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COMPARATIVE EVALUATION OF SUBURBAN BUSHLAND AS FORAGING HABITAT FOR THE GLOSSY BLACK-COCKATOO

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An understanding of habitat suitability and utility across a given landscape is fundamental in effective threatened species management; particularly in regions where decisions are being made that cause habitat loss. This study develops the use of chewed *Allocasuarina littoralis* cone fragments as an index of foraging habitat suitability for the Glossy Black-Cockatoo *Calyptorhyncus lathami*, and demonstrates a practical methodology to evaluate and compare Glossy Black-Cockatoo foraging habitat within a landscape. Abundance of 'foraging sign' and stem-density was measured to produce an index of foraging habitat utility across a 4 300-hectare study area. All sites surveyed (n = 46) showed evidence of Glossy Black-Cockatoo foraging, with a mean of 16 per cent of cone bearing trees (n = 2 300) exhibiting foraging sign. Foraged *A. littoralis* trees were categorised individually according to the degree they were used as a food resource by Glossy Black-Cockatoos. Within the study area, five per cent of cone-bearing *A. littoralis* displayed greater than 20 cone fragments, and less than two per cent displayed greater than 100 fragments, highlighting the importance of feed tree retention when land use changes are proposed. The study found that high value foraging habitat occurs outside the protective boundaries of conservation reserves, and on the suburban edge, emphasising the importance of off-reserve conservation strategies to protect this threatened species.

INTRODUCTION

Many localities along the New South Wales (NSW) coast are struggling to accommodate an increasing human population whilst conserving biodiversity. The Glossy Black-Cockatoo *Calyptorhyncus lathami* is a threatened species listed as Vulnerable on Schedule 2 of the NSW *Threatened Species Conservation Act* 1995. The species is distributed widely along the NSW coast and is found in many areas currently undergoing land use changes to make way for residential development. In NSW, the cockatoo forages almost exclusively on the seeds inside the woody cones of *Allocasuarina* spp., favouring particular foraging trees to which they will often return (Crowley and Garnett 2001; Daly 2001). The key threats to the Glossy Black-Cockatoo in NSW are the loss of foraging and nesting habitat, both from land clearing and fire (Clout 1989; Garnett *et al.* 2000; NPWS 1999; Mount King Ecological Surveys 1992). It is hypothesised that global warming will be a future threat to the cockatoos in some areas. Higher evaporation rates reduce the moisture available to *Allocasuarina* spp., diminishing cone crop size, and in turn, reducing breeding success of the cockatoos (Cameron 2007). On the south coast of NSW, there is concern that the steadily accumulating loss of foraging habitat from bushland released to residential development is having a detrimental effect on the viability of Glossy Black-Cockatoos at a landscape scale (Mills 1996). To make informed decisions determining the significance of habitat loss, land managers must be able to identify and comparatively evaluate habitat at a landscape scale.

Detection of 'foraging sign' at the base of *Allocasuarina* spp. trees is the preferred method by which Glossy Black-Cockatoo habitat is identified (Clout 1989; Crowley and Garnett 2001; Daly 2001; Joseph 1981, 1983; Pepper 1997). Each foraged *A. littoralis* cone is chewed into a number of fragments that are scattered below the feed tree. These light coloured fragments are readily visible following the foraging event. The Glossy Black-Cockatoo is the only species to leave this distinctive sign, and chewed cone fragments remain visible for upwards of five months in the study area, discolouring from white to sand, russet, brown and finally grey as the fragments decompose (Robinson 2004). This helpful signature of foraging is both unique, easily identifiable, and long lasting, alleviating problems encountered in the use of sign abundance as an index of habitat utility for other species (Wilson and Delahay 2001; Westcott 1999). Measuring cone fragment abundance across the landscape enables the comparative evaluation of habitat utility for this threatened species.

The Glossy Black-Cockatoo is very particular in its selection of trees for foraging, and is thought to use a number of cues for assessing the suitability of particular *Allocasuarina* sp. trees. These commence with visual cues such as cone yield on the tree, and evidence of previous foraging as shown by cone fragments scattered beneath it (Clout 1989; Crowley and Garnett 2001). Once selecting a tree as likely suitable, the Glossy Black-Cockatoo routinely samples a number of cones to determine the seed mass relative to the mass of the total seed and cone mass 'Clout's Index' (Clout 1989; Pepper *et al.* 2000). By feeding in trees with a high 'Clout's Index', the cockatoo ensures maximum food returns for the effort required to tear apart each woody cone. If the tree is not suitable, it is rejected, and the sampling process recommences. Because of this sampling technique, some *A. littoralis* will have only a few cone fragments littered beneath it whilst others may display hundreds. Crowley and Garnett (2001) found that the seed-fill and kernel ratio of *A. verticillata* remained relatively constant between seasons, facilitating the Glossy Black-Cockatoo's fidelity to specific feed trees, and suggesting that the birds in fact remember the locations of specific feed trees. A similar consistency of inter-season seed fill characteristics is possible for *A. littoralis* given similar observations of feed tree fidelity on the NSW south coast (Daly 2001; Robinson 2004)

This study develops a landscape approach to comparatively evaluate urban and near-urban bushland as foraging habitat for the Glossy Black-Cockatoo, and presents a practical methodology that can be used by environmental planners and field workers. The study demonstrates the usefulness of the methodology through the assessment of habitat provided to the Glossy Black-Cockatoo in a bushland fringe surrounding an expanding urban area. Replication of the proposed methodology in other regions will facilitate the development of regional strategic planning approaches for the conservation of this threatened species.

STUDY AREA

The study area is located within the Shoalhaven Region on the NSW south coast (150° 67'S, 35° 07'E). To the north and west, the study area is defined by the limit of a large bushfire that burnt significant areas of the Shoalhaven in the summer of 2001–2002. The study is bordered to the south by St George's Basin and to the east by Jervis Bay. Land is predominantly bushland, adjacent to suburban and rural areas. There is an annual average 1 135 millimetres of rainfall (BOM 2004), and vegetation is predominately open sclerophyll forest with Blackbutt *Eucalyptus pilularis*, Scribbly Gum *E. sclerophylla, A. littoralis* and Red Bloodwood *Corymbia gummifera* being the dominate species. In the study area, there are contiguous heathland areas characterised by *Banksia serrata*, *B. ericifolia* and *Hakea teretifolia*. Urban growth in the study area is expected to substantially increase in the near future, with an estimated 51–55 per cent increase in human population within this part of the Shoalhaven Local Government Planning Area by 2016 (SCC 2003).

METHODS

Foraging Habitat Identification

Field surveys identified *A. littoralis* to exist as a sub-canopy species predominantly in association with Blackbutt, *Banksia serrata*, Red Bloodwood, Scribbly Gum and Turpentine *Syncarpia glomulifera.* To identify the extent of *A. littoralis* within the study area, aerial photographs scaled at 1:25 000 were digitised to 1 x 1 metre pixels and rectified using ER Mapper 6.0. Ground Control Points were identified on a digitised cadastral layer obtained from Shoalhaven City Council. Using ArcView 3.3, rectified aerial photographs were polygon screen digitised to identify areas of open forest and tall heathland vegetation communities displaying the characteristic brown tinge of male *A. littoralis* trees. Polygons were screen-digitised around community edges, producing a map of native vegetation remnants that could potentially contain *A. littoralis.*

The predictive map of *A. littoralis* was ground truthed when not restricted by private land access. Where restricted, an assessment of *A. littoralis* presence was made from outside the boundary fence. Polygons found not to contain *A. littoralis* were edited from the habitat map.

Historical Extent of Habitat

A. littoralis was observed during ground truthing to show a preference for well-drained sites. Stands had a high likelihood of occurring on a Wandrawandian Siltstone substrate, a low likelihood of occurring on alluvial gravel in swamp deposits, and along creek lines, particularly in areas predisposed to estuarine influence. To estimate the pre-European extent of *A. littoralis,* a predictive map of *A. littoralis* distribution was compiled using geological substrate and topographic data. To determine recent *A. littoralis* loss, digitised historic aerial photographs and topographic maps were rectified, and when digitally overlayed using ArcView 3.3, allowed the decline and fragmentation of *A. littoralis* bushland within the study area to be mapped at a temporal scale.

Habitat Evaluation

Once bushland containing *A. littoralis* was identified across the study area, 46 sites were selected for comparative evaluation. Each site was six hectares or less in size, and either sampled part of a larger contiguous stand, or encompassed an entire *A. littoralis* stand. To assess suitability for Glossy Black-Cockatoo foraging, sites were evaluated in two steps; firstly determining the stem-density of *A. littoralis* and, secondly measuring the abundance of foraging sign (cone fragments) beneath a sample of these trees.

The heterogeneity of *A. littoralis* stem-density within the study area meant that a number of quadrat surveys needed to be conducted to gain a representative assessment of stem density for each site. At each of the 46 sites, five individual 400 square metres (20 x 20 m) quadrats were surveyed to find the number of cone-bearing *A. littoralis* present. When averaged, this data provided a mean index of stem-density for each site.

A single chewed *A. littoralis* cone will produce a varying number of fragments dependent on factors such as the size of the cone and the manner in which the individual cockatoo tears it apart. Pepper *et al*. (2000) found Glossy Black-Cockatoos required an average of 1.8 cones to assess the suitability of a tree for further foraging, either rejecting the trees as a food source, or exploiting its suitability. They often foraged in the same tree for several hours. To distinguish between trees that were chosen for long bouts of foraging and those rejected by the Glossy Black-Cockatoos, trees were categorised by the quantity of cone fragments littered beneath them. Trees with less than 21 fragments were classed as 'sampled but rejected', 21–100 as 'accepted' and greater than 100 as 'preferred'. Trees that displayed 21 or more fragments were considered to have been assessed as a suitable foraging resource by the Glossy Black-Cockatoos, and will be referred to in this study as 'feed trees'.

To measure the degree to which the 46 sites were foraged, a path was made from the patch edge towards the interior and return. The path followed maximised encounters of cone-bearing *A. littoralis*. At each cone-bearing tree, a visual search was made for the distinctive chewed cone fragments beneath the first 50 cone-bearing *A. littoralis* encountered. A pilot study found a sample size of 50 cone-bearing trees per site was large enough to mitigate against clumping of foraged trees, and ensure a sample of trees representative of varying age-classes of *A. littoralis* found within each site. Cone fragment abundance littered beneath each foraged tree was recorded as less than 21, 21–100, or greater than100. Abundance of unforaged cones remaining on the tree was recorded as less than 50, 50–200, or greater than 200. Data analysis was conducted using equal variance two-tailed t-tests with a significance level of 0.05.

RESULTS

Identification of Foraging Habitat

An area of 618 hectares of extant foraging habitat was identified within the 4 320 hectares study area. Figure 1 shows that the remaining habitat in the study area is fragmented, with some small remnants occurring within suburban areas and larger patches on adjacent rural lands. Of the 618 hectares of foraging habitat available to the Glossy Black-Cockatoo, 275 hectares is reserved for conservation and contained within National Park or Council Reserve.

Evaluation of Foraging Habitat

The stem-density of cone-bearing *A. littoralis* was highly variable across the study area. Sites exhibited varying vegetation age-classes with *A. littoralis* occurring at some sites as densely packed saplings of 3–6 metres height, and also as more sparsely distributed mature trees that were in excess of ten metres height. Stem density averaged 127 cone-bearing trees per hectares (s.d. = 71.8). In total, of 2300 cone-bearing trees examined at 46 sites, 15.6 per cent (s.d. = 10) exhibited signs of Glossy Black-Cockatoo foraging activity. 10.8 per cent of trees (n = 2300) were sampled but rejected by the Glossy Black-Cockatoos and exhibited less than 21 fragments, three per cent of trees were accepted, and 1.9 per cent were preferred, exhibiting greater than 100 cone fragments (Figure 2). The number of observable chewed cone fragments underneath foraged trees varied from one to approximately 2000 per tree. The abundance of lightly coloured fragments beneath feed trees made it easy to distinguish feed tree acceptance by the Glossy Black-Cockatoo, compared with the handful of fragments observed beneath trees that were sampled but rejected. 'Foraging sign' was often located beneath clumps of three or four trees, which often displayed a disproportionate abundance of cone fragments. Whilst most trees in the study area were observed to yield a cone crop less than 200, 50 per cent of feed trees displayed a cone crop greater than 200 cones, supporting the observations of Clout (1989) that the Glossy Black-Cockatoo is biased towards trees with a high cone yield.

Whilst all sites showed evidence of foraging, the intensity at which trees were foraged between stands was noticeably varied (range = 2–44%) There was no statistical difference between

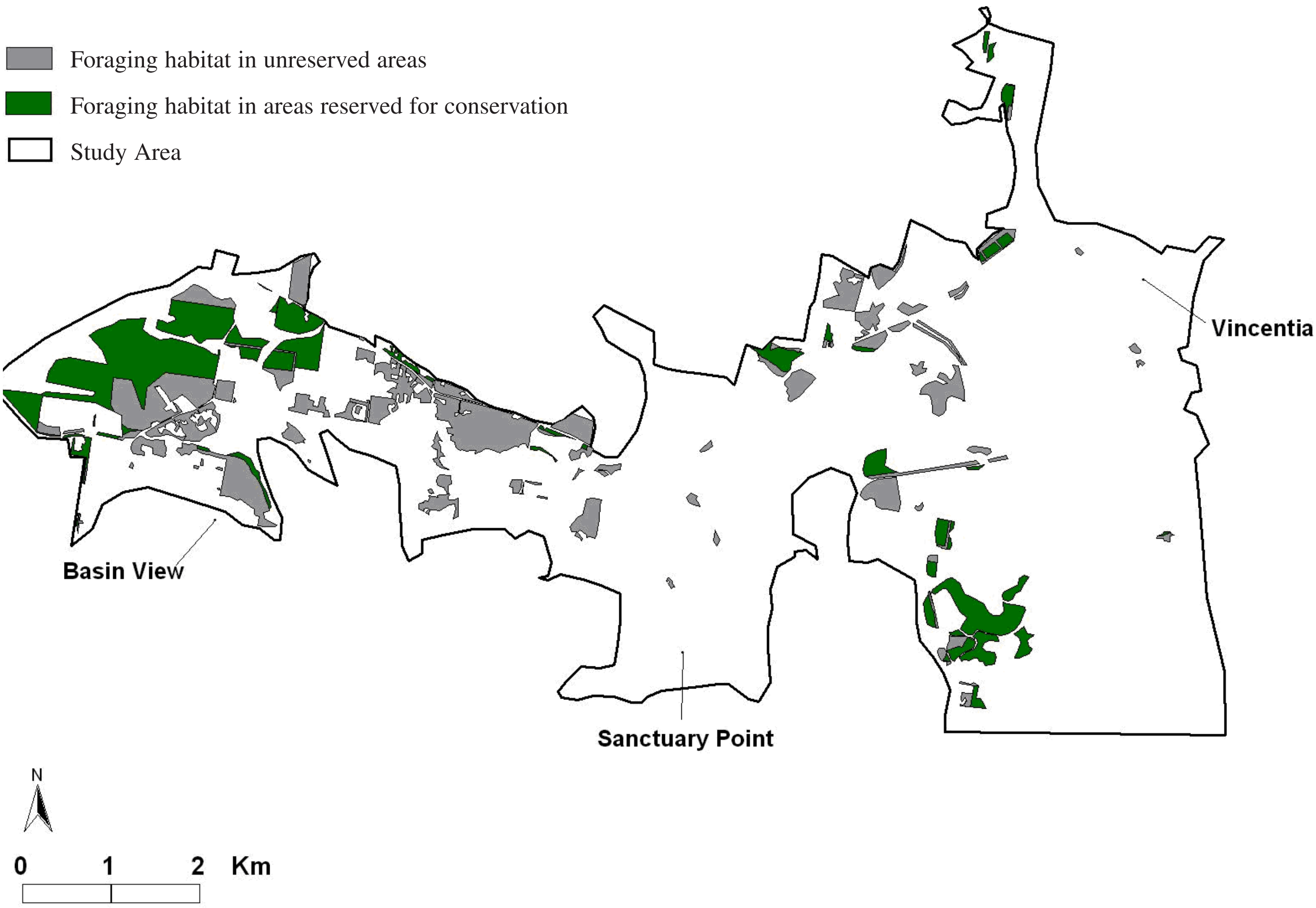

Figure 1. *Foraging habitat located in reserved and un-reserved areas of the study area. Figure compiled using ArcView 3.3, additional data sourced from SCC (2004).*

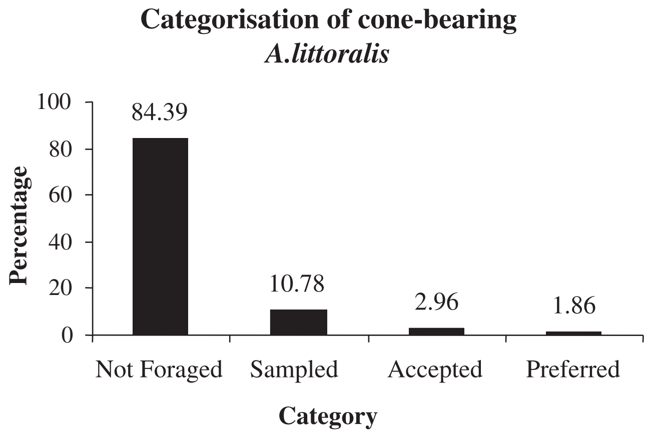

Figure 2. *Categorisation of cone-bearing A. littoralis in terms of observed cone fragment abundance. Not foraged = nil fragments, Sampled = 1-20 fragments, Intermediate = 21-100 fragments, and preferred = > 100 fragments.*

the percentage of *A. littoralis* foraged at sites bordering suburban areas (n = 20) and those further away from human settlement t = 0.44 (s.d. = 9.96, 44 d.f.). 'Foraging sign' was often observed beneath *A. littoralis* trees within a few metres of suburban roads and footpaths.

Discarding the trees rejected by the Glossy Black-Cockatoos, and multiplying the known stem-density of cone-bearing *A. littoralis* with the percentage of trees displaying greater than 20 fragments, an estimate of feed trees per hectare was calculated for each of the 46 sites (Figure 3). This index quantified each site in terms of its observed suitability as a food resource for the Glossy Black-Cockatoo. For the study area, feed trees per hectare ranged from 0 to 57.6 with an average of 6.8 (± 9.6, n = 46). An analysis of foraging habitat suitability outside the boundaries of conservation reserves showed the average number of feed trees per hectare at off-reserve sites to be 8.35 (± 11.72, n = 28), and greater than at sites reserved for conservation 4.44 (± 4.24, n = 18), but not statistically different t = 0.18 (s.d. = 9.64, 44 d.f.).

Historical Changes in Foraging Habitat

The historical decline in foraging habitat in the study area is shown in Figure 4. There was estimated to be 1 343 hectares of suitable foraging habitat available to the Glossy Black-Cockatoo in the study area before European settlement, this has since declined by 54 per cent to a current total of 618 hectares. Over the last 200 years, foraging habitat has increasingly been fragmented with residual habitat diminishing in total area primarily due to urban expansion. Relatively large patches of *A. littoralis* are now found only in the west of the study area on land that is predominately zoned for rural land-use.

DISCUSSION

This study found that the area of foraging habitat in the study area has decreased markedly since European settlement, and that at present, all remaining *A. littoralis* stands provide

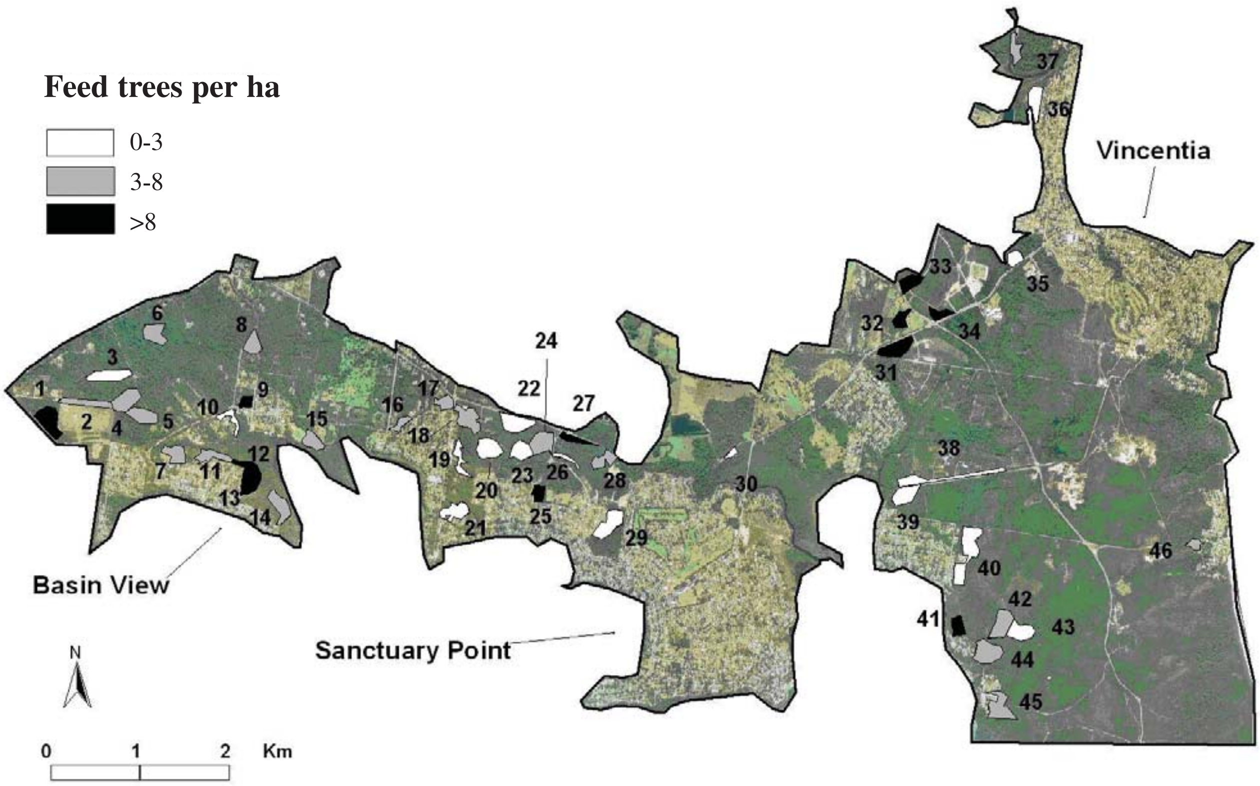

Figure 3. *The suitability of Glossy Black-Cockatoo foraging habitat across the study area. Cone-bearing A. littoralis exhibiting > 20 cone fragments were classed as 'feed trees'.*

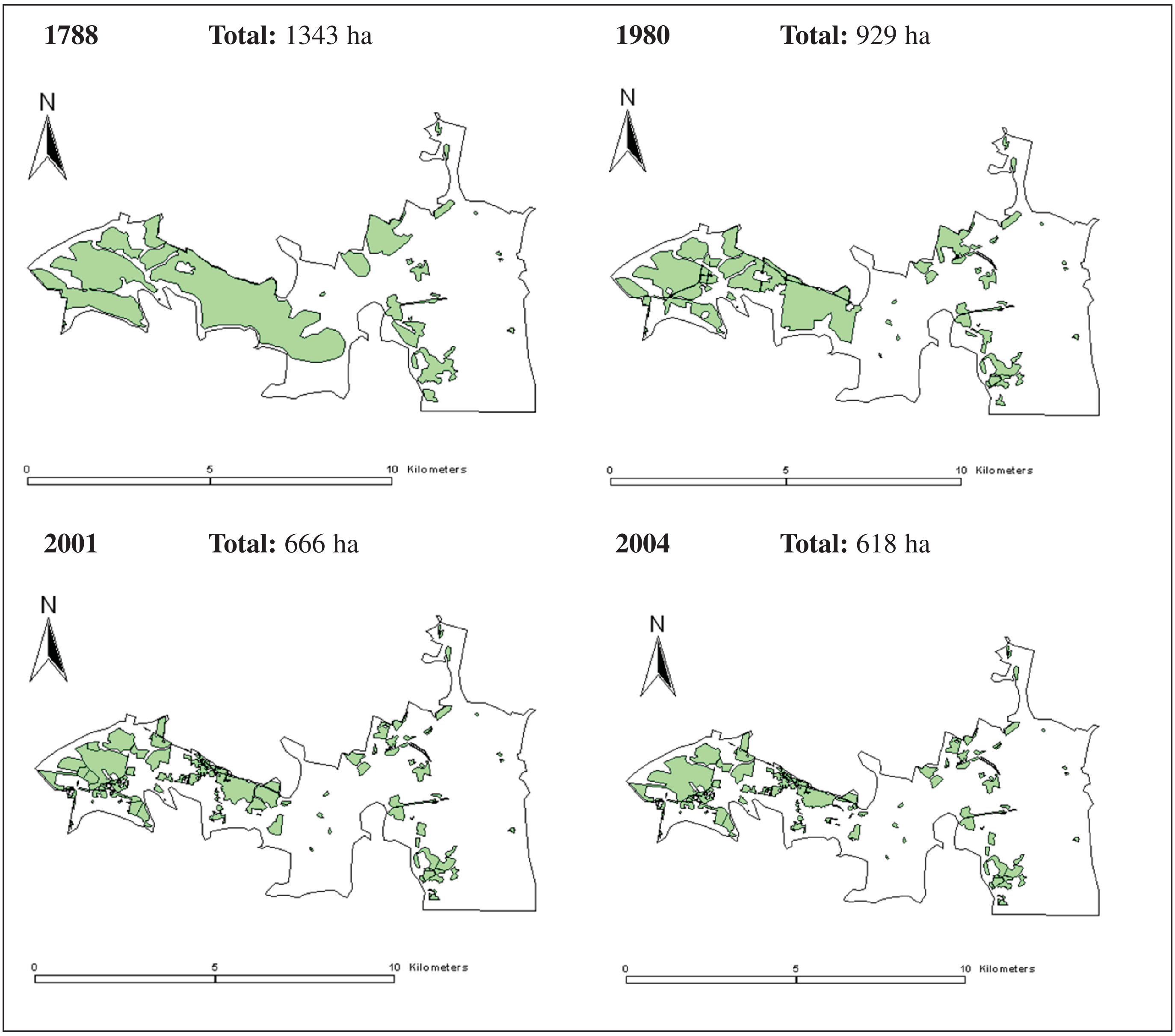

Figure 4. *The historical decline of foraging habitat for the Glossy Black-Cockatoo. Figures compiled using ArcView 3.3. 1788 map inferred by data sourced from S1 56-13 Ulladulla 1:250,000 Geological Series Sheet and identified remnant A. littoralis patches. 9027-4-N Huskisson 1:25,000 topographic map shows extent of land-clearing in 1980. Remainder of historic habitat maps compiled from digitised aerial photographs dated 14 Apr 2001, and field observations made by TR from March to July 2004.*

habitat to Glossy Black-Cockatoos. Because the loss and fragmentation of *A. littoralis* trees is deemed as a threatening process to the Glossy Black-Cockatoo (NPWS 1999), an off-reserve approach to managing the conservation of these species appears essential. In a comparable scenario of human induced habitat loss, Saunders (1977, 1990) and Saunders *et al.* (1991) attributed foraging habitat fragmentation to reduced breeding success and local extinction amongst Carnaby's Black Cockatoos *C. latirostris* in Western Australia. The increased energy expenditure of these birds searching for food within a fragmented landscape decreased their ability to adequately provide for their young. The effects of habitat fragmentation on Glossy Black-Cockatoo breeding success within the study area are unknown.

A reality of urban growth in the coastal hinterland of NSW is that foraging habitat will continue to be cleared for development. Asset protection zones, bulldozed to diminish the threat of bushfire, sub-division and the development of new residential estates, all contribute to cumulative habitat loss for the Glossy Black-Cockatoo. In consideration of likely landscape change, prioritising the retention of existing habitat is essential to allow land managers to minimise impacts of urban growth on this species.

The index of feed trees per hectare is a useful indication of foraging habitat utility across the landscape. The 'foraging sign' is unique to the target species, and will remain visible for extended periods, reducing problematic biases in variability as sign deteriorates (Westcott 1999). Fire will often kill *A. littoralis* (Clout 1989; Robinson 2004) and the cones of surviving trees will open, releasing their seeds, and causing burnt areas to be unsuitable habitat until the cones are renewed. These aspects of *A. littoralis* ecology limit the suitability of this index in assessing locations regenerating post the fire event.

Because the Glossy Black-Cockatoo has a sampling bias for trees with an abundant cone crop (Clout 1989), it is likely that some sites surveyed in the study area currently exhibiting less mature *A. littoralis* will increase in their observed suitability as a foraging resource with an increase in vegetation age. This preference for trees with large cone yields also reiterates the merit of low intensity hazard reduction burns, limiting the mortality of mature *A. littoralis*. The index of feed trees per hectare will further shift with the dynamics of food availability and corresponding foraging intensity of the Glossy Black-Cockatoos population within a landscape. For example, temporary habitat destruction from hazard reduction burns and bushfire may increase the observed abundance of foraging sign in unburnt areas. For these reasons, sites should only be compared at a local level and with other sites of a similar fire age.

Articulating the relative importance of foraged trees to the Glossy Black-Cockatoo has previously been difficult for those wishing to conduct impact assessment. Uncertainty surrounding the significance of individual feed tree loss, and justifying the importance of individual tree retention when land use changes are proposed, can be difficult when there are seemingly many alternative suitable foraging trees for Glossy Black-Cockatoos in the locality. This study provides the data to support feed tree retention, and places the relative worth of feed trees within a landscape perspective. That trees in the study area displaying greater than 20 fragments encompass only five per cent of cone-bearing *A. littoralis*, and 'preferred trees', displaying greater than 100 fragments consist of less than two per cent of total cone bearing *A. littoralis,* demonstrates the significance of feed trees as a foraging resource. Because feed trees are often returned to for future foraging on an annual basis (Crowley and Garnett 2001; Daly 2001; pers. obs.) their retention is an essential element of conservation planning for the Glossy Black-Cockatoo.

Observations during this study of heavily utilised 'preferred trees' on the suburban edge, and within suburbia, validate management strategies that seek to retain feed trees when human induced habitat loss occurs. Further research is required to investigate the long-term suitability of suburban feed trees as a foraging resource, particularly in the development of strategies to ensure maintenance of suitable foraging habitat following the death of retained feed trees.

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