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# The influence of land-use history on roadside conservation values in an Australian agricultural landscape[1]

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Peer reviewed contribution

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ABSTRACT: We investigated the influence of land-use history on roadside conservation values in a typical agricultural landscape of southern New South Wales, Australia. Historical information on the development of rural road reserves was collated from recently digitised 19$^{th}$ and 20$^{th}$ century pastoral and parish maps, such as road reserve age and original survey width, as well as data relating to locations of old fencelines, county or parish boundaries, previous reserves, stock routes and road re-alignments. Ordinal regression statistics showed that road reserve age and road width were significant predictors of roadside conservation values. Importantly, analyses showed that the first roads surveyed during the pastoral era (1840–1860s) were often of lower conservation value than roads surveyed in the 1870s, when major clearing of these landscapes commenced. Most roads were surveyed at one-chain width (20.12m); however, pre-1870s historic roads, Travelling Stock Routes (TSRs) and county or parish boundaries were significantly wider, decisions that have indirectly led to higher present-day conservation values. In separate analyses, historical data also formed a useful model to predict the absence of short-lived shrub species. These results highlight the influence and prevailing imprint of historical land-use on current roadside conservation values.

## 1 INTRODUCTION

Change in land use and land cover, and associated fragmentation of habitat, is one of the most pervasive effects of human activities on the face of the globe (Davies *et al.* 2001). In Australia for example, it is estimated that between 1893 and 1921, 25.7 million hectares of native vegetation was cleared for agriculture in New South Wales, an area greater than England, Scotland and Wales combined (Reed 1990) — truly an 'apocalyptic event' (Adamson and Fox 1982). The cycle of destruction of forests, over-exploitation of the land and agricultural development has been repeated throughout recorded history (Henle *et al.* 1996), and we should be both surprised and grateful that any vestiges of the natural landscape remain at all (Main 1993). Many landscape elements may still be experiencing major community changes as a consequence of recovery from intense historical land use (Foster 2000). Therefore understanding the history of the land, its biota, and its anthropogenic interrelations must be treated as an integral aspect of any ecological study, and of critical importance to conservation planning (Motzkin *et al.* 1996).

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Road verge, or roadside environments are gaining greater recognition for their role in nature conservation, as agricultural landscapes become increasing impoverished (Bennett 1991; Dennis 1992; Pauwels and Gulinck 2000). In 1991, it was estimated that road reserves (i.e. the total strip of land reserved for transportation purposes: Bennett 1991) occupied 80% of the combined area of national parks in New South Wales. Yet despite this, the importance to conservation of roadsides is often undervalued, perhaps due to the ubiquitous nature of roads in the landscape (Cooper 1991). Roadsides often constitute a significant proportion of native vegetation remaining in agriculture areas (Hobbs and Saunders 1994), and provide important refuges for populations of many native plants such as shrub species, which are vital for providing habitat for threatened avifauna (Cale 1990; Leach and Recher 1993). Similarly in Europe, the USA and New Zealand, agricultural habitats such as field margins, hedgerows and green lanes are gaining greater recognition for their importance in providing agronomic functions and refugia for biodiversity (e.g. Dover *et al.* 2000; Viles and Rosier 2001; Marshall and Moonen 2002; Forman *et al.* 2003).

In studies of roadside environments, it is important to recognise that roads have developed for human use, and therefore have many social, economic and cultural values, including the transportation of people and agricultural produce, and provision of infrastructure (Pauwels and Gulinck 2000). Despite this, roadside vegetation is often regarded as temporally inert and devoid of human impacts, as some relic of past conditions. As Fensham (1989) states, it is short sighted to assume that the makeup of remnant vegetation can automatically be interpreted as being representative of the historical condition of a site. Remnant vegetation in human altered landscapes may be vastly different from the original ecosystems from which it developed (Foster *et al.* 2003), depending on the land-use history of the area in which the road was first surveyed.

In North America, historical information such as records of land surveyors, early maps and survey trees, in conjunction with dendrochronological and other data sources has been used in many studies to reconstruct pre-European settlement vegetation patterns. This work has shown that historical land-use and its legacies are important in understanding present day ecosystems (e.g. Foster and Motzkin 1998; Bellemare *et al.* 2002). In Australia, historical information has been used to a lesser extent to recreate pre-European vegetation patterns or describe changes in vegetation structure (see summaries by Lunt 2002, and Stubbs and Specht 2002). In many of these studies, roadside vegetation is often used to benchmark or verify past conditions, and is selected for sampling based on subjective measures of 'intactness', such as the degree of weed invasion (Fensham 1989) or presence of mature overstorey trees (van der Ree and Bennett 2001). To our knowledge, no studies have investigated the extent that historical land-use information may explain present day roadside conditions. In this paper, we investigated the use of 19$^{th}$ and 20$^{th}$ century pastoral and parish maps to gain a better understanding of the development history of road reserves in a typical agricultural area of NSW, and examined relationships between land-use history and current roadside conservation values, and the distribution of native shrub species.

## 2 STUDY AREA

The study was conducted in the Lockhart Shire, a rural local government area in southern New South Wales, Australia (Fig. 1). The area has a cool temperate climate, with mean annual rainfall ranging from 500–600 mm, and altitude ranging from 200 to 450 m. Topography consists of low undulating hills and flat riverine plains, with occasional granitic outcrops. Dry-land farming systems, typically of cereal, oilseed crops and pasture/livestock in rotation, now dominate a mostly cleared agricultural landscape (Murray Catchment Management Committee 2003). Native vegetation is mostly restricted to roadside corridors, riparian zones or isolated hilly outcrops, and consists mainly of open *Eucalyptus* woodlands (e.g. *Eucalyptus microcarpa, E. melliodora, E. blakelyi* and

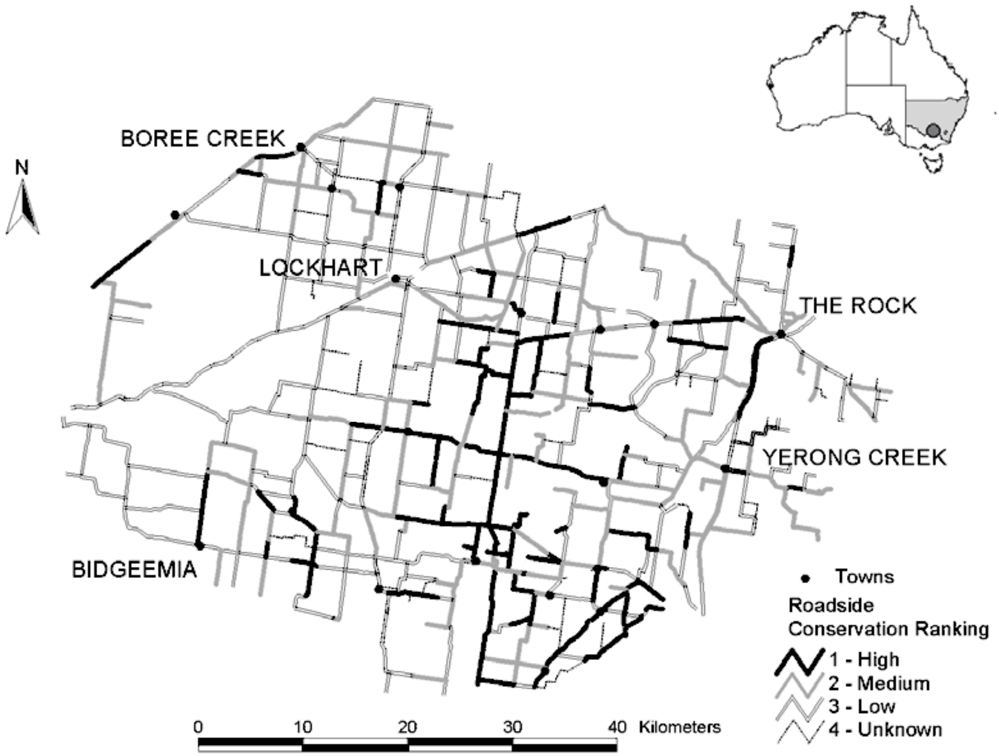


Figure 1. Location of the study area in southern NSW, Australia, showing roadside conservation rankings for the Lockhart shire council area (based on data in Bull 1997).

*E. albens*), as well as mixed *Eucalyptus, Callitris glaucophylla* or *Allocasuarina leuhmannii* communities (Moore 1953). Woodlands in the Lockhart Shire have historically supported a rich and diverse shrubby understorey (McBarron 1955), as well as native grasses (*Poaceae*) and herbs from the families *Asteraceae, Fabaceae, Liliaceae, Orchidaceae, Juncaceae* and *Cyperaceae* (Moore 1953; Prober & Thiele 1995). The dominant woodland vegetation types of the region are now listed as endangered ecosystems in Australia (e.g. *E. melliodora – E. blakelyi, E. albens* grassy woodlands and *Allocasuarina leuhmannii* woodlands; DEH 2003).

## 2.1 *History of European settlement and road survey*

The indigenous inhabitants of much of southern New South Wales are the Wiradjuri people, who are thought to have lived in the area for at least 40 000 years (Gammage 1986). In the 1840s, early European pastoralists took up most of southern NSW in leasehold arrangements in ‘runs’ of up to 100 000 acres (Roberts 1935). The pastoral era continued until 1861, when legislation was enacted in NSW to allow new settlers to purchase leasehold crown lands. To maintain control of ‘their’ land, pastoralists could exercise pre-emptive purchase rights by way of ‘improvements’, and clearing the land by ringbarking was a popular and cost-effective choice. But despite their wealth, early pastoralists could not afford to purchase runs outright, and instead used influence with surveyors to request that certain areas be reserved as travelling stock, water, timber or gold mining reserves. Such reserves were often revoked later and shrewdly purchased by squatters when funding permitted (Gammage 1986). In the 1870–1890s, pastoralists cleared the land at a feverish pace to gain pre-emptive rights of purchase. During this time, hundreds of new settlers arrived in the area to stake out claims, and promptly cleared the land for cropping. By the 1890s, apart from road and forest reserves, most of the land had been cleared for agriculture (Buxton 1967).

During this period of rapid land settlement, surveys were completed to subdivide southern NSW into the English system of counties and parishes. In many cases, parishes were not subdivided in a grid-based system as in the United States, but proceeded in an ad-hoc fashion as land was purchased, partly due to the chaotic state of the NSW Survey and Land Departments in the 1800s (Hallman 1973). Survey data from previous pastoral maps were used as templates for succeeding parish maps, which were then updated as land was claimed or changed ownership (Read 2003). Surveyors were instructed to allocate one chain (20.12m) road reserves in rural areas so all titles could access vital water resources. However, road reserves were sometimes surveyed at 2 or 3 chains width to allow for expected high usage, or to provide materials for road construction (Marshall 1999). Travelling Stock Routes (TSRs) were also surveyed of varying widths from 1 to 80 chains (one mile) wide (Hibberd 1978). In the early 1900s, from the hundreds of road reserves surveyed across the landscape, local government authorities then identified and declared all road reserves that were currently in-use (or projected) as ‘public roads’, and commenced construction of the present day rural road networks in southern NSW (Prichard 1991; Spooner unpub. data 2004).

## 3 MATERIALS AND METHODS

### 3.1 *Roadside conservation mapping*

The Lockhart area road network (approx. 1200 km) was mapped in ESRI ArcMap, based on maps provided by the Lockhart Shire Council. Roads were then categorised according to their roadside conservation ranking (RCR), as previously assessed in roadside vegetation surveys by Bull (1997). In these surveys, attributes such as overall vegetation condition, level of weed infestation, extent of natural regeneration and various wildlife habitat attributes (e.g. trees with hollows) were assessed using ordinal scales, and combined scores were used to assign an integrated conservation value or ranking for each road (full details: NSW REC 1996). Roads (as named on shire road maps) were divided into road segments, where sections of a road from one intersection to the next, or to a point on the road where vegetation conditions changed, were identified as described in previous surveys. This process resulted in 419 road segments, each approximately 3–4 km long for analysis.

### 3.2 *Use of historic parish and pastoral maps*

The New South Wales Department of Information Technology and Management, Department of Infrastructure Planning and Natural Resources and the State Records Authority have recently completed the Parish Map Preservation Project, which digitised the state’s historical parish, town and pastoral maps (Read 2003). Digital maps were obtained on CD for the following pastoral runs: Brookong, Bullenbung, Grubben Plains, Hanging Rock, Mahonga, Mittagong, Mundawaddera, Tootool, and Wallandoon (NSW LPI 2001a). These pastoral maps are thought to contain the only records of land use and road survey details prior to the 1880s, as nearly all Crown land maps and documents were destroyed in a fire at the Garden Palace exhibition building in the Sydney Botanic Gardens in 1882 (Read 2003). In the County of Mitchell, digital maps were obtained for the parishes of Ashcroft, Burke, Cox, Edgehill, Grubben, Hanging Rock, Leitch, Milbrulong, Mundawaddery, Tootool, Vincent and Yerong. In the County of Urana, digital maps were obtained for the parishes of Clive, Finlay, Hebden, Lockhart, Munyabla, Napier, Ross and Wallandoon (NSW LPI 2001b–d). For each parish map, all successive versions were inspected, from originals that date back to the late 1880s, to the most recently cancelled maps of the 1970s, to document chronological changes in land-use and road reserve development.

Ten historical variables were recorded for each road segment (Table 1). Pre-1870s historic roads (R_HIST) were identified as those that preceded the Crown Lands Acts in 1861, as opposed to roads that originated during rectangular land surveys after the 1870s, as shown on historical pastoral maps. Historical roads often connected pastoral homesteads to reserves, watercourses or major stock routes (Fig. 2). On some pastoral maps, only a few sections of historical roads could be discerned, 'overlaid' by a mosaic of new land titles. Other information on early pastoral maps includes original parish boundaries (e.g. Fig. 2: 'Parish of Vincent'), as well as county and pastoral district boundaries. Land use patterns are also shown on these maps: freehold purchases were usually shaded pink, conditional purchases blue or purple, reserves green, and leased crown land remained unshaded.

Table 1. Historical land-use variables recorded for 419 road segments in the Lockhart study area, NSW.

| Variable | Abbreviation | Description and scale |
|---|---|---|
| *Dependent variables:* | | |
| Roadsideconservation ranking | Rcr | 1 = high, 2 = medium and 3 = low |
| Shrub diversity | Shrubd | 1 = 0–1 species, 2 = 2–3 species, 3 = 4–5 species, 4 = 6–8 species. |
| *Independent variables:* | | |
| Pre-1870s historic road | R_hist | Roads that existed prior to land subdivision of the 1870s, as identified on pastoral maps |
| Road reserve survey age | R_age | Years (in 10 year intervals) since a road segment was surveyed (as at 2003). |
| Road in-use age | R_use | Years (in 10 year intervals) since a road segment was put in public use (as at 2003). |
| Historic pastoral fence-line | Fence | Boundaries of previous pastoral runs (in existence 1840-1870s) |
| Reserve | Oldres | Road segment that either bounded or was situated in a previously gazetted reserve (water reserve or other) |
| Travelling stock route - historic | Tsrold | Road segment that was once a travelling stock route (tsr), or situated in a tsr reserve |
| Travelling stock route - current | Tsrnow | Road segment that is currently a tsr |
| County or parish boundary | Bound | Road segments situated on county and/or parish boundaries |
| Re-alignment | Realign | Road segments that have been realigned from original survey position |
| Road width | R_width | Width of road segments as originally gazetted (converted to metric measure) |

Table 2. Metric conversion of typical imperical measures used in the late 1800s to survey road reserve width (R_WIDTH) in Australia

| Survey width | Distance (m) | Common use |
|---|---|---|
| 1 chain / 100 links / 66 feet | 20.12 | 'Default' width used for most access roads |
| 150 links | 30.18 | Main connecting roads |
| 2 chains / 200 links | 40.23 | High use roads, or county and parish boundaries |
| 3 chains / 300 links | 60.36 | Minor Travelling Stock Routes (TSRs) |
| 5 chains | 100.60 | Combined road and railway reserve |
| 80 chains / 1 mile | 1609.63 | Major Travelling Stock Routes (TSRs) |

The date of survey of road reserves was usually not recorded on early editions of pastoral and parish maps. Road reserve survey age (R_AGE) was determined by viewing sequential editions of parish maps, and recording the cancellation date (in decades) of the map on which the road segment was first clearly annotated. For example, for a road segment identified on a parish map raised in 1888 and cancelled and re-issued in 1898, the date '1890' was recorded. This method facilitated the collation of multiple parish data, as the date of issue of maps for adjoining parishes was not synchronised. On more recent parish maps, the actual date of the road survey was sometimes gazetted and thus recorded. The same method was used to record the date that roads were declared as 'public roads' (R_USE), however the actual dates that roads were opened was often annotated on parish maps, and thus recorded. Public roads were annotated on parish maps with a dashed line within the road width (Fig. 3). Many road reserves were surveyed but not put into public use for some time, if at all.

Road reserve segments were also coded based on the following land-use criteria:

(1) located on an old pastoral boundary (< 1861) or other fence-line (FENCE),
(2) located in, or formed the boundary of a former water or other reserve (OLDRES),
(3) was previously a Travelling Stock Route (TSROLD),
(4) is currently a TSR (TSRNOW),
(5) located along a county or parish boundary (BOUND),
(6) the road reserve segment has been re-aligned (REALIGN) (Fig. 4).

As well, the original survey width of roads (R_WIDTH) was recorded (Table 2), which was independently verified by field survey. The presence or absence of 11 regionally common and rare shrubs (Bull 1997) was also recorded for each road segment, to investigate correlations between historical land-use and shrub distributions (Table 3). Shrub presence absence data were combined into an ordinal variable for shrub diversity (SHRUBD) for each road segment.

Table 3. Eleven common shrubs in the Lockhart study area in southern NSW, with relative abundance ex pressed as number of road segments present.

| Species | No. of road segments |
|---|---|
| Acacia acinacea | 46 |
| *Acacia deanei* | 59 |
| *Acacia decora* | 93 |
| Acacia montana | 105 |
| Acacia paradoxa | 10 |
| *Acacia pycnantha* | 221 |
| *Bursaria spinosa* | 120 |
| *Dodonaea viscosa* subsp. c*uneata* | 219 |
| *Eutaxia microphylla* | 30 |
| *Indigofera australis* | 11 |
| *Senna artemisioides* varieties | 69 |

Figure 2. Section of a pastoral map of the late 1870s (Mittagong run composite image). (A) points to a pre-1870s road adjacent to a watercourse. Note, a large reserve (dated 1874) which has 'overlaid' this road; and (B) points to another pre-1870s road that extends from a creek crossing near Mittagong homestead (bottom of map), to a nearby locality via Lake Gilman. Both these roads most probably originated as informal stock routes in the 1840s.

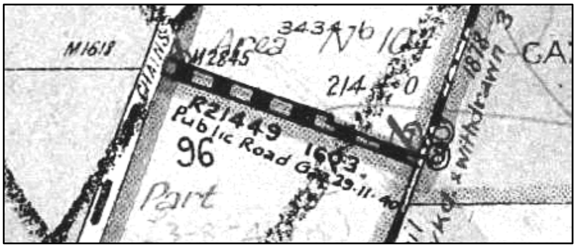


Figure 3. Section of a parish map (Parish of Grubben map 1928-1967) showing how public roads were annotated. In this example, the road is shown as dashed lines inside the road reserve boundaries, and the date the reserve was declared open to the public shown: i.e. 'R21449 Public road gazetted 29/11/1940'. Road reserves that were not public roads were shown as blank corridors between portions, and most were eventually resumed or closed (see Fig 4d).

### 3.3 *Statistical analysis*

Ordinal regression analysis was used to predict the probable roadside conservation ranking (RCR) of road segments as a function of continuous and dichotomous historical variables (Table 1), using default Logit link options in SPSS version 10.0.7. Ordinal regression analysis in SPSS uses the Polytomous Logit Universal Models (PLUM) procedure, where model fitting Chi-square statistics (based on Log-likelihood ratio tests), goodness-of-fit, Nagelkerke's Pseudo $R^2$ and Wald parameter estimates statistics were used to determine a significant predictor set of RCR (McCullagh and Nelder 1989; Agresti 1990). However, goodness-of-fit tests were mostly informative due to the large number of zero frequencies (Agresti 1990, p. 483). Initially all independent variables were entered for analysis, and subsequently removed and re-analysed based on parameter estimates and model fit (Log-likelihood $P < 0.01$), until a satisfactory model was obtained. Where independent variables were significantly correlated (Pearsons: $P < 0.01$), correlation and co-variance matrices were used to check independence of variables in the final model. Once the final model was determined, predicted RCR scores were saved to calculate classification statistics to show the success of the model (Hosmer and Lemeshow 2000).

Similarly, ordinal regression analysis was used to predict probable shrub diversity (SHRUBD) of road segments as a function of continuous and dichotomous historical variables (Table 1). Logistic regression analysis was also used to predict the probability of occurrence of individual shrub species as a function of historical variables. Variables were backwards entered using the Log-likelihood ratio statistic, and significance of explanatory variables was based on Wald statistics. The Hosmer and Lemenshow (2000) goodness-of-fit test was used to determine the significance of the model in discriminating where each species occurred, in conjunction with parameter estimates. Goodness-of-fit was also determined by analysing the proportion of cases that were classified correctly (Hosmer and Lemeshow 2000; Pallant 2001).

Individual Kruskal-Wallace non-parametric tests were also used to test for differences in road reserve width (R_WIDTH), and road reserve survey age (R_AGE) using road conservation ranking (RCR) or shrub diversity (SHRUBD) as a grouping variable. Similarly, Mann-Whitney U tests were used to test for differences in R_WIDTH and R_AGE based on historical dichotomous variables. Correlations between historical variables and the presence of shrub species were explored using Spearman's non-parametric rank-order correlation statistics (Pallant 2001).

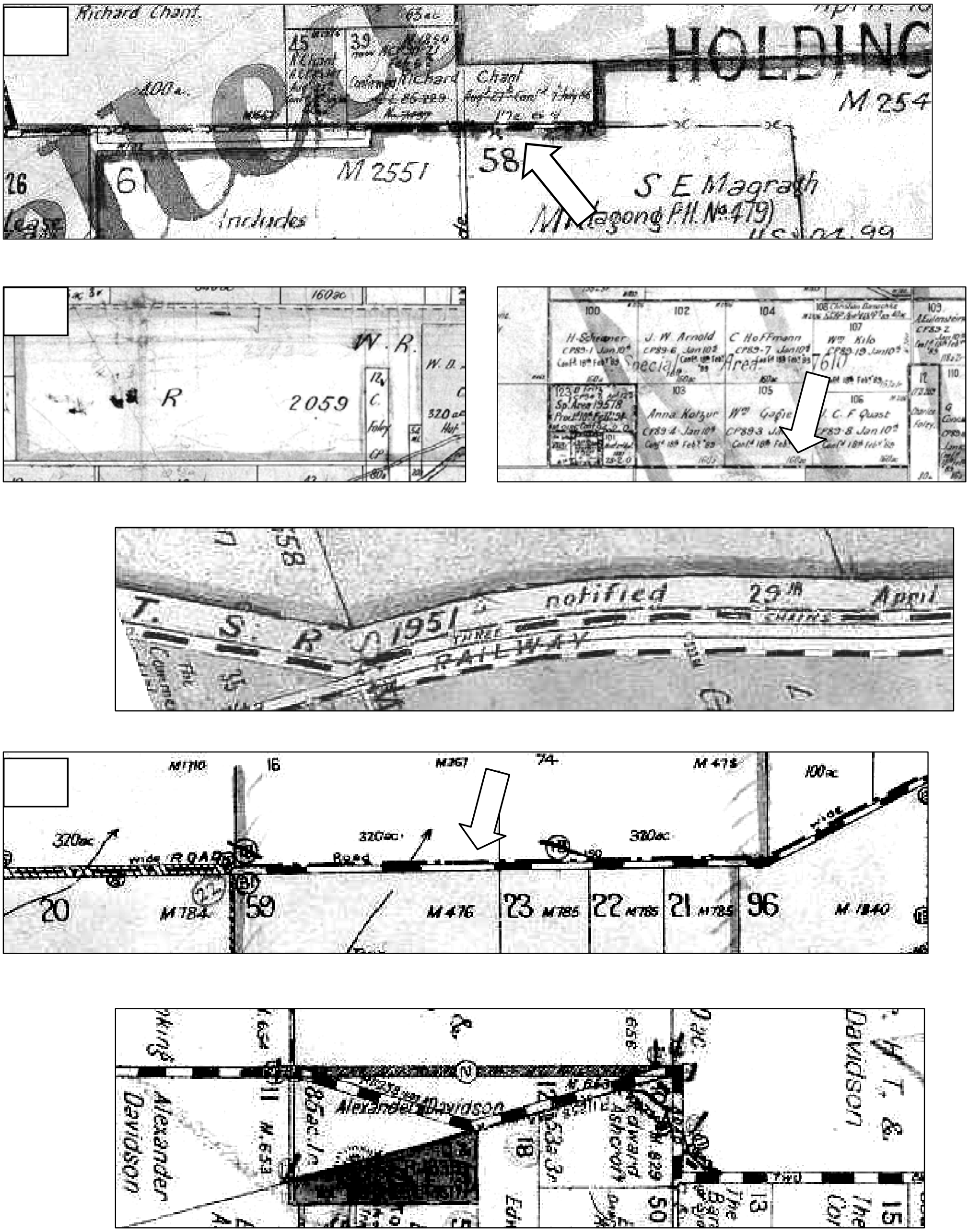


Figure 4. Examples of historical aspects of road reserve design. (A) road reserve surveyed along a section of a previous pastoral boundary (fence-line indicated with alternate dashed line and crosses); (B) part of an old 'water reserve': the left image shows the reserve as it existed in the 1870s, the right image shows the reserve was subsequently revoked, settled and cleared (1889), with only a narrow road reserve (arrow) and small cemetery remaining along the southern boundary; (C) Travelling Stock Route (TSR), this example shows a roadway 'three chains wide' in conjunction with an adjacent TSR No. 1951, railway, and secondary road

reserve; (D) road reserve surveyed along a parish boundary (boundary indicated with alternate dash-dots). The road width is shown as '150 (links) wide'. Also shown on the left is a road reserve closure (marked with cross-hatches); and (E) re-alignment of a section of road reserve (twice in this example). The circled numbers shown on road reserve segments are map index numbers which show re-alignment details (e.g. date), which are listed at the sides of the relevant parish map.

## 4 RESULTS

### 4.1 *Roadside conservation ranking (RCR)*

We tested whether the roadside conservation ranking (RCR) of 419 road segments could be predicted from various combinations of independent historical road variables. Ordinal regression analysis produced a highly significant predictive model ($\lambda^2 = 56.736$, $P < 0.001$) that classified 49.8% of road segments RCR correctly (47.2% high, 49.4% medium and 52.9% of low RCR). In the final model, road width (R_WIDTH), road survey-age (R_AGE) and pre-1870s historic roads (R_HIST) were a significant predictor set ($P < 0.001$) of RCR (Model 1: Table 4). However, as road reserve width is a small component in assessments of RCR (Bull 1997), a separate analysis was carried out with the variable R_WIDTH excluded. This analysis also produced a significant, though less powerful model ($\lambda^2 = 16.083$, $P < 0.001$), which classified 43.5% of road segment RCR correctly (47.2% high, 45.5% medium and 37.7% of low RCR), where R_AGE was a significant individual predictor of RCR (Model 2: Table 4). The differences in the classification statistics of these two models also showed that R_WIDTH was an important predictor of the conservation values of road segments of low RCR.

Table 4. Parameter estimates, standard errors and Wald statistics for the fitted ordinal regression models for predicting roadside conservation ranking (RCR), based on road historical variables.

| Predictor variable | Estimate | S.e. | df | Wald | *P* |
|---|---|---|---|---|---|
| *Model 1 (All variables entered)* [a] | | | | | |
| R_AGE | -0.018 | 0.006 | 1 | 8.888 | 0.003 |
| R_WIDTH | -0.036 | 0.006 | 1 | 34.667 | < 0.001 |
| R_HIST | 1.111 | 0.314 | 1 | 12.538 | < 0.001 |
| *Model 2 (R_WIDTH excluded from analysis)* [b] | | | | | |
| R_AGE | - 0.024 | 0.006 | 1 | 15.696 | < 0.001 |

[a] Log-likelihood $\lambda^2 = 56.736$, $P < 0.001$

[b] Log-likelihood $\lambda^2 = 16.083$, $P < 0.001$

Table 5. Comparisons of mean road width (R_WIDTH) and mean road survey age (R_AGE) for road segments of different roadside conservation ranking (RCR) ($P < 0.01$; Kruskal-Wallace tests)

| Roadside conservation ranking (RCR) | Road width (m) | Road survey age (years) |
|---|---|---|
| 1 (High) | 46.3 | 121.9 |
| 2 (Medium) | 37.7 | 117.9 |
| 3 (Low) | 31.9 | 113.3 |

The above ordinal regression analysis showed that R_WIDTH and R_AGE were important predictors of roads segments with a high conservation ranking (e.g. RCR = 1). Using Kruskal Wallace tests, there was a significant difference in mean R_WIDTH ($\lambda^2 = 44.485$, $P < 0.001$) and R_AGE ($\lambda^2 = 15.971$, $P < 0.001$) between road segments of different RCR (Table 5). In general, wide road reserves had a higher percentage of roads segments classified as high conservation status (> 300 links: 43%) than narrow roads (100 links: 15%) (Fig. 5). Correspondingly, there was a trend for older road reserves to have a higher percentage of roads segments classified as high conservation status (1870s: 40%) than more recently surveyed road reserves (1900–1970s: 22%), with the exception of pre-1870s historic roads (R_HIST = 1) (Fig. 6). Further analysis with individual Mann-Whitney U tests showed that mean R_WIDTH and R_AGE were significantly greater on historic roads (R_HIST), county or parish boundaries (BOUND) and travelling stock routes (TSROLD) (Table 6).

Table 6. Comparisons in mean road width (R_WIDTH) and road survey age (R_AGE) for road segments according to dichotomous historical variables ($P < 0.01$; Mann-Whitney U-tests)

| Variable | Road width (R_WIDTH) | | | Road reserve survey age (R_AGE) | | |
|---|---|---|---|---|---|---|
| | Mean (m) | Statistics *Z* | *P* | Mean (years) | Statistics *Z* | *P* |
| R_HIST | 58.8 | -8.635 | < 0.001 | 126.7 | -5.722 | < 0.001 |
| FENCE | 35.8 | ns | ns | 119.5 | ns | ns |
| OLDRES | 39.9 | ns | ns | 116.9 | ns | ns |
| TSROLD | 52.7 | -6.605 | < 0.001 | 121.8 | -6.605 | < 0.001 |
| BOUND | 42.7 | -2.611 | 0.009 | 118.0 | ns | ns |
| REALIGN | 38.6 | ns | ns | 112.6 | ns | ns |

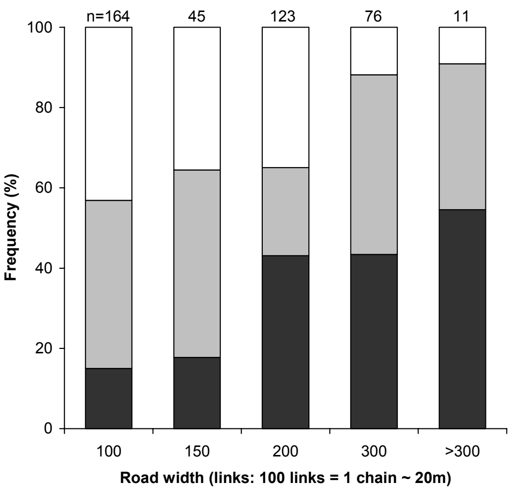


Figure 5. Frequency distribution of roadside conservation ranking's (RCR) in five road width categories (R_WIDTH; original empirical units shown), showing road segments scored as 'High' RCR (black bars), 'Medium' RCR (grey bars) and 'Low' RCR (white bars). n = sample size.

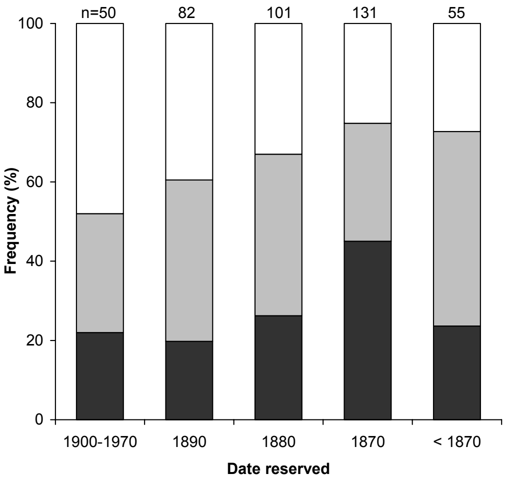


Figure 6. Frequency distribution of roadside conservation rankings (RCR) in five road survey date categories (R_AGE, expressed as date reserved; R_HIST used for category < 1870), showing the proportion of road reserves scored as 'High' RCR (black bars), 'Medium' RCR (grey bars) and 'Low' RCR (white bars). n = sample size.

Table 7. Parameter estimates, standard errors and Wald statistics for the fitted ordinal regression models predicting shrub diversity (SHRUBD), based on road historical variables

| Predictor variable | Estimate | S.e. | df | Wald | *P* |
|---|---|---|---|---|---|
| *Model 3(All variables entered)*[a] | | | | | |
| R_WIDTH | 0.042 | 0.006 | 1 | 52.282 | < 0.001 |
| R_HIST | -1.635 | 0.315 | 1 | 26.964 | < 0.001 |

[a] Log-likelihood $\lambda^2 = 56.631$, $P < 0.001$

## 4.2 *Shrub diveristy (SHRUBD)*

Separate analyses were carried out to investigate the role of land-use history on shrub diversity. Ordinal regression analysis produced a significant predictive model ($\lambda^2 = 56.631$, $P < 0.001$) that classified the shrub diversity (SHRUBD) of 29.5% of road segments correctly (63.8% 0–1 species, 33.1% 2–3 species, 21.2% 4–5 species and 0% 6–8 Species). In contrast to RCR, road reserve age was not a significant predictor of shrub diversity. Rather, R_WIDTH and R_HIST were a significant predictor set of road segments with low shrub diversity (Table 7). Similarly, individual logistic regression analyses of shrub presence showed that, in general, most historical variables were poor predictors of the presence of individual shrub species on road segments, particularly those species with limited distributions. However, logistic analyses showed that the variables R_WIDTH (positive estimate; greater width increased the likelihood of species occurrence) and R_HIST (negative estimate; greater age decreased the likelihood of species occurrence) were useful predictors of the more common shrubs *Acacia montana* (70% = 1), *A. pycnantha* (64% = 1), and *Dodonaea viscosa* (66% = 1). Further correlation analysis showed that overall shrub diversity, and likewise a number of individual shrub species, were significantly positively correlated with R_WIDTH, and negatively correlated with R_HIST (Table 8). Thus shrub diversity tended to be high on the widest roads, and low on historic (pre-1870s) roads.

Table 8. Correlations between the presence of 11 shrub species, shrub diversity (SHRUBD), road survey width (R_WIDTH) and historical roads (R_HIST) (n=419). * = $P < 0.05$; ** = $P < 0.01$

| Species | Road width (R_WIDTH)<br><br>Rs | Pre-1870s road (R_HIST)<br>*Rs* |
|---|---|---|
| Acacia acinacea | 0.174 ** | -0.023 |
| *Acacia deanei* | 0.104 * | -0.137 ** |
| *Acacia decora* | 0.076 | -0.021 |
| Acacia montana | 0.257 ** | -0.031 |
| *Acacia paradoxa* | 0.189 ** | 0.124 * |
| *Acacia pycnantha* | 0.293 ** | -0.085 |
| *Bursaria spinosa* | 0.082 | -0.137 ** |
| *Dodonaea viscosa* subsp. *cuneata* | 0.212 ** | -0.053 |
| *Eutaxia microphylla* | 0.188 ** | 0.084 |
| *Indigofera australis* | 0.165 ** | -0.020 |
| *Senna artemisioides* varieties | 0.068 | -0.058 |
| Shrub diversity (SHRUBD) | 0.268 ** | -0.098 * |

## 5 DISCUSSION

Much of the variability in roadside conservation rankings was attributed to historical determinants, specifically road reserve age, confirming the importance of land-use history in understanding changes to biota in fragmented agricultural landscapes (Hobbs *et al.* 1993). Though the impacts of land use history on Australian ecosystems are well documented (e.g. Benson 1991; Main 1993; Lunt 1998), as far as we are aware, this is the first Australian study that explicitly describes the influence of land-use history on the conservation values of roadside ecosystems. Intuitively, land managers may recognise older more ‘intact’ roadsides in a general sense, based on ecosystem variables such as the presence of native understorey and mature hollow-baring eucalypt trees, and they may therefore indirectly assign higher conservation scores to older road reserves. However, variability in roadside conservation values is usually attributed not to patch age, but to internal processes such as grazing by stock, or external process such as edge effects, weed invasions, and nutrient transfers from the agricultural matrix (see below). As this study has demonstrated, an explicit understanding of road development history can explain much of the variability in RCR and associated vegetation condition. Therefore, as least some of the variability in RCR can be directly attributed to activities that occurred before road reserves were declared, rather than solely being a function of roadside disturbance regimes or edge effects.

A limitation of this study is that combined RCR scores were used in analyses, rather than individual scores for attributes such as presence of mature hollow-bearing trees or overall vegetation condition. Unfortunately, these raw data are no longer available (L. Bull, Greening Australia 2003 pers. comm.). Despite this limitation, the results demonstrate a strong historical imprint on present-day roadside conservation values. The use of historical data in conjunction with specific structural or vegetation condition variables can further enhance our ecological understanding of roadside ecosystems.

## 5.1 *Road reserve age*

The results of this study show that road reserve age was important in predicting roadside conservation values. In contrast, the date that road reserves were put in public use (R_USE) was not correlated to current RCR, which suggests that land-use activities that took place prior to road survey were of greater significance to RCR than subsequent road-use activities (e.g. roadworks). This pattern can be best explained in the context of land clearance history. In the 1870s, when major clearing of this landscape commenced, land that had already been surveyed for roads effectively protected narrow corridors of mostly 'intact' native vegetation, much of which is now of high conservation status. The surrounding landscape was then progressively and rapidly cleared. By contrast, road reserves that were surveyed in the 1880s and 1890s are in poorer condition owing to greater intensities of anthropogenic disturbance prior to road survey, as suggested by van der Ree and Bennett (2001). Depending on locality, extent of land clearance and associated agricultural development, roads surveyed across developing farmlands would be expected to contain native vegetation in increasing states of degradation. By the early 1900s, much of the landscape was cleared for cropping or grazing, therefore understandably, roads surveyed and resumed across cleared or ploughed paddocks contained vegetation that had little in common with previous natural ecosystems. These roadsides are often corridors of exotic weeds of low conservation value.

Age of the road reserve, or fragment age, may also be important in understanding the degree to which road ecosystems have adjusted to new environmental conditions associated with fragmentation of the landscape (Lugo and Gucinski 2000). However, as road fragments are relatively young (< 200 years), and dominant eucalypt trees have potential longevities of 400 years (Banks 1997), most roadside ecosystems would still be recovering from historical land-use impacts. Though the results of this study suggest that roadsides offer a unique insight into past vegetation structures and dynamics, owing to relatively recent effects of fragmentation, this relationship may not hold true in the future. Populations of dominant tree species may persist for long periods simply because of the longevity of individuals (Saunders *et al.* 1991), therefore the condition of individual roadside ecosystems may change over time, depending on levels of recovery or degradation.

A glimpse of potential future conditions of roadside remnants is perhaps shown by results for pre-1870s historic roads. It was expected that the oldest road reserves in the region would contain native vegetation in the highest level of 'intactness'. Unexpectedly, the positive relationship between road survey age and roadside conservation values reversed, and many (49%) of these oldest roads was only of medium conservation status. A likely explanation is that the oldest roads in many agricultural regions of Australia originated as stock routes in the 1840s, most of which were later formally gazetted in the 1870s as Travelling Stock Routes (Spooner submitted). During the pastoral era of the 1840–1860s, these 'roads' were used to move stock to markets, many of which are still used for this purpose (Buxton 1967; Hibberd 1978). The deleterious impact of grazing on Australian vegetation has been well documented, resulting in mostly disturbance tolerant species. It is most likely that the understorey components of older road reserves (see below) have been modified or severely depleted from a long history of heavy grazing (Benson 1991; Tiver and Andrew 1997).

A fundamental assumption of this study is that all road types (i.e. ages) provide a representative sub-sample of natural vegetation patterns across the region, and that road surveyors did not intentionally select (or avoid) certain vegetation types or landscape features. This assumption is likely to be met for roads surveyed after the 1870s, since these roads were mostly surveyed in rectangular grid patterns (Benson 1991; Hobbs and Saunders 1994). However this assumption may not be fully met for road reserves established before this period (pre-1870s roads), which often followed rivers and creek-lines, and linked other watering points (as shown in Fig. 2). However, at the large scale documented in this study, we have no evidence to suggest that pre-1870s roads are likely to have supported distinctly different veg types (or structures) prior to European settlement.

## 5.2 *Importance of road reserve width*

Road width had a strong influence on roadside conservation values. Various studies have described how remnants with high edge-to-area ratios, such as linear road reserves, are highly susceptible to modification from altered hydrological cycles, wind, increased nutrient influx from the matrix, soil erosion effects and changed microclimate (e.g. Saunders *et al.* 1991; Hobbs *et al.* 1993; Goosem 1997). As average road reserve widths were approximately 30 m, and road verge widths often less than 5 m, most roadside environments would classify as being completely 'edge' habitat. One of the principal effects of edges is an increase of light into local environments, in effect creating gaps, which can result in increased stem density of plants along edges (e.g. Murcia 1995; Goosem 1997). Wider patch areas have bigger 'core' areas which provide an element of buffering to external processes (Saunders *et al.* 1991), and in larger areas, it is more likely that populations are a sufficient size to resist external threats, and less prone to inbreeding depression (Gilpin and Soulé 1986). This would partly explain the condition of roadsides in this study, where wider reserves were in generally in good condition and of high conservational value, as compared to narrow roads, which were mostly in poorer condition and lower conservational status.

Wider road reserves not only buffer populations from edge effects and other external processes, but also provide space for populations of species to disperse, establish and colonise (Harper 1977; Davies *et al.* 2001). For example, in studies of roadside vegetation in woodlands of NSW, Schabel and Eldridge (2001) found that wider roads generally had greater structural diversity, and supported more healthy and diverse trees and shrubs, than narrower roads. For most plants in fragmented landscapes, when a previously more continuous population becomes divided into smaller units such as road reserves, there is often a lack of migration between patches due to limited dispersal of propagules. As the surrounding matrix is hostile to most roadside species, plants with limited dispersal ability (e.g. *Acacia* species) may not persist in narrow road reserves owing to limited opportunities for recruitment (Poschlod *et al.* 1996; Spooner *et al.* 2004a).

However, due to the unique nature of roadside environments, key threats to roadside vegetation are not just external landscape processes, but more immediate anthropogenic disturbance processes. As road reserves contain roads and other infrastructure, they are periodically impacted upon by in the form of road construction and maintenance activities (Lugo and Gucinski 2000; Spooner *et al.* 2004a; 2004b). The 'road effect zone' (Andrews 1990; Foreman *et al.* 2003) can extend a considerable distance into roadside environments, depending on road surface, road type and usage. Intensified road traffic can also have important negative impacts on roadside qualities (Pauwels and Gulinck 2000). For example, 39% of roads in this study were only one-chain (20.12 m) wide, and as the road surface of minor rural roads is often 8–12 m wide, roadside verges were little more than narrow lines of dense woody vegetation (Spooner *et al.* 2004a). As the impacts of roadworks are generally confined to the road surface area, wider road reserves are less susceptible to such impacts. Many road reserves such as TSRs are also periodically grazed, particularly in time of drought (Hibberd 1978). Again, wider roads with larger populations lessen the risk of degradation and possible extinction from such impacts.

Most wide roads in Australian agricultural landscapes are Travelling Stock Routes (TSRs) or rail reserves. During the 1860–1890s, many TSRs were surveyed at various widths up to one mile wide, depending on stock usage, to provide enough fodder for stock travelling to markets. This highlights the important, albeit unintended, role of early surveyors in conserving native biota in roadside environments. For example, their decisions also led to the survey of roads that were significantly wider along county or parish boundaries. Though investigations failed to find any regulations regarding the survey of roads along these boundaries, surveyors did clearly mark these boundaries across the landscape (Marshall 1999). Furthermore, individual roads were surveyed at widths greater than one-chain to provide materials for road construction, or to circumnavigate problem areas (NSW DMR 1976). These results show that in many cases, roadside conservation values are a direct legacy of 19th century land-use decisions.

### 5.3 *Presence of short-lived species – shrubs*

As roadside vegetation assessments record the presence of older mature trees, some level of correlation was anticipated between road reserve age and roadside conservation ranking. The presence of major shrub species, important for fauna habitat, was also analysed to investigate possible historical linkages to shrub diversity. In contrast to dominant eucalypts, as most shrub species are short-lived (< 50 years), and most road reserves are old (> 100 years), it was anticipated that there would be few if any correlations. Unexpectedly, a highly significant model was produced to predict shrub absences, where most species were positively correlated with road width, and negatively correlated with pre-1870s historic roads. In other-words, there were few shrub species in the oldest road reserves, many of which are stock routes.

The most likely explanation for an absence of shrubs in old road reserves is a long history of grazing by stock, as described by Tiver and Andrew (1997). Grazing is an important factor contributing to the decline of native plant populations in Australian agricultural landscapes (e.g. Yates and Hobbs 1997), and many road reserves have been grazed by domestic stock for up to 150 years (Wilson 1990; Benson 1991). The intrusion of stock into roadsides leads to the depletion or total removal of understorey vegetation, and prevents regeneration. Frequent grazing by stock along pre-1870s historic roads may have defoliated plants and inhibited regeneration to the extent that local populations of many shrub species have become extinct. As the results show, most species were negatively correlated to historic roads, and only one species (*Acacia paradoxa*) showed a significant positive correlation, and this species is a thorny non-palatable species (Stelling 1998).

The positive relationship between shrub diversity and road width also suggests that species richness is directly proportional to fragment size, a relationship that has been well documented in the literature, based on the theory of island biogeography (Macarthur and Wilson 1967). However species-area relationships have often come into question (Debinski and Holt 2000), mainly because of variation in patch quality, the surrounding matrix, edge effects, and lack of consideration of individual species life-history attributes (e.g. Wilcove *et al.* 1986). For example, in studies of woodland edges in Europe, patch width was an important spatial predictor of species richness, but this was attributed to edge effects that increased structural diversity, and provided a buffer to transfers from the agricultural matrix (Fry and Sarlöv-Herlin 1997; Ma *et al.* 2002).

In this study, three common shrub species (*Acacia decora, Bursaria spinosa* and *Senna artemisioides*) showed no correlation with historical data, which suggests that natural environmental gradients or anthropogenic disturbance regimes may also be important in determining roadside plant distributions (McIntyre and Lavorel 1994a; Ullman *et al.* 1995). Recent studies have shown that soil disturbance from roadworks is an important process which may override natural disturbance processes in road reserves, which may explain distribution patterns of disturbance tolerant species such as *Acacia decora* (Spooner *et al.* 2004a, 2004b). Further research is required regarding individual species distributions in relation to environmental and disturbance gradients, however these results suggest that the impacts of anthropogenic disturbances are most likely intensified in narrow road reserves, which explains their generally low conservation status.

## 6 CONCLUSIONS

As this study has demonstrated, an historical perspective can greatly assist our interpretation of roadside and remnant ecosystems. Importantly, we identified that the oldest roadsides which date back to first settlement (e.g. < 1870s) are not necessarily in the best condition, and may in fact be quite degraded from their original pre-European condition. Instead, most roadsides of high conservation value were wide road reserves surveyed in the 1870s, when major clearing of these landscapes commenced. These dates are contingent on regional development patterns, therefore to extrapolate these results to other landscapes requires an understanding of local settlement histories, and dates of land survey. For example, agricultural landscapes near Sydney have a longer development history (~1840s) than similar regions in Western Australia (~1900s) (Main 1993; Bauer and Goldney 1999).

These results have a number of important implications. First, the results suggest that in areas where vegetation surveys of roadside environments have not been carried out, historical pastoral and parish maps could be used to predict roadside conservation values. This could be a useful approach in conducting rapid regional or state-wide assessments of biodiversity values of roadsides.

However model predictions were not ideal, and further studies are required to develop the methodology using historical predictors, in conjunction with more formal vegetative composition and structural attributes (e.g. McIntyre & Lavorel 1994b). Second, as formal surveys of biodiversity are costly, identification of wide 1870s roads may be useful to rapidly identify potential habitat for many endangered or vulnerable fauna species, particularly those that rely on tree hollows for habitat (e.g. Superb Parrot, *Polytelis swainsonii*; Squirrel Glider, *Petaurus norfolcensis*; and Greater Broad-nosed Bat, *Scoteanax ruppellii*) (Oliver 1999). Finally, understanding the land-use history of agricultural landscapes, and associated development of roads, can provide new insights of the social and cultural values of roadside environments; a key issue to the successful conservation of these unusual landscape elements (Foster 2000).

Roadside vegetation was created by humans, has a history of human impacts, and exists in highly modified human landscape. Many populations may exist in roadsides because of anthropogenic disturbance processes (Foster and Motzkin 1998; Spooner *et al.* 2004a, 2004b). Recognition of land-use history, its legacies, and human relationships can only enrich our understanding of roadside environments.

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