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## THE CONDITION AND VULNERABILITY OF BLACKBUTT FOREST WITHIN THE GOLD COAST CITY COUNCIL LOCAL GOVERNMENT AREA

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### Abstract

The extent of Blackbutt Forest within the Gold Coast City Council Local Government area has declined since pre-European records to just 7% of its original extent, and now exists as endangered fragmented urban bushland. The preservation of this community in the landscape is important for the maintenance of biodiversity and parklands containing Blackbutt Forest contribute to urban bushland in an otherwise developed landscape. To better understand this endangered community and to inform conservation strategies, a vegetation condition assessment was undertaken using BioCondition - a benchmarking methodology developed by the Queensland Government. The vulnerability of Blackbutt Forest to threatening processes was predicted using a hierarchical decision tree based on land tenure, predicted risk of habitat loss and indirect threats from urbanisation. From the findings it was determined that Blackbutt Forest is vulnerable to threatening processes associated with urbanisation, particularly from land clearing, invasive species and altered fire regimes. Strategies to mitigate against threatening process should come from all levels of Government and the community by way of policy change, bushland management and education.

**Key Words:** Blackbutt; *Eucalyptus pilularis*; vegetation condition; vulnerability; threatening processes; biodiversity

### Introduction

One of the most significant global threats to biodiversity is habitat loss from land cover and landuse change (Lambin et al. 2001; Koh & Sodhi 2010). Human activities that cause landuse and land cover change are typically associated with vegetation clearing for agriculture, mining and urbanisation. Direct threats from vegetation clearing are habitat loss, fragmentation and isolation (St-Laurent et al. 2009; Czech 2000). More indirect or 'diffuse threats' are impacts from recreation, livestock grazing, inappropriate fire regimes, invasive species, pollution and disease (Earn et al. 2000; Franklin 1993; Gibbs 2001).

Urban development is a primary driver of landscape change and ecosystem modification. Natural landscapes are converted into a heterogeneous matrix of built environments, open space, road networks and fragmented remnant vegetation patches of differing sizes and quality (Garden et al 2010). Effects of these changes are well documented (McKinney 2006; Lambin et al. 2001; McDonald 2009) including reduced native species richness, increased extinctions, increased predators and invasive plants, and reduced biodiversity.

Southeast Queensland (SEQ) including the Gold Coast City Council (GCCC) Local Government Area (LGA) is one of the most biodiverse regions in Australia, however, urban development pressures are putting biodiversity at risk. Key threat issues specific to this area are native vegetation loss, landuse change and climate change (GCCC 2009).

One consequence of these key threat issues is the potential for the extent of native vegetation to be reduced to a level where it is classified as endangered. Under the Queensland Government's *Vegetation Management Act 1999* (VMA), discreet vegetation communities are described as regional ecosystems (REs) and endangered REs are defined as areas of remnant vegetation containing either a) less than 10% of the pre-clearing extent of the regional ecosystem; b) between 10 – 30% of the pre-clear extent if there is less than 10 000Ha remaining.

One such vegetation community that has become endangered due to historic and current land clearing practices is *Eucalyptus pilularis* Open Forest (Blackbutt Forest). This community, classified as Regional Ecosystem 12.11.23 (DERM 2010), is found only on low coastal metamorphics and interbedded volcanics, endemic to South Eastern Queensland (SEQ), specifically to the Gold Coast and Redland Bay areas south of Brisbane.

The community exists as Open Woodland and Tall Open Forest with the dominant canopy species *E. pilularis*. Threatened flora and many plants of local significance are associated with this system. In its remnant form large trees provide habitat for fauna, particularly avian and arboreal species. Blackbutt trees are aesthetically significant and urban parklands containing Blackbutt Forest provide bushland context in an otherwise developed landscape.

Blackbutt Forest now exists as a fragmented vegetation community listed as endangered under Schedule 1 of the *Vegetation Management Regulation 2000* (QLD).

In 2007 the GCCC LGA recorded the largest population increase (17,900) of all Australian LGAs (Australian Bureau of Statistics 2007) and population predictions forecast an increase from 496,906 to 900 000 in 2030 (Gold Coast City Council 2009). Urban development required to support population growth results in land cover and landuse change from expanding residential areas, road upgrades, provision of water and electricity, and increased recreational demands. In addition to direct and indirect threats already mentioned, Blackbutt Forest is not well represented in protected areas within the Gold Coast region (Queensland Herbarium 2009) potentially putting this vegetation community at a high risk of further decline from urbanisation, and in need of conservation management.

The Queensland Government uses regional ecosystem mapping supported by site based data as a primary tool for landscape planning and conservation. These systems are based on landform, geology, soils and floristics, and show a general measure of biodiversity (Neldner 2003; Salter and Williams 1999). While regional ecosystem mapping provides important information on vegetation distribution and changes (Lawson 2006a) it provides little information on vegetation condition. Condition is important because it provides a tool for effective biodiversity management, defines triggers for resource management and a medium through which funding and regulation can be transferred to on-ground actions (Gibbons 2006). Vegetation condition also informs regulators when assessing vegetation clearing applications, offset proposals and determining incentive payments (Keith & Gorrod, 2006). Consequently, vegetation assessments including condition are required to better inform landscape planning and conservation (Wilson 2002).

This paper presents the findings of a vegetation condition and vulnerability assessment of the endangered Blackbutt Forest in the GCCC LGA.

In doing so, the paper also identifies threatening processes and aims to establish an understanding of the vulnerability of the Blackbutt Forest to these processes.

Results of this project are aimed at informing conservation policy at the local and state government level, specifically in relation to endangered Blackbutt Forest protection and management within the Gold Coast area. Importantly, the methodology and results of this assessment can be used to inform regulators of other endangered and fragmented forest types.

## **Methods**

### ***Study Region***

Blackbutt Forest exists as a fragmented representation of its pre-clear extent within the Gold Coast and Redland Bay areas. The southern Gold Coast community was identified as being at greater risk of threatening process due to landscape and demographic conditions, and as such this project is focussed on the Blackbutt Forest communities within the GCCC LGA. Blackbutt Forest communities defined for the purpose of this project are those displayed in DERM regional ecosystem mapping (version 6) as a polygon containing RE 12.11.23 100%. It is recognised that additional communities of Blackbutt Forest are located in the Tugun and Currumbin areas which are mapped as mixed polygons containing different REs. While these communities were not included in this assessment, it is recommended they are considered in future vulnerability assessments. Table 1 describes the distribution of Blackbutt Forest.

**Table 1: Distribution of Blackbutt Forest in the GCCC LGA**

	<b>Gold Coast Community (Ha)</b>
Pre-Clear Blackbutt Forest	7 824
Total Remaining Blackbutt Forest	554
Extent of Blackbutt Forest located within the Urban Footprint	413

The GCCC LGA, for the purpose of this project, is defined by land south of the Logan River and north of the QLD/NSW state border (Fig 1). This region is Australia's fastest growing metropolitan area (Department of Infrastructure and Planning 2009) resulting in on-going changes to land cover and landuse for housing and infrastructure. Between 1998 and 2005, 422 Ha of vegetation was cleared on average per year (GCCC 2009), leaving 49% of the city area covered by native vegetation.

Of this remaining native vegetation, 14% occurs within the urban footprint<sup>1</sup>, which is the area designated for future urban development, and this is the area where 74.5% of remaining Blackbutt Forest of the Gold Coast area exists.

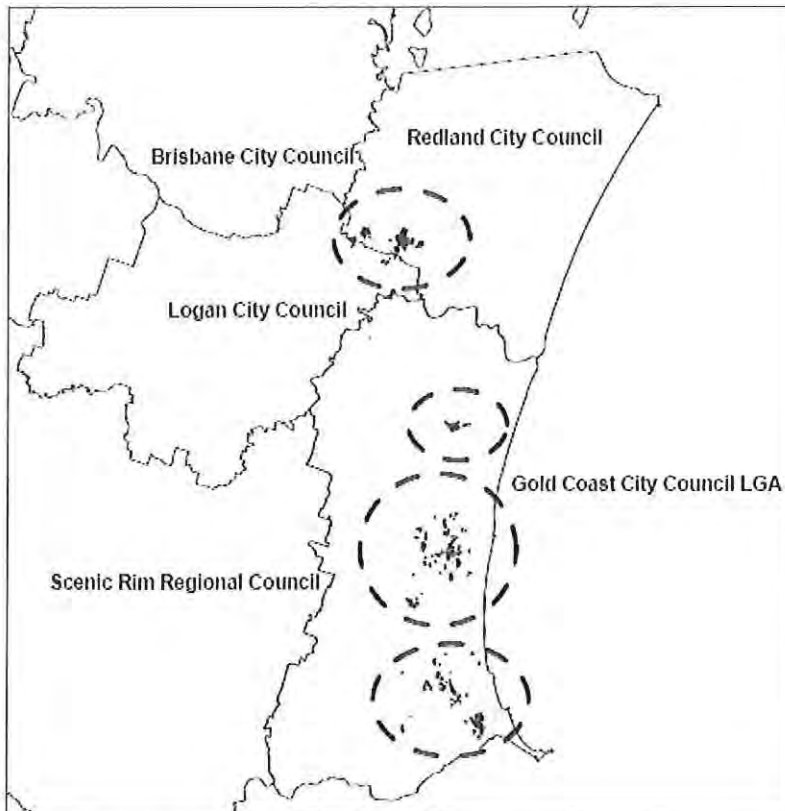


Figure 1: Study Area: Blackbutt Forest patches are circled

### ***Distribution of Blackbutt Forest in the Gold Coast Region***

Regional ecosystem (RE) mapping provides a legal and scientific basis for vegetation coverage assessment in Queensland. It is based on Landsat imagery (The Statewide Landcover and Trees Study - SLATS) interpretation combined with landform data which establishes individual polygons representing unique vegetation communities. RE mapping at 1:50,000 and 1:25,000 was used to determine pre-clear and current extents of Blackbutt Forest described as 'RE 12.11.23 - Tall open forest of *Eucalyptus pilularis* open forest on metamorphics and interbedded volcanics'. While it is recognised that some inaccuracies in the RE mapping occur (Lawson

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<sup>1</sup> South East Queensland Regional Plan 2009 - 2031. Department of Infrastructure & Planning.



2006b), groundtruthing determined the RE mapping for Blackbutt Forest to be largely accurate and was adopted for the Geographic Information System (GIS) analysis of this project. Where inconsistencies between the mapping and field condition occurred, field conditions prevailed. Typically, differences between the RE mapping and the field extent of Blackbutt Forest were represented by clearing or modification that has not been captured in the current mapping. Approximately 41 Ha (7.4%) of Blackbutt Forest has been cleared or significantly modified since the last update of the RE mapping in 2006.

### ***Vegetation Condition - Benchmarking***

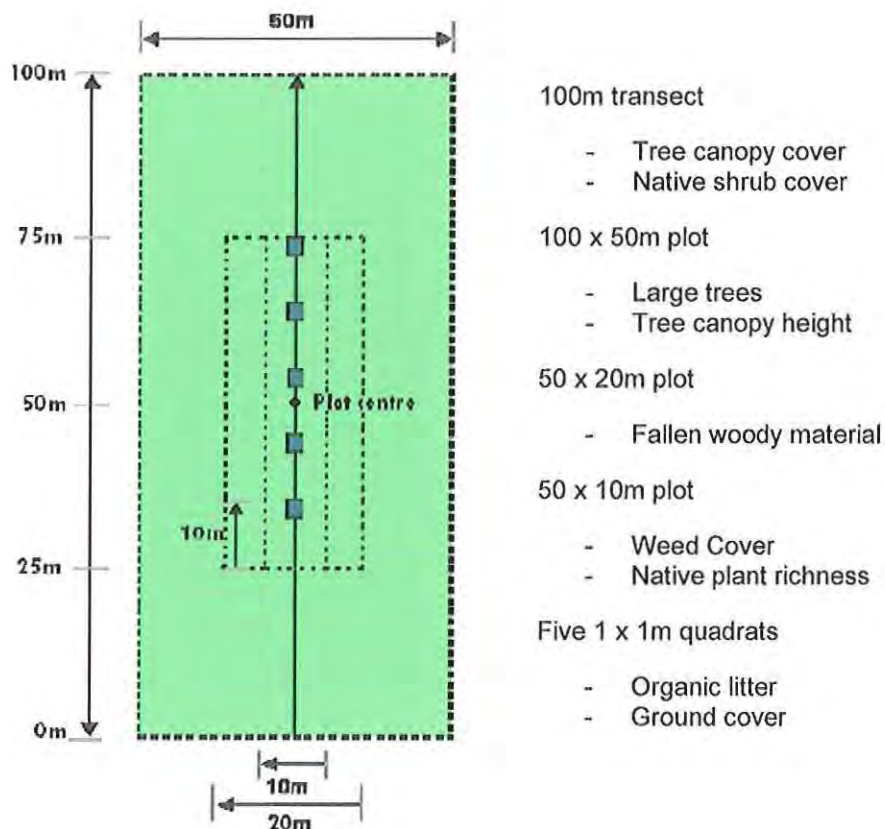
BioCondition (Eyre et. al. 2010) is a condition assessment framework for terrestrial biodiversity and was used in this study to quantify the condition of the remaining Blackbutt Forest within the GCCG LGA. The assessment is a site based measure of how well an ecosystem is functioning for biodiversity values compared to the same system in its reference state (referred to as a benchmark). Ideally, benchmarks represents pre-European disturbance state, but given disturbance to natural systems is so wide spread, sites least impacted by local threats constitute the best available sites for benchmarking (Eyre et. al. 2010).

BioCondition assessment requires that a benchmark (reference state) is first established. As this had not been undertaken for Blackbutt Forest in SEQ, we established a reference state using the DERM *Methodology for the Establishment and Survey of Reference Sites for BioCondition*. Results were used for the subsequent BioCondition assessments.

A criticism of the benchmark methodology is the potential for the full range of variation represented by a benchmark site not to be included in the scoring due to temporal and spatial conditions excluding natural variation and disturbance (Gibbons 2006). To minimise the influence of variation described as clementsian, and the ecosystem variation within regional ecosystems, benchmark sites were chosen as Best-On-Offer, which represent natural variability or range in attributes of an ecosystem relatively unmodified since European settlement (Eyre et al 2006). Anecdotally, two distinct ecosystem types were observed within Blackbutt Forest: 1) Open woodland with a shrub & grass understorey, and 2) Tall open forest with wet sclerophyll and rainforest understory species. Benchmark sites were established in each system to capture maximum variability.

Benchmarking sites were selected using 1) GIS analysis to determine the largest remnant patches offering the greatest core habitat; 2) CORVEG database (the Queensland Herbarium ecological site database); 3) groundtruthing for site features representing the least disturbed patches; and 4) sites that offered a full range of variation within forest types for 12.11.23 (open woodland and tall open forest structures).

Surveys were conducted in May 2010 and consisted of the establishment of a 100 x 50m plot and 100m transect for the assessment of attributes as described in Figure 2.



**Figure 2: BioCondition Reference Site Plot Description:** adapted from: *Reference Sites for BioCondition – Assessment Manual, Version 1.4*

Site based attributes measured at each reference site are described in Table 2. The benchmark value for each attribute is derived by taking the median value of scores across the three sites.

**Table 2: Site-based attributes that are compared against benchmark values in BioCondition surveys**

Attributes	Benchmark Survey	BioCondition Survey	
	Measure	Measure	Weighting (%)
<b>Site Based Attributes</b>			
Native plant species richness	Number	Number	20
Tree canopy cover	Percentage	Percentage	5
Tree canopy height	Median	Median	5
Shrub layer cover	Percentage	Percentage	5
Native perennial grass cover	Percentage	Percentage	5
Native perennial forb and non-grass cover	Percentage	-	
Native annual grass, forb and non-grass cover	Percentage	-	
Large trees	Number	Number	15
Fallen woody material	Number	Number	5
Litter cover	Percentage	Percentage	5
Recruitment of woody perennial species	-	Percentage	5
Weed Cover	-	Percentage	10
<b>Landscape Attributes</b>			
Size of patch	-	Number	10
Context	-	Percentage	5
Connectivity	-	Percentage	5

**Vegetation Condition - Surveys**



BioCondition surveys were conducted to quantify the condition of remaining Blackbutt Forest within the GCCC LGA. BioCondition survey sites were selected from RE maps (DERM 2010) to 1) represent the least disturbed Blackbutt Forest remaining; 2) meet a minimum size of 4Ha to allow plots to be positioned at least 50m from patch edges or disturbance (Eyre et al 2010; Gibbons et al 2008); and 3) contain representative RE 12.11.23 vegetation as described by DERM (2010). Patches < 4Ha were surveyed using a modified methodology described below. A combination of GIS analysis and field observations determined final patch selection. Table 3 summarises the representative portions of Blackbutt Forest greater than and less than 4Ha.

**Table 3: Survey Status of Blackbutt Forest Patches**

Site	Number of Sites (n)	Area of Blackbutt Forest (Ha)	Percentage (%) of Blackbutt Forest represented by n
<b>Patches &gt;4Ha</b>			
Reference Sites	3	51.5	12.9
BioCondition Sites	12	153	38.3
Modified Survey Sites	8	59.2	14.8
No Access or not suitable <sup>2</sup>	11	102.6	25.7
Cleared <sup>3</sup>	5	33.7	8.3
<b>Total</b>	<b>39</b>	<b>400</b>	<b>100</b>
<b>Patches &lt;4Ha</b>			
Patches <60m wide	60	54	35.1
Modified Survey Sites	30	53.4	34.7
No Access or not suitable <sup>2</sup>	16	28.2	18.3
Cleared <sup>4</sup>	5	7.3	4.7
Possibly Incorrect RE	1	2.8	1.8
Residual	7	8.3	5.4
<b>Total</b>	<b>119</b>	<b>154</b>	<b>100</b>

Survey methodology followed the *BioCondition Assessment Methodology Manual Version 2* (Eyre et. al. 2010) with additional threat data included for vulnerability assessment. Surveys occurred between May and October 2010 and used the same plot and transect layout as depicted in Figure 2. Attributes measured are outlined in Table 2.

<sup>2</sup> These sites were typically narrow (<200m), lineal, riparian strips of vegetation heavily impacted by introduced species, or they were not accessible.

<sup>3</sup> These sites were either cleared or in the process of being cleared or modified. Modification included the removal of all understory, groundcovers and tree species other than individual *E. pilularis* and other associated canopy species.

Each site attribute was assigned a score based on its measure compared to the reference state, or in the case of weed cover and recruitment, to relevant acceptable standards as described in *BioCondition Assessment Methodology Manual Version 2* (Eyre et. al. 2010).

For example, the site based attribute 'tree canopy height' is scored as follows:

Description	Score
<25% of benchmark height	0
>or= 25% to 70% of benchmark height	3
>= 70% of benchmark height	5

Landscape attributes were assessed using GIS analysis for patch size, connectivity and context and scored according to the methodology outlined in the *BioCondition Assessment Methodology Manual Version 2* (Eyre et. al. 2010).

The final BioCondition score for each surveyed patch was determined by summing individual attribute scores and dividing by 100 to standardise the score to between 0-1. This allows for equivalence between different ecosystems if required.

The final classification of BioCondition scores is provided in Table 4.

**Table 4: Final BioCondition Classification Scores**

Condition Class	Value
1	>0.80
2	>0.60 – 0.80
3	0.40 – 0.59
4	<0.40

The methodology combines a weighting system with a scoring system to obtain a final BioCondition score. The weighting system is used to standardise relative importance of attributes and their contribution towards biodiversity.

In a weighting system, the assignment of weights for different variables, in this case attributes, requires judgement that can be interpreted as subjective (Gibbons 2006). A comparison of the BioCondition and NSW BioBanking weighting system was comparable, although there was some variation in the weight assigned to recruitment and weed cover. Additionally, the NSW system separated site values and landscape values whereas these are combined in the BioCondition methodology. This resulted in higher weights being applied to attributes in BioBanking (Gibbons et al 2005) for direct comparison purposes, but were rationalised when metrics were applied for determining final scores.

An example where a scoring system has been used in Australia is Habitat Hectares (Parkes et al. 2003) and a problem with the additive scoring system is that an increase contribution of one attribute can compensate for the loss in another. Gibbons (2006) suggests a way of overcoming this is to multiply attribute scores together so the condition score is defined by the co-occurrence of more than one attribute.

#### ***Vegetation Condition – Modified Surveys***

One hundred and nineteen patches of Blackbutt Forest covering 154Ha were identified through GIS analysis with a patch size of less than 4Ha. A modified survey methodology for these patches was developed using attributes and scoring from the BioCondition methodology (Table 2) to enable comparisons between BioCondition surveys and results from the modified surveys.

Modified surveys were conducted in 30 patches representing 34.7% of the area covered by patches less than 4Ha. In addition, modified surveys were also conducted in 8 BioCondition survey sites to allow comparison between BioCondition scores and modified survey scores. Condition scores were assessed from both methodologies using a paired t-test and found there was no significant difference ( $P=0.13$ ) between the survey methodologies. This allows data sets from both methodologies to be combined for further analysis.

Anecdotal evidence collected during site inspections and BioCondition surveys found that patches of Blackbutt Forest immediately adjacent to housing or industry displayed a consistent 10m to 30m zone of impact from introduced invasive species and other edge effects. As such, all patches of Blackbutt Forest less than 60m at the widest segment were not surveyed and assigned a Condition Class 4 (lowest score).

In the 30 sites suitable for a survey, a 10 x 10m plot was established in the core habitat of each patch and species richness was calculated for four floristic life-forms (tree, shrub, forb, grass). Other site attributes were measured within sight of the centre of the plot and scored as described in (Table 5). Final site scores were determined as for the BioCondition Survey identified in Table 4.

Table 5: Modified Survey Details for Patches < 4Ha

Attributes	Weighting	Modified Survey Score
<b>Site Based Attributes: measured within sight of the centre of the plot. Native species richness measured within the 10m x 10m plot.</b>		
Recruitment of woody perennial species	5	Recruitment of woody perennial species present = 5 Recruitment of woody perennial species absent = 0
Native plant species richness (measured)	20	<25% of benchmark # of species within each life-form = 0 <=25% - 90% of benchmark # of species within each life-form = 2 >=90% of benchmark # of species within each life-form = 4
Tree canopy cover (estimate)	5	If canopy health is good (category 1 or 2 in BioCondition): <10 % of benchmark = 0 10 – 50% of benchmark = 2.5 >51% of benchmark = 5 If canopy health is poor (category 3, 4 or 5 in BioCondition) reduce score by a factor of 2
Tree canopy height (measured)	5	< 25% of benchmark height = 0 25% to 70% of benchmark height = 2.5 >71% of benchmark height = 5
Shrub layer cover (estimate)	5	Shrub layer absent = 0 Shrub layer < 50% or > 200% of benchmark = 2.5 Shrub layer >50% or <200% of benchmark = 5
Native perennial grass cover (estimate)	5	Native perennial grass cover absent = 0 Native perennial grass cover >10% or <90% of benchmark = 2.5 Native perennial grass cover >90% of benchmark = 5
Large trees (Measure)	15	No large trees = 0 Large trees present without hollow = 10 Large trees present with hollows = 15
Fallen woody material (estimate)	5	<10% of benchmark value as an estimate = 0 <50% or >200% of benchmark = 2.5 >50 or <200% of benchmark = 5
Litter cover (estimate)	5	<5% litter on the ground = 0 >5% or <25% litter on ground = 2.5 >25% litter on the ground = 5
Weed Cover (estimate)	10	>50% weed cover on ground = 0 5 to 50% weed cover on ground =5 <5% weed cover on ground = 10

Attributes	Weighting	Modified Survey Score
<b>Landscape Attributes: Measured using GIS</b>		
Size of patch (measured)	10	Default to 0 as < 5Ha = 0 in BioCondition
Connectivity (measured)	5	Patch not connected to remnant or regrowth vegetation = 0 Patch connected along 0 to 50% of boundary by remnant or regrowth vegetation = 2.5 Patch connected along >50% of boundary by remnant or regrowth vegetation = 5
Context (measured)	5	No remnant/regrowth vegetation within 1km radius of centre of patch = 0 0 to 30% remnant/regrowth vegetation within 1km radius of centre of patch = 2.5 > 30% remnant/regrowth vegetation within 1km radius of centre of patch = 2.5

### ***Vulnerability***

Vulnerability of Blackbutt Forest in the Gold Coast area to further decline was assessed using a combination of spatial overlays, rule-based methods and expert local knowledge.

#### *Clearing for significant infrastructure (roads, rail, water & energy)*

Spatial overlays from the Gold Coast City Council planning scheme and Main Roads UBD were applied to regional ecosystem mapping to identify Blackbutt Forest polygons located within infrastructure corridors or proposed road widening alignments. Under QLD vegetation management legislation, clearing for state controlled roads, electricity infrastructure and transport corridors are exempt from assessment and biodiversity offset requirements, and as such clearing will result in a net loss of Blackbutt Forest equal to the amount cleared and are rated a high risk of clearing. Field assessment determined that easements were largely already established and subject to maintenance rather than to clearing and were therefore considered a low risk for clearing.

#### *Clearing for urban development (housing, industry, commercial)*

Spatial overlays from the GCCC planning scheme were applied to regional ecosystem mapping to identify landuse designations of the remaining Blackbutt Forest polygons. Landuse categories were identified as 1) Easements; 2) Community Purpose - land intended for future development typically associated with community infrastructure; 3) Rural; 4) Residential; 5) Industrial; 6) Park Living - large lots and 7) Public/Private Open Space. Potentially, Blackbutt Forest polygons located within 1) to 5) are at risk of landuse change and subsequent clearing for development

and rated a high risk of clearing. Public open space and park living lots, which were largely established or intended as open space/conservation, were assigned a low risk of clearing.

#### Invasive Species

Field investigation determined invasive domestic garden species such as *Sphagneticola trilobata* (Singapore daisy) to dominate Blackbutt Forest edges adjacent to urban landuse consistently between 10 - 30m. Distribution modelling is not available for these types of species, however, the likelihood of invasive species threatening forest patches was estimated based on the percentage of patch area adjacent to urban landuse. To predict threats to Blackbutt Forest from weed species, a simplistic rule based model was developed (Table 6).

**Table 6: Threat level from invasive species**

Level of Threat	Percentage of Patch Perimeter Adjacent to Urban Landuse
High	>50%
Medium	1 – 49%
Low	0%

*Lantana camara* (lantana) is not a dominant weed by abundance in the core habitat of Blackbutt Forest. However, it was present and spacial overlays for *Lantana camara* (lantana) have been developed by the National Lantana Management Group using satellite imagery and mapped at a regional scale (100 m<sup>2</sup> pixel area with approximately 80 percent accuracy). These overlays were applied to regional ecosystem mapping to identify if lantana is mapped as a threat to Blackbutt Forest.

#### Fire

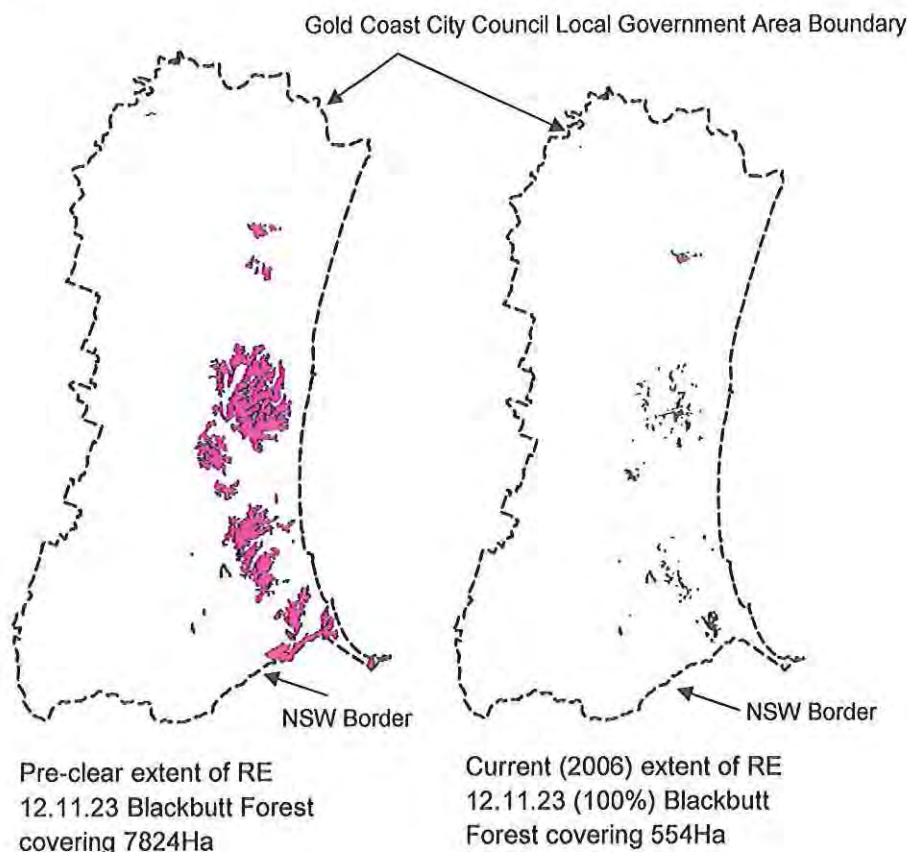
Fire was identified by the Redland City Council as a threat to the biodiversity of Blackbutt Forest, particularly with respect to wildfires, and recommended long-term low intensity burns to maintain forest structure. Data was obtained from the GCCC's Natural Areas Management Unit (NAMU) on fire occurrences within Blackbutt Forest polygons for the past 10 years. An unpaired t-test was performed to determine if there was any significant difference between the BioCondition score of patches which were subject to burn and those that had not burnt.

## Results

### *Distribution of Blackbutt Forest*

Blackbutt Forest was observed throughout the study area as a highly fragmented vegetation community situated within an expanding urban area. Pre-clear mapping (DERM 2010) indicates Blackbutt Forest once occupied approximately 7824Ha which has been reduced to 554Ha (Figure 3). This represents 7% of the original extent of Blackbutt Forest within the GCCC LGA, comprising fragmented patches ranging in size from 0.2Ha to 64.8Ha (mean = 3.5Ha).

**Figure3: Extent of Blackbutt Forest pre-clearing and current**



The distribution of Blackbutt Forest within these patches is described in Table 7. Thirty six percent of the area mapped as Blackbutt Forest exists as small patches less than 5Ha in size, while nearly half the area is represented by just 14 patches between 10 and 64.8 ha.

**Table 7: Distribution of Mapped Blackbutt Forest**

Patch Size	Patch Size Range (Ha)	Number of Patches	Area (Ha)	% of Blackbutt Forest in Each Patch Type
<5H	0.2 - 5	130	197.5	36
5Ha to 10Ha		14	91.0	16
>10Ha	10 – 64.8	14	265.5	48

### **Benchmark Establishment**

Benchmark condition scores were established for Regional Ecosystem 12.11.23 (Blackbutt Forest) and benchmark scores on which subsequent BioCondition attribute assessments were assessed are provided in Table 8.

**Table 8: Benchmark Scores for Biodiversity Attributes of RE 12.11.23**



	Reference Sites			Benchmark Score
	Southport S27°58.04 E153°22.65	Miami S28°04.36 E153°25.75	Tallebudgera S28°10.09 E153°21.39	
<b>Large Tree Diameter DBH (cm)</b>				
<i>Eucalypt</i>	44	50.56	48.3	<b>48.3</b>
<i>Non Eucalypt</i>	–	–	27.6	<b>27.6</b>
<b>Number of Large Trees</b>	15	7	21	<b>15.0</b>
<b>Tree Height (m)</b>	36	34	38	<b>36.0</b>
<b>Tree Canopy Cover (%)</b>	93.2	84.4	89.4	<b>89.4</b>
<b>Shrub Canopy Cover (%)</b>	12.1	14	28.6	<b>14.0</b>
<b>Ground Cover (%)</b>				
<i>Native Non-preferred grass</i>	6.6	8.6	3.2	<b>6.6</b>
<i>Native forbs and other sp</i>	10.4	20.4	40	<b>20.4</b>
<i>Native Shrub</i>	17	16.4	5	<b>16.4</b>
<i>Litter</i>	66	54.6	47.6	<b>54.6</b>
<i>Rock</i>	–	–	2.4	<b>2.4</b>
<i>Bare Ground</i>	–	–	1	<b>1.0</b>
<i>Cryptograms</i>	–	–	0.8	<b>0.8</b>
<b>Fallen Woody Material (m)</b>	75.7	20.8	46.6	<b>46.6</b>
<b>Native Plant Species Richness</b>				
<i>Tree</i>	9	7	22	<b>9.0</b>
<i>Shrub</i>	8	11	16	<b>11.0</b>
<i>Grass</i>	3	4	5	<b>4.0</b>
<i>Herbs &amp; Forbes</i>	8	6	13	<b>8.0</b>
<i>Other</i>	4	7	18	<b>7.0</b>



### Biodiversity Assessments

One vegetation condition assessment team, comprising the same two people, conducted all field surveys to ensure consistency of assessment results.

Fifty surveys were conducted using the BioCondition and modified assessment methodologies. Site scores ranged from 0.075 to 0.86 (mean = 0.58) based on a possible score range from 0 to 1. From the scoring system identified in Table 4, values were assigned a condition score from 1 to 4 (highest to lowest) and corresponding biodiversity attributes for Blackbutt Forest are described in Table 9.

**Table 9: Biodiversity Attributes for Blackbutt Forest (RE 12.11.23) in the Study Area**

Condition Score	Biodiversity Attributes	Typical Scene
1	<p>Condition 1 sites typically displayed high species diversity close to that found in benchmarks. Large trees greater than 48.3cm were common, generally with hollows. Fallen woody material exceeded 46 lineal metres and litter cover was greater than 50%. Recruitment was generally 100% of canopy species and there was minimal weed infestation. Patches are large &gt;40Ha and well connected to surrounding remnant vegetation.</p>	
2	<p>Condition 2 sites displayed reduced species diversity from that found in benchmark sites. Large trees greater than 48.3cm were present generally with or without hollows. Fallen woody material was less than 46 lineal metres and litter cover remained greater than 50%. Recruitment was generally 100% of canopy species and there was minimal weed infestation. Patch sizes vary but are generally larger than 5Ha and are occasionally connected to surrounding remnant vegetation.</p>	

3	<p>Condition 3 sites displayed reduced species diversity from that found in benchmark sites. Large trees greater than 48.3cm were occasional with or without hollows. Fallen woody material was intermittent and litter cover was greater than 10% of the benchmark. Recruitment of canopy species was evident and weed infestation was common. Patch sizes are small and generally less than 5Ha. Patches are occasionally connected to surrounding remnant vegetation.</p>	
4	<p>Condition 4 sites have a very low species diversity compared to that found in benchmarks. Large trees with or without hollows were generally absent. Fallen woody material was uncommon and litter cover was generally absent or less than 10% of the benchmark. Recruitment was only sometimes evident. These sites displayed a high dominance and/or diversity of weed species. Patches are small and often less than 60m wide with little connectivity to other bushland areas.</p>	

During the field investigation it was found that forty four hectares of Blackbutt Forest mapped in Version 6 of the Regional Ecosystem Maps (DERM 2010) had been cleared or significantly modified such that the forest patch would no longer meet remnant vegetation status. The estimated remaining area of Blackbutt Forest is 511 Ha (as opposed to 554 ha).

The BioCondition assessment found 200Ha of Blackbutt Forest achieved a condition score of 2, and only 26.4 Ha achieved a condition score of 1 (Figure 4). These higher scoring areas are derived from less than 30 individual patches of forest, whilst the remaining patches returned a category 3 or 4 condition score. Analysis of patch size and condition score found a significant difference ( $P=0.01$ ) between condition scores in patches <5ha compared to patches >5Ha. Figure 5 shows condition scores based on the number of patches.

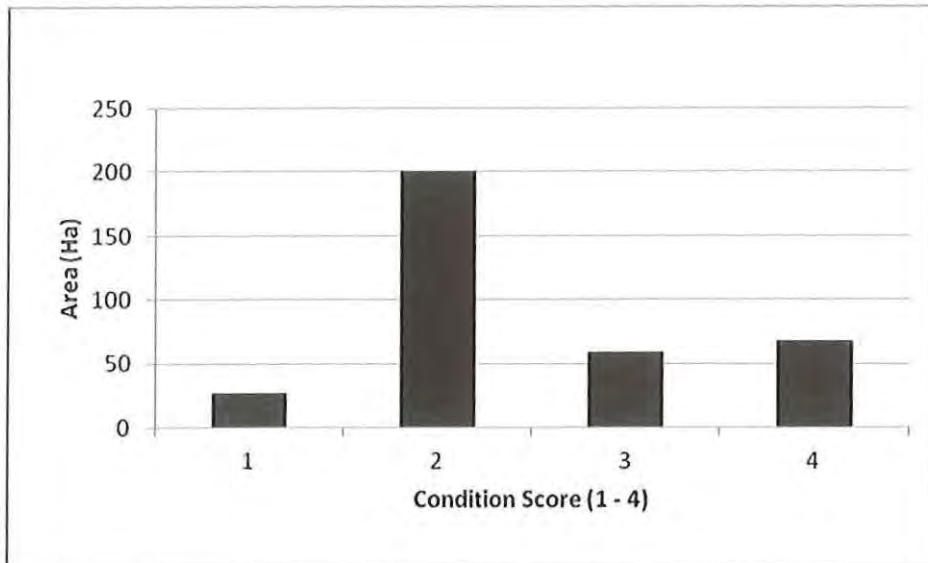


Figure 4 Blackbutt Forest condition scores based on total patch area

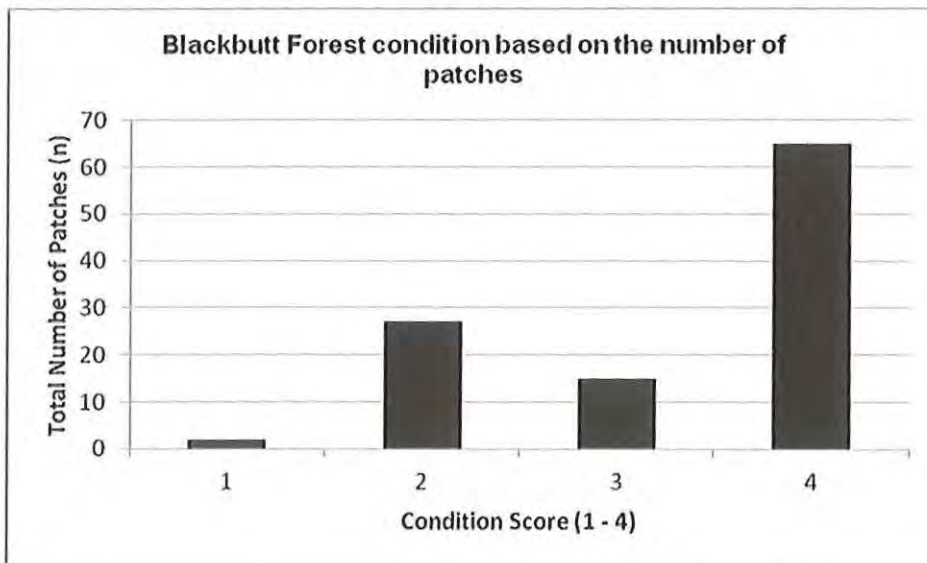


Figure 5 Blackbutt Forest condition scores based on the number of patches

## **Vulnerability**

### Clearing for significant infrastructure (roads, rail, water & energy)

Vegetation clearing for the establishment and/or maintenance of infrastructure such as roads and rail lines will result in a reduction of Blackbutt Forest within the Gold Coast area. The extent of potential loss is 24.6Ha described in Table 10.

**Table 10: Vulnerability of Blackbutt Forest to Threats Associated with Essential Infrastructure**

Threat	Risk of Clearing		
	Number of Patches at risk	Area of habitat at risk (Ha)	
Rail Line	2	0.85	High
Roads	13	23.8	High

Thirteen patches of Blackbutt Forest in three localities are at most risk from road re-alignments, these being in the vicinity of the Reedy Creek and Smith Street interchanges on the Pacific Motorway, and future road upgrades along Old Coach Road at Reedy Creek. Similarly, future rail corridors run through two small patches of Blackbutt Forest, south of the existing Varsity Lakes Station.

In addition to road and rail easements, 21 patches of Blackbutt Forest covering 96Ha are subject to Council easements for the provision of essential services such as water, sewerage and electricity. Field observations in many of these existing easements revealed that they had already been cleared of vegetation and were subject to ongoing maintenance. This typically involves slashing, mowing and pruning of vegetation.

### Clearing for urban development (housing, industry, commercial)

Clearing for urban development remains a high risk for Blackbutt Forest with approximately 164Ha located in planning scheme landuse domains intended for urban development. The remaining 321 Ha likely to persist will be subject to more diffuse threats.

The GCCC planning scheme landuse domains associated with each Blackbutt Forest polygon was recorded (Table 11). Park living represents acreage lots consisting of low density residential use, and was observed to be largely established. Threats to Blackbutt Forest in these areas are not likely to be associated with large scale clearing. Rural areas are typically undeveloped land in the Elanora and Tallebudgera region, fringing urban development and as such are at risk of landuse change involving significant clearing. Similarly, residential areas are semi or undeveloped sites with a high potential for development involving land clearing.

Land identified as community purpose is largely undeveloped land set aside for future community purposes. This land is typically owned or leased by local and state government and is generally at high risk of being cleared.

The landuse category containing the largest area of Blackbutt Forest is the Open Space category. This consists of public and private open space as well as land dedicated to conservation. Land within this category has a lower risk of being subject to landuse change involving vegetation clearing.

**Table 11: Risk of Clearing**

Landuse Category	Number of Patches	Area (Ha)	Risk of Clearing
Freehold			
Park Living	20	103.9	Low
Rural	8	53.6	High
Residential	9	14.2	High
Community Purpose	29	90.9	High
Industry	2	4.9	High
Open Space	58	217	Low
Road Easement and other	21	26.5	High

### Threatening Species

BioCondition and modified surveys within the study area recorded 89 exotic plant species of which 53 are listed by Gold Coast City Council (NAMU undated) as threatening local biodiversity. The ten most common weed species and known invasive species recorded during the surveys are listed in Table (12). Threatening species were recorded within the core habitat of each vegetation patch surveyed, and hence results do not represent all weed species in

patches, including those within edge habitat where conditions are more favourable to these species (Lindenmayer & Fischer 2006).

**Table 12: Ten most common weed species recorded in Blackbutt Forest in the study area**

Weed Species		Number of patches Recorded In	Threat to Biodiversity in the Gold Coast area
Species name	Common name		
<i>Bidens pilosa</i>	Cobbler's Pegs	11	Yes
<i>Paspalum mandiocanum</i>	Broad-leaved Paspalum	11	Yes
<i>Melinis minutiflora</i>	Molasses Grass	12	Yes
<i>Cinnamomum camphora</i>	Camphor Laurel *C3*	13	Yes
<i>Ochna serrulata</i>	Mickey Mouse Plant	13	Yes
<i>Schefflera actinophylla</i>	Umbrella Tree (Nth Qld)	14	Yes
<i>Senna pendula</i> var. <i>glabrata</i>	Winter Senna	14	Yes
<i>Syagrus romanzoffiana</i>	Cocos Palm	16	Yes
<i>Asparagus aethiopicus</i> 'Sprengeri'	Asparagus Fern *C3*	20	Yes
<i>Lantana camara</i>	Lantana *C3*	20	Yes
<i>Passiflora suberosa</i>	Small Passionfruit	26	Yes

\*C3\* Declared pests under the *Land Protection (Pest & Stock Route Management) Act 2002* and *Regulation 2003*.

Threat analysis from invasive species (Table 13) found 39% of Blackbutt Forest likely to persist is at a high risk of threat from invasive weeds, 40% were at a medium risk level and 21% were rated a low risk.

**Table 13: Risk from invasive plant species**

Land Use	Risk		
	High (Ha)	Medium (Ha)	Low (Ha)
Open Space	74	87	56
Park Living	69	35	0
Total	143	122	56

Lantana was recorded as the 2nd most frequently occurring weed in the survey. Spatial overlays using satellite imagery were applied to regional ecosystem mapping for Blackbutt Forest. Results on the occurrence of lantana obtained from field surveys and satellite imagery were found to be comparable. Although the abundance of lantana was not measured for this project, density mapping has been produced by the National Lantana Management Group. A lower density of lantana was observed in the surveyed patches than that shown on the mapping. These differences could be explained by the lower occurrence of weeds, in general, within the core habitat areas surveyed, as opposed to the edge habitat that is more suitable to lantana growth and likely to be exposed to satellite imagery and not obscured by forest canopy (Stewart et al 2008). Predictive lantana modelling over Blackbutt Forest polygons did not identify potential future outbreaks in existing forest patches.

#### Fire

Historical fire records obtained from Gold Coast City Council recorded 22 fires in Blackbutt Forest over the past 10 years. Analysis of BioCondition scores from patches of forest subject to fire and those without were found to be significantly different ( $P=.0002$ ).

#### Other Threats

Waste dumping and recreational use were observed & recorded during the field surveys. Recreational use of Blackbutt Forest patches was not high and was limited to walking tracks and occasional bike tracks and is therefore not considered a high threat. Waste dumping was, however, more impactful, particularly when residential properties adjoined bushland. The practice of disposing of garden waste 'over the fence' was high and impacts from invasive garden escapees were obvious. Whilst not measured in this project, impacts were anecdotally observed to be high.

#### **Vulnerability of Blackbutt Forest**

A decision tree (Figure 6) was used to determine the on-ground vulnerability of Blackbutt Forest to threatening processes. Potentially 189Ha of this forest type remains at risk from clearing for urban development based on planning scheme land use designation and infrastructure status. Vulnerability assessment also determined that while the remaining 321 Ha is likely to persist, it

will be subject to indirect threats from urban development particularly from invasive species, altered fire regimes and waste dumping.

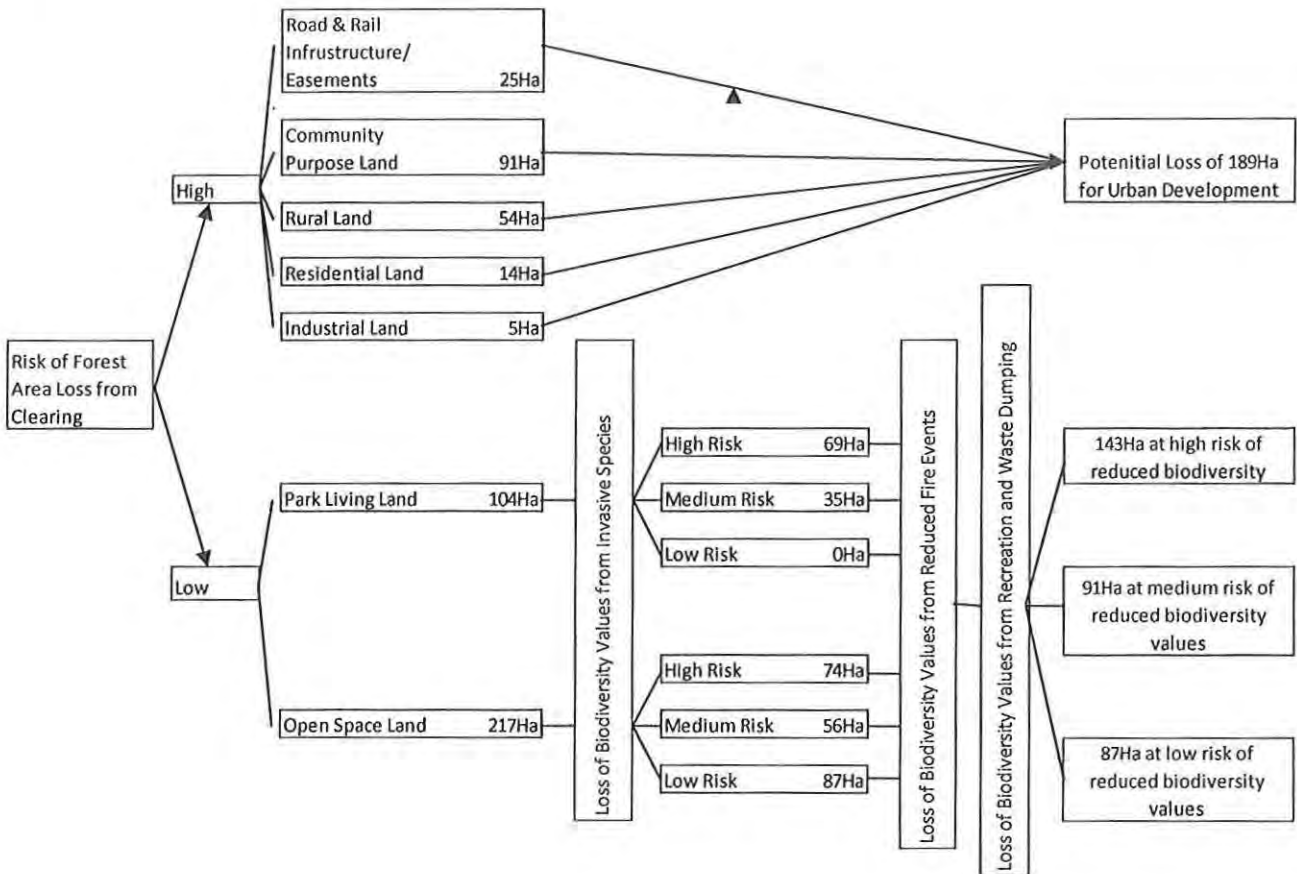


Figure 6: Vulnerability of Blackbutt Forest

## Discussion

### *Remaining Blackbutt Forest: extent and condition*

Five hundred and eleven hectares of Blackbutt Forest remain within the GCCC LGA, the majority of which exists as fragmented patches of forest within an urban environment. Thirty six percent of Blackbutt Forest exists as small patches ranging from 0.2 Ha to 5Ha which is below the recommended minimum 5Ha – 10Ha patch size to maintain plant and animal species associated with grassy woodlands in South East Queensland (McIntyre et al. 2000).

The remaining 64% is located in just 28 larger forest patches of 5Ha - 64Ha. Landscape modification and habitat loss such as that experienced by Blackbutt Forest typically leads to local or regional species declines (Saunders 1989). It is evident from our research that habitat loss is occurring in Blackbutt Forest, in conjunction with other process of landscape change such as habitat degradation from invasive species. This can lead to species biology and behavioural change. For example, Luck and Daily (2003) showed visitation rates of fruit trees by small birds declined with increasing distance from a large area of relatively unmodified native rainforest.

RE Maps (DERM 2010) used to determine the extent of Blackbutt Forest also provides information on biodiversity status, however, this is based on the extent of remnant vegetation of different type and does not consider vegetation condition. Historically in Queensland, biodiversity assessments for the development of conservation strategies and for assessing the impacts of development were largely based on the impact on the extent of remnant vegetation. However, the condition of remnant vegetation is emerging as an important characteristic and is being used by regulators in assessing vegetation clearing applications, offset proposals and determining incentive payments (Keith & Gorrod, 2006). Importantly, vegetation condition also provides a guide for developing conservation strategies to mitigate threatening processes and reduce vulnerability of remaining habitat.

The vegetation condition assessment of Blackbutt Forest found only two patches that received the highest score of 1. These patches cover 5% of the remaining Blackbutt Forest area and are located in a planning scheme area for low density residential development with a low risk of clearing. These patches displayed high scores for site attributes such as species diversity and habitat trees as well as landscape attributes such as connectivity, patch size and context, compared to the majority of patches which scored low for landscape attributes because they are small, isolated and fragmented. Landscape attributes are important for the long-term viability of patches for biodiversity values (Fahrig 2001) and are assigned a 20% weight in the BioCondition score. In the NSW BioBanking Assessment Methodology (Gibbons et al 2008), landscape attributes are not included in the site value score, rather they are calculated as a landscape value score and used separately as a metric to calculate ecosystem credits for offsetting. On a site value basis without landscape attributes, and an adjusted weighting system, the 2 highest scoring patches would likely have scored a two rather than a one.

A further 39% of the remaining forest area (made up of 27 patches) recorded a reasonably good condition score of two, however 11 of these patches, consisting of 67Ha is at high risk from clearing as they are located on land intended for urban development. The remaining 66% of Blackbutt Forest scored either a three or four indicating a large portion of the forest is in a poorer condition.

In this study, condition scores were significantly different between patch sizes <5Ha and those >5Ha. Although patch size is a component of the weighted scoring system (<5Ha=0; 5-25Ha=2; >25Ha=5...>200=10), only 16% of patches were >5Ha and 1% was > 25Ha, suggesting that the distribution of condition scores were not a direct function of patch size.

BioCondition scores obtained in this project are however potentially biased towards higher score. This is because the sites surveyed represented core habitat within each patch excluding degraded edges habitats, considered to comprise 10 – 30m (personal observation) around the perimeter of patches adjoining urban land uses. Future condition assessments could include multiple surveys within individual patches to ensure the variability of patch condition is captured.

Impacts from edge effects are related to the difference between the matrix and other landscape units, such as those observed in urban environments where landscape units vary often and boundaries are sharp (Laurance et al 1997; Wilcove 1985) This is particularly relevant to the Blackbutt Forest community where patches are generally small and fragmented and situated within an urban context. For example, Lindenmayer & Fisher (2006) report the number of absences of reptile species increases significantly within 30m from the edge of a patch. When considering the Blackbutt Forest community, 35% of all small patches are less than 60m wide suggesting the impact of the observed 10 - 30m edge habitat is very significant in small patches.

Edge habitat can affect biotic systems such as reproduction, growth, seed dispersal and mortality in plants (Hobbs and Yates, 2003). Weed invasion, particularly from exotic garden escapees, was commonly observed in edge habitat of Blackbutt Forest adjacent to urban landuses. Altered micro climatic conditions created from clearing and changed drainage patterns are likely to have created favourable conditions for the establishment and growth of these weeds (Carr et al, 1992).

Vegetation condition scores alone do not provide sufficient information to develop conservation planning strategies, and the integration and assessment of threatening process and vulnerability is required for informative decision making (Briggs, 2006; Gibbons, 2006).

### ***Vulnerability of Remaining Blackbutt Forest***

An understanding of the vulnerability of habitat to threatening process is a critical component of conservation planning (Wilson et 2005) and entails determining the possible timing or likelihood of loss or degradation (Pressey & Taffs). The vulnerability of remaining patches of Blackbutt Forest was predicted using a hierarchical decision tree, starting with the landuse designation under the local planning scheme, moving down to predictions associated with the impacts of diffuse threats associated with urbanisation as identified during the field component of this project.

According to DERM records (2010), 5 patches of Blackbutt Forest are listed as protected at the State Government Level. Four of these are within the Redland City Council LGA and one is located in the GCCC LGA. Field investigation of this patch of bushland suggests the patch may not in fact be representative of RE 12.11.23, which further reduces the area of Blackbutt Forest within protected areas.

The vulnerability of Blackbutt Forest to continued clearing was assessed using spatial landuse planning overlays to identify undeveloped patches located in planning scheme domains intended for development. Whilst it is recognised that not all patches that meet this determination will be cleared, they are recognised as vulnerable. The most significant threat of clearing is from government owned or leased land designated as community purpose under the Gold Coast City Council Planning Scheme. This threat covers 90Ha or 18% of remaining Blackbutt Forest and is land retained and reserved for community purposes and public infrastructure such as schools, emergency services, community halls, transport services etc.

Fifty Four hectares of Blackbutt Forest is contained in the Rural Domain which is typically private land that has the potential for development and was rated as a high threat to clearing. This was substantiated recently when approximately 28Ha of endangered Blackbutt Forest in the Rural Domain was subject to lawful clearing and modification for forestry activities.

A further 19Ha of Blackbutt Forest on privately owned land and 25Ha for road and rail infrastructure is also at risk of being cleared.

In contrast to the high risk landuses for clearing, are the low risk landuses identified as private park living lots, and open space areas largely owned and management by the local government. Although not as vulnerable to direct clearing as the 189Ha described above, we have identified that the remaining 321Ha is vulnerable to diffuse threats which are likely to reduce functionality of biological interactions in these systems. 217Ha of Blackbutt Forest is located within public and private open space largely managed by the Gold Coast City Council.

Invasive species were identified as the greatest threat to patches of Blackbutt Forest likely to remain in the landscape. From studies of the effects of invasive species on biodiversity, several generalisations have emerged about the impacts of invasive species (Gooden 2009, McGeoch 2010), including 1) reduced abundance of native plant and animal species; and 2) altered fire regimes associated with the increased abundance of invasive species. However, the survey methodology selectively favoured undisturbed core habitat, which may have resulted in an underestimation of weed species, particularly those which occur in response to disturbance commonly found in the edge habitat. For example, the invasive success of Lantana is significantly correlated to disturbance intensity (Duggin & Gentle, 1998). As previously suggested, future surveys could include multiple survey sites within the one patch to capture site variability.

Fire is an important ecological occurrence in most Australian ecosystems and the management of fire regimes is important for the conservation of biodiversity (Jurskis 2005).

In this study higher biodiversity values were found in patches of Blackbutt Forest which had burnt in the previous 10 years than non-burnt patches. DERM (2006) report that Blackbutt Forest (RE 12.11.23) requires frequent fire to maintain RE structure, particularly understorey integrity, and to keep mesic species low in the profile of the understorey so other species can compete. A study of Blackbutt Forest in SEQ (Russell and Roberts 1996) found low intensity prescribed burning of Blackbutt Forest produced less change in flora species density than non-burned areas, however, the changes in the non-burned forest areas may have been attributed to changes in exotic species rather than the burn event.

This finding was anecdotally supported in this study. From the literature and the field work it is evident that fire is an important ecological process for Blackbutt Forest, however given its proximity to urban housing, industry and commercial premise, and the need for property protection, it is unlikely to receive the required burn intensity and frequency needed to maintain ideal biodiversity.

### **Management and Conservation Implications**

One hundred and eighty nine hectares of Blackbutt Forest is located in planning scheme domains intended for development. To develop these sites, vegetation clearing and development permits will be required. In 1999 the Queensland State Government passed the *Vegetation Management Act (VMA)* which regulates vegetation clearing in accordance with the *Sustainable Planning Act 2009 (SPA)*. These acts make vegetation clearing, in some circumstances, 'assessable development' for which a permit is required to lawfully clear vegetation. Exemptions from requiring a permit to clear endangered REs are provided for certain activities including forestry practices, road construction, maintenance of infrastructure, fire breaks, drain construction and where a development approval for a material change of use or reconfiguration of a lot has been assessed by the Department of Environment and Resource Management (DERM 2009). The VMA seeks to protect endangered REs through the Regional Vegetation Management Codes. However a review of the Codes found some non-exempt activities can obtain approval for clearing in endangered REs if the extent of the RE is maintained i.e. through the provision of an environmental offset. There is substantial debate in the literature as to the appropriateness and success of environmental offsets (Gibbons & Lindenmayer 2007; ten Kate et al 2004) particularly with respect to an endangered community (BBOP 2009). Field survey for this project identified a number of patches of Blackbutt Forest that have recently been cleared for industrial development, forest practices, community health services and government officers. In the event that the clearing was appropriately offset, it is not certain in the literature that ecological functions of endangered forests can be maintained through offsets, which questions whether the objectives of the VMA are being achieved. As vegetation clearing can occur lawfully in endangered Blackbutt Forest, and patches that will persist in the landscape will be subject to degradation, it is clear that additional strategies are required to protect this forest from further decline.

Based on the findings of this project, strategies which could assist in the management of Blackbutt Forest within the GCCC LGA are:

1. Enhanced regulation of the clearing of Blackbutt Forest patches to reduce its vulnerability to clearing and further fragmentation. This could only be achieved through a change in legislative policy, for example by excluding the use of offsets to satisfy performance requirements (in clearing codes) in endangered REs.
2. Commitment from Local Government to manage and maintain Blackbutt Forest in public open space. Invasive weed management and the reintroduction of appropriate fire regimes will improve the vegetation condition and reduce the vulnerability of these patches to other threatening process such as disease and climate change. commitment should be complemented by public education of the impact of exotic garden escapees.
3. Commitment from Local Government to maintain and restore connectivity and patch size through the retention of all patches of Blackbutt Forest and connected different REs to support the functionality of the Blackbutt Forest type overall.
4. Conservation and education initiatives need to be directed towards management of fragmented forest on privately owned land. This requirement has been identified in North America (Bean & Wilcove, 1997) due to extensive habitat loss from urban development and difficulties faced by government in managing, purchasing and protecting this land.

### **Summary**

The extent of Blackbutt Forest has declined since pre-European records to just 7% of its original extent and this research has identified further losses of forest coverage since the 2006 release of RE coverage. Our results demonstrate that a significant percentage of existing Blackbutt Forest obtained BioCondition Scores of 3 & 4 representing poorer biodiversity condition. Blackbutt Forest is vulnerable to direct and diffuse threatening processes which will result in a further reduction in extent and condition. The predicted direct loss of Blackbutt Forest from clearing combined with the likely reduction of condition of remaining patches, points to the need for urgent conservation planning for the remaining Blackbutt Forest within the GCCC LGA if this ecological community is to persist. All levels of government and the community have a responsibility to maintain well functioning ecosystems. This is a key strategy that will protect against existing threatening process as well as future threats such as climate change and the emergence of additional threats associated with global change.

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