is evidence of feeding activity by the glossy black-cockatoo.

Feeding activity at a site was scored as 'recent', 'old' or 'none' as defined below.

- Recent - orts below feeding trees and which had been deposited within 12 months of the search.
- Old – orts below feeding trees and which had been deposited more than 12 months prior to the search.
- None – no signs of orts.

Incidental records

Incidental searches for glossy black-cockatoos were conducted during extensive field trips in the Surat CMA that were focussed on other activities. A total of 26 full days was spent by each of the 3 members of the project team in suitable glossy black-cockatoo habitat within the Surat CMA during the study period.

In addition, sightings of birds were reported to the authors by Origin Energy field staff during the study period. The location of these sightings were recorded and mapped. In all cases, sightings were accompanied by digital images of the birds and/or by collection of orts.

2.4 Statistical Analysis

Statistical analysis was undertaken on some of our datasets. The details of statistical analyses are provided briefly in the relevant subsection of the Results.

3 Results

3.1 Golden-tailed Gecko

We observed 11 species of gecko including the golden-tailed gecko during the surveys. The other gecko species observed were: Eastern stone gecko (*Diplodactylus vittatus*), dubious dtella (*Gehyra dubia*), chain-backed dtella (*Gehyra catenata*), Bynoe's gecko (*Heteronotia binoei*), box-patterned gecko (*Lucasium steindachneri*), prickly knob-tailed gecko (*Nephrurus asper*), ocellated velvet gecko (*Oedura monilis*), zigzag velvet gecko (*Amalosia rhombifer*), clouded velvet gecko (*Amalosia jacovae*) and robust velvet gecko (*Nebulifera robusta*).

The golden-tailed gecko was detected in 40% of small sites, 56% of medium sites and 78% of large sites across the study area. The most frequently recorded gecko was *Gehyra dubia*. It is an arboreal species that can occupy golden-tailed gecko habitat, but is much more widely distributed within Queensland, and occupies a wider variety of habitat types. The abundance of *G. dubia* and its overlap with our target species led to us considering it in our analyses. The rationale for this is that management actions that influence the abundance of *G. dubia* may potentially have direct or indirect impacts on populations of golden-tailed gecko. We wanted to consider the potential interaction between the two species in our analyses.

3.1.1 Influence of Patch Size on Abundance of Golden-tailed Gecko

Methods

The relationship between patch size and the abundance of a) golden-tailed gecko and b) *Gehyra dubia* was assessed using a nested analysis of variance (nested ANOVA). In this analysis, the response variable was the abundance of each of the two gecko species. The independent (explanatory) variable was patch size, a categorical variable with three levels (large, medium, small). The random effect was region (South, Central, North) with patch size nested within region. The error term was adjusted to reflect the nested effect of patch size within region. The analysis was carried out with gecko abundance summed across sampling times (February, October).

Results

Patch size did not have a statistically significant effect on the abundance of the golden-tailed gecko. Specifically, there were no differences in abundance of golden-tailed gecko ($F = 1.71$; d.f. = 2, 6; $P = 0.26$) across patches of different size-classes, after accounting for the effects of region (Figure 7). A similar pattern was found for Gehyra dubia ($F = 1.63$; d.f. = 2, 6; $P = 0.27$) (Figure 7).

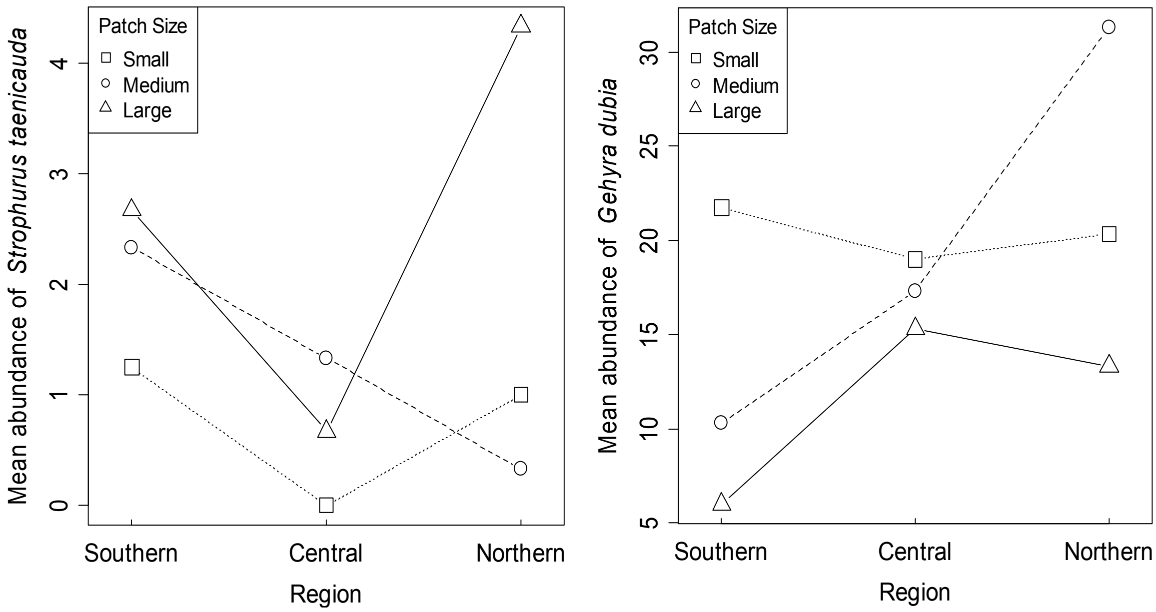

Figure 7 Abundance of the golden-tailed gecko (*Strophurus taenicauda*) (left panel) and the other commonly observed arboreal gecko the dubious dtella (*Gehyra dubia*) (right panel), as influenced by patch size, across southern, central and northern parts of its range in the Surat CMA of Queensland.

3.1.2 Influence of Patch Size and Abundance of Gehyra dubia on Abundance of Golden-tailed Gecko

Instead of treating patch size as a categorical variable, two sets of analyses that treate it as a continuous variable were considered. We carried out multiple regression analyses and path analysis as alternative approaches to examine the data.

Multiple Regression Models

Methods

We carried out multiple regression with abundance (log-transformed) of the golden-tailed gecko at each site as the response variable. The independent variables were patch size (ha) and the abundance of Gehyra dubia (log- transformed). We then used partial regression coefficients and partial plots to examine the effect of each variable independent of the effects of other variables.

Results

Stratified Survey. First, we assessed the influence of both patch size and the abundance of *Gehyra dubia* on the abundance of golden-tailed gecko using data from the stratified survey (February and October 2015; refer to section 2.2.2.1 for design details). The multiple regression model relating the abundance of golden-tailed gecko to *Gehyra dubia* abundance and patch area was marginally significant ($F = 3.08$; d.f. 2, 25; $p = 0.06$; $R2 = 0.13$). Examination of partial plots revealed that the influence of area on golden-tailed gecko was marginally positive ($F = 3.62$; d.f. = 1, 25; $P = 0.07$; Figure 8a), whereas the abundance of *Gehyra dubia* was negatively correlated with golden-tailed gecko abundance ($F = 2.54$; d.f. = 1, 25; $P = 0.12$; Figure 8b).

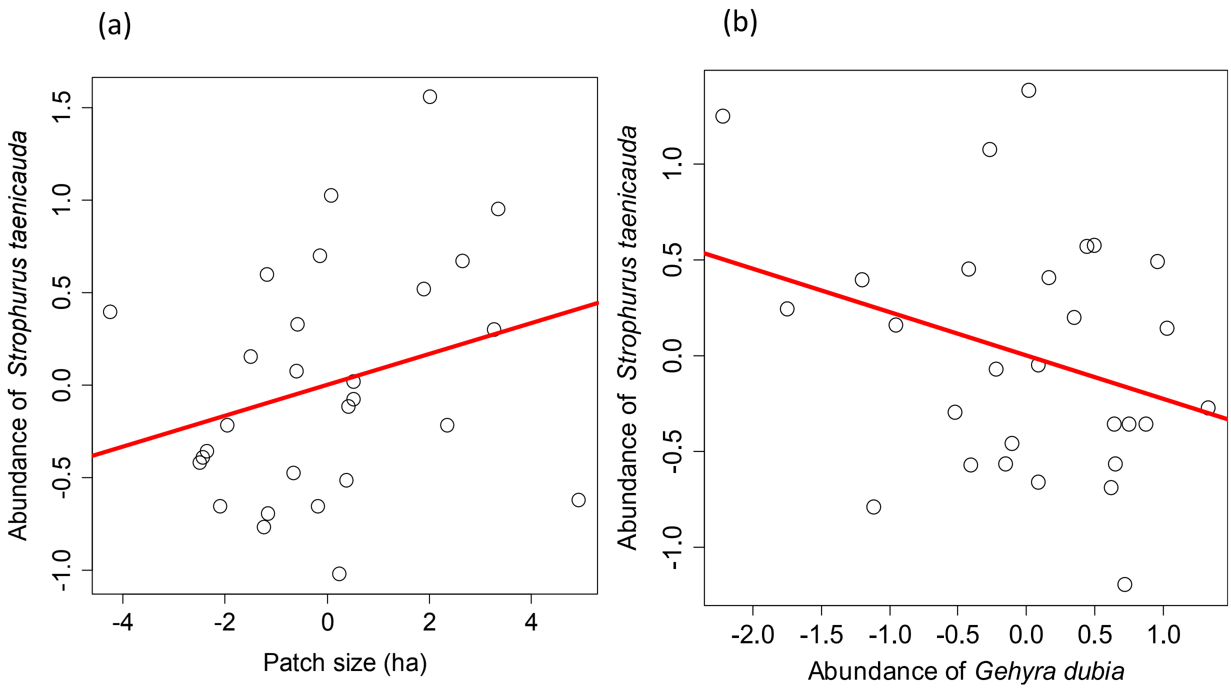

Figure 8 Partial regression plots showing the effect of (a) patch size (ha; log-transformed) and (b) abundance (log-transformed) of the dubious dtella (*Gehyra dubia*) on the abundance (log-transformed) of the golden-tailed gecko (*Strophurus taenicauda*), after controlling for the effects of other independent variables. Data are from the stratified surveys.

Survey of Small Sites. Next, we assessed the influence of both patch size and the abundance of *Gehyra dubia* on the abundance of golden-tailed gecko using data from the survey of small sites in the southern study region (November 2015; refer to section 2.2.2.2 for design details). The multiple regression model relating the abundance of golden-tailed gecko to *Gehyra dubia* abundance and patch area was statistically significant (F = 6.01; d.f. 2, 7; p = 0.03; R2 = 0.53). Examination of partial plots revealed that the influence of area on golden-tailed gecko abundance was not significant (F = 0.52; d.f. = 1, 7; P = 0.49; Figure 9a). In contrast, the abundance of *Gehyra dubia* appears to have a negative influence on golden-tailed gecko abundance (F = 12.50; d.f. = 1, 7; P = 0.01; Figure 9b).

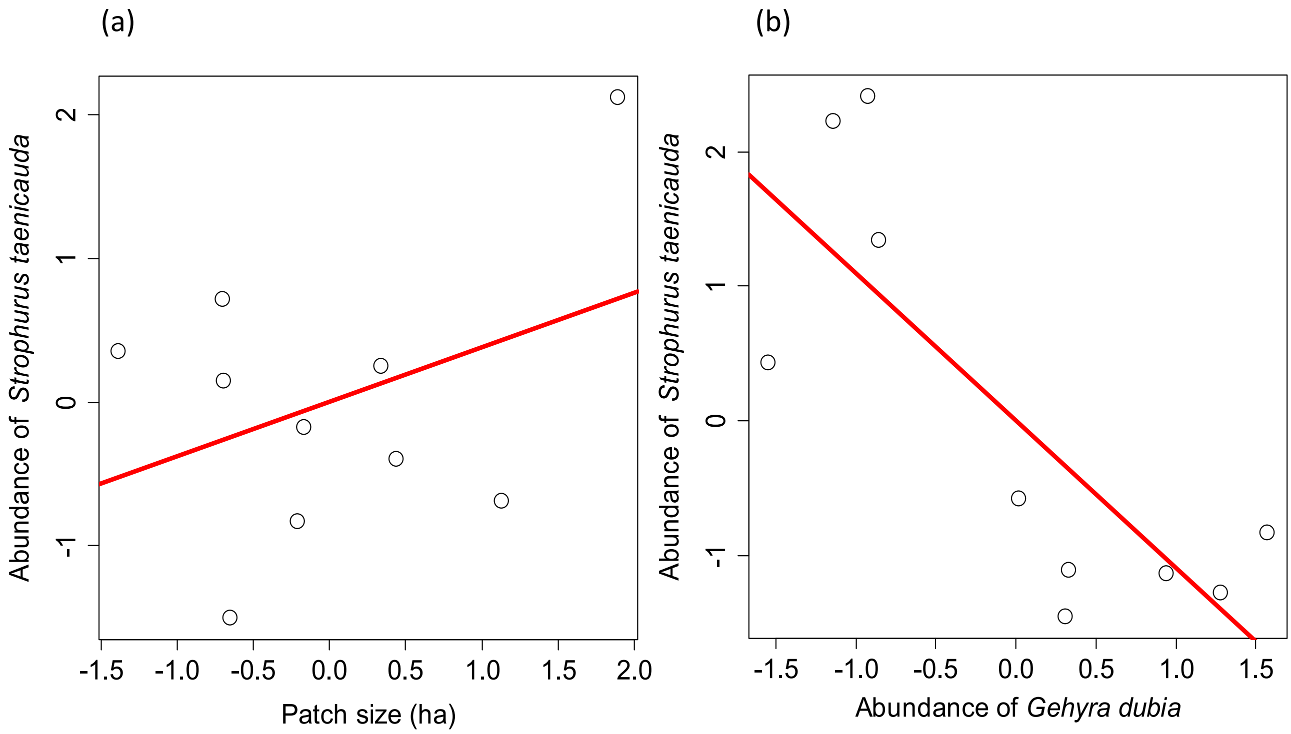

Figure 9 Partial regression plots showing the effect of (a) patch size (ha) and (b) abundance (log-transformed) of the dubious dtella (*Gehyra dubia*) on the abundance (log-transformed) of the golden-tailed gecko (*Strophurus taenicauda*), after controlling for the effects of other independent variables. Data are from the survey of small sites (< 10 ha).

Last, to determine if the pattern from the November surveys of small sites was consistent with the overall pattern across the study area, data from only the small sites surveyed during the stratified survey of the entire Surat CMA were examined. The multiple regression model relating the abundance of golden-tailed gecko to the abundance of *Gehyra dubia* and patch area was marginally significant (F = 3.81; d.f. 2, 5; p < 0.10; R2 = 0.45). Examination of partial plots revealed that the influence of area on golden-tailed gecko was not significant (F = 1.42; d.f. = 1, 5; P = 0.29; Figure 10a). In contrast, the abundance of *Gehyra dubia* appears to have a negative influence on the abundance of golden-tailed gecko (F = 6.19; d.f. = 1, 5; P = 0.055; Figure 10b).

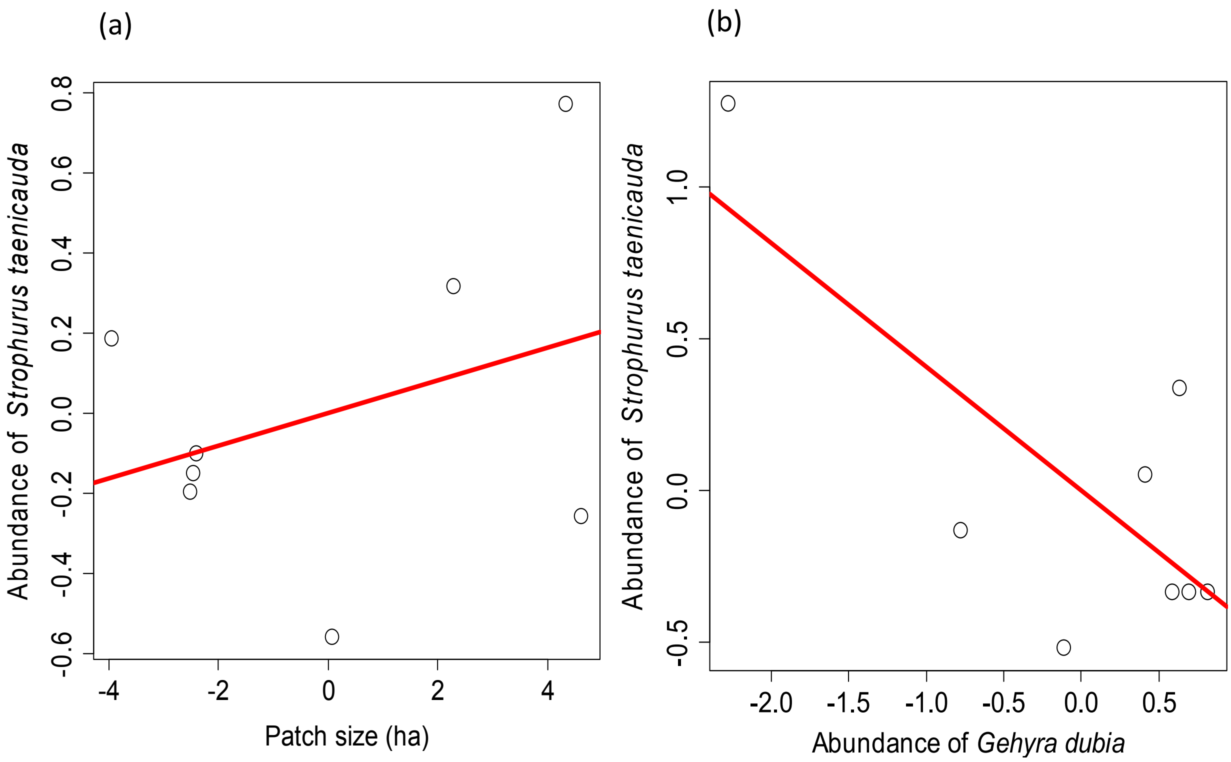

Figure 10 Partial regression plots showing the effect of (a) patch size (ha) and (b) abundance (log-transformed) of the dubious dtella (*Gehyra dubia*) on the abundance (log-transformed) of the golden-tailed gecko (*Strophurus taenicauda*), after controlling for the effects of other independent variables. Data are the subset of small (<10 ha) sites from the stratified surveys.

<u>Summary.</u> Across the three spatial scales of patch size (large, medium, small), the effect of patch size on the abundance of golden-tailed gecko is positive but weak (i.e. rarely statistically significant). At small patch sizes, the abundance of golden-tailed gecko is strongly negatively associated with the abundance of *Gehyra dubia*. This association may be the consequence of a direct negative impact or an indirect effect of patch area. These alternatives are explored in the analysis below.

Path Analysis

Methods

We carried out a path analysis as an alternative approach to multiple regression to examine the data. Path analyses (a subset of approaches that are broadly referred to as structural equation models) enable the simultaneous examination of the nature and magnitude of direct and indirect effects of multiple factors influencing a response variable (Grace, 2006). For these analyses, the response variable was again the abundance (log-transformed) of the golden-tailed gecko at each site. The independent variables were patch size (ha) and the abundance of *Gehyra dubia* (log-transformed).

Results

The general inference from the path analyses is the same from all three sources of data i.e. stratified survey (February 2015, October 2015; Figure 11a), survey of small sites (November 2015; Figure 11b) and the data from the subset of small sites (<10 ha) from the stratified surveys (February 2015, October 2015, Figure 11c). Examination of the fit indices indicated that the model was a good fit to all three datasets. The direct influence of patch area on the abundance of both golden-tailed gecko and *Gehyra dubia* was weak (and not statistically significant), but the negative effect of *Gehyra dubia* abundance on golden-tailed gecko abundance was statistically significant for all three datasets.

It is important to note that while the statistical models were a good fit, the overall variance in golden-tailed gecko abundance explained by the models was between 12 and 47% (see standardized path coefficients adjacent to arrow from ξ_2 in Figure 11). This result suggests that there is a need to consider other factors influencing the abundance of the golden-tailed gecko. We do this in the next subsection by considering the influence of habitat characteristics on the abundance of the species.

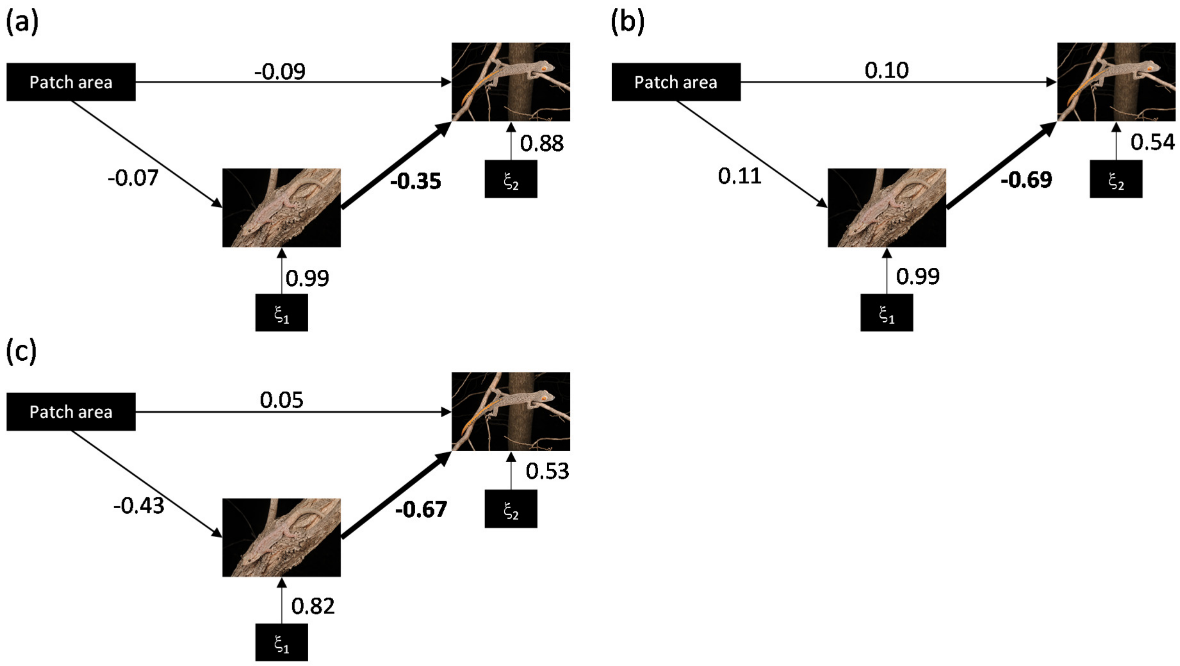

Figure 11 Path analyses showing the direct effect of patch size (ha) on the abundance of the dubious dtella (*Gehyra dubia*) and golden-tailed gecko (*Strophurus taenicauda*) and its indirect effect on golden-tailed gecko (i.e. via its influence on *Gehyra dubia*) for three datasets. The datasets are from: (a) stratified surveys spanning patches of different size, (b) a survey of small sites (<10 ha) and (c) a subset of the small sites (<10 ha) from the stratified survey. Abundance of golden-tailed gecko was log-transformed. Standardized coefficients are indicated above the arrows. Statistically significant ($p \leq 0.05$) paths are shown in bold. Residual variances in response variables are indicated adjacent to arrows from ξ.

3.1.3 Influence of Habitat Characteristics on Abundance of Golden-tailed Gecko

Methods

The relationship between habitat variables and the abundance of golden-tailed gecko was carried out using classification and regression tree analysis (CARTs). CARTs are a simple but analytically robust technique of describing variation in a single response variable through the splitting of multiple independent variables using a technique referred to as recursive binary partitioning (De'Ath & Fabricius 2000). CART algorithms work by selecting a single explanatory variable and a value for that variable, that best splits the dataset into two mutually-exclusive groups that are most homogenous. This process of splitting the dataset in to two mutually exclusive groups is repeated for each sub-group until a threshold is reached. CARTs can handle multiple types of covariates, collinearity and missing values, and they are relatively simple to construct and interpret. CART modelling can be used for both data exploration and prediction. This approach is valuable, and is used here, because CARTs can often detect patterns that are not obvious from linear modelling.

The independent variables used in our analyses were a subset of the habitat variables collected. This subset was based on the assessment of one of the authors (C. Pavey). The variables included in the analysis and whether they were on an ordinal or continuous scale were: wildfire (ordinal), grazing (ordinal), weeds (ordinal), erosion (ordinal), patch size (ordinal), basal area of non-cypress trees (continuous), basal area of white cypress trees (continuous), fallen woody material (continuous), % cover of trees (continuous); % cover of native shrubs (continuous), % cover of litter (continuous), and % cover of bare ground (continuous).

The response variable was either the presence/absence (binomial variable) of golden-tailed gecko, used in classification tree analysis, or the abundance (continuous variable) of golden-tailed gecko, used in regression tree analysis.

Results

For data from the stratified survey, a classification tree analysis revealed that the presence of golden-tailed geckos was influenced by the Average Basal Area (AVE_BA) at the site (Figure 12a). When AVE_BA was greater than 22.8 cm, the chance of the presence of golden-tailed gecko was about 90%; when below this threshold the likelihood of presence was about 38%. In regression tree analyses that used relative abundance of golden-tailed gecko (instead of presence/absence) as the response variable, the dominant partition in the dataset was the area of the site (Figure 12b). When the patch area exceeded 46 ha, golden-tailed gecko abundance was 2.46 ± 0.69 individuals/observation period (mean ± SE); when site area was below this threshold abundance was 0.73 ± 0.30 individuals/observation period.

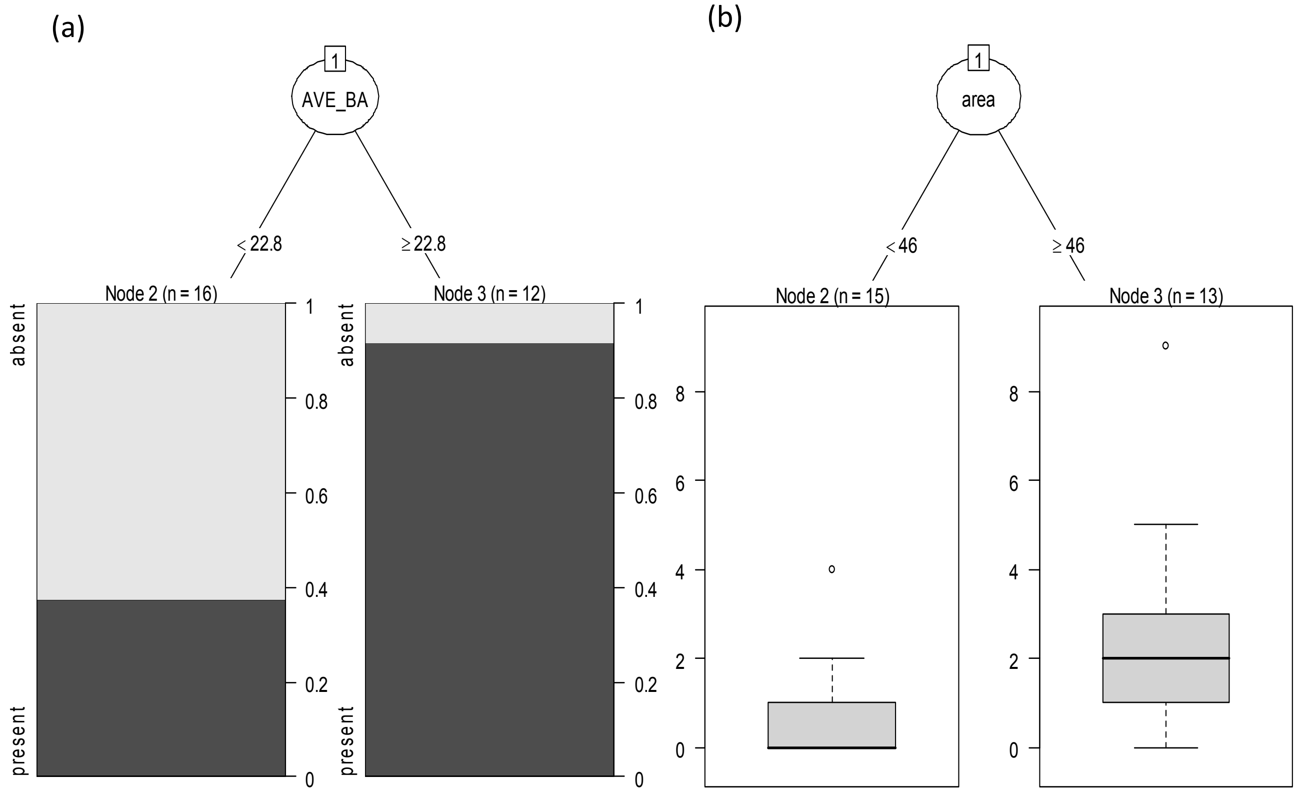

Figure 12 (a) Classification and (b) regression trees showing the effects of habitat attributes on the presence/absence and abundance of golden-tailed gecko, respectively, based on the stratified sampling.

For data from the survey of small sites (<10 ha), a classification tree analysis revealed that the presence/absence of golden-tailed gecko was equivalently influenced by Grazing (Figure 13a) and the Average Basal Area of white cypress (AVE_BA_Callitris) at the site (Figure 13b). When Grazing was negligible/absent or when Average Basal Area of white cypress was greater than 10.35 cm the chance of golden-tailed gecko presence was 100%; when these conditions were not met, the chance of golden-tailed gecko presence was about 17%. In regression tree analyses of the same dataset that used relative abundance of golden-tailed gecko (instead of presence/absence) as the response variable, the dominant partition in the dataset was again, equivalently, Grazing (Figure 14a) and Average Basal Area of white cypress at the site (Fig 14b). When Grazing was negligible/absent or when Average Basal Area of white cypress was greater than 10.35 cm, golden-tailed gecko abundance was 22.75 ± 11.85 individuals/observation period (mean ± SE); when these conditions were not met, gecko abundance was 0.17 ± 0.17 individuals/observation period.

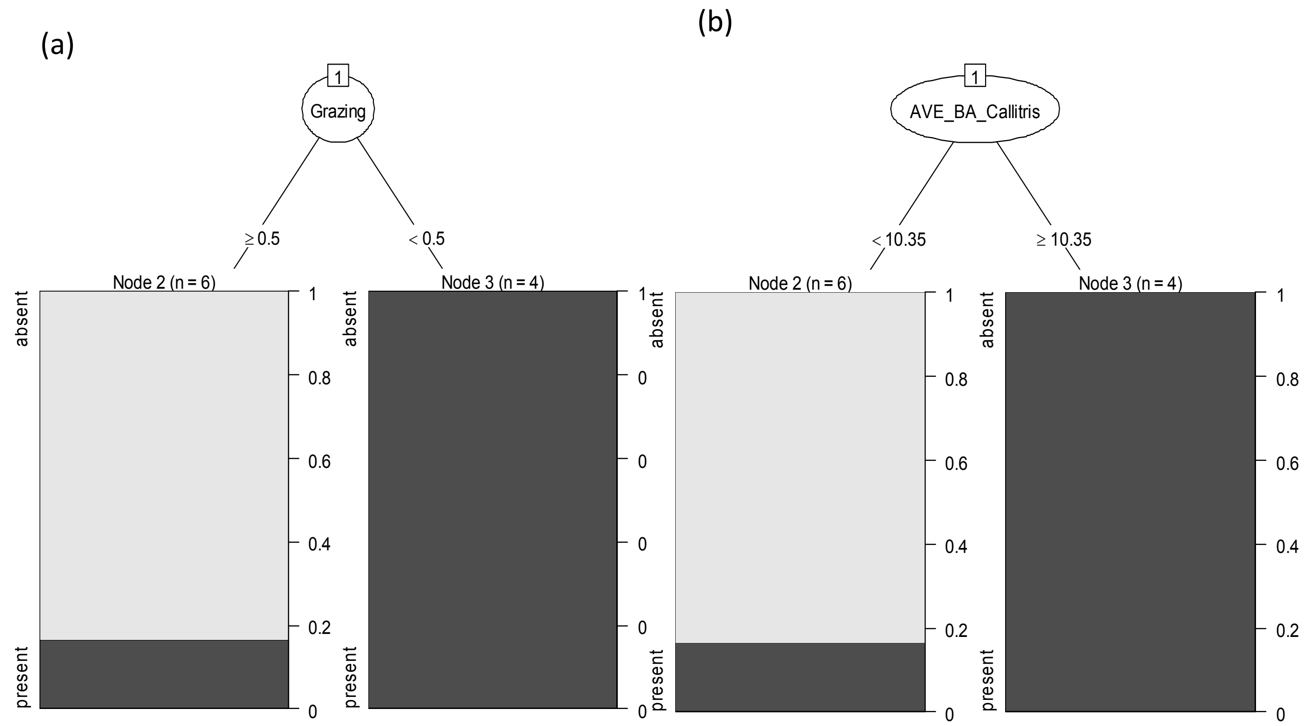

Figure 13 Classification trees showing the effects of habitat attributes on the presence/absence of golden-tailed gecko based on the survey of small sites. Figures (a) and (b) are equivalent trees as the analysis identified Grazing and Average Basal Area of white cypress as surrogate splits.

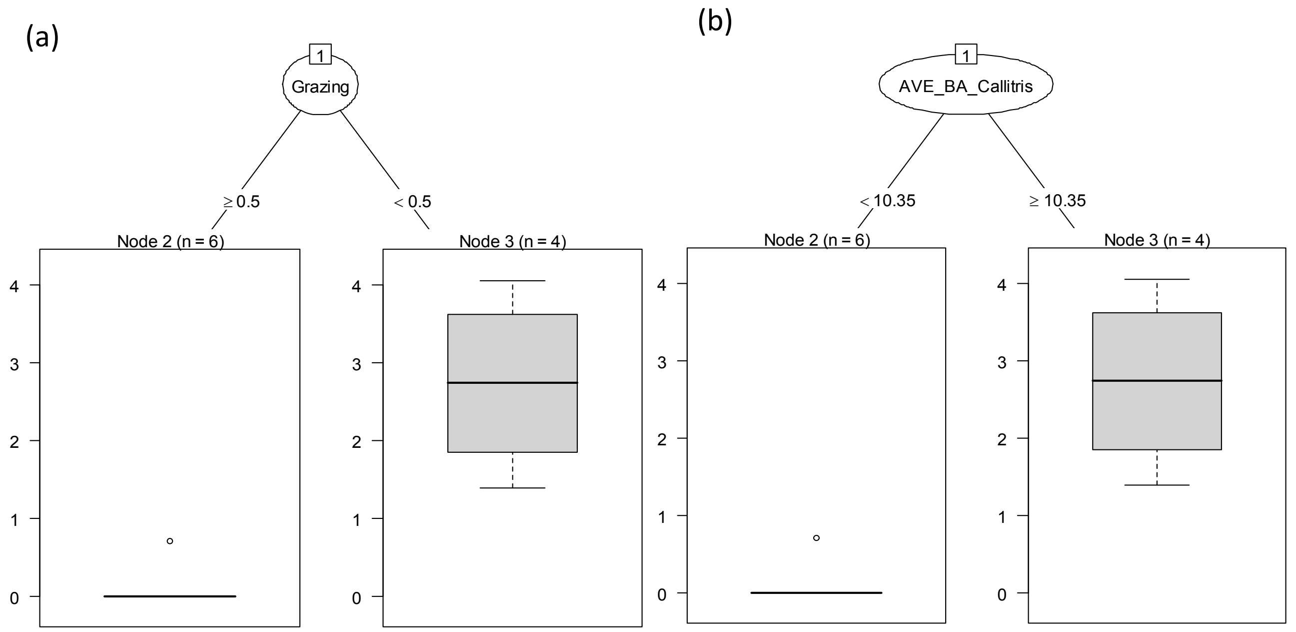

Figure 14 Regression trees showing the effects of habitat attributes on the abundance of golden-tailed gecko based on the survey of small sites. Figures (a) and (b) are equivalent trees as the analysis identified Grazing and Average Basal Area of white cypress as surrogate splits. Y-axis of terminal boxplots in (b) are on a natural log scale.

3.2 Glossy Black-Cockatoo

3.2.1 Occurrence of Glossy Black-Cockatoo within the Surat Cumulative Management Area

A large number of records were obtained of the glossy black-cockatoo within the Surat CMA (Figures 15 and 16). The distribution of the species within the region is highly clumped. The majority of records are from the vicinity of extensive forest areas.

3.2.2 Models of Glossy Black-Cockatoo Habitat

The bioclimatic model of glossy black-cockatoo habitat suitability (Figure 17) suggests that not all of the Surat CMA contains suitable habitat for the species. The majority of glossy black-cockatoo records are in the south-east third of the Surat CMA, concentrated in areas with extensive *Allocasuarina* REs and high bioclimatic suitability (compare Figures 16 and 17). Clusters of glossy black-cockatoo records in the west (southwest of Rolleston) and north (west of Duaringa) of the Surat CMA are also associated with relatively large *Allocasuarina* remnants within high bioclimatic suitability areas (Figures 16 and 17).

3.2.3 Field Searches

Detailed searches for glossy black-cockatoo took place at 26 sites. No birds were seen or heard but evidence of feeding was found at 19 (73%) sites (Table 1). However, evidence of recent feeding was only found at 2 sites. The subset of sites where evidence of feeding was the highest and where the only evidence of recent feeding was obtained were from sites from the Origin Energy database. Some of the older sites, especially those in the east of the study area, no longer supported suitable vegetation.

The project team obtained 1 incidental record of glossy black-cockatoo during the study. Four records of glossy black-cockatoo were provided by Origin Energy field staff during the study period.

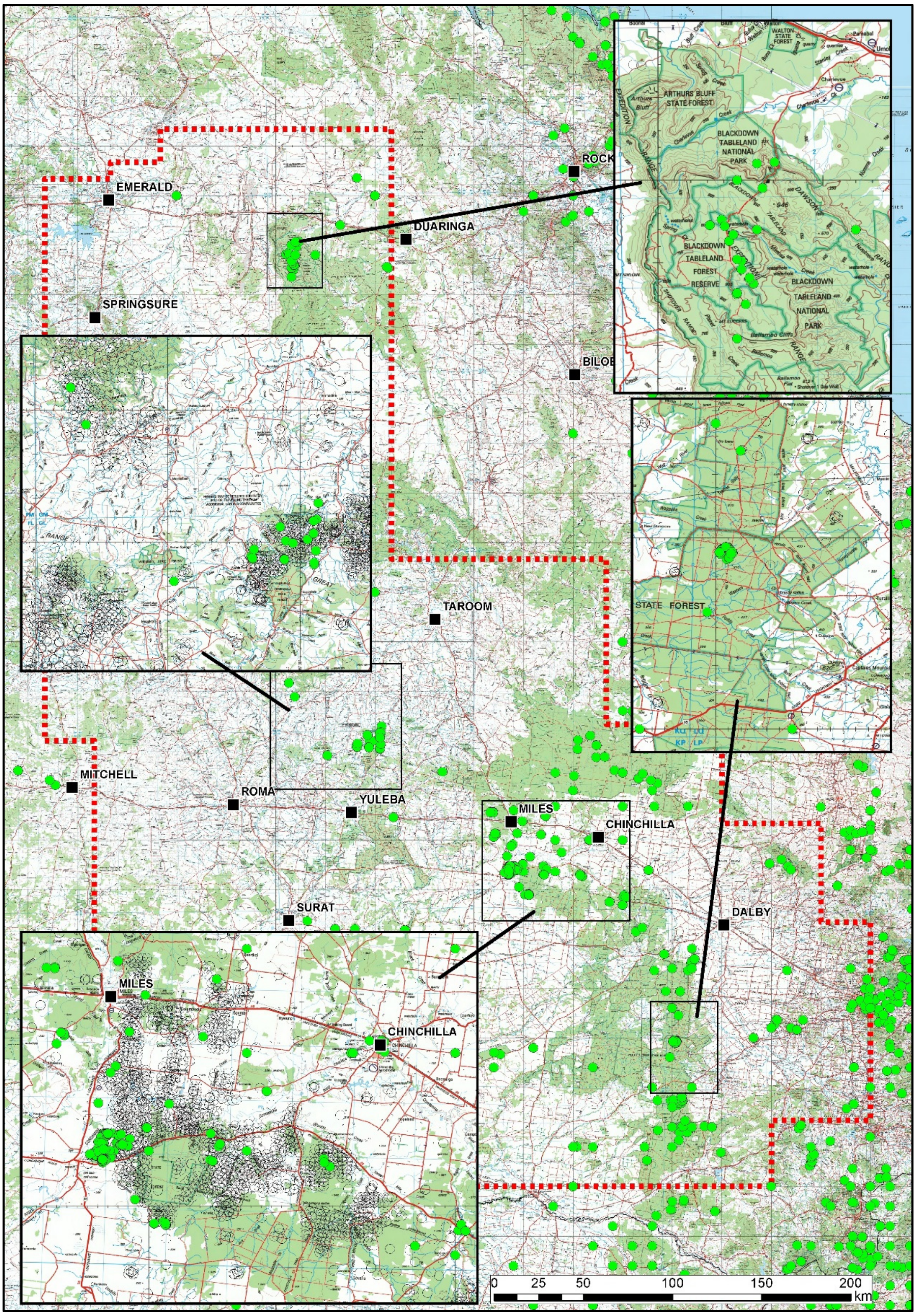

Figure 15 Records (filled green circles) of the glossy black-cockatoo within the Surat CMA (dotted red outline) with inset maps for, from north to south, Blackdown Tableland, Roma-Yuleba area, Miles-Chinchilla area and west of Moonie. Gas wells are shown as open black circles on inset maps.

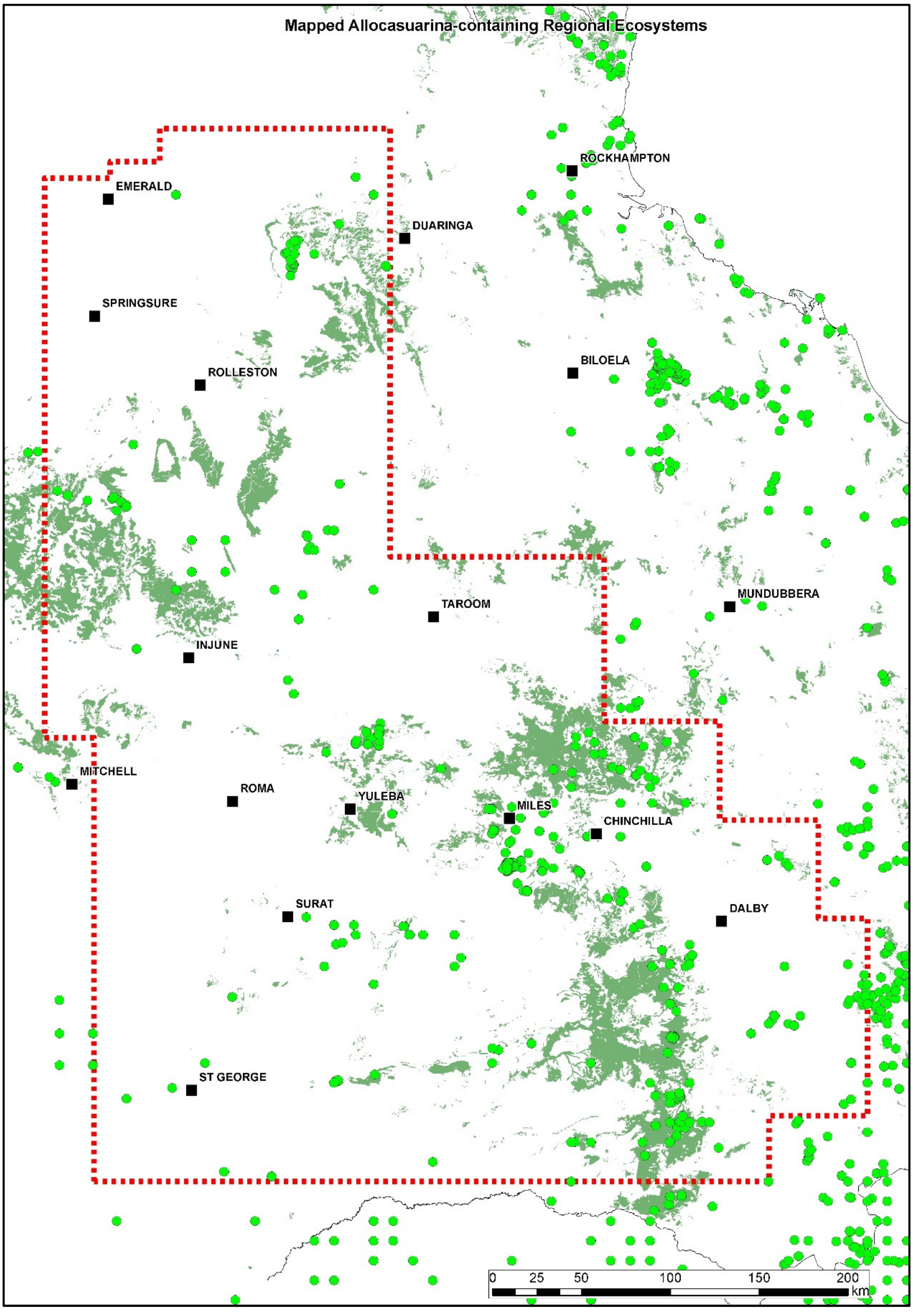

Figure 16 Records (filled green circles) of glossy black-cockatoo and areas with regional ecosystems containing Allocasuarina (dark green) within the Surat CMA.

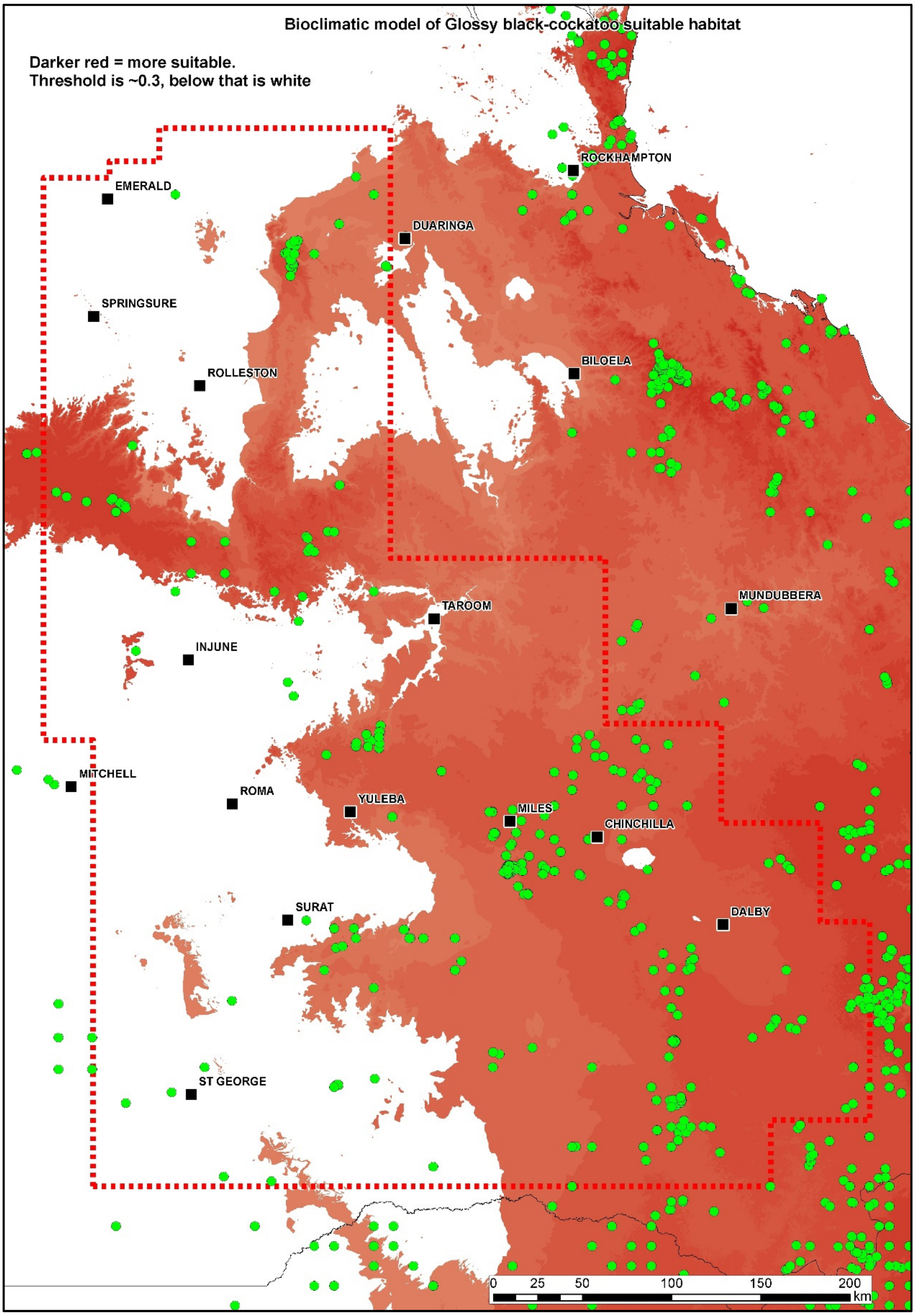

Figure 17 Bioclimatic model of glossy black-cockatoo habitat within the Surat CMA.

Table 1 A summary of results from field surveys for the glossy black-cockatoo in the southern and central areas of the Surat CMA. Each site visited (n = 26) was scored as either: recent - recently fallen orts; old – old orts present below trees; and none.

Type of records	Recent Cones	Old Cones	No evidence	Total
Origin Energy records	2	6	1	9
Other Sources	0	9	5	14
New Sites	0	2	1	3
TOTAL	2	17	7	26

4 Interpretation of Results

4.1 Golden-tailed Gecko

Our study shows that the golden-tailed gecko is a relatively widespread and, in places, a common arboreal gecko within the Surat CMA. The golden-tailed gecko was located across patches of all sizes including in patches of small size with a high edge to interior ratio. The smallest patch it was located in had an area of 1.11 ha; however, it was also located in isolated trees in parkland within the urban area of Chinchilla. The species occurred at high abundance in some of these patches. As an example, 12 and 9 individuals were observed during 2 nights of sampling at the 1.11 ha patch in November 2015.

Patch size was weakly positively correlated with golden-tailed gecko abundance. However, this relationship was rarely statistically significant. Although not a factor we knew of at the outset of our research, we found that the other commonly occurring arboreal gecko, *Gehyra dubia*, was negatively correlated with golden-tailed gecko abundance. Small patches in particular showed a strongly negative association between the two species. This negative correlation was recorded in areas where other factors were not significantly different, suggesting there may be a causal relationship between golden-tail gecko and *G. dubia* abundances. Whether this is because of aggressive interaction, competition or other factors that we did not measure cannot be determined from our study.

When examining the abundance of the golden-tailed gecko, the most important of the habitat variables we collected was the average basal area. As this increased, especially above 22.8 cm, this species was more likely to be present. When we replaced presence with abundance, the main positive influence on the species was the area of patches. When we considered only the survey of small patches, the main factors influencing presence and abundance of the golden-tailed gecko were the average basal area of white cypress and grazing. As average basal area of white cypress increased, the species was more likely to be present (and occur at a higher abundance) in small patches and was only likely to be present when grazing was low or absent.

Taken together, these findings characterise the golden-tailed gecko within the Surat CMA as a species that can occupy patches of all sizes if trees, especially white cypress, of sufficient basal area are present and if there is no or limited grazing. This suggests that the golden-tailed gecko has a tolerance to fragmentation.

4.2 Glossy Black-Cockatoo

Our study shows that the glossy black-cockatoo has a clumped distribution within the Surat CMA. Our bioclimatic model shows that most of the suitable habitat for the glossy black-cockatoo occurs in the south-east third of the study area with smaller areas in the central and northern regions.

The assessment of records that we carried out indicates that there are perhaps 6 'hotspots' of glossy black-cockatoo occurrence within the study area. The majority of these are centred on large areas of continuous forest, mostly national parks and state forests. Four of the 'hotspots' are in the south of the Surat CMA as detailed below.

1. An area of high CSG well activity from 25 to 50 km north of Yuleba – all the records from here are from the Origin Energy database.
2. In the Miles-Chinchilla region, both to the north and south of the Warrego Highway. The records to the north are almost all in areas of low CSG activity centred on Barakula State Forest. The records in the south are from an area of intense CSG development.
3. Within 125 km south-west and south-east of Dalby.
4. Within 100 km south-east of Surat.

There is little CSG activity in the last 2 hotspots.

There are also concentrations of records in the central and northern areas. Here records are concentrated on Blackdown Tableland National Park and Carnarvon National Park. CSG activity is minimal in these 2 hotspots.

During field surveys and while working in the Surat CMA, we obtained very few recent records of the species. Although preliminary in nature, our results lead us to suggest that the glossy black-cockatoo is scarce within extensive cleared tracts of the Surat CMA and that its patchy distribution is centred on large areas of suitable remnant (uncleared) habitat. The species is clearly capably of accessing small, relatively remote, patches of remnant vegetation in which it feeds but it does not appear to be resident within these patches. Therefore, clearing of habitat and any other pressure that results in the loss of suitable tree hollows (e.g. competition with more aggressive species) remain key issues for the conservation of the glossy black-cockatoo in the Surat CMA.

5 Management Recommendations

5.1 Golden-tailed Gecko

Golden-tailed geckos can persist in small patches of remnant vegetation within fragmented landscapes. The species' occupation of sites is related to the presence of large enough trees, particularly white cypress, in small patches. Based on these key findings we recommend the following management actions.

1. Manage the landscape such that small patches of trees (even as small as 1 ha) are maintained. This recommendation also applies to linear landscape elements such as groups of trees lining roads and fencerows.

2. Within small patches of trees, minimise disturbances that remove or kill trees, especially white cypress, with DBH >10 cm.
3. Ensure the presence of trees and/or shrubs in the matrix of grassland between habitat patches to increase the likelihood of individuals moving between patches.
4. If clearing of vegetation is essential, preferentially conserve patches of trees that contain a high proportion of white cypress.
5. Minimise access by cattle to patches of vegetation that may support the golden-tailed gecko.

5.2 Glossy Black-Cockatoo

The main management recommendations regarding this species involve the opportunity to manage and maintain suitable nesting habitat and to maintain and improve feeding habitat within the Surat CMA.

1. Minimise clearing of vegetation that supports mature hollow-bearing eucalypts and/or stands of *Casuarina* and *Allocasuarina*. Stands of vegetation that support both mature hollow-bearing eucalypts with *Casuarina* and *Allocasuarina* in close proximity should be especially protected. Apparent clumping of glossy black-cockatoo nests suggests that any nests identified within the Surat CMA should be identified in future management plans and buffers established around them to a distance of 1 km, where no large (>39 cm DBH), hollow-bearing eucalypts can be cleared.
2. Observe weed hygiene protocols to avoid the introduction of new weed species into valuable large tracks of remnant forest and woodland. This is a known risk, and especially important for weedy grass species that might significantly alter the potential fire regime in such tracts, e.g. *Megathyrsus maximus* (Guinea grass), and *Cenchrus ciliaris* (buffel grass). There may be other unknown weed species that could significantly alter forest and woodland composition; effective weed hygiene protocols are likely to be effective for these unknowns.
3. If clearing vegetation, maintain a minimum number of hollow-bearing individuals of eucalypt species, especially large ironbarks such as *Eucalyptus crebra* which are widely distributed throughout the Surat CMA. Any large tree (DBH >39 cm) that contains a hollow with the following criteria should be identified and maintained if possible: the hollow has an entrance ≥15 cm diameter; the hollow is in a stem angled at 45^{o} to vertical; the hollow is ≥8 m from the ground and; the hollow is in a branch ≥30 cm diameter. We recommend that five hollow-bearing trees per hectare be maintained.
4. If clearing vegetation, maintain all large (>0.5 ha) stands of *Allocasuarina* and *Casuarina*.
5. Minimise physical disturbance in the vicinity of hollow-bearing eucalypts during the nesting season i.e. March to August.
6. Revegetate disturbed patches of *Allocasuarina* and *Casuarina*.
7. Investigate the feasibility of providing artificial hollows (i.e. nest boxes) in stands of young eucalypts (i.e. those without hollow-bearing trees) that are within a 5 km radius of large stands of *Allocasuarina* and *Casuarina*.

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