Land and Water Australia Project QNR28

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Ecological thresholds for vegetation management in southern Queensland

Final Report

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Final Report

1. Project Details

LWA Project reference no.	QNR 28
Project Title	Ecological thresholds for native vegetation management in southern Queensland
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Due date for milestone report	31 January 2004
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2. Project Objectives

Clearing remnant vegetation for agricultural development has lead to habitat loss, fragmentation and the disruption of important ecosystem processes. This project aims to improve the knowledge of ecological thresholds for habitat retention and management in southern Queensland. The project had the following objectives:

1. Establish relationships between degree and patterns of fragmentation, and selected ecological indicators, as a means to assess long-term ecological sustainability of remnants in agricultural landscapes.
2. Quantify thresholds for management of ecologically viable remnant vegetation.

3. Provide tools for rapid assessment of ecological condition of remnants for use by vegetation management officers and / or land managers.
4. Recommend modifications to policies relating to native vegetation management and their associated performance requirements and acceptable solutions.
5. Communicate major findings to the wider scientific and land management communities, regional vegetation management committees and government policy advisors for adoption and application in native vegetation management in particular within the Murray-Darling basin.

3. Summary of method

Study Area and Site selection: The study area was in the Maranoa Balonne catchment in the Queensland Murray Darling Basin, approximately 275 km west of Brisbane. The study area extends from the townships of Miles in the east to Morven in the west, Injune in the north to Surat in the south, covering approximately 4.5 million hectares (147º 09′E and 150º 10′E and 25º 44′S and 27º 07′S). The region was selected on the basis of the level of retain remnant vegetation (approximately 36% at the commencement of the study), but was undergoing a rapid landscape change with clearing for agricultural and pastoral development. In the years prior to the study, clearing rate had accelerated throughout Queensland, with 425 000 ha/year cleared between 1997-99 (Department of Natural Resources, 2000) increasing to 758,000 ha in 1999-2000, prior to the introduction of vegetation management legislature, after which the rate of clearing was reduced to 378,000 ha in 2000-2001 (Department of Natural Resources and Mines, 2003). The area of most intensive clearing was the Murray Darling basin, accounting for 52% of all clearing statewide during 1997-99, and 46% in 1999-2001. The vegetation types in the study area vary greatly, but mostly consist of eucalypt and cypress pine woodlands, brigalow (*Acacia harpophylla*) and riparian communities, with 80 dominant regional ecosystems identified in the study area (as defined by Sattler and Williams (1999) and mapped by the Queensland Herbarium (Environmental Protection Agency, 2003). The regional ecosystem mapping was used to identify poplar box (*Eucalyptus populnea*) communities; with sixty sites selected on the basis of remnant poplar box occurrence and site accessibility. Sites were selected to encompass a range of landscape alteration in terms of the size of the patch, the level of isolation and the amount of fragmentation in the surrounding landscape. Access to sites was gained through the cooperation of landholders, and through the assistance of Landcare groups, Catchment Management Association officers, Local government officers and state agency staff in the region. Site selection was limited by the ability to gain continual access from landholders throughout the life of the study, so sites were often grouped on properties where access was guaranteed by willing collaborators, rather than spread uniformly across the study region.

Quantification of landscape structure and thresholds: A critical component of the identification of landscape thresholds and interpretation of field data is the quantification of landscape structure (See Attachment 1. Quantification of Landscape Structure and Thresholds for full description of method). Developing methods to define landscape patterns and the interactions among components of the landscape mosaic have been widely explored in recent ecological studies. Popular approaches employ landscape metrics (McGarigal and Marks 1994, Debinski and Holt 2000, Herzog *et al*. 2001), where the fundamental principles used in deriving metrics are based on studies of island biogeography (MacArthur and Wilson 1967). In this study we analysed landscape structure with FRAGSTATS v 3.3 (McGarigal *et al*. 2002), based on the pre-clearing and remnant 2001 regional ecosystem mapping (Environmental Protection Agency, 2003). As remnant regional ecosystem (RE) mapping has an accuracy of 100m, nine sites were incorrectly categorised as non-poplar box RE's or cleared, contradicting the physical ground surveys. Modifications to the mapping were made and the new polygons were used in all analysis (See Technical Milestone 4 for full description). For each of the 60 sites, metrics were derived at three scales: paddock (500 ha); property (8000 ha); and subcatchment scales (275,000 ha), reflecting different management regimes. Landuse of the surrounding matrix, distance to neighbouring remnants and historical disturbance (1988 to present) were determined, using the dataset from the Statewide Land and Trees Study (SLATS) (Department of Natural Resources and Mines 2003), with weightings assigned to different land uses based on their similarity to *E. populnea* (eg. other native vegetation scored 0.2, cropping 0.6). Isolation and proximity metrics were calculated using land use contrast weightings that describe the similarity between patch types. Nearest neighbour distances were calculated for patches within a radius of 5 km and edge distance and core area metrics were calculated assuming a 100 m edge. FRAGSTATS v 3.3 produced 240 metrics, so the initial set of metrics was reduced following a series of rules (See Attachment 1. Quantification of Landscape Structure and Thresholds). The remaining metrics were categorised into three groups: metrics describing area; metrics describing shape; and metrics describing diversity. Within these groups, the information provided by a metrics was assessed against information given by a similar metric and the least information removed if retention provided redundant information. Their exclusion removed the remaining highly correlated relationships among metrics. Each of the ecological descriptors selected different metrics depending on the likely responses of the biota or function, and the number of sites within the analyses.

Ecological Measurements: A core set of data of ecological condition, genetic diversity, and forest structure, floristic diversity, ecosystem function and soil health were measured at the study sites to determine indicators of status and condition, measures of viability and, where possible, threshold values. A permanent plot was established at sites where all measurements were taken (See Attachment 10. Previous Milestone Reports). Plots were located as far as possible from the edge of remnants or unique landscape features or structure (ie. water troughs, dams or fences), and following the contour. Site descriptions, environmental descriptors and disturbance and management history were recorded at each site (See Attachment 2. Floristic Surveys). It was not possible to measure all ecological markers at all sites, so three different intensities of sampling were employed:

- **Low intensity (60 Sites)**, where the sites are visited once or twice to assess habitat value, vegetation structure and tree health, conduct flora and reptile surveys and landscape function analysis. Data collected at these sites will be used to develop rapid assessment toolkit for vegetation management officers, regional natural resources management bodies and land-owners.
- **Medium intensity (20 of 60 sites)**, with the same assessments as above plus assessments of the genetic diversity of poplar box, installations of artificial reptile habitat and ground-active invertebrate surveys.

- **High intensity (9 of 60 sites)**, where all the same measurements as above are taken, plus detailed experimental assessments designed to test the validity of the rapid assessments used in the low and medium intensity sites. Detailed measurements undertaken include litter decomposition experiments, litter fall traps, soil biological activity measurement and detailed soil profiles, tree pest agents of dieback assessment and salinity risk assessments. The high intensity sites have had small exclosures built to protect equipment from livestock. These sites were visited every 2 months throughout the project.

The detailed methods used to collect the ecological data are given in the Appendices, and summarised below:

- Floristic surveys (See Attachment 2. Floristic Surveys) were conducted in the ground, shrub and tree layers at all sites between November 2002 and November 2003. Ten 1 x 1m quadrats were established 10 m apart along the centre of the plot, where the composition and cover abundance of all herbaceous species (less than 1m in height) was recorded. All woody species were surveyed within a 50 m x 10 m sub-plot and distinguished as either in the shrub layer (>1m and < 4 m height, and/or less than 5cm diameter at breast height, dbh) or tree layer (> 5cm dbh and >4m height). The most abundant native species in the different strata were analysed against four environmental datasets describing disturbance, habitat, contextual and landscape variables.
- Reptile Surveys (See Attachment 3. Reptile Surveys) were conducted on all sixty sites using area-and-time-constrained active searches consisting of one person-hour over 0.5 ha area. Active searches involve the displacement of habitat (rolling logs, raking leaf litter) to find cryptic species, and gives relative abundance rather than a complete sensus of the reptile fauna. Searches were carried out during fine weather in the morning (0700-1200) and afternoon (1300-1800), over two survey periods, October 2002–May 2003 and September 2003–January 2004). Each site was searched twice (morning and afternoon) during each sampling period. Abundance data were analysed against a number of environmental variables collected at the plot, patch and landscape level using constrained canonical analysis (CCA) in CANOCO version 4.0 (ter Braak and Smilauer, 1998). Ordination bi-plots and logistic regression analyses were used to interpret individual species responses to significant environmental variables. Artificial reptile habitats (two sheets of corrugated iron covered by soil and leaf litter) were installed at Medium Intensity sites, and inspected three times for sheltering reptiles during the course of the project. Results, however, were disappointing, and were not included in final analyses.
- Ant Surveys (See Attachment 4. Ant Surveys) were conducted at the medium intensity sites in March and August 2003, following an initial survey of 11 of the 20 sites in October 2002 (only March and August data were used in the analyses). Ants were collected in pitfall traps (40 mm in diameter containing ethanol and glycerol), with two grids of nine traps (5 m apart in a 3x3 configuration) located at either end of the permanent plot. Traps were opened for 4 days, after which ants were sorted to species or morpho-species, the abundance of each recorded using an abundance scale, and functional group identified (Andersen, 1995). Species abundance data were analysed against landscape structure data at the paddock scale and site-specific data reflecting habitat quality. Ordination analysis on species abundance and occurrence (using Non-metric multi-dimensional

scaling based on Bray-Curtis similarities) were carried out to examine similarities in ant assemblages. Partial redundancy analyses in CANOCO version 4.5 (ter Braak and Smilauer, 2002) were used to determine the variation explained by landscape structure and habitat quality.

- Forest Structure (See Attachment 5. Forest Structure) sampling was conducted on all 60 permanent plots. Tree species, height, DBH (at 1.3m) and position were recorded for live and dead trees (≥ 5 cm DBH), except for *Opuntia tomentosa* (Prickly Pear), which was excluded. The growth stages of trees (sapling, juvenile, pole, mature, senescent) were used to assign trees into maturity classes. Sapling and juvenile growth stage trees that constituted part of the understorey were classed as 'regeneration stage', pole stage and mature stage trees were classed as 'early maturity' and senescent trees were classed as 'late maturity' trees. Forest structure data were analysed against landscape structure data at the paddock scale and site-specific data reflecting patch quality.
- Tree Health (See Attachment 6. Tree Health) measurements were conducted at all permanent plots during October 2002 –October 2003. The crown condition of all trees (≥ 5 cm DBH) was rated on a scale of 1 to 5, with 1 being a healthy crown and 5 dead. The type and severity of any damage caused by abiotic and biotic agents recorded, including the activity of insects, fungus blight or cankers, galls and stem swelling and mistletoe presence and fire damage. The percentage of the crown in epicormic growth and number of hollows was also recorded. Tree health data were analysed against landscape structure data at a number of scales, site-specific data reflecting patch condition. These data were also compared against previous recordings of tree health undertaken in the late 1980's (Wylie *et al*., 1992).
- Litter decomposition rates (See Attachment 7. Litter decomposition) were quantified using mesh litterbags at the nine high intensity sites. A total of 72 litterbags were placed at each permanent plot. Bags were filled with recently fallen poplar box leaves were placed in bags, tethered to the ground, and a subset collected after 4, 8, 12, 16, 24, 32, 48, and 62 weeks. Litter decomposition rates were calculated with an exponential model described by Olsen (1963). Litter fall rates were also measured with traps set above ground during the study. Correlations and linear regressions were conducted to determine relationships between decomposition and edaphic and biotic variable, climate and landscape structure. Repeated measures analysis and estimates of variance component of litter loss variable were conducted using restricted maximum likelihood correlation models.
- Rapid assessments of ecosystem function (See Attachment 8. Rapid Assessment of Ecosystem Function) were undertaken using landscape function analysis (LFA; Tongway and Hindley, 1995) at all permanent sites and cotton strip assay (Harrison, *et al*., 1988) at the medium intensity sites. LFA measurements are taken on two landscape elements, patch and inter-patch, along transect along the direction of resource movement (generally down-slope). The status of the patch and inter-patch is assessed against 11 indicators of soil surface condition and texture, which are synthesized into three indices (Stability, Infiltration, Nutrient Cycling). Measures are comparative, not giving a single measure of condition, rather allowing comparison against either standards or similar vegetation types. Cotton strip assays provide an index of soil biological condition. The technique involves collecting topsoil (0-5cm) for the permanent transect, placing soils in a drainable tray under controlled conditions, and burying a standard cotton material for 7 days. Strips are then removed

and placed in a tensometer to measure the load required to break the strips, and compared against a standard (same strip not placed in the ground), giving a percentage loss in tensile strength. These rapid measures were firstly compared against the litter decomposition data to assess whether rapid techniques could be developed, then analysed against landscape structure data at different scale and site-specific data reflecting patch quality and disturbance.

- DNA was extracted from poplar box trees at the medium intensity sites to assess the genetic diversity (See Attachment 9. Genetic Diversity). Leaf samples were taken from 28-30 reproductive adults within the permanent plots, or the next nearest reproductive tree were insufficient numbers were available. Four polymorphic microsatellite loci were used to assess the levels of genetic diversity and inbreeding (F_{IS}). Step-wise linear regressions and principal components analysis were used to identify relationship between genetic diversity and landscape structure and site-specific data reflecting patch quality and disturbance.

4. Results and practical significance

Condition of the poplar box woodlands: Prior to European settlement, poplar box dominated communities accounted for 63% of the landscape within the study area. Agricultural development has dramatically influenced the land use in the region, leading to a reduction in the extent of poplar box communities to 23% of the landscape in 1999, and total remaining native vegetation coverage to approximately 36% of the study area. Poplar box woodlands were under increasing clearing pressure, as the most fertile vegetation types were targeted first (generally the brigalow woodlands and softwood vine scrub), with more agriculturally marginal the eucalypt woodlands and land types near riparian areas (frontage country) targeted next. Chilcott *et al*. (2004) ranked the grazing potential of the land types of the region supporting the preference for brigalow and softwood scrub, flooded and frontage country, and then eucalypt woodlands that were dominated by poplar box, silver leaf ironbark and narrow leaf ironbark. During this study, clearing of remnant vegetation continued with 2% of the total area of remaining native vegetation was cleared, equating to 35000 ha and including one of our permanent plots.

The study has revealed some signs of loss of condition most likely due to recent rapid land use change and associated disturbances to remnants (eg. grazing, changed fire regimes, exotic species). The health of poplar box trees throughout the study area is generally poor (Attachment 6), with a number of dieback agents identified, principal amongst these being sap-sucking insects. The average poplar box dieback index was 3.1 (indicative of moderate dieback), with all other species present at 2.3 (minor dieback). Moderate to severe (3 – 4) dieback was observed at 95% of sites, and observed across all tree age class (although worse in older trees). Comparison of the study area against a 1980’s survey (Wylie *et al*., 1992) showed an increase in dieback: from patchy, light to moderate dieback in the 1980’s to widespread moderate to severe dieback at present. There was a positive relationship between the proportion of sand and the presence of buffel grass and dieback, and a positive relationship between dieback in older trees and soil nitrogen. What is not clear from our investigations is the extent to which this dieback can be attributed to drought conditions prior to the study, acting directly or indirectly to cause tree disorder.

The occurrence of dieback has been related to periodic severe droughts associated with El Nino (Fensham and Holman, 1999), although the most widely accepted view is that drought predisposes trees to other agents of decline, and most authors agree a complex of factors rather than a single-agent lead to dieback (Landsberg and Wylie, 1983; Lowman and Heathwole, 1992, Rice *et al*., 2004). The continued decline in tree health from the late 1980's seemed to suggest an underlying symptomatic tree disorder, irrespective of the prevailing climatic conditions.

The response of density and diameter of stems to landscape pattern and site characteristics varied amongst plant taxa, which may reflect variation in life-history traits. Smaller patches, and those with higher edge/area ratio tend to have higher densities of young trees. The structure of the woodlands is undergoing significant change and woodland thickening is apparent (Attachment 5), with stands of old growth Poplar Box mixed with even aged stands of Sandalwood Box (*Eremophila mitchellii*). There is a higher density of larger *E. mitchelli* regeneration and early mature trees in the eastern portion of the study area, where the proportion of cropping, grazing and high intensity agriculture is greater, and this may be a fragmentation effect. Regenerating *E. mitchelli* is found at sites with higher levels of disturbance, which might be due to disturbance from historic clearing of the original vegetation. Dissociating the effect of recent fragmentation from historic site disturbance requires further research. The variation in density of early mature trees of all species was significantly related to patch area (P= 0.002), patch shape (P= 0.018) and contrast weighted edge density of the patch, explaining 18% of the variation. These results indicate that landscape pattern has a greater influence on the density of older growth stage trees than localised site effects (eg. disturbance), while the reverse is true for regeneration stage vegetation. This may suggest that past clearing has influenced forest structure in patches by changing the understorey vegetation structure, with an underlying east-west gradient influencing the resulting structure.

Assessments of landscape function (Attachment 8) show that values observed for site stability, infiltration and nutrient cycling indices are at levels considered in “average to poor condition” when compared to other grassy woodlands in Australia (Tongway and Hindley, 2002; McIntyre *et al*., 2003). Sites in the east of the study area, and/or with higher ground cover and litter mass have higher infiltration and nutrient cycling indices. It is more than likely poor grazing management is contributing to the loss of landscape function, implicated by the relationship with higher ground cover. Detailed measurements of litter decomposition (Attachment 7) differed little across plots, although litter half-lives were much higher (double) than other studies in woodlands in Australia. After 433 days, the loss of original litter mass was approximately 41% across all sites with the greatest loss observed following rainfall. Only one landscape structure metric, Euclidean nearest neighbour, was significant in explaining variation in end decay rates. More isolated patches had higher decay rates, which generally occurred in the easterly, more intensively managed parts of the study areas. No other relationships between decay rates and landscape structure, patch size or shape were found in this study.

Implications for management: The consequence of continued thickening is the loss of the herbaceous layer, ground cover and increased risk of erosion and runoff. This may have consequences for the future health of the overstorey species by altering the hydrological balance of the woodlands. There is a close relationship between rainfall and the leaf area able to be maintained at a site. Ellis *et al*., (1999) found that the leaf area index of a site reached a predictable, dynamic equilibrium with the amount of water available. The consequence for the poplar box woodlands of increased densities of *E. mitchellii* is an increase in site LAI. If climatic pulses are the dominant driver of population dynamics in these woodlands, increased densities of mid-storey species and decline in landscape function (increased runoff) will exacerbating drought effects. If drought-mediated dieback provides a mechanism for reducing the density of timber, our concern is where will the next cohort of poplar box canopy trees come from, as there is little evidence of poplar box recruitment (Attachment 2) and high levels of inbreeding in maternal stock (see below). Understanding the mechanisms of recruitment are critical, especially given the last pulse of recruitment most likely occurred in a less-fragmented landscape.

Genetic diversity of Poplar box woodlands: Genetic diversity (Attachment 9) measures were similar to those observed in other widely distributed eucalypt species. There was little geographic structure evident among the populations (18) surveys at the permanent plots, reflecting the high levels of pre-fragmentation gene flow. Linear regressions highlighted important associations between genetic diversity measures and ecological and demographic variables. Increasing isolation was associated with both elevated inbreeding and reduced heterozygosity while inbreeding was also influenced by greater edge contrast. There was some evidence that disturbance had a positive influence on allelic richness while patch irregularity and elevated inbreeding was also associated. More isolated sites also tended to have fewer rare alleles. Although these analyses indicated that relationships between some ecological and demographic variables and genetic diversity exist, the responses were not always clearly predicted for all sites. The difference in responses probably reflect complex spatial and temporal dynamics at each site, making interpretation related to ecological and demographic variables challenging. Linear regressions between Principal Component Analysis landscape structure and site-specific data components identified that inbreeding was negatively associated with regeneration and plant density as well as isolation and the proportion of poplar box to other species on site.

Implications for management: There was considerable difficulty in interpreting these data and assessing the management implications for a number of reasons. Interpretation of the genetic data using standard univariate techniques was often ambiguous. For example, allelic richness was negatively associated with patch area and positively associated with disturbance both trends are counter-intuitive. The difference in responses probably reflect complex spatial and temporal dynamics at each site, making interpretation related to ecological and demographic variables challenging. Determining correlations between landscape structure and genetic diversity is difficult in landscapes where recurrent clearing and regrowth occur (Jacquemyn, *et al*., 2004). High levels of inbreeding probably represent the most important genetic threat to the future of poplar box remnants. Isolation in combination with patch irregularity and edge contrast provide some predictability for assessing poplar box thresholds, with sites with similar levels of isolation, patch irregularity and edge contrast to that observed in AL01 being most at risk. In addition, landscape context appears to be important since most of the sites that were surrounded by grazing tended to have higher levels of inbreeding suggesting that pollinator movement among remnants patches within an agricultural landscape is limited. A mating system and fitness trial for poplar box would now be a valuable addition to this study. This will provide an important comparison to the historic levels of inbreeding observed while the fitness trial will establish whether any consequential deleterious effects are present in the offspring. Such an analysis may prove critical for the management of poplar box woodlands in southern Queensland given those higher levels of inbreeding present in maternal stock evident a number of sites.

Biodiversity Indicators: Individual species responses varied within the reptile and ant fauna, with increaser, decreaser and neutral species identified. The reptile surveys (Attachment 3) yielded 1779 reptile observations, representing six families and 42 species. The five most abundant species accounted for over 70% of the observations, with the terrestrial gecko *Heteronotia bineoi* observed at 95% of sites. Eighteen of the species recorded were observed at less than 10% of the sites, with six only recorded once. Reptile community composition was influenced by both remnant characteristics and condition, and habitat fragmentation. Measures of remnant habitat condition such as the amount of fallen woody material, weeds and cover of tussock grasses were significant predictors of reptile community structure. The percentage of sand and the rainfall history in the previous 35 years were also found to be determinant of reptile community structure. These plot level characteristics accounted for most of the observed variation in the reptile dataset, however several patch and landscape-scale variables were also significant predictors of reptile species abundance. Significant patch metrics included the Perimeter-to-Area Ratio of the patch and the Edge Contrast Index (ie. a relative measure of the contrast between the patch and the surrounding matrix). At the landscape scale, retained native vegetation cover (remnant and regrowth) and the average shape of vegetation patches were also important predictors of the reptile community. Furthermore, the landscape variables when calculated at the property scale (5 km surrounding each plot) explained more variation in the reptile dataset than those calculated at smaller or larger scales. Although habitat fragmentation influenced the whole reptile community, responses amongst individual species were not uniform. Species sensitive to fragmentation (decreasers) included: the fossorial skink *Lerista meulleri*, the arboreal skink *Cryptoblepharus carnabyi*, and the arboreal velvet gecko *Oedura monilis*. Several species appeared to be tolerant of fragmentation, including: the terrestrial gecko *Heteronotia bineoi*, the tree skink *Egernia striolata* and the litter skink *Morethia boulengeri*, but it unclear whether these species persist because they are able to exploit the groundcover and woody fallen materials in the surrounding pastoral matrix, but will decline if habitat condition in the surrounding pastures deteriorates, or they are destined to decline over time as the effects of fragmentation are fully realised on their dispersal, survival and reproductive abilities. The clearest evidence of an increaser species (with clearing) came from the arboreal gecko *Gehyra dubia*, which was twice as abundant in areas with <30% remnant vegetation on the property. This species seems favoured by more disturbed remnants and is able to outcompete other similar species in more disturbed and fragmented patches.

The ant surveys (Attachment 4) yielded 177 species from 26 genera, which were representative of seven functional groups. Dominant Dolichoderinae were the most prevalent group sampled at most sites; Cryptic Species and Tropical Climate Specialists were not recorded at all. Analyses of the data were conducted on species composition abundance and occurrence, and functional group occurrence and abundance. Species abundance site differences were significantly related to five predictors of landscape fragmentation including Poplar box patch area and isolation, measured as mean Euclidean nearest neighbour distance between Poplar box patches (PBX ENN_MN). Of the five landscape metrics, the degree of irregularity of Poplar box patch distribution (PBX ENN_CV) was the strongest predictor of species abundance differences. Area and isolation were the strongest predictors of ant community assemblages, in particular the coefficient of variation in distance between poplar box (PBX ENN_CV) and mean Euclidean nearest neighbour distance. Differences in species occurrence among sites were significantly related to two landscape metrics: PBX ENN_CV which describe the degree of irregular distribution of Poplar Box patches across the landscape, and the degree of intermixing of Poplar Box patches in the landscape (PBX IJI). These results partially support the equilibrium theory of island biogeography theory, which predicts that area and isolation will influence the colonisation and extinction rates resulting in changes to species abundance (MacArthur and Wilson, 1967). This suggests the increasing irregularity of Poplar box patches may influence ant colonisation patterns by reducing the proportion of patches that can be colonised, since a greater proportion of patches should be located beyond the nuptial flight range of the queen (Hölldobler & Wilson 1990) for a given mean isolation distance between patches. This should only occur if the number of Poplar box patches in a landscape was not strongly influenced by PBX ENN_CV, as occurred in this study. These impacts are particularly strong for cold climate specialists (Holt 1997) that are less suited to moving between patches through the cleared agricultural matrix, compared to habitat generalists and Hot Climate Specialists. We would also expect more isolated and less connected Poplar box remnants (as measured by PBX IJI) to be more heavily colonised by habitat generalists or species with high-dispersal abilities from the matrix (Sobrinho *et al.* 2003), effectively replacing more specialised species lost through fragmentation (the 'rescue effect'; Brown & Kodric-Brown 1977).

Site characteristics such as soil clay content, % bare earth, understorey vegetation structure and disturbance were weaker predictors of community change than PBX ENN_CV, but stronger than other significant landscape metrics. The response to site conditions by different species varied within genera, although the response of functional groups was more predictable. Hot Climate Specialists were favoured by the % bare ground and negatively correlated to understorey vegetation density. The amount of bare ground and soil properties, such as percent clay content, should be important influences on the abundance and size of nest sites present within a patch for ground-dwelling species that are able to colonise bare ground. As expected, site disturbance was significantly associated with changes in species and functional group dynamics. The positive relationship between Dominant Dolichoderinae and disturbance and the negative relationship between Cold Climate Specialists and disturbance is supported by Hoffmann & Andersen (2003) in their review of 45 disturbance studies in Australia. However, disturbance was the weakest significant predictor of changes in functional group abundance, suggesting that either fragmentation and other site characteristics have a stronger direct impact on ant community dynamics at the functional group level, or that the impact of disturbance has been diluted by the variation in disturbance history, type and severity among sites. These functional groups may be useful as bio-indicators of site disturbance, and with more work, may also have the potential as bio-indicators of fragmentation.

A total of 219 plant species (202 natives and 17 exotics) were recorded at the sites (Attachment 2). Most of the variation in the herbaceous species data were explained by landscape variables; increasing with increasing mean patch size of poplar box remnants within 1 and 5 km of the plot. There was also a strong relationship between herbaceous layer and the amount of clearing within 5km and the severity of grazing in the patch. There is a strong association between the presence of *Aristida ramosa* (purple wiregrass) and the mean patch size of poplar box patches within 5 km, and *Themeda triandra* (kangaroo grass) was positively associated with grazing. These results are interesting; *Aristida ramosa* is generally associated with open (ie. cleared) condition (Chilcott *et al*., 1997), and is considered an increaser species (favoured by overgrazing); *Themeda triandra* while favoured by light grazing (Fensham, 1988), is generally known to decline under heavy, continuous grazing (Lodge and Whalley, 1989). *E. mitchellii* was associated with soil percentage and mean patch size of remnant vegetation within 1km when less than 1m in height, but weed severity when counted as a shrub supporting the findings of the forest structure surveys, and confirming that further investigations between fragmentation and shrub dynamics are warranted. Shrub species were mostly associated with plot-level disturbance and habitat measures, a finding consistent with Henderson and Keith (2002) who concluded exogenous disturbance explained more variation in shrub populations than environmental or spatial factors.

Implications for management: There are detectable responses in biodiversity groups to landscape fragmentation at the paddock scale (500 ha) and also at the property scale (8000 ha), but the direction of the responses varies among and within the genera. The variability of species responses within genera implies that taxonomically related species can exhibit different susceptibilities to fragmentation and these may be affected or mediated by localised site effects. Thus, it may be difficult to use the biota study here as viable indicators of fragmentation in semi-arid and arid zones until more information on behavioural and physiological characteristics of individual species is available. However, a number of indicator species (eg. the fossorial skink *Lerista meulleri*, the arboreal skink *Cryptoblepharus carnabyi*, and the arboreal velvet gecko *Oedura monilis*) or functional groups (eg. Dominant Dolichoderinae and Cold Climate Specialists) could be identified.

The implication for management being that positive biodiversity outcomes are possible at the patch level (if disturbance is managed sympathetically), but better outcomes can be achieved if a range of landscape patterns are maintained at the property scale (8000 ha) and beyond. The impact of disturbance and management of remnants (through grazing and fire), and the resulting changes in habitat such as fallen woody material, weeds and the cover of tussock grasses seems to be the overriding determinant of species responses and changes in landscape function, and are likely to exacerbate fragmentation effects. Disturbances (eg. grazing, +/- fire) are major contributor to loss of remnant condition. In some cases the amount of disturbance and the grazing management can override fragmentation effects. Importantly, multiple management outcomes might not be possible, if the primary purpose of the remnant is nature conservation, then management must reflect this. If grazing is to occur, then appropriate utilisation rates (ie. 10% of pasture growth over the growing season) and timing of grazing warrant further investigation. The amount of native vegetation cover at the paddock and property scales proved important for some taxa, so it is likely that future management of regrowth vegetation will play an important role in biodiversity outcomes, both on farm, and in the local area.

5. Comparison of results against the Objectives

Objective 1: Establish relationships between degree and patterns of fragmentation, and selected ecological indicators, as a means to assess long-term ecological sustainability of remnants in agricultural landscapes.

We were able to identify some signs of loss of condition (tree health, woodland thickening, landscape function) and a number of bio-indicators of the effects of clearing and fragmentation of remnants in agriculture landscapes, as outlined in the Results and Practical significance section above.

Objective 2: Quantify thresholds for management of ecologically viable remnant vegetation.

A critical component of the identification of landscape thresholds and interpretation of field data is the quantification of landscape structure. In this study we were able to develop a method to quantify landscape structure using FRAGSTATS, a widely accepted tool for quantifying landscape structure (Herzog *et al*., 2001, McAlpine and Eyre, 2002). It would not be possible to classify such a large study area without access to pre-clearing and current remnant vegetation coverage as mapped by the Queensland Herbarium (Environmental Protection Agency, 2003), and land cover datasets from the State Land and Trees Study (SLATS, Department of Natural Resources and Mines, 2003). We were able to isolate a number of landscape metrics in order to investigate threshold responses. Few thresholds were apparent in the study. The most striking was an increase in *E. mitchelli* dominance in the mid-storey, in remnants less than 150 ha (Attachment 1). Whether this is merely a correlation, or revealing an underlying process warrants further investigation. The lack of obvious thresholds shouldn't be interpreted, as meaning there are no thresholds. We believe we are yet to see the consequences of recent clearing, and species presence should not be confused with persistence; the time lag between fragmentation and effect may mean species are observed, despite their inability to ultimately sustain their populations (Tilman *et al*., 1994). This is supported by the findings of the Ant surveys, where metrics were more common predictors of ant species abundance than occurrence. Likewise, results from the Reptile Surveys showed that abundances of key indicator species declined with increased levels of clearing in the surrounding landscape. Species loss will arise from a decrease in population size since small populations are more vulnerable to environmental stochasticity. Thus it follows that effects on abundance are currently occurring while the impacts on species extinction are yet to be realised. The decline in tree condition, presence of buffel grass, woodland thickening, landscape function may all be key indicators of the loss of viability of remnant, the decline condition of the remnants suggests we may have passed a viability threshold, with obvious implications for the management of the remnants in the future.

Objective 3: Provide tools for rapid assessment of ecological condition of remnants for use by vegetation management officers and / or land managers.

We have found several rapid assessment techniques that could be used to assess the condition of remnants, in particular tree health, cotton strip assays, and the presence of bio-indicators (eg. three lizard taxa and two ant functional groups). Importantly the biodiversity assessments demonstrated the need to assess site habitat value. Measures of remnant habitat condition such as the amount of fallen woody material, weeds, cover of tussock grasses, % bare ground and the presence of *E. mitchelli* and buffel grass were found to correlate with species presence and/or abundance. A number of landscape metrics related to area and isolation at the paddock and sub-catchment scale also show promise for providing a rapid assessment of the condition and viability of remnant vegetation.

The Queensland Government is currently developing a BioCondition toolkit for the rapid assessment of ecological condition of regional ecosystems by resource managers (Eyre 2004). BioCondition is a site-based, quantitative and repeatable assessment of ecological based on the approach of Habitat Hectares in Victoria (Parkes *et al*. 2003) and BioMetric in New South Wales (Oliver 2004; Gibbons *et al.* 2004). Data and outcomes from the project have been used directly in the development of the BioCondition toolkit, both in the identification of surrogates of ecological condition (the assessable attributes) and in the setting of benchmarks (against which the attributes are assessed) for poplar box dominant regional ecosystems. The project partners (Chilcott and Eyre) have submitted a proposal to Meat and Livestock Australia to support a project aimed at incorporating BioCondition into the Grazing Land Management (GLM) education package. The aim of the GLM is to promote rapid assessment of productive land condition as a key part of sustainable management of grazed lands in northern Australia (Chilcott, *et al*., 2003; Quirk *et al*., 2002).

Objective 4: Recommend modifications to policies relating to native vegetation management and their associated performance requirements and acceptable solutions.

While our modelling indicates the existence of thresholds, we have not yet been able to collect sufficient empirical data to test the relationship between the landscape metrics and species or functional responses. The search for thresholds has highlighted the difficulty in applying findings of these investigations in either policy or landscape planning. The difficulty in using threshold levels to set legislative controls are two-fold. Firstly it is unlikely there will be a single threshold that will protect all species and processes. By definition thresholds are a condition beyond which there is an abrupt change in a quality, property or phenomenon of the ecosystem. Even if a single all-encompassing threshold retention level was found, surely the threshold wouldn't be the most appropriate level for retention, but rather some point above it. The accuracy of the prediction would then be questioned. In our case we were able to model a threshold at approximately 150 ha, below which remnants suffered invasion of *E. mitchelli.* The error associated with the response and independent variable were considerable, so if applied to regulation, the threshold may be 150 ha + the error term to ensure adequate protection. Conversely, if conservation measures at both a property and sub-catchment scale aren't sufficient in staying above critical thresholds for maintain ecosystem viability, the effort and resources expended through regional NRM groups and state government initiatives will be wasted. Thus sensible application of thresholds in landscape design principles needs careful consideration of scale and the desired outcome to avoid detrimental conservation outcomes beyond property (ie. at the sub-catchment scale), while avoiding onerous conservation measures at the paddock and property scale.

When the project was first conceived the emphasis in native vegetation management (and the supporting policies and regulations) was to better understand the ecological and conservation implication of broad-scale retention levels. This was driven by the enactment of State Legislation (*viz*, Vegetation Management Act (Qld) 1999). This policy aimed to restrict clearing of remnant vegetation to at least 30% of the pre-clearing extent, thus effectively setting testable thresholds. In that context Objective 2 of this project was based, where the quantification of thresholds could provide meaningful results for both policy and on-farm management. Recent changes to the policy and the formation of regional natural resource management bodies has lessened the importance of understanding threshold retention levels. Emerging from the new policy initiatives is the need for better understanding the future management needs of retained vegetation. In particular regional NRM bodies have set target for retaining greater extent of remnant vegetation through the conservation of regrowth areas, and strive to maintain the condition of protected remnant vegetation through investment in fencing and property planning. Two future research activities that would support the current policy settings have emerged:

- Understanding the role of regrowth vegetation surrounding remnants is of concern given current regulations neither protect it from clearing, impose minimum management standards, or recognise it in formal mapping. The capacity of these landscapes to absorb future shocks such as species declines or loss, weed invasion, climate change, salinisation, woodland thickening, or thinning, will more than likely come through the strategic retention and management of regrowth vegetation.
- Maintaining the condition of retained vegetation through active management. The changes in policy plus the desire of regional bodies to maintain the condition of retain remnant vegetation, has led to the need for better management guidelines of remnants. In particular, this study demonstrated the impact grazing management can have on remnant condition, thus information on better grazing management strategies are required. The provision of this information through relevant education packages should also be considered in any future research.

Objective 5: Communicate major findings to the wider scientific and land management communities, regional vegetation management committees and government policy advisors for adoption and application in native vegetation management in particular within the Murray-Darling basin.

See Adoption of Results and Communication Activities below

6. Adoption of Results and Communication Activities

The following activities will enhance the adoption of results:

Delivery through NRM regional Bodies: The Queensland Murray Darling Basin Committee (QMDC) will implement their NRM Plan at the local and the sub-catchment level through locally integrated projects. We are able to inform this process by meeting with the local landcare and sub-catchment groups to discuss the implications of the findings of this study for the retention and management of native vegetation within their sub-catchment. To date the QMDC has approved one sub-catchment plans (of 52 currently under review), and the project team presented the findings of this study to the group. Highlighted at this meeting was the need to produce management guidelines for remnant and regrowth vegetation. QMDC have established a regional support network comprising of multi-skilled teams of technical and extension staff support sub-catchment and property planning processes. Within this team is a vegetation management and nature conservation technical officer. Most NRM regional bodies propose a similar model to support vegetation and natural conservation management. These people provide technical and extension support to landcare and sub-catchment groups, thus providing a conduit to adoption. We will provide them with the findings of this study (March 2005) and hope to continue to support the integration of the findings of this and other native vegetation management research into their management guidelines for landholders and sub-catchment groups.

Extension materials and integration into industry best practice guidelines: Enhancing property level management, resource condition and minimizing off-site impacts of agricultural production particularly in grazing lands is being promoted through industry based education and best practice guidelines. For example, Meat and Livestock Australia working with a range of partners in Northern Australia has developed the Grazing Land Management (GLM) education package as a major vehicle for promoting sustainable management of grazing lands in Northern Australia (Chilcott, *et al*., 2003; Quirk *et al*., 2002). The GLM package has developed a land condition framework for assessing the impact of reduced land condition on carrying capacity. However the GLM package and the land condition framework is currently limited in the information delivered about broader-scale natural resource management issues such as nature conservation. There is an opportunity to integrate the results from this project (and others within the Native Vegetation Program) within this package, firstly by the addition of concepts and principles to the core educational materials, as well as add-on activities and exercises, or as information handouts as part of the GLM toolkit.

Additional publications: This project (along with past projects) has compiled a large pool of natural history and ecological information related to the Poplar Box woodlands. There is an opportunity to compile this information into a formal publication, to serve as reference materials for those managing these ecosystems or with an interest in future research. Also QMDC have identified their desire to have extension booklets produced from the project on: The management of poplar box woodlands or remnant vegetation in general; Condition assessment and monitoring approaches; and soil biota management guide and identification kit. We are meeting with the QMDC land management scientist in March to plan publication and extension materials based on the rapid assessments of landscape function results.

The following communication activities have been undertaken as part of this project:

Scientific Publications

All attached manuscripts will be submitted to refereed journals throughout 2005.

Scientific papers presented

Venz, M. and Eyre, T. (2005) Habitat fragmentation of Poplar Box (Eucalyptus populnea) woodlands in southern Queensland: lessons from the lizards. Australian Society of Herpetologists (ASH/SRARNZ) Conference, Springbrook, 8/02/2005

King, J. Debuse, V., Taylor, D. and Swift, S. (2004) Ants as indicators in the quest for landscape thresholds in southern Queensland Poplar box woodlands, Proceedings of the XXII International Congress of Entomology, Brisbane August 2004

King, J. Debuse, V., Taylor, D. and Swift, S. (2004) Ants as indicators of the health of Poplar box, *Eucalyptus populnea*, in southern Queensland, Proceedings of ICE satellite meeting - Meeting the Montreal Process: sustaining Forest Health and Biodiversity, Brisbane August 2004.

Chilcott, C. Crimp, S and McKeon, G. (2003). Potential future impacts of climate change in Queensland rangelands, in Howden, M. Hughes, L., Dunlop, M. Zethoven, I., Hilbert, D. and Chilcott, C. (eds) *Climate change impacts on biodiversity in Australia*, Outcomes of a workshop sponsored by the Biological Diversity Advisory Committee, 1-2 October 2002, Commonwealth of Australia, Canberra, pp. 22-24

Chilcott, C. Hilbert, D. and M. Howden (2003) Modelling biodiversity and climate change, in Howden, M. Hughes, L., Dunlop, M. Zethoven, I., Hilbert, D. and Chilcott, C. (eds) *Climate change impacts on biodiversity in Australia*, Outcomes of a workshop sponsored by the Biological Diversity Advisory Committee, 1-2 October 2002, Commonwealth of Australia, Canberra, pp. 63-66.

Chilcott, C., Eyre, T. J., Lawrence, A., Taylor, D., and Wylie, R. (2003). Deriving landscape thresholds for Poplar Box (*Eucalpytus populnea*) woodlands in a changing climate- risks and challenges. Paper presented at the Climate Change – Implications for Biodiversity Conference, November 2003, Gold Coast, Queensland

Chilcott, C., Lawrence, A., Debuse, V., Taylor, D., Whish, G., Venz, M., Wang, J., and Kelly A., (2003) The quest for landscape thresholds in southern Queensland, Proceedings of the Ecological Society of Australia Annual Conference, Armidale December.

Chilcott, C, Lawrence, A., Debuse, V., Taylor, D., Whish, G., Wang, J. and Kelly A. (2003) Quantifying landscape thresholds in southern Queensland. Proceedings of the Consequences of Habitat Fragmentation Workshop, Sydney July 2003

Debuse, V., Taylor, D., Swift, S., Lawrence, A., Wylie, R. and Chilcott, C. (2003). Broken sticks, bent cables and ecological thresholds. *Proceedings of the* Ecological Society of Australia Annual Conference, Armidale December.

Lawrence, A. and Eyre, T.J. 2002. Quantitatively describing the vegetated landscape: the value of GIS in designing regional ecological threshold studies. Paper presentation at Ecological Society of Australia Annual Conference, Cairns, 2-6 December 2002.

House, A.P.N. 2002. Ecological thresholds for native vegetation management in southern Queensland. LWA Annual Native Vegetation Program meeting, Keith, South Australia, 11-12 September 2002.

Venz, M. 2002. Sustainable Forest Management in the Brigalow Belt. Biodiversity and Agricultural Production in Southern Inland Queensland: Current Awareness and Future Directions. A Landcare Forum hosted by North East Downs Landcare Inc. Adora Downs, Queensland, 8-10 October 2002. (Audience of Landcare Officers, landowners, scientists, Greening Australia officers)

Scientific posters presented

Venz, M.F., Eyre, T.J., Lawrence, A. and Chilcott, C. (2003). Ecological thresholds in southern Queensland: Lessons from the lizards. Poster presented at the Ecological Society of Australia Conference, Armidale, New South Wales.

House, A.P.N., Chilcott, C.R., Eyre, T.J., Hardaker, T.L., Jian Wang, Lawrence, A., Swift, S., Taylor, D.W., Venz, M., Young, A., Whish, G.L. and Wylie, F.R. 2002. Ecological thresholds for native vegetation management in southern Queensland. Poster presentation at Ecological Society of Australia Annual Conference, Cairns, 2-6 December 2002.

Whish, G.L. and Chilcott, C.R. 2002. Ecological thresholds for native vegetation management in southern Queensland: Ecosystem functions and landscape health. Poster presentation at Ecological Society of Australia Annual Conference, Cairns, 2-6 December 2002.

Presentations at field days, meetings, workshops and seminars

Mel Venz and Teresa Eyre. Scales of influence:- responses of a reptile community in fragmented woodlands in southern Queensland, Australia. Seminar given for QPWS Southern Region Seminar Series 2005, 21/03/2005

Valerie Debuse, Presentation at the NRMSEQ Forum titled: Combining sustainable production and protection, Brisbane, July 2004

Giselle Whish, Presentation at Southern Queensland Regional Science Forum presentation titled: Mixing Cattle With Our Furry and Feathered Friends - Grazing Ecosystem Thresholds, University of Southern Queensland, 18th August 2003

Chris Chilcott, Seminar titled: Fragmentation and biodiversity in Queensland's poplar box woodlands, Environmental Protection Agency Herbarium Research Seminar Series, August 2003

Chris Chilcott, Central Queensland salinity Workshop, Sponsored by the CRC for Plant-Based Management of Dryland Salinity, presentation titled: The production and hydrological outcomes from grazing on rangelands, 27^{th}- 28^{th} May 2003 and 3^{rd} – 4^{th} December 2003

Chris Chilcott and Giselle Whish, Rural Landscapes- Vegetation Planning and design Forum- University of Southern Queensland Toowoomba,: The effect of clearing on water and nutrient cycles- results from 2 trials and some modelling. 26^{th} –27^{th} February 2003

Ross Wylie, Rural Landscapes- Vegetation Planning and design Forum- University of Southern Queensland Toowoomba, 26^{th} –27^{th} February 2003: Tree Dieback. 26^{th} –27^{th} February 2003

Chris Chilcott and Teresa Eyre, Organised a Resource Condition and Monitoring Assessment Workshop, with DPI, CSIRO, TS-CRC and NR&M, to ascertain which are the most appropriate methodologies for assessing and monitoring resource condition at the property level on grazing lands throughout the State, and include biodiversity assessments, Brisbane November 2003.

Chris Chilcott, Presentation on the findings of the project as part of the Tropical Savannas CRC workshop on tree retention workshop, 2^{nd} –5^{th} February 2004

Chris Chilcott, Presentation to Landmark regional managers titled: Emerging issues in rangeland managements: Trees, salt and carbon. Brisbane, 5^{th} August 2004.

Chris Chilcott, Regrowth Management and grazing field days- Injune and Wandoan organised by the Roma District Landcare group and the Taroom Landcare Group, 10-11^{th} November 2004

Teresa Eyre and Annie Kelly, Assessing the quality and condition of the remnant- 'Habitat Hectares' - the Qld model, at the Australian Network for Plant Conservation Workshop on Approaches and Techniques for the Rehabilitation of Native Vegetation in South East Queensland, 30^{th} November and 2^{nd} December 2004

Chris Chilcott, Warrick McGrath and Steve Cuppitt, Experimental treatments in rehabilitation, at the Australian Network for Plant Conservation Workshop on Approaches and Techniques for the Rehabilitation of Native Vegetation in South East Queensland, 30^{th} November and 2^{nd} December 2004

Chris Chilcott and Melanie Venz, Bymount sub-catchment group, presentation of project findings and implications for their sub-catchment plan, 17^{th} November 2004.

Contributions to scientific or extension publication

Information and findings from this project have been included in the following extension materials:

Chilcott, C.R., Oxley, T.J., Dyer R.M. and MacDonald R.N. (2004) Grazing Land Management Education Package Workshop Notes – Katherine, Meat and Livestock Australia Limited, Sydney.

Chilcott, C.R., Milson, J.A. and Phelps, D.G. (2004) Grazing Land Management Education Package Workshop Notes – Mitchell Grass Downs , Meat and Livestock Australia Limited, Sydney.

Chilcott, C.R., Paton, C.J., Quirk, M.F. and McCallum B.S. (2003) Grazing Land Management Education Package Workshop Notes – Burnett, Meat and Livestock Australia Limited, Sydney.

Chilcott, C.R., McCallum, B.S., Quirk, M.F. and Paton, C.J., (2003) Grazing Land Management Education Package Workshop Notes – Burdekin, Meat and Livestock Australia Limited, Sydney.

Native Vegetation R&D Program Communications
The project team has attended three Annual Program Coordination meetings and presented updates on the project progress. The most recent meeting held in Brisbane, included a review of the project in conjunction with other Native Vegetation R&D projects in South-eastern Queensland, and presentation to science leaders from the Departments of Natural Resources and Mines and Primary Industries and Fisheries. We have also prepared a fact sheet on the project and two articles for publication in Thinking Bush.

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8. List of Attachments

	Title	Status
1.	Quantification of Landscape Structure and Thresholds	This manuscript is in draft form, under review with the results of analysis of the floristic data and landscape function analysis to be added. It will be submitted to Pacific Conservation Biology in April 2005.
2.	Floristic Surveys	This manuscript is in draft form, under review and when completed will be submitted for publication in a refereed journal in June 2005 (most likely the Australian Journal of Botany).
3.	Reptile Survey	This manuscript is in draft form, currently under review and when completed will be submitted for publication in a refereed journal in June 2005 (most likely Austral Ecology).
4.	Ant Survey	This manuscript is in draft form, currently under review and when completed will be submitted for publication in a refereed journal in June 2005 (most like the Journal of Applied Ecology).
5.	Forest Structure	This manuscript is in draft form, currently under review and when completed will be submitted for publication in a refereed journal in June 2005 (most like the Australian Journal of Botany).
6.	Tree Health	This manuscript is in draft form, currently under review and when completed will be submitted for publication in a refereed journal in June 2005.
7.	Litter Decomposition	This manuscript is in draft form, currently under review and when completed will be submitted for publication in a refereed journal in May 2005 (most like Austral Ecology).
8.	Rapid Assessment of Ecosystem Function	This manuscript is in draft form, currently under review and when completed will be submitted for publication in a refereed journal in May 2005 (most like Austral Ecology).
9.	Genetic Diversity	This manuscript is in draft form, currently under review and when completed will be submitted for publication in the Australian Journal of Botany in March 2005.
10	Previous Milestone Reports	